PUBLIC NOTICE

Federal Communications Commission
445 12th St., S.W.
Washington, D.C. 20554

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Internet: http://www.fcc.gov
TTY: 1-888-835-5322

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COMMENT SOUGHT ON COMPETITIVE BIDDING PROCEDURES FOR BROADCAST INCENTIVE AUCTION 1000, INCLUDING AUCTIONS 1001 AND 1002

AU Docket No. 14-252
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I. INTRODUCTION

1. By this Public Notice, we take another important step toward conducting the broadcast television spectrum incentive auction, a new tool to help meet the Nation's accelerating spectrum needs.[1] We established the rules and policies for the incentive auction in the *Incentive Auction R&O*.[2] This Public Notice initiates the pre-auction process by which we will develop, based on additional public input, the detailed procedures necessary to carry out the auction.[3] It includes specific proposals on crucial auction design issues such as determination of the initial broadcast television spectrum clearing target, opening bid prices, benchmarks for the final stage rule, and the final television channel assignment process.[4]

2. The incentive auction will include a "reverse auction" in which broadcasters will offer to voluntarily relinquish some or all of their spectrum usage rights, and a "forward auction" of new, flexible-use licenses suitable for providing mobile broadband services.[5] Forward auction proceeds will be used to pay broadcasters that relinquish rights in the reverse auction.[6] As part of the reverse auction, the Commission will reorganize or "repack" the broadcast TV spectrum so that the television stations that remain on the air after the incentive auction occupy a smaller portion of the UHF band.[7] For the incentive auction to succeed, the reverse and forward auctions and the repacking process must work seamlessly.[8]

3. To encourage voluntary broadcaster participation, we are striving to make the reverse auction design simple and transparent from the perspective of the broadcaster bidder.[9] Broadcasters will be able to participate online through an easy-to-use computer interface and will be able to react to prices provided by the auction system rather than having to formulate their own bids.[10] They will have multiple options to relinquish their spectrum usage rights in exchange for a share of auction proceeds—including to cease broadcasting, to continue broadcasting in a different band, or to share a channel with another station. Broadcasters can decide whether to participate after opening prices are announced, and may drop

[1] *See* Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, §§ 6402 (codified at 47 U.S.C. § 309(j)(8)(G), 6403 (codified at 47 U.S.C. § 1452), 126 Stat. 156 (2012) (Spectrum Act); *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Report and Order, 29 FCC Rcd 6567, 6569, para. 1 (2014) (*Incentive Auction R&O*) (petitions for reconsideration pending).

[2] *See Incentive Auction R&O*, 29 FCC Rcd at 6573–74, paras. 13–16.

[3] *See id.* at 6574, para. 15. Consistent with the provisions of section 309(j)(3)(E)(i) of the Communications Act of 1934, as amended, and to ensure that potential bidders have adequate time to familiarize themselves with the specific rules that will govern the day-to-day conduct of a given auction, the Commission (often through the Wireless Telecommunications Bureau) seeks comment on auction-specific procedures prior to the start of each auction. 47 U.S.C. § 309(j)(3)(E)(i).

[4] This Public Notice opens a new docket at the Commission to receive focused comment on proposed auction procedures. Parties filing comments in response to this Public Notice should do so in AU Docket No. 14–252.

[5] *See Incentive Auction R&O*, 29 FCC Rcd at 6569, para. 1, 6572–73, paras. 9–10.

[6] *See id.*

[7] *See id.* at 6570–71, para. 3.

[8] *See id.* at 6572–73, para. 10.

[9] *See id.* at 6572, para. 9. We are committed to providing broadcasters with information about the incentive auction process and the financial opportunities it represents in order to enable them to make informed business decisions about whether and how to participate. *See Incentive Auction R&O*, 29 FCC Rcd at 6570-71, para. 3. In addition to developing an up-to-date broadcaster-specific LEARN website, wireless.fcc.gov/Incentiveauctions/learn-program/broadcaster.html, we anticipate offering demonstrations of the auction bidding system, interactive tutorials, and other opportunities for broadcasters to familiarize themselves with the reverse auction application and bidding processes in advance of the reverse auction.

[10] *See id.*

out of the bidding in any subsequent round if they decide the prices are too low. Stations will be treated the same in the repacking process whether or not they participate in the reverse auction.[11] Except for broadcasters that receive auction proceeds in exchange for relinquishing spectrum usage rights, the identities of broadcasters that participate in the auction will remain confidential for a period of two years after the incentive auction.[12]

4. Because the reverse auction and the repacking process are interdependent, this Public Notice includes proposals that may affect broadcasters that do not choose to participate in the reverse auction, such as objectives for optimizing final channel assignments in the remaining television bands.[13] In making such proposals, we are mindful of Congress's directive to make all reasonable efforts to preserve the coverage area and population served of eligible broadcasters that remain on the air following the auction, and we seek to avoid unnecessary disruption to free, over-the-air television service.[14]

5. The proposals in this Public Notice are organized into three major sections. First, the integration section addresses how the reverse and forward auctions will be integrated. Among other things, the integration section addresses the determination of an initial spectrum clearing target, how much market variation to accommodate, and the process of moving to subsequent stages of the auction if necessary.[15] The issues and proposals discussed in the integration section may be of interest to potential participants in both the reverse and the forward auctions, as well as to broadcasters that do not choose to participate in the reverse auction. The second and third sections of this Public Notice focus on the reverse and forward auctions, respectively.[16] They address opening prices, details of the application process, and bidding procedures for each auction, as well as issues unique to each auction, such as how the repacking process will work in the context of the reverse auction and the final frequency assignment process for licenses won in the forward auction.

6. This Public Notice also includes a number of technical appendices, which detail the mechanics of the proposed auction design, such as use of data from the inter-service interference ("ISIX") methodology in order to identify potential "impairments" to 600 MHz Band spectrum blocks,[17] optimization procedures for determining the spectrum clearing target and final TV channel assignments,[18] and algorithms for the reverse and forward auctions.[19] The information in the appendices supplements the description of these elements in this Public Notice, but the Public Notice itself contains the information necessary for an interested party to evaluate participation in the reverse or forward auction.

7. The major steps of the incentive auction process, based on the proposals in this Public Notice, together with the decisions in the *Incentive Auction R&O*, are illustrated in the flow chart attached as Appendix A. From the perspective of potential bidders, the major steps will be as follows:

- *Procedures PN*. After considering the record produced in response to this Public Notice, the Commission will adopt final auction procedures and provide detailed explanations and instructions for potential auction participants in a future public notice ("*Procedures PN*").

[11] *See id.*

[12] *See id.*

[13] *See id.* at 6571–72, paras. 6–7, 6621, para. 118.

[14] *See* Spectrum Act § 6403(b)(2); *Incentive Auction R&O*, 29 FCC Rcd at 6572, para. 7.

[15] *See* § III (Proposed Procedures for Overall Incentive Auction Structure, Including Integration of Reverse and Forward Auctions).

[16] *See* §§ IV (Proposed Reverse Auction Procedures); V (Proposed Forward Auction Procedures).

[17] *See* Appendix B.

[18] *See* Appendices C and E.

[19] *See* Appendices D and G.

- *Auction application*. Any party wishing to participate in the bidding in either the reverse auction or the forward auction must submit an auction application by a date to be specified in the *Procedures PN*. Opening prices in the auction will be made available at least 60 days in advance of the deadline for applications to participate in either the reverse or the forward auction. An auction applicant must disclose to the Commission on the application, among other things, specified information about the applicant's identity, certifications, and, for reverse and forward auction applications, respectively, selections regarding bid options or licenses it may wish to bid on. Each applicant will be informed whether its application is complete or deficient in particular respects after Commission staff reviews it for completeness and consistency with the relevant auction rules. Any applicant whose application is incomplete will have a specified period of time within which to resubmit its application to correct deficiencies.
- *Reverse auction initial bid commitment*. In order to qualify to bid in the reverse auction, each reverse auction applicant that successfully completes an application must identify one of the bid options it selected on its application as its preferred option, thereby indicating its commitment to relinquish the spectrum usage rights associated with that option at the opening price for that option.
- *Clearing target determination*. Based on the commitments of broadcasters in response to the opening prices, the auction system will determine the broadcast TV spectrum clearing target for the initial stage of the auction, which will have an associated 600 MHz Band plan.
- *Forward auction upfront payment*. After the clearing target along with the associated band plan is determined, forward auction bidders must submit upfront payments to qualify to bid. Each applicant's upfront payment will establish its bidding eligibility in terms of bidding units.
- *Reverse auction bidding clock phase*. Reverse auction bidding will begin. Each qualified bidder will have an opportunity to bid by responding in successive clock bidding rounds to price offers, which may be reduced as bidding progresses. If at any time the price offered is lower than a bidder wants to accept, the bidder can drop out of the bidding.
- *Forward auction bidding clock phase*. Forward auction bidding will begin on two different categories of licenses. The license categories will reflect the extent of potential impairments from television stations to a given license. Each qualified bidder will have an opportunity to bid by indicating in successive clock bidding rounds its demands for categories of generic license blocks in specific geographic areas. The auction system will check after each round of clock bidding to determine whether the final stage rule has been satisfied. If bidding stops in "high-demand" markets before the final stage rule is satisfied, the auction system will initiate an extended round of bidding for licenses in those markets aimed at satisfying the final stage rule. If the final stage rule is met after any forward auction round (clock or extended), the auction system will implement the market-based spectrum reserve. Bidding rounds will continue in all markets after the final stage rule is met, ending when demand does not exceed supply.
- *Subsequent auction stage if necessary*. If the final stage rule is not satisfied in the forward auction portion of the initial stage, the auction system will move to the next stage of the auction.
- *Final TV channel assignment optimization*. After the final stage rule is satisfied, the auction system will determine final television channel assignments for all television stations that will remain on the air following the incentive auction.
- *Forward auction assignment phase*. After bidding stops in the clock phase of the forward auction, the forward auction assignment rounds will be conducted to assign frequency-specific 600 MHz Band licenses consistent with the demands of specific bidders in specific geographic areas.

8. We intend to begin accepting applications to participate in the broadcast television spectrum incentive auction in the fall of 2015, and to start the bidding process in early 2016. We will

finalize specific deadlines in the *Procedures PN*, but recognize the need to give parties adequate notice prior to the application filing date. We will endeavor to give several months' notice prior to the application filing deadline. Parties who may be interested in participating in the reverse or forward auction should regularly monitor the LEARN website. The broadcast spectrum incentive auction, which is designated as Auction 1000, will begin with bidding in the reverse auction, designated as Auction 1001, followed by bidding in the forward auction, designated as Auction 1002. Since adopting the *Incentive Auction R&O* in May, we have made progress on a number of auction-related issues, including how to predict potential inter-service interference in certain areas and the auction's potential impact on low-power television stations, wireless microphones, and unlicensed white space devices.[20] The staff also has released additional information regarding the reverse auction and the repacking process.[21] Well in advance of the auction, the *Procedures PN* will establish final auction procedures and provide detailed explanations and instructions for potential auction participants.[22] We will resolve outstanding issues outside the scope of the pre-auction process in advance of the *Procedures PN*.[23]

II. BACKGROUND

A. Incentive Auction Order

1. 600 MHz Band Plan

9. Pursuant to the *Incentive Auction R&O*, in the forward auction we will offer licenses for the UHF band spectrum that is repurposed through the incentive auction on a geographic area basis.[24] The service areas for these licenses will be Partial Economic Areas ("PEAs").[25] The 600 MHz Band will be licensed in 5+5 megahertz paired uplink and downlink blocks, which will be authorized for fixed and mobile Frequency Division Duplex ("FDD") operations.[26]

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[20] *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Second Report and Order and Further Notice of Proposed Rulemaking, 29 FCC Rcd 13071 (2014) (*ISIX R&O and Further Notice*) (As applicable, we refer below separately to the *ISIX R&O* and *ISIX Further Notice*); *Amendment of Parts 73 and 74 of the Commission's Rules to Establish Rules for Digital Low Power Television and Television Translator Stations*, MB Docket No. 03-185, Third Notice of Proposed Rulemaking, 29 FCC Rcd 12,536 (2014); *Promoting Spectrum Access for Wireless Microphone Operations*, GN Docket No. 14-166, Notice of Proposed Rulemaking, 29 FCC Rcd 12,343 (2014); *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the TV Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap*, ET Docket No. 14-165, Notice of Proposed Rulemaking, 29 FCC Rcd 12248 (2014) (*"Part 15 NPRM")*.

[21] *See Letter from Gary Epstein, Chair, Incentive Auction Task Force, to Rick Kaplan, Executive Vice President, Strategic Planning, NAB*, GN Docket No. 12-268, ET Docket No. 13-26 (filed June 30, 2014); *Incentive Auction Task Force Releases Constraint File Data Using Actual Channels and Staff Analysis Regarding Pairwise Approach to Preserving Population Served*, GN Docket No. 12-268, ET Docket No. 13-26, Public Notice, 29 FCC Rcd 5687 (2014); *Incentive Auction Task Force Releases Information Related to Repacking; Announces Workshop/Webinar to Provide Additional Detail*, GN Docket No. 12-268, ET Docket No. 13-26, Public Notice, 29 FCC Rcd 47 (2014); *Incentive Auction Task Force Releases Information Related to Incentive Auction Repacking*, GN Docket No. 12-268, ET Docket No. 13-26, Public Notice, 28 FCC Rcd 10370 (2013).

[22] *See Incentive Auction R&O*, 29 FCC Rcd at 6574, para. 15.

[23] *See id.* at 6574, para. 16.

[24] Consistent with the *Incentive Auction R&O*, we refer throughout this Public Notice to the UHF band spectrum that is repurposed through the incentive auction as "the 600 MHz Band," and to the band plan scenarios adopted in the *Incentive Auction R&O* as "the 600 MHz Band Plan."

[25] *Wireless Telecommunications Bureau Provides Details about Partial Economic Areas*, GN Docket No. 12-268, Public Notice, 29 FCC Rcd 6491 (2014) (*"PEAs PN"*). *See* 47 C.F.R. § 27.6(l).

[26] *Incentive Auction R&O*, 29 FCC Rcd at 6587, 6706, paras. 51, 319.

10. The 600 MHz Band Plan we adopted in the *Incentive Auction R&O* consists of an uplink band that will begin at channel 51 (698 MHz), followed by a duplex gap, and then a downlink band.[27] Because the incentive auction may be conducted in several stages, each for a different "spectrum clearing target," we adopted a set of band plan scenarios based on the number of television channels cleared.[28] Figure 1 shows the band plan scenario associated with each potential spectrum clearing target.

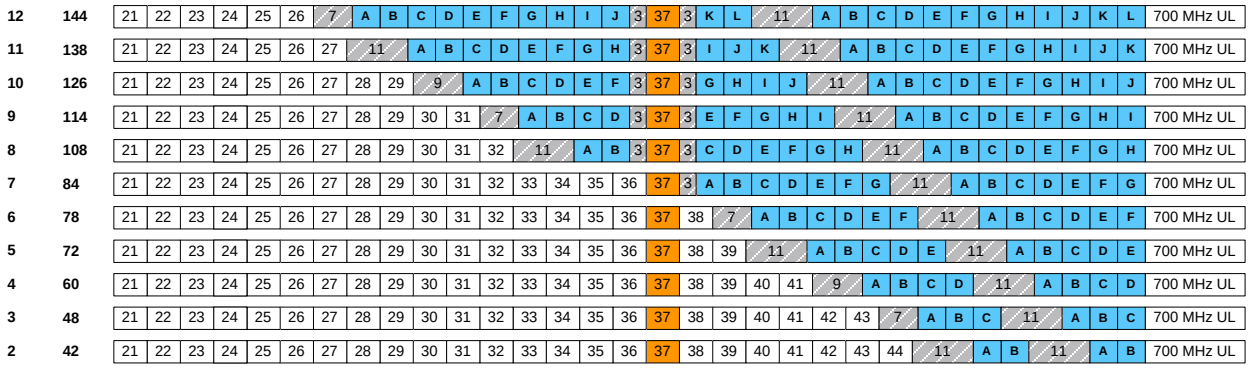

Figure 1: Band Plan Scenarios

11. The first stage of the forward auction will offer licenses corresponding to one of these band plan scenarios, and subsequent stages, if necessary, will offer licenses for scenarios corresponding to lower clearing targets—that is, moving down in the table above. The 600 MHz Band Plan can accommodate variation in the amount of spectrum recovered in different geographic areas in order to prevent the most restricted market from limiting the quantity of spectrum we can offer generally across the nation.[29] If not all PEAs can be cleared, the 600 MHz Band Plan will accommodate market variation either by including some spectrum blocks subject to inter-service interference,[30] or alternatively, fewer spectrum blocks than in most PEAs across the country.[31]

2. Repacking Process

12. Repacking involves reorganizing television stations in the broadcast television bands so that the stations that remain on the air after the incentive auction will occupy a smaller portion of the UHF band, thereby freeing up a portion of that band for new wireless uses. Prior to the commencement of the reverse auction, the staff will determine the coverage area and population served of every television station whose coverage area and population served we will make "all reasonable efforts" to preserve in the repacking process, using the methodology described in the Office of Engineering and Technology

[27] *Incentive Auction R&O*, 29 FCC Rcd at 6585, para. 45.

[28] *Incentive Auction R&O*, 29 FCC Rcd at 6585, para. 46.

[29] *Incentive Auction R&O*, 29 FCC Rcd at 6605, para. 82. Because the amount of UHF spectrum recovered through the reverse auction and the repacking process depends on broadcaster participation and other factors, we found it necessary to accommodate market variation in order to ensure that broadcasters can participate in the reverse auction in markets where interest is high, thereby making more spectrum available nationwide in the forward auction. *Id.*

[30] *See ISIX R&O*, 29 FCC Rcd at 13083–104, paras. 23–60.

[31] *Incentive Auction R&O*, 29 FCC Rcd at 6605, para. 83. A PEA that has a TV station assigned to the 600 MHz Band in that PEA (or a nearby PEA) would still follow the same band plan structure as the rest of the country, but, depending on the location of the TV station, for example, we might not offer the A block in that PEA and the B block would be considered impaired. *See* § II.B (Inter-Service Interference ("ISIX") Order and Further Notice).

Bulletin No. 69.[32] Based on this data, the staff will develop "constraint files" for each station that will be used to check the feasibility of assigning permissible channels to stations that will remain on the air.[33]

13. Before bidding in the reverse auction begins, the initial "clearing target" for how much broadcast TV spectrum will be repurposed through the reverse auction and the repacking process will be determined based on broadcasters' collective willingness to relinquish spectrum usage rights at the opening prices announced by the Commission.[34] The clearing target will dictate the total number of remaining television channels available for the repacking process.

14. At the start of the reverse auction bidding process, television stations will fall into two general categories: non-participating stations that will remain on the air after the incentive auction, and participating stations that may or may not remain on the air, depending on the reverse auction outcome.[35] The auction system will use a "repacking feasibility checker" to ensure that every non-participating station is assigned a television channel in its pre-auction band consistent with our statutory obligation to make reasonable efforts to preserve its population and coverage area.[36] Each time a participating station drops out of the auction, it will be assigned a channel in its pre-auction band consistent with this obligation, and the repacking feasibility checker will determine whether a channel that meets these requirements is available for each individual station that continues to participate in the bidding.[37]

15. Television station channel assignments in the remaining television bands will be provisional throughout the bidding stages of the auction.[38] Final channel assignments will be made after the final stage rule is satisfied and bidding ends in the reverse and forward auctions.[39] At that point, the assignments for each television station that will be assigned a channel in the remaining TV bands will be optimized to ensure efficient final channel assignments that preserve the coverage area and population served of each station and account for the additional goals that we have adopted or will adopt in this pre-auction process.[40]

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[32] Spectrum Act § 6403(b)(2); *see Incentive Auction R&O*, 29 FCC Rcd at 6619–20, para.114. The staff will determine the coverage area and population served of each station as of February 22, 2012 (the date of the enactment of the Spectrum Act) or as of later dates appropriate to certain facilities that we are exercising discretion to protect. *See id.*

[33] *Incentive Auction R&O*, 29 FCC Rcd at 6619, para. 114. The constraint files for each station will consist of a "domain" file that lists all the channels to which a station could be assigned considering fixed constraints (that is, incumbents in the broadcast TV bands other than domestic TV stations that are entitled to interference protection at fixed geographic locations and on specific channels) and an "interference-paired" file that lists all the other stations that could *not* be assigned to operate on the same channel or an adjacent channel with the station. *Id. See also id.* at 6635, para. 145 (directing OET to release a detailed summary of baseline coverage area and population served by each television station to be protected in the repacking process, and to provide an opportunity for additional public input, in advance of the auction).

[34] *Id.* at para. 116.

[35] *Id.* at para. 117.

[36] *Id.*

[37] *Id.*

[38] *Id.* at paras. 117–18.

[39] *Id.*; *see* § IV.E (Determining a Final Television Channel Assignment Plan).

[40] *Incentive Auction R&O*, 29 FCC Rcd at para. 118; *see ISIX R&O*, 29 FCC Rcd at 13079, 13082–83, paras. 14, 22 (adopting two optimization goals: avoiding channel assignments that would result in aggregate new interference over one percent, and avoiding channel assignments that would result in significant viewer losses due to terrain losses).

3. Auction Process

16. The incentive auction will consist of reverse and forward auctions.[41] The reverse auction will collect information about the prices at which broadcast television licensees would be willing to voluntarily relinquish some or all of their spectrum usage rights. The forward auction will consist of a clock phase and an assignment phase. The clock phase will identify the prices that potential users of repurposed broadcast television spectrum will pay for generic spectrum blocks. In the assignment phase, winners of blocks in the clock phase will bid for specific licenses to use the spectrum. The results of both auctions will be used to determine whether the overall reserve price, or final stage rule, has been satisfied. Once the reserve price requirements of the final stage rule are met and bidding meets the conditions of a stopping rule, the overall results of the bidding in both auctions will determine those broadcasters selected to relinquish spectrum usage rights and the amounts of their incentive payments from the reverse auction, as well as the winning bidders for flexible-use 600 MHz Band licenses and the prices they will pay for those licenses from the forward auction.[42] After the final stage rule is satisfied and there is no excess demand for licenses, broadcasters that will remain on the air will receive final channel assignments and winners of generic licenses will have the opportunity to bid for specific frequencies.[43] Then the incentive auction will close.

17. The reverse and forward auctions will be integrated in one or more stages.[44] Each stage will consist of a reverse auction and a forward auction bidding process; multiple stages will be run only if necessary. The forward auction bidding process will follow the reverse auction bidding process. If bidding in the forward auction does not satisfy the final stage rule, additional stages will be run with progressively lower spectrum clearing targets in the reverse auction and fewer licenses available in the forward auction, until the final stage rule is satisfied.

18. In the *Incentive Auction R&O,* the Commission adopted a descending clock format for the reverse auction in which, in each bidding round, stations will be offered prices for one or more bid options and indicate their choices at those prices.[45] The prices offered to each station for options will be adjusted downward as the rounds progress in a way that accounts for the availability of television channels in different bands in the repacking process. A station will continue to be offered prices for bid options until its voluntary relinquishment of rights becomes needed to meet the current spectrum clearing target.[46] When all remaining bidders' relinquishments are needed in this way, the reverse auction for the stage will end. If the final stage rule is satisfied in that stage, then those bidders will be winning bidders, and the price paid to each will be at least as high as the last price it agreed to accept.

19. For the clock phase of the forward auction, the Commission adopted an ascending clock auction format in which bidders will be able to bid for generic spectrum blocks in one or more license categories, to be followed by an assignment mechanism for frequency-specific licenses.[47] Consistent with the *Mobile Spectrum Holdings R&O,* the forward auction will incorporate a market-based spectrum

[41] *Incentive Auction R&O,* 29 FCC Rcd at 6708, para. 325.

[42] *Id.* The results of the forward auction will include bids from the clock phase, including any extended round, and bids from the assignment phase. Only the results from the clock phase, including any extended round, will be used to determine whether the final stage rule has been satisfied.

[43] *Incentive Auction R&O,* 29 FCC Rcd at 6757, para. 458 n.1319.

[44] *See id.* at 6708, para. 326.

[45] *Id.* at 6753, para. 449.

[46] *Id.* at 6755, para. 453.

[47] *Id.* at 6775, para. 503.

reserve of blocks for certain eligible bidders.[48] There will be a separate clock price for each license category in each PEA, and bidders will indicate the number of blocks that they demand at the current prices. The prices generally will rise from round to round, as long as the demand for blocks exceeds availability.[49] Bidders still demanding blocks when the clock prices stop rising in every license category in every PEA will become winners provided the final stage rule is satisfied. If the rule is not satisfied, bidders will have an opportunity to make additional bids to meet the rule in an extended bidding round.[50] Once the final stage rule is satisfied, winners may indicate their preferences for frequency-specific licenses in the assignment phase of the forward auction.[51] Final license prices will reflect the winning bid amounts from the clock bidding rounds as well as any adjustments from the extended bidding and assignment rounds.[52]

B. Inter-Service Interference ("ISIX") Order and Further Notice

20. We recently issued an order establishing a methodology for use during the incentive auction to predict inter-service interference in areas where broadcast and wireless services operate on the same or adjacent channels as a result of market variation.[53] In such areas, television channels may not be available in the remaining television bands for all of the stations that will remain on the air, and one or more stations may have to be assigned channels in the 600 MHz Band, that is, in the portion of the UHF spectrum that generally will be repurposed.[54] Assigning channels to television stations in the 600 MHz Band creates a potential for harmful interference to both broadcast and wireless operations. The *ISIX Order* established a methodology (the "ISIX methodology") for predicting such interference.[55]

21. The ISIX methodology varies depending on the applicable interference scenario or case. Cases 1 and 2 relate to interference from television to wireless operations (base stations and user equipment, respectively). Cases 3 and 4 relate to interference from wireless operations (base stations and user equipment, respectively) to digital TV receivers. The applicable interference case depends on where television stations are placed in the 600 MHz Band.[56]

22. In the *Incentive Auction R&O*, the Commission defined an "impaired" PEA as one in which a 600 MHz Band licensee is restricted to some extent from operating within the geographic boundary of the PEA in order prevent harmful interference to television operations in the 600 MHz Band; and conversely, one in which a 600 MHz Band licensee may receive harmful interference from television operations in the 600 MHz Band.[57] In the *ISIX Order*, we further clarified that impairments may result in

[48] *See Id.* at 6573–74, para. 10; *see also Policies Regarding Mobile Spectrum Holdings*, WT Docket No. 12-269, Report and Order, 29 FCC 6133 at 6193, para. 146 (2014) (*Mobile Spectrum Holdings R&O).*

[49] *Incentive Auction R&O*, 29 FCC Rcd at 6776, para. 508.

[50] *Id.* at 6778, para. 512.

[51] *Id.* at 6779, para. 515.

[52] *Id.* at 6580, para. 32.

[53] *See generally ISIX Further Notice*, 29 FCC Rcd at 13104–114, paras. 61–89 (inviting comment on use of the ISIX methodology to predict and prevent inter-service interference post-auction and proposing rules to govern post-auction operations.).

[54] *Incentive Auction R&O*, 29 FCC Rcd at 6604, para. 81. In addition, some areas may be subject to inter-service interference resulting from existing television stations along the borders in Canada and Mexico.

[55] *See ISIX R&O*, 29 FCC Rcd at 13083–104, paras. 23–60.

[56] *See id.* at 13086–87, para. 31. *See also* § II.A.2 (Repacking Process). If stations are placed in the uplink portion of the Band, Cases 1 and 4 will apply. If stations are placed in the downlink, Cases 2 and 3 will apply.

[57] *See Incentive Auction R&O*, 29 FCC Rcd at 6604–05, para. 81.

"restricted" and "infringed" areas within a 600 MHz Band service area.[58] A "restricted" area is one in which the wireless operator could cause harmful interference to a television station.[59] An "infringed" area is one in which the wireless operator may receive harmful interference from a television station.[60] We proposed in the *ISIX Further Notice* to allow wireless carriers to operate in areas where they may *receive* interference from TV stations,[61] but not in areas where they may *cause* any harmful interference to television operations in the 600 MHz Band.[62] We further proposed that a 600 MHz Band licensee with an "impaired" license would hold the license for the entire PEA but would be limited to operations within the boundaries permitted under the inter-service interference rules.[63] The *ISIX Further Notice* also proposed a methodology for use after the auction to prevent inter-service interference based on actual deployment of wireless networks, including a zero-percent threshold for interference to TV stations from wireless services.[64]

C. Mobile Spectrum Holdings Order

23. As illustrated in the chart below, in the *Mobile Spectrum Holdings R&O* we established the *maximum* amount of licensed spectrum that will be reserved in each PEA for eligible entities ("reserve-eligible" entities) in the forward auction for different initial stage spectrum clearing targets.[65] If the auction does not close in the initial stage, the maximum amount of reserved licensed spectrum in each PEA in subsequent stages will be the smaller of (1) the maximum amount in the previous stage, or (2) the amount that the reserve-eligible bidders demanded at the end of the previous stage.[66]

Licensed Spectrum In the Initial Clearing Target (in megahertz)	100	90	80	70	60	50	40
Minimum Unreserved Spectrum	70	60	50	40	40	40	30
Maximum Reserved Spectrum	30	30	30	30	20	10	10

Figure 2: Maximum Amount of Reserved Spectrum

[58] See *ISIX R&O*, 29 FCC Rcd at 13082, para. 21.

[59] *Id.* at 13083, para. 23.

[60] *Id.*

[61] *ISIX Further Notice*, 29 FCC Rcd at 13109–10, para. 76; *see Incentive Auction R&O*, 29 FCC Rcd at 6606, para. 86 n.276.

[62] *ISIX Further Notice*, 29 FCC Rcd at 13109–10, para. 76.

[63] *Incentive Auction R&O*, 29 FCC Rcd at 6606, para. 86. *See also ISIX Further Notice*, 29 FCC Rcd at 13109–10, para. 76. Such licensees would be required to meet the build-out requirements only for the area they are permitted to serve within each PEA. *See ISIX Further Notice*, 29 FCC Rcd at 13110–11, para.77; *see generally Incentive Auction R&O* at § VI.B.2.c.ii (Performance Requirements).

[64] *See ISIX Further Notice*, 29 FCC Rcd at 13106, paras. 65–66 (proposing zero-percent-interference-to-TV-stations standard).

[65] *Mobile Spectrum Holdings R&*O, 29 FCC Rcd at 6208, para. 184. A spectrum clearing target will include licensed spectrum and guard bands; the chart refers only to the amount of licensed spectrum included in each target because only licensed spectrum is relevant to determination of the reserve.

[66] *Id.* at 6208, para. 184. For example, if the initial clearing target is 70 megahertz, the maximum reserve will be 30 megahertz in the initial and subsequent stages, provided that reserve-eligible bidders continue to demand that amount. If reserve-eligible bidders demand less than 30 megahertz at the end of a stage, the maximum reserve for the subsequent stage will be that demand.

The maximum amount of reserved spectrum is 30 megahertz for initial clearing targets with more than 100 megahertz of licensed spectrum.[67] The *actual* amount of reserved spectrum will depend on the demand by reserve-eligible bidders when the auction reaches a "spectrum reserve trigger."[68] The auction system will set the spectrum reserve trigger at the point when the final stage rule is satisfied.[69]

III. PROPOSED PROCEDURES FOR OVERALL INCENTIVE AUCTION STRUCTURE, INCLUDING INTEGRATION OF REVERSE AND FORWARD AUCTIONS

24. In this section, we seek comment on integrating the reverse and forward auction bidding processes consistent with the staged structure we established in the *Incentive Auction R&O*.[70] In particular, we seek comment on procedures for setting the broadcast television spectrum clearing target and for determining whether the final stage rule is satisfied, as well as on the steps triggered by the determination that the final stage rule is satisfied.

A. Setting an Initial Spectrum Clearing Target and Determining Impairments

25. We propose procedures for setting the initial clearing target for the auction. The approach we propose will establish the highest clearing target possible from among the available options given broadcaster participation in the reverse auction.[71] Alternatively, we seek comment on whether we should omit any initial clearing targets, such as the 108 MHz clearing target.[72] The auction system will use mathematical optimization techniques to identify provisional TV channel assignments that protect the coverage area and population served of non-participating television stations as required by the Spectrum Act. Where necessary, non-participating stations will be assigned to channels in the 600 MHz Band.[73] In making such assignments, we propose that the auction system will minimize potential inter-service interference to 600 MHz Band licenses. To limit the extent of market variation in the provisional TV channel assignment plan, we propose to limit impairments on a nationwide aggregated basis to less than 20 percent of the total U.S. population (measured on a weighted basis). If a provisional channel plan does not exceed this limit, the auction system may apply any secondary objectives for TV channel assignments that we establish after considering comments on the proposals below. If a provisional channel plan exceeds the less than 20 percent limit, however, the process will start again with the next lower clearing target.

26. Below, we first address our proposed approach to measuring the extent of potential inter-service interference to 600 MHz Band PEAs in order to set the clearing target. Second, we address

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[67] The *Mobile Spectrum Holdings R&O* inadvertently omitted the 80 megahertz clearing scenario established by the Commission (as set forth in the technical appendix to the *Incentive Auction R&O*) from the chart reproduced above. 80 megahertz corresponds to the 108 megahertz clearing target in Figure 1 above. Consistent with our finding that a maximum spectrum reserve of 30 megahertz is appropriate for most levels of total available spectrum licenses except for levels less than 70 megahertz, the maximum amount of reserved spectrum for an 80 megahertz clearing scenario is 30 megahertz. *See Mobile Spectrum Holdings R&*O, 29 FCC Rcd at 6210–11, para. 191.

[68] *Id.* at 6208, para. 184. Because the actual amount of reserved spectrum depends on auction participation, we called this a "market-based spectrum reserve."

[69] *Id.* at 6209, para. 187.

[70] *Incentive Auction R&O*, 29 FCC Rcd at 6708, para. 326.

[71] As illustrated in Figure 1 above, the highest clearing target included in the 600 MHz Band Plan is 144 MHz of repurposed broadcast television spectrum, corresponding to 12 paired 5+5 megahertz 600 MHz Band licenses.

[72] *See* § III.C.3 (Transition to Any Subsequent Stages).

[73] Any stations assigned to channels in the 600 MHz Band will be entitled to the same protection in the repacking process as other TV stations, and will be protected from inter-service interference under the standards we adopt in the *ISIX* proceeding, in which we have proposed strict standards to protect TV stations from such interference. *See* § III.A.2 (Assigning TV Stations to the 600 MHz Band as Necessary to Accommodate Market Variation).

objectives for determining the location of any TV stations that must be assigned to the 600 MHz Band to accommodate market variation. Third, we explain our proposal to use "weighted-pops" to calculate the market variation associated with a clearing target and propose a standard for limiting market variation.[74] Fourth, we address the use of optimization techniques under our proposed approach to setting a clearing target.

1. Measuring the Extent of Potential Impairments

27. In order to determine a clearing target, the auction system must be able to evaluate the extent of any potential impairments to licenses in the 600 MHz Band as a result of market variation. In the *ISIX R&O*, we adopted the ISIX methodology to predict potential inter-service interference between TV and wireless services.[75] The attached Appendix B details how we propose to use the data produced using this methodology to generate mathematical constraints that enable the auction system to measure the extent of potential impairments to 600 MHz Band licenses in order to set a clearing target. We summarize this procedure below.

28. Under the proposed procedure, the raw data the ISIX methodology produced at the two-by-two kilometer cell level would be aggregated into uplink and downlink, county-level data sets[76] and mapped to specific 600 MHz Band licenses in advance of the incentive auction. The percentage of the population of each county subject to inter-service interference then would be calculated for every TV station eligible for protection in the repacking process on every possible channel in the 600 MHz Band.[77] Consistent with the ISIX methodology, which defines each cell as "impaired" or "unimpaired" depending on whether it is subject to any inter-service interference,[78] the procedure would apply a threshold to determine whether a county is "impaired" for each possible TV station and channel combination.[79]

29. We invite comment on a threshold for determining whether a county is "impaired" for purposes of determining impairments for a given clearing target. In particular, we invite comment on setting a threshold within the range of 10-to-20 percent. Under our proposed methodology, a county with predicted impairment above the threshold for a specific station-channel assignment would be considered wholly impaired, i.e., 100 percent of the county population, for purposes of measuring the extent of impairment in the PEA when setting the clearing target. In considering the impaired population to which we will apply the threshold, we also propose to distinguish between uplink and downlink impairments. In this regard, a TV station in the uplink portion of the 600 MHz Band might allow unimpaired use of the downlink portion of a paired 5+5 megahertz license.[80] Accordingly, we propose that rather than consider uplink impairments above the threshold to be wholly impaired as we do with downlink impairments, we consider a county with uplink impairments above the threshold to be 50 percent impaired. Commenters

[74] We use the term "weighted-pops" herein to refer to our proposed approach to weighting the population in a given PEA based on the number of blocks in the PEA and an index of area-specific prices from prior auctions. *See* § III.A.3 (Standard for Limiting Market Variation).

[75] *ISIX R&O*, 29 FCC Rcd at 13083–104, paras. 23–60.

[76] A table cross-referencing counties to PEAs is available on the Commission website at http://transition.fcc.gov/oet/info/maps/areas/.

[77] The procedure would ensure that the population of a county that is subject to potential inter-service interference from more than one TV station would not be double-counted.

[78] *See ISIX R&O*, 29 FCC Rcd at 13087, para. 32.

[79] We propose a binary impaired or unimpaired approach only to determine a clearing target. Specific information regarding the percentage of the impaired population would be provided in the forward auction, and as discussed in the forward auction section, licenses will be categorized as either Category 1 or Category 2 to reflect the general level of impairment. *See* § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses).

[80] *See* § III.A.2 (Assigning TV Stations to the 600 MHz Band as Necessary to Accommodate Market Variation).

that advocate a different threshold or approach should explain why they believe their approach would better inform the setting of a clearing target.

30. We propose to aggregate the data as set forth above in order to reduce the volume of data inputs to a quantity that reasonably can be utilized in setting a clearing target.[81] The data would be aggregated to this level only for use in the optimization procedure to set a clearing target; we propose that the auction system would provide more detailed data on the location and extent of impairment to 600 MHz Band licenses during the forward auction.[82] Moreover, we propose to use more detailed data when categorizing blocks for bidding, as addressed in the forward auction section of this document.[83]

31. Under our proposed procedure for setting an initial clearing target, the mathematical constraints for measuring impairments discussed above that are the inputs to the optimization procedure would be generated before the auction, so that during the auction the optimization can dynamically calculate the percentage of impaired population within each license for any possible combination of TV stations and channel assignments in the 600 MHz Band by adding the total population of the "impaired" counties within the PEA and dividing that sum by the total population of all of the counties within the PEA. We propose that if a 600 MHz Band license is more than 50 percent impaired by the assignment, the optimization procedure will consider all of the associated weighted-pops to be impaired, consistent with our proposal not to offer such licenses in the forward auction.[84]

2. Assigning TV Stations to the 600 MHz Band as Necessary to Accommodate Market Variation

32. We seek comment on certain details for assigning television stations to the 600 MHz Band as necessary to accommodate market variation. Under our proposed approach, the auction system will use mathematical optimization techniques to identify a provisional TV channel assignment plan for stations that elect not to participate in the auction that best meets certain primary objectives, as discussed in more detail below. While these techniques will identify channels in the remaining TV bands for as many of these stations as possible, the auction system may not be able to assign channels in the remaining bands to all of the stations that must be assigned channels in areas that are constrained due to factors such as lack of broadcaster participation in the reverse auction or international border-related issues. Under such circumstances, the auction system will assign television stations to channels in the 600 MHz Band. Any television stations assigned to channels in the 600 MHz Band will be entitled to the same protection in the repacking process as other TV stations, and will be protected from inter-service interference under the standards we adopt in the *ISIX* proceeding, in which we have proposed not to allow any harmful interference to TV stations from wireless services.[85]

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[81] Given all of the possible TV station and channel combinations under different spectrum clearing targets, the ISIX methodology produces a quantity of data that exceeds the current capabilities of optimization techniques. When aggregated to a county level, the ISIX methodology produces 3.7 billion separate records of data for the 3,000 counties in the United States. Use of data at the next possible level of granularity—the Census tract—would result in a 20-fold increase in the number of data records, and use of data at the cell level would result in a 650-fold increase. As it stands at the county level, the optimization software we propose to use must consider more than 100,000 decision variables and over two million constraints. At a more granular level than the county, the number of decision variables and constraints that must be considered would increase to an unsolvable number.

[82] We propose that the auction system will provide forward auction bidders with specific information on the location of impairments. *See* § V.A.1 (Forward Auction Information Available During the Auction).

[83] *See* § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses).

[84] *See id.*

[85] *See ISIX Further Notice*, 29 FCC Rcd at 13106, paras. 65–66 (proposing zero-percent-interference-to-TV-stations standard).

33. Importantly, although TV channel assignments in the broadcasting portion of the band will be provisional until the final channel assignment process, which occurs after bidding ends in the final stage of the auction, under our proposed approach any assignments of television stations to channels in the 600 MHz Band will be fixed prior to the start of the forward auction for that stage, and those assignments will be final if no subsequent stages of the auction are necessary.[86] Thus, a television station's assignment to a channel in the 600 MHz Band for purposes of setting a clearing target may determine both its post-auction channel assignment and the specific impairments to 600 MHz Band blocks that will be offered in the forward auction, depending on whether the final stage rule is satisfied in that stage. If subsequent stages are necessary, the auction system will generate a new band plan that may involve different provisional TV station and channel assignments in the 600 MHz Band. In contrast to any TV channel assignments in the 600 MHz Band, the vast majority of assignments to channels in the remaining television bands will change constantly during the repacking process.

34. Because of differences in wireless uplink and downlink transmission technologies, location of a television station in the downlink or uplink portion of the 600 MHz Band is likely to affect the extent of impairments to affected PEAs and, therefore, 600 MHz Band license prices.[87] In particular, uplink impairments are likely to affect larger geographic areas than downlink impairments,[88] although whether that interference to a larger area translates into a significantly larger impact on value to the forward auction licenses depends on the population density within a PEA. Uplink impairments also may affect fewer spectrum blocks than downlink impairments, however, because they would allow for unimpaired use of the downlink portion of a 600 MHz Band license by carriers with below-1 GHz uplink spectrum. On the other hand, assigning stations to the downlink band would limit the geographic reach of impairments and promote greater contiguity with television stations in the remaining TV bands. Assigning stations to the downlink band, and/or only to the licensed portion of the uplink band, would also result in more consistently usable nationwide spectrum for wireless microphones and unlicensed devices that will operate in the duplex gap, i.e., the guard band between 600 MHz Band uplink and downlink services. The illustrations below show the potential impact of assigning a TV station to the uplink or downlink (overlapping with the guard bands) under a clearing target of 126 MHz.

[86] By fixing the impairments for a stage, our approach ensures that forward auction bidders know what to expect in the assignment phase of the forward auction and can bid accordingly during the clock phase.

[87] The 600 MHz Band Plan established in the *Incentive Auction R&O* includes an uplink and a downlink portion, as well as guard bands between the uplink and downlink (the duplex gap) and between TV and wireless services. Thus, TV stations assigned to channels in the 600 MHz Band could be located in the uplink and/or the downlink bands, and could overlap with the guard bands. If TV stations are assigned to frequencies that will be used as the 600 MHz Band guard band in other areas, the ISIX methodology proposed in the *ISIX Further Notice* would determine the proper geographic and frequency separations between wireless and television services to prevent harmful inter-service interference, even in the absence of a specifically designated guard band in that PEA.

[88] Because of their height and other factors, base station receive antennas are potentially susceptible to interference from more distant as well as nearby TV stations. Locating TV stations in the uplink portion of the 600 MHz Band may therefore prevent base stations from receiving transmissions from mobile devices to base stations across a relatively wide geographic area. Since this interference would only affect uplink frequencies, however, it potentially leaves the associated downlink spectrum block(s) available for wireless use. By contrast, locating TV stations in the downlink portion of the Band will generally affect a smaller geographical area because mobile stations operate very close to the ground and would therefore receive interference only from the closest TV station or stations. While the associated uplink portion would remain available in that instance, there is less demand for unpaired uplink frequencies.

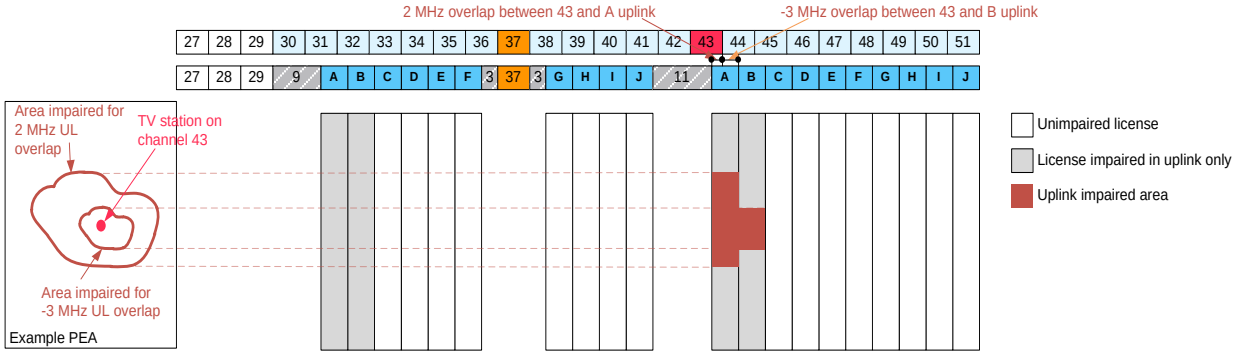

Figure 3: Impairments from a TV station on Channel 43 in 126 MHz Band Plan[89]

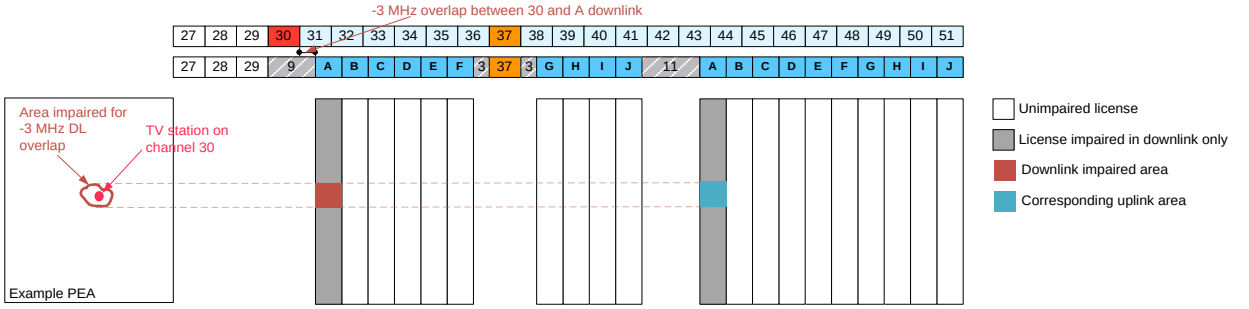

Figure 4: Impairments from a TV station on Channel 30 in 126 MHz Band Plan

35. In cases where a television station must be assigned to a channel in the 600 MHz Band in order to meet a given clearing target, we propose to assign these stations based on our goal of minimizing the loss of value due to impairments, i.e., minimizing the total impaired weighted-pops nationwide. Under this proposal, the optimization procedure could assign TV stations to any frequency in the 600 MHz Band. This could lead to assignments in the uplink portion of the 600 MHz Band in some markets, and in the downlink portion in others. We propose to include this objective in the optimization procedure consistent with our goals of limiting the potential for inter-service interference and maintaining a generally consistent band plan.[90] In addition, the proposed objective will increase the likelihood of meeting the incentive auction reserve price conditions at the initial clearing target. On the other hand, we recognize that this approach may result in assigning television stations to the duplex gap or other guard bands in some markets, and limit the contiguity of TV stations if they are not assigned to the downlink portion of the 600 MHz Band.

36. Alternatively, we seek comment on whether we should assign stations to the downlink portion of the 600 MHz Band whenever feasible to do so, in the interest of greater contiguity and ensuring more consistently usable nationwide unlicensed spectrum. We note that by limiting the choice of assignments, a downlink-only approach may make it more difficult to identify an assignment of TV stations that meets the less than 20 percent standard proposed below than would our more flexible proposed approach and, therefore, could result in setting a lower clearing target. We invite commenters

[89] The *ISIX R&O* defines "co-channel operations" as any spectral overlap between a wireless spectrum block and a television channel in one megahertz increments ranging from +5 (complete overlap) to +1 megahertz, and "adjacent channel operations" as a wireless spectrum block and television channel that do not overlap but are separated by less than five megahertz (edge to edge separation of five megahertz or less). *ISIX R&O*, 29 FCC Rcd at 13085, para. 27. *See also Office of Engineering and Technology Seeks to Supplement the Incentive Auction Proceeding Record Regarding Potential Interference Between Broadcast Television and Wireless Services*, GN Docket No. 12-268, ET Docket No. 14-14, Public Notice, 29 FCC Rcd 712, 723–724 (2014) (identifying co-channel operations in the tables as +5 MHz to +1 MHz and adjacent channel operations as 0MHz to -5MHz).

[90] *See Incentive Auction R&O*, 29 FCC Rcd at 6605, para. 83.

to address the costs and benefits of our proposal and the alternative described above, including the potential impact on broadcast and wireless licensees, as well as on wireless microphones and unlicensed devices,[91] and to discuss how we should prioritize objectives where multiple outcomes are possible.

3. Standard for Limiting Market Variation

37. In the *Incentive Auction R&O*, we established that the 600 MHz Band Plan will allow for market variation, while recognizing that it is important to limit the potential for inter-service interference and maintain a generally consistent band plan nationwide by applying a "near-nationwide" standard.[92] We therefore propose to limit the amount of market variation associated with the initial spectrum clearing target by limiting impairments on a nationwide aggregated basis to less than 20 percent of "weighted-pops," as described in the following paragraphs. We believe that our proposed approach will promote the central goal of a successful auction that allows market forces to determine the highest and best use of spectrum. By accommodating market variation, it will ensure that broadcasters have the opportunity to participate in the reverse auction in markets where interest is high, and avoid the need to restrict the licenses offered in the forward auction to the number available in the most constrained market. At the same time, by strictly limiting the total amount of market variation associated with a clearing target, it will limit the potential for inter-service interference and help 600 MHz Band licensees achieve economies of scale when deploying their new networks. As explained below, our proposed approach also takes into account the relative costs and benefits of impairing licenses in different PEAs.

38. For purposes of applying the near-nationwide standard, we propose to measure the impact of potential impairments in terms of "weighted-pops," weighting the affected population in a license area by an index of area-specific prices from prior auctions.[93] Under this approach, for a given clearing target and assignment of TV stations to channels, we calculate the percentage of the population impaired in every PEA for each license using the county level data generated using the measurement approach set forth above.[94] We multiply that percentage by the weighted-pops associated with the PEA to determine the "impaired weighted-pops" for the license.[95] To calculate a nationwide total of impaired weighted-pops, the impaired weighted-pops for all licenses associated with a clearing target will be added together. This total will then be divided by the nationwide total number of weighted-pops for all licenses associated with that clearing target to determine whether the maximum aggregate nationwide impairment

[91] The Commission has proposed technical criteria for wireless microphones and unlicensed devices for each possible guard band size (7, 9, or 11 megahertz). *See Part 15 NPRM*.

[92] *See Incentive Auction R&O*, 29 FCC Rcd at 6606, para. 85 n.275.

[93] The same weighted-pops amount will be applied for each spectrum block in a PEA. This index is the same index used for calculating bidding units as discussed below in § V.B.1 (Bidding Units) before applying the proposed decile approach. Both indices are provided in Appendix F. Consistent with our proposal for bidding units, we propose to incorporate the final results of the auction of AWS-3 licenses (Auction 97) when calculating the indices. We seek comment on whether we should group the index by deciles for purposes of applying the near-nationwide standard as we propose for calculating bidding units.

[94] *See* § III.A.1 (Measuring the Extent of Potential Impairments). For example, suppose that for a possible clearing target and assignment of stations to channels, two out of five of the counties in the downlink portion of a license area are considered "impaired." Suppose further that the populations of the impaired counties are 15,000 and 30,000 and the total population of the license area is 100,000. We sum the populations of the impaired counties (15,000 + 30,000 = 45,000) and divide it by the total population (45,000/100,000 = .45). Therefore we consider this license to have 45 percent of its population impaired.

[95] For example, suppose for a given clearing target and assignment of stations to channels in the 600 MHz Band, license PEA005-A is 45 percent impaired—measured using the mathematical constraints described in § II.A.1 (600 MHz Band Plan) and detailed in Appendix B. The weighted-pops associated with PEA005 are 8,456,976 (see Appendix F). To calculate the "impaired weighted-pops" for that license, we multiply 0.45 * 8,456,976 = 3,805,639.2.

standard or threshold is satisfied.[96] We believe that our proposed approach to applying a threshold provides for flexibility in balancing the population that will be affected by potential inter-service interference with the number of markets that will be affected, and accounts for the relative value of the market to wireless providers based on past auction prices.[97] Alternatively, we seek comment on whether we should use a metric that does not weight population by the amount of bandwidth and/or by a price index. For example, an alternative metric could require that 80 percent of the U.S. population (or price-weighted population) must be in areas not considered impaired, regardless of the quantity of impaired spectrum in any one area.

39. We propose to set the near-nationwide standard at less than 20 percent. Under this standard, a clearing target could be chosen only if 80 percent or more of the weighted-pops in the targeted amount of spectrum nationwide is considered unimpaired according to our methodology.[98] If the provisional TV channel assignment plan associated with a clearing target results in potential impairments to 20 percent or more of the total number of weighted-pops nationwide, the auction system would consider a lower clearing target. We believe that a less than 20 percent limit is appropriate to avoid reducing the amount of spectrum that will be available in most areas nationwide while ensuring that, for any given clearing target, 600 MHz Band Plan licenses generally will not be affected by inter-service interference. As noted above, our proposal to use weighted-pops also will help to ensure that most of the spectrum in the most heavily-weighted PEAs remains unimpaired.

40. We seek comment on these proposals. We also invite comment on alternatives to our proposed near-nationwide standard. For example, should we set a lower standard? Should we require that certain PEAs, or a specific number of PEAs (e.g., 40 of the top 50 PEAs as measured by total population), not have any Category 2 licenses in order to choose a clearing target?[99] We encourage commenters to address the trade-offs involved in any alternative approach that they advocate.

4. Clearing Target Optimization Procedure

41. Consistent with the *Incentive Auction R&O*,[100] the process we will use to set the initial clearing target will incorporate mathematical optimization techniques. The proposed optimization procedure is set forth in detail in Appendix C and summarized here. This process will also provisionally assign television stations to channels under an assignment plan that best meets the rules and objectives proposed below. Once a clearing target is set, the resulting provisional assignment plan of television stations to channels in the television bands will be used by the reverse auction system as the initial tentative assignment, and information about license impairments due to stations assigned in the 600 MHz Band will be used in the forward auction portion of the stage.

42. The proposed procedure will apply a number of rules or constraints that any provisional assignment plan must satisfy. It will ensure that any assignment plan includes a permissible channel in its

[96] This process is different from—and happens before—the process used to determine the impairments for licenses offered in the forward auction, which is discussed in § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses). Like the procedure for measuring the extent of potential impairments described above, this proposed approach would not double-count the population of a PEA that is subject to potential inter-service interference from multiple stations. *See* note 77 and accompanying text.

[97] Some markets are likely to be more valuable than others (e.g., New York) and under this weighted-pops approach, will be weighted more heavily. This weighting will help to ensure that most of the spectrum in the most heavily-weighted PEAs remains unimpaired.

[98] *See* § III.A.1 (Measuring the Extent of Potential Impairments).

[99] A Category 2 license, as explained below in § V.A.2. (Forward Auction Inventory: Determining Categories of Generic Licenses), is any license with potential impairments that affect greater than 15 percent but less than or equal to 50 percent of the population.

[100] *Incentive Auction R&O*, 29 FCC Rcd at 6709–10, para. 330.

pre-auction band for every television station that is not participating in the reverse auction. The procedure will apply the technical repacking constraints established in the *Incentive Auction R&O*,[101] taking into account any fixed constraints specific to an area or a channel that would prevent an assignment of a station to a channel, as well as all other stations that cannot be located on a co- or adjacent channel. The procedure also will determine an initial assignment of participating stations to relinquishment options consistent with the station's initial commitments made during the application process as described in the reverse auction section, and will attempt to assign as many stations as possible to their preferred option.[102]

43. We propose that the primary objective of the proposed clearing target optimization procedure will be to minimize the total impaired weighted-pops nationwide, consistent with our proposal above.[103] The optimization procedure will measure the percentage of population impaired in a PEA for a given television station and channel assignment using the measurement approach set forth above[104] and described in more detail in Appendix C. Thus, the optimization procedure will determine a feasible assignment of television stations to channels in the remaining TV bands where possible and, as necessary, assign stations to channels in the 600 MHz Band so as to minimize potential impairments to 600 MHz Band licenses.

44. In addition to these primary rules and objectives, the procedure could consider additional criteria in setting a clearing target. For example, should the procedure apply criteria to account for operation of the proposed dynamic reserve price process?[105] Should it apply criteria to increase the likelihood of satisfying the final stage rule?[106] We seek comment on whether to apply additional criteria in setting a clearing target. We ask commenters to keep in mind that the tradeoff from stricter requirements may be to move to a lower clearing target, where fewer licenses will be available and fewer stations will be needed to relinquish spectrum usage rights.

45. Any channel assignment plan that satisfies the primary rules and objectives proposed above also may be modified for secondary objectives, provided that it does not violate our less than 20 percent standard for impairments. Should we incorporate a secondary objective that would favor an initial channel assignment with at least a minimum level of vacancy in the broadcasting portion of the band, so as to give the auction system more flexibility to find feasible assignments during the bidding rounds, potentially avoiding the need to move to a lower clearing target because we failed to meet the final stage rule?[107] We seek comment on possible secondary objectives to be applied in the optimization procedure. Because the optimization procedure may identify more than one possible assignment plan that satisfies the primary rules and objectives, we particularly seek comment on how the procedure should choose between plans to best meet the goals of the incentive auction. For example, we ask commenters to consider whether the procedure should favor an assignment in which the number of 600 MHz Band

[101] *Id.* at 6619–20, para. 114.

[102] For example, if a station's preferred option is a move from the UHF to the High-VHF band, the procedure will seek to ensure that such a move is feasible for the station.

[103] *See* § III.A.3 (Threshold for Limiting Market Variation).

[104] See § III.A.1 (Measuring the Extend of Potential Impairments).

[105] *See* § IV.C.1.c (Dynamic Reserve Prices in Early Rounds of the First Stage).

[106] *See* § III.B (Final Stage Rule).

[107] *See* § IV.C.1.c (Dynamic Reserve Prices in Early Rounds of the First Stage) (discussing how we propose to consider changes to the channel assignment during dynamic reserve price procedures). In this context, should we consider requiring that the 20 percent nationwide standard should include sufficient vacancy to accommodate additional impairments created during the DRP procedures?

blocks, or the number of Category 1 blocks,[108] is most nearly the same in the largest number of PEAs, in order to promote the geographic contiguity of the band plan. Alternatively, we invite comment on whether the optimization procedure should try to minimize the number of PEAs—or the number of particular PEAs—in which Category 2 blocks outnumber Category 1 blocks, to avoid having PEAs with significantly fewer Category 1 blocks than are available in most areas nationwide.

B. Final Stage Rule

46. The final stage rule we adopted in the *Incentive Auction R&O* incorporates an aggregate reserve price based on the bids in the forward auction.[109] Satisfaction of the rule conditions will cause the current stage to become the final stage for the auction's clock bidding rounds.[110] The rule has two components, both of which must be satisfied.[111] We seek comment below on determining the price and spectrum clearing benchmarks for the first component of the rule, as well as on other rule implementation issues.

1. First Component: Average / Aggregate Prices in Forward Auction

47. We propose an average price per MHz-pop[112] benchmark of $1.25 for spectrum offered in the largest 40 PEAs by population in the forward auction and a forward auction spectrum benchmark of 70 megahertz, corresponding to a broadcast spectrum clearing target of 84 megahertz.[113] We also seek comment on our proposal to consider a subset of those licenses in applying the first component of the final stage rule.

48. The first component ensures that winning bids for the licenses in the forward auction reflect competitive prices.[114] We explained in the *Incentive Auction R&O* that "the first component of the reserve price will be satisfied if, for a given stage of the auction:

- the average price per MHz-pop for licenses in the forward auction meets a price benchmark that will be set by the Commission in the pre-auction process, *or*

[108] *See* § III.A.1 (Measuring the Extent of Potential Impairments) (proposing a threshold for determining whether a county is "impaired" for the purposes of setting an initial clearing target). A Category 1 license, as explained below in § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses), is any license with potential impairments that do not exceed 15 percent of the population.

[109] *See Incentive Auction R&O*, 29 FCC Rcd at 6713–14, para. 343.

[110] As discussed in more detail below, satisfaction of the final stage rule does not conclude the bidding process; rather, the clock phase bidding process will continue until there is no more demand for spectrum blocks. *See* § V.C.5 (Forward Auction – Stopping Rule).

[111] We note that the first and second components are complementary and not cumulative. The auction must satisfy both components, but it need not raise sufficient proceeds to satisfy the first *in addition to* the second. Rather, the same bids and proceeds can be considered when satisfying each component. We discuss further below which bids will be considered and how they will be considered when evaluating whether the final stage rule is satisfied.

[112] The term "MHz-pop" is defined as the product derived from multiplying the number of megahertz associated with a license by the population of the license's service area (i.e., PEA, for the 600 MHz Band, specifically).

[113] *See* § III.B.1 (First Component: Average / Aggregate Prices in Forward Auction) at para. 51 (proposing to determine whether the first component of the final stage rule is satisfied based on the average prices per MHz-pop for the 40 largest PEAs by population).

[114] *Incentive Auction R&O*, 29 FCC Rcd at 6712–13, paras. 338–41. *See* 47 U.S.C. § 309(j)(3)(C) (in designing competitive bidding methodologies, "the Commission . . . shall seek to promote . . . recovery for the public of a portion of the value of the public spectrum resource made available for commercial use[.]").

- the total proceeds associated with licenses in the forward auction exceed the product of the price benchmark, the [forward auction spectrum] benchmark, and the total number of pops for those licenses."[115]

The determination of the average price and spectrum clearing benchmarks is therefore essential to the implementation of the first component of the final stage rule.

49. Setting an average unit price benchmark of $1.25 per MHz-pop in the largest 40 PEAs by population will accomplish our goal of "assur[ing] that prices for licenses in the forward auction reflect competitive values without reducing the amount of spectrum repurposed for new, flexible-use licenses."[116] The closest comparable spectrum auction—Auction 73—generated an auction-wide average price per MHz-pop of $1.28 and an average price among paired spectrum blocks of $1.36. Since that auction closed in early 2008, spectrum prices generally appear to have increased, although the growth rate cannot be validated based on comparable data due to the absence of final results for a large-scale auction in that period.[117] Moreover, because the prices of 600 MHz Band licenses will be determined by the forward auction bidding, we believe that any aggregate reserve price we set should reflect a "floor" and not a "ceiling" of the "competitive values" of these licenses, in order to provide sufficient margin to account for the inherent price uncertainty present in any auction.

50. We propose to set the forward auction spectrum benchmark to correspond with the spectrum recovery scenario in which we clear 84 megahertz of broadcast TV spectrum and offer licenses for 70 megahertz of spectrum in the forward auction. The spectrum benchmark will be used as part of the alternative formulation of the final stage rule's first component, which "recognizes that if the incentive auction repurposes a relatively large amount of spectrum for flexible uses, per-unit market prices may be expected to decline consistent with the increase in available supply."[118] An 84 megahertz broadcast TV spectrum clearing target, which would repurpose all of the spectrum between TV channel 37 and the 700 MHz Band and provide 70 megahertz of spectrum in the forward auction, would promote our competitive goals by enabling multiple bidders to obtain low-band spectrum. Therefore, we believe that this threshold is appropriate for the forward auction spectrum benchmark.

51. We propose to determine whether the first component of the final stage rule is satisfied based on the average prices for a subset of PEAs likely to be subject to the greatest level of demand. We propose to include in the subset the 40 largest PEAs by population because they cover geographic areas that have usually generated the highest average prices per MHz-pop in prior spectrum license auctions. In previous auctions, prices for licenses in these "high-demand" areas have accounted for a substantial fraction of total auction revenues, and further, licenses in "high-demand" areas tend to reach their final prices well before bidding stops on all licenses, making these markets a good leading indicator of final auction revenues.[119] Further, using this subset of PEAs will promote a speedy auction by enabling the auction system to determine quickly when the final stage rule will not be met necessitating a new stage with a lower clearing target. We seek comment on this use of "high-demand" PEAs and the proposed definition of this "high-demand" subset.[120]

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[115] *Incentive Auction R&O*, 29 FCC Rcd at 6712, para. 340.

[116] *Id.* at 6714, para. 343 (footnotes omitted).

[117] We note that Auction 97 is currently ongoing and may provide additional data to inform our ultimate decision on this matter.

[118] *Incentive Auction R&O*, 29 FCC Rcd at 6713, para. 342.

[119] See the auction results from Auction 66, Advanced Wireless Services (AWS-1), and Auction 73, 700 MHz Band, available at http://wireless.fcc.gov/auctions.

[120] The subset of "high-demand" areas that have generated the highest average price per MHz-pop in prior spectrum license auctions are used in several other contexts in this Public Notice. *See* §§ III.B.1 (First Component: Average / (continued….)

52. We further propose, in considering whether average prices meet the benchmark, to consider only bids for spectrum blocks in Category 1.[121] Limiting our consideration of blocks in this manner is consistent with our proposed use of data from other auctions in determining the relevant average price, as the licenses in those prior auctions were not impaired in a manner comparable to the proposed licenses in Category 2.

53. As explained in more detail in Appendix G, applying our proposals to the first component of the final stage rule, the first component will be satisfied if the average price per MHz-pop for Category 1 licenses in "high-demand" PEAs in the forward auction equals or exceeds $1.25 per MHz-pop at clearing targets at or below the benchmark clearing target. For clearing targets above the benchmark clearing target, we propose to consider current auction proceeds for all licenses when comparing to the proceeds that would be generated by the benchmark price for "high demand" PEAs and the benchmark clearing target. This simplifies the evaluation of the formulation since we will compare a number publicly announced at the end of every round (the total forward auction proceeds) to a fixed number known in advance (the product of the price and spectrum benchmarks that we adopt, and the total number of pops covered by licenses in "high-demand" PEAs).[122] Under this formula, the first component of the final stage rule may be satisfied even if the overall average price per MHz-pop in the "high-demand" PEAs fails to meet the proposed $1.25 price benchmark.

54. In evaluating whether the first component of the final stage rule is satisfied, we also propose not to take into account any adjustments to final clock prices. Thus, we propose to rely on gross bids, rather than bids net of individual bidders' bidding credits or any adjustments for impairments.[123] The first component is intended to assess whether the bids reflect competitive prices for the licenses. We tentatively conclude that the clock prices will adequately measure competitive prices for the licenses in the proposed Category 1, even though the full amount of the clock price may not be collected from every winning bidder. Moreover, since winning bidders will not yet be determined at the time the final stage rule is met, it will not be clear which licenses will be subject to bidding credits. The clock price reflects a common metric for pricing the licenses and is appropriate to use in assessing whether the first component of the final stage rule has been satisfied.

2. Second Component: Covering Costs

55. The second component of the final stage rule requires that the proceeds of the forward auction be sufficient to meet mandatory costs and expenses set forth in the Spectrum Act and any Public Safety Trust Fund amounts needed in connection with FirstNet. Given the purpose of assuring sufficient proceeds for specified purposes, we propose a conservative approach to estimating the proceeds resulting from forward auction bids for evaluating whether the second component is met, as detailed below.

56. The Spectrum Act requires that the forward auction generate proceeds sufficient to pay three types of expenses: payments to winning bidders in the reverse auction;[124] the Commission's relevant administrative costs of the auction; and an estimate of broadcaster relocation costs eligible for

(Continued from previous page)
Aggregate Prices in Forward Auction); III.C.2 (Implementation of Extended Round); V.D (Bidding Procedures in Assignment Phase).

[121] In the forward auction section of this Public Notice, we propose to offer spectrum blocks in two categories of generic licenses for bidding in the forward auction. Specifically, we define a Category 1 license as any license with potential impairments that affect zero to 15 percent of the population of a specific PEA and as Category 2, any license with potential impairments that affect greater than 15 percent but less than or equal to 50 percent of the population). *See* § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses).

[122] *See* § V.A.1 (Forward Auction Information Available During the Auction).

[123] *See* § V.D.3 (Acceptable Bids and Bid Processing).

[124] The total amount of this expense will decline from stage to stage in the auction as the amount of spectrum to be cleared is reduced.

reimbursement.[125] In addition, the Commission concluded that the forward auction proceeds also must cover a fourth expense: any Public Safety Trust Fund amounts still needed to provide funding for FirstNet as contemplated in the Spectrum Act.[126]

57. The reverse auction itself will determine the amount of the first above-stated expense. With regard to the second expense, we cannot yet provide a reliable estimate of the amount of the Commission's expenses in conducting the incentive auction[127] because there is still much work to do before we can conduct the auction. We therefore propose here to provide an estimate in the *Procedures PN* and a maximum percentage by which the final amount might vary from that estimate. The final amount for purposes of the final stage rule would be provided no later than the commencement of bidding. The flexibility in this approach will enable the Commission to discharge its statutory obligation to recover the relevant expenses from auction proceeds while providing adequate information to potential and actual auction participants to make informed decisions about participating and bidding.[128]

58. With regard to the third expense that must be covered, the actual amount that will be needed to reimburse broadcasters from the TV Broadcaster Relocation Fund ("Reimbursement Fund") will not be known until sometime after the auction. In any event, the Spectrum Act provides that the forward auction must generate proceeds sufficient to meet the Commission's *estimate* of the total expenses, as opposed to the actual amount.[129] We propose to estimate this amount at $1.75 billion, the maximum amount that the Spectrum Act permits the Commission to deposit in the Reimbursement Fund. We consider setting this expense at the maximum amount to be prudent in light of the difficulty of estimating the amount in advance and the substantially conflicting range of estimates suggested in the record to date.[130]

59. With regard to the fourth expense, we propose to announce in the *Procedures PN* any amount needed in the Public Safety Trust Fund to provide funding for FirstNet. The maximum amount of the Public Safety Trust Fund deposits to be made available to FirstNet for build out under the Spectrum Act is $7 billion.[131] The amount that the incentive auction must provide will depend on the proceeds generated for FirstNet by the auction of AWS-3 licenses (Auction 97) and whether, once Auction 97 has been concluded, there are any Public Safety Trust Fund amounts still needed to provide funding for FirstNet as contemplated in the Spectrum Act. As discussed in the *Incentive Auction R&*O, we are optimistic that upon the conclusion of Auction 97, it will be clear that deposits to the Public Safety Trust Fund will be sufficient to fully fund requisite amounts for FirstNet.[132]

60. We propose to take into account discounts that may affect actual amounts paid by winning bidders when evaluating whether the second component of the final stage rule is satisfied. Given the second component's purpose of assuring sufficient proceeds for specified purposes, we believe a more conservative approach to estimating the ultimate proceeds resulting from forward auction bids is

[125] *See* Spectrum Act § 6403(c)(2).

[126] *Incentive Auction R&O*, 29 FCC Rcd at 6712, para. 341.

[127] *See* Spectrum Act § 6403(c)(2).

[128] We note that this process will provide a maximum potential amount by the date of the *Procedures PN* before parties will apply to participate in the auction and the actual amount before bidding commences.

[129] *See* Spectrum Act § 6403(c)(2).

[130] We note that the range of potential amounts may vary from stage to stage of the auction, as the number of relocated broadcasters not receiving incentive payments and other parties eligible for reimbursement from the Reimbursement Fund changes. This variability is another reason to adopt a conservative approach and estimate the amount at the maximum permitted by the statute.

[131] *See* 47 U.S.C. § 1457(b).

[132] *Incentive Auction R&O*, 29 FCC Rcd at 6714, para. 345.

appropriate than for the first component of the final stage rule. Accordingly, in determining whether the second component has been satisfied, we propose to take into account any discounts based on impairments, as well as discounts based on small business bidding credits applicable to particular bidders.

61. As discussed in connection with prices in the forward auction, a final license price may be adjusted to take into account the extent of any impairments that exist in the license.[133] Accordingly, we propose here that we use the available information regarding the extent of the impairments when evaluating the final stage rule to discount the current clock price by the impairments. Doing so effectively will apply the same percentage discount that will be applied to the final price for the license, presuming the final stage rule is satisfied. The estimate used will be the lowest amount possible for the final price, which ultimately may be larger based on bidding in clock rounds and any additional bidding on the license in the assignment phase.

62. It is more difficult to estimate the final effect of small business bidding credits on auction proceeds prior to the conclusion of the auction. In order to do so, we propose that the auction system will presume that the bidder with the largest bidding credit will win the blocks it is bidding on and then proceed to the bidder with the next largest bidding credit and so on, until there are no more blocks left.[134] Moreover, we propose to presume that the bidders with the largest bidding credits will win the blocks that are least impaired and thus, subject to the least adjustment based on the extent of impairment. We believe that this approach is appropriate in light of the purpose of the second component.[135] We note that a more conservative approach would be to discount all bids by the largest bidding credit claimed by any bidder in the auction, thereby assuring that the final winning bids could not be any lower than the estimate. However, we do not propose to take this more conservative approach because it likely would overestimate substantially the discounts on final winning bids.[136]

63. Unlike other bidding credits, winning bidders initially apply for Tribal lands bidding credits after the close of bidding, and so the amount of any potential Tribal lands bidding credits after the close of bidding, and so the amount of any Tribal lands bidding credits will not be known until after the auction, making it very difficult to assess their effect on auction proceeds. In past auctions, the Commission addressed this difficulty with a rule (section 1.2110(f)(3)(v)) that limits any amounts disbursed as Tribal lands bidding credits based on the available funds that exceed the relevant reserve price.[137] The rule thus allows the award of Tribal lands bidding credits so long as the awards do not reduce the amount of funds otherwise required by a reserve price. The second component of the final stage rule specifically functions to assure that auction proceeds will equal or exceed the total of the four expenses that the second component reflects. Accordingly, we propose to apply section 1.2110(f)(3)(v) with respect to the amount of the second component to preclude the possibility that the post-auction

[133] *See* § V.D.3 (Acceptable Bids and Bid Processing).

[134] Under our proposed approach, the auction system must evaluate whether the final stage rule has been satisfied without knowing whether or not a small business bidder ultimately will win a license and apply its bidding credit to the final bid. For example, in a given PEA with six available licenses, bidders could seek eight licenses in a given round, so we will not know which bidders ultimately will win. One of those bidders may be entitled to a 15 percent bidding credit and seeking one license and another may be entitled to a 25 percent bidding credit and also seeking one license. Ultimately, both, either, or neither of these bidders might win one or more of licenses in that PEA.

[135] Details of the proposed calculations are provided in Appendix G.

[136] So long as any active bidder qualified for a 25 percent small business bidding credit, this more conservative approach would require discounting all the bids by 25 percent, even though it may be completely implausible that one such bidder would win all the licenses.

[137] *See* 47 C.F.R. § 1.2110(f)(3)(v). This rule is applicable in, among others, "any auction with reserve price(s) in which the Commission specifies that the provision will apply." *Id. See, e.g., Auction of Advanced Wireless Licenses Scheduled for June 29, 2006*, AU Docket 06-30, Public Notice, 21 FCC Rcd 4562, 4625–27, paras. 251–56.

award of Tribal lands bidding credits could reduce auction proceeds below the total of the four expenses. Under this proposal, so long as there are sufficient proceeds to fund both the four expenses and any Tribal lands bidding credits, the credits will be awarded in full. If the proceeds are not sufficient to cover both the four expenses and any such Tribal lands bidding credits, the credits will be reduced proportionally as provided in section 1.2110(f)(3)(v) so that the four expenses will be covered in full and any credits awarded will use only proceeds in excess of the total of the four expenses. Commenters objecting to this proposal should specify an alternative approach to prevent total auction proceeds from falling below the amount of the final stage rule's second component.

C. Stage Structure

64. In the *Incentive Auction R&O*, we decided that the incentive auction will begin with reverse auction bidding followed by forward auction bidding in the initial stage and that, if necessary, bidding will continue over multiple stages, each including reverse and forward auctions, for successively lower clearing targets, until the final stage rule is met.[138] Here we seek comment on remaining issues related to the stage structure.[139] In particular, we propose procedures to determine whether the auction is in its final stage. We also propose procedures for moving to an extended round if certain conditions are met, as well as steps for transitioning to a new stage if necessary.

1. Sequence of Reverse and Forward Auctions

65. Consistent with our decision in the *Incentive Auction R&O* regarding the first stage, we intend that in any stage, the reverse auction will occur first, to be followed by the forward auction.[140] Under this proposal, the reverse auction will run until the reverse auction stopping rules are met.[141] The forward auction will commence once the reverse auction has stopped.

66. We seek to provide the minimum necessary time between the reverse and forward auctions in any stage. We therefore propose to start forward auction bidding in the initial stage on the second business day after the close of bidding in the stage's reverse auction. With respect to any subsequent stages, we propose to start forward auction bidding on the next business day after the close of reverse auction bidding. Before forward auction bidding commences in any stage of the auction, forward auction bidders will be informed of the number of blocks to be offered in each PEA and the degree to which any of those blocks are impaired.[142] We seek comment on this proposal. If commenters suggest a longer interval, we ask that they provide details on why a longer period is desirable.

2. Final Stage Determination and Implementation of Extended Round

67. We propose to evaluate whether the final stage rule is met throughout forward auction bidding in order to determine as quickly as possible whether the auction is in its final stage. This approach will allow the auction system to implement procedures triggered by satisfaction of the rule as early as possible and promote the speedy conclusion of the overall auction process.[143] Specifically, the auction system will evaluate whether forward auction proceeds are sufficient to satisfy the final stage rule

[138] *Incentive Auction R&O*, 29 FCC Rcd at 6708, para. 326.

[139] *Id*.

[140] *See Incentive Auction R&O*, 29 FCC Rcd at 6708, para. 326.

[141] *See* § IV.C.3 (Reverse Auction – Stopping Rule).

[142] The 600 MHz Band Plan for the forward auction and any potential impairments to 600 MHz Band licenses in the plan will be determined at the time the spectrum clearing target for a stage is determined. The impairments will not be final for the initial stage until after DRP mode is off and any adjustments have been made. *See* § IV.C.1.c (Dynamic Reserve Prices in Early Rounds of the First Stage). In any subsequent stages, the impairments will be final before the start of the reverse auction.

[143] *See* § V.A.3 (Implementation of the Spectrum Reserve).

as part of the bid processing that occurs after each round of forward auction bidding. As prices and associated auction proceeds increase during the forward auction, the auction system will have the needed information to evaluate whether all required conditions of the final stage rule have been met.

68. We also propose to implement an "extended round" in which bidders will have the opportunity to increase their bids to make up any shortfall in the final stage rule under the circumstances we describe here.[144] As described in the *Incentive Auction R&O*, the purpose of an extended round is to attempt to satisfy the final stage rule without moving to a new stage and lower clearing target.[145] In the absence of an extended round, the current stage of the auction would be deemed to have failed and the auction would move to a new stage with a reduced clearing target. Proposed procedures for the extended round are discussed in more detail below.[146]

3. Transition to Any Subsequent Stages

69. After the conclusion of a stage that has ended without satisfying the final stage rule, and prior to beginning of any subsequent stage, we propose that the auction system will announce the new bidding schedule, including the date and time that bidding will start in the reverse auction portion of the next stage. If the auction must move to a new stage, we propose to set the clearing target for the next stage as the next lowest clearing target.[147] Alternatively, we seek comment on whether the benefits outweigh the costs of skipping some clearing targets. For example, should we skip the 108 MHz clearing target when moving to a lower clearing target because under that scenario two downlink blocks are separated from the remaining downlink blocks by channel 37?

D. After the Final Stage Rule Is Satisfied

70. When forward auction bidding satisfies the final stage rule, that stage of the auction will be the final stage. Meeting the final stage rule will not "close" the forward auction, however, as long as demand exceeds supply in any PEA. Rather, bidding will continue until demand does not exceed supply for all blocks in all PEAs. When this clock phase of the auction ends, the next step in the forward auction will be the assignment phase in which successful forward auction bidders will bid for frequency-specific licenses equal to the number of blocks they won in the clock phase.[148] The proposed assignment phase is described in more detail below.[149] We propose that bidding in the assignment phase of the forward auction will start five business days after the auction system provides more detailed information about the assignment phase.[150] We recognize that forward auction bidders will need a period of time to develop bidding strategies for the assignment phase, particularly since this is the first time the Commission has conducted a frequency assignment phase. However, our goal is to conclude the incentive auction as efficiently as possible. Thus, we believe the interval we propose before beginning the assignment phase should be adequate.

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[144] The *Incentive Auction R&O* allows for but did not require implementation of an extended bidding round. *Incentive Auction R&O*, 29 FCC Rcd at 6778, para. 512.

[145] *See Incentive Auction R&O*, 29 FCC Rcd at 6778, para. 512.

[146] *See* § V.C.4 (Extended Round).

[147] We discuss other aspects of transitioning to any subsequent stage in the reverse and forward auction sections below. *See* §§ IV.D (New Stage Procedures); V.C.6 (New Stage Transition).

[148] In the forward auction, upon satisfaction of the final stage rule the auction system will implement the spectrum reserve and clock phase bidding will continue until the stopping rule is satisfied. Procedures for these steps and for the forward auction assignment phase are proposed below. *See* § V.D (Bidding Procedures in the Assignment Phase). Procedures for final television channel assignments also are proposed below. *See* § IV.E (Determining a Final Television Channel Assignment Plan).

[149] *See* § V.D (Bidding Procedures in the Assignment Phase).

[150] *See* Appendix H.

IV. PROPOSED REVERSE AUCTION PROCEDURES

A. Relinquishment Options and Information Available

71. We explained in the *Incentive Auction R&O* that the purpose of the reverse auction is to identify broadcasters willing to relinquish some or all of their spectrum usage rights, and the corresponding incentive payments those broadcasters will require, in order to clear a stage-specific spectrum clearing target.[151] To this end, we adopted a descending clock auction format, relinquishment options, and a repacking methodology that will be incorporated into the reverse auction system.[152] Bidding will take place in a series of rounds in which a bidder will be presented with price offers for each of its valid options for relinquishing spectrum usage rights. In this section, consistent with the pre-auction process we outlined in the *Incentive Auction R&O*, we seek comment on procedures to implement the various relinquishment options we established. We also address the information that will be made available to bidders and to the public during the reverse auction bidding process.

1. Options for Relinquishing Spectrum Usage Rights

72. We propose to implement the relinquishment options established in the *Incentive Auction R&O* by giving each bidder the opportunity to bid for the various options that are open to it given the station's pre-auction band location (UHF, High-VHF, or Low-VHF).[153] Specifically, a licensee with a UHF station can bid to relinquish all spectrum usage rights and go off-air, or to move to a High-VHF channel or a Low-VHF channel. A licensee with a High-VHF station can bid to go off-air or to move to a Low-VHF channel. A licensee with a Low-VHF station can bid only to go off-air. To incorporate the channel sharing option into the bidding process, we propose that a participant that wishes to relinquish rights in order to share another licensee's channel will bid to go off-air, following the same bidding procedures as bidders that wish to go off-air without retaining a license. Throughout the auction, all bidders will maintain the option of declining to accept a price offer for an option, indicating that at this price or lower, they choose to drop out of the bidding.

73. We propose to treat the various options available to broadcasters, from license relinquishment to remaining on the air in their pre-auction bands, as a hierarchy in order of relinquishment and value to the auction, as illustrated below:

UHF Station	High-VHF Station	Low-VHF Station
Remain in UHF		
↑		
Move to High-VHF	Remain in High-VHF	
↑	↑	
Move to Low-VHF	Move to Low-VHF	Remain in Low-VHF
↑	↑	↑
Go Off-Air	Go Off-Air	Go Off-Air

[151] Above we address procedures for setting an initial clearing target and for reducing the target in subsequent stages as necessary to meet overall incentive auction reserve price conditions. *See* § III.A (Setting an Initial Spectrum Clearing Target and Determining Impairments).

[152] *Incentive Auction R&O*, 29 FCC Rcd at 6753, 6756, paras. 449, 457 & n.1314. *See also* Spectrum Act § 6403(b)(2).

[153] *See Incentive Auction R&O*, 29 FCC Rcd at 6723–30 at paras. 365–83.

With regard to a UHF station, bidding to go off-air would be first in the hierarchy, followed by a move to Low-VHF, then to High-VHF, and finally, remaining on the air in its pre-auction band. Bidding to go off-air would be first in the hierarchy for High-VHF and Low-VHF stations as well, followed by a move to Low-VHF (for High-VHF stations only), and then remaining on the air in their respective pre-auction bands. We will later refer to this ordering in addressing several of our proposed reverse auction implementation procedures.

74. We propose that a bidder will not be permitted to bid for options that would involve greater relinquishments than the most recent option selected.[154] Under our proposal, the auction system will permit a bidder to move up (from greater relinquishment to less), but not down. For example, assuming a bidder with a UHF station selects all three relinquishment options in its application and then indicates its preferred option is to go off-air, the auction system will allow the bidder to choose the option of moving to a Low-VHF channel (if there is a vacancy in the Low-VHF band) later in the bidding, but not vice versa. If and when the auction system accepts that change in the bidder's preferred option, the bidder will not be allowed to request to go off-air later because that would represent a move down in the hierarchy of options. Likewise, selecting the option of moving to a High-VHF bid would preclude later bidding to go off-air. We propose this approach so that the auction system can calculate price offers based on consistent indications of bidder preferences, which will simplify bidding choices and lead to a speedier reverse auction.[155]

75. We propose to treat a channel-sharing bid as we do a bid to go off-air because, from the perspective of the auction system, a channel sharing bid is identical to a license relinquishment bid. Under this proposal, a bidder that seeks to relinquish its rights and share a channel with another broadcaster will be required to enter into a channel sharing agreement before the bidding, and will continue to hold a broadcasting license following the auction, but will not be subject to different bidding procedures during the auction than other participants that are going off the air. A broadcaster that relinquishes spectrum usage rights in order to share a channel will have its post-auction channel determined according to its contract with its channel sharer—that is, another broadcaster that remains on-air. We note that parties to a channel sharing agreement bear the consequences of any defects in the agreement or the failure of either party to perform pursuant to its terms. The Commission is not a guarantor or an enforcer of channel sharing agreements.

2. Reverse Auction Information Available During the Auction

76. We propose to limit the disclosure of information regarding bidding during the auction. This proposal is separate and apart from the Commission's statutory obligation to maintain the confidentiality of information regarding the identity of participating broadcasters.

77. Specifically, we propose that the auction system will offer each reverse auction bidder only the prices for options specific to its station(s). Under our proposed approach, therefore, bidders will not know the prices being offered to other bidders.

78. We propose that while the incentive auction is open, the Commission will disclose to the public the current stage status, specifically the stage number and whether or not bidding is still open in the reverse auction for that stage. When bidding in the reverse auction for a stage is closed, the Commission also will disclose to the public the total of reverse auction bids that the forward auction proceeds must satisfy as part of the second component of the final stage rule.[156]

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[154] We note that this restriction applies only during the clock phase bidding and does not apply when establishing the starting point for bidding. *Cf.* § IV.B.4 (Committing to an Initial Relinquishment Option).

[155] Below we further address the proposed details of bidding on multiple bid options. *See* § IV.C.2.b (Multiple Option Bidding).

[156] *See* § III.B.2 (Second Component: Covering Costs).

B. Application to Participate and Commitment to Initial Relinquishment Option

79. In this section, we seek comment on particular aspects of the reverse auction application process. Specifically, we seek comment on information to be provided from potential channel sharers, i.e., stations that may or may not participate directly in the auction and that have agreed to share a channel with an auction participant that relinquishes its spectrum usage rights in the auction. We also seek comment on information to be required from certain participants whose eligibility is uncertain, and from all participants with respect to their exercise of due diligence prior to participating. In addition, we describe how each applicant will identify—and commit to—its initial preferred option among the available options for relinquishing spectrum usage rights.

80. Staff review of applications prior to the auction will provide an opportunity to address any concerns regarding the information. The entire application process will confirm each applicant's eligibility to participate, without unduly limiting participation.[157]

1. Information from Channel Sharing Participants

81. We propose that any auction applicant submitting a channel sharing agreement with its application also be required to submit a separate certification by the channel sharer that the channel sharing agreement submitted is a true, correct, and complete copy of the channel sharing agreement between the parties.[158] This certification must be executed by a party with authority to make such representations on behalf of the channel sharer.[159] We adopted rules in the *Incentive Auction R&O* outlining the information required of an applicant seeking to participate in the auction in order to share a channel after the auction.[160] Under these rules, channel sharers—stations that agree to share their channels after the auction with stations that relinquish rights in the auction in order to channel share—need not apply to participate in the auction. However, they must provide any "necessary" certifications.[161] We believe that the proposed certification is necessary in order to smooth the post-auction transition by helping to assure the accuracy of the channel sharing agreement submitted with the application.

2. Agreement to Escrow, if Necessary for Participation

82. The *Incentive Auction R&O* considered the circumstances of broadcasters that have licenses that have expired or are subject to a revocation order (collectively a "license validity proceeding"), or that have Class A stations subject to a downgrade order, when the license validity proceeding or Class A downgrade order has not become final and non-reviewable by a date prior to commencement of the auction that will be specified in the *Procedures PN*.[162] In those circumstances, the Commission established that the broadcaster is allowed to participate provided that its reverse auction proceeds would be placed in escrow pending the final outcome of the license validity proceeding or

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[157] *Incentive Auction R&O*, 29 FCC Rcd at 6750–52, paras. 442–44. Additional specific details regarding the application process will be addressed in the *Procedures PN*.

[158] *See* 47 C.F.R. § 1.2204(c)(5)(ii) (requiring submission of an executed copy of the channel sharing agreement by the auction participant).

[159] We note that this channel sharing agreement information will be subject to the requirement that the Commission take all reasonable steps necessary to maintain the confidentiality of Commission-held data of broadcast television licensees participating in the reverse auction. *See Incentive Auction R&O*, 29 FCC Rcd at 6749, para. 437.

[160] 47 C.F.R. § 1.2204(c)(5). Details regarding the precise information to be provided to meet these requirements will be set forth in the *Procedures PN* and the final application form.

[161] *Incentive Auction R&O*, 29 FCC Rcd at 6746–47, para. 428.

[162] *See id.* at 6722, para. 363. If the license invalidity determination becomes final between the time a broadcaster is found to be qualified to participate in the reverse auction and commencement of reverse auction bidding, the broadcaster will be excluded from participating in the reverse auction.

order.[163] Similarly, the Commission established that a broadcaster with a pending enforcement matter or a pending license renewal application that raises an enforcement issue is allowed to participate in the reverse auction, on condition that such a broadcaster that no longer would hold any broadcast licenses upon acceptance of a license relinquishment bid agrees that a share of its reverse auction proceeds be placed by the Commission in escrow to cover potential forfeiture costs.[164] We now propose the mechanism for implementing this arrangement in those circumstances where it is appropriate. Specifically, we propose that broadcasters with pending enforcement, license renewal, or other potential eligibility impediments must agree, as part of their application to participate in the auction, that auction proceeds which they otherwise could receive for relinquishing spectrum usage rights will be held by the U.S. Treasury.[165] In addition, all such broadcasters that would not control any other television stations if its bid or bids were accepted must agree to remain subject to the Commission's jurisdiction and authority to impose enforcement or other FCC liability post-auction.[166] We seek comment on this proposal.

83. This proposal implements our determination that such broadcasters may be qualified to participate even though they (a) have uncertain eligibility to participate due to particular circumstances or (b) have certain outstanding potential liabilities to the Commission.[167] More specifically, the Commission provided that a broadcaster that has a license that is subject to pending proceedings that, if resolved against the broadcaster, would make the broadcaster ineligible to participate, might become qualified to bid if the broadcaster agrees to have the full amount of any incentive auction proceeds it might win held by the U.S. Treasury, pending resolution of the outstanding proceedings.[168]

84. The Commission also concluded that a broadcaster might participate in the reverse auction even though the relinquishment of its broadcast spectrum usage rights might otherwise limit the Commission's ability to recover potential liabilities to the Commission, provided that the broadcaster agrees that some of any incentive payment would be held by the U.S. Treasury to cover potential forfeiture amounts.[169] In the second case, when such a broadcaster is notified of its eligibility to participate in the reverse auction after filing an application, the Wireless Telecommunications, Media, and Enforcement Bureaus will provide that broadcaster with information about any pending enforcement matter that cannot be resolved before the reverse auction.[170] In addition, the Bureaus will indicate the amount of reverse auction proceeds that will be held should the broadcaster relinquish its license(s) as a result of the auction and therefore otherwise no longer be subject to the Commission's jurisdiction.

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[163] *Incentive Auction R&O*, 29 FCC Rcd at 6722, para. 363.

[164] *See id.* at 6719, para. 359. We described, in general, the process broadcasters would follow: "To implement this policy, if a broadcaster indicates in its pre-auction application that (1) it might place one or more license relinquishment bids, and (2) it would not control any other broadcast stations if its bid or bids were accepted, then we will review our records to determine whether any outstanding enforcement matters exist pertaining to the broadcaster's stations, including complaints for which a proceeding has not yet been initiated and violations disclosed during the license renewal process." *Id*.

[165] The U.S. Treasury would maintain the funds that are held back in a manner that accounts for each broadcaster's potential share pending the final resolution of specified issues, or for two years, as described in the *Incentive Auction R&O*. *Id*. at 6721–22, para. 361 & nn.1071–72.

[166] *Id*. at 6721, para. 360.

[167] *See id.* at 6719, para. 359.

[168] *Incentive Auction R&O*, 29 FCC Rcd at 6722, para. 363. Such broadcasters include those with licenses subject to non-final, i.e., reviewable, expiration or revocation orders, or with a Class A station downgraded as a result of a non-final order.

[169] *Incentive Auction R&O*, 29 FCC Rcd at 6720–21, para. 359.

[170] *Id.* at 6721, para. 361.

85. As to the amount to be held with respect to a particular broadcaster, all of the relevant auction proceeds would be held pending the final resolution of the status of the license in the case of a broadcaster with a license that may be determined post-auction not to have been eligible for relinquishment at the time of the auction. In the case of a broadcaster that has outstanding potential liabilities and might cease to be subject to Commission jurisdiction after relinquishing all of its broadcast spectrum usage rights, the amount determined prior to the auction by the Bureaus, as described above, would be held. As described in the *Incentive Auction R&O*, amounts held will be released to the broadcaster or the Commission, as appropriate in light of the final resolution of the relevant specified issues.[171]

86. We also invite comment on an alternative proposal, under which, instead of holding the funds in the U.S. Treasury, the Commission would deposit the relevant amounts in a third party financial institution to serve as a private escrow agent. Under this alternative, prior to the auction, the Commission would designate a private escrow agent, such as US Bank, for each broadcaster agreeing to the escrow in its application.[172] We will require that any escrow agent maintain the confidentiality of Commission-held data of broadcasters participating in the reverse auction.[173] We seek comment on this alternative, including the terms of any escrow agreement with a third-party agent.

3. Certification Regarding Due Diligence

87. We propose that all applicants will be required to certify the truth of the following statement as a part of their application to participate in the reverse auction: "The applicant acknowledges and agrees that any information provided by the Commission's outside contractors who are advising and assisting the Commission with education and outreach in connection with the reverse auction is for informational purposes only and that neither the Commission nor any of the Commission's outside contractors makes any representations or warranties with respect to any such information and shall have no liability to the applicant in connection therewith." Our rules already provide that an applicant to participate in the reverse auction must certify that it has sole responsibility for investigating and evaluating all technical and marketplace factors that may have a bearing on the bids it submits in the reverse auction.[174] Our proposed additional certification will likewise help assure that each applicant accepts responsibility for its bids and will not attempt to place responsibility for its bids on either the Commission or the information provided by third parties as part of the Commission's outreach. Requiring this proposed certification is also consistent with our rule providing that an application will contain "[s]uch additional information as may be required."[175]

4. Committing to an Initial Relinquishment Option

88. The specific opening prices for each bidding option available to each station eligible to participate in the reverse auction will be provided at least 60 days in advance of the deadline to apply to participate in the reverse auction.[176] We propose that each applicant to participate in the reverse auction will indicate for each of its stations listed in its application all of the spectrum relinquishment options available to it that it may be willing to consider. After Commission staff reviews a submitted application

[171] *Id.*

[172] US Bank currently holds deposits of upfront payments made by participants in the Commission's spectrum license auctions.

[173] *Incentive Auction R&O*, 29 FCC Rcd at 6732, para. 388.

[174] 47 C.F.R. § 1.2204(c)(7).

[175] 47 C.F.R. § 1.2204 (c)(11).

[176] *See* § IV.C.1.a (Opening Price Methodology).

and the applicant has resolved any issues regarding the information provided,[177] the applicant will be required to indicate a single preferred relinquishment option for each of its stations from among those that it previously indicated it would be willing to consider. An applicant must indicate a preferred relinquishment option and in certain cases, as described below, may also specify alternative(s) for that preferred option. An applicant must specify a preferred option (and any alternative(s), if it so chooses) for each station listed in its application in order to qualify as a bidder with respect to those stations in the reverse auction. This step will constitute a commitment by the applicant to fulfilling the terms of its preferred option (or alternative(s)) for a particular station, i.e., relinquishing the relevant spectrum usage rights in exchange for the opening price in the event the auction system can accommodate the preference (or an alternative). This first commitment will establish the starting point for bidding in the clock rounds.

89. In order for an applicant's commitment for a station to be a valid starting point for bidding, it must be feasible for the auction system to accommodate an option for that station. The auction system can always accommodate going off-air as a preferred option because going off-air does not require finding a feasible channel assignment. However, the auction system may not be able to accommodate moving to either the Low-VHF or High-VHF band as a preferred option if there are not enough channels available in that band ("vacancy") at the start of the auction to accommodate all stations with such a preference. Accordingly, we propose that an applicant that selects moving to either Low-VHF or High-VHF as its preferred option for a station may indicate alternative options for that station, which would be used in the event that the preferred option cannot be accommodated. Under our proposal, the auction system will attempt to accommodate the preferred option.[178] If it cannot and the applicant indicated one or more alternative options for the station, the system will attempt to accommodate one of the alternative options when determining an initial assignment of stations to relinquishment options. If the system assigns the station to one of its alternative options, that option will constitute the applicant's commitment and become that station's assigned option at the start of bidding. If the auction system cannot accommodate an applicant's preferred option or any of its alternative options for a station, that station will be assigned a channel in its pre-auction band. Thus, an applicant that wants to guarantee a station's participation in the bidding should indicate going off-air as either its preferred option or as an alternative option, as a vacancy for every station to move to Low-VHF or High-VHF cannot be guaranteed.[179]

90. Above we propose that once bidding begins in the clock rounds a bidder will not be permitted to bid for options that would involve greater relinquishments than the previous option selected.[180] Thus, under our proposal, an applicant considering multiple relinquishment options for a station will need to consider the restriction on moving one way up the hierarchy of options in deciding which option to commit to at the commitment stage of the application process, since its choice may preclude later being able to bid for other options below it. For example, initially committing to moving to Low-VHF would preclude later switching options to going off-air; initially committing to moving to High-VHF would preclude later switching options to going off-air or moving to Low-VHF; and initially committing only to moving to either Low-VHF or High-VHF, without committing as an alternative to

[177] As noted above, any applicant whose application is incomplete will have a specific period of time within which to resubmit its application to correct deficiencies. *See* § I (Introduction).

[178] *See* Appendix C (detailing how the auction system will assign initial commitments).

[179] An applicant that selects going off-air as an acceptable alternative relinquishment option is guaranteed to be assigned a relinquishment option–its preferred option, if feasible, or its alternative to go off-air (in the event its preferred option is not feasible).

[180] *See* § IV.A.1 (Options for Relinquishing Spectrum Usage Rights) (proposing the following hierarchy: go off-air, move to Low-VHF, move to High-VHF). Below, we propose procedures to allow bidders to switch to bidding for different available options during the clock rounds. *See* § IV.C (Descending Clock Bidding Procedures). The proposed hierarchy will not limit the auction system's ability to assign a station to its preferred or alternative options. However, once the auction system assigns an option to a station and bidding begins in the clock rounds, the hierarchy may limit a station's ability to move to other options later in the auction. *See* note 154.

going off-air, could result in non-participation if there is no vacancy in either of these bands at the start of the auction.

91. *Initial Assignment.* Once each station has made an initial commitment(s), the auction system will determine an initial assignment of stations to relinquishment options using optimization techniques. This initial assignment will determine the relinquishment option for which a station will be offered prices at the beginning of the reverse auction. Due to the limited availability of VHF channels, we propose to prioritize rules that will be used to determine, in the event that all participating stations cannot be assigned to their preferred options, how to choose an alternative option for some stations. If a station cannot be assigned to its preferred option or an alternative option, it will not participate in the reverse auction bidding and will be assigned to a channel in its pre-auction band. As set forth in detail in Appendix C, we propose the following rules in order of priority:

(1) Minimize the number of UHF participating stations that must be assigned to their pre-auction band.

(2) Minimize the number of VHF participating stations that must be assigned to their pre-auction band.

(3) Maximize the number of participating stations that can be assigned to their preferred relinquishment option.

(4) Maximize the number of participating stations that can be assigned to go off the air as an alternative option.

(5) Minimize the sum of impaired weighted-pops across all licenses (i.e. solve for the primary objective of the clearing target optimization).

We propose to give rules (1) and (2) the highest priority to minimize the number of stations that are assigned to their pre-auction band and, therefore, cannot participate in the reverse auction. Rule (1) precedes all others to minimize the likelihood of creating additional impairing stations in the 600 MHz Band. If not all stations can simultaneously be assigned to their preferred option pursuant to rule (3), rule (4) would ensure that the maximum number of stations that must be assigned an alternative option are assigned the option to go off the air, in order to provide the most opportunities for bidding in the reverse auction. Finally, rule (5) would require the optimization to choose among the remaining options based on the primary objective of minimizing the sum of impaired weight-pops across all licenses in the 600 MHz Band.

C. Descending Clock Bidding Procedures

92. In adopting a descending clock format for the reverse auction, the *Incentive Auction R&O* explained that "bidders will be faced with relatively simple choices of determining whether or not they are still willing to accept the current prices for bid options."[181] It determined that price offers for bid options generally will start high and descend between rounds for each participating station, and indicated that price offers for each station may be adjusted based upon factors reflecting that particular station's impact on the repacking process.[182] In the *Incentive Auction R&O*, we adopted rules allowing for the use of reserve pricing in the reverse auction, and noted that we may adopt procedures to implement a form of dynamic reserve pricing ("DRP").[183] We also explained in general terms the descending clock auction procedures for selecting winning bids and determining prices to be paid to winning bidders.[184]

[181] *Incentive Auction R&O*, 29 FCC Rcd at 6753, para. 449.

[182] *Id.* at 6753–54, paras. 450–51.

[183] *Id.* at 6758, para. 463.

[184] *Id.* at 6755–57, paras. 456–61.

93. Below, we propose procedures for determining the prices reverse auction bidders will be offered during the bidding rounds. We then address the bidding process in detail, proposing procedures for the types of acceptable bidder responses to price offers in a round, including procedures for bidding for multiple relinquishment options. We also address how the auction system will process bidder responses to determine which stations will have their bids accepted. Finally, we propose procedures to implement bidding activity and stopping rules.

1. Determining Price Offers

94. As an initial matter, we clarify that a "bid" in this descending clock auction means a response to a price that is offered to the bidder. This is consistent with the fundamental premise of a clock auction, where bidders do not initiate bids but rather indicate over a series of rounds whether they are willing to accept offered prices that increase or decrease, depending upon whether it is an auction to sell or buy. The clock prices stop increasing or decreasing when there is no longer competition among the bidders to buy or sell an item. For example, in a simple procurement auction to buy one item, the auction stops when only one bidder is left that is willing to supply the item at the current price offer. In the reverse auction, the Commission will aim to "procure" a targeted amount of cleared television spectrum and bidders will compete to relinquish spectrum usage rights to enable that clearing. Through their bids in each round, bidders will indicate their continued willingness to accept a given offer price for a relinquishment option, which will constitute a commitment to relinquish their spectrum usage rights at that price, or they will reject the offer, possibly indicating a lowest price they are willing to accept. We address proposals for specific acceptable bids below.

a. Opening Price Methodology

95. Opening prices must be high enough to encourage robust participation in the reverse auction, but not so high that the reverse auction requires many hundreds of rounds to reach final clearing prices. In designing a system of competitive bidding, which includes setting opening prices, we promote several statutory goals, including "recovery for the public of a portion of the value of the public spectrum resource made available for commercial use and avoidance of unjust enrichment through the methods employed to award uses of that resource."[185] To balance these objectives, we propose to calculate an opening bid price for each station,[186] using a station-specific "volume" factor and an underlying base clock price for a UHF station going off air.[187] The opening off-air bid for UHF stations would be the product of each station's volume factor and the base clock price. Opening bid prices for a move from the UHF band to the Low-VHF or High-VHF band would be calculated by applying a specific discount to the off-air bid amount for each of these options.

96. We propose to calculate a station's volume using this formula:

$$\text{Station Volume} = (\text{Interference})^{0.5} * (\text{Population})^{0.5}$$

We propose to set *interference* equal to the number of co- and adjacent channel constraints a station would impose on repacking on a pairwise basis. The interference component measures a station's potential impact on repacking. More specifically, for each station pairing, we first determine the

[185] 47 U.S.C. § 309(j)(3)(C).

[186] 47 C.F.R. § 1.2203(a)(3). Because we will not know the initial clearing target prior to accepting bidder applications, and therefore will not exclude any stations or markets from the auction in advance, we intend to provide opening prices to every eligible broadcaster. If, upon establishing the initial clearing target, the auction system identifies markets where broadcaster participation is not needed, it will so inform broadcasters in any such market and provisionally assign each of them channels in their pre-auction bands. The opening prices may be zero for stations that the auction system determines do not constrain us from reorganizing the UHF band.

[187] Consistent with the discussion above, the opening bid for the UHF off-air and channel sharing options will be the same, as both would result in the return of a full six megahertz of UHF spectrum for reallocation to flexible-use licenses. *See* § IV.A.1 (Options for Relinquishing Spectrum Usage Rights).

maximum number of constraints that can exist between the two stations on any channel in bands into which both stations can be repacked.[188] Thus, between two UHF stations, we would consider all channels in the UHF, High-VHF or Low-VHF bands (channels 2-51) to determine the maximum number of constraints that exist between the two stations consistent with the hierarchy of relinquishment options discussed above.[189] Between a UHF station and a High-VHF station, we would consider only channels in the High-VHF band (channels 7-13) and Low-VHF band (channels 2-6) to determine the maximum number of constraints that exist between the two stations. Between a UHF station and a Low-VHF station, we would consider only channels in the Low-VHF band (channels 2-6) to determine the maximum number of constraints that exist between the two stations. We then sum up these maximums for each station to set its interference metric. We propose to measure *population* as the number of people residing within the station's interference-free service area.[190] A fuller description of this calculation is set out in Appendix D.

97. To calculate a station's opening bid price, we will multiply its volume times a base clock price. The base clock price is a constant amount per unit of volume. Based on our work to date on the design of the incentive auction, we expect that a base predicated on an opening bid price of $900 million for the station with the highest volume will achieve robust participation by stations across multiple markets. We therefore propose to set the base clock price so as to yield an opening bid of $900 million for this station.[191] To do this, we will calculate volume for all stations and then rescale so that the maximum station volume is one million. Dividing the $900 million opening bid price for the highest volume station by one million results in a base clock price of 900. The base clock price will drop in each round of the reverse auction, while a station's volume will remain constant. The price offered to a bidder to go off air in a given round will be the product of the base clock price in that round and the station's volume. The markets and stations needed in the reverse auction will depend on which stations choose to participate, and actual compensation to stations will be determined by the auction.

98. We tentatively conclude that this formula appropriately balances the manifold goals that Congress has charged us with in connection with the incentive auction. First, a combined interference-population volume establishes opening bid prices that should provide the necessary incentive for broadcaster participation.[192] Consistent with our determination in the *Incentive Auction R&O*, our proposed approach will yield opening bid prices that reasonably approximate underlying relative differences in value of stations to the auction.[193] Our proposed formula is not based on a station's market

[188] This data is available in the interference_paired.csv file, which is available at http://data.fcc.gov/download/incentive-auctions/Constraint_Files/.

[189] *See* § IV.A.1 (Options for Relinquishing Spectrum Usage Rights).

[190] A station's interference-free population can be obtained from the *baseline.csv* file generated by *TVStudy*. Alternatively, we will also release prior to the auction a final Pre-Auction Baseline Data file similar to Baseline_Data_and_Maps_2013July.pdf file released in July 2013 and available at http://data.fcc.gov/download/incentive-auctions/OET-69/Baseline_Data_and_Maps_2013July.pdf. Under the proposed formula, a station's interference and population would be scaled equally, i.e., a 10 percent increase in population would increase station volume by approximately five percent, while a 10 percent increase in interference would increase station volume by approximately five percent.

[191] It should be noted that if this highest volume station is not in UHF, its base clock price would be decreased by the discount applied to its pre-auction band.

[192] 47 U.S.C. § 309(g)(i).

[193] *Incentive Auction R&O*, 29 FCC Rcd at 6753, para. 450 ("[E]ach station will see a price that takes into account objective factors, such as location and potential for interference with other stations, that affect the availability of channels in the repacking process and, therefore, the value of a station's bid to voluntarily relinquish spectrum usage rights. Thus, a station with a high potential for interference will be offered a price that is higher than a station with less potential for interference to other stations.") (footnote omitted); *id.*, para. 451 (noting that possible factors in (continued….)

or enterprise value.[194] If a station has many constraints and blocks many other stations from being repacked, then under our proposal its opening price will reflect that contribution to the auction's ability to clear spectrum. The population component complements the interference metric by enabling us to clear more spectrum in markets where the forward auction value of relinquished spectrum usage rights is apt to be higher. Second, the opening bid price set using the proposed methodology will enable us to close the auction in a reasonable number of rounds, providing ease of participation for broadcasters and enhancing the prospects for a successful auction. Third, the balanced approach we propose will meet our statutory obligation to promote the interests of taxpayers in getting a portion of the value of the spectrum sold at the forward auction.[195] Finally, use of a population factor is consistent with the fact that the spectrum recovered from broadcasters will enable flexible use licenses to be offered in the forward auction subject to procedures that are based, among other things, on the population covered by each PEA.[196]

99. Under our proposed approach, opening bid prices for moving from the UHF band to the Low-VHF or to the High-VHF band (the "VHF options") will be set at a value relative to the opening price for going off-air. For moving from UHF or High-VHF to Low-VHF, we tentatively conclude that a station's opening price should be between 67 and 80 percent of the station's price to go off-air. For moving from UHF to High-VHF, we tentatively conclude that a station's opening bid price should be between 33 and 50 percent of the station's off-air price. Below we discuss the rationale for these discounts. We seek comment on where in these ranges we should set the discounts or whether some other discount is appropriate for these bid options. We emphasize that these would only be opening discounts. Final discounts for the VHF options will be determined by the demand by bidders for VHF channels and the availability of those channels.

100. As an initial matter, we propose to calculate the opening prices for the VHF options as a discount off the off-air opening price because a winning bidder electing one of the VHF options will retain a full six megahertz channel, and thus should not receive the same compensation as bidder that relinquishes its rights to a six megahertz channel. The proposed level of the discounts reflects a comparison of the technical characteristics of UHF and VHF channels and of the characteristics of Low-VHF and High-VHF channels. In particular, VHF frequencies are more susceptible to interference than UHF frequencies. Specifically, noise from nearby electrical devices can disrupt reception on these lower frequencies, especially indoor reception. While present across the VHF bands, this issue is more pronounced on low-VHF channels than on High-VHF channels.[197] Thus, while the opening price for a VHF option should not be the same as for the off-air relinquishment option, it should be high enough to offset the potential loss in value associated with this increased interference potential.[198]

(Continued from previous page)
setting opening prices include "the number of stations that a station would interfere with and block from being assigned channels, the population the station covers, or a combination of such factors.") (footnotes omitted).

[194] *Incentive Auction R&O*, 29 FCC Rcd at 6753, para. 450 ("We emphasize that we do not intend to set prices to reflect the potential market or enterprise value of stations, as opposed to their impact on the repacking process.")

[195] 47 U.S.C. § 309(j)(3)(C).

[196] *See* §§ III.B.1 (First Component: Average / Aggregate Prices in Forward Auction); V.B.1 (Bidding Units); V.C.1 (Setting Prices in the Clock Rounds).

[197] *See Innovation in the Broadcast Television Bands: Allocations, Channel Sharing and Improvements to VHF*, Notice of Proposed Rulemaking, ET Docket No. 10-235, 25 FCC Rcd 16498, 16511, para. 42 (2010).

[198] A must carry station moving to a VHF channel would still be entitled to MVPD carriage and thus retain viewability by its existing cable and satellite customers notwithstanding the change in frequency band. Differences in TV reception in the VHF bands compared to UHF can also be addressed by antenna placement. In addition, the Commission will allow successful VHF option bidders to apply for "expanded facilities" on their new channels and to seek waivers of the VHF power and height restrictions. *See Incentive Auction R&O*, 29 FCC Rcd at 6725–26, paras. 369–71; *id.* at 6792, para. 553.

101. The smaller discount for the Low-VHF option as compared to High-VHF reflects that television receivers are subject to greater interference in the Low-VHF band. The proposed respective discounts for the Low-VHF and High-VHF options also reflect the relative number of unoccupied channels in each band. There are substantially more unoccupied Low-VHF channels than High-VHF channels. As a result, in nearly all markets, a station could move to a Low-VHF channel without the need to reassign any channels in that band. Conversely, there are relatively few markets where a station could move to High-VHF channels unless other stations vacate that band or are repacked within the band. In at least some scenarios, therefore, we may need to pay two stations in connection with a UHF-to-High-VHF move: a High-VHF station to vacate its channel, and UHF licensee to move to High-VHF. A smaller discount, i.e., a higher opening price, for the Low-VHF option would signal the greater value of this option to the auction. We seek comment on our proposed approach to setting opening prices for the VHF options, the appropriate discount levels, or whether there are additional factors or approaches that we should consider.

a. Price Offers in Initial and Subsequent Rounds

102. We propose that, in the first clock round of the reverse auction, a bidder whose commitment to a preferred or assigned alternative option at the opening price is not provisionally accepted by the auction system will be offered a lower price for the assigned option.[199] As long as the bidder indicates it is willing to accept the offered prices, and if a feasible channel assignment exists for the station in its pre-auction band, the auction system will progressively offer lower prices for that option.[200] A bidder that indicates it will consider multiple bidding options will be informed of current prices for those options and will have the opportunity to request to switch to bidding for another option. Under conditions which we address in more detail below, a bidder that switches bidding options will then be offered progressively lower prices for that option, but only so long as a feasible channel assignment exists for the station in its pre-auction band.

103. We propose to offer a bidder lower prices for relinquishment options as long as the bidder is still competing with other stations to relinquish rights, consistent with the basic clock auction's competitive framework.[201] When a station's relinquishment becomes essential to meeting the clearing target (because there is no longer room for it in its pre-auction band), the auction system will stop offering lower prices to that station, and will provisionally accept the station's offer to relinquish its usage rights.

104. More specifically, whenever a station is provisionally assigned to a band, either because it dropped out of bidding or because its bid to switch to a different relinquishment option was applied, the repacking feasibility checker will consider for each station that remains active whether a channel can still be found in its pre-auction band, given all other stations that need to be assigned channels in that band (i.e., non-participants and other stations that have previously dropped out of the bidding and are assigned to that band).[202] When the feasibility checker cannot find a way to repack a station into its pre-auction band because of the other stations that must be accommodated, the auction system will not reduce the

[199] As noted above, for a bidder that preferred an on-air option for which there was no vacancy (e.g., a move to a High-VHF channel) and agreed to accept one or more alternative options (e.g., a move to a Low-VHF channel or bidding to go off-air), the auction system will offer the bidder a price for an alternative option. Bidders that prefer off-air as their initial option will always be offered a price for that option at the start of the auction, since it will always be feasible for them to go off-air. *See* § IV.B.4 (Committing to an Initial Relinquishment Option).

[200] When we refer to checking a feasible channel assignment in a station's pre-auction band when determining price offers, for stations with a pre-auction band of UHF we are referring to the remaining television portion of the UHF band.

[201] This proposed approach is analogous to the simple procurement auction noted above, where the clock stops when only one bidder is still willing to supply the item. *See* § IV.C.1 (Determining Price Offers).

[202] For stations with a pre-auction band in either High-VHF or Low-VHF the feasibility checker will also consider the stations with a pre-auction band of UHF that are currently provisionally assigned to a VHF band.

station's price in that auction round. If the feasibility checker determines that the station cannot be repacked in its pre-auction band for the remainder of the stage, then the auction system will notify the bidder that the station's prices and relinquishment offer are "frozen" for the remainder of the stage.[203] If the system determines that the station can feasibly be assigned a channel, however, then the station will be offered a lower price in the next bidding round.[204]

105. Price reductions in each round, explained in detail in Appendix D, will be based on the base clock price. The base clock price is calculated for the case of a station whose pre-auction band is UHF that is still feasible to repack in the UHF band and still bidding to go off-air. We propose to reduce this base clock price by between three percent and 10 percent per round. We also propose that the amount may be changed at any point during the reverse auction based on bidding activity during the auction.[205] This range will enable the auction to move at an appropriate pace while also providing the flexibility to offer bidders appropriate price choices as the auction progresses. For instance, if the decrement in a round is four percent, this means that the price offered per volume in this round to a UHF station for going off-air is four percent lower than what the base clock price was after the bid processing of the previous round. Appendix D describes how we propose to compute the prices that are offered to VHF stations for going off-air and/or for relinquishment options that are different from going off-air.[206]

b. Dynamic Reserve Prices in Early Rounds of the First Stage

106. We propose to implement dynamic reserve price ("DRP") procedures in the early rounds of the reverse auction in the first stage.[207] The DRP procedures we propose implement a limited exception to the proposal regarding price reductions above and enable the auction system to reduce the price offered a station below the opening or previous round's price even when the station cannot feasibly be assigned a channel in its pre-auction band, so long as assigning the station a channel in the 600 MHz Band will not result in inter-service interference that exceeds the nationwide standard for market variation.[208] Accordingly, while DRP procedures are in effect, a UHF station may be offered a lower price for an option even if it cannot feasibly be assigned a channel in the remaining TV portions of the

[203] An exception to the general case that a station's relinquishment offer is accepted for the stage may occur for VHF stations. For a VHF station, the amount of vacancy in its pre-auction band may increase as bidding rounds progress, so a station that had a relinquishment bid accepted because it was infeasible to accommodate in its pre-auction band can later become feasible. For instance, if a UHF station is currently assigned to move to upper-VHF but subsequently drops out of the bidding to remain in UHF, that move may create a vacancy in upper-VHF. Because of this, unlike UHF stations, stations with pre-auction channels in the VHF band may unfreeze in later rounds of the same stage if it becomes possible to accommodate the station in its pre-auction VHF band.

[204] Below we address proposed bidding procedures in more detail, particularly with respect to bidding for multiple relinquishment options. *See* § IV.C.2 (Bidding and Bid Processing).

[205] Using smaller decrements is likely to increase the number of rounds necessary to reach final auction prices. We seek comment on the possibility of using proxy bidding, which could reduce the bidders' need to closely monitor numerous, frequent bidding rounds. With proxy bidding, a bidder could ask the system to continue to bid for its current relinquishment option in every round until either its price falls below a bidder-specified threshold or the bidder intervenes to change its bid, whichever happens first. In each round, the bidder would be informed of the first round in which the price of its option could possibly fall below its specified threshold. This notice would allow the bidder to anticipate the timing of when it may need to change its bid or update its proxy bid.

[206] Appendix D alternatively considers adjusting the decrement of each station as a function of its vacancy in the various bands. We seek comment on this alternative proposal.

[207] *See Incentive Auction R&O*, 29 FCC Rcd at 6711, para. 335.

[208] *See Id.* at 6758, para. 463. *See also* 47 C.F.R. § 1.2203(a)(2).

UHF band; if it refuses the offer, it may be assigned to a channel in the 600 MHz Band.[209] By mitigating the risk that a station may be awarded its opening price merely because there is no channel to offer in its pre-auction band—a result that would have little or nothing to do with what the station would be willing to accept in exchange for relinquishing its spectrum usage rights—these procedures will increase the likelihood of a successful auction. This is because DRP procedures make it possible to offer higher opening prices, thereby attracting greater broadcaster participation, than would otherwise be the case. Absent DRP, lower opening prices would be necessary. Because the procedures we propose below for discontinuing DRP will limit the extent to which opening prices can fall, even as reduced by DRP, the higher opening prices may ultimately provide higher incentive payments to broadcasters. In addition, by enabling the reduction in broadcaster payments where such payments are acceptable to broadcasters, the proposed DRP procedures will make it easier to satisfy the second component of the final stage rule.

107. Under our proposed approach, the reverse auction will begin in the first stage with DRP procedures in effect. While DRP procedures are in effect, participating UHF stations that cannot feasibly be assigned a channel in the remaining TV portion of the UHF band will be treated differently than when DRP procedures are not in effect: the prices offered to such stations will be reduced. In contrast, the prices of such stations will not be reduced when DRP procedures are not in effect.[210] Should such a station decline to accept a price offer when DRP procedures are in effect, the station may provisionally be assigned a channel in the 600 MHz Band, creating potential impairments to one or more 600 MHz Band blocks.[211]

108. We propose to discontinue DRP procedures when their application risks exceeding the less than 20 percent nationwide standard for limiting market variation proposed above.[212] More specifically, we propose that DRP procedures be discontinued when, if we were to assign all of the participating UHF stations for which the auction system cannot find a feasible channel in the remaining TV portion of the UHF band, the predicted aggregate level of impairments to licenses in the 600 MHz Band would exceed this standard.

109. We seek comment on this proposal and on how to determine whether the standard would be exceeded, as a full channel assignment optimization would be too time consuming to run during the reverse auction clock rounds. One approach would be for the auction system to use a limited version of the channel assignment optimization procedures proposed for setting a clearing target to determine when the aggregate level of potential impairments from participating stations dropping out of the auction could exceed the proposed national standard.[213] Once DRP procedures are discontinued, however, we propose

[209] Regardless of whether dynamic reserve pricing procedures are in effect, prices will continue to fall where more stations that can feasibly be assigned channels in the TV portion of their pre-auction bands are willing to relinquish rights than are needed to meet clearing target.

[210] Regardless of whether dynamic reserve pricing procedures are in effect, the prices of a participating VHF station will not be reduced during bid processing if that station cannot be feasibly assigned a channel in its pre-auction band.

[211] As discussed above, any television stations assigned to channels in the 600 MHz Band will be entitled to the same protection in the repacking process as other TV stations, and will be protected from inter-service interference under the strict standards proposed in the *ISIX Further Notice*. S*ee* § III.A.2 (Assigning TV Stations to the 600 MHz Band As Necessary to Accommodate Market Variation).

[212] *See* § III.A.3 (Standard for Limiting Market Variation). As stated above, DRP procedures may result in additional TV stations being assigned to channels in the 600 MHz Band, increasing the impairments determined during the initial clearing target optimization. Under this proposal, the nationwide standard would be compared to previously-determined impairments as well as potential new impairments.

[213] *See* § III.A.4 (Clearing Target Optimization Procedure).

that the system fully optimize the provisional channel assignments to minimize the impact of any impairments created during DRP.[214]

110. We also seek comment on alternative approaches for determining when DRP would be discontinued in order to avoid the risk described above. For instance, DRP procedures could be discontinued when there is the potential that the next participating station for which the auction system cannot find a feasible channel in the remaining TV portion of its pre-auction band, if it chose to drop out of the auction, would cause the predicted aggregate level of impairments to licenses in the 600 MHz Band to exceed this threshold. This alternative approach would always result in aggregate impairment that is just one station short of the threshold, while the proposed approach could result in a lower level of impairment, and possibly even no additional impairment, due to DRP. We also seek comment on whether, instead of determining when to discontinue DRP using predicted aggregate impairments, we should use the population served by UHF stations that cannot be feasibly assigned a channel in the TV portion of UHF as a proxy for predicted aggregate impairments.

2. Bidding and Bid Processing

111. Some bidders in the reverse auction will be interested in only a single relinquishment option ("single-option bidder"). Other bidders may wish to consider price offers for multiple relinquishment options ("multiple-option bidder"). We propose detailed procedures for bidder responses and bid processing for bidders in both categories.

a. Bidding for a Single Relinquishment Option

112. At the start of the clock rounds, we propose that a single-option bidder whose commitment to a bid option at the opening price is not provisionally accepted will be presented with a price offer lower than the opening price it committed to accept and asked if it is willing to accept the lower price.[215] We propose that the bidder will have three choices: it may accept the offered price (i.e., submit a bid at the clock price), submit an intra-round bid, or not respond. If the bidder accepts the offered price, it will be finished bidding for that round and can await the results of the round.

113. If the bidder does not place a bid, the auction system will treat the bidder as unwilling to relinquish its rights for less than it previously accepted.[216] If the bidder places an intra-round bid, the bidder's intra-round bid will indicate to the auction system that, at prices at least as high as the intra-round bid (including the opening price), the bidder is willing to relinquish its spectrum usage rights, but at lower prices the bidder's station must be provisionally assigned a channel in its pre-auction band.

114. During each subsequent bidding round, a bidder that continues to participate in the bidding—that is, a bidder that accepted the clock price offered during the previous round—will be presented with a new, lower price offer, and will have the same response choices as during the first round.

115. Under our proposed procedures, which are described in detail in Appendix D, the auction system will process the bids submitted during a bidding round at the close of the round based on bid prices. If prices in the round drop below the level of an intra-round bid, the single option bidder will drop out of further bidding in the auction. As described above, the auction system will then evaluate the feasibility of repacking (that is, assigning permissible channels to) all other stations that continue to

[214] These optimization procedures are set forth in detail in Appendix B and addressed above in § III.A.4 (Clearing Target Optimization Procedure).

[215] As discussed above, if a bidder initially commits only to an option or options that the bidding system is unable to accommodate because of a lack of vacancy in the band, that bidder will be reassigned a channel in its pre-auction band and will not see prices in the clock rounds. *See* § IV.B.4 (Committing to an Initial Relinquishment Option).

[216] This proposed treatment would require bidders to participate actively throughout the reverse auction bidding rounds, i.e., to indicate acceptable lower prices until the price gets too low.

participate in the bidding in their pre-auction bands.[217] If the system determines that a participating station cannot feasibly be accommodated in its pre-auction band, the system will stop reducing the station's price at the point at which the station is infeasible to repack.[218] Acceptance of a bid will be provisional until the final stage rule is satisfied, at which point provisionally-accepted bids will become winning bids. Appendix D describes in detail the process by which we propose to integrate the repacking feasibility checking methodology into the reverse auction process.

116. As the auction system iteratively considers bids and potential channel assignments, it may determine that it will accept a relinquishment offer at a price higher than the lowest price the bidder indicated it would accept. Hence, a bidder that makes an intra-round bid during a round may have its bid accepted at a price higher than the intra-round bid.[219]

117. Once the auction system has processed all of the bids submitted in a round and the results of the round have been determined, the auction system will indicate to each bidder its status—that is, whether its relinquishment bid has been provisionally accepted,[220] whether it is still bidding for the option, or whether it is designated to be assigned a channel in its pre-auction band because it dropped out of the bidding. A bidder that accepted the clock price offered during the round whose station feasibly can be repacked in its pre-auction band will be offered a lower price for the next round.

118. As an alternative, we invite comment on whether we should simplify the reverse auction bidding process by not providing the option to place an intra-round bid, and instead simply ask each bidder if it is willing to accept the new lower price for its relinquishment option. If the bidder is unwilling to accept the lower offered price, the auction system would not ask for an intra-round bid. This approach could simplify both bidding and bid processing, as all bids would be processed at the clock prices. This would eliminate uncertainty about the price a bidder may receive at the start of the next round for the different relinquishment options. Implementing this alternative would require that we use generally smaller increments for price reductions, and could reduce to some degree the flexibility afforded to bidders to choose specific price points within a round.

b. Multiple Option Bidding

119. Above, we propose that with respect to a particular station a bidder's initial commitment will determine which option the bidder will be bidding for initially and explain that its bid option selections on the pre-auction application will determine which options it may later consider, consistent with the proposed hierarchy of options. Accordingly, at the start of the first clock round, as for a single-option bidder, a multiple-option bidder in an area where there are more stations willing to accept relinquishment options than needed to meet the clearing target will be presented with a price offer for its option that is lower than the opening price it committed to accept. The multiple-option bidder will also be able to see current prices for each of its other bid options.

120. In addition to being able to accept the lower price for its preferred option or place an intra-round bid as discussed above, a multiple-option bidder will have the option, at current prices, to request to switch to any other of its eligible relinquishment options, consistent with the option

[217] *See* § IV.C.1.b (Price Offers in Initial and Subsequent Rounds).

[218] If a station becomes feasible to repack in its home band at a later point (e.g., a High-VHF channel becomes vacant for a station whose pre-auction band is High-VHF) the system will resume its price reductions.

[219] The "price" at which a bid is accepted is the base price prevailing at that point, adjusted for the station's volume, pre-auction band, and currently selected relinquishment option. *See* § IV.C.1.a (Opening Price Methodology).

[220] As noted above, a UHF bidder whose bid is provisionally accepted will be frozen for the remainder of the stage. However, stations with pre-auction channels in the VHF band may unfreeze in later rounds of the same stage if it becomes possible to accommodate the station in its pre-auction VHF band. *See* § IV.C.1.b (Price Offers in Initial and Subsequent Rounds).

hierarchy.[221] The auction system will implement the switch if the feasibility checker determines that it is feasible to assign the station to a channel in the band associated with the new option. The bidder will then be offered a lower price for the new relinquishment option in the next round unless the bidder becomes frozen. However, if the system is unable to assign the bidder a channel in its newly preferred option, the system will still consider the bidder to be bidding for its previous option at the last price it agreed to accept.[222]

121. In the event that multiple bidders request to switch to bid on moving to the same band in the same round, the auction system may not be able to accommodate each request.[223] As a result, we propose that a multiple-option bidder requesting to switch options must also indicate whether it is willing to accept the lower clock price for its currently assigned option, in case the system cannot accommodate its request to switch. A bidder unwilling to accept the lower price offer for its current option may place an intra-round bid to indicate a specific price at which it wishes to drop out of bidding for its current option. If there is not a channel available in the option to which a multiple-option bidder requests to switch, and the price for its assigned option drops below the intra-round bid amount during bid processing for the round, the bidder will drop out of the bidding and be designated to be assigned a channel in its pre-auction band.

122. At the close of the bidding round the auction system will process the bids submitted during the round as in the single option bidder scenario described above, by considering the bids in decreasing order of bid price, consistent with the descending clock format.[224] Once the auction system has processed all of the bids submitted in a round, the auction system will indicate to each bidder whether its request to switch bidding options was accepted, as well as whether it had a bid provisionally accepted or whether it dropped out of the bidding during the round.

123. Under the alternative "no intra-round bidding" discussed above, multi-option bidders would simply respond to single price offers without the opportunity to place intra-round bids. Submitted bids would be processed by attempting to accommodate a station's requests to switch options (if any) and processing the station's election to drop out of the bidding (if any). If as a result of another station's bid, a bidder cannot be feasibly assigned a channel in its pre-auction band, the system would not lower the bidder's prices.

3. Stopping Rule

124. We propose a stopping rule for the reverse auction whereby bidding rounds will continue until no stations are still bidding—that is, each participating station either has had a bid to relinquish

[221] A multiple-option bidder's eligibility to bid on other options will be based on its responses on the pre-auction application and on which option it is currently assigned to within the bid option hierarchy. *See* §§ IV.A.1 (Options for Relinquishing Spectrum Usage Rights); IV.B.4 (Committing to an Initial Relinquishment Option).

[222] For example, a multiple-option bidder that selected all three options on its pre-auction application and preferred at the commitment stage to go off-air may in a subsequent round request to switch to moving to Low-VHF or High-VHF. If the bidder selects moving to Low-VHF, the auction system will switch the bidder's assigned option to moving to Low-VHF at the price indicated, provided that there is currently a feasible channel available in Low-VHF for the bidder. The bidder will no longer be able to switch back to going off-air once the auction system has accepted the bidder's decision to switch its option to moving to Low-VHF (an option above going off-air on the hierarchy). If the auction system determines that moving to Low-VHF is not feasible, however, the bidder will remain in the bidding for the off-air option.

[223] There are a limited number of channels available in the VHF band. The number of channels available may change from round to round. For instance, in one round it may not be feasible to move a UHF bidder into the VHF band, but if a bidder drops out of the VHF band in a later round, the band may now be able to accommodate a UHF bidder that wishes to switch its bid from going off-air.

[224] *See* § IV.C.2.a (Bidding for a Single Relinquishment Option) (describing the process by which the auction system will evaluate the feasibility of repacking stations and determine provisional channel assignments).

rights accepted or has been assigned to a channel in its pre-auction band. Both acceptance of a bid and assignment to a channel will be provisional until the final stage of the auction.

D. New Stage Procedures

125. If a stage of the auction fails to satisfy the final stage rule, we will run a new stage of the auction at the next lower clearing target as identified in the Technical Appendix of the *Incentive Auction R&O*. We propose that at the start of any subsequent stages of the incentive auction, the auction system will conduct another clearing target optimization that will take into account the additional channel that will be available for broadcasting in the UHF band as a result of the reduction in the amount of UHF spectrum reallocated for flexible-use licenses under the next lower clearing target.[225] The optimization procedure will "re-shuffle" the assignment of stations in the UHF band (both the television portion and the 600 MHz Band) using the ISIX constraints and based upon the new clearing target with the objective of minimizing the number of impaired "weighted-pops."[226]

126. With a reduced clearing target, the auction system may be able to find a feasible channel assignment for some bidders that had been provisional winners in the prior stage, that is, bidders that were frozen in a relinquishment option when the auction system determined that they could no longer be assigned a channel in their pre-auction bands. These bidders will resume bidding.[227] We propose to reset the base clock price to the highest point at which any newly-feasible bidder was frozen in a prior stage. Then, in each round, as the clock price descends to reach the point at which a newly-feasible bidder was frozen in the previous stage, the bidder will again see lower price offers and will resume active bidding. Consequently, in a new stage, such bidders may not see their prices decrease for many rounds as the clock catches up to the point where each station had been previously frozen.[228]

127. The auction system will calculate price offers for bidders that can now be assigned a channel in their pre-auction bands using the descending clock pricing procedures proposed above, provided that the clock price is at or below the level at which these bidders had their relinquishment offers provisionally accepted in the prior stage. Bidders will respond to these prices, and reverse auction bidding rounds in the new stage will continue, according to the bidding procedures proposed above.

128. We seek comment generally on these proposed procedures for initiating bidding in a new stage of the reverse auction. We also seek comment more specifically on whether, in order to reduce the number of rounds, especially where some bidders may have had their offers accepted in significantly earlier rounds of the prior stage, we should increase the rate at which price offers descend for all newly-feasible bidders that are again actively bidding.

E. Determining a Final Television Channel Assignment Plan

129. We invite comment on appropriate objectives in optimizing the final television channel assignment plan and on how to prioritize those objectives. Further detail on this process can be found in Appendix E. As set forth above, at the end of each reverse auction stage, all channel assignments in the remaining television bands will be provisional. After the final stage rule is satisfied, we will determine

[225] *See* § III.A.4 (Clearing Target Optimization Procedure) and Appendix C.

[226] *See* § III.A.3 (Threshold for Limiting Market Variation) (proposing use of weighted-pops).

[227] Stations that dropped out of the bidding in a prior stage to be assigned a channel in their pre-auction band will retain that status and will not resume bidding.

[228] A bidder that had its price decrements frozen toward the end of the prior stage may therefore have a feasible assignment at the beginning of the new stage yet remain frozen long enough that another bidder drops out and it no longer has a feasible assignment. These bidders would therefore not see their price offers decrease at all in this subsequent stage.

final television channel assignments.[229] Like the provisional assignments made during the clearing target optimization and repacking processes, final TV channel assignments will be subject to the constraints adopted in the *Incentive Auction R&O* in order to preserve each eligible station's coverage area and population served.[230] Unlike the provisional assignments made during the reverse auction clock rounds, which will be based solely on such constraints, final channel assignments will be made applying optimization techniques that take into account additional objectives.[231] We stated in the *Incentive Auction R&O* that we would seek comment on the details of the final channel assignment optimization in this Public Notice,[232] and expressed our intention to optimize the final channel assignment plan to minimize relocation costs.[233] In the recent *ISIX R&O and Further Notice*, we adopted two additional objectives for the final optimization: avoiding channel assignments that would result in aggregate new interference to any individual station over one percent;"[234] and avoiding significant viewer losses due to terrain losses.[235] We deferred a decision as to how to optimize for the latter objective, recognizing that it could be accomplished in different ways.[236]

130. Consistent with our prior determinations, we now propose to determine the final TV channel assignment plan based on the following objectives, listed in order of priority: (1) maximizing the number of stations assigned to their pre-auction channel; (2) minimizing the number of stations predicted to receive aggregate (that is, from multiple stations) new interference above one percent; and (3) avoiding reassignments of stations with high anticipated relocation costs in order to minimize total relocation costs. We discuss these objectives and how they might work together in further detail below, and seek comment on any other possible final TV channel assignment plan objectives.

131. *Maximizing Channel "Stays."* In order to repurpose a contiguous portion of the current UHF television band for new, flexible uses, some television stations currently operating on higher UHF channels will need to be reassigned lower channels in the UHF band.[237] While some channel reassignments are inevitable in order to clear any spectrum, we seek to minimize the disruption that channel reassignments will have on both broadcasters and their viewers, as well as to reduce the overall

[229] We note that reassigned broadcasters will have the opportunity, after the release of the final channel assignment plan, to seek an alternative channel. *See Incentive Auction R&O*, 29 FCC Rcd at 6793 para. 553 (recognizing that, in some cases, a broadcaster may determine that a different channel will be more desirable or will make the transition process simpler and less costly).

[230] *Incentive Auction R&O*, 29 FCC Rcd at 6621, para. 118. More specifically, as set forth in Appendix D, a feasible assignment is one in which: (1) all stations are given a channel assignment, either to a channel or to go off the air; (2) a station can only be assigned to one of its allowable channels as defined in the domain.csv file; (3) stations' channel assignments must not violate adjacent and co-channel pairwise interference restrictions as defined in the interference_paired.csv file; (4) all non-participating stations and stations that have dropped out of bidding in the reverse auction are assigned a channel in their pre-auction band; and (5) all participating stations in the reverse auction must be assigned to a valid relinquishment option, that is, an option consistent with the relinquishment options the bidder selected during the application process and with the bidding rules of the reverse auction.

[231] *Id.* As we explained in the *ISIX R&O*, 29 FCC Rcd at 13079, para. 14, we can take time to account for such factors during the final TV channel assignment process without compromising the speed of the reverse auction bidding process.

[232] *See Incentive Auction R&O*, 29 FCC Rcd at 6621, para. 118.

[233] *Id.* at 6832, para. 650.

[234] *ISIX R&O*, 29 FCC Rcd at 13079, para. 14 ("Among other objectives, we intend to seek a final channel assignment that minimizes new aggregate interference above one percent.").

[235] *Id.* at 13082–83, paras. 23–25.

[236] *Id.* at 13082–83, paras. 22–25.

[237] *Incentive Auction R&O*, 29 FCC Rcd at 6570–71, para. 3.

cost of the repacking process.[238] In addition, avoiding new channel assignments where possible will help to avoid viewer losses due to terrain losses that can result when a station is reassigned to a different channel.[239] We therefore propose to maximize the number of stations that stay on their pre-auction channel as our first objective in the final channel assignment optimization. By maximizing the number of stations that stay on their pre-auction channels, we can reduce repacking costs, avoid disruption to broadcasters and their viewers and avoid losses in viewers and coverage area due to terrain that may result from channel reassignments.

132. *Minimizing Aggregate New Interference Over One Percent*. As we previously determined, we will optimize the final channel assignment plan to avoid channel assignments that would result in aggregate new interference of more than one percent to any individual station.[240] We invite comment on two possible approaches to implementing this objective using optimization techniques. The first approach is to minimize the maximum amount of aggregate new interference that any one station could receive. The second approach is to minimize the *number* of stations predicted to receive aggregate new interference above one percent. The former approach will ensure that the amount of aggregate new interference that any one station receives is as small as possible but could have the drawback of creating more stations with aggregate new interference above one percent. The latter approach ensures that the number of stations with aggregate new interference above one percent is minimal but could have the drawback of not explicitly restricting the amount of aggregate new interference for any one station.[241] As we discussed recently in the *ISIX Order*, however, we anticipate that the worst cases will be limited in number and will not exceed two percent, and stations may remedy any such situations by seeking alternative channel assignments in the post-auction transition process. We also invite comment on combining the two approaches. We seek comment on these and other possible approaches to optimizing to reduce aggregate new interference.

133. *Minimizing Relocation Expenses.* The costs associated with reassigning a station to a new channel in the repacking process vary from station to station. For example, some stations broadcast from antenna structures that may be particularly difficult to modify due to height, geography, or weather conditions; other stations may need to acquire significant new equipment in order to broadcast from their reassigned channels. In the *Incentive Auction R&O*, we stated our intention to disburse funds from the $1.75 billion TV Broadcaster Relocation Fund as fairly and efficiently as possible.[242] In order to carry out this intention, we propose to minimize the total relocation costs using the most accurate publicly available data to measure such costs.[243] Recognizing that we may not have perfectly accurate data on equipment, facilities, and other factors relevant to determining anticipated relocation costs, we seek comment on this proposal and specifically on how to determine these expenses.

134. *Prioritizing Multiple Objectives*. We further seek comment on prioritizing objectives in the final TV channel assignment plan objectives. In order to combine the objectives proposed above into a single process, we propose that the final TV channel assignment procedure first solve or optimize for a primary objective and use that outcome as a constraint on solving the secondary objective, which would

[238] *See id.* at 6832, para. 650.

[239] *Id.* at 6646, para. 170.

[240] *ISIX R&O*, 29 FCC Rcd at 13079–80, paras. 14–15.

[241] For either alternative, the optimization would use the pairwise constraints to calculate aggregate interference, which would result in some double counting and provide a conservative approach to calculating aggregate interference.

[242] *See Incentive Auction R&O*, 29 FCC Rcd at 6832, para. 650.

[243] We could use, for example, data compiled for the Media Bureau by Widelity, Inc., *see Media Bureau Seeks Comment on Widelity Report and Catalog of Potential Expenses and Estimated Costs*, Public Notice, 29 FCC Rcd 2989 (MB 2014) (Widelity Report), or data provided by broadcasters as part of the CDBS verification process.

then constrain solving the tertiary objective. Given that minimizing channel moves will promote multiple objectives, we propose to make it the primary objective. Under our proposed approach, the final channel optimization procedure first would determine an assignment of stations that maximizes the number of stations assigned to their pre-auction channel. The procedure then would apply our proposed secondary objective by determining another assignment that minimizes the total number of stations predicted to receive new aggregate interference over one percent, but would restrict that assignment such that the number of stations assigned to their pre-auction channel is within 95 percent of the maximum number in the first step. We propose to set the percentage to 95 percent to allow some flexibility in the second assignment while mostly restricting the assignment to maintain the maximum number in the first assignment. Finally, the procedure would apply these two restrictions to the determination of a third assignment of stations that minimizes anticipated relocation expenses. We seek comment on these priorities given that the objective with highest priority necessarily restricts the objective with next priority and so on.

F. Incentive Payments

135. As noted in the *Incentive Auction R&O*, the process by which auction proceeds will become available to pay reverse auction participants their shares precludes a specific deadline for sharing proceeds.[244] The Commission will share auction proceeds with broadcasters relinquishing spectrum usage rights as soon as practicable following the conclusion of the incentive auction. We note that circumstances regarding the post-auction clearing and relocation of broadcasters may make it in the public interest to prioritize payments to some broadcasters over others in order to expedite the entire post-auction transition process.[245] We retain discretion to take factors that facilitate the transition process into account when determining the sequence of payments sharing auction proceeds.

V. PROPOSED FORWARD AUCTION PROCEDURES

136. In this section, we seek comment on proposed forward auction procedures to implement the ascending clock auction format adopted in the *Incentive Auction R&O*.

A. Information Available During the Auction, Inventory, and Implementation of the Spectrum Reserve

137. This section addresses proposals regarding the information that will be available to forward auction bidders at various times during the auction, the categories of generic licenses that will be available for forward auction bidding, and creation of separate categories of "reserved" and "unreserved" spectrum blocks at the time the final stage rule is met pursuant to the *Mobile Spectrum Holdings R&O*.

1. Forward Auction Information Available During the Auction

138. As with most recent spectrum license auctions, we propose to limit information available in the forward auction in order to prevent the identification of bidders placing particular bids until after the auction is over.[246] More specifically, we propose to not make public the PEAs that an applicant selects for bidding in its application, the amount of any upfront payment made by or on behalf of the applicant, or any other bidding-related information that might reveal the identity of the bidder placing the

[244] *Incentive Auction R&O*, 29 FCC Rcd at 6786, para. 534.

[245] For example, the Commission determined in the *Incentive Auction R&O* that winning bidders in the reverse auction would be required to vacate their pre-auction channels within three months of receiving payment of their share of auction proceeds. As the Commission explained in the *Incentive Auction R&O*, the ability of stations that are assigned to new channels in the repacking process may be dependent on other stations' moves. Hence, there may be situations in which prioritizing payment to a particular winning bidder may expedite the transition process for other broadcasters.

[246] As discussed elsewhere, pursuant to the mandate of the Spectrum Act, we will keep confidential information regarding the identities of participants in the reverse auction. Spectrum Act § 6403(a)(3).

bid. Concerns about anti-competitive bidding and other factors that the Commission has relied on to prevent identification of particular bidders during auctions also apply to the forward auction portion of the incentive auction.[247] We invite commenters that disagree with our proposal to address why they support a different approach.

139. Notwithstanding the foregoing, in order to facilitate compliance with section 1.2105(c) of the Commission's rules, which prohibits parties seeking licenses in the same geographic area from communicating with one another regarding certain bidding-related information, we propose to notify each forward auction applicant of the identities of other forward auction applicants that have selected geographic areas that overlap with the applicant's own selection and, therefore, fall within the scope of the rule.[248] We note that as the information we will provide relates to the bids and bidding strategies of the other participants, applicants are prohibited from communicating the information that they receive to other auction participants unless doing so comes within one of the exceptions provided in the rule.[249]

140. We also propose that the auction system will provide forward auction bidders with the following information, at the times indicated:[250]

- Prior to bidding in the clock phase of each stage, the clearing target for that stage;
- After the reverse auction portion of any stage ends, the number of spectrum blocks in each license category in each PEA and the percentage impairment of each block and the location of those impairments, as well as the ISIX data for such impairments;[251] and
- After the reverse auction portion of each stage ends, the total dollar amount of forward auction proceeds needed to satisfy the second component of the final stage rule.

141. As described above in connection with the reverse auction, we propose to make public the total of reverse auction bids when bidding in the reverse auction for a stage is closed, as that is part of the second component of the final stage rule.[252] Similarly, we will make public the forward auction bid amounts at the end of each round, as those are the amounts that will be used to determine whether the first component of the final stage rule has been satisfied.

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[247] *See, e.g., Auction of Advanced Wireless Services (AWS-3) Licenses Scheduled for November 13, 2014; Notice and Filing Requirements, Reserve Prices, Minimum Opening Bids, Upfront Payments, and Other Procedures for Auction 97*, AU Docket No. 14-78, Public Notice, 29 FCC Rcd 8386, 8429–30, para. 150 & n.240 (2014) ("[t]he limited information disclosure procedures used in past auctions have helped safeguard against potential anticompetitive behavior such as retaliatory bidding and collusion") ("*Auction 97 Procedures PN*"); *Auction of H Block Licenses in the 1915-1920 MHz and 1995-2000 MHz Bands Scheduled for January 14, 2014; Notice and Filing Requirements, Reserve Price, Minimum Opening Bids, Upfront Payments, and Other Procedures for Auction 96*, AU Docket No. 13-178, Public Notice, 28 FCC Rcd 13019, 13055–56, paras. 136–37 (2013) (finding that "the competitive benefits associated with anonymous bidding outweigh the potential benefits of full information disclosure" and concluding that "[n]othing in the record persuades us that we should depart from the now-established Commission practice of implementing anonymous bidding procedures in wireless spectrum auctions") ("*H Block Procedures PN*").

[248] We have used the same approach as proposed here in other auctions with limited information procedures. *See, e.g., Auction 97 Procedures PN*, 29 FCC Rcd at 8430, para. 154.

[249] *See* 47 C.F.R. § 1.2105(c).

[250] As described above, for each stage, we propose to run a complete reverse auction before running a forward auction. *See* § III.C (Stage Structure).

[251] ISIX data will include, among other things, such information as whether the impairment is located in the uplink or downlink portion of the license and the location of the hypothetical base stations used to predict interference. For more detailed information, see Appendix B. *See generally ISIX R&O*, 29 FCC Rcd at 13071.

[252] *See* § IV.A.2 (Reverse Auction Information Available During the Auction).

2. Forward Auction Inventory: Determining Categories of Generic Licenses

142. In the *Incentive Auction R&O*, we decided we would conduct bidding for categories of generic licenses in the clock phase of the forward auction, recognizing that we would need to consider "a number of factors, such as proximity to television stations or guard bands" when determining how to group license blocks into categories for bidding.[253] Here we seek comment on a proposal to offer two categories of licenses in the clock phase of the forward auction based on relative levels of impairment caused by proximity to television stations in the 600 MHz Band.

143. We propose to offer spectrum blocks in two different categories of generic licenses for bidding in the forward auction ("Category 1" and "Category 2"), based on the extent of potential impairments in those specific PEA license areas.[254] We also propose thresholds for distinguishing between the two categories, as well as for determining when a license is sufficiently impaired that it will not be offered for sale in the clock phase of the forward auction. In addition, we propose a price adjustment procedure to account for varying degrees of impairment in the licenses offered. We emphasize that, consistent with our determination in the *Incentive Auction R&O* to accommodate market variation to a limited extent only, and with our proposal above to strictly limit the amount of market variation in determining an initial clearing target, we anticipate that most licenses offered in the forward auction will fall into Category 1 as defined below and, therefore, will have potential impairments affecting 15 percent or less of the population in the license area.[255] Nevertheless, we must be able to distinguish between Category 1 and Category 2 licenses in order to achieve our auction goals. The *Incentive Auction R&O* adopted a strong interoperability rule that requires that any user equipment certified to operate in any portion of the 600 MHz Band must be capable of operating, using the same technology that the licensee has elected to use, throughout the entire 600 MHz Band.[256] We emphasize that offering multiple categories of licenses during the auction will have no effect on interoperability because the same rules apply to all 600 MHz Band licenses regardless of whether the license is offered in Category 1 or Category 2.

144. Minimizing the number of separate bidding categories to the extent possible serves our goal of speeding up the forward auction bidding process.[257] In light of this goal, and because we created the 600 MHz Band guard bands in the *Incentive Auction R&O* to provide sufficient protection from harmful interference to make 600 MHz Band licenses fungible in areas not affected by market variation, we do not propose to establish separate categories of generic licenses based on proximity to television stations or guard bands in areas that are not affected by market variation.[258]

145. We propose to categorize as Category 1 any license with potential impairments that affect zero to 15 percent of the population of the PEA and as Category 2 any license with potential impairments that affect greater than 15 percent but less than or equal to 50 percent of the population. Under this proposal, a license with potential impairments that affect more than 50 percent of the population will not be offered in the forward auction. We propose to calculate the extent of impairment on a granular basis, using cell-level data. Specifically, we propose to calculate the percentage of population impaired in each

[253] *Incentive Auction R&O*, 29 FCC Rcd at 6775–76, para. 506.

[254] As discussed below, we propose to "split" one of these categories at the time the final stage rule is met, to accommodate separate bidding by reserve-eligible entities. *See* § V.A.3.b (Bidding on Reserved Licenses).

[255] *Incentive Auction R&O*, 29 FCC Rcd at 6605, para. 83. *See also* § III.A.3 (Standard for Limiting Market Variation).

[256] *Incentive Auction R&O*, 29 FCC Rcd at 6866–67, para. 732.

[257] *See Incentive Auction R&O*, 29 FCC Rcd at 6594, para. 66.

[258] *See Incentive Auction R&O*, 29 FCC Rcd at 6607–14, paras. 88–97. In the *Incentive Auction R&O*, the Commission stated its intent to allow unlicensed use of the guard bands, subject to the establishment of technical standards to prevent harmful interference to licensed services. *Id.* at 6686, para. 273; *see also Part 15 NPRM*.

block at a two-by-two kilometer cell level by applying the ISIX methodology to the assignment plan determined by the clearing target optimization procedure.[259] With regard to the proposed 15 percent threshold for Category 1 licenses, wireless operators normally can expect some degree of interference to service in their license areas due to terrain and other factors. A 15 percent threshold would provide flexibility for the auction system to assign licenses to Category 1 even if they are subject to a limited degree of inter-service interference, and winners of generic licenses will have the opportunity to bid for frequency-specific licenses within each category during the assignment phase of the forward auction. Moreover, we propose below to apply discounts at the end of the assignment phase to reflect the extent to which a generic license is subject to impairment, i.e., we would discount Category 1 licenses based on their specific degree of predicted impairment.[260] Accordingly, we believe that licenses with potential impairments that affect between zero and 15 percent of the population reasonably may be considered fungible. We invite comment on this proposal. As an alternative, we seek comment on whether to limit the proposed Category 1 to licenses that are not predicted to be subject to any inter-service interference, that is, with potential impairments that affect zero percent of the PEA population. This would enhance fungibility but reduce the number of licenses available in Category 1.

146. We propose a 50 percent threshold for determining whether an impaired license will be offered in the clock phase of the forward auction for several reasons. We believe that even with up to 50 percent impairment, particularly given the proposed availability of discounts based on degree of impairment at the end of the assignment phase, bidders would find a license usable. At the same time, we recognize that there is a limit to the extent that impaired licenses reasonably can be considered fungible, and even assuming that bidders would be interested in bidding for highly impaired licenses, our goal of simplicity militates against creation of an additional generic category. Under the circumstances, we believe that 50 percent represents a reasonable threshold. We seek comment on this proposal. If given the opportunity, would bidders be interested in bidding on licenses that are more than 50 percent impaired? If we adopt the alternative proposal above of strictly limiting Category 1, should we modify the proposed range of Category 2 licenses or expand it to between one and 50 percent? Commenters who advocate alternative thresholds or approaches should address the potential tradeoffs associated with their proposed alternatives.

147. We further propose to incorporate a price adjustment into the auction system at the end of the assignment phase of the forward auction to account for varying degrees of predicted impairment to the licenses offered for sale, regardless of whether such licenses are in Category 1 or Category 2. Specifically, we propose to discount the final clock price by one percent for each one percent of predicted impairment. For example, under this proposal a 10 percent discount would be applied to a license that is 10 percent impaired following the clock phase of the forward auction impairment. We address procedures for applying the proposed discount in detail below.[261] We propose such price adjustments in order to help accommodate a range of values among generic licenses within a proposed category, while minimizing the number of bidding categories in the interest of simplicity. We also seek comment on an alternative approach, under which the proposed discount would be applied only to licenses in Category 2 in light of the wider range of degrees of impairment in that category.

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[259] Because an assignment plan will be determined at the time we propose to categorize licenses, the auction system will be able to feasibly calculate impairment data at a more granular level than when the system determines the initial clearing target or re-optimizes the channel assignment plan for a new stage. In the latter situations, in contrast, the auction system must consider all possible assignment combinations, and the computational complexity of that optimization problem precludes the system from considering impairment data at the cell level. *See* note 81. In using the cell level data to categorize licenses, we would apply the same approach for downlink/uplink impairments as described in § III.A.1 (Measuring the Extent of Potential Impairments) above, but at a two-by-two kilometer cell level.

[260] The auction system will display the percentage of impairment for each block in each category during biding.

[261] *See* § V.D.3 (Acceptable Bids and Bid Processing).

148. We also invite comment on how to treat heavily impaired spectrum blocks (i.e., those in which more than 50 percent of the population is impaired in a PEA) that we do not propose to offer in the clock round of the forward auction. Should we make such "overlay" licenses available to bidders in the assignment phase in conjunction with adjacent licenses offered in the same PEA? Under this alternative, in the assignment phase, we would bundle these heavily impaired licenses with the most impaired frequency-adjacent licenses. We ask commenters to address tradeoffs of this alternative compared to our main proposal and, specifically, to address performance requirements in the context of heavily-impaired overlay licenses.

3. Implementation of the Spectrum Reserve

149. Here we seek comment on implementing the market-based spectrum reserve at the time the final stage rule is satisfied, consistent with the decisions made in the *Mobile Spectrum Holdings R&O* to reserve a portion of the licensed spectrum made available in the forward auction for reserve-eligible entities and to determine the amount of reserved spectrum through a market-based process during the auction.[262] We propose procedures for implementing the market-based spectrum reserve in various potential contexts, including how we will offer Category 2 licenses and the presence of only one reserve-eligible bidder in a PEA.

a. Determining the Number and Category of Reserved Licenses.

150. We propose that the maximum number of reserved licenses, as set forth in the *Mobile Spectrum Holdings R&O* and illustrated in the chart above,[263] will be based on the total number of Category 1 and Category 2 blocks offered in a PEA.[264] For example, if there are 60 megahertz of Category 1 blocks and 10 megahertz of Category 2 blocks made available in a PEA, under our proposal we will consider the available amount of spectrum offered in that PEA to be 70 megahertz, with a corresponding reserve of 30 megahertz.

151. We propose that only Category 1 blocks will be designated for bidding by reserve-eligible entities. The *Mobile Spectrum Holdings R&O* determined that the actual amount of reserved spectrum will be based on the quantity of blocks demanded by reserve-eligible bidders.[265] Under our proposal, the actual number of blocks reserved in a PEA will be based on demand for Category 1 blocks by reserve-eligible bidders at the time the auction reaches the trigger, i.e., when the final stage rule is satisfied. That is, if demand for Category 1 blocks in a PEA by reserve-eligible bidders is less than the maximum reserved spectrum, then fewer reserved blocks will be available in that PEA. Consistent with this proposal, the actual amount of reserved spectrum can be no greater than that corresponding to the supply of Category 1 blocks in the PEA.[266] We seek comment on this proposal. Alternatively, we seek

[262] *See Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6208, para. 184. We stated in the *Mobile Spectrum Holdings R&O* that we would seek comment in this Public Notice on any further implementation issues that may affect our market-based spectrum reserve, and whether and if so how the policies and rules we adopted should apply or be adjusted based on any auction details that might be relevant to the process. *Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6213, para. 201.

[263] *See* § II.C (Mobile Spectrum Holdings Order).

[264] *See* § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses) (proposing to assign spectrum blocks to either Category 1 or Category 2 based on the extent of predicted impairments to the blocks).

[265] *Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6209, para. 187.

[266] For example, in the event that only one Category 1 block is available in a PEA and the remaining amount of available spectrum offered in that PEA consists of Category 2 blocks, we would designate only the single Category 1 block as reserved spectrum even if reserve-eligible bidders are actively bidding for Category 2 blocks. Conversely, in the event that there are only three Category 1 blocks available in a market, all of which are demanded by reserve-eligible bidders at the time the auction reaches the trigger, non-reserve-eligible bidders could be limited to bidding on Category 2 blocks, depending on the specific circumstances. Either of these scenarios is unlikely to occur in many markets.

comment on whether we should include Category 2 blocks in the spectrum reserve in any PEAs with fewer Category 1 blocks than in the maximum spectrum reserve, assuming sufficient demand for Category 2 blocks by reserve-eligible bidders at the time the auction reaches the final stage rule trigger. Under this approach, the total number of Category 1 and Category 2 blocks in the reserve would be no greater than the maximum spectrum reserve.

152. Overall, our approach seeks to ensure that the need to offer fewer Category 1 blocks in certain PEAs in order to accommodate market variation does not reduce the benefits to competition and consumers from providing opportunities for multiple providers to gain access to low-band spectrum. First, because we anticipate that most licenses offered for sale in the forward auction will fall into Category 1[267] the impact of the proposals described above should be limited to the relatively few markets that are affected by market variation. In such markets, however, we believe our proposal to count both categories of licenses toward determining the maximum number of reserved licenses is consistent with the competition goals discussed in the *Mobile Spectrum Holdings R&O*, including facilitating access to below-1-GHz spectrum by multiple providers.[268]

153. Our competition goals will be further accomplished by designating only Category 1 blocks for reserve-eligible bidders, which are likely to be more reliant on 600 MHz Band spectrum to expand coverage and to compete in the mobile wireless marketplace. As discussed in the *Mobile Spectrum Holdings R&O*, we are striving "to promote competition by ensuring that in the near future, more providers would hold a sufficient mix of spectrum to compete robustly."[269] We believe this proposal is also consistent with our statutory obligation to promote access to spectrum for a variety of licensees, including entities seeking to serve rural areas or improve services in rural areas.[270]

154. It would significantly complicate the auction to create an additional generic bidding category to implement separate reserved categories for both Category 1 and Category 2 licenses. Doing so would undercut the benefits from bidding for categories of generic licenses, potentially extending the length of the auction, necessitating additional procedures for dividing bidder demands, and making it harder for bidders to switch their demands across categories.[271] Therefore, our proposed approach of reserving only Category 1 licenses for reserve-eligible bidders promotes good auction design and is consistent with our established policy to promote access to spectrum for a variety of licensees, including entities seeking to serve rural areas or improved services in rural areas.[272]

155. *One Reserve-Eligible Bidder*. In the *Mobile Spectrum Holdings R&O*, we indicated that we intend, after opportunity for comment in the *Incentive Auction Comment PN*, not to allow reserve-eligible bidders to acquire more than 20 megahertz of reserved spectrum in a PEA unless there is another bidder for reserved spectrum in that PEA.[273] We do not believe the public interest benefits of a maximum of 30 megahertz of reserved spectrum would be realized without more than one reserve-eligible bidder in a PEA.[274] In particular, we explained in the *Mobile Spectrum Holdings R&O* that a maximum of 30 megahertz of reserved spectrum could permit at least two reserve-eligible bidders to acquire paired 5+5 megahertz blocks in a PEA for deployment of next-generation networks, with one of the bidders

[267] *See* § V.A.2 (Forward Auction Inventory: Determining Categories of Generic Licenses).

[268] *See Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6204, para. 174.

[269] *Id.* at 6198, para. 159.

[270] *See* 47 U.S.C. § 309(j)(3)(A)&(B); *see also Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6207, para. 180.

[271] *See Incentive Auction R&O*, 29 FCC Rcd at 6775, para. 505. *See also* §§ V.A.3.b (Bidding on Reserved Licenses); V.C (Clock Phase Bidding Procedures).

[272] *See Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6207, para. 180; 47 U.S.C. § 309(j)(3)(A)&(B).

[273] *Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6209, para. 187.

[274] *Id.* at 6210, para. 190.

potentially acquiring two paired blocks (20 megahertz).[275] We also anticipated that a maximum of 30 megahertz—three paired 5+5 megahertz spectrum blocks—would facilitate competition among bidders seeking to acquire two paired 5+5 megahertz blocks.[276] In contrast, more than 20 megahertz of reserved spectrum is neither necessary for a single reserve-eligible bidder to deploy next-generation networks nor likely to facilitate competitive bidding. Accordingly, we propose to limit the maximum amount of reserved spectrum in a PEA to 20 megahertz if there is only one reserve-eligible bidder demanding blocks when the trigger is reached.

b. Bidding on Reserved Licenses

156. We propose specific procedures to govern bidding on the reserved licenses after the final stage rule is met.[277] As set forth above, we propose to implement separate bidding for the reserved licenses in the clock bidding round that follows the round in which the final stage rule is met, regardless of whether the final stage rule is met in the course of regular clock bidding rounds or an extended round. Up to the point at which the auction reaches the spectrum reserve trigger, all bidders, including reserve-eligible bidders, will be bidding on a single category of Category 1 blocks in a PEA. In order to implement bidding on reserved spectrum after the final stage rule is met, we propose to split the Category 1 licenses in each PEA into two new categories, a reserved category, on which only reserve-eligible bidders may bid, and an unreserved category, on which any bidder may bid.[278] Because a uniform clock price will apply to all the Category 1 spectrum blocks in a PEA at the time of the split, the clock price will be the same for both the reserved and the unreserved Category 1 blocks in the first bidding round after the auction reaches the spectrum reserve trigger. From that point forward, however, we propose to treat the reserved and the unreserved Category 1 blocks as separate bidding categories. That is, bids will be processed separately following the split for the license categories in each PEA of reserved Category 1, unreserved Category 1, and Category 2, as they were for Category 1 and Category 2 prior to the split. Prices for generic blocks in each category will be based on relative supply and demand for each, and thus may diverge based on the bidding in subsequent rounds.[279]

157. We propose to allocate the demands for Category 1 blocks in each PEA among the available reserved and unreserved blocks.[280] The auction system will have to allocate demand for that single category between the two new categories (reserved Category 1 and unreserved Category 1) of blocks as a starting point for bidding in the following round. Under our proposal, the auction system first will assign all demand by non-reserve-eligible bidders to unreserved Category 1, and then will assign demand by reserve-eligible bidders to the reserved category up to the point where demand for reserved Category 1 blocks is equal to supply. The auction system will apply the remaining demand of reserve-

[275] *Id.*

[276] *Id.*

[277] Above we address in detail and seek comment on the proposed conditions for meeting the final stage rule. *See* § III.B (Final Stage Rule). In the *Mobile Spectrum Holdings R&O*, we stated we would consider whether the spectrum reserve trigger should be based solely on prices or revenues in the "major markets" and, if so, how to identify such markets. *See Mobile Spectrum Holdings R&*O, 29 FCC Rcd at 6211, para. 195. We note that the proposed final stage rule would include a "high-demand" PEA component. Specifically, in this Public Notice we consider whether to limit the evaluation of whether the first component of the final stage rule has been met to a subset of "high-demand" PEAs, which we also propose to use when determining whether to implement an extended round. *See* §§ III.B (Final Stage Rule); III.C.2 (Final Stage Determination and Implementation of Extended Round).

[278] The supply of blocks in reserved Category 1 will be determined as proposed above in § V.A.3.a (Determining the Number and Category of Reserved Licenses) and the remainder will constitute the supply of unreserved licenses.

[279] Below we address in more detail proposed bid processing procedures to govern how prices will be set in a bidding category. *See* § V.C.1 (Setting Prices in the Clock Rounds).

[280] Our proposal for allocating supply of Category 1 blocks among the reserved and unreserved categories is set forth in the preceding section.

eligible bidders to unreserved Category 1.[281] In the bidding rounds that follow the implementation of the spectrum reserve, bidders will be able to switch their bids between the separate categories of reserved Category 1, unreserved Category 1, and Category 2 blocks, subject to their eligibility for reserved blocks and procedures on acceptable bids proposed below.

158. Once we apply our proposed approach, demand in the reserved category will equal supply, and any excess demand for the pre-split Category 1 blocks will be allocated to the unreserved category. We propose to allocate demands in this way—as opposed to assigning all demand by reserve-eligible bidders to the reserved category—to avoid the possibility of excess supply for unreserved blocks after the split in the case that the pre-split Category 1 does not have excess supply,[282] which could result in auction revenue declining below the level required by the final stage rule at a point at which the final stage rule had been declared satisfied.[283]

B. Forward Auction Application Process

159. The Commission's general competitive bidding rules, as modified in the *Incentive Auction R&O*, apply to the forward auction.[284] Those rules require that parties apply to participate in the forward auction and that applicants satisfy certain requirements before bidding in the auction.[285] We seek comment below on discrete issues relating to the upfront payment each applicant must make and on how an applicant must certify its eligibility to bid for reserved licenses if it wishes to do so. We will provide detailed instructions for the pre-auction application process in the *Procedures PN*.

1. Bidding Units

160. Consistent with prior FCC spectrum license auctions, we propose to assign to each spectrum block that will be available in the forward auction a specific number of bidding units. We propose to use the bidding units for purposes of calculating minimum opening bids, upfront payments, and bidder eligibility, and for measuring bidding activity.[286] Under our proposed approach, the number of bidding units for a given license will be fixed and will not change during the auction, regardless of price changes.

161. In assigning bidding units to licenses, we propose to use a weighted population method similar to what we propose for our "near nationwide" threshold.[287] We start with the total population in

[281] Under our proposal, we will first allocate demand for one block to the reserved category for each reserve-eligible bidder in turn, then a second block, and so on until the total demands allocated to the reserved category equal the supply of reserved blocks. We propose to choose the order of reserve-eligible bidders pseudo-randomly.

[282] This could occur, for example, if the demands for Category 1 prior to the split came more than proportionately from reserve-eligible bidders. If all those demands were transferred to the reserved category after the split, demand for unreserved Category 1 blocks could be less than the supply, even if demand for the pre-split Category 1 exceeds the supply of the pre-split Category 1. The same possibility is not present with regard to the reserved category because the actual number of blocks that will be reserved in a PEA will not be greater than the number of Category 1 licenses demanded by reserve-eligible bidders at the time the auction reaches the spectrum reserve trigger. *See Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6209, para. 187; *see also* § V.A.3.a (Determining the Number and Category of Reserved Licenses).

[283] This approach is consistent with bidding procedures proposed below that prevent bidders from reducing demand for a category if the reduction would result in total demand for the category falling below the supply. *See* § V.C.2 (Acceptable Bids).

[284] *See* 47 C.F.R. § 27.1300.

[285] 47 C.F.R. § 1.2105(a).

[286] Proposed procedures for using the bidding units as we intend are set forth below. *See* § V.C (Clock Phase Bidding Procedures).

[287] *See* § III.A.3 (Standard for Limiting Market Variation).

each PEA. Because the 600 MHz Band Plan consists entirely of paired 5+5 megahertz blocks, bidding units do not need to reflect differences in bandwidth across licenses; thus, there is no need to use megahertz per population (MHz-pops), as the Commission typically does for spectrum license auctions. Further, we propose to assign Category 1 and Category 2 blocks in a PEA the same number of bidding units to facilitate bidding across categories. Hence, all generic licenses in a PEA would be assigned the same number of bidding units.

162. We propose to weight population using an index of relative prices for each geographic area based on data from previous auctions. Consistent with the approach we used for Auction 97, the auction of Advanced Wireless Services ("AWS-3") licenses, we will multiply the population of each PEA by an index value for the PEA. As we did for Auction 97, we propose to group the price index by deciles and apply the lowest index value in each decile to all PEAs in that decile.[288] The attached Appendix F sets forth the indices and number of bidding units that would be assigned to licenses in each PEA under our proposed approach using currently-available data.[289] We further propose to incorporate the final results of Auction 97 (the AWS-3 auction) in calculating the index of relative prices for PEAs that will be used to determine bidding units, upfront payments, and minimum opening bids.

163. By incorporating past prices, our proposed approach better reflects the relative weight bidders have assigned to the different markets in the past than would a calculation based solely on population. Consequently, service areas that have received similar winning bid amounts in past auctions will be similar to one another with respect to the activity rule. To simplify the number of units, we propose to divide the result of the above calculation by 1,000 and round it using the Commission's standard rounding procedures for auctions.[290] Thus, we propose to calculate bidding units for most licenses as (pops * index)/1000, rounded. Because there were no winning bidders for several licenses covering US territories and protectorates in past auctions, for licenses in the PEAs for Puerto Rico, Guam-Northern Mariana Islands, US Virgin Islands, and American Samoa, we propose to divide the results of the weighted population calculation by 2,000 and round the results. Finally, we propose to assign one bidding unit to licenses for the Gulf of Mexico.

2. Upfront Payments

164. In keeping with the Commission's usual practice in spectrum license auctions, we propose that applicants be required to submit upfront payments as a prerequisite to being found qualified to bid.[291] An upfront payment is a refundable deposit made by each bidder to establish its eligibility to bid on licenses. Upfront payments protect against frivolous or insincere bidding and provide the Commission with a source of funds from which to collect payments owed at the close of the auction.[292]

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[288] This index is substantially the same as that proposed above for measuring the effect of impairments for purposes of limiting market variation, i.e., applying the near-nationwide standard. *See* § III.A.3 (Standard for Limiting Market Variation). *See also generally Auction 97 Procedures PN*. However, for the near-nationwide standard, we do not propose to group the price index by deciles.

[289] The auction results used were from Auction 66, Advanced Wireless Services (AWS-1), and Auction 73, 700 MHz Band.

[290] Specifically, we would round numbers greater than 10,000 to the nearest thousand; numbers less than 10,000 and greater than 1,000 to the nearest hundred; numbers less than 1,000 and more than 10 to the nearest ten; and numbers less than 10 to the nearest one. All PEAs would have at least one bidding unit.

[291] 47 C.F.R. § 1.2106.

[292] *See Implementation of Section 309(j) of the Communications Act—Competitive Bidding*, PP Docket No. 93-253, Second Report and Order, 9 FCC Rcd 2348, at 2377–79, paras. 169–76 (1994). We note that the Commission's rules currently require that "[a]ny auction applicant that has previously been in default on any Commission license or has previously been delinquent on any non-tax debt owed to any Federal agency must submit an upfront payment equal to 50 percent more than that set for each particular license." 47 C.F.R. § 1.2106(a). The Commission recently proposed narrowing the scope of the defaults and delinquencies considered for purposes of this rule. *See Updating* (continued….)

165. We propose to base the upfront payment for each license on the number of bidding units associated with that license. Specifically, we propose an upfront payment amount of $2,500 per bidding unit, rounded.[293] These bidding unit amounts pertain to a single 5+5 megahertz generic license for each PEA. To the extent that bidders wish to bid on multiple generic licenses simultaneously, they will need to ensure that their upfront payment provides enough eligibility to cover more than one 5+5 megahertz generic license in a given PEA. The number of bidding units for a given license will be fixed and will not change during the auction as prices change. Appendix F shows the upfront payment amounts that would be calculated based on current data. As set forth above, we propose to incorporate the final results of Auction 97 in the calculation of bidding units.[294]

166. Under our proposed approach, a bidder's upfront payment will not be attributed to a specific license or licenses. Rather, the bidder may place bids on any combination of the licenses it selects on its application to participate in the forward auction, provided that the total number of bidding units associated with those licenses will not exceed its eligibility when it places the bid(s). Bidders will not be able to increase their eligibility during the auction; bidders only will be able to maintain or decrease their eligibility. Thus, in calculating its upfront payment amount and hence its initial bidding eligibility, an applicant must determine the maximum number of bidding units on which it may wish to bid in any single round and submit an upfront payment amount covering that total number of bidding units. We seek comment on these proposals.

167. For the forward auction, we propose to set a deadline for the submission of upfront payments that will occur after determination of the initial clearing target, based on commitments of reverse auction applicants. This proposed deadline will enable a participant to take into account the number of licenses in the initial clearing target when determining the amount of its upfront payment. We note that an applicant will be able to consider the amount of its upfront payment and prepare accordingly well in advance of this date. For example, an applicant would be able to determine the number of licenses it is likely to seek in various PEAs prior to knowing the number of licenses that will be available. Nevertheless, given that the upfront payment will determine the participant's maximum bidding eligibility in the forward auction, we conclude that we should require the submission of the upfront payment only after the determination of the initial clearing target.[295]

3. Eligibility for Spectrum Reserve

168. We propose to require an applicant seeking to participate in the forward auction as a reserve-eligible entity to certify in its application that it is a reserve-eligible entity with respect to each PEA in which it wishes to be able to bid for reserved blocks.[296] We further propose that an applicant must make this certification in its application and that it shall not be able to revise its certification thereafter. Under the *Mobile Spectrum Holdings R&O*, reserve-eligible entities may bid on unreserved spectrum blocks as well as reserved spectrum blocks.[297] Nevertheless, applicants that otherwise would be eligible to bid on reserved spectrum blocks may prefer to forego reserved-eligible status generally, or with respect

(Continued from previous page)
Part 1 Competitive Bidding Rules, WT Docket No. 14-170, Notice of Proposed Rulemaking, 29 FCC Rcd 12426, 12457–63, paras. 86–97 (2014).

[293] *See* note 290 (concerning rounding).

[294] *See* § V.B.1 (Bidding Units).

[295] *See* § I (Introduction) (identifying the major steps in the incentive auction process).

[296] We can implement this proposal without imposing undue burden on applicants by, for example, enabling an applicant to make a single certification that covers all of the PEAs in which it may wish to bid for reserved blocks.

[297] *Mobile Spectrum Holdings R&O*, 29 FCC Rcd at 6211, para. 192 ("Once the spectrum reserve is established, bidders will bid separately for generic reserved and unreserved spectrum licenses, with reserve-eligible bidders able to bid for spectrum in either category, and the other bidders able to bid only for the unreserved spectrum.").

to licenses in particular areas. In particular, reserved spectrum blocks will be subject to restrictions on subsequent transactions to which unreserved spectrum blocks will not be subject. The approach we propose will enable potentially reserve-eligible applicants to forego reserve-eligible status on a PEA-by-PEA basis. In addition, by requiring applicants intending to bid for reserved spectrum blocks to affirmatively declare their eligibility to do so, our proposed approach will avoid any subsequent ambiguity or uncertainty regarding an applicant's status.

C. Clock Phase Bidding Procedures

169. As discussed above, the first phase of the forward auction will include the clock bidding rounds, and after the clock bidding for generic licenses ends in the final stage, the assignment phase will commence.[298] In this section, we propose specific bidding procedures for the clock rounds of the forward auction. We seek comment on setting the minimum opening prices, setting prices between rounds of the auction and between stages of the auction.[299] We propose and seek comment on specific types of bids that participants will be able to place in the forward auction, including how those types of bids will be processed by the auction system, as well as the activity rule that bidders must meet to retain their eligibility. We propose a number of changes to the procedures the Commission has traditionally used when holding forward auctions, such as bid withdrawals and proactive waivers. We are changing these procedures for this auction to reduce complexity and uncertainty about bidder demand for spectrum. We seek comment on what effect these changes could have on participation by small business in the forward auction. This section also sets out detailed proposals on implementing the extended round and seeks comment on those.

1. Setting Prices in the Clock Rounds

170. *Minimum Opening Bids in the First Stage.* At the beginning of the clock phase of the forward auction in the initial stage, a bidder will indicate how many blocks in a generic license category in a PEA it demands at the minimum opening bid price. We propose to establish initial clock prices, or minimum opening bids, for each license based on the number of bidding units associated with the license.[300] Our proposed approach is intended to be consistent with section 309(j) of the Communications Act, as amended, which calls for prescribed methods of establishing minimum opening bid amounts when FCC licenses are subject to auction, unless the Commission determines that a minimum opening bid amount is not in the public interest.[301]

171. Specifically, we propose a minimum opening bid amount of $5,000 per bidding unit. This proposal is consistent with the precedent of our AWS-3 auction procedures, where we set the minimum opening bid amount at twice the upfront payment for each license. Because the number of bidding units for each license incorporates pricing information from previous auctions, this proposal appropriately adjusts opening bids to reflect value differences that bidders have placed on different geographic areas. Appendix F shows the minimum opening bid amounts that would be calculated based

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[298] *See* §§ V.C (Clock Phase Bidding Procedures); V.D (Bidding Procedures in the Assignment Phase).

[299] Consistent with a clock auction format with categories of generic licenses, a uniform minimum opening price or clock price applies to all the blocks in a category and a PEA.

[300] This formula uses the upfront payment schedule depicted in Appendix F. Although former defaulters must submit higher upfront payments than other applicants to establish the same amount of eligibility, the minimum opening bid amounts will be the same for all bidders.

[301] 47 U.S.C. § 309(j)(4)(F); *see also* 47 C.F.R. § 1.2104(d) ("The Commission may, by announcement before or during an auction, require minimum bid increments in dollar or percentage terms. The Commission also may establish minimum opening bids and maximum bid increments on a service-specific basis."); *Amendment of Part 1 of the Commission's Rules—Competitive Bidding Procedures*, WT Docket No. 97-82, Third Report and Order and Second Further Notice of Proposed Rule Making, 13 FCC Rcd 374 at 455–56, para. 141 (1997) ("*Part 1 Third Report and Order*").

on current data. As set forth above, we propose to incorporate the final results of Auction 97 in the calculation of bidding units.[302]

172. Our experience in past auctions indicates that minimum opening bid amounts calculated in this manner will be an effective tool for accelerating the competitive bidding process, a particularly important goal for the incentive auction given the interdependency between the reverse and forward auctions. One of the primary purposes of a minimum opening bid is to speed up the course of an auction.[303] By incorporating past pricing information into our calculation of minimum opening prices, we intend to reduce the number of rounds it will take for demand to equal supply in markets that have historically commanded relatively higher prices.

173. We seek comment on our proposal. If commenters believe that this approach will result in unsold licenses or unreasonable minimum opening bid amounts, they should explain why this is so, suggest an alternative approach, and explain why such an alternative is desirable. We also seek comment on whether we should discount minimum opening bids for licenses in Category 2.

174. *Clock Price Increments Across Rounds.* After bidding in the first round and before each subsequent round, the system will announce a clock price for the next round, which is the highest price to which bidders can respond during the round. We propose to set the clock price for each category available in each specific PEA for a round by adding a fixed percentage increment to the price for the previous round.[304] As long as total demand for blocks in a category exceeds the supply of blocks, the percentage increment will be added to the clock price from the prior round. If demand equaled supply at an intra-round bid price in a previous round, then the clock price for the next round will be set by adding the percentage increment to the intra-round bid price.[305]

175. We propose to apply an increment that is between five and 15 percent and generally to apply the same increment percentage to all categories in all PEAs. We propose to set the initial increment within this range, and to adjust the increment as stages and rounds continue. The proposed five-to-15 percent increment range will allow the auction system to set a percentage that manages the auction pace, taking into account bidders' needs to evaluate their bidding strategies while moving the forward auction along quickly. We also propose that increments may be changed during the auction on a PEA-by-PEA or category-by-category basis based on bidding activity to assure that the system can offer appropriate price choices to bidders.

2. Acceptable Bids

a. Types of Bids

176. Here we propose specific bidding procedures for the clock phase of the forward auction, and address how the auction system will process the proposed types of permitted bids. We provide complete forward auction clock phase bid types and bid processing details in Appendix G. As an initial matter, we propose that the auction system not allow a bidder to reduce the quantity of blocks it demands in a category if the reduction will result in aggregate demand falling below the available supply of licenses in the category. The alternative would risk significant reductions in aggregate forward auction proceeds from round to round, impeding progress toward satisfying the final stage rule. It could also potentially undermine a prior determination that the final stage rule had been satisfied. Under the ascending clock format adopted for the forward auction, a bidder will indicate in each round the quantity of blocks in each category in each PEA that it demands at a given price, indicating that it is willing to pay

[302] *See* § V.B.1 (Bidding Units).

[303] *Part 1 Third Report and Order*, 13 FCC Rcd at 455, para. 140.

[304] For example, if the price for the first round is $10, and the price increment is 20 percent, the clock price for second round will be $12.

[305] Final clock prices, however, will not increase above the intra-round price as long as there is no excess demand.

up to that price for its current quantity.[306] In addition to making bids at the clock price, the adopted clock auction format will permit bidders to make bids at amounts smaller than the clock price ("intra-round bids").[307]

177. Under our proposal, if a bidder demands fewer blocks in a category than it did in the previous round, the auction system will treat the bid as a request to reduce demand which will be implemented only if aggregate demand will not fall below the available supply of licenses in the category.

178. Once a round ends, the auction system will process the bids submitted in the round and determine the extent to which there is excess demand for each category in each PEA in order to determine whether a bidder's requested change(s) in demand can be implemented.[308]

179. In order to facilitate bidding for multiple licenses in a category, and to help bidders manage their bidding given the requirement that a request to reduce demand may not be accepted, we propose that bidders will be permitted to make the following three types of bids: simple bids, all-or-nothing bids, and switch bids. All three types of bids can indicate multiple quantities of licenses. The attached Appendix G provides examples of each of the proposed types of bids and discusses how the auction system would treat them under our proposal.

- A "simple" bid indicates a desired quantity of licenses in a category at a price (either the clock price or an intra-round price). A simple bid may be implemented partially if it involves a reduction from the bidder's previous demands, and aggregate excess demand is insufficient to support the entire reduction.
- An "all-or-nothing" bid also indicates a desired quantity of licenses in a category, but allows the bidder to indicate that it wants the bid to be implemented fully or not at all.
- A "switch" bid allows the bidder to request to move its demand for a quantity of licenses from one category of generic licenses to another category within the same PEA. A switch bid may be applied partially, but the increase in demand in the "to" category will always match in quantity the reduction in the "from" category.

180. We emphasize that the proposed bid types will allow bidders to express their demand for blocks in the next clock round without running the risk that they will be forced to purchase more spectrum at a higher price than they wish. When a bid can be applied only partially, the uniform price for the category will stop increasing at that point, since the partial application of the bid results in demand falling to equal supply. Hence, a bidder that makes a simple bid or a switch bid that cannot be fully applied will not face a price for the remaining demand that is higher than its bid price. On the other hand, if a bidder uses an all-or-nothing bid to request a reduction that cannot be applied because excess demand is insufficient to cover the entire requested reduction, the price for the category may continue to increase if there is any excess demand. In such cases, we provide for an optional "backstop" bid to ensure the price for the category does not go above the amount the bidder specifies in its bid, as explained and illustrated with examples in Appendix G.

181. Because bids to reduce demand will not be accepted (or not fully accepted) to the extent they would bring demand below the available supply, and because in any given round some bidders may increase demands for licenses in a category while others may request reductions, the order in which the bids are considered can affect which bids are accepted. We propose that bids be considered by the

[306] *Incentive Auction R&O*, 29 FCC Rcd at 6776, para. 507. For example, a bidder may indicate that it demands two blocks in Category 2 in a given PEA.

[307] As the *Incentive Auction R&O* explained, providing for intra-round bids allows the auction to use relatively large clock increments while still giving bidders the flexibility to express their demands at sufficiently frequent price intervals. *Incentive Auction R&O*, 29 FCC Rcd at 6776–77, para. 509.

[308] This and other forward auction bid processing details are addressed in Appendix G.

auction system first in order of increasing "price point" (expressed as a percentage of the bidding interval for the round)[309] and in the case of ties, then using a pseudo-random number applied to the bid when it is submitted.[310] We further propose that bids not accepted because of insufficient aggregate demand or insufficient eligibility be held in a queue and considered, again in order, if there should be excess supply or sufficient eligibility later in the processing after other bids are processed.

182. More specifically, under our proposed procedures, once a round closes, the auction system will process the bids by first considering the bid submitted at the lowest price point and determine whether it can be accepted given aggregate demand as determined most recently and given the associated bidder's eligibility. If the bid can be accepted, or if it is a simple bid or a switch bid that can be only partially accepted, the number of licenses the bidder demands will be adjusted, and aggregate demand will be recalculated accordingly. If the bid cannot be accepted in part or in full, the unfulfilled bid, or portion thereof, will be held in a queue to be considered later during bid processing for that round. The auction system will then consider the bid submitted at the next highest price point, accepting it in full, in part, or not at all, given recalculated aggregate demand and given the associated bidder's eligibility. Any unfulfilled requests will again be held in a queue, and aggregate demand will again be recalculated. Every time a bid or part of a bid is accepted and aggregate demand has been recalculated, the unfulfilled bids held in queue will be reconsidered, in the order of their original price points (and by pseudo-random number, in the case of tied price points). The auction system will not carry over unfulfilled bid requests to the next round, however. The auction system will advise bidders of the status of their bids when round results are released.

183. After the bids are processed in each round, the auction system will announce new clock prices to indicate a range of acceptable bids for the next round. Each bidder will be informed of the number of blocks in a category on which it holds bids, the extent of excess demand for each category, and, if demand fell to equal supply during the round, the intra-round price point at which that occurred.[311]

b. No Bidding Aggregation

184. In the *Incentive Auction R&O*, we stated that we did not intend to incorporate package bidding procedures into the forward auction because of the additional complexity such procedures would introduce into the auction, but that we would seek input in this Public Notice on an alternative to package bidding under which the Commission would create an aggregation of the largest PEAs in advance of the auction.[312] We have significant concerns with a "major markets" aggregation approach, however. We tentatively conclude that such an approach would not be consistent with our goal of encouraging entry by providers that contemplate offering wireless broadband service on a localized basis.[313] As we discussed

[309] For example, if the previous round's clock price was $100,000 and the current round's clock price is $105,000, then an intra-round price of $101,000 is the 20 percent price point, as it is 20 percent of the difference between $100,000 and $105,000.

[310] We note that the use of the pseudo-random number to break a tie does not constitute the issuance of a license using a system of random selection. *Cf.* 47 U.S.C. § 309(i)(5) (prohibiting the use of such a system with limited exceptions not relevant here). The bidders will select the point at which they seek to reduce their demand. In the event that two bidders should choose to do so at precisely the same price, use of a pseudo-random number simply breaks the tie; it does not constitute a system of random selection for the issuance of a license. Furthermore, there may be subsequent opportunity for the bidder whose demand is reduced to reconsider its decision if it retains sufficient eligibility based on other bids.

[311] As discussed above, we propose that if there is excess demand, a fixed percentage increment will be added to the clock price for the previous round, and this percentage will be the same for all categories in all PEAs. However, if in the round, an intra-round bid brings demand down to the point at which it is equal to supply, we propose that the clock increment will be added to that intra-round price. *See* § V.C.1 (Setting Prices in the Clock Rounds).

[312] *Incentive Auction R&O*, 29 FCC Rcd at 6777–78, paras. 510–11.

[313] *See id.* at 6597, para. 71.

when adopting PEAs rather than the larger Economic Area ("EA") service areas,[314] offering single PEA licenses in the largest markets will best promote entry by the broadest range of potential wireless service providers. In addition, we are concerned an aggregation approach would discourage bidders, particularly small or regional entities with an interest in only a subset of "major markets," from participating in the forward auction. For these reasons, we do not propose to adopt a "major markets" aggregation. We invite comment on our tentative conclusion. Commenters supporting a "major markets" aggregation should explain how such an approach would be consistent with our goals of promoting competition in the provision of mobile wireless services and broad participation in the forward auction.

185. In the event we decide to adopt a "major markets" aggregation approach, we seek comment on which PEAs should be included in the "major markets" aggregation, and on how to apply the market-based spectrum reserve to the aggregation.

3. Activity Rule

186. To ensure that the auction moves as quickly as possible, we propose to require that bidders maintain a fixed, high level of activity in each round of the auction in order to maintain bidding eligibility. Specifically, we propose to require that bidders be active on between 92 and 97 percent of their bidding eligibility in all regular clock rounds.[315] We propose to calculate activity using bidding units. Thus, the activity rule would be satisfied when a bidder has bidding activity on blocks with bidding units that total 92 to 97 percent of its current eligibility in the round. If the activity rule is met, then the bidder's eligibility does not change in the next round. We further propose to calculate bidding activity based on the bids that are accepted by the auction system. That is, if a bidder requests a reduction in the quantity of blocks it demands in a category, but the auction system does not accept the request because demand for the category would fall below the available supply, the bidder's activity will reflect its unreduced demand.[316] If the activity rule is not met in a round, a bidder's eligibility automatically would be reduced. We invite comment on this proposal, in particular on where to set the activity requirement between 92 and 97 percent. Commenters may wish to address the relationship between the proposed activity rule and the ability of bidders to switch their demands across PEAs or across categories of licenses within a PEA.[317] We encourage any commenters that oppose an activity rule in this range to explain their reasons with specificity.

187. In addition, we propose that if subsequent stages of the auction are required, a bidder will begin the first round of a new stage with its eligibility reset to equal its bidding activity when the final round of the previous stage concluded.[318]

188. We do not propose to provide for activity rule waivers to preserve a bidder's eligibility. In previous FCC multiple round auctions, when a bidder's eligibility in the current round was below a required minimum level, the bidder was able to preserve its current level of eligibility with a limited number of activity rule waivers.[319] The clock auction portion of the forward auction, however, relies on

[314] *See id.*

[315] An activity rule requires bidders to bid actively throughout the auction, rather than wait until late in the auction before participating. In the forward auction, the proposed activity rule would ensure that bidders participate in each round of the auction.

[316] *See* § V.C.2.a (Types of Bids) (proposing that the auction system not allow a bidder to reduce the quantity of blocks it demands in a category if the reduction will result in aggregate demand falling below the available supply of licenses in the category).

[317] *See* § V.C.2.a (Types of Bids).

[318] This eligibility will be based on bidding in the extended round for licenses for which there was bidding in the extended round and for other licenses, on bidding in the last regular clock round.

[319] *See, e.g., H Block Procedures PN*, at 13060, paras. 157–60.

precisely identifying the point at which demand falls to equal supply to determine winning bidders and final prices.[320] Allowing waivers would create uncertainty with respect to the exact level of bidder demand, interfering with the basic clock price-setting and winner determination mechanism. Moreover, uncertainty about the level of demand would affect the way bidders' requests to reduce demand are processed by the auction system, as discussed above.[321] Under our proposal, bidders would be required to reconfirm their bids in every round.[322]

4. Extended Round

189. In the *Incentive Auction R&O*, we provided for an extended bidding round "to increase the likelihood that the auction will conclude at the end of the current stage, thereby avoiding the need to move to another stage in which less spectrum would be available for licensing in the forward auction."[323] We propose to implement an extended round whenever a round of the forward auction ends and (1) the demand for licenses in "high-demand" PEAs does not exceed the available supply, and (2) the final stage rule has not been met.[324] The extended round will interrupt the clock phase of the forward auction, which will resume if bidding in the extended round satisfies the final stage rule. If the final stage rule is not satisfied at the conclusion of the extended round, the auction stage will end and a new stage will commence with a reduced clearing target.

190. We propose to base the extended round clock price on the additional proceeds needed to meet the final stage rule, which is consistent with the purpose of the extended round of attempting to meet the final stage rule and avoid the need for a new stage with a lower clearing target. Specifically, we propose to increase the extended round clock prices for Category 1 in the "high-demand" PEAs in aggregate by 33 percent more than the additional proceeds needed to meet the final stage rule. We propose a percentage that is greater than the minimum amount required to meet the final stage rule to account for the possibility that, in some PEAs, demand may not be sufficient to increase prices to the minimum amount required, whereas in others, demand may be more than sufficient to meet the minimum, in order to increase the likelihood of satisfying the final stage rule.

191. We further propose to conduct extended round bidding only for Category 1 blocks in the "high-demand" PEAs with no excess supply. This approach is consistent with our proposal above to implement an extended round when bidding activity for such blocks stops in such areas (that is, when demand does not exceed supply). Because spectrum auctions typically reach near-final auction prices in such areas much sooner than in other areas, this approach will obviate the need to wait for bidding to stop in all areas before deciding that a subsequent stage is necessary.

192. We propose to permit bidders in the extended round to make a single simple bid for Category 1 blocks in each "high-demand" PEA, indicating a desired quantity of blocks, and we propose to allow for intra-round bidding as in the regular clock rounds of the forward auction. Under our proposal, in each "high-demand" PEA, a bidder can either maintain its current demand or request to reduce its demand by one block at a specified intra-round price point. The auction system will process requested demand reductions differently depending upon whether the final stage rule is met, in keeping with our proposed rule that bidders will not be allowed to reduce their demand if the reduction would result in demand falling below the available supply. Accordingly, if the final stage rule cannot be met in the

[320] *See* § V.C (Clock Phase Bidding Procedures).

[321] *See* § V.C.2 (Acceptable Bids).

[322] *Id.*

[323] *Incentive Auction R&O*, 29 FCC Rcd at 6778, para. 512.

[324] Above we seek comment on our proposal to use a subset of PEAs for the purpose of evaluation the final stage rule. *See* § III.B.1 (First Component: Average / Aggregate Prices in Forward Auction) (proposing to include in the subset the 40 largest PEAs by population because they cover geographic areas that have generated the highest average prices per MHz-pop in prior spectrum license auctions).

extended round, so that the auction will move to a new stage with fewer available licenses, the system will process a demand reduction of up to one block per "high-demand" PEA, because there is little likelihood of demand being below supply when bidding resumes in the next stage.[325] However, if the final stage rule is met in the extended round, the system will not process any requested reductions in demand, to avoid reducing demand below supply at the current clearing target with the current supply of blocks.[326]

193. Once bids in the extended round are placed, we propose that the auction system will consider the bids sequentially in ascending order of price points, as proposed above for the regular clock rounds of the forward auction.[327] As addressed in greater detail in Appendix G, the auction system will process bids and set clock prices for the subsequent bidding round—either a regular clock bidding round with the spectrum reserve in place or the first round of a new stage—differently according to whether the final stage rule is satisfied. If the final stage rule cannot be met in the extended round, the auction system will allow for a single reduction as discussed above, and otherwise process bids as they are processed in regular clock rounds.

194. If the final stage rule can be met in the extended round, the auction system will process extended round bids only up to the lowest price point at which the rule is satisfied.[328] Clock prices for the next round will be based on that price point, unless a reduction was requested at a lower price point in a PEA, in which case the clock price in that PEA will be based on the intra-round price at which the reduction was requested (but not accepted, as discussed above).[329] Regular clock bidding rounds will resume for all categories in all PEAs, with the spectrum reserve in place.[330] For those blocks not subject to extended round bidding, that is, non-"high-demand" PEAs as well as Category 2 blocks of the "high-demand" PEAs, rounds will resume with clock prices for the next round based on prices from the round preceding the extended round.[331] Under our proposed procedures, the price for blocks in the same category in a PEA will be the same for all bidders at the end of an extended round, as is also the case for

[325] Hence, the bidder's demands going into the next stage will reflect the reduced quantity. *See* § V.C.2 (Acceptable Bids) (proposing to not allow a bidder to reduce the quantity of blocks it demands in a category if the reduction will result in aggregate demand falling below the available supply of licenses in a category). In some cases the supply of Category 1 blocks in a PEA may not decrease because at a lower clearing target the re-optimized channel assignment may be able to reduce impairments to licenses in the PEA sufficiently that one or more licenses previously considered Category 2 will be considered Category 1 in the new stage, so that even with a lower total number of blocks, the number of Category 1 blocks will not decrease. We anticipate that, in such cases, bidders previously demanding a Category 2 block, the supply of which will be reduced disproportionately, are likely to shift to bid on the Category 1 blocks, so that demand for the Category 1 blocks will at least equal supply.

[326] As discussed above, the extended round will only be implemented when demand does not exceed supply in these markets. *See* § III.C.2 (Final Stage Determination and Implementation of Extended Round).

[327] *See* § V.C.2 (Acceptable Bids).

[328] For example, if while processing bids at the 20 percent price point, overall demands at that price point are sufficient to meet the requirements of the final stage rule, the auction system will not continue to process bids at higher price points. Thus, for a given PEA with no requested reductions at prices below the 20 percent point, the uniform price for Category 1 blocks will be set at 20 percent of the increment between the price going into the extended round for that PEA's Category 1 blocks and its extended round clock price. That is, if the price in the PEA is 100 going into the extended round and the extended round clock price is 110, the clock price for the next round will be based on a price of 102, regardless of bidding at higher price points. *See* Appendix G for more detail.

[329] If more than one bidder in a PEA requested a reduction, this will be the lowest price point.

[330] *See* § V.C.1 (Setting Prices in the Clock Rounds).

[331] If the final stage rule is not met, clock prices for the next round—that is, the first round of the new stage—will also be based on prices from the round preceding the extended round for blocks not subject to extended round bidding.

the other clock rounds. Accordingly, in a PEA, clock prices for reserved spectrum blocks going into the next round will be the same as for unreserved spectrum blocks.

5. Stopping Rule

195. Consistent with the Commission's practice of using stopping rules in multi-round auctions to ensure completion within a reasonable time,[332] we propose to employ a simultaneous stopping rule for the clock phase of the forward auction in the final stage. Under this proposal, all categories of licenses in all PEAs would remain available for bidding until the bidding stops on every category. More specifically, if the final stage rule has been met, with or without an extended round, the clock phase of bidding will end for all categories of licenses following the first round in which there is no excess demand in any category in any PEA. Since bidding will remain open on all categories of licenses until bidding stops on every category, it is not possible to determine in advance how long the forward auction will last. We seek comment on permitting new bids to be made in one additional bidding round following the first round in which there is no excess demand.

6. New Stage Transition

196. We propose to initiate bidding in any subsequent stage of the forward auction based on the bidder demands and prices from the end of the previous stage, except as described below. In some cases, these demands and prices will have been determined in the extended round, and in others, from the last regular clock round. The price increment in the first round of the next stage will be added to the last clock price from the previous stage, or to the intra-round price at which a reduction that brought demand down to equal supply was processed.

197. We propose that for categories of blocks for which all bidders indicated that they were willing to accept the full extended round price increment, bidder demands will carry over from the extended round. Because our proposed procedures for processing extended round bids when the final stage rule is not met will allow at most one request for a reduction in demand to be accepted in each category,[333] in categories where a reduction was accepted, bidder demands from the start of the extended round will carry over to the new stage for all but the bidder whose requested reduction was accepted. That bidder's demand will reflect the reduction, consistent with extended round bid processing. For blocks that were not included in bidding in the extended round, we propose that bidder demands that were accepted by the auction system at the end of the last regular clock round of the previous stage will carry over to the beginning of the next stage.

198. Under our proposal, a bidder will begin the first round of a new stage with its eligibility reset to equal its bidding activity when the final round of the previous stage concluded.[334] As discussed above, because the re-optimization at the start of a new stage may "re-shuffle" the assignment of stations to the 600 MHz Band, the extent and location of impairments to the blocks available may change from stage to stage of the forward auction.[335] The auction system will advise forward auction bidders of any such changes before bidding begins.[336] Because we recognize that bidder demand for Category 2 blocks in a PEA may be reduced if the extent of impairments increase, we propose that the auction system will accept requests to reduce demand for Category 2 blocks in the first round of a new stage, even if the reduction will result in demand falling below supply for that category.

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[332] *See, e.g., Auction 97 Procedures PN*, 29 FCC Rcd at 8434–36, paras. 172–78; *H Block Procedures PN*, 28 FCC Rcd at 13061, paras. 161–63. *See also* 47 C.F.R. § 1.2104(e).

[333] *See* § V.C.4 (Extended Round).

[334] *See* § V.C.3 (Activity Rule).

[335] *See* § IV.D (New Stage Procedures).

[336] *See* § V.A.1 (Forward Auction Information Available During the Auction).

D. Bidding Procedures in Assignment Phase

199. In the *Incentive Auction R&O*, we adopted a two-step forward auction procedure, with a separate assignment phase "in which bidders will bid for priority in selecting bands or for a preferred frequency within a geographic area."[337] Here we propose procedures to implement the assignment phase, which we also explain in detail in Appendix H. Under our proposal, winning bidders from the clock phase that have a preference for specific frequencies will have an opportunity to submit sealed bids for particular frequency blocks in a separate single assignment round for each particular PEA or group of PEAs. We propose that this assignment phase be voluntary: winning bidders in the clock phase of the forward auction need not participate in order to be assigned a number of licenses corresponding to the outcome of the clock phase.[338] We propose to group bidding for multiple PEAs where possible, so as to reduce the number of separate assignment rounds required, and to sequence the bidding for the various PEAs.

200. In determining specific frequency assignments during the assignment phase of the forward auction, the auction system will take into account bid amounts as well as other efficiency objectives, such as maximizing contiguity for winners of multiple blocks in an area. Under our proposed approach, these overall efficiency considerations will affect the way the auction system processes the bids to determine the optimal assignment of frequencies. We seek comment below on these proposed objectives and their relative priority in determining the best way to structure bidding and bid processing in each assignment round.

1. Grouping of PEAs

201. We propose to conduct bidding for specific frequencies grouped by different geographic areas in each assignment round. This will reduce the complexity for the bidder and the auction system that would be inherent in considering simultaneously the preferences of multiple bidders for various configurations of Category 1 and Category 2 license blocks in hundreds of PEAs.[339] However, to the extent that the set of clock-phase winning bidders and their winning bids for Category 1 and Category 2 blocks are consistent across a group of PEAs, we propose to conduct the single-round bidding jointly for multiple areas. Under such circumstances, joint bidding would not increase the complexity of the bidding or the winner determination process. Moreover, joint bidding can reduce the overall number of assignment rounds needed and facilitate assigning contiguous blocks to bidders that won multiple blocks in a group, potentially enhancing the efficiency of the assignment.

202. Specifically, we propose to group together:

- "High-demand" PEAs with the same number of Category 1 and Category 2 blocks, where the same frequency blocks are in Category 2, and where the same bidders won the same quantities of Category 1 and Category 2 blocks.
- All PEAs other than the "high-demand" PEAs in a Regional Economic Area Grouping ("REAG") with the same number of Category 1 and Category 2 blocks, where the same frequency blocks are in Category 2, and where the same bidders won the same quantities of Category 1 and Category 2 blocks.

We further propose to group PEAs together when to do so will not create any conflicting interests among bidders. This could occur, for example, if the bidder mix of generic blocks differs only in that there is an unsold license in one PEA but not in another.[340] Under our proposal, bidders would bid for their specific

[337] *See Incentive Auction R&O*, 29 FCC Rcd at 6780, para. 517.

[338] *See also* Appendix H.

[339] Considering all such combinations simultaneously would lead to an intractable mathematical optimization problem.

[340] *See* Appendix H.

preferred frequencies across all the PEAs in a group, and the auction system will determine a frequency assignment that will apply to all the licenses in the group.

2. Sequencing of PEAs

203. We propose to sequence assignment rounds so as to make it easier for bidders to incorporate frequency assignments from previously-assigned areas into their bid preferences for other areas, recognizing that bidders winning multiple blocks of licenses generally will prefer contiguous blocks across adjacent PEAs. To that end, we propose to conduct rounds for the largest groups of markets first to enable bidders to establish a "footprint" from which to work. Specifically, we propose to conduct assignment rounds sequentially, generally in order of "weighted-pops."[341] Under this proposal, we will first conduct an assignment round for the largest PEA or PEA group, based on total weighted-pops, and continue in order of weighted-pops until specific frequencies have been assigned for all the "high-demand" PEAs (individually or in groups).

204. Once frequencies have been assigned for the "high-demand" PEAs, we propose to conduct for each REAG a series of assignment rounds for non-high-demand PEAs within that region, in descending order of weighted-pops for a PEA group or individual PEAs. We further propose, to the extent practical, to conduct the assignment rounds for the different REAGs in parallel, to reduce the total amount of time required.

3. Acceptable Bids and Bid Processing

205. Under our proposal, described in more detail in Appendix H, bidders will be asked to assign a price to their various frequency preferences, consistent with their winning bids for generic blocks in the clock phase. We propose not to differentiate in the assignment rounds between licenses that were reserved for certain eligible bidders pursuant to the *Mobile Spectrum Holdings R&O* and unreserved blocks. This proposed approach is consistent with the auction design we adopted in the *Incentive Auction R&O*: bidders in the clock phase will have competed for generic blocks, not specific licenses. We also believe this approach is consistent with our competitive goals in the *Mobile Spectrum Holdings R&O*, as winning bidders will be assured of low-band spectrum based on the results of the clock phase. Winners of either reserved or unreserved Category 1 blocks will be able to bid for the available frequencies in Category 1, and the auction system will assign specific frequencies without regard to the reserve-eligible status of the bidder.

206. In each assignment round, a bidder will be asked to assign a price to one or more possible frequency assignments for which it wishes to express a preference. The price will represent a maximum payment that the bidder is willing to pay, in addition to the base price established in the clock phase for the generic blocks, for the frequency-specific license or licenses. At the end of the assignment phase, the clock price will be discounted to the extent the licenses included are subject to impairments.[342]

207. Given that it may not be possible to assign contiguous blocks to all bidders within a PEA,[343] we propose to use an optimization approach to determine the winning frequency assignment for

[341] *See* § III.A.3 (Standard for Limiting Market Variation) (discussing how we propose to calculate weighted-pops).

[342] As discussed above, we propose to apply a discount on the clock prices of generic blocks to reflect the varying degrees of impairment to the blocks within a category. Specifically, for a given frequency-specific license, we propose to reduce the base price for the assignment round by one percent of the final clock price for each one percent of impairment to the license. Under this proposal and our proposed assignment phase procedures, if a bidder indicates it is willing to pay an additional amount in the assignment round for a specific block that is available in the category, and it wins that license, the additional payment will be applied to a base price that reflects a discount from the final clock price for the category.

[343] Contiguity cannot be guaranteed because of the possibility that some contiguous blocks are in different categories due to the amount of their impairment, and in the case of clearing targets over 84 megahertz, TV Channel 37 will separate some blocks.

each assignment round. We propose that the auction system will consider a number of objectives aimed at assigning contiguous blocks fairly and to the extent possible. As set forth in Appendix H, we propose a sequence of optimizations using the following objectives: (1) maximizing the number of bidders that won multiple blocks that are assigned at least two contiguous blocks; (2) minimizing for all bidders that won two or more blocks in the clock phase the number of blocks that are non-contiguous to any of the bidder's other blocks; and (3) maximizing the number of bidders that are assigned only contiguous blocks. Under our proposed procedures, the auction system will first solve or optimize for the first objective and use that outcome as a constraint in solving the second objective, which would then constrain solving the third objective. The winning bids in each assignment round will be bids for which the assignment satisfies these three constraints and for which the bidders in that round are willing to pay the most.

208. As described in Appendix H, we propose that the additional price a bidder will pay for a specific frequency (above the discounted final clock price) will be calculated consistent with a generalized "second price" approach—that is, the winner will pay a price that would be just sufficient to result in the bidder receiving that same winning frequency assignment. This price will be less than or equal to the price the bidder indicated it was willing to pay for the assignment. We propose to determine prices in this way because it facilitates bidding strategy for the bidders, giving them an incentive to bid their full value for the assignment, knowing that if the assignment is selected, they will pay no more than would have been necessary to ensure that the assignment won.[344]

E. Additional Default Payment Percentage

209. The Commission's competitive bidding rules provide that the Commission shall establish the percentage of any defaulted bid that will be assessed as a payment owed by the defaulter in addition to the difference between with defaulted bid and a subsequent winning bid for the same license.[345] In an auction without combinatorial bidding, such as the forward auction we propose here, the percentage shall be between three and 20 percent.[346] We propose that the percentage shall be 20 percent in the forward auction. We tentatively conclude that the maximum amount is in the public interest, given the importance of deterring defaults in order to minimize the possibility that the auction will not generate shortly after its conclusion the full amount of the proceeds indicated by winning bids.[347]

VI. DEADLINES AND FILING PROCEDURES

210. Comments are due on or before January 30, 2015, and reply comments are due on or before February 27, 2015. All filings related to procedures for Auctions 1000, 1001, and 1002 must refer to AU Docket No. 14-252. Comments may be submitted using the Commission's Electronic Comment Filing System ("ECFS") or by filing paper copies.[348] We strongly encourage interested parties to file comments electronically.

211. *Electronic Filers*: Comments may be filed electronically using the Internet by accessing the ECFS at http://www.fcc.gov/cgb/ecfs. Filers should follow the instructions provided on the website for submitting comments. In completing the transmittal screen, filers should include their full name, U.S.

[344] The pricing approach we propose is a version of a Vickrey-Clarke-Groves mechanism. It is described in Appendix H.

[345] 47 C.F.R. § 1.2104(g)(2)(ii).

[346] *Id.*

[347] As noted in the *Incentive Auction R&O*, parties receiving the first disbursements of auction proceeds once amounts become available for distribution—including broadcasters relinquishing spectrum usage rights—will be insulated from the effects of any forward auction bidder defaults. *See Incentive Auction R&O*, 29 FCC Rcd at 6787, para. 536 n.1526.

[348] *See Electronic Filing of Documents in Rulemaking Proceedings*, GC Docket No. 97-113, Report and Order, 13 FCC Rcd 11322 (1998).

Postal Service mailing address, and the applicable docket number, AU Docket No. 14-252. To get filing instructions, filers should send an e-mail to ecfs@fcc.gov, and include the following words in the body of the message: "get form." A sample form and directions will be sent in response.

212. *Paper Filers*: Parties who choose to file by paper must file an original and four copies of each filing. Filings can be sent by hand or messenger delivery, by commercial overnight courier, or by first-class or overnight U.S. Postal Service mail. All filings must be addressed to the Commission's Secretary Attn: WTB/ASAD, Office of the Secretary, Federal Communications Commission.

- The Commission's contractor will receive hand-delivered or messenger-delivered paper filings for the Commission's Secretary at the FCC Headquarters building located at 445 12th Street, SW, Room TW-A325, Washington, DC 20554. The filing hours at this location are 8:00 a.m. to 7:00 p.m. Eastern Time (ET). All hand deliveries must be held together with rubber bands or fasteners. Any envelopes must be disposed of before entering the building.
- Commercial overnight mail (other than U.S. Postal Service Express Mail and Priority Mail) must be sent to 9300 East Hampton Drive, Capitol Heights, MD 20743.
- U.S. Postal Service first-class, Express, and Priority mail must be addressed to 445 12th Street, SW, Washington DC 20554.

213. *E-mail*: We also request that a copy of all comments and reply comments be submitted electronically to the following address: auction1000@fcc.gov.

214. Copies of comments and reply comments will be available for public inspection between 8:00 a.m. and 4:30 p.m. ET Monday through Thursday, or 8:00 a.m. to 11:30 a.m. ET on Fridays, in the FCC Reference Information Center, Room CY-A257, 445 12th Street, SW, Washington, DC 20554, and will also be accessible through the search function on the ECFS web page at http://www.fcc.gov/cgb/ecfs.

215. This proceeding has been designated as a "permit-but-disclose" proceeding in accordance with the Commission's *ex parte* rules.[349] Persons making oral *ex parte* presentations are reminded that memoranda summarizing the presentations must contain summaries of the substance of the presentations and not merely a listing of the subjects discussed. More than a one or two sentence description of the views and arguments presented is generally required. Other provisions pertaining to oral and written *ex parte* presentations in permit-but-disclose proceedings are set forth in section 1.1206(b) of the Commission's rules.[350]

216. To request materials in accessible formats (Braille, large print, electronic files, audio format) for people with disabilities, send an e-mail to fcc504@fcc.gov or call the Consumer and Government Affairs Bureau at (202) 418-0530 or (202) 418-0432 (TTY).

VII. CONTACTS

217. For further information concerning this proceeding, contact the offices listed below:

Broadband Division, Wireless Telecommunications Bureau

For 600 MHz Band service rule questions: Madelaine Maior at (202) 418-1466

[349] 47 C.F.R. §§ 1.1200(a), 1.1206.

[350] The Commission substantially revised its *ex parte* rules in 2011. These revised rules require for example, that an *ex parte* notice must be filed for each oral *ex parte* presentation, not just for those presentations that involve new information or arguments not already in the record. Further, a filer typically must submit an *ex parte* notice electronically in machine-readable format. A filer may not submit a PDF image created by scanning a paper document, except in a situation in which a word processing version of the document is not available. *See Amendment of the Commission's Ex Parte Rules and Other Procedural Rules*, GC Docket No. 10-43, Report and Order and Further Notice of Proposed Rulemaking, 26 FCC Rcd 4517 (2011).

Auctions and Spectrum Access Division, Wireless Telecommunications Bureau

For general auction questions:	Linda Sanderson at (717) 338-2868
For auctions legal questions:	Erin Griffith at (202) 418-0660

Spectrum and Competition Policy Division, Wireless Telecommunications Bureau

For mobile spectrum holding questions:	Amy Brett at (202) 418-1310

Video Division, Media Bureau

For broadcaster questions:	Dorann Bunkin at (202) 418-1636

Office of Engineering and Technology

For repacking and inter-service interference questions:	Aspasia Paroutsas (legal) at (202) 418-7285 or Martin Doczkat (technical) at (202) 418-2435

Office of Communications Business Opportunities

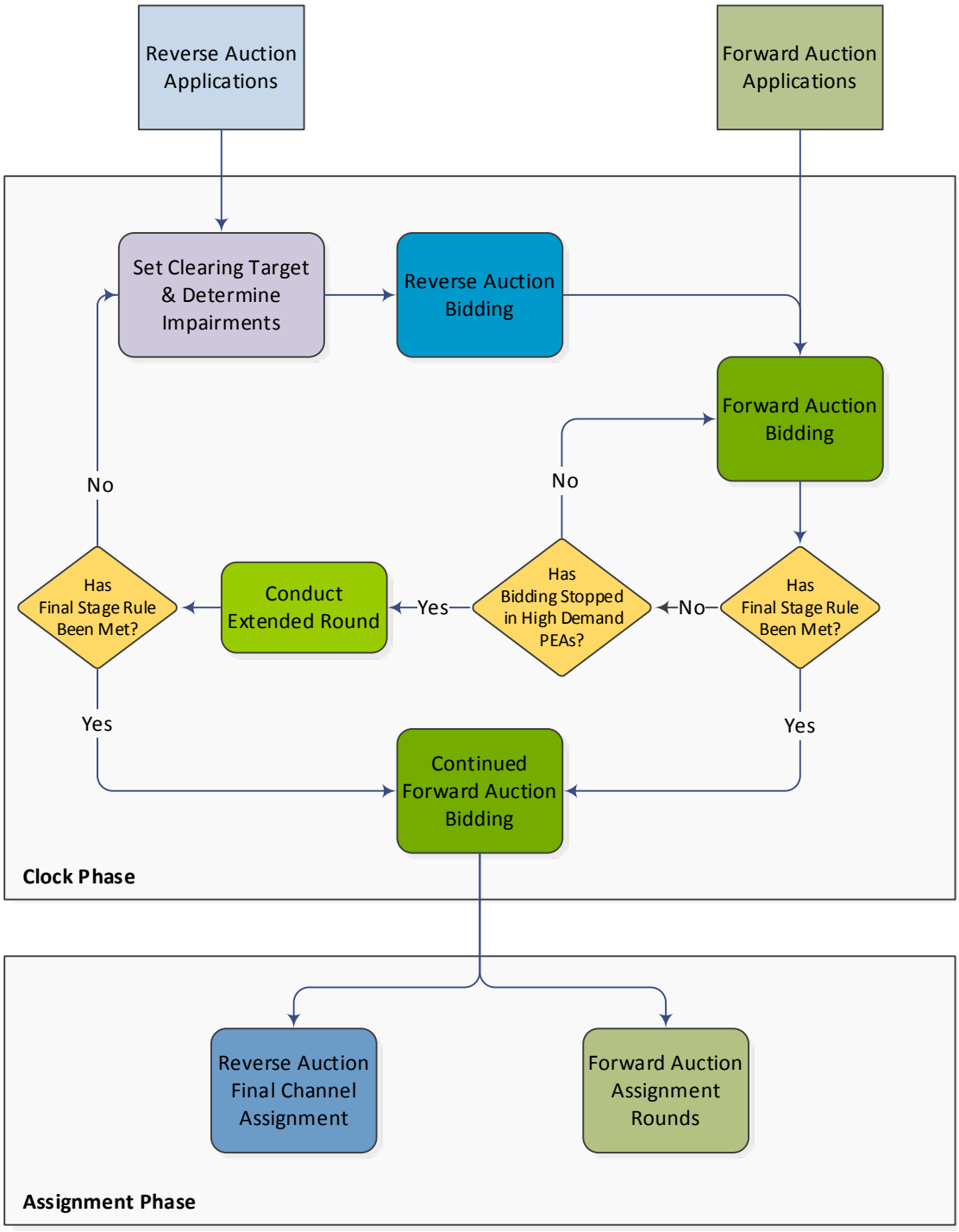
For questions concerning small business inquiries:	(202) 418-0990

Action by the Commission on December 11, 2014: Chairman Wheeler and Commissioners Clyburn and Rosenworcel issuing separate statements; Commissioners Pai and O'Rielly dissenting and issuing separate statements.

–FCC–

APPENDIX A

Incentive Auction General Flow



APPENDIX B

ISIX Constraints

1 Introduction

This appendix details the process of how raw interference data generated by Inter-Service Interference ("ISIX") Methodology is turned into constraints that will be used by the Clearing Target Optimization.

In the *ISIX R&O*, the Commission adopted the ISIX Methodology which details the approach for determining the extent to which wireless licenses in the 600 MHz Band may be impaired.[1] The ISIX Methodology and the necessary input values specified in this Appendix are important first steps for defining the products to be sold in the auction.[2] This document describes the next two steps for defining the products to be sold during the auction. First, this document specifies the method by which the 2x2 kilometer ISIX data for all four ISIX cases is reduced to a county level and grouped by uplink and downlink. Second, this document specifies how this consolidated data is then processed to create constraints used to measure the impaired population in a license area for a given clearing target. These constraints are then used in determining a clearing target by providing a means by which we can measure the amount of market variation we will allow.

In the sections that follow, the methodology used to process the raw ISIX data produced by following the ISIX Methodology is described. The final result of the ISIX data processing is two tables, one for *Downlink* and the other for *Uplink*, that provide an impairment percentage for each county (based on the clearing target and band plan) for every facility-channel assignment combination.

2 Reference Tables

To process raw ISIX data, several pieces of reference data are required.

2.1 Spectrum Information

To determine the extent of interference caused and received by a TV station on a given channel, overlap values are required. Overlap refers to the amount of spectral overlap, in MHz, between the interfering transmitter channel and the interfered-with receiver channel.[3] As explained further in the *ISIX R&O*, the overlap number is used as a reference to define the interference threshold.[4] The band plan, based on the total amount of cleared spectrum, determines overlap values for each channel.

A sample overlap table for 126 MHz clearing is shown below. In this band plan, stations placed on channels 30 to 42 would cause *downlink* impairments, while stations placed on channels 42 to 51 would cause impairments in the *uplink*. For example, placing a TV Station on channel 43 would potentially

[1] *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Second Report & Order and Further Notice of Proposed Rulemaking, 29 FCC Rcd 13071, 13083, para. 23 (2014) (*ISIX R&O*).

[2] *See ISIX R&O*, Appendix A, 29 FCC Rcd at 13118–37.

[3] Under the 600 MHz Band Plan adopted in the *Incentive Auction R&O*, six megahertz broadcast television channels will be repurposed as five megahertz wireless blocks. *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Report and Order, 29 FCC Rcd. 6593 (2014). (*Incentive Auctions R&O*). The difference in channel bandwidth (six vs. five megahertz) means that the wireless spectrum blocks will not perfectly align with the existing television channels and, where market variation exists, there will be varying degrees of spectral overlap between the channels.

[4] The *ISIX R&O* specifies that the overlaps considered will range from +5 MHz to -5 MHz in 1 MHz increments. *See ISIX R&O*, Appendix A, 29 FCC Rcd at 13120, para. 7.

create impairments of the A and B blocks, with overlap values of 2 and -3, respectively. Placing a TV station on channel 36 would affect the E and F blocks, with overlap values of -2 and 3, respectively.

			Spectrum Overlap (by channel)																				
MHz Cleared	**Uplink/ Downlink**	**Block**	**51**	**50**	**49**	**48**	**47**	**46**	**45**	**44**	**43**	**42**	**41**	**40**	**39**	**38**	**37**	**36**	**35**	**34**	**33**	**32**	**31**	**30**
126	U	J	5	-1																				
126	U	I	1	4	-2																			
126	U	H	-4	2	3	-3																		
126	U	G		-3	3	2	-4																	
126	U	F			-2	4	1	-5																
126	U	E				-1	5	0																
126	U	D					0	5	-1															
126	U	C					-5	1	4	-2														
126	U	B						-4	2	3	-3													
126	U	A							-3	3	2	-4												
126	D	J										-1	5	0										
126	D	I											0	5	-1									
126	D	H											-5	1	4	-2								
126	D	G												-4	2	3								
126	D	F																3	2	-4				
126	D	E																-2	4	1	-5			
126	D	D																	-1	5	0			
126	D	C																		0	5	-1		
126	D	B																		-5	1	4	-2	
126	D	A																			-4	2	3	-3

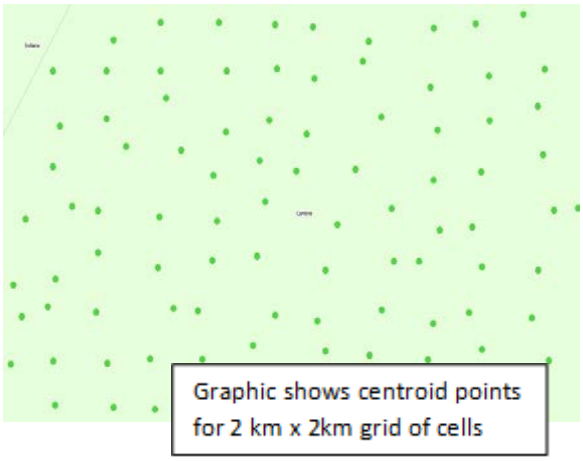
2.2 Geographic Information

Global Superset of Points

The nation is split into a global 2 x 2 kilometer grid of cells. Each cell has a centroid point and a unique identifier.

Data elements

- *pointkey* – Unique ID of each 2x2 km cell
- *area* – Area of 2x2 km cell
- *latitude* – Latitude of centroid point
- *longitude* – Longitude of centroid point
- *population* – Population of 2x2 km cell

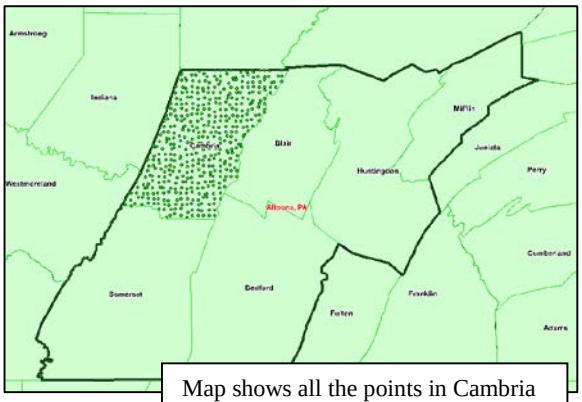


Point to County Mapping

Each point in the global set of 2 x 2 kilometer grid of cells lies in a single US county. A lookup table is created by performing a spatial overlay of the global points superset with the 2010 County layer from the U.S. Census Bureau. With this data, the population of each county can also be calculated.

Data elements

- *pointkey* – Unique ID of each 2x2 km cell
- *county FIPS* – 5 character Census identifier of county in which point resides
- *county name* – Name of county in which point resides



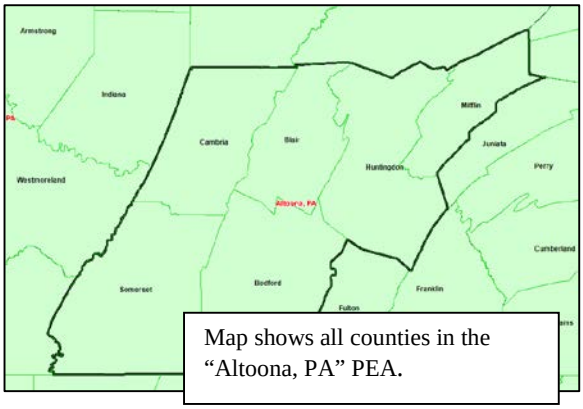
Map shows all the points in Cambria County in Pennsylvania

County to PEA Mapping

Each US county resides in a Partial Economic Area (PEA). A lookup table can be created with this information.

Data elements

- *county FIPS* – 5 character Census identifier for the county
- *PEA ID* – Three digit PEA identifier
- *PEA name* – Name of the PEA

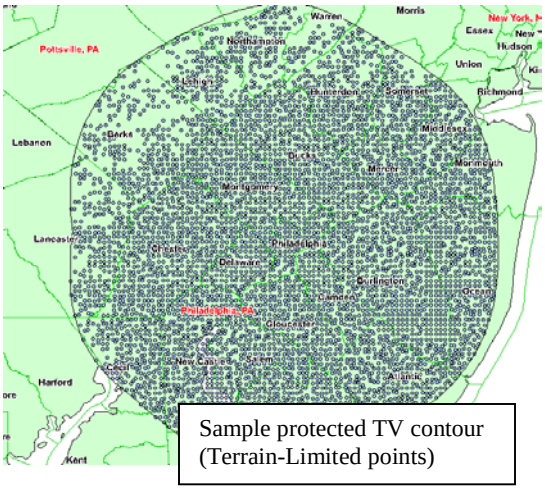


Map shows all counties in the "Altoona, PA" PEA.

2.3 TV Station Information

Protected Contour and Terrain-Limited area

The ISIX Methodology, as adopted in the *ISIX R&O*, uses TV channel 38 as a proxy channel and produces information on both the protected contour and the 2 x 2 kilometer grid cells within the contour that are above the service threshold.[5] For purposes of this appendix, the protected contour is defined as the noise limited contour of a full-power station or the protected contour of a Class A station. Terrain-limited area refers to the 2 x 2 kilometer grid cells where the predicted service is above the service threshold.



Sample protected TV contour (Terrain-Limited points)

[5] Channel 38 is selected as the proxy channel because it is approximately in the middle of where a repacked DTV station may potentially be in the 600 MHz Band. *See ISIX R&O*, Appendix A, 29 FCC Rcd at 13121–22, para. 8 n.10.

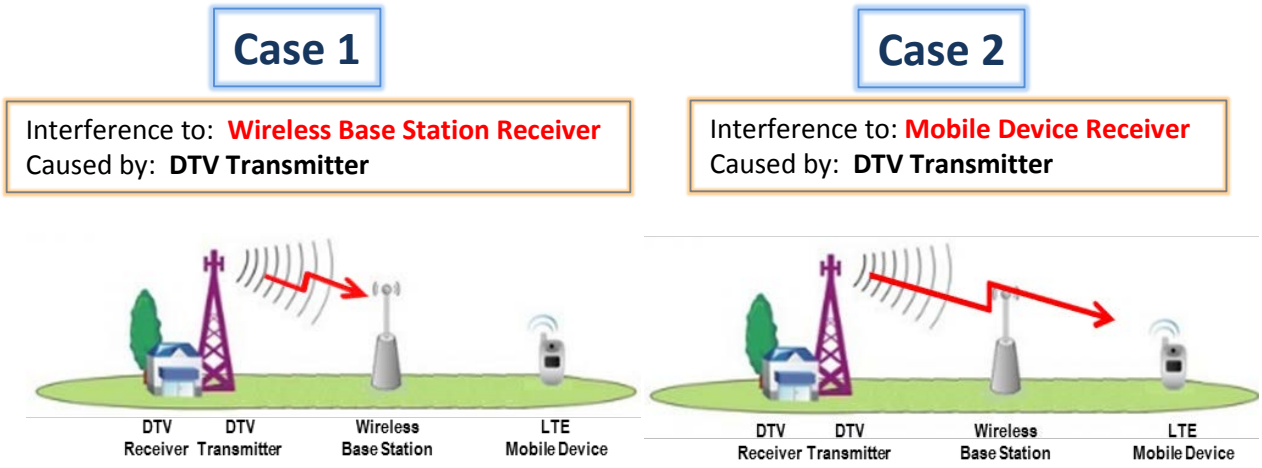
3 ISIX Data

Two types of ISIX raw data are produced by the ISIX Methodology:

(1) ***Wireless Interference*** – Interference to wireless operations caused by TV stations (ISIX Cases 1 & 2)

(2) ***TV Interference*** – Interference to TV stations caused by wireless operations (ISIX Cases 3 & 4)[6]

3.1 Interference to Wireless (ISIX Cases 1 & 2)



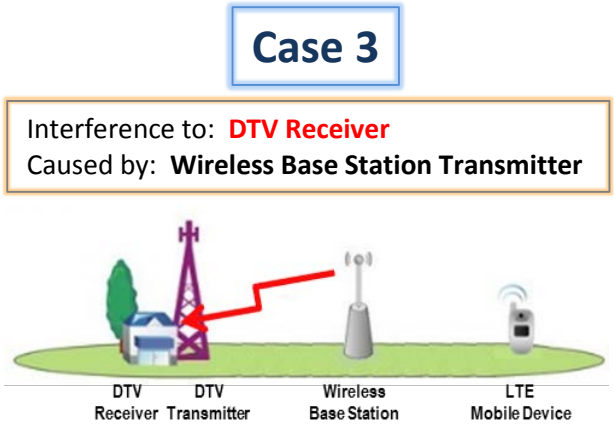
The ISIX Methodology produces the following wireless interference data which is then used as inputs for ISIX data process.

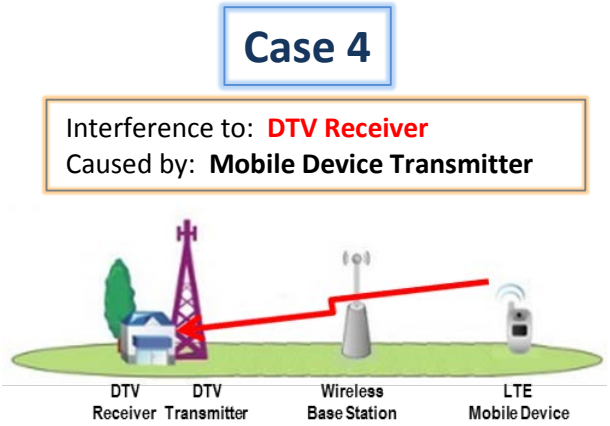
column 1	column 2	column 3	column 4	column 5	column 6	column 7
facid	**ol**	**ul_dl**	**incon**	**ix**	**pointKey**	**margin**

- *facid* – Facility ID of the interfering TV station. (*Note*: This analysis includes only UHF stations.)
- *ol* – Spectrum overlap used to define the interference threshold. This analysis considers every overlap case from -5 to +5 MHz for every facility ID.
- *ul_dl* – Flags whether data is for downlink interference or uplink interference.
- *incon* – Flags whether a particular interference points falls within the protected TV contour. For the purposes of this analysis, we include all points inside the protected TV contour and any interference points outside the protected TV contour.
- *ix* – Flags whether interference exists at this point above the threshold.
- *pointkey* – Unique identifier for each 2 x 2 kilometer cell.
- *margin* – Difference between the interference threshold and the interfering field strength. This analysis does not currently consider this field as it is used to derive the *ix* flag.

[6] The four cases of interference that the ISIX Methodology considers are described in the Technical Appendix of the *ISIX R&O*. *See ISIX R&O*, Appendix A, 29 FCC Rcd at 13119–20, para. 5.

3.2 Interference to TV (ISIX Cases 3 & 4)





The ISIX Methodology produces the following TV interference raw data which is then used as input for ISIX data processing.

column 1	column 2	column 3	column 4	column 5	column 6	column 7
facid	**ol**	**ul_dl**	**incon2**	**ix**	**pointKey**	**cntyid**

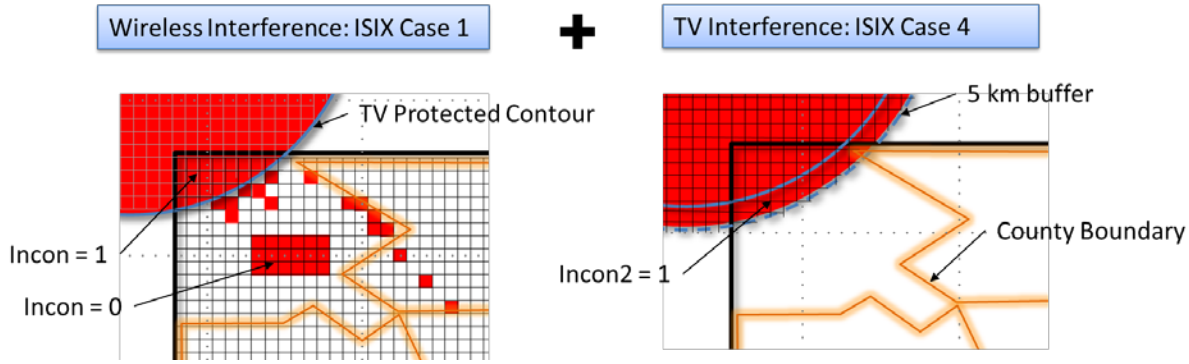
- *facid* – Facility ID of the TV station interfered with. This analysis includes only UHF stations.
- *ol* – Spectrum overlap used to define the interference threshold. This analysis considers every overlap case from -5 to +5 MHz for every facility ID.
- *ul_dl* – Flags whether data is for downlink interference or uplink interference. (*Note*: Only downlink interference is included in this file because the uplink interference created by a mobile LTE device is handled separately.)
- *incon2* – Flags whether a particular county intersects or comes within 5 km of a protected TV contour. All counties that touch on the protected contour are flagged. For ISIX Case 3 data we include all grid points that fall inside a county boundary where incon2 = 1 plus all points that are within a county boundary where interference could originate. For ISIX Case 4 data all grid points that are inside the protected TV contour or within 5 kilometers of the contour are included.
- *ix* – Flags whether interference exists at this point above the threshold.
- *pointkey* – Unique identifier for the point found within each 2 x 2 kilometer cell.
- *cntyid* – The 5 character county FIPS code (from the U.S. Census Bureau) from which interference could originate.

4 Calculating Percent of Population Impaired

Downlink and Uplink impairments are pre-calculated for every facility and for all applicable overlap values (which are determined by the combination of the clearing target and band plan).

4.1 Uplink Impairment

To calculate Uplink Impairments, Wireless Interference data (ISIX Case 1) and TV Interference Data (ISIX Case 4) are used.



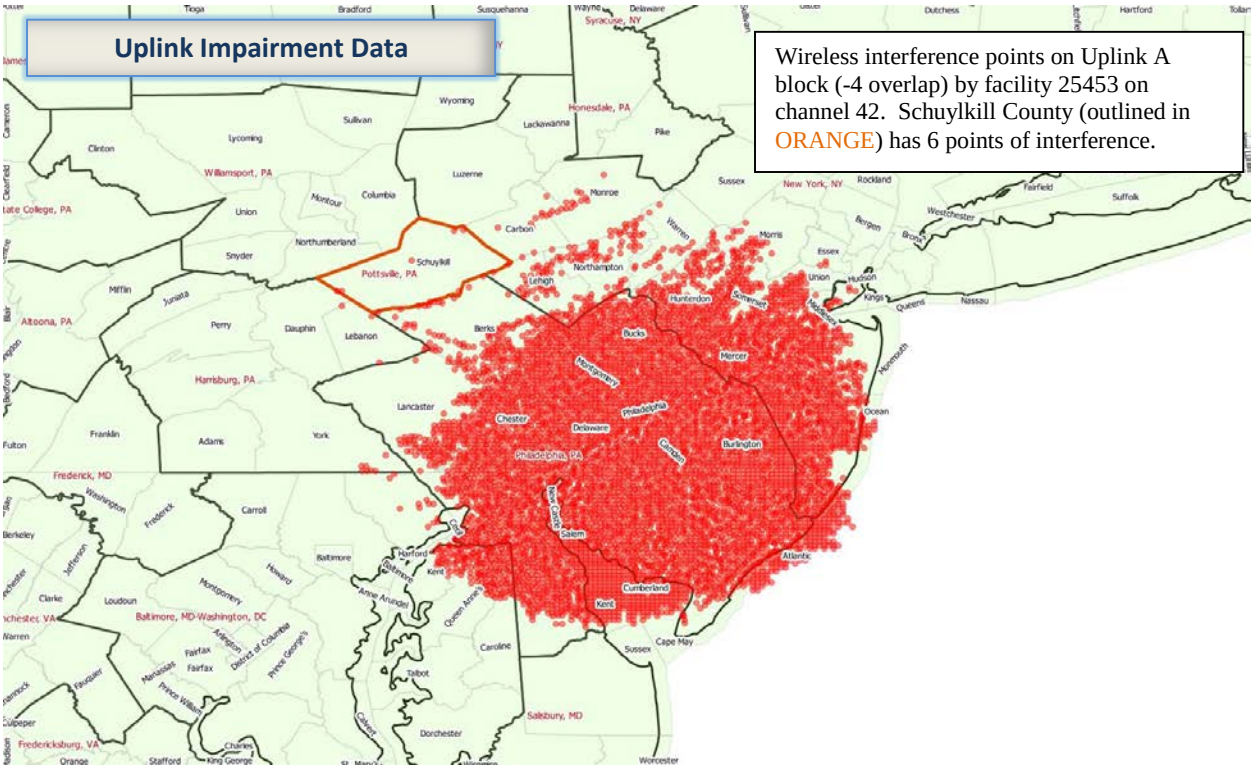
Processing Steps

1) Given a facility's channel assignment, use spectrum overlap table to determine the overlap values that must be considered.
2) For Case 1, determine the set of grid points that fall within the protected contour (incon=1) or are predicted to cause interference to wireless base station receivers. All of these grid points are marked as impaired.
3) For Case 4, determine the set of grid points that fall within the protected contour or within 5 kilometers of the protected contour (incon2=1). All of these grid points are marked as impaired.
4) Find the unique set of impaired points from Steps 2 and 3.
5) Sum the population of the impaired points by county using the *Points to County* mapping table.
6) Determine the percent of uplink impairment in each county by dividing the sum calculated in Step 3 by the total population of each county.

Example: Uplink Impairment from Facility 25453 on Channel 42

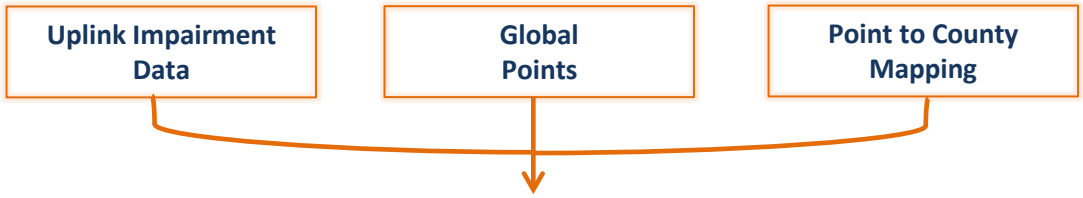
In this example, the *Uplink* Impairment caused by **facility 25453** (A UHF station in Philadelphia, PA) when it is assigned to **channel 42** is measured. In that case, at a clearing of 126 MHz, the A-block would be impaired and an overlap value of -4 would need to be considered.[7]

			Spectrum Overlap (by channel)																				
MHz Cleared	**Uplink/ Downlink**	**Block**	**51**	**50**	**49**	**48**	**47**	**46**	**45**	**44**	**43**	**42**	**41**	**40**	**39**	**38**	**37**	**36**	**35**	**34**	**33**	**32**	**31**	**30**
126	U	J	5	-1																				
126	U	I	1	4	-2																			
126	U	H	-4	2	3	-3																		
126	U	G		-3	3	2	-4																	
126	U	F			-2	4	1	-5																
126	U	E				-1	5	0																
126	U	D					0	5	-1															
126	U	C					-5	1	4	-2														
126	U	B						-4	2	3	-3													
126	U	A							-3	3	2	-4												
126	D	J										-1	5	0										
126	D	I											0	5	-1									
126	D	H											-5	1	4	-2								
126	D	G												-4	2	3								
126	D	F																3	2	-4				
126	D	E																-2	4	1	-5			
126	D	D																	-1	5	0			
126	D	C																		0	5	-1		
126	D	B																		-5	1	4	-2	
126	D	A																			-4	2	3	-3



[7] It should be noted that placing a station on channel 42 could also impact the Downlink with an overlap value of -1. In this section, however, only the impact on the Uplink is considered.

Placing facility 25453 on channel 42 would cause A-block interference in 41 counties. For example, there are six grid points of interference exist in Schuylkill County, Pennsylvania. Merging the wireless interference table with the reference tables yields the following data for that county.



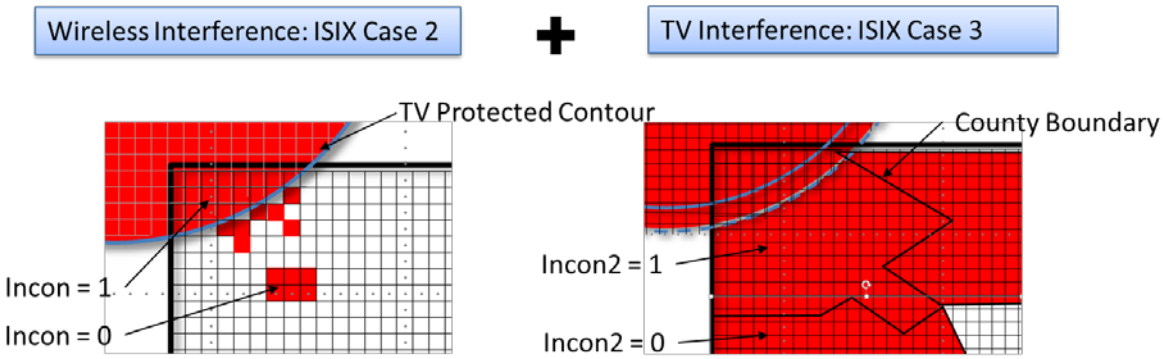
	facilityid character varying(10)	channel integer	block character varying(2)	ol integer	ptkey integer	county_fips character varying(5)	county_name character varying(100)	population numeric
1	25453	42	A	-4	67160601	42107	Schuylkill	0
2	25453	42	A	-4	67250307	42107	Schuylkill	0
3	25453	42	A	-4	67250400	42107	Schuylkill	0
4	25453	42	A	-4	67489626	42107	Schuylkill	32
5	25453	42	A	-4	67728864	42107	Schuylkill	637
6	25453	42	A	-4	67728870	42107	Schuylkill	0

The total population of Schuylkill County is 147,465. To calculate the A-block impairment population percentage, the interference population is divided by the total population of the county.

Impairment % = impairment population/county population
Impairment % = 669/147,465 = **0.454%**

4.2 Downlink Impairment

To calculate Downlink Impairments, Wireless Interference data (ISIX Case 2) and TV Interference data (ISIX Case 3) are used.



Processing Steps

1) Given a facility's channel assignment, use the spectrum overlap table to determine the overlap values that must be considered.

2) For Case 2, find all points that are either flagged as falling within the protected contour (incon=1) or are flagged with interference. All these points are marked as impaired.

3) For Case 3, find all grid points that are within county boundaries that intersect with the TV protected contour (incon2=1) and all grid points within county boundaries where a wireless base station transmission could cause interference to a grid point inside the TV protected contour. All these grid points are marked as impaired.

4) Find the set of unique impaired points from Steps 2 and 3.

5) Sum the population of each impaired point by county using the *Point to County Mapping* reference table.

6) Determine the percent of population in each county with downlink impairments by dividing the sum of impaired population by the total county population under Case 2. Then, determine if a county should be considered 100% impaired under Case 3. Finally, take the greater of Case 2 and Case 3.

Example: Downlink Impairment from Facility 24543 on Channel 32

In this example, the *Downlink* Impairment caused by **facility 25453** (A UHF station in Philadelphia, PA) when it is assigned to **channel 32** is measured. In that case, at a clearing of 126 MHz, the A-block, B-block, and C-block would have the possibility of being impaired. Overlap values of 2, 4, and -1 would need to be considered, respectively. An illustrative example for the calculation of impairments on block A-block in Hartford County, Maryland (population 245,073) is shown below.

			Spectrum Overlap (by channel)																				
MHz Cleared	Uplink/ Downlink	Block	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
126	U	J	5	-1																				
126	U	I	1	4	-2																			
126	U	H	-4	2	3	-3																		
126	U	G		-3	3	2	-4																	
126	U	F			-2	4	1	-5																
126	U	E				-1	5	0																
126	U	D					0	5	-1															
126	U	C					-5	1	4	-2														
126	U	B						-4	2	3	-3													
126	U	A							-3	3	2	-4												
126	D	J										-1	5	0										
126	D	I											0	5	-1									
126	D	H											-5	1	4	-2								
126	D	G												-4	2	3								
126	D	F																3	2	-4				
126	D	E																-2	4	1	-5			
126	D	D																	-1	5	0			
126	D	C																		0	5	-1		
126	D	B																		-5	1	4	-2	
126	D	A																			-4	2	3	-3

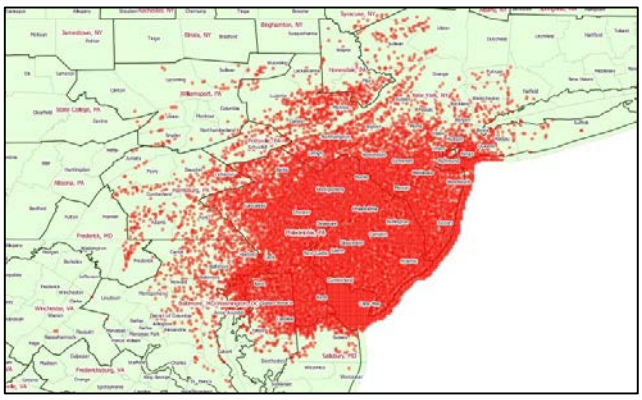


Figure (a)

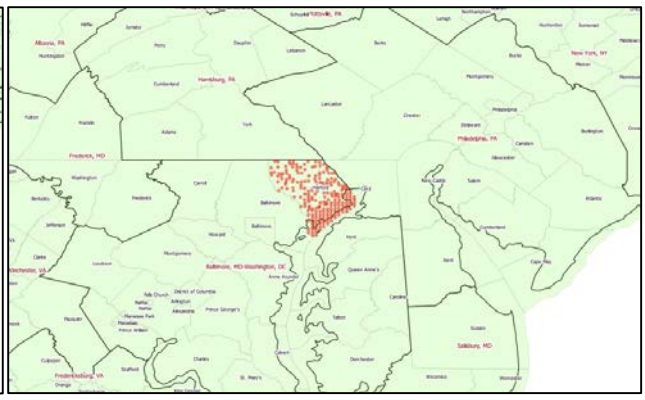
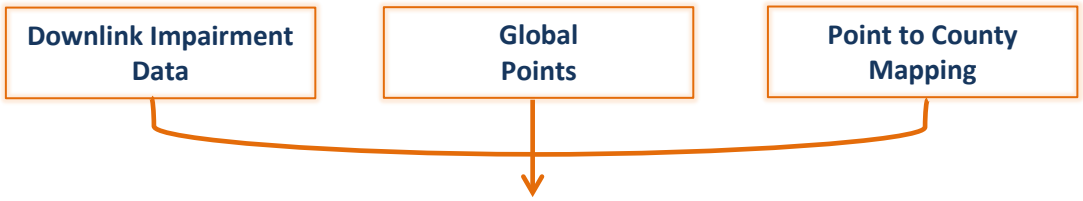


Figure (b)

Placing facility 25453 on channel 32 would cause A-block impairments to wireless UEs (ISIX Case 2) in 118 counties (see (a) in figure above). The relevant data from the Downlink Impairment data is shown below.



	facilityid character varying(10)	channel integer	block character varying(2)	ol integer	ptkey integer	county_fips character varying(5)	county_name character varying(100)	population numeric
1	25453	32	A	2	605302	24025	Harford	192
2	25453	32	A	2	216454	24025	Harford	0
3	25453	32	A	2	276271	24025	Harford	0
4	25453	32	A	2	635218	24025	Harford	243
5	25453	32	A	2	246364	24025	Harford	0
6	25453	32	A	2	575413	24025	Harford	214
7	25453	32	A	2	276259	24025	Harford	0
8	25453	32	A	2	336085	24025	Harford	0
9	25453	32	A	2	455734	24025	Harford	3864
10	25453	32	A	2	395899	24025	Harford	0
11	25453	32	B	4	605302	24025	Harford	192
12	25453	32	B	4	216454	24025	Harford	0
13	25453	32	B	4	276271	24025	Harford	0

.
.
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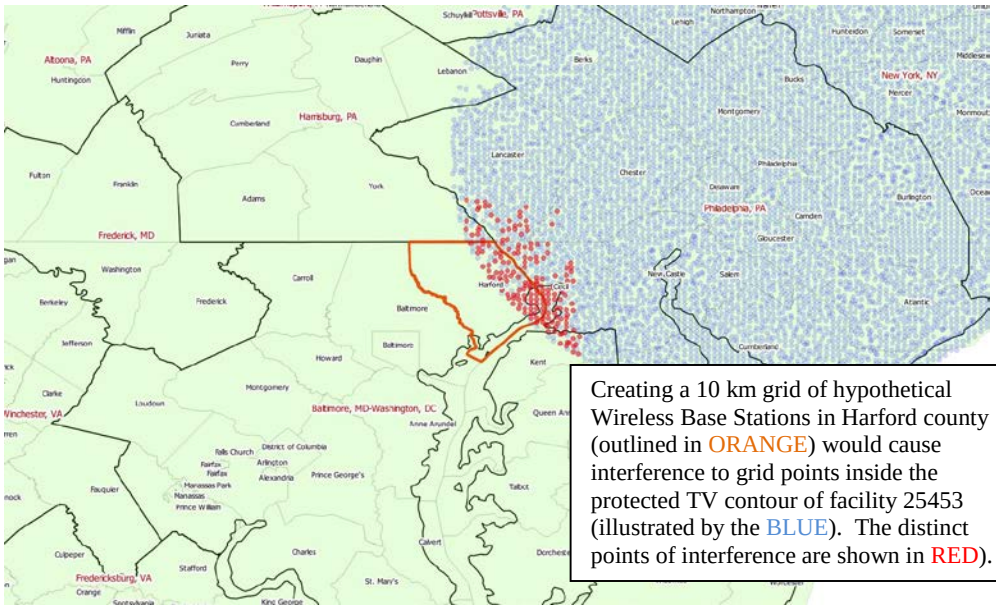
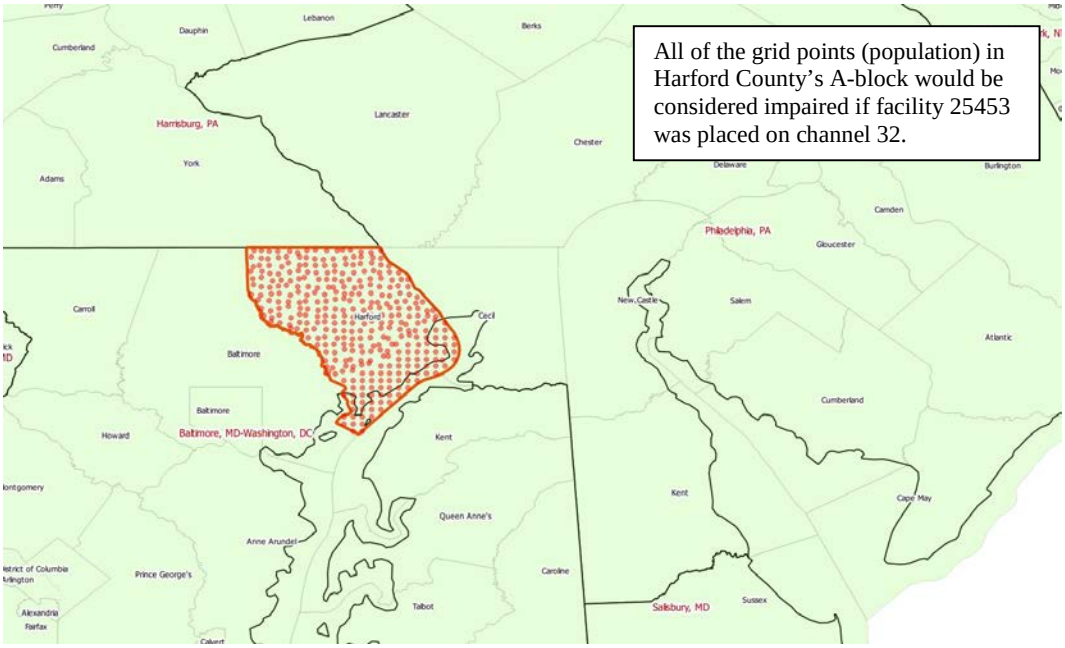
454	25453	32	B	4	575386	24025	Harford	266
455	25453	32	B	4	605296	24025	Harford	63
456	25453	32	B	4	784756	24025	Harford	175
457	25453	32	C	-1	575386	24025	Harford	266

Placing facility 25453 on channel 32 would cause 10 points of impairment in Hartford County for Block A, which accounts for a population of 4,153 (1.7% of the total county population).

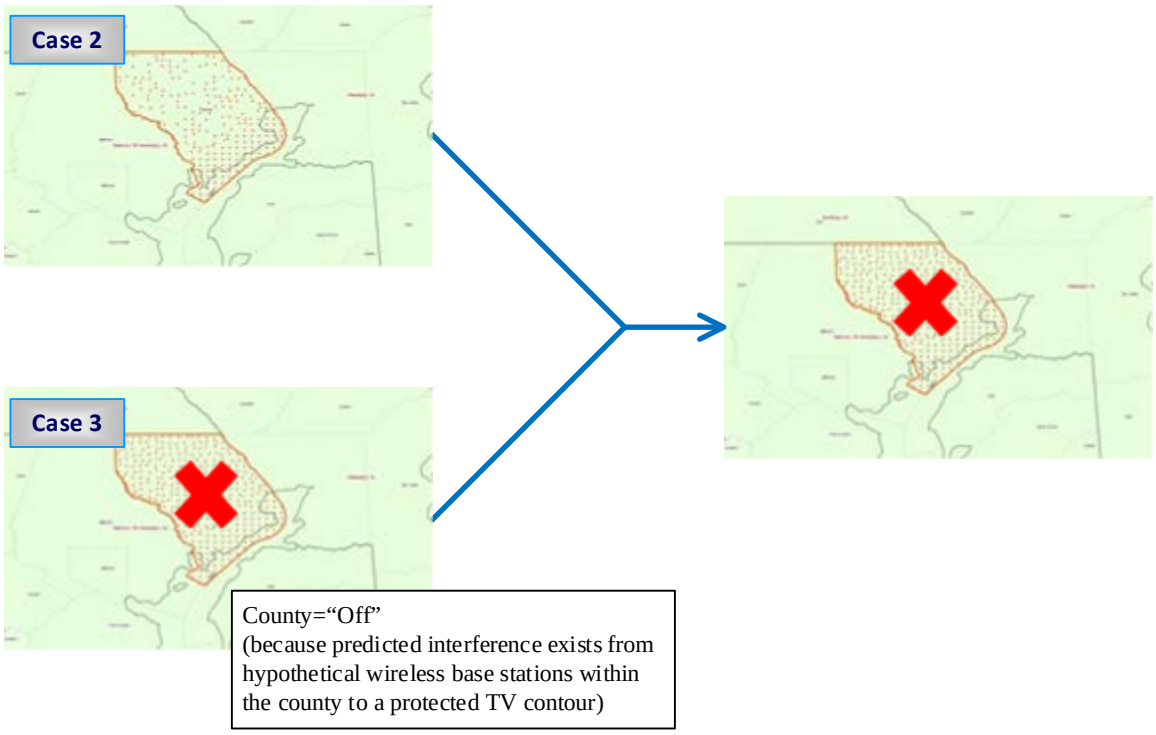
In addition to considering data from the *Wireless Interference* table (Case 2), data from the *TV Interference* table (Case 3) must also be considered. The ISIX raw data shows that wireless base stations in Harford County causes interference to 186 grid points inside the TV protected contour of facility 25453. The total population of those points is 65,663. As noted above, as long as even one point within the protected contour of a station is interfered with by a wireless base station in Harford County, then Harford County would be considered totally impaired.



Because there are points of interference within the protected TV contour of facility 25453, placing Wireless Base Stations anywhere in Harford County is not allowed. To account for this, all points in the county are marked as impaired.



To determine the final downlink interference, data from Case 2 and Case 3 must be merged. However, because Case 3 is essentially an "on/off" county-level switch, merging distinct points is very straightforward.



Impairment % = impairment population/county population
Impairment % = 245,073/245,073 = **100% → Because of Case 3**

4.3 Summary

The final result of the ISIX data processing is two county percentage impairment tables, one for *Downlink* and the other for *Uplink*, that provides the percent of population impaired for each county (based on the clearing target and band plan) for every facility-channel assignment versus wireless channel combination.

As illustrated in the examples provided in 3A and 3B, placing facility 25453 on channels 42 or 32 would cause Wireless impairments.

Schuylkill County, Pennsylvania (FIPS=42107) – A-Block - Uplink
Impairment caused by placing facility 25453 on channel 42 = 0.454%

Harford County, Pennsylvania (FIPS=24025)– A-Block - Downlink
Impairment caused by placing facility 25453 on channel 32 = 100%

Sample Uplink County Percentage Impairment Table[8]

	region_id character varying(15)	block character varying(2)	ol integer	facilityid character varying(10)	channel integer	county_fips character varying(5)	county_population numeric	pop_wrt_county numeric	pop_pct_wrt_county numeric	mktid character varying(10)
1	00610001	A	-4	25453	42	10001	163484	134139	82.050	006
2	00610003	A	-4	25453	42	10003	538416	536787	99.697	006
3	14710005	A	-4	25453	42	10005	195362	0	0.000	147
4	00524011	A	-4	25453	42	24011	33907	363	1.071	005
5	00624015	A	-4	25453	42	24015	100360	81557	81.264	006
6	00524025	A	-4	25453	42	24025	245073	5773	2.356	005
7	00524029	A	-4	25453	42	24029	19758	10163	51.437	005
8	00524035	A	-4	25453	42	24035	48192	4721	9.796	005
9	00634001	A	-4	25453	42	34001	273876	258498	94.385	006
10	00634005	A	-4	25453	42	34005	451264	451264	100.000	006
11	00634007	A	-4	25453	42	34007	518211	518211	100.000	006
12	00634009	A	-4	25453	42	34009	97461	48788	50.059	006
13	00634011	A	-4	25453	42	34011	156977	156977	100.000	006
14	00134013	A	-4	25453	42	34013	800007	62106	7.763	001
15	00634015	A	-4	25453	42	34015	282525	282525	100.000	006
16	00134019	A	-4	25453	42	34019	126181	92510	73.315	001
17	00134021	A	-4	25453	42	34021	370093	370093	100.000	001
18	00134023	A	-4	25453	42	34023	798066	673262	84.362	001
19	00134025	A	-4	25453	42	34025	633792	270725	42.715	001
20	00134027	A	-4	25453	42	34027	486084	51239	10.541	001
21	00134029	A	-4	25453	42	34029	577369	514890	89.179	001
22	00634033	A	-4	25453	42	34033	66267	66267	100.000	006
23	00134035	A	-4	25453	42	34035	331684	224165	67.584	001
24	00134039	A	-4	25453	42	34039	533427	100669	18.872	001
25	00134041	A	-4	25453	42	34041	109031	7819	7.171	001
26	00136085	A	-4	25453	42	36085	468581	114487	24.433	001
27	00642011	A	-4	25453	42	42011	411344	126942	30.860	006

Sample Downlink County Percentage Impairment Table[9]

	region_id character varying(15)	block character varying(2)	ol integer	facilityid character varying(10)	channel integer	county_fips character varying(5)	county_population numeric	pop_wrt_county numeric	pop_pct_wrt_county numeric	mktid character varying(10)
1	00109001	B	4	25453	32	09001	914834	212190	23.194	001
2	00109001	A	2	25453	32	09001	914834	76009	8.309	001
3	00109005	B	4	25453	32	09005	191185	2054	1.074	001
4	00109007	B	4	25453	32	09007	165845	558	0.336	001
5	00109009	B	4	25453	32	09009	854577	6987	0.818	001
6	00610001	A	2	25453	32	10001	163484	163484	100.000	006
7	00610001	B	4	25453	32	10001	163484	163484	100.000	006
8	00610001	C	-1	25453	32	10001	163484	163484	100.000	006
9	00610003	B	4	25453	32	10003	538416	538416	100.000	006
10	00610003	C	-1	25453	32	10003	538416	538416	100.000	006
11	00610003	A	2	25453	32	10003	538416	538416	100.000	006
12	14710005	A	2	25453	32	10005	195362	195362	100.000	147
13	14710005	B	4	25453	32	10005	195362	195362	100.000	147
14	00511001	A	2	25453	32	11001	634036	77643	12.246	005
15	00511001	B	4	25453	32	11001	634036	158355	24.976	005
16	00524003	A	2	25453	32	24003	533459	533459	100.000	005
17	00524003	B	4	25453	32	24003	533459	533459	100.000	005
18	00524005	A	2	25453	32	24005	769048	769048	100.000	005
19	00524005	B	4	25453	32	24005	769048	769048	100.000	005
20	00524009	A	2	25453	32	24009	89392	6965	7.792	005
21	00524009	B	4	25453	32	24009	89392	23039	25.773	005
22	00524011	A	2	25453	32	24011	33907	33907	100.000	005
23	00524011	B	4	25453	32	24011	33907	33907	100.000	005
24	00524013	A	2	25453	32	24013	168927	168927	100.000	005
25	00524013	B	4	25453	32	24013	168927	168927	100.000	005
26	00624015	A	2	25453	32	24015	100360	100360	100.000	006
27	00624015	B	4	25453	32	24015	100360	100360	100.000	006

[8] This is just a snapshot of the Uplink County Impairment Percentage Table and does not include data from Schuylkill County which was used in the example above.

[9] This is just a snapshot of the Downlink County Impairment Percentage Table and does not include data from Harford County which was used in the example above.

5 ISIX Constraint Generation

5.1 Introduction

This section describes the process of taking the uplink and downlink county percentage impairment tables and generating constraints that can be used to measure the amount of predicted impairment for each license in the wireless band for a given assignment of TV stations to channels in the UHF band. This document describes only the ISIX constraints. The full set of constraints that will be used in any repacking algorithm will also include the TV to TV pairwise interference constraints.

5.2 Setting a County Impairment Threshold

As discussed in the introduction, the ISIX data is aggregated to a county tile level because that is a tile size that can be solved in a reasonable amount of time with current optimization techniques and software/hardware. Creating the county level tiles for every impairing facility-channel assignment involves choosing a threshold value for the percent of population impaired in a county above which the county is considered to be impaired and below which is considered to be unimpaired. Threshold values between 10% and 20% are currently being tested, and the Comment PN seeks comment on the appropriate value.

Using a threshold value of 10% and the sample county percentage impairment table below, four of the seven counties listed (Counties 10001, 10003, 24015, and 24029) would be considered to be 100% impaired because the percent of population impaired in the county is greater than 10%. The other three counties (Counties 10005, 24011, and 24025) would be considered to be unimpaired. Thus, the only information that will be used from the county percentage impairment tables when generating the ISIX constraints is whether an impairment percentage is above or below the threshold. The impairment percentages from the county percentage impairment tables will not be used directly in the constraints.

	region_id character varying(15)	block character varying(2)	ol integer	facilityid character varying(10)	channel integer	county_fips character varying(5)	county_population numeric	pop_wrt_county numeric	pop_p numeri	_wrt_county	mktid charac	er varying(10)
1	00610001	A	-4	25453	42	10001	163484	134139		82.050	006	
2	00610003	A	-4	25453	42	10003	538416	536787		99.697	006	
3	14710005	A	-4	25453	42	10005	195362	0		0.000	147	
4	00524011	A	-4	25453	42	24011	33907	363		1.071	005	
5	00624015	A	-4	25453	42	24015	100360	81557		81.264	006	
6	00524025	A	-4	25453	42	24025	245073	5773		2.356	005	
7	00524029	A	-4	25453	42	24029	19758	10163		51.437	005	

5.3 Uplink-Downlink Rules

In the Incentive Auction spectrum blocks will be sold in 5+5 MHz pairs of uplink and downlink spectrum. In creating constraints to measure the level of impairment of a license, the impact to the usability of the license if the downlink portion of the license is impaired also must be captured. Specifically, a rule is implemented that if the downlink portion of a license is impaired for a particular county, the same county in the uplink portion of the license is also considered impaired. Since downlink spectrum can be used by itself, the converse will not be implemented (an impaired county in the uplink does not mean the downlink for that county is also considered impaired).

5.4 Generating Constraints

The following constraints are generated to identify counties that are impaired by any combination of stations based on the county impairment threshold. These constraints will determine for a given clearing target and channel assignment the percent of population in each license area that is predicted to receive impairment. The constraints are constructed in such a way as to avoid double counting of population where the contour of assigned TV stations overlap with each other.

Licenses that are greater than $z \cdot 100\%$ impaired will not be sold in the allocation phase of the forward auction. The Comment PN proposes to set the value of z at 0.5.[10] Because licenses in this category will not be offered in the forward auction we propose to consider them 100% impaired. Constraints that enforce this rule are also provided below.

Decision Variables

$x_{s,c}$ is a binary decision variable which has a value of 1 if station *s* is assigned to channel *c* and 0 otherwise

$y^D_{(a,l)}$ or $y^U_{(a,l)}$ is a binary decision variable which has a value of 1 if county-tile *a* has impairment in the downlink or uplink portion of license *l* respectively and 0 otherwise

ρ_l represents the total percent of population with predicted impairment in license *l*

N_l is a binary variable which has a value of 1 if the license is more than $z \cdot 100\%$ impaired.

Set Definitions

A_l is the set of county-tiles *a* covered by license *l* which is impaired partially or fully by at least one (facility, channel) pair

L is the set of impaired licenses; each license is defined by a clearing target, market id, block, and link types (uplink and downlink)

$SC^D_{(a,l)}$ and $SC^U_{(a,l)}$ are the set of impairing (facility, channel) pairs which impair county-tile *a* in license *l* for downlink and uplink respectively

Constants

z is a threshold value between 0 and 1 that determines when a license *l* is considered too impaired to be auctioned

$pct^D_{(a,l)}$ and $pct^U_{(a,l)}$ are the percent of license l's population in county-tile a divided in half between the downlink and uplink respectively;

Constraints

$$\sum_{a \in A_l} pct^D_{(a,l)}\, y^D_{(a,l)} + \sum_{a \in A_l} pct^U_{(a,l)}\, y^U_{(a,l)} = \rho_l \qquad \forall l \in L \qquad (1)$$

$$x_{(s,c)} \le y^D_{(a,l)} \qquad \forall (s,c) \in SC^D_{(a,l)}, a \in A_l, l \in L \qquad (2)$$

$$x_{(s,c)} \le y^U_{(a,l)} \qquad \forall (s,c) \in SC^D_{(a,l)}, a \in A_l, l \in L \qquad (3)$$

$$x_{(s,c)} \le y^U_{(a,l)} \qquad \forall (s,c) \in SC^U_{(a,l)}, a \in A_l, l \in L \qquad (4)$$

$$0 \le y^D_{(a,l)} \le 1 \qquad \forall a \in A_l, l \in L \qquad (5)$$

$$0 \le y^U_{(a,l)} \le 1 \qquad \forall a \in A_l, l \in L \qquad (6)$$

$$0 \le \rho_l \le 1 \qquad \forall l \in L \qquad (7)$$

$$\rho_l \le z + (1 - z) N_l \qquad \forall l \in L \qquad (8)$$

$$\rho_l \ge N_l \qquad \forall l \in L \qquad (9)$$

$$N_l \in \{0,1\} \qquad \forall l \in L \qquad (10)$$

[10] *See* § III.A.1 (Measuring the Extent of Potential Impairments).

Explanation of Constraints

1. **Calculation of the total percent of population impaired in each license**

$$\sum_{a \in A_l} pct^D_{(a,l)}\, y^D_{(a,l)} + \sum_{a \in A_l} pct^U_{(a,l)}\, y^U_{(a,l)} = \rho_l \qquad \forall l \in L$$

For every license, this constraint calculates the total percent of population impaired in the license by summing the percent of population impaired with respect to the market for all the county-tiles *a* that have downlink or uplink broadband service respectively in license *l*.

2. **Constraints that set the downlink county variables to 1**

$$x_{(s,c)} \leq y^D_{(a,l)} \qquad \forall (s,c) \in SC^D_{(a,l)}, a \in A_l, l \in L$$

For each county in each license, these constraints set a downlink county variable to 1 when a specific (facility, channel) assignment creates impairment in the downlink portion of the license in that county. Note that the value of $y^D_{(a,l)}$ remains 1 even if multiple channel assignments force the county to be impaired. Thus the percent of license *l*'s population impaired by a county will only be counted once in the associated constraints of (1).

3. **Constraints that set the uplink county variables to 1 when the associated downlink variables are set to 1**

$$x_{(s,c)} \leq y^U_{(a,l)} \qquad \forall (s,c) \in SC^D_{(a,l)}, a \in A_l, l \in L$$

For each county in each license, these constraints set the uplink county variable to 1 when a specific (facility, channel) assignment creates impairment in the associated downlink portion of the license in that county. This ensures the rule that the uplink spectrum is of no value if the downlink spectrum is impaired.

4. **Constraints that set the uplink county variables to 1**

$$x_{(s,c)} \leq y^U_{(a,l)} \qquad \forall (s,c) \in SC^U_{(a,l)}, a \in A_l, l \in L$$

For each county in each license, these constraints set an uplink county variable to 1 when a specific (facility, channel) assignment creates impairment in the uplink portion of the license in that county. Note that the value of $y^U_{(a,l)}$ remains 1 even if multiple channel assignments force the county to be impaired. Thus the percent of license *l*'s population impaired by a county will only be counted once in the associated constraints of (1).

5. **Constraints that restrict the value of the downlink county variables**

$$0 \leq y^D_{(a,l)} \leq 1 \qquad \forall a \in A_l, l \in L$$

For each county in each license, these constraints restrict the value of the downlink county variables to be between 0 and 1 inclusive. Note that the constraints are constructed in such a way that, when combined with the objective to minimize the sum of impaired weighted-pops (see Appendix C), these variables will take on the value 0 when the county is not impaired, or 1 when it is. As a result, the model can consider the variables to be continuous but in practice they will be binary.

6. **Constraints that restrict the value of the uplink county variables**

$$0 \leq y^U_{(a,l)} \leq 1 \qquad \forall a \in A_l, l \in L$$

For each county in each license, these constraints restrict the value of the uplink county variables to be between 0 and 1 inclusive. Note that the constraints are constructed in such a way that,

when combined with the objective to minimize the sum of impaired weighted-pops (see Appendix C), these variables will take on the value 0 when the county is not impaired, or 1 when it is. As a result, the model can consider the variables to be continuous but in practice they will be binary.

7. Constraints that restrict the values of the total percent of population with predicted impairment variables

$$0 \leq \rho_l \leq 1 \qquad \forall l \in L$$

For each license *l*, these constraints restrict the value of the total percent of population with predicted impairment variables to be between 0 and 1 inclusive. A solution value of 0 indicates that there is no predicted impairment in license *l*, while a value of 1 indicates that this license is predicted to be 100% impaired.

8. Constraints that set binary variable N_l to 1

$$\rho_l \leq z + (1 - z)N_l \qquad \forall l \in L$$

For each license *l*, this constraint will force the variable N_l to be 1 whenever the calculated value of ρ_l is greater than or equal to some threshold *z*.

9. Constraints that set the percentage of impairment, ρ_l, to 1

$$\rho_l \geq N_l \qquad \forall l \in L$$

For each license *l*, this constraint will set the impairment percentage of license *l* to be 100% whenever the variable N_l is set to 1. This constraint is coupled with constraint (8) to force the total impairment of the license. Thus, whenever the population impairment percentage is greater than $z \cdot 100\%$, we consider the license completely impaired since it will not be available in the forward auction.

10. Constraints that restrict the value of variable N_l

$$N_l \in \{0,1\} \qquad \forall l \in L$$

For each license *l*, the variable N_l is restricted to the value 0 or 1.

Illustration of the ISIX Constraints

This illustration shows how the ISIX constraints measure impairment for a single license. For the following example, consider a license made up of the "A" block in the "Altoona, PA" PEA (PEA # 121) which is made of 6 counties, as shown in Figure 1.

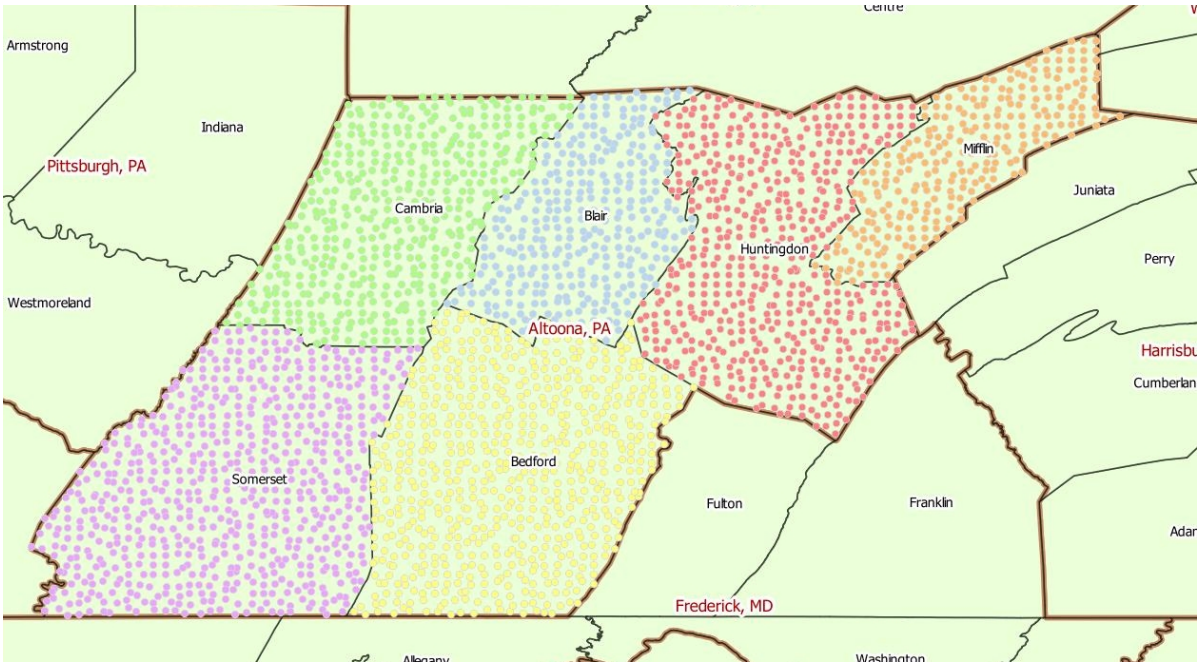


Figure 1. "Altoona, PA" PEA made of 6 counties

For purposes of this example, assume there exists inter-service interference between license A and only three television stations: S1, S2 and S3. Specifically there exists inter-service interference in license A if station S1 is assigned to channels 42 or 51, if station S2 is assigned to channels 41 or 50, and if station S3 is assigned to channels 41 or 50. The amount of interference will change depending on the channel on which the stations broadcast. Generally, interference areas are larger in the uplink portion of the license. Figure 2 shows how the three stations broadcasting on the lower channels cause interference with the downlink portion of the license and Figure 3 shows how the same stations on higher channels cause interference with the uplink portion of the same license.

If the stations broadcast on channels other than these, we will assume there is no interference with license A. Assume also that there are no co-channel or adjacent channel restrictions among the stations. Finally, in this example we apply a county threshold value. That is, based on the calculated county percentage impairment tables, counties whose percent of population impaired are below the threshold will not be considered impaired and ISIX constraints for those counties will not be generated for the associated station-channel pair. Table 1 and Table 2 show the counties where inter-service interference is above and below the acceptable threshold for downlink and uplink respectively.

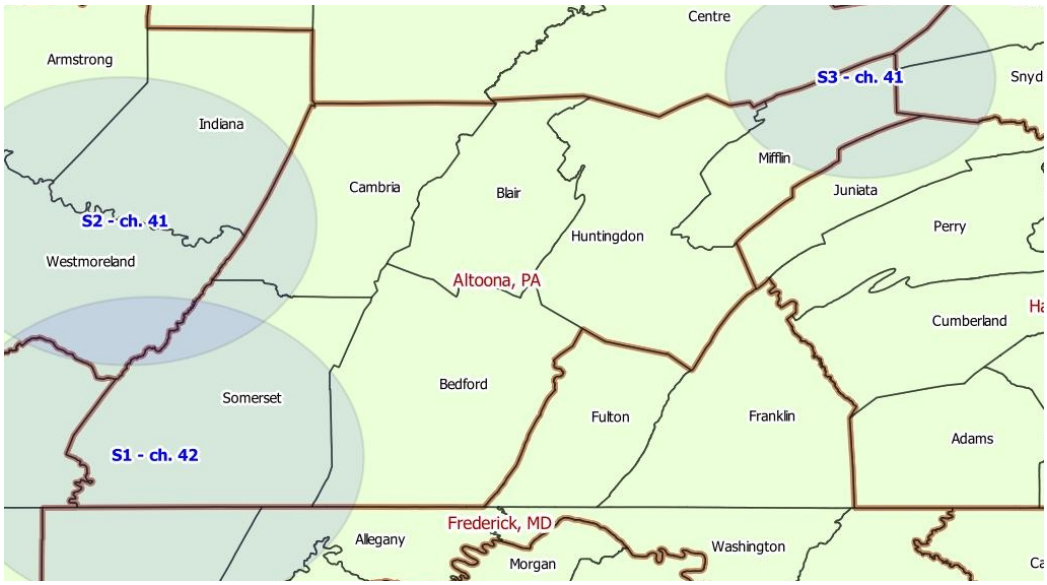


Figure 2. Downlink license interfered by Stations S1, S2, and S3

Station	Channel	Counties with Interference above Threshold	Counties with Interference below Threshold
S1	42	Somerset	Bedford
S2	41	Cambria, Somerset	
S3	41	Mifflin	Huntington

Table 1. Counties with Downlink Interference Above and Below the Threshold

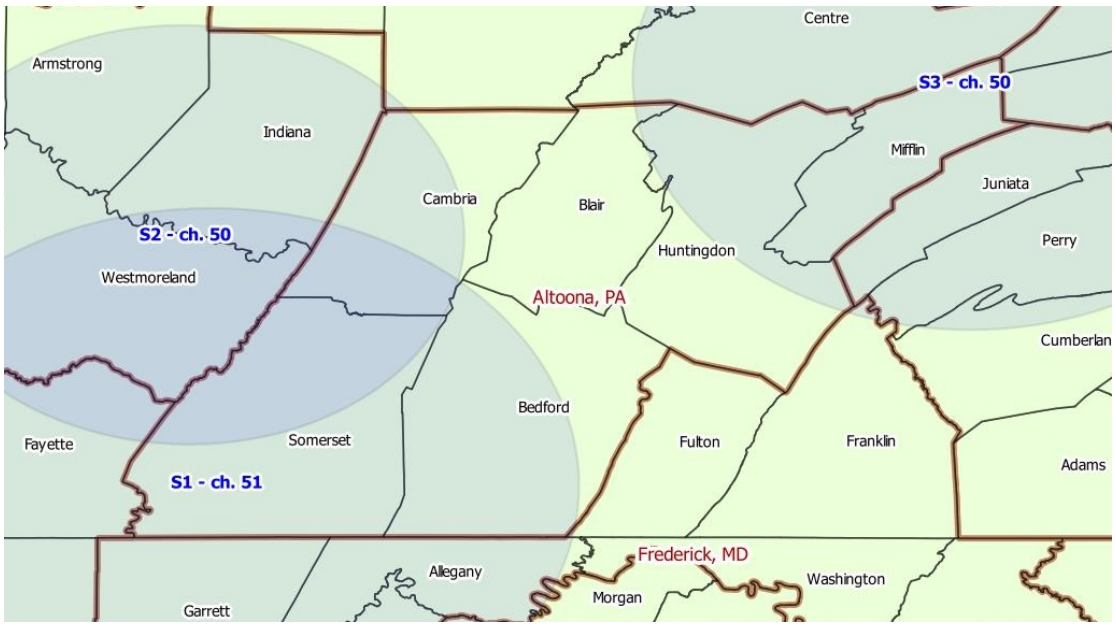


Figure 3. Uplink license interfered by Stations S1, S2, and S3

Station	Channel	Counties with Interference above Threshold	Counties with Interference below Threshold
S1	51	Bedford, Cambria, Somerset	
S2	50	Cambria, Somerset	
S3	50	Huntingdon, Mifflin	Blair

Table 2. Counties with Uplink Interference Above and Below the Threshold

The following shows how the variables and constraints for the station-channel pairs that impair counties above the threshold are created for this license.

Decision Variables

In this small example, station S1 will create interference only if it is assigned either channel 42 or 51. Variables $x_{(S1,42)}$ and $x_{(S1,51)}$ are created for station S1. Similarly variables $x_{(S2,41)}$ and $x_{(S2,50)}$ are created for station S2 and $x_{(S3,41)}$ and $x_{(S3,50)}$ for station S3.

Decision variables are then created for both the downlink and uplink of each county in this license with predicted interference above the threshold:

$$y^{D}_{(\text{Cambria, A})};\ y^{D}_{(\text{Mifflin, A})};y^{D}_{(\text{Somerset, A})};\ y^{U}_{(\text{Bedford, A})};y^{U}_{(\text{Cambria, A})};y^{U}_{(\text{Huntingdon, A})};y^{U}_{(\text{Mifflin, A})};y^{U}_{(\text{Somerset, A})}$$

Finally a variable is created that represents the total percent of population impaired in license A of PEA Altoona, PA.

$$\rho_{(\text{Altoona, A})}$$

Constraints

Given these variables, the constraints that calculate the amount of impairment incurred in license A in both the uplink and the downlink portion of the license for the set of possible station-channel assignments are presented below.

The first constraint captures the total percent of population impaired in the PEA by summing the percent of population impaired in the county with respect to the PEA. Table 3 shows the population for each county in the example and its associated percent of the PEA's population.

County Name	Population	Percent of the PEA's Population
Bedford	50237	10.2%
Blair	126884	25.9%
Cambria	144123	29.4%
Huntingdon	45549	9.3%
Mifflin	46792	9.5%
Somerset	77204	15.7%

Table 3. County Population and Percent of PEA Population

With this information a constraint is created that will capture the percent of population in license A of PEA "Altoona" that has predicted impairment by summing the percent of population in each county in which the uplink/downlink county variables are set to 1. Note the population percentage of a county is divided in half between the uplink and the downlink portion of the license.

$$14.7\, y^{D}_{(\text{Cambria, A})} + 4.75\, y^{D}_{(\text{Mifflin, A})} + 7.85\, y^{D}_{(\text{Somerset, A})} + 5.1\, y^{U}_{(\text{Bedford, A})} + 14.7\, y^{U}_{(\text{Cambria, A})} + 4.65\, y^{U}_{(\text{Huntingdon, A})} + 4.75\, y^{U}_{(\text{Mifflin, A})} + 7.85\, y^{U}_{(\text{Somerset, A})} = \rho_{(\text{Altoona, A})}$$

Continuing on with the formulation we create the constraints for the downlink county variables.

$x_{(\text{S1,42})} \le y^{D}_{(\text{Somerset, A})}$; (Downlink of Somerset County is impaired if station S1 is assigned channel 42)
$x_{(\text{S2,41})} \le y^{D}_{(\text{Cambria, A})}$; (Downlink of Cambria County is impaired if station S2 is assigned channel 41)
$x_{(\text{S3,41})} \le y^{D}_{(\text{Mifflin, A})}$; (Downlink of Mifflin County is impaired if station S3 is assigned channel 41)

When a station at a specific channel impairs a county on the downlink portion of a license, the uplink portion of the license also is considered impaired, resulting in the following constraints:

$x_{(\text{S1,42})} \le y^{U}_{(\text{Somerset, A})}$; (Uplink of Somerset County is impaired if station S1 is assigned channel 42)
$x_{(\text{S2,41})} \le y^{U}_{(\text{Cambria, A})}$; (Uplink of Cambria County is impaired if station S2 is assigned channel 41)
$x_{(\text{S3,41})} \le y^{U}_{(\text{Mifflin, A})}$ (Uplink of Mifflin County is impaired if station S3 is assigned channel 41)

Next the constraints for the uplink county variables are created.

$x_{(\text{S1,51})} \le y^{U}_{(\text{Bedford, A})}$; (Uplink of Bedford County is impaired if station S1 is assigned channel 51)
$x_{(\text{S1,51})} \le y^{U}_{(\text{Cambria, A})}$; (Uplink of Cambria County is impaired if station S1 is assigned channel 51)
$x_{(\text{S1,51})} \le y^{U}_{(\text{Somerset, A})}$; (Uplink of Somerset County is impaired if station S1 is assigned channel 51)
$x_{(\text{S2,50})} \le y^{U}_{(\text{Cambria, A})}$; (Uplink of Cambria County is impaired if station S2 is assigned channel 50)
$x_{(\text{S2,50})} \le y^{U}_{(\text{Somerset, A})}$; (Uplink of Somerset County is impaired if station S2 is assigned channel 50)
$x_{(\text{S3,50})} \le y^{U}_{(\text{Huntingdon, A})}$; (Uplink of Huntingdon County is impaired if station S3 is assigned channel 50)
$x_{(\text{S3,50})} \le y^{U}_{(\text{Mifflin, A})}$; (Uplink of Mifflin County is impaired if station S3 is assigned channel 50)

In this example, assume that the optimization determines that station S1 should be assigned to channel 42 and station S3 should be assigned to channel 50. S2 is assigned a channel that does not impair license A. The interference between S1 and Somerset County is in the downlink so both the uplink and downlink would be blocked and the county would be 100% impaired. The interference between S3 and Huntingdon and Mifflin counties is in the uplink so only the uplink would be blocked and 50% of the population of the counties would be considered impaired. Combining the impairment percentages with the county population percentages, the total impairment of this license for this PEA can be found, as shown in Table 4.

County Name	Percent of the PEA's Population	Percent Impaired	Percent of PEA's Population Impaired
Bedford	10.2%	0%	0%
Blair	25.9%	0%	0%
Cambria	29.4%	0%	0%
Huntingdon	9.3%	50%	4.65%
Mifflin	9.5%	50%	4.75%
Somerset	15.7%	100%	15.7%
TOTAL IMPAIRMENT FOR PEA			25.1%

Table 4. Impairment of license A for this assignment

Using the constraints, the variables would be set as: $x_{(S1,42)} = x_{(S3,50)} = 1$ and $x_{(S2,41)} = x_{(S3,41)} = x_{(S1,51)} = x_{(S2,50)} = 0$. The downlink constraints force both the downlink and uplink variables for Somerset County to be 1. The uplink constraints force the uplink variables for Huntingdon and Mifflin Counties to be 1. Since this assignment does not create any downlink impairment for Cambria and Mifflin Counties, the associated downlink variables will be 0. Since this assignment also does not create any uplink impairment for Bedford and Cambria Counties, the associated uplink variables are equal to zero. Therefore, the amount of impairment for this license is set to:

$$14.7\ (0) + 4.75(0) + 7.85\ (1) + 5.1\ (0) + 14.7(0) + 4.65\ (1) + 4.75\ (1) + 7.85(1) = 25.1 = \rho_{(PEA\#,A)}$$

APPENDIX C

Clearing Target Optimization

1 Introduction

This appendix provides the technical specifications for the Clearing Target Optimization - the mathematical optimization problem that is solved when setting a clearing target and determining impairments. The Clearing Target Optimization determines for a given clearing target, an assignment of stations[1] that minimizes the impact to forward auction licenses of assigning stations to channels in the 600 MHz Band (also known as impairments to forward auction licenses).

The Clearing Target Optimization is run in several different scenarios. It is first run before the start of the auction as part of the process of setting an initial clearing target. The optimization is also run after the completion of Dynamic Reserve Pricing in the first stage of the reverse auction, in order to assign UHF stations that have dropped out of bidding and cannot feasibly be assigned in the television portion of the UHF band in the existing assignment.[2] The optimization is also run between stages once the clearing target has been lowered in order to determine a new assignment of impairing UHF stations considering the participating stations that dropped out of bidding in the previous stage.

The first section of this appendix provides a detailed description of the initial clearing target optimization process including the definition of a feasible assignment, the rules that are enforced when assigning participating stations to an initial relinquishment option and a complete mathematical formulation of the primary model solved in the Clearing Target Optimization. The last section describes the other instances in which the Clearing Target Optimization is run.

2 Initial Clearing Target Optimization

The *initial* clearing target optimization takes place before the first stage of the Incentive Auction. It determines an initial feasible assignment of stations such that the impact of impairing stations to forward auction licenses is minimized. In determining an initial feasible assignment, the optimization must assign all participating stations to a relinquishment option considering the initial commitment(s) each qualified bidder selected during the application process. The outcome of the initial clearing target optimization is used in selecting an *initial clearing target* for the auction.

This section first defines a feasible assignment in the initial clearing target optimization and provides the formulation of the mathematical constraints added to the model to enforce feasibility. The next section describes a series of optimizations solved to generate additional constraints on the primary optimization model. These constraints are used to enforce rules about how participating stations are assigned to an initial relinquishment option. The last section describes the full initial clearing target optimization model and provides the details of the mathematical formulation.

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[1] Note that in the auction, any assignment of stations to channels in the remaining television bands is considered provisional in the sense that it may change during the course of bidding, and final channels for those stations remaining on air after the auction will be determined in the Final Channel Assignment Optimization. However, the assignment of stations to channels in the 600 MHz Band (those stations that cause impairments to forward auction licenses) will not change until another clearing target optimization is run (e.g. after Dynamic Reserve Pricing is turned off in the first stage, or before a new stage). Thus, stations assigned in the 600 MHz Band in the final stage of the auction will not change during the Final Channel Assignment Optimization while those assigned in the remaining television bands may.

[2] The Clearing Target Optimization may also be run at other points in the reverse auction, as determined by the Commission.

2.1 Feasible Assignment

In the initial clearing target optimization a feasible assignment is defined as an assignment of TV stations that meets the following conditions:

(1) All stations are assigned, either to a channel or to go off-air.

(2) A station can only be assigned to one of its allowable channels as defined in the domain.csv file.

(3) Stations' assignments must not violate adjacent and co-channel pairwise interference restrictions as defined in the interference_paired.csv file.

(4) All non-participating stations are assigned a channel in their pre-auction band.

(5) All participating stations in the reverse auction are assigned to either go off-air or to a channel in a band associated the bidder's initial commitment(s) or to a channel in the bidder's pre-auction band.

An assignment of stations that meets all of the above conditions is considered feasible. All solutions to the initial clearing target optimization must be feasible. The linear constraints that enforce conditions (1) through (5) are provided below.

Set Definitions:

S is the set of all stations (both participating and non-participating)

C_s is the set of allowable channels for station s

For non-participating stations, the set C_s consists exclusively of allowable channels in their pre-auction band, which for UHF stations, includes their allowable channels in the 600 MHz Band. For participating stations, the set C_s consists of allowable channels in their pre-auction band as well as channels in the bands associated with their initial commitment(s) of relinquishment options. For participating stations that made an initial commitment to go off-air, the set C_s also consists of channel 0 which indicates an assignment of going off-air.

Variable Definitions:

$x_{s,c}$ is a binary decision variable which has a value of 1 if station *s* is assigned to channel *c* and 0 otherwise. Note $c = 0$ indicates the option to go off-air.

Feasibility Constraints:

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s\prime,c\prime} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)

Explanation of Feasibility Constraints:

1. **Each station must be assigned.**

$$\sum_{c \in C_s} x_{s,c} = 1 \qquad \forall s \in S$$

The set C_s is the set of all allowable channel assignments for station s. This constraint assures that every station is assigned to exactly one channel from that set. For some stations, the set $c \in C_s$ includes channel *0*, i.e. that the station can be assigned to go off the air.

2. Station assignments must adhere to the co-channel interference restrictions.

$$x_{s,c} + x_{s',c} \leq 1 \qquad \forall\{(s,c),(s',c)\} \in CoPairs$$

For every pairwise restriction that precludes two stations from occupying the same channel, a constraint is created that indicates at most one of the two stations (*s and s'*) can be assigned to that channel *c*. The set includes all station pairs that cannot occupy the same channel.

3. Station assignments must adhere to the adjacent channel restrictions.

$$x_{s,c} + x_{s\prime,c\prime} \leq 1 \qquad \forall\{(s,c),(s',c')\} \in AdjPairs$$

Similarly, for every two station-pairs (s,c) and (s',c') where channels *c* and *c'* are adjacent and where if station *s* is on channel *c* then station *s'* cannot be on channel *c'*, a constraint is created that allows only one of these two assignments. That is, the constraints enforce the adjacent channel requirements.

4. The decision variables can only take on the values zero or one.

$$x_{s,c} \in \{0,1\} \qquad \forall s \in S, \forall c \in C_s$$

For each allowable station-channel combination, the value of the variable $x_{(s,c)}$ is restricted to be either 0 or 1 i.e. the station is either assigned to the channel or it is not.

2.2 Constraints for Initial Commitments

The optimization seeks to assign as many participating stations as possible to the preferred relinquishment option they selected during the initial commitments process. Given the limited capacity of the VHF bands, it may not be possible to assign all participating bidders to their preferred relinquishment option. That is, if more bidders prefer a move to low-VHF or a move to high-VHF than can be accommodated in those bands, then the optimization procedure must assign some bidders to either an alternative relinquishment option or their pre-auction band in the initial assignment. If some participating stations *only* selected a move to a VHF band in their initial commitments and the optimization does not assign them a channel in that VHF band, they will be assigned a channel in their pre-auction band in lieu of participating in the auction.

The optimization employs a sequence of steps to determine, in the event that all participating stations cannot be assigned to their preferred option, how to choose alternative relinquishment options for some bidders. Specifically, considering all preferred and alternative relinquishment options indicated by bidders as well as the option for each station to be assigned to its pre-auction band, the following steps are employed:

(1) Determine the minimum number of UHF participating stations that must be assigned to their pre-auction band.

(2) Add the outcome of (1) as a constraint on the optimization model, and then determine the minimum number of VHF participating stations that must be assigned to their pre-auction band.

(3) Add the outcome of (2) as a constraint on the optimization model, and then determine the maximum number of participating stations that can be assigned to their preferred relinquishment option.

(4) Add the outcome of (3) as a constraint on the optimization model, and then determine the maximum number of participating stations that can be assigned to go off the air.

(5) Add the outcome of (4) as a constraint on the optimization model, and then minimize the sum of impaired weighted-pops across all licenses (i.e. solve the primary clearing target optimization model).

Steps (1) and (2) two are given the highest priority in order to ensure that a minimal number of participating stations get assigned to their pre-auction band and therefore cannot participate in the reverse auction. The minimal number of UHF participating stations assigned to their pre-auction band precedes all other steps in order to minimize the likelihood of creating additional impairing stations in the 600 MHz Band. Step (3) seeks to assign as many participating stations to their preferred option as possible while still ensuring that no more than the minimal number of stations is assigned to their pre-auction band. If not all stations can simultaneously be assigned to their preferred option, step (4) ensures that the maximum number of stations that must be assigned an alternative relinquishment option are assigned the option to go off the air since doing so provides the most opportunities for bidding on other options in the reverse auction. Finally, in the last step of the initial clearing target optimization process, the optimization chooses among the remaining options based on the primary objective in setting a clearing target, namely, an assignment of stations that minimizes the sum of impaired weight-pops across all licenses in the 600 MHz Band.

The steps outlined above ensure an initial feasible assignment of stations in the event that all participating stations cannot be assigned to their preferred options. The following section provides the mathematical formulations of the optimization models solved in steps (1)-(4) to generate a set of constraints that will be added to the primary clearing target optimization model.

2.3 Step (1): Minimize the number of UHF stations assigned to their pre-auction band.

In the first step of determining an initial feasible assignment, the optimization seeks a feasible solution that minimizes the number of UHF participating stations that must be assigned to their pre-auction band in lieu of participating in the auction. The constraints for this first optimization are the same as those defined in Section 2.1 above. In addition to the variables and sets defined in that section, the subsets of the sets *S* and C_s are defined here.

Subsets:

S_P is the set of participating stations

SP_U is the set of participating stations whose pre-auction band is UHF

C_s^H is the set of allowable pre-auction band channels for station *s*

Model Formulation for Step (1):

$$min\ \ Z_1 = \sum_{s \in S_{P_U}, c \in C_s^H} x_{s,c}$$

Subject to

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s\prime,c\prime} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{(s,c)} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)

Explanation of Objective Function:

The objective function minimizes the number Z_1 of UHF participating bidders that are assigned to their pre-auction band. Thus, the optimization sums only the set of participating stations whose pre-auction band is UHF ($s \in SP_U$**)** and determines the minimum number of such stations that must be assigned some

channel in their pre-auction band ($c \in C_s^H$) considering all stations and their allowable channels and relinquishment options. The value of Z_1 will be an integer greater than or equal to zero.

2.4 Step (2): Minimize VHF stations assigned to their pre-auction band.

In the second step of determining an initial feasible assignment, a new constraint is added to enforce the objective function value found in the first set. That is, the optimization ensures a feasible assignment that has the minimum number of participating UHF stations assigned to their pre-auction band, and now seeks an assignment that minimizes the number of participating VHF stations assigned to their respective pre-auction band. The constraints for the optimization in Step (2) are the same as those defined in Step (1) with the result of Step (1) added as an additional constraint. In addition to the variables and sets defined in Step (1), an additional subset of the set *S* is defined here.

Subsets:

SP_V is the set of participating stations whose pre-auction band is VHF

Model Formulation for Step (2):

$$min\ Z_2 = \sum_{s \in S_{P_V}, c \in C_s^H} x_{s,c}$$

Subject to

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s\prime,c\prime} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{(s,c)} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)
$\sum_{s \in S_{P_U}, c \in C_s^H} x_{s,c} \leq Z_1$		(5)

Explanation of New Constraint:

Constraint (5) states that the number of the UHF participating stations assigned to their pre-auction band must be less than or equal to the count obtained in the first optimization, namely the value Z_1.

Explanation of Objective Function:

The objective function minimizes the number Z_2 of VHF participating stations that are assigned to their pre-auction band. Thus, the optimization sums only the set of participating stations whose pre-auction band is VHF ($s \in S_{P_V}$) and determines the minimum number of such stations that must be assigned some channel in their pre-auction band ($c \in C_s^H$) considering all stations and their allowable channels and relinquishment options and the minimum number Z_1 of UHF stations that must be assigned to their pre-auction band. The value of Z_2 will be an integer number greater than or equal to zero.

2.5 Step (3): Maximize the number of stations assigned to their preferred relinquishment option

Given that all participating stations have identified a preferred relinquishment option, Step (3) attempts to maximize the number of stations that are assigned to their preferred relinquishment option, while ensuring that the assignment is feasible and the number of stations assigned to their pre-auction band is the same as in Step (2). Additional subsets of the sets S and C_s are defined here.

Subsets:

C_s^{pref} = the set of allowable channels for a participating station s in its preferred option.

Note: For stations whose preferred option is to go off-air, the set C_s^{pref} consists solely of 0.

Model Formulation for Step (3):

$$max\ \ Z_3\ =\ \sum_{s\in S_P, c\in C_s^{pref}} x_{s,c}$$

Subject to

$\sum_{c\in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall\{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s\prime,c\prime} \leq 1$	$\forall\{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)
$\sum_{s\in S_{P_U}, c\in C_s^H} x_{s,c}\ \leq\ Z_1$		(5)
$\sum_{s\in S_{P_V}, c\in C_s^H} x_{s,c}\ \leq\ Z_2$		(6)

Explanation of New Constraint:

Constraint (6) states that the sum of the VHF participating stations assigned to their pre-auction band must be less than or equal to the result of the second optimization, namely the value Z_2.

Explanation of Objective Function:

The objective function maximizes the total number Z_3 of participating stations that are assigned to their preferred option. The value of Z_3will be an integer greater than or equal to zero.

2.6 Step (4): Maximize the number of stations assigned to their option of going off the air

If it is not possible to assign all participating stations to their preferred relinquishment option, Step (4) seeks to maximize the number of participating stations assigned to going off the air as an alternative option. This ensures that as many of the stations assigned to an alternative option as possible have the flexibility to move to their other relinquishment options during the reverse auction. The optimization model solved in Step (4) determines a feasible assignment and assigns as many participating stations as possible to go off the air given the constraints that (a) there cannot be more than Z_1 UHF participating stations assigned to channels in the UHF band (b) there cannot be more than Z_2 VHF participating stations assigned to pre-auction band channels in the VHF band, and (c) at least Z_3 participating stations are assigned to their preferred option.

Model Formulation for Step (4):

$$max\ \ Z_4\ =\ \sum_{s\in S_P} x_{s,0}$$

Subject to:

$\sum_{c \in C_s} x_{s,c} = 1$ $\forall s \in S$ (1)

$x_{s,c} + x_{s',c} \leq 1$ $\forall \{(s,c),(s',c)\} \in CoPairs$ (2)

$x_{s,c} + x_{s',c'} \leq 1$ $\forall \{(s,c),(s',c')\} \in AdjPairs$ (3)

$x_{s,c} \in \{0,1\}$ $\forall s \in S, \forall c \in C_s$ (4)

$\sum_{s \in S_{P_U}, c \in C_s^H} x_{s,c} \leq Z_1$ (5)

$\sum_{s \in S_{P_V}, c \in C_s^H} x_{s,c} \leq Z_2$ (6)

$\sum_{s \in S_P, c \in C_s^{pref}} x_{s,c} \geq Z_3$ (7)

Explanation of New Constraint:

Constraint (7) requires that the number of participating stations assigned to their preferred option must be greater than or equal to the result of the third optimization, namely the value Z_3.

Explanation of Objective Function:

The objective function maximizes the number Z_4 of participating stations that are assigned to go off the air. The value of Z_4 will be an integer number greater than or equal to zero.

2.7 Primary Clearing Target Optimization

The final step in determining an initial assignment of participating and non-participating stations is to solve the primary clearing target optimization, which minimizes the impact of impairing TV stations to forward auction licenses, given a specified clearing target and subject to feasibility constraints and the results of Steps (1) through (4) above. Specifically, the optimization model determines a feasible assignment of stations such that the sum of impaired weighted-pops across all licenses is minimized. If the result of this optimization does not satisfy the near-nationwide threshold for impairments, the model will be run for a lower clearing target, but the results of Steps (1) through (4) will still be enforced.

In addition to the constraints necessary to ensure a feasible assignment as defined in Section 2.1, the primary clearing target optimization adds two additional sets of constraints.

The first additional set of constraints added to the model consists of the four constraints determined in the first four steps of the initial clearing target procedure namely:

1. The number of UHF participating stations assigned to the UHF band is no more than Z_1.

   $\sum_{s \in S_{P_U}, c \in C_s^H} x_{s,c} \leq Z_1$

2. The number of VHF participating stations assigned to the VHF band is no more than Z_2.

   $\sum_{s \in S_{P_V}, c \in C_s^H} x_{s,c} \leq Z_2$

3. The number of participating stations assigned to their preferred option must be at least Z_3.

   $\sum_{s \in S_P, c \in C_s^{pref}} x_{s,c} \geq Z_3$

4. The number of participating stations assigned off-air must be at least Z_4.

   $\sum_{s \in S_P} x_{s,0} \geq Z_4$

The ISIX constraints[3] are the second set of constraints added to the primary clearing target optimization. For an assignment of stations to channels, these constraints determine the percent of population with predicted impairment for each license, and are constructed in such a way as to avoid double counting of population where the contours of assigned TV stations overlap with each other. The ISIX constraints also include constraints used to ensure that a license that is above *z*% impaired is considered 100% impaired, where z is the value set by the Commission to identify heavily impaired spectrum that will not be sold in the clock phase of the forward auction.[4]

The following is the full formulation of the Primary Clearing Target Optimization.

Decision Variables

$x_{s,c}$ is a binary decision variable which has a value of 1 if station s is assigned to channel c and 0 otherwise. Note: $c = 0$ indicates the option to go off-air.

$y_{a,l}^{D}$ and $y_{a,l}^{U}$ are decision variables which have a value of 1 if county-tile a has impairment in the downlink or uplink portion of license l respectively and 0 otherwise.

ρ_l is the percentage of population in license l with predicted impairment.

N_l is a binary variable which has a value of 1 if the license is more than $z \cdot 100\%$ impaired.

Set Definitions

S is the set of all stations (both participating and non-participating)

C_s is the set of allowable channels for station s

Note: For non-participating stations the set C_s consists exclusively of allowable channels in their pre-auction band, which for UHF stations, includes their allowable channels in the 600 MHz Band. For participating stations, the set C_s consists of allowable channels in their pre-auction band as well as channels in the bands associated with their initial commitment of relinquishment options. For participating stations that made an initial commitment to go off-air, the set C_s also consists of channel 0 which indicates an assignment of going off-air.

S_P is the set of participating stations

S_{P_U} is the set of participating stations whose pre-auction band is UHF

S_{P_V} is the set of participating stations whose pre-auction band is VHF

C_s^H is the set of allowable pre-auction band channels station s

A_l is the set of county-tiles a covered by license l which can be impaired partially or fully by at least one (facility, channel) pair

L is the set of potentially impaired licenses; each license is defined by a clearing target, market id, block, and link types (uplink and downlink)

$SC_{a,l}^{D}$ and $SC_{a,l}^{U}$ are the sets of impairing (facility, channel) pairs which impair county-tile a in license l for downlink and uplink respectively

[3] The ISIX Constraints are described in Appendix B.

[4] *See* § III.A.1 Measuring the Extent of Potential Impairments.

Constants

z is a threshold value between 0 and 1 that determines when a license l is considered too impaired to be auctioned

w_l is the weighted-pops associated with license l

$pct_{a,l}^{D}$ and $pct_{a,l}^{U}$ are the percent of license l's population in county-tile a divided in half between the downlink and uplink respectively;

Model Formulation for the Primary Clearing Target Optimization:

$$min \sum_{l \in L} w_l \, \rho_l$$

Subject to:

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s\prime,c\prime} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)
$\sum_{s \in S_{P_U}, c \in C_s^H} x_{s,c} \leq Z_1$		(5)
$\sum_{s \in S_{P_V}, c \in C_s^H} x_{s,c} \leq Z_2$		(6)
$\sum_{s \in S_P, c \in C_s^{pref}} x_{s,c} \geq Z_3$		(7)
$\sum_{s \in S_P} x_{s,0} \geq Z_4$		(8)
$\sum_{a \in A_l} pct_{a,l}^{D} \, y_{a,l}^{D} + \sum_{a \in A_l} pct_{a,l}^{U} \, y_{a,l}^{U} = \rho_l$	$\forall l \in L$	(9)
$x_{s,c} \leq y_{a,l}^{D}$	$\forall (s,c) \in SC_{a,l}^{D}, a \in A_l, l \in L$	(10)
$x_{s,c} \leq y_{a,l}^{U}$	$\forall (s,c) \in SC_{a,l}^{D}, a \in A_l, l \in L$	(11)
$x_{s,c} \leq y_{a,l}^{U}$	$\forall (s,c) \in SC_{a,l}^{U}, a \in A_l, l \in L$	(12)
$0 \leq y_{a,l}^{D} \leq 1$	$\forall a \in A_l, l \in L$	(13)
$0 \leq y_{a,l}^{U} \leq 1$	$\forall a \in A_l, l \in L$	(14)
$0 \leq \rho_l \leq 1$	$\forall l \in L$	(15)
$\rho_l \leq z + (1-z)N_l$	$\forall l \in L$	(16)
$\rho_l \geq N_l$	$\forall l \in L$	(17)
$N_l \in \{0,1\}$	$\forall l \in L$	(18)

Explanation of Constraints:

1–4: Feasibility Constraints

Constraints (1) through (4) are explained in Section 2.1.

5–8: *Z* Constraints

Constraints (5) through (8) have been explained in Steps (1) through (4) of the Constraints for Initial Commitments section and also summarized at the beginning of this section.

9–18: ISIX Constraints

Constraints (9) through (18) are explained in Appendix B (ISIX Constraints).

3 Clearing Target Optimization during the Auction

There are two additional scenarios during the proposed Incentive Auction process where the Clearing Target Optimization is utilized. The first occurs during the first stage of the reverse auction, once Dynamic Reserve Pricing is complete, and possibly at other points during the reverse auction, as determined by the Commission. The second occurs between stages, when the Clearing Target Optimization is used in determining impairments for the next stage. In this section, these scenarios and the mathematical formulation of the optimization models are discussed.

3.1 Clearing Target Optimization after Dynamic Reserve Pricing

The reverse auction bidding software begins stage one of the auction at the initial feasible assignment found by the initial Clearing Target Optimization, fixing the assignment of those stations assigned in the 600 MHz Band and keeping tentative those assigned in the remaining television bands. The bid-processing algorithm then maintains a feasible assignment as stations elect to drop out of bidding or move to other relinquishment options. [5] While Dynamic Reserve Pricing is engaged, some stations may drop out of bidding that do not have a feasible assignment in the television portion of the UHF band. The bid-processing algorithm does not have the data necessary to assign those stations a specific channel in the 600 MHz Band,[6] therefore, after Dynamic Reserve Pricing has ended, the Clearing Target Optimization software will solve an optimization problem that will re-shuffle the UHF channel assignments incorporating the ISIX constraints and clearing target objective to minimize impaired weighted-pops when assigning non-participating stations to channels in the 600 MHz Band. [7] The reverse auction bidding system will then use the new assignment of stations, specifically, fixing the assignment of those stations assigned to the 600 MHz Band and keeping tentative those assigned in the remaining television bands, and the reverse auction will continue.

3.2 Clearing Target Optimization between Stages

The Clearing Target Optimization will be run between stages to account for the additional UHF channel available in the band designated for television, which will impact the channel assignments made in the 600 MHz Band. Thus, before the start of a new stage, the Clearing Target Optimization software will re-shuffle the UHF band based on the new clearing target and incorporating the ISIX constraints and clearing target objective to minimize impaired weighted-pops when assigning stations to channels in the 600 MHz Band. The reverse auction bidding system will then use the new assignment of stations as the initial assignment of UHF stations for the next stage, specifically, fixing the assignment of those stations assigned in the 600 MHz Band and keeping tentative those assigned to television portion of the UHF band, and the forward auction will use the corresponding impairments for the next stage of the forward auction.

[5] The auction system uses a feasibility checker to ensure feasible assignments.

[6] The feasibility checker does not take the ISIX constraints into account since considering this vast amount of data would unduly slow down the bid processing of the reverse auction.

[7] Since the reverse auction bidding software maintains a feasible assignment of stations, constraints (5) – (8) are not necessary.

3.3 Model Formulation

The formulation of the optimization model is the same in both scenarios as both "reshuffle" the assignment of stations to channels in the UHF band. Specifically, the Clearing Target Optimization solved in these two scenarios differs from the Primary Clearing Target Optimization in two ways:

(1) The set of stations S is reduced to stations currently assigned to the UHF band.

(2) Constraints (5) through (8) *i.e.*, the "Z" constraints, are not needed since all participating stations are already assigned to a relinquishment option.

APPENDIX D

Reverse Auction Pricing and Bid Processing Algorithm

1 Introduction

This appendix details our proposed process for calculating clock prices, both initially and throughout the reverse auction, and for processing the bids made by stations. This introduction to the appendix gives an overview of the proposed process.

Generally, the descending clock reverse auction presents stations with prices for a hierarchy of relinquishment options. For UHF stations (participating stations whose pre-auction band is UHF), the highest clock price is associated with the option of going off-air, the second-highest with the option of moving to Low-VHF, and the lowest with the option of moving to High-VHF. A UHF station that finds none of these three options acceptable can drop out of the bidding and continue to broadcast in the UHF band.

For High-VHF stations (participating stations whose pre-auction band is High-VHF), the auction system shows clock prices for two options: the higher priced option is to go off-air and the lower priced one is to move to Low-VHF. For Low-VHF stations (participating stations whose pre-auction band is Low-VHF), the auction system shows just one clock price, which is for the option of going off-air.

1.1 Four Design Challenges

The design of the auction balances four main challenges. The first is simplicity for the participating stations, both in terms of the mechanics of bidding and in terms of bidding strategy. Although the repacking process is unavoidably complex, the goal is to minimize the complexities of the bidder interface and to make understanding the repacking process unnecessary for effective bidding. This goal is achieved in our proposal by the adoption of a "ladder clock" auction. The "clock" auction portion of this description means that active bidders are shown a declining sequence of prices and asked to choose their preferred option at each. The "ladder" portion of the description means that stations can only change during the auction from lower options in the hierarchy to higher options. The order of options from lowest to highest is (1) going off-air, (2) moving to Low-VHF, (3) moving to High-VHF, and (4) dropping out of the bidding. The bidding interface associated with a clock auction can be relatively simple and the ladder structure prevents bidders from moving back and forth between options, thereby eliminating complex bidding strategies. This makes bidding easier for bidders and also gives the auction system more reliable information to use in setting clock prices.

The second challenge is to set clock prices for the UHF stations in a way that recognizes and accommodates the differences in interference patterns and channel availability in UHF, High-VHF, and Low-VHF that are found between stations in different places, including ones between stations that are near neighbors. In every round, for the off-air option, the auction sets the same UHF clock price per unit of volume (the "base clock price") across the whole country. The mathematical formula for computing clock prices per unit volume for all the other options, which is given in Section 2 below, is designed to promote a balance of supply and demand for each option in the neighborhood of each station.

The third challenge is to maintain a proper relationship between the prices offered to UHF stations and the ones offered to VHF stations, when closely comparable stations are available. For example, if the prices offered to a UHF station for the options go off-air, move to Low-VHF, and move to High-VHF are $\$X$, $\$Y$ and $\$Z$, respectively, what prices should be offered to nearby VHF stations? This is easiest to answer for the case when there are three stations: a UHF station, a High-VHF station, and a Low-VHF station, that serve exactly the same populations and have the property that if the UHF station were to move into either of the two VHF bands, it would create exactly the same interference constraints on neighboring stations. In such a case, there are four ways, to clear the UHF channel. These possibilities

are listed below alongside the proposed VHF clock prices. These VHF clock prices have the property that the total price for clearing a UHF channel always equals the price $*X*, regardless of which moves are required to achieve clearing.

1. The UHF station could go off-air at a clock price of $*X*.
2. The UHF station could move to Low-VHF at a clock price of $*Y* (where $*Y* is less than $*X*), and the Low-VHF station could go off-air at a clock price of $*X*-$*Y*.
3. The UHF station could move to High-VHF at a clock price of $*Z* (where $*Z* is less than $*Y*), and the High-VHF station could go off-air at a clock price of $*X*-$*Z*.
4. The UHF station could move to High-VHF at a clock price of $*Z*; the Low-VHF station could go off-air at a clock price of $*X*-$*Y*; and the High-VHF station could move to Low-VHF at a clock price of $*Y*-$*Z*.

This relationship is illustrated in the following figure:

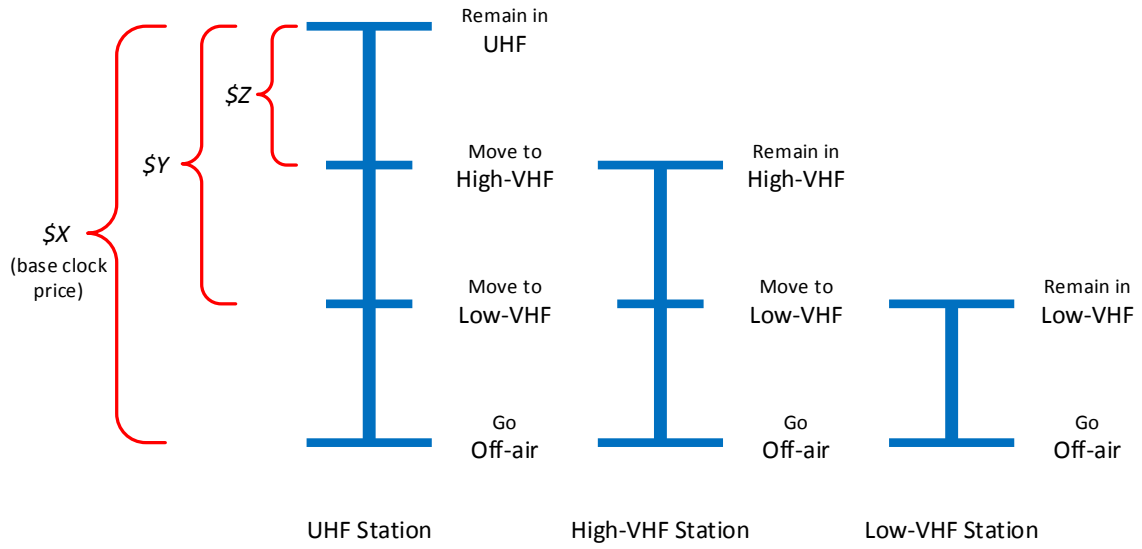


Figure 1: Prices for each pre-auction band relative to the UHF prices

The fourth and final challenge is to set appropriate VHF prices even for stations for which there is no exactly comparable UHF station. This is accomplished by the use of *benchmark prices*, that is, we compute the clock prices per unit of volume, $*x*, $*y* and $*z*, that would apply to an exactly comparable UHF station if there were such a station. We use those benchmark prices to set the clock prices for VHF stations, as described below. For compactness, we use the term "benchmark prices" to refer to the UHF prices per unit of volume for both actual UHF stations and the possibly imaginary stations used in the VHF price computations. The *base clock price* is the benchmark price for going off-air for a UHF station.

For every station in every round, the proposed algorithm sets the clock prices by first determining the appropriate benchmark prices and then deriving appropriate prices per unit of volume for each option. We then multiply those prices by the volume of the individual station to obtain the clock prices in every round. We propose that the volume of each station be determined using its covered population and an index of the number of interference constraints in which the station participates, as described in detail below.

1.2 Conducting the Bidding Rounds

Before a bidding round begins, the auction system announces to each station the prices for every relinquishment option available to it. The auction collects bids and after each round the auction system processes the bids in order to determine the *current relinquishment option* to which each station is assigned, update the *bidding status* of all stations, and set clock prices for the next round. In any round, a station may be assigned one of four statuses.

1. A station can be *active*, in which case its bid at the clock prices is processed to determine its current relinquishment option, and its clock prices will be reduced for the next round.
2. A station can be *frozen*, in the case where the auction system cannot currently assign it a channel in its pre-auction band. In that case, the station's assigned option at the time that the system determined that the station was frozen remains its current relinquishment option and its current price is "frozen" at its *current compensation* as described in Section 4.
    a. A frozen station becomes *provisionally winning* once the auction system has determined that it cannot assign the station to its pre-auction band.[1]
3. A station is considered *inactive*, in all other cases. A station may be inactive because (i) it is not participating in the auction, or (ii) its bid to drop out of the auction has previously been accepted, or (iii) the system has determined that its bids in the auction can never become winning.[2]

The auction system iterates through the bids and assigns each station a status until there are no more active bids. When this happens, the current stage of the reverse auction ends.

1.3 Winners and Winning Prices

A provisional winner in a stage of the reverse auction becomes a *winner* if the final stage rule is satisfied for the current stage of the auction. In that event, the provisional winner's current relinquishment option will be its winning option, and its provisionally winning price will be its winning price. If the final stage rule is not satisfied, however, then the clearing target will be reduced and the system will determine which provisional winners will be returned to the status of active stations at the beginning of the next stage as a result of the additional channel available in the television portion of the UHF band.

2 Opening Prices

Before the auction, we will set an *opening price* (reserve price) for each relinquishment option for each station. The opening price for a UHF station to go off-air is computed by multiplying that station's volume by the base clock price (described in more detail in Section 2.2). There is just one base clock price and it applies to all UHF stations.

[1] The auction system determines that a UHF station is a provisional winner when the feasibility checker either proves that the station is infeasible to add to the UHF TV band or when it decides that it cannot prove feasibility in the allotted time or times for processing that station. It determines that a VHF station is a provisional winner when the feasibility checker proves that this station is infeasible to add to its pre-auction band in that stage for any possible bidding behavior of stations that are still active in the auction.

[2] Case (iii) may happen because a station is unconstrained, that is, it is always possible to find a channel for that station in its pre-auction band.

2.1 Calculating Volume

We propose to calculate the volume of each station s using this formula:

$$VOLUME(s) = A \cdot (Population(s))^{0.5} \cdot (Interference(s))^{0.5}$$

In this formula, A is a scaling constant, which is chosen for convenience so that the largest volume for any station is one million; $Population(s)$ is the number of people residing within the interference-free service area of station s;[3] and $Interference(s)$ is an index of the number and significance of co- and adjacent channel interference constraints that station s would impose on repacking. The computation of this index is described below.

2.2 Determining the Interference Component

For each pair of stations (i, j) and channel c, let O_{ij}^c be a count of the number the applicable adjacent-channel or co-channel interference constraints as further defined below. $O_{ij}^c = 0$ indicates that there is no applicable interference constraint limiting the assignment of i to channel c and j to channel c or $c - 1$ or $c + 1$; $O_{ij}^c = 1$ indicates that one such constraint is applicable; $O_{ij}^c = 2$ indicates that two such constraints are applicable; and $O_{ij}^c = 3$ indicates that three such constraints are applicable.[4] O_{ij}^c is always 0, 1, 2, or 3. We then define $O_j^i = \max_{c \in C_{ij}} O_{ij}^c$, which is the maximum of O_{ij}^c over the set C_{ij} of *relevant channels*, to index the potential interference between stations i and j. The relevant channels for any pair of stations are determined as follows.

- Between two UHF stations, the relevant channels are all the channels in the UHF, High-VHF and Low-VHF bands (channels 2-51).
- Between a UHF station and a High-VHF station or between two High-VHF stations, the relevant channels are those in the High-VHF band (channels 7-13) and Low-VHF band (channels 2-6).
- Between a UHF or High-VHF station and a Low-VHF station or between two Low-VHF stations, the relevant channels are those in the Low-VHF band (channels 2-6).

The interference metric for station i is $Interference(i) = \sum_j O_j^i$.

2.3 Setting the Base Clock Price and the Opening Prices

For the second component of the opening price, the base clock price, we propose to set the base clock price so as to yield an opening bid of $900 million for the station with the highest volume.[5] To do this, we will choose the constant A in the volume formula so that the maximum station volume is 1 million. Dividing the $900 million opening bid price by the highest volume of 1 million gives us the opening base clock price of $900 per unit of volume.

[3] A station's interference-free population can be obtained from the *baseline.csv* file generated by *TVStudy*. Alternatively, we will also release prior to the auction a final Pre-Auction Baseline Data file similar to Baseline_Data_and_Maps_2013July.pdf file released in July 2013 and available at http://data.fcc.gov/download/incentive-auctions/OET-69/Baseline_Data_and_Maps_2013July.pdf.

[4] This data is available in the *interference_paired.csv* file, which is available at http://data.fcc.gov/download/incentive-auctions/Constraint_Files/.

[5] It should be noted that if this highest volume station has a pre-auction band not in UHF, its opening price would be decreased by the discount applied to the pre-auction band in which it is located. This is explained further in this section.

The opening benchmark prices will be calculated from the base clock price. The benchmark price for going off-air will be the base clock price, $p_{0,OFF} = \$900$. The opening benchmark prices for moving to Low-VHF and moving to High-VHF will be denoted by $p_{0,LV}$ and $p_{0,HV}$ respectively. These prices will be chosen so that $p_{0,HV} < p_{0,LV} < p_{0,OFF}$. In the Comment PN, we propose to set $p_{0,HV}$ between 33–50% of the base clock price and to set $p_{0,LV}$ between 67–80% of the base clock price. The opening benchmark prices $p_{0,HV}, p_{0,LV}, p_{0,OFF}$ will be set to the same values for every station.[6] This is illustrated in Figure 2.

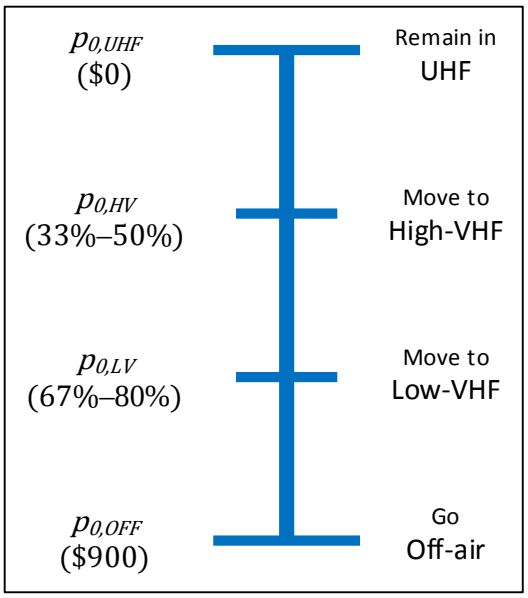


Figure 2: Benchmark prices in round 0

The opening clock prices for each UHF station for its three options will be the station's volume multiplied by $p_{0,HV}, p_{0,LV}$, and $p_{0,OFF}$, respectively. For High-VHF and Low-VHF stations, the opening prices for going off-air will be the station's volume multiplied by $(p_{0,OFF} - p_{0,HV})$ and $(p_{0,OFF} - p_{0,LV})$, respectively, and the per-volume opening price for High-VHF stations moving to Low-VHF will be $(p_{0,LV} - p_{0,HV})$. A consequence of this computation is that the total per-volume opening price is the same for taking a UHF station off-air directly as for taking a VHF station off-air and moving that UHF station into its place in the VHF band.

3 Notation and Definitions

This section describes the notation and definitions that we use in the following section to describe the clock price calculation and the bid-processing algorithm.

3.1 Ordering of Relinquishment Options and Bands

For the purposes of this appendix, we order the possible assignments for a station as (1) off-air, (2) Low-VHF, (3) High-VHF and (4) UHF, with the understanding that these numbers are also used to describe the ordering of bands and options from lowest to highest. The notation $b < b'$ is used to denote that band b is strictly below band b' in this ordering and the notation $b \leq b'$ is used to denote that either b and b' are the same band or band b is below band b'.

3.2 Current Relinquishment Option and Current Compensation

The *current relinquishment option* of station s in round t, denoted by $b_{t,s}$, is the relinquishment option that the station is tentatively assigned to at the start of round t. The *current compensation* of station s in round t, denoted by $\hat{P}_{t,s}$, is the compensation the station is tentatively given at the start of round t.

3.3 Assignments, Feasibility and Frozen Stations

A channel assignment plan specifies a particular channel for each station that is not currently holding its off-air option. Such a plan is feasible if:

1. Each non-participating station is assigned to a channel in its pre-auction band;
2. Each station that has dropped out of bidding in the reverse auction is assigned to a channel in its pre-auction band;

[6] The benchmark price for remaining in UHF, $p_{0,UHF}$ is always set to \$0.

3. Every other station is assigned to a channel consistent with its current relinquishment option;
4. All stations are assigned channels in the TV band, except for those currently deemed as impairing that are assigned channels in the 600 MHz Band; and
5. All pairwise interference constraints are satisfied.

The *current tentative assignment* used by the auction system describes, for each station, the band and channel to which it is tentatively assigned. Given a current tentative assignment, a station is said to be *feasible in band b* if the system can find a feasible channel assignment plan in which that station is assigned to a channel in band b and the other stations are assigned to channels in the same bands as in the current tentative assignment.

At any point during bid processing when a station's bid to drop out or move to a VHF band is accepted, the system will determine for each remaining active station if it is still feasible to assign the station in its pre-auction band. If the auction system cannot assign the station to its pre-auction band at that point, the station is *frozen*, except in the case where the Dynamic Reserve Pricing procedure is in effect in which case UHF stations are not frozen. In the algorithm description below, the status of the Dynamic Reserve Pricing procedure is indicated by the DRP flag: the procedure is in effect when DRP is "ON."

3.4 Permissible Options

Band b is *permissible* for station s if either:

(i) Band b is the pre-auction band of station s; or

(ii) Band b is below the station's pre-auction band according to the ordering described in Section 3.1.

The set of permissible options for station s includes all its permissible bands and the option to go off-air. For example, the permissible options of a High-VHF station are {OFF-AIR, Low-VHF, High-VHF}.

3.5 Neighborhood of Station s in Band b

The *neighborhood* of station s in band b is the set of stations, including station s, that are within some distance k from station s in the interference graph for band b. For instance, if $k = 1$, the neighborhood of station s in High-VHF includes station s and all stations that interfere with station s in High-VHF.

Example: Suppose there are four stations: {1,2,3,4}. The following pairs of stations have adjacent-channel interference constraints in band b: (1,2), (2,3), (3,4). There are no other interference constraints between the stations. Then, if $k = 1$, the neighborhood of station 1 in band b is {1,2}, and the neighborhood of station 2 in band b is {1,2,3}. On the other hand, if $k = 2$, the neighborhood of station 1 in band b is {1,2,3}, and the neighborhood of station 2 in band b is {1,2,3,4}.

3.6 Congestion and Vacancy

Before each bidding round t, for each station s and band b, we calculate the *vacancy* $V_{t,s,b}$, which is a number greater than 0 and less than or equal to 1. Vacancy is the opposite of congestion: a larger value of $V_{t,s,b}$ indicates that band b is relatively less congested in the station's neighborhood, given the current relinquishment options of every station and the options that may become available to them. The vacancy is calculated as a weighted average, as follows:

- $f(t, s, b) = \frac{X}{Y}$, where X is the maximum of (1) the number of channels in band b to which station s can be feasibly assigned given the current tentative assignment and (2) the parameter VAC_FLOOR, and Y is the number of channels in band b. For instance, parameter VAC_FLOOR could be equal to 0.5.

- $N(t,s,b)$ is a set consisting of all active stations in the neighborhood of station s in band b whose current relinquishment option is below band b, and for which band b is a permissible band. (These stations are implicitly understood to be the potential competitors for station *s* for the remaining vacant spaces in band b.)

If $N(t,s,b)$ is an empty set, then $V_{t,s,b} = 1$. Otherwise,

$$V_{t,s,b} = \frac{\sum_{s' \in N(t,s,b)} VOLUME(s') \cdot f(t,s',b)}{\sum_{s' \in N(t,s,b)} VOLUME(s')}$$

3.7 Reduction Coefficients

The auction system uses the calculated vacancy for each station in each band to compute "reduction coefficients" $r_{t,s,b}$, which determine the relative price reductions in the benchmark prices of moving to the VHF bands compared to the reduction in the benchmark price for going off-air. Benchmark prices are described in greater detail in the next section. For bands $b = Low-VHF$ (LV), $High-VHF$ (HV) the reduction coefficients are computed as follows:

- The reduction coefficient for moving to High-VHF is:

$$r_{t,s,HV} = \frac{p_{0,HV} \cdot \left(V_{t,s,UHF}\right)^c}{\left(p_{0,OFF} - p_{0,HV}\right) \cdot \left(V_{t,s,HV}\right)^c + p_{0,HV} \cdot \left(V_{t,s,UHF}\right)^c}$$

- The reduction coefficient for moving to Low-VHF is:

$$r_{t,s,LV} = \frac{(p_{0,LV} - p_{0,HV}) \cdot (V_{t,s,HV})^c}{(p_{0,OFF} - p_{0,LV}) \cdot \left(V_{t,s,LV}\right)^c + (p_{0,LV} - p_{0,HV}) \cdot (V_{t,s,HV})^c} (1 - r_{t,s,HV}) + r_{t,s,HV}$$

where c is a non-negative parameter. Each reduction coefficient is greater than 0 and less than or equal to 1.

3.8 Benchmark Prices

The clock price calculation (described in Section 4.2) is based on benchmark prices, which are prices expressed per unit of volume that are updated in every round. In round t, the benchmark price of station s for the option or band b is denoted by $p_{t,s,b}$. The benchmark prices of all stations for round 0 are set equal to the opening prices of UHF stations, that is, $p_{0,s,b} = p_{0,b}$ for every station s, irrespective of its pre-auction band. Note that $p_{t,s,UHF} = 0$ for all rounds t and all stations s, because any UHF station *s* that is assigned to continue UHF broadcasting receives zero compensation.

4 Price Calculations and Bid Processing

4.1 Overview

The algorithm maintains a tentative feasible assignment to guide its various computations.

At the start of each round $t \geq 1$, each station s is displayed its current option $b_{t,s}$ and its current compensation $\hat{P}_{t,s}$ for that option. Each active station *s* is also quoted clock prices $P_{t,s,b}$ for all the higher relinquishment options b (that is, ones for which $b \geq b_{t,s}$) that the station indicated as acceptable in its application.

A station can submit a bid to switch to a different relinquishment option at the clock price of that option. Moreover, a station can submit an intra-round bid to drop out of the auction by specifying a price between last round's clock price and this round's clock price for its current relinquishment option. If a station

does not submit a bid to drop out of the auction, it indicates that it is willing to get its current option for the corresponding clock price.

At the beginning of the auction, the current relinquishment options $b_{1,s}$ are determined by an initial clearing target optimization (described in Appendix C). The corresponding current compensation $\hat{P}_{1,s}$ is set equal to the opening price of station s for band $b_{1,s}$. The DRP flag is set to "ON" and the algorithm checks the feasibility of each station to determine which stations are active at the start of the auction.

In each round, the system (1) calculates the clock prices to be quoted to stations, (2) solicits stations' bids at the quoted prices, and (3) processes those bids to determine a new tentative feasible assignment and the sets of provisionally winning bids and active stations for the next round. If there are no more active stations at the end of the round, then this stage of the reverse auction is completed.

4.2 Clock Price Calculation

Before the start of each round *t*, the system calculates clock prices for this round. A clock price is calculated for each relinquishment option of each station that is at or above the station's current relinquishment option and that the station indicated, in its auction application, that it is willing to consider.

For a given active station and a given relinquishment option, the clock price is the lowest price that the station could be offered for that option in this round if it bids for that option. Clock prices for every option decrease from round to round.

The clock prices are calculated from the benchmark prices $p_{t,s,b}$ for each option b as follows:

$$P_{t,s,b} = (Volume\ of\ station\ s) \cdot \left(p_{t,s,b} - p_{t,s,HOME_BAND(s)}\right).$$

According to this formula, the per-volume price for a VHF station for an option *b* is less than that of an otherwise identical UHF station. The difference is equal to the UHF station's benchmark price for moving into the VHF station's pre-auction band.

Example: Station s is a UHF station and its volume is equal to 2. Then, its clock price for option b in round t is $P_{t,s,b} = 2 \cdot p_{t,s,b}$. That is, every clock price of the station is equal to two times the corresponding benchmark price.

Example: Station s is a High-VHF station and its volume is equal to 2. Then, its clock price for option b in round t is $P_{t,s,b} = 2 \cdot \left(p_{t,s,b} - p_{t,s,HV}\right)$. That is, its clock price for option b in round t is equal to two times the difference between its benchmark price for option b in round t and its benchmark price for HV in round t.

As discussed in the *Comment PN*, we propose that in each round *t* the algorithm update the base clock price $p_{t,s,OFF}$ for all the stations (this is the per-volume clock price for stations whose pre-auction band is UHF and who have a current relinquishment option of going off-air), by decrementing it by a pre-specified percentage *R* (between 3 and 10 percent).[7] Next we describe how the prices for the options to move to VHF are reduced. These reductions are linked to the reductions in the base clock price in a way that promotes the efficiency of packing VHF bands, which is in turn facilitated by balancing the packing of all the bands during the auction. For this purpose, prices will be reduced relatively faster for bands that are in high demand (as measured by a low vacancy value) in the station's area and relatively slower for bands that are in low demand (as measured by a high vacancy value). In addition, we will maintain the property that each station's price for a lower relinquishment option will be reduced at least as fast as for a

[7] *See* § IV.C.1.a Price Offers in Initial and Subsequent Rounds

higher relinquishment option, so as to encourage stations to switch to higher relinquishment options as the auction progresses. These properties will be achieved by using the price reduction coefficients $r_{t,s,b}$, defined in Section 3.7, to compute the new prices in each round.[8]

Specifically, we propose that the benchmark price for going off-air for each round be computed as $p_{t,s,OFF} := p_{t-1,s,OFF} \cdot (1 - R)$, and that the benchmark prices for bands *b*=Low-VHF, High-VHF be computed as:

$$p_{t,s,b} \coloneqq \max\{0, \min\{p_{t,s,OFF}, p_{t-1,s,b} - r_{t,s,b} \cdot Rp_{t-1,s,OFF}\}\}.$$

Thus, the benchmark price for each VHF option is reduced by a fraction (equal to the reduction coefficient) of the reduction of the benchmark price of the going off-air option, except that the price offered for any option may not exceed the corresponding price for going off-air and may not become negative.

4.3 Bid Processing

With intra-round bidding, each active station *s* may bid to switch to a new permissible option $b^o_{t,s} > b_{t,s}$ and/or to drop out when the price of its current relinquishment option $b_{t,s}$ falls below some price $P^0_{t,s} > P_{t,s,b_{t,s}}$. For each station *s*, define the *interpolation functions* to describe the intermediate benchmark prices during a round. For going off-air, these functions are given by:

$$\bar{p}_{t,s,OFF}(\Delta) \coloneqq p_{t-1,s,OFF} \cdot (1 - \Delta \cdot R)$$

and, for the VHF options $b = LV, HV$, these are given by:

$$\bar{p}_{t,s,b}(\Delta) \coloneqq \max\{0, \min\{\bar{p}_{t,s,OFF}(\Delta), p_{t-1,s,b} - r_{t,s,b} \cdot \Delta \cdot Rp_{t-1,s,OFF}\}\},$$

and $\bar{p}_{t,s,UHF}(\Delta) \coloneqq 0$. The interpolation functions trace the progress of benchmark prices during the round, because $\bar{p}_{t,s,b}(0) = p_{t-1,s,b}$ and $\bar{p}_{t,s,b}(1) = p_{t,s,b}$. Also, define the function

$$\bar{P}_{t,s}(\Delta) \coloneqq (Volume\ of\ s) * \left(\bar{p}_{t,s,b_{t,s}}(\Delta) - \bar{p}_{t,s,HOME_BAND(s)}(\Delta)\right)$$

to describe the station's intermediate clock price for its current relinquishment option during the round. For each station *s* that submitted an intra-round bid $P^0_{t,s}$ to drop out, let $\Delta_s \in [0,1)$ be the solution to the equation $\bar{P}_{t,s}(\Delta_s) = P^0_{t,s}$ if $P^0_{t,s} \leq P_{t-1,s,b_{t,s}}$, and let $\Delta_s := 0$ if $P^0_{t,s} > P_{t-1,s,b_{t,s}}$ (that is, the station submitted a bid to drop out at a price above the clock price of the previous round).[9] For each station *s* that did not submit a bid to drop out, let $\Delta_s \coloneqq 1$.

To process bids and update prices, for each active station *s*, we initialize $\hat{P}_{t+1,s} \coloneqq \hat{P}_{t,s}$, and place all these stations in a queue in the ascending order of Δ_s, breaking ties using pseudo-random numbers. Repeat the following steps until every station remaining in the queue is frozen:

[8] The definitions of vacancies and price reduction coefficients given in Sections 3.6 and 3.7 are possible formulations and we seek comment on alternative formulations that may promote more efficient packing of the VHF bands.

[9] This can happen only for stations that were frozen in a previous round but are still active.

- For every station still in the queue and given the current tentative assignment, check whether the station is feasible in its pre-auction band.
- If DRP is "OFF," move to the next bulleted step. Otherwise, compute the aggregate impairment in the 600 MHz Band that would occur if all the UHF stations that are infeasible in the television band (given the current tentative assignment) had to be assigned to the 600 MHz Band. If that impairment would exceed the specified DRP threshold, then set DRP to "OFF."
- Mark as frozen any VHF stations that are infeasible in their pre-auction bands, given the current tentative assignment. If DRP is "OFF," mark as frozen any UHF stations that are infeasible their pre-auction bands, given the current tentative assignment.
- Find the first station *s* in the queue that is not frozen. If the queue contains no such station, finish queue processing.
- If $\Delta_s > 0$, then for every station s' in the queue (including station s) that is not frozen, set $\hat{P}_{t+1,s'} \coloneqq \min\{\bar{P}_{t,s'}(\Delta_s), \hat{P}_{t+1,s'}\}$.
- If station *s* submitted a bid to switch to band $b^o_{t,s}$ and is feasible in this band given the current tentative assignment, process the bid (*i.e.*, set $b_{t+1,s} := b^o_{t,s}$ and $\hat{P}_{t+1,s} := P_{t,s,b_{t+1,s}}$). Otherwise, if station *s* submitted a bid to drop out, process this bid (*i.e.*, set $b_{t+1,s} \coloneqq HOME_BAND(s)$ and $\hat{P}_{t+1,s} \coloneqq 0$) and remove *s* from the list of active stations. (If $HOME_BAND(s) = UHF$ but the station has no feasibility in the UHF band (because DRP is "ON"), mark it to be assigned to the 600 MHz Band in the next clearing target optimization.) If station *s* submitted neither a bid to drop out nor a switch bid, set $b_{t+1,s} := b_{t,s}$.
- Remove station *s* from the queue and start a new processing loop.

After queue processing is finished, the stations that remain in the queue are all frozen. For each such station *s*, set $b_{t+1,s} := b_{t,s}$ (that is, keep station *s*'s current relinquishment option unchanged for the next round). For every such station, check whether it will remain frozen for the remainder of the current clock stage, and if so, mark it as a provisional winner and remove it from the list of active stations.

Note: "intra-round bidding" derives its name from the observation that the auction algorithm proceeds as if current prices declined continuously within the round for all stations that are not frozen. When the price of some station reaches the price point of its bid to drop out, the system processes this station's bid: its bid to switch if it submitted one and it is feasible or its bid to drop out otherwise. For a station that did not submit a bid to drop out but submitted a switch bid, the latter is processed if and when the station is not frozen, its current price has reached its clock level, and the switch is feasible. Any ties are broken using pseudo-random numbers.

4.4 Alternative Approach: Bid Processing *without* Intra-Round Bidding

A station submits a ranked list of its permissible relinquishment options that are at or above its current relinquishment option, with the ranking indicating its preferences at the clock prices. To ensure that at least one option is feasible, the list must include either the station's current relinquishment option or a bid to drop out, and the rules may restrict the list to include just one of those options as its lowest-ranked one. This restriction does not reduce flexibility for the bidder: since a bid for a station can be processed only when both dropping out and staying in the current relinquishment option are feasible, if a station names both then the lower-ranked of those two options can never be chosen.[10]

[10] For example, the list could be elicited sequentially starting from the highest-ranked option down, and stopping as soon as the station names either the current option or drop out. For example, if a station first bids for the current (continued….)

To process the bids, place all the active stations in a queue in descending order of $\frac{\hat{P}_{t,s}-P_{t,s,b_{t,s}}}{Volume\ of\ station\ s}$ (their *benchmark overpricing*), breaking ties in a pseudo-random order, and repeat the following steps (which end when only frozen stations remain in the queue):

- For every station still in the queue and given the current tentative assignment, check whether the station is feasible in its pre-auction band.
- If DRP is "OFF," move to the next bulleted step. Otherwise, compute the aggregate impairment in the 600 MHz Band that would occur if all the UHF stations that are infeasible in UHF (given the current tentative assignment) were to drop out at once. If that impairment would exceed the specified DRP threshold, then set DRP to "OFF."
- Mark as frozen any VHF stations that are infeasible in their pre-auction bands, given the current tentative assignment. If DRP is "OFF," mark as frozen any UHF stations that are infeasible their pre-auction bands, given the current tentative assignment.
- Find the first station *s* in the queue that is not frozen. If the queue contains no such station, finish queue processing.
- Check the feasibility of station s in all permissible bands above $b_{t,s}$ given the current tentative assignment. Determine which feasible option b^* was ranked highest for station s (treating dropping out as feasible for a UHF station if DRP is "ON"). (There is always at least one feasible option, because a station must include either its current relinquishment option, which is feasible, or a bid to drop out, which is also feasible.) Set the station's new current relinquishment option to be this highest ranked option, $b_{t+1,s} = b^*$, and set its new current compensation according to the quoted price for that option, *i.e.*, $\hat{P}_{t+1,s} \coloneqq P_{t,s,b_{t+1,s}}$. (If $b_{t+1,s} = UHF$ but the station has no feasibility in the UHF band because DRP is "ON," mark it to be assigned to the 600 MHz Band in the next clearing target optimization.)
- Remove station *s* from the queue and start a new processing loop.

After queue processing is finished, all stations left in the queue are frozen. Set their current relinquishment option and current compensation to be unchanged for the next round: $b_{t+1,s} \coloneqq b_{t,s}$ and $\hat{P}_{t+1,s} \coloneqq \hat{P}_{t,s}$. For every station left in the queue, check whether it will remain frozen for the remainder of the current clock stage, and if so, mark it as a provisional winner and remove it from the list of active stations.

5 Reverse Auction Example

We illustrate the mechanics of the clock price calculation and the bid processing algorithm described in Section 4.3, for a simple example. The setup and outcome are intended to be illustrative, rather than realistic or typical. For expository ease, the example corresponds to a hypothetical world in which each band has just one channel.

There are two locations: A and B. Stations 1, 2, and 3 are in location A. Stations 4, 5, and 6 are in location B. The pre-auction band of all six stations is UHF. The volume of each of these stations is equal to 1.

(Continued from previous page)
option or to drop out, it is asked no further questions, while if it first bids to switch to a VHF option, it is asked to name its next-best option, until it names either the current option or drop out. Another possible interface simplification is to limit the station to list at most one option to switch.

The three stations of each location are interfering with each other in Low-VHF and High-VHF. Specifically, we assume that there is one channel available in Low-VHF in location A, and one in location B. That is, if one of the stations in location A is in Low-VHF, no other station in location A can be assigned there. We make the same assumption for the High-VHF band.

All six stations are interfering in UHF. We assume that there is one available channel in UHF across both locations. That is, if one of the six stations is assigned in UHF, then no other station can be assigned there.

The opening prices are: $1000 for going off-air, $700 for moving to Low-VHF and $400 for moving to High-VHF.[11] In the application process, every station indicates going off-air as its preferred option.

For the purposes of this example, we assume that the decrement is $R = 5\%$, $c = 0.5$, $VAC_FLOOR = 0.1$,[12] and that DRP is "OFF". In the calculations, we round prices to the nearest integer, and we round the values of Δ_s to two decimal points.

5.1 Round 1

5.1.1 Clock Price Calculation

In the initial assignment, the current relinquishment option of every station is to go off-air. For round 1, the vacancies are $V_{1,s,b} = 1$ for all stations s and all bands b. This implies that the reduction coefficients are: $r_{1,s,HV} = 0.4$ and $r_{1,s,LV} = 0.7$ for all stations s. After computing the benchmark prices for round 1, we conclude that the clock prices are: $P_{1,s,OFF} = \$950$, $P_{1,s,LV} = \$665$, and $P_{1,s,HV} = \$380$ for all stations s.[13]

5.1.2 Bidding

We assume that in round 1, every station accepts the offer for going off-air at the clock price (that is, no station submits a bid to drop out of the auction), and no station submits a bid to switch to another option.

5.1.3 Bid Processing

$\Delta_s = 1$ for all stations s, since no station submitted a bid to drop out. The stations are placed in the queue in a pseudorandom order. The result of bid processing is that $b_{2,s} = OFF$ and $\hat{P}_{2,s} = \$950$ for all stations s. That is, for every station the current relinquishment option is going off-air and the current compensation is $950.

[11] The opening bid price discount of 30% for the moving to Low-VHF option and 60% for the moving High-VHF option are illustrative values falling within the range proposed in the Comment PN.

[12] We set VAC_FLOOR at 0.1 just for purposes of this simplified example.

[13] In this example, the clock prices are equal to the corresponding benchmark prices, because the volume of every station is equal to 1 and UHF is the pre-auction band of every station.

This is illustrated in Figure 3 below:

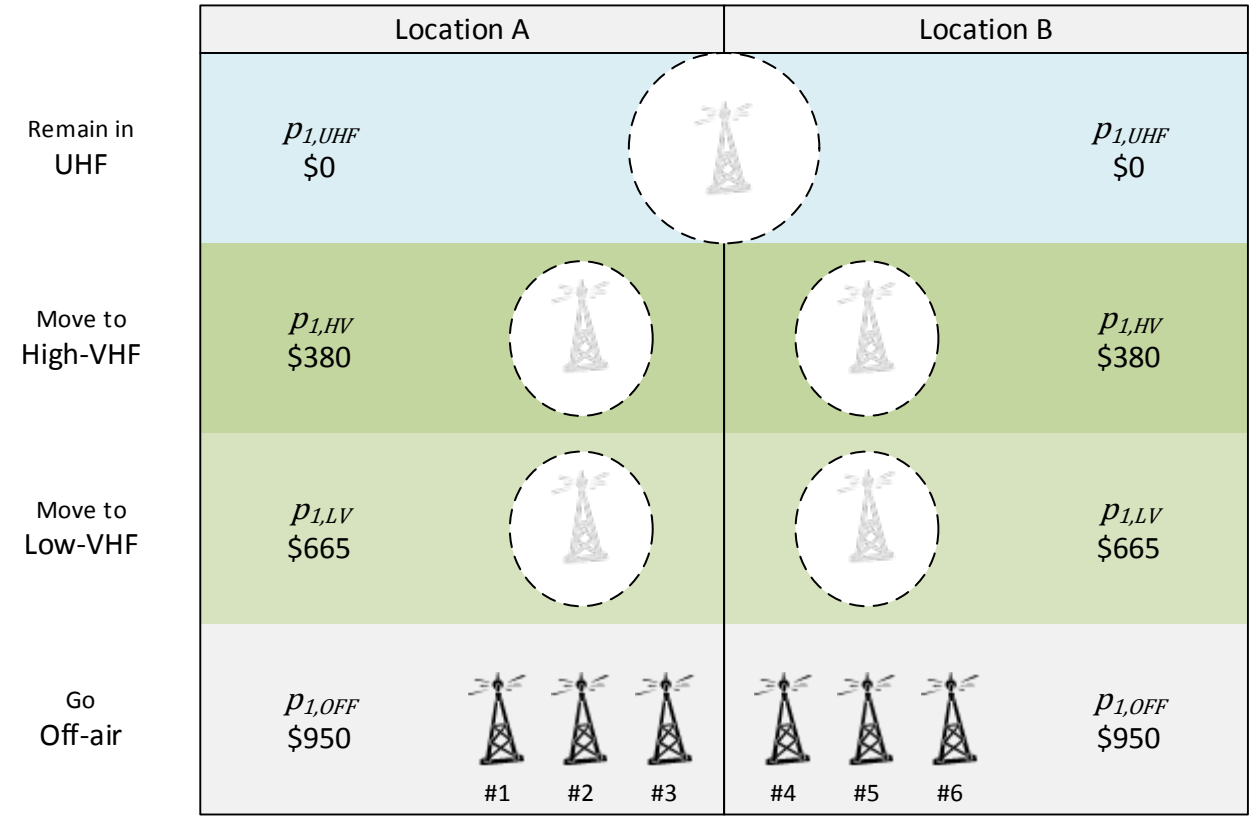


Figure 3: Round 1 benchmark prices and current relinquishment options after bid processing

5.2 Round 2

5.2.1 Clock Price Calculation

Since all stations are currently off-air, the vacancies are $V_{2,s,b} = 1$ for all stations s and all bands b. This implies that the reduction coefficients are: $r_{2,s,HV} = 0.4$ and $r_{2,s,LV} = 0.7$ for all stations s. After computing the benchmark prices for round 2, we conclude that the clock prices are: $P_{2,s,OFF} = \$903$, $P_{2,s,LV} = \$632$, and $P_{2,s,HV} = \$361$ for all stations s.

5.2.2 Bidding

We assume that in round 2, station 1 submits a bid to switch to move to Low-VHF, and no other station submits a bid to switch. Moreover, every station accepts the offer for going off-air at the clock price (that is, no station submits a bid to drop out of the auction).

5.2.3 Bid Processing

$\Delta_s = 1$ for all stations s, since no station submitted a bid to drop out of the auction. The stations are placed in the queue in a pseudorandom order. The result of bid processing is that $b_{3,1} = LV$, $\hat{P}_{3,1} = \$632$; and $b_{3,s} = OFF$ and $\hat{P}_{3,s} = \$903$ for stations $s \in \{2,3,4,5,6\}$.

This is illustrated in Figure 4 below:

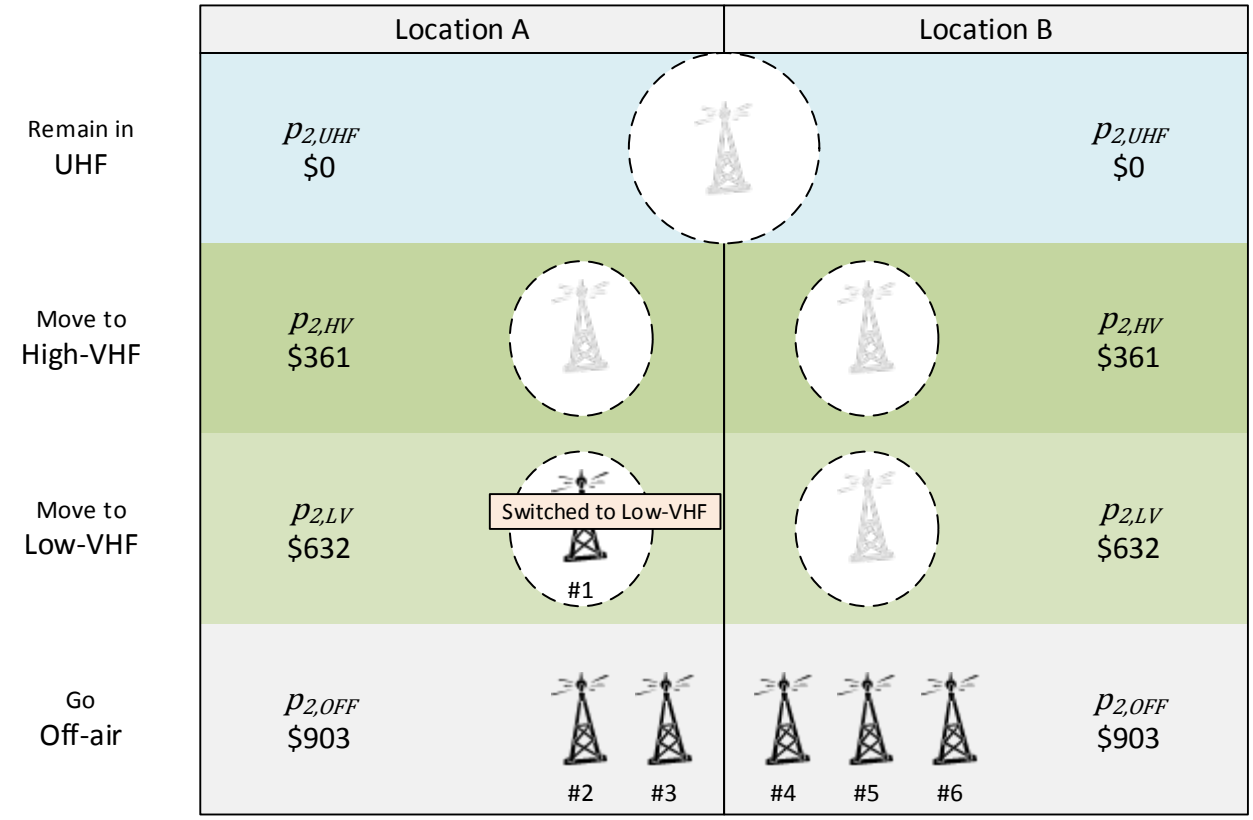


Figure 4: Round 2 benchmark prices and current relinquishment options after bid processing

5.3 Round 3

5.3.1 Clock Price Calculation

In location A, one of the stations (station 1) is currently in Low-VHF and the other two stations are off-air. In location B, all stations are currently off-air. The vacancies are $V_{3,s,b} = 1$ for all stations s and bands $b \in \{HV, UHF\}$. Moreover, $V_{3,s,LV} = 0.5$ for $s \in \{1,2,3\}$ and $V_{3,s,LV} = 1$ for $s \in \{4,5,6\}$. That is, in location A the vacancy in Low-VHF is smaller than in location B, because a station is currently assigned in Low-VHF in location A. This implies that the reduction coefficients are: $r_{3,s,HV} = 0.4$ for all stations s; and $r_{3,s,LV} = 0.8558$for $s \in \{1,2,3\}$ and $r_{3,s,LV} = 0.7$ for $s \in \{4,5,6\}$. After computing the benchmark prices for round 3, we conclude that the clock prices are: $P_{3,s,OFF} = \$858$, and $P_{1,s,HV} = \$343$ for all stations s. Moreover, $P_{3,s,LV} = \$\,593$ for $s \in \{1,2,3\}$ and $P_{3,s,LV} = \$600$ for $s \in \{4,5,6\}$.

5.3.2 Bidding

We assume that in round 3,

- Station 1 accepts the clock price for Low-VHF. It submits neither a bid to switch nor a bid to drop out.
- Station 2 submits a bid to switch to move to High-VHF, and a bid to drop out of the auction when the price of off-air drops to $880.
- Station 3 submits a bid to switch to move to High-VHF, and a bid to drop out of the auction when the price of off-air drops to $870.

- Station 4 submits a bid to switch to move to Low-VHF, and a bid to drop out of the auction when the price of off-air drops to $890.
- Station 5 submits a bid to drop out of the auction when the price of off-air drops to $860.
- Station 6 accepts the clock price for going off-air. It submits neither a bid to switch nor a bid to drop out.

5.3.3 Bid Processing

Given the bids that were submitted in this round, the algorithm computes that $\Delta_1 = 1$, $\Delta_2 = 0.51$, $\Delta_3 = 0.73$, $\Delta_4 = 0.29$, $\Delta_5 = 0.95$, and $\Delta_6 = 1$. The station's compensations are initialized to $\hat{P}_{4,1} = \$632$, and $\hat{P}_{4,s} = \$903$ for stations $s \in \{2,3,4,5,6\}$. The stations are placed in the queue in the following order: 4, 2, 3, 5, 1, 6 (where the tie between stations 1 and 6 was broken pseudo-randomly).

- In the first iteration, station 4 is considered and $\Delta_4 = 0.29$. Given that none of the stations are frozen, the current compensation of station 1 is updated to $\hat{P}_{4,1} = \min\{\bar{P}_{3,1}(0.29), 632\} = \$621$ and the current compensation of every other station $s \in \{2,3,4,5,6\}$ is updated to $\hat{P}_{4,s} = \min\{\bar{P}_{4,s}(0.29), 903\} = \$890$. Station 4 is then switched to Low-VHF and removed from the queue, and its current compensation is set to $\hat{P}_{4,4} = \$600$.
- In the second iteration, the current compensations of stations in the queue are updated as a function of $\Delta_2 = 0.51$. Station 2 is then switched to High-VHF, it is removed from the queue, and its current compensation is updated.
- In the third iteration, station 3 is considered and the current compensations are updated as a function of $\Delta_3 = 0.73$. Station 3 is not feasible in High-VHF (because station 2 is currently assigned there), so station 3 drops out of the auction and is assigned a channel in UHF. This causes all other stations to be "frozen", since they are now infeasible in UHF. The current compensation of stations 2 and 4 is equal to the clock price of their current options, respectively. For stations 1, 5, and 6, the current compensation is determined by $\Delta_3 = 0.73$.

5.3.4 Outcome

At this point, station 3 is inactive (because it has dropped out of the auction) and all other stations are provisionally winning. As a result, this stage of the reverse auction ends. The provisionally winning options are: Low-VHF for station 1, High-VHF for station 2, Low-VHF for station 4, and off-air for stations 5 and 6. The provisionally winning prices are $604 for station 1, $343 for station 2, $600 for station 4, and $870 for stations 5 and 6.

This is illustrated in Figure 5 below:

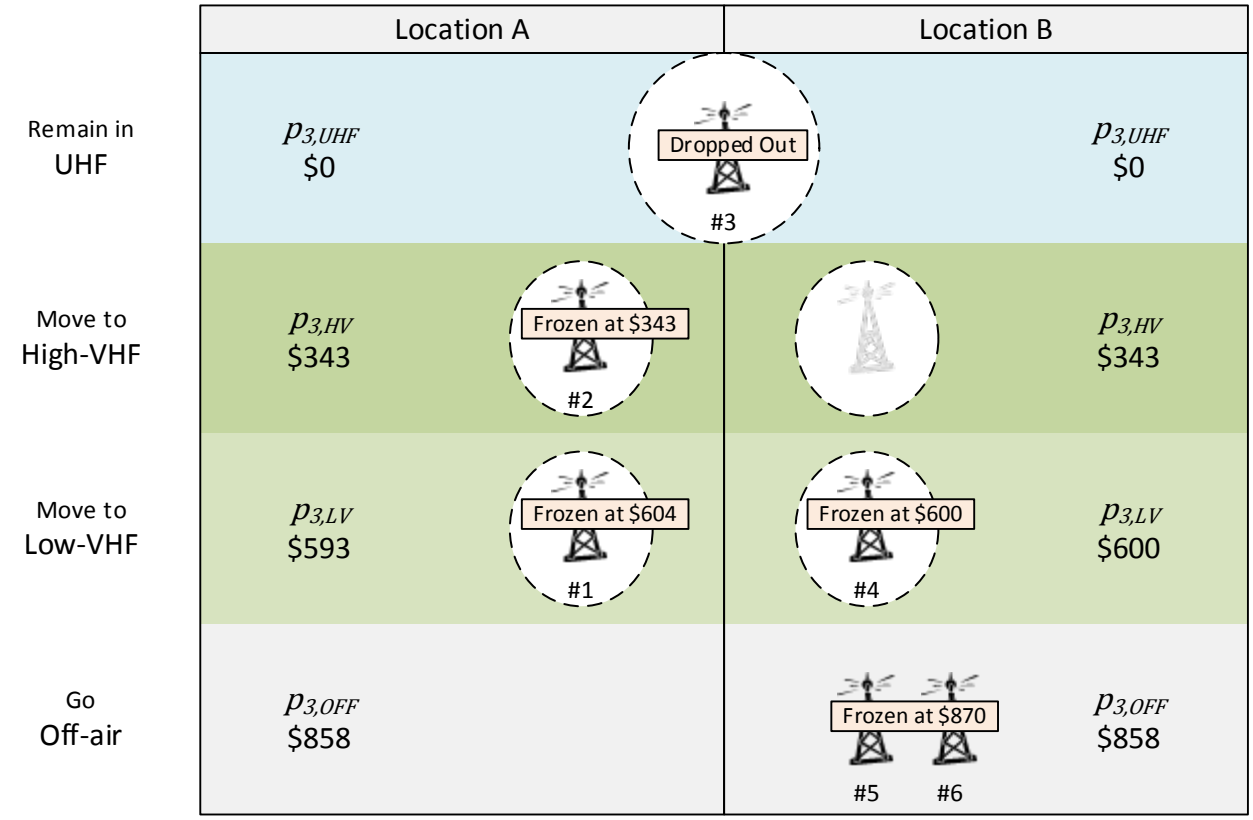


Figure 5: Provisionally winning prices and options after bid processing in round 3

The following tables show the benchmark prices that are updated for each round.

For stations in Location A:

t	$p_{t,s,OFF}$	$p_{t,s,LV}$	$p_{t,s,HV}$
0	$1000	$700	$400
1	$950	$665	$380
2	$903	$632	$361
3	$858	**$593**	$343

For stations in Location B:

t	$p_{t,s,OFF}$	$p_{t,s,LV}$	$p_{t,s,HV}$
0	$1000	$700	$400
1	$950	$665	$380
2	$903	$632	$361
3	$858	**$600**	$343

6 Alternative without Intra-Round Bidding

Here, we briefly describe the mechanics of how the alternative algorithm without intra-round bidding, described in Section 4.4, would work in the previous example. Since the clock prices in each round coincide with the clock prices in the previous example, we instead focus on how bids are processed based on the ranked list of bids submitted by each bidder in each round.

In round 1, every station submits a list consisting only of its current relinquishment option, to go off-air. After bid processing, every station's current relinquishment option is still to go off-air, and every station's current compensation is equal to the clock price for going off-air ($950).

In round 2, station 1 submits its preferred list ranking the options as (1) move to Low-VHF, and (2) go off-air, while the other stations submit preferred lists ranking only the option (1) to go off-air. Station 1's bid to switch to Low-VHF is processed, and the other stations keep their current relinquishment options. For every station, its current compensation is equal to the clock price of its current relinquishment option.

In round 3, the stations submit the following ranked lists:

- Station 1: (1) move to Low-VHF
- Station 2: (1) move to High-VHF, and (2) drop out of the bidding
- Station 3: (1) move to High-VHF, and (2) drop out of the bidding
- Station 4: (1) move of Low-VHF, and (2) drop out of the bidding
- Station 5: (1) drop out of the bidding
- Station 6: (1) go off-air.

First, the bid processing algorithm considers the bids of stations 2-6 in a pseudo-random order, giving priority to stations 2-6 (since $\hat{P}_{3,1} - P_{3,1,b_{3,1}} < \hat{P}_{3,s} - P_{3,s,b_{3,s}}$ for every $s \in \{2,3,4,5,6\}$).[14] Suppose that station 6 is considered first: the station's current option remains the same (*i.e.*, to go off-air), and its current compensation is set equal to the clock price of that option. Suppose that station 5 is considered next: its bid to drop out of the bidding is processed. Then, all the other stations are frozen, so they all keep their current relinquishment options and their current compensations from the previous round. This stage of the reverse auction ends because all stations that have not dropped out are provisionally winning.

[14] This simplified example is for illustrative purposes only. For a reasonable size of R, we expect far fewer stations as a percentage of the total would exit in the same round.

APPENDIX E

Final Channel Assignment Optimization

1 Introduction

This technical appendix provides the details of our proposal for determining a final assignment of television stations to channels in the remaining television bands. Once the final stage rule has been met, a station's provisional assignment to a selected relinquishment option will become final. The final channel assignment procedure will determine a final channel assignment for stations that won a relinquishment bid to move to a VHF band as well as all eligible stations that chose not to participate in the auction or dropped out of bidding during the auction. Non-participating stations and stations that dropped out of bidding will be assigned final channels in their pre-auction bands. Under the proposed approach in the Comment PN, any assignments of UHF stations to channels in the 600 MHz Band in a stage will be final if no subsequent stages are necessary, that is, impairments to forward auction licenses will not change during the final channel assignment procedure.

The Final Channel Assignment Optimization procedure will employ mathematical optimization techniques to determine a final channel assignment considering three objectives in the following order of priority: (1) maximize the number of stations that remain on their pre-auction channel; (2) minimize aggregate new interference by (a) minimizing the maximum aggregate new interference any station receives or (b) minimizing the number of stations with aggregate new interference over one percent; (3) minimize relocation expenses. The resulting objective value of each optimization will become a constraint on the next optimization problem to be solved.

This appendix first defines the concept of a feasible assignment of TV stations in the context of the Final Channel Assignment Optimization, and then continues with a detailed discussion of the optimization process and mathematical formulations for each problem.

2 Feasible Assignments

After the final stage rule has been met, the Final Channel Assignment Optimization will determine an assignment of TV stations that meets the following conditions:

(1) All stations are given an assignment to a channel in the same band assigned at the close of the auction.

(2) Each station is assigned to one of its allowable channels, as defined in the domain.csv file.

(3) Station channel assignments must not violate adjacent and co-channel pairwise interference restrictions as defined in the interference_paired.csv file.

(4) Stations assigned to the 600 MHz Band remain on the same channel assigned during the last stage of the auction.

An assignment of stations that meets all of the above conditions is considered feasible. All solutions to the Final Channel Assignment Optimization must be feasible. The linear constraints that enforce conditions (1) – (4) are provided below.

Set Definitions:

S is the set of all stations remaining on air at the conclusion of the Incentive Auction

C_s is the set of allowable channels for station s in the band where s is tentatively assigned

For stations assigned to a channel in the 600 MHz Band, C_s consists of only the channel that they were assigned during the last Clearing Target Optimization. For UHF stations assigned to a channel in the remaining TV bands, C_s consists of only allowable UHF channels within the remaining TV bands.

Variable Definitions:

$x_{s,c}$ is a binary decision variable which has a value of 1 if station s is assigned to channel c and 0 otherwise.

Feasibility Constraints:

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s',c'} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)

Explanation of Constraints:

1. **Each station must be assigned.**

   $$\sum_{c \in C_s} x_{s,c} = 1 \qquad \forall s \in S$$

   The set C_s is the set of allowable channels for station s in the band where s was assigned. This constraint assures that every station is assigned to exactly one channel from that set.

2. **Station assignments must adhere to the co-channel interference restrictions.**

   $$x_{s,c} + x_{s',c} \leq 1 \qquad \forall \{(s,c),(s',c)\} \in CoPairs$$

   For every pairwise restriction that precludes two stations from occupying the same channel, a constraint is created that indicates that at most one of the two stations (s and s') can be assigned to that channel *c*. The set includes all station pairs that cannot occupy the same channel.

3. **Station assignments must adhere to the adjacent channel restrictions.**

   $$x_{s,c} + x_{s',c'} \leq 1 \qquad \forall \{(s,c),(s',c')\} \in AdjPairs$$

   Similarly, for every two station pairs (s,c) and (s',c') where channels c and c' are adjacent and where if station s is on channel c then station s' cannot be on channel c', a constraint is created that allows only one of these two assignments. That is, the constraints enforce the adjacent channel requirements.

4. **The decision variables can only take on the values zero or one.**

   $$x_{s,c} \in \{0,1\} \qquad \forall s \in S, \forall c \in C_s$$

   For each allowable station-channel combination, the value of the variable $x_{s,c}$ is restricted to be either 0 or 1; *i.e.*, the station is either assigned to the channel or it is not.

3 Determining the Final Channel Assignment

The goals of the final channel assignment are to minimize viewer losses due to aggregate new interference and terrain and to minimize cost and inconvenience due to relocation. The Comment PN proposes the following sequence of steps to achieve those goals:

(1) Maximize the number of stations that remain on their pre-auction channel.

(2) Among solutions that keep at least 95% of the maximum number of stations found in (1) on their pre-auction channel, minimize aggregate new interference by:

a. Minimizing the maximum amount of aggregate new interference that any station receives.

OR

b. Minimizing the number of stations with aggregate new interference over one percent.

(3) Among solutions that that satisfy the restrictions of (1) and (2), minimize the costs of relocating stations to channels.

Step (1) is given highest priority due to its potential to satisfy multiple objectives. Stations that are assigned to their pre-auction channel will not experience terrain loss and will not incur any expense or disruption due to their own relocation. Step (2) will minimize aggregate new interference subject to the restriction that the number of stations that remain on their pre-auction channel is at least 95% of the maximum number found in the first step. This optimization calculates aggregate interferences as a sum of pairwise interferences and so provides an upper bound on true aggregate interference. Step (3) will attempt to find an assignment that minimizes the total cost of relocating stations to new channels while ensuring that the objectives from the previous two steps are met.

This section lists the mathematical formulation for each of the three steps.

3.1 Step (1): Maximize the number of stations that remain on their pre-auction channel.

In the first step of determining a Final Channel Assignment, the optimization seeks a feasible solution that maximizes the number of stations that remain on their pre-auction channel. The constraints for this optimization are the same as those defined in Section 2. In addition to the variables and sets defined in that section, a new constant and a subset of S for this optimization are defined below.

Subset:

S^o is the set of stations whose pre-auction channel is in their assigned band (*i.e.*, identify the stations that will stay in their pre-auction band).

Constant:

c_s^o is the pre-auction channel for each station $s \in S^o$

Model Formulation for Step (1):

$$max \;\; Z_1 \;=\; \sum_{s \in S^o} x_{s,c_s^o}$$

Subject to

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s',c'} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)

Explanation of Objective Function:

The objective function maximizes the number Z_1 of stations that are assigned to their pre-auction channel. The objective function does not consider any station that moved to a new band or if their pre-auction channel is now part of the wireless band. The value of Z_1 will be an integer greater than or equal to zero.

3.2 Step (2): Minimize aggregate new interference

This appendix discusses two potential optimization approaches that could be adopted for minimizing the amount of aggregate new interference that any station receives. One method minimizes the maximum aggregate new interference that any station receives. This optimization attempts to push down the upper limit for aggregate new interference for all stations. Another method is to minimize the total number of stations that receive aggregate interference above a threshold, proposed to be 1%. Both optimizations are done using the pairwise interference percentages as determined by TV Study. This only applies for pairs of stations whose interference is less than 0.5%, as any assignment with interference greater than 0.5% is forbidden by the interference restrictions. Relying in this way on pairwise interference introduces potential double counting of interference, meaning that the actual aggregate new interference may be lower than the result of these optimizations.[1] The first potential optimization introduces one new variable and one constraint for every possible station channel combination (potentially around 100,000 constraints). The second potential optimization introduces two new variables for each station channel combination and five new constraints for each station channel combination.[2]

In Step (2), a new constraint is added to enforce the objective value Z_1 from the first optimization. However, in order to provide a little more flexibility in minimizing the amount of aggregate new interference, the constraint will only require b% of Z_1. Based on initial studies conducted by the staff, the Comment PN proposes that this percentage be 95%. The optimization ensures that at least the same number of stations, or nearly the same, will be on their original channel while seeking to minimize the amount of aggregate new interference that any station receives. The constraint may be made less restrictive to allow for additional improvement in aggregate new interference and relocation costs.

3.2.1 Step (2) option (a): Minimizing the maximum amount of aggregate new interference that any station receives.

The additional variable, subset and constant for this optimization are defined here.

Variable:

y is the maximum amount of aggregate new interference

Subset:

$SC_{(s,c)}$ is the set of allowable station-channel assignments when station s is assigned to channel c.

Constants:

$pct_{s',c'}$ is the percent of interfered population for station s by station s' broadcasting on channel c' if station s broadcasts on channel c.

[1] Removing double counting and using actual aggregate new interference would require millions of new variables and tens of millions of new constraints making the problem intractable.

[2] An optimization will be used prior to this step to determine if a station can possibly receive aggregate new interference greater than 1%. If a station cannot receive more than 1% aggregate new interference, the station's constraints are removed from the problem, making the optimization smaller and easier to solve.

y_{max} is the maximum amount of possible aggregate new interference for any station including double counting.[3]

b is the scale factor for the number of stations required to stay on their original channel. b must be between 0 and 1.

Model Formulation for Step (2) option (a):

$$min\ Z_2 = y$$

Subject to

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s',c'} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)
$\sum_{s \in S^o} x_{s,c_s^o} \geq b\, Z_1$		(5)
$\sum_{(s',c') \in SC_{(s,c)}} pct_{s',c'}\, x_{s',c'} \leq y + y_{max}(1 - x_{s,c})$	$\forall s \in S, c \in C_s$	(6)
$0 \leq y \leq y_{max}$		(7)

Explanation of New Constraints:

Constraint (5) requires that b% of the same number of stations as found in Step (1) remain on their pre-auction channel.

Constraint (6) determines the aggregate new interference for a station on a specific channel. The left hand side calculates the amount of interference created by interfering station channels. The right hand side equals y when a station s is assigned to channel c. This means y will take the value of whatever station currently has the highest aggregate new interference. As the optimization finds better assignments the value y will decrease. If a station is not broadcasting on that channel, the right hand side is $y + y_{max}$. This renders the constraint non-binding, and therefore will not alter the value of y. The highest possible aggregate new interference, y_{max}, can be determined given the remaining stations prior to determining the Final Channel Assignment.

Constraint (7) requires that y be between 0 and y_{max}.

Explanation of Objective Function:

The objective function minimizes Z_2, the highest amount of aggregate new interference that any station receives. This objective looks at all stations simultaneously, attempting to find the minimum upper limit of aggregate new interference. The value of Z_2 will be greater than or equal to 0 and less than or equal to y_{max}.

[3] To calculate y_{max}, find $\max_{s \in S, c \in C_s} \{\sum_{(s',c') \in SC_{(s,c)}} pct_{s',c'}\}$.

3.2.2 Step (2) option (b): Minimizing the number of stations that receive aggregate new interference above a threshold.

The additional variables and constant for this optimization are defined here.

Variables:

$y_{s,c}$ is the amount of aggregate new interference that station s receives broadcasting on channel c

$m_{s,c}$ is a binary decision variable which has a value of 1 if station s is assigned to channel c with aggregate new interference greater than ϕ and 0 otherwise.

Constant:

ϕ is the threshold for aggregate new interference. We propose to use 1% for this threshold.

Model Formulation for Step (2) option (b):

$$min\ \ Z_3\ = \sum\nolimits_{s\in S} \sum\nolimits_{c\in C_s} m_{s,c}$$

Subject to

$\sum_{c\in C_s} x_{s,c} = 1$	$\forall s \in S$	(1)
$x_{s,c} + x_{s',c} \le 1$	$\forall\{(s,c),(s',c)\} \in CoPairs$	(2)
$x_{s,c} + x_{s',c'} \le 1$	$\forall\{(s,c),(s',c')\} \in AdjPairs$	(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(4)
$\sum_{s\in S^o} x_{s,c_s^o} \ge b\, Z_1$		(5)
$\sum_{(s',c')\in SC_{(s,c)}} pct_{s',c'}\, x_{s',c'} \le y_{s,c} + y_{max}(1 - x_{s,c})$	$\forall s \in S, c \in C_s$	(6)
$0 \le y_{s,c} \le y_{max} x_{s,c}$	$\forall s \in S, c \in C_s$	(7)
$y_{s,c} \ge \phi m_{s,c}$	$\forall s \in S, c \in C_s$	(8)
$y_{s,c} \le \phi + y_{max} m_{s,c}$	$\forall s \in S, c \in C_s$	(9)
$m_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$	(10)

Explanation of New Constraints:

Constraint (6) determines the aggregate new interference for a station on a specific channel. The left hand side calculates the amount of interference created by interfering station channels. The right hand side equals $y_{s,c}$ when station s is assigned to channel c. If a station is not broadcasting on that channel, the right hand side is $y_{s,c} + y_{max}$. This renders the constraint non-binding, and therefore will not alter the value of $y_{s,c}$. The highest possible aggregate new interference, y_{max}, can be determined given the remaining stations prior to determining the Final Channel Assignment.

Constraint (7) requires that $y_{s,c}$ be between 0 and y_{max} when station s is broadcasting on channel c. Otherwise, this forces $y_{s,c}$ to be zero.

Constraint (8) forces $m_{s,c}$ to be zero when $y_{s,c}$ is less than ϕ.

Constraint (9) forces $m_{s,c}$ to be one when $y_{s,c}$ is greater than ϕ.

Constraint (10) limits $m_{s,c}$ to be either one or zero.

Explanation of Objective Function:

The objective function minimizes Z_3, the total number of stations whose aggregate new interference is greater than ϕ. The value of Z_3 will be an integer greater than or equal to 0.

3.3 Step (3): Minimize the costs due to relocation.

The final step in determining the Final Channel Assignment is to minimize the total costs due to relocation. If there are multiple solutions where the same, or nearly the same, number of stations remain on their pre-auction channels and the amount of aggregate new interference is the same, there may be an assignment with a lower total relocation cost. This optimization will seek an assignment that has the least cost for stations remaining on air among all solutions that satisfy the objectives of Steps 1 and 2.

This optimization will use cost estimates to represent likely costs for a station to move to a specific new channel using the best publicly available resources.

The additional constant and subset for this optimization are defined here.

Subset:

S_H is the set of stations that remain in their pre-auction, or pre-auction bands.

Constant:

$r_{s,c}$ is the estimated cost associated with moving station s to channel c.

Model Formulation for Step (3):

$$min\ Z_4 = \sum_{s \in S_H} \sum_{c \in C_s} r_{s,c} x_{s,c}$$

Subject to

$\sum_{c \in C_s} x_{s,c} = 1$	$\forall s \in S$		(1)
$x_{s,c} + x_{s',c} \leq 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$		(2)
$x_{s,c} + x_{s',c'} \leq 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$		(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$		(4)
$\sum_{s \in S^o} x_{s,c_s^o} \geq b\, Z_1$			(5)
$\sum_{(s',c') \in SC_{(s,c)}} pct_{s',c'}\, x_{s',c'} \leq Z_2 + y_{max}(1 - x_{s,c})$		$\forall s \in S, c \in C_s$	(6)
$\sum_{(s',c') \in SC_{(s,c)}} pct_{s',c'}\, x_{s',c'} \leq y_{s,c} + y_{max}(1 - x_{s,c})$		$\forall s \in S, c \in C_s$	(7)
$0 \leq y_{s,c} \leq y_{max} x_{s,c}$			(8)
$y_{s,c} \geq \phi m_{s,c}$	$\forall s \in S, c \in C_s$		(9)
$y_{s,c} \leq \phi + y_{max} m_{s,c}$	$\forall s \in S, c \in C_s$		(10)
$m_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$		(11)
$\sum_{s \in S} \sum_{c \in C_s} m_{s,c} \leq Z_3$			(12)

Explanation of New Constraint:

Constraint (6) limits the aggregate new interference that any station can receive to be less than or equal to the value found if Step (2) option A is used.

Constraint (12) limits the total number of stations whose aggregate new interference is greater than ϕ to be less than or equal to the value found if Step (2) option B is used.

Explanation of Objective Function:

The objective function minimizes the number Z_4, the total relocation costs. Z_4 will be greater than or equal to 0.

3.4 Alternative formulation of Step (3) including fixed costs

Additionally, some fixed costs could be considered in Step (3). Fixed costs could be used to model a situation in which stations sharing the same tower only need to upgrade the tower once, or in which stations sharing the same antenna will not each need to buy a new antenna.

The additional variables, sets and constants for this optimization are defined here.

Sets:

Q_i is a set of station-channels that incur a fixed costs.

Q is the set of all Q_i.

Variables:

q_i is the binary variable associated with the set of station-channels in Q_i. If a station-channel in Q_i is 1, then q_i equals 1. Otherwise, q_i equals 0.

Constant:

f_i is the estimated fixed cost associated with the set Q_i.

Model Formulation for Step (3) with fixed costs:

$$min\ \ Z_3 = \sum_{s\in S_H} \sum_{c\in C_s} r_{s,c} x_{s,c} + \sum_{Q_i\in Q} f_i q_i$$

Subject to

$\sum_{c\in C_s} x_{s,c} = 1$	$\forall s \in S$		(1)
$x_{s,c} + x_{s',c} \le 1$	$\forall \{(s,c),(s',c)\} \in CoPairs$		(2)
$x_{s,c} + x_{s',c'} \le 1$	$\forall \{(s,c),(s',c')\} \in AdjPairs$		(3)
$x_{s,c} \in \{0,1\}$	$\forall s \in S, \forall c \in C_s$		(4)
$\sum_{s\in S^o} x_{s,c_s^o} \ge b\, Z_1$			(5)
$\sum_{(s',c')\in SC_{(s,c)}} pct_{s',c'}\, x_{s',c'} \le Z_2 + y_{max}(1 - x_{s,c})$		$\forall s \in S, c \in C_s$	(6)
$\sum_{(s',c')\in SC_{(s,c)}} pct_{s',c'}\, x_{s',c'} \le y_{s,c} + y_{max}(1 - x_{s,c})$		$\forall s \in S, c \in C_s$	(7)
$0 \le y_{s,c} \le y_{max} x_{s,c}$			(8)
$y_{s,c} \ge \phi m_{s,c}$	$\forall s \in S, c \in C_s$		(9)
$y_{s,c} \le \phi + y_{max} m_{s,c}$	$\forall s \in S, c \in C_s$		(10)

$$\sum_{s \in S} \sum_{c \in C_s} m_{s,c} \leq Z_3 \quad (11)$$

$$m_{s,c} \in \{0,1\} \qquad \forall s \in S, \forall c \in C_s \quad (12)$$

$$\sum_{(s,c) \in Q_i} x_{s,c} \geq q_i \qquad \forall Q_i \in Q \quad (13)$$

$$x_{s,c} \leq q_i \qquad \forall (s,c) \in Q_i, \forall Q_i \in Q \quad (14)$$

$$0 \leq q_i \leq 1 \qquad \forall Q_i \in Q \quad (15)$$

Explanation of New Constraints:

Constraint (13) forces q_i to be 0 if no station-channel in Q_i is in the assignment.

Constraint (14) forces q_i to be 1 if station-channel (s,c) in Q_i is in the assignment.

Constraint (15) states that q_i must be between 0 and 1.

Explanation of Objective Function:

The objective function minimizes the number Z_3, the total relocation costs. Z_3 will be greater than or equal to 0.

APPENDIX F

Bidding Units, Upfront Payments, and Minimum Opening Bids

This page was intentionally inserted as a placeholder for Appendix F, which is available as a separate file.

APPENDIX G

Forward Auction Clock Phase

1 Introduction

This appendix details the first part of our proposed forward auction procedure: the clock phase. Overall, our clock auction has been designed to share some major features with the simultaneous multiple round auction (SMRA) format, but to run to completion in a fraction of the time that an SMRA would require. Like an SMRA, the clock phase of the forward auction proceeds through a sequence of ascending prices for the licenses. Also, like an SMRA with no bid withdrawals, once there is demand for a license in the auction, the license will not then go unsold. Our proposed clock auction design, however, includes three features that allow it to run in less time than the corresponding SMRA.

The first of these features is that the clock auction aggregates demand within each category of generic licenses, rather than treating each license as a distinct item for bidding. In a traditional SMRA, if during the auction, there were five units of demand for four licenses in the same category, then at each round of the bidding, only one of the four licenses would have a new bid to raise its price. With that pattern of bidding it would take four rounds for all the license prices to rise by one bid increment. In a clock auction, by treating all four licenses as a single product, a single price increment applies to all, so the same price increase takes just one round, instead of four.

The second feature that is different in the clock auction design is the assignment phase, details of which are described in Appendix H. This feature is made necessary by the generic licenses structure, and highlights another important advantage of generic licenses in the incentive auction context. If the incentive auction used an SMRA with individually identified licenses, the auction rules would need to specify which of those licenses would be eliminated whenever the auction moves into a new stage. Uncertainty about not just the number of blocks that will be available, but also about which particular frequencies will be associated with the available blocks, would complicate bidding in the forward auction. By having a separate assignment phase to determine which particular frequencies each bidder will acquire, the auction allows each phase of the auction to perform a function for which it is best suited. Specifically, the clock phase identifies the number of licenses in each category that each bidder will acquire in a PEA, while the assignment phase determines the particular frequencies. This separation makes bidding much easier and, because it avoids solving the assignment problem except in the final stage, it reduces the time required for the auction.

The third feature that distinguishes our proposed clock auction from the SMRA is *intra-round bidding*. This feature performs two important functions. First, it avoids price overshooting. If there were no intra-round bidding, the price for a category of blocks might rise so high in a round that a category with excess demand at the start of a round would have insufficient demand at the end of the round. With intra-round bidding, the price for a category stops rising as soon as demand falls to the level of supply, so there is no risk of overshooting. Second, intra-round bidding allows a clock auction to utilize larger bid increments than a corresponding SMRA, which helps help bring the auction to a close more quickly. In an SMRA, the bid increments must be set small enough that a bidder who is willing to raise a price can afford to do so without exceeding its maximum price. In a clock auction with intra-round bidding, however, a bidder can specify that it wishes to reduce demand or switch to a different category at any price between the prices at the beginning and end of the round and, so bidders will not be deterred from further bidding when the full bid increment is larger than it is willing to pay.

In order for the proposed clock auction design to achieve these benefits, it needs to include bid types that allow bidders to execute strategies similar to the ones they would use in an SMRA. We describe three kinds of bidding plans that bidders commonly execute in an SMRA, and the corresponding three types of bids in our proposal that facilitate those strategies in our proposed clock auction. First, in an SMRA,

when the price of a license becomes too high, a bidder can reduce demand by refraining from bidding again on that license. In our clock auction design, the *simple* bid performs that same function, that is, it allows a bidder to reduce demand for a category when its price rises above any price that the bidder may identify. Second, in an SMRA, when one license price rises too high compared to that of another license (in the same PEA), a bidder can stop bidding for the first license and start bidding for the second. In our proposed clock auction, a bidder can do the same by making a *switch* bid, in which it specifies that it will shift demand from one category to the other when the price of the first category gets too high. Finally, suppose that for some category, a bidder wants to buy two blocks if the price is sufficiently low, but wants to avoid acquiring just one block of that type. In an SMRA, when the prices of a set of licenses are rising, the bidder can limit the possible outcomes by refraining from raising its bid on one license and waiting to see what happens, possibly using a waiver. If there is demand by other bidders for both of its licenses, it can then stop bidding on both. In our clock auction design, a bidder can accomplish the same by use of an *all-or-nothing* bid for a category. In the example, a bidder that is currently demanding two blocks of one category can specify that it will reduce its demand for that category to zero, but that it will not reduce its demand to just one block at the specified price.

The remainder of this document describes the procedures that accomplish all this in more detail, including technical descriptions of the various calculations.

2 Overview

The clock phase of the forward auction will consist of a series of timed bidding rounds. During each bidding round, bidders will place bids indicating demand for generic blocks in a particular license category in a particular PEA, at a price they specify between the start of round price and the end of round price (the *clock price*). After bids are collected in each bidding round, the bids are processed. The results of bid processing include the quantity of a bidder's requested demand that, after bid processing, was accepted (the *processed demand*) and the price at which those bids were processed (the *posted price*). After the bids are processed the system determines whether the next round will be a regular clock round or an *extended round*, or, if the final stage rule is met and there is no excess demand for blocks in any category in any PEA (indicating satisfaction of the closing conditions), the clock phase of the forward auction will end. Finally, the auction system sets up the next round, if there is to be one, including calculating the prices for each category in each PEA for the next round.

Section 3 describes several rules and definitions that are useful in understanding how the forward auction functions. Section 4 describes the types of bids bidders can place in the clock rounds of the forward auction. Section 5 describes bid processing in a regular clock round. Section 6 describes how the system checks whether the closing conditions have been met, and if not, determines the round type for the next bidding round. Section 7 describes how the system sets up that next round. Finally, Section 8 describes bidding in an extended round and the bid processing steps performed for an extended round.

3 Rules and Definitions

This section describes the applicable rules for the forward auction clock phase and provides definitions for terms that will be used throughout this appendix.

3.1 Acceptable Bids

The Comment PN proposes not to allow a bidder to reduce the quantity of blocks it demands if processing the reduction would result in aggregate demand for blocks in a category falling below the available supply. This restriction ensures that once the final stage rule has been met, revenue cannot fall below what is required to meet the final stage rule. Specifically, by not allowing aggregate demand to fall below supply, the total proceeds of the forward auction can only stay the same or increase each round.

As a result of this restriction, some bids that request a reduction in the number of blocks in a category demanded by a bidder may not be accepted in their entirety. This section describes the circumstances under which a bid is accepted either fully or partially.

3.1.1 Fully Acceptable Bids

A bid is *fully acceptable* if the following conditions both hold:

(a) If the bid were applied in its entirety, the total number of bidding units associated with the bidder's demand would not exceed the bidder's eligibility in the current round;

(b) If the bid were applied in its entirety, the aggregate demand would not be less than the supply for that product.

Only bids that are fully acceptable will be applied in their entirety during bid processing.

3.1.2 Partially Acceptable Bids

If a bid is not fully acceptable, it may be considered *partially acceptable* if the following conditions both hold:

(a') If the bid were applied *partially*, the total number of bidding units associated with the bidder's demand would not exceed the bidder's eligibility in the current round; and

(b') If the bid were applied *partially*, the aggregate demand would not be less than the supply for that product.

Examples of fully and partially applied bids are provided in Section 4.

3.2 Activity and Eligibility

An activity rule is used in the forward auction in order to require bidders to participate in each round of the auction. A bidder's eligibility in round 1 of stage 1 of the forward auction is determined by the bidding units associated with its upfront payment. A bidder's eligibility in the first round of a new stage is set equal to the bidder's *processed activity* after the last round of the previous stage.[1]

The Comment PN proposes an activity rule that will require bidders to be active on a percentage of their bidding eligibility between 92 and 97 percent, and that we will calculate activity based on their *processed activity* as described in Section 7.1.[2] If the activity rule is met, then the bidder's eligibility does not change in the next round. If the activity rule is not met in a round, a bidder's eligibility automatically will be reduced to the level of its processed activity.

3.3 Discounts for Impairments

The final stage rule calculation must account for the fact that in determining final payments due by bidders after the assignment phase, the base price of a block in each category will be discounted depending on the block's impairment percentage. Bidders only see the clock price (without discounts) for each product during the clock phase.

The base price for a block that is x% impaired will be discounted by x%. That is, the base price will be set to be equal to the product of $\frac{(100-x)}{100}$ times the final clock price of the corresponding category.

[1] This eligibility will be based on bidding in the extended round, for licenses for which there was bidding in the extended round, and for other licenses, on bidding in the last regular clock round.

[2] Thus, if the auction system does not accept a request for a reduction in demand because aggregate demand for the category would fall below the available supply, the bidder's activity will reflect its unreduced demand.

Example: Suppose that
Block A is 25% impaired
Block B is 16% impaired
Block C is 8% impaired
Block D is 4% impaired

Blocks A and B are Category 2 blocks (because each is more than 15% impaired). If the final clock price for Category 2 blocks is $20 million, then the base price of Block B is $(0.84) \cdot (\$20\ million) = \$16.8\ million$ and the base price of Block A is $(0.75) \cdot (\$20\ million) = \$15\ million$.

Blocks C and D are Category 1 blocks (because each is 15% or less impaired). If the final clock price for Category 1 blocks is $25 million, then the base price of Block C is $(0.92) \cdot (\$25\ million) = \$23\ million$ and Block D is $(0.96) \cdot (\$25\ million) = \$24\ million$.

4 Bidding

A bidder in the forward auction responds in each round by indicating its demand for blocks for the products it desires at current prices. A product is defined to be the pairing of a PEA and a license category. When submitting a bid, the bidder specifies a quantity and a price. The price can be last round's posted price, this round's clock price, or any price in between (an "intra-round bid").

In order to give bidders flexibility to express their demands, our proposal includes three different types of bids: simple bids, all-or-nothing bids (with an option of "backstopping" the all-or-nothing bid), and switch bids. In any round, a bidder is only allowed to submit one of the three types of bids involving a given product (but may submit more than one of the same type of bid for the same product at different prices). For example, if a bidder places a simple bid for product A, then it cannot enter an all-or-nothing bid for product A nor can it enter a switch bid that involves product A in the same round.

The proposed types of bids are:

- **Simple Bids**: these bids indicate a desired quantity of a product at a price. During processing, if it is not possible to apply the simple bid in its entirety, it may be applied partially.
- **All-or-Nothing Bids:** these bids indicate a desired quantity of a product at a price, just like simple bids. However, all-or-nothing bids are either applied in full or not at all. These bids are available for a bidder that does not wish to place bids that may only be applied partially. As described in more detail below, if a bidder's all-or-nothing bid is not applied (because it cannot be applied in full), the proposal allows a bidder to place a "backstop" bid if it is not willing to demand its current quantity at the current clock price.
- **Switch Bids:** these bids allow a bidder to request to switch its demand for a quantity of a product from one category of generic blocks to another category within the same PEA. Switch bids may be applied partially, but the increase in demand in the "to" category will always match in quantity the reduction in the "from" category.

Below, we provide a more detailed explanation along with examples to illustrate each of these bid types and how the auction system would process them under our proposal.

4.1 Simple Bids

A *simple bid* for a quantity q for a product r at price p in a round indicates that:

(1) At all prices above p and less than or equal to the clock price (or the next price at which it enters a bid, whichever is lower), the bidder is willing to buy an exact quantity of q; and

(2) At price p, the bidder is willing to buy any quantity between q and its processed demand.

Note that p can be equal to the current clock price of product r, and q can be equal to the bidder's processed demand for product r after bid processing of the previous round. By placing such a bid, the bidder indicates that it is willing to buy a quantity equal to the last round's processed demand at this round's clock price.

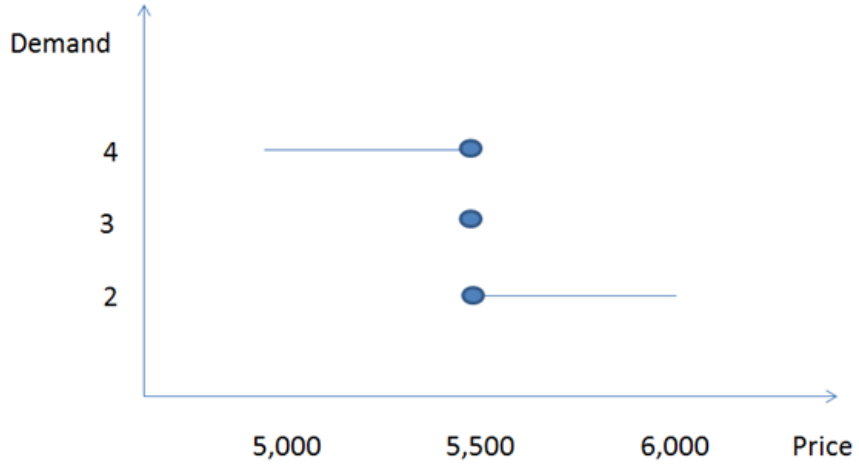
Example: Bidder Places a Simple Bid Demanding 2 Blocks at $5,500

Suppose that in the prior round, the bidder demanded 4 blocks at the previous round's clock price of $5,000. In the current round, the clock price is $6,000, and the bidder places a simple bid reducing its demand to 2 blocks at price $5,500.

To the auction system, this bid means the following:

- If the price is below $5,500, the bidder is willing to purchase 4 blocks.
- If the price is exactly $5,500, the bidder is willing to purchase 2, 3, or 4 blocks.
- If the price is above $5,500, the bidder is willing to purchase only 2 blocks.

The graph below illustrates how the auction system interprets this simple bid:



If a simple bid is partially applied, then the processed demand of the bidder is a quantity that is strictly between the bidder's processed demand before the simple bid was applied and the quantity that the bidder specified in the bid.

The simple bid is applied depending on the level of excess demand for the product at $5,500:

- If demand exceeds supply by more than 2 blocks, the bid is fully applied:
  - The bidder will hold 2 blocks and the clock increases up to $6,000.
- If demand exceeds supply by exactly 2 blocks, the bid is also fully applied:
  - The bidder will hold 2 blocks and the clock stops at $5,500
- If demand exceeds supply by only 1 block, the bid is partially applied:
  - The bidder will hold 3 blocks and the clock stops at $5,500.
- If demand does not exceed supply, the clock has already stopped and the bid is not applied:
  - The bidder will continue to hold 4 blocks at a price below $5,500.

Note that prices continue to increase up to the clock price in a round as long as demand exceeds supply. If demand equals supply after applying a simple bid either in full or in part, the clock stops at the price where this occurred.

Therefore, in the example above, if the simple bid is applied in full at $5,500 and there is still excess demand, the bidder may end the round holding 2 blocks at the clock price of $6,000. Otherwise, if applying the simple bid fully or partially results in supply equaling demand, the clock price stops at that point, in this case $5,500. Hence, the remaining demands of a bidder whose bid is partially applied will be accepted at the stopped clock price of $5,500.

4.2 All-or-Nothing Bids

An *all-or-nothing bid* is a request to increase or reduce demand for a given product by two or more blocks. An all-or-nothing bid for a quantity q for a product r at price p in a round indicates that:

(1) If the bid can be fully applied, the bidder is willing to buy an exact quantity of q of product r when the price is greater than or equal to p and less than or equal to the current clock price.

(2) If the bid cannot be fully applied, the bidder is willing to buy a quantity equal to its processed demand for product r without applying this bid when the price is greater than or equal to p and less than or equal to the current clock price.

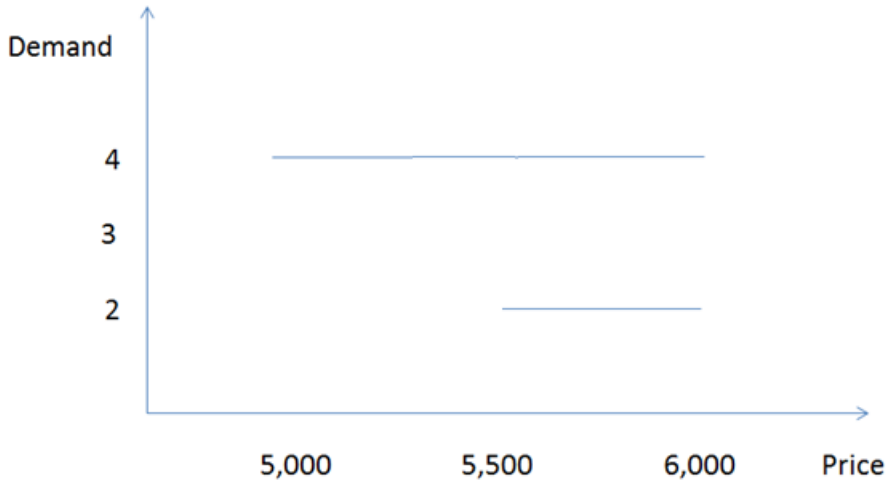
Example: Bidder Places an All-or-Nothing Bid Demanding 2 Blocks at $5,500

Suppose that in the prior round, the bidder demanded 4 blocks at that round's clock price of $5,000. In the current round, the clock price is $6,000, and the bidder places an all-or-nothing bid reducing its demand to 2 blocks at price $5,500.

To the auction system, this bid means the following:

- If the price is below $5,500, the bidder is willing to purchase 4 blocks.
- If the price is $5,500 or higher, the bidder is willing to purchase either 2 or 4 blocks, but not 3 blocks.

The graph below illustrates how the auction system interprets this all-or-nothing bid:



This all-or-nothing bid is applied depending on the level of excess demand at $5,500:

- If demand exceeds supply by more than 2 blocks, the bid is fully applied:
    - The bidder will hold 2 blocks and the clock continues increasing, up to $6,000.
- If demand exceeds supply by exactly 2 blocks, the bid is also fully applied:
    - The bidder will hold 2 blocks and the clock stops at $5,500.
- If demand exceeds supply by 1 block, the bid is not applied at all:
    - The bidder will hold 4 blocks and the clock continues increasing, up to $6000.
- If demand does not exceed supply, the bid is not applied at all:
    - The bidder will hold 4 blocks at a price below $5,500.

An all-or-nothing bid is either applied in full or is not applied at all; it is never applied partially. However, unlike the simple bid above, the all-or-nothing bid will not stop the clock if it cannot be applied. This leaves the possibility that the bidder may continue to hold 4 blocks as the price rises all the way to the current clock price. If the bidder wishes to prevent this, it has the option of associating a "backstop" with an all-or-nothing bid to reduce its demand.

4.2.1 Backstopping

If a bidder submits exactly one all-or-nothing bid for a reduction in quantity for a given product in a given round, the bidder has the option of *backstopping* at a higher price.[3] This means that, if the price reaches the specified backstop price, the bid may be applied in part (like a simple bid for the same quantity). If there is more than one all-or-nothing bid by a bidder for a given product in the round, backstopping is not permitted.[4]

Example: Bidder Places an All-or-nothing Bid Demanding 2 Blocks at $5,500 with a Backstop of $5,700

Suppose that in the prior round, the bidder demanded 4 blocks at that round's clock price of $5,000. In the current round, the clock price is $6,000, and the bidder places an all-or-nothing bid reducing its demand to 2 blocks at price $5,500 with a backstop at $5,700.

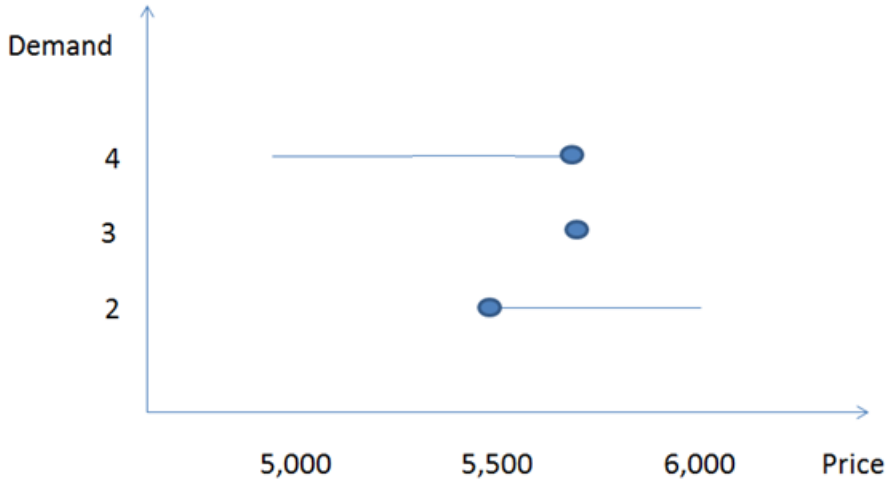
To the auction system, this bid means the following:

- If the price is below $5,500, the bidder is willing to purchase 4 blocks.
- If the price is between $5,500 and $5,700, the bidder is willing to hold either 2 or 4 blocks, but not 3 blocks.
- If the price is exactly $5,700, the bidder is willing to hold either 2, 3, or 4 blocks.
- If the price is above $5,700, the bidder is willing to hold only 2 blocks.

[3] Note backstopping an all-or-nothing bid at the same price as the all-or-nothing bid is equivalent to submitting a simple bid at that price for the same reduction in quantity.

[4] Permitting bidders to submit multiple all-or-nothing bids for the same product along with one or more backstop prices would significantly complicate the bid processing algorithm and the bidding experience.

The graph below illustrates how the auction system interprets this all-or-nothing bid with a backstop:



This all-or-nothing bid with backstopping is applied as described above, depending on the level of excess demand for the product at $5,500. However, if the all-or-nothing bid was not applied at $5,500 and the bidder continues to hold 4 blocks, the backstop indicates that at a price of $5,700, the bidder would accept a partial reduction in demand if the full bid cannot be applied. Therefore, in the example without the backstop bid, depending on the amount of excess demand, the bidder could have ended the round with processed demand of 4 blocks at the clock price of $6,000, but with the backstop bid, if the price rose above $5,700, the bidder would only have processed demand of 2 blocks.

4.3 Switch Bids

A *switch bid* is a request to move demand for up to n blocks in a given PEA from one category to another category. For instance, a bidder can request to switch up to two blocks from Category 1 to Category 2 in a given PEA. A bidder may wish to switch between categories depending on the relative prices of the two categories. Switch bids may be partially applied.

For each switch bid, the bidder specifies two products within the same PEA (a "from" product and a "to" product), a price for the "from" product, and a quantity for the "from" category; the bidder does not specify a quantity for the "to" category. In processing the switch bid, the auction system will determine the maximum number of blocks by which demand in the "from" category can be reduced (such that demand does not fall below supply) and will then switch an equal number of blocks to the "to" category.

Such a bid indicates that:

(1) At all prices that are strictly greater than p and less than or equal to the clock price (or the next price at which the bidder enters a bid involving the "from" product, whichever is lower), the bidder is willing to buy an exact quantity of q of the "from" product;

(2) At price p, the bidder is willing to buy any quantity between q and its processed demand of the "from" product; and

(3) The bidder is willing to buy up to a quantity of $d_t + (d_f - q)$ of the "to" product at the clock price, where d_t and d_f denote the bidder's processed demand for the "to" and "from" products respectively before the switch bid is applied.

If a switch bid for n blocks from product A to product B is partially applied, then the processed demand of the bidder for product A is reduced by m blocks and the processed demand of the bidder for product B is increased by m blocks, where $1 \leq m < n$. A switch bid for 1 block cannot be partially applied.

Example: Bidder Places a Switch Bid for 2 Blocks from Category 1 to Category 2 at $5,500

Suppose that in the prior round, the bidder demanded 4 blocks in Category 1 at that round's clock price of $5,000, and no blocks in Category 2. In the current round, the clock price for Category 1 blocks is $6,000, and the bidder places a bid to switch its demand by 2 blocks from Category 1 to Category 2 at price $5,500.

To the auction system, this bid means the following:

- If the price of Category 1 is below $5,500, the bidder is willing to purchase 4 blocks in Category 1.
- If the price of Category 1 is exactly $5,500, the bidder wishes to switch demand from Category 1 to Category 2 by up to 2 blocks.

Note that the bidder does not specify a quantity for Category 2 blocks in its bid. By placing the bid, the bidder indicates a willingness to purchase up to 2 blocks of Category 2 at the current clock price.

This switch bid is applied depending on the level of excess demand in Category 1 at $5,500:

- If demand exceeds supply by 2 or more blocks in Category 1, the bid is fully applied:
    - The bidder will hold 2 blocks in Category 1 and 2 blocks in Category 2.
- If demand exceeds supply by only 1 block in Category 1, the bid is partially applied:
    - The bidder will hold 3 blocks in Category 1 and 1 block in Category 2.
- If demand does not exceed supply, the bid is not applied at all:
    - The bidder will continue to hold 4 blocks in Category 1 and none in Category 2.

In all cases, the bidder's total demand across the categories is still 4. However, a switch bid may be applied partially in the sense that the number of blocks that are switched from Category 1 to Category 2 may be smaller than the maximum number of blocks that the bidder was willing to switch, depending on whether it is possible to reduce the bidder's demand for Category 1.

5 Processing Bids for a Regular Clock Round

This section describes bid processing in the regular clock rounds. The purpose of bid processing is to determine at the conclusion of a round of bidding, the processed demands for all bidders and the posted prices for all the products. This section provides a definition of *price points* and the details of how bid processing is done in a regular clock round.

5.1 Price Points

A *price point* is used to evaluate prices for bids within a round. The price point indicates the percentage of the distance from the posted price of the previous round and the clock price of the current round for the price of a bid. For example, the 0% price point refers to the last round's posted price, the 100% price point refers to the clock price, and the 50% price point refers to the average of the last round posted price and the clock price of this round. As another example, if the last round's posted price is $5,000 and the clock price of this round is $6,000, the price $5,100 corresponds to the 10% price point, and the price $5,500 corresponds to the 50% price point.

5.2 Processed Demands

For processing bids after each round, bids are prioritized in the following order: price point (from lowest to highest) across all bids, and then a bid-specific pseudorandom number (from lowest to highest). The priority ordering of bids remains the same throughout bid processing of a round (that is, only one pseudorandom number is associated with a given bid in a round).

The bid processing algorithm described here maintains a *queue* of all bids from the round that have not been applied in their entirety.[5] The highest-priority bid that has not yet been considered is processed. The algorithm checks whether the bid is fully acceptable using the most-recently-determined aggregate demand.[6] If the bid is fully acceptable, then it is applied (in its entirety). If the bid is not fully acceptable, then it is placed in the queue. If the bid is a simple bid or a switch bid, then the algorithm checks whether the bid is partially acceptable using the most-recently-determined aggregate demand. If the bid is partially acceptable, then it is partially applied (to the maximum extent possible).

Whenever a bid is applied either partially or in its entirety, the queue is re-tested to determine whether any bids in the queue have become fully acceptable and whether any simple bids or switch bids have become partially acceptable; if so, the highest-priority fully acceptable or partially acceptable bid is applied. When a bid has been applied in its entirety, it is removed from the queue; otherwise, it is kept in the queue so that the remaining part may be applied later. The re-testing of the queue is iterated until no bids remaining in the queue are fully acceptable and no simple or switch bids are partially acceptable. Then the next bid from the round is processed, until (1) all bids from the round have been processed, (2) no bids in the queue are fully acceptable and (3) no simple or switch bids in the queue are partially acceptable. At that point, all bids remaining in the queue are discarded.

The demands of a bidder following the processing of the bids for the round are referred to as its *processed demands*.

Example 1: Suppose that at the beginning of the round the bidder's processed demand for product A is 4 blocks and the bidder has submitted a simple bid for 0 blocks of product A. If the bid is not fully acceptable (because applying the bid in its entirety would lead to excess supply for product A), but it is possible to apply 1, 2, or 3 blocks of the reduction without creating excess supply for product A, then 3 blocks of the reduction will be applied. The bid for a quantity of 0 blocks for product A will be placed in the queue, so that the remaining one block may be applied later, if conditions permit after other bids have been processed.

If a bidder has backstopped an all-or-nothing bid, the bid processing algorithm uses a simple bid to represent the backstopped price.

Example 2: The bidder's processed demand at the beginning of the round is 4 blocks for product A. There are two other bidders, each with a processed demand of 4 blocks for product A at the beginning of the round. Thus, the aggregate demand for product A at the beginning of the round is 12 blocks. The supply for product A is 10 blocks. The bidder has submitted an all-or-nothing bid to reduce his demand for A to 0 blocks at price $1,500 and has backstopped that bid at price $1,700. The bid processing works as follows:

- The all-or-nothing bid is not fully acceptable (because it would lead to excess supply) and it thus placed in the queue.
- The system uses a simple bid for 0 blocks at price $1,700 to represent the backstopping of the all-or-nothing bid.

[5] The implementation does not necessarily require a queue, but this description is used here for expository ease.

[6] Note that a bid may be found not acceptable because of insufficient bidding eligibility if another bid submitted by the bidder, requesting a reduction, is not processed due to insufficient aggregate demand, thereby not freeing up bidding units needed to support the requested bid to increase demand for another product. This can occur even when the bidder's bidding activity overall does not exceed its eligibility.

- The simple bid is partially acceptable. The maximum extent to which it can be applied is for 2 blocks, since then the aggregate demand is equal to supply for product A. The simple bid is placed in the queue.
- If there are no other bids involving product A, then the bidder's processed demand for product A is 2 blocks at the end of the round at a price of $1,700.

5.3 Posted Prices

Let $P_{r,t}$ denote the clock price for product r in round t. After the bids of a regular clock round t have been processed, the *posted price* $p_{r,t}$ for product r in round t is set as follows:

- If aggregate demand (evaluated using the processed demands) exceeds supply, the posted price will be set equal to the clock price for the round ($p_{r,t} = P_{r,t}$).
- If aggregate demand (evaluated using the processed demands) is equal to the supply and at least one bid that included a reduction in the quantity demanded of that product was applied (either entirely or partially), the posted price ($p_{r,t}$) will be set to be equal to the product price associated with the highest price of any bid from round t that included a reduction in demand for the product and that was applied (either entirely or partially).
- If either of the following two conditions holds:
    - The aggregate demand (evaluated using the processed demands) is less than the supply[7]
    - The aggregate demand (evaluated using the processed demands) is equal to the supply and no bid that included a reduction in quantity for that product was applied (either as a whole or partially)

  Then the posted price will be set to be equal to the posted price of the previous round ($p_{r,t} = p_{r,t-1}$).

These rules ensure that the posted price will not be higher than the price of a simple bid or a switch that was not applied (either entirely or in part). However, the posted price could be higher than the price of an all-or-nothing that was not applied.

6 Checking Closing Conditions and Determining Next Round Type

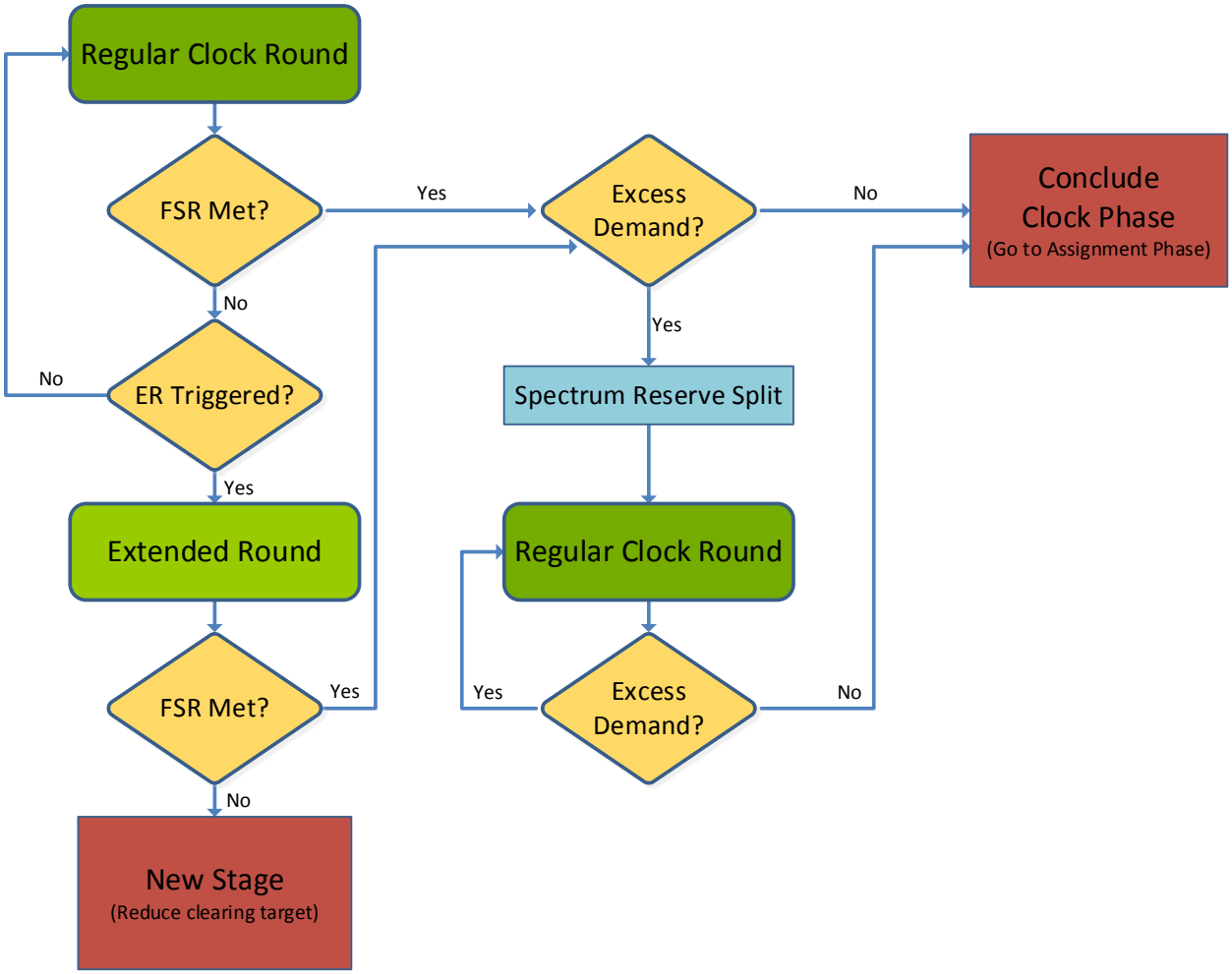
Once bid processing for a regular clock round is complete and the final stage rule has not previously been met, the auction system will determine if bidding will continue in the current stage and if so whether the next round will be a regular clock round or an extended round.[8] Bidding will not continue in the case where the final stage rule is met and there is no excess demand for any product. If the last round was an extended round, after bid processing the auction system will determine if the final stage rule was met and thus if bidding continues or if the auction moves to a new stage. If the last round was a regular clock round after the final stage rule has been met, after bid processing the auction system will determine if the closing conditions for the auction are met otherwise bidding will continue with a regular clock round.

[7] For example, because of insufficient demand at opening prices.

[8] An extended round is triggered when aggregate demand does not exceed supply in all Category 1 "high demand" PEA products and the final stage rule has not been met.

This process is illustrated in the following flowchart. Note that:

- FSR stands for Final Stage Rule
- ER stands for Extended Round
- "Excess demand?" stands for "Is demand strictly greater than supply for at least one product?"



6.1 Final Stage Rule Calculations

The final stage rule is based on two benchmarks: the price per MHz-pop benchmark X and the spectrum clearing benchmark T (in megahertz). The *Comment PN* proposes to set X to $1.25 per MHz-pop and to set T at 70 megahertz.

In each round, after all bids are processed, the current stage will be the final stage if both of the following two components are met:

(1) Average / Aggregate Prices in Forward Auction Component:

a) For clearing targets at or below T, the average price per MHz-pop for Category 1 "high-demand" PEA products is greater than or equal to X.

This clause of the first component of the final stage rule is satisfied if and only if the following inequality holds:

$$\frac{\sum_{i \in F} p_i \cdot q_i}{10 \sum_{i \in F} pop_i \cdot s_i} \geq X$$

Where:

- F denotes the set of Category 1 "high-demand" PEA products
- N denotes the set of all products
- p_i is the posted price for product i
- s_i is the supply (number of blocks) for product i
- q_i is the smaller of aggregate demand and supply for product i
- pop_i is the population of the PEA that corresponds to product i

OR

b) For all spectrum clearing targets above T, the current total proceeds of the forward auction is greater than or equal to the product of X, T, and the total number of pops for the "high-demand" PEAs in this stage. In particular, using the notation above, this clause of the first component of the final stage rule is satisfied if and only if the following inequality holds:

$$\sum_{i \in N} p_i \cdot q_i \geq X \cdot T \cdot \sum_{i \in F} pop_i$$

Note that the sum on the left hand side includes all products whereas the sum on the right hand side only includes the "high-demand" PEAs.

(2) Covering Costs Component:

The net forward auction revenue, which is the gross forward auction revenue incorporating discounts for impairments within a product less small business bidding credits, is sufficient to meet the sum of the following four expenses:

- Payments to winning bidders in the reverse auction
- The Commission's administrative costs of the auction
- An estimate of broadcaster relocation costs
- Any Public Safety Trust Fund amounts still needed to provide funding for FirstNet

Let C denote the sum of the aforementioned expenses.

The second component of the final stage rule incorporates both bidding credits and discounts for impairments within a product, whereas the first component does not. Bidding credits and impairment discounts are incorporated with a worst case calculation in the second component. In particular, the net revenue of a product will be calculated as the lowest possible revenue that could be expected given the bidders that currently have strictly positive processed demand for that product, their associated bidding credits, and the impairment discount of each block. This is the revenue that would arise if bidders with the largest bidding credits were assigned the least impaired blocks.

To give a specific formula for the gross revenue of product i when taking into account bidding credits and impairment discounts, we use the following notation:

- $d_{j,i}$ is the processed demand of bidder j for product i
- d_i is the aggregate processed demand for product i
- s_i is the supply for product i
- p_i is the posted price for product i
- y_j is equal to 1 minus the bidding credit of bidder j. For example, if bidder j has no discount, then $y_j = 1$. If bidder j has a 25% discount, then $y_j = 0.75$.
- $x_{i,l}$ is equal to 1 minus the impairment discount for block l of product i (see Section 3.3)

Now consider product i. Bidders with strictly positive processed demand for product i are ordered in increasing order of y_j. Suppose that there are n such bidders. The blocks of product i are ordered in increasing order of $x_{i,l}$.

The (worst case) net revenue from product i is equal to $p_i \cdot \delta_i$, where δ_i adjusts for bidding credits and impairments and is defined as follows:

$$\delta_i \equiv \sum_{j=1}^{n} y_j \cdot \sum_{l=1+\sum_{k=1}^{j-1} d_{k,i}}^{\min(s_i, \sum_{k=1}^{j} d_{k,i})} x_{i,l}$$

To explain the formula, first consider the case that for product i supply is greater than or equal to aggregate demand. In this case, the formula assumes that the bidder with the largest bidding credit (Bidder 1) gets the $d_{1,i}$ least impaired blocks, the bidder with the second largest bidding credit (Bidder 2) gets the $d_{2,i}$ next least impaired blocks, etc.

In the case that supply of product i is strictly smaller than aggregate demand, then the formula follows the same process but stops "assigning" blocks to bidders when there are no more available blocks.

For example, if supply is 10 and there are 3 bidders each with a processed demand of 4 for that product, then the formula assumes that:

- Bidder 1 gets the 4 least impaired blocks
- Bidder 2 gets the 4 next least impaired blocks
- Bidder 3 gets the 2 most impaired blocks

The second component of the final stage rule is satisfied if the following inequality holds:

$$\sum_{i \in N} p_i \cdot \delta_i \geq C$$

7 Setting Up the Next Round

If the auction system determines that the closing conditions have not been met in a round then the system continues to set up the next round. For each round the system must calculate for each bidder its eligibility for the round based on the activity associated with its processed bids in the previous round. The clock prices for the new round must also be calculated. These prices will be calculated differently depending on whether the round is a regular clock round or an extended round. This section provides the details of these calculations.

7.1 Processed Activity and Next Round Eligibility

A bidder's *processed activity* for a round is the total number of bidding units associated with the bidder's *processed demand* after the bid processing is complete for that round. The bidder's eligibility for a new round is calculated based on its processed activity in the previous round.

Specifically, a bidder's eligibility for round t is calculated according to the following formula:

$$Eligibility(t) = \min\left\{ Eligibility(t-1), \frac{ProcActivity(t-1)}{ActivityRequirement} \right\}$$

Where:

- $Eligibility(t)$ denotes the bidder's eligibility in round t
- $ProcActivity(t-1)$ denotes the bidder's *processed activity* from round $t-1$
- $ActivityRequirement$ denotes the activity requirement. This is the percentage (up to 100%) set by the Commission.

7.2 Clock Prices for Regular Round

Once the posted prices for a round are calculated and the system has determined that the next round will be a regular clock round, the clock price for each product in the round is calculated as the product's posted price from the previous round multiplied by an increment.

Specifically, the clock price $P_{r,t}$ for product r in round t is calculated as:

$$P_{r,t} = (p_{r,t-1}) \cdot (1+y) \text{ rounded up to the nearest \$1,000}$$

Where:

- y denotes the price increment for round t
- $p_{r,t-1}$ denotes the posted price for product r in round $t-1$

Note that this calculation applies to every product, irrespective of whether the product is in excess demand.

7.3 Clock Prices for Extended Round

If the auction system has determined that the next round will be an extended round, the system will calculate the clock price for each product in the extended round. Similar to a regular round, the clock price for a product in an extended round is calculated as the product's posted price from the previous round multiplied by an increment. However, the price increment in an extended round is set so that the price increase is some amount greater than the amount needed to reach the final stage rule. In the Comment PN, we propose to set this amount to be 33 percent greater than the amount needed. The same percentage of price increase will be applied to all products that are part of the extended round.

The specific formula detailing how the increment is calculated is given below using the following notation:

- w denotes the amount above the increment needed to meet the final stage rule
- F denotes the set of Category 1 "high-demand" PEA products
- N denotes the set of all products
- p_i denotes the posted price for product i
- s_i denotes the supply (number of blocks) for product i
- q_i denotes the smaller of aggregate demand and supply for product i
- pop_i denotes the population of the PEA that corresponds to product i

- C denotes the sum of the expenses required for the second component of the final stage rule
- X denotes the price per MHz-pop benchmark
- T denotes the spectrum clearing benchmark in MHz

The amount needed to meet the final stage rule will be the greater of the amount needed to meet the Average / Aggregate Prices component and the amount needed to meet the Covering Costs component of the final stage rule. The increment for the extended round will be set to be equal to:

$$w \cdot \max\{min\{z_{1a}, z_{1b}\}, z_2\}$$

Where:[9]

- $z_{1a} = 0$ if the first clause of the first component of the final stage rule is satisfied, and

  $z_{1a} = \frac{X \cdot 10 \sum_{i \in F} pop_i \cdot s_i}{\sum_{i \in F} p_i \cdot q_i} - 1$ otherwise.

- $z_{1b} = 0$ if the second clause of the first component of the final stage rule is satisfied, and

  $z_{1b} = \frac{X \cdot T \sum_{i \in F} pop_i - \sum_{i \in N \setminus F} p_i \cdot q_i}{\sum_{i \in F} p_i \cdot q_i} - 1$ otherwise.

- $z_2 = 0$ if the second component of the final stage rule is satisfied, and

  $z_2 = \frac{C - \sum_{i \in N \setminus F} p_i \cdot \delta_i}{\sum_{i \in F} p_i \cdot \delta_i} - 1$ otherwise (δ_i is defined in Section 6.1)

8 Bidding and Processing Bids for an Extended Round

In an extended round, bidders can only bid on Category 1 blocks in "high-demand" PEAs for which aggregate processed demand does not exceed supply. For the purposes of this section, we refer to such products as *ER products*. All other products are referred to as *non-ER products*.

Bids are processed sequentially in the following order: price point (from lowest to highest) across all bids,[10] and then a bid-specific pseudorandom number (from lowest to highest). If a bid for product r at price p is processed, the price for product r is set to be equal to p. The prices of products for which no bid has been processed so far continue increasing. During the extended round, processing ends if, at any time, the final stage rule is met given the current prices and the processed demand at the beginning of the round. The prices at which the final stage rule is met do not necessarily correspond to a price point with a bid.

For purposes of calculating whether the final stage rule is met, non-ER products are factored in using the aggregate demand and the posted prices from the previous round.

If the final stage rule is met, the prices at which the final stage rule is met are called the *extended round clearing prices*.

If the final stage rule is not met, the prices that arise after having processed all bids of the extended round are called the *extended round processed prices*. In particular, for a product for which a reduction bid was processed during the extended round, the extended round processed price is equal to the price of the bid

[9] If demand is less than supply for some Category 1 "high-demand" PEA products at the time that the extended round is triggered, the formulas will be adjusted to take that into account by removing those PEAs from consideration where applicable.

[10] See Section 5.1 for a definition of price point.

associated with the reduction. For a product for which there was no reduction bid during the extended round, the extended round processed price is equal to its clock price.

Example 1: There are three products (A, B, and C). For all three products, in the extended round the last round's posted price is $1,000 and the clock price is $1,200. There is a bid to reduce demand for product A by one at price $1,050 (*i.e.*, the 25% price point), and a bid to reduce demand for product B by one at price $1,150 (*i.e.*, the 75% price point). There is no reduction bid for product C. If 50% is the lowest price point at which the final stage rule is met, then the extended round clearing prices are: $1,050 for product A, $1,100 for product B and $1,100 for product C (corresponding to the 50% price point). If the final stage rule is not met during the extended round, then the extended round processed prices are $1,050 for product A, $1,150 for product B, and $1,200 for product C.

If the final stage rule is met during the extended round, then:

- The processed demand of each bidder is set to be equal to its processed demand at the start of the extended round (reductions in demand are not applied)
- For every ER product, the posted price is set to be equal to its extended round clearing price
- For every non-ER product, the posted price for the extended round is equal to the posted price of the previous round
- If there is still excess demand for any products, market-based spectrum reserve is applied for Category 1 products and the forward auction is run until completion after the extended round. In this case, in every round after the extended round, bidding will be open on all products (including the "high-demand" PEAs).

If, after processing all bids of the extended round, the final stage rule is not met, a new stage commences and the reductions of bids that were processed during the extended round are applied; these reductions carry over to the next regular round of the forward auction (*i.e.*, the first round of the next stage). Note that this means that for a given product, only one bidder's demand reduction will be processed and thus carried over to the next round. If multiple bidders bid for a reduction at the same price for the same product, the determination of which bidder is reduced is based on pseudorandom numbers. For an ER product, the posted price is set to be equal to its extended round processed price. For non-ER products, the posted price for the extended round is equal to the posted price of the previous round.

Example 2: In the extended round, for product A the clock price is $1,200 and the last round posted price is $1,000. The processed demand of bidder 1 for product A at the beginning of the extended round is 2 blocks. Bidder 1 had submitted a bid to reduce his demand for A by one at price $1,050. Suppose that this bid is processed. Then, the price of product A will stop increasing, so the posted price for product A in the extended round will be $1,050. If the final stage rule is met during the extended round, then the processed demand of bidder 1 will be 2 blocks. On the other hand, if the final stage rule is not met during the extended round, then a new stage starts and the processed demand of bidder 1 for product A is 1 block.

APPENDIX H

Forward Auction Assignment Phase

1 Introduction

There are considerable benefits to the overall incentive auction from using generic blocks for each product category in the forward auction (as explained in Appendix G). Capturing those benefits requires conducting the forward auction in two phases: a clock phase, in which the auction determines the number of licenses of each product type that various bidders will acquire, and an assignment phase, in which the auction determines the particular frequency blocks to be assigned to each winner. This appendix details the procedures of the assignment phase.

The proposed assignment phase has been designed to promote two major goals. One of these is to make bidding relatively easy in what is an inherently complex allocation problem. Our proposal promotes simplicity in several ways. First, to reduce the total number of bids that each bidder must make, it groups together PEAs with similar winners to the maximum extent possible. Second, to simplify bidding strategy for bidders, it adopts a *second-price* type of pricing rule that encourages bidders to bid according to their actual values for different blocks. Third, a winner need not make any additional payment to acquire valuable spectrum. This makes bidding easier not only in the assignment phase of the forward auction but in the clock phase as well, because bidders in the clock phase will know that they can win blocks of spectrum for the prices bid in the clock phase. Finally, after being grouped together, blocks in the assignment phase are offered in carefully chosen sequences to avoid the additional complexity that would come from combinatorial bidding across PEAs.

A second, equally important goal is to promote efficient and intensive use of the spectrum. To achieve that, proposed assignment phase rules give highest priority to assigning to the extent possible a set of contiguous frequencies to each bidder within each PEA.

2 Assignment Rounds

The assignment phase consists of a series of *assignment rounds.* In each assignment round, winning bidders from the clock phase that have a preference for specific frequencies submit sealed bids for specific frequency licenses in an *assignment phase market*; an assignment phase market is either a single PEA or a collection of PEAs. Once an assignment round concludes, an optimization is solved to assign specific frequency licenses in the assignment phase market to each winning bidder from the clock phase.

For the purposes of the assignment phase, the reserved and the unreserved spectrum will be considered one product. Thus, there are at most two products per PEA(s): Category 1 blocks and Category 2 blocks.

In an assignment round, a bidder is allowed to bid for a set of licenses if that set corresponds to what the bidder won in the clock phase for that PEA(s). For instance, if a bidder won two Category 1 blocks and one Category 2 block in the clock phase, then it is only allowed to bid on sets of licenses that contain exactly two Category 1 blocks and one Category 2 block. A bidder bids on a set of licenses by specifying a bid value for that set.

A winner of the clock phase is not required to bid in the assignment phase. In particular, such a bidder may not wish to bid if the bidder is indifferent among all assignments that it may get. The auction system will enter a bid value of zero for any set for which a bidder submits no bid.

2.1 Assignment Phase Markets

The Comment PN proposes to conduct bidding for specific frequencies grouped by different geographic areas in each assignment round, but to consider separately the set of “high-demand” PEAs. Within each group, to the extent that the set of clock phase winning bidders and their blocks are consistent, the

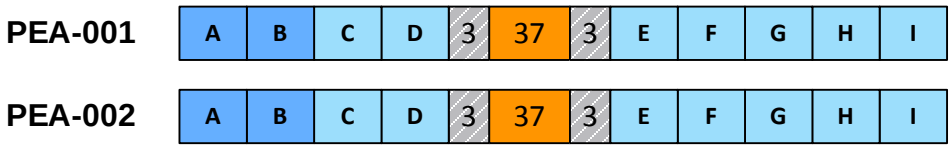
Comment PN proposes to conduct the bidding jointly for those areas. A set of PEAs will be "merged" into one *assignment phase market* for:

(i) "High-demand" PEAs with the same number of Category 1 and Category 2 blocks, where the same frequency blocks are in Category 2, and where the same bidders won the same quantities of Category 1 and Category 2 blocks.

(ii) All PEAs other than the "high-demand" PEAs in a Regional Economic Area Grouping ("REAG")[1] with the same number of Category 1 and Category 2 blocks, where the same frequency blocks are in Category 2, and where the same bidders won the same quantities of Category 1 and Category 2 blocks.

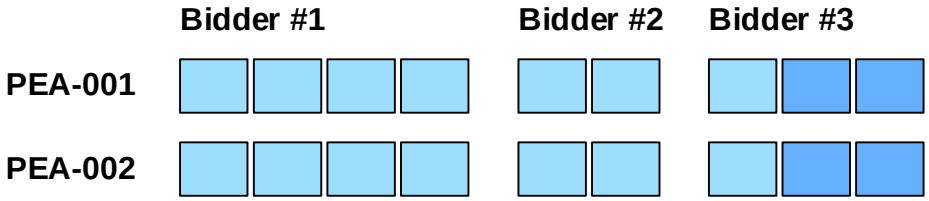
Because of this merging of PEAs, the number of assignment phase markets will be smaller than or equal to the number of PEAs. For PEAs that cannot be merged, separate assignment rounds will be conducted.

Example 1: Merging PEA-001 and PEA-002



The band plan is 114 MHz (i.e., blocks A-I). Suppose that PEA-001 and PEA-002 are both "high-demand" PEAs. In these PEAs:

- Blocks A and B are Category 2 blocks, and the remaining blocks are Category 1.
- Seven Category 1 blocks and two Category 2 blocks were won in each PEA.
- Bidder #1 won four Category 1 blocks in both PEAs.
- Bidder #2 won two Category 1 blocks in both PEAs.
- Bidder #3 won one Category 1 block and two Category 2 blocks in both PEAs.



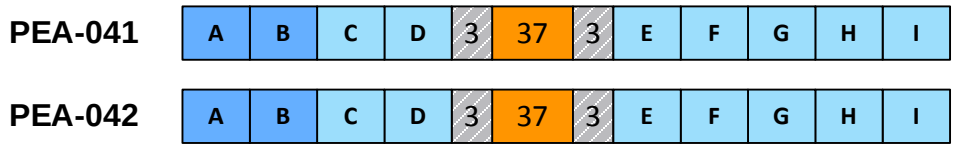
Then PEA-001 and PEA-002 are merged and treated as a single combined market for the assignment phase.

We may also combine a set of markets if conditions (ii) and (iii) are satisfied and:

- The identities of the winners and the number of blocks of each product that they have won in the clock phase are sufficiently similar in each of the combined markets

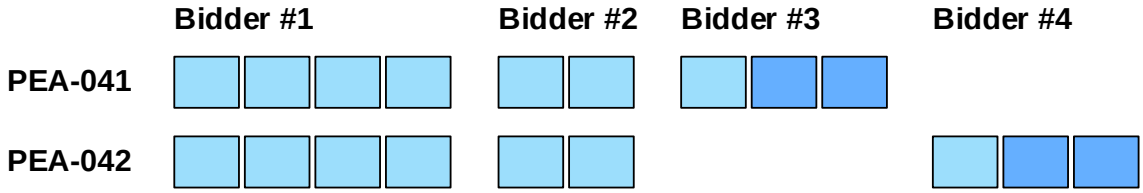
[1] The six Regional Economic Area Groupings (REAG) are: Northeast, Southeast, Great Lakes, Mississippi Valley, Central, and West. Each of the remaining REAGs (i.e., Alaska, Hawaii, Puerto Rico and US Virgin Islands, Guam and the Northern Mariana Islands, American Samoa, and the Gulf of Mexico) will be merged in one of the 6 main REAGs.

Example 2: Merging PEA-041 and PEA-042



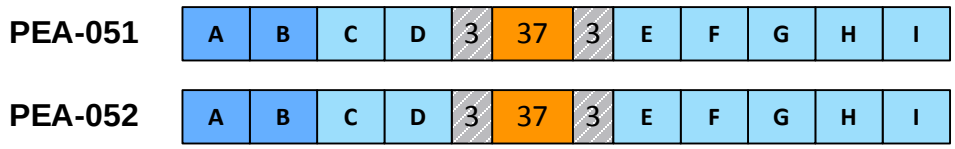
The band plan is 114 MHz (i.e., blocks A-I). Suppose that PEA-041 and PEA-042 are not "high-demand" PEAs and are both located in the same REAG. In these PEAs:

- Blocks A and B are Category 2, and the remaining blocks are Category 1.
- Seven Category 1 blocks and two Category 2 blocks were won in each PEA.
- Bidder #1 won four Category 1 blocks in both PEAs.
- Bidder #2 won two Category 1 blocks in both PEAs.
- Bidder #3 won one Category 1 block and two Category 2 blocks in PEA-041.
- Bidder #4 won one Category 1 block and two Category 2 blocks in PEA-042.



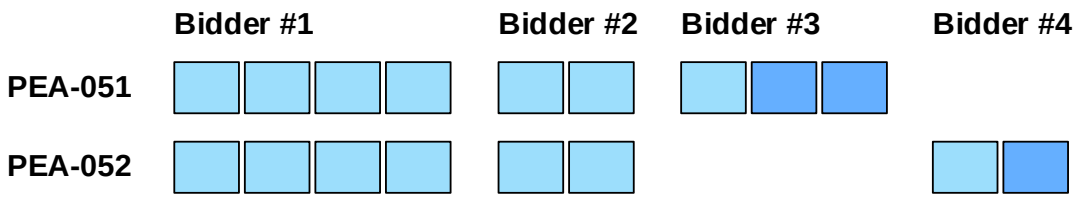
In this example, we may merge PEA-041 and PEA-042 and treat them as a single combined market for the assignment phase.

Example 3: Merging PEA-051 and PEA-052



The band plan is 114 MHz (i.e., blocks A-I). Suppose that PEA-051 and PEA-052 are not "high-demand" PEAs and are both located in the same REAG. In these PEAs:

- Blocks A and B are Category 2, and the remaining blocks are Category 1.
- Seven Category 1 blocks and two Category 2 blocks were won in PEA-051
- Seven Category 1 blocks and one Category 2 block were won in PEA-052, leaving one Category 2 block unsold.
- Bidder #1 won four Category 1 blocks in both PEAs.
- Bidder #2 won two Category 1 blocks in both PEAs.
- Bidder #3 won one Category 1 block and two Category 2 blocks in PEA-051.
- Bidder #4 won one Category 1 block and one Category 2 block in PEA-052.



In this example, we may merge PEA-051 and PEA-052 and treat them as a single combined market for the assignment phase.

2.2 Prioritization Order of Assignment Rounds

Assignment rounds for different assignment phase markets will be ordered in descending order of weighted-pops, first conducting rounds for all "high-demand" PEAs, and then among the remaining markets within each REAG.

Bidders will be informed about the sequencing of assignment rounds before bidding for the assignment phase starts.

2.3 Sequential and Simultaneous Assignment Rounds

The assignment phase begins with assignment rounds, one at a time, for each assignment phase market that includes "high-demand" PEAs (according to the prioritization specified above). After the "high-demand" PEAs are exhausted, we will conduct assignment rounds in parallel for each of the six REAGs. Within each REAG, these are conducted one assignment phase market at a time, sequentially. The rounds continue until all assignment phase markets are assigned.

The purpose of running rounds for the six REAGs in parallel is to economize on time. Since the markets that are assigned in parallel are not "high-demand" PEAs and are located in different parts of the country, this process should be workable for bidders.

3 Assignment Phase Efficiency Objectives

Because it may not be possible to guarantee contiguous assignments to all bidders within a market, the Comment PN proposes that assignments attempt to satisfy the following objectives in a given market:

(1) Maximize the number of bidders that are assigned at least two contiguous spectrum blocks.

(2) Minimize the number of stranded blocks across all bidders. Block j is *stranded* for bidder i if (i) bidder i won two or more blocks in the clock phase for that market, (ii) bidder i is assigned block j, and (iii) block j is not contiguous with the bidder's other winnings in the market.

(3) Maximize the number of bidders whose blocks in a market are all contiguous with one another.

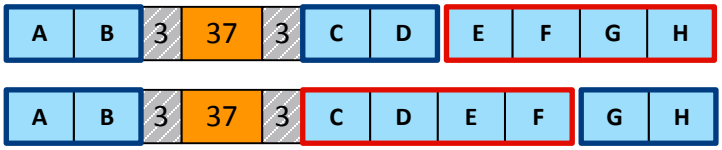
These objectives will be optimized lexicographically in the order that they are given. In particular, Step 1 is to maximize the number of bidders that are assigned at least two contiguous blocks. Step 2 is to minimize the number of stranded blocks among all allocations that optimize the first objective. Step 3 is to maximize the number of bidders whose blocks in a market are all contiguous with one another among all allocations that optimize the objectives of Step 1 and Step 2.

3.1 Examples

Example 1: Contiguity in 108 MHz Clearing

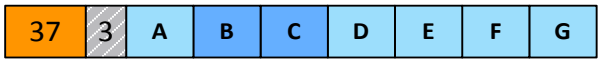
In this example, the clearing target in the final stage is 108 MHz. As a result, two blocks (A and B) will be located below Channel 37, and six blocks (C through H) will be located above Channel 37. Thus, the available blocks in a PEA with no Category 2 blocks would be as follows:

If there are two winners from the clock phase and each has won four blocks, it will not be possible to give each bidder four contiguous blocks. The auction system will be able to fully satisfy the first objective (to give each bidder at least two contiguous blocks) and the second objective (to prevent any assignments that strand single blocks). However, the third objective cannot be fully satisfied (to assign both bidders only contiguous blocks) due to the presence of Channel 37. Thus, the possible assignments are that one bidder would be assigned blocks ABCD and the other blocks EFGH, or that one bidder would be assigned blocks ABGH and the other blocks CDEF:

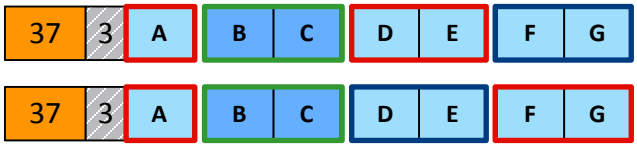


Example 2: Contiguity in 84 MHz Clearing

In this example, the clearing target in the final stage is 84 MHz. Here, all blocks (A through G) will be located above Channel 37. However, suppose that in a PEA, two blocks (B and C) are Category 2, while the rest are Category 1 blocks. The available blocks in the PEA would be as follows:



If there are three winners from the clock phase, where one bidder has won three Category 1 blocks, one bidder has won two Category 1 blocks, and one bidder has won two Category 2 blocks, it will not be possible to assign each bidder only contiguous blocks. The first objective (to assign every bidder at least two contiguous blocks) can be satisfied in full, but the second objective cannot be fully satisfied because the bidder that won three Category 1 blocks can only be assigned combinations that included the stranded A block.[2] Thus, the bidder that won three Category 1 blocks could be assigned either blocks ADE or AFG, the bidder that won two Category 1 blocks could be assigned either blocks FG or blocks DE, and the bidder that won two Category 2 blocks could only be assigned blocks BC:



3.2 Mathematical Formulation of Steps 1, 2, and 3

In the mathematical formulations below, the index i is used to denote a bidder and the index j is used to denote a block. Moreover, we use the following notation:

- N denotes the set of bidders in that assignment round, that is, the set of winners for the corresponding market in the clock phase
- N_2 denotes the set of bidders in that assignment round that have won at least two blocks in that assignment phase market across both categories
- K denotes the set of blocks that were available for sale in that market. For instance, K may be {A, B, C, D, E, F, G, H} or {A, C, D, E, F, G, H}. The latter could represent a case where block B was not auctioned at all (in that market) because it was too impaired.

[2] Since in this example it is possible to satisfy the first objective in full, the stranded A block must be assigned to the bidder that won three Category 1 blocks, because the first objective cannot still be satisfied if the stranded block is assigned to the bidder that won two Category 1 blocks.

- K_U denotes the set of blocks in Category 1
- K_I denotes the set of blocks in Category 2
- q_i^U denotes the number of blocks in Category 1 that bidder i has won in that assignment phase market.
- q_i^I denotes the number of blocks in Category 2 that bidder i has won in that assignment phase market.
- q_i denotes the total number of blocks that bidder i has won in that assignment phase market. That is, $q_i = q_i^U + q_i^I$.
- C denotes the set of pairs of blocks that are contiguous in that assignment phase market. In particular, $(j,k) \in C$ if and only if blocks j and k are contiguous.

Variable Definitions:

$x_{i,j}$ is a binary decision variable which has a value of 1 if bidder i is assigned block j and 0 otherwise. This variable is defined for all bidders $i \in N$ and all blocks $j \in K$.

z_i is a binary decision variable which at the optimal solution has a value of 1 if bidder i is assigned at least two contiguous blocks and 0 otherwise. This variable is defined only for bidders $i \in N_2$, that is, for bidders that won at least two blocks in the allocation phase in that market.

Model Formulation for Step 1:

$$max \ A_1 = \sum_{i \in N_2} z_i$$

Subject to

$\sum_{j \in K_U} x_{i,j} = q_i^U$	$\forall i \in N$	(1)
$\sum_{j \in K_I} x_{i,j} = q_i^I$	$\forall i \in N$	(2)
$\sum_{i \in N} x_{i,j} \leq 1$	$\forall j \in K$	(3)
$x_{i,j} \in \{0,1\}$	$\forall i \in N, \forall j \in K$	(4)
$z_i \leq \sum_{(j,k) \in C} x_{i,j} \cdot x_{i,k}$	$\forall i \in N_2$	(5)
$z_i \in \{0,1\}$	$\forall i \in N_2$	(6)

The objective in this optimization problem is to maximize the number of bidders that are assigned at least two contiguous blocks.

Explanation of Constraints:

- Constraint (1) ensures that each bidder is assigned the number of Category 1 blocks that it won during the clock phase.
- Constraint (2) ensures that each bidder is assigned the number of Category 2 blocks that it won during the clock phase.
- Constraint (3) ensures that each block is assigned to at most one bidder.
- Constraint (4) states that each decision variable $x_{i,j}$ can be either equal to 0 or 1.

- Constraints (5) and (6) along with the objective function imply that at an optimal solution $z_i = 1$ if bidder i is assigned at least two contiguous blocks and $z_i = 0$ if bidder i is not assigned any contiguous blocks. In particular:
    - If bidder i is not assigned any contiguous blocks then $\sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k} = 0$, and therefore (5) and (6) imply that $z_i = 0$.
    - If bidder i is assigned at least two contiguous blocks, then $\sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k} \geq 1$, and therefore (5) and (6) imply that $z_i \in \{0,1\}$. Since the objective is to maximize the sum of z_i across all bidders in N_2, in this case at the optimal solution $z_i = 1$.

After solving the optimization problem described above as Step 1, the algorithm proceeds to Step 2. In Step 2, the goal is to minimize the number of stranded blocks among all allocations that optimize the first objective.

Additional Variable Definitions for Step 2:

$y_{i,j}$ is a binary decision variable which at the optimal solution has a value of 1 if block j is stranded for bidder i and 0 otherwise. In particular, $y_{i,j} = 1$ if and only if bidder $i \in N_2$ is assigned block j and bidder i is not assigned any block that is contiguous to block j. This variable is defined for all bidders $i \in N_2$ and all blocks $j \in K$.

Model Formulation for Step 2:

$$min\ A_2 = \sum_{i\in N_2} \sum_{j\in K} y_{i,j}$$

Subject to

$\sum_{j\in K_U} x_{i,j} = q_i^U$	$\forall i \in N$	(1)
$\sum_{j\in K_I} x_{i,j} = q_i^I$	$\forall i \in N$	(2)
$\sum_{i\in N} x_{i,j} \leq 1$	$\forall j \in K$	(3)
$x_{i,j} \in \{0,1\}$	$\forall i \in N, \forall j \in K$	(4)
$z_i \leq \sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k}$	$\forall i \in N_2$	(5)
$z_i \in \{0,1\}$	$\forall i \in N_2$	(6)
$\sum_{i\in N_2} z_i \geq A_1$		(7)
$y_{i,j} \geq x_{i,j} - \sum_{k:(j,k)\in C} x_{i,k}$	$\forall i \in N_2,\ \forall j \in K$	(8)
$y_{i,j} \in \{0,1\}$	$\forall i \in N_2, \forall j \in K$	(9)

The objective in this optimization problem is to minimize the number of stranded blocks. Constraints (1)–(6) are the same as in Step 1.

Explanation of New Constraints:

- Constraint (7) states that the number of bidders that are assigned at least two contiguous blocks must be greater than or equal to the result of the first optimization.
- Constraints (8) and (9) along with the objective function imply that at an optimal solution $y_{i,j} = 1$ if block j is a stranded block for bidder i, and $y_{i,j} = 0$ if block j is not a stranded block for bidder i. In particular:

- If block j is a stranded block for bidder i, then $x_{i,j} = 1$ (that is, bidder i is assigned block j) and $\sum_{k:(j,k)\in C} x_{i,k} = 0$ (that is, bidder i is not assigned any block that is contiguous to block j). These imply that $x_{i,j} - \sum_{k:(j,k)\in C} x_{i,k} = 1$. Therefore, $y_{i,j} = 1$, because of (8) and (9).
- If block j is not a stranded block for bidder i, then either (i) $x_{i,j} = 0$ (that is, bidder i is not assigned block j) or (ii) $x_{i,j} = 1$ and $\sum_{k:(j,k)\in C} x_{i,k} \geq 1$ (that is, bidder i is assigned block j and at least one block that is contiguous to block j). In either case, $x_{i,j} - \sum_{k:(j,k)\in C} x_{i,k} \leq 0$. Then, (8) and (9) imply that $y_{i,j} \in \{0,1\}$. Since the objective is to minimize the sum of $y_{i,j}$ across all bidders in N_2 and all blocks in K, in this case at the optimal solution $y_{i,j} = 0$.

After solving the optimization problem described above as Step 2, the algorithm proceeds to Step 3. In Step 3, the goal is to maximize the number of bidders whose blocks are all contiguous with one another among all allocations that optimize Step 2.

Additional Variable Definitions for Step 3:

w_i is a binary decision variable which at the optimal solution has a value of 1 if all the blocks assigned to bidder i are contiguous and 0 otherwise. This variable is defined for all bidders $i \in N_2$.

Model Formulation for Step 3:

$$max \ A_3 = \sum_{i\in N_2} w_i$$

Subject to

$\sum_{j\in K_U} x_{i,j} = q_i^U$	$\forall i \in N$	(1)
$\sum_{j\in K_I} x_{i,j} = q_i^I$	$\forall i \in N$	(2)
$\sum_{i\in N} x_{i,j} \leq 1$	$\forall j \in K$	(3)
$x_{i,j} \in \{0,1\}$	$\forall i \in N, \forall j \in K$	(4)
$z_i \leq \sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k}$	$\forall i \in N_2$	(5)
$z_i \in \{0,1\}$	$\forall i \in N_2$	(6)
$\sum_{i\in N_2} z_i \geq A_1$		(7)
$y_{i,j} \geq x_{i,j} - \sum_{k:(j,k)\in C} x_{i,k}$	$\forall i \in N_2, \forall j \in K$	(8)
$y_{i,j} \in \{0,1\}$	$\forall i \in N_2, \forall j \in K$	(9)
$\sum_{i\in N_2} \sum_{j\in K} y_{i,j} \leq A_2$		(10)
$w_i \leq \frac{1}{q_i - 1} \sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k}$	$\forall i \in N_2$	(11)
$w_i \in \{0,1\}$	$\forall i \in N_2$	(12)

The objective in this optimization problem is to maximize the number of bidders whose blocks are all contiguous with one another. Constraints (1)–(9) are the same as in Step 2.

Explanation of New Constraints:

- Constraint (10) states that the number of stranded blocks must be less than or equal to the result of the second optimization.
- Constraints (11) and (12) along with the objective function imply that at an optimal solution $w_i = 1$ if all blocks assigned to bidder i are contiguous and $w_i = 0$ otherwise. In particular:
  - If not all blocks assigned to bidder i are contiguous with one another, then $\sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k} \leq q_i - 2$. Then, (11) and (12) imply that $w_i = 0$.
  - If all blocks assigned to bidder i are contiguous with one another, then $\sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k} = q_i - 1$. Then, (11) and (12) imply that $w_i \in \{0,1\}$. Since the objective is to maximize the sum of w_i across all bidders in N_2, in this case at the optimal solution $w_i = 1$.

4 Winner Determination Problem

The assignment is determined by maximizing the sum of bid values subject to all of the assignment phase objectives being maximized lexicographically. The maximization problem is called the Winner Determination Problem (WDP). The solution to WDP is selected as the assignment. Ties, if any, are broken by including pseudo-random numbers in the optimization.

To mathematically formulate WDP, we use the following notation in addition to the notation of Section 3:

- S denotes a set of blocks. For each block j, S_j denotes the indicator variable of whether block j is in set S. That is, $S_j = 1$ if $j \in S$, and $S_j = 0$ if $j \notin S$.
- $b_i(S)$ denotes the bid value of bidder i
- b denotes the set of bid values

Additional Variable Definitions for WDP:

$X_i(S)$ is a binary decision variable which has a value of 1 if exactly the blocks of set S are assigned to bidder i and 0 otherwise. This variable is defined for all bidders $i \in N$.

Winner Determination Problem:[3]

$$\max \; wd(N,b) = \sum_{i\in N} \sum_{S\subseteq K} b_i(S) \cdot X_i(S)$$

Subject to

$\sum_{j\in K_U} x_{i,j} = q_i^U$	$\forall i \in N$	(1)
$\sum_{j\in K_I} x_{i,j} = q_i^I$	$\forall i \in N$	(2)
$\sum_{i\in N} x_{i,j} \leq 1$	$\forall j \in K$	(3)
$x_{i,j} \in \{0,1\}$	$\forall i \in N, \forall j \in K$	(4)
$z_i \leq \sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k}$	$\forall i \in N_2$	(5)

[3] At the optimal solution, (i) $z_i = 1$ if and only if bidder i is assigned at least two contiguous blocks, (ii) $y_{i,j} = 1$ if and only if block j is stranded for bidder i, and (iii) $w_i = 1$ if and only if bidder i is assigned blocks that are all contiguous to one another. If either of these conditions were violated, that would imply that A_1, A_2, and A_3 do not represent the optimal values of the assignment phase objectives when optimizing lexicographically.

$z_i \in \{0,1\}$	$\forall i \in N_2$	(6)
$\sum_{i \in N_2} z_i \geq A_1$		(7)
$y_{i,j} \geq x_{i,j} - \sum_{k:(j,k)\in C} x_{i,k}$	$\forall i \in N_2, \forall j \in K$	(8)
$y_{i,j} \in \{0,1\}$	$\forall i \in N_2, \forall j \in K$	(9)
$\sum_{i \in N_2} \sum_{j \in K} y_{i,j} \leq A_2$		(10)
$w_i \leq \frac{1}{q_i - 1} \sum_{(j,k)\in C} x_{i,j} \cdot x_{i,k}$	$\forall i \in N_2$	(11)
$w_i \in \{0,1\}$	$\forall i \in N_2$	(12)
$\sum_{i \in N_2} w_i \geq A_3$		(13)
$x_{i,j} \geq S_j \cdot X_i(S)$	$\forall i \in N, \forall j \in K, \forall S \subseteq K$	(14)
$x_{i,j} \leq S_j + 1 - X_i(S)$	$\forall i \in N, \forall j \in K, \forall S \subseteq K$	(15)
$\sum_{S \subseteq K} X_i(S) = 1$	$\forall i \in N$	(16)
$X_i(S) \in \{0,1\}$	$\forall i \in N, \forall S \subseteq K$	(17)

The objective function is equal to the sum of bid values of an assignment. Constraints (1)–(12) are the same as in the optimization of Step 3 in Section 3.

Explanation of New Constraints:

- Constraint (13) states that the number of bidders that are assigned blocks that are all contiguous to one another must be greater than or equal to the result of the optimization of Step 3 in Section 3.
- Constraints (14) and (15) ensure that the set S is assigned to bidder i (that is, $X_i(S) = 1$) if and only if $x_{ij} = 1$ for all blocks j in set S (that is, with $S_j = 1$) and $x_{ij} =$ 0 for all blocks j not in S (that is, with $S_j = 0$).
- Constraint (16) ensures that each bidder is assigned exactly one set of blocks.
- Constraint (17) states that each decision variable $X_i(S)$ can be either equal to 0 or 1.

5 Payment Determination

The final assignment phase calculation is to determine the additional payment amount above the discounted final clock price, if any, that each bidder will pay for the set of licenses it is assigned in the winner-determination problem. If a bidder placed a bid of zero in the assignment round (or did not bid), then no additional calculation is necessary, and the bidder will not have any additional assignment phase payment for that assignment round. If, on the other hand, the bidder placed a positive bid in the winning assignment, then the auction system will calculate a type of 'second-price' assignment phase payment.

To determine this price, the auction system will calculate a price that would have been "just sufficient" to result in the same winning assignment set. For each bidder, the auction system will re-solve the winner determination problem of Section 4, but setting all bids of the bidder to zero while keeping the bids of every other bidder unchanged from the prior WDP optimization, and calculate a hypothetical maximum revenue from that optimization. The difference between the revenue associated with the actual WDP optimization and the hypothetical maximum revenue will indicate the amount by which the bidder's winning bid amount exceeded the minimum amount it would have needed to bid to ensure the same winning assignment set. Its assignment phase payment will reflect a discount of that amount from its actual assignment round bid amount.

Specifically: Recall that $wd(N, b)$ denotes the maximum value attained by solving the Winner Determination Problem of Section 4, when the set of winners is N and the set of bid values is b. Note that in the solution of the Winner Determination Problem of Section 4, $X_j(S)$ is equal to 1 for exactly one set S. Let S_j^* denote the set for which $X_j(S) = 1$ at the optimal solution. That is, S_j^* is the set of blocks/assignment that bidder j is assigned in the optimal solution (*i.e.*, when solving the WDP with the actual bid values of all bidders).

The payment of bidder j in a given assignment round is set to be equal to:

$$b_j(S_j^*) - (wd(N, b) - wd(N, b_{j\to 0}))$$

where $b_{j\to 0}$ represents the set of bid values where the bid values of all bids of bidder j are set to zero (and the bid values of every other bidder are not changed).

STATEMENT OF
COMMISSIONER TOM WHEELER

Re: *In re Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, AU Docket No. 14-256; *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268

Ever since Congress authorized the world's first incentive auction in early 2012, the Commission's leadership has consistently stated that this first-of-its-kind auction was a really, really big deal. The spectrum reclaimed through the incentive auction will enable increased speed, capacity and ubiquity of mobile broadband services such as 4G LTE and Wi-Fi-like networks, all while providing a significant financial opportunity for many broadcasters. The still-ongoing AWS-3 auction has only reinforced the view that carriers need spectrum to serve the voracious appetite of a data consuming public. This bodes well for the incentive auction.

I have repeatedly stated that we need to get it right; and we will do whatever it takes to make sure we get it right. Accordingly, Commission staff has been working tirelessly to design this unprecedented auction, and we have made steady and significant progress. Today, we take another important step forward.

With this Public Notice, we are initiating the public comment period on detailed proposals about how key aspects of the auction will work. And I think it's an appropriate time to remember how we got here.

The auction design the Commission adopted last May in the Incentive Auction Report & Order continues the path to reality with today's Public Notice. This Notice is the result of years of work by a large team of auction experts inside the FCC, as well as world-renowned auction design consultants who literally wrote the book on auction design. These are the same experts who were responsible for developing the FCC's simultaneous multi-round (SMR) auction that has proven to be so successful for the last quarter century.

Pursuing projects of this magnitude necessarily involves complexity and subtlety. We have strived to simplify wherever possible, but the auction is a series of interlinked variables. It is a far cry from a cattle auction, or even the auctions we have previously conducted.

Throughout this process, I have directed the Incentive Auction Task Force and our outside experts to respect the FCC's unique role in upholding the public interest. That necessarily involves balancing a range of considerations, which are laid out in the auction statute: increasing wireless broadband, promoting competition, giving opportunities to a range of different bidders of different shapes and sizes, and providing a fair return to the treasury, among others. I believe the proposed design respects these principles.

We have worked hard to make sure that the incentive auction will be a win for multiple stakeholder groups—broadcasters, carriers big and small, consumers, and taxpayers. I am confident that the proposals in today's item will lead to an auction that creates value for the public and all stakeholders.

Of course, today's item is a Notice. We are seeking input on these proposals. But I want to emphasize that the detailed proposals on which we are seeking comment reflect many of the ideas, concerns, and input that we've heard throughout our transparent and open process.

In many respects, today's Notice simply fleshes out decisions that the Commission made in May, such as a "near-nationwide" clearing target to take account of the possibility that we may need to assign some broadcasters to the portion of the 600 MHz Band that will be allocated for mobile broadband; the use of a clock auction format to make it easy for broadcasters to participate; and a market-based spectrum reserve to promote competition. It is my hope that parties will focus on the proposals we put forward today to implement these decisions, rather than seeking to re-litigate these basic determinations.

While the Public Notice addresses a wide range of matters, two proposals in particular should be highlighted:

First, as I just mentioned, we propose detailed procedures to implement the market-based-reserve of spectrum that the Commission adopted last May. As I said at the time, I'm an unabashed believer in competition, and I'm committed to our revitalized Mobile Spectrum Holdings policies and the implementing procedures we propose today because they begin and end with one basic goal—how best to preserve and promote competition to the benefit of all Americans.

Under those policies, every bidder in the Incentive Auction, regardless of size or spectrum holdings, will be able to bid on spectrum in every market throughout the country.

We will use a "market-based reserve" for bidders that do not currently hold significant amounts of low-band spectrum in specific markets, provided that these "reserve bidders" pay their fair share of auction costs. Because reserve-eligible bidders are those with the least low-band spectrum nationwide today—and are therefore likely to be more reliant on 600 MHz Band spectrum to expand coverage and service—we are proposing that the reserve spectrum consist solely of licenses with the least interference from broadcasters who are assigned channels in the 600 MHz band. This reserve will make sure that consumers are more likely to benefit directly from increased competition in all parts of the country—rural, suburban, and urban areas included.

Second, we propose a specific methodology for setting opening prices for the reverse auction.

Our proposed opening prices will be very generous—as they should be in order to encourage robust broadcaster participation. Under the proposed formula, opening prices for most stations will be higher than the high-end compensation estimates developed by FCC staff and included in the information materials prepared by the Greenhill investment banking firm. But opening prices are just that—the starting point for the auction. Our proposed mechanism will also facilitate price competition in all markets, enabling us to offer high opening prices to every broadcaster and letting the auction process determine the final prices. At any point if a broadcaster feels the price has dropped too low, they may exit the auction without penalty.

We must also be mindful of our obligation to promote the interests of the public in sharing a portion of the value of the spectrum sold at the forward auction, while making sure we have enough forward auction revenue to successfully close the auction, including making incentive payments to all of the broadcasters we need in order to meet our clearing target. I believe our proposed formula for calculating opening prices strikes the right balance between these objectives.

The "under-the-hood" proposals contained in this Public Notice are purposefully detailed in order to solicit meaningful input from the public. But broadcasters will have a simple yardstick for deciding whether to participate and whether to remain in the auction—their own assessment of whether they consider the prices offered to them are sufficient.

Finally, because we realize that broadcasters' participation is critical to the success of the Incentive Auction, we are also continuing our broadcaster outreach and education efforts. Early next year, the Incentive Auction Task Force is poised to begin its field visits to every region of the Continental U.S., including both larger and smaller television markets. The Task Force will be announcing more details soon.

Thank you to the Task Force, the Wireless Bureau, and other staff from across the Commission for their continued hard, creative, and tireless work on this item.

STATEMENT OF
COMMISSIONER MIGNON L. CLYBURN

Re: *In re Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, AU Docket No. 14-256; *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268

When Congress gave us authority to hold the world's first voluntary reverse auction of broadcast spectrum, it presented the Commission and the communications industry with more than engineering and auction design challenges. We were faced with a character challenge. We could let doubt and acrimony minimize the success of the auction. Or, when it comes to a few topics, we could agree to disagree then, through collaboration, proceed to design a framework that would honor the ingenuity that brought us the Internet and fuel the next generation of mobile broadband innovation.

There are more than a few reasons why I am optimistic that the industry will work with us to make the incentive auction a success. First, there is the current total of winning bids in the AWS-3 Auction: a record setting $43.2 billion in an auction that has yet to close. While we should be cautious about reading too much into it at this point, what is undeniable is that the current total bid amount far exceeds analysts' predictions. Wireless carriers are opening their checkbooks to acquire spectrum—that finite resource which is the lifeblood of wireless services. And because the 600 MHz band has superior engineering characteristics, we adopted a band plan, spectrum aggregation rules, and a strong interoperability mandate in order to encourage robust participation from small and large carriers. We should continue to see great demand from carriers for the spectrum offered in the incentive auction.

Second, we have provided broadcast television stations with substantial information to encourage their participation in the reverse auction. The Commission has made clear that broadcasters in small and large markets are pivotal to clearing spectrum on a nationwide basis. The staff estimates contained in the Greenhill & Company report offer attractive valuation levels.

Third, despite disagreements with the reserved spectrum cuts in our Mobile Spectrum Holdings Order and the repacking section of our Incentive Auction Order, wireless carriers and broadcasters are still at the table helping us develop the proper technical rules in the Part 15, wireless microphone, and inter-service interference proceedings.

With all of these reasons to be optimistic, now is the time to focus on what comes next. We also need relevant stakeholders to carefully consider the details of the proposals in this Auctions Comment Public Notice. Since the 2012 Notice that initiated this proceeding, we have known generally about proposals such as dynamic descending prices for the reverse auction and ascending clock auctions, for the forward auction. But the current Public Notice provides considerably more detail, on both aspects which should encourage broad input. For those broadcasters who want to stay on the air, take a close look at how we are determining final TV channel assignments. To those who are interested in participating in the reverse auction, are there ways to improve our reverse auction pricing, while properly balancing the other policy goals for the auction?

With regard to the option to move from the UHF band to the VHF band, since TV stations would maintain their must carry rights with cable and satellite providers, this option should seem attractive to broadcasters. If this is your preferred option, does the procedure for choosing different relinquishment options give you enough information to know if you should choose the low VHF or high VHF band? For wireless carriers, this is the first time the Commission will use ascending clock auctions, spectrum reserves, and an assignment round, in a forward auction. Are there any details we should consider adding?

I want to again commend Gary Epstein and his staff on the Incentive Auction Task Force, for their hard work throughout this proceeding and for presenting us with an excellent item. I am grateful for the time they took to brief me and my staff on the Public Notice.

STATEMENT OF
COMMISSIONER JESSICA ROSENWORCEL

Re: *In re Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, AU Docket No. 14-256; *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268

In many ways, the Public Notice we adopt today is similar to so many others that the Federal Communications Commission has issued in advance of major spectrum auctions. We outline the application process for potential bidders. We ask what information participants should disclose to the Commission and conversely, what information we should provide to participants. These are the kind of details that make all of our spectrum auctions work.

But this auction is not like the others. That's because this Commission has been charged by Congress with holding the world's first spectrum incentive auctions. The art and science of reclaiming old airwaves and repurposing them for new wireless use are not for the timid or fainthearted. There is a lot of work to do. The novel, thorny, and flat-out hard come together in an auction like this—and it is the responsibility of the Commission and our terrific auction experts to make it all work.

So in this Public Notice we ask about a lot that is new. That includes questions about how to integrate a forward auction with a reverse auction, how to determine prices for broadcast stations, and how to ultimately close this two-sided auction.

But one novel issue strikes me as deserving special attention—what to do when new wireless licenses are impaired by interference. This is important because with these new wireless licenses the potential for co-channel interference and adjacent channel interference is real. After all, this auction is bound to introduce new border issues and challenges from having broadband next to broadcasting in our airwaves.

To manage this kind of interference, this Public Notice proposes to create new categories of impaired wireless licenses to sell side by side with unimpaired wireless licenses. In turn, that means our auction software must identify impairments, notify wireless bidders, and assign these licenses to different categories for the forward auction. It also means we may need to repack some remaining broadcasters within the wireless band plan.

I think this proposal shows an admirable bias toward maximizing the number of licenses we can offer in the forward auction—and put to new mobile broadband use. This is a good and respectable goal.

But if we are honest, we must also acknowledge that our commitment to this objective here comes at a cost. By adding this layer of complexity we sacrifice simplicity. That's because under this proposal we need to identify what broadcast stations could be relocated into broadband spectrum. Then we need to determine the interference these stations could cause to adjacent wireless services in order to develop a new category of impaired wireless licenses. Our bidders will need to decide how to value not one but two categories of licenses—impaired and unimpaired. Then, when we reach the last stage of the auction, we will have to determine which bidders in reserved and unreserved categories are eligible to bid on both categories of licenses.

This is challenging. So as the record develops, I hope we can consider other ways forward. We might want to limit the number of impaired licenses we offer. We might want to distinguish between short-term interference along the Canadian border and longer-term encumbrances. In short, we need to ask if instead of trying to maximize licenses through a complex architecture we should be trying to attract more participation through simplicity of design.

These are not easy issues. But then again, this is not your typical Public Notice—or your average spectrum auction. With incentive auctions, we are in new territory. We have hard choices to make, big decision to reach, and promises to keep.

DISSENTING STATEMENT OF COMMISSIONER AJIT PAI

Re: *In re Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, AU Docket No. 14-256; *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268

When it comes to spectrum auctions, we know what works. Keep it simple. Don't restrict participation. And let the outcome be driven by market forces, not centralized planning. We stayed true to these principles in the AWS-3 auction and the results are obvious. We've already raised approximately $43 billion, more than twice as much as the most optimistic predictions.

What does that mean? Over $5 billion in additional funds for FirstNet to construct a nationwide, interoperable public safety broadband network, hundreds of millions of dollars for Next-Generation 911 implementation and public safety research, over $20 billion for deficit reduction, and 65 MHz of new spectrum for mobile broadband.

If we want to maximize the chances that the broadcast incentive auction will succeed, we should stick to these proven principles. That's why I was disappointed by the rules that the Commission adopted on a party-line vote back in May. These rules introduce unnecessary complexity into the incentive auction. They restrict participation in the forward auction. Instead of allowing market forces to govern, they attempt to manipulate the results through the blunt levers of command and control. And they unnecessarily provoked litigation—now the incentive auction won't start until at least 2016.

But what's done is done. So while I voted against the incentive auction rules, I approached today's Public Notice with an open mind. I did not expect that it would propose to reverse any of the decisions made back in May. Instead, I accepted those decisions as a given and hoped that the Commission would seek comment on a set of auction procedures that would implement the incentive auction rules in the best manner possible.

It was in that spirit that I offered twelve proposed edits to this item. I did not expect all of them to be accepted. But I did hope that we could come together and reach a compromise. That hope was dashed when I received the response. The answers were "no," "no," "no," "no," "no," "no," "no," "no," "no," "no," and "no" to eleven of my suggestions—and "maybe" to the twelfth.

Could we give stakeholders more time to digest these exceedingly complicated proposals and provide more meaningful feedback to the Commission, with the auction well over a year away? No. Instead of arbitrarily proposing, with no real explanation, a 20 percent threshold for the amount of spectrum that could be impaired in our "near-nationwide" band plan, could we just seek comment on what the appropriate percentage would be? No. Rather than proposing to use a single, sealed round bid for the assignment round in the forward auction, could we seek comment on different approaches, including a single, sealed round bid and a traditional multiple round auction process? No. I could go on, but you get the point.

I have no idea why these relatively modest asks—a short extension of comment deadlines for what's acknowledged to be a "complex undertaking"[1]?—should have divided Republicans and Democrats. But that seems to happen a lot around here these days. Edmund Burke said in 1775 that

[1] "The Path to a Successful Incentive Auction" (Dec. 6, 2013), *available at* http://www.fcc.gov/blog/path-successful-incentive-auction-0. The refusal to compromise on even a modest increase in the comment cycle today is puzzling to say the least. Just this week, the Wireless Telecommunications Bureau granted, on its own motion, an extension of the comment cycle for the competitive bidding rules that will apply in the incentive auction. *See Updating Part 1 Competitive Bidding Rules*, Order, WT Docket No. 14-170, DA 14-1784 (Dec. 8, 2014), http://go.usa.gov/FBUw. It did so to give the public a chance to reflect on the results of the AWS-3 auction and thus provide the Commission with a more comprehensive record. That reasoning would suggest (notwithstanding the fact that I proposed it) that additional time is needed here as well.

"[a]ll government, indeed every human benefit and enjoyment, every virtue, and every prudent act, is founded on compromise." Needless to say, Burke hadn't seen the FCC of 2014.

Today's Public Notice contains proposals that unnecessarily layer even more complexity on top of the already complicated rules we adopted in May. I wish stakeholders that plan to comment on them the best of luck; they will need it as they try to decipher what these proposals mean and how they are supposed to work. Today's Public Notice includes proposals that would discourage broadcasters from participating in the reverse auction. And it also contains proposals that would further manipulate the forward auction for the benefit of favored companies and further restrict the participation of disfavored ones. For these reasons, I dissent.

I.

Let's start with the reverse auction. Although I have a number of disagreements with the proposed reverse auction procedures, two are the most critical.

First, I cannot support the Commission's proposal to implement dynamic reserve prices. Instead of allowing the prices paid to broadcasters in the reverse auction to be determined by the laws of supply and demand, the Commission intends to intervene in the reverse auction process. Specifically, for certain television stations, the Commission will continue to lower the price offered "even when the station cannot feasibly be assigned a channel in its pre-auction band."[2] Essentially, it will try to get away with paying some broadcasters a below-market price. What happens if the broadcaster will not accept that lower price and instead drops out of the reverse auction? The Commission will have to change the band plan and assign that broadcaster a channel that will create more impaired spectrum.

It is easy to see why dynamic reserve prices are bad for broadcasters. They mean lower compensation and thus could discourage broadcaster participation. But dynamic reserve prices are bad for other stakeholders as well. For wireless carriers, they would produce less cleared spectrum for purchase in the forward auction, and more of the spectrum that *is* made available would be impaired. And for unlicensed advocates, it could lead to less spectrum for unlicensed use. After all, the television stations that drop out of the auction due to dynamic reserve prices could end up being placed in the duplex gap or guard bands, limiting the entry points for unlicensed operations.

The purpose of dynamic reserve prices, as I understand it, is to try to save the Commission money by reducing payments to broadcasters that some might think are too high. But the proposal, in my view, is penny-wise and pound foolish. Less cleared spectrum and more impaired spectrum will mean lower revenues in the forward auction. And policies that discourage broadcaster participation in the reverse auction jeopardize the entire auction's success.

Speaking of policies that discourage broadcaster participation, my second principal objection to the proposed reverse auction procedures involves the opening price methodology. To be sure, my preference would have been for the Commission not to get involved in the business of setting opening prices at all and instead to leave that function to the market. But that ship sailed in May, so now we should focus on formulating the best possible methodology.

To calculate the prices that will be offered to each station at the beginning of the reverse auction, the Commission proposes a formula that relies substantially on the population of a station's interference-free service area. Indeed, the formula only has two factors, one of which is population served. The formula does *not* take into account such things as the population of the markets where a station blocks other stations from being repacked. These omissions matter.

Consider the example of College Station, Texas. The television station serving Aggieland has an interference-free service area covering about 330,000 people. That isn't large in the grand scheme of things. But College Station is located within driving distance of Dallas, Houston, Austin, and San

[2] Public Notice at para. 107.

Antonio. If the College Station television station does not relinquish its spectrum rights during the spectrum auction, it will preclude certain stations in each of those large Texas markets from being repacked. And rest assured, the population of Texas's four largest metropolitan areas is a big deal in the grand scheme of things.

The Commission's proposed opening price methodology therefore will undervalue the spectrum rights offered by stations in markets like College Station. My view is that the prices that we offer broadcasters in the reverse auction should be based on a station's preclusive effect in preventing the clearing of spectrum. Obviously, one factor in determining a station's preclusive effect is likely to be its interference-free service area. That factor, however, is a relatively minor one and certainly shouldn't be responsible for 50% of a station's opening price. Once again, I worry that the Commission's proposal is motivated by a desire to underpay broadcasters—this time, those in smaller markets. And once again, I worry that our proposal could ultimately jeopardize the success of the auction.

II.

I have serious concerns with the Commission's proposals with respect to the forward auction as well. Let's start with its implementation of our spectrum set-asides. Back in May, I dissented from the Commission's decision to create "reserved" and "unreserved" spectrum blocks based on the low-band holdings of particular providers.[3] I said at the time that attempting to manipulate the market by reducing competition in the forward auction would inject needless complexity into the auction process, reduce auction revenues, and result in less spectrum repurposed for mobile broadband.

But again, I recognize that I was on the losing end of our May order. So I approached this issue with the goal of finding the best way forward given the existing framework. Unfortunately, my suggestions again were rejected. As a result, at nearly every turn, the Commission's proposals forsake simplicity for unnecessary complexity, all for the purpose of rewarding certain companies and punishing others.

How so? Well, to start, the Commission proposes to further skew the auction by setting aside only clean, unimpaired spectrum for bidding by preferred providers. And it proposes to do so by arbitrarily dividing the spectrum into "Category 1" and "Category 2" buckets based on whether a license is more or less than 15% impaired. Here's how this would work (or not). Let's say in a given market we are auctioning 7 blocks of spectrum. It could be the case that 3 blocks of unimpaired spectrum would be set aside for certain companies while their competitors would only be allowed to bid on 4 blocks of spectrum that are 49% impaired. To state the obvious, this puts an even heavier thumb on the scale than our May decision, shaping outcomes and depressing revenues.

The Public Notice's efforts to engineer particular results don't end there. For example, when determining the number of blocks that the Commission will set aside, it proposes to count both the number of impaired and unimpaired blocks available in a market. But when it comes to deciding which blocks would actually be set aside, the Commission shifts course, recognizes that the blocks are not at all equal, and proposes to reserve only unimpaired blocks. This just skews the auction in favor of creating more reserved spectrum.[4] If spectrum isn't good enough to set aside as reserved spectrum, then it

[3] *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Report and Order, 29 FCC Rcd 6567, 7038, 7040, 4073 (2014) (*Incentive Auction R&O*) (Dissenting Statement of Commissioner Ajit Pai); *see also Policies Regarding Mobile Spectrum Holdings*, WT Docket No. 12-269, Report and Order, 29 FCC Rcd 6133, 6268-74 (2014) (*Mobile Spectrum Holdings R&O*) (Dissenting Statement of Commissioner Ajit Pai).

[4] I am also disappointed that the Public Notice continues down the path of making a disproportionate amount of spectrum off limits to free and open competition. It would proposes to continue to allow 50%, 60%, or even 75% of the available spectrum in a market to be reserved for select bidders since, under the Commission's approach, the amount of reserved spectrum could remain 30 MHz at the 60 MHz, 50 MHz, and 40 MHz clearing targets. *See* Public Notice at para. 23; *see also Mobile Spectrum Holdings R&O*, 29 FCC at 6208 para. 184. At a minimum, the

(continued….)

shouldn't be counted for purposes of determining how much spectrum should be set aside.

Other proposals being made today would simply add unnecessary layers of complexity to the auction. For example, the Public Notice proposes that one (but not both) of the two categories of licenses in the forward auction may (or may not) be split into two sub-categories of licenses. Thus, we would create three different categories of licenses for providers to bid on in some (but not all) markets. And how would providers express those bids? Not in a straightforward way, to say the least. The Public Notice's approach would require providers to select from a complicated mix of "switch bids," "all-or-nothing bids," and/or "simple bids," all of which could be implemented fully, partially, or not at all, depending on the circumstances.

And that's just the clock round of the forward auction. The Public Notice's proposals for implementing the extended and assignments rounds suffer from many of the same flaws. For instance, the proposed assignment round process gives companies zero certainty that they could obtain their preferred blocks of spectrum, regardless of how much they bid.

Stepping back from each particular proposal, it's important to look at the big picture. From the start of this proceeding, we've been sold a vision of a simple forward auction where companies would be bidding on generic spectrum blocks. Anyone reading today's Public Notice should now realize that this vision was nothing but a mirage.

The spectrum blocks offered in the forward auction are not going to be generic. They will have different levels of impairments and may be divided into three categories in the same geographic area. Instead of making one type of bid, as is standard in our auctions, companies will have to choose from among three types of bids without knowing how the Commission will process them. And the clock phase of our auction is just the first part. It might be followed by an extended round and will be followed by an assignment round. If this is the Commission's idea of simplicity, I would hate to see its idea of complexity.

* * *

At the end of the day, I hope that the Commission will be more receptive to feedback from outside parties than it was to my input. Otherwise, I fear that we will continue heading down the wrong path—one that leads to further delays, less broadcaster participation, less participation by wireless carriers, less revenue for the federal government, and less cleared spectrum for mobile broadband.

The shame is that we could have easily had a unanimous vote on today's Public Notice. But there was no interest in working towards consensus. Virtually every line drawn in the item was painted a single color: red. As a result, I dissent.

(Continued from previous page)
maximum amount of reserved spectrum should never exceed the levels the Commission specified in the *Mobile Spectrum Holdings R&O*, regardless of the Commission's initial spectrum clearing target.

DISSENTING STATEMENT OF
COMMISSIONER MICHAEL O'RIELLY

Re: *In re Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, AU Docket No. 14-256; *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268

As with the Commission's May Incentive Auction Order, today's notice rushes forward in an attempt to put some of the pieces of this very important puzzle together. Yet, it still lacks a solid foundation. Many of my concerns from the earlier item either still remain or have come to fruition. Although I requested several edits to this Public Notice to enable us to seek comment and have a fulsome record to base our decisions, they mostly fell on deaf ears. Rather than shore up our overall path, the Commission proposes a series of unnecessary, outcome-driven machinations and tentative conclusions to bolster its ability to claim success at the close of the auction. Some may say that tentative conclusions are helpful to provide a plan that commenters can approve or criticize, but experience shows that what you see proposed is essentially set in stone. In other words, the outcome of many of these issues seems predetermined. Hopefully, I am wrong and the Commission will listen to the concerns of my fellow Commissioners. I think staff can realize that more work is necessary. Sadly, at this point, I do not have confidence that the complex and confusing proposals in this public notice will maximize revenues or ensure that the spectrum goes to its highest value use.

First, how can one conclude that an auction is successful if close to 20 percent of Americans (measured on a weighted basis) would be covered by impaired licenses? While we would all concede that some market variation may be inevitable, a nationwide impairment threshold of an arbitrary number of 20 percent is both unsupported by any facts and could effect a large part of the country, and therefore too many American consumers. Additionally, this is likely to deflate auction revenues. If impairment is to actually be retained and permitted, I sought that we actually have a number anchored in fact based on projections of likely auction outcomes, but that was dismissed.

Second, I strongly oppose the Commission's continued exploration of dynamic reserve pricing, which would only increase impairments and market variation. Under this system, a broadcaster, who is willing to accept a Commission offer and cannot be repacked in the TV band, would nonetheless see the price of their station drop. This is just plain wrong; a station that would cause impairments that agrees to go off air for a certain price should be bought out. Instead, this broadcaster would be forced to either take a lower price or possibly drop out of the auction to be relocated to a spectrum channel that will be allocated for mobile wireless use. How does this provide the certainty and comfort to broadcasters needed to be willing to participate in an auction that risks their livelihood? This idea should have been dumped months ago.

Third, the Commission's generic license blocks are no longer truly fungible. Auction participants will bid on two separate categories of licenses based on the amount of interference that the license may receive from broadcasters. The parameters for "Category 1" and "Category 2" licenses are not grounded in facts or data. Accordingly, I suggested that, if separate categories of licenses are pursued, we seek general comment on what percentage of impairments should be used to define these two categories. That didn't make it either.

Fourth, to add insult to injury, it is now proposed that entities eligible for reserve licenses—which were created so that selected participants could obtain sub-1 GHz spectrum at below market rates—will receive further preferential treatment by having greater access to license blocks with the fewest impairments. In effect, today's Public Notice doubles down on the proposal to provide extra benefits to a select subset of companies that feel that they are disadvantaged because of their low band spectrum holdings. Many of these companies, however, are in their predicaments due to past company decisions. It is not the role of the Federal Government to resolve such issues. Simply put, under this proposal, reserved-eligible entities would have access to the licenses with the least impairments; the largest companies could be relegated to bidding on the more impaired licenses. Why would anyone depress the

bidding activity for the most valuable licenses? The licenses with the least impairments should be going for full market value.

Fifth, the complexity of the forward auction structure may limit the ability of participants to bid vigorously for the spectrum. In their bidding plans, applicants will have to take into account the questionable extended and the assignment rounds. Establishing such extra rounds means bidders may hold back funds because it's unknown whether they will need to contribute more under these two bidding structures.

Lastly, there are a host of other problems with this item, including the possibility that broadcast stations could be placed in the duplex gap or guard bands, issues about how reverse auction opening prices should be set, whether impairment discounts should be offered and how they should be calculated and continued concerns about the final stage rule. These should have benefitted from further comment instead of jumping to tentative conclusions.

As I have said before, Congress challenged the Commission with a complex technical undertaking with this incentive auction. I do not minimize the efforts of staff in preparing this document. However, I must dissent to today's notice for all of the reasons above. Fortunately, this is a notice and we still have time to get this right. Although my input is not reflected in this notice, I remain determined that this should be a collaborative process and that the opinions of all should be considered. This auction is of utmost importance and we must work with all interested parties to ensure success.