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Collusive Bidding in the FCC Spectrum Auctions

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Collusive Bidding in the FCC Spectrum Auctions

Abstract

This paper describes the bid signaling that occurred in many of the FCC spectrum auctions. Bidders in these auctions bid on numerous spectrum licenses simultaneously, with bidding remaining open on all licenses until no bidder is willing to raise the bid on any license. Simultaneous open bidding allows bidders to send messages to their rivals, telling them on which licenses to bid and which to avoid. This "code bidding" occurs when one bidder tags the last few digits of its bid with the market number of a related license. We examine how extensively bidders signaled each other with retaliating bids and code bids in the DEF−block PCS spectrum auction. We find that only a small fraction of the bidders commonly used retaliating bids and code bids. These bidders won more than 40% of the spectrum for sale and paid significantly less for their overall winnings.

1 Introduction

In 1994, the United States Federal Communications Commission (FCC) began auctioning spectrum licenses. A license allows the winning bidder to use a specified frequency band to provide wireless communication services to customers in a particular market. A collection of related licenses, typically all licenses in one or more bands, would be sold using a simultaneous ascending auction. The simultaneous ascending auction is a natural generalization of the English auction when selling many interdependent items.[1] Bidding occurs in rounds. In each round, bidders place dollar bids on any of the different licenses, raising the standing high bid by at least one bid increment. The auction continues until a round passes with no new bids; that is, no bidder is willing to raise the bid on any license. The licenses then are awarded to the highest bidders, who pay the FCC the final bids.

During the DEF auction (the Personal Communications Services (PCS) auction for broadband frequency blocks D, E, and F) the FCC and the Department of Justice observed that some bidders signaled each other with *code bids*. A code bid uses the *trailing digits* of the bid to tell other bidders on which licenses to bid or not bid. Since bids were often in the millions of dollars, yet were specified in dollars, bidders at negligible cost could use the last three digits—the trailing digits—to specify a market number. Often, a bidder (the sender) would use these code bids as retaliation against another bidder (the receiver) who was bidding on a license desired by the sender. The sender would raise the price on some license the receiver wanted, and use the trailing digits to tell the receiver on which market to cease bidding. Although the trailing digits are useful in making clear which market the receiver is to avoid, *retaliating bids* without the trailing digits can also send a clear message. The concern of the FCC is that this type of coordination may be collusive and may dampen revenues. The purpose of this paper is twofold: (1) to find the extent to which code bidding and retaliation occurred in the DEF auction, and (2) to determine if there is any evidence that bid signaling reduced prices.

The DEF auction is especially well suited for a study of collusive bidding strategies in a simultaneous ascending auction. The auction featured both small markets and light competition. Small markets enhanced the scope for splitting up the licenses in the sense that each bidder can win many licenses. The collusive strategies that we observe would be impossible if all of the spectrum were bundled into a single license and sold to the highest bidder. Light competition increased the possibility that collusive bidding strategies would be successful. Indeed, prices in the DEF auction were much lower than prices in the two earlier broadband PCS auctions.

From a strategic viewpoint, the simultaneous ascending auction can be thought of as a negotiation among the bidders. The bidders are negotiating how to allocate the licenses among themselves, but only can use their bids for communication. The auction ends when the bidders agree on the allocation of the licenses. Retaliating bids and code bids are strategies to coordinate the allocation of licenses at low prices. Moreover, bidders with a reputation for retaliation may scare off potential competitors. Our hypothesis is that bidders that commonly use these strategies pay less for the spectrum they ultimately win.

We find that six of the 153 bidders in the DEF auction regularly signaled using code bids or retaliating bids. These bidders won 476 of the 1,479 licenses for sale in the auction, or about 40% of the available spectrum in terms of population covered. These signaling bidders paid about the same as other bidders for the F-block licenses, but on the D and E blocks, the signaling bidders paid \$2.50/person, whereas nonsignaling bidders paid \$4.34/person.[2] Moreover, when we control for market characteristics,

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[1] See McMillan (1994), Cramton (1995, 1997), McAfee and McMillan (1996), and Milgrom (2000) for detailed descriptions of the simultaneous ascending auction.

[2] Each license was for 10 MHz of bandwidth. Licenses in different markets covered a different population. Since license value tends to be proportional to the population covered, it is common to compare licenses of equal bandwidth in terms of the bid per person covered, or \$/person. Population is measured as of 1994.

we find that bidders that used code bids or retaliating bids paid significantly less for not only the D and E licenses, but also for the F licenses.[3] We take this as evidence that the bid signaling strategies were effective at keeping prices low on the collection of licenses desired by the signaling bidders.

Further, there was a tendency for bidders to avoid bidding against AT&T, a large bidder with a reputation for retaliation. Bidders frequently bid substantially more for an identical license, rather than bid on the cheaper license held by AT&T.

An alternative approach to assess whether bid signaling is successful in reducing prices is to look at prices in markets where bid signaling deters a rival. The hypothesis is that prices are lower on the licenses won after bid signaling deters a rival. There are two problems with this approach. The first is selection bias. The markets where we observe bid signaling may be especially contested. Second, the threat of using signaling as a punishment against those bidders not adhering to some coordinated split of the licenses can be used as leverage to lower prices on all licenses the bidder is bidding on, not just those licenses where the threat is made good. For these reasons we do not focus on this alternative hypothesis.[4]

The paper is organized as follows. In Section 2, we review the relevant literature on multiple-item auctions and discuss how bidders' incentives may have induced them to use signaling to coordinate on a low-revenue equilibrium. We elaborate in Section 3 on the auction rules and how these rules enabled bidders to use signaling. In Section 4, we describe the technique we used to find evidence that bidders were signaling, and then summarize the code bidding and retaliation that occurred in the DEF auction. Section 5 looks at evidence that the bid signaling reduced prices.

2 Demand Reduction and Collusion in Ascending Multiple-Unit Auctions

Bidders may wish to reduce their demands to keep prices low in a multiple-unit auction with uniform pricing (or, as in the case of the spectrum auctions, where prices can be arbitraged). To illustrate this, consider the following example. Suppose that the simultaneous ascending auction is used to sell only two licenses, the New York D and E licenses. And suppose there are two bidders. Each bidder views the licenses as perfect substitutes and values each at $100 million (and the pair at $200 million). What strategy should a bidder use? A bidder could bid sincerely, placing bids on both licenses as long as the price of each is less than $100 million. But if the other bidder also bids sincerely, the price on each license will rise up to $100 million. Neither bidder will obtain a bargain. Alternatively, suppose that a bidder decides to bid for just one of the two licenses, leaving the other license for the other bidder. Let the bidder's strategy be to bid on the cheaper of the two licenses, or if they are the same price, to bid on the D license. Then the other bidder's best response is to use the same strategy, only bidding on the E license. In this way, each bidder can win one license at a low price. Further, if one bidder uses this strategy it can punish the other bidder if it bids on both licenses. After a few rounds of bidding, the bidder bidding on both licenses would soon see that it can either win one license at a low price or otherwise face high prices. The multiple-unit auction literature has recognized the incentive to demand reduce for sealed-bid uniform-price auctions; see for example Ausubel and Cramton (1996). However, we believe that these incentive may be more pronounced in the simultaneous ascending version of the uniform-price auction. Inherently, there may be multiple demand reducing equilibria in uniform-price auctions. Without communication there may be no way for the bidders to coordinate on one of these equilibria. But in the

[3] Although for each market, the D, E, and F licenses were near perfect substitutes, the F block was set aside for small bidders with annual revenues less than $125 million and with assets valued at less than $500 million. These small bidders could bid on the D, E, and F blocks, but larger bidders could not bid on the F licenses. Additionally, small bidders received both bidding credits and installment payments for F licenses, but not for D and E licenses, making the F licenses more attractive to them than the D and E blocks.

[4] Consistent with these two problems, we find no support for the hypothesis that prices are lower on licenses won after successful bid signaling.

simultaneous ascending auction, coordination can be resolved within a few rounds of bidding. In the above example, if both bidders decide to bid for just one license, but both bid on the D license in the first round, then it is likely that one of the bidders will then bid on the E license, allowing each bidder to win one license at a low price.

The above example illustrates that in simple settings with few goods and few bidders, bidders have the incentive to reduce demands. Engelbrecht-Wiggans and Kahn (1999) and Brusco and Lopomo (2002) show that for an auction format like the FCC's, where the bidding occurs in rounds and bidding can be done on distinct units, there exist equilibria where bidders coordinate a division of the available units at low prices (relative to own values). Bidders achieve these low-revenue equilibria by threatening to punish those bidders that deviate from the cooperative division of the units. The idea in both the example and in these papers is that bidders have the incentive to allocate the available units ending the auction at low prices. With heterogeneous goods and asymmetric bidders in terms of budgets, capacities, and current holdings of complementary goods, it is unlikely that bidders would be aware of simple equilibrium strategies that indicate which licenses to bid on and which to avoid. Rather, we believe that bidders in the DEF auction took advantage of signaling opportunities to coordinate how to assign the licenses. With signaling, bidders could indicate which licenses they most wanted and which licenses they would be willing to forgo. Often this communication took the form of punishments.

We view the type of coordination achieved with bid signaling as *tacit* collusion. Specifically, we borrow the working definition given in Cramton and Schwartz (2000):

> *Collusion* occurs between two bidders if they have overlapping interests on several licenses and if these bidders agree to allocate these licenses such that each bidder wins a license for a price substantially (more than a bid increment) below what the other bidder is willing to pay. This working definition can be expanded to include more than two bidders.

It should be noted that this definition does not coincide with legal definitions of collusion or how economists have traditionally viewed collusion in auctions. For single-unit auctions, other work has modeled *explicit* collusion with a ring of bidders that meets before the actual auction to decide how to cooperatively bid in the auction (see, for instance, Graham and Marshall 1997, Mailath and Zemsky 1991).[5] Although the collusion we study differs from the standard treatment in the auction literature, it conforms closely to the tacit collusion in the oligopoly literature. Oligopolists who repeatedly compete against each other can settle on an equilibrium where they collectively restrict output or raise the price toward the monopoly level, and enforce this equilibrium by threatened punishments.[6] Likewise, the collusion we consider consists of bidders restricting their demands for licenses in order to achieve more favorable prices, and allows bidders to punish each other for deviating.

3 Auction Rules and Signaling Techniques

3.1 Auction Rules

In this section, we summarize the rules for the DEF auction. The nation was divided into 493 markets. There were three 10 MHz licenses in each market, the D, E, and F blocks. In each round, each bidder could place bids on any of the licenses it was eligible to win. At the end of each round, the FCC reported the dollar amount of each bid on each license, along with which bidder placed the bid. If a license received new bids, then the highest bid became the standing high bid, and the corresponding bidder became the standing high bidder. Bids are made in whole dollars and must be above the minimum bid

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[5] Baldwin, Marshall, and Richard (1997) provide a brief review of the theoretical and empirical work on collusion in auctions. See also Marshall and Meurer (2001) for a legal perspective; this paper also reviews much of the economic literature on collusion.

[6] For references to this literature, see Athey, Bagwell, and Sanchirico (2002).

determined by the FCC. The FCC posted the minimum bids for the next round at the conclusion of each round. The minimum bid typically was 5%, 10%, or 15% higher than the standing high bid. The auction would not end until a round passed in which no new bids are placed. The standing high bidders win the corresponding licenses at a gross price of their standing high bid. Some bidders had bidding preferences, however, that reduced the amount they paid the FCC if they won licenses in the F-block, which were set aside for preferenced bidders (larger bidders like AT&T could not bid on the F-block licenses, although smaller, preferenced bidders could bid on the D and E-block licenses).[7]

For more on the auction rules that we have not discussed, such as activity rules and withdrawal rules, see Cramton (1995, 1997); for the precise rules of the DEF auction, see the Bidder Information Package located on the FCC's web site (at http://www.fcc.gov/wtb/auctions).

3.2 Signaling Techniques

Code bidding occurs when one bidder encodes a meaningful market number in the trailing digits of its bid. A bidder can signal a rival by bidding on a license that the rival is the standing high bidder on, while ending its bid with the three-digit number of the market it wants the rival to stop bidding on. This signal can impose a cost on the rival. If the rival wants to win the license it was bumped from, it will have to place a higher bid on the license (bids must be raised by at least a bid increment, typically 10%). An example of this signaling technique is shown below.

Table 1: Example of Code Bidding

	Marshalltown, IA 283 E		**Rochester, MN 378 D**		Waterloo, IA 452 E		
Round	McLeod	USWest	McLeod	**USWest**	AT&T	McLeod	USWest
24	56,000					287,000	
…			…	…			
46				568,000			
52			689,000				
55				723,000			
58			795,000				
59				875,000			**313,378**
60						345,000	
62			963,000				
64		**62,378**		1,059,000			
65	69,000						
68					371,000		

Table 1 shows all of the bids that were made on Marshalltown, block E and Waterloo, block E after round 24, and all of the bids on Rochester, block D after round 46. USWest and McLeod were contesting

[7] If a bidder had annual average income of less than $40 million over the last three years, it received a credit on the price it paid for the F-block licenses it won, the credit being either 15% or 25% depending on how small its annual average was. Additionally, bidders with revenues less than $75 million could receive special financing from the FCC on those F-block licenses it won; some were eligible for eight to ten year loans at the ten-year US Treasury obligation rate depending on their annual average income. For precise specifications, see the DEF Bidder Information Package located on the FCC's web site at http://www.fcc.gov/wtb/auctions. When calculating losses and gains subsequently in this paper, we discount the F-block gross bids according to the precise preferences of the winning bidders; a good rule of thumb is that the bidding credit and the special financing arrangement are worth about a 50% bidding credit, meaning a preferenced bidder is indifferent between winning the F-block of Richmond, VA for a gross bid of $2 million and winning the D or E block of Richmond with a bid of $1 million.

Rochester, trading bids in rounds 52, 55, 58, and 59. Rather than continue to contest Rochester, raising the price for the eventual winner, USWest bumped McLeod from Waterloo in round 59 with a code bid, $313,378. The "378" signified market 378—Rochester. USWest's bid revealed that McLeod was being punished on Waterloo for bidding on Rochester. In round 60, McLeod retook Waterloo, bidding $345,000, $58,000 more than its round 24 bid. But McLeod did not yet concede Rochester—it placed another bid on Rochester in round 62. USWest then used the same technique in round 64, punishing in Marshalltown instead. USWest's bid in round 64 on Rochester won the license. (We have shown only two of the markets on which USWest punished McLeod; USWest had actually punished McLeod on several markets contemporaneously.)

There are several variations of this type of code bidding. For example, after bumping a rival with a code bid, a bidder can then withdraw its bid. In this case, the rival can regain the license it was bumped from by placing its prior bid. This does not raise the price for the rival, but rather is a warning to the rival. Sometimes, a bidder will code bid on the market it wants the rival to stop bidding on; in this case, the market number contains the market number that will be punished should the rival not cease its bidding on the market the code bidder wants. When this type of code bid is used in tandem with a punishing code bid, it is called *reflexive code bidding*.

Although in the above example of code bidding, USWest uses "378" in its bids to signal its intent, retaliation in no way requires the "378." So long as it is clear which market the signaling bidder wants its rival to cease bidding on, the same sorts of punishments can be made without the trailing digits. When a punishment is made without the trailing digits we call this a *retaliating bid*.

Table 2 shows how retaliation works. It shows all of the bids that were made on block F of Canton and Harrisburg after round 56. NextWave and NorthCoast were contesting Canton, trading bids in rounds 158, 159, and 160. Rather than continue to bid on Canton, raising the price for the eventual winner, NorthCoast retaliates. The retaliation was the bid of $1,339,011 on Harrisburg in round 161, which bumped NextWave on a market it held since round 56. *Aside:* The "011" that NorthCoast ends its bid with is not in itself a code bid; NorthCoast ended many of its bids with "011" as its signature, similar to GTE ending its bids in prior auctions with GTE's telephone numeric representation "483."

Table 2: Example of Retaliation

	Canton, OH 65 F			Harrisburg, PA 181 F	
Round	NextWave	**NorthCoast**	OPCSE	NextWave	NorthCoast
56			358,000	1,217,000	
57		409,011			
78	460,000				
82		511,011			
125			562,000		
136		618,011			
158	680,000				
159		748,011			
160	861,000				
161					**1,339,011**
162				1,473,000	
163		947,011			

Other types of signaling include jump bidding, double bidding, and raising one's own bids. The interested reader is referred to Cramton (1997). We do not treat these here: these strategies involve punishing oneself to intimidate others and it is unclear what agreement this suggests. A bilateral signaling technique that we do not discuss in this paper is that of strategic withdrawals, where a bidder withdraws from a license that a rival desires as an inducement to get the rival to stop competing on another market (see Cramton and Schwartz, 2000, who discuss the few occurrences of this in the DEF auction).

4 Code Bidding and Retaliation

4.1 Detection Methodology

To find the retaliating bids and code bids in the DEF auction, we needed a consistent way to comb through the 23,157 bids, looking for those bids resembling those examples in Section 3. Our strategy was to loop through each bid, to tentatively assume the bid was a retaliating bid, and then to check whether the bid met criteria characteristic of retaliating bids. For each bid, we used the reported information to determine which bidder made the bid, which bidder it bumped when it placed the bid (i.e., the standing high bidder as of the prior round), the market and block, and the round the bid was placed. For a bid to be a retaliating bid, it must be clear to the bidder being bumped that the bid was not meant to win the license, but was only meant to punish. Therefore, we first eliminated all bids made by a bidder that had shown interest by bidding on any block of the same market in the prior 10 rounds. Of course, if a retaliating bid was made in the previous 10 rounds, and then a follow-up retaliating bid was made, our algorithm did not catch the second retaliating bid—the program was designed to catch only the first retaliating bid.

To be a retaliating bid, we required a clear motive: the bumped bidder must have recently been bidding for a market the retaliating bidder wanted. To ensure this, we required that the bumped bidder bumped the retaliating bidder from some license in the prior two rounds. We also required that within two rounds of placing the retaliating bid, the retaliating bidder had bid on the contested market; otherwise, it is unclear what the retaliating bid was meant to accomplish.

If a bid met the above criteria, then it certainly met many characteristics of a retaliating bid. Our next step was to examine all of the bids returned from the above algorithm to further check that they resemble code bidding or retaliating bidding. Sometimes by looking at the retaliating bid we learned that the bid was not intended as retaliation. For example, if the bidder had bid on this market intermittently throughout the auction, then the bid was probably not meant to punish. Looking at the bids manually, we then eliminated any results returned by our algorithm included if:

1. The bidder did not consistently adhere to a punishment strategy. If it punished once and it was not successful in deterring its rival, and then no follow-up retaliating bids were placed, then we did not view this as a retaliating bid.

2. The retaliating bid worked too quickly. If only one retaliating bid was placed and on a market the retaliating bidder had shown interest on earlier in the auction, if the retaliating bid did not contain a relevant market number, and if the competitor conceded, then we view this as coincidental, and not strong enough evidence to conclude that this was a retaliating bid.[8]

3. The intentions of the bidder were unclear. If the bidder and the punished bidder were competing contemporaneously on several markets, and the punishing bid did not contain a market number, then we view these bids as being ambiguous in intent.

[8] This may be the most serious omission in our technique: we are omitting those cases that worked the fastest. However, our intention is to isolate those bidders who show ample evidence of using punishment strategies.

4. The punished bidder did not securely hold the high bid on the license being punished. If a third bidder was bidding on this market in the three rounds prior to the punishing bid, then it is not clear that the punishment had any bite.

Because our program returned 1,397 retaliating bids in rounds 10 to 40, we only considered retaliating bids (that did not include trailing digits) which occurred after round 40. This omission was probably innocuous since in this 275 round auction, few markets were settled by round 40 if two bidders were actively contesting these markets. From round 40 and up, our program returned 559 bids for us to check. We should note here that many of our criteria listed above appear to be formed quite arbitrarily in the specifics (for example, in requiring that that the bumped bidder bumped the retaliating bidder from some license in the prior *two* rounds). However, our general rule was to create some condition that a bid had to pass to qualify as a retaliating bid, and then loosen that condition by a round so as to not eliminate any bids that may resemble a retaliating bid.

4.2 Evidence of Signaling

After eliminating many of the 559 candidate retaliating bids using the criteria specified above, we found 37 separate bouts of retaliation and code bidding, where a bout can involve several rounds of retaliation over several markets.

Table 3: Bouts of Retaliation in the DEF Auction

	With Code Bids		Without Code Bids		
Blocks	D & E	F	D & E	F	Total
Successful	5	7	3	4	19
Unsuccessful	3	8	4	3	18
Total	8	15	7	7	37

Table 3 classifies the retaliation bouts by which blocks they occurred in, by whether code bids were used (as opposed to retaliating bids without trailing digits), and whether the signals were successful. Though we distinguish here between retaliating bids with and without code bids for descriptive purposes, we do not carry this distinction when we test for differences in prices in the next section. Our definition of successful is strict: the signaling bidder must have placed the winning bid on the license it sought within five rounds of placing its retaliating bid(s). Unsuccessful is simply the negative of successful—it includes cases where the signaling bidder was unable to dissuade its rival from the license it desired and cases where another bidder later bids on the license. Bidders used code bidding to try to win licenses 23 (= 8 + 15) times, 12 times successfully. Retaliations that did not include code bids occurred 14 times, 7 times successfully. We have found more cases of code bidding, but we note that code bids were easier to find.[9]

Table 4 shows all of those bidders that initiated more than one bout of retaliation or code bidding. The table shows that these bidders mostly used one technique or the other. AT&T used code bidding early

[9] Finding code bids was easier since we could narrow our search to just bids ending in market numbers (1-493). There were 1,551 bids ending in 1 which we ignored, since it is unlikely these bids had anything to do with market 001 (Aberdeen, SD), but more likely that these bids were simply a trick to top—by a $1—an opponent bidding in the same round. Also, note that we allowed code bids in the first 40 rounds and that criterion 2 in the prior subsection admits more code bids than retaliating bids, but otherwise, code bids and retaliating bids are treated identically. All of the code bids occurring prior to round 40 were not successful, and all of the bidders using code bids before round 40 also retaliated after round 40. See Appendix I for a more detailed listing of the retaliating bids. The FCC's web site, http://www.fcc.gov/wtb/auctions, contains links to the bidding data for the DEF auction as well as the other spectrum auctions.

in the auction (round 20) expelling Powertel from Birmingham, AL, but for whatever reason decided not to use trailing digits in its retaliating bids thereafter. It is likely that a bidder like AT&T knew it had much to lose if it attracted the FCC's attention by code bidding. Another interesting point to note is that 75 licenses were punished with code bids and retaliating bids. Over 90 bids ending in market numbers were part of code bids; some of these bids were placed on the same license repeatedly.

Table 4: The Main Retaliating Bidders

	Bouts Initiated		
	With Code Bids	Without Code Bids	Total
21Century	3	0	3
AT&T	1	3	4
Mercury	7	1	8
NorthCoast	0	5	5
OPCSE	7	1	8
USWest	3	1	4

5 Did Code Bidding and Retaliation Reduce Prices?

In a simultaneous ascending auction, effective bid signaling should reduce the prices paid by all bidders by facilitating a rapid agreement on the allocation of the licenses. The DEF auction did end with prices far below prices in earlier and later auctions, providing weak evidence that the bid signaling was effective. Further evidence comes from determining whether signaling bidders paid lower prices than nonsignaling bidders in the same auction.

5.1 Signaling Bidders Paid Lower Prices

We find that six of the 153 registered bidders in the DEF auction regularly signaled in the auction. These bidders won 476 of the 1,479 licenses for sale in the auction, or about 40% of the available spectrum measured by 1994 population. We now ask whether the bidders that actively used punishments were able to achieve favorable prices relative to bidders that did not use signaling.

Table 5: Average Prices Paid ($/person)

	Blocks	
	D & E	F
Signaling Bidders	**2.52**	**1.67**
AT&T	2.77	—
21Century, Mercury, NorthCoast, OPSCE, USWest	2.07	1.67
Nonsignaling Bidders	**4.34**	**1.65**
Sprint	6.16	—
Excluding Sprint	3.58	1.65

Note: Averages computed by summing net winning bids and dividing by the total population won.

Table 5 shows that those bidders that used signaling as a part of their strategy paid much lower prices on the D and E blocks relative to those bidders that did not signal. Yet, on the F block, where there was more competition, average prices are nearly the same for the signaling and nonsignaling bidders.

Note that we have included separately the winnings of Sprint, who did not engage in signaling, but paid much more than other bidders. Aside: Sprint was second to AT&T in the number of licenses it won and third to AT&T in the amount of population it won. AT&T won about 75% more population than Sprint, but paid about 25% less. Alternatively, OPCSE—another of the signaling bidders—won slightly more population than Sprint, but had *gross* winning bids of about half that of AT&T.

Although Table 5 suggests that signaling bidders achieved favorable prices—at least on the D and E blocks—it might be that the signaling bidders are winning markets with less desirable characteristics. To control for market desirability and to see whether the price difference is statistically significant, we use a regression that is a variant of the one in Ausubel et al. (1997), which develops a parsimonious benchmark model to predict prices in the AB and C auctions.[10] The idea is to regress the natural logarithm of the price of the license on a host of explanatory variables, and then to add a dummy variable to see if there is a significant difference in the amount that the signaling bidders paid. Specifically, our regression is of the form:

$$\ln(y_i) = D_i\alpha + x_i\beta + \varepsilon_i$$

where y_i is the price of license i, D_i is a dummy variable that takes the value of 1 if a signaling bidder[11] won the license and 0 otherwise, x_i is a vector of explanatory variables for market i, ε_i is an error term, and α and the vector β are parameters to estimate. The price of license i is the net winning bid on the license divided by 1994 population (for the D and E blocks, the net winning bid is equal to the winning bid since there were no preferences granted for these blocks). The explanatory variables include the population density of the build-out area, microwave links per million people in 1994 (these links must be moved at the operators expense), the natural logarithm of 1994 population, the fraction of households with income more than $35k, and a competition variable. Other than our competition variable, these variables are the same as those used in the benchmark model of Ausubel et al., and we discuss them in more detail when describing some of the regressions below. The competition variable we use differs from that in Ausubel et al. They are able to exploit the restrictions, based on the then current cellular holdings of each bidder, limiting the licenses bidders could bid on. However, since in the DEF auction there were much fewer restrictions stating which bidders can bid on which licenses, we formed a new competition variable. For the F-block our competition variable is the cumulative number of bidders that place a serious bid (more than $500) on the license in the first five rounds of the auction. For the D and E-blocks, our competition variable is the cumulative number of bidders placing a serious bid on either block in the first five rounds. Since an auction with 153 registered bidders and 1,479 licenses is likely to take many rounds to settle (the earlier AB and C block auctions each lasted more than 100 rounds), the decision of a bidder to bid in the first five rounds is exogenous, not influenced by the final price in the market. We have considered other versions of a competition variable; for instance, counting the number of bidders placing bids only in the first round and counting the number of bidders in the first 10 rounds. None of our results are sensitive to these specifications of the competition variable. We also take as regressors the natural logarithms of the C block price ($/person) and the AB price ($/person) since these variables may help explain the variability in the DEF auction prices. All the PCS licenses (A-F) within a market, regardless of block, can be regarded as close substitutes. An operator's primary concern is the bandwidth it holds in a market. In particular, all equipment works without modification across all blocks. Given the competitiveness in the C-block auction, these prices should be expected to fairly reflect the relative value differences between the different Basic Trading Areas (BTAs). The AB auction prices are cruder since in this auction the country was split into 51 Major Trading Areas (MTAs) rather than 493 BTAs as in the C and DEF auctions. The means for the variables we have used for these regressions are listed in Table 6.

[10] A similar regression is done in Moreton and Spiller (1998).

[11] The signaling bidders won the following number of licenses: 21Century (10), AT&T (223), Mercury (32), NorthCoast (49), OPCSE (109), USWest (53).

Table 7 and Table 8 show means, separating the data according to whether a signaling bidder won the license.

Table 6: Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max
Log of price on D & E licenses ($/person)	986	0.400	1.166	-4.619	3.882
Log of price on F licenses ($/person)	493	-0.319	1.176	-4.711	2.111
Log of price on C license ($/person)	493	2.233	0.730	-0.280	3.687
Log of price on A & B licenses ($/person)	493	2.417	0.625	-0.368	3.414
Cumulative number of bidders on D & E blocks in first 5 rounds	986	2.402	1.203	0	7
Cumulative number of bidders on F block in first 5 rounds	493	0.696	0.763	0	4
Log of population density of buildout area	493	5.349	1.459	0.465	8.779
Ten-year population growth, 1990-1999	493	0.098	0.089	-0.190	0.494
Microwave links per 100 million people	493	0.149	0.230	0	1.909
Log of 1994 population in millions	493	12.383	1.086	10.203	16.721
Fraction of households with annual income > $35k	493	0.466	0.092	0.095	0.753
Dummy = 1 if signaling bidder won a D or E license	986	0.350	0.477	0	1
Dummy = 1 if signaling bidder won an F license	493	0.266	0.442	0	1

Notes: The market data have N = 493 observations, since there are 493 BTAs. Because there were 986 = 493 × 2 D and E licenses, the data pertaining to these licenses have 986 observations.

Table 7: Summary Statistics For D and E Licenses: Signaling Bidders vs. Nonsignaling Bidders

	Nonsignaling Bidder Won License			Signaling Bidder Won License		
Variable	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Ln of price on D & E licenses ($/person)	641	0.622	1.102	345	-0.012	1.171
Ln of price on C license ($/person)	641	2.168	0.730	345	2.352	0.714
Ln of price on A & B licenses ($/person)	641	2.340	0.660	345	2.559	0.525
Cumulative number of bidders on D & E blocks in first 5 rounds	641	2.537	1.206	345	2.151	1.157
Ln of population density of buildout area	641	5.242	1.445	345	5.549	1.464
Ten-year population growth, 1990-1999	641	0.093	0.084	345	0.108	0.097
Microwave links per 100 million people	641	0.156	0.226	345	0.136	0.236
Ln of 1994 population in millions	641	12.326	1.050	345	12.490	1.142
Fraction of households with annual income > $35k	641	0.455	0.091	345	0.487	0.090

Notes: The means for the prices of the D & E licenses do not directly correspond to those in Table 5 because those were population-weighted-average prices, whereas this table reports straight averages of (the log) of prices.

Table 8: Summary Statistics For F Licenses: Signaling Bidders vs. Nonsignaling Bidders

	Nonsignaling Bidder Won License			Signaling Bidder Won License		
Variable	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Ln of price on F licenses ($/person)	362	-0.236	1.060	131	-0.546	1.429
Ln of price on C license ($/person)	362	2.208	0.755	131	2.301	0.654
Ln of price on A & B licenses ($/person)	362	2.338	0.653	131	2.633	0.477
Cumulative number of bidders on D & E blocks in first 5 rounds	362	0.727	0.770	131	0.611	0.740
Ln of population density of buildout area	362	5.198	1.525	131	5.766	1.168
Ten-year population growth, 1990-1999	362	0.106	0.096	131	0.076	0.059
Microwave links per 100 million people	362	0.158	0.241	131	0.125	0.194
Ln of 1994 population in millions	362	12.276	1.073	131	12.680	1.070
Fraction of households with annual income > $35k	362	0.464	0.092	131	0.472	0.090

Notes: The means for the prices of the F licenses do not directly correspond to those in Table 5 because those were population-weighted-average prices, whereas this table reports straight averages of (the log) of prices.

In column 1 of Table 9, we show the ordinary least squares regression using all 1479 (= 493 markets × 3 licenses per market) observations. The coefficient on the signaling dummy variable is negative and is significantly different from 0 at the 95% confidence level. However, our prior was that price formation on the D and E licenses might not follow the same process as on the F license, since the F licenses were set-aside from competition from the non-preferenced bidders. Indeed, when we conducted a Chow test to test the restriction that a single regression should be used for the F prices and the D and E prices, we rejected this restriction. Accordingly, in the remainder of the analysis we use separate regressions for the D and E prices and the F price.

Column 2 of Table 9 shows an ordinary least squares (OLS) regression of the logged D and E prices on a constant and the dummy variable indicating whether a signaling bidder won the license. The estimated coefficient on the dummy variable is –0.634 and is significant at the 95% confidence level.[12] The interpretation is that, on average, signaling bidders paid prices 53% (= exp(–0.634)) of what nonsignaling bidders paid for licenses, not controlling for any of the determinants of price.[13] In the F price OLS regression on a constant and the signaling dummy, shown in Column 5 of Table 9, the estimated coefficient on the signaling dummy is –0.309 and is significant, indicating that signaling bidders paid 73% of what nonsignaling bidders paid for F licenses. When we control for market characteristics and

[12] In all of the reported regressions, we show the robust (White corrected) standard errors because we have found evidence of heteroskedasticity, with there being smaller error variance for licenses with large populations.

[13] It should be noted that this interpretation is not comparable to the average prices given in Table 5. In Table 5, average prices were computed by summing winning bids in dollars and dividing by the population covered by the licenses won. In the regressions, alternatively, each license is a different observation. This means that if signaling bidders won many licenses for markets with very low population, and paid high prices for these licenses, and won a few licenses with a large population, and paid a negligible prices for these licenses, then the regressions could show that signaling bidders did not pay significantly less for licenses, even if Table 5 indicates that signaling bidders paid lower average prices. In short, the Table 5 prices are computed using a population-weighted average, but the regressions are not weighted. In fact, given that the regressions use logged prices as the dependent variable, even weighting the regressions by license population would not give comparable figures.

competition on the D and E licenses, as shown in column 3 of Table 9, the estimated coefficient on the signaling dummy variable is –0.599, and it is significant at conventional levels. The interpretation is that signaling bidders paid 55% (= exp(–0.599)) of what nonsignaling bidders paid for D and E licenses. On the F license regression shown in column 6, the estimated coefficient on the signaling dummy is –0.291, and it is significant. This indicates that the signaling bidders paid 75% of what nonsignaling bidders paid for F licenses.

Our competition variable—the cumulative number of bidders in the first five rounds—does very well in the regressions shown in columns (3) and (6) of Table 9, having a positive slope that is significant at conventional levels. Indeed, the interpretation of the 0.329 coefficient in column (3), is that an extra bidder can raise the price of a license by 39% (= exp(0.329)). Also, the C-block is a strong regressor, having a positive coefficient that is significant at conventional levels. The coefficient on the AB price shows up insignificant in both the DE and F regressions. The slope of the population growth variable is significant in both regressions. The slope on the population density variable is significant in the DE price regression, but insignificant (at the 5% level) in the F price regression. The microwave links per 100 million people is of the wrong sign in both regressions. This variable measures the number of microwave links in the C-block, a proxy for the number in the D, E, and F blocks, and can be viewed as encumbrances on the license. The winning bidder on a block with a microwave link is responsible for the costs of relocating it. Therefore, prices on these licenses should be lower since the winner must bear the cost of moving the microwave link. Since the dependent variable is in per capita terms, we had no expectation on whether the population variable would positively or negatively affect price (the elasticity of the winning net *bid* with respect to population is equal to one plus the coefficient on the population variable). Of the wrong sign is the coefficient on the income variable, the fraction of households earning more than $35 thousand per year. The coefficient implies a negative relationship between this variable and prices. One might presume that this means that low income families consume more PCS than higher income families (this is possible!), but a better story is that the fraction of households earning more than $35k is capitalized in the C prices, which is positively related with the DE and F prices. On all of the demographic regressors the interpretation should be how the variable affects the dependent variable aside from its indirect effect through C prices.

Because the DE and F prices were determined in the same auction, it makes sense that their prices are simultaneously determined—the F prices affected the D and E prices and vice versa. This is especially true since many preferenced bidders had bid on D and E licenses during the auction, and in fact, preferenced bidders won 147 of the 986 D- and E-block licenses. To this end, we also performed our analysis using as regressors the log of the F price in the DE regression, and the log of the average of the D and E prices in the F regression. Since these variables are endogenous, we used two-staged least squares (2SLS) to estimate the regression. For the DE regression, our first stage was to predict the F license prices using as regressors the demographic and price variables, and also the competition variable for the F license. The second stage did the DE regression adding as a regressor the predicted price of the F license. These results are shown in column (4) of Table 9. Likewise, we performed a 2SLS regression for the F prices, using the predicted price of the D and E blocks. This is shown in column (4) of Table 9. This procedure determines that signaling bidders paid 64% of what nonsignaling bidders paid for D and E licenses, and 73% of what nonsignaling bidders paid for F licenses.

So far our evidence has been circumstantial. We have identified a set of bidders that used bid signaling and we have provided evidence that these bidders paid less for their spectrum than other bidders. Undoubtedly, some of this evidence results from Sprint spending so much for its licenses, though Table 5 indicates that even if we omit Sprint, there are price differences between signaling and nonsignaling bidders (and regressions omitting the licenses won by Sprint and AT&T maintains these price differences). On the F-block, where both AT&T and Sprint—as large bidders—were prohibited from bidding, we find in our regressions that the signaling bidders paid less for their licenses. We interpret these results as evidence of tacit collusion, although we recognize that we have not provided any causal evidence that it was specifically the signaling that allowed the signaling bidders to achieve low prices.

Table 9: Regressions Showing That Signaling Bidders Paid Less

	Dependent Variable: ln of license price ($/person)						
	D, E & F Licenses	D & E Licenses			F Licenses		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	OLS	OLS	OLS	2SLS	OLS	OLS	2SLS
Dummy = 1 if signaling bidder won license	-0.491 (0.057)	-0.634 (0.077)	-0.599 (0.066)	-0.439 (0.061)	-0.309 (0.137)	-0.291 (0.124)	-0.321 (0.088)
Constant	-2.037 (0.312)	0.622 (0.044)	-2.191 (0.337)	-1.409 (0.350)	-0.236 (0.056)	-1.746 (0.653)	-0.593 (0.539)
ln of C price ($/person)	0.438 (0.051)		0.358 (0.059)	0.072 (0.079)		0.643 (0.096)	0.414 (0.069)
ln of AB price ($/person)	-0.018 (0.044)		-0.009 (0.054)	0.025 (0.043)		-0.054 (0.077)	-0.024 (0.057)
Number of bidders in first 5 rounds[1]	0.373 (0.020)		0.329 (0.027)	0.238 (0.032)		0.285 (0.060)	0.129 (0.045)
ln of density of build out area	0.099 (0.023)		0.091 (0.028)	0.041 (0.025)		0.093 (0.039)	0.072 (0.030)
Ten-year population growth, 1990-1999	1.509 (0.259)		1.790 (0.306)	1.192 (0.287)		1.281 (0.497)	0.008 (0.421)
Microwave links per 100 million people	0.551 (0.105)		0.512 (0.125)	0.263 (0.117)		0.676 (0.199)	0.281 (0.140)
ln of 1994 population	0.028 (0.030)		0.073 (0.034)	0.115 (0.029)		-0.047 (0.060)	-0.132 (0.048)
Fraction of households w/ annual income>35k	-0.791 (0.318)		-0.886 (0.391)	-1.067 (0.326)		-0.305 (0.510)	0.744 (0.410)
ln of F price, or ln of avg of D and E price[2]				0.431 (0.111)			0.615 (0.062)
number of observations	1479	986	986	986	493	493	493
R-squared	0.375	0.067	0.358	0.603	0.014	0.289	0.632

Notes: Robust standard errors in parentheses.
[1]For the DE regressions, the competition variable is the cumulative number of bidders bidding on either the D or E license in the first five rounds; for the F regressions, the competition variable is the cumulative number of bidders bidding on the F license in the first five rounds.
[2]For the DE 2SLS regression (4), the variable is the ln of the F-license price; for the F 2SLS regression (7), the variable is the ln of the average of the D license price and the E license price.

5.2 Rivals May Be Deterred by a Reputation for Retaliation

Further evidence that retaliation was effective in reducing prices is seen by the absence of arbitrage between the D and E blocks in each market. In particular, we find that there was a tendency for bidders to avoid AT&T, a large bidder with a reputation for retaliation.

In the DEF auction, AT&T won 223 licenses—more licenses than anyone else. These licenses covered 140 million people, over 50% more than any other bidder. To explore whether bidders avoided AT&T, we looked at all of the bids that occurred after round 10 on the D and E blocks in markets on which AT&T was the high bidder.[14] We ask the question: Did bidders bump AT&T when AT&T was the high bidder on the less expensive of the two blocks? If bidders did not care about the identity of the high bidder, they would arbitrage the prices of the D and E blocks, and bid against AT&T if the other block were more expensive. This did not happen. Even when the price of the other block was 50% higher, bidders bid on the higher priced block 27% of the time.

As a comparison, we performed this same exercise to see if bidders systematically avoided smaller bidders in the same way. We chose five bidders that won between 9 and 14 licenses—ACCPCS, Comcast, Rivgam, PAccess, and Touch. We counted all of the bids made by other bidders when one of these five bidders was the standing high bidder on the D or the E block. When the other blocks were 50% more expensive, bidders avoided these five bidders 15% of the time; whereas, AT&T was avoided 27% of the time. AT&T's avoidance percentage is significantly larger than that of the other bidders at the 5% level. Even when the price discrepancy was more than $½ million, bidders often bid against the other bidder rather than bid against AT&T.

Examining the final prices reveals that the within-market avoidance of AT&T was less pronounced at that end of the auction. In the 166 markets where AT&T won the D or the E license, but not both, we find that AT&T won the less expensive license 60 percent of the time. However, when we sum the final bids in these markets, AT&T paid $303 million overall, while the other winners paid $298 million. If we restrict attention to the 123 markets where AT&T's rival was a nonsignaling bidder, then AT&T paid $187 million, while the nonsignaling bidders paid $195 million. Hence, the tendency for AT&T to pay less, as seen in Table 5, stems more from across-market avoidance of AT&T, rather than within-market avoidance.

6 Conclusions

We find that the simultaneous ascending auction is vulnerable to revenue-reducing strategies when competition is weak. In the DEF auction, six of the bidders frequently used code bids or retaliating bids to signal a split of the licenses. These bidders won over 40% of the spectrum and paid significantly lower prices for licenses than the other winners. Further evidence that the signaling was effective comes from the fact that bidders tended to refrain from bidding against AT&T, a large bidder with a reputation for retaliation.

Following the experience in the DEF auction, the FCC restricted bids to a whole number of bid increments (typically between 1 and 9) above the standing high bid. This eliminates code bidding, but it does nothing to prevent retaliating bids. Retaliating bids may be just as effective as code bids in signaling a split of the licenses, when competition is weak.

The auctioneer has many instruments to reduce the effectiveness of bid signaling. These include:

- Concealing bidder identities. This prevents the use of targeted punishments against rivals. Unless there are strong efficiency reasons for revealing identities, anonymous auctions may be preferable.

[14] AT&T, as a large bidder, was only eligible to bid on the D and E blocks in the DEF auction, since the FCC set aside the F-block licenses for small bidders.

- Setting high reserve prices. High reserve prices reduce the incentive for demand reduction in a multiple-item auction, since as the reserve price increases the benefit from reducing demands falls. Moreover, higher reserve prices reduce the number of rounds that the bidders have to coordinate a split of the licenses and still face low prices. Higher reserve prices can potentially reduce efficiency, but curtailing demand reduction may increase efficiency. The net effect is ambiguous.
- Offering preferences for small businesses and non-incumbents. Competition is encouraged by favoring bidders that may otherwise be disadvantaged ex ante. In the DEF auction, competition for the D and E license could have been increased by extending small business preferences to the D and E blocks, rather than restricting the preferences to the F block.
- Offering larger licenses. Many small licenses are more easily split up. At the other extreme a single nationwide license is impossible to split up. Nevertheless, using larger licenses may create inefficiency if doing so reduces competition in the communications industry after the auction.
- Allowing bids on packages of licenses. Package auctions mitigate the incentive for demand reduction. See Ausubel and Milgrom (2002).

Given the evidence that bid signaling can indeed affect the proper functioning of the simultaneous ascending auction, it is worthwhile for the seller to consider how specific auction rules inhibit or allow such bidding coordination.

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Appendix – Signaling Summary

Signaling Bidder	Punished Bidder	Rounds	Markets Sought	1994 Pop k	C	R	S	Markets Punished		
21Century	AT&TWire	110-115	Poughkeepsie, NY,361,D	425	1			Bloomington, IN,47,D	Muncie, IN,309,D,E	
	Mercury	123-125	Indianapolis, IN,204,F	1,322	1		1	Baton Rouge, LA,32,F	Biloxi, MS,42,F	
	VtelWire	123	Albany, NY,7,F	1,029	1			Glens Falls, NY,164,F	Plattsburgh, NY,352,F	Rutland, VT,388,F
ACCPCS	Rivgam	78-79	Providence, RI,364,D	1,510		1		Baltimore, MD,29,E		
AirGate	Western	83-85	Miami, FL,293,D	3,271	1			Seattle, WA,413,E		
AllTel	Western	48-49	Little Rock, AR,257,D	852		1		Austin, TX,27,D		
AT&TWire	MVI	59-109	Pueblo, CO,366,D	266		1	1	Anchorage, AK,14,D,E		
			Salem, OR,395,D	440		1	1			
	PCPCS	43	Poughkeepsie, NY,361,D	425		1		Brainerd, MN,54,E		
	Powertel	20-21	Birmingham, AL,44,E	1,200	1			Clarksville, TN,83,D,E	Nashville, TN,314,D,E	
	Touch	51-68	Seattle, WA,413,D	2,709		1	1	Bozeman, MT,53,D	Butte, MT,64,E	Great Falls, MT,171,D
								Helena, MT,188,D	Kalispell, MT,224,D	Missoula, MT,300,D
Mercury	Americall	161-165	San Angelo, T,400,F	156	1		1	Vicotria, TX,456,F		
	HighPlains	121-127	Lubbock, TX,264,F	393	1		1	Amarillo, TX,13,F		
	MercuryM	64-68	McComb, MS,269,F	107	1			Lake Charles, LA,238,F		
	Montana	117-132	Missoula, MT,300,F	139		1		Billings, MT,41,F	Butte, MT,64,F	Great Falls, MT,171,F
	PCSouth	10-25	Ft Walton Beach, FL,154,F	172	1			Jackson, MS,210,F		
	PCSouth	13-15	Pensacola, FL,343,F	344	1			McComb, MS,269,F		
	Technicom	12-16	Panama City, FL,340,F	171	1			Anniston, AL,17,F	Dothan, AL,115,F	
	Western	175-177	Eagle Pass, TX,121,D	101	1		1	Brownwood, TX,57,D		
NorthCoast	21Century	83-84	New Haven, CT,318,F	978		1	1	Albany, NY,7,F		
			New London, CT,319,F	357		1	1			
	Alpine	239-241	Hyannis, MA,201,E	204		1	1	Petoskey, MI,345,F		
	NextWave	68-70	Boston, MA,51,F	4,134		1	1	San Francisco, CA,404,F		
	NextWave	145-155	Rockford, IL,380,F	412		1		St Louis, MO,394,F		
	NextWave	161-163	Canton, OH,65,F	514		1	1	Harrisburg, PA,181,F		

Key: C takes the value of 1 if a code bid was used. R takes the value of 1 if retaliation was used. S takes the value of 1 is signaling was successful.

Signaling Bidder	Punished Bidder	Rounds	Markets Sought	1994 Pop k	C	R	S	Markets Punished		
OPCSE	Alpine	142-146	Saginaw, MI,390,F	615		1		Salinas, CA,397,F		
	Eldorado	118-128	Benton Harbor, MI,39,F	161	1		1	Fayetteville, AR,140,F	Michigan City, IN,294,F	
	LiteWave	163-165	Mt Pleasant, MI,307,F	119	1			Farmington, NM,139,F		
	NextWave	170-171	Toledo, OH,444,F	782	1		1	Lancaster, PA,240,F	Salisbury, MD,398,F	
	NorthCoast	78-86	Detroit, MI,112,F	4,705	1			Cincinnati, OH,81,F	Cleveland, OH,84,F	
	NorthCoast	142-149	San Juan, PR,488,F	2,170	1		1	Minneapolis, MN,298,F		
	TroupEMC	162	Gadsden, AL,158,F	174	1		1	Rome, GA,384,F		
	Virginia1	110	Fredericksburg, VA,156,D	125	1		1	Charleston, WV,73,F		
Telecorp	OPCSE	70	New Orleans, LA,320,F	1,367		1	1	Richmond, VA,374,F		
USWest	McLeod	59-64	Rochester, MN,378,D	233	1		1	Cedar Rapids, IA,70,E	Davenport, IA,105,E	Iowa City, IA,205,E
								Marshalltown, IA,283,E	Waterloo, IA,462,E	
	MVI	57-79	Salem, OR,395,E	440	1		1	Aberdeen, WA,2,E	Appleton, WI,18,E	Bremerton, WA,55,E
								Duluth, MN,119,E	Green Bay, WI,173,E	Juneau, AK,221,E
								Kalispell, MT,224,E	Madison, WI,272,E	Manitowoc, WI,276,E
								Marquette, MI,282,E	Pueblo, CO,366,E	Sault Ste. Marie, MI,409,E
								Sheboygan WI,417,E	Spokane, Wa,425,E	
	Touch	57-61	Boise, ID,50,E	417		1		Bozeman, MT,53,E	Fergus Falls, MN,142,E	Helena, MT,188,E
			Minneapolis, MN,298,D	2,841		1		Missoula, MT,300,E	Wenatchee, WA,468,E	
	Triad	89-100	Provo, UT,365,E	269	1		1	Lubbock, TX,264,E		
WebTel	Magnacom	112	Flagstaff, AZ,144,F	97	1			Lihue, HI,254,F		

Key: C takes the value of 1 if a code bid was used. R takes the value of 1 if retaliation was used. S takes the value of 1 is signaling was successful.