Auction 102 Clock Phase Technical Guide

1 Introduction

This technical guide details the first phase—the clock phase—of the two-part clock auction bidding procedures adopted by the Commission for the 24 GHz Band in the *Auctions 101 and 102 Procedures Public Notice*.[1] The *Assignment Phase Technical Guide* sets forth the bidding procedures for the second part of Auction 102—the assignment phase.

The clock auction adopted for Auction 102 shares some major features with the simultaneous multiple-round (SMR) auction format adopted for Auction 101. Like an SMR auction, the clock phase of Auction 102 will proceed through a sequence of ascending prices for the licenses. Also, like an SMR auction with no bid withdrawals, once there is demand for a license in the auction, the license will not then go unsold. The clock auction design, however, includes three features that allow it to run in less time than the corresponding SMR auction design.

The first of these features is that the clock auction aggregates demand within categories of generic licenses, rather than treating each license as a distinct item for bidding. In a traditional SMR auction, if during the auction, there were five units of demand for four very similar licenses, 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 for bidding, a single price increment applies to all, so the same price increase takes just one round instead of four. The relatively unimpaired nature of the 24 GHz Band means that in almost all the Partial Economic Areas (PEAs), the seven available licenses can be grouped into just two categories of very similar blocks.

The second feature that is different in the clock auction design is the assignment phase, details of which are described in the *Assignment Phase Technical Guide*. 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 blocks in each category that each bidder will acquire in a PEA, while the assignment phase determines the particular frequencies.

The third feature that distinguishes this clock auction from the SMR auction is intra-round bidding. This feature performs two important functions. First, intra-round bidding allows a clock auction to utilize larger bid increments than a corresponding SMR auction, which helps bring the auction to a close more quickly. In an SMR auction, 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 the highest price between the beginning and end of round prices at which it will maintain its current demand, so that a bidder will not be deterred from further bidding when the full bid increment is larger than it is willing to pay. Second, intra-round bidding 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.

[1] *See Auctions of Upper Microwave Flexible Use Licenses for Next-Generation Wireless Services*; *Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments, and Other Procedures for Auctions 101 (28 GHz) and 102 (24 GHz); Bidding in Auction 101 Scheduled to Begin November 14, 2018*, Public Notice, FCC 18-109 at 70, para. 216 & n.406 (Aug. 3, 2018) (*Auctions 101 and 102 Procedures Public Notice*).

The remainder of this document describes the clock phase bidding procedures in more detail and provides technical descriptions of the various calculations.

2 Overview

The clock phase will consist of a series of timed bidding rounds. In the first round, bidders will indicate their demands at the opening prices, or minimum opening bids. After the first round and before each later round, the bidding system will announce a *clock price* for the next round. During the round, bidders will place bids indicating demand for generic blocks in a license category in a PEA, at a price they specify that is equal to or greater than the *posted price*[2] of the previous round and equal to or less than the clock price. After each bidding round closes, the bids are processed. Bid processing determines the quantity of a bidder's requested demand that is applied (the *processed demand*), and the posted price of each product for the round. If, after the bids are processed, there is no excess demand for blocks in any category in any PEA, the clock phase of the auction will end and the *final clock phase price* for each product is equal to the posted price of the last round. Otherwise, the auction will continue with a new clock round.

Section 3 describes several rules and definitions that are useful in understanding how the clock phase functions. Section 4 describes the bidding rules. Section 5 describes the calculations for the bidding information that is shown to bidders. Section 6 describes the types of bids bidders can place. Section 7 describes bid processing in a clock round. Section 8 describes how the system sets up the next round if the closing conditions are not met at the end of a round.

3 Rules and Definitions

This section describes several rules and definitions that are useful in understanding how the clock phase functions.

3.1 Products

A product is defined to be the pairing of a PEA and a license category. There will be two products (i.e., two categories of generic blocks) in most PEAs, two generic blocks in the Lower category (Category L) and five generic blocks in the Upper category (Category U).[3] The supply of a product is the number of blocks in the category available in the auction.

3.2 Acceptable Bids

Acceptable bids are ones that can be applied in full or in part when they are considered during bid processing after the round.

No bid will be applied that reduces the aggregate demand for blocks in a category below the available supply. 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 applied in their entirety.

[2] The posted price of Round 1 is equal to the opening price.

[3] As described in the *Auctions 101 and 102 Procedures Public Notice*, it may be necessary to include one or two additional categories to accommodate any blocks with reduced bandwidth due to an existing licensee's holdings in up to nine of the PEAs. If included, we would refer to these categories as UI and/or LI, as needed. The existing licensee has pending applications to modify its holdings that, if granted, would change the number of bidding categories and blocks available in Auction 102. Once the Wireless Telecommunications Bureau (Bureau) acts on these applications, it will adjust the categories and numbers of generic blocks that will be available in Auction 102, to the extent necessary, and will provide public notice of any such adjustment. *Auctions 101 and 102 Procedures Public Notice* at 70, para. 220 (delegating authority to the Bureau to make such adjustment).

A bid that requests an increase in the number of blocks in a category demanded by a bidder will not be applied in its entirety if the bidder does not have sufficient bidding eligibility.

The following sub-sections describe the circumstances under which a bid is applied either fully or partially.

3.2.1 Fully Acceptable Bids

A bid is *fully acceptable* if, at the time it is considered during processing, 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, it would not cause the aggregate demand to be less than the supply for that product.

Only bids that are fully acceptable will be applied in their entirety during bid processing.

3.2.2 Partially Acceptable Bids

A bid is *partially acceptable* if, at the time it is considered during processing, it is not fully acceptable and 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*, it would not cause the aggregate demand to be less than the supply for that product.

Examples of fully and partially applied bids are provided in Section 6.

3.3 Activity and Eligibility

A bidder's *processed activity* is equal to the total number of bidding units associated with the bidder's processed demand after the bid processing of the round.

An activity rule is used to require bidders to participate in each round of the auction. A bidder's *eligibility* in round 1 of the auction is determined by the bidding units associated with its upfront payment. A bidder's eligibility in subsequent rounds is calculated based on its eligibility in the previous round, its processed activity, and the activity requirement (see Section 8.1).

4 Bidding

A bidder in the auction indicates in each round its demand for blocks of the products it desires at current prices. When submitting a bid, the bidder specifies a quantity and a price. The price can be the previous round's posted price, the current round's clock price, or any price in between (an "intra-round bid"). In each round, bidders may place multiple bids, including multiple bids for the same product. For example, a bidder that begins a round with processed demand of 4 units for a product might place one bid to reduce its demand for that product from 4 to 3 at a price of $5,500 and another bid to reduce its demand for the product from 3 to 2 at a price of $5,800.

In order to give bidders flexibility to express their demands, the auction includes two types of bids: simple bids and switch bids. Section 6 provides detailed explanations and examples of these bid types and how the auction system will process them.

4.1 Bidding Rules

In the first round of the auction, a bidder may only submit a bid for a product at the opening price (or minimum opening bid) for that product. For all rounds subsequent to round one, a bidder may either submit a bid to maintain its demand for a product at the round's clock price or submit a bid to change its demand for the product at a price that is greater than or equal to the previous round's posted price for that product and less than or equal to the current round's clock price for that product.

In every round, a bidder may only bid for a quantity that is greater than or equal to 0 and less than or equal to the supply for that product.

A bidder will *not* be allowed to submit a bid or collection of bids if the bidder's *activity* for the round would exceed its *current eligibility*.

In any clock round, a bidder may only submit one of the two types of bids for a given product: simple bids or switch bids. However, it can submit multiple bids of the same type for a given product. For example, if a bidder places a simple bid for product A, then it cannot submit a switch bid that involves product A in the same round.

A switch bid can be *either* from Category L to Category U *or* from Category U to Category L within the same PEA. A bidder will not be allowed to submit a switch bid that involves Category LI or Category UI, if those categories are available.

A bidder may *not* submit two different bids that involve the same product at the same price. For example, the bidder cannot submit a simple bid for 2 blocks of product A and a simple bid for 0 blocks of product A both at the same price.[4]

A bidder may *not* submit two bids for the same product that involve the same quantity at different prices. For example, the bidder cannot submit a simple bid for 2 blocks of product A at a price of $1,050 and a simple bid for 2 blocks of product A at a price of $1,070 in the same round.

All of the bids submitted by a bidder in a round for a product must be *one-directional* in terms of price. That is, if all of the bids submitted by a bidder in a round for a product are put in ascending order by price, the corresponding quantities must all either increase or decrease starting from the bidder's processed demand from the previous round. The algorithm that determines *one-directionality* is described below.

4.1.1 Algorithm for One-Directionality

The following algorithm illustrates how one can check one-directionality for a bidder with respect to a given product r. Let A denote the set of bids that the bidder has just requested to submit, and B denote the set of bids that the bidder has already submitted in this round. This section describes how to check one-directionality when the set $A \cup B$ contains at least two bids that involve product r.

If the set of bids $A \cup B$ includes at least one switch bid where product r is the "to" product, then one-directionality for product r is satisfied if and only if all bids in $A \cup B$ that involve product r are switch bids with r as the "to" product. See Section 6.2 for details on switch bids.

The remainder of this section describes how to check one-directionality when all bids involving product r are simple bids or are switch bids with r as the "from" product. The algorithm looks at all bids for product r in A and B. It ranks them in price order, then checks the direction of the change and validates that all bids at higher prices maintain the same direction.

[4] This avoids having to randomly select which of the bidder's bids to process first.

- Let A_r consist of all bids in A that involve product r. Each element of A_r is represented by the pair (price, quantity for product r).
- Similarly, let B_r consist of all bids in B that involve product r. Each element of B_r is represented by the pair (price, quantity for product r).
- Let S denote the union of A_r, B_r and the following element: (posted price of previous round for product r, the bidder's processed demand from previous round for product r)
- Rank all elements of S in ascending order of price, and let q be the corresponding vector of quantities. That is, $q(1)$ is the processed demand from the previous round, $q(2)$ is the quantity associated with the lowest-price bid for product r in $A \cup B$, etc. Let N be the number of elements in q.
- Check whether one of the following conditions holds:

  (i) $q(k) > q(k-1)$ for $k = 2, 3, \ldots, N$.

  (ii) $q(k) < q(k-1)$ for $k = 2, 3, \ldots, N$.

  If either (i) or (ii) is satisfied, then the bids in A are one-directional with the bids in B and the bidder's processed demand from the previous round for product r. If the bids in A are one-directional with the bids in B and the bidder's processed demand from the previous round for all products, then the system allows the bidder to submit the bids in A. Otherwise, the bids in A are not submitted.

Example 1:

Suppose that the bidder's processed demand for product r from the previous round is 4, and the posted price is \$5,000. In the current round, the clock price is \$6,000. The bidder has already submitted the bids $B_r = \{(\$5{,}300, 2), (\$5{,}400, 0)\}$ for product r in this round. The bidder is now trying to submit the bids $A_r = \{(\$5{,}100, 3), (\$5{,}200, 1)\}$ for product r. Then,

$$S = \{(\$5{,}000, 4), (\$5{,}100, 3), (\$5{,}200, 1), (\$5{,}300, 2), (\$5{,}400, 0)\}$$

The following table shows the prices and quantities of the elements of S, ranked in order of price:

k	Price	$q(k)$
1	\$5,000	4
2	\$5,100	3
3	\$5,200	1
4	\$5,300	2
5	\$5,400	0

Observe that $q(2) < q(1)$ but q$(4) > q(3)$. Thus, the bidder will not be allowed to submit the bids in A_r.

5 Calculations for Bidding Information

In the following sections, N denotes the set of all products.

5.1 Activity

When a clock round is open for bidding, the *activity* of a bidder is calculated as the total number of bidding units associated with the demand the bidder indicates it is willing to accept at the clock price,

given all bids that the bidder has submitted.[5] In other words, the activity of bidder i is given by the following sum:

$$\sum_{r \in N} q_{i,r} \cdot b_r$$

Where:

- $q_{i,r}$ denotes the requested demand of bidder i for product r at the clock price, given all bids that bidder i has submitted so far in this round. In particular, if all the bids that are submitted by bidder i for product r are applied during bid processing, then its processed demand will be $q_{i,r}$.
- b_r denotes the number of bidding units associated with product r

At the beginning of a round, *i.e.*, before the bidder has submitted any bids in this round, the bidder's activity is equal to 0.

Example 2:

Product A has 10 bidding units and product B has 8 bidding units. For product A, the clock price is $6,000, and the previous round's posted price is $5,000. For product B, the clock price is $4,800, and the previous round's posted price is $4,000. Suppose that bidder i has submitted the following bids in the current bidding round:

- Product A: a simple bid for 4 blocks at price $5,500, and a simple bid for 2 blocks at price $5,700. (See Section 6.1 for description of simple bids.)
- Product B: a simple bid for 2 blocks at price $4,500.

After the bidder has submitted these three bids, its activity is: $(2 \cdot 10) + (2 \cdot 8) = 36$ bidding units.

5.2 Required Activity

A bidder's *required activity* in round t is the minimum total number of bidding units associated with the bidder's processed demand that the bidder should have after the bid processing of round t in order to maintain the same eligibility in round $t + 1$. The bidder's required activity in round t is calculated according to the following formula:

$$Required\ Activity(t) = Eligibility(t) \cdot ActivityRequirement$$

Where:

- $Eligibility(t)$ denotes the bidder's eligibility in round t.
- $ActivityRequirement$ denotes the activity requirement. This is a percentage (up to 100 percent) set by the Commission.

5.3 Requested Commitment

For the convenience of bidders, the auction software will provide the following additional information about the financial exposure created by bids during the course of the auction. A bidder's *requested commitment* during a clock round t is the total gross bid amount calculated at the round's clock prices, given the bids that the bidder has submitted so far in round t. During the round, bids for the round have

[5] The bidding system provides the activity calculation, as described here, during the bidding round. Processed activity and processed demand cannot be determined until after the round's bids have been processed, so will be made available to bidders at that time.

not yet been processed, so the requested commitment is an estimate of a bidder's commitment, which is updated as bids are submitted. The requested commitment of bidder i in a clock round t is calculated according to the following formula:

$$\sum_{r \in N} q_{i,r} \cdot P_{t,r}$$

Where:

- $q_{i,r}$ denotes the requested demand of bidder i for product r at the clock price, given all bids that bidder i has submitted so far in this round. In particular, if all the bids that are submitted by bidder i for product r are applied during bid processing, then its processed demand will be $q_{i,r}$
- $P_{t,r}$ denotes the clock price in round t for product r

At the beginning of a round, *i.e.*, before the bidder has submitted any bids in this round, the bidder's requested commitment is equal to 0.

Example 3:

For product A, the clock price is $6,000, and the previous round's posted price is $5,000. For product B, the clock price is $4,800, and the previous round's posted price is $4,000. Suppose that bidder i has submitted the following bids in the current bidding round:

- Product A: a simple bid for 4 blocks at price $5,500, and a simple bid for 2 blocks at price $5,700. (See Section 6.1 for description of simple bids.[6])
- Product B: a simple bid for 2 blocks at price $4,500

By placing these bids, the bidder indicates that it is willing to buy 2 blocks of product A up to and including the clock price of $6,000 per block, and 2 blocks of product B up to and including the clock price of $4,800 per block. After submitting these three bids, the bidder's requested commitment is:

$$(2 \cdot \$6{,}000) + (2 \cdot \$4{,}800) = \$21{,}600$$

5.4 Bidding Credit Discounts on Requested Commitment

This section describes the calculations for requested commitment bidding credit discounts in a round t. All bidding credit discounts are rounded to the nearest dollar.

The following notation is used:

- BC_i denotes the bidding credit percentage of bidder i.
- $RC_{t,i}$ denotes the requested commitment of bidder i in round t.[7]
- S denotes the set of all products in *small markets* (*i.e.*, markets subject to the small market bidding cap)[8]

[6] For example, a simple bid for 2 blocks at a price of $5,700 indicates that at a price of $5,700 up to the clock price of $6,000, the bidder demands 2 blocks.

[7] Note that a bidder's requested commitment may change when the bidder submits or changes its bids.

[8] Markets that are subject to the small market bidding credit cap are those PEAs with a population of 500,000 or less, which corresponds to PEAs 118–416, excluding PEA 412. *Updating Part 1 Competitive Bidding Rules*, WT Docket No. 14-170, Report and Order, 30 FCC Rcd 7493, 7546, para. 127 (2015) ("[N]o winning DE bidder will be

5.4.1 Rural Service Provider Bidding Credit

If bidder i qualifies for the rural service provider bidding credit, then in round t

Its *uncapped requested commitment discount* is:

$$BC_i \cdot RC_{t,i}$$

Its *capped requested commitment discount* is:

$$min\{\$10 \text{ million}, BC_i \cdot RC_{t,i}\}$$

This is equal to the bidder's requested commitment multiplied by its bidding credit and then capped at $10 million.

5.4.2 Small Business Bidding Credit

If bidder i qualifies for the small business bidding credit, then in a regular clock round t

Its *uncapped requested commitment discount in small markets* is:

$$BC_i \cdot \sum_{r \in S} q_{i,r} \cdot P_{t,r}$$

Note that the summation is across all products in small markets. The uncapped requested commitment discount in small markets is calculated by multiplying the bidder's requested commitment in small markets with its bidding credit.

Its *uncapped requested commitment discount* (across all markets) is:

$$BC_i \cdot RC_{t,i}$$

Its *capped requested commitment discount* (across all markets) is:

$$min\left\{\$25 \text{ million}, BC_i \cdot \sum_{r \in N \setminus S} q_{i,r} \cdot P_{t,r} + min\left\{\$10 \text{ million}, BC_i \cdot \sum_{r \in S} q_{i,r} \cdot P_{t,r}\right\}\right\}$$

This calculation first caps the bidder's discount in small markets at $10 million, then adds the bidder's discount from all other markets (*i.e.*, markets that are not subject to the small market bidding cap) and caps the sum at $25 million.

5.5 Requested Net Commitment

A bidder's *requested net commitment* is equal to the difference between its requested commitment and its capped requested commitment discount.

able to obtain more than $10 million in bidding credits for licenses won in PEAs 118–416, with the exception of PEA 412 (Puerto Rico), which exceeds the 500,000 pop threshold.").

5.6 Commitment (from previous round)

The bidder's *commitment* from the previous round is a dollar value that is calculated from the bidder's processed demand and the posted prices after the bid processing of the previous round.

The commitment of bidder i after round t is given by the following formula:

$$\sum_{r \in N} d_{t,i,r} \cdot p_{t,r}$$

Where:

- $d_{t,i,r}$ denotes the processed demand of bidder i for product r after round t.
- $p_{t,r}$ denotes the posted price of product r after round t.

5.7 Bidding Credit Discounts on Commitment (from previous round)

This section describes the calculations for commitment bidding credit discounts after a round t. All bidding credit discounts are rounded to the nearest dollar.

The following notation is used:

- BC_i denotes the bidding credit percentage of bidder i.
- $C_{t,i}$ denotes the commitment of bidder i after round t.
- S denotes the set of all products in *small markets* (*i.e.*, markets subject to the small market bidding cap).

5.7.1 Rural Service Provider Bidding Credit

If bidder i qualifies for the rural service provider bidding credit, then after round t

Its *uncapped commitment discount* is:

$$BC_i \cdot C_{t,i}$$

Its *capped commitment discount* is:

$$min\{\$10 \text{ million}, BC_i \cdot C_{t,i}\}$$

This is equal to the bidder's commitment multiplied by its bidding credit and then capped at $10 million.

5.7.2 Small Business Bidding Credit

If bidder i qualifies for the small business bidding credit, then after round t

Its *uncapped commitment discount in small markets* is:

$$BC_i \cdot \sum_{r \in S} d_{t,i,r} \cdot p_{t,r}$$

Note that the summation is across all products in small markets. The uncapped commitment discount in small markets is calculated by multiplying the bidder's commitment in small markets with its bidding credit.

Its *uncapped commitment discount* (across all markets) is:

$$BC_i \cdot C_{t,i}$$

Its *capped commitment discount* (across all markets) is:

$$min\left\{\$25 \text{ million}, BC_i \cdot \sum_{r \in N \setminus S} d_{t,i,r} \cdot p_{t,r} + min\left\{\$10 \text{ million}, BC_i \cdot \sum_{r \in S} d_{t,i,r} \cdot p_{t,r}\right\}\right\}$$

This calculation first caps the bidder's discount in small markets at $10 million, then adds the bidder's discount from all other markets (i.e., markets that are not subject to the small market bidding cap) and caps the sum at $25 million.

5.8 Net Commitment (from previous round)

A bidder's *net commitment* after round t is the bidder's commitment after round t minus its capped commitment discount.

6 Bid Types

There are two types of bids:

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.[9]

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.[10] 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, a more detailed explanation is provided along with examples to illustrate each of these bid types and how the bidding system will process them.

6.1 Simple Bids

In Round 1, bidders will place simple bids to indicate their initial demands for blocks in a category in a geographic area in which they are qualified to bid. In subsequent rounds, they may wish to reduce, increase, or maintain those demands using simple bids.

A *simple bid requesting to reduce demand* to 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 the bidder submitted a bid, if the bidder submitted multiple bids for the product), the bidder is willing to buy an exact quantity equal to q; and

[9] Bids requesting a reduction in demand may not be fully applied if the reduction would cause the demand for blocks in the category to fall below the supply. Simple bids requesting an increase in demand may not be fully applied if that would cause the bidder's activity to exceed its eligibility. *See* Procedures PN at IV.B.2.d ("Changing Demand, Bid Types, and Bid Processing")

[10] As noted below, a switch bid may not be used to switch to or from a category of blocks with reduced bandwidth.

(2) At price p, the bidder is willing to buy any quantity between q and its previous demand for product r.[11]

By placing one (or more) *simple bid(s) requesting to increase demand* for a product r at one (or more) price(s) in a round, the bidder indicates that at all prices associated with this round (*i.e.*, prices that are greater than or equal to the last round's posted price and less than or equal to the clock price) it is willing to buy any quantity that is greater than or equal to its processed demand and less than or equal to the maximum quantity that it specifies in a bid for product r.[12]

A *simple bid to maintain a quantity* equal to the bidder's processed demand for a product r at the round's clock price indicates that the bidder is willing to buy a quantity equal to the previous round's processed demand at all prices in this round up to and including this round's clock price. Intra-round bids to maintain demand are not permitted.[13]

Example 4: Bidder Places a Simple Bid Requesting to Reduce Demand to 2 Blocks at $5,500

Suppose that after the bids of the previous round are processed, the bidder's processed demand for a product is 4 blocks and the posted price is $5,000. In the current round, the clock price is $6,000, and the bidder places a single simple bid for the product requesting to reduce its demand to 2 blocks at price $5,500.

To the bidding system, this bid means the following:

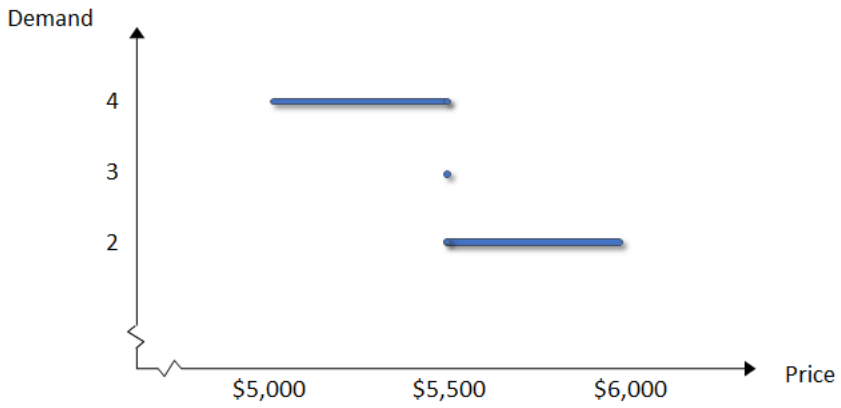
- If the price is below $5,500, the bidder is willing to purchase 4 blocks.
- If the price is exactly $5,500, the bidder is willing to purchase 2, 3, or 4 blocks.
- If the price is above $5,500, the bidder is willing to purchase only 2 blocks.

[11] The bidder's previous demand for product r is either equal to its processed demand from the previous round or, if the bidder has placed a simple bid at a price below p for product r, the quantity in the bid for product r with the highest price below p.

[12] The auction system will not process the requested increase until bid processing reaches the price point at which the bid was made, but depending upon demand for the product relative to its supply and upon which bids to reduce demand for the product are applied, the posted price for the current round may be above or below the bid price of the requested increase. The posted price may be lower if, for example, applying the increase allows another bidder's requested decrease at a lower price point to be applied.

[13] A bidder cannot submit a bid to maintain its demand at a price below the round's clock price. Bids made at intra-round price points are used to indicate the price point at which the bidder's requested demand changes from its processed demand from the previous round, or if the bidder requested a change at a lower intra-round price in the round, from its requested demand at the next lowest price point.

The graph below illustrates how the bidding 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.

When the bidding system processes the bids at price $5,500, the simple bid will be applied fully, partially, or not at all depending on the level of excess demand at that point in the bid processing.

(a) If demand exceeds supply by more than 2 blocks, the bid is fully applied. The bidder will hold 2 blocks.

(b) If demand exceeds supply by exactly 2 blocks, the bid is also fully applied. The bidder will hold 2 blocks.

(c) If demand exceeds supply by only 1 block, the bid is partially applied. The bidder will hold 3 blocks.

(d) If demand does not exceed supply, the bid is not applied. The bidder will continue to hold 4 blocks.

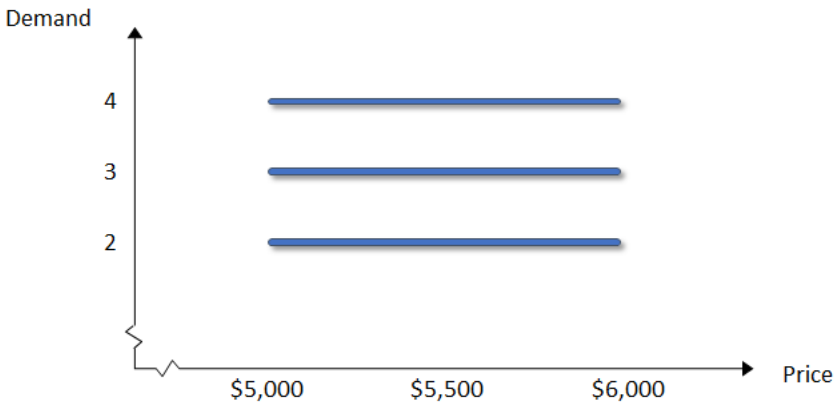
Using the same bid, if no other bidder has submitted a bid requesting to change its demand for this product, then:

- In case (a), the posted price will be equal to $6,000.
- In cases (b) and (c), the posted price will be equal to $5,500.

In case (d), the posted price will be equal to $5,000

Example 5: Bidder Places a Simple Bid Requesting to Increase Demand to 4 Blocks at $5,500

Suppose that, after the bids of the previous round are processed, the bidder's processed demand for a product is 2 blocks and the posted price is $5,000. In the current round, the clock price is $6,000, and the bidder places a single simple bid for the product requesting to increase its demand to 4 blocks at price $5,500. This means that for all prices p such that $\$5{,}000 \leq p \leq \$6{,}000$, the bidder is willing to buy 2, 3, or 4 blocks. The corresponding demand graph is shown in the following figure:



6.2 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 two blocks from Category L to Category U in a given PEA. Switch bids may be applied partially or in full. Note that switch bids may not be used to switch to or from a category of reduced bandwidth blocks (Category UI or LI, if any).

For each switch bid, the bidder specifies the "from" product as well as a price p and a quantity q for the "from" product. If the "from" product is the Category L (respectively, U) product in a PEA, then the "to" product is the Category U (respectively, L) product in that PEA. The bidder does not specify a quantity or a price for the "to" product. In processing the switch bid, the bidding 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 submitted a bid involving the "from" product), 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 previous demand for the "from" product;[14] 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 previous demand for the "to" and "from" products respectively before the switch bid is applied. [15]

Regardless of whether a bid to switch n blocks from product A to product B is fully or partially applied, if the processed demand of the bidder for product A is reduced by m blocks, then the processed demand of

[14] The bidder's previous demand for the "from" product is either equal to its processed demand from the previous round or, if the bidder has placed a switch bid at a price below p involving that product, the quantity in the bid involving that product with the highest price below p.

[15] The bidder's previous demand for the "to" product is either equal to its processed demand from the previous round or, if the bidder has placed another switch bid involving that product, the quantity that has already been applied for this product during bid processing at the point this switch bid is considered.

the bidder for product B is increased by m blocks, where $1 \leq m \leq n$. A switch bid for 1 block cannot be partially applied.

Example 6: Bidder Places a Switch Bid for 2 Blocks from Category U to Category L at $5,500

Suppose that after the bids of the previous round are processed, the bidder's processed demand is 4 blocks in Category U and 0 blocks in Category L in some PEA, and the posted price of the Category U product in that PEA is $5,000. In the current round, the clock price for the Category U product in that PEA is $6,000, and the bidder places a single switch bid involving that PEA requesting to switch its demand by 2 blocks from Category U to Category L at price $5,500.

To the bidding system, this bid means the following:

- If the price of Category U is below $5,500, the bidder is willing to purchase 4 Category U blocks.
- If the price of Category U is exactly $5,500, the bidder wishes to switch demand from Category U to Category L by up to 2 blocks.

Note that the bidder does not specify a quantity or a price for Category L blocks in its bid. By placing the bid, the bidder indicates a willingness to purchase up to 2 blocks of Category L at the current clock price.

When the bidding system processes the bids at price $5,500, this switch bid will be applied fully, partially, or not at all depending on the level of excess demand at that point in the bid processing:

- If demand exceeds supply by 2 or more blocks in Category U, the bid is fully applied. The bidder will then hold 2 blocks in Category U and 2 blocks in Category L.
- If demand exceeds supply by only 1 block in Category U, the bid is partially applied. The bidder then will hold 3 blocks in Category U and 1 block in Category L.
- If demand does not exceed supply, the bid is not applied at all. The bidder will continue to hold 4 blocks in Category U and none in Category L.

In all cases, the bidder's total processed 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 U to Category L 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 U.

7 Processing Bids for a Clock Round

This section describes bid processing in the 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 clock round.

7.1 Missing Bids

For each product for which the bidder had positive processed demand in the previous round, if the bidder did not submit a bid for that product during the current round, it will be deemed to have bid a simple bid for that product with a quantity of 0 at a price equal to the previous round's posted price. For example, if the previous round's posted price for a particular product is $6,000 and the bidder does not submit a bid in this round for that product, it will be deemed to have bid a quantity of 0 at $6,000. Note that this does not necessarily mean that a bidder will receive 0 blocks at $6,000. The missing bid will be processed just as if the bidder submitted a simple bid for 0 blocks at $6,000. All missing bids are subject to the same checks as those submitted by a bidder.

7.2 Price Points

The *price point* indicates the percentage of the distance between the posted price of the previous round and the clock price of the current round. For example, the 0 percent price point refers to the previous round's posted price, the 100 percent price point refers to the clock price, and the 50 percent price point refers to the average of the previous round's posted price and the clock price of this round. As another example, if the previous 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 percent price point, and the price $5,500 corresponds to the 50 percent price point.

7.3 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 the 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.[16] 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.[17] 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. The algorithm then 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 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 none 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 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 7: 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 reduction of the remaining one block may be applied later, if conditions permit after other bids have been processed.

[16] The implementation does not necessarily require a queue, but this description is used here for expository ease.

[17] 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 activity overall does not exceed its eligibility.

Example 8: There are three bidders (bidders 1, 2 and 3). At the beginning of the round, bidder 1 has 3 blocks of processed demand, bidder 2 has 2 blocks of processed demand and bidder 3 has 1 block of processed demand. Thus, the aggregate demand for product A at the beginning of the round is 6 blocks. The supply for product A is 5 blocks. The following bids are submitted in the round:

- Bidder 1 has submitted a simple bid to reduce its demand for A to 0 blocks at price $1,500.
- Bidder 2 has placed a bid to increase its demand to 3 blocks at price $1,800.
- Bidder 3 has placed a simple bid to maintain its demand of 1 block at the clock price.

The bid processing works as follows:

- The simple bid of bidder 1 is processed first because it is at the lowest price point. It is not fully acceptable (because it would lead to excess supply), but it is partially acceptable. One block of the reduction is applied, and the bid for a quantity of 0 blocks is placed in the queue.
- At this point there is no excess demand for product A, and the processed demand of bidder 1 is 2 blocks.
- The bid of bidder 2 is processed, creating 1 unit of excess demand for product A. The simple bid of bidder 1 in the queue is considered and a reduction of an additional 1 block is applied. Bidder 1's bid for a quantity of 0 blocks remains in the queue.
- Bid processing ends (and the bid in the queue is discarded), and the bidders' processed demands for product A are:
    - Bidder 1: 1 block
    - Bidder 2: 3 blocks
    - Bidder 3: 1 blocks

7.4 Posted Prices

Let $P_{t,r}$ denote the clock price for product r in round t. After the bids of a clock round t have been processed, the *posted price* $p_{t,r}$ 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 ($p_{t,r} = P_{t,r}$).
- 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 ($p_{t,r}$) will be set to be equal to the product price associated with the bid that has the highest price for product r among all bids from round t that included a reduction in demand for the product and that were applied (either entirely or partially). That is, the *posted price* will be the price at which a reduction caused demand to equal supply.
- If either of the following two conditions holds:
    - The aggregate demand (evaluated using the processed demands) is less than the supply[18]
    - 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 ($p_{t,r} = p_{t-1,r}$).

[18] For example, because of insufficient demand at opening prices.

These rules ensure that the posted price of a product will not be higher than the price of a simple bid or a switch that requested a reduction for that product and was not applied (either entirely or in part).

Therefore, in Example 8 in Section 7.3, the posted price is $1,500.

8 Checking Closing Conditions and Setting Up the Next Round

After bid processing the bidding system will determine if the closing conditions for the auction have been met or if bidding will continue with a new clock round.

If there is no excess demand for any product, the clock phase of the auction will close. The final clock phase price of a product will be set to be equal to the product's posted price for the last round.

If the bidding system determines that there is excess demand for at least one product, then the system sets 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. This section provides the details of these calculations.

8.1 Next Round Eligibility

After any clock round t, the bidder's eligibility for the next round $t+1$ is set to be equal to:

$$min\left\{ Eligibility(t), \frac{ProcActivity(t)}{ActivityRequirement} \right\}$$

Where:

- $Eligibility(t)$ denotes the bidder's eligibility in round t
- $ProcActivity(t)$ denotes the bidder's *processed activity* from round t, that is, the total number of bidding units associated with the bidder's processed demand after the bid processing of round t. Using the notation of Sections 5.1 and 5.6, $ProcActivity(t) = \sum_{r \in N} d_{t,i,r} \cdot b_r$
- $ActivityRequirement$ denotes the activity requirement. This is a percentage (up to 100 percent) set by the Commission.

8.2 Clock Prices for Next Round

Once the posted prices for a round are calculated and the system has determined that there will be another clock round, the clock price for each product in the next round is calculated as the product's posted price from the previous round multiplied by an increment.

Specifically, the clock price $P_{t,r}$ for product r in round t is calculated as:

$$P_{t,r} = (p_{t-1,r}) \cdot (1 + y)$$

rounded up to the nearest $1,000.

Where:

- y denotes the price increment for round t.
- $p_{t-1,r}$ denotes the posted price for product r after round $t-1$.

Note that this calculation applies to every product, irrespective of whether the product is in excess demand.