Alex Starr
Assistant Vice President-
Senior Legal Counsel

AT&T Services, Inc.
1120 20th Street NW Ste. 1000
Washington, D.C. 20036

Phone: 202.457.2044
E-mail: alex.starr@att.com

December 12, 2017

EX PARTE VIA ELECTRONIC FILING

Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street SW
Washington DC 20554

Re: *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, GN Docket No. 14-177; IB Docket No. 15-256; WT Docket No. 10-112; IB Docket No. 97-95.

Dear Ms. Dortch:

AT&T Services, Inc., on behalf of the subsidiaries and affiliates of AT&T Inc. (collectively, "AT&T"), submits this letter and its attachment for consideration by the Federal Communications Commission ("Commission" or "FCC") in the above-referenced proceedings.

FCC Chairman Ajit Pai recently declared that "I want to move forward with a high-band spectrum auction in 2018."[1] To help achieve that goal – which AT&T believes is crucial to satisfying the exponential growth in demand for mobile wireless broadband services and to maintaining the United States' leadership in developing 5G functionalities – AT&T submits the white paper attached to this letter, which is authored by Economists Incorporated and entitled "An Auction Design for Millimeter Wave Spectrum" ("Auction White Paper"). The attached Auction White Paper warrants careful examination. To provide an introductory overview, however, AT&T highlights the following points:

- Although the FCC has now authorized mobile wireless terrestrial use in the 24 GHz, 28 GHz, 37 GHz, 39 GHz, and 47 GHz bands, the attached Auction White Paper focuses on the 39 GHz band due to the challenges presented by the presence of commercial incumbents with 50x50 MHz paired assignments. This complicates any technology-neutral transition to the FCC's band plan of contiguous, unpaired 200 MHz blocks, i.e., the kind of adjacent, large-bandwidth blocks necessary to maximize the utility of the 39 GHz band for 5G purposes. However, the Auction White Paper notes that this approach is extensible to the auction of other mmWave bands to include the 28 GHz band.

- The fundamental auction design would involve a familiar two-phase procedure. Phase I would involve the allocation of generic 200 MHz blocks via a clock auction format with

[1] *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, GN Docket No. 14-177; IB Docket No. 15-256; WT Docket No. 10-112; IB Docket No. 97-95, Second Report and Order, Second Further Notice of Proposed Rulemaking, Order on Reconsideration, and Memorandum Opinion and Order, FCC 17-152, at 131 (Statement of Chairman Ajit Pai) (rel. Nov. 22, 2017).

a uniform price in each PEA. Phase II would involve a second-price, sealed-bid Assignment Phase, with contiguity guaranteed.

- The auction design contemplates auctioning the upper 37 GHz band (37.6-38.6) along with the 39 GHz band, a total of 12 blocks of 200 MHz each.

- Participation in the auction by incumbents would be voluntary. Any current EA or RSA license holder that wishes to participate in the auction would receive financial vouchers in exchange for its current licenses. An incumbent voucher for a given PEA would reflect the incumbent's proportionate holdings in that PEA in terms of the number of 200 MHz blocks in that PEA.

- An incumbent's voucher is a financial instrument that entitles the incumbent to either a gross payment after the auction or a credit toward the purchase of 200 MHz blocks. It specifically does not entitle the incumbent to any amount of spectrum. Rather, it is up to the incumbent to win any licenses that it wants through the auction.

- Incumbents who choose not to participate in the auction would be repacked prior to the auction at one end of the band, to leave the maximum number of contiguous 200 MHz blocks available for auction.

- During the assignment phase, all auction winners would bid in a single round assignment phase, with contiguity guaranteed, to determine which blocks they would be assigned. This would negate any advantage that incumbents might otherwise be afforded to obtain contiguous spectrum, and complete the "repacking" process.

- The foregoing voucher system would create a level playing field for incumbents and new entrants alike by allowing all bidders to participate equally in the auction without strategic advantages or disadvantages arising from the idiosyncratic nature of current holdings. In sum, all auction participants would have an equal chance to acquire contiguous 200 MHz blocks at generic prices. In other words, this auction proposal wipes the slate clean – to the extent incumbents voluntarily wish to do so -- for the purposes of holding the most efficient and equitable auction possible.

Pursuant to the Commission's rules, a copy of this letter and its attachment are being filed electronically in the above-referenced docket. Please do not hesitate to call me if you have questions.

Sincerely,

/s/ Alex Starr

Attachment

cc: Donald Stockdale, FCC/WTB/FO
Joel Taubenblatt, FCC/WTB/FO
Matthew Pearl, FCC/WTB/FO
Margaret Wiener, FCC/WTB/ASAD
Gary Michaels, FCC/WTB/ASAD
Craig Bomberger, FCC/WTB/ASAD
William Huber, FCC/WTB/ASAD
Erik Salovaara, FCC/WTB/ASAD
Martha Stancill, FCC/WTB/ASAD
Rita Cookmeyer, FCC/WTB/ASAD
Eliot Maenner, FCC/WTB/ASAD
Blaise Scinto, FCC/WTB/BD
John Schauble, FCC/WTB/BD
Simon Banyai, FCC/WTB/BD

Attachment to Ex Parte Letter Dated December 12, 2017 from Alex Starr, AT&T, to Marlene Dortch, FCC,
GN Docket No. 14-177

An Auction Design for Millimeter Wave Spectrum

November 30, 2017

James Bono, Ph.D.

Allan Ingraham, Ph.D.[1]

[1] James Bono is Senior Economist at Economists Incorporated. Allan Ingraham is Principal at Economists Incorporated. This research was funded by AT&T. The analysis expressed here is our own and may not reflect beliefs held by others at Economists Incorporated.

Contents

Motivation and High-Level Auction Features 2
Incumbent Vouchers 3
Incumbents that Choose not to Participate – The Holdout Segment 5
The Supply of Spectrum in the Auction 5
The Holdout Segment and Leftover Segments in the Assignment Phase 5
Approaches to Repacking the Holdout Segment 6
Voucher Systems in other Auctions 11

Millimeter Wave Auction Design

Motivation and High-Level Auction Features

The millimeter wave spectrum represents an opportunity to provide 5G service to wireless consumers in the United States by as early as 2019. Presently both the 28 GHz and 37 to 40 GHz bands have been identified as 5G capacity bands. Because 5G service requires large swaths of contiguous spectrum, an ideal auction design would have the following characteristics:

- It would be a two-phase procedure. Phase I would involve the allocation of generic blocks, and Phase II would involve assignment, with contiguity guaranteed;
- The auction would follow a clock auction format with uniform price in each geographic service area, which simplifies the design; and
- The auction would conclude with a second-price, sealed-bid Assignment Phase that would move rapidly.

5G service, however, requires large and contiguous spectrum assignments, and significant quantities of spectrum in these bands has already been assigned in a manner that is less than ideal from the standpoint of 5G service. An auction design such as the one contemplated above has become popular for high-stakes spectrum tenders worldwide. Countries such as Singapore, the Kingdom of Saudi Arabia, Mexico, the United Kingdom, and the United States have conducted or are in the process of finalizing rules for auctions of this design.

In the case of the millimeter wave bands in the USA, however, there are incumbent licensees with licenses assigned according to different geographic license sizes and block assignments. This would frustrate the implementation of the auction design unless additional design components are in place:

- including frequencies from 37.6 GHz to 40.0 GHz in 200 MHz blocks licensed at the Partial Economic Area (PEA) level;
- optionally including frequencies from 27.5 GHz to 28.35 GHz in 425 MHz blocks licensed at the county level; and
- a mechanism to credit incumbents for existing spectrum positions while clearing as much of the encumbered spectrum as possible to be let as unencumbered spectrum at auction.

The final point—the mechanism to credit incumbents while enabling realignment of the band—is a primary focus of this paper, which proposes a financial voucher system for incumbent licenses. The purpose of the voucher system is to promote the efficient use of millimeter wave spectrum while respecting incumbent license holdings and creating a level playing field for incumbents and new entrants alike. The voucher system is applicable to the 28 and 39 GHz bands. However, for concreteness, we focus here on the more complex case of 39 GHz.

In promoting efficiency, the vouchers enable a transition from the current license structure, which consists of often-overlapping PEA and RSA licenses in often-discontiguous, 2x50 MHz blocks, to a technology-neutral band of PEA licenses in contiguous, unpaired, 200 MHz blocks.[2] This transition unlocks substantial value relative to an alternative that holds current licenses constant while auctioning residual spectrum.

In respecting incumbent license holders, the vouchers allow incumbent auction participants to be financially credited for their current holdings at values determined by the auction. The vouchers also permit incumbents to expand their spectrum holdings in the 39 GHz band with a guarantee of contiguity. By facilitating the sale of clean, 200 MHz blocks that are better suited to 5G uses, this promises to incent participation and increase auction valuations over an SMR auction offering only residual portions of the band.

And finally, in creating a level playing field for incumbents and new entrants alike, the voucher system will allow all bidders to participate equally in the auction without strategic advantages or disadvantages arising from the idiosyncratic nature of current holdings. The voucher system wipes the slate clean for the purposes of holding the most efficient and equitable auction possible and for promoting an efficient band configuration that will expedite the deployment of 5G services to consumers.

Incumbent Vouchers

Any current PEA or RSA license holder that wishes to participate in the auction would receive financial vouchers in exchange for its current licenses. Such an incumbent would receive a voucher for each PEA in which it has current license holdings. Both PEA licensees and Rectangular Service Area ("RSA") licensees would be eligible to receive vouchers. An incumbent voucher for a given PEA would reflect the incumbent's current holdings in that PEA in terms of a number of 200 MHz blocks in that PEA. For example, in a PEA with a population of 1 million, a 200 MHz block represents 200 million MHz-pops. So, a bidder with current license holdings that sum to 90 million MHz-pops would receive a voucher worth 90 million MHz-pops divided by 200 million MHz-pops, which equals 0.45. The maximum possible total vouchers in a PEA is 7, which corresponds to the size of the current band (1.4 GHz, 38.6 GHz to 40.0 GHz), divided by the proposed block size (200 MHz). We assume that incumbents that do not exchange their current licenses for vouchers cannot participate in the auction. The FCC has the option of repacking them into a "holdout segment" as discussed below.

An incumbent's voucher is a financial instrument that entitles the incumbent to a gross payment after the auction (or, in some cases, a credit toward its auction payments). It specifically does not entitle the incumbent to any amount of spectrum. Rather, it is up to the incumbent to win any licenses that it

[2] As PEAs nest inside EAs, we use the two definitions interchangeably when referring to the geographic areas of incumbent, non-RSA licenses.

wants through the auction. When an incumbent participates in the auction, its net payment in a PEA is the value of the spectrum it wins (base prices plus assignment payment) minus the gross voucher payment it receives.

At the end of the allocation phase, an incumbent's voucher payment in a PEA will be calculated based on a number of factors, including:

- (v) the value of the incumbent's voucher,
- (V) the total value of vouchers in that PEA,
- (D) the total demand for spectrum in that PEA,
- (P) the base price for a generic block in that PEA, and
- (S) the total supply of blocks in that PEA.

In the simplest case, where demand equals supply, an incumbent is paid an amount equal to its voucher times the base price in that PEA. An incumbent with a voucher worth 0.45 blocks in a PEA with a base price of $30 million would receive 0.45*$30 million = $13.5 million in net financial credits to be applied to its total financial position in the allocation phase. In this case, the FCC (and ultimately the US Treasury) receives the balance of the PEA revenue, equal to the FCC's own blocks evaluated at the base price, $(S – V)$*P.

However, when demand is less than supply, the PEA revenues will not be sufficient to compensate both the incumbents for their vouchers and the FCC for its blocks. Based on prior FCC broadband auctions, this is expected to be uncommon, but, nevertheless, it is something auction practitioners must consider. We therefore propose a method for calculating voucher payments in such situations. Although one could imagine other methods, the most efficient in principle, would be to make proportional payments to the FCC and the incumbents. If demand is less than supply in a PEA, then both the incumbents and the FCC receive payment in proportion to their total share of PEA revenue, $D*P$. The share of an incumbent is proportional to its voucher, v, and the FCC's share is proportional to supply minus total vouchers, $S – V$. This approach is sensible in that excess supply would indicate that the clock price for spectrum blocks in the PEA is higher than the market clearing price—the price at which demand would equal supply. Accordingly, the compensation to the FCC as well as the incumbents should reflect some amount lower than the clock price paid by the winning bidders in a market with excess supply. In the absence of accurate information about the actual market clearing price, proportionate distribution of the aggregate proceeds is a proxy for the market clearing price.[3]

A potential concern with the voucher system is that participants could engage in insincere bidding to inflate the value of their vouchers. However, with the appropriate auction rules in place, such gaming is unlikely to be a problem. A "no-excess-supply" rule – like that used in the forward phase of the Incentive Auction – that rejects requests to reduce demand when such reductions would result in excess supply

[3] Alternative schemes include prioritizing payments to the FCC and prioritizing payments to voucher holders. Both of these alternatives have the potential to create undesirable incentives that could be deemed suboptimal. In the case of prioritizing payments to the FCC, where vouchers would be paid proportionally with any funds that remain, incumbent voucher holders face the prospect of giving up their licenses in exchange for little or no compensation. This has the effect of discouraging participation at the margin. In the case of prioritizing payments to voucher holders, where the FCC would receive remaining funds, the possibility exists that the US Treasury receives little or no revenue from a particular PEA.

would frustrate insincere bidding. Furthermore, a lack of withdrawals would also decrease the incentive to bid purely to push up the price within PEA(s) where one was a voucher holder. Under these rules, insincere bids placed merely to drive up the value of a voucher would always be at risk of becoming winning bids. In taking this risk, a bidder that wished to win less spectrum than its vouchers at current prices would forego a known surplus on its current position to assume uncertainty over marginal increases to that surplus versus having to overpay for additional, undesired spectrum. Although no bidding behavior can be ruled out entirely, gaming to inflate the voucher value would be unlikely given the risks and rewards under the proposed rules. A bidder that wished to win less than its vouchers in a PEA would have a strong incentive to bid sincerely.

Incumbents that Choose not to Participate – The Holdout Segment

We propose that incumbents who choose not to participate in the auction be considered ineligible to receive voucher payments for their current license holdings, ineligible to acquire additional spectrum in the auction, and ineligible to bid in the assignment phase to determine a new frequency for their current holdings. Instead, we propose that all such non-participating incumbents within a PEA will be repacked into one minimal segment of the band. We refer to this segment as the "holdout segment" and denote the size of the holdout segment as H.

The Supply of Spectrum in the Auction

The supply of spectrum available for auction in a PEA is determined by subtracting the holdout spectrum (H) from the total spectrum in the band. With the inclusion of frequencies from 37.6 GHz to 38.6 GHz, the total spectrum in the auction is 2.4 GHz. The supply of 200 MHz spectrum blocks available for auction, S_{200}, is obtained by taking the difference 2.4 GHz – H, dividing by 200 MHz, and rounding to the next lowest integer. For example, if H=350 MHz, then $S_{200} = 10$. The calculation is (2.4 GHz – 350 MHz)/200 MHz = 10.25, rounded down to the next lowest integer, which is 10.

There may be a leftover amount of unencumbered spectrum that cannot be packaged into a standard 200 MHz block. We refer to this as the "leftover segment." In the example above, the leftover segment is 50 MHz. The FCC has options for how it wants to allocate the leftover segment. It can either include it in the auction as a separate product with a separate clock price, or it can make this spectrum available at a future auction. One benefit of including it in the initial auction is to encourage participation from smaller participants (either incumbent licensees or entrants) that might want to acquire something less than a standard 200 MHz block.

If the leftover segment is included in the auction, then the supply from the leftover segment is S_L, expressed as a fraction of a 200 MHz block. In the example above, when the leftover segment is 70 MHz, $S_L = 0.35$. Then total supply in terms of 200 MHz blocks is $S = S_{200} + S_L$. The addition of a separate product category and accompanying clock price does not affect the voucher payment calculations described above. When including the leftover category, the price, P, in those calculations is the spectrum-weighted average price.

The Holdout Segment and Leftover Segments in the Assignment Phase

The greatest concern in the assignment phase is ensuring that all winning bidders are assigned contiguous spectrum within each PEA. Another concern is to preserve as much uniformity in channels across PEAs as possible. In light of these concerns, we propose that the holdout segment be located at the top of the band. That is, the holdout segment should start at 40 GHz and extend as far *down* into the band as necessary. For example, a holdout segment of 250 GHz would be assigned to the range 39.75 GHz to 40 GHz.

Because the leftover segment will be smaller than the standard 200 MHz, it should be located immediately below the holdout segment, again maximizing channel uniformity across PEAs. Using the example above, the leftover segment of 150 MHz would be assigned to the range 39.6 to 39.75 GHz. Should the FCC elect to offer the leftover segment in this auction, and it is sold to a bidder that also wins some number of 200 MHz blocks, then that winner's assignment will be fixed by the location of the leftover segment. In the example above, a bidder that wins the leftover segment and two clean 200 MHz blocks would be assigned to the range 39.2 GHz to 39.75 GHz.

Finally, we propose that in the event there is excess supply in a PEA, the excess supply is assigned contiguously. This will maximize the spectrum's value for future offerings. It also incentivizes participation by ensuring that allocation phase winners are not disadvantaged relative to non-participants in their access to the excess supply segment under whatever option the FCC chooses for handling it after the auction.

Approaches to Repacking the Holdout Segment

There are two types of incumbent licenses that could require repacking into a holdout segment, RSAs and PEAs. PEA licenses are relatively easy to repack because they match the geography of the restructured band.[4] However, RSAs are generally more challenging to repack because they do not coincide with the proposed PEA license structure. Therefore, in the remainder of this section we focus on approaches to repacking holdout RSA licenses.

In repacking RSA licenses, we seek to minimize the total bandwidth of the repacked spectrum. This minimization should conform to the following constraints.[5]

a. **Preserving block size:** the block size, in terms of bandwidth, should remain unchanged in the repacked assignment.
b. **Preserving geography:** the license's geographic coverage area should remain unchanged in the repacked assignment.
c. **Assigning the same frequencies in each PEA:** where an RSA license overlaps multiple PEAs, the repacked frequency assignments should be the same in each PEA.
d. **Preserving contiguity of RSAs:** where an incumbent has multiple RSAs that are contiguous both geographically and in frequency, the repacked frequency assignments of those licenses should also be contiguous.

[4] One potential issue is that it is possible for a nonparticipating PEA license to become less encumbered as a result of the repack because RSA licensees that currently encumber the PEA choose to participate in the auction. As we propose, the FCC should guarantee that the PEA licensee will not have greater encumbrance in the repack, but in the event that the repack presents the possibility of decreased encumbrance, we simply note that the FCC has the option to either maintain pre-auction levels of encumbrance or allow them to decrease as a result of the repack.
[5] Adding constraints can increase the size of the holdout segment.

Because constraints (c) and (d) cut across PEAs, the repack for different PEAs can be interdependent.[6] In principle, this can lead to larger repacked holdout segments than would be possible without such constraints. However, this did not occur in the examples we considered. There is generally enough room in the holdout segment to allow for assigning the same frequencies to the same RSA across PEAs without burning additional spectrum. We also did not encounter a situation that necessitated a tradeoff between a larger holdout segment in one PEA and a smaller holdout segment in another PEA. That means, in our examples, we did not need to define a global objective, such as minimizing total MHz-pops to reconcile such tradeoffs.[7] The following steps approximate our approach:[8]

1. Start with a collection of PEAs that do not contain RSAs with overlap into PEAs outside the collection.
2. Sort the RSAs in that collection in (i) descending order of geographic area, then (ii) by licensee name, then (iii) by call sign, and mark each clean 50 MHz frequency channel as “not full.”
3. Assign the first RSA in the list to the highest 50 MHz frequency channel that is marked “not full,” and remove it from the list. Terminate if the list is empty.
4. Iterate through the list to find the next largest RSA that can also fit inside this channel without overlap.
5. If none are found, mark the channel as full and return to step 3.
6. If one is found, assign it to the channel, remove it from the list, and return to step 4.

Figure 1 below illustrates the repack of all California RSAs.[9] Each channel is 50 MHz. Individual RSA licenses that appear in two consecutive channels are 100 MHz. Note that the encumbered area declines as the channel number increases. This is a result of the steps given above that focus on repacking the most licenses (in number, area, and bandwidth) into the first channels.

[6] We recognize that the stated objective “to minimize the total bandwidth of the repacked spectrum” can be ambiguous in the presence of PEA interdependence. As discussed, the examples we analyzed did not feature any interdependence that affected the interpretation of this objective. However, there are clearly defined single-valued objectives that quantify MHz tradeoffs across PEAs should that be an issue. MHz-pops is a standard way to make this tradeoff.

[7] All of our examples assume that all RSA holders are holdouts except FiberTower and Straightpath.

[8] This approach has minimized the repack in certain geographies that we have specifically analyzed. We recognize that it may fail to find an optimal repack in other settings, e.g., for certain types of daisy chain effects. However, it does serve as an example of a candidate algorithm that could be considered.

[9] The data and analysis in the repack examples have been provided by AT&T.

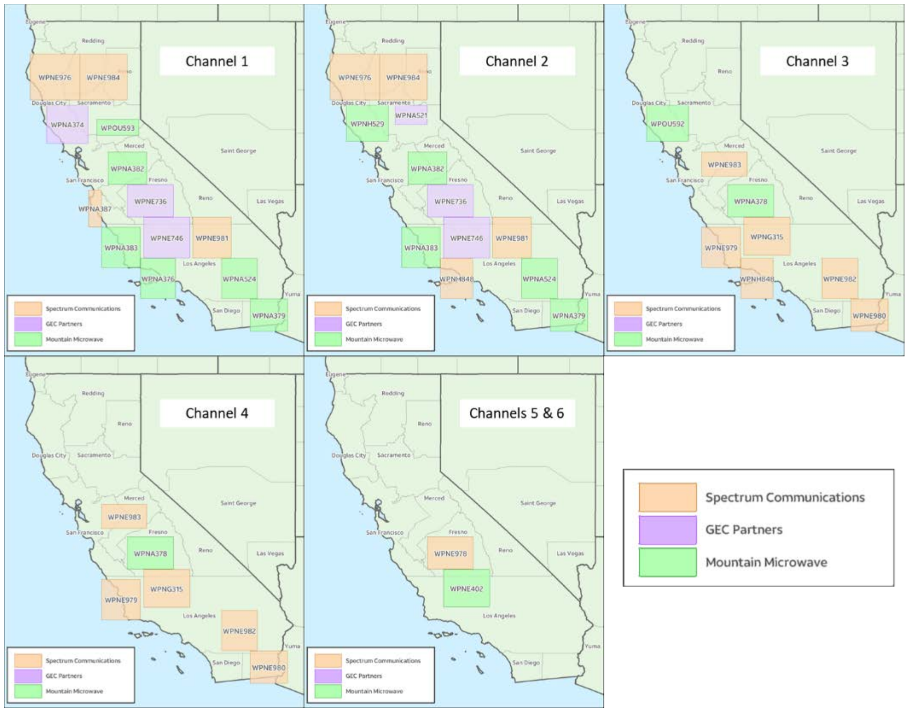

Figure 1 - Repack of California using six 50 MHz channels

Conforming strictly to these constraints may be neither necessary nor desirable, and some may be relaxed. In the case of constraint (b), there are many RSAs that overlap small and sparsely populated regions of one or more PEAs. Preserving the RSA license in these insignificant regions has the potential to encumber an additional 200 MHz block in the overlapped PEAs. For example, in the San Francisco PEA, there is a small amount of overlap in the southeast from an RSA centered in the Fresno PEA as indicated by the red arrow in the illustration below. This overlap represents 0.01% of the area of the San Francisco PEA and less than 0.01% of its population. However, were the repack to strictly preserve the geography of that RSA license, the San Francisco PEA would have one less completely unencumbered block available for auction.

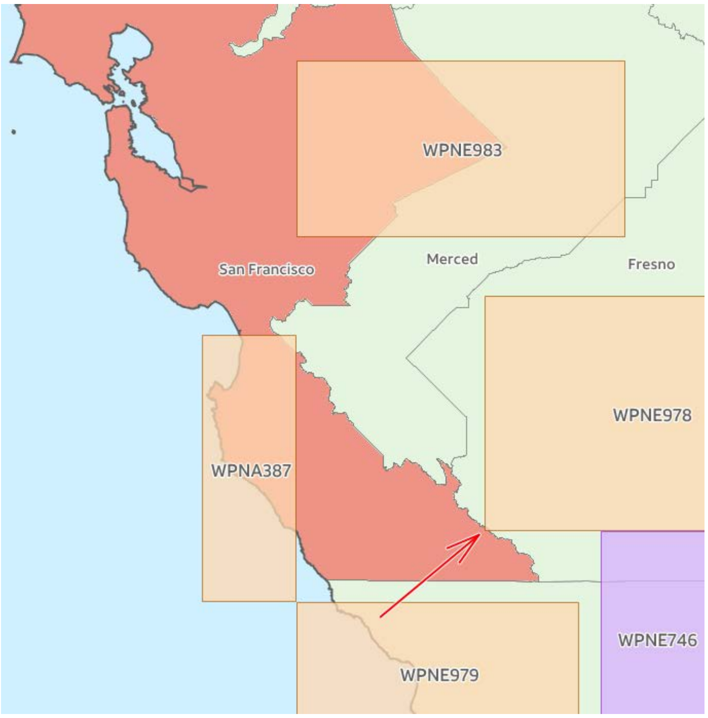

Figure 2 - An RSA in the Fresno, CA PEA overlaps into the San Francisco, CA PEA, slightly impairing an additional channel

To address this, the FCC may consider systematically determining which overlap regions it wants to preserve by using a cutoff percentage based on PEA pops. RSA licenses that overlap PEAs for a percentage of the PEA population less than that cutoff percentage would receive vouchers in exchange for the overlap portion of the RSA license. In this way, the FCC could offer more clean blocks in the auction and compensate RSA holdouts for the overlap areas they lose in the repack. As an illustration, there are six PEAs that have two encumbered 200 MHz channels when the constraints above are strictly applied.

- 002 - Los Angeles, CA
- 004 - San Francisco, CA
- 009 - Miami, FL
- 034 - Fresno, CA
- 065 - Cape Coral, FL
- 067 - Sarasota, FL

Using a rather modest cutoff percentage of only 3 percent of PEA pops, the auction gains one unencumbered block in San Francisco and two unencumbered blocks in Miami and Sarasota. The gains are reflected in the table below where the impaired area goes from positive under the strict constraints to zero under the 3% cutoff (shown in green).

PEA	PEA Pops	PEA Area (sq mi)	Impaired Channel	Impaired Area Pct. (Strict)	Impaired Area Pct. (3% cutoff)
002 - Los Angeles, CA	20.06M	48.4K	1st	55.91	15.48
002 - Los Angeles, CA	20.06M	48.4K	2nd	13.73	12.28
004 - San Francisco, CA	9.76M	13.8K	1st	40.43	28.19
004 - San Francisco, CA	9.76M	13.8K	2nd	0.01	0.00
009 - Miami, FL	6.86M	12.2K	1st	1.67	0.00
009 - Miami, FL	6.86M	12.2K	2nd	1.23	0.00
034 - Fresno, CA	1.71M	14.4K	1st	61.39	47.11
034 - Fresno, CA	1.71M	14.4K	2nd	57.17	47.11
065 - Cape Coral, FL	1.07M	3.1K	1st	57.53	57.53
065 - Cape Coral, FL	1.07M	3.1K	2nd	57.53	57.53
067 - Sarasota, FL	969.9K	2.8K	1st	4.31	0.00
067 - Sarasota, FL	969.9K	2.8K	2nd	4.31	0.00

Table 1 - PEAs where two 200 MHz blocks are required for the holdout segment

In other areas, there may be slight overlap between RSAs, requiring an extra channel to strictly preserve license areas. In such cases, the FCC may consider an approach similar to the one outlined above. That is, subject to a cutoff percentage, the FCC may repack the overlapping RSAs into the same channel and credit a voucher for the area of overlap. Where the overlap is between licenses held by the same incumbent, it is straightforward to credit that licensee with a voucher. When the overlap is between licenses held by different incumbents, the FCC may consider crediting the licensee for which the overlap represents a smaller percentage of its license, either in population or geographic area. The figure below illustrates such an example, where two RSAs held by different licensees are centered in the Fresno, CA PEA, and the overlap forces an extra channel to be added to the holdout segment.

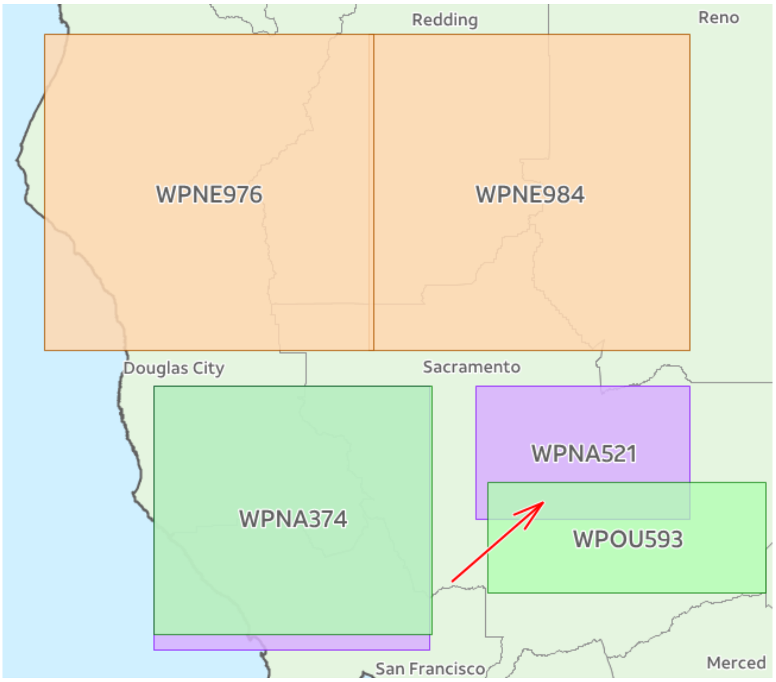

Figure 3 - Two RSAs overlap in the Sacramento, CA PEA, slightly impairing an additional channel

The FCC has additional discretion in deciding the internal structure of the holdout segment. This includes the relative locations of the RSA and PEA portions of the holdout segment, i.e., which should occupy the lower frequencies and which should occupy the higher frequencies within the holdout segment. Also at the FCC's discretion are the channel assignments within the RSA and PEA portions of the holdout segment. That is, there may be multiple holdouts of a given type – RSA or PEA – and multiple channel assignments that meet the constraints suggested above. Options for the FCC include FCC discretion or even allowing holdouts to bid for preferred assignments within the set of allowed assignments.

Regardless of how the FCC decides to repack the holdouts, the fact that RSAs do not coincide with PEAs means that there will likely be some channels in the holdout segment that are partially encumbered in a geographic sense – that is, they are encumbered over only a portion of the area of the PEA. Note that these partially encumbered holdout channels are different than the leftover segment, which is unencumbered over the entire PEA but contains less bandwidth than the standard 200 MHz block. The FCC has options in handling partially encumbered holdout channels. It can choose to offer them as separate products at auction, each with its own price clock, or they can be withheld from the auction. Were the FCC to offer them at auction, the FCC should carefully consider whether to include them in spectrum supply for the purposes of voucher payment calculations.

Voucher Systems in other Auctions

The voucher system described here facilitates the restructuring of millimeter wave bands through an auction. This is not the first time such a mechanism has been proposed. In an FCC working paper dating back to 2002, Kwerel and Williams describe a very similar framework for band restructuring in the presence of encumbered spectrum.[10] Our proposal follows theirs. They propose that sellers should be compensated based on the share of the MHz-pops associated with their licenses relative to the others sold. In the voucher system we propose, the MHz-pops are indeed the foundation for compensating incumbents, and the proposed payment rules are designed to accurately capture each seller's share of licenses sold. The authors also emphasize that "voluntary participation is the *quid pro quo* for flexibility." Here that exchange comes in at least three forms. The first is the flexibility to decide at auction, based on auction prices, whether to become a net buyer or net seller of spectrum in any given PEA. The second is the ability to bid for specific frequency assignments in the assignment phase. The third is the flexibility associated with a technology-neutral band that promises contiguous holdings. Similar market mechanisms are discussed elsewhere.[11]

While not a full band-restructuring auction like the one discussed here, the Mexican AWS auction of 2016 simultaneously accommodated the auction of unsold blocks and the relocation of incumbent holders to achieve contiguous within-band holdings. The Mexican regulatory body achieved this in much the same way that our proposal would work with vouchers. The net payment to (from) an incumbent was given by the difference between the spectrum they won and the spectrum they supplied. Just like the voucher scheme proposed here, a bidder's compensation was for its share of the sold spectrum at values determined by the auction.[12] This proved an effective and equitable method for rationalizing the AWS band plan.

Vouchers have also been proposed by multiple authors as a method of compensation for incumbent holdings in the context of auctions for airport departure and arrival slots.[13] In that context, airlines inherited slots from a time when there was no scarcity or congestion, much like over-the-air broadcasters. However, as increasing demand for air travel created congestion at major US airports, policy makers became interested in relieving congestion by efficiently allocating slots through auctions. Incumbents balked at the notion of paying for something they already had for free, even if it was efficiency-enhancing. So, vouchers were proposed as a manner of converting incumbent slot holdings into cash, valued at auction prices, for the purpose of reallocation through auctions. Much as we argue here in the context the millimeter wave spectrum, the benefit of vouchers for airport slot auctions is that a clean schedule would allow the FAA to design a more efficient slot plan and encourage entry while respecting the value of incumbent holdings.

---

[10] FCC, OPP Working Paper Series #38, November 2002. Kwerel and Williams, "A Proposal for a Rapid Transition to Market Allocation of Spectrum." https://apps.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf

[11] Peter Cramton , Evan Kwerel , and John Williams , "Efficient Relocation of Spectrum Incumbents," The Journal of Law and Economics 41, no. S2 (October 1998): 647-676. https://doi.org/10.1086/467407

[12] Licitacion No. IFT-3. Apendice B, pp 28-29. "Procedimiento de Presentacion de la Oferta Economica y Determinacion de Frecuencias Especificas a ser Asignadas." http://www.ift.org.mx/sites/default/files/industria/espectro-radioelectrico/espectro/2015/3/apendiceb.pdf

[13] See, e.g., "A Voucher Proposal to Redevelop Encumbered Airport Slots", Evan Kwerel, Nextor Workshop, 2004. http://www.nextor.org/Conferences/200406_Industry_Public/2004_06_22_Evan_Kwerel.pdf; *Combinatorial Clock Auction of Airport Time Slots: An Agent-Based Analysis*. Thesis of Rui Dong, Department of Computer Science, Harvard University, 2005. http://econcs.seas.harvard.edu/files/econcs/files/rui_thesis.pdf; and *Mitigating Airport Congestion: Market Mechanisms and Airline Response Models.* Dissertation of Pavithra Harsha, Sloan School of Management, Department of Operations Research, Massachusetts Institute of Technology, February 2009. http://web.mit.edu/pavithra/www/papers/thesis/Pavithra-thesis.pdf.