The mmWave Auction

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Economists
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Agenda

- Introductions and Objective
- Description of the Voucher System
- Calculation of Voucher Payments
- Repacking Holdouts
- Supply of Spectrum in the Auction
- Precedent for the Voucher System
- Q&A

Objective

Today's objective:

Outline an auction design to facilitate restructuring of millimeter wave bands

Discussion Topics:

- Voucher system to restructure millimeter wave bands for auction
- The approach to repacking holdout incumbents
- The choice of spectrum supply in the auction

mmWave Auction Design
Incumbent Vouchers for Band Restructuring

Problem: how to restructure the band while respecting incumbent holdings and providing a level playing field for new entrants

Solution: issue *vouchers* for current licenses

Vouchers Explained:

➔ Exchange based on existing in-band licenses

➔ Capture MHz-pops covered by an incumbent's holdings in a PEA

➔ Valued at auction prices and settled via net-payments

➔ Solely a financial instrument, and provide flexibility to incumbents *and entrants*

mmWave Auction Design
Incumbent Vouchers Calculation

How the vouchers work:

- A single voucher amount for each incumbent in each PEA

- Calculated to reflect *actual* MHz-pops for the incumbent's license(s)

- Between 0 and 7 and reflects a number (possibly fractional) of 200 MHz vouchers in the 39 GHz band (1.4 GHz in size)

- Redeemed for a lump-sum payment at the end of the auction

	MHz-Pops of Current Holdings	PEA Pops	MHz-Pops of 200MHz Block	Voucher Quantity	Final Price per 200 MHz block
Bidder 1	650m	1m	200m	3.25	$1,000
Bidder 2	150m			0.75	

Voucher Payment when Demand = Supply

Final price of 200 MHz block * voucher quantity

Demand= Supply	Sum of Vouchers		Voucher Payment
7	4	Bidder 1	$3,250
		Bidder 2	$750
		Total	$4,000

Repacking the Holdouts

For holdout incumbents who don't participate in the auction and don't receive vouchers, the FCC repacks them at the top of the band

Repacking Holdouts: minimize the total bandwidth of the repacked spectrum given the following constraints

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) **Consistent frequencies for RSA incumbents:** 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.

Repack: Important high-level points

- The holdout repack is far simpler than the broadcaster repack

- The daisy-chain problem is very limited

- Formal optimization is unnecessary to provide meaningful examples

Repacking the Holdouts Illustrative Steps

A simple set of steps works for our examples:

1. Start with a "self-contained" collection of PEAs

   - Make sure there are no RSAs that overlap outside of this collection to avoid daisy chain effects.

2. Start filling 50 MHz channels with non-overlapping RSAs as follows:

   a) Attempt to fill largest RSAs first

   b) But respect the following:

      i. Licensee name (allows contiguous assignments where possible)

      ii. Call sign (maintains contiguity of 100 MHz allocations)

Result: in any channel, RSAs do not overlap.

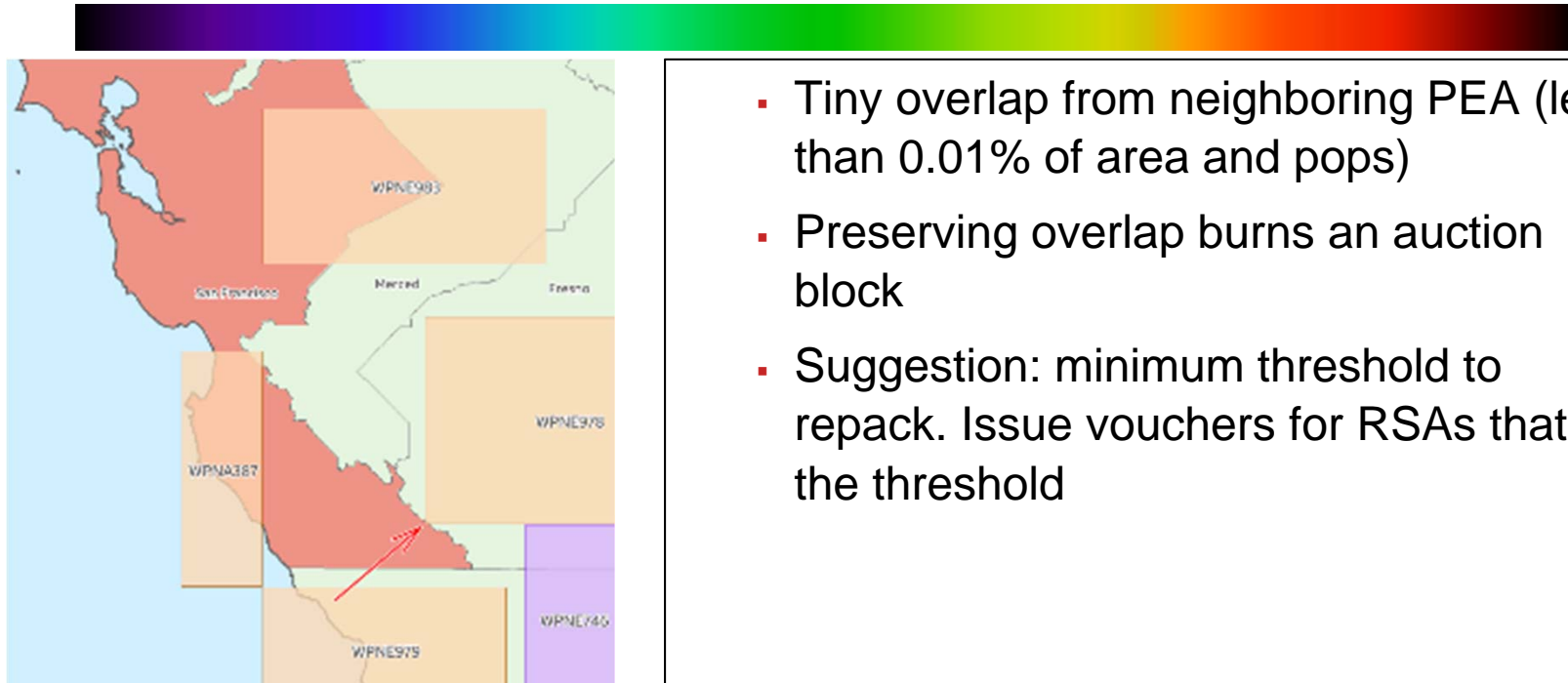# RSA Repack Example: California
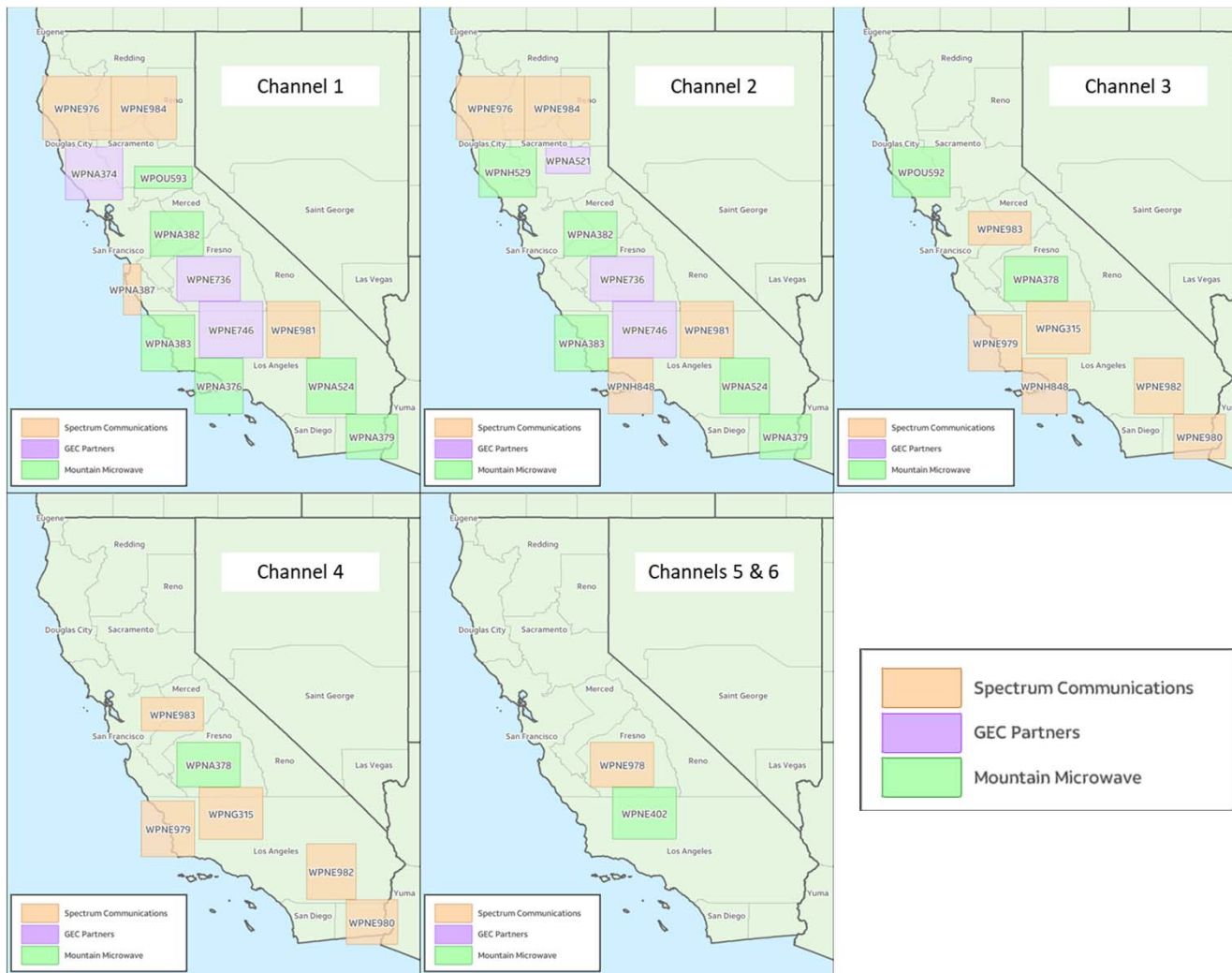
- CA requires six 50 MHz channels for the most encumbered PEAs:
  - LA and Fresno
  - assumes all holdouts except FT & SP

Relaxing Geography Constraints for RSAs
Extreme Example: SF Bay Area

- Tiny overlap from neighboring PEA (less than 0.01% of area and pops)

- Preserving overlap burns an auction block

- Suggestion: minimum threshold to repack. Issue vouchers for RSAs that fail the threshold

Areas with two RSA encumbered 200 MHz blocks

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

*Applying 3% cutoff ➜ 1 more block free in SF and 2 more free blocks each in Miami and Sarasota.

Relaxing Geographic Constraints for RSAs
Example 2: 700 sq Mile Overlap in Northern CA

In other areas, a relatively small overlap between RSAs could require extra channels

- Two licenses overlap in geography 12 miles by 60 miles

- Different licensees

- Strictly preserving the overlap area forces a new channel to be used
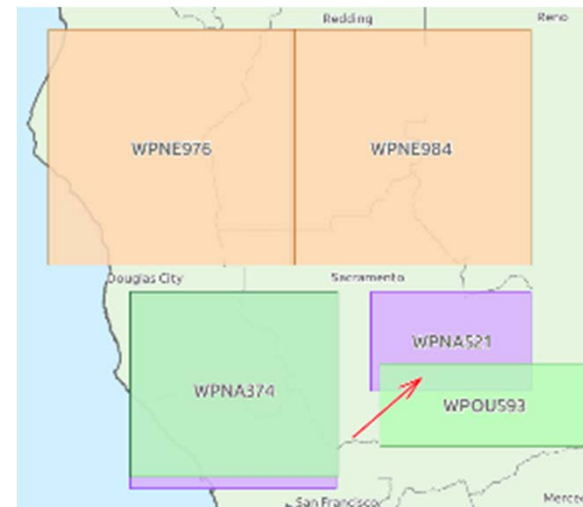
Subject to a percentage overlap threshold, e.g., X% of PEA pops, the FCC can choose to save spectrum by repacking both RSA licenses into the same channel and awarding a voucher for the overlap.

- <u>When the RSA licenses are both held by the same entity</u>, the FCC can repack both RSAs to the same channel and issue a voucher for the overlap.

- <u>When the RSA licenses are not held by the same entity</u>, the FCC can issue a voucher for the overlap to the entity for which the overlap represents the smallest % pops of the RSA as a whole.

Total Supply in the Auction

After repacking the Holdouts, the FCC will have three types of supply

1. **Unencumbered 200 MHz blocks:** an integer number.

2. **Leftover Segment:** a single unencumbered block smaller than 200 MHz that results from packing the holdouts into a non-integer quantity of 200 MHz blocks.

3. **Holdout "Donuts":** bandwidth that falls within the frequency range of the holdout segment but is still unencumbered in some geographies due to the mismatch between RSAs and PEAs. Located at the "top" of the band.

Example:

37.6 GHz →	10 Unencumbered 200 MHz blocks	Leftover Segment – 50 MHz	Holdout Segment – 350 MHz	← 40 GHz

Additional Choices for the FCC:

- Include the leftover segment in auction ➜ 1 or more extra product categories
- Include holdout donuts in auction ➜ multiple extra product categories
- The internal structure of the holdout segment: RSAs or PEAs next to leftover?
- Decreased encumbrance for holdout PEAs due to removal of RSAs

Precedent for the Voucher System

- **<u>Mexico AWS 2016:</u>** credits issued for incumbent licenses to handle band restructuring around stranded 2x5 MHz lot; payments based on auction clearing prices.

- **<u>Airport Slot Auctions:</u>** vouchers issued for incumbent slots to restructure slot assignments and schedules; payments based on auction clearing prices. (Kwerel 2004; Dong 2005; Harsha 2009)

- **<u>Kwerel and Williams, "A Proposal for a Rapid Transition to Market Allocation of Spectrum."</u>** FCC, OPP Working Paper Series #38, November 2002.

- **<u>Reimbursing Hold-out Incumbents for Band Restructuring:</u>**
  - 600 MHz (Incentive Auction) 2016
  - 1.8 GHz PCS 1994/95

Q&A

Backup

mmWave Auction Design
Separate Allocation and Assignment Phases

Very simple clock auction for allocation phase

- Bid units purchased with upfront payment before the auction

- One clock per product category (geography-band)

- Price clock increases for products with excess demand

- Allocation phase complete when no excess demand

- FCC discretion on items such as activity rule and withdrawals, however, a no withdrawal rule would be sensible and justifiable

Assignment Phase guarantees fully contiguous assignments

- Sealed-bid process with second price rule

- Product groupings possible to shorten auction

- Revenues exempted from voucher payments