Repurposing Spectrum

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Spectrum Policy and Auctions: Best Practices from Around the World
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Disclaimer

• The opinions expressed in this talk are those of the authors and do not necessarily represent the views of the FCC or any other members of its staff.
Policy Tools for Repurposing Spectrum

• Mandatory clearing
  • Without compensation
    • 1968 -1980 FCC relocated 2 full power and 600 translators on UHF channels 70-83.
  • With compensation
    • AWS-1 federal users in the lower 45 MHz pair (1710-1755 MHz) were required to clear and compensated for relocation costs under the Commercial Spectrum Enhancement Act (auction held in 2006).

• Overlay licenses
  • New licensees awarded exhaustive area licenses but must protect incumbents.
  • New flexible-use licensees compensate incumbents for clearing.
  • Incumbents required to clear by a fixed time if paid by new flexible-use licensees for moving costs (or more if clear earlier).
  • PCS – incumbent microwave cleared by PCS licensees –A & B block completed 1995.

• Incentive auctions
  • Auction compensates incumbent licensees for relinquishing spectrum usage rights.
Broadcast Incentive Auction: The Problem

- Misallocation of spectrum between TV broadcasting and mobile broadband.
- Demand for mobile broadband has grown exponentially.
- Demand for over-the-air broadcast television has been decreasing.
  - In 1960 virtually all television households received video programming service by viewing a broadcast television station’s over-the-air signal.
  - Now, only about 10 percent of television households rely solely on over-the-air broadcast television service.
- Structure of broadcast licenses not suitable for mobile services.
- How much of the band should be restructured for mobile use?
Broadcast Incentive Auction: The Solution

• Two-sided auction determines
  • How much of 600 MHz band reallocated from broadcasting to flexible use (including mobile broadband) and restructured.
  • How much incumbent broadcasters are paid for relinquishing spectrum usage rights (going off the air or moving to a lower TV band).
  • How much new flexible-use licensees pay.

• Clears spectrum at the least cost, given available information.

• Provides revenue for the government.
Broadcast Incentive Auction: The Mechanism

- **Set initial clearing target** at maximum feasible clearing amount.
- **Reverse Auction.** Current (TV) licensees bid to voluntarily relinquish spectrum usage rights.
  - TV stations faced competition because FCC can relocate them to an equivalent channel.
- **Forward Auction.** Potential new (wireless) licensees bid on restructured cleared spectrum.
- **Closing rule.**
  - *Auctions closes.* If proceeds from the forward auction are sufficient to pay the licensees that relinquished their spectrum rights plus auction expenses.
  - *Auction continues at a reduced clearing target.* If forward auction proceeds are insufficient.
- **Repacking.** Remaining incumbents (TV) efficiently repacked in a reduced amount of spectrum in separate part of band.
# Broadcast Incentive Auction: Results

<table>
<thead>
<tr>
<th>Stage</th>
<th>Clearing Target</th>
<th>Licensed Spectrum</th>
<th>Clearing Cost (billions)</th>
<th>Auction Proceeds (billions)</th>
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<tbody>
<tr>
<td>1</td>
<td>126</td>
<td>100</td>
<td>$86.4</td>
<td>$23.1</td>
</tr>
<tr>
<td>2</td>
<td>114</td>
<td>90</td>
<td>$54.6</td>
<td>$21.5</td>
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<td>3</td>
<td>108</td>
<td>80</td>
<td>$40.3</td>
<td>$19.7</td>
</tr>
<tr>
<td>4</td>
<td>84</td>
<td>70</td>
<td>$10.1</td>
<td>$19.6</td>
</tr>
</tbody>
</table>
Why Didn’t the FCC Use the Overlay License Approach to Repurpose the TV Band?

• Even with mandatory relocation, overlay licensees would find it difficult and costly to clear incumbents.
  • Without optimal simultaneous repacking there would be far fewer channels to which incumbents could be relocated.
  • Without space to relocate an incumbent the holdout problem could be severe.

• Difficult coordination problem for new licensees to clear incumbents.
  • Same broadcast station may impair spectrum of more than one overlay licensee.
  • Efficient clearing requires repacking into a separate part of the band.

• Centralized simultaneous optimization minimizes spectrum needed to repack remaining broadcasters.

• Centralized reverse auction picks least costly TV stations to clear.
A Single TV Station Can Impair Four Wireless Frequency Blocks and Many PEAs

WXFT-DT Chicago on Channel 50 Impairs Four Wireless Blocks
WXFT-DT Impairments to PEAs on Block D

<table>
<thead>
<tr>
<th>Impaired PEAs</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEAs impaired &gt;95%</td>
<td>2</td>
</tr>
<tr>
<td>PEAs impaired &gt;50%</td>
<td>3</td>
</tr>
<tr>
<td>Impaired pops (millions)</td>
<td>10</td>
</tr>
<tr>
<td>% of US pops impaired</td>
<td>3.2</td>
</tr>
</tbody>
</table>
WXFT-DT Impairments to PEAs on Block E

- Impaired PEAs: 42
- PEAs impaired >95%: 16
- PEAs impaired >50%: 25
- Impaired pops (millions): 21
- % of US pops impaired: 6.6
WXFT-DT Impairments to PEAs on Block F

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired PEAs</td>
<td>48</td>
</tr>
<tr>
<td>PEAs impaired &gt;95%</td>
<td>18</td>
</tr>
<tr>
<td>PEAs impaired &gt;50%</td>
<td>29</td>
</tr>
<tr>
<td>Impaired pops (millions)</td>
<td>23</td>
</tr>
<tr>
<td>% of US pops impaired</td>
<td>7.2</td>
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</tbody>
</table>
WXFT-DT Impairments to PEAs on Block G

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Impaired PEAs</td>
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<tr>
<td>PEAs impaired &gt;95%</td>
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<tr>
<td>PEAs impaired &gt;50%</td>
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</tr>
<tr>
<td>Impaired pops (millions)</td>
<td>10</td>
</tr>
<tr>
<td>% of US pops impaired</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Simulation of Impairment by A Few Stations

• Small number of stations could impair a large share of the spectrum available for mobile broadband use.
  • Simulation – on average, in 50 random samples of stations in the top 40 markets (PEAs) – if
    • 15% of stations remained on their original channels -- 65% of weighted MHz-pops would be impaired.
    • 25% of stations remained-- 84% of weighted MHz-pops would be impaired.
39 GHz Band: The Problem

• Misallocation between fixed wireless and 5G mobile services
  • Almost two-thirds of the 39 GHz band (38.6 – 40 GHz) was licensed for high-capacity microwave services (mostly backhaul for wireless carriers).
  • Commission reallocated spectrum for flexible use.

• Current fragmented license structure not suitable for 5G mobile services
  • 5G operators want unimpaired PEA licenses nationwide.
  • Current licenses
    • Rectangular Service Area (RSA) - Pre-existing licenses that don’t conform to PEA boundaries.
    • Partial Economic Area (PEA) – Overlap with RSA licenses. PEA licensees must protect spectrum rights of existing RSA licensees.
39 GHz Band - Partial PEA Licensee and Three RSA Licensees

Los Angeles, CA (PEA002)
Voucher Incentive Auction: The Solution

• Compensate incumbents at market-determined prices to relinquish all licenses (including non-conforming licenses).
• If all incumbents commit to participating, all spectrum is cleared and available for auction.
• Incumbents can buy back spectrum covering existing license areas, generally at no net expenditure.
39 GHz Voucher Auction: The Mechanism

• Current PEA or RSA license holders that participate in the auction receive vouchers in exchange for their current licenses.
• Vouchers for different frequency blocks within a PEA are aggregated.
• The value of a voucher for holdings in a PEA is the incumbent’s proportionate holdings (MHz-pops/total MHz-pops) in that PEA times the PEA price determined in the auction.
• Vouchers can be used as an auction credit or cashed out.
• Incumbents who choose not to participate in the auction
  • Receive modified licenses with unchanged total weighted MHz-pops.
  • Cannot bid for licenses in the auction.
39 MHz Voucher Auction: Implementation

• A single auction of the Upper 37 GHz, 47 GHz and 39 GHz bands (auction 103) is scheduled to begin December 10, 2019.
• The auction will offer unencumbered generic blocks in each PEA in a clock phase with a subsequent assignment phase.
Comparison of Broadcast Incentive Auction and 39 GHz Incentive Auction

• Broadcast Incentive Auction
  • Market determination of amount of spectrum.
  • Determined the least amount needed to pay the incumbents.
  • Captured for the Treasury some of the increased value from reallocation.
  • Required the development of an entirely new auction mechanism.

• 39 GHz Incentive Auction
  • Entire 39 GHz band reallocated for flexible use as part of the rulemaking
  • Pays incumbents the full market price for flexible use spectrum.
  • No government revenues except from “white space.”
  • Simple to implement – can use existing one-sided auction mechanisms.
    • Voucher payments are just a financial transaction outside of the auction.
Additional Material
Why Repurpose Spectrum?

• Historically, allocations narrowly specified the services and technologies that can make use of specific frequencies.
• Changes in consumer preferences and technology make current uses less than optimal.
• Reallocating and reconfiguring the spectrum allows spectrum to be put in higher value uses.
Why Isn’t Granting Licensees Flexibility Sufficient to Allow New Higher Value Uses?

• Spectrum rights for existing uses often defined very differently than for new uses.
  • E.g., TV broadcasting (high power, specific antenna location, no defined service area, unpaired 6 MHz blocks,) vs. cellular (low power, antenna locations not specified, defined geographic service area, larger paired blocks).
  • Need to reconfigure definition of spectrum rights.

• Existing rights often highly fragmented.
  • Costly to rationalize ownership.

• Spectrum often not exhaustively licensed.
  • E.g., TV “white space.”
  • Need to assign all rights.

• Old and new uses may not coexist well (high interference).
  • E.g., high power and low power.
  • May need to separate old and new uses in different parts of the band, or relocate existing users to another band.
Pre-Auction vs. Post-Auction 600 MHz Band

Pre-Auction Spectrum Allocation

TV Channels

TV Channels

700 MHz Broadband Uplink

Post-Auction Spectrum Allocation

Repacked TV Channels

Guard

600 MHz Downlink

Duplex

600 MHz Uplink

700 MHz Broadband Uplink

Cleared Spectrum
Why Didn’t the FCC Use the Overlay License Approach to Repurpose the TV Band?

• Reverse auction with simultaneous repacking increased competition among incumbents, reduced clearing costs and increased the amount of spectrum cleared.

• Even with mandatory relocation, overlay licensees would find it difficult and costly to clear incumbents.
  • Incumbent broadcasters would have much greater opportunity to hold out because there would be far fewer channels to which they could be relocated without optimal simultaneous repacking.
  • Without space to relocate an incumbent the holdout problem could be severe.

• Optimal simultaneous repacking into a separate part of the band is a complex optimization problem that would require coordination of all overlay licensees, and was unlikely to be achieved.
Problems With Overlay Approach

• To fully clear the same 84 MHz cleared by the Incentive Auction, overlay licensees would need to negotiate with 582 broadcasters.
• Same broadcast station may impair spectrum of more than one overlay licensee.
  • Complicates bargaining problem for overlay licensees (free rider problem).
• Small number of stations could impair a large share of the spectrum available for mobile broadband use.
  • Simulation – on average, in 50 random samples of stations in the top 40 markets (PEAs) – if
    • 15% of stations remained on their original channels -- 65% of weighted MHz-pops would be impaired.
    • 25% of stations remained-- 84% of weighted MHz-pops would be impaired.
39 GHz Pre-auction Voucher Exchange

- A pre-auction “voucher exchange” facilitates incumbents buying back spectrum covering existing license areas at no net expenditure.
  - Allows incumbents to convert partial vouchers to whole vouchers
- After vouchers for impaired blocks within PEAs are aggregated, a single fractional voucher may remain in each PEA.
- These fractional vouchers may be exchanged across PEAs to create whole vouchers.
  - Vouchers can be traded between PEAs at an FCC-specified exchange rate per MHz-pop based on the relative value of PEA licenses estimated from previous auctions.
  - Vouchers can be traded up or down to the nearest whole number of vouchers in a PEA.