

Television Spectrum Repacking



An Auction on the Move - Time line



Event	Current Estimate
FCC issues <i>Auction Procedures Public Notice</i>	August 11, 2015
FCC issues opening price offers to all eligible stations	October 2015
FCC issues <i>Auction Application Public Notice</i>	October 2015
Stations file <i>Application to Participate in Reverse Auctions</i>	October - December 2015
Prohibition begins on certain auction related communications	December 2015 On Registration deadline
Broadcasters make minor corrections and modifications necessary to complete their applications	January - March 2016



An Auction on the Move – Time line



Event	Current Estimate
Deadline for broadcasters that registered for reverse auction to commit to preferred bidding option. A binding commitment to accept FCC's initial offer	March 29, 2016 <i>Announced</i>
FCC notifies each reverse auction applicant that either: (1) the station is qualified to bid; (2) the station is not qualified because no initial commitment was made; (3) the commitment could not be accommodated and the station will be designated for repack; or (4) the station is not needed and will be repacked	April – May 2016
FCC runs initial clearing target optimization and sets initial clearing target	April – May 2016



An Auction on the Move – Time line



Event	Current Estimate
Reverse auction bidding rounds commence – bidding continues for about 1 month	May 2016
Forward auction bidding commences second day after reverse auction completion – bidding continues for approximately 2 – 4 months	June 2016
FCC completes forward auction. If revenues are sufficient to satisfy the final stage rule(revenues must cover reverse auction payments, TV Broadcaster Relocation Fund and auction costs) the auction closes. If not, the FCC lowers the spectrum clearing target and reruns the reverse auction	September 2016
FCC issues PN announcing winning bidders	September 2016



An Auction on the Move – Time line



Event	Current Estimate
FCC issues <i>Channel Reassignment Public Notice</i>	September 2016
FCC commences payments to winning bidders on a rolling basis, as forward auction licenses are issued	November 2106
Repacked stations must file construction permits (CPs) for new facilities and submit repacking cost estimates	December 2016 FCC set 90 day timeline to file CP applications following <i>Channel Reassignment Public Notice</i>
Stations electing to channel share must file minor change application at least 60 days prior to the date by which they must commence sharing	December 2016
Station deadlines to build out CPs (station-specific deadlines)	February 2017 – December 2019



An Auction on the Move – Time line



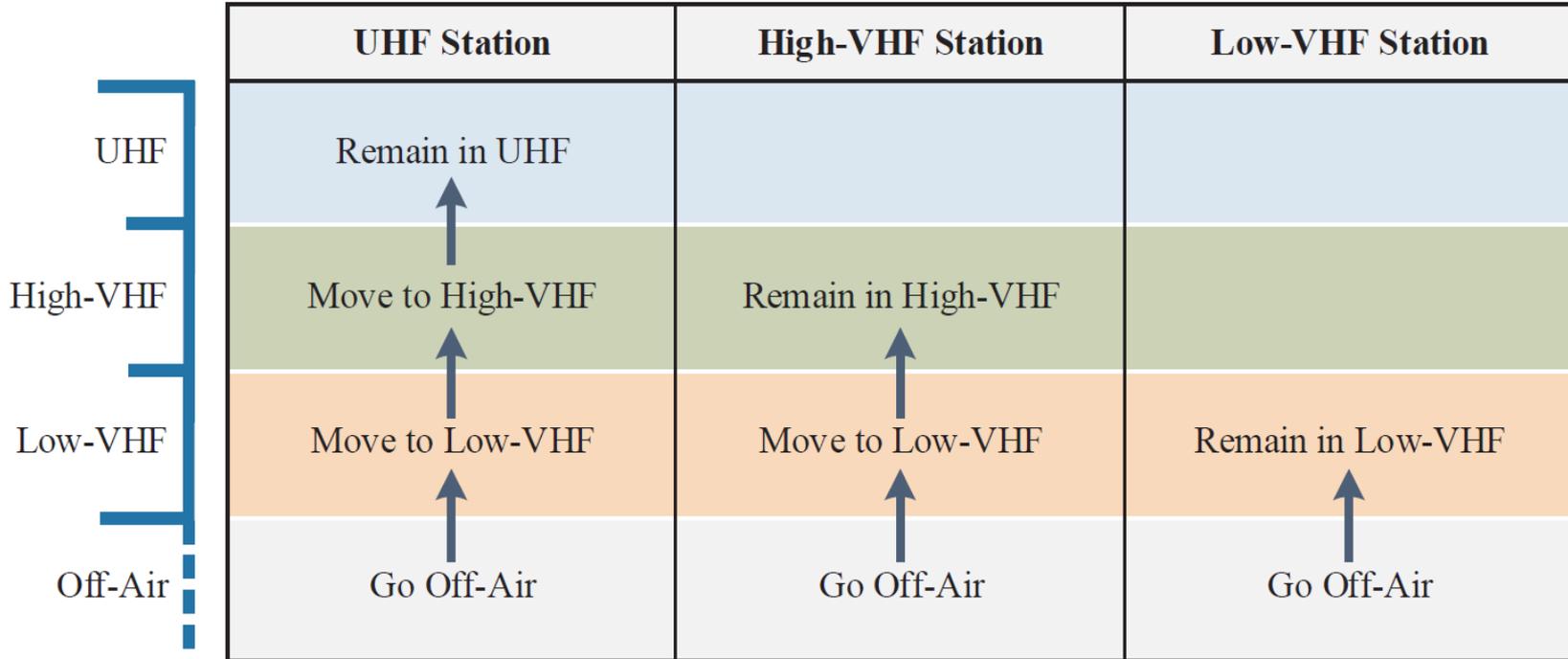
Event	Current Estimate
Filing window opens for expanded facilities or alternate channel assignments	February 2017
Stations relinquishing channels (entirely or to channel share) must end broadcasts and turn in licenses (stations may seek 3 month extension)	February 2017
Filing window for displaced translators	August 2017
Deadline for repacking expense finalization and true-up process	September 2019
All repacked stations to be operating on new channels; all broadcasts on pre-auction channels end	December 2019



- **All TV licensees**, *whether participating in the reverse auction or not*, are barred from disclosing info about:
 - Any broadcaster's planned bid amount
 - Any broadcaster's bidding strategy
 - Applies to all broadcasters nationwide, not just your local market info
- **Exceptions:**
 - Parties to channel-sharing agreements or co-owned stations
- **Ban kicks in** at deadline for pre-auction application and remains in place until FCC officially declares auction closed



One Way Hierarchy of Bid Options for Stations

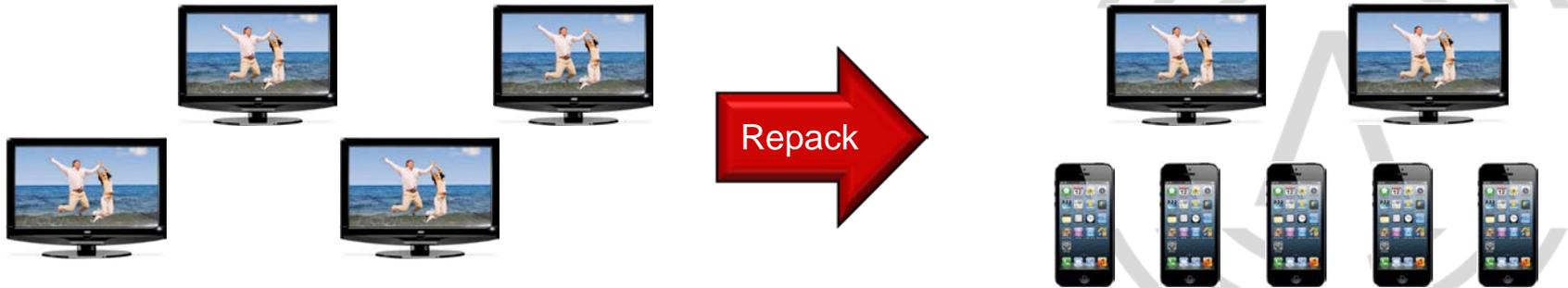


What is TV Spectrum “Repack”?

- FCC’s Definition of “Repacking”

(Source: <http://wireless.fcc.gov/incentiveauctions/learn-program/repacking.html>)

“Repacking involves reorganizing television stations in the broadcast television bands so that stations that remain on the air after the incentive auction occupy a smaller portion of the UHF band, thereby freeing up a portion of that band for new wireless services uses.”



- Nationwide clearing target
 - Minimum 84 MHz up to 126 MHz (Original 120MHz + CH37 = 126MHz)
- Guard bands between Wireless and TV services
 - Between 3 and 11 MHz depending on actual clearing
- Wireless duplex gap
 - Nationwide uniform position of 11 MHz gap required for mobile device interoperability
 - TV assignments may be made in wireless channels, duplex gap or both as *impaired spectrum*
- Channel 37 remains and protected by 3 MHz guard bands....but not assigned for TV service



UHF Band Plan specified by FCC PN 14-191A1



2	144	21	22	23	24	25	26	7	A	B	C	D	E	F	G	H	I	J	3	37	3	K	L	11	A	B	C	D	E	F	G	H	I	J	K	L	700 MHz UL
1	138	21	22	23	24	25	26	27	11	A	B	C	D	E	F	G	H	3	37	3	I	J	K	11	A	B	C	D	E	F	G	H	I	J	K	700 MHz IJL	
10	126	21	22	23	24	25	26	27	28	29	9	A	B	C	D	E	F	3	37	3	G	H	I	J	11	A	B	C	D	E	F	G	H	I	J	700 MHz UL	
9	114	21	22	23	24	25	26	27	28	29	30	31	7	A	B	C	D	3	37	3	E	F	G	H	I	11	A	B	C	D	E	F	G	H	I	700 MHz UL	
8	108	21	22	23	24	25	26	27	28	29	30	31	32	11	A	B	3	37	3	C	D	E	F	G	H	11	A	B	C	D	E	F	G	H	700 MHz IJL		
7	84	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	3	A	B	C	D	E	F	G	11	A	B	C	D	E	F	G	700 MHz IJL		
5	78	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	7	A	B	C	D	E	F	11	A	B	C	D	E	F	700 MHz UL			
5	72	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	11	A	B	C	D	E	11	A	B	C	D	E	700 MHz UL				
4	60	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	9	A	B	C	D	11	A	B	C	D	700 MHz UL				
3	48	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	7	A	B	C	11	A	B	C	700 MHz UL				
2	42	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	11	A	B	11	A	B	700 MHz UL					

- Wireless spectrum channelized into 5 MHz pairs
- TV service remains 6 MHz channels
- Duplex gap between wireless uplink and downlink
- Guard band spectrum between services

WHITE – TV Channels

Gray – Guard bands

Blue – Wireless Channels



How Many Stations Directly Impacted?

Spectrum Recovered MHz	Highest Remaining TV Channel	Stations Directly Impacted
84	36	543
108	32	729
114	31	770
126	29	860

- **Directly impacted** stations are those currently assigned to spectrum that is cleared for wireless services
 - Some might be participating in the auction while others will be forced to relocate
- **Indirectly impacted** stations are those in lower channels required to move to accommodate relocated stations



Spectrum Clearing Impact For 126 MHz

	Low	High
Eligible UHF Stations	1675	1675
Stations Eliminated (No Impaired Spectrum)	415	443
Stations Remaining On Channel (No Optimization)	71	92
Stations Required to Repack (No Optimization)	1147	1184
Stations Remaining On Channel (Optimized)	400	167
Stations Required to Repack (Optimized)	860	1065

- Data based on FCC's 100 repack simulations
- High – Low Estimates based on optimization range from 10% to 25%



Spectrum Clearing Impact For 84 MHz



	Low	High
Eligible UHF Stations	1675	1675
Stations Eliminated (No Impaired Spectrum)	222	249
Stations Remaining On Channel (No Optimization)	92	132
Stations Required to Repack (No Optimization)	1361	1294
Stations Remaining On Channel (Optimized)	433	262
Stations Required to Repack (Optimized)	1020	1164

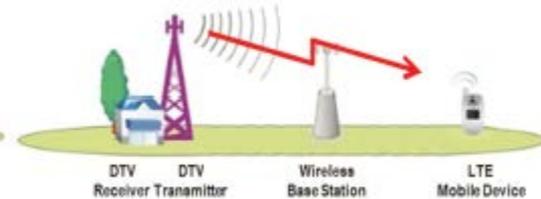
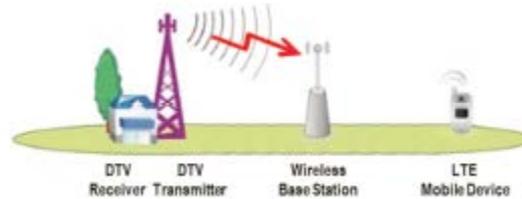
- Data based on FCC's 100 repack simulations
- High – Low Estimates based on optimization range from 10% to 25%



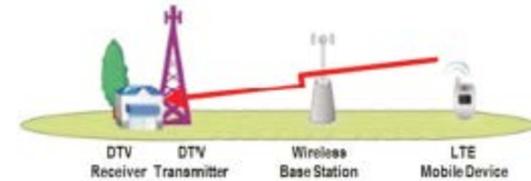
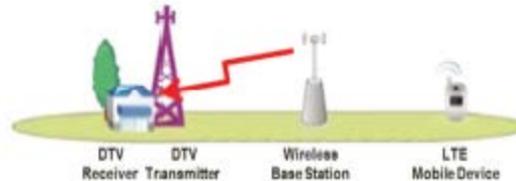
Impaired Spectrum

- **Impaired Spectrum** is primarily assigned to wireless services but regionally assigned to TV broadcast
 - Risk of inter-service interference (ISIX)

DTV to Wireless



Wireless to DTV



Impaired Spectrum – TV Assignment in Wireless Channels

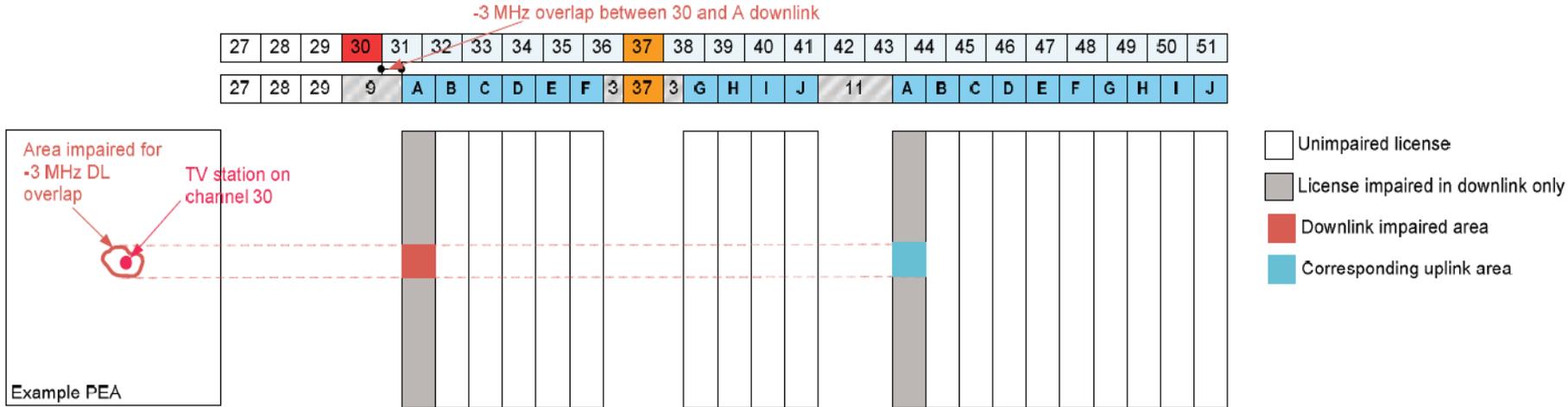


Figure 4: Impairments from a TV station on Channel 30 in 126 MHz Band Plan



Impaired Spectrum – TV Assignment in Wireless Duplex Gap

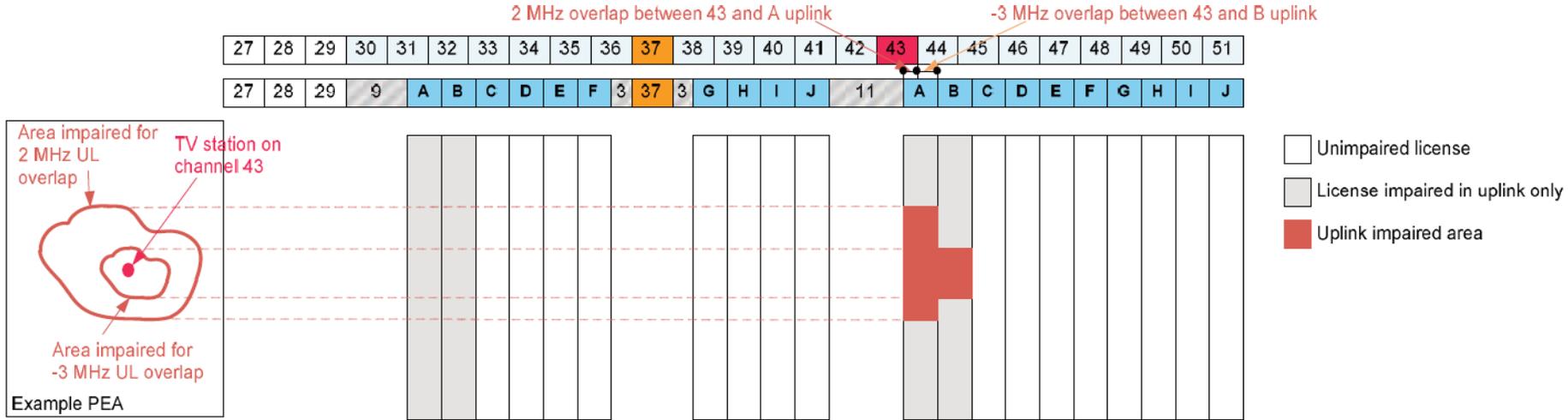


Figure 3: Impairments from a TV station on Channel 43 in 126 MHz Band Plan⁸⁹

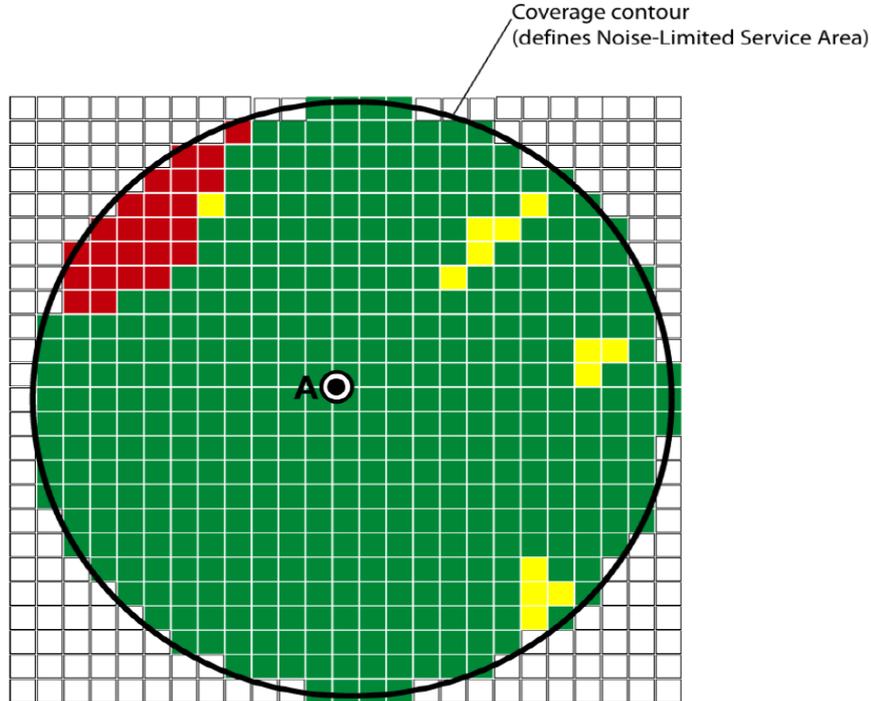


- Implementation of the repacking process is driven by the Spectrum Act's express requirement that the FCC must "make all reasonable efforts to preserve, as of February 22, 2012, the coverage area and population served of each broadcast licensee, as determined by the Commission's Office of Engineering and Technology (OET-69)". The Commission has stated " rather than merely attempting to preserve the same total population served by each station, all reasonable efforts will be made to preserve the same specific viewers".
- Latest and final version of *TVStudy* software and supporting data files was released by the FCC on June 30, 2015



What is OET 69?

Interfering Station **B**

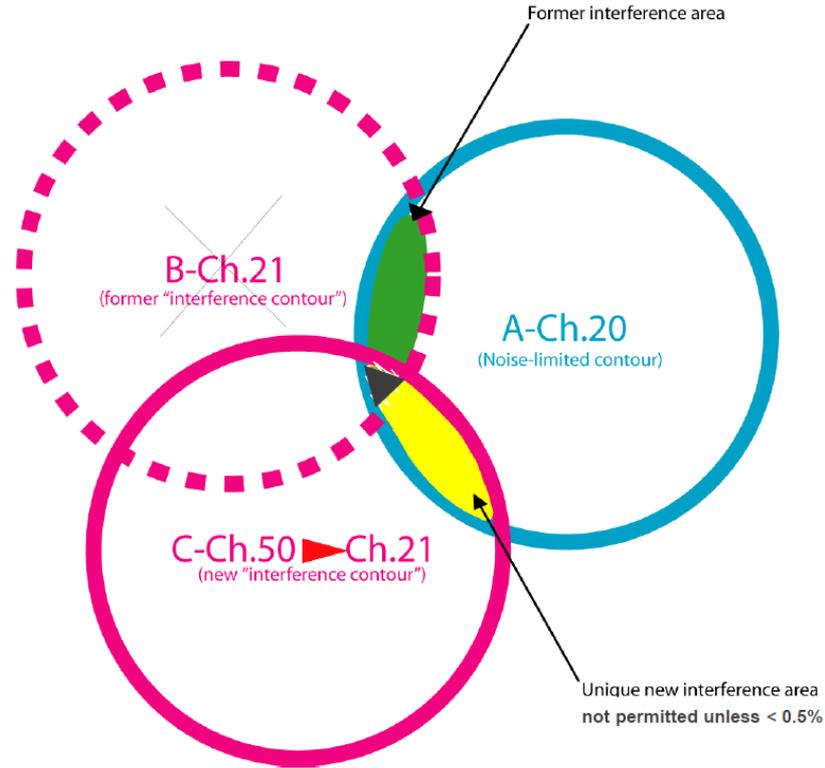


- Cell with service from Station A
- Cell with no service due to interference from Station B
- Cell with no service due to terrain obstruction (weak signal)



Preserving Population Served

- Repack can only “replace” population interference existing as of 2/22/12
- Potential to gain new viewers (green)
- Channel assignment not permitted if population served loss exceeds 0.5% (yellow) (“pairwise interference”)
- Predicted areas of no change (black)
- New coverage area will replicate station’s contour on its new channel



- How important are future services reaching Mobile and alternative devices to your stations business plan?
 - ATSC 3.0 opens new opportunities but VHF has inherent limitations for mobile delivery
- Is **In-Home reception** without outdoor antennas important?
 - UHF penetration is superior to VHF
- How will future VHF noise floor growth impact VHF reception?



- **Construction Permit & Budget Application Preparation**
 - Determine transmission facility requirements
 - Identify resources
 - Develop high accuracy budget
 - Prepare and file CP application
- **Construction Permit & Budget Processing**
 - FCC activity combined with 3rd party administrator
- **Post CP Construction**
 - Hire resources and make purchases
 - Complete construction
 - File for final reimbursement
 - File for license under new facilities



Summary of Available Industry Resources



- RF Consulting Engineers
 - 35...down from more that 70 during DTV transition
- Tower Structural Engineers
 - 5 firms...typically 1 or 2 engineers per firm
- Antenna and RF System Component Manufacturers
 - 2 primary manufactures of slot array UHF antennas...both at reduced work force
- Transmitter Manufacturers
 - 3 companies...down from 6 during DTV transition
- Tower/Antenna Rigging Crews
 - 13 firms...down from more than 21 during DTV transition
- Transmission System Installers
 - About 10 -12 crews
- Communications Attorneys
 - More than enough!



- RF Consulting Engineers
 - Determine transmission system requirements to replicate coverage on previous channel assignment
 - Work interactively with tower structural engineers, tower rigging crews and equipment suppliers to configure a solution
- Tower Structural Engineers
 - Determine capability of the tower structure to support new antenna and compliance with current tower standards where required
- Antenna and RF System Component Manufacturers
 - Provide component specifications and budgetary estimates for new components



- Transmitter Manufacturers
 - Provide specifications and budgetary estimates for new transmission equipment
- Tower/Antenna Rigging Crews
 - Document current tower if documentation is not up to date
 - Provide cost and time estimates for antenna change and tower modifications if required
 - Develop a rigging plan acceptable for local permitting
- Transmission System Installers
 - Provide cost and time estimates for the installation of the new transmission system
- Communications Attorneys
 - Finalize CP application and file with FCC



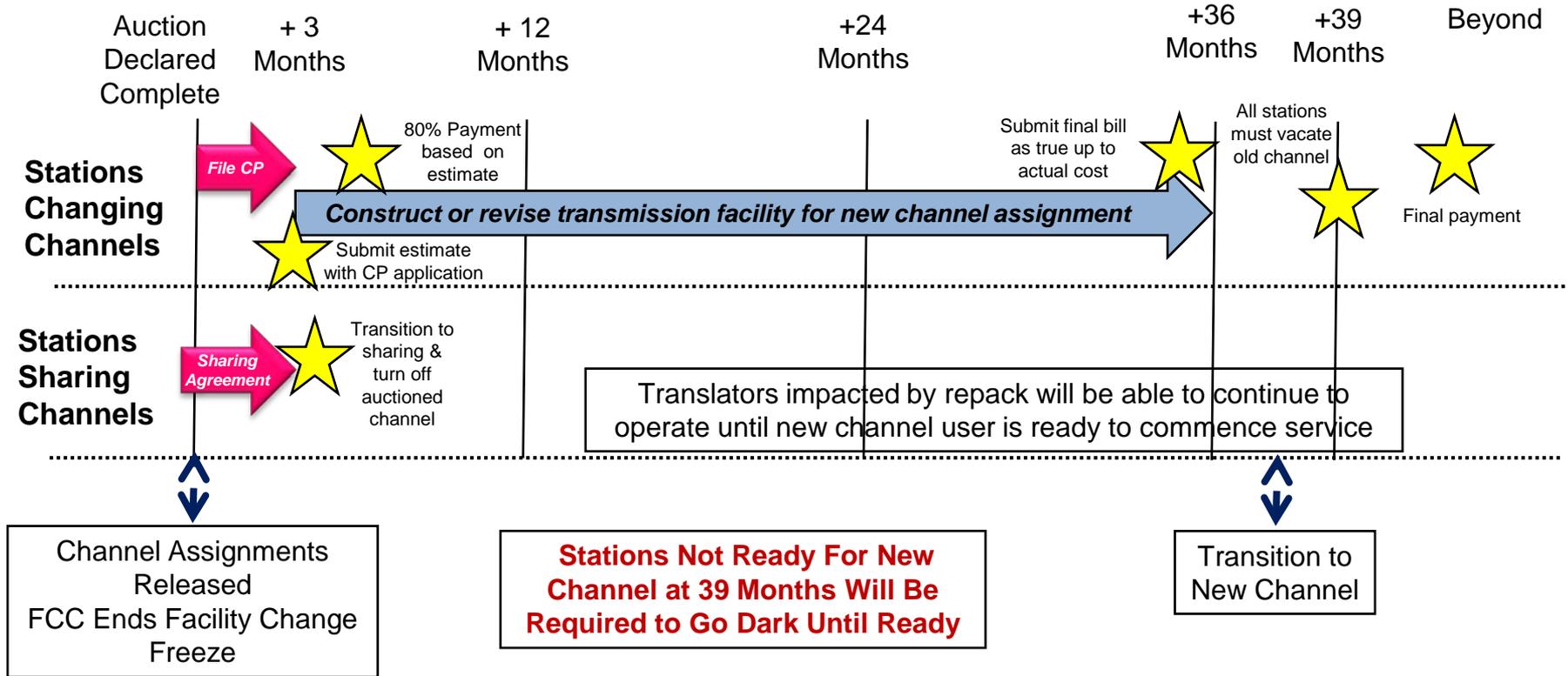
- Antenna and RF System Component Manufacturers
 - Supply products
 - Provide technical support during installation and testing
- Transmitter Manufacturers
 - Supply products
 - Provide technical support during installation and testing
- Tower/Antenna Rigging Crews
 - Reinforce tower if required
 - Install temporary antenna and transmission line if required
 - Remove current antenna and perhaps transmission line
 - Install new antenna and perhaps transmission line
 - Remove temporary antenna and transmission line if required



- Transmission System Installers
 - Install new transmitter
 - Install new RF mask filter and RF system components
 - Test new system
 - Remove or channel change old transmitter
 - Remove old RF system components
- RF Consulting Engineers
 - Verify RF system performance
 - Possibly verify coverage on new channel
- Communications Attorneys
 - File STA when ready to switch to new channel
 - File license amendment



Repack Timeline – FCC’s Plan



- Report & Order states the FCC will determine individual timetables for each station
 - FCC has stated that they intend to determine an individual stations allocated time to transition based on their opinion on how complex the transition requirements and factors will be for each station
 - Their plan shows no apparent consideration for supplier deliveries, resources such as tower crews, local permitting, weather or other un-controllable factors
 - FCC indicates that one extension might be granted for due cause.



- Tower/Antenna rigging crews
- Tower structural engineers
- Antenna and RF component manufacturers
- RF consulting engineers
- RF system installers



Estimated Repack Timeline w/ Industry Resources

- Actual repack timeline for the industry will depend on channel clearing target selected by FCC....84 or 126 MHz.
 - Smaller clearing target forces more stations to relocate
- Time estimates for the CP & Budget Application Preparation Phase range from **14 to 21 months** to complete
 - FCC has allocated 3 Months to complete
- Time estimates for CP & Budget Application processing are not available from the FCC
 - FCC staffers have expressed caution based on limited resources
- Time estimates for Construction Phase range from **6.5 to 9.5 years** to complete
 - FCC has allocated 36 months to complete



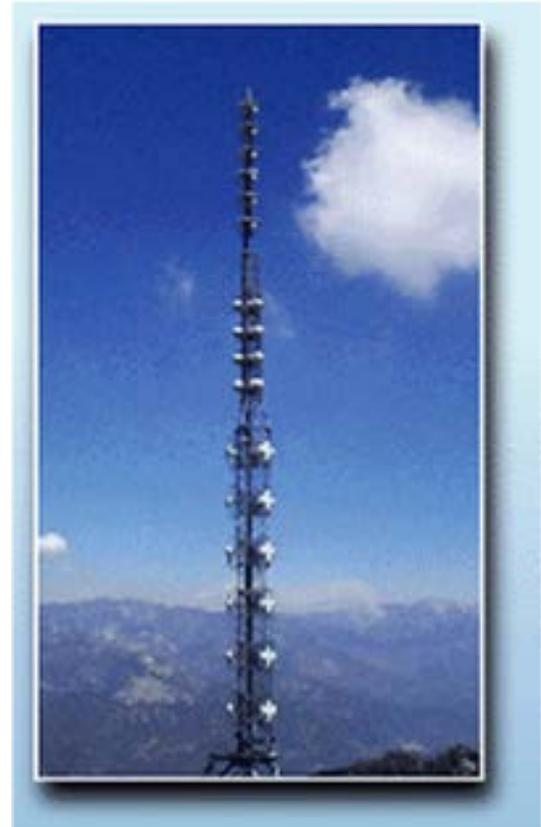
Possibly if stations....

- Share a Tower
- Have stacked antennas
- Operate on a shared antenna, transmission line and combiner

...with a station that is forced to change channel

Additional issues

- Who will pay the cost for accommodating these stations?...No provision in FCC's plan
- FM antennas on shared towers may have to be relocated or stations might have to temporarily reduce power or suspend operation...No provision for compensation in FCC's plan.



- Congress set aside \$1.75 B to reimburse...
 - Stations forced to change channels
 - **NOTE:** Stations moving voluntarily or electing to channel share must pay for their move costs out of their auction proceeds.
 - Multi-channel video providers who use OTA broadcast signals as source

But... What about stations indirectly impacted?



- An initial allocation of funds will be available to stations on an estimated cost basis
 - Funds will cover up to 80% of the eligible expenses for commercial stations and 90% for non commercial stations
 - Funds will be placed in designated accounts by the U.S. Treasury and will be available for draw down as expenses are incurred
 - Stations will be required to provide actual cost information before the end of the 3 year reimbursement period and may be issued a final allocation to cover the remainder of the costs
- All payments must be made within 3years from the end of the auction



- Actual repack costs for the industry will depend on channel clearing target selected by FCC....84 or 126 MHz.
 - Smaller clearing target forces more stations to relocate thus greater costs
- Industry cost estimates range from \$1.98B (800 stations) to \$2.94B (1200 stations) for repacking the remaining television stations post auction
 - This estimate does not include compensation for MCVP operators



Proposed TV Station Reimbursement Items



- Engineering study
- Transmitter(s)
- Transmitter installation
- Channel mask filter
- Antenna
- Tower rigging
- Permits
- Building modifications
- Electrical service modifications
- Tower loading study
- Proof of performance testing
- Coverage verification
- Transmission line
- Channel combiners at common sites
- Constructing a new tower if needed
- Legal services for filing
- Clean up and removal of old equipment
- Leasing temporary antenna and transmission line

NOTE: Widely's Dec. 2013 report provides greater detail and estimates



A Typical DTV Transmission Plant

- Basic transmission system blocks:

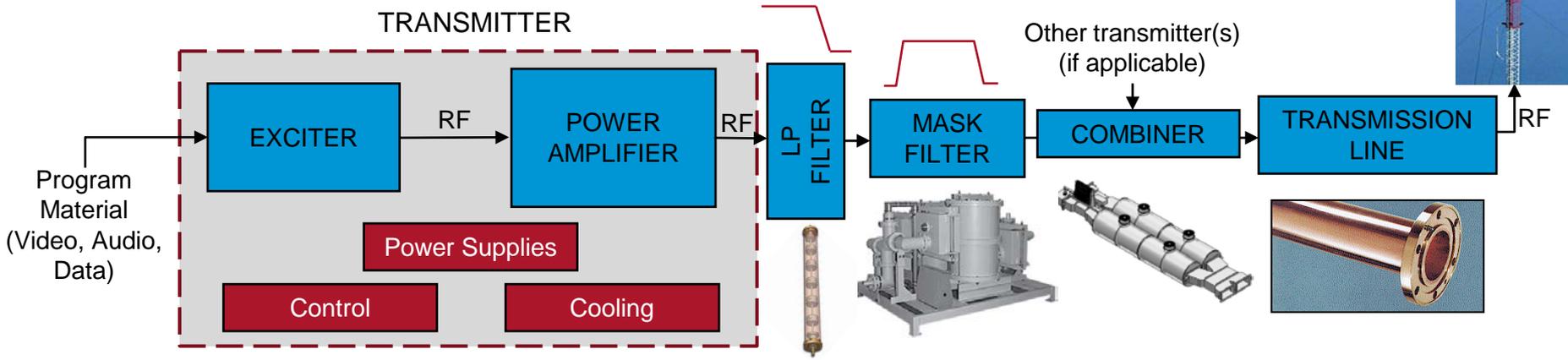
- Transmitter, comprising:

- Exciter
- Amplifier
- Power Supplies
- Control
- Cooling System

- External RF Items:

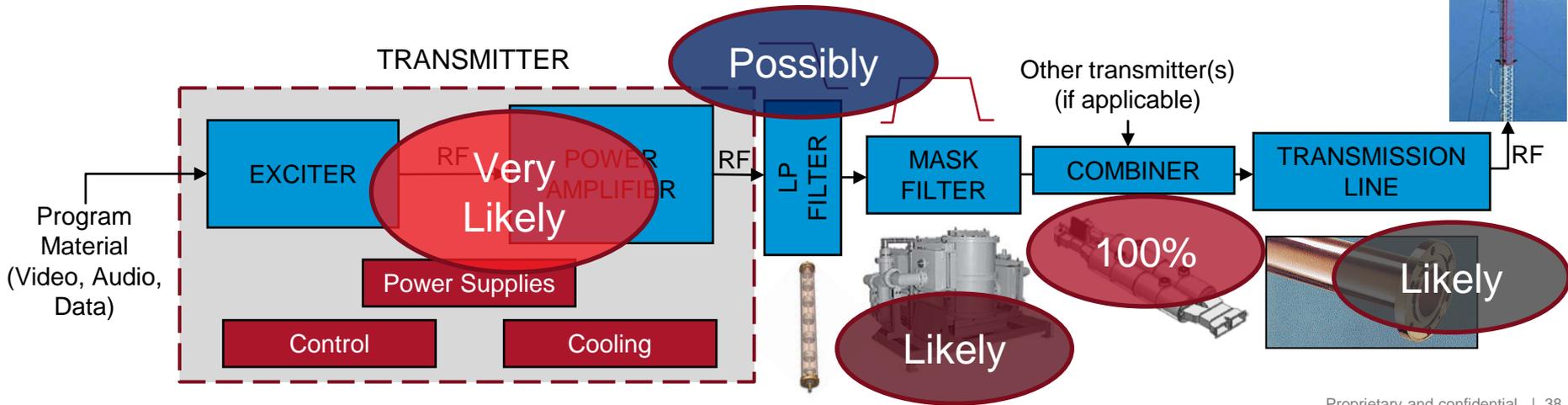
- Mask Filter
- RF Combiner
- Transmission line
- Antenna

ANTENNA

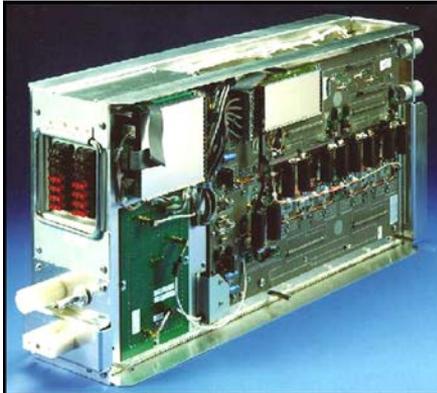
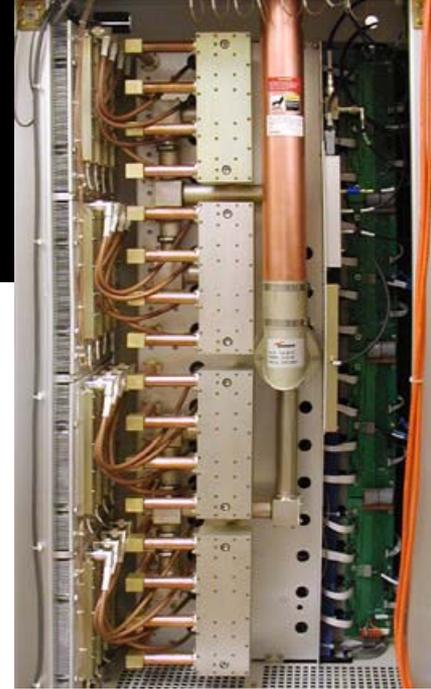


What's Impacted by Repack?

- If moving from an affected channel to a new one:
 - The following items will need to be looked at for retune or replacement:



Examples of Banded Tx Parts...



Example of PA & Circulator Bands



PA Module Channels

14 – 26

27 - 41

42 - 58

59 – 69 (no longer used)

Circulator Channels

14 - 21

22 - 34

35 - 52

53 – 69 (No longer used)

PA Modules	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
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Circulators	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
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Low Pass Filter Bands:

- 470-596 MHz (Ch 14-34)
- 596-704 MHz (Ch 35-52)
- 736-860 MHz (Ch 52 and up)



- Waveguide bands
- WR1800, WR1500, WR1150
- Mask Filter Cavities per Channel
- In general, a new RF system will be needed



Channel Compatibility of Transmission Line

Transmission
Line
Section Lengths

	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
20			■	■			■	■				■	■			■	■		
19 ¾	■			■	■				■	■			■	■			■	■	
19 ½	■	■			■	■				■	■			■	■			■	■

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
20	■	■			■	■			■	■			■	■			■	■	
19 ¾		■	■			■	■			■	■			■	■			■	■
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Prohibited Channel per catalog

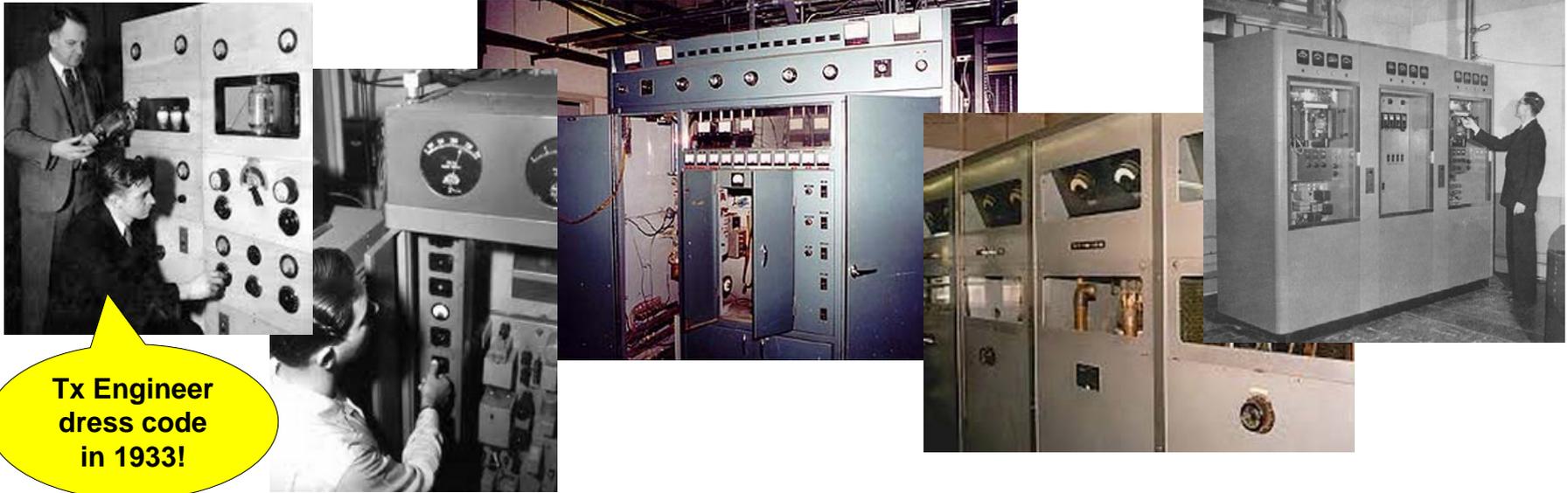


Changing Channels

- Tube (IOT) Transmitters
- Solid State Transmitters



Transmitter: Channel Change or Replace?



**Tx Engineer
dress code
in 1933!**

- You are moving how many channels from the current assignment?
 - Tube Technology Transmitters or Solid State Transmitters
- What about efficiency and power costs?
- How about staying “On Air” during repack



Single Collector IOT Transmitter



- Parts impacted by channel change may include:
 - Exciters
 - IPA
 - Circulators (if used)
 - Special input cavity parts
 - IOT Coupling Loops and Cavity Domes
 - RF System Components (Low Pass filter, Mask Filter, Magic Tee, etc.)
 - Re-Tuning and Power Calibration
 - Tube re-tuning requires expertise, tube damage possible (***Tube experts getting rarer***)

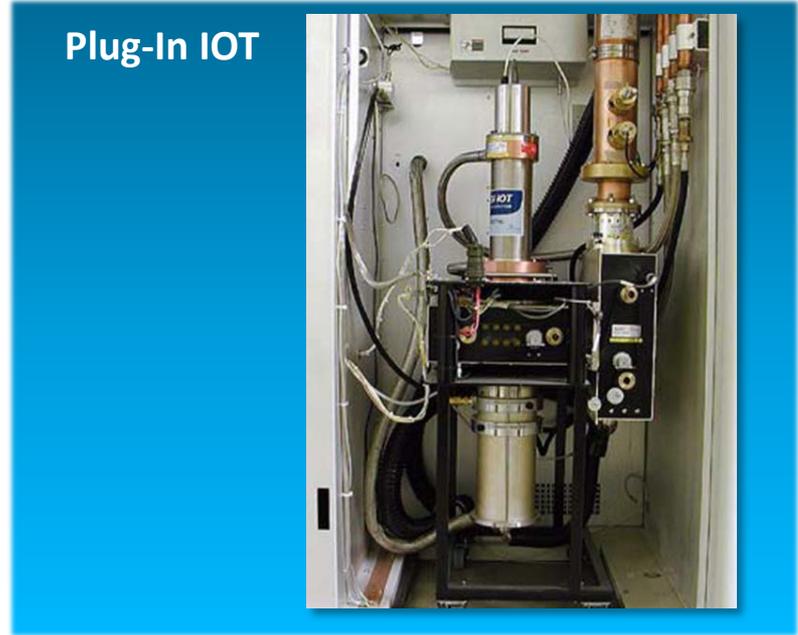


Harris/GatesAir SigmaCD

Single Collector IOT Transmitter



Types of Single Collector IOT's



- Low Pass Filter in break-away per Band (14-34, 35-52, 52+)
- Directional Coupler Ratio and Directivity Set Up
 - Note: Precise load and optimized adapters are needed to properly check directivity of couplers



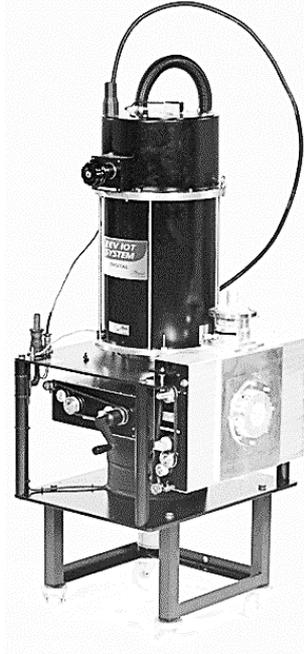
Different IOT's



Litton / L3



E2V ESCIOT



E2V

- Different flavors of IOT's may impact which items need to be replaced
- Can vary with the tube type and supplier
- Lead times and availability are valid concerns



Channel Change Cost vs. New

- Carefully evaluate the cost of conversion versus replacement
- In many cases, a good argument for tx replacement can be made:
 - Much higher efficiency
 - Save on Electricity costs (over 50% in some cases)
 - Broadband
 - Spares consolidation
 - Serviceability – ease of maintenance
 - Save on service costs
 - Long-term support
 - Tube prices and availability
 - Safety (low Voltage vs. High)

Cost Estimate Checklist:

Tx upgrade in-band
or - Tx upgrade out-of-band
or - New Transmitter

RF System Components (Mask Filter, etc.)

Antenna

+ Antenna change-out cost

RF Line

+ RF Line change-out cost

Tower Study & modifications (if needed)



VHF SS Replacement With New



- Old - PlatinumCD channel 12
 - 4kW Maximum power per PA cabinet
 - Approx. 20% AC to RF efficiency
- New - Maxiva VAX-3D
 - 6kW Maximum power per single rack
 - Typically over 40% AC to RF efficiency
 - This tx measured ~43% efficiency @ 6kW
- Dramatic Space Savings
 - Old Tx Footprint = 57 x 61.3 = 24.3 ft²
 - New Tx Footprint = 23.4 x 36 = 5.85 ft²
 - **Floor Space savings = 76%**



50% Reduction in Power Bill

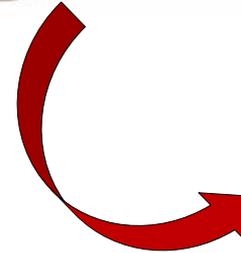


- Twice the efficiency = *Less than half the heat dissipated into room*
- Added savings on HVAC running costs further improves the ROI
- Example for 6kW VHF:
 - Old tx @20% Efficiency – Heat load is 24kW
(total input power $6/0.2 = 30\text{kW}$)
 - New tx @ 40% Efficiency – Heat load is 9kW
(total input power = $6/0.4 = 15\text{kW}$)
- Heat load to room drops by 63%



IOT Replacement with New SS

- Major benefits include:
 - Dramatic reduction in system electrical power consumption
 - Much smaller footprint – Room space savings
 - Safer - No High Voltage, No Vacuum Tubes
 - Broadband design – minimizes group spares holdings
 - High efficiency and broadband PA modules
 - Less maintenance – additional cost savings
 - No unexpected costly tube replacements

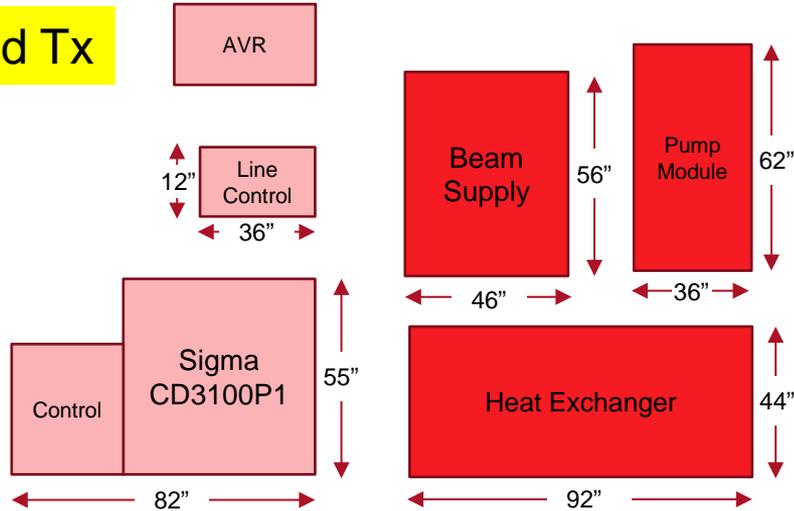


61% Less Floor Space



Space Savings Benefit (1 Tube)

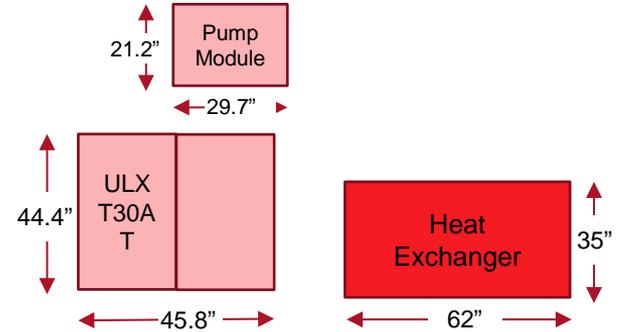
Old Tx



Tube Tx – Example Sigma 1-Tube

Power	25kW average power after filter
Indoor footprint	34.3 ft ²
Outdoor footprint	61.5 ft ²
Total footprint	95.8 ft ²

New Tx



Solid State Tx – Example ULXT 30 (2 x 37RU)

Power	Up to 25kW average power after filter
Indoor footprint	18.5 ft ²
Outdoor footprint	15.1 ft ²
Total footprint	33.6 ft ²

Total Space Savings: 65%



Summary IOT → New SS Transmitter



- High Efficiency Without High Voltages.
- Broadband for Future Channel Change and Spares Sharing
- No Tube Replacements
- Easier Maintenance.
- Better Architecture for Transmitter Up-Time and Redundancy.
- Longer Coolant Life (lower temperatures)



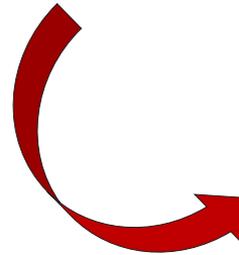
Older SS UHF Replacement

- Major benefits include:
 - Dramatic reduction in system electrical power consumption (**HUGE** efficiency improvement)
 - Broadband design – minimizes group spares holdings
 - High efficiency and broadband PA modules
 - Less maintenance – additional cost savings
 - Power Density = much smaller footprint = Room space savings

ULXT-20 saves 87% floor space and volume versus the DHD90P3 it replaces



Diamond DHD90P3
W: 125.1"
D: 61.0"
H: 72"
Footprint = 52.9 ft²
Volume = 317.9 ft³



ULXT-20AT (37RU rack)
W: 23.51"
D: 44.43"
H: 70.86"
Footprint = 7.25 ft²
Volume = 42.8 ft³



Summary: Old SS to New



- More than Double the Efficiency
- Dramatic Power Savings
- Dramatic Floor Space Savings (86% smaller tx footprint)
- No huge Gysel Combiner (even more floor space savings)
- Broadband
- Simple Maintenance
- Liquid Cooled vs. Air Cooled ~ 90% Waste Heat is Transferred to Outside (Reduced HVAC)



- All stations are possible repack candidates
- Even stations not required to change channels can be impacted
- Staying ON AIR during repack will most likely require some temporary transmission equipment
- Converting from UHF to VHF will impose future limitations on the station's coverage and ability to deliver mobile service
- Channel sharing will create some limitations for future delivery of mobile, multichannel, and UHD TV services



- Impaired spectrum including wireless duplex gap will create interference issues for broadcasters and wireless operators
- FCC's repack time line is substantially inadequate for the number of stations forced to repack as constrained by available industry resources
- Congressional approved \$1.75B reimbursement fund is insufficient to fully compensate stations and MCVP operators



- Many FM radio stations will be impacted during the antenna construction activity of repack
 - RF exposure hazard may force some stations to substantially reduce power or go off air during construction
- Wireless microphone services will be required to relocate or be relegated to unlicensed non interfering activity
- Unlicensed white space services will share spectrum
- Stations are unable to be reimbursed for any preparation activity prior to CP grant due to federal statutory regulations

