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Broadcast Spectrum Repacking Timeline, Resource and Cost Analysis Study

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Executive Summary

The subject of this study is the movement of a large number of television broadcast stations to new channel assignments at the conclusion of the Federal Communications Commission's (FCC) broadcast television spectrum incentive auction.

Since the FCC released its auction rules and related spectrum repacking data, there has been little public analysis concerning the tasks that must be accomplished to effectuate a nationwide repack of TV spectrum, the amount of time those tasks will take given the anticipated resources available, and the estimated costs. To date, the only in-depth analysis has been conducted by Widelity, Inc., which looked at repacking on a per-station rather than nationwide basis.

For the first time, this study, which was produced on behalf of the National Association of Broadcasters (NAB), develops estimates for the entire repacking exercise and lays out the corresponding analysis.

The conclusion of this study is that it will not be possible for all the assumed number of TV stations required to transition to new channels to do so within the stated FCC deadlines. In addition, this study concludes that the approach will result in a shortfall of funds for compensating broadcasters required to relocate to new channel assignments.

The study concludes that the Commission's three-month window for filing for construction permits (CP) falls well short of the actual time needed to submit and process the applications for the 860 to 1,164 stations that will likely be required to move to new channels (This study estimates 12-18 months). Likewise, the study concludes it is not possible that an industrywide transition of such a large number of TV stations to new channels can be completed in the three-year window currently required. In fact, the study's research and analysis estimates a far greater amount of time to accomplish the transitions. This study forecasts that, at best, between 297 and 445 stations can complete the required tasks in that time period, assuming normal conditions.

As noted above, the only public repacking work completed to date is known as the "Widelity Report," which was commissioned by the FCC and completed by Widelity, Inc. on December 30, 2013. This study analyzed the estimated time and financial resources required for individual stations to move to new channel assignments. While well researched and useful in certain respects, the Widelity Report does not account for the length of time necessary to repack the number of stations contemplated by the FCC. This study examines the task from a whole-industry perspective and differs from the Widelity report in the following ways:

- The Widelity Report estimates costs and amount of time required for several individual model stations but it does not provide a total industry estimate.
- The Widelity Report does not analyze or use estimates to simulate the total number of stations that will likely receive new channel assignments.
- Each timeline provided in the Widelity case studies is for an *individual station type* and does not take into account how the amount of resources available to the entire industry in a compressed amount of time will impact those individual timelines.

- This study assumes higher average prices for required transmitters. The Widelity individual case studies assumed that those stations transitioning to a new channel will retain existing Inductive Output Tube (IOT) transmitters and in many cases where new transmitters will be required, will purchase new IOT rather than solid state transmitters. This study assumes that all new transmitters purchased will be of the solid state variety as IOT transmitters are rapidly falling out of favor due to recent evolution of high-power solid state transmitters, and lack of timely availability of replacement IOT tubes and skilled technical operators to align and maintain transmitters based on IOT technology.
- Although this study differs with the Widelity Report on the average transmitter costs, it is in general agreement with most other costs outlined in the report. This study uses the Widelity Report's cost estimations as a guide in its cost estimates. In some cases small adjustments were made from the input received from industry resources that were interviewed.

Objectives and Tasks

The objective of the study is to provide an estimated time and cost quantification, as well as detailed descriptions of the processes required. To meet the stated objective, Digital Tech Consulting (DTC) was faced with several fundamental tasks:

- Quantifying the estimated number of TV stations that may be subject to changing channel assignments at the end of the FCC auction. Only when the auction is concluded will anyone know the exact number of stations that will be required to transition to new channel assignments. But given DTC's technical analysis based on target clearance slots, and analyzing simulations run by the FCC over the past year, we estimate that after optimizing the FCC's simulations, the number of stations will range from 800 to 1,200. Details on this analysis are outlined in the Spectrum Reclamation and Stations Affected by Repack section on pages 5-7.
- Identifying and explaining the various levels of complexity broadcasters may encounter when planning and implementing the change from one channel assignment to another. We have presented these in three levels, and provided a list of tasks that must be accomplished according to these different levels. The detailed level analysis is found in the Levels of Complexity section on pages 8-14.
- Identifying and analyzing the current and likely future levels of equipment and services that will be available to stations moving to a new channel assignment. Resources for which stations will need to contract are, in general, antenna, RF component, transmitter and transmission line suppliers, RF and structural consulting engineers, communications attorneys, and installation crews for tower work. Detail regarding the companies that provide these resources, their participation, and their limitations can be found in the State of Broadcaster Resources on pages 15-37. In addition, DTC provides a table of known equipment suppliers and service providers in the Appendix on page 56.

- Applying and analyzing the required tasks and resources to a series of timelines that reflect the different levels of complexity for all projected repack TV stations, and the availability of resources to perform the tasks in the context of 800-1,200 simultaneous projects. The timelines are presented in the following combinations: a) Preparation of Construction Permit Application Phase (PCPA Phase) for 800 stations, b) PCPA for 1,200 stations and c) Repack Construction Phase (RC Phase) for 800 stations, and d) RC Phase for 1,200 stations. This detail and corresponding timeline graphics are found in the Timelines section on pages 38-43.
- Comparing cost estimates outlined in the Widelity Report with DTC-gathered research from equipment and service providers, and identifying and making any necessary adjustments to the Widelity published cost estimates. More detail can be found in the Review of Estimated Costs section on pages 44-55.
- Estimating the total costs for 800-1,200 stations changing channels based on five examples of station types that will likely be subject to moving to new channel assignments. Line-item detail can be found in the Review of Estimated Costs section on pages 47-55.

The Challenges to Nationwide Repacking

Below is a high-level explanation of the most significant issues that DTC projects will result in a process that is anticipated to take far more than the 39 months currently allotted by the FCC and cost between $1.98 billion and $2.94 billion. The accompanying detail in the body of this report provides in-depth analysis of these conditions and circumstances.

- The two most significant bottlenecks in the process will be the small number of qualified crews for implementing tower modifications and installing antennas and transmission lines, and an anticipated shortage of antennas. There are other possible delaying factors, such as waiting for zoning and building permits, negotiating tower lease modifications, navigating the bureaucracy associated with federal and state-owned lands where some transmission sites are located, and both seasonal and extreme weather that will likely occur in many cases. These estimates only factor in the time required for what we refer to as “normal” circumstances and do not account for “unusual” cases.
- There are only two industry-accepted manufacturers of the primary type of antennas used by U.S. broadcasters, and they currently operate at minimum capacity due to the current lack of demand. Both report they will not hire and train new workers until they have received enough orders to begin that process, and will operate at a significant backlog once a critical mass of orders is received.
- The current broadcast supply chain, seven years after the analog TV shutoff, is much diminished, and is unlikely to regain the robustness it exhibited during the more than 10-year transition from analog to digital TV broadcasting. There are portions of the supply chain, such as transmitter suppliers and legal services, that DTC concludes could potentially handle

the capacity, but they are dependent on other members of the supply chain, such as consulting engineers and tower crews, to complete their work.

- The vast majority of broadcast towers are owned by the broadcasters themselves, and most of these towers are not TIA-222G compliant for tower safety code. Therefore, DTC anticipates that there will be a significant number of towers that will require modifications to meet code. These modifications represent both a high-cost and lengthy time component of a channel change project.
- Many broadcasters will likely move down the band to a lower frequency when receiving a new channel assignment. This will, in most cases, require broadcasters to install new auxiliary and main antennas, which can cost up to $450,000.
- Many stations do not have the backup transmitters that will be required to keep the station on air if a transmitter channel conversion is possible. Advances in solid state transmitter technology will drive broadcasters to purchase solid state transmitters, rather than transmitters employing the dwindling IOT technology. These transmitter costs can range from $100,000 to $2.6 million depending on power level.

There are a myriad of other elements that will play a role in the repack process, timeline and costs, and they are presented in greater detail within the body of this report.

Methodology

The main method of gathering the required information and data to estimate timelines and costs was to conduct primary research through identifying the principal companies, owners and executives that will be directly involved in supplying broadcasters with goods and services for stations that will be required to move to a new channel assignment. Once identified, written surveys were distributed, followed up by in-depth interviews with parties that will be directly providing equipment, engineering, installations, and other required consultations.

Additional methods included studying the FCC's repacking simulations, interviewing broadcasters, conducting additional research within publicly available documents, and news articles from reputable sources.

Lay of the Land

In accordance with Title VI of the Middle Class Tax Relief and Job Creation Act of 2012 (also known as the Spectrum Act), the FCC has been authorized to conduct an incentive auction within the broadcast TV spectrum. At the end of the auction, the UHF-TV band will be reduced in size by eliminating a group of upper channels. A result of this reduction is that there will be a significant number of stations that will be required to change channel assignment. The process of relocating stations to new channel assignments, known as repacking, is the subject of this study.

In this section, DTC analyzes and estimates the number of stations that may be subject to moving to a new channel assignment, as well as the variable complexities that must be contended with depending on the situation of individual stations. Taken into account are current transmission infrastructures, tower conditions, antenna redundancies and new equipment and material needs.

In the section that follows the analysis of various complexities, DTC examines the resources currently and likely to be available to these stations once they receive new channel assignments.

Spectrum Reclamation and Stations Affected by Repack

The exact magnitude of the FCC's spectrum reclamation and the associated repacking of the remaining television stations into a smaller number of TV channels is at best an estimate driven by many factors.

Two specific spectrum reclamation goals are evident in the FCC's various communications. First, the FCC has proposed a minimum clearing of 84 MHz as the appropriate threshold for the forward-auction spectrum benchmark. The second point is the potential clearing of 120 MHz, which was the original goal when the spectrum reclamation project was proposed. The most recent Public Notice 14-191A1 illustrates clearing models that are in between the 84 MHz and 120 MHz models, as well as models above 120 MHz and up to 144 MHz

For the purpose of this analysis, the focus will be on the 84 MHz and 120 MHz approaches set forth in the FCC's repacking studies.

Over the past year, the FCC ran at least 100 simulations that assumed either 84 MHz or 120 MHz clearing targets. Its approach considered 1,675 eligible UHF TV stations, and developed spectrum repacking plans based on either population, DMA markets served, or blocked channels. All approaches yielded results that were within reliable range of each other. Analysis of the data has resulted in information that defines a numerical range of stations that will be bought, taken off air, agree to share a channel with another station, or changed to a VHF channel to make the clearing. The simulations also produced a numerical range of stations that would be able to remain on their existing channel assignment. By deducting these numbers from the 1,675 targeted stations, the remainder will indicate the number of stations that will likely need to be relocated within the remaining television spectrum.

It is important to note that the FCC did not optimize its simulations to minimize the number of stations required to change channels. Several RF engineers who have reviewed the simulations believe that a 10% to 25% decrease in stations required to channel change might be possible. To create an overall range for analysis in this report, we have scaled down the un-optimized station repack numbers by the following factors: the highest number of stations by 10% and the lowest number by 25%.

The data shown below illustrate the ranges for each of the two clearing target models. This information was built on the analysis of the FCC's DMA simulations.

120 MHz Clearing Targets

Data from FCC 120 MHz Repacking Simulations		
Eligible UHF Stations	1,675	
Stations Eliminated	415	443
Stations Remaining on Channel (No Optimization)	71	92
Stations Required to Repack (No Optimization)	1,147	1,184
DTC Estimated Stations Remaining on Channel (After Optimization)	400	167
DTC Estimated Stations Required to Repack (After Optimization)	860	1,065

Sources: FCC DMA Simulations and DTC Analysis

84 MHz Clearing Targets

Data from FCC 84 MHz Repacking Simulations		
Eligible UHF Stations	1,675	
Stations Eliminated	222	249
Stations Remaining on Channel (No Optimization)	92	132
Stations Required to Repack (No Optimization)	1,361	1,294
DTC Estimated Stations Remaining on Channel (After Optimization)	433	262
DTC Estimated Stations Required to Repack (After Optimization)	1,020	1,164

Sources: FCC DMA Simulations and DTC Analysis

From the data analysis illustrated above, the range of stations likely to be required to change channels could range from 860 up to 1,164. There is also variability in the number of stations deciding to participate in the auction, and on the location of these stations. Since there are so many factors that could impact the simulations, the lower number could be rounded down to 800 and the upper number rounded up to 1,200 to create the widest possible, but reasonable, range as well as to simplify the available-resources analysis during spectrum repacking.

Levels of Complexity

Below we detail the repack challenges for broadcasters in three major levels of complexity. Each level might have some variations that are unique to one or more groups of stations, depending on their current transmission plant configuration. These do not include costs broadcasters will incur for viewer education.

Level 1 Repack

Criteria: A Level 1 repack is defined as those stations with one or more transmitters, with each being reasonably and economically capable of moving from the current channel assignment to a new assignment within the same television band. It is also assumed that the RF filters and antennas will require replacement as they are channelized, and the transmission line will likely need to be replaced depending on the new channel assigned. It is further assumed that the tower or antenna support structure is capable of supporting the change-out of the antenna system without any structural modification, and that a temporary antenna and transmission line will be necessary in order to keep the station on air during the antenna change-out.

Configuration A is defined as those stations operating with a single transmitter, RF system and antenna meeting the criteria set forth in Level 1.

Level 1, Configuration A

- Station is informed by FCC of the new channel assignment.
- If station is leasing space on a tower, the tower lessor must be engaged to determine possible antenna solutions, the need to modify the tower structure to accommodate the new antenna(s), and the impact on other tower tenants.
- Tower structural engineer is engaged to analyze the current status of the tower and its capability to support a new antenna and a temporary antenna + transmission line (assumes tower is station owned. If the tower is leased, the tower landlord is contacted and the landlord and his approved structural engineer join the process).
- Antenna supplier is engaged to provide antenna options and pricing.
- Decision is made to purchase a temporary antenna + transmission line or purchase a standby antenna + transmission line.
- Antenna and RF system planning is completed, allowing RF consultant to prepare technical information for CP application.
- Transmitter manufacturer and/or RF system installer is engaged to review procedure and pricing to retune the transmitter to a new channel assignment.
- Tower rigging company is engaged for pricing and schedule for installation.
- Station might decide to purchase a frequency-agile transmitter to provide interim service during the re-channeling process and be used later as a backup transmitter.
- Station engineers finalize budget estimates for repack.
- Station’s legal representation prepares CP and STA applications and justification for replacement equipment and services required to repack, including a documented budget estimate to the FCC.

Level 1, Configuration A

- Wait for FCC to process.
- FCC issues CP and advanced payment for channel change.
- Orders placed for new main antenna, transmission line and RF system components and a temporary or standby antenna and transmission line.
- Contracts placed with RF systems installer and tower rigging companies.
- Station files for local zoning or building permits to cover antenna changes.
- Project schedule and plan is finalized.
- Wait for deliveries.
- Alternate transmitter is received and installed.
- Tower crew installs temporary or standby antenna + transmission line.
- Station switches operation over to alternate transmitter and standby antenna.
- Tower crew removes main antenna and transmission line.
- Tower crew installs new main antenna and transmission line.
- RF system installation crew installs new RF system, and tests new RF system and antenna.
- RF system crew retunes and tests transmitter.
- Station PSIP is updated to reflect new channel assignment.
- Station ceases operation on old channel and begins operation on new channel.
- Tower crew returns to remove temporary antenna and transmission line if rented.
- RF system crew retunes and tests alternate transmitter for new channel assignment.
- Station personnel assemble final invoices for submission to true up channel change compensation.

Configuration B is defined by those stations operating with a main and alternate transmitter and either a single main RF system and antenna, or possibly having a main-plus-standby RF system and antenna.

Level 1, Configuration B

- Station is informed by FCC of the new channel assignment.
- RF consulting engineer is engaged to plan antenna, transmission line and RF filter requirements.
- If station is leasing space on a tower, the tower lessor must be engaged to determine possible antenna solutions, the need to modify the tower structure to accommodate the new antenna(s), and the impact on other tower tenants.
- Tower structural engineer is engaged to analyze the current status of the tower and its capability to support a new antenna and a temporary antenna + transmission line (assumes tower is station owned. If the tower is leased, the tower landlord is contacted and the landlord and his approved structural engineer join the process).
- Antenna supplier is engaged to provide antenna options and pricing.
- Decision is made to purchase a temporary antenna + transmission line or purchase a standby antenna + transmission line, unless the station already has a standby antenna (>10%).
- Antenna and RF system planning is completed, allowing RF consultant to prepare technical information for CP application.

Level 1, Configuration B

- Transmitter manufacturer and/or RF system installer is engaged to review procedure and pricing to retune the transmitters to a new channel assignment.
- Tower rigging company is engaged for pricing and schedule for installation.
- Station engineers finalize budget estimates for repack.
- Station’s legal representation prepares CP and STA applications and justification for replacement equipment and services required to repack, including a documented budget estimate to the FCC.
- Wait for FCC to process.
- FCC issues CP and advanced payment for channel change.
- Orders placed for new antenna, transmission line and RF system components. (Note: If the station already owns a standby antenna, channelized RF components for that system will also be ordered; if not, the station also orders a temporary antenna and transmission line.)
- Contracts placed with RF systems installer and tower rigging companies.
- Station files for local zoning or building permits to cover antenna changes.
- Project schedule and plan is finalized.
- Wait for deliveries.
- RF System crew retunes one transmitter to new channel assignment.
- Tower crew installs temporary or standby antenna + transmission line if required.
- Station switches operation over to temporary or standby antenna.
- Tower crew removes main antenna and transmission line.
- Tower crew installs new main antenna and transmission line.
- RF system installation crew installs new RF system and tests RF system and new antenna.
- Station PSIP is updated to reflect new channel assignment.
- Station ceases operation on old channel and begins operation on new channel.
- Tower crew returns to remove temporary antenna and transmission line if rented.
- RF system crew retunes and tests second transmitter for new channel assignment. Station personnel assemble final invoices for submission to true up channel change compensation.

Level 2 Repack

Criteria: A Level 2 repack is defined as those stations with one or more transmitters that are neither reasonably, technically, nor economically capable of moving from the current channel assignment to a new assignment within the same television band. It is also assumed that the RF filters and antennas will also require replacement as they are typically single channel devices, while the transmission line might require replacement depending on the new channel assignment. It is further assumed that the tower or antenna support structure is capable of supporting the change-out of the antenna system without any structural modification.

Configuration A is defined as those stations operating with a single transmitter, RF system and antenna meeting the criteria set forth in Level 1.

Level 2, Configuration A

- Station is informed by FCC of the new channel assignment.
- RF consulting engineer is engaged to plan transmitter, antenna, transmission line, RF filter and system requirements.
- If station is leasing space on a tower, the tower lessor must be engaged to determine possible antenna solutions, the need to modify the tower structure to accommodate the new antenna(s), and the impact on other tower tenants.
- Tower structural engineer is engaged to analyze the current status of the tower and its capability to support a new antenna and a temporary antenna + transmission line (assumes tower is station owned. If the tower is leased, the tower landlord is contacted and the landlord and his approved structural engineer join the process).
- Transmitter supplier is engaged to provide transmitter configuration option and pricing.
- Antenna supplier is engaged to provide antenna options and pricing.
- Decision is made to purchase a temporary antenna + transmission line or purchase a standby antenna + transmission line.
- Transmitter, antenna and RF system planning is completed, allowing RF consultant to prepare technical information for CP application.
- Transmitter and RF system installer is engaged to review project scope and schedule and to provide pricing.
- Transmitter building is evaluated to determine adequate floor space, power, cooling and associated requirements for installation of new transmitter. Pricing estimates are developed for any required building modifications.
- Tower rigging company is engaged for pricing and schedule for installation.
- Station engineers finalize budget estimates for repack.
- Station's legal representation prepares CP and STA applications and justification for replacement equipment and services required to repack, including a documented budget estimate to the FCC.
- Wait for FCC to process.
- FCC issues CP, STA and advanced payment for channel change.
- Orders placed for new transmitter, antenna, transmission line and RF system components.

Level 2, Configuration A

- Contracts placed with RF systems installer and tower rigging companies.
- Station files for local zoning or building permits to cover antenna changes.
- Project schedule and plan is finalized.
- Wait for deliveries.
- Building modifications, including clearing space, AC power, air conditioning etc. are accomplished.
- Transmitter arrives and installation commences.
- Tower crew arrives, rigs tower and installs temporary or standby antenna + transmission line.
- Station switches operation over to temporary or standby antenna.
- Tower crew removes main antenna and transmission line.
- Tower crew installs new main antenna and transmission line.
- RF system installation crew completes transmitter installation and new RF system installation and tests complete RF transmission system and antenna.
- Station PSIP is updated to reflect new channel assignment.
- Station ceases operation on old channel and begins operation on new channel.
- Tower crew returns to remove temporary antenna and transmission line if rented.
- RF system crew removes and disposes of old transmitter and RF system components.
- Station personnel assemble final invoices for submission to true up channel change compensation.

Configuration B is defined as those stations operating with a main and alternate transmitter and either a single main RF system and antenna or possibly having a main plus standby RF system and antenna.

Level 2, Configuration B

- Station is informed by FCC of the new channel assignment.
- RF consulting engineer is engaged to plan transmitter, antenna, transmission line, RF filter and system requirements.
- If station is leasing space on a tower, the tower lessor must be engaged to determine possible antenna solutions, the need to modify the tower structure to accommodate the new antenna(s) and the impact on other tower tenants.
- Tower structural engineer is engaged to analyze the current status of the tower and its capability to support a new antenna and a temporary antenna + transmission line (assumes tower is station owned. If the tower is leased, the tower landlord is contacted and the landlord and his approved structural engineer join the process.).
- Transmitter supplier is engaged to provide transmitter configuration option and pricing.
- Antenna supplier is engaged to provide antenna options and pricing. Decision is made to purchase a temporary antenna + transmission line or purchase a standby antenna + transmission line.

Level 2, Configuration B

- Transmitter, antenna and RF system planning is completed, allowing RF consultant to prepare technical information for CP application.
- Transmitter and RF system installer is engaged to review project scope and schedule and to provide pricing.
- Transmitter building is evaluated to determine adequate floor space, power, cooling, and associated requirements for installation of new transmitter. Pricing estimates are developed for any required building modifications.
- Tower rigging company is engaged for pricing and schedule for installation.
- Station engineers finalize budget estimates for repack.
- Station's legal representation prepares CP and STA applications and justification for replacement equipment and services required to repack, including a documented budget estimate to the FCC.
- Wait for FCC to process.
- FCC issues CP and advanced payment for channel change.
- Orders placed for new transmitters, antenna, transmission line and RF system components.
- Contracts placed with RF systems installer and tower rigging companies.
- Station files for local zoning or building permits to cover antenna changes.
- Project schedule and plan is finalized.
- Wait for deliveries.
- Either the main or auxiliary transmitter is removed from service and removed from the site to allow installation of a replacement transmitter.
- Building modifications, including clearing space, AC power, air conditioning, etc. are accomplished.
- First transmitter arrives and installation commences.
- Tower crew arrives, rigs tower and installs temporary or standby antenna + transmission line.
- Station switches operation over to temporary or standby antenna.
- Tower crew removes main antenna and transmission line.
- Tower crew installs new main antenna and transmission line.
- RF system installation crew completes first transmitter installation and new RF system installation, and tests complete RF transmission system and antenna.
- Station PSIP is updated to reflect new channel assignment.
- Station ceases operation on old channel and begins operation on new channel.
- Tower crew returns to remove temporary antenna and transmission line if rented.
- RF system crew removes and disposes of second transmitter and RF system components.
- Second transmitter arrives and RF system installation crew installs transmitter and related RF system. Crew tests second transmitter.
- Station personnel assemble final invoices for submission to true up channel change compensation.

Level 3 Repack

Criteria: A Level 3 repack has either the criteria of a Level 1 or Level 2 repack with one major difference: the antenna's supporting structure or tower is incapable of supporting the change-out of the antenna and transmission line. The structure or tower must be modified or reinforced prior to changing out the antenna and transmission line.

Since tower modifications typically take much longer to complete, the approach would likely be to place a temporary side-mounted antenna and transmission line in service for the new channel assignment. This will allow the station to channel change when the transmitter and RF system is ready for the new channel.

Tower modifications can be made at a later date, and the new main antenna and transmission line installed upon completion of the tower modifications. When completed, the station will be able to switch over and commence broadcasting at full power.

State of Broadcaster Resources

Some DTV History

The U.S. high-power TV stations went from broadcasting only analog TV signals to simulcasting both analog and digital, and ultimately only digital signals. This occurred over a period of more than 10 years, and culminated in the shut off of all high-power analog TV broadcasts. According to FCC estimates, U.S. broadcasters paid about $10 billion for the transition, with each station spending on average $1 to $2 million[1] for construction of new transmission and broadcasting facilities during this time period, which began in 1996 and concluded in early 2009, throughout which all high-power TV stations were required to simulcast digital and analog TV signals.

Since 2009, the level of transmission infrastructure activity has been limited mostly to maintenance or disaster recovery. All suppliers of transmission equipment and services have either gone out of business, reduced their personnel and output, focused on other world regions, or been acquired by other providers.

Because the analog-to-digital transition was the largest and most expensive coordinated television transmission build-out in U.S. broadcast history, all broadcast industry suppliers were staffed and operating at their maximum capacity. At the height of DTV infrastructure work there were no fewer than seven high-power transmitter suppliers, compared to today's three. Since the DTV transition, both primary antenna suppliers have reduced their staff and production capacities to minimal support level. Many field, structural and RF engineers have either retired or transitioned to the wireless industry since 2009.

During the 10-year DTV transition there were about 30 tower crews capable of doing the tall tower work mandatory for replacing transmission lines and antennas, and fortifying broadcast towers to accommodate those changes. DTC's research shows that there are currently about 13 qualified crews today, and the companies that employ them forecast that there will be no more than 16 for the repack work. These companies tell DTC that they are working now to identify as many qualified crews as possible, but have had little success in identifying additional possible crews due to the dearth of qualified foremen and trained workers.

The TV broadcast equipment and services industry segments have gone through a series of downsizing and consolidations that began with a management buyout of transmitter supplier Comark in 2012. The company was minimally profitable in 2013 after trying to shift its business outside of the U.S. In 2014, Hitachi Kokusai Electric made a majority investment in the company.

In July 2014, transmitter supplier Larcan closed its operations. A recent announcement that Larcan assets have been purchased by Unique Broadband Systems (UBS) didn't specify the practical significance of the transaction. UBS also purchased the assets of another DTV transition-era transmitter manufacturer, Axcera, but the company only services existing Axcera transmitters. A similar arrangement may be planned for Larcan, although UBS has not confirmed this.

[1] Digital Television Transition: Policy and Regulatory Issues presentation to CTU/ITU April 29-May 3, 2013 Seminar on Spectrum Management. Presented by Jonathan Levy of the FCC.

Even the perennial market share leader Harris Broadcast has experienced a post-DTV transition shake up after Harris Corp. sold its Broadcast Communications Division (BCD) to the investment firm Gores Group in 2013. In 2014, the transmission division of the business was separated from the rest of the former Harris Broadcast and was rebranded as GatesAir. GatesAir's success in markets outside of the U.S. has kept it viable after the U.S. DTV transition.

Further consolidation in the broadcast antenna business has been more severe than that of the transmitter business. In April 2013, Dielectric, the U.S.'s leading antenna supplier, ceased its radio and TV antenna operations, citing the "difficult economic and global conditions in the broadcast market." Later in the year, Sinclair Broadcast Group purchased Dielectric's assets and announced that it would retain 33 employees, down from about 300 employees during the peak of the DTV transition.

Current State of Resources

As outlined above, the state of the professional broadcast equipment and service business is dramatically different than it was 15-17 years ago. Because designing, building, installing, and servicing professional high-power broadcast transmission equipment is so specialized and customized, ramping up production for made-to-order systems that cost anywhere from $75,000 to more than $2 million is difficult and capital intensive.

Therefore, based on DTC's interviews with suppliers and service providers from all parts of the broadcast supply chain, it appears unlikely that all industry segments will be able to supply the anticipated demand without operating with a significant backlog.

Resources for Repack

The process of moving television stations to different channels can be divided in two phases. The Preparation of the Construction Permit Application Phase (PCPA Phase) encompasses all activity required to organize, plan and engineer the transmission system that will be presented to the FCC for the agency's CP application process. This includes preparation of applications and the proposed budget that will be used to request the initial payment from the repack compensation fund.

The Repack Construction Phase (RC Phase) of the process takes place after the FCC issues a CP authorizing the station to proceed with the necessary construction involved in making the channel change.

There are eight groups of essential industry resources that provide equipment and services to television broadcast station operators that will be required during these two phases:

- RF Consulting Engineers
- Tower Structural Engineers
- Broadcast Communications Legal Services
- Antenna Manufacturers
- RF Component Manufacturers
- Transmitter Manufacturers
- RF Transmission System Installers
- Tower and Antenna Installers

In addition, there could be several other groups, such as third party tower companies and local or regional governments, that may be involved depending on individual station circumstances and operating models.

Most of the eight resource groups are part of each of the two phases of the process; however, some only contribute to a single phase.

The following summary of these resources is based on numerous interviews conducted with participants in each of the resource groups over the past few months. The summary includes the number of identified viable and qualified suppliers for each group. The summary also provides an estimate of the project capacity of each group, typical time to perform the tasks per station, and typical cost ranges for their services and products. These resource groups are presented in the logical order that they will be required to initially participate in a station's channel-change project.

The identified resources are limited to those that operate in the U.S. broadcast market, or have services or products that meet the requirements of the U.S. broadcast market. As an example, there are many companies worldwide that manufacturer television broadcast antennas. Most of these specialize in lower power levels and/or panel-type antennas, rather than the pylon-type slot radiators and high power levels that make up nearly 97% of the U.S. television broadcast market.

A similar comparison exists with tower and antenna installation firms. There are many firms in the antenna installation business. Only a small number of these firms have the experience, the necessary rigging equipment, and the skills required to install heavy antennas on tall towers. The remaining tower and antenna installation providers are only equipped to work in the wireless, microwave and 2-way radio markets, where antennas are small and lightweight, and towers usually do not exceed 350 feet in height.

The time indicated for the performance of each group's services or delivery of their products is based on an average quoted during normal business conditions. Most of the resources have indicated that these times will increase during periods of high demand, such as those expected during the repack window. Many of the service providers anticipate that they won't be able to meet the needs of their regular clients in a timely manner, given the time allotted in the repack rules.

RF Consulting Engineers

The RF consulting engineer will become engaged with a station's channel-change project as soon as the station receives a new channel assignment and any other data related to the intended coverage of the repacked station. The RF consultant's responsibility in the PCPA Phase is to determine the antenna characteristics, transmitter power-out requirements, and the design characteristics of the RF system connecting the transmitter to the antenna, and designing an overall system that meets the coverage requirements of the station. The RF consultant must work in concert with the tower structural consultant to develop a configuration that minimizes the impact on the existing tower structure, while replicating the coverage of the previous transmission system on the previous channel.

In addition to the RF engineering study, the RF consultant provides the technical information that is required for filing FCC applications for the CP. The consultant with the station's communications counsel also prepares the Special Temporary Authorization application for temporary operation while at reduced power and antenna configuration during the antenna and transmitter change-out process.

There is also likely a post-construction involvement, where the RF consultant may be involved in final verification of an antenna's performance and checkout of the overall transmission system installation. The consultant may also be involved in coverage verification after the completion of construction.

Most station group owners work with the same consulting firm over a period of years, thus providing continuity and easy access to the many details involved when making critical decisions related to their station's coverage. Changing consultants is not advisable when time constraints such as those associated with repack are imposed.

Information gathered through interviews with personnel from selected RF engineering consultants and firms indicates that the average pre-CP engineering project involving a channel change and replication of coverage for an existing television station will take between two and eight work weeks to complete.

Currently there are about 35 individual qualified RF consultants that specialize in television transmission system engineering. The number of consultants still in this practice is significantly reduced from the number that was available during the analog-to-digital TV transition era. There are five firms that employ between three and five consultants each, for a total of 20 of the 35 consultants. The remainders are primarily one-person consulting practices, with a couple of two-person practices. After interviewing several of the consultants, it is estimated that the collective monthly output of engineering projects from the five larger consulting firms is about 95 projects. The remaining 15 consultants will have a collective capacity of about 75 projects per month; thus this resource group will be able to deliver about 170 RF consulting projects over a one-month time span. The costs for an RF consultant's services in the PCPA Phase will range from $2,500 to more than $25,000, with an average of about $11,500 per station. This amount includes the RF system design, CP application and STA filing.

Assuming no unusual circumstances and no diversions to respond to a station's emergency technical issues, this resource group is able to support no more than about 510 stations within the FCC's allocated three-month CP filing window. This estimate, however, also assumes that the other inputs, such as the tower structural analyses needed before RF consultants can complete their studies, will be available in a timely manner. The pool of qualified structural engineers is smaller than that of the RF engineers, and this dependency will likely hold up the CP application process.

Based on the assumption of between 800 and 1,200 stations that will be required to change channel assignments, the availability of RF consulting engineering resources will be one of the limiting factors in the PCPA Phase process of preparing CP applications. Since the RF consultants' work will be interactive with that of the structural engineers and transmitter suppliers, there is a cumulative delay built into this part of the project. Because the overall PCPA Phase process is estimated to take between 15 and 21 months, some stations will not make the FCC's planned three-month window for filing, due to the limited number of RF consulting resources available.

Tower Structural Engineers

Tower structural engineering services will be required early in the PCPA Phase of the transmission system planning process, to determine if the existing tower structure will require any modification or fortification. This includes assessing whether the tower is currently in compliance with industry standards, and determining how much additional loading and height is possible to accommodate typically taller and heavier replacement antennas for lower frequencies. This structural analysis is essential to determine if the structure is safe in supporting a temporary antenna and transmission line used during the channel change. This work is performed interactively with the RF engineering consultant, and usually begins after the RF consultant has made some determination as to the proposed antenna requirements.

If it is determined that the tower structure requires modifications to support antenna changes and meet code standards, the consulting firm will take on a substantial amount of additional work in designing and specifying the requirements for the modifications.

In addition, as part of the RC Phase, the structural engineers will develop an engineering rigging plan for the antenna change-out that fulfills the EIA 1019 planning requirements. This includes a complete review of the proposed tower rigging process. It is possible that this portion of the work could be completed after the CP application is submitted, but will need to be completed prior to applying for either zoning or building permits.

Most towers that are owned by third parties have been brought up to the G revision of the TIA-222 Standard. However, the majority of towers are owned by broadcasters, and it is estimated by at least two of the industry experts that 75% of broadcaster-owned towers currently do not meet the TIA-222G structural standards.

This condition, as well as the added height and weight for the typical lower-frequency antenna, will likely result in a large number of stations requiring this additional design work. It must also be pointed out that when new towers were built during the DTV transition, almost all were built to the maximum height allowed by the FAA. Because any antenna will be replaced by one that is taller, stations will not be able to install top-mounted antennas without additional tower modifications. If side mounted, additional weight will be placed on the tower thus also requiring additional tower modifications.

Once designed, this work is contracted to a steel fabrication company that specializes in this type of work. For those tower modifications that specify new guy-wires, structural engineers and equipment installers informed us that it can take from four months to a year from time of order to receive the finished wire that is socketed and ready for installation.

And finally, the tower structural engineers will create the official drawings and calculations necessary to obtain zoning approval and building permits from local authorities.

There are seven identified firms, and perhaps one or two additional, that are capable, experienced and specialize in tall tower analysis, modification design and rigging plans. Some of these have access to the current tower data for their customers, making the process flow more easily.

The time required to conduct a tower structural analysis is dependent on how much information exists and is available to the structural engineer. The process typically consumes between two and four weeks, depending on the size of the tower and the availability of information. When data does not exist, the tower structural consultant will turn to a tower rigging firm to measure and collect the data needed for analysis. This could add up to six additional weeks to the analysis process, depending on the availability of a tower crew to collect the information.

If it is determined that tower modifications are required, the design and specification development for the modifications could also add an additional four weeks of project time for the structural engineer.

Based on input from several consultants, the project capacity of the available tower structural consultants is estimated to be about 40 projects per month. While the number of stations estimated to be repacked ranges from 800 to 1,200, the number of tower structures involved are fewer, because about 35% of the stations share tower structures, and in a few cases even share antennas. Factoring in this sharing, the number of towers to be analyzed will range from about 520 to more than 780. This equates to between 13 and 20 months to complete the tower analysis step.

The cost for a typical tower structural analysis services ranges from $4,500 to $12,000, with an average price of $6,500, assuming that the tower data is available and no tower modifications are required. Projects involving tower modification could add costs of $2,500 to $25,000 per tower project, depending on the type and amount of modification required.

The availability of tower structural engineering resources will likely be the most significant limiting factor in preparing a station’s CP applications and repack cost estimates.

Broadcast Communications Legal Services

Changing television broadcast frequencies, facilities, and equipment amounts to a complex business transaction for each station involved. Broadcast and business attorneys may need to be consulted for basic information about the auction process, strategic opportunities, and legal compliance requirements. Almost always, communications counsel will prepare, file, and shepherd CP applications and related documents through the FCC approval process. Communications attorneys and paralegals will prepare applications for STAs, requests for extensions of time, and other regulatory filings required in specific situations. In addition, FCC counsel is likely to be consulted and engaged to understand and comply with the financial reimbursement program – an entirely new regulatory process.

Some legal fees and time will be spent evaluating options before filing a CP application. For example, flexible use applications will be due at the FCC 30 days after the public channel assignment Public Notice. Channel sharing agreements may be an option for some broadcasters after the repack, but will be subject to detailed new regulation, and will likely require FCC counsel and consulting engineering time and expense.

Estimated time and legal costs associated with a simple, straightforward application for a CP may be in the range of $5,000, with additional time and fees for STAs, or other special client needs. FCC counsel typically works closely with each station's consulting engineers to put together complete, customized applications. Communications lawyers interviewed expect to handle the crunch of applications with current staff, and do not plan to add attorneys or paralegals at this time.

The Commission's announced timeframe is that applications will be filed within three months from the release of the channel reassignment Public Notice. It is not clear how soon the FCC will be able to act on the large number of applications, including some number of waiver requests to be filed 30 days prior to the CP application deadline.

FCC counsel mentions several potential issues complicating the preparation of CP applications. These and other issues may warrant requests for waivers from the application deadline.

- Local zoning issues
- Environmental approvals and restrictions
- FAA approvals
- Backlog of tower structural plans for towers that will need modification
- Tower sites leased from U.S. Government
- U.S.-Canada and U.S.-Mexico coordination

Each of these may add many months and thousands of dollars to the time and cost associated with legal services, some of which will involve local or other specialized legal counsel. While the FCC has been advised of a handful of special site issues, FCC counsel interviewed felt that there may be many more markets and broadcasters affected by special circumstances. Some broadcasters may incur hundreds of thousands of dollars in legal fees over several years to modify their facilities.

Antenna Manufacturers

Antenna systems utilized by U.S. broadcasters for UHF television transmission are primarily of the slot radiator pylon type, designed for either tower top or tower side mounting. Surveys indicate that nearly 97% of the antennas are of this type, with the remaining antennas being primarily broadband panel-type antennas. It should be noted that broadband does not necessarily mean that the antenna covers all UHF channels. Most only cover a segment of the band.

There are primarily two antenna manufacturers that have the product designs, experience and the confidence of U.S. broadcasters that utilize their products. Combined, these two companies, Dielectric and ERI Inc., represent about 95% of the U.S. television broadcast antenna market. In addition to UHF antennas, both companies manufacture VHF antennas, RF combiners, RF mask filters and other essential RF system components. Dielectric is also a major supplier of rigid transmission line and associated components. Both companies also manufacture side-mounted temporary and standby antennas, such as the types that will be required to keep stations “on air” during the channel change process.

There are other antenna manufacturers that primarily supply lower-power antennas and antenna types used for specialized applications such as translators. For the purposes of this study, we assume that most antennas will be supplied by Dielectric and ERI.

PCPA Phase activity involves antenna type selection, preliminary engineering and quoting to support the pre-CP process. During these steps, station personnel work with the antenna manufacturer and the RF consultant to focus in on the precise antenna performance characteristics. At the same time, the tower structural engineer is involved in determining the ability of the tower to support the proposed antenna. It is important that all three of these resources are able to sync up in time to prevent project delays. Proposal and quoting time for both manufacturers is currently about two weeks per project; however, one of the suppliers indicated that it anticipates this will likely lengthen to about six weeks during peak activity periods. It is estimated that this resource group has the capacity to deliver about 100 antenna proposals and quotations per month.

Based on the estimated number of stations that will be required to repack, antenna manufacturers have indicated that the pre-engineering and quoting process will be a limiting factor during the FCC’s proposed three-month CP preparation time window.

In the RC Phase, the next step is for the station to place an order with the selected manufacturer. Once placed, the average manufacturing and test time for most antenna designs ranges between 90 and 180 days.

The current industry capacity for high-power television broadcast antennas is about 104 units per year. The manufacturing rate could be ramped up to about 390 units per year; however, both companies reported that the ramp-up time would take 12 months once started. If the manufacturers start ramping up about six months into the repack order period, second-year production could be 280 units, and then 390 units beginning in the third year. The long ramp-up time, according to both major suppliers, is because of a lack of qualified antenna design engineers. Both companies reported that it can take anywhere from 12-24 months to train new electrical-engineering graduates to work on antenna design. Both companies also reported that they would not be ramping up production until they have sufficient hard orders in hand.

Under normal conditions, a TV station without a backup might be able to rent a temporary antenna that keeps the station on the air while a permanent antenna is being installed. Antenna suppliers informed us that less than 10% of the TV stations have backup antennas. The rest of the stations will most likely require a temporary/auxiliary antenna solution during the channel change. There are currently about 10 “temporary” antennas available for rent. Manufacturers have reported that they do not plan to build more temporary antennas for rental. They do plan to produce standby or temporary antennas for sale to stations. When looking at the antenna requirements for repack, both the main antenna and the temporary or standby antenna requirements must be considered. Between the stations that are already equipped with standby antennas, the availability of a few rental temporary antennas, and some purchased temporary antennas that are likely to be shared within a station group, the planning factor for temporary antennas should be about 80% of the requirements for main antennas. This equates to 1,400 antennas for 800 stations in repack, or 2,160 antennas for 1,200 stations in repack.

Antenna production and delivery will also be a limiting factor in the ability to repack stations. The first antennas will likely be available about three to four months after CPs are issued. This will be a limiting factor for the start timing of the tower and antenna installation teams.

Television transmission antennas have a wide price range based on many factors, including the type of mounting, power handling capability, radiation pattern and polarization configuration. At the very low end, main antennas might cost $75,000, and at the top end over $300,000. The average main antenna costs range from $150,000 to $185,000. An auxiliary or standby antenna used during the tower/antenna reconfiguration is estimated to cost in the range of $45,000 to $75,000.

RF Component Manufacturers

RF system component manufacturers supply combiners, filters, patch panels, RF switching, dummy loads, coaxial fittings and transmission line components. Some of these items are supplied to transmitter manufacturers for integration within the transmitter, while the remaining components are deployed external to the transmitter, connecting it to the antenna system.

Both of the major antenna manufacturers are engaged in all or some of the manufacturing of these types of components. In addition, there are additional specialty companies that manufacture some or all these items.

RF system components, including transmission line, RF mask filters and associated components will cost from $60,000 up to $600,000 for the main antenna installation. More than 80% of the stations in repack will require a temporary or standby RF system to keep the station on air during the transition. These are usually lower-power installations with the costs ranging from $40,000 up to $200,000.

All indications are that there are sufficient industry resources to supply the needed components during the repack time window.

Transmitter Manufacturers

During the transition from analog to digital transmission, U.S. full-power and Class A broadcasters had a choice of at least six different manufacturers. Since the end of the DTV transition, three of the manufacturers, representing less than 12% of the U.S. DTV transmitter market, have exited the business. Two of the three remaining manufacturers have survived primarily on international business, and a third survived due to speculative investment by a foreign company. All three companies have reduced their current production capacity; however, they have indicated that they are prepared to ramp up production when orders are in hand.

Transmission technology for UHF has evolved since the end on the DTV transition. Solid state transmitters have been the norm in VHF at all power levels since the late 1980s. For UHF, solid state was limited to lower power levels by both equipment cost and operational efficiency. These transmitters were also narrow-banded by design limitations of the components that were utilized. More recently, however, newer types of amplification devices and circuit design have led to transmitters that are both efficient and affordable at all power levels typically found in full-power UHF television stations. These transmitters are usually liquid-cooled at power levels above 3 kW and air-cooled at power levels below this level.

IOT transmitters are becoming harder to maintain, due to the lack of skilled transmitter technicians familiar with tube technology and the delays in availability of replacement IOT tube devices. In general, IOT technology for television transmission has run its course, and would not be desirable for replacement installations.

A very large percentage of the transmitters currently in use by UHF stations will be incapable of making major channel changes, and in some cases even minor changes. Many of the components needed to re-channel these transmitters are no longer available; therefore it is expected that most of the stations required to channel change will need replacement transmitters.

The newer transmitter designs and technologies that make replacement transmitters modular and frequency-agile will enable manufacturers to build amplifiers and other sub-assemblies for stock. Upon a station's order, these components can be more easily integrated into a final configuration, thus smoothing out production and helping to maintain delivery schedules. Increased transmitter production anticipated during repack will require additional training and staffing which will take about 6 months.

The typical order cycle for a transmitter varies from 60 to 120 days, depending on power levels, options and the availability of frequency-selective components such as filters and combiners. Several manufacturers indicated that their production times are likely to extend up to 60 days during periods of heavy orders.

PCPA Phase activities for transmitter suppliers will be to provide system configurations, technical proposals and financial quotations. This activity typically takes about five days. A high volume of proposal requests in a short period of time will create a backlog. To solve this issue, transmitter manufacturers have indicated that they will create standard proposals for the various power levels of transmitters and the associated installation costs so that when requests come in, the response time can be maintained. During the PCPA Phase, transmitter suppliers will not be a limiting factor in the process.

RC Phase activities for the transmitter manufacturers will encompass building products to order and delivering to schedule. The typical order cycle for a transmitter varies from 60 to 120 days depending on power levels, options and the availability of frequency-selective components such as filters and combiners. Several manufacturers indicated that their production times could extend up to an additional 60 days during periods of heavy orders.

Based on input from the manufacturers, the combined production capacity of the three primary suppliers could be in excess of 1,000 transmitters over a 12-month period of time, assuming that the transmitters are solid state and not IOT technology. It is not anticipated that transmitter production and delivery will be a time-limiting factor during repack if stations promptly order their equipment after receiving their CP.

The table in The Review of Estimated Costs on page 44 shows the average prices of solid state air and liquid-cooled UHF transmitters for each of the commonly utilized power levels.

RF Transmission System Installers

RF transmission system installation typically includes the transmitter, combiners, RF mask filters, RF patching, switching, reject and dummy loads and transmission line to the tower base. Also included are the liquid cooling systems, AC power, and connection to remote control equipment and input signal connections. Once installed, the project also includes system testing, equipment configuration and commissioning.

While a few stations might attempt their own installation of the transmission system, most will either purchase these services from the transmitter manufacturer or they will hire an independent contractor specializing in these services. Two of the transmitter manufacturers have limited in-house installation resources and about 8-10 certified installer teams that they use as subcontractors.

Typically, transmitter and RF system installation projects are led by one or two engineers and technicians experienced with high-power RF and trained on the particular brand and model of transmitter being installed. Supplemental help will come from local electricians for the power service, local plumbers or HVAC installers for the cooling systems, and perhaps some local labor to help with unpacking, moving and installing heavy equipment.

Many of the engineers and technicians that were available during the analog-to-digital transition have retired or changed their field of employment, so the number of qualified RF installation engineers and technicians is now about 30 in the U.S.

These resources will be initially participating in the PCPA Phase of the repack activity by providing installation quotations. This will create the need to review the proposed system configuration and equipment list as well as the installation facility for space, power, HVAC and other support factors. Most installation proposals will be provided to the transmitter manufacturer and will be standardized based on transmitter type. There may be some variance factor for local labor costs and conditions that can be quickly added to the standard proposals. In a few cases, complex installation situations may require a custom installation proposal. In this case, a proposal might take from one to two weeks to develop.

In the RC Phase, the time to install a transmission system will vary with a number of site factors and the power level of the transmitter system. Typical installations will vary from three days to 14 days. The average is five days; however, there will be some complex sites where installation might take several months to complete. Installation crews will not be able to commence activity until transmitters and RF components are delivered to the job site, and any work assigned to the local trades has been completed. The installation activity is likely to begin about three to four months after the start of the RC Phase activity. Since the completion of tasks in this phase is dependent on the antenna and transmission line installation, multiple site visits might be necessary if the antenna and transmission line installation is delayed. The in-building portion of the installation work, however, may be completed prior to completion of the antenna and transmission line installations.

It is anticipated that this resource group has the capacity to complete about 690 installations per year once they begin. This completion rate assumes that electrical, plumbing, HVAC and building modifications are completed by local resources skilled in those trades.

It is not anticipated that this resource group will be a constraining factor in the repack process, unless transmitter or RF components are delayed in delivery to the project site.

The base costs for installing television RF transmission systems will range from $12,000 up to about $55,000 per station excluding building modifications, AC power service and HVAC systems. Building modifications, power service installation and HVAC systems will have a wide range of costs depending on local labor costs, project scope and complexity, condition of the existing transmitter site and more. Location and labor requirements will also have some impact on these costs.

Tower and Antenna Installers

Extensive research with antenna manufacturers, tower structural engineering firms, tower and installation firms and tower owners has led to the identification of 13 qualified tower and antenna installation firms that have the equipment and experience to work on tall (over 800 feet) broadcast towers supporting large and heavy television transmission antennas. This number is greatly reduced from when tower work was done during the analog-to-digital transition. As a result of the FCC-imposed TV freeze since 2012, many of the skilled workers have either retired or moved on to the cellular/wireless antenna business, where the jobs are easier, more plentiful and have far less risk.

All but a few of the firms interviewed have the equipment and skilled manpower to operate a single crew. For planning purposes, it should be assumed that there will be a total of 16 qualified crews available during the repack transition.

During the PCPA Phase, the tower and antenna installation resources will participate in the process by reviewing each station's installation project requirements and parameters, and providing the cost estimate required for stations to participate in the reimbursement program. Several firms have indicated that they could provide installation proposals and costs at the rate of about 20 per month if no other emergency jobs come along. With 13 qualified firms, the estimated proposal capacity from this resource group is no more than 260 per month. It should also be recognized that this group's quoting activity cannot begin until the RF and tower structural consultants are far enough along in their work to provide data and drawings to the installers. For planning purposes, there will be about a one-month offset in the start of this activity.

The RC Phase is highly dependent on this group's resources. Activity in this phase will consist of several major steps. The first step is to install a temporary side-mounted antenna and transmission line to allow the station to continue operation at reduced power levels during the change-out of the main antenna. The second step is to remove the old main antenna and, in most cases, the associated transmission line. The third step is to install the new antenna and transmission line, and the fourth step is to remove the temporary antenna and transmission line. All of this assumes that no tower modifications are necessary prior to the installation of the new antenna.

The tower and antenna installation firms reported that typical time allocation for the above-described type of project is about four weeks on site, and a week before to move equipment to site. The time assumes only minor weather-related interruptions. Weather, however, is likely to be a significant factor, because wind is the greatest weather obstacle on towers 1,000 feet and higher. With the use of gin poles to hoist antennas at high altitude, work must be suspended if the wind blows more than 20 mph.

There have been suggestions made that crews could use heavy lifting helicopters to lift and replace antennas on tall towers and buildings. While this is possible and even likely in a few cases, the availability of this type of helicopter is often limited during summer fire season. Further, many communities will not allow this type of activity in residential and urban areas. Where the use of helicopters has been done in cities such as in Chicago with antennas on the Willis Tower, the work required shutting down all traffic and access in a large perimeter around the site. This could only be accomplished within a very limited time period, early on a Sunday morning.

This approach to antenna change-out will also be very costly, and can only be used for top-mounted antennas. Rigging and gin pole apparatus will still be necessary for transmission line removal and replacement, as well as for placing side-mounted standby or temporary antennas.

Tower crews usually work long hours when on the job site. Since the personnel involved in these projects are working away from home, they typically take a week between jobs to take care of home issues and to recover from the intense work. The crews also take breaks for major holidays. Thus it is safe to assume for planning purposes that each crew will be able to complete eight to nine antenna change projects per year.

The above time estimates do not include any time allocated to making tower modifications. Several installation firms, structural consulting engineers and tower owners provided estimates of an additional 2-25 weeks to the tower work if modifications are necessary.

The time for modification is dependent on the tasks that must be performed, the types of modification required, the height of the tower and the local environment surrounding the tower site.

In addition to antenna installations and tower modifications, the same crews support emergency service for broadcast stations such as transmission line or antenna RF burnouts, tower lighting issues and ENG/STL antenna repairs. The same crews also support the FM radio industry, which utilizes large antennas on tall towers as well. While some of this might be assigned to personnel who are not qualified for the heavy television antenna projects, we were advised to expect crew interruptions and scheduling delays caused by such events.

Weather will also play a significant role in performing these types of antenna projects. It was indicated that from November through March, sites in the upper half of the U.S. will be unlikely candidates for antenna change-out projects.

With a maximum of 16 qualified crews, the available industry resources will be able to change out up to 130 antenna installations per year.

It should also be noted that the first antenna change-out projects are unlikely to commence until about three to four months into the RC Phase repack timeline, due to all of the prior administrative, engineering, production and delivery activities leading up to delivery of the replacement antennas on the station’s transmission site.

In the remaining 33 months of the repack timeline, the industry can expect that no more than 360 antenna systems will be changed out. This is the most limiting factor in the entire chain of events related to the channel change process.

On the assumption that the repack will affect between 800 and 1,200 stations, the available resources for tower and antenna installations will take between 6.5 and 9.5 years to complete; far outside of the allocated 39-month timeline for repack set by the FCC.

Typical costs for antenna and transmission line change-out projects described above will range from $60,000 up to $300,000, depending on conditions, antenna size, weight, tower height, etc. The average is expected to be about $150,000 per antenna installation. This does not include tower modification cost. There is a wide range of possible modification costs, from $100,000 to $1,000,000 or more, depending on a number of factors including the types of modification required, the height of the tower and the local environment surrounding the tower site.

Third-Party Tower Suppliers

At the time of this report, about 20% of the 1,675 UHF stations that may be impacted by channel change have their transmission sites on leased towers and tall building sites. American Tower represents the largest share of this vertical real estate leasing business currently, with 284 UHF full-power and Class A tenant stations on its sites. An additional 31 UHF stations are tenants on Crown Castle/Pinnacle-owned towers, and 17 UHF stations occupy towers owned by SBAC. The remaining 80% of the stations operate from towers that are wholly owned or owned in part by the stations.

There are approximately 1,421 unique towers or tall building antenna sites utilized by full-power and Class A UHF stations. It is also reported that the number of stations utilizing leased tower sites is likely to increase as station owners divest their vertical real estate holdings. These transactions will add complexity and time to the planning process leading up to antenna change-out.

American Tower indicated that an antenna change-out project on any of its properties would require its participation in the engineering process, to make certain that the activity would be coordinated with tower structural analysis to maintain compliance with current tower loading standards, and to insure that the other tower tenants will not be unduly impacted by the construction activity. Tower leasing companies will require stations to use their approved structural consultants, and run that activity through the tower owner, rather than the station going directly to the consultant. This will likely add additional time to the PCPA Phase planning activity.

American Tower personnel indicated that the antenna change-out activity will also require a complete contractual review between the tenant and its company. This is estimated to be about a 90-day process, running parallel with the engineering activities.

Other Factors Affecting Tower Modifications and/or Antenna Installations

Before any tower or antenna construction can take place, zoning and building permit hurdles must be cleared. Since 2007, tower standards have been upgraded, and these new standards, known as EIA 222G, have been adopted by most local governmental bodies. Any proposed modifications to the tower and antennas will require that the process include either certification or an upgrade to the EIA 222G standard.

The American Tower organization owns thousands of towers, and its personnel have vast experience with local zoning and permitting for tower work. The average station, according to ATC, can expect about three months for obtaining the necessary zoning or building permits for this type of construction.

An estimate provided by a knowledgeable tower engineering professional indicates that about 75% of the station-owned towers currently do not meet the most recent tower standards. This means that these towers will require additional engineering and modifications to bring them up to compliance once the project is completed. None of this work is factored into the resource capacity for tower or antenna installation associated with the repack.

Another factor for time and expense planning for some stations will come into play when towers and antennas are located on land regulated by either the U.S. Forest Service or the Bureau of Land Management. There are a number of such sites around the country, with Mount Wilson in the Los Angeles market and Sandia Crest in Albuquerque, NM being more widely known.

These sites require additional communication plans and authorizations from a review board or forest ranger before any site changes can be made. Delays of many months, and even several years, have been cited by experienced professionals who have worked on projects located on such sites.

Special Challenges

As pointed out in the Executive Summary and throughout the body of this report, antenna and transmission line installation on towers, as well as any modifications required to those towers, will create the biggest logjam for stations to complete their channel changes within the allotted time.

Inclement weather, space-constrained urban tower sites, government-protected lands, residential zoning objections, local bureaucracy related to building permits, and other unforeseen circumstances can result in delays of up to multiple years. While extraordinary delays will not be the norm, they will exist. Many were encountered during the analog-to-digital TV transition, while others have been more recent. We include below brief accounts of a select few situations as examples of potential roadblocks.

- An Iowa station went off the air during the winter of this year. To return it to air, an installation of a temporary antenna, as well as a transmission-line removal were required. Because of weather, the installation crew was limited to working one day a week for several weeks. Several weeks after, the installation crew was still waiting for winds to die down so it could complete the line removal. Once that has been completed the crew must return for two additional weeks of work to reinstall the line.

- A tower job in Florida experienced a major delay when work could not be done while protected Ospreys were nesting.

- The majority of TV stations in Los Angeles have towers on Mount Wilson in the San Gabriel Mountains, which is on U.S. Forest Service land. In order to have a channel change, stations must submit a detailed communications plan to the U.S. Forest Service and get approval from the ranger in charge. In addition, all other tenants on a given tower must be notified of the change, as there is a process for tenants objecting to the change. During the DTV transition, one tower owner reported that the entire process (which included a lawsuit) was resolved after two years of negotiations and waiting.

- Several of the Vermont TV stations operate from Mt. Mansfield. The land is leased from the University of Vermont and is regulated under ACT 250, which is a state land use law. All changes to the structures on the land and the use of the land will require an amendment to the ACT 250 law and approval by the University of Vermont board. The Vermont Agency of Natural Resources must also participate in the planning process. The previous work for the analog-to-digital transition took several years to gain approval.

- The Empire State building is one of the tall-building sites in New York City from which multiple television stations transmit their signals. On UHF, there is a multichannel panel antenna that is optimized from CH 28 to the mid-CH 40's. Under the proposed UHF band plan, this antenna will need to be replaced with one that covers a lower segment of the UHF band. Replacing this antenna will involve major structural modifications to the mast, moving the FM stations to their auxiliary antennas, and limiting all antenna work to a four-hour window from 1 A.M. to 5 A.M. due to RF levels on the upper decks of the building.

The inside work will require extensive relocation of transmission lines and building out a new TV combiner area to accommodate a new channelized combining system. It is estimated that the permitting process and lease re-negotiation will consume 12 to 18 months before any work can be started.

- Mt. Sutro Tower in San Francisco is the home for most of the SF/Oakland TV stations. There are requests for building permits to modify some antennas on this tower that have been in the approval cycle for more than two years.

Timelines

Determining the length of time to move a single television station from one channel to another within a spectrum band, or perhaps moving from a channel in one band to a new channel in another band, is relatively easy to do when the project is contemplated under normal industry circumstances. The process begins by bringing the array of resources together and gathering the projected performance durations of each resource. Since there are often interdependencies between resources, these have to be factored into the project schedule. Often the data from each resource is visually documented and displayed by the use of a Gantt chart. The completed process results in a project timeline and schedule that indicates both when and for how long each resource will be engaged in the project.

Prior industry repack analysis, such as the “Widelity Report,” illustrated several station channel-change examples. These examples identified the resources and the typical time duration for each to perform their services, leading to an overall individual station project timeline. While these timelines are within reasonable completion range under normal industry circumstances, the situation during repack will be anything but normal.

Conducting the same process during an industry event that involves 800 to 1,200 television stations making the same types of conversions all at the same time is an entirely different matter. Imagine a single important resource such as the RF engineering consultants that have, as a group, the capacity to analyze and process about 170 channel change scenarios per month, suddenly being tasked to complete between 800 and 1,200 in something less than 2.5 months in order for stations to make the FCC’s three-month deadline for filing a CP application.

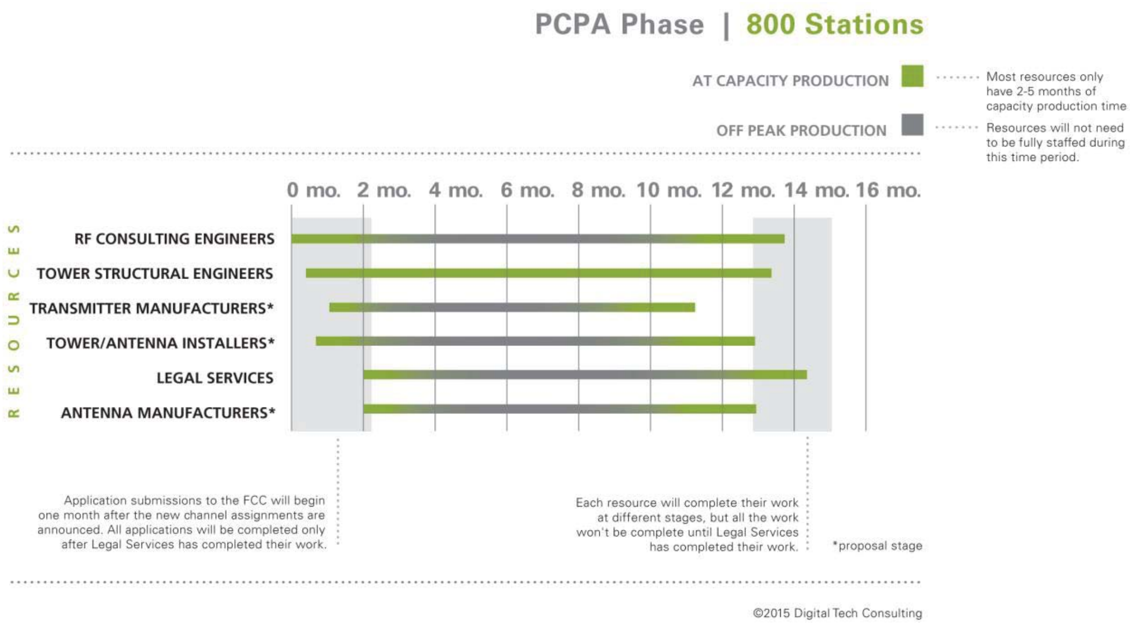
In the repack scenario, all of the same resources will be needed, and each resource segment will have a unique level of capacity to process the workload from the vast number of stations forced to move channels. Further, station owners will likely want to be selective with their choice of suppliers within a resource group. This is often driven by prior experience with the supplier, or situations where information or data is held by a particular resource from a prior engagement with a station or group owner, and any change of resource may add both cost and time to a project.

A logical way to analyze the timeline needed for all stations to complete the channel change is to determine the capacity of each resource group, stated in the number of stations that could be serviced by that resource group during a unit of duration, such as one week or one month.

The following illustrations show the essential resources for each of the two phases of the repack process. The PCPA Phase covers the activity from the FCC’s announcement of which stations will be required to channel change, and to which channel they are being assigned, through the point where all stations have filed CP applications and submitted budgets for repack reimbursement. The RC Phase spans the time from when stations receive their CP through the completion of all channel changes mandated by the repack.

Preparation of Construction Permit Application Phase

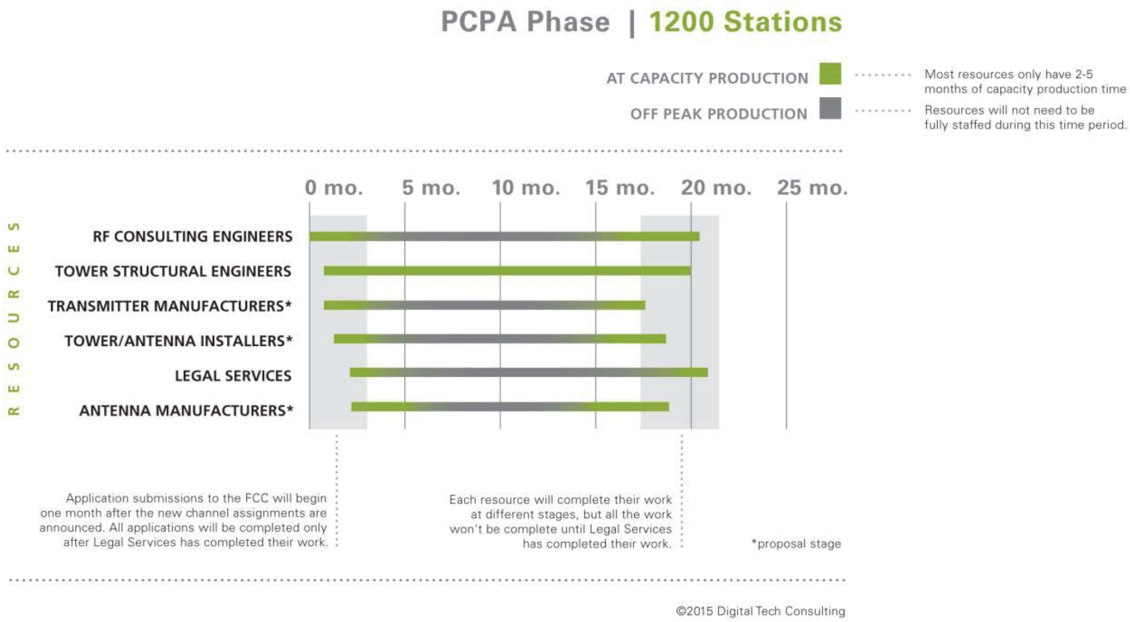
Because this study is designed to analyze the estimated amount of total time required by a range from 800 to 1,200 stations, which was estimated in the Spectrum Reclamation and Stations Affected by Repack section beginning on page 5, DTC presents two estimated timelines for the PCPA Phase of the repack project.



The resources outlined in the table above represent tasks that must be accomplished from the time a station receives its new channel assignment to when it submits its FCC CP application and budget. The engineering tasks occur at the process' beginning, and due to the dearth of tower structural engineers, will delay all other tasks to be accomplished. DTC estimates that it will take the tower structural engineers nearly 14 months to clear the backlog anticipated when all potential repack stations receive notification of channel change. This estimate factors in towers shared by multiple television broadcasters.

We estimate that the entire process will take about 15 months as RF engineering, legal work and equipment quotes must wait on structural engineering reports to finish their tasks. RF consulting engineers cannot complete their reports without knowing what, if any, structural changes will be required for towers, and communications attorneys will be unable to complete their reports and filings until the structural and RF engineers complete their reports.

The equipment manufacturers (bottom portion of graphic) also have long periods of "off-peak production" because they, too, must wait for the engineers to complete their studies before completing the quotes for their customers. Although that work, under normal circumstances, would be completed in a much shorter period of time, we estimate the process will be complete in about 15 months if 800 stations receive new channel assignments.



The graphic above uses the same methodology as in the PCPA Phase: 800 Stations chart, but is calculated for the upper end of estimated stations that will be subject to channel change. The 1,200-station estimate yields an estimate of about 21 months to complete the PCPA Phase tasks.

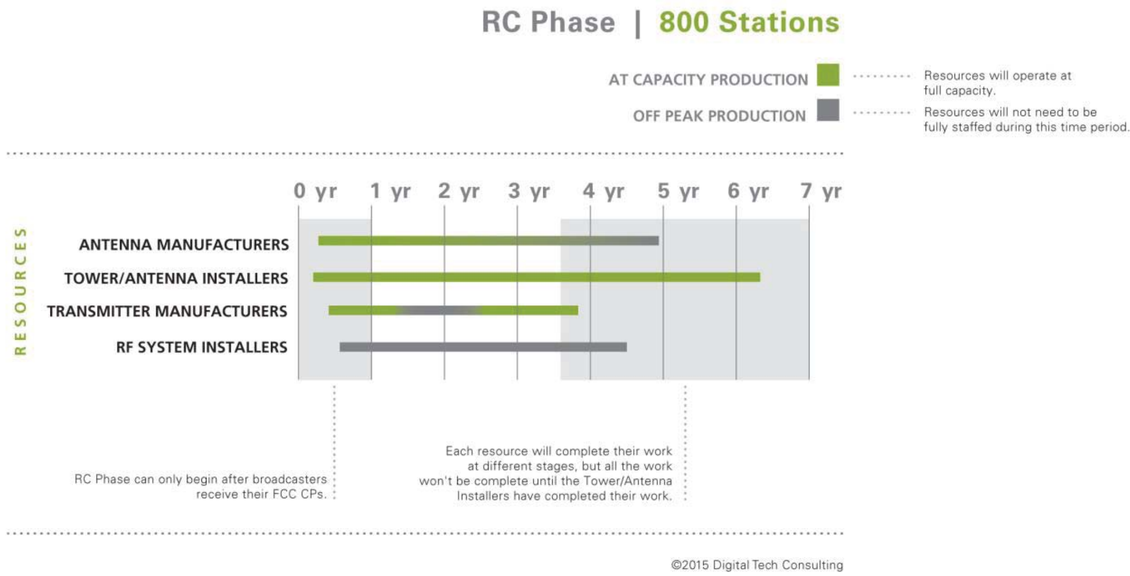
Application and Budget Processing Phase

Between the PCPA Phase and the RC Phase is the FCC CP and Budget Processing Phase. Because there is little available information regarding how the FCC will review and process the large number of CPs and budgets, DTC is unable to estimate the amount of time it will take for a given station to receive a permit, budget approval and an individualized deadline for completing the transition to a new channel. Therefore, please note that there will be an un-estimated period of time between the PCPA and RC Phases added to the overall process.

Repack Construction Phase

Because this study is designed to analyze the estimated amount of total time required by a range from 800 to 1,200 stations, which was calculated in the Spectrum Reclamation and Stations Affected by Repack section beginning on page 5, DTC presents two timelines (below) for the RC Phase. Because this is the most time-intensive phase, DTC represents the time in the charts below in years rather than months (time representation for the PCPA Phase).

It is important to note that DTC is not able to pinpoint how far into the FCC-mandated 39 months the RC Phase process can begin, because of the inability to estimate how much time the FCC CP and budget processing will take. Therefore the starting points on the following timelines cannot begin for individual stations until the PCPA and FCC CP and Budget Processing Phases are complete. Please note that the starting times are not from the beginning of when station reassignments are delivered, but at least some 14-20 months after that point. DTC estimates that the RC Phase process will likely require about 6.5 years to complete for 800 stations.

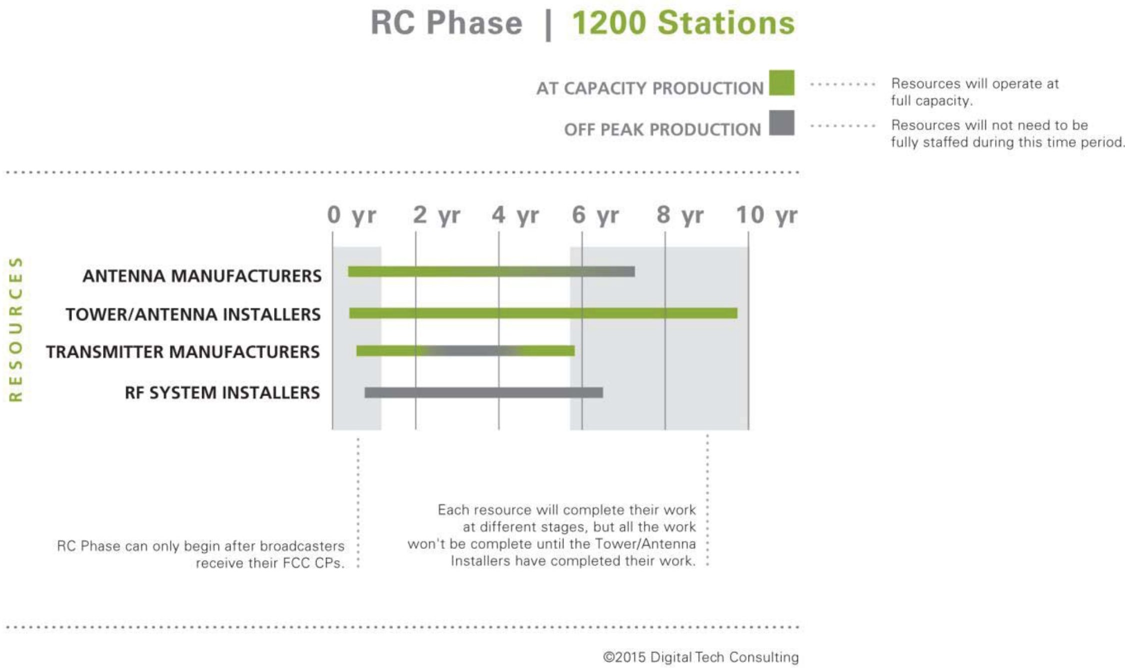


As with the PCPA Phase, tower work (both structural modifications and installation of antennas, transmitters and other RF components) will cause a severe backlog in completing the estimated 800 stations that may require a channel change.

The first element, transmitter and antenna installation, represents such a backlog for three primary reasons: 1) Most high-power stations will require work to be done on towers that are more than 800 feet, which presents a series of challenges including weather conditions such as high wind, ice and snow, 2) the need for specialized rigging and lifting equipment, and 3) the highly specialized requirements of installation crews.

The second element, tower structural modifications, compounds the time challenges for two primary reasons: 1) The anticipated high number of projects estimated to require tower modifications because of increased equipment load on existing towers, many of which have not been brought up to the latest tower structural code, and 2) the insufficient number of tower crews (same crews that install the equipment) to make the tower modifications. There are a myriad of other factors that contribute to these two conditions, and they are outlined in the Broadcaster Resources section which begins on page 15.

Delaying the ability of tower crews to begin installation of equipment at the beginning of this project phase will be the antenna manufacturers. As pointed out in the Broadcaster Resources section, there remain only two primary suppliers of slot antennas, and both are currently operating at minimum capacity. Both report they will delay increasing manufacturing capacity until they receive a sufficient number of initial repack orders.



The table above uses the same methodology as for the RC Phase: 800 Stations chart but is calculated for the upper end of estimated stations that will be subject to channel change. The 1,200-station analysis yields an estimate of about more than nine years to complete the RC Phase tasks.

An Alternate View of Time Analysis

The analysis above illustrates the total amount of time estimated for the assumed number of stations moving to new channel assignments. The analysis below illustrates the number of stations that can likely complete their transitions in the 39-month period specified in the spectrum repack rules.

In summary, whether the number of stations that require repacking is 800 or 1,200, the maximum number of stations that can actually be repacked within a 39 month period will be significantly less due to the limited number of tower crews and personnel qualified to perform tower structural work and antenna and related equipment installation. DTC estimates that no more than 445 stations can be moved to new channel assignments within the 39 month mandatory period under "best case" conditions. "Best case" conditions are outlined in the assumptions below the table. "Best case" assumes that stations are able to complete channel change in about 20% less time than the estimated average completion rate.

The following table represents DTC's estimates on the number of stations that can be repacked based primarily on tower crew capacity:

Time in Years	1	2	3	3.25 (39 mo.)
Est. range of stations that can complete move to new channel	65-97	169-252	273-409	297-445

Source: DTC

This "best case" assumes that a large number of the initial stations moving to a new channel would be those stations where the transitions would not require major tower work or upgrades and therefore the completion rate for these initial stations would be about 20% greater than the average completion rate over the entire period required for completing spectrum repacking. This analysis also assumes:

- The FCC processes initial CP applications and grants CPs to individual stations in two weeks or less.
- The FCC issues new channel assignments about 60 days prior to "officially declaring the auction is completed "and then starts the 39 month construction period.
- Extreme weather conditions are not encountered.
- Early station moves are not impacted by major tower compliance or local permitting issues.

Review of Estimated Costs

DTC gathered cost estimates from the companies and individuals it surveyed, and also reviewed the catalog of costs published in the December 2013, Widelity study commissioned by the FCC. DTC's comparisons of the Widelity estimates with those DTC gathered are largely in agreement with the exception that DTC believes that given technology improvements in UHF transmitters, broadcasters will replace older IOT transmitters with more current solid-state designs. There have been significant improvements recently in solid state transmitters that result in both greater obsolescence of IOT (tube) transmitters and increases in pricing for UHF transmitters. The table below summarizes the more recent transmitter costs, including costs for high-power solid state UHF transmitters which were not practical as few as 12-18 months ago. As pointed out in the Transmitter Supplier section, these high-power UHF solid state transmitters are moving the industry to one in which nearly all new transmitters will be solid state.

Because IOT transmitters are more difficult and expensive to maintain, DTC has concentrated on solid state transmitters in terms of realistic transmitter costs. The table below shows industry average costs for UHF solid state transmitters.

AVERAGE SOLID STATE UHF TRANSMITTER COSTS			
Power Level	**System**	**Installation**	**Total Cost**
10 kW	$347,490	$43,325	$390,815
20 kW	$670,223	$43,325	$713,548
30 kW	$877,467	$53,338	$930,805
40 kW	$1,218,431	$53,338	$1,271,769
50 kW	$1,360,013	$56,338	$1,416,350
60 kW	$1,571,932	$64,418	$1,636,349
70 kW	$1,949,875	$67,918	$2,017,793
80 kW	$2,093,982	$67,918	$2,161,899

Source: Transmitter company list prices and DTC

Total Industry-wide Estimated Costs

There are inherent complexities to account for when estimating costs for the entire 800-1,200 stations anticipated to receive channel changes during the spectrum repack. They include: accounting for the varying levels of infrastructure in place, varying needs of tower modifications, varying needs for replacement antennas and/or transmitters, and estimating the number of stations that will represent each of these conditions (as well as other secondary conditions). DTC's method for doing so accounts for five types of stations that are presented here as examples:

- Full Power UHF (moves from UHF to UHF) stations
  - Represent an estimated 40% of potential repack stations
- Medium Power (moves from UHF to UHF) stations
  - Represent an estimated 50% of potential repack stations
- 50 kW ERP (Typical Class A) (moves from UHF to UHF) stations
  - Represent an estimated 10% of potential repack stations

- Full Power site with three stations operating on a shared tower and broadband antenna system
  - Represent an estimated total of three sites
- Full Power site with five stations operating on a shared tower and broadband antenna systems
  - Represent an estimated total of two sites

Please note that the costs associated with power levels enumerated in the cost-analysis tables below are independent of the complexity levels detailed in the Levels of Complexity section on pages 8-14.

As pointed out above, because DTC's research resulted in a general agreement of the costs (with the exception of transmitters) with those cited in the "Widelity Report," we used the four case studies outlined in the "Widelity Report" on pages 44-50 as a base point (with select modifications) for estimating costs for the individual examples or cases. The primary variances of DTC's estimations from those of the Widelity estimations are as follows:

- Some minor adjustments have been made for administration/permit work. In some cases we have reduced the amount, while in others we have increased the amount.
- All transmitter estimates are for solid state transmitters, which require no retuning. Transmitter costs represent the greatest difference between the Widelity case studies and DTC's examples.
- Some structural analysis and tower work estimated costs have been adjusted to reflect information gathered in interviews with tower-crew companies, installers and tower owners. In some cases we have reduced the amount, while in others, we have increased the amount.

This study calculates these estimated costs by each example station, which yields a per-station estimate. Two additional steps in the analysis derive estimated costs for the entire repack project based on the 800-1,200 stations likely to receive new channel assignments: 1) the estimated percentages of stations that represent each of the station examples are applied to the corresponding station example, and 2) the estimates are further adjusted by the percentage of stations that will require a backup transmitter. These calculations, plus those from the five sites in New York City, Chicago, Los Angeles, and San Francisco, yield the estimated range of costs.

The example stations all assume a UHF to UHF channel change. There is the possibility, however, that some stations may elect to move to a VHF channel from a UHF channel. DTC's research suggests that because most stations will want to have the option of delivering future mobile services, and mobile transmissions will not be optimal on the VHF band, only a small percentage of stations will elect to move to the VHF band.

For those who do elect to move to a VHF channel, there will be some cost savings as lower-power and lower-cost transmitters can be installed over higher-cost high-power transmitters. As an example, a station moving from a 40kW UHF transmitter to a 6.5 kW VHF transmitter will realize about a $700,000 reduction in transmitter price. If we assume 100 stations elect to move to VHF, the industry-wide savings is likely to be about $70 million over an "all UHF to UHF" transition. All savings will be realized in transmitter costs as most other equipment and services activities will be similar. However, the reduction in transmitter costs might be offset by the cost of VHF antennas which can be larger and heavier and more expensive. That increased size and weight will also likely result in the need to modify towers, which represents another added expense that may further offset the savings realized on a less-expensive transmitter.

The final estimated cost for 800 stations to move to new channel assignments is $1.98 billion and for 1,200 stations, $2.94 billion. The details of these cost estimates are shown in the following tables.

REPACK COST ESTIMATES		
Example #1 Full Power UHF (Moves UHF to UHF)	**Costs**	**Comments**
FCC Post Channel Assignment Work	**$17,000**	RF engineering antenna studies and other supporting technical documentation and legal fees for FCC CP, STAs, and licenses (Source: Widelity, case study #1)
Tower		
Structural analysis	$10,000	
Structural modification	$200,000	Structural modification estimate is an average. Some towers will not require modification others will require either moderate or extensive modification
Install temporary or interim antenna and transmission line. Remove old antenna and transmission line and install new antenna and transmission line	$175,000	
SUBTOTAL	**$385,000**	
Antenna System		
Top mounted slot antenna	$225,000	Source: Widelity Report Case Study #1; High power design
Transmission line (1,600 feet of 7-3/16 inch rigid line)	$420,800	Source: Widelity Report Case Study #1
Standby/auxiliary antenna and transmission line	$170,000	During channel change used to keep station on air becomes standby antenna after repack
SUBTOTAL	**$815,800**	
Transmitter System		Transmitter estimates reflect latest transmitter prices and assuming all transmitter sales will be for solid state.
New transmitter 60 kW solid state including installation	$1,640,000	
Optional 20 kW solid state including installation	$713,548	Only required if stations already have a backup transmitter
SUBTOTAL	**$2,353,548**	
Per Station Total (with backup transmitter)	**$3,571,348**	
Per Station Total (without backup transmitter)	**$2,857,800**	

Total Cost for Stations in Full Power Category

Assumptions

- About 40% of all stations are in the Full Power category
- About 36% of these stations currently operate with a main and a backup transmitter
- About 64% of these stations operate with a main transmitter only

Cost Summary For Full Power Stations if Repack is 800 Stations

Total stations in Full Power category	320
Total stations requiring backup transmitter	115
Total stations not requiring backup transmitter	205

115 stations @ $3,571,348 each = $410,705,020
205 stations @ $2,857,800 each = $585,849,000

Total Cost of Full Power Stations = $996,554,020

Cost Summary For Full Power Stations if Repack is 1200 Stations

Total stations in Full Power category	480
Total stations requiring backup transmitter	173
Total stations not requiring backup transmitter	307

173 stations @ $3,571,348 each = $617,843,204
307 stations @ $2,857,800 each = $877,344,600

Total Cost of Full Power Stations = $1,495,187,804

Example #2 Medium Power Level (Moves UHF to UHF)	Costs	Comments
FCC Post Channel Assignment Work	**$17,000**	RF engineering antenna studies and other supporting technical documentation and legal fees for FCC CP, STAs, and licenses (Source: Widelity, case study #2)
Tower		
Structural analysis	$7,000	Source: Widelity Report Case Study #2
Structural modification	$100,000	Structural modification estimate is an average. Some towers will not require modification others will require either moderate or extensive modification
Install temporary or interim antenna and transmission line. Remove old antenna and transmission line, install new antenna and transmission line	$175,000	
SUBTOTAL	**$282,000**	
Antenna System		
New interim/auxiliary side mounted antenna and transmission line	$180,000	Source: Widelity Report Case Study #2
New top mounted slot antenna	$180,000	
Add new transmission line 1200' 6-1/8' line	$160,000	
SUBTOTAL	**$520,000**	
Transmitter System		Transmitter estimates updated to reflect latest transmitter prices and assuming all transmitter sales will be for solid state.
New main 40 kW transmitter and RF system installation	$1,271,769	
Optional standby 10 kW transmitter and RF system installation	$390,815	Only required if stations already has a backup transmitter
SUBTOTAL	**$1,662,584**	
Per Station Total (with backup transmitter)	**$2,481,584**	
Per Station Total (without backup transmitter)	**$2,090,769**	

Total Cost for Stations in Medium Power Category

Assumptions

- About 50% of all stations are in the Medium Power category
- About 36% of these stations currently operate with a main and a backup transmitter
- About 64% of these stations operate with a main transmitter only

Cost Summary For Full Power Stations if Repack is 800 Stations

Total stations in Medium Power category	400
Total stations requiring backup transmitter	144
Total stations not requiring backup transmitter	256

144 Stations @ $2,481,584 each = $357,348,096
256 Stations @ $2,090,769 each = $535,236,864

Total Cost of Medium Power Stations = $892,584,960

Cost Summary For Medium Power Stations if Repack is 1200 Stations

Total stations in Medium Power category	600
Total stations requiring backup transmitter	216
Total stations not requiring backup transmitter	384

216 Stations @ $2,481,584 each = $536,022,144
384 Stations @ $2,090,769 each = $802,855,296

Total Cost of Medium Power Stations = $1,338,877,440

Example #3 50 kW ERP (Typical Class A) Moves UHF to UHF	Costs	Comments
FCC post-channel assignment work	**$12,500**	RF engineering antenna studies and other supporting technical documentation and legal fees for FCC CP, STAs, and licenses (Source: DTC Analysis/Widelity, case study #3)
Tower		
Structural analysis	$7,000	
Structural modification	$50,000	Cost represents estimated amount single station will pay for its share of tower modification on a shared tower.
Install new interim/auxiliary side-mount antenna and transmission line. Remove old main antenna and replace with new antenna	$110,000	
SUBTOTAL	**$167,000**	
Antenna System		
New side mounted slot antenna	$60,000	
500' of 3" transmission line for interim/aux antenna	$26,500	Source: Widelity Report Case Study #3
SUBTOTAL	**$86,500**	
Transmitter System		Transmitter estimates updated to reflect latest transmitter prices and assuming all transmitter sales will be for solid state.
New 5 kW solid state transmitter including installation	$127,500	
SUBTOTAL	**$127,500**	
Per Station Total	**$393,500**	DTC assumes nearly 100% of Class A type stations will require a new transmitter

Total Cost for Stations in Lower Power Category		
Assumptions		
About 10% of remaining stations are in the Lower Power category		
All of these stations operate with a main transmitter only		
Cost Summary For Low Power Stations if Repack is 800 Stations		
Total stations in Lower Power category		80
80 Stations @ $393,500 each =	**$31,480,000**	
Cost Summary For Low Power Stations if Repack is 1200 Stations		
Total stations in Low Power category		120
120 Stations @ $393,500 each =	**$47,220,000**	

Example #4 Full Power with 3 stations with shared tower and broadband antenna	Costs	Comments
Post Channel Assignment Work	**$558,000**	RF engineering, antenna studies, and other supporting technical documentation, project management and legal fees for FCC applications, permits, zoning and other approvals (Source: DTC analysis/Widelity Report)
Tower		
Structural analysis	$50,000	Assuming tower is properly documented
Structural modification	$175,000	
Remove existing 3-station panel antenna and existing transmission line. Install new 3-station panel antenna and new transmission line.	$300,000	
Remove existing 3-station auxiliary antenna and existing transmission line. Install new 3-station auxiliary antenna and new transmission line.	$250,000	
SUBTOTAL	**$775,000**	
Antenna System		
New 3-station panel antenna includes V-Pol, combiner and transmission line	$2,269,000	Source: DTC/Widelity
New auxiliary 3-station panel antenna, new combiner and transmission line	$1,120,000	Source: DTC/Widelity
Replace one main and one auxiliary combiner module	$100,000	Source: DTC/Widelity
SUBTOTAL	**$3,489,000**	
Transmitter System		
Replace 3 main transmitters with 60 kW solid state transmitters (including installation)	$4,909,000	
Replace 3 auxiliary transmitters with 10 kW solid state transmitters (including installation)	$1,172,445	
SUBTOTAL	**$6,081,445**	
Per Station Total	**$10,903,445**	
TOTAL costs assuming 3 sites	**$32,710,335**	

Example #5 Full Power with 5 stations with shared tower and broadband antenna	Costs	Comments
Post Channel Assignment Work	**$798,000**	RF engineering, antenna studies, and other supporting technical documentation, project management and legal fees for FCC applications, permits, zoning and other approvals (Source: DTC/Widelity Report)
Tower		
Structural analysis	$100,000	Assuming tower is properly documented
Structural modification	$200,000	
Remove existing 5-station panel antenna and existing transmission line. Install new 5-station panel antenna and new transmission line.	$375,000	
Remove existing 5-station auxiliary antenna and existing transmission line. Install new 5-station auxiliary antenna and new transmission line.	$375,000	
SUBTOTAL	**$1,050,000**	
Antenna System		
New auxiliary 5-station panel antenna, new combiner and transmission line	$1,220,000	
New 5-station panel antenna includes V-Pol, combiner and transmission line	$2,269,000	
Replace one main and one auxiliary combiner module	$100,000	
SUBTOTAL	**$3,589,000**	
Replace 5 main transmitters with 60 kW solid state transmitters (including installation)	$8,181,745	
Replace 5 auxiliary transmitters with 10 kW solid state transmitters (including installation)	$1,954,075	
SUBTOTAL	**$10,135,820**	
Per Station Total	**$15,572,820**	
TOTAL costs assuming 2 sites	**$31,145,640**	

Total Cost Summary if Repack is 800 Stations	
Cost for Full Power Stations	$996,554,020
Cost for Medium Power Stations	$892,584,960
Cost for Lower Power Stations	$31,480,000
Cost for Special Case Stations*	$63,855,975
Total Cost for Repack of 800 Stations	**$1,984,474,955**

Total Cost Summary if Repack is 1200 Stations	
Cost for Full Power Stations	$1,495,187,804
Cost for Medium Power Stations	$1,338,877,440
Cost for Lower Power Stations	$47,220,000
Cost for Special Case Stations*	$63,855,975
Total Cost for Repack of 1,200 Stations	**$2,945,141,219**

** Represents shared sites with shared antennas such as 4 Times Square and Empire State Building in NYC, Willis and Hancock Towers in Chicago, Mt. Wilson in LA, and Mt. Sutro in San Francisco.*

Appendix

Below is a resources guide of manufacturers and service providers that DTC has identified as necessary for stations to transition to a new channel assignment. This list is not comprehensive, but DTC believes that it includes most suppliers and service providers that can provide relevant equipment and services during the repack process. For the purposes of this study DTC surveyed a significant number of executives who operate these companies.

EQUIPMENT & SERVICE SUPPLIERS	COMMENTS
ANTENNA SUPPLIERS	
Dielectric	Largest US Market share Pylon slot array-type UHF antennas
Electronics Research, Inc.	Second largest share Pylon slot array-type UHF antennas
Jampro Antennas, Inc.	Primarily lower-power antennas as used by Class A stations and LPTV
Radio Frequency Systems	UHF Panel antennas
TRANSMITTER SUPPLIERS	
Comark Communications LLC	Formerly Thomson-owned, now Hitachi Was number 2 for market share
GatesAir, Inc	Largest U.S. market share …about 70%
Rohde & Schwarz	Growing market share German company
Thomson Broadcast	Currently not active in U.S. market
RF SYSTEM SUPPLIERS	Includes transmission line, mask filters, circulators, reject and dummy loads
Commscope	Transmission line only
Dielectric	Transmission line and filters
Electronics Research, Inc.	Transmission line and filters
Jampro Antennas, Inc.	Filters Lower power levels
Myat, Inc.	Transmission line and filters
Micro Communications, Inc.	Spanish company
Radio Frequency Systems	Australian company
Spinner GmbH	German Company Filters
TOWER RIGGING COMPANIES	
Coast to Coast Tower Service, Inc.	
ERI Installation Services	

EQUIPMENT & SERVICE SUPPLIERS	COMMENTS
H.C. Jeffries Tower Company, Inc.	
Northeast Towers, Inc.	
Precision Communications, Inc.	
Seacomm Erectors, Inc.	
Sioux Falls Tower & Communications	
Tower King II, Inc.	
Tower Communications	
Tower Systems, Inc.	
Velocitel, Inc.	Formerly Doty-Moore
Vertical Technology Services, LLC	
Wallen Communications, LLC	
TOWER LEASING SUPPLIERS	
American Tower Corporation	Over 300 TV stations on ATC towers
Crown Castle/Pinnacle	
Durst Organization	New York City only
SBA Communications (SBAC)	
TRANSMISSION SYSTEMS INSTALLERS	
Comark Communications LLC	
DSI RF Systems, Inc.	
Doug Holland Inc.	
GatesAir, Inc.	
J.M. Stitt and Associates, Inc.	
Marsand, Inc.	
RF ENGINEERING CONSULTANTS	
Carl T. Jones Corporation	
Cavell, Mertz & Associates	
Chesapeake RF Consultants, LLP	
Cohen, Dippell & Everist, P.C.	
Communications Technologies Inc.	
duTreil, Lundin & Rackley, Inc.	
Greg Best Consulting, Inc.	
Hammett & Edison, Inc.	
Hatfield & Dawson	
Kessler & Gehman Associates	
Meintel Sgrignoli & Wallace	
Merrill Weiss Group, LLC	
Vir James PC	

EQUIPMENT & SERVICE SUPPLIERS	COMMENTS
STRUCTURAL ENGINEERING CONSULTANTS	
4SE Inc.	
Anderson Foreman	
Consolidated Engineering, Inc.	
Malouf Engineering International, Inc.	
Morrison Hershfield	
Turris Corp.	Located in Canada
Tower Consultants, Inc.	

Principal Team

Below is a list of the principals of DTC's Digital TV Transition Group and a brief description of their credentials. All team members contributed to this study.

Jay Adrick

Jay has been in the broadcast industry for more than 50 years. As the industry has transitioned from analog to digital television, he's been actively involved in designing and building some of the world's leading broadcast facilities. As a former engineer and executive at Harris Broadcast, Jay led technical teams that designed and built encoding, multiplexing, monitoring and control products during the rollout of digital terrestrial TV in the U.S. and globally. In fact, he's worked with broadcasters in more than 30 countries, including Iraq, South Africa, Mexico, Brazil, Korea and Thailand. Today, he develops new television broadcast standards, shapes regulatory/spectrum issues and serves as a technology advisor for GatesAir, Inc. Jay was the 2013 recipient of the National Association of Broadcasters Television Engineering Achievement Award.

Peter Barnett

Peter Barnett specializes in transmission, reception and distribution of digital TV signals. He has executed numerous studies related to digital switchover for the UK Department of Trade and Industry; the Department for Culture, Media and Sports; Digital UK and Ofcom (the UK regulator). For more than 10 years, he has given lectures and taught continuing education courses on both digital and satellite television.

Eric Moerman

Eric has extensive experience working with broadcasters and governments to engineer and implement digital terrestrial TV networks. His experience includes the migration of a nationwide analog media distribution network in the Netherlands, the implementation of a fully digital multiplexed network, and the analog-to-digital switchover and national rollout of the Dutch DVB-T network. Eric's experience extends to the mobile arena. In the Netherlands, he led the implementation of a DVB-H network and a mobile data network upgrade for a large network operator.

Myra Moore

As the president of Digital Tech Consulting, Myra has more than 20 years in the digital TV market. She created and contributed to DTC's Digital-to-Analog Converter Box Quarterly Research Service that provided vital data and analysis for digital-to-analog converter box sales in the U.S. from 2008-2010. Myra has provided DTT transition services to telecommunications and broadcast regulators in countries such as Israel and Curacao. In addition, she has presented DTC's findings on the digital TV market to organizations such as the DVB Forum and the MPEG Industry Forum. Myra is a member of the Academy of Digital Television Pioneers.

Anita Wallgren

Anita has over 25 years of experience as a business executive, government attorney and program director. For four years, she was the Program Director for the U.S. Government's TV Converter Box Coupon Program, a $2 billion subsidy program that assisted almost 35 million households in making the transition from analog to digital broadcast television. Throughout her career, Anita has advised companies and governments on a wide range of regulatory, policy, legislative, strategic and business issues especially related to new media technologies, intellectual property and privacy.