WHITE PAPER

RADIO FREQUENCY SYSTEMS
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Know Your Options: Future-Proof Antennas for the US Repack

Written by Timo Brouwer and Nick Wymant, Broadcast Division

May 2016

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Executive Summary

As the North America broadcast market embarks on the spectrum repack later in 2016 there are many decisions to be made. One of those is antenna technology selection. The US market has traditionally opted for the narrowband antenna known as a slotted pole or pylon. There are many advantages in choosing a pylon antenna, but also several limitations, including lack of flexibility for future channel changes. Broadband antennas provide advantages, especially those using variable polarization technologies. Furthermore, broadband slot antennas, pylon alternative antennas, and master panel antennas can be used by multiple broadcasters to share costly site infrastructure and significantly reduce operating costs, while adding flexibility of site redundancy for very high availability networks.

This white paper explores the pros and cons of these antenna technologies.

March 2016 Pre-installation inspection of PEP-Lite low wind load, broadband pylon alternative antenna on site at Cedar Hill Texas. (Photo courtesy of Jim Stenberg with American Tower)

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US Repack Some of the alternative UHF antenna solutions available from RFS for the US repack program

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Antenna Technologies Compared

I. Narrowband Antennas

Traditionally, the slotted pole or pylon antenna has been used for high power UHF broadcast transmission in North America. Simple construction and low wind load characteristics make this antenna a popular choice. The downside is single channel operation, (noting that in rare cases some may operate across up to three channels). When manufacturing a slotted pole antenna, the slots are "cut" to exact dimensions prescribed by the operating channel. A change of frequency nearly always involves antenna replacement and scrap of the existing antenna.

Every channel and every radiation pattern is a unique manufacturing variant, literally a thousand designs. For many manufacturers, not knowing the channel is the limitation on commencing manufacture ahead of an order. Since the pole sizes are channel dependant, knowing which materials to pre-order is also important information. Given the number of variables involved, building inventory of components for slotted poles ties up capital in stock that may not be required.

Flexibility is another consideration and the slotted pole is not as flexible as other solutions. Why? Once the slots are cut into the pole, the radiation characteristics and operating frequency are locked in. This means that reconfiguration of radiation patterns or polarization ratios in the field is not possible for the slotted pole antenna.

It is estimated that more than 90% of antennas currently installed in the US are narrowband pylons and would need to be replaced where a channel change occurs.

II. Broadband Antennas

In contrast, a broadband antenna system is generally designed to operate on any frequency in a particular broadcast band. Components of the broadband antenna are flexible building blocks that can be configured into antenna systems providing a wide range of azimuth and elevation radiation pattern options. The final radiation patterns are determined by the system configuration. The universal nature and frequency independence of the components allows manufacture in advance and quantities of stock can be held, based on the demand forecast.

For the repack, it is anticipated that replacement antenna radiation patterns will be similar to the existing antenna. So a broadband antenna could be fully manufactured before knowing the final operating channel or channels.

During large digital roll-out programs the scarce resource of experienced installers and uncertainty surrounding the future operating channels is

San Francisco RFS broadband slot antenna on Sutro tower. (Photo courtesy of Merrill Weiss)

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eliminated by early manufacture and installation, sometimes years in advance, of the transition date. This levels the loading in equipment manufacture, installation and field support for towers, antennas combiners and switching. By implementing fully automated test procedures, RFS has instituted antenna factory and field performance testing/recording on every channel in the operating band ensuring that for any channel, the test data is already available for every frequency when the antenna is delivered to site.

The systems approach has other advantages too. Broadband antennas have flexibility built in to allow for changes should they be required. For example, in some transition projects, RFS has designed antenna systems to allow reconfiguration of the radiation characteristics in the field after installation. This is accomplished by replacing some elbow complexes at the base of the antenna system. Broadcasters located in international border regions can use this feature to optimize their coverage and comply with interference protection constraints consequent on transition to the new channels.

The recent FCC decision to refund broadcasters who purchase antennas ahead of the auction opens many opportunities to prepare early. As broadband antennas are frequency agile, implementing the transition to a new channel can be implemented easily, even after the antenna is installed, and even when the antenna has been operating on another frequency for many months. The choice of a broadband antenna enables a smooth transition for suppliers, broadcasters and installers alike.

Broadband antennas incorporate many features and technologies: of these, three main types account for the majority of popular options.

Broadband Antenna Options

The broadband slot antenna (SBB), broadband pylon alternative antenna (PEP Lite) and broadband master panel antenna (PEP) are broadband UHF antennas providing flexibility for the broadcast spectrum repack.

I. Broadband Slot Antenna

Broadband slot antennas share some advantages of the narrowband slotted pole, such as reduced wind load and fewer interconnections inside the antenna. The range includes antennas with wide cardioid, narrow cardioid and skull radiation pattern characteristics.

Because of its wide bandwidth, low wind load, and good null fill performance the broadband slot antenna is ideally suited to high performance, frequency-agile, temporary antenna use. At different times during the repack program, a **broadband slot antenna (SBB)** could operate on the

Outdoor Testing Typical pattern verification and impedance testing of an SBB broadband slot antenna at RFS

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original channel, an interim channel if required, and the final channel providing flexibility in the sequence of events for the facility upgrade.

A broadcaster using a broadband slot as an interim antenna could leave it in place after the repack as a permanent back-up facility with added advantages: eliminating the expense of removing the antenna and associated feed-line, and, freeing scarce tower crew resources for other sites.

II. Broadband Pylon Alternative Antenna

Broadband pylon alternative antennas, like the PEP Lite being deployed by RFS, are a more recent development and provide both better performance when compared to broadband slot antennas and less wind load than a master panel antenna. They also provide flexible polarization configuration options such as circular, elliptical, horizontal and vertical polarization. Upgrade capability for future MIMO or MISO operation can be provided. The broadband pylon alternative antenna is a good solution for a single station seeking the channel independence and flexibility of a broadband solution or the ability to upgrade to EP, CP or MIMO transmission.

The broadband pylon alternative antenna could also be used by two full power stations to reduce costs and tower loading by sharing a common antenna, either during the transition phase or on a more permanent basis. This same array could be configured to allow each station to define its' respective polarization ratios independent of the other.

III. Broadband Master Panel Antenna

The broadband master panel antenna is generally a top mounted or wrap around antenna into which a number of services are combined. These antennas offer increased flexibility in attainable power ratings, radiation pattern configurations, redundancy, polarization options and future upgrade capability for MIMO or MISO. The wind load of a single master PEP antenna is higher than the wind load of a single narrowband slotted cylinder antenna. However, for multiple service operation the master antenna system normally provides reduced tower loading compared to multiple narrowband slotted cylinder antennas and their associated transmission lines.

The use of a master antenna during a frequency transition minimizes the amount of tower work compared to installing many single channel antennas and the associated transmission lines. In repack and digital switch over (DSO) programs where minimizing the install program is a key requirement, the master antenna solution has been favored, particularly in regions where weather can have a major impact on the schedule. In 2016, RFS will install UHF and VHF master antenna systems with Variable Polarization on the spire of the iconic **One World Trade Center** building in Manhattan.

Freedom Tower At One World Trade Center, RFS is installing three antenna arrays with Variable Polarization to support multiple broadcasters' coverage requirements for New York City.

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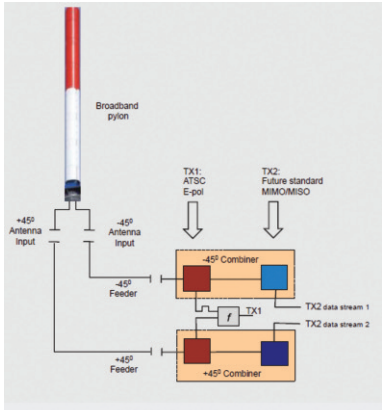
IV. Multiple Shared Sites with Broadband Antennas

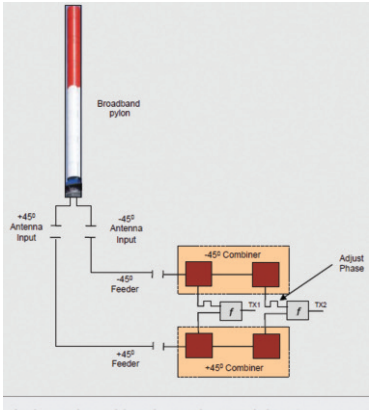
Two separate sites, each having a broadband master antenna and a set of transmitters, offers a very high level of redundancy. Maintenance and transition programs are simplified, as an entire site can be switched off for upgrade or maintenance. The multiple site approach has been adopted in a number of major cities around the world at both UHF and VHF frequencies. This technique has been shown to simplify repack procedures.

The multiple site approach could be used on a smaller scale by two stations sharing at each other's sites. Each station would install a low wind load broadband slot antenna, (for example, an SBB antenna or PEP Lite antenna) and a backup transmitter at the alternate station site.

Should the next generation broadcast standard support it, an additional advantage is that **multi-site multi-polarization MIMO** could be adopted in this scenario.

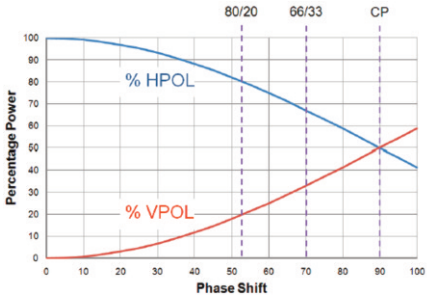


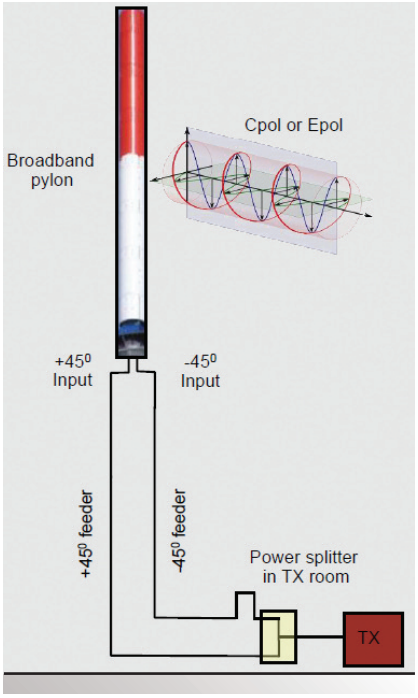
Future configuration: TX2 upgrades to a future transmission standard that incorporates MIMO/MISO. TX1 remains on the current standard.



A channel combiner is used on each input. TX's have independent power splitters with phase control => Independent polarization for each TX.

Above left and center Solutions using multiple sites and broadband antennas with combiners





VPT Technology Variable polarization is critical to increasing the receive probability by a fixed or mobile device. RFS has adopted VPT and builds it into antennas and internal distribution networks to achieve flexible and future-proof systems

Antenna Polarization Options

The adoption of the RFS patented system and method for providing independent polarization control known as variable polarization technology or VPT is critical to any pursuit of the mobile broadcast market and for terrestrial broadcasters to regain the leadership position against other delivery platforms (satellite, cable and cellular networks). Adding a vertical polarization component to existing horizontally polarized transmissions **increases the receive probability by a fixed or mobile receive device** and is increasingly popular. The best way to achieve variable polarization is through the use of elliptical or circular polarization where a single phase

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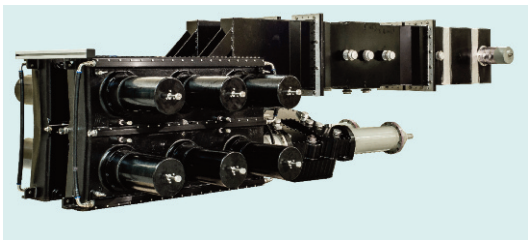
center allows the radiation patterns (both elevation and azimuth) to be nearly identical. Typical polarization ratios in use are 50/50 (C-Pol), 70/30 and 80/20 (elliptical). The FCC rules allow an increase in total ERP for antennas broadcasting circular or elliptical polarization.

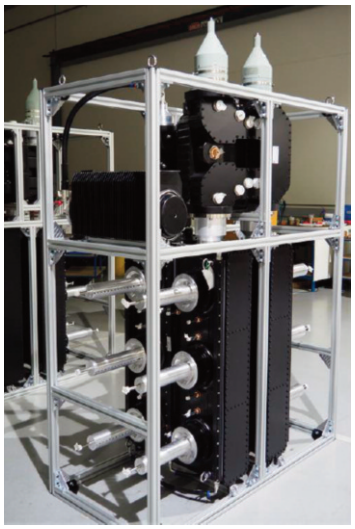
A feature of the broadband pylon alternative antennas and broadband master antennas already discussed is that they can be configured to allow a future change to the polarization ratio by a simple modification at the elbow complex. When many broadcasters share the antenna, the system can be configured to provide each channel an independent polarization ratio selection [1]. The same system can allow independent MIMO/MISO transmission. For example, one broadcaster could transmit horizontal polarization; another could transmit circular polarization, another elliptical polarization and another MIMO. This flexibility allows broadcasters at a shared site independent polarization control and the ability to independently upgrade to MIMO as future requirements dictate.

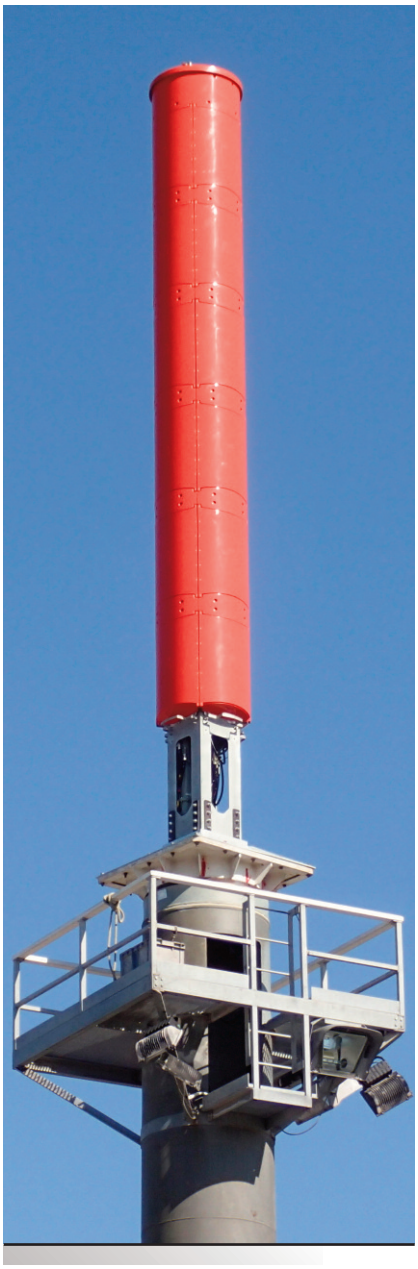
Towers and Antenna Wind Loads

Broadband antennas are often regarded as having a much higher wind load compared to a slotted pole antenna of the same gain. However, when comparing wind loads, it is important to ensure that the same calculation method and criteria are applied, and all factors are considered. As a general guide, an RFS side mounted broadband slot antenna (SBB) has the same or lower wind load than side-mounted single channel slotted antennas manufactured by others. The RFS pylon alternative (PEP Lite) can have between 1.1 and 1.4 times the effective wind area of a side-mounted single channel slotted antenna. However, if the associated transmission line is included in the calculations, the total loads of the two antenna systems are generally within a few percent of each other.

The current version of the TIA-222 Standard, Rev G – "Structural Standards for Antenna Supporting Structures and Antennas" requires that existing structures







Flexible System Design An antenna system solution incorporating RFS VPT components includes a broadband antenna such as the low wind load pylon alternative antenna (above) and RF system with retuneable filters and high power couplers (similar to those shown at immediate left).

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be analyzed in accordance with the code if a change in type, size or number of antennas or appurtenances occurs. Given that a large number of the installed antennas are single channel devices, most of them will require replacement. Therefore it is likely that the structure will need to be analyzed to the latest revision of the standard. Adding a side mounted interim antenna and its associated transmission line will most likely invoke an analysis to the latest revision of the code. Unfortunately, revision G of the standard presents additional factors to be considered in the calculation, and it often happens that even with no increase in loading, some form of strengthening may be required to existing towers that are analyzed to revision G.

Given the inherent advantages that broadband antennas offer for a flexible transition plan, and the possibility of obtaining and installing broadband hardware early in the program, it would be prudent when analyzing the tower to include an analysis based on the broadband antenna scenario. The fixed dimensions of a broadband antenna allow this analysis to be performed early in the project.

Conclusion

The spectrum (reverse) auction and consequent repack of frequencies offers an unparalleled opportunity to take advantage of the new technologies, to compete but also co-operate with more recent arrivals in the broadcast market (cable, satellite, cellular/ mobile). By adopting variable polarization options, broadcasters have the key to secure service to both fixed and mobile audiences. In choosing the most flexible antenna type, broadcasters can order an antenna ahead of the frequency allocation, install early to minimize reliance on scarce installation resources when the repack program gathers momentum, and maximize the opportunity to satisfy loyal viewers with continued transmissions of favored programs regardless of how long the repack project takes to complete. This paper has contrasted the features of old, recent and emerging antenna technologies and presented the value in choosing to install a broadband antenna.

RFS VPT antenna arrays are designed for maximum versatility, flexibility and functionality. They are the trusted solution sought by market leaders to keep them ahead of the game.

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1. RFS White Paper, December 2010: “Polarization Diversity – Variable Polarization Technology and the Mobile Broadcasting Environment”
2. NAB Presentation, April 2014: “Future Proofing your DTV Transmission Facility”, Nicholas Wymant
3. RFS White Paper, April 2016: “RFS Prepares for US Repack – Are You Ready?” Timo Brouwer

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RFS is a global broadcast, telecommunications and defense manufacturer, a systems solutions provider with follow-the-sun service

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