Transmission System Design Considerations For Analog FM Facilities With 400 kHz Spaced Allocations

Nicholas A. Paulin
Electronics Research, Inc.

***Abstract*—FM Broadcast facilities with reduced guard bands require special consideration to prevent interference.**

***Index Terms*—Antenna Arrays, Antenna Polarization, Band Pass Filtering, Intermodulation products**

I. Introduction

When building a facility that is allocated 400 kHz from another high power facility, protection has to be at the forefront of the system design process. Antenna design, filter design, and transmitter design will also play critical roles in the reduction of potential interference to other broadcasters. One goal will be of high importance, and that is to isolate the two RF systems as much as possible to prevent any intermodulation mixes from being possible.

II. Antenna design considerations

The two main antenna design considerations that need to be addressed are **array design factor** and **propagation polarization**. These considerations alone, will not be enough to eliminate possible interference and should be used with one of the filtering solutions discussed later. The design goal is to achieve high isolation between the antenna arrays. 40 dB or greater isolation is typically sufficient.

A. Propagation Polarization

It's convenient to think about each antenna as both a transmit antenna and a receive antenna. Each antenna at each facility has the capability of both transmit and receive, so designing the propagation between the two to isolate, or prevent reception from the other, is desirable.

Circularly polarized antennas are very popular for FM broadcast. This allows the transmission signal to be broadcast in both the vertical and horizontal planes. This achieves the result of better reception at the intended receivers, which are usually linearly polarized as horizontal or vertical antennas. To minimize the two broadcasting antennas from coupling to one another, one of the two antennas should be Right Hand Circular Polarized and the other should be Left Hand Circular Polarized. Because the polarization has a phase component to the transmission, by reversing the angle of rotation of the phase the signal will be less likely to be received by the antenna of the opposite polarity.

B. Array Factor Design

If the individual broadcast antennas are on the same tower, it is unlikely they are at the same center of radiation (COR). By controlling the array factor of the antenna, energy directed straight up to the sky, or straight down to the base of the tower can be reduced significantly. This means there is less energy directed towards each of the antennas as well. All 3 plots in *Figure 1* show an 8 Bay Array with varying element spacing.

The full wave spaced array and shows significant upward and downward radiation between 75 and 90 degrees. This is not an ideal design.

The ½ wave spaced array and shows no upward or downward radiation at 90 degrees. Because the array is ½ wave, the gain is decreased from the full wave array

The $\frac{N-1}{N}$ spaced array has the same decreased radiation as the ½ wave array at 90 degrees while maintaining most of the gain of the full wave array.

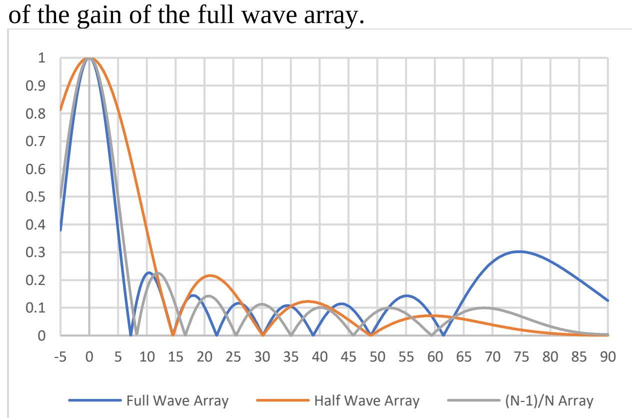

Figure 1: Array Factor Comparison

C. Interleaved Antenna Design

One antenna design exists that uses two Full Wave Spaced antenna arrays that share the same COR. These are antennas that are not individually multiplexed. The two antennas are interleaved within one another. The resulting antenna can appear to be a half wave spaced antenna from afar, but are actually two independent antenna arrays. By using the propagation polarization diversity discussed earlier, when one is right hand circular polarized and one is left hand circular polarized, isolation between the two arrays is greater than 40 dB after a factory tune.

III. Filtering Design Considerations

Adding filtering to the output of a transmitter can reduce any emissions that are being generated. There are two types of commonly used filters for closely spaced frequencies, Band Pass filters and Band Stop filters (Notch Filters).

A. Band Pass Filters

The response, *Figure 2*, is a modified FM 4 Pole Cross coupled filter. These filters are typically tuned to 400 kHz bandwidth to keep insertion losses and Group Delay variation low. The response shown is designed for 300 kHz bandwidth and is only suitable for Analog FM service. A cross coupling is added between the 1st and 4th Resonant cavities to achieve additional rejection close to the pass band. As shown, the closest frequencies of an adjacent channel would be attenuated by 18 dB while the center frequency of the neighboring channel would be attenuated 35 dB. Any intermodulation (IM) products generated would appear on the opposite side of the pass band and be attenuated a second time before escaping to be rebroadcast. This solution alone, may not be enough to eliminate interference and should be used with an antenna configuration discussed previously. A constant impedance arrangement, Figure 4, should be used for this application. The absorptive resistive loads connected to the combiner's ports will dissipate the rejected energy from filters and prevent any additional mixing within the transmitter. Band Pass filtering will provide better interference performance than the notch filtering solution discussed next. Group Delay variation, Figure 3, will be higher with more tightly tuned filtering and compensation may be required to preserve audio quality at the receivers. This can be done in either the transmitter, by using a passive group delay compensation module, or both.

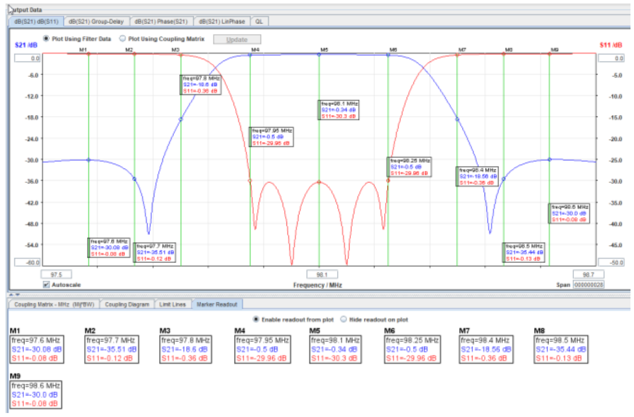

Figure 2: Band Pass Filter Mask Response

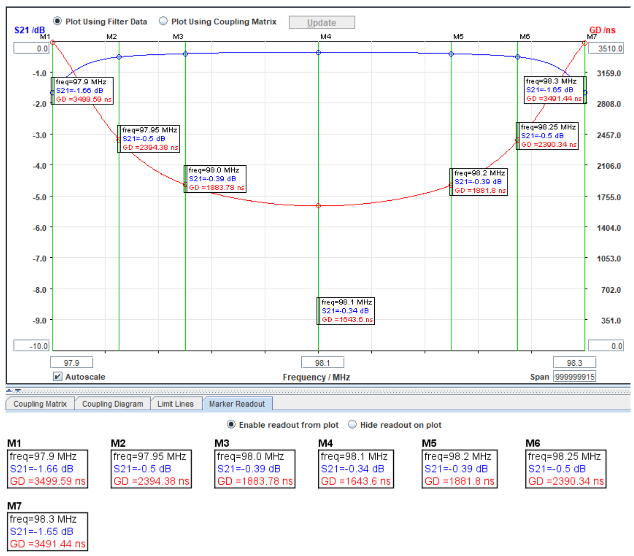

Figure 3: Group Delay Variation Response

<u>Summary of Group Delay Variation</u>

+/- 100 kHz 238 ns
+/- 150 kHz 747 ns
+/- 200 kHz 1848 ns
*Actual measured values will vary

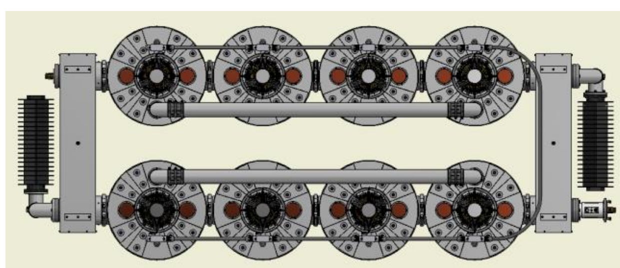

Figure 4: Constant Impedance, 4 Pole Cross Coupled FM Filter

B. Band Stop Filters

A Band Stop Filter is tuned to provide additional isolation to another broadcaster and thus prevent the received signal from mixing in the transmitter. To achieve a notch only 400 kHz from the passband, multiple cavities are required. This approach only rejects the interfering frequency. If enough energy passes the notch filtering and mixes in the transmitter, no additional attenuation well be achieved, unlike the bandpass filter solution previously discussed, and the IM product will be broadcast.

IV. Transmitter consideration

Turn Around Loss is the value of attenuation the transmitter achieves when creating spurs. Tube type transmitters typically achieve 6-13 dB while solid state transmitters achieve 15-25 dB. Solid state transmitters would be preferrable to minimize any emissions in a 400 kHz allocation plan.

Most state-of-the-art transmitters now have the capability of precorrecting group delay variations in the transmission chain. The method of correction may vary between manufacturers. Some methods rely on taking real time measurements of the system to account for any changes over time. Other methods involve using a data measurement from a network analyzer.

V. Conclusions

The items discussed should not be seen as “à la carte” menu items, but rather as a complete package where all items should be implemented.

- Opposite polarities for closely spaced allocations.
- Optimize antenna array factor to eliminate any radiation towards the closely spaced antenna.
- Use constant impedance band pass filtering and group delay compensation to preserve audio quality.
- Use solid state transmitters with the ability to adjust for group delay variation

Doing everything on this list gives the highest probability of an interference free broadcast.

For More Information Contact:

Sales@eriinc.com
CustomerSuport@eriinc.com
www.eriinc.com

Electronics Research, Inc.
7777 Gardner Road
Chandler, IN 47610-9219
USA

+1 812 925-6000 (tel)
+1 812 925-4030 (fax)
877 ERI-LINE (toll-free)