Antenna Pattern and Coverage Optimization

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***Abstract*—Antenna patterns of end-fed and center-fed antenna arrays are compared. Coverage improvements are produced by end-fed array elevation patterns.**

***Index Terms*—Antenna Arrays, Coverage Optimization, Elevation Pattern, Azimuth Pattern, Propagation**

I. Introduction

Coverage may be optimized by careful design of the patterns of a broadcast antenna array. Elevation and azimuth patterns are generally independent of each other, and may be altered to create improvements in coverage. End-fed antenna arrays provide superior beam-tilt, side-lobe, and null-fill characteristics when typical elevation patterns are compared.

II. Elevation Pattern Considerations

2.1 Beam-tilt Improvements

Often overlooked as a source of coverage improvement, beam-tilt optimization can yield 10dB signal strength increases over large areas [1]. Beam-tilt may be optimized in end-fed arrays with virtually no trade-off costs. The antenna will not be more expensive to produce, nor will the array increase in size. Center-fed arrays will be longer to overcome gain degradations associated with increased beam-tilt.

Primarily the antenna beam is positioned to the radio horizon to overcome the loss of free-space propagation. As simple as this principal seems, the majority of center-fed and many corporate-fed antennas in service have positioned the antenna beam above the radio horizon. End-fed antenna arrays have beam-tilts that prevent this condition naturally.

Even positioning the peak of the antenna main beam on the radio horizon places nearly half of the energy in the sky. With this in view, the first steps to selecting beam-tilt include placing the upper 1dB point of the antenna pattern on the radio horizon. End-fed and center-fed antenna patterns and the resulting signal on the earth are compared in Figures 1 and 2 respectively. Note the 1dB difference at the radio horizon and the 10dB and greater differences under 10mi.

There are improvements possible by tilting the beam beyond this point. Depending on the shape of the antenna beam, side-lobes and nulls can create signal increases on the order of 5-10dB with degradations at the horizon on the order of 1dB. This may be desirable in municipal environments where 10dB increased signal in major population areas improves signal-to-noise parameters and overcomes the multi-path degradations in urban canyons [2]. Also, tilting the beam further below the radio horizon can be used as a tool to improve low-power station coverage of near-in areas and to reduce interference with other services.

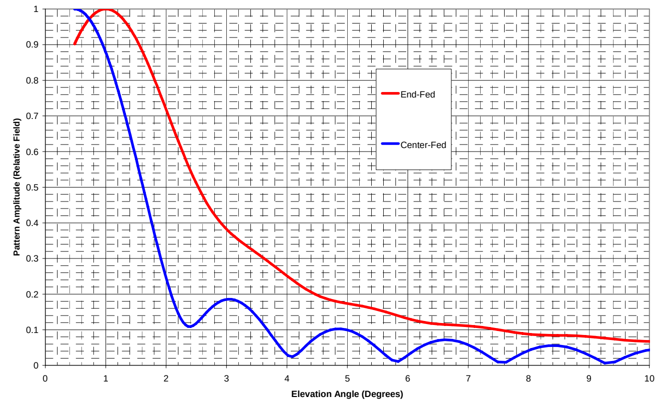

Figure 1: End-Fed and Center-Fed Array Patterns

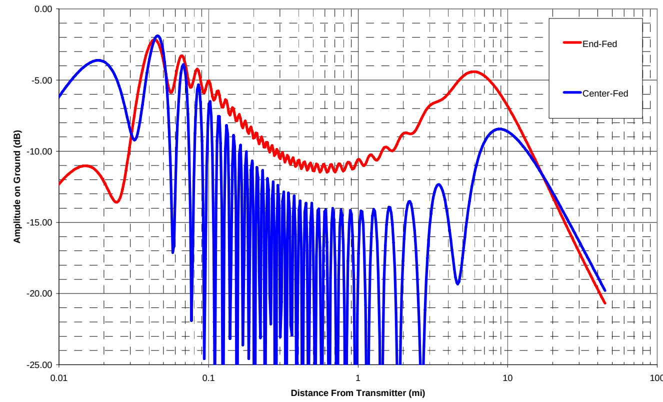

Figure 2: Relative Signal Strength on Smooth Earth

2.2 Null-fill and Side-lobe Improvements

Like beam-tilt improvements, increasing side-lobe and null-fill levels may be accomplished at no cost in end-fed arrays because the patterns naturally possess these characteristics; see Figure 1. Most center-fed arrays must increase in length to overcome the gain lost in improving their naturally low side-lobes and deep nulls, also shown in Figure 1. Increasing the null-fill and side-lobe levels improves the coverage in areas under 10mi from the transmitter on the order of 5dB. The high null-fill in end-fed arrays has the additional benefit of reducing the variation of received signal amplitude and phase with frequency, its frequency response and group delay.

III. Azimuth Pattern Considerations

Coverage improvements may be realized with an azimuth pattern that optimizes the antenna transmission with the local environment.

3.1 Geography Factors

Features of terrain and local geography determine the major portion of azimuth pattern shape. As obvious as it may seem, many on-air stations are wasting much of their transmitted power over bodies of water. This may be due to the selection of a standard model omni-directional antenna and not knowing the tools available to increase station efficiency.

Population centers are inevitably near bodies of water. Shaping the antenna beam to fit the coast-line, transmitter location, and population areas is very straight forward. Plotting the desired signal areas on a map will closely resemble a plot of the antenna pattern with a log scale. Most applications begin with a “wide-cardioid” or “peanut” shaped pattern.

The location of mountain ranges, valleys, and dense vegetation also rank highly among factors affecting propagation. With digital modulation, the multi-path interference created by mountains and large buildings is easily eliminated by the receiver with little reduction in signal-to-noise ratio. Aside from the population changes in these areas, the propagation of energy to and along these features varies, and the azimuth pattern may be optimized to account for it. For example, increasing energy may be in order to overcome the loss of vegetation or the shadowing effect of a mountain ridge.

3.2 Population Factors

The distribution of population is included in many models of propagation. Some populations are required to receive coverage of certain minimum signal strengths. Others need to be reached for commercial and demographic reasons. To optimize coverage areas of dense population, the azimuth pattern may be shaped to increase signals in those areas. Pattern nulls may be placed in areas of little population of interest, perhaps along a highway or over a large forest preserve.

3.3 Interference Factors

The azimuth pattern may also be shaped to eliminate interference issues. Nulls in the pattern may be positioned in the direction of protected areas. Azimuth patterns may have areas of large signal strength change, called high roll-off areas, which accommodate the rapid transition from protected areas to covered areas. Coverage in urban environments packed with transmitters may be optimized with interference canceling nulls.

3.4 Mounting Factors

Positioning the antenna near conductors significantly alters the azimuth pattern. Mounting an omni-directional antenna 24in from a pole 8in in diameter introduces about six 5dB nulls into a UHF pattern. As the mounting distance increases, the magnitude of the null decreases and the number of nulls increases. With conductive masts 12ft in diameter atop urban broadcast facilities, improper antenna position could destroy coverage over large areas.

The fundamental principal of reducing the pattern changes due to scattering is: avoid illumination of the source of the scattering. Position the antenna so that nulls are oriented toward the nearest tower legs. The mounting distance and orientation may be optimized with a full electromagnetic analysis of the geometry, pattern, and coverage goals.

IV. Design of Azimuth Patterns

The physical limitations on possible azimuth patterns arise from the mechanical configuration of the antenna. High roll-off regions and high gain patterns require larger areas. This in turn increases the loading on the mounts and tower support structure. With these limits in mind, the azimuth pattern of a broadcast antenna may be designed using computational tools and empirical methods.

4.1 Computational Methods

The basic shape of a slot antenna may be computed using an analytical solution of the radiation from slots in a conductive cylinder [3]. This accurately predicts the fundamental patterns of a number of slots in a pipe of a given diameter. Full 3D simulation of the antenna configuration, including slots, radomes, and conductive cylinder may be accomplished with the Finite Element Method (FEM) or other methods.

4.2 Empirical Design and Validation

The design of azimuth patterns may be validated with the use of an anechoic chamber. The nature of antenna arrays equates the final azimuth pattern of a single bay and the entire array. This is known as the factorization of the element pattern and the array patterns.

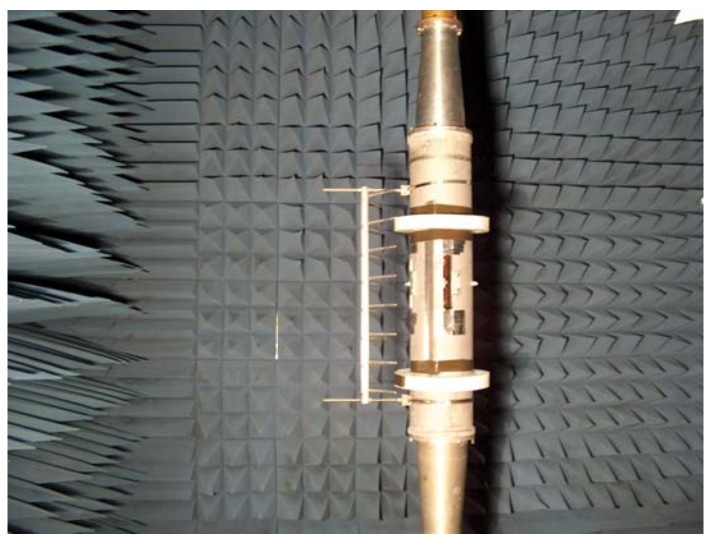

Figure 3: Anechoic Chamber (Courtesy ERI)

A one-bay model may be created of the antenna and measured in an anechoic chamber. These measurements validate the radiation of the configuration of slots on the conductive pipe, and they allow for the adjustment of the pattern using parasitic elements. Rapid modeling of the scattering and propagation effects allow for empirical optimization of the pattern.

REFERENCES

[1] Smith, S.A., *System and Method for Determining Optimal Broadcast Area of an Antenna,* US Patent No. 7006038, 28 Feb 2006.

[2] G.W. Collins, *Fundamentals of Digital Television Transmission,* John Wiley & Sons, Inc., New York, 2001.

[3] Wittaker, Jerry, ed., *NAB Engineering Handbook, 9th Edition*, Washingtion, DC, 1999

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