Analysis of Antenna Beam-tilt and Broadcast Coverage

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Abstract—**Antenna beam tilt affects areas covered by strong signals. Improvements greater than 10dB are realized using greater beam-tilts offered in end-fed arrays.**

Index Terms—**Antenna Arrays, Antenna Beam Tilt, Coverage, Propagation**

I. INTRODUCTION

Coverage is the key parameter in broadcast system engineering. A great deal of effort is exerted to position the antenna and select antenna patterns to enhance the signal at the receiver. Many analyses of propagation to date have not accounted for antenna beam-tilt, though now technology, products, and analytical techniques [1] can optimize the coverage with increased beam-tilt.

II. SMOOTH EARTH PROPAGATION

Associating the elevation pattern of an antenna with the distance from the transmitter site provides an understanding of the key areas of the pattern. A mapping of elevation angle and distance from the transmitter is shown in Figure 1. The Standard (4/3) Radio Horizon is also noted on the plot.

For typical tower heights, the radio horizon occurs at elevation angles between 0.1 and 1 degrees and distances of 10 to 100 miles. The distance from 1 to 10 miles from the transmitter site corresponds to elevation angle between 1 and 10 degrees, and the region less than one mile from the tower is greater than 10 degrees in elevation angle.

Placing the antenna peak of beam on the radio horizon does not ensure optimum coverage on the surface of the earth. The energy transmitted from an antenna propagates as a spherical wave away from the phase center.
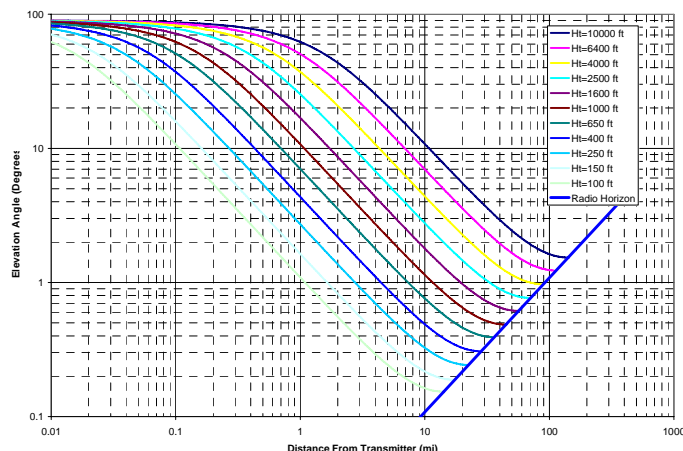

Figure 1: Elevation Angle and Distance From Transmitter

The energy density, *S*, at a distance, *R*, from the antenna is given by the following equation [2],

$$S = \frac{P}{4\pi R^2} \quad (1),$$

where *P* is the ERP of the antenna at the elevation angle of interest.
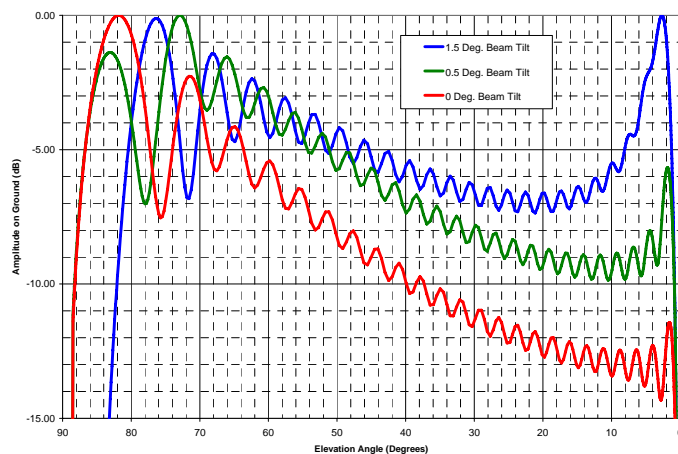

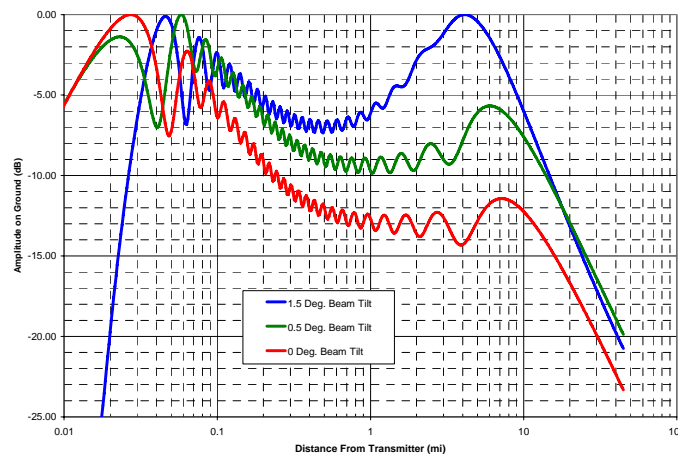Figure 2a: Energy Density Elevation Angle Scale

Figure 2b: Energy Density Log Distance Scale

The antenna pattern must overcome the inverse-square nature of path loss. Tilting the beam below the radio horizon is an effective method of improving coverage [3]. Figure 2 shows the normalized energy density at the surface of the earth for an antenna 1000ft above the surface. The radio horizon for this case is 44mi or 0.5 deg. elevation angle. With no tilting of the antenna beam, the signal energy density at the 10mi radius is

more than 10dB below the energy near the transmitter.   By tilting the beam 1.5 degrees, the energy is balanced between this 10mi region and the tower site, an improvement of 10dB.
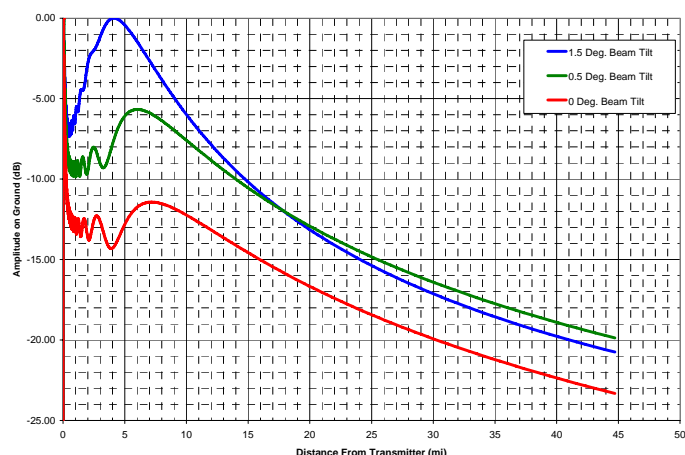

Figure 2c: Energy Density Linear Distance Scale

Note that from Figure 2b this coverage improvement includes the entire area. Figure 2c gives an indication that areas significant signal change occur at about 10% of the distance from the transmitter to the radio horizon, while looking on a linear-scale map.

III. SPECIFIC PROPAGATION STUDIES

Numerical models of propagation with greater sophistication exist, accounting for terrain and population. Figure 3 shows graphic results using the Longley-Rice propagation model to predict signal strength from a 1000ft tower surrounding Chandler, Indiana.

Increasing the beam tilt from 0 to 0.5 degrees significantly increases the area of signal strength from 5 to 10 mi from the transmitter site. Note the increase in diameter of the central, yellow graduation.
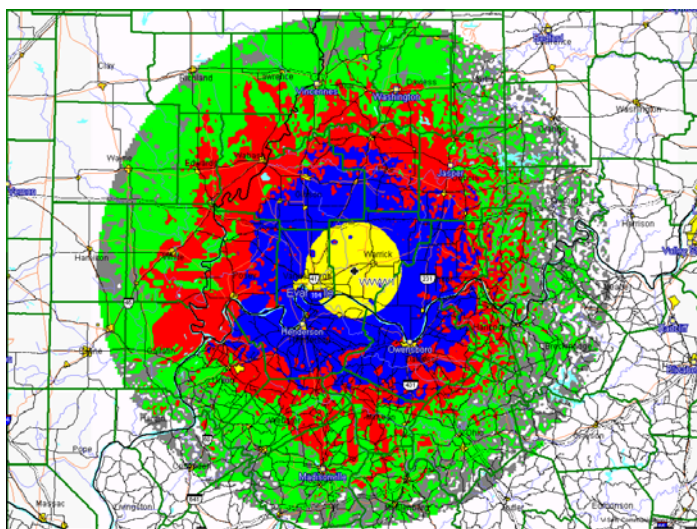

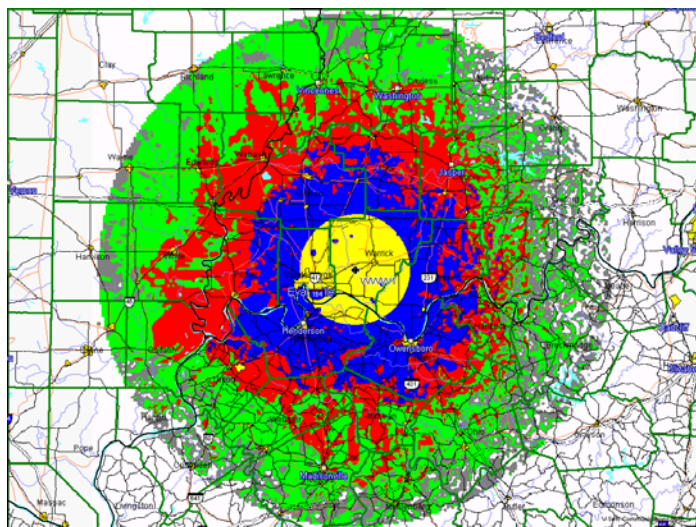Figure 3a: Energy Density Map: 0.0 Deg. Beam Tilt

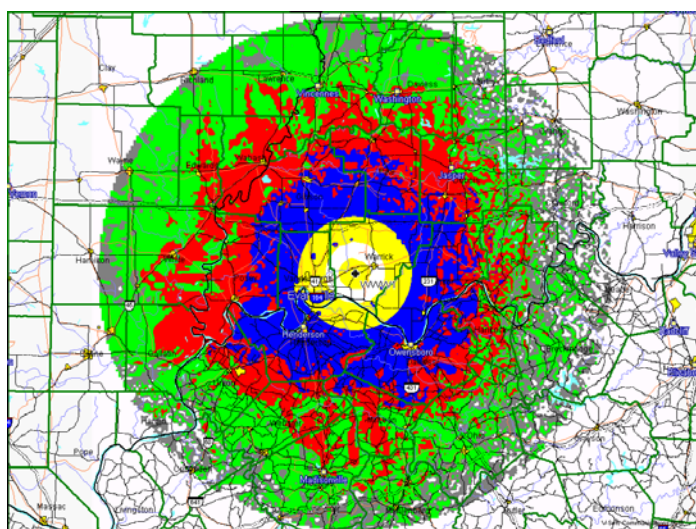Figure 3b: Energy Density Map: 0.5 Deg. Beam Tilt

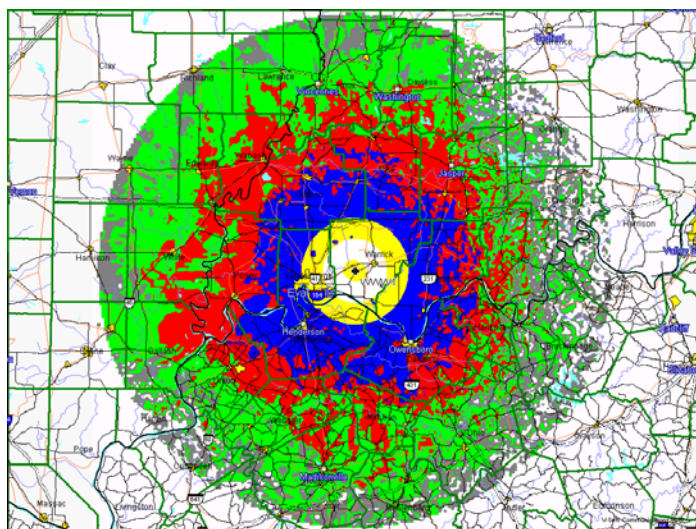Figure 3c: Energy Density Map: 1.0 Deg. Beam Tilt

Figure 3d: Energy Density Map: 1.5 Deg. Beam Tilt

With additional increase in beam tilt, an area of increased signal is introduced within the 10mi area. Note the white ring within

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the yellow graduation in Figures 3c and 3d. With no degradation of signal to the outer limits of the coverage area, a large area of viewers is delivered 10dB greater signal strength. Note that the coverage maps of Figure 3 have an outer radius of 60mi and the color graduations are 10dB.

IV. ANTENNA LIMITATIONS

End-fed broadcast antennas have no practical limitation on the beam tilt. The slot radiators may be freely positioned in the array to form a pattern that has optimal beam-tilts, high side-lobes and high null-fill. The patterns generated by end-fed arrays have low differential amplitude and phase characteristics, important for digital modulation [4]. Center-fed arrays have patterns will low side-lobes and low null fill, and they have a troublesome limitation on beam-tilt. The amplitude and phase patterns of the two antennas are shown in Figure 4.
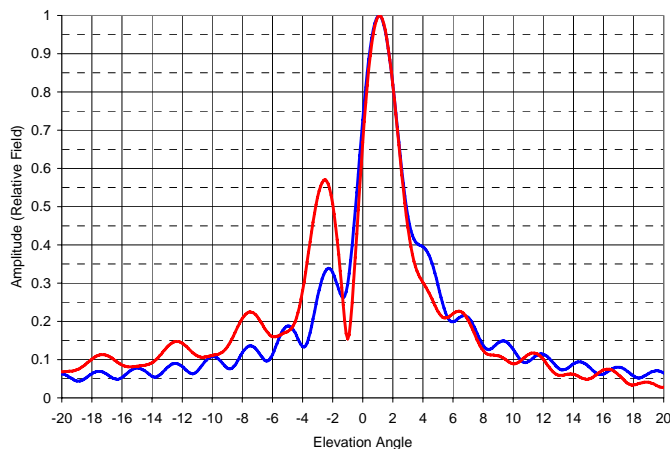

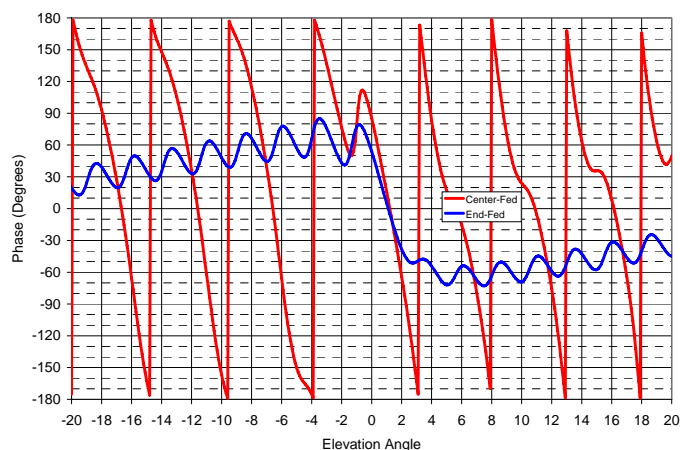Figure 4a: End and Center-Fed Amplitude Patterns

Figure 4b: End and Center-Fed Phase Patterns

The beam-tilt in a center-fed antenna arises chiefly from an offset in the feed-point. This causes a step function in phase as well as an increase in the spacing between the center-most bays. The center-fed array behaves like two small arrays with distinct phase-centers, separated by a large distance and interfering with each other. When the phase shift is increased to generate beam-tilts greater than 0.5 degrees, a large upper side-lobe is generated, and the gain of the array is degraded. Figure 5

shows the patterns of a center-fed array with the array pattern of the two sub-arrays and explains the existence of the large upper side-lobes.
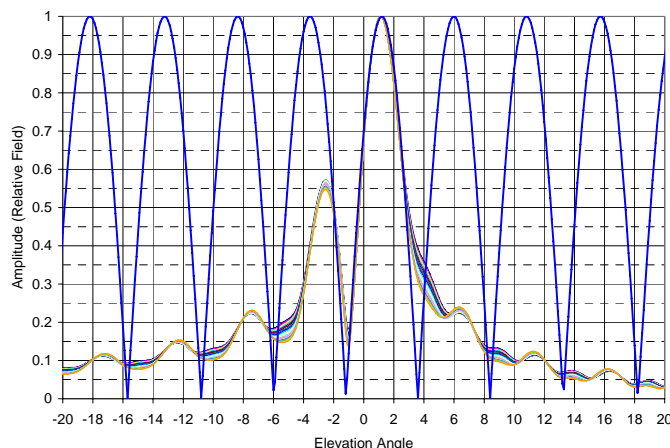

Figure 5: Center-Fed Patterns with Interference Pattern

V. CONCLUSIONS

Propagation analysis using smooth-earth and Longley-Rice models has shown that significant improvements in coverage may be obtained by simply increasing the antenna beam tilt. Gains greater than 10dB are realized when the beam is tilted below the radio horizon. The greatest gains occur in the region between 1 and 10 miles, a key area in metropolitan areas where interference and low-gain receive antennas abound. The beam-tilt constraints on center-fed antennas make end-fed arrays more attractive for realizing the coverage benefits of increased beam tilt.

REFERENCES

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