Analysis of Dual-Channel Broadcast Antennas

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***Abstract*—The design concept is discussed for slotted UHF antennas that allows the combining of a high power NTSC channel with an adjacent DTV channel assignment using a single transmission line and antenna.**

***Index Terms*—Antenna Array, Slot Antennas, Antenna Bandwidth.**

I. INTRODUCTION

For UHF channels in the United States, slotted antenna designs are typically used [1]. A primary factor in their use has been the ability to make the support structure of the antenna an integral part of the transmitting components. Because the frequencies assigned to UHF allow the use of relatively small antenna elements, the removal of part of the pipe wall to create slots was possible with only a minimal impact an its structural integrity. This resulted in an antenna with low wind-load characteristics and was relatively economical to fabricate.

As television markets expanded, demographics changed and competitive pressures fostered the need for UHF stations to increase their coverage. This required higher effective radiated powers (ERP). And as higher power transmitters came to market, other benefits unique to the slotted antenna design became evident: exceptional reliability even at extremely high input power levels and more precise control over the shaping of the elevation pattern. This performance was not present in other antenna designs and by 1985 the slotted array was the antenna of choice for UHF broadcasters in America.

Most full service UHF broadcasters operate at power levels typical1y considered to be “high power.” These stations have antenna input power levels of 80 kW (NTSC) or more and use rigid coaxial transmission lines or waveguide as the main feeder between the transmitter and antenna. For simulcast operation, UHF broadcasters are assigned another UHF channel for HDTV transmission that will require typical antenna input powers of approximately 20 kW (DTV average). Of tremendous benefit to the broadcaster, nearly the exact configuration presently in use for the NTSC channel is also used for both the NTSC and HDTV transmission. This results in minimal changes to the tower loading by the new transmission system and minimizes any changes to the present NTSC coverage due to compromises that may be required when changing antenna types.

II. SLOT ARRAY APPLICATIONS

First, if it has been determined that the tower can (or could) support another transmission line and antenna for the HDTV channel, then the same criteria used for NTSC choices can be used. If the available location for the antenna is at the top of the tower, then a slotted antenna design will probably provide superior electrical and structural performance. If the antenna is to be located on the side of the tower, then the coverage needs of the station must be reviewed prior to making a decision on the antenna type. Slotted antenna designs have been used extensively for directional side mounted antennas and for extremely high power (200 kW NTSC) side mounted omni-directional antennas.

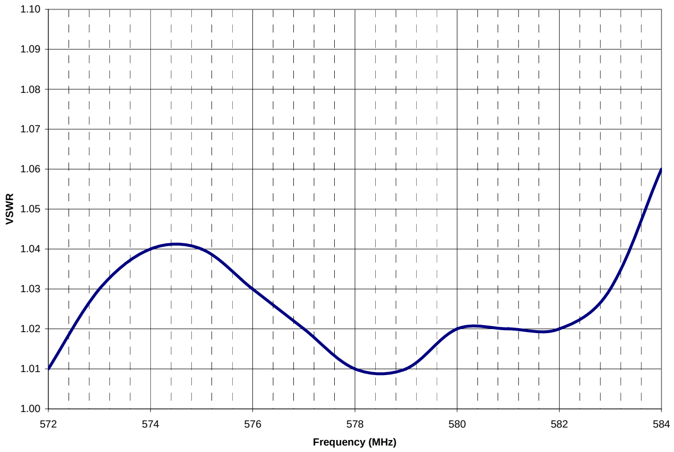

Figure 1: Dual Channel Antenna VSWR

Slotted antennas have not been used for multi-channel applications primarily because of their narrow bandwidth characteristics, particularly for low VSWR applications. For NTSC, the minimum bandwidth that would typically be required is 42 MHz (30 MHz between two channels). With adjacent channel assignments, the situation is created where the slotted antenna design can be used for the simulcast period and the transition to digital television.

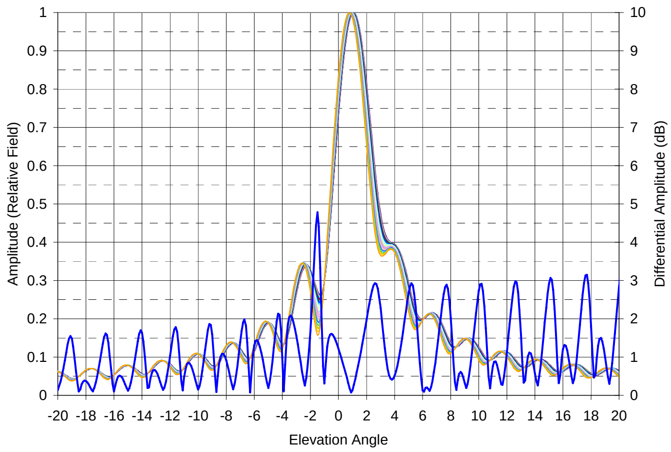

Figure 2a: DTV Channel Antenna Amplitude Pattern

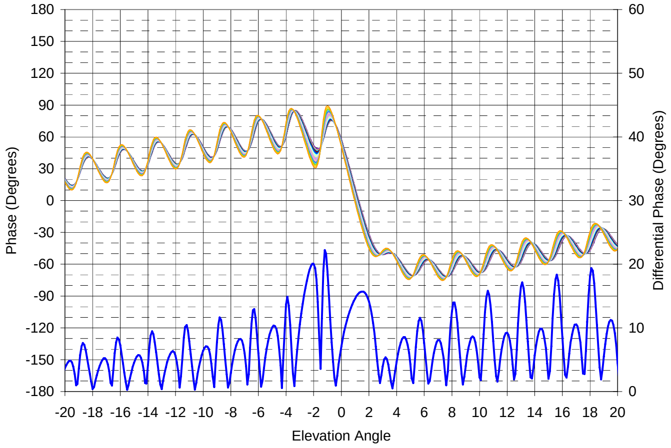

Figure 2b: DTV Channel Antenna Phase Pattern

For UHF broadcasters, the allocation table has nearly 400 adjacent channel assignments. This is over 1/3 of the total UHF licenses. With the constraints on tower loading and industry resources for building and installing the new equipment, it is essential to review the slotted antenna design for these applications. An advantage that this condition provides is that the bandwidth required for operation now limited to 12 MHz. There is little doubt that a slotted antenna design will be the preferred component for these stations. Assuming no change in transmission line size, there can be a net zero change in tower loading and the elimination of costs associated with upgrading a tower for additional loading that would be required for other options. It may also eliminate the need for negotiating new space on the tower or sharing transmission components with a competitive station

III. PERFORMANCE ISSUES

Typically, there are four principal antenna characteristics that are reviewed when choosing a broadcast transmitting antenna: azimuth pattern, power handling, VSWR and elevation pattern. For a 12 MHz bandwidth, the azimuth pattern will remain essentially constant across the band. This is due primarily to the small diameter of the antenna and the small percentage change in frequency across the band (a maximum of 2.6% across channels 14 and 15). This is in contrast to the bandwidth of a single VHF station on Channel 12 which is 2.9%.

The power handling of the slotted antenna design meets the adjacent channel requirements. Depending on the margins used in the NTSC system design, the transmission line size presently used may need to be reviewed. Also, since the digital channel is adjacent to the NTSC, the effect of flange reflections may not be a significant factor in rigid line lengths. This would allow use of the existing transmission line.

The VSWR across the two channels will have two different requirements. Ideally, the digital channel VSWR response should be flat across the band with a maximum of approximately 1.10. The NTSC VSWR requirement has typically been 1.05 at the visual carrier with a worse case of 1.10 at other frequencies in the channel. The design criteria for an adjacent channel combined antenna are typically stated as a worse case VSWR of 1.10 with optimization of 1.05 at the visual carrier of the NTSC channel. Figure 1 shows the VSWR of the dual-channel design.

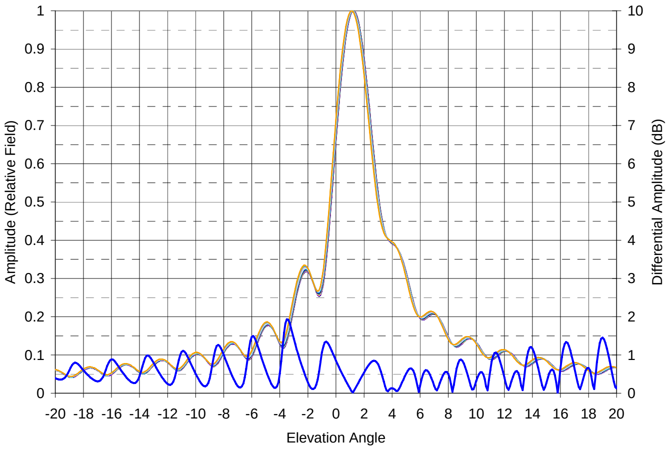

Figure 3a: NTSC Channel Antenna Amplitude Pattern

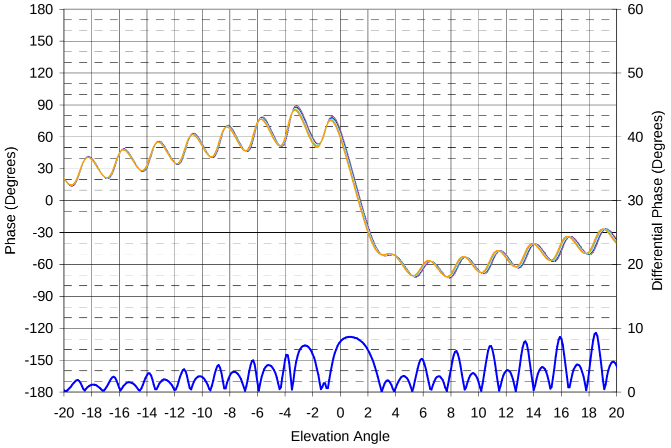

Figure 3b: NTSC Channel Antenna Phase Pattern

The change of elevation pattern characteristics as a function of frequency is well known [2]. It depends on how the input signal is distributed to the radiating elements. The types of distribution systems are typically called “end-fed” or “center-fed.” The performance differences between the two types include changes in the electrical beam tilt as a function of frequency. This effect is not sufficient to determine the quality of performance of the antenna. In fact, a measure of merit called antenna “differential gain” or “frequency response” presents a better understanding of the amplitude variation of the pattern as a function of frequency.

By analyzing the change of gain as functions of frequency and elevation angle, the response flatness can be determined. The criteria presently being used for NTSC transmission is that the gain flatness should be better than 3 db from visual carrier through the color sub-carrier, or over about 4 MHz. While it has been suggested that this gain flatness should be better than 0.5dB over 6 MHz for a digital channel, the results of numerous field tests indicate that a gain flatness of 3 to 4dB is not unreasonable as a specification. The phase variation with frequency is also important as it is directly related to group-delay [3]. The elevation patterns, differential amplitude, and differential phase are plotted in Figures 2 and 3.

Finally, it is desirable to have the transmission of adjacent channels to occur from the same physical location to minimize interference compensation issues. Obviously, the use of a single antenna will accomplish this. The next step is to analyze a slotted antenna array and meet these specification goals.

IV. MULTI-CHANNEL SLOT ANTENNA DESIGN

The above design parameters can be realized in a production antenna. A design based on a full scale model was first investigated. Data taken on a single bay antenna was collected and then used in antenna array design software to produce calculated responses. A directional antenna with an RMS gain of 25 (14 dBd) operating on channels 31 and 32 was used as the model. Also, a standard {versus a "smooth") elevation pattern was chosen to determine a worst-case condition for the differential gain. The results of the design are shown in Figures 1 through 3.

The design parameters show an excellent slotted antenna design for adjacent channel combining of NTSC and digital television signals. Final testing on the full production antenna was completed and verified that variations to the design due to manufacturing and testing tolerances were insignificant. Close agreement was observed between the software and design process and the measured results.

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