UHF Flared Notch Antenna Design for Linear Arrays

Lance Bradstreet, Harvey K. Schuman, Ken Hinman, Don McPherson

Syracuse Research Corporation
6225 Running Ridge Rd., North Syracuse, NY 13212, USA
lbradstreet@syrres.com, schuman@syrres.com, hinman@syrres.com, mcpher@syrres.com

Abstract: A wideband UHF antenna was designed for use in a linear array. The array was to be scanned in the H-Plane. The principal design constraints were wide bandwidth, broad array plane pattern (for scanning), light weight, and small overall size. The Balanced Antipodal Vivaldi antenna [1] was employed as a starting design because it met several of these criteria, because its unbalanced construction facilitated feeding via a coaxial line, and because of its low cross polarization. The resulting antenna was shortened considerably and the high dielectric substrate replaced with foam. The resulting antenna was further reshaped to meet impedance and pattern constraints, and suppress mutual coupling effects. WIPL-D [2] was used extensively in the design process. Three prototypes were built. Measurements agreed well with analysis, but small shape adjustments were required to optimize performance.

Keywords: UHF Antenna, Flared Notch, Vivaldi, Array, Wideband Antenna, WIPL-D

1. Introduction

As part of a system development program, The U.S Army, via the Intelligence and Information Warfare Directorate (I2WD) of the Communications Electronics Research Development & Engineering Center (CERDEC), funded the design and test of an antenna that could be placed in an H-Plane-scanned linear array. The array beam was to be steered over +/- 30 degrees with at least a 36 percent bandwidth in the UHF band. The Balanced Antipodal Vivaldi antenna [1] was a good candidate for initiating the design, although the operating band of that design was too high for our applications. Simple scaling and replacing the high dielectric substrate with low dielectric, low weight foam resulted in too large an antenna. In particular, a stripline-like feed section added substantially to the size. Consequently the antenna was redesigned with the computational EM code WIPL-D [2] and fine tuned with measurement. Effects of a finite conducting back plane, mutual coupling, and radome were considered in the design with the assistance of detailed WIPL-D modeling. Section 2 contains key points in the WIPL-D design process and Section 3 contains key modifications identified via measurement.

2. Design

A. Balanced Antipodal Vivaldi

The Balanced Antipodal Vivaldi flared notch antenna is composed of flared planar conductors in three parallel planes (Figure 1). The center conductor flares in one direction and the outer conductors flare in the opposite direction. The spacing of the elements shown below is expanded for viewing purposes. This antenna is naturally fed with stripline or coax or other unbalanced line without need of a balun. The stripline (or coax) center conductor connects to the center flare and the stripline outer conductors (or coax outer conductor) connect to the lower and upper flares.

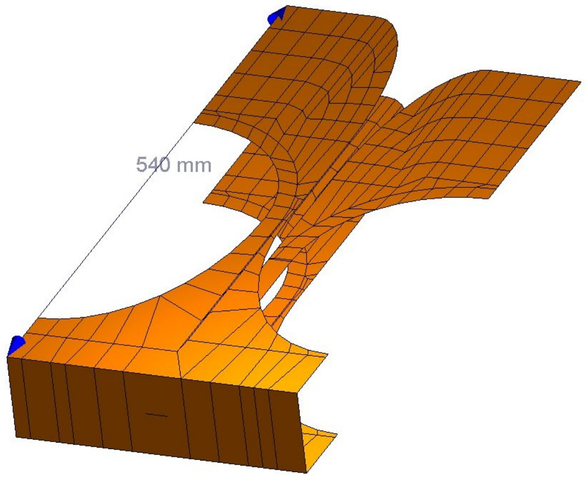

Fig. 1. Original Design of Balanced Antipodal Vivaldi

B. Isolated Element Design

The original Balanced Antipodal Vivaldi antenna was redesigned to operate between 512 and 740 MHz, employ foam dielectric spacing between conductor layers, and eliminate the large matching section. The taper of the slot was elliptic. The antenna was designed first in isolation. The final design resulted in a ~.7 m square, ~15 mm thick element. Initial modifications of the original design, such as replacing the high dielectric substrate with low dielectric foam, resulted in an antenna of good impedance match from 3-4 GHz. Simple scaling to move this region to the band of interest would have increased the length to an unacceptable 1.8 m. Alternatively, the scaling was limited to 2:1. This modest scaling moved a relatively small band, where performance was more band limited but reasonable, into the band of interest. Scaling and further reshaping resulted in the design of Figure 2. The impedance and radiation pattern are shown in Figures 3 and 4.

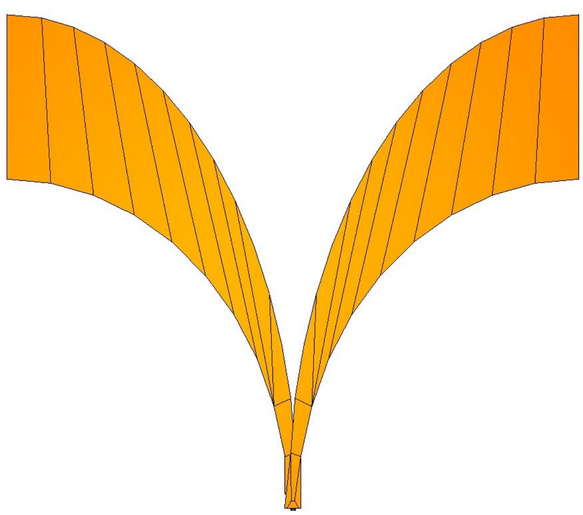

Fig. 2. Modified Design

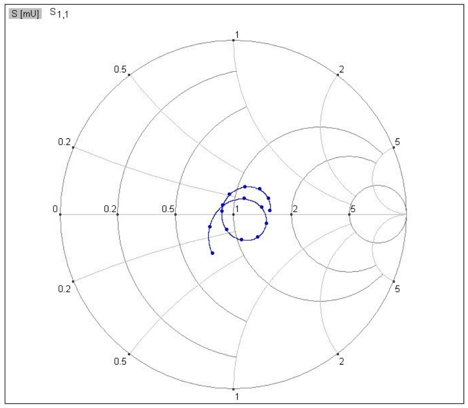

Fig. 3. Redesigned Isolated Element Impedance

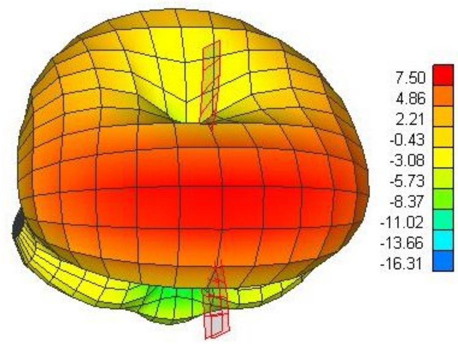

Fig. 4. Redesigned Isolated Element H-Plane Gain Pattern (dBi)

C. Conducting Back Plane and Array Environment

A conducting back plane was added to reduce the back lobe, and the antenna was situated in an H-Plane linear array to assess mutual coupling effects. The array spacing was commensurate with the exclusion of grating lobes for scanning +/-30 degrees. A 1 m wide conducting back plane was required to realize ~30 dB back lobe throughout most of band. The antenna was redesigned further to suppress a resonance appearing at about 535 MHz that was thought to be associated with mutual coupling. Figure 5 below shows the result with only a slight resonance effect still evident. Figure 6 shows the backlobe levels in the elevation pattern.

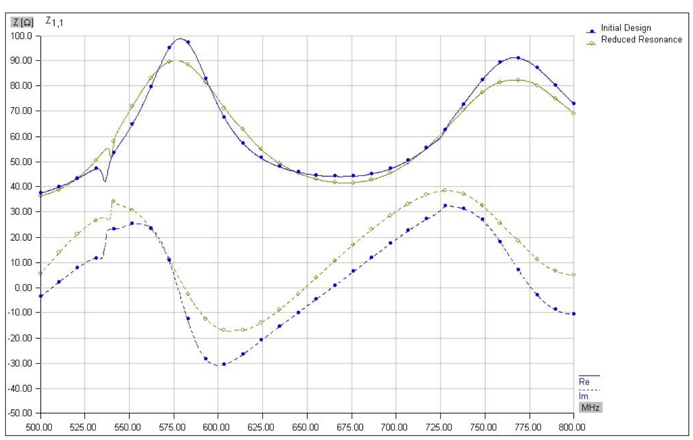

Fig. 5. Resonance Reduction in Array Environment

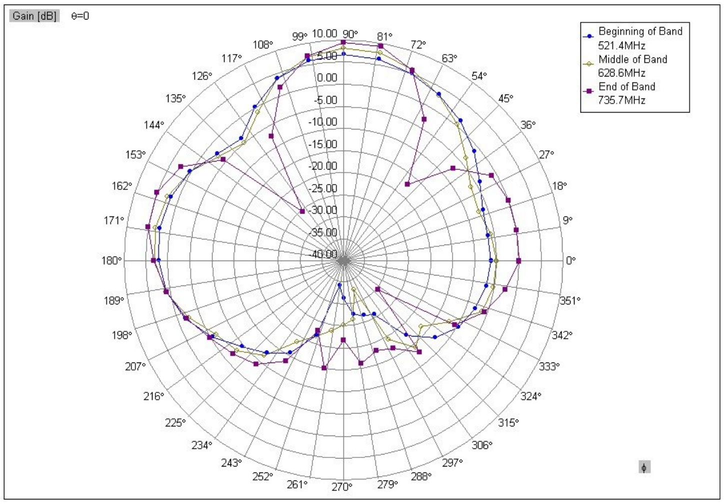

Fig. 6. Elevation Patterns Showing Low Backlobes

3. Measurement

A. *Single Element*

The three conductors of the antenna were each fabricated on FR-4 circuit boards. The dielectric constant of the FR-4 material was approximately four. The circuit boards were made as thin as possible to mitigate the effects of the high permittivity. The resultant printed circuit boards came out to be 10 mils thick which is approximately 3% of the spacing. It is assumed that the FR-4 will contribute little to the resultant permittivity.

A plot of the impedance is shown below in Figure 6. The blue plot corresponds to the metallic model in free space shown in Figure 2. The yellow plot corresponds to a model where the dielectric foam layer with an assumed permittivity of 1.1 was simulated. The purple plot is the actual measured data. It can be seen that there is slightly better agreement in the more complex dielectric model.

The measurement came out slightly more inductive than the simulation. Copper tape was then added to increase capacitance.

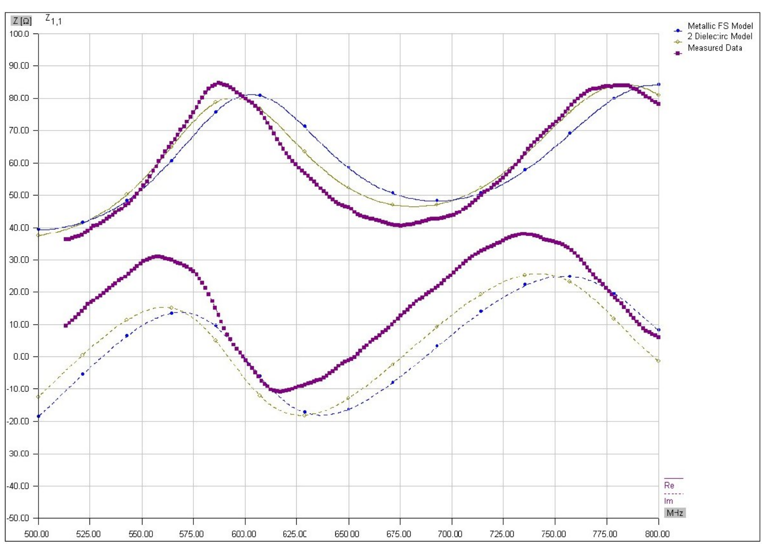

Fig. 6. Impedance Plot of Measured vs. Simulation

B. Array Environment

The antenna was then put into the array environment to assess the effects of mutual coupling on the impedance match. It was found through simulation that the significant effects were evident in a three-element array. The change in the impedance between an array of three and an array of five or more elements was minimal. Therefore, measurements were only taken with an array of three elements.

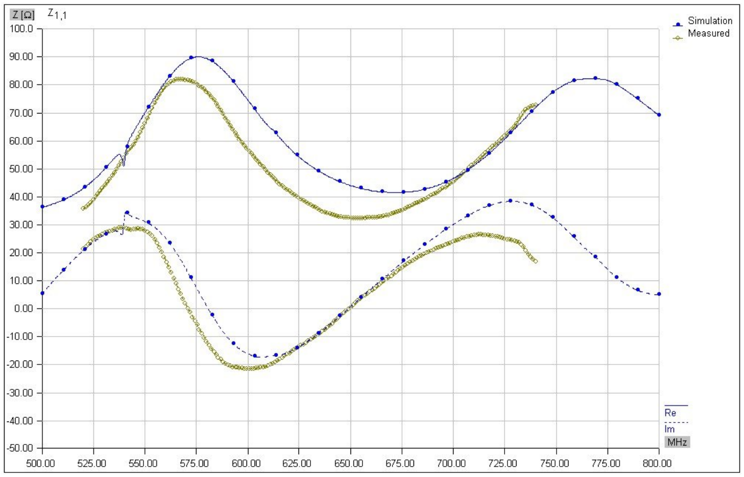

Fig. 7. Impedance of Measured vs. Simulated Data in Array Environment

The above figure shows that the resonance was not present in the measured data. The resonance did show up in the measured data of our initial design. The redesign to reduce the resonance appeared to correct the problem in the measured data even though it was still apparent in the simulated data. Figure 8 shows that we maintained a good match across the band of interest. Figure 9 also shows the dielectric model of the final design including the foam dielectric.

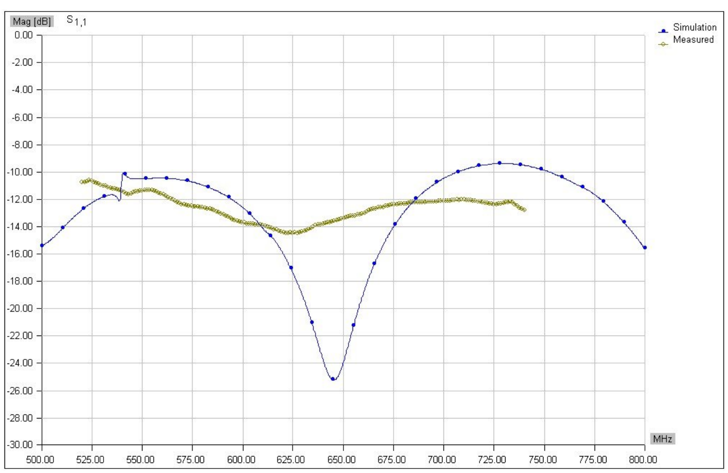

Fig. 8. Return Loss of Simulation vs. Measured Data in Array Environment

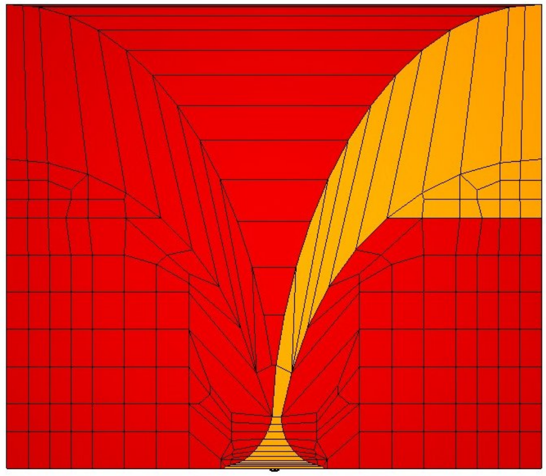

Fig. 9. Final Element Design, Red is the Foam Dielectric, Copper Color is the Conductor

4. Conclusions

A variant of the Balanced Antipodal Vivaldi antenna was designed to operate between 510-740 MHz. The antenna also required a gain of between 6-10 dBi and backlobe levels ~30 dB below the main beam. The resulting antenna was well matched with a VSWR< 2:1 across the band of interest. There were also size constraints to adhere to along with a specified spacing of the elements in the array. This array spacing presented mutual coupling issues resulting in resonances which could have affected performance. Through iterations between simulation and measured data, these resonances were suppressed.

References

[1] Langley, et. al., "Balanced Antipodal Vivaldi Antenna for Wide Bandwidth Phased Arrays,",*IEE Proceedings-Microwave Antennas and Propagation*, Vol. 143, No. 2, April 1996.

[2] WIPL-D, http:www.wipl-d.com.