Development of a Novel Faceted, Conformal, Slotted-Waveguide Subarray for Sensor Applications with Full 360° Azimuth Tracking Capabilities

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Abstract — This paper describes the design and implementation of a conformal subarray antenna that was developed as part of a larger circular array which is intended to provide full 360° azimuth coverage for a sensing system operating from 16-16.6 GHz. Despite the fact that several technologies from prior art were incorporated into the design of the presented center-fed, narrow-wall slotted waveguide array, the innovative character of this approach lies in the development of a faceted conformal waveguide subarray and its use with neighboring similar arrays to provide azimuth angular tracking information. The measured reflection coefficient and radiation patterns of two fabricated prototypes demonstrate good agreement with those predicted by FEM simulations.

1. INTRODUCTION

A low-cost circular antenna was desired to provide full 360° azimuth angle coverage for a sensing system. Additional goals included high efficiency, horizontal linear polarization, sidelobe minimization in the principal polarization, and low-cost fabrication. The system was desired to operate throughout 16.0 to 16.6 GHz, a very reasonable bandwidth of only 3.7%. The desired main lobe 3dB beamwidth was 11.25°, arising from the system specification of a circular array of 32 subarrays. The first sidelobe level was desired to be -25 dB below the main beam peak. Slotted waveguide arrays are known to provide an efficient and convenient form factor to meet these objectives. The following sections present the prior art incorporated into the design of the conformal linear array, the configuration of the new faceted subarray, and a comparison between measured and simulated results.

2. THE CENTER-FED, NARROW-WALL SLOTTED WAVEGUIDE APPROACH

A center-fed, narrow-wall slotted waveguide was selected to meet the electrical-performance and form-factor goals. Initial analysis verified that an eight-element array with conventional spacing would meet the 3dB main beamwidth goal of 11.25° while incorporating the Taylor amplitude taper to achieve the -25 dB first sidelobe goal [1]. A straight eight-element narrow-wall slotted waveguide array that was end-fed has been reported by Dunn [2]. Muller, et al, presented the concept of the center feed to increase the impedance bandwidth of the slotted array in [3]. To realize effectively the center feed, a simple-to-construct, yet well-matched H-plane T-junction was required. The H-plane T-junction presented by Hirokawa, et al, [4], which employed a single inductive post, was used and optimized to achieve a reflection coefficient magnitude < -20 dB throughout the desired band. To satisfy both the amplitude distribution for sidelobe level

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control and simultaneous impedance matching requirements, the methods described by Stevenson [5] and Das [6] were used to achieve the desired slot conductivities versus slot tilt angles. The Taylor amplitude coefficients calculated were 0.330, 0.552, 0.830, and 1.0000 for the four radiators from the outside toward the center. Following Stevenson's [5] approach led to the solution that a WR-51 waveguide should have slots tilted to the angles of 12º, 19º, 31º, and 39º, respectively. The system waveguide interface was specified as WR-62; therefore a taper in the height of the feeding waveguide was incorporated into the T-junction to transition to the WR-51 dimensions of the radiator stick. Computer simulations of the faceted subarray, shown in Figure 1, were completed using Ansoft's HFSS. The inclusion of the T-junction and the two bends in the straight slotted waveguide stick did not significantly perturb the baseline slotted waveguide design, as the impedance match and radiation patterns were virtually unchanged from that of the straight stick.

The faceted design using three flat faces was selected using a Fourier Transform model of subarrays employing different shapes (e.g. truly circular) and different amplitude distributions for sidelobe reduction. The sensor system intends to use adjacent subarrays to form azimuth tracking patterns as well as sum patterns. When straight subarrays were used with boresights pointed at 11.25° increments, the sum beam resulting from the combination of two adjacent subarrays demonstrated multi-lobing of the main beam. Likewise, the monopulse error slope was not monotonic in the tracking beamwidth of 11.25°. The faceted design shown herein effectively broadened the subarray beam, reduced the multi-lobing, and provided a single valued azimuth monopulse error slope.

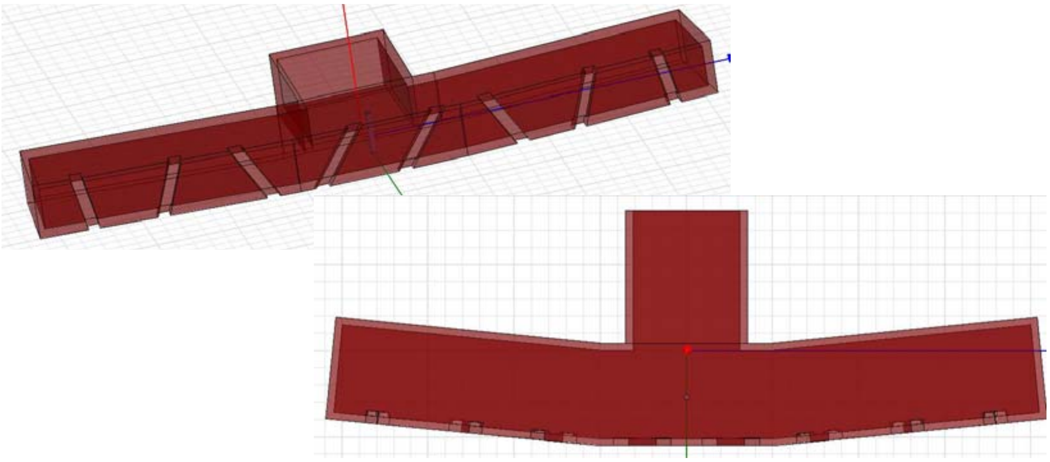

Figure 1. HFSS CAD Model of the Faceted Conformal Subarray

3. FACETED CONFORMAL SUBARRAY PROTOTYPE DEVELOPMENT

Two benchmarking prototypes of the slotted waveguide subarray were fabricated from solid brass stock. Standard WR-62 flanges were added to match the system waveguide interface.

4. COMPARISON BETWEEN MEASURED AND MODELED PERFORMANCE

Figure 2 presents a comparison between the HFSS-modeled and the measured reflection coefficients. Measured and modeled performance agreed well with levels < -20 dB throughout the frequency range from 16.0 to 16.6 GHz. The radiation patterns of the faceted conformal subarrays were measured one at a time in GTRI's indoor shielded anechoic chamber. Photographs of the subarrays in the anechoic chamber are presented in Figure 3. As with the reflection coefficient comparison, the measured directivity patterns compared well with that predicted by the FEM simulation. Figures 4, 5, and 6 present the pattern comparisons for both horizontal (co-) and vertical (cross-) linear polarizations at 16.0 and 16.3 GHz. Pattern comparisons at other frequencies matched similarly well.

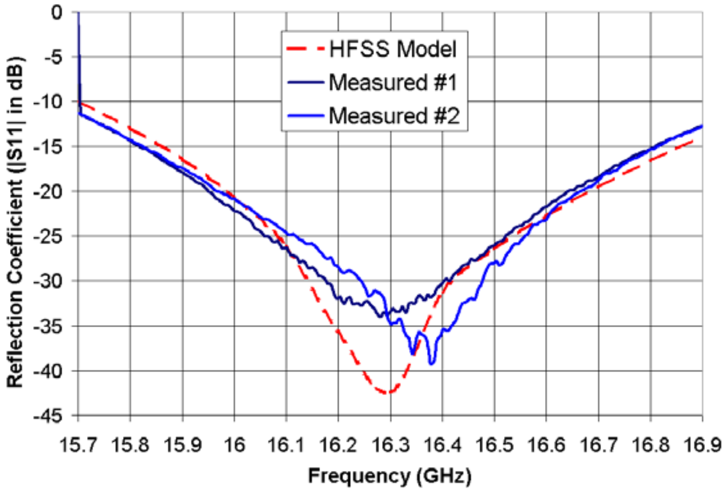

Figure 2. A Comparison of the Measured and Modeled Reflection Coefficients

Figure 3. Photographs of the faceted conformal slotted waveguide array in GTRI's anechoic chamber.

5. CONCLUSIONS

The design and development of a novel faceted conformal narrow-wall slotted waveguide array were presented for sensing applications around 16-16.6 GHz with requirements for a 360deg azimuth tracking capabilities. Measured and modeled reflection coefficient and directivity pattern data were compared showing good agreement in terms of return loss (below –20 dB throughout the bandwidth of operation), cross-pol levels (below –10 dB) and 1st sidelobe suppression (below -25 dB). In addition, they demonstrated that the introduction of two bends and a T-junction does not affect significantly the radiation performance. The proposed antenna could be utilized for a truly 360° coverage in a configuration of 32 similar subarrays.

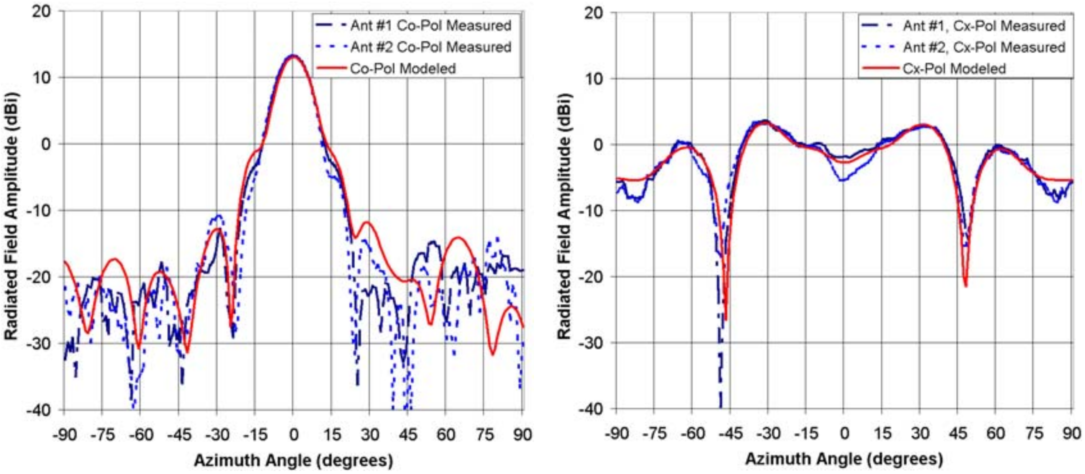

Figure 4. Measured and Modeled Patterns at 16.0 GHz (Co- and cross polarization)

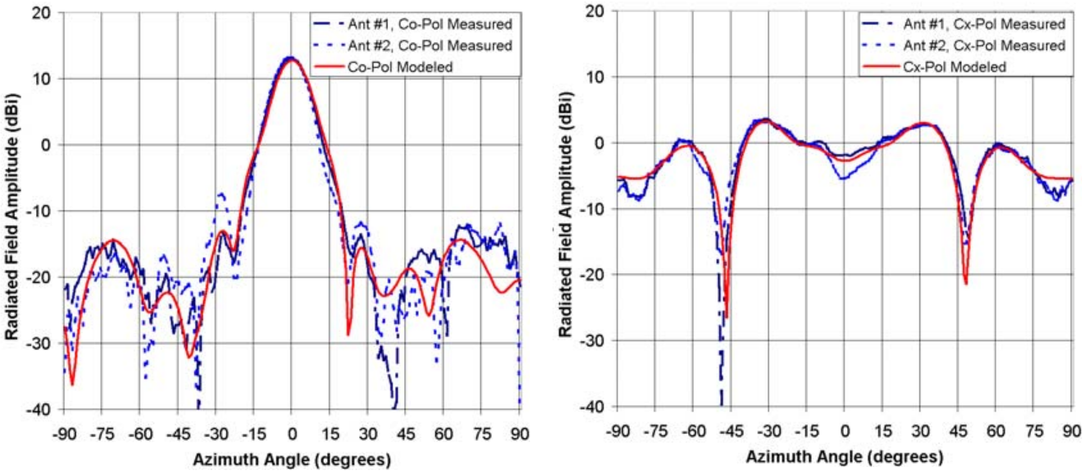

Figure 5. Measured and Modeled Patterns at 16.3 GHz (Co- and cross polarization)

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