A Broadband Array with Unbalanced Feeds:

Elements and Power Combiners Based on the Fragmented Aperture Principle

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***Abstract*—A fully combined, fixed-beam, ultra-wideband array with unbalanced feeds is described. Both the array elements and power combiners are based on the fragmented aperture principle. Each was designed separately using a genetic algorithm, then combined to form an integrated version of the array. Measured results are reported including realized gain, and beamwidths in the principal planes.**

Keywords—antenna array; unbalanced feed; fragmented aperture; power combiner

I. Introduction and Approach

The antenna design presented in this work is intended for an outdoor range at the U. S. Army Aberdeen Test Center. The antenna specifications were: single linear polarization, medium gain ranging from 10 dBiL to 20 dBiL across an instantaneous bandwidth from 1.435 GHz to 6.7 GHz (~4.7:1), and beamwidths for both principal planes of 20 degrees and 6 degrees for the lowest and highest frequencies, respectively. In addition, the aperture had to fit within a circle of radius 30.5 cm (12"), weigh under 20 lbs, and be covered by a radome.

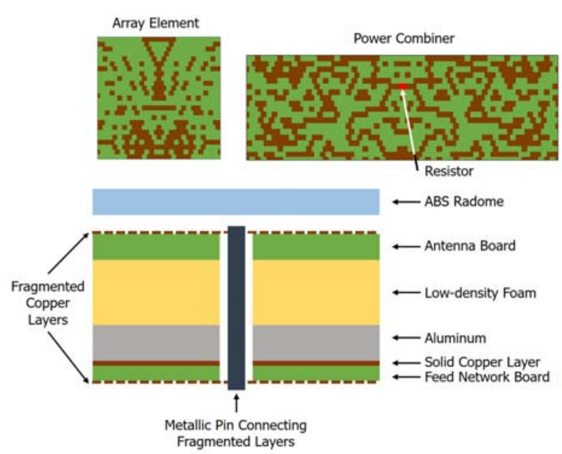

Fig. 1. **Bottom:** Antenna stack-up. **Top:** The fragmented aperture layers for an element of the array and a power combiner. The brown is copper and the green is the dielectric substrate.

To meet these specifications, GTRI developed a fixed beam, 16 x 16 element antenna array and the associated feed network. Novel aspects of the design are the use of an unbalanced feed for each element, which greatly reduces the complexity of the construction, and the use of fragmented aperture technology in the design of both the antenna elements and the power combiners [1]-[4]. Images of the antenna stack-up and each of the fragmented layers are shown in Fig. 1.

II. Design And Measurement

The inter-element spacing of the array is 2.54 cm (1") or approximately 0.57λ at the highest frequency of operation. As mentioned above, both the array elements and power combiners were designed based on the fragmented aperture principle, which requires an optimization technique, in this case a genetic algorithm. During the design, certain parameters were varied, including: the metal patterning on the antenna and feed network layers, thicknesses of the various materials, and the permittivity of the radome. For each power combiner, a single 50 Ω resistor was placed along the center line.

The insertion loss in the 256:1 corporate feed network (eight stages of 2:1 combiners) was expected to be a significant factor, so the goal for the design of the power combiners was minimum insertion loss across the design bandwidth.

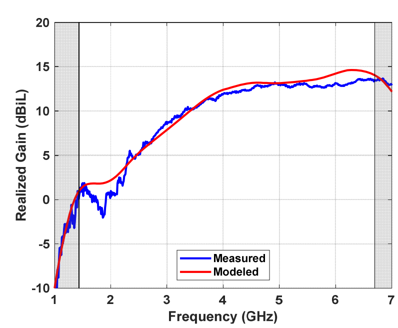

Fig. 2. Realized gain at broadside versus frequency for an array of 4 x 4 elements, without power combiners.

To obtain confidence in the design, both the antenna array and feed network were initially fabricated and tested with a smaller number of elements. A 4 x 4 element array was fabricated with an SMA connector at each element. The broadside embedded-element gain was measured for each of the 16 elements, and these results were mathematically combined to obtain the results (blue) for the measured realized gain of the array, shown in Fig. 2. The realized gain predicted by the

Distribution Statement A. Approved for public release by the Test Resource Management Center (TRMC); Distribution is unlimited 412TW-PA-18922 theoretical model (red) is also shown in the figure, and the two results, theory and measurement, are seen to be in good agreement for frequencies across the design bandwidth.

The 16:1 feed network that would accompany this 4 x 4 array was also fabricated, and the measured scattering parameters $|S_{11}|$ and $|S_{21}|$ are shown in Fig. 3. These are the reflection and insertion loss, respectively, from a single element port (port 2) and the array common port (port 1). Again, the measured results (blue) are compared to those from the theoretical model (red) and the two are seen to be in reasonable agreement for frequencies across the design bandwidth.

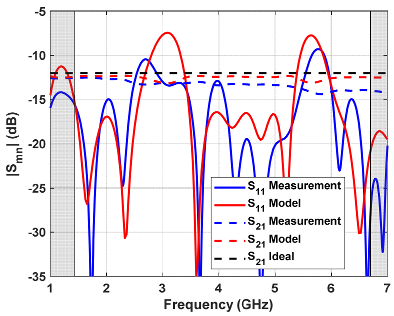

Fig. 3. Scattering parameters versus frequency for the 16:1 feed network that was based on the fragmented aperture principle. The ideal curve is for perfect combining with no loss.

A 16:1 feed network was also fabricated from the best commercial off-the-shelf (COTS) components, and the average (across all 16 ports) measured insertion loss for this network is compared with that for the feed network with fragmented power combiners in Fig. 4. The insertion loss is seen to be lower for the fragmented case, which shows the efficacy of the design.

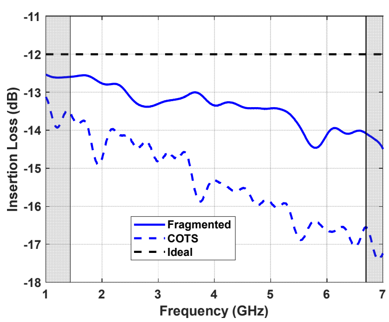

Fig. 4. A comparison of the measured insertion loss for the two 16:1 feed networks: fragmented and COTS components.

With the confidence obtained from the good agreement of theory with measurements for the smaller 4 x 4 array, GTRI was ready to fabricate and test the full 16 x 16 array. The realized gain versus frequency for this array is shown in Fig. 5. The realized gain predicted by the theoretical model for the antenna array with no feed network (solid red line) is seen to be within a few dB of the directivity of a uniformly illuminated aperture of the same size (dashed black line). For the complete array, the measured gain (blue line) varies from about 2 dB to 8 dB below that for the theoretical model. Most of this difference is attributed to the insertion loss in the feed network. The measured gain equals or exceeds the goal for the program (solid black line) across the whole design bandwidth.

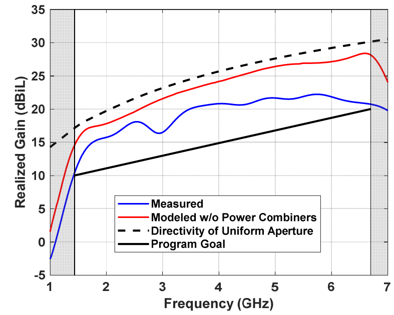

Fig. 5. Realized gain at broadside versus frequency for the array of 16 x 16 elements.

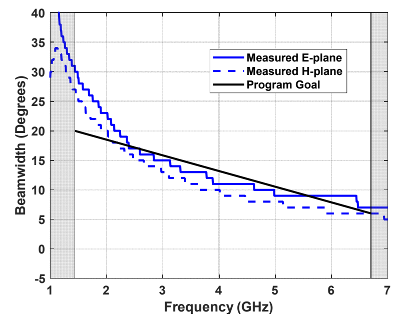

Fig. 6. Beamwidths in the principal planes versus frequency for the array of 16 x 16 elements.

Lastly, the measured beamwidths in the principal planes versus frequency are shown in Fig. 6, and they are seen to closely follow the goal for the program.

ACKNOWLEDGMENT

This project is managed by the Test Resource Management Center (TRMC) and funded through the Spectrum Access R&D (SAR&D) Program via Picatinny Arsenal under Contract No. WL5QKN-15-9-1004. The Executing Agent and Program Manager work out of the AFTC. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of TRMC, the SAR&D Program and/or the Picatinny Arsenal.

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