Design of Mutually Transparent Antenna Arrays

Eric K. Walton*(1), Eugene Lee (1),
Bruce Montgomery(2) and Gary Bruce(2)
(1) The Ohio State Univ. 1320 Kinnear Rd. Columbus, OH 43212,
(2) Syntonics LLC, Columbia, MD.

Introduction

There have been many techniques used to develop multiple high gain antenna arrays in a confined space. Some authors have used multiple feeds with frequency selective surface (FSS) [1] dichotic subreflectors and a parabolic reflector [2], but all of the beams must point in the same direction. Other authors have used multiband array elements and true time delay techniques for beam steering to form multiple-band steerable arrays [3], but these techniques are very expensive because of the very complex feed systems and have limited horizon-to-horizon coverage.

This paper will discuss the use of mutually EM transparent arrays mounted on EM transparent positioner arms. Three such arrays are mounted in a single radome and configured to independently track three separate signals. Frequency selective surface concepts are used in the design of the ground plane surface and the transmission lines to mitigate blockage effects.

Basic Concepts of the Multiple Antenna System

A photograph of one such system (set up for measurement in the Ohio State Univ. Compact range) is shown in Fig. 1. Note that the three antennas are on pivoting arms that permit full horizon-to-horizon coverage without collision with the other antennas. The outer antennas are transparent at the operational frequencies of the inner antennas. FSS concepts are used in the design of the feed elements, the ground plane and the feed array. A side view of an individual array is shown in Fig. 2. Note that it is necessary to adjust the orientation of the FSS elements and the feed array to ground plane spacing so as to optimize the EM transmission coefficient of the array at the frequencies used by the inner antenna arrays. The entire array antenna is built up of layers of foam with Mylar skins. The FSS elements and the array elements are conductive lines deposited on the Mylar dielectric.

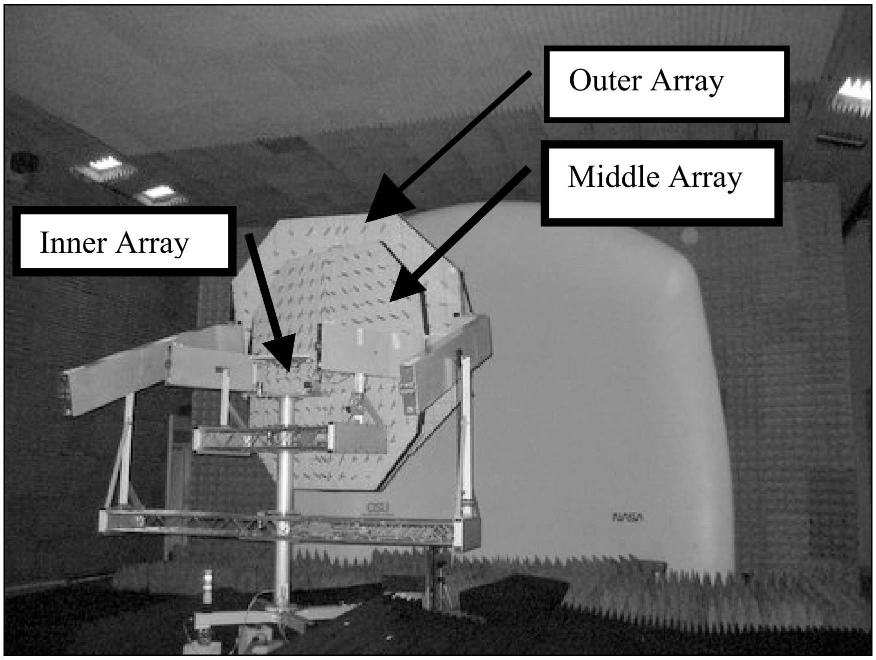

Fig. 1. Photograph of set of 3 mutually transparent arrays (set up for measurement in the Ohio State Univ. Compact Range)

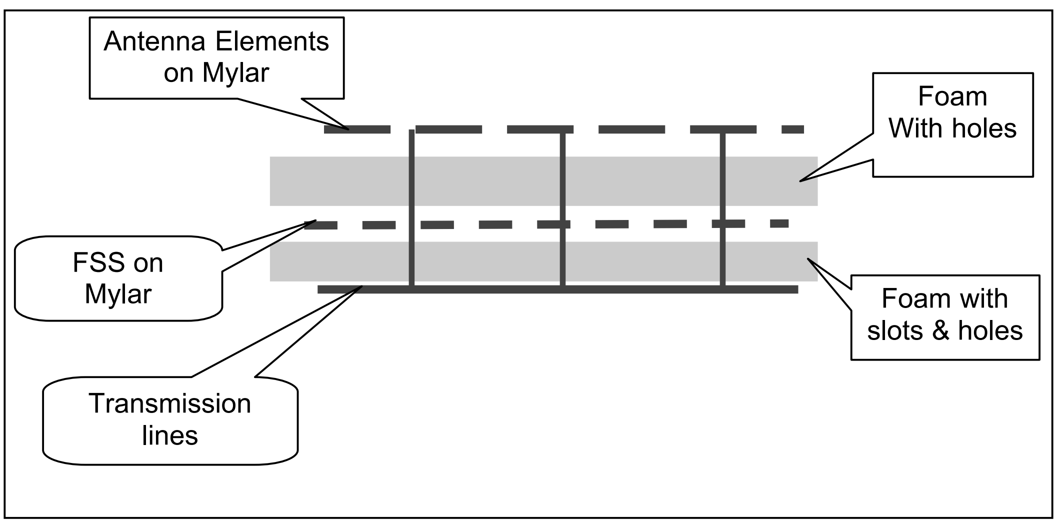

Fig. 2. Side diagram of an individual array

An example of an effective FSS layer is shown in Fig. 3. This array of tuned crosses (polarization independent for a circularly polarized array) is designed to be reflective at the frequency of the associated array, and transparent at the frequency bands of the inner antenna arrays. Note that in order to make this FSS have a more narrow operational band, the crossing array elements are printed on opposite sides of the substrate.

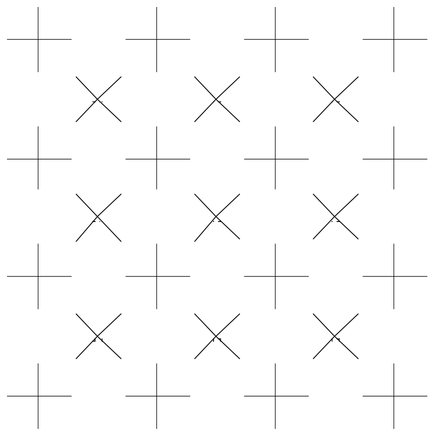

Fig. 3. Example FSS layer

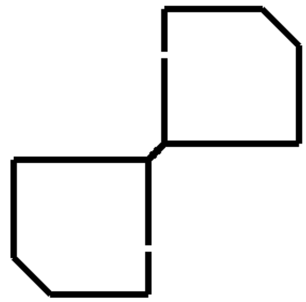

Fig. 4. Example CP array element.

An effective circularly polarized array element is shown in Fig. 4. This element uses carefully positioned slots in the elements to introduce the phase shifts that give it a good circular polarization characteristic [4]. It was computed and measured to have an element gain of approximately 8 dBiC.

Feed network

The feed network must provide a uniform (or tapered) amplitude and equal radiated phase from each of the elements. A more detailed description will be given in a companion paper during this conference. In this design, the feed is created using a twin-line concept by using printed copper strips on either side of a dielectric substrate (a balanced transmission line). Adjustable power division directional couplers are created using a printed pattern on the dielectric substrate. The stub of the transmission line that passes upward through the FSS layer (not touching the FSS elements) and connects to the CP element is twisted to introduce the necessary compensation phase shift so that uniform phase is radiated from each element. (Rotation of a CP element yields a phase shift for the radiated signal.)

Final integration and testing

An example set of antennas was theoretically designed using wire segment models and the method of moments (MOM). A number of configurations were tested for effectiveness and the final configuration was constructed using Mylar skin on Styrofoam. The 12 element by 12 element octagonal arrays were shown both theoretically and experimentally to be capable of gains in excess of 28 dBiC. The blockage of the overlying antennas attenuates the gain by only 2 dB or so but does not degrade the beamwidth.

An example set of experimental data from a prototype test is shown in Fig. 5. In this set of plots, the gain pattern of an S-band array is shown as an L-band array is progressively moved in front of it (0% to 100% blockage). Note that the general beam pattern is not seriously changed, and that the blockage attenuation is less than 3 dB.

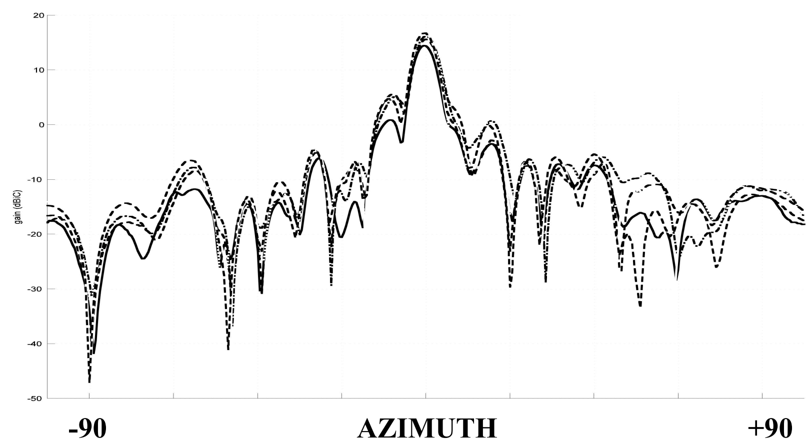

Fig. 5. Gain pattern of S-band array for various blockage levels by the S-band array

References:

[1] B. A. Munk, <u>Frequency Selective Surfaces: Theory and Design</u>, John Wiley & Sons, Inc., New York, N.Y., 2000.

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[3] Ng, W. et al., "The First Demonstration of an Optically Steered Microwave Phased array Antenna Using True-Time-Delay," J. of Lightwave Technology, v.9, No. 9. pp.1124-1132, Sept. 1991.

[4] Rong-Lin Li and F. F. Vincent, "Circularly Polarized Twisted Loop Antenna," IEEE Tran. Ant & Prop., v. 50, No. 10, pp. 1377-1803, Oct. 2002