COMMON-MODULE APPROACH FOR LOW-COST BEAM-SCANNING ARRAYS FOR COMMERCIAL APPLICATIONS

Gregory T. Thompson, James K. Tillery, and Johnson J. H. Wang
Wang Electro-Opto Corporation
Marietta, Georgia USA
E-mail: gthompson@weo.com

1. Introduction

Beam-scanning arrays have been extremely expensive, even for military and space users. For commercial applications in mobile and fixed-point terminals, cost is an even more overriding design consideration. To meet the cost demand as well as platform compatibility, the use of a spiral-type element for array antennas has been investigated for both beam-scanning arrays as well as the non-scanning arrays [1-5]. In this paper we will present a "common-module" approach as a solution for low-cost beam-scanning arrays.

2. The common-module approach to reduce production cost

Since the application of phased arrays has historically been small-quantity military and aerospace systems, antenna engineers have failed to recognize that the real cost contributor is low quantity. This point can be easily demonstrated by the low production cost of complex consumer products with high-volume sales, for example, VCR (< $100) and camcorders (< $300). Now, with the ongoing wireless revolution, high-volume demands for beam-scanning arrays in the commercial and consumer world are emerging and have been recognized and widely publicized in the business community. In the technical community, antenna engineers have only recently begun to examine the cost issue from the viewpoint of volume.

The first question is "Can beam-scanning array be made in large volumes of millions?" Traditionally, a beam-scanning array is invariably system specific and frequency specific. As a result, its volume is limited to the specific system and frequency it is designed for. An approach for large cost reduction is to develop a set of "common modules", each of which can be shared by a variety of systems or subsystems. In addition, these common modules in the set should share some common features that could be taken advantage of to further lower their costs. This is how the production costs were reduced, for the screws in the 18th century and for camcorders today.

3. The first common module for beam-scanning arrays --- IAPS

The spiral antenna is probably one of very few antennas that can be produced by the common-module approach because of its ultra-wide bandwidth and physical structure that makes it amenable to the common-module approach. In addition, its inherent phase pattern can be utilized to achieve phase shift. A common module covering a 10:1 bandwidth, called an integrated antenna/phase-shifter (IAPS), was developed based on these features [4]. In a recent study, the manufacturing technique for a 3-bit IAPS common module was focused on the common feed and phase-switching mechanism at the center of the spiral as a MMIC chip shown conceptually by the shaded circular region in Fig. 1. The MMIC device will be manufactured by using precision silicon HMIC process, with an estimated $9 to $19 per piece for the first 100,000 pieces. The MMIC device will be Flip-Chip mounted to the spiral arms. Fig. 2 shows measured and calculated patterns exemplifying the fairly good beam scanning performance of a 3-element IAPS subarray.

4. The second common module --- based on amplitude-switched SMM antenna array

For many mobile Satcom (satellite communication) terminals and basestations, a moderate gain of 9 to 16 dBi is often adequate. However, a nearly hemispherical coverage is generally needed. The polarization for Satcom is circular polarization, predominantly right-hand. We are developing a common-module element based on the ultra-wideband spiral-mode microstrip (SMM) antenna [6] to cover multiple systems in the L- to lower S-band region.

Although the SMM antenna is wideband and compatible with platforms, its manufacturing cost has been much higher than the patch antenna, a competing antenna technology that suffers from narrow bandwidth. We have recently developed a design which brings the balun to the center of the spiral, effectively created a common module for the array element. This concept is applied to a 2X6 slanted cylindrical array shown in Fig. 3 without the radome attached, operating over 1.2-2.5 GHz for mobile earth terminals. This array consists of 6 2X1 panels, measuring about 40 cm (16 inches) in diameter at its base and is 20 cm (8 inches) tall. Figure 4 shows typical azimuth and elevation patterns for one 2X1 panel of the array at various frequencies in the operating band.

By using an amplitude-switched feed network, the 2X6-element array has 12 azimuth beams and 3 elevation beams. Sequential switching similar to the "Wheeler Lab approach" [7], with variable phase shifters, was employed, with a unique modification to achieve 12 azimuthal beams, which should be adequate for the broad-beam array, from the 6 azimuthal array elements. Each elevation beam, as shown in Figure 4, has a 3-dB beamwidth of about 50^o at 1.3 GHz, decreasing to 28^o at 2.5 GHz, as expected. Each azimuth beam has a 3-dB beamwidth of 60^o to 80^o over the operating band. These beam patterns are expected to yield a directivity of 10 to 11 dB at 1.3 GHz , increasing to 13 to 14 dB at 2.5 GHz. The performance is dependent on the amplitude-switching matrix, which is under continuing development. For applications with higher gain requirements, a similar 3X6 array would be used having 3 elements in elevation and producing directivity up to and beyond 16 dB.

5. Conclusions

Low-cost designs using the common-module approach to increase the volume of production, thus reducing costs, have been generated for beam-scanning arrays for major high-volume applications in the rapidly growing commercial market.

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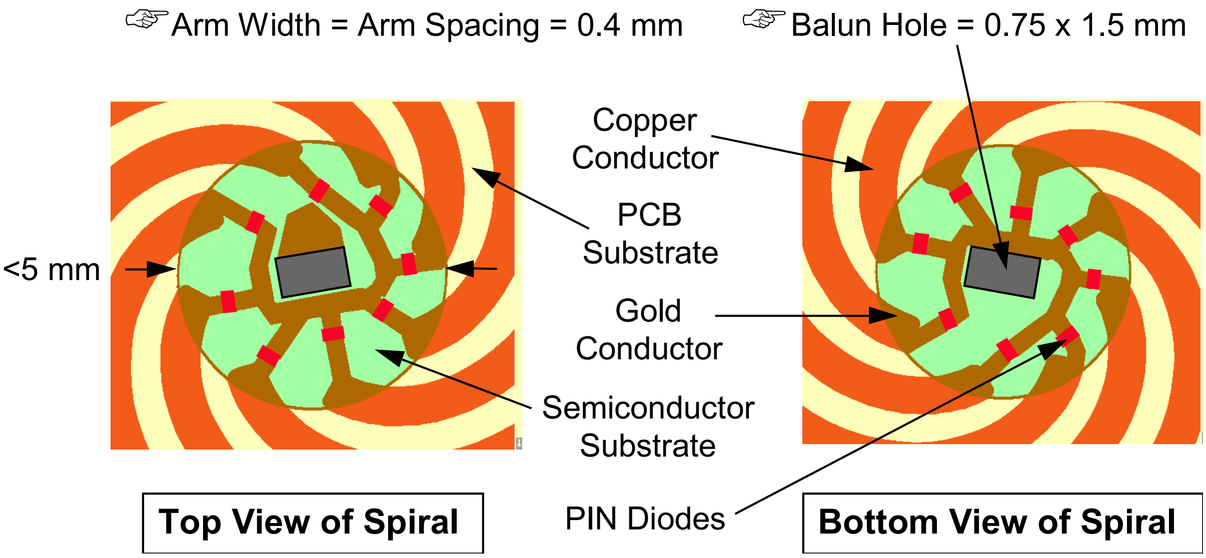

Fig. 1. Design of a IAPS common module with a MMIC chip in the center circle.

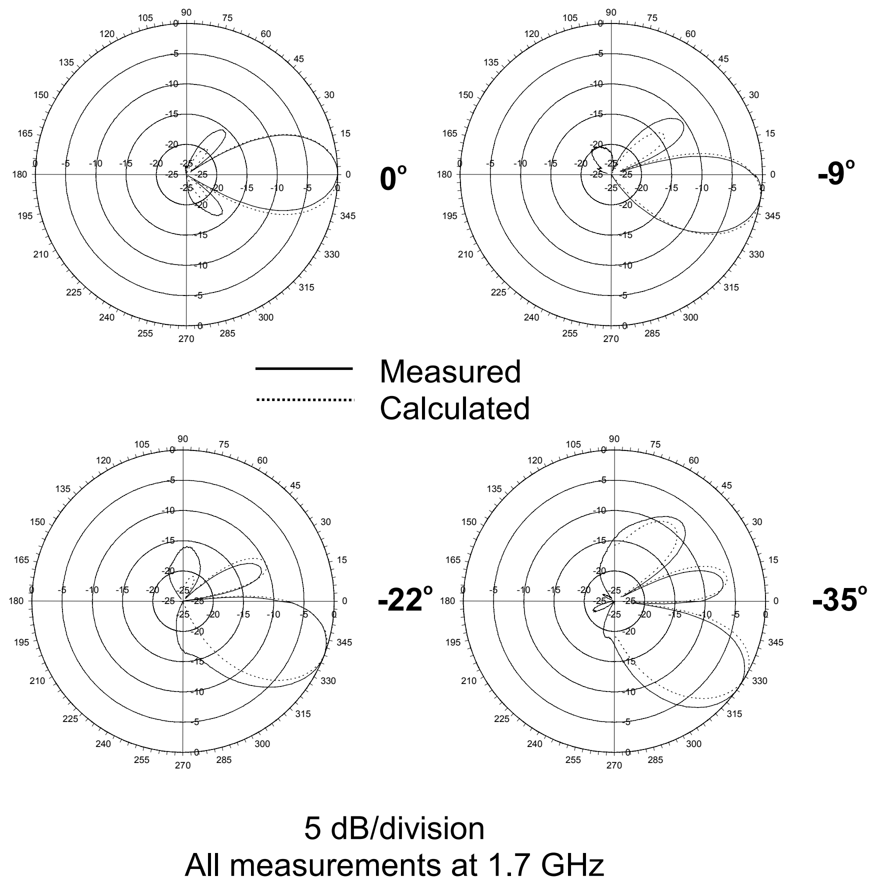

Fig. 2. Measured and calculated beam-scanning patterns of a 3-element 3-bit IAPS subarray.

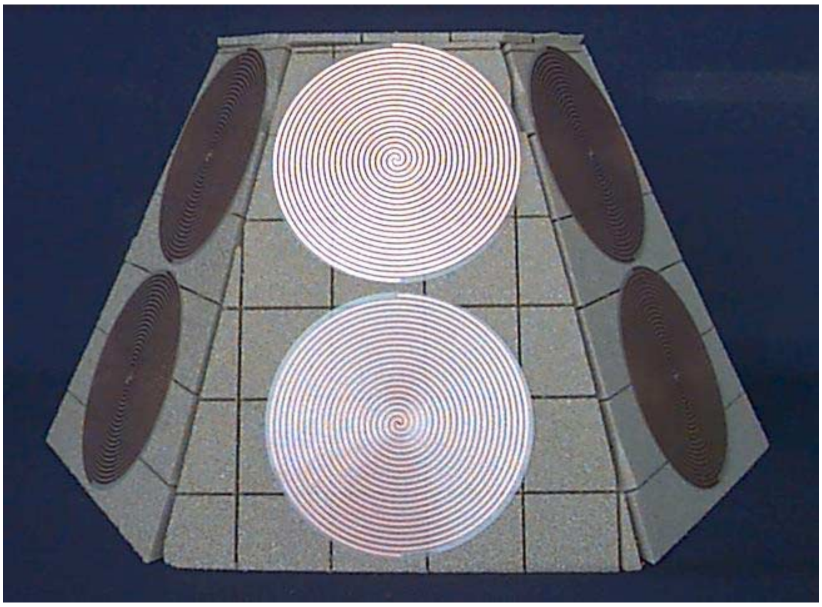

Figure 3. 2X6 slanted cylindrical array prototype model.

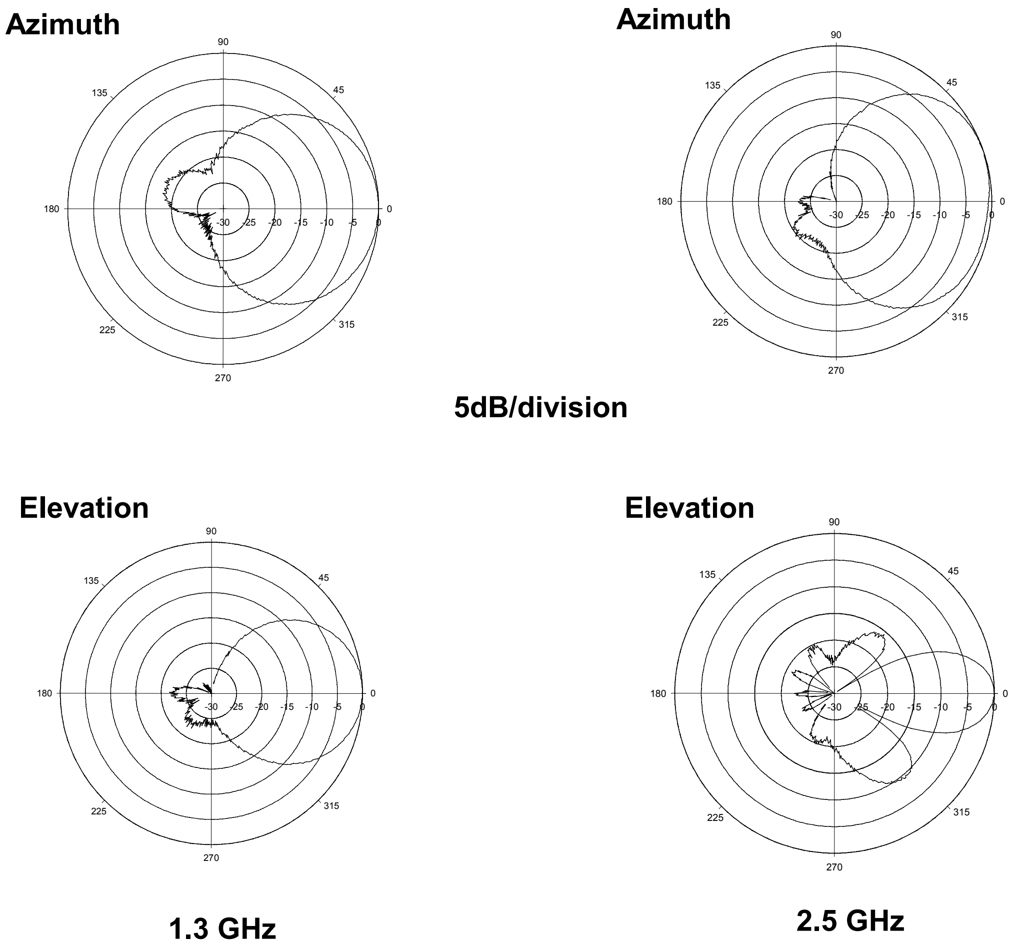

Figure 4. Azimuth and elevation patterns for one 2X1 panel of the cylindrical array.