

AMCs Comprised of Interdigital Capacitor FSS Layers Enable Lower Cost Applications

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Abstract: The focus of this work was to reduce manufacturing costs of printed artificial magnetic conductors (AMCs) by employing interdigital capacitors to enhance the effective sheet capacitance of the FSS without resorting to a second layer of overlapping patches. A 2.8 GHz AMC was fabricated and tested to demonstrate the concept. This AMC was then used to demonstrate a 2.9 GHz low profile antenna. Cost savings for this alternative manufacturing technique are estimated to be at least 50%.

I. Introduction

The first practical method of fabrication for low frequency artificial magnetic conductors (AMCs), resonant below 3 GHz, was to build them as a three-layer printed circuit board (PCB) employing a flex-rigid construction of polyimide and FR4 [1]. However, flex-rigid PCBs are too expensive for many high volume commercial applications. Here we demonstrate an alternative geometry for the capacitive FSS layer of an AMC that employs a single layer of metal as opposed to two layers of metal separated by polyimide. We estimate the cost reduction for manufacturing AMCs in this manner to be a savings of approximately 52% to 58% for low and high volume quantities respectively. This does not even include potential cost savings due to yield improvements in the 2-layer AMC.

II. AMC Design

This AMC concept employs interdigital capacitors (ICAPs) to increase the effective sheet capacitance in the FSS layer of an AMC such that overlapping patches may be avoided [2]. Figure 1 shows the FSS pattern where male and female patches (red and green) alternate in checkerboard fashion. Plated through holes (PTH) of 20 mil diameter are arranged on a square lattice with a period P of 315 mils. Each PTH is located at the center of a patch. The substrate is a nominal 93 mil FR4 double sided board, which is etched on one side.

The FSS pattern was designed using a TLM full wave simulator such that the effective sheet capacitance is near 1.4 pF/sq. Using nominal lines and gaps of 10 mils, the intended reflection phase resonance was 2.475 GHz with a $\pm 90^\circ$ phase bandwidth of 2.355 to 2.594 GHz. However, the prototype ICAP AMC exhibited a higher resonant frequency due to over-etching in fabrication.

III. AMC Measurements

Sample measured data for a 10" x 16" ICAP AMC panel are shown in Figure 2. Reflection phase (in blue), measured at normal incidence, reveals the resonant frequency to be close to 2800 MHz. Surface wave coupling measurements are made using a pair of broadband horns with the AMC panel under test placed in a tunnel lined with absorber. The TM mode coupling curve (in red) measures transmission of the vertical (normal) electric field polarization relative to a metal surface (0 dB) the same size as the AMC

panel under test. The TM mode cutoff frequency of about 2.5 GHz is clearly seen where the coupling curve crosses 0 dB. The TE mode coupling curve (in black) measures transmission for the horizontal (tangential) electric field polarization. There are two very unusual features in the TE mode response for this ICAP AMC relative to a more conventional Sievenpiper AMC [1]: (1) the peak of the TE mode coupling appears to coincide with the AMC resonance (zero degree reflection phase), and (2) a very sharp cutoff is observed near the frequency of the -90° reflection phase. These phenomena merit further investigation.

IV. Antenna Measurements

A low profile monopole antenna, shown in Figure 3, was assembled using the ICAP AMC shown in Figure 1. It is comprised of a 50 mil wide printed trace on a 31 mil FR4 superstrate, attached to the AMC surface with pressure sensitive adhesive. The driven end is probe fed from below the ground plane using an extended center conductor from a .085" coaxial cable. The feed probe was centered on a via which was drilled out. The printed monopole is end loaded with a 0.5 pF to 2.5 pF trimmer capacitor connected to ground so as to improve the match and pattern. The overall dimensions for this ICAP AMC antenna are 1.9" x 3" x 0.13", or $0.47\lambda_0 \times 0.74\lambda_0 \times .032\lambda_0$, where λ_0 is the free space wavelength at the antenna resonant frequency of 2.9 GHz.

Antenna return loss and efficiency are shown in Figure 3. Over a 200 MHz bandwidth centered at 2.9 GHz, the measured efficiency exceeds 50% and the return loss is better than -10 dB. Note that the antenna resonant frequency of 2.9 GHz is about 3.6% higher than the AMC resonance of 2.8 GHz. Peak directivity is fairly high, exceeding +6 dBil, and the peak gain, shown in Figure 4, is +4.6 dBil. Although this is a relatively narrow antenna at less than $\lambda_0/2$ in width, the front-to-back ratio is a respectable 14 dB.

V. Conclusions

Through the use of printed interdigital capacitors, we have demonstrated an electrically thin 2.8 GHz AMC ($\lambda_0/43$ in nominal thickness) that can be fabricated as a simple conventional 2-layer PCB. The relatively small period ($P = \lambda_0/13$) of this ICAP AMC is suitable for antenna integration. It was used to demonstrate a low profile 2.9 GHz antenna element, which was shown to have at least 50% antenna efficiency and better than a -10 dB return loss over a 200 MHz bandwidth. Peak gain was about +4.6 dBil, and the peak directivity exceeded +6 dBil. The reduction in fabrication cost of this 2-layer ICAP AMC approach relative to the conventional 3-layer flex-rigid PCB is a cost savings of at least 50%.

VI. References

- [1] Daniel F. Sievenpiper, "High-Impedance Electromagnetic Surfaces," Ph.D. dissertation, UCLA, 1999.
- [2] Greg Mendolia, Etenna Engineering Notebook E00-024, pp. 26.

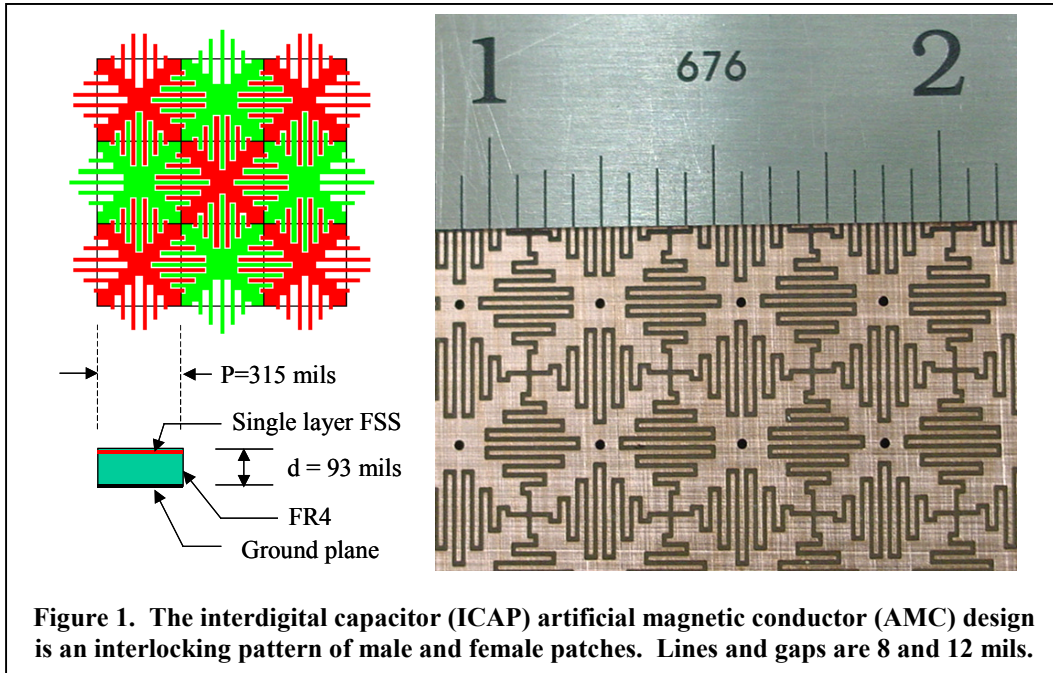


Figure 1. The interdigital capacitor (ICAP) artificial magnetic conductor (AMC) design is an interlocking pattern of male and female patches. Lines and gaps are 8 and 12 mils.

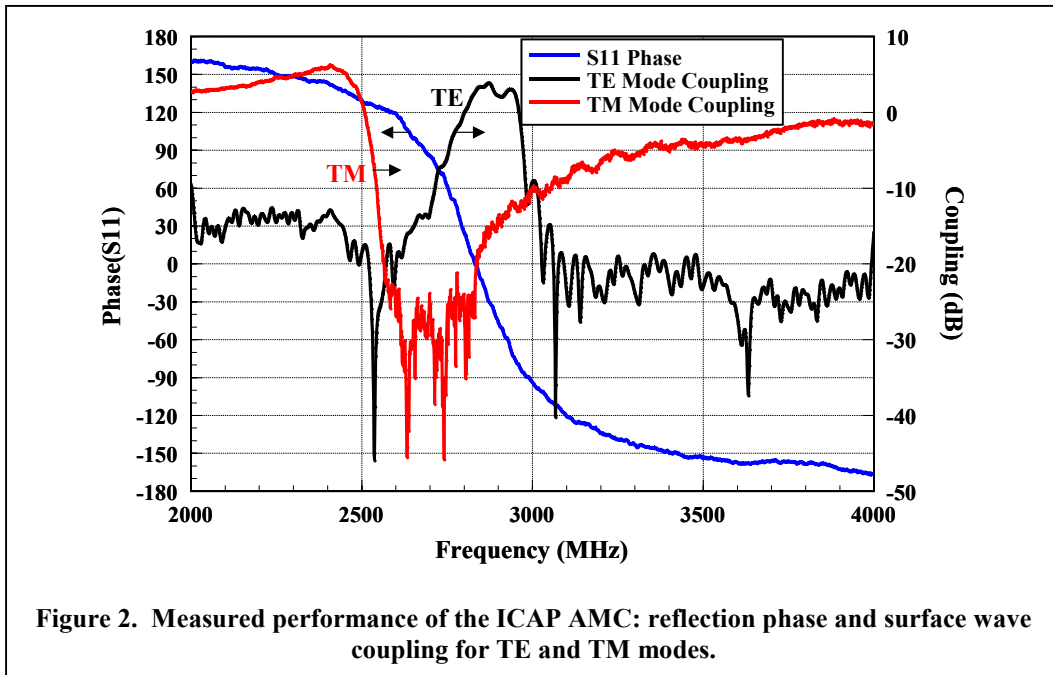


Figure 2. Measured performance of the ICAP AMC: reflection phase and surface wave coupling for TE and TM modes.

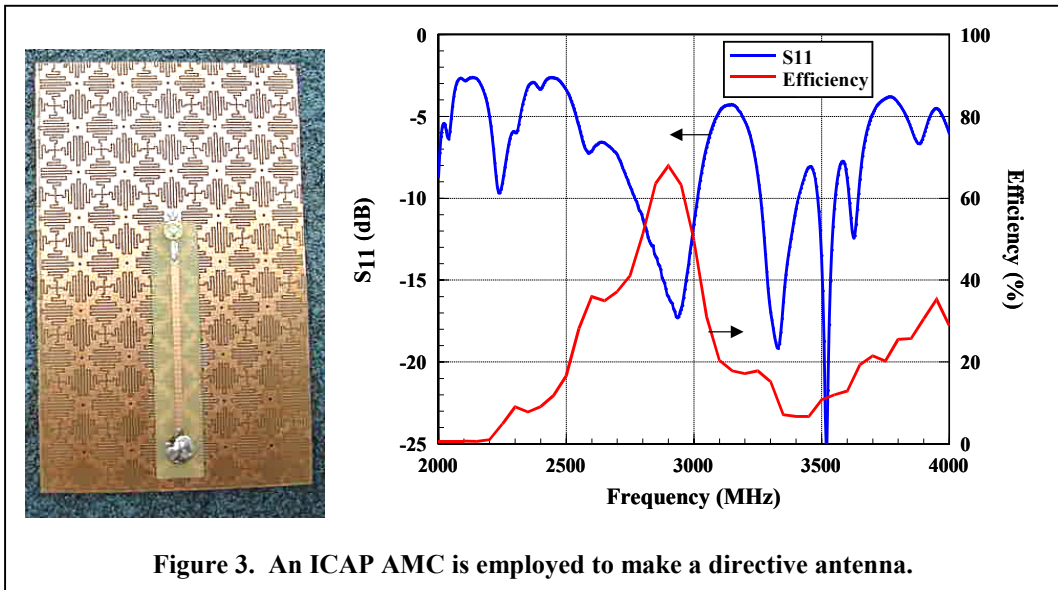


Figure 3. An ICAP AMC is employed to make a directive antenna.

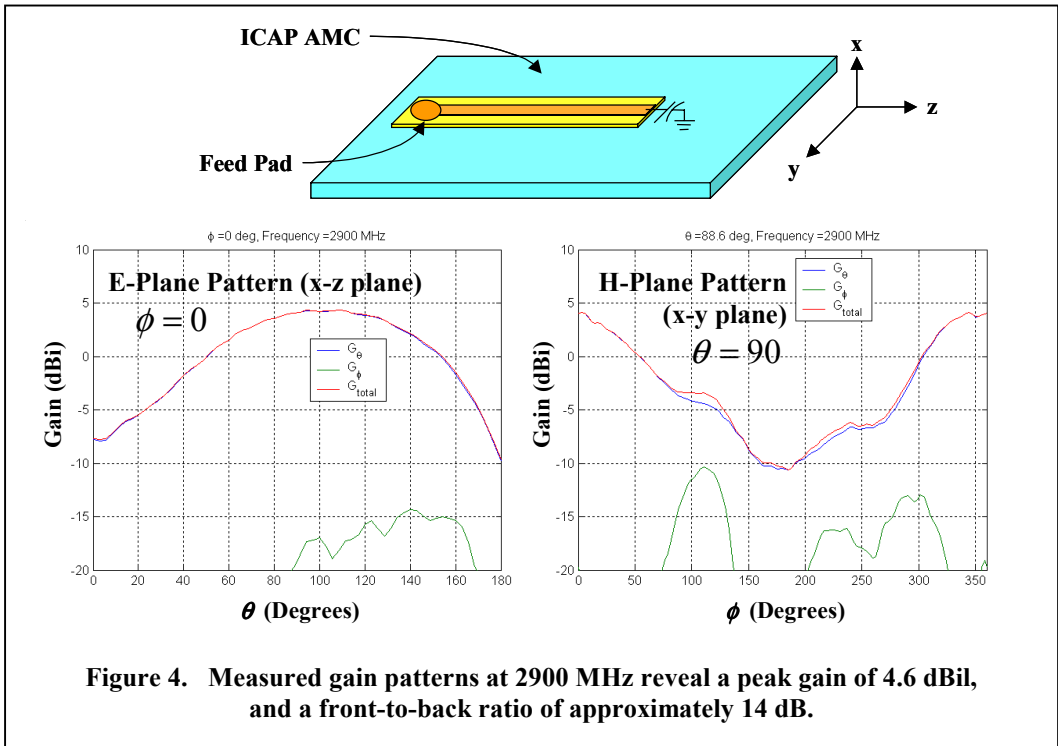


Figure 4. Measured gain patterns at 2900 MHz reveal a peak gain of 4.6 dBi, and a front-to-back ratio of approximately 14 dB.