Simulation of a Sievenpiper Artificial Magnetic Conductor using WIPL-D

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Abstract: Artificial Magnetic Conductors (AMCs) are a relatively recent invention [1,2,3], and hold significant promise in reducing antenna size, particularly thickness [4]. It is important to be able to simulate these complex structures accurately in order to better understand their behavior and improve their design. A Sievenpiper AMC [3] with a UHF dipole was designed, and WIPL-D [5] was used to model this structure. The simulated results were compared with S11 measurements on a prototype structure. WIPL-D returned results that predicted the resonance frequency and in-band behavior of the structure with high accuracy, and also showed some of the observed behavior at frequencies other than the main resonance.

Keywords: Artificial Magnetic Conductor, Sievenpiper, WIPL-D

1. Introduction

An artificial magnetic conductor, the structure of which was introduced by Dan Sievenpiper, et al. as a high-impedance surface [1,2,3], was used as the basis of this research. In close proximity to the surface of these structures, wire radiators have radiation and impedance properties similar to being near a magnetic conductor over a limited frequency range [4]. In its operating band, it is an electrically-thin, in-phase reflector with surface wave suppression [6]. This property makes it a promising candidate for decreasing the height required for a wire dipole radiator suspended over a ground plane, usually required to be ¼ wavelength to ensure constructive interference with the reflected wave.

In this research, we designed and built a Sievenpiper AMC that operated at a frequency of about 340 MHz.

2. AMC Design and Simulation

The basic structure of the AMC is a metal patch on the upper surface, connected with a shorting post in its center to a ground plane. In this design, we included lumped capacitors between adjacent metal patches on the upper surface to decrease the operational frequency of the structure.

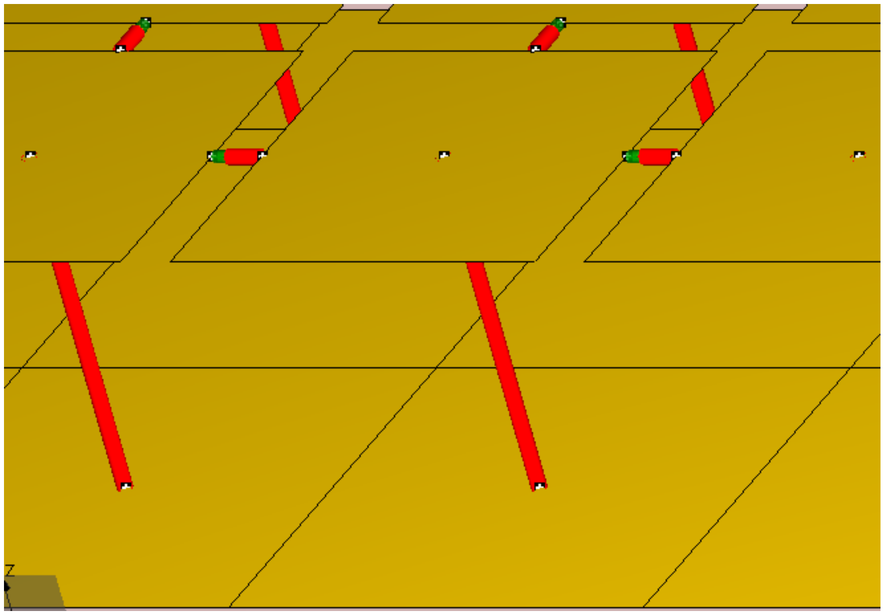

Figure 1. Close-up of AMC element

The specifics of the AMC design, particularly the patch dimensions, thickness, and capacitance, was created using proprietary tools. The complete structure is shown below.

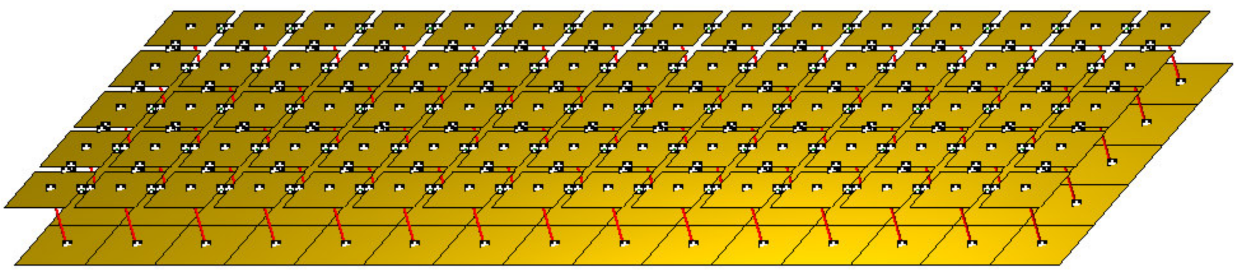

Figure 2. AMC structure

Each of the small white squares indicates a wire-to-plate junction. The small green dot on each wire connecting adjacent plates, shown in Figure 1, represents a capacitive load, which in this design was 12 pF.

Each patch was 0.990 inches square, with a height of 1.0 inches. The period of the array was 1.125 inches. The structure, as can be seen, was 15 patches long x 5 patches wide.

3. Simulation

The structure was simulated using WIPL-D. Only the metal structure was modeled—the dielectrics that were used in construction were considered to be irrelevant to its operation. A thin wire dipole, 13" long with wires 0.02 inches in diameter, was placed 0.1 inches above the structure to serve as the radiator, as shown in Figure 3. This dipole included a 70 nH inductor at the feedpoint to account for the effect of the balun.

A symmetry plane ran through the center of the model to reduce the number of unknowns. Note that the wires connecting the center patches, as well as the dipole, are in the plane of symmetry. We found that we needed to decrease the capacitance of the loads in the plane of symmetry by a factor of two, as it appeared the capacitance was doubled by the symmetry plane.

This model required only 1372 unknowns and 16.1 minutes to run 61 frequency points across the range of 100 MHz to 600 MHz using WIPL 6.4 and an Intel X9000 CPU running at 2.79 GHz.

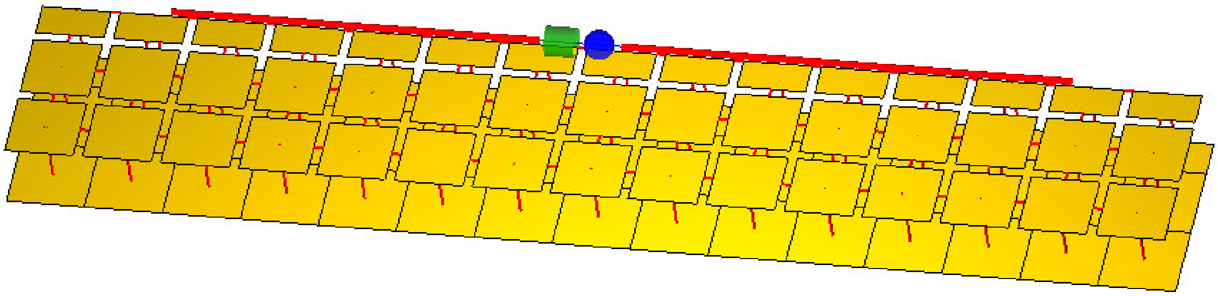

Figure 3. AMC structure with Dipole. Blue sphere on dipole is the generator, green cylinder indicates the 70 nH load to simulate the balun effect. For clarity, the junctions and plane of symmetry are removed and dipole wire radius is increased in the model shown.

4. Fabrication and Measurement

The AMC that was designed in this research was fabricated using metal patches on a thin FR4 substrate, metal shorting posts connected to a copper-clad FR4 backplane, and small lumped capacitors between patches. A photo of the AMC structure is shown in Figure 4, with the dipole laying on its surface.

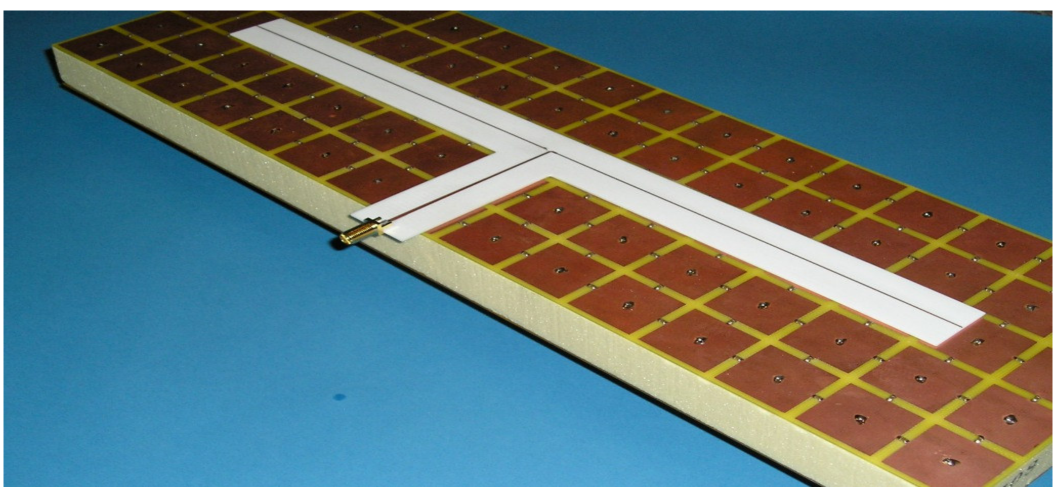

Figure 4 AMC with dipole antenna in WIPL-D

To check that the model of the dipole in free space is valid, a WIPL-D model of the dipole with the inductive load was run. The comparison of the simulation and measurement is shown in Figure 5, and shows very good agreement.

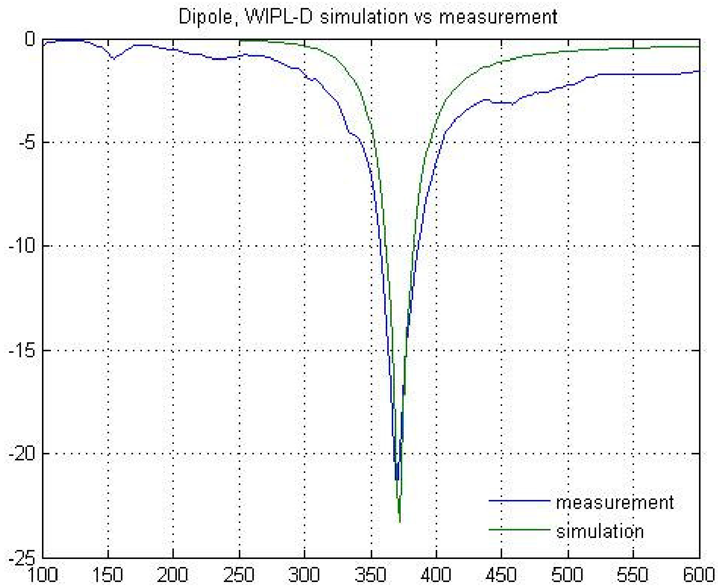

Figure 5. Comparison of modeled vs. measured return loss for 13" dipole in free space (WIPL-D)

The result of the full AMC model vs measured data are shown in Figure 6.

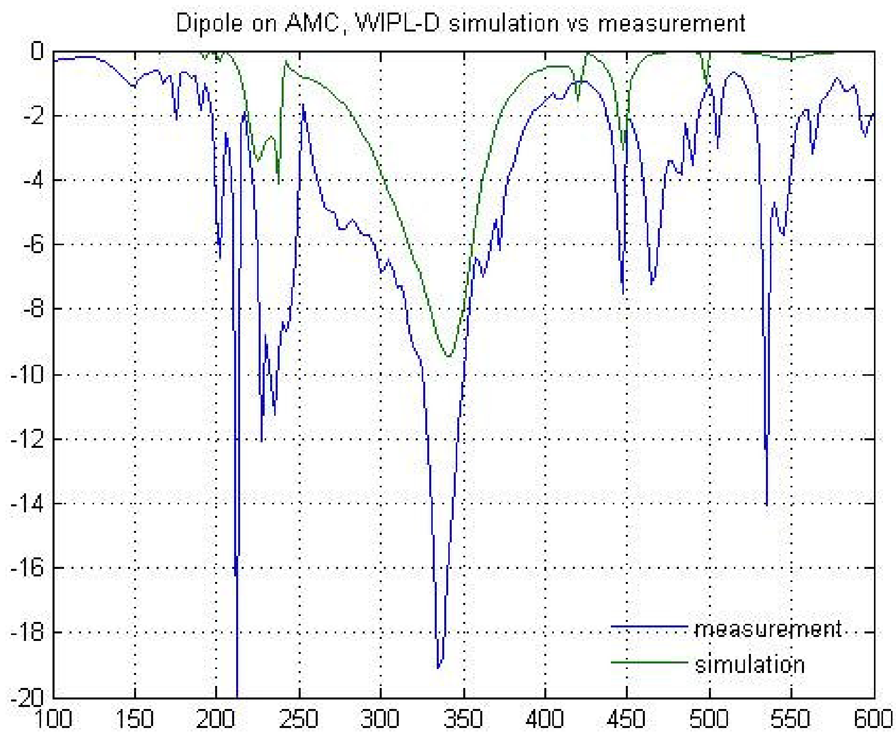

Figure 6. Comparison of modeling vs. measured return loss for AMC antenna for WIPL-D model

While the magnitude of the S11 parameter in the model is not exactly the same (the model is more conservative in its estimate of behavior), the overall behavior is very similar, including frequencies outside the resonance band of the dipole. This model also could be made more accurate to the AMC physical and electrical characteristics. For instance, it does not include extra meshing to include the edge effects of the plates, and the plates could be subdivided to provide a more accurate handling of the wire-to-plate junctions in the model. It also does not include any dielectrics, through the measured AMC material has thin sheets of FR-4. However, the behavior is sufficiently similar to be very useful for design, modeling the in-band behavior very well, and showing out-of-band characteristics also.

Conclusion

WIPL-D was used very effectively to simulate the AMC behavior. Not only was the resonance frequency correct, but some of the complex behavior out-of-band was also shown. In addition, the model was relatively easy to construct, did not require inclusion of dielectrics to give us these results, and required little finesse other than to properly scale the capacitors in the plane of symmetry. This gives us confidence that WIPL-D can be used as an effective design tool for these complex structures.

References

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