UHF SATCOM Antenna Using a Magnetically Loaded Artificial Magnetic Conductor

Frank A. Vassallo[1], *Member, IEEE* Kate J. Duncan[2], *Sr. Member, IEEE* Daniel T Bennett[2], *Sr. Member,* Juan C. Correa[3], Thomas P. Ketterl[4], *Member, IEEE and Thomas Weller[4], Sr. Member*
[1]TECOMSYS, Clearwater, FL,
[2]United States Military Academy, West Point NY
[3]Department of Defense, Baltimore MD,
[4]University of South Florida, Tampa, FL

Abstract – The use of Magnetically Loaded Artificial Magnetic Conductors (Mag-AMC) have shown promise in antenna size reduction and increased bandwidth. It is the intent of this paper to present a design approach using HFSS simulations whereby a multilayer Printed Circuit Board (PCB) stack up consisting of a radiating element, a High Impedance Surface (HIS) and magneto dielectric substrate reduces an antennas height from 9.5" to approximately 0.7".

Index: Magneto-Dielectric, Artificial Magnetic Conductor (AMC), UHF Planar Antenna, Antenna Size Reduction

I. INTRODUCTION

With the advent of multifunction, wideband, low cost Software Defined Radios (SDRs) there is a trend to place multiple radios within a portable platform (aircraft, ship or vehicle) for a multitude of reasons. Dedicated antennas are often required for each SDR, and the need for multiple antennas operating within a limited area poses a challenge for Antenna Engineers. The easy solution is reduce the SDR count or dual-use multiple wideband antennas while sacrificing performance. The more difficult challenge is to reduce the size of the antenna while maintaining its performance. Size reductions becomes particularly more challenging when targeting antenna systems in the High Frequency (HF), Very High Frequency (VHF), and Ultra High Frequency (UHF) frequency bands due to the large wavelength.

Two techniques have shown promise in reducing antenna size and volume. The first is the implementation of an AMC [2,3,6], which can consist of a specially designed Frequency Selective Surface (FSS), and/or a HIS structure that allows the antenna to be located closer to its ground plane. A properly designed AMC provides a 0 degree reflected phase shift from the radiating antenna, versus a 180-degree phase shift, typically seen by using a Perfect Electrical Conductive (PEC) ground planes. The second approach to antenna reduction is in the development and implementation of Magneto-Dielectric materials that further inhibit phase reflection and have shown to increase an antenna's bandwidth [8]. An ideal solution to maximize size reduction would be the optimization of both techniques with the more challenging task of developing a custom Magneto-Dielectric with the magnetic properties to complement the AMC approach. For the approach below, a planar array of square FSS is used as the HIS, and a material mix of Barium Cobalt Hexaferrite (Co2Z) with ε_r=10 and μ_r=10 are presented below.

II. MAGNETICALLY LOADED ARTIFICIAL MAGNETIC CONDUCTORS

A Properly designed Artificial Magnetic Conductor can fully reflect incident waves with a near zero degrees reflection phase [2]. This allows the incident wave to reflect back in-phase and provide constructive interference at distances much smaller than a quarter wavelength. Below, in Figure 1b, a HIS is shown in use as an AMC. Without the use of an AMC, the antenna would need to be physically located λ/4 (quarter wavelength) away for constructive interference to occur. Therefore, in terms of height above a ground-plane, using an AMC can reduce the overall height of an antenna for a given design. In addition to a near zero phase reflection, the AMC bandwidth must be considered. The useful bandwidth of an AMC generally defined as +/- 90^0 on either side of the central frequency, since these phase values would minimize the amount of destructive interference between direct and reflected waves [2].

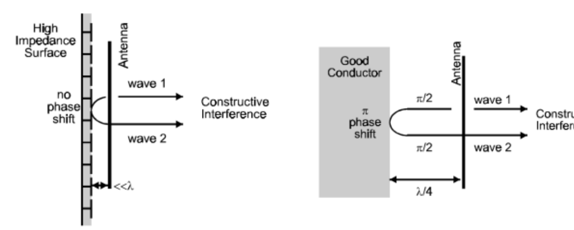

Fig. 1a/b AMC Ground plane, non-AMC ground plane [7]

Costas [4] assumes the FSS element is a pure capacitive element and derives the bandwidth of the HIS structure as the bandwidth of a parallel LC circuit:

$$\frac{BW}{\omega_0} = \frac{1}{R}\sqrt{\frac{L_{Substr}}{C_{FSS}}} \qquad (1)$$

Moreover, he concludes that an increase of the substrate thickness corresponds to a bandwidth enlargement due to the

The views expressed herein are those of the author and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

growth of the inductance value. Therefore, the use of a magnetic substrate would be a good strategy to further increase bandwidth [4]. Earlier research by Diaz [1] demonstrated an approach for bandwidth enhancement using a Co2Z in conjunction with an AMC. His conclusion was that using this Mag-AMC structure, it is then possible to build an antenna to instantaneously cover the Ultra High Frequency (UHF) Line of Sight (LOS) frequency band in a depth of about 1.5". The benefits of antenna size reduction, and bandwidth enhancement, are realized by examining the following real world example, which is the focus of this research. Figure 3a below is a standard UHF SATCOM "X-Wing" or turnstile antenna. This antenna operates in the UHF Frequency band of 240-320 MHz. It is constructed of horizontal dipoles located approximately λ/4 at a center frequency of 280 MHz, or approx. 10" above a ground plane. The antenna has an upward pointing hemispherical antenna pattern as shown in Figure 2b below.

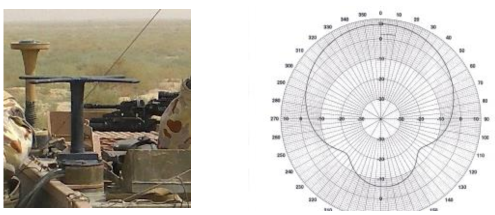

Fig. 2.a/b UHF SATCOM antenna and Antenna Pattern

III DESIGN APPROACH

The design approach to reduce the size of the standard X-wing antenna, is to model an antenna design using both a magneto dielectric, Barium Cobalt Hexaferrite (Co2Z) with properties of ε_r=10 and μ_r=10, and a High Impedance Surface (HIS) consisting of a planar array of square patches without vias, or a Mag-AMC structure. In addition, a stack up layer of dielectric was used to help for the lower frequency bands of operation. The initial design is shown below with an overall height of approximately 0.7" (1.8cm). The cross dipole (double bow-tie) antenna is located on top of the HIS and Magneto-Dielectric materials, with a bottom layer of FR4.

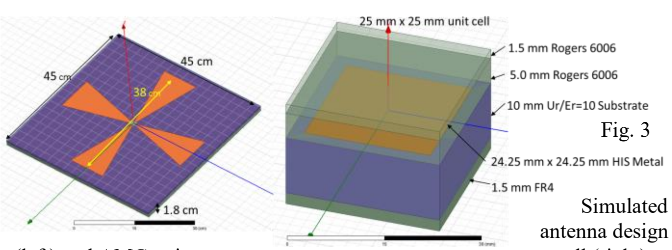

Fig. 3 Simulated antenna design (left) and AMC unit cell (right).

IV SIMULATIONS

Initial simulations show a 50% BW of the HIS unit cell, peak gain of 3.1dB. Additionally S_{11} is shown below, with and without the addition of the HIS.

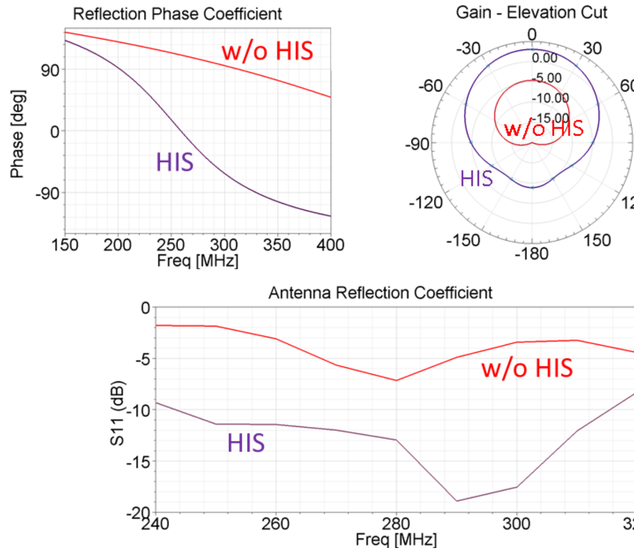

Fig. 4 UHF SATCOM antenna with HIS Reflection phase (top left), gain at 280 MHz (top right) and USF SATCOM antenna S_{11} (bottom); all show a comparison to identical antenna without AMS.

V. CONCLUSIONS

In this paper, we demonstrate size reduction of a cross dipole UHF SATCOM antenna using a Mag-AMC approach. Simulations show a wide bandwidth (50%), and a 92% size reduction. In the near future, the proposed antenna will be fabricated and tested against simulated results.

REFERENCES

[1] R. Diaz, V. Sanchez, E. Vaswell, and A. Miller, "Magnetic loading of artificial magnetic conductors for bandwidth enhancement," *IEEE Antennas and Propagation Society International Symposium*, Vol. 2, pp. 431-434, June 2003

[2] A.P. Feresidis, G. Goussetis, Shenhong Wang, J.C. Vardaxoglou, "Artificial magnetic conductor surfaces and their application to low-profile high-gain planar antennas," IEEE Transactions on Antennas and Propagation, V. 53, pp. 209-215, January 2015

[3] Leila Yousefi, Banharak Moajer-Iravani, and Omar M. Ramahi, "Enhanced Bandwidth Artificial Magnetic Ground Plane for Low-Profile Antennas", *IEEE Antennas and Wireless Propagation Letters*, Vol. 6, 2007

[4] Filippo costa, Simone Genovesi, Agostino Monorchio, "On the Bandwidth of Printed Frequency Selective Surfaces for Designing High Impedance Surfaces," Antennas and Propagation Society International Symposium, 2009. June 2009

[5] D. Singh, A. Kumar, S. Meena, and V.Agarwala, "Analysis of Frequency Selective Surfaces For RADAR Absorbing Materials, Progress in Electromagnetics Research B, Vol. 38, pp. 297-314, February 2012

[6] Nora Mohamed Mohamed-Hicho, Eva Antonino-Daviu, Marta Cabedo-Fabres, Miguel Ferrando-Bataller, "A Novel Low-Profile High-Gain UHF Antenna Using High-Impedance Surface, IEEE Antennas and Wireless Propagation Letters, Vo. 14, 2015

[7] D. Sievenpiper, "High-impedance electromagnetic surfaces." Ph.D. dissertation, UCLA electrical engineering department, filed January 1999

[8] Frank A. Vassallo, Kate J. Duncan, Orion Boylston, Adam Kratch, Daniel Bennett, Juan C. Correa, USNC-URSI Radio Science Meeting, pp. 93-94, 2016