A Broadband Open-Sleeve Dipole Antenna Mounted Above a Tunable EBG AMC Ground Plane

M. G. Bray* and D. H. Werner
The Pennsylvania State University
Department of Electrical Engineering
mgb144@psu.edu and dhw@psu.edu

Abstract: A broadband open-sleeve dipole antenna is mounted above a tunable Electromagnetic Bandgap (EBG) surface resulting in a low-profile narrowband antenna system that is tunable over an octave bandwidth. The EBG surface is composed of an array of square metallic patches connected via tunable capacitors over a thin PEC backed dielectric substrate. The capacitors tune the resonance of the surface down in frequency resulting in a low-profile antenna system that can be tuned from 1.2 GHz to 2.3 GHz with a relative thickness of only $\lambda/30$ to $\lambda/15$ at the lower and upper frequency limits respectively.

I. Introduction

The Electromagnetic Bandgap (EBG) surface has been used in recent years to mimic a Perfect Magnetic Conductor (PMC) over a finite frequency range for use as a ground plane in low-profile antenna configurations. This physical realization of a PMC, known as an Artificial Magnetic Conductor (AMC), is relatively narrowband leading to antenna configurations that are also narrowband. To extend the useable frequency range of an AMC, the reflection response of the surface can be tuned electronically using lumped elements. One such method is to take an EBG surface composed of a periodic array of metallic patches mounted on top of a thin PEC backed dielectric substrate and insert tunable capacitors (varactors) between the metallic patches [1,2]. Using this method, it has been shown that the first resonance of the EBG structure can be tuned down in frequency.

Previous work involving the placement of narrowband antennas, such as dipoles [3] and bent-wire monopoles [4], above AMC ground planes demonstrates that the best match of the antenna to the surface does not necessarily occur at the PMC condition of 0° . In such cases it was found that a reflection phase in the proximity of 90° or -90° usually results in the best match. In this paper a broadband linearly polarized antenna optimized via a genetic algorithm is placed above a tunable AMC ground plane. This antenna exhibits matches in both the 90° or -90° regions over an entire octave of tuning.

II. Antenna System Design

A microstrip version of the conventional open-sleeve cylindrical wire dipole [5] was used for a broadband linearly polarized antenna element. Figure 1 shows the geometry of the microstrip open-sleeve dipole placed in free space 5 mm above a tunable EBG surface. The tunable EBG surface consists of a 6x6 array of metal patches on top of a 3.6 mm PEC backed dielectric substrate with $\epsilon_r = 13$. Thin metal wires with a radius of 0.16 mm connect the metal patches with tunable capacitors located at the center of each wire.

The microstrip open-sleeve dipole was optimized in free-space without the EBG surface via a genetic algorithm to have the largest possible bandwidth centered around 2 GHz.

Figure 2 shows the return loss plotted versus frequency for this antenna in free-space. The return loss remains below 10 dB from 1.75 GHz to 2.35 GHz. Once the free-space antenna design was completed, an EBG surface with no loads was then designed to have its first resonance just above the upper frequency limit of the open-sleeve dipole. This allows for the EBG surface to be tuned through the entire frequency range of the antenna using capacitive loads. The placement of the antenna above the EBG surface was chosen by tuning the surface to 2.0 GHz and evaluating the return loss for several different antenna positions. A height of 5 mm was found to provide the best compromise between return loss and antenna system thickness.

III. Antenna Simulation and Analysis

The complete antenna system including the tunable EBG ground plane was simulated using the method of moments. To reduce simulation time, the ground plane and dielectric substrate were assumed infinite in extent so that a layered media Green's function could be employed. Figures 4 and 5 show the return loss of the entire antenna system (including the EBG AMC ground plane) in combination with the reflection phase of the EBG surface for several different capacitive loads. For comparison purposes, the reflection phase has the 10 dB bandwidth of the corresponding return loss superimposed on each curve. The antenna is tunable from 2.3 GHz down to 1.2 GHz resulting in an octave bandwidth. It is interesting to note that the best match for the antenna/EBG system occurs in the region from -100° to -150° at the upper frequency limit and then shifts up from 100° to 25° at the lower frequency limit. Figure 3 shows the E-plane (along the length of the dipole) and H-plane radiation pattern at 1.4 GHz and 2.0 GHz. The maximum gain at broadside is 7.73 dBi at 2.0 GHz and 6.27 dBi at 1.4 GHz.

IV. Conclusions

An optimized broadband open-sleeve dipole antenna is mounted above a tunable EBG surface resulting in a narrowband low-profile antenna system that is tunable over an entire octave. This low-profile antenna has a relative thickness which ranges from $\lambda/30$ at 1.2 GHz to $\lambda/15$ at 2.3 GHz, with a VSWR that is below 2:1 over the entire frequency range.

References

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Figure 1. Geometry of the Microstrip Open-Sleeve Dipole Over a Tunable EBG.

Figure 2. Return Loss of the Microstrip Open-Sleeve Dipole in Free-Space.

Figure 3. Radiation Patterns of the Open-Sleeve Dipole Over the Tunable EBG.

Figure 4. Antenna Return Loss and EBG Surface Reflection Phase.

Figure 5. Antenna Return Loss and EBG Surface Reflection Phase.