Design Synthesis of Fractal Antenna on Mushroom type AMC in the Vicinity of 2.4 Ghz

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Abstract- Artificial magnetic conductors (AMCs), also known as high-impedance surfaces, have received considerable attention in recent years. Artificial Magnetic Conductor surface is a kind of electromagnetic band gap (EBG) or artificially designed structure having a magnetic conductor surface for some particular frequency band. These engineered surfaces consist of a periodic arrangement of unit cells having specific metallization patterns. Two most important properties which make it suitable for low profile antenna applications are: In- phase reflection and Surface wave suppression. In the proposed work, Fractal antenna on Mushroom type AMC surface with vias and without vias is designed and simulated in IE3D version 14.62 electromagnetic software. After comparison of simulated results like Return Loss, VSWR and Directivity obtained using IE3D software of both types of AMC surfaces, it is found that Fractal antenna on AMC surface with vias is better as compared to AMC surface without vias. Hence Fractal antenna on AMC surface with vias is fabricated using a FR4 substrate. The designed Fractal antenna over AMC surface operates effectively at 2.4 GHz frequency with a bandwidth of 450 MHz which ranges from 2.3 GHz to 2.75 GHz. After fabrication of the Fractal antenna on AMC surface with vias the simulated results are tested using VNA (Vector Network Analyzer). After testing it is verified that simulated results and measured results obtained using VNA are in good match with each other.

Keywords – AMC (Artificial Magnetic Conductor), EBG (Electromagnetic Band gap Material), PEC (Perfect Electrical Conductor), PMC (Perfect Magnetic Conductor)

I. INTRODUCTION

In today’s world, communication technology becomes one of the most important branches of technical science and essentially changed the life of humankind. In telecommunication; electromagnetic waves are most frequently used to transmit information. The communication channel can be a wireless one (propagation in free space) or as wired one (waveguides, optical cables, co-axial cables etc.). The rapid increase in the need and demand for wireless technology in the recent years has driven the antenna designers to design new antennas that simultaneously appear miniaturized and at the same time useful for many wireless standards. Fractal technology is therefore used in the proposed work. Fractal geometries show properties like space filling, self-similarity and complexity in their design. It reduces the physical size of antenna, which makes it a good candidate for miniature antenna design.

Artificial Magnetic Conductor (AMC): - These engineered surfaces consist of a periodic arrangement of unit cells having specific metallization patterns. EBG have been proposed to enhance the radiation performances of printed antennas. At particular frequencies, they provide a zero-degree phase shift for reflected plane waves and effectively act as High Impedance Surfaces (HIS) [1].Since, their band-limited electromagnetic field behavior is quite similar to a hypothetical magnetic conductor; they are also referred to as artificial magnetic conductors (AMCs). AMC surfaces have been proposed to improve performance of many antenna configurations, such as dipoles and patches. AMC structure has a distinct property regarding its reflection phase. Reflection phase is the phase of reflected electric field on a surface relative to the incident phase. As is well-known, a perfect electric conductor (PEC) is a material that can exhibit 180 degree reflection phase. The theoretical opposite of PEC called as a perfect magnetic conductor (PMC) defined as a material that is naturally unavailable and can exhibit zero degree reflection phase relative to the incident wave [3].
Two important properties of AMC surfaces that do not available in nature and which led to a wide range of microwave circuit applications: -

[1] AMC surfaces have a forbidden frequency band which prevents the propagation of surface waves and currents making them useful as ground planes or waveguide type filters [2]. For example, antenna ground planes that use AMC surfaces as a ground plane shows good radiation pattern without unwanted ripples because of suppression of the surface waves in the band gap of frequency range.

[2] Second property of AMC surfaces states that these surfaces consists of a have very high surface impedance for a particular range of frequencies, where the tangential magnetic field is small, as compared to the large electric field along the surface. At these frequencies, they provide a zero-degree phase shift for reflected waves and effectively act as high impedance surfaces.

The rest of the paper is organized as follows. Design structure of the Fractal antenna on AMC surface without vias and with vias using IE3D software is explained in the section II. Fabrication of the proposed Fractal antenna on AMC surface with vias is discussed in section III. Simulation results and experimental results are presented in section IV. Concluding remarks are given in section V.

II. DESIGN

Artificial Magnetic Conductor (AMC) Design: Mushroom type AMC surface as ground plane for designing an antenna is used in a proposed work. This AMC surface is a arrangement of square metallic patches with a gap between each unit cell. Design specifications are given below: -

For AMC surface without vias and with vias:
- FR4 substrate height = 1.5 mm
- Dielectric constant = 4.4
- Loss Tangent = .02
- Overall size = 123mm ×123mm
- Unit Cell size = 30mm ×30mm
- Gap between each unit cell= 1mm
- Vias radius = 0.9mm
Fractal antenna Antenna design: Design specifications for the Fractal antenna design are given below. Designed antenna consists of three iterations; each iteration is a one-third of the previous iteration. Figure 2 (a) and (b) shows the designed Fractal antenna on AMC surface without vias and with vias.

- **FR4 substrate height**: 1.4 mm
- **Dielectric constant**: 4.4
- **Loss Tangent**: 0.02

Overall size of Fractal antenna = 30mm ×38 mm

Radius of first circle = 8mm

III. FABRICATION

After comparing all the simulated results like Return Loss, VSWR, and Directivity, it is found that Fractal antenna designed on AMC surface with vias is better as compared to the AMC surface without vias. Therefore Fractal
antenna over AMC surface with vias is fabricated using FR4 substrate. For AMC surface 1.5 mm substrate thickness and for antenna design 1.4 mm substrate thickness is used for fabrication. Vias are introduced in the AMC surface from top of the centers of each unit cell to the bottom of the ground plane through a conducting wire, in order to make conductivity between individual metallic patches. Figure 3(a) and (b) shows the top and bottom view of a fabricated Fractal antenna on Mushroom type AMC surface.

![Antenna Image]

**Figure 3.** Fabricated Fractal antenna on Mushroom type AMC with vias (a) Top View (b) Bottom View

**IV. RESULTS AND DISCUSSIONS**

**Reflection Phase of AMC:** As it is known that AMC surface has a property that reflection phase of Artificial Magnetic Conductor at one particular frequency is zero. So the reflection phase of AMC surface used for designing antenna over it has a reflection phase of zero degree at 2.4 GHz frequency.

![Reflection Phase Diagram]

**Figure 4.** Reflection Phase diagram of AMC surface

**Simulated S- parameter display :**
S-parameter results obtained after simulation shows that Fractal antenna designed on AMC surface with vias is better as compared to the Fractal antenna over AMC surface without vias. The Return loss is found to be -21 dB for AMC surface with vias having a bandwidth of 450MHz ranging from 2.3 GHz to 2.75 GHz.

Figure 5.  Simulated S-parameter plot for Fractal antenna on AMC surface without vias and with vias

Figure 6. VSWR plot for Fractal antenna on AMC surface with vias and without vias
VSWR obtained after simulation also shows that Fractal antenna on AMC surface with vias is better as compared to AMC surface without vias. VSWR obtained lies below 2 in the operating bandwidth and is found to be 1.24 at the frequency 2.4 GHz which is near to the idle value 1. Directivity results obtained after simulation shows that directivity of Fractal antenna designed on AMC surface i.e. 9.3 dB is better as compared to AMC surface without vias i.e. 8.8 dB.

**EXPERIMENTAL RESULTS**

After fabrication of Fractal antenna on AMC surface with vias, the simulated results are tested using Rohde and Schwarz vector network analyzer (VNA).
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The above shown measured results obtained from VNA are in good match with the simulated results. Return loss measured from VNA is -22.28 dB with a bandwidth of 450 MHz ranging from 2.3 GHz to 2.75 GHz. VSWR measured from the VNA also is in good match with the simulated results. VSWR measured using VNA is less than 2 in the operating frequency range.

V. CONCLUSION

In the proposed work Fractal antenna on AMC surface with vias and without vias is designed and simulated using IE3D version 14.62 electromagnetic software. The two unique electromagnetic properties of AMC surfaces i.e. in phase reflection and surface wave suppression allow antenna designer to make low profile antennas with superior performance as compared to conventional PEC ground planes. After comparison of simulated results of both designs, it is found that Fractal antenna on AMC surface with vias has better performance as compared to AMC surface without vias. Therefore Fractal antenna on AMC surface is fabricated using FR4 substrate. Vias are introduced in the AMC surface from top of the centers of each unit cell to the bottom of the ground plane through a conducting wire, in order to make conductivity between individual metallic patches. After fabrication of the fractal antenna over AMC surface with vias simulated results are verified using VNA (Vector Network Analyzer).

After measuring the results from VNA it is concluded that proposed antenna simulated results and measured results are in good match with each other. Obtained results shows that antenna operates effectively at 2.4 Gzh frequency with a bandwidth of 450 MHz ranging from 2.3GHz to 2.75GHz. This frequency range is used in many applications including Wi-Fi (2.4-2.48 GHz), Bluetooth (2.4 GHz), LTE (2.45 GHz) and WLAN (2.45 GHz). AMC structure used has many advantages like larger bandwidth, higher directivity, and good unidirectional radiation by alleviating the field cancellation effects observed in ground plane backed antenna configurations.

REFERENCE


