Design and Analysis of the Fractal Antenna over Mushroom Type AMC in the Vicinity of 2-5 Ghz

Sandeep Singh* and Chahat Jain**
*Post Graduate student, GNDEC Ludhiana, Punjab
ssmomi48@gmail.com
**Assistant Professor, *GNDEC* Ludhiana, Punjab
Chahatjain26@gmail.com

Abstract: Periodic metallic arrays act as AMC surfaces when positioned on a dielectric material and they provide a zero degree reflection phase to incoming waves**.** In-phase reflection and surface wave suppression are two vital characteristics of AMC which make it a perfect candidate for low profile antenna applications. In this paper, fractal antenna with AMC and without AMC is designed and simulated in the IE3D software. It is observed that the fractal antenna designed over AMC shows better VSWR characteristics, better return loss, better directivity and raises the impedance bandwidth upto 66% as compared to fractal antenna over conventional ground plane (without AMC). FR4 material is used for the fabrication of planned antenna. Designed antenna works effectively at three frequencies i.e. 2.15GHz with impedance bandwidth 167MHz (2.070-2.237GHz), 3.86GHz having impedance bandwidth of 261 MHz (3.736-3.997GHz) and 4.67 GHz having impedance bandwidth of 173MHz (4.610-4.783GHz). The fabricated antenna is tested for the specified bands using VNA. After testing it is confirmed that the simulated results and the measured results through VNA match with each other.

Keywords: Artificial magnetic conductor (AMC), Perfect magnetic conductor (PEC), Vector network analyzer (VNA), Voltage standing wave ratio (VSWR), Integral equation three dimensional (IE3D).

Introduction

With the quality of low profile, light weight, low cost, etc., microstrip antennas are commonly employed in radar, imaging, and wireless communication systems. Fractal shape is considerably sub-divisible in which each section is the replica of the basic geometry. The fractal shape increases flexibility of the antenna designs. It illustrates a branch of complex designs which have characteristics of self-similarity. Fractal geometry was established from brief study of various patterns of nature. Fractal shapes can be related with complex geometrical patterns of nature such as galaxies, clouds, trees, leaves and many other shapes. Fractional or integral dimensions are possible for fractal geometries . Fractal geometry is employed in various applications and fields such as image optimization, and also can be applied to create new type of antennas.

Though, normal microstrip antennas experience inherent less impedance bandwidth. Various methods have been developed to enhance the impedance bandwidth [1]. Mushroom-like AMC compositions are usually realized by using 2-D or 3-D periodic metallic structures. The local resonant behavior provides high-impedance reflectivity and prevents the propagation of radio-frequency surface waves along the structure [9–11]. traditionally, the mushroom-like AMC structures were widely employed as antenna substrates because their band gap features were revealed in two ways: the suppression of surface-wave propagation and an in-phase reflection to incident waves [9]–[14]. Suppression of surface-wave improves antenna performance by, for example, increasing antenna gain, increasing the impedance bandwidth, reducing back radiation [10–13]. The in-phase reflection coefficient facilitate the design of artificial magnetic conductors and low-profile antennas [10], [11], [14]. A good model of metamaterial-based broadband low-profile mushroom antenna was presented in [15], in which case the mushroom-like AMC compositions were utilized as antenna substrate.

In this paper, a circle inscribed rectangular fractal antenna integrated with square mushroom-like artificial magnetic conductor is proposed. The antenna made of two parts, i.e., a square mushroom type AMC structure consists of 8 unit cells arranged in a layout printed on a FR4 substrate, and a fractal antenna is placed over the AMC. The square mushroom array and the fractal antenna are placed together in direct contact. The three operational bands are produced by this design. Fractal antenna with AMC is compared with fractal antenna without AMC. Fractal antenna with AMC provides better performance. The simulated and measured results are in good match to verify the good performance of the proposed antenna.

Proposed Work

Design of AMC

The geometry of the proposed square mushroom-like AMC made up of of two parts: One is the mushroom-like square patch array with metal-plated vias, and the other is circle inscribed rectangular fractal antenna over AMC. To integrate the mushroom type AMC with the fractal antenna the co-axial feed is used in the proposed design. The parameters of mushroom structure are as follows: overall dimensions of AMC are 82×82mm. size of each unit cell is 19.75×19.75mm. Spacing between adjacent unit cells is 1mm. Height of the FR4 substrate is 1.5mm. The value of dielectric constant for antenna and AMC are 4.4 and 0.02 respectively. By using these parameters mushroom type AMC is designed and simulated in the IE3D software. Fig.1 shows the 2D and 3D view of of the proposed AMC and Fig2. shows the reflection phase of AMC.

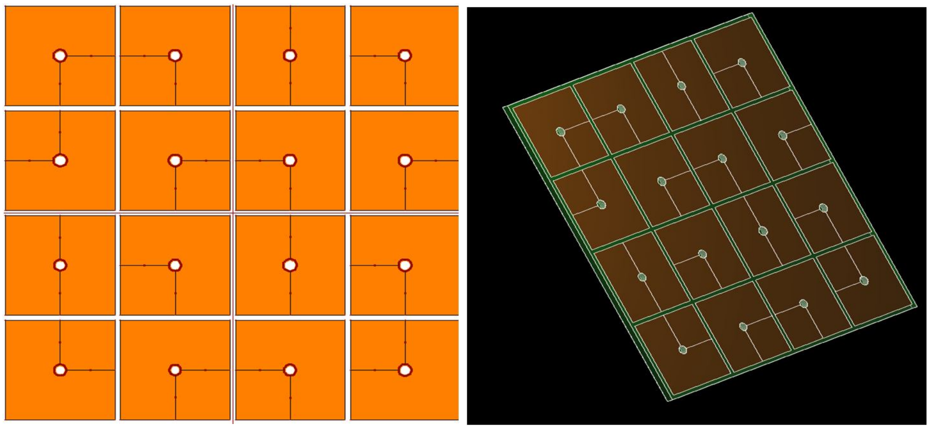

Figure1. 2D and 3D view of 4× 4 AMC surface with vias

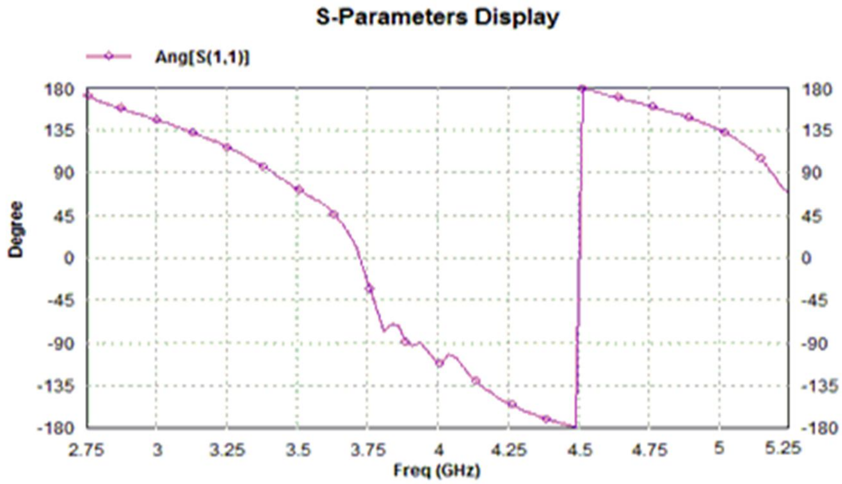

Figure 2. Reflection phase characteristics of AMC

Design of fractal antenna

After designing the AMC, circle inscribed fractal antenna is designed over conventional ground plane in IE3D and three iterations are done to design this antenna. Each iteration have the dimension half of the previous iteration. Fractal antenna is designed and simulated which have the resonant frequency matched with resonant frequency of AMC. The parameters for the fractal antenna are as follows: Dimensions of first rectangle are 24×29mm and radius of circle of first iteration is 9.4mm. FR4 substrate is used with height 1.5mm. Dielectric constant and loss tangent are 4.4 and 0.02 respectively. When this antenna is simulated in IE3D it operates at two resonant frequencies 2.24GHz and 3.42 GHz which provides overall impedance bandwidth 200MHz. Fig.3 shows the 2D and 3D view of the fractal antenna.

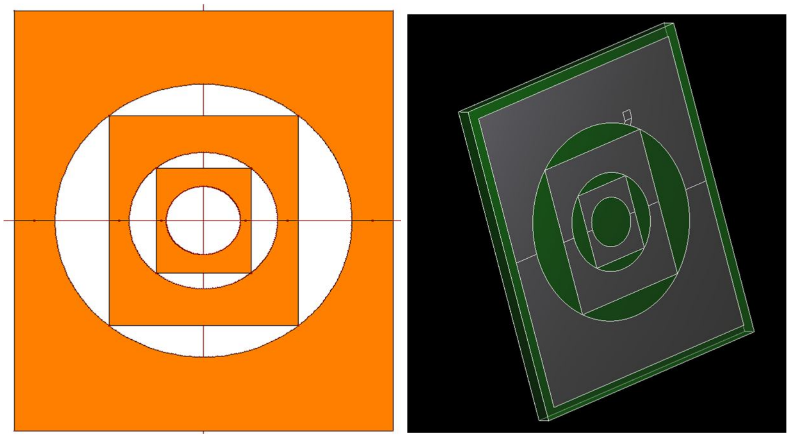

Figure 3. 2D and 3D view of conventional fractal antenna

Design of fractal antenna over AMC surface

Fractal antenna with same dimensions and parameters as listed above, is placed over the designed mushroom like AMC which acts as the ground plane for the antenna which suppresses the surface waves and provide in phase reflection in specific frequency band which is called band gap. These properties of AMC make the performance of fractal antenna better as compared to the fractal antenna without AMC. The overall thickness comes to be 3mm and all other parameters remain unchanged. By using AMC the performance parameters like return loss, directivity and impedance bandwidth are improved which increases the performance of the fractal antenna. Fig.4 shows the 2D and 3D view of the proposed fractal antenna.

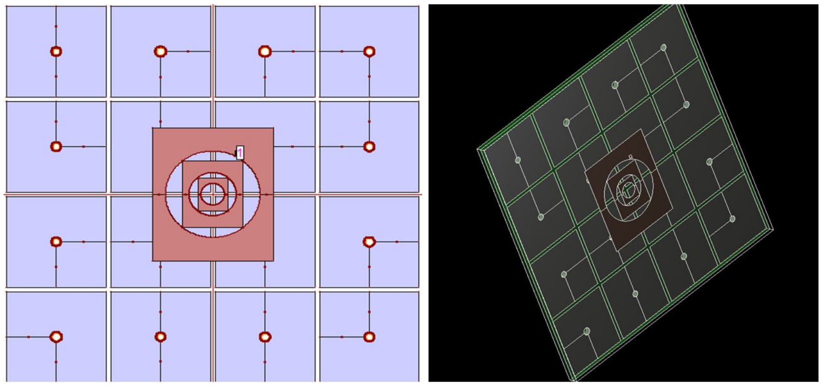

Figure 4. 2D and 3D view of fractal antenna over AMC

After simulation the proposed antenna with AMC resonate at three frequencies which provides total impedance bandwidth of 601MHz which is increased by 66% as compared to fractal antenna over conventional ground plane.
After getting the simulation results prototype of simulated antenna is fabricated by using FR4 substrate with specified parameters as mentioned above. Fabricated antenna is tested by using VNA (vector network analyzer). Fig.5 shows the fabricated antenna.

Results

Comparison results of fractal antenna with AMC and fractal antenna without AMC

The designed antenna over AMC resonate at three frequencies 2.15GH, 3.86GHz and 4.67GHz and having impedance bandwidths of 167MHz, 261MHz and 173MHz respectively. The return losses calculated for 2.15GHz, 3.86GHz and 4.67GHz are -22.50dB, -25.83dB, -20.07dB. For fractal antenna with AMC the values of directivity for three resonant frequencies 2.15GHz, 3.86GHz and 4.67GHz are 7.62, 8.19 and 7.02 respectively. It is verified that the simulated results like return loss, impedance bandwidth and directivity of fractal antenna with AMC are better as compared to fractal antenna without AMC or fractal antenna with PEC surface. Fig.6 shows the comparison of return losses of fractal antenna with AMC and fractal antenna without AMC. Fig.7 shows comparison of directivities of fractal antenna with AMC and fractal antenna without AMC .

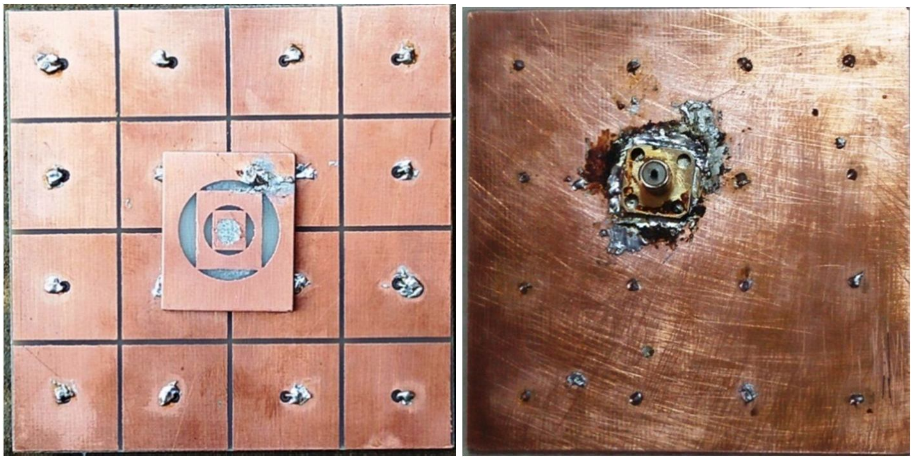

Figure 5. Fabricated Fractal antenna on Mushroom type AMC

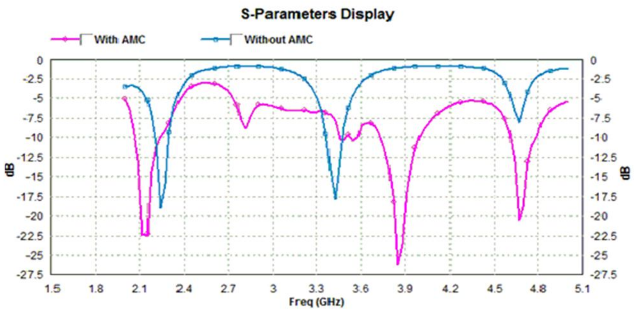

Figure 6. Return Loss of fractal antenna with and without AMC

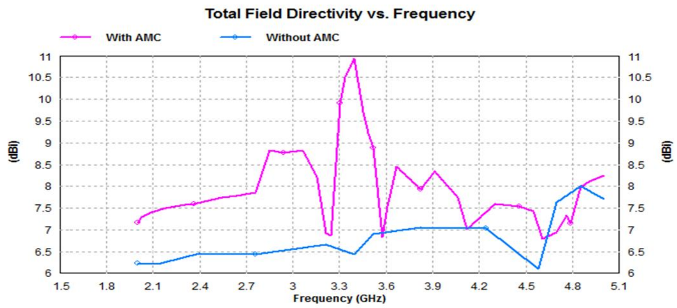

Figure7. Directivity of Fractal antenna with and without AMC

Table 1. Comparison of design parameters of Fractal antenna

Design Parameters	Fractal Antenna Without AMC		Fractal Antenna With AMC		
Resonant Frequency in GHz	2.24	3.47	2.15	3.86	4.67
Reflection Coefficient S11	-17.74	-17.49	-22.50	-25.83	-20.07
Directivity	6.31	6.54	7.62	8.19	7.02
Impedance Bandwidth in MHz	95	105	167	261	173

When fabrication is done then the Fractal Antenna over the AMC is tested with the use of VNA. It is confirmed that simulated results are in good match with measured results of VNA.

Table 2. Comparison of simulated and measured results of fractal antenna over AMC

Design Parameters	Simulated Results			Measured Results		
Resonant Frequency in GHz	2.15	3.86	4.67	2.19	3.83	4.62
Reflection Coefficient S_{11}	-22.50	-25.83	-20.07	-19.16	-26.28	-22.28
Impedance Bandwidth in MHz	167	261	173	220	180	205

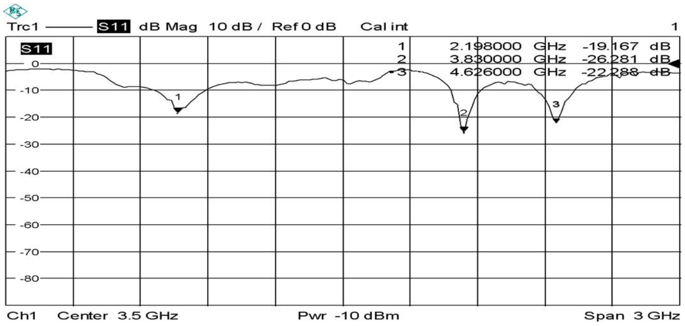

Figure 8. Return loss measured by VN

Conclusion

Fractal antenna over the Artificial Magnetic Conductor (AMC) surface and without AMC i.e. conventional PEC surface is modelled and simulated with the help of IE3D software. Two sole specifications of the Artificial Magnetic Conductor like reflection in phase and suppression of surface waves which allow us to compose low profile antennas with better performance compared to the conventional PEC as ground planes. After the design of the fractal antenna on the AMC surface the results obtained by simulation for eg. Return loss, Directivity and are related with the fractal antenna on conventional PEC plane. It is observed after simulation results that the performance of fractal antenna is better as compared to Conventional fractal antenna. Simulation results are confirmed by using VNA after the fabrication of fractal antenna over AMC. . The designed antenna works effectively at three frequencies i.e. 2.15GHz with impedance bandwidth 167MHz (2.070-2.237GHz), 3.86GHz having impedance bandwidth of 261 MHz (3.736-3.997GHz) and 4.67 GHz having impedance bandwidth 1of 173MHz (4.610-4.783GHz). In future by using many optimization algorithms the optimization of the antenna over the AMC can be done. Other Antenna structures and other feeding techniques can be used. Hybridized AMC structures can be analyzed.

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