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A Novel 2D Sierpinski Gasket Electromagnetic Band Gap Structure for Multiband Microstrip Antenna

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1. Introduction

Surface waves appear in many situations involving antenna. Also described as surface current, they occur on the interface between two dissimilar materials, such as metal and free space. They are bound to the interface and decay exponentially into the surrounding materials. Their existence causes degradations in the radiation patterns of the particular antenna, especially microstrip antennas. Surface waves radiates from the edges of the ground plane causing ripples in the antenna patterns and radiation in the backward direction. This situation is exacerbated when the substrate is electrically thick or it has a high dielectric constant [1]. An antenna with less or without surface waves should produce a smoother radiation profile and less power wasted in the backward direction due to their reduction of side lobes and back lobes [4][5][6][7]. This includes improved gain, more coverage distance with the same amount of energy usage, more directionality which leads to improved systems' performance, electrically.

In this research, the authors propose a 2D single layered high impedance surface Sierpinski EBG structure that exhibit more than one 'band gaps' characteristics that can be incorporated with a planar fractal or multiband patch antenna. An initial numerical design was done using user friendly but advanced CAD software i.e. the microwave office 2006. After the optimal design was confirmed, models of these structures was developed and constructed on an inexpensive Fire Retardant-4 (FR4) board, using wet etching techniques. The EBG structures were simulated and measured using the method of suspended microstrip recommended by [2] and their results were validated and found to be correlating well.

2. Miniaturaization through Fractalization Technique

The non-electrical characteristics of the particular antenna should be taken into consideration because with the additional parasitic elements such as the EBG structure, means adding additional space and size. One possibility to design a miniaturized multi band-gaps EBG structure is to use fractalized periodic structures [3]. Applying fractals techniques to EBG structure/elements and arrays will also allows for smaller compact structure and further more, they are multiband/broadband. So, this interesting future of fractal characteristics is a good potential area for further investigation and application on EBG structures. Hence, the analysis and design of fractalized EBG structure is important, especially for miniaturizing the size of the overall structure of the antennas and for usage with multi frequencies application and systems.

3. The Design and Construction

High-impedance electromagnetic surfaces have been studied by Sievenpiper [1]. In his approach, high-impedance surfaces (in general) consist of a lattice of metal plates, connected to a solid metal sheet by vertical conducting vias. In this paper, novel high impedance fractalized Sierpinski Gasket surface structure was introduced to produce a dual band gaps and as a means to suppress surface

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waves effectively. The one layered Sierpinski Gasket EBG structure possesses multi band-gaps and has been simulated using the microwave office 2006 method of moment techniques.

The configuration of the proposed Sierpinski Gasket EBG structure is shown in Fig. 1 below. The design detail consists of a one layer substrate; printed on FR4 board of thickness 1.6 mm. Gray parts in this figure represent the metallic periodic structure, which is etched on a dielectric substrate. The main element of this EBG lattice is fractalized to the 1'st iteration to introduce the second band gap.

Two of the four triangular (0'th and 1'st iteration of the Sierpinski) patches are connected to the solid lower ground plane by a metal plated via. The length of the 0'th iteration triangular patch is 12mm and the base is 17 mm and those 1'st iteration (three) smaller patch lengths are 6mm respectively and their bases are 8.5 mm each. The distance between the adjacent patches (0'th and 1'st iteration patches) is 0.75 mm. The period of the lattice is 1mm apart. Additional capacitance is formed between the neighbouring edges /sides of the triangular patches. Increasing or changing the position of the vias, embedded in the patches, will change the value of the inductance.

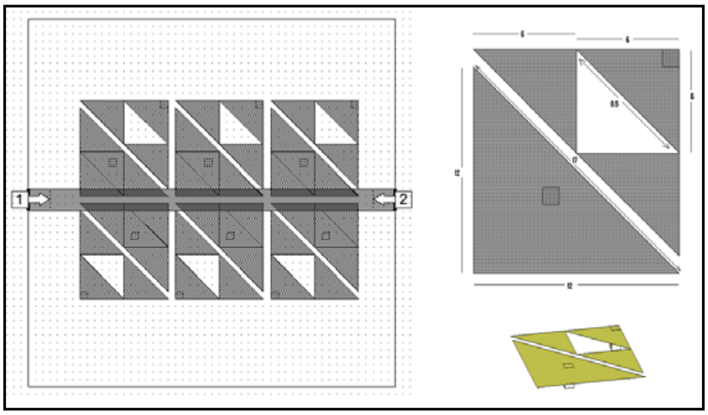

Figure 1: The geometry of the Sierpinski Gasket EBG Structure

4. Results and Discussions

A demonstration of 2 x 3 Sierpinski Gasket EBG patch array has been simulated, fabricated, and measured. The method of suspended microstrip as recommended by [2] was applied to measure the band gap characteristics of the Sierpinski Gasket EBG structure. The measured EBG material is inserted between the microstrip and ground, forming a sandwich-like structure. The suspended microstrip is soldered with subminiature A (SMA) connectors to measure the parameters.

In simulation, the array is built on a 1.6mm-thick substrate with the relative permittivity of 5.4. During fabrication process, extra precaution must be taken when drilling the vias' holes because a small shift might change the inductance values thus affect the measured results. For mass production purposes, the usage of automated and precision controlled machines will take care of this problem. Thus, in this design, the EBG structure works at a lower frequency, which usually needs a larger size of conventional EBG structures.

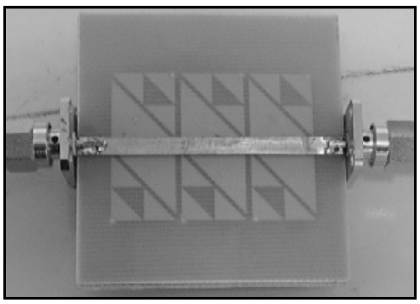

Figure 2: The fabricated Sierpinski EBG structure ready for S_{21} measurement test.

In fabrication, the distance between the microstrip line and the EBG surface is 0.5 mm. The size of the FR4 board is 50 by 50mm², as shown in Fig. 2 above. Agilent 8722ES, an S Parameter Network Analyzer as shown in figure 3 below, was used to measure the forward-transmission coefficient, S_{21}.

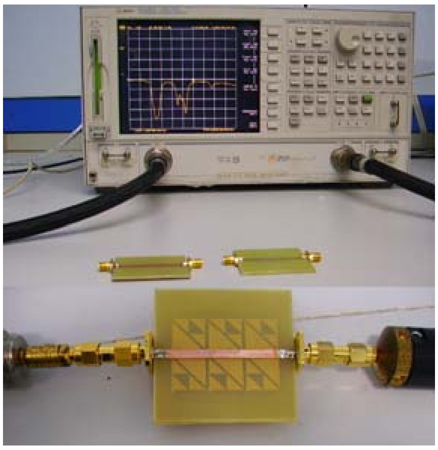

Figure 3: Forward-transmission coefficient S_{21} measurement using the Agilent 8722ES, an S Parameter Network Analyzer.

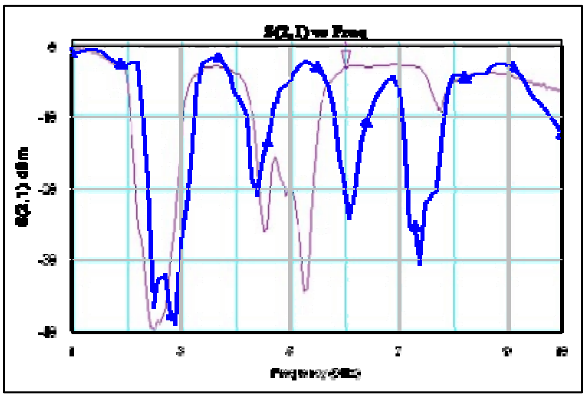

Figure 4: Simulated and measured S_{21} results of the Sierpinski Gasket EBG.

From the simulated and measured results shown in figure 4 above, the distinctive stop bands can be observe, starting with the simulated one, with their central frequencies of 2.725 GHz, 4.35 GHz, 6.1 GHz and 7.5 GHz and . The frequency range with S_{21} below -20dB extends from 2.35 GHz to 3.1 GHz, 4.34 GHz to 4.35, 6.0 GHz to 6.2 GHz and 7.1 GHz to 7.6 GHz, whereas from the measured results, the frequency span starts from 2.1 GHz to 2.9 GHz, 4.35 GHz to 4.6 GHz and 4.85 GHz to 5.35 GHz with their central frequencies of 2.5 GHz, 4.475 GHz and 5.1 GHz respectively. It was also observed that the shape of the simulated and measured waves shows multi band-gaps characteristics, although their reading points vary a little. Our next step is to incorporate this structure with a particular multiband (ISM bands) microstrip antenna to investigate the effect it will have on the antenna's 'electrical' performances.

5. Conclusion

An initial novel Sierpinski Gasket High Impedance EBG structures, based on two dimensional fractalized structure technique incorporated with vias have been produced. The EBG structure was fabricated by etching a single side of a unitary metallically clad FR4 dielectric and measured using the method of suspended microstrip. This EBG structure which possess multi band-gaps' characteristics, act as a means to suppress the surface waves of a multiband microstrip antennas' effectively, thus should improves the performance of the antenna.

Acknowledgment

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