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Performance Improvement of Microstrip antenna using Fractal EBG structure and vias

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Abstract: *This paper investigates the effect of fractal EBG structure on performance of Microstrip antenna. It also studies the effect of vias (Connection from EBG center to ground plane) on performance of antenna. EBG structure is designed with 2 iterations considering the square shape of unit cell. The results show that the bandwidth of MSA with EBG structure with vias antenna is increased by 1.125% over MSA without EBG structure. Also S_{11} is decreased a-4.188dB for MSA with EBG structure with vias. Also back radiations are decreased due to use of EBG structure with vias.*
Keywords: *Electronic Band gap structure (EBG), Bandwidth, Vias.*

I. Introduction:

Modern communication requires low profile and smaller antennas. Important considerations for antenna designers of compact high data rate wireless communications systems are wideband performance and antenna size reduction. Microstrip antenna is popular for light weight, small size and planar characteristics [1-2]. The Microstrip antennas are used for Personal Digital Applications (PDA), laptops for Wi-Fi, Wi-max etc. A typical antenna consists of antenna element and the finite ground plane. The ground plane resolves two purposes-To redirect the back radiations ii) To shield the antenna.

Both antenna element and ground plane are made up of perfect conductive materials (PEC).

Antenna size reduction can be done by the reduction of ground plane size, given that limited area available on the platforms. Such reduction means an increase in antenna backward radiation. Further, Perfect electric conductor ground planes tend to give phase reversal to incident currents casing the destructive interference between original and image currents. This can be avoided if ground plane and antenna are placed quarter wavelength apart which makes the antenna bulky at low frequencies. Again, for larger sizes, a normal conducting metal ground plane allows for surface wave propagation, which also contributes to backward radiation via edge diffraction.

Moreover the widespread use of wireless devices, together with the requirement to fit them in ever smaller packages, places radiating antennas in close proximity to sensitive electronic and biological systems. As a result the antenna design faces the competing requirements of maximum radiated gain with minimized near-field coupling to the environment. In traditional Microstrip Antenna , the ground surface is made up of conducting material (Perfect Electric Conductor). The active patch element is placed above this ground surface and dielectric layer is present between them. When the antenna radiates, some radiations are incident on conductive ground surface. The ground surface reflects the radiations with phase reversal (180^0) with respect to incident radiations. Then incident and reflected radiations cancel each other which reduce the overall efficiency of antenna. Therefore a new kind of ground surface can be developed which will suppress the propagation of radio frequency surface current (reflections from ground surface).The surface has the property of providing partial isolation between radiating element and surrounding surface. Textured ground surface is new kind of modification to make antenna compact and increase directivity of Microstrip antenna. There are different forms of textured ground surface which includes, EBG (Electronic Band Gap) structure, HIS (High Impedance Surface), PBG(Photonic Band Gap), AMC (Artificial Magnetic Conductor),FSS (Frequency Selective Surface) etc. These surfaces can be realized by array of metal protrusions on a flat metal sheet which are arranged in a two-dimensional lattice, and can be visualized as mushrooms or thumbtacks protruding from the surface[1]. The protrusions are formed as metal patches on the top surface of the board. These patches are connected to ground plane with vias(conducting wires from metal protrusions to ground plane.)In this paper, Electronic Band Gap structure is designed , fabricated and studied along with Microstrip patch antenna for improvement in antenna parameters.

II. Design of EBG cell and structure:

EBG structure is periodic metal patches(which are also called as unit cell)placed on the dielectric layer. The shape of cell can be regular or irregular. In this paper, fractal shaped cell is designed for better directivity and bandwidth. The Microstrip patch is surrounded by EBG cells.

In this paper the Microstrip antenna at 2.4 GHz is designed and its length and width are optimized. Microstrip antenna is feed using coaxially feed in which feed location is optimized for impedance matching. The substrate layer is FR4 dielectric material (εr = 4.4) with dielectric loss tangent (tan δ) of 0.02.
The EBG structure is fractal shape of square element.

Figure 1 shows the geometry of unit cell of EBG which is based on fractal shape. A square of 3mm x3mm is considered and it is cut along four corners with squares of 2mm x 2mm which is second iteration. In third iteration, squares of 1 mm x 1mm are used to cut the corners of 2 mm x 2mm squares. A shape of unit cell shown has the footprint of 6mm x 6mm.

The ground surface of PEC of 80mm x 90mm is considered and a substrate layer of height 1.6 mm is placed on ground surface. Two dimensional structure of EBG cells of 11 x 12 unit are etched on substarte layer. On the same layer , the micro-strip patch is also etched at the centre. The dimensions of Micro-strip patch are 28 mm x37mm.

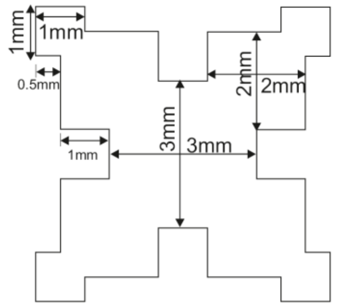

Fig.1 EBG Unit cell structure

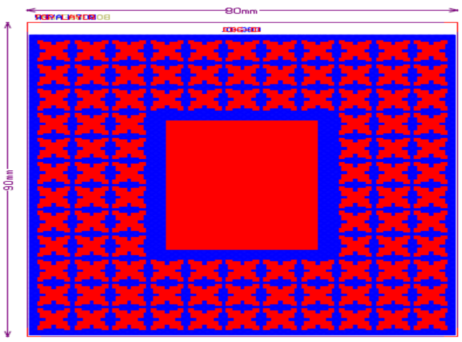

Figure 2 Top view of Microstrip Antenna with EBG structure without vias

Figure 2 shows the Microstrip antenna with EBG structure without vias.The Microstrip antenna is designed with vias (PTH at the centre of each EBG cell which is the connection from plane of micro strip patch to the ground surface). Figure 3 shows the top view of designed antenna with EBG structure with vias.

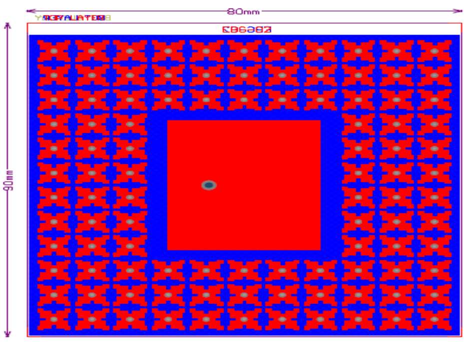

Figure 3 Top view of Microstrip Antenna with EBG structure without vias

Each EBG cell in antenna acts a low pass filter where the gap between two consecutive cells acts as capacitor and the thickness of substrate layer acts as inductance. Fig. shows the representation of filter.

The fractal shape makes different gaps between inner squares and outer 2 squares and so there are different values of capacitances present between the gaps. The equivalent circuit can be shown in figure 4.Figure 5,6 and 7 show photographs of fabricated antennae.

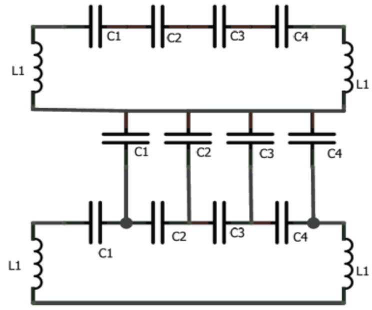

Figure 4 Equivalent circuit for Fractal EBG cell

III. Testing & Measurements of Antenna

Figures 5, 6 and 7 show the photographs of fabricated antennae**.**

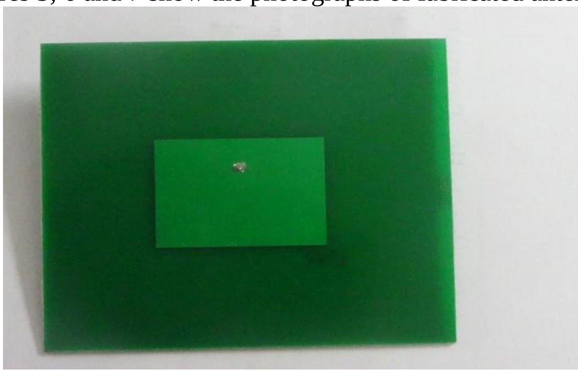

Figure 5 Photograph of Fabricated Microstrip antenna

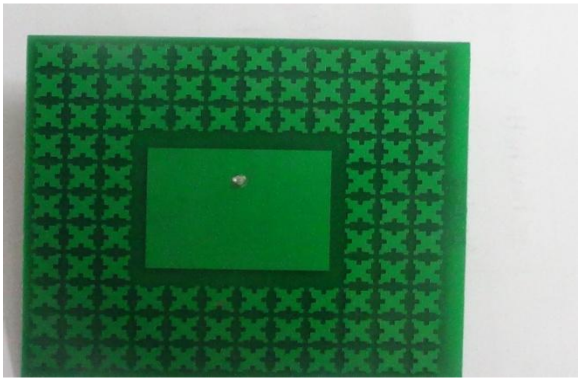

Figure 6 Photograph of Fabricated Microstrip antenna with EBG structure without vias

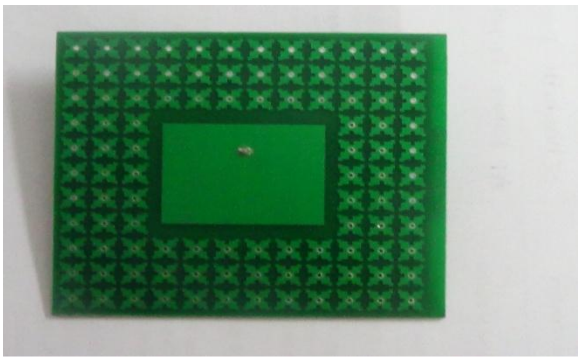

Figure 7 Photograph of Fabricated Microstrip antenna with EBG structure with vias

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The Microstrip antenna with and without vias are tested using Vector Network Analyzer for S_{11} and SWR. For measurement, R&S®ZNB Vector Network Analyzer was used with frequency span 1 GHz to 3 GHz. These antennae are tested using antenna measurement system and parameters like directivity, radiation pattern were found out, front to back ratio, XPD levels have measured and compared.

IV. Results and discussion:

Figures 8,9 and 10 show the radiation patterns of Micro strip antenna , Microstrip antenna with EBG structure and Microstrip antenna with EBG structure with vias.

From the patterns, it is observed that the back radiations are removed for Microstrip antenna with EBG structure with vias. The cross polarized radiation patterns also measured for these antennae.

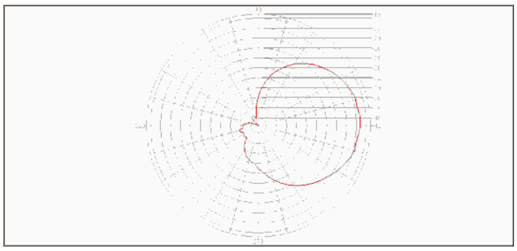

Figure 8. Radiation pattern for Microstrip antenna without EBG structure

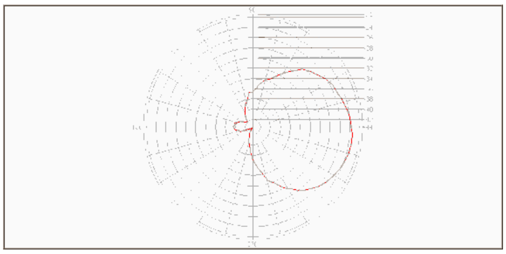

Figure 9 Radiation pattern for Microstrip antenna with EBG structure without vias

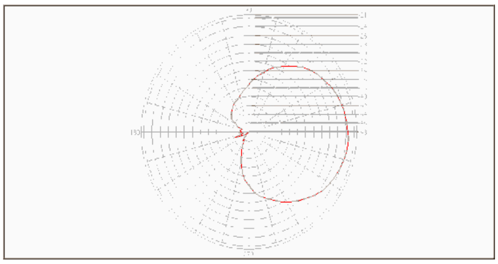

Figure 10 Radiation pattern for Microstrip antenna with EBG structure with vias

. Figures 11,12 and 13 show the SWR graphs vs frequency. The SWR values are closer to unity all three antennae.

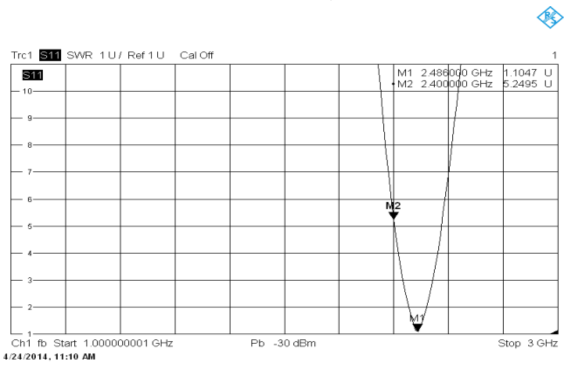

Figure11 VSWR vs Frequency graph for Microstrip patch antenna without EBG

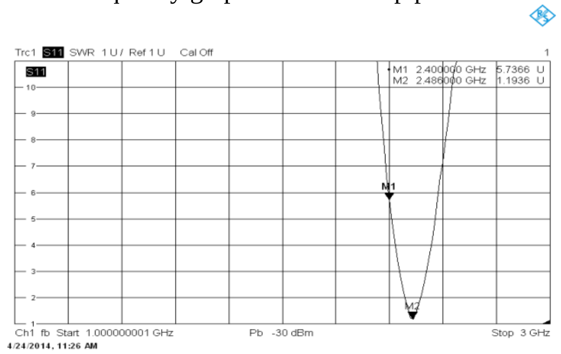

Figure 12 VSWR vs Frequency graph for Microstrip patch antenna with EBG structure without Vias

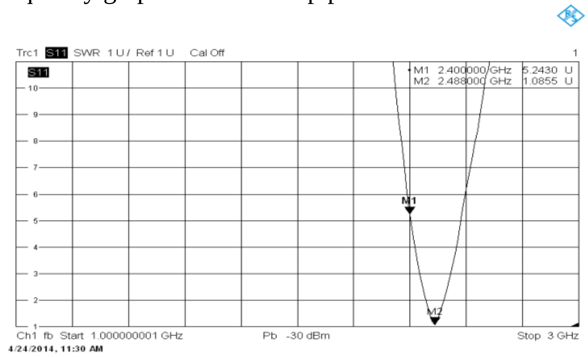

Figure 13 VSWR vs Frequency graph for Microstrip patch antenna with EBG structure with vias

The SWR values are also maintained closer to unity for designed antennae. Microstrip antenna with EBG structure with vias has SWR value closest to unity out of three antennae.

Parameter	**Microstrip antenna without EBG structure**	**Microstrip antenna with EBG structure without vias**	**Microstrip antenna with EBG structure with Vias**
VSWR	1.1047	1.1936	1.0855
Impedance bandwidth	32 MHz	53 MHz	59 MHz
Reflection loss S_{11}	-25.255 dB	-20.745 dB	-29.443 dB
Gain	10.48 dB	9.34 dB	9.44 dB
Directivity	10.82dB	11.06 dB	12.47 dB
HPBW	75.6^0	81^0	75.6^0
FNBW	151.2^0	162^0	151.2^0
Front to back ratio	17dBm	15.75 dBm	22.87dBm
XPD level	-20.8075	-24.1582	-12.3402

Table 1 Comparison of parameters of antenna

V. Conclusion

This paper outlines new type of fractal EBG structure with 2 iterations of square shaped unit cell. The bandwidth of MSA with EBG structure with vias antenna is increased by 1.125% over MSA without EBG structure. Also S_{11} is decreased a-4.188dB for MSA with EBG structure with vias. VSWR is maintained around unity resulting into better radiation and minimum reflection loss. VSWR is closer to unity for Micro-strip antenna with EBG structure with vias. Back-lobes are reduced up-to 22 dB using micro-strip antenna with EBG structure with vias. Directivity is increased by 1.62 dB using EBG with vias and 0.24 dB using EBG without vias wrt to Microstrip antenna without EBG structure.

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