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Miniaturization of Conformal Equilateral Patch Antenna Using EBG for Satellite Application

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***Abstract* — The microstrip antenna is small in size, light in weight, with the ability to be conformed on to the curved surface. The structure can be cylindrical, spherical, prism, etc. Since, the cylindrical geometry can offer certain desirable antenna characteristics that are not provided by planar elements. Also, they have good potential for application in aerospace vehicles with excellent aerodynamics. This paper proposes the design of miniaturized conformal equilateral patch antenna using EBG. EBG [1] are periodic objects that assist the propagation of EM waves in a specified band. In this way, this improves the return loss, radiation performances and bandwidth. The patch is fed through microstrip line. The proposed antenna operates at 1.28 GHz. Modeling and simulation of antenna has been carried out using CST Studio Suite™ 2010[2]. Return loss of -38.12 dB with VSWR 1.02 with bandwidth is 41.51 MHz.**

***Index Terms*—Conformal patch antenna, CST Studio Suite 2010, EBG, Microstrip feed, Return Loss, Taconic TLT-0, VSWR.**

I. INTRODUCTION

Antennas are the most important devices to transmit electromagnetic waves through the space from source to destination. Microstrip antennas are often used because of their thin profile, light weight and low cost. Furthermore, they can be made conformal to the structure. A conformal antenna has to conform geometrically to some shaped surface, like that on an aircraft, rocket or a smaller flying platform. The attachment to surface is may be due to reasons of payload space limitations, for aerodynamic reasons, where the antenna shape has to adapt to an aerodynamically optimized non-planar surface to reduce air friction, or the antenna has to be non-planar in order to reduce its radar cross-section again to reduce air friction. Conformal antenna is one of the most important innovations in modern antenna technology of telecommunication field. Here, conformal microstrip patch antennas, in [3] are widely used where size, aerodynamics, cost and ease of operation are the major factors. In [3], the performance evaluation of rectangular patch array conformed on cylindrical surface revealed that curvature affects the radiation pattern. Low profile, light weight, loss cost and conformal shape make them to use as RFID in [4]. They have good potential for application in aerospace vehicles with excellent aerodynamic characteristics.

Cylindrical antennas in [3], [4], [5] have attracted the greatest attention amongst conformal antennas. When the radius of the curved structure is kept large, the antenna can be analyzed as the planar one. However, for the structure with smaller radii, since in conformal structure complexity is increased, more rigorous analysis methods should be used. If the antenna has a cylindrical shape, i.e., in 3D coordinate, if one principal curvature is zero, the antenna can be analyzed as a circular-cylindrical one. Similarly, in the case where both principal curvatures are different from zero, the antenna can be analyzed as a spherical one.

Microstrip antenna possesses small bandwidth which limits its application in large data transmission. But there are various techniques by which it can be improved. By controlling the distance between two patch antennas and by adjusting the length of transmission line in, the bandwidth is improved [6]. EBG also helps in improving the bandwidth with size reduction of antenna used in [7].

Now this research paper continues in the following manner: Section 2 of paper presents the design of antenna with EBG structure. In Section 3, involved formulation and calculation in [8], [9], [10] is discussed. Section 4 shows the simulated results and in section 5, we will conclude our work with its applications & in section 6 are references.

II. ANTENNA DESIGN WITH EBG

In this paper, an equilateral triangular patch antenna conformed on cylindrical surface with EBG is considered which is fed through microstrip line. The design of triangular patch antenna conformed on cylindrical surface is given in [5].

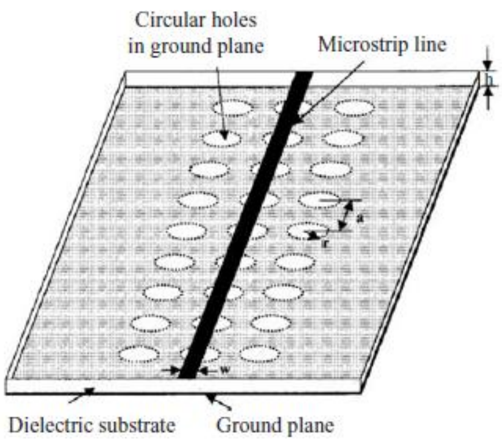

Fig.1. One dimensional transmission line: Microstrip line with periodic holes on the ground plane [1].

Fig. 1 shows EBG in ground plane. Fig. 2 shows the proposed equilateral triangular patch antenna of 73 mm side and is fed from microstrip line of width 4.467 mm and length 54.8 mm. The antenna is conformed on a finite cylindrical surface of radius 139.5 mm of substrate material Taconic TLT-0 (lossy) of 1.6 mm thickness and relative permittivity

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ϵ_r of 2.45. The structure is simulated using CST Studio Suite^{TM} 2010[2]. Result obtained on return loss, VSWR and radiation pattern are presented and discussed.

An Electromagnetic band gap structures (EBG) [1] is defined as the artificial periodic (or non periodic) objects that prevent/assist the propagation of electromagnetic waves in a specified band of frequency for all the incidents angles and all polarization states. This feature is useful in suppressing the surface waves. This improves radiation performance and bandwidth.

Fig. 2 shows the ground with holes of radius equal to 1/10 times wavelength forming EBG structure.

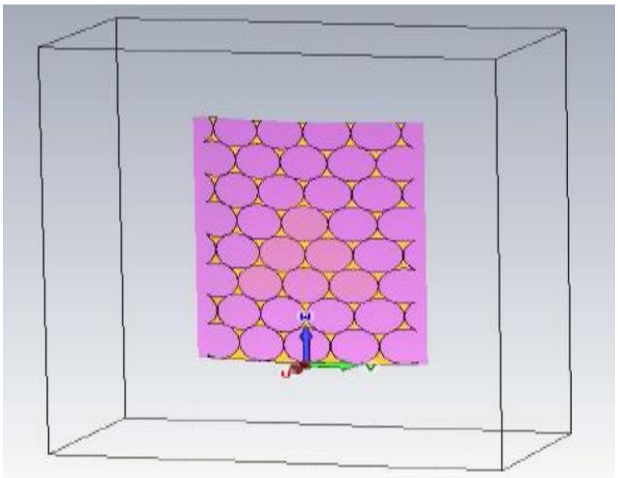

Fig. 2. Ground plane of antenna with holes r = 10.6 mm.

TABLE 1 Parameters of Antenna

Substrate (Outer Cylinder)	
Radius	139.5 mm
Thickness	1.6 mm
Material	Taconic TLT-0 (Lossy)
Epsilon ϵ_r	2.45
Loss Tangent	0.0019
Thermal Conductivity	0.19 W/K/m
Ground (Inner Cylinder)	
Radius	137.9 mm
Thickness h	0.1 mm
Material	Copper
Electric Conductivity	5.8e+007 S/m
Thermal Conductivity	401 W/K/m
Equilateral Triangle Patch	
Side a	73 mm
Microstrip Feed Line	
Length	54.8 mm
Width	4.467 mm
Wave Port	
Length	21.4 mm
Width	8.1 mm
Holes	
Radius	10.6 mm

III. FORMULATION & CALCULATION

In [8], an approximate solution of capacitance of circular microstrip disk to account for the fringing field is used for calculation of resonant frequency of the equilateral microstrip patch antenna, which is further modified in [10], [11].

For equilateral triangular patch antenna, the resonant frequency using formula in [10], [11]is calculated where effective side length and permittivity is also calculated.

The resonant frequency of proposed equilateral triangular microstrip patch antenna is calculated by following equations[10], [13]:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{a}\right]^{-(1/2)}$$

and

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}}$$

Hence, resonant frequency

$$f_r = \frac{2\,c}{3a\sqrt{\varepsilon_{eff}}}$$

For $\epsilon_r = 2.45$, a = 72 mm , h = 1.6 mm, c = 3x10^{11} mm, the calculated results are $\epsilon_{eff} = 2.36$, $a_{eff} = 73.02$ mm, f_r =1.80 GHz.

The feed location of the patch is found experimantally [12], by changing probe location and making measurements, a suitable feed point is determined.

IV. PERFORMANCE EVALUATION

Now we are going to show the return loss plot and VSWR [13] of the antenna. The conformal triangular patch antenna is simulated using CST Studio Suite.

Fig. 3 shows the return loss response of conformal antenna with EBG. It is clearly indicating that the antenna resonate at frequency at 1.28 GHz with return loss -38.12 dB while without EBG it was -26.81 at 1.52 GHz which shows the size reduction of the patch. The bandwidth is improved to 41.56 MHz.

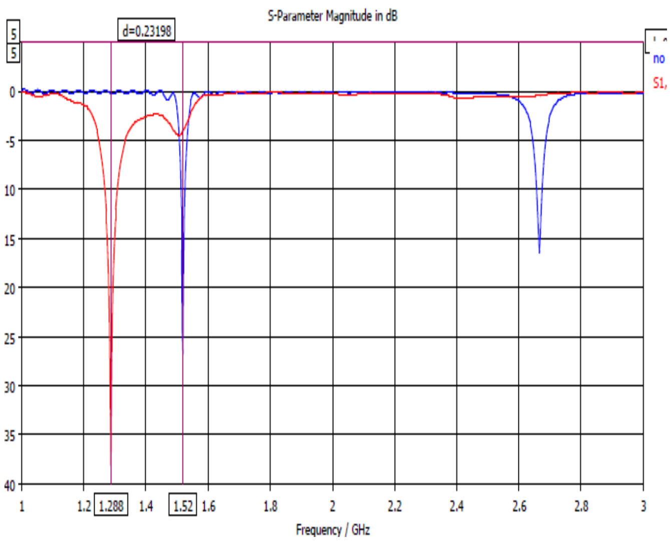

Fig. 3. Return loss vs Frequency of patch with Holes (Red) and without hole (Blue).

Fig. 4 shows the VSWR of 1.02 at central angle 30^0. Fig. 5 shows the far field radiation pattern of proposed antenna with EBG.

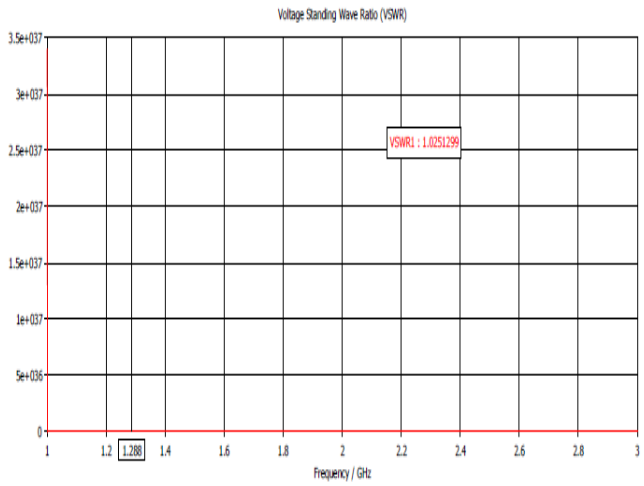

Fig. 4. VSWR vs Frequency of patch.

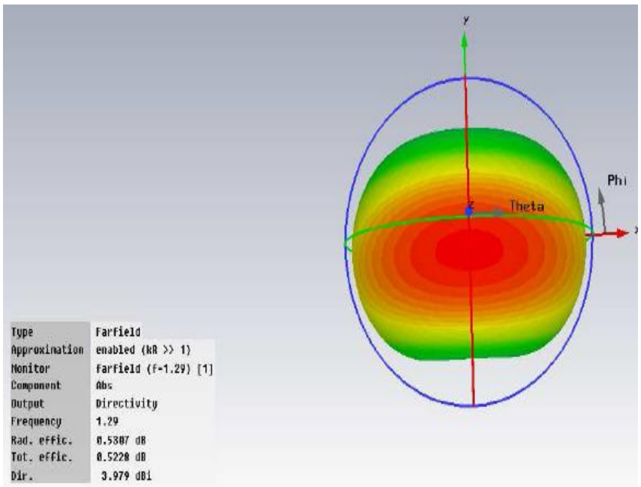

Fig. 5. Radiation Pattern of patch.

V. CONCLUSION

In this manner, finally it may efficiently be concluded that the antenna is miniaturized using the size reduction technique of EBG in equilateral triangular patch antenna conformed on cylindrical surface. Also, the radiation performance is improved as the surface wave is suppressed. The return loss is increased to -36.81 GHz at 1.28 GHz. A good VSWR of 1.02 is obtained which shows good impedance matching. The bandwidth is improved to 41.56 MHz. We received return losses at resonance frequency of 1.2 GHz which is a part of band used for satellite communication.

In addition to military applications where projectiles like rockets, missiles, armaments, the conformal antennas are also important in mobile communication and can conform geometrically to some shaped surface, like that on an aircraft, or a smaller flying platform. The most important application of the conformal antenna concept in the future will be found in the smart skin approach, which envisages the integration of non-planar active antenna apertures in curved surfaces adapted to the skin of the platform like aircraft, satellite, car, war ships etc.

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