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DESIGN AND ANALYSIS OF RECTANGULAR MICROSTRIP ANTENNA WITH PBG STRUCTURE FOR ENHANCEMENT OF BANDWIDTH

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Kapil Goswami[1], Ashutosh Dubey[2], Girish Chandra Tripathi[3], Birbal Singh[4]

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I. INTRODUCTION

Antenna is one of the important elements in the RF system for receiving or transmitting the radio wave signals from and into the air as the medium. Without proper design of the antenna, the signal generated by the RF system will not be transmitted and no signal can be detected at the receiver. The development of MIC and HF semiconductor devices and printed circuits has drawn the maximum attention of the antenna community in recent years. In spite of its various attractive features like light weight, low cost, easy fabrication, conformability on curved surface etc, the microstrip element suffers from an inherent disadvantage of narrow impedance bandwidth and low gain. In principle, bandwidth enhancement can be achieved by several approaches [1]. In this paper, we remove such type of disadvantage of rectangular microstrip antenna by adding a structure, that is made by a PBG material [2], in this type of antenna. The coaxial feed technique is used for the analysis of this antenna because it occupies less space and has low spurious radiations by using Teflon connector. The Method of Moment (MOM) [3] is used to discuss the electromagnetic radiation characteristics of the microstrip antenna.

II. ANALYSIS OF MICROSTRIP PATCH ANTENNA

Microstrip patch antenna with PBG structure (Fig-1) can be designed by using a cavity model [4] suitable for moderate bandwidth antennas. The lowest order mode, TM_{10}, resonates when effective length across a patch is half of wavelength. Radiations occur due to fringing field. A brief description of resonant frequency, cavity model and PBG structure is given as follows;

a) Resonance Frequency:

The resonance frequency f_{mn} depends on the patch size, cavity dimensions, and the filling material dielectric constant.

It is expressed as follows;

$$f_{mn}=\frac{K_{mn}c}{2\pi\sqrt{\varepsilon_r}} \qquad (1)$$

Where m, n = 0, 1, 2… K_{mn} = wave number at m, n mode, c is the velocity of light, ε_r is the dielectric constant of the substrate, and

$$K_{mn}=\sqrt{\left(\frac{m\pi}{W}\right)^2+\left(\frac{n\pi}{L}\right)^2} \qquad (2)$$

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For TM_{01} mode, length and width of non radiating rectangular patch's edge at a certain resonance frequency and dielectric constant is given by:

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}} \qquad (3)$$

$$W = \frac{c}{f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (4)$$

Where f_r is the resonance frequency at which the rectangular microstrip antenna is to be designed. The radiating edge W, patch width is usually kept such that it lies within the range $L < W > 2L$ for efficient radiation. The ratio $W/L = 1.5$ gives good performance according to the side lobe appearances. The actual value of resonant frequency is slightly less than f_r because fringing effect causes the effective distance between the radiating edges of the patch to be slightly greater than L. By using the above equations we can find the values of actual length of the patch as:

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta l \qquad (5)$$

Whereε_{eff} is the effective dielectric constant and Δl is the line extension which is given as:

$$\varepsilon_{eff} = \left(\frac{\varepsilon_r+1}{2}\right) + \left(\frac{\varepsilon_r+1}{2}\right) \cdot \frac{1}{\sqrt{1+12\frac{h}{W}}} \qquad (6)$$

$$\frac{\Delta l}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (7)$$

b) Cavity Model:

Transmission line model ignores field variations along the radiating edges. This disadvantage can be overcome by using cavity model in which interior region of dielectric substrate is modeled as cavity bounded by electric walls on the top and bottom. The basis for the assumption is the following observations for thin substrate ($h \ll \lambda$). Since the substrate is thin; the field in interior region does not vary much in Z direction that is normal to the path.

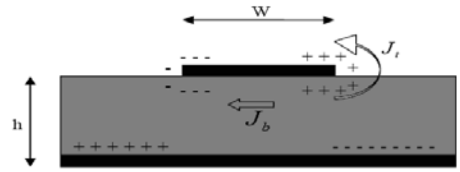

Figure1 .Charge distribution and current density creation on the patch.

Consider Fig 1, when the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms-an attractive mechanism and a repulsive mechanism. The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces.

c) Principle Of Photonic Band Gap (Pbg) Structure:

Photonic band gap (PBG) structures are periodic structures in which propagation of certain bands of frequencies is prohibited. Original PBG research was done in the optical region, but PBG properties are scalable and applicable to a wide range of frequencies. PBG structure can be achieved by using metallic, dielectric, ferromagnetic, or ferroelectric implants. Dielectric PBG structures have been used for microstrip circuits. Photonic band gap depends on the diffraction, reflection, and refraction.

Photonic band gap structures (PBG) are very promising building blocks of novel photonic components and devices representing the highest level of innovation in light generation, routing, and switching. As the fully three-dimensional (3D) PCs working in the optical domain are still difficult to fabricate, two-dimensional (2D) PCs formed in a dielectric slab ('membrane') or in a slab waveguide represent an attractive alternative. In these structures, light propagation is governed by diffractive effects in the two dimensions of the 2D photonic crystal, and by the classical 'refractive guiding' in the third (usually vertical) dimension.

III. DESIGN PARAMETERS FOR PROPOSED ANTENNA

The various design parameters of antenna which are calculated using the standard equations (1-7) are as follows:-

Substrate material used is glass epoxy.

a) Designed Parameter Of Rectangular Microstrip Antenna With Pbg Structure:

Length of Patch (L) = 29 mm
Width of Patch (W) = 37 mm
Length of ground plate (L_0) = 42 mm
Width of ground plate (W_0) = 55 mm
Regular square shape length and width (a) = 10 mm
Gap of regular square shape (b) = 03 mm
Dielectric Constant of the Substrate (ε_r) = 4.2

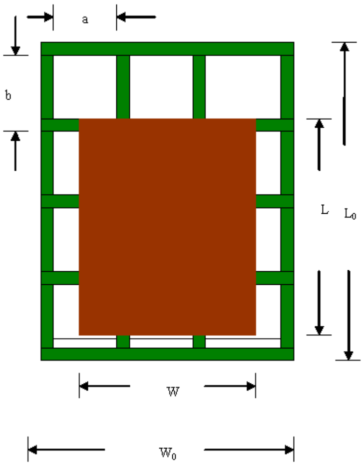

Figure 2 : Geometry of proposed antenna with PBG structure

IV. RESULT ANALYSIS BY SIMULATION AND DISCUSSION:

By using MATLAB [5], we find the values of return loss and VSWR of Rectangular microstrip patch antenna (RMSPA) with 3 by 4 regular square shape PBG structure on ground plane and also simulate the proposed antenna with IE3D [6]. Finally we compare output of simulated and measured results with the support of various graphs and charts given below.

a) Rectangular Microstrip Patch Antenna (RMSPA) with 3 by 4 regular square shape PBG structure on ground plane:

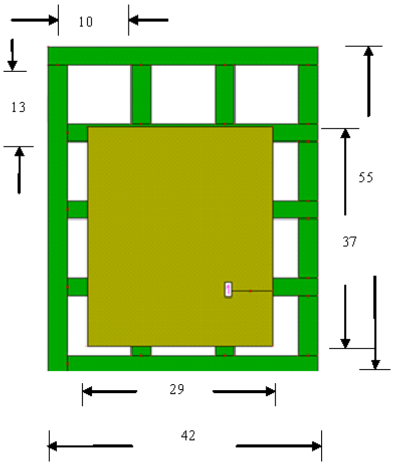

Figure 3: Antenna shape with feed point

b) Simulated result by IE3D based on MOM Method:

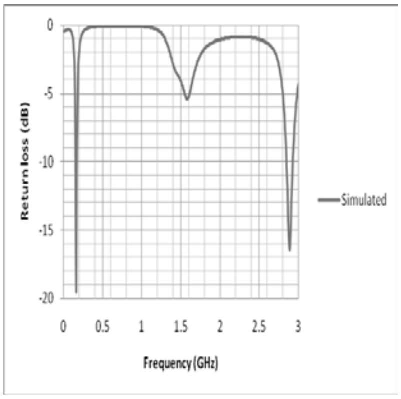

Figure 4: Return loss verses frequency plot

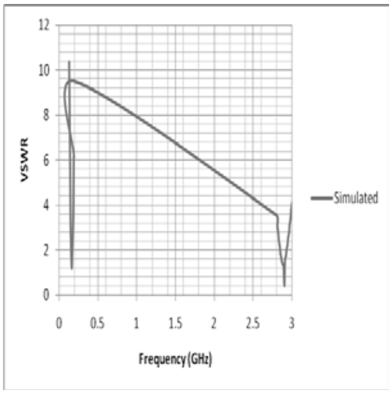

Figure 5: VSWR verses frequency plot

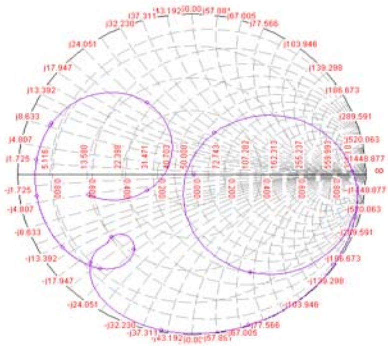

Figure 6 : Impedance verses frequency plot on smith chart

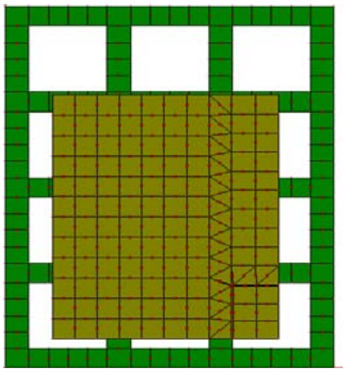

Figure 7 : Current distribution on positive plate

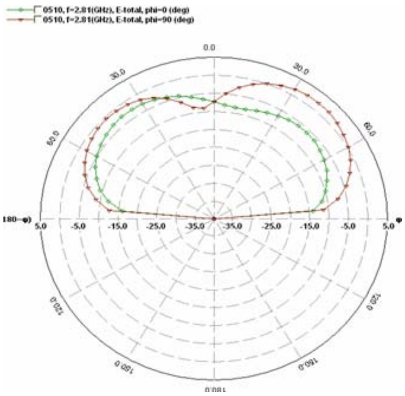

Figure 8 : Radiation pattern of E and H plane plot

c) *Discussion:*

The results of microstrip antenna designs such as the return loss, VSWR and the radiation pattern can be obtained by using the IE3D are shown in Fig 4, 5 and Fig 8 respectively. The results for the antenna simulation does not accurately give similar result as measured. Based on the simulations and measurements that have been done, the operating frequency of the antenna fabricated is shifting to the lower frequency because of PBG structure. Fig. 9 shows a graph which compares the simulation and measurement return loss results of rectangular microstrip patch antenna with PBG structure. For the simulation results the resonant frequency is exactly at 2.89 GHz with a return loss -15.95 dB. The operational frequency of the antenna is 2.85 GHz to 2.93 GHz measured at a return loss value below -10 dB. The bandwidth is about 2.78%. From the measurement result, the resonant frequency shifts to the lower frequency at 2.26 GHz. The return loss value at the resonant frequency is -18.4 dB. The operational frequency of the antenna shifts from 2.21 GHz to 2.30 GHz. The bandwidth is 3.99%.

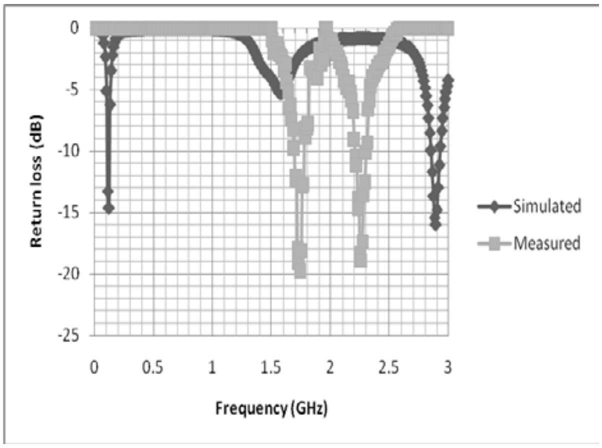

Figure 9 : Return Loss verses frequency plot

Through simulated and measurement analysis (Fig-9), we observe that the bandwidth increases when resonance frequency is greater than working frequency and addition of a PBG structure with rectangular microstrip antenna is very helpful for the same.

V. CONCLUSION

Based on the theoretical, simulated and analysis of the microstrip antenna with PBG structure, we have discussed the size and design parameters. Then we simulated the antennas that can run at 2.5 GHz frequency and calculated its return loss by using IE3D based on Method of Moment. Through theoretical and simulated analysis, we find bandwidth increases when resonance frequency is greater than the working frequency and this can be easily found by adding a PBG structure with rectangular microstrip antenna.

VI. ACKNOWLEDGMENT

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