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Design and Analysis of Miniaturized Microstrip Patch Antenna with Electromagnetic Band GAP Structures

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ABSTRACT

Modern telecommunication system requires antennas with wider bandwidth and smaller dimensions than conventional antennas. Operators are looking for systems that can perform over several frequency bands. This has initiated antenna research in various directions, such as EBG,DGS and the combination of fractal shaped antenna elements and split ring resonator structure. The EBG structure and characteristics have been investigated. Both simulated and analyzed results show the performance of the EBG structure toward microstrip antenna. EBG structure reduce surface waves which leads to higher antenna bandwidth, improve return loss and reduce antenna size significantly. A rectangular microstrip patch antenna with EBG structure has been designed for wireless application and WIMAX. The patch antenna along with the Electromagnetic Band Gap structure is designed to resonate at 2.9 GHz. Simulations and analysis has been carried out to verify the performance of Electromagnetic Band Gap structures in patch antenna. All the simulation work is done by using HFSS. it is observed that return loss and bandwidth have increased but the gain, directivity and efficiency shows good aggrement.
Keywords: Biometric, RF, Radio System, SWR, SRR, EBG, WIMAX, EBG, NRW, DGS

I. INTRODUCTION

An antenna is a device used to transform an RF signal, traveling on a conductor, into an electromagnetic wave in free space". Antennas tells the property which is known as reciprocity, that means an antenna will maintain the same characteristics regardless of that if it is transmitting or receiving. Antennas are mostly resonant devices, which operate efficiently in narrow frequency band. An antenna has been tuned to the same frequency band of the radio system to which it is connected; otherwise the reception and the transmission will be impaired. The range of frequencies over which the antenna can operate correctly is referred to as the bandwidth of an antenna. The antenna's bandwidth is the number of Hertz for which the antenna will exhibit an SWR less than 2:1. In order to transfer maximum power between a transmitter and a receiver antenna, the antennas must have the same spatial orientation, the same polarization sense and the same axial ratio . When the antennas are not aligned properly or do not have the same polarization, there will be a reduction in power transfer between the two antennas. This reduction in power transfer will reduce the overall system efficiency and performance . When the transmitted and received antennas are both linearly polarized, physical antenna misalignment will result in a polarization mismatch loss which can be determined using the following formula given in eq

Polarization Mismatch Loss (dB) = 20 log (cosβ).Where β is the misalignment angle between the two antennas. For 15° we have a loss of 0.3 dB, for 30° we have 1.25 dB, for 45° we have 3 dB and for 90° we have an infinite loss.

II. METHODS AND MATERIAL

A. Literature Survey

Proposed works of different researchers are discussed on microstrip patch antenna with electromagnetic band gap structures and their effect on the patch antenna. Different structures of antenna are studied on the basis of the work done by each of them and on the basis of it will be helpful to do research work further.

B. Related Work

S. H. Kim, et.al [1], stated one-dimensional electromagnetic bandgap (1-D EBG) and split ring resonator (SRR) structures were inserted between two closely located monopole antennas to suppress mutual coupling. With the effect of these two structures, the mutual coupling between the two antennas is reduced by more than 42 dB and the back lobes are reduced by 6 dB. Thereby, the radiation efficiency of the antenna is also improved. The two fabricated antennas with $0.19\lambda0$ spacing exhibit mutual coupling (S21, S12) of less than -30 dB from 2.43 to 2.54 GHz. A minimum correlation coefficient of 0.002 and maximum radiation efficiency of 82% are also demonstrated. Osama M. Haraz, et.al [2], presented a new dense dielectric (DD) patch array antenna prototype operating at 28 GHz for future fifth generation (5G) cellular networks. The proposed structure employs four circular-shaped DD patch radiator antenna elements fed by a 1-to-4 Wilkinson power divider. Han Xiaoke, Adnet Nicolas, et.al [3], The work dealt with the behavior of a patch antenna equipped with squared electromagnetic band gap (EBG) structures and subjected to various mechanical deformations (twisting and bending deformations). Han Xiaoke, Adnet Nicolas, et.al [3], The work dealt with the behavior of a patch antenna equipped with squared electromagnetic band gap (EBG) structures and subjected to various mechanical deformations (twisting and bending deformations). Krishnananda, Rukmini T. S. [4], Microstrip patch antennas became very popular in mobile and radio wireless communication, due to ease of their analysis, fabrication, and attractive radiation characteristics. The use of microstrip antenna in wireless communication found advantageous compared to other types of antenna due to their low fabrication cost, small size, supporting character to linear as well as circular polarization, robustness when mounted on rigid surfaces. However, they have their own limitations due to low efficiency, narrow bandwidth, surface wave loss and low gain. Electromagnetic Band Gap materials, as superstrate is used to overcome the limitations of Microstrip patch antenna. The main aim of this paper is to implement EBG antenna and compare their characteristics at the frequency 2.4GHz using simulation.

C. Problem Formulation

The main application of Microstrip antenna at 3GHz frequency is in WIMAX technology. But in the referred work the combination of the rectangular microstrip patch antenna was fabricated on the top of the substrate Rogers RO3003 with Electromagnetic Band Gap structures at the ground plane and then investigated the metamaterial characteristics in antenna design for satellite application. The patch antenna along with the EBG structure was designed to resonate at 7.3 GHz. Simulations and measurements were carried out to verify the performance of EBG structures in patch antenna. Metamaterial characteristics exhibits negative permittivity and permeability of the proposed EBG structures which was been verified using Nicolson-Ross-Weir (NRW) method. And hence results in combining the rectangular patch with EBG structure, the bandwidth of the antenna got increased by 39.63% and the size of the antenna reduced by 22.38% compared to the antenna without EBG. The return loss also met the specification of -10 dB cut off. But the limitation of this antenna was that it was having some strong spurious bands at lower frequencies which can be useful for the purposes of WIMAX applications and hence the work has to be done for designing the antenna for this band and also the decreasing the size of antenna with improved parameters such as return loss and efficiency of the antenna. The antenna is designed using software HFSS 10.0 version. Lot of optimization is done on the antenna by varying its parameters such as length, width, height, material used, feeding techniques and applying different geometries to the patch antenna. Also DGS was applied to the existing structure by applying various slots at different locations and of different shapes. In the reference design the slots are cut on the ground plane of butterfly shape which is not easy to designed and fabricate. Hence the structure is made simpler by applying rectangular shape slots at the ground plane. The optimization was done by applying circular and triangular shape slots and finally rectangular was proposed.

D. Objective

To design an antenna at low frequency i.e. around 3GHz and using electromagnetic band gap structures for improving its performance which was reduced due to spurious band radiations around the substrate with low cost FR4 material and reducing the structure complexity.

E. Work Methodology

The following is the flow chart showing the method of preceding the work during the dissertation.

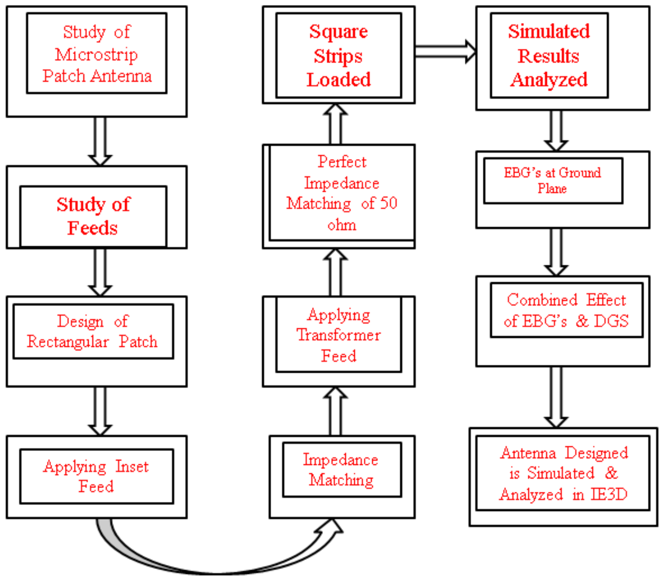

Figure 1: Flow Chart of Methodology

Design and Calculation of Dimension of Rectangular Patch

For designing the rectangular patch, firstly one has to calculate the length and width of the patch with the help of following formulas.

Step1: Determine the width of the rectangular patch by the equation given below:

$$W=\frac{1}{2F_r\sqrt{\epsilon_0\mu_0}}\sqrt{\frac{2}{\epsilon_0+1}} \qquad (3.1)$$

Step2: Determine the effective dielectric constant of microstrip antenna:

$$\epsilon_{eff}=\frac{\epsilon_r+1}{2}+\frac{\epsilon_r-1}{2}\left[1+\frac{12h}{w}\right]^{-1/2}$$

Step3: The actual length of patch can now be determine by solving for L

$$L=\frac{1}{2F_r\sqrt{\epsilon_{eff}\sqrt{\epsilon_0\mu_0}}}-2\Delta l \qquad (3.2)$$

Now the length and width calculated after giving the specification i.e. height and frequency will be:-

Er = 3.2
h = 0.762mm
F_r = 3GHz
L = 27.746mm
W = 34.5mm

The structure drawn in HFSS is given below

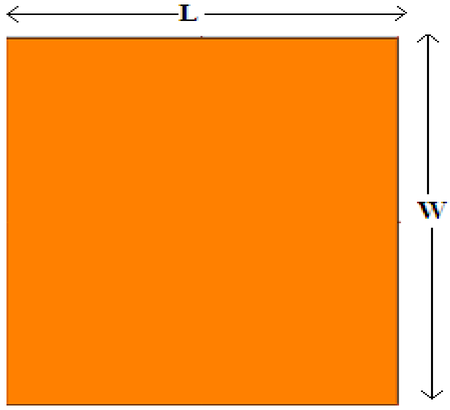

Figure 2 : Rectangular Patch Antenna

III. RESULTS AND DISCUSSION

The results of microstrip patch antenna with EBG and DGS structures as given below:

Pictorial representation of simulated return loss parameter of the designed antenna.

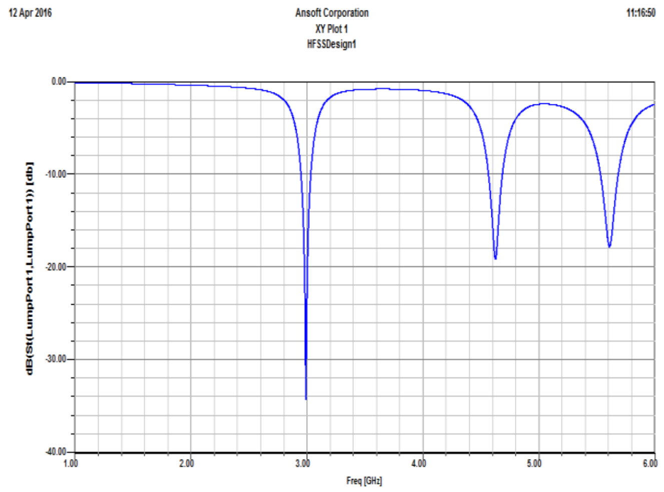

Figure 3. Simuated Return Loss Parameter At 2.9GHz

Pictorial representation of simulated VSWR of the antenna

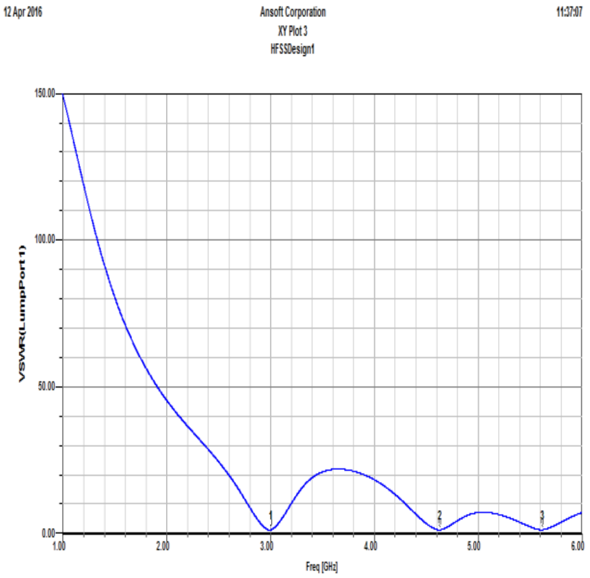

Figure 4. Simulated VSWR vs Frequency Graph

Pictorial representation of simulated current distribution of antenna.

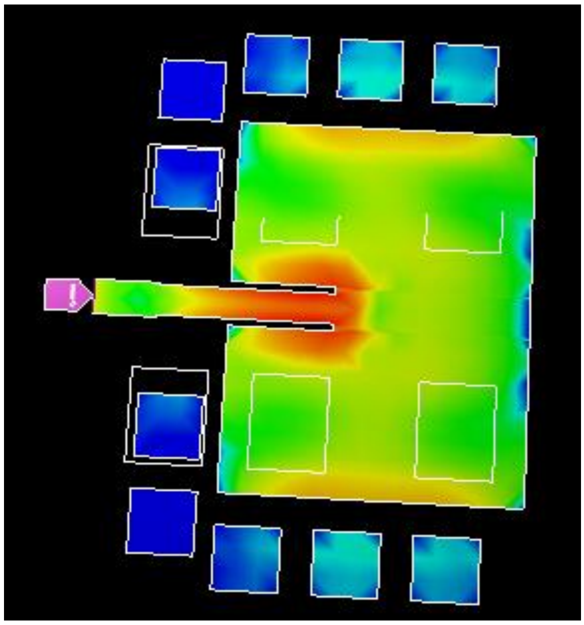

Figure 5. Pictorial representation of simulated current distribution of antenna.

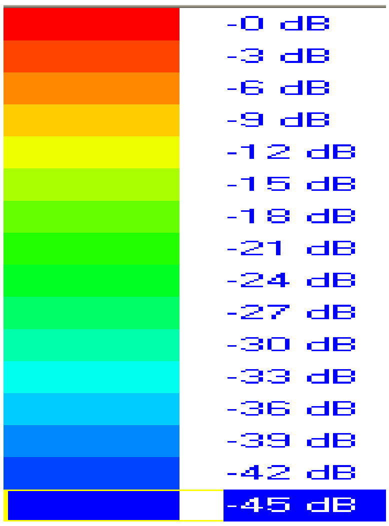

Figure 6. Simulated 3D Current Distribution Pattern at 2.9 GHz Frequency

Pictorial representation of radiation pattern of antenna in 3D

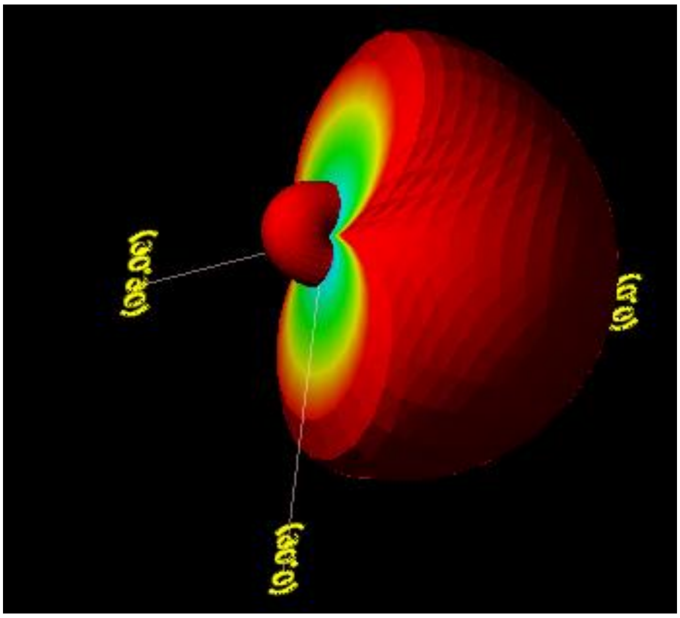

Figure 7. Simulated 3D Radiation Pattern of proposed Antenna at 2.9GHz Frequency

Pictorial representation of simulated Gain vs frequency of antenna

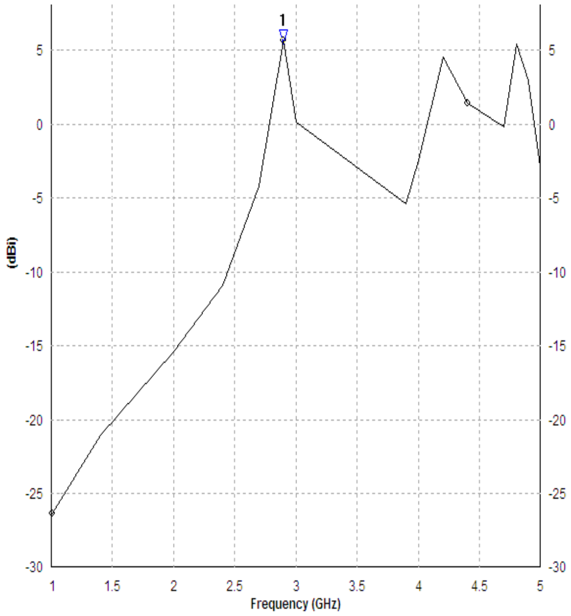

Figure 8: Simulated Gain Vs Frequency

The results are compared with the reference antenna and the improvement is seen in different parameters as in table 1.

Table 1 : Simulated Results of Proposed with Referred Antenna

Results	Reference Paper without EBG	Reference Paper with EBG	Design of normal patch antenna	Design of patch with only EBG	Design of patch with only DGS	Design of patch with EBG and DGS both
Return loss	-31dB	-28 dB	-29.18 dB	-23.39 dB	-33dB	-34.24 dB
Bandwidth	23MHz	34MHz	137MHz	90MHz	90MHz	80MHz
Directivity	5.95 dBi	6.84 dBi	6.42 dBi	3 dBi	2.87 dB	4.6 dBi
Area	926.756mm²		699.8418mm²		= 24.48% reduced area	

IV. CONCLUSION

After this proposed design, it is observed that return loss and bandwidth have increased but the gain, directivity and efficiency shows good aggrement. the rectangular microstrip patch antenna with EBG structure has been designed and analyzed. The EBG structure and characteristics have been investigated. Both simulated and analyzed results show the performance of the EBG structure toward microstrip antenna. EBG structure reduce surface waves which leads to higher antenna bandwidth, improve return loss and reduce antenna size significantly. The S11 parameter (return loss) comes out to be -34.243dB with directivity of 4.63dBi with improved bandwidth. For application point of view, this antenna can be best use for Wi-Max, C band, X band, Ku band application. This antenna can also be useful for RADAR and Satellite and military application.

V. FUTURE SCOPE

A comprehensive survey is presented on the electromagnetic band gap structure, their various configurations, and successive improvement up to today's uni-planar design. For the RF and microwave researchers, the EBG terminology is a hot research direction to solve out many problems that degrade the functional efficiency of a system. An antenna is an indispensable part of a communication system to receive and transmit electromagnetic energy. Being completely planar, microstrip antennas are very attractive and widely used for applications starting from MHz to GHz frequency range. The low gain, narrow bandwidth, and poor radiation performance has limited their applications for many purposes.

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