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Design and Analysis of Wideband Microstip Patch Antenna Employing EBG and Partial Ground Plane

Gurpreet Singh Saini[1], Amandeep Singh[2]
[1] *(Department ECE, Arni University, HP, India)*
[2] *(Department ECE, CTIEMT Jalandhar, Punjab, India)*

Abstract: *In this paper a new technique to widen bandwidth of a microstrip patch antenna is proposed. For the proposed antenna, shape and dimensions are chosen for obtaining wide bandwidth and small size. First a simple patch antenna is designed for the test, and then a microstrip patch antenna employing EBG structures with partial ground is demonstrated. This proposed design exhibits wide band behavior of resonant frequencies 2.5 GHz, 7.2 GHz, 10.6 GHz and 12.9 GHz frequencies with good return loss values -13.96 dB,-12.08 dB, -13.8 dB and -19.0 dB respectively. The design is analyzed with Ansoft HFSS 13.0 electromagnetic field solver.*
Keywords: *EBG (Electromagnetic Band Gap), Microstrip Patch Antenna (MPA),*

I. Introduction

Microstrip patch antenna is promising to be a good candidate for future wireless technologies, as wireless communication industry is adding leaps and bounds. With the rapid growth of wireless markets [mobile communication, wireless local area network (WLAN) networking, global positioning system (GPS) services, and radio-frequency identification (RFID) applications], radio-frequency (RF) engineers are facing continuing challenges of small-volume, wide-bandwidth, power efficient, and low-cost system designs. To achieve the desired goal the level of integration and miniaturization of antenna is also increasing and their comes the need to design a conformal small antenna for wideband applications. Microstrip patch antenna are low profile, light weight, easy to feed and have good radiation pattern, easy to manufacture and hence they are the demand of the new era of wireless technology. A Microstrip patch antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. However, at the same time they have disadvantages of low efficiency, narrow bandwidth and surface wave losses.

Due to recent research in the electromagnetic band gap (EBG) structure for antenna application to suppress the surface wave losses and improve the radiation performance of the antenna. When source signal is applied at metal ground plane and patch, the electromagnetic waves will be radiated. This radiation will not be perfect as there are some losses due to dielectric substrate and to minimize these losses we will insert EBG structures with microstrip patch antenna. Electromagnetic band gap structures are defined as artificial periodic or sometimes non-periodic objects or say that dielectric materials and metallic conductors that prevent the propagation of electromagnetic waves in a specified band of frequency for all incident angles and all polarization states. At present time, there is a need of smaller and broad bandwidth antennas. This can be achieved by fabrication of antenna on thick piece of high permittivity substrate. The main disadvantage is that, the unwanted substrate modes begin to form and propagate towards the edges of the substrate, which have a deadly effect on the antenna radiation pattern[13].

The innovation in the field Microstrip patch antenna is succeeding day to day As Jiejun Zhang [1] presented a paper based on RCS reduction of patch array antenna by electromagnetic band-gap structure. The results show that the RCS can be significantly reduced when the band-gap of the EBG is designed out of the band of antenna, and the performance of the antenna has no degradation. Nargis Aktar [2] proposed enhanced gain and bandwidth of patch antenna using EBG substrates. Due to the presence of the EBG structure in the dielectric substrates, the electromagnetic band gap is created that reduces the surface waves considerably. Jatinderpal Singh [3] projected design analysis of a hexaband slot loaded microstrip patch antenna for wireless applications. The antenna design is suitably recommended for the applications like WLAN (2.44 GHz at -12.29 dB), Radio astronomy (6.48 GHz at -16.43 dB), Passive sensors (7 GHz at -15.05 dB) and Point to Point defence system (8.25 GHz at -27.81 dB) wireless applications. José Felipe Almeida [4] demonstrated study of a microstrip antenna with PBG considering the substrate thickness variation by which improvement of the efficiency and bandwidth is verified when the substrate thickness is increased. Zhenghua Li [5] anticipated investigation of patch antenna based on photonic band-gap substrate with heterostructures and realized that radiation efficiency and return loss is significantly improved. Amandeep Singh [6]proposed design analysis of a circular polarized slot loaded microstrip patch antenna for multiband applications and is rightfully recommended for the applications like WLAN (2.44 GHz at -12.29 dB),Radio astronomy (6.48 GHz at -16.43 dB), Passive sensors (7 GHz at -15.05 dB) and Point to Point. R.N.Tiwari [7] introduced rectangular microstrip patch antenna with photonic band gap crystal for 60 GHz communications and this antenna gives high bandwidth and gain with radiation pattern omidirectional in nature. Rachmansyah [8] presented designing and manufacturing microstrip antenna for wireless communication at 2.4 GHz and found that antenna can be used as client antenna in computer and workable antenna for wireless fidelity. Sahar Naserzadeh [9] demonstrated mushroom-like EBG structure for enhancement of circular polarization array antenna performances and results show that, these techniques cause axial ratio bandwidth enhancement and gain improvement, also it decrease side lobe levels. Amandeep Singh [10] presented miniaturized wideband aperture coupled microstrip patch antenna by using inverted U-slot and showed the measured return loss within acceptable range throughout the band (11.08 GHz–13.25 GHz) and maximum return loss is achieved with proper impedance matching. Jagdish M. Rathod [11] studied comparative study of microstrip patch antenna for wireless communication application and realized that good impedance matching condition between the line and patch without any additional matching elements depends heavily on feeding techniques used. In present work we have proposed an antenna which exhibits a good value of return loss at four resonant frequencies. The details of the development of the proposed antenna are available in the next sections.

II. Design Methodology

To design and analyze the proposed antenna, High Frequency structure Simulator (HFSS) electromagnetic software tool is utilized. HFSS is a high performance full-wave electromagnetic (EM) field solver for arbitrary 3D volumetric passive device modeling. It integrates visualization, simulation, solid modeling and automation in an easy-to-learn environment where solutions to 3D EM problems are quickly and accurately obtained [12]. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give unparalleled performance and insight to all 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. HFSS is an interactive simulation system whose basic mesh element is a tetrahedron thus allowing us to solve any arbitrary 3D geometry.

III. Antenna Design

The structure of the proposed antenna design has been studied in this section. Fig 1 represents the architectural view of the proposed antenna. This antenna is made up of three layers in which first layer comprises the conductive ground plane, second layer comprises the substrate i.e. dielectric material and third layer comprises the conductive patch. In the proposed design electronic band gap structures are made in the substrate in the shapes of cubes, patch is cut in the form star and a partial ground plane is employed. The different shapes by cutting slots in the proposed antenna design have been decided after proper parametric analysis to achieve the appropriate microstrip patch antenna that can be used for wideband wireless applications.

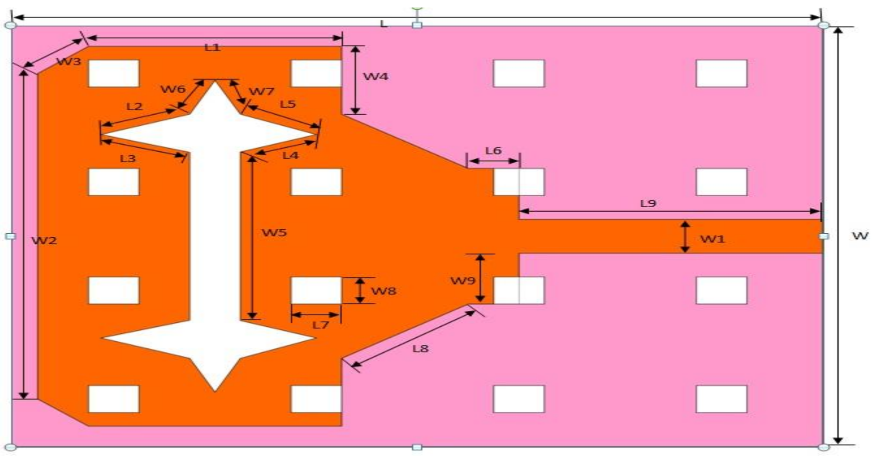

Figure 1: Geometry of the proposed microstrip patch antenna

In the proposed design, slots are cut in the metallic patch to enhance its bandwidth so that this microstrip patch antenna can be used for wideband applications. The dimensions of the patch play a vital role in deciding the overall characteristics of the analyzed microstrip patch antenna. Dimensions of the proposed antenna are optimized by iterative trials on the software. Length and width of the ground plane is half in size as compared to the substrate. In the substrate of proposed design sixteen cube slots are cut in the of 1 m^3 to integrate electromagnetic band gap structures. Patch of the proposed antenna is shown by orange color in figure 1 and in this star shaped slot is cut to enhance the bandwidth and gain of the antenna. This antenna is fed with microstrip feed line technique as this is simple to match by controlling the inset feed position. All the important design parameters of the proposed antenna are represented in form of Ttable 1 which clearly indicate the actual physical interpretation of the proposed design.

Antenna Parameters			
ε_r	2,2	L	32.00 mm
W	31.00 mm	L1	10.00 mm
W1	2.00 mm	L2	3.80 mm
W2	24.00 mm	L3	3.73 mm
W3	2.82 mm	L4	3.26 mm
W4	5.00 mm	L5	3.35 mm
W5	12.42 mm	L6	2.00 mm
W6	2.69 mm	L7	2.00 mm
W7	2.69 mm	L8	6.40 mm
W8	2.00 mm	L9	12.00 mm
W9	3.75 mm		

Table 1: Design parameters of the proposed antenna

IV. Results And Discussions

To check the performance of the proposed antenna different microstrip patch antenna are designed and their parametric analysis is done which is shown in Table 2 as well as through a graph between frequency and return loss shown in fig 2. Initially a simple patch antenna is intended which resonates at operating frequencies 2.3 GHz, 7.2 GHz, 10.8 GHz and 12.8 GHz frequencies with return loss values -3.76 dB, -6.2 dB, -8.35 dB and -10.7 dB respectively shown by black line in fig 2.Characteristics of antenna changes when H slot is cut in patch of antenna, it resonates at 2.3 GHz, 6.9 GHz, 10.0 GHz and 12.6 GHz exhibits return loss of -12.1 dB, -6.9 dB, -9.29 dB and -16.66 dB respectively, represented by orange line in fig 2. Further patch is cut in the form star, then antenna resonates at operating frequencies 2.3 GHz, 6.7 GHz, 10.0 GHz and 13.0 GHz frequencies with return loss values -12.4 dB,-12.0 dB, -12.0 dB and -9.0 dB respectively shown by sky blue line in fig 2. Further EBG(electronic band gap) structures is employed in the patch of the antenna, it exhibits resonant operating frequencies at 2.3 GHz, 6.3 GHz, 10.0 GHz and 12.1 GHz exhibits return loss of -11.75 dB, -10.8 dB, -18.0 dB and -10.59 dB respectively, represented by pink line in fig 2. In the next design DGS structure is engaged in the patch of the antenna, and the results show that antenna resonates on operating frequencies at 2.3 GHz, 6.8 GHz, 10.8 GHz and 12.5 GHz frequencies with return loss values -11.7 dB, -6.8 dB, -10.2 dB and -15.3 dB respectively, represented by green line in fig 2.

Antenna type	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB
Simple Patch	2.3	-3.76	7.2	-6.2	10.8	-8.35	12.8	-10.7
Patch with H slot	2.3	-12.1	6.9	-6.9	10.0	-9.29	12.5	-16.66
Patch with star slot	2.3	-12.4	6.7	-12.0	10.0	-12.0	13.0	-9.0
Patch with EBG	2.3	-11.75	6.3	-10.1	10.0	-18.0	12.1	-10.59
Patch with DGS	2.3	-11.7	6.8	-6.8	10.8	-10.2	12.5	-15.3
Patch with EBG and partial ground	2.5	-13.96	7.2	-12.08	10.6	-13.8	12.9	-19.0

Table 2: Resonant frequencies and return loss characteristics at different values for the different shapes of antenna

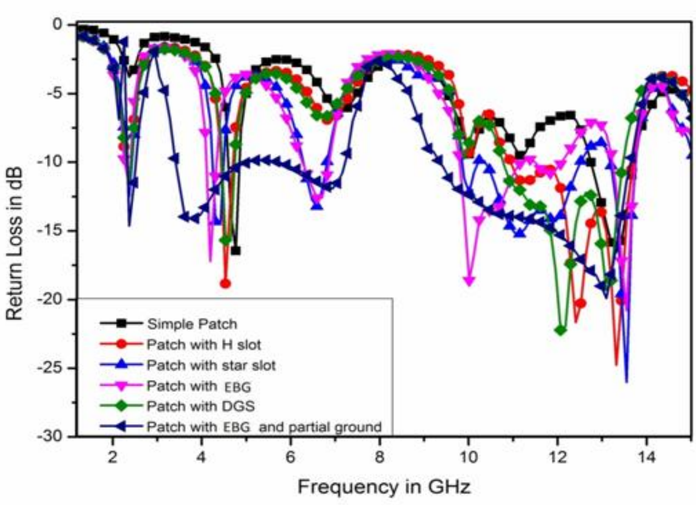

Figure 2: Return Loss versus operating frequency characteristics for the proposed antenna by employing different shapes in the patch

Finally we have proposed an antenna design employing EBG structures in patch and using partial ground plane and this antenna exhibits on operating frequencies at 2.5 GHz, 7.2 GHz, 10.6 GHz and 12.9 GHz frequencies with return loss values -13.96 dB,-12.08 dB, -13.8 dB and -19.0 dB respectively. This is represented by dark blue curve plot of fig 2.Lastly, from the above parametric observations, we have choose the antenna design using EBG structures in patch and using partial ground plane. The analysis of antenna is generally based upon two broad categories, one is input parameters and another is output parameters. Return loss characteristics as shown in fig 2 representing the input characteristics and gain of the antenna comes under the output characteristics. Therefore, it is important to analyze the gain response of the proposed antenna to confirm the antenna as a good radiator. From the above analysis, it can be seen that for the proposed antenna design that is microstrip using EBG structures and partial ground plane resonates absolutely at specific values of return loss as shown in Table 2.

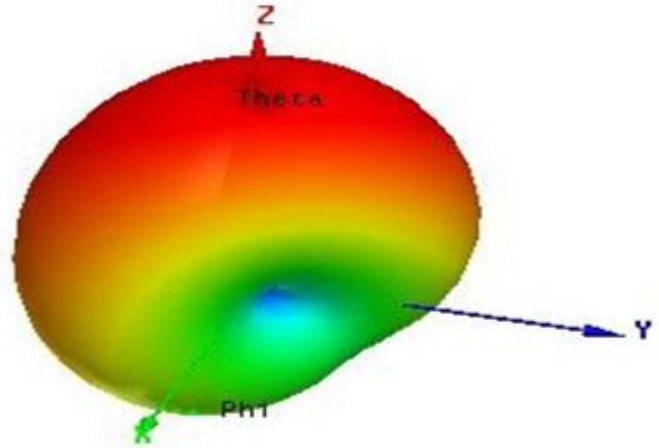

Figure 3: 3D gain plot of the proposed antenna design

Moreover, it can be seen in the fig 2 that the proposed antenna employing EBG structures and partial ground plane which is represented by blue line resonates below -10 dB for almost all frequencies between 2 GHz and 13 GHz which makes this proposed antenna to be used for the wideband wireless applications. Fig 3 is representing the 3D gain plot of the proposed antenna that it radiates almost equally in all directions normal to the patch means it exhibits Omni directional characteristics. The gain of 6.33 dBi is obtained from the antenna which is very sufficient for the small distance wireless applications.

V. Conclusion

In this paper antenna with different shapes are designed and their parametric analysis has be done. Finally the proposed antenna employing EBG structures in patch and using partial ground plane is analyzed to know the characteristics of antenna. It has observed that the proposed antenna is multiband in nature and resonant exhibits on operating frequencies at 2.5 GHz, 7.2 GHz, 10.6 GHz and 12.9 GHz frequencies with return loss values -13.96 dB,-12.08 dB, -13.8 dB and -19.0 dB respectively. It is found that proposed antenna has good value of gain of 6.33 dBi and can be used for various wideband applications such as WLAN, Radio astronomy, Passive sensors, Wi-MAX band, Wireless local loop and Point to Point defence system wireless applications.

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