DESIGN OF SQUARE MICROSTRIP PATCH MULTI BAND ANTENNA FOR WIRELESS COMMUNICATION USING EBG STRUCTURE

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Abstract: Application of electromagnetic band-gap (EBG) structure and its use in the design of antenna and microwave integrated circuits is becoming more attractive. The recent electromagnetic band-gap structure method is capturing more importance in antenna design due to its uniqueness properties to suppress the propagation of surface waves in microstrip patch antenna. In this paper a square microstrip antenna is designed and its performance parameters are compared with geometry designed on EBG structure. The square antenna of 29 mm x29 mm size is designed at 2.455 GHz and analysis is done using IE3D simulation software. The proposed work mainly focuses on modification of antenna using electronic band gap structure (EBG). The antenna parameters such as Return loss, VSWR, Gain and Bandwidth, with and without EBG are obtained using IE3D simulation tool. The Electromagnetic band-gap structures have been used to improve the performance of the gain of the antennas and radiation patterns. One of the main advantages of electromagnetic band-gap structure is its ability to suppress the surface wave current present on the microstrip antenna. Combining the square patch with EBG structure, the bandwidth of the antenna has been increased by 34.66%, and attained gain of 44.44% at resonant frequency around 2.4 GHz as compared to the antenna without EBG..

***Keywords*: Eectronic band gap structure (EBG), Return Loss, Microstrip Patch Antenna , VSWR, Multiband antennas**

1. Introduction

In the present scenario there has been a tremendous ever-growing demand, for planar antennas especially microstrip antenna designs and fabrications for consumer and defense applications because of their attractive features (thin, having small size, conformal and operating in multi-band). Conventional antennas generally operate at a single frequency band, where a different antennas are needed for separate communication applications. Hence there exists the need of requirement of large space for different antennas. In order to overcome this problem, multi frequency microstrip antenna can be used where a single antenna can operate at many different frequency bands. As stated earlier, microstrip patch antennas are suitable for dual-band and/or multi-band wireless applications.

There are a number of approaches and methods that have been suggested over the past years by several researchers which can be used to achieve one or more of these design objectives [1, 2]. Since conventional micro strip antennas have a conducting patch generally fabricated on a grounded dielectric material and operates as resonant cavity elements therefore its operation leads naturally to a narrow impedance bandwidth which is a drawback for micro strip antenna applications in wireless telecommunications system also the radiation of electromagnetic energy in different directions from the radiating element and excitation of surface waves that are formed in the dielectric substrate layer. Because of this when a patch antenna radiates the undesired surface waves trap a portion of total available radiated power along the surface of the substrate, due to this reason i.e. generation of surface waves decreases the antenna efficiency and degrades the antenna patterns [3-4].

In order to improve the antenna performance the electromagnetic band gap (EBG) structure method is employed on microstrip antenna. Due to possession of its periodic lattices, the electromagnetic band gap structure can provide effective and flexible control over the propagation of the electromagnetic waves within a particular frequency band. The electromagnetic band gap structures exhibit multiband, increase impedance bandwidth and improve the input return loss S_{11} of microstrip patch antenna by suppressing the unwanted surface waves as shown in Figure 1[5]. The application of electromagnetic band gap structures in microstrip patch antenna design allows enhancement of gain,

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increased directivity, widening of impedance bandwidth occurs [6].

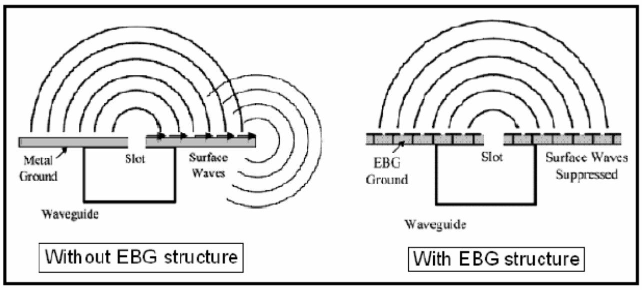

Figure 1: The suppression of surface waves by EBG structure [5].

In this work, the proposed design offers multi frequency operation with wide bandwidth and good gain. These results are obtained by making use of EBG structure. The simulation results show that the designed square microstrip antenna with EBG resonates at multiband frequencies with improved impedance bandwidth, increased return loss, and improved antenna gain. Therefore, the enhancement of the bandwidth, the achievement of multi frequency and enhancement of gain of square patch antenna is proposed by EBG. Section 2 covers Antenna design. Results and discussions are presented in Section 3 followed by its conclusions in Section 4.

2. Antenna Design

A. Antenna 1, Square Microstrip Without Ebg Structure

The microstrip antenna is fed with coaxial probe and a square microstrip antenna size is related to the center frequency f_r.

In the proposed design of square microstrip antenna without EBG, the Length "L" and width "W" of the patch antenna performs an important role in determining the resonant frequency of operation patch antenna. For square Microstrip antennas, the length (L) and width (W) of the radiating patch antenna maintained at 29 mm and the effective dielectric permittivity of the microstrip patch antenna (ε_r) at the required resonant frequency as it supports the operation of patch or λ_0 which is wavelength of free-space and can be designed using the antenna design equations 1 to 5 as given in [7-8]

$$W = \left(\frac{c}{2fr}\right)\left(\frac{\sqrt{2}}{\sqrt{\varepsilon r + 1}}\right) - - - - - - - - - - - - - - -1$$

$$\varepsilon r_{eff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\sqrt{1 + 12h/w} - - - - - - -2$$

$$L = \frac{c}{2fr\sqrt{\varepsilon r_{ef}f}} - - - - - - - - -3$$

$$\Delta L = L + 2\Delta L - - - - - - -4$$

$$\Delta L = 0.412h\frac{(\varepsilon r_{eff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon r_{eff} - 0.258)(\frac{w}{h} + 0.8)} - -5$$

where

ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

ΔL= Extension of patch Length

The antenna is optimized using IE3D simulation software ver. 15. The antenna 1 is designed on dielectric substrate FR-4 with εr = 4.4 as the dielectric constant, substrate thickness 1.6 mm, and the loss tangent = 0.02. The antenna designed values are optimized with IE3D antenna simulation software tool. The optimization was performed with number of iterations for the best impedance bandwidth, gain and for multiband operation. Figure 1 shows the geometry of the proposed antenna. The overall dimension of the antenna is 29 mm x 29 mm.

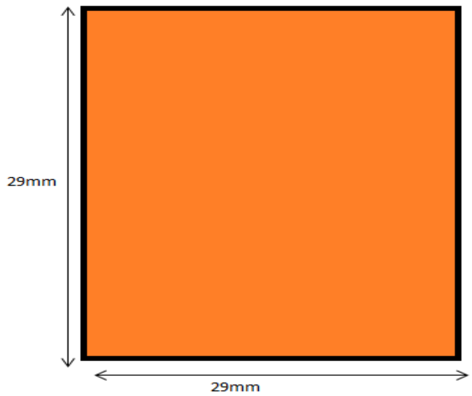

Figure 2. Basic square microstrip antenna.

B. Antenna 2, Square Microstrip With Ebg Structure

Figure 3 shows the configuration of the proposed square antenna with electronic band gap structure of square of 6.5mm size with 1mm gap between them. This structure is compact which has good potential to give high efficiency antenna surface and to build low profile. The antenna is simulated using IE3D simulation software Ver 15. The antenna 2 is designed using substrate FR-4 with εr = 4.4 as the dielectric constant , substrate thickness 1.6 mm, and the loss tangent = 0.02. The antenna designed values are optimized with IE3D antenna simulation software tool. The optimization was performed with number of iterations for the best impedance bandwidth, gain and for multiband operation. Figure 2 shows the geometry of the proposed antenna. The overall dimension of the antenna with EBG structures is 44 mm x 44 mm.

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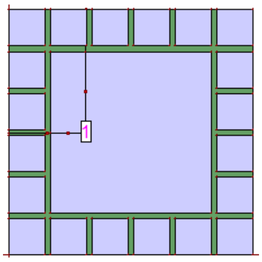

Figure 3.Square Microstrip Antenna with EBG structure

3. Results And Discussion

Methods to increase gain can be acquired by changing the material or by use of substrate, but by using simple design and applying EBG structure on patch a well desired gain as well bandwidth can be obtained. Many optimizations are performed by changing the EBG size to obtain optimum values of radiating parameters as listed in Table 1. Figure 4 shows the comparative analysis of return loss (S_{11}) for the proposed antennas 1 and 2. The Figures 5 and 6 show the 2D radiation patterns of the proposed antennas 1and 2.

Table 1. Design parameters with optimized values.

Type of Antenna	Resonant Frequency	VSWR In dB	BW In MHz	Gain db
Without EBG	2.44914	-23.4234	49.0927	-3.239
	4.49829	-14.0018	111.0170	-2.807
	5.51057	-11.4546	60.4930	-8.310
	7.28298	-25.1392	172.1380	0.287
	8.97482	-27.6555	176.1940	-7.782
	12.3907	-13.057	165.112	7.618
With EBG	2.3957	16.9489	75.511	2.590
	4.7432	17.4004	131.794	2.540
	5.46828	24.2630	178.797	0.581

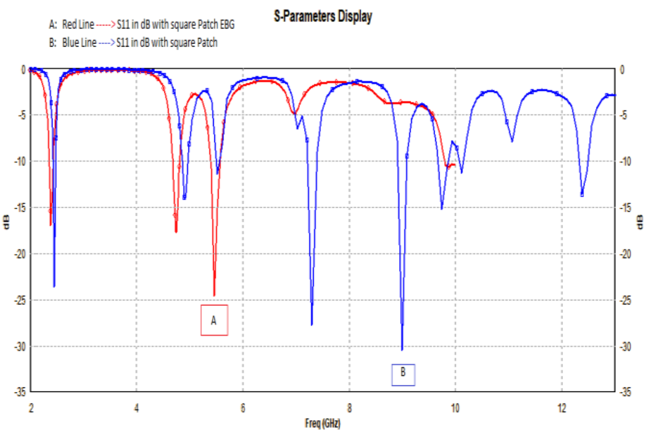

Figure 4. Comparison of S11 characteristics of square microstrip antenna with and without EBG.

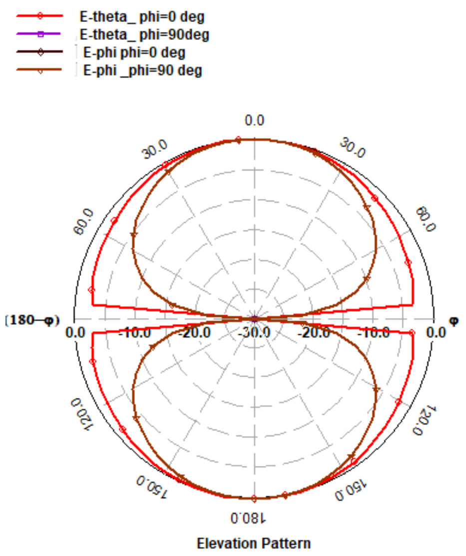

Figure 5. Simulated 2D radiation pattern (phi = 90)

The result shows that the antenna 1 (square patch without EBG) has omni-directional radiation pattern at 2.44GHz as shown in Figure 5. The simulated antenna gain is -3.2dbi at 2.44GHz. The antenna 1 operates at multiband having good return loss at frequencies of 2.44914 GHz, 4.49829 GHz & 5.51057 GHz, 7.28298 8.9748212.3907 with BW of 49.0927 MHz, 111.0170 MHz, 60.4930 MHz, 172.1380 MHz, 176.1940 MHz & 165.112MHz with gain of -3.239 dB, -2.807 dB, -8.310 dB, 0.287dB, and -7.782dB respectively which are well suited for ISM and Bluetooth.The antenna radiation pattern shows omni-directional characteristics.

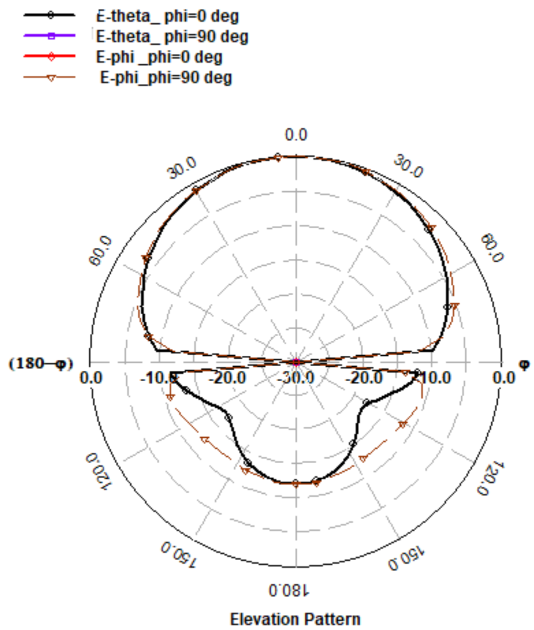

Figure 6. Simulated 2D radiation pattern (phi = 90)

The antenna 2 (square microstrip antenna with EBG) operates with multiband characteristics having good return loss of 16.9489 dB , 17.4004 dB & 24.2630dB at resonant frequencies 2.3957 GHz, 4.7432 GHz & 5.46828GHz with

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BW of 75.511 MHz, 131.794 MHz & 178.797 MHz and gain of 2.590dB, 2.540 dB & 0.581dB respectively which are well suited for ISM, Bluetooth, Wi-Fi and Wi-Max applications. The antenna radiation pattern shows omni-directional characteristic at 2.3957GHz. The diagram depicts that antenna 2 (square microstrip antenna with EBG) is more directive and has higher gain and BW with respect to antenna 1.

4. Conclusion

Square shaped patch antenna with EBG structures has been presented. The presented geometry shows overall optimum results compared to the conventional squarer microstrip antenna. From the proposed antenna design and analysis done here, it is clear that the square patch with EBG structure offers better results over conventional square patch. The operating frequencies obtained with optimum results are 2.3957GHz with the BW of 75.511MHz and 5.46828GHz with BW of 178.797MHz. These frequencies are useful for applications in S band (unlicensed applications) like Wi-Fi, ISM, LTE, and Blue tooth modules. The third frequency is obtained at 4.7432 GHz frequency with a bandwidth of 131.794 MHz and Gain of 2.540dB. With these results the proposed geometry is suitable for WIMAX applications.

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