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MUTUAL COUPLING REDUCTION BETWEEN MICROSTRIP ANTENNAS USING ELECTROMAGNETIC BANDGAP STRUCTURE

G.N. Gaikwad[1], V.V. Dixit[2], D.G. Ganage[3], Y.D. Chincholkar[4], U.P. Alwandi[5], S.R. Pawar[6] and J.P. Kolhe[7]

[1, 2, 3, 4] *Department of Electronics and Telecommunication Engineering, Sinhgad College of Engineering, Maharashtra, India*

E-mail: ganesh1426@gmail.com

[5, 6] *Department of Electronics and Telecommunication Engineering, Sou. Venutai Chavan Polytechnic, Maharashtra, India*

[7] *Department of Aerospace Engineering, Defence Institute of Advanced Technology, Maharashtra, India*

Abstract

When the number of antenna elements is placed in forming the arrays, mutual coupling between the antenna elements is a critical issue. This is particularly concern in phase array antennas. Mutual coupling is a potential source of performance degradation in the form of deviation of the radiation pattern from the desired one, gain reduction due to excitation of surface wave, increased side lobe levels etc. EBG (Electromagnetic Band Gap) structure (also called as Photonic Bandgap Structure PBG) not only enhances the performance of the patch antennas but also provides greater amount of isolation when placed between the microstrip arrays. This greatly reduces the mutual coupling between the antenna elements. The radiation efficiency, gain, antenna efficiency, VSWR, frequency, directivity etc greatly improves over the conventional patch antennas using EBG. The EBG structure and normal patch antenna is simulated using IE3D antenna simulation software.

Keywords:

Antenna, Electromagnetic Band Gap (EBG), Mutual Coupling, Surface Waves, Antenna Efficiency

1. INTRODUCTION

There are many methods to reduce the mutual coupling between antenna elements [1]-[10]. In [1], an efficient technique for reducing the coupling is machining the dielectric below the patch, so that there is free space below the patch. In [2], it reduces the horizontal radiation and coupling by using the shorting pins to cancel out the capacitive polarization currents of the substrate. Some techniques are explicitly designed to suppress the surface wave. It also include optimizing the antenna dimensions so that the surface wave is not excited [3][4], grooving the dielectric [5], covering the patch by additional dielectric layers [6], or making the dielectric be a band-gap structure by printing various patterns on it [7],[8]. A straightforward way to reduce the mutual coupling of monopole antennas on high-impedance ground plane was developed in [9]. A thin piece of conducting tape is placed in the middle between the two horizontal monopoles, extending throughout the ground plane. The same thought has been adopted in a MIMO microstrip antenna array to reduce the mutual coupling [10]. Recently the structure consists of a slit pattern etched onto a single ground plane was proposed to reduce the mutual coupling between closely-packed antenna elements [11]. For radar using continuous wave, when the scheme of twin antennas is used, the transmitting antenna array and the receiving antenna array will be closely placed side by side. If the mutual coupling is too strong, the transmitting energy will blockade the receiver. Therefore the reduction of mutual coupling between two arrays is very important. An important function of an adaptive array is to suppress interferences. This is achieved by steering the nulls of the radiation pattern toward the interferences. However, the depths and the accuracy of the positions of the nulls will be significantly affected by the existence of the mutual coupling between the antenna elements. In other cases, such as design of low side lobe level array or phased array, the mutual coupling effect is also not negligible and should be carefully examined. In this paper, the mutual coupling effect is discussed using Electromagnetic Bandgap structure (EBG).EBG structure when placed between two antenna elements it provides greater isolation and thus reduces mutual coupling between antenna elements.

2. ANALYSIS METHODS FOR EBG STRUCTURE

To characterize and design EBG structure various analysis methods have been developed over the years. The lumped LC model shown in Fig.1 is used to explain the working mechanism of EBG structure and to predict their operational bands. In the frequency where the surface impedance is very high, the equivalent LC circuit acts as a two dimensional electric filter to block the flow of surface waves.

The central frequency of the bandgap is given by:

$$f_o = 1/2\pi\sqrt{LC}$$

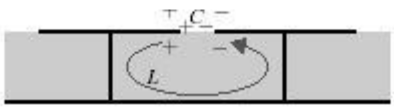

Fig.1. Lumped LC model for EBG analysis

The inductor L results from the current flowing through the vias, and the capacitance C due to the gap effect between the adjacent patches. Thus the approach to increase the inductance or capacitance will naturally result in the decrease of bandgap position.

3. MICROSTRIP PATCH ANTENNA

A square dielectric substrate 60mmx60mm with permittivity (dielectric constant) 4.4 and substrate thickness of 1.60 mm is taken. The dimensions of the patch are 13mmx16mm.The typical microstrip square patch consists of ground plane, dielectric substrate and square patch .The antenna is fed by coaxial probe and is located at the distance (dx) of 4mm away from the edge of the patch. The given antenna is simulated using IE3D and its layout is as shown in Fig.2.The antenna is resonated to a frequency of 2.4GHz with return loss of -19dB as shown in Fig.3.

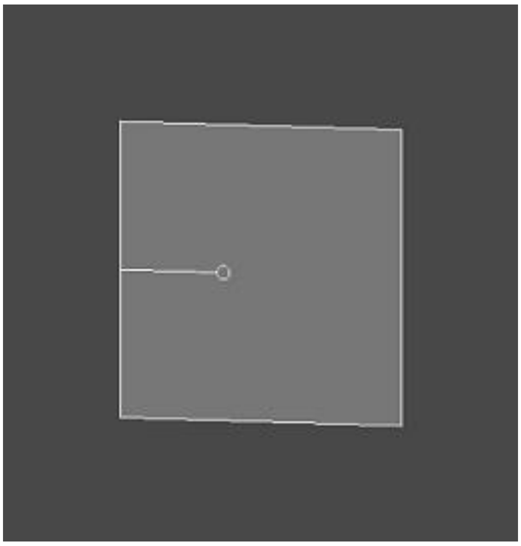

Fig.2. Square Microstrip Patch Antenna

As can be observed from the figure, the return loss for the conventional patch antenna is -19dB at 2.4GHz. A negative value of return loss shows that this antenna had not many losses while transmitting the signals. From the same figure the antenna bandwidth was calculated by using formula

$$Bandwidth = \frac{f2 - f1}{\sqrt{f1xf2}} \times 100\%$$

The value of f1 and f2 were taken at –10dB or 10% from the transmitted power.

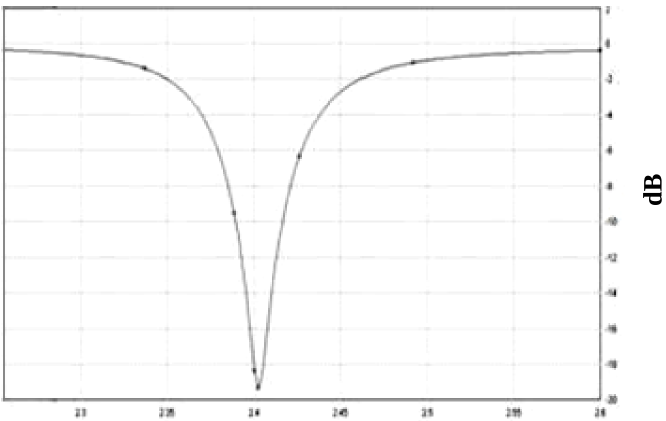

Fig.3. Return loss Vs Frequency for Patch

Since a microstrip patch antenna radiates normal to its patch surface, the elevation for $E_\theta = 0°$ (zero degree) and $E\varphi = 90°$ would be important. Fig.4 below shows the maximum radiation occurs at 0° with gain of 5.32 dB.

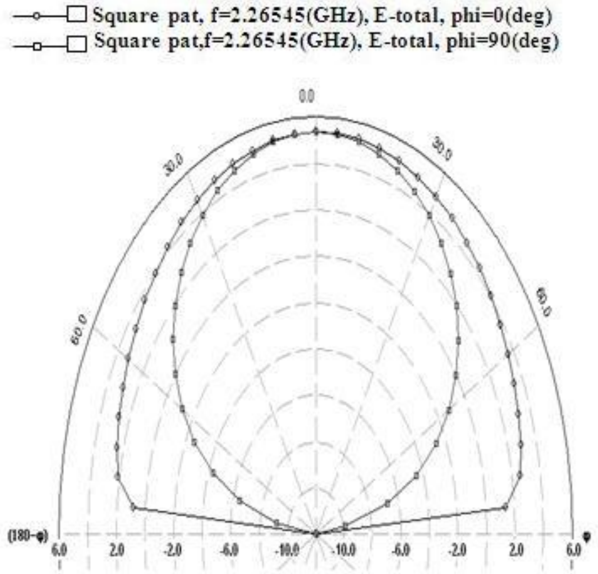

Fig.4. Gain Polar Plot

4. MICROSTRIP ANTENNA WITH EBG

Since the late 1990s, EBG designs have flourished, and a wide variety of materials and geometries have been investigated. EBG structures are periodic composite materials where the metal and dielectric materials are arranged in a specific pattern.

The EBG structure in this paper consists of a dielectric substrate with permittivity of 4.4 and thickness of 1.59mm as shown in Fig.5.The patch dimensions are 13mmx16mm.

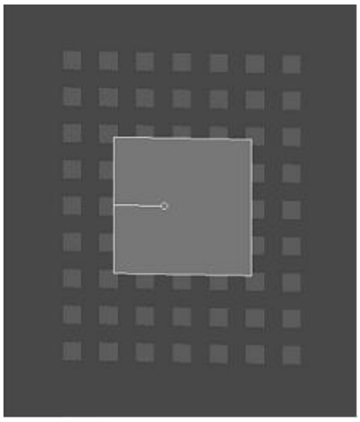

Fig.5. EBG structure 9x7 matrix

The dimensions of the slots 8mmx8mm and the distance between the centres is 14 mm .The lattice of the square hole acts as an electromagnetic bandgap structure (EBG).

This EBG structure prohibits prorogation of electromagnetic waves in a certain frequency bands. This suppresses the surface waves and hence gives enhancement in the performance of the antenna.

5. MUTUAL COUPLING REDUCTION USING EBG

When two microstrip antennas are placed from one another by quarter the wavelength [11], the performance degrades as performance parameters shows some degradation. To overcome this EBG structure can be placed between the two microstrip antenna elements. In present paper mutual coupling is reduced first by forming two antennas separated by 48mm.15 × 5 matrix EBG structure isolates these two antennas. Further some geometry is added in the form of a cross structure in the lattice with the total length of 4 mm between extreme ends and width of 1mm.Width and length of the both antennas are 29mm each separated by 48mm.This EBG structure is formed on both sides of the substrate (Double layer structure).This antenna has been fabricated as shown in Fig.6.

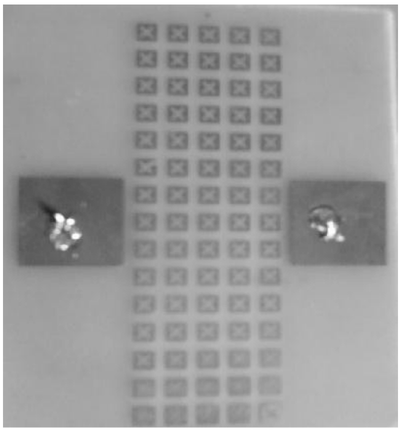

Fig.6. Fabricated EBG Structure

6. RESULTS AND DISCUSSION

Simple patch is first simulated using IE3D to obtain its return loss and frequency as shown in Fig.7.The resonant frequency is 2.4 GHz and return loss of -25 dB. The same patch antenna has VSWR almost equal to unity.

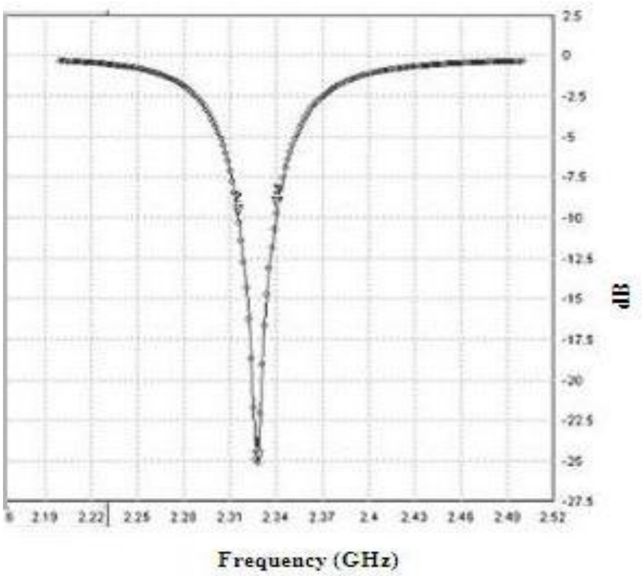

Fig.7. Return loss Versus Frequency

Fig.8 shows the antenna efficiencies for simple patch. Radiation efficiency is around 80 % for 2.35GHz.

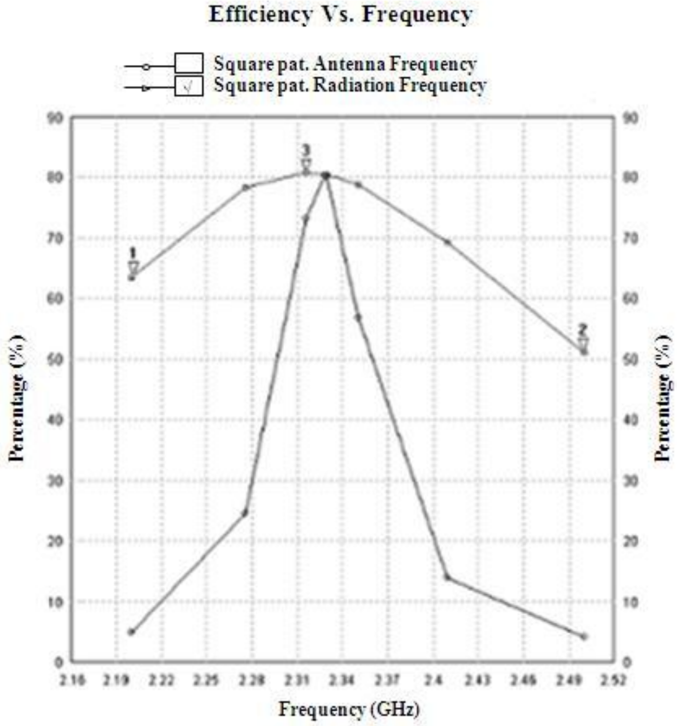

Fig.8. Antenna Efficiency for Patch

S11 of the EBG structure is shown in Fig.9. The resonant frequency drops to 2.265GHz; hence the miniaturization is achieved as compared to single patch.

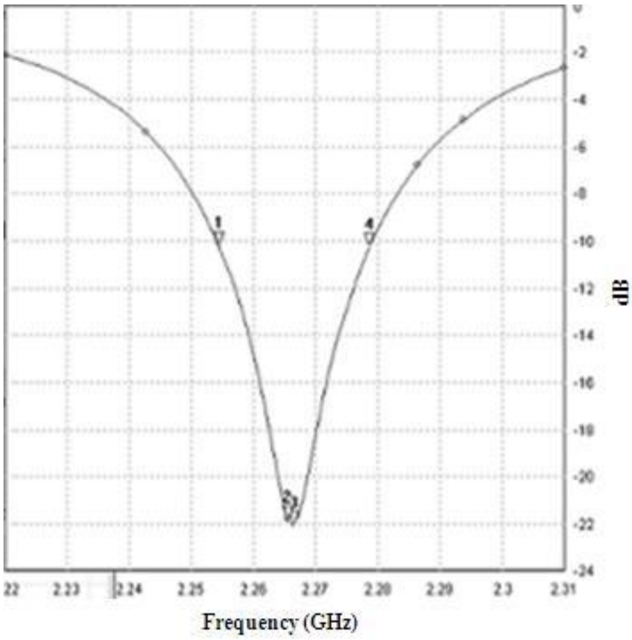

Fig.9. S11 of EBG structure

The antenna remains more efficient for most of the range of frequencies due to EBG structure as shown in Fig.10.

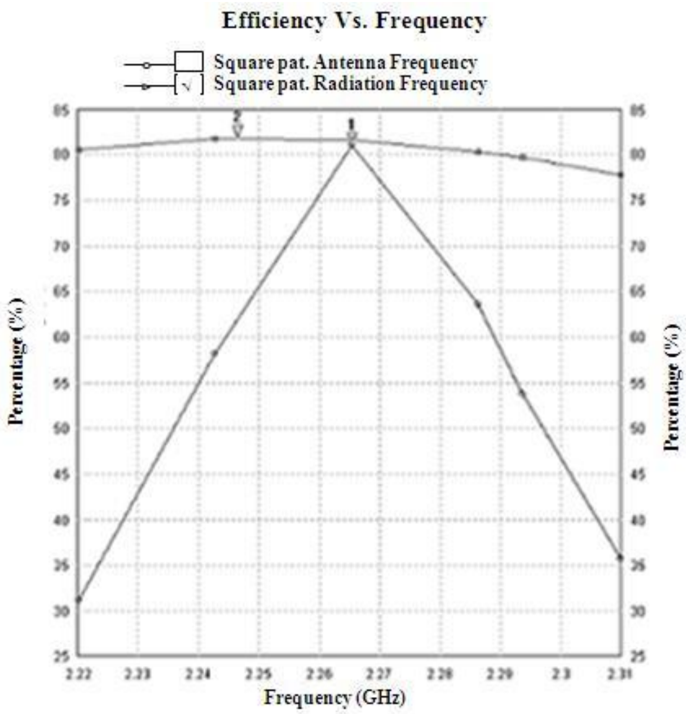

Fig.10. Antenna Efficiency for EBG structure

The simulated result for Fig.6 is shown in Fig.11.

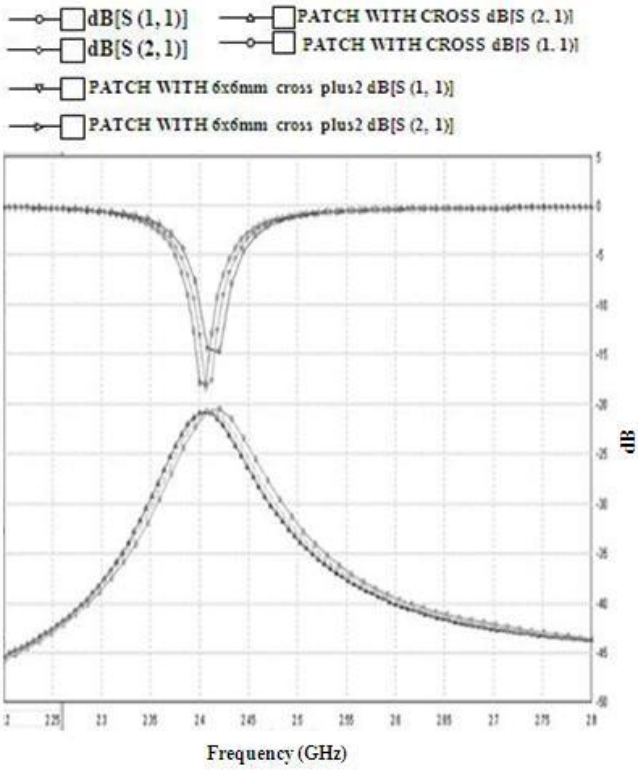

Fig.11. S_{21} of EBG structure isolating two antennas

The results are compared like with and without EBG Structure, single layer structure and followed by two layer structures as shown in Fig.11. From Fig.11 it is clear that the mutual coupling is reduced by almost 2dB for the operating frequency of 2.4 GHz. At higher frequencies mutual coupling increases, so this EBG technique is useful in reducing mutual coupling between antenna elements particularly at microwave frequencies.

6.1 MEASURED RESULTS

The performance of above antennas is measured on Agilent's 8714ET 300KHz - 3000MHz RF network analyzer. The fabricated structures are shown in following Fig.12.

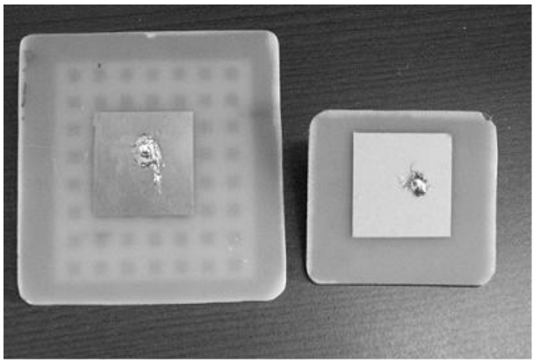

Fig.12. EBG antenna and simple patch antenna

In Fig.13 the left side antenna is EBG antenna and the right picture shows patch antenna. Both antennas are tested using network analyzer. The VSWR obtained using EBG antenna is 1.0 as shown in Fig.13.

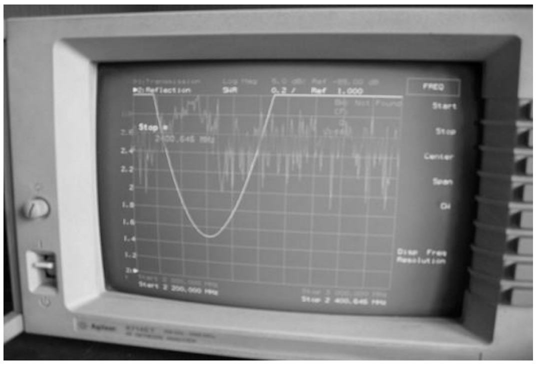

Fig.13. VSWR of EBG antenna

The fabricated structure as shown in Fig.6is measured for S_{21} using network analyzer. This is shown in Fig.14. S_{21} is almost -55 dB which shows good isolation between antenna elements.

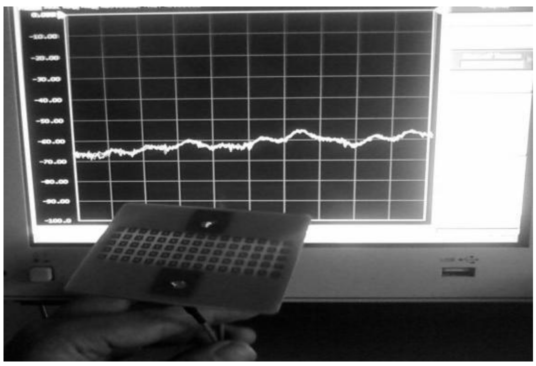

Fig.14. S_{21} of fabricated structure to minimize mutual coupling

The measured results are summarized in Table.1.

Table.1 Measured Results

Parameters	**Simple patch without EBG for FR 4**	**Simple patch with EBG**
Dimensions	28 mm × 28 mm	8 × 7 matrix structure with each square lattice of 4 mm × 4mm
Feed	4 mm from edge of patch	40 mm in X direction
VSWR	1.5	1.0
Transmitted Power	96%	100%
S21 of EBG	-----	-55 dB

7. CONCLUSION

Using EBG structure greater amount of isolation can be achieved in microstrip antenna elements. With EBG placed between two antenna elements S_{21} of -55 dB is achieved. This will be an important way of reducing mutual coupling in case of phase array antennas. So as microwave frequency increase and number of antennas increases, mutual coupling can be reduced and hence greater performance of the antennas can be achieved.

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