JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Microstrip Antenna Integrated with TVS-EBG Structure to Reduce Mutual Coupling

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Abstract

A Microstrip Antenna is well suited to compact patch array configuration for ISM band applications. A Two Electromagnetic Band-Gap (TVS-EBG) structure through slot form is used for reduction of mutual coupling in patch antenna. This paper present TVS-EBG structure for the dielectric constant FR4 substratum (πr) = 4.4 and the thickness (h) = 1.60 mm. High Frequency Structure Simulation (HFSS) software is used for the modeling and simulation of patch antennas. Parameters like S11 (return loss), bandwidth & VSWR will be measured using a vector network analyzer (VNA) meter to evaluate the reduction of mutual coupling.

Keywords: Microstrip Antenna, Two Electromagnetic Band-Gap (TVS-EBG), High Frequency Structure Simulation (HFSS), vector network analyzer (VNA) meter.

1. INTRODUCTION

A macro strip antenna was initiated in the early 1970's when the missiles needed conformal antennas. The light eight, conformability and low cost make these antennas appealing. These antennas can be combined with printed strip line feed networks and active devices. A Microstrip patch antenna consists of a radiating patch on one side of a dielectric substratum that on the other side has a ground plane as shown in Figure 1. The patch is typically made of material such as copper or gold, and may take any shape. On the dielectric substratum, the radiating patch and the feed lines are normally photo engraved [1].

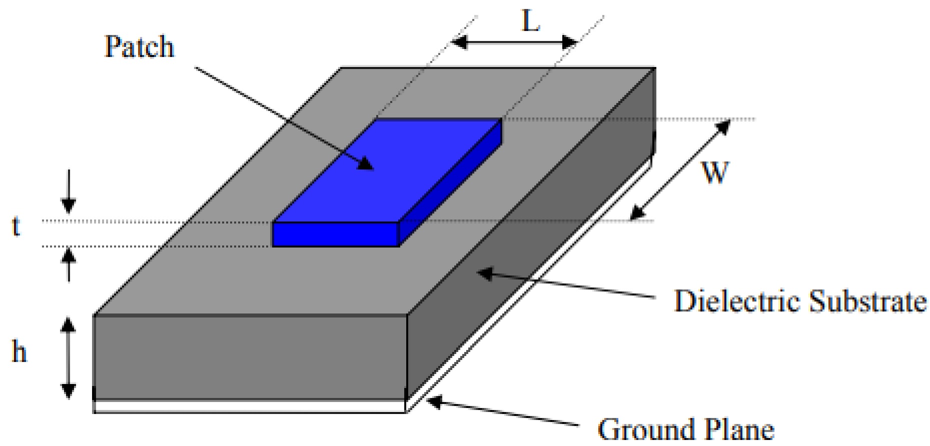

Figure 1 Structure of a Microstrip Patch Antenna

In this paper, A Two Via Slot Type Electromagnetic Band-Gap (TVS-EBG) structure is used to reduce patch antenna coupling to one another. The TVS-EBG structure raises the equivalent value of C and L per unit EBG cell by making slots on the TVS-EBG cell's square patch and two slots between the TVS-EBG cell's square patch and ground plane. Application of TVS-EBG structure in patch array was planned and validated at ISM band to minimize mutual coupling [2].

2. LITERATURE REVIEW

H. R. Cheng et al. [3] proposed a novel electromagnetic band gap structure (EBGs) and implemented fractal Microstrip antenna using the EBGs as a ground plane. In this proposed work double reverse split rings (RSR) into the square patch and as a result size of EBG cell is reduced by 30% as well as the band gap achieves bandwidth about 65%. Result shows that, when this proposed antenna is compared with the reference antenna at 5 GHz, we achieved the return loss approximately 8 dB improvements, also in *E* plane *H* plane the back lobe is reduced by 10 dB and 8.73 dB at the resonant frequency, respectively.

S Vasuhi et al. [4] proposed a wearable antenna with semicircular ring slot patch with Electromagnetic Band Gap (EBG). It is useful for medical applications such as health monitoring and for smart application by stitching the antenna to the dress. In this proposed system, they designed Wearable Antenna with Electromagnetic Band Gap (EBG) Structure for WBAN (wireless body area network). As a result they measured impedance bandwidth and the return loss for this antenna lies between 2.2-2.98GHz and -42.68 respectively. Specific Absorption Rate (SAR) is calculated using CST (Computer Simulation Technology) software, for 1 gram and for 10gram of tissue is 0.348W/kg and 0.368W/kg respectively and are both less than the U.S standard for specific absorption rate.

Mohamed I. Ahmed et al. [5] present UWB (Ultra Wide Band) KSA (Kingdom of Saudi Arabia) sign shape slot Microstrip antenna and designed and fabricated on a substrate with dielectric constant of 4.4, thickness of 1.6 mm, and tan $\delta = 0.02$. It is useful for the military application like older belts, any commodity, etc or

RFID applications. This proposed antenna was studied by CST simulator and fabricated by proto laser machine with precision 25µm. The testing result shows that at first band (2.1 - 2.99) GHz and at second band (5 – 9.43) GHz a reduction in mutual coupling of 8 dB and 33dB achieved respectively.

Komal V. Tumsare and Dr. P. L. Zade [6] present a Microstrip patch antenna with plus shape Electromagnetic Band Gap (EBG) substrate for WLAN i.e. WiFi and Wi-Max applications. Developer proposed symmetric antenna with the letters Y, C, C and E (logo of Yeshwantrao chavan college of Engg. YCCE Nagpur, India) are arranged horizontally in a straight line and the rectangular patch. Here the letters and the rectangular patch are main controlling parameter of proposed Microstrip patch antenna and operates from 2.3088 GHz to 2.6651GHz frequency. Result shows that microstrip antenna with EBG substrate covers the band of WiFi with proper gain as the return loss, realized gain and radiation patterns measurements at 2.486.

M. R. Ahsan et al. [7] present inset-fed rectangular Microstrip patch antenna embedded with double-P slots and fabricated on ceramic-PTFE composite material substrate. The printed planar antenna has acquired 1.5GHz and 4GHz operating frequencies and can be used for GPS operating frequency and C-band applications. The designed and developed antenna has achieved bandwidths of 200MHz with gain of 3.52 dBi and for 300MHz with gain of 5.72 dBi. It also achieved radiation efficiency of 81% for lower band and 87% for upper band.

M. Ramesh et al. [8] present the rectangular textile antenna with E-shape Electromagnetic Band Gap (EBG) Structure for reduction of Specific Absorption Rate, here for 10g of tissue SAR value is reduced from 9.45W/kg (without EBG) to 1.36 W/kg (with E shape EBG). The Reflection coefficient is -8.67dB without EBG and textile antenna with EBG is resonant at 2.4GHz with Reflection coefficient of -24.05 dB on phantom model. Here due to the E-shape EBG structure the impedance bandwidth is increased and also 85.6% reduction in SAR value is obtained.

Miss Sanjiwani S. Patil and Prof. V.V. Joshi [9] proposed fractal EBG structure and designed on substrate with dielectric constant 4.4 and thickness 1.6 mm. This paper proposed the design, simulate and fabricate the new EBG structure operating at 2.4GHz frequency, here design simulation was done using the high frequency structure simulator (HFSS). Result shows that at 2.57GHz, return loss are -11.392dB and Bandwidth of conventional rectangular micro strip patch antenna are 2.57GHz-2.59GHz. EBG layer provide improvement in return loss and Bandwidth, result shows that stop band is obtained at 2.38 GHz with return loss reached at - 11.397dB and bandwidth reached at 2.37GHz-2.4 GHz.

3. DESIGN AND CHARACTERISTICS OF EBG

Between two patch antennas Conventional Mushroom Electromagnetic Band Gap (CM-EBG) structure gives 8 dB reduction of mutual coupling but when we compared to patch size and the size of each CM-EBG cell is

83.1%. For EBG, the band-gap center frequency (fc) is obtained by equation 1 and the band gap bandwidth is approximately determined by equation 2, given below [10].

$$f_c = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

$$BW = \frac{\triangle\omega}{\omega} = \frac{\sqrt{LC}}{\eta o} \quad (2)$$

The compact EBG structure is designed to Increase in corresponding values of C and L. From design point of view values of L and h is kept constant; here L depends on μ0 which is constant. By changing the distance between two neighboring EBG cells, the patch width is used in CM-EBG to increase the value of C. Structure of TVS-EBG, as shown in Figure 1 Makes use of this Unused EBG patch area by making slot on it to increase equivalent C. By equation 1 the equivalent value of C should be increased to get compact EBG structure.

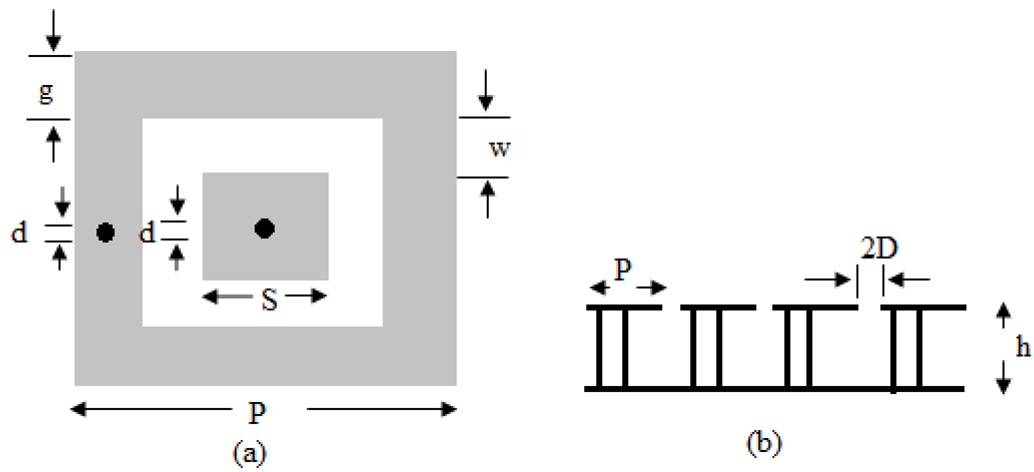

Figure 1 Two via Slot type Electromagnetic Band Gap (TVS-EBG) structureat ISM 5.80 GHz (a) top view (b) side view.

However, band gap bandwidth (BW) decreases as compared to CM-EBG due to increase in C and from equation 2. In Ansoft HFSS a TVS-EBG structure is simulated to verify the properties of the proposed TVS-EBG structure. For structure of TVS-EBG is shown in Figure 1. The size of each portion is chosen as follows:

- the distance between two EBGs is (2D) = 0.25 mm
- the periodic spacing (P) = 4.50 mm
- the distance between the inner square patch and the outer slot is (w) = 0.25 mm,
- the outer slot width (g) = 1.00 mm,
- the inner patch width (S) = 2.00 mm,
- Each through (d) = 0.80 mm.

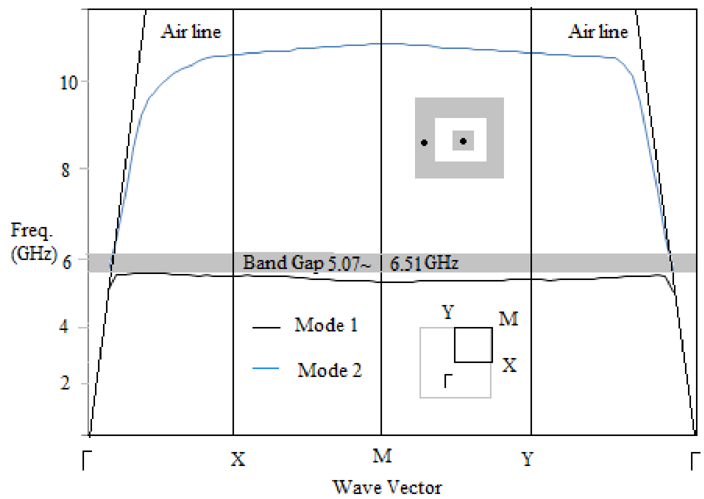

Figure 2 Dispersion diagram of TVS-EBG structure

Figure 2 shows the Dispersion diagram of TVS-EBG structure with (2D) = 0.25 mm, (P) = 4.50 mm, (w) = 0.25 mm, (g) = 1.00 mm, (S) = 2.00 mm, (d) = 0.80 mm. We note that from the figure 2, the frequency band difference for TVS-EBG exists between mode 1 and mode 2 and the band gap is centered at 5.79 GHz with lower frequency cutoff (fl) = 5.07 GHz and higher frequency cutoff (fh) = 6.51 GHz with BG-BW 24.87%.

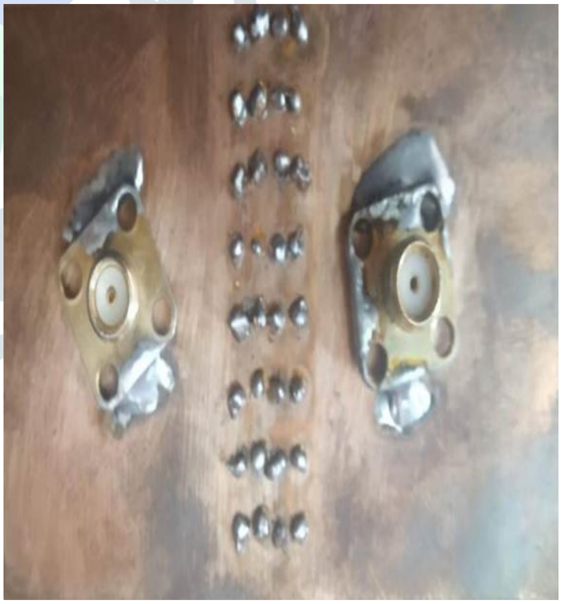

Figure 3 Photos of fabricated microstrip patch antenna with TVS-EBG Structure, where substrate dimensions are (Ly) = 75.75 mm and (Lx) = 43.00 mm, each patch size (py) = 11.31 mm and (px) =15.74 mm, probe fed placed along Y-axis with (fy) = 3.10 mm, distance between two patches (dy) = 25.94 mm, and distance between TVS-EBG and each patch (Ey) = 8.22 mm

4. RESULT AND DISCUSSION

Experimental Results:

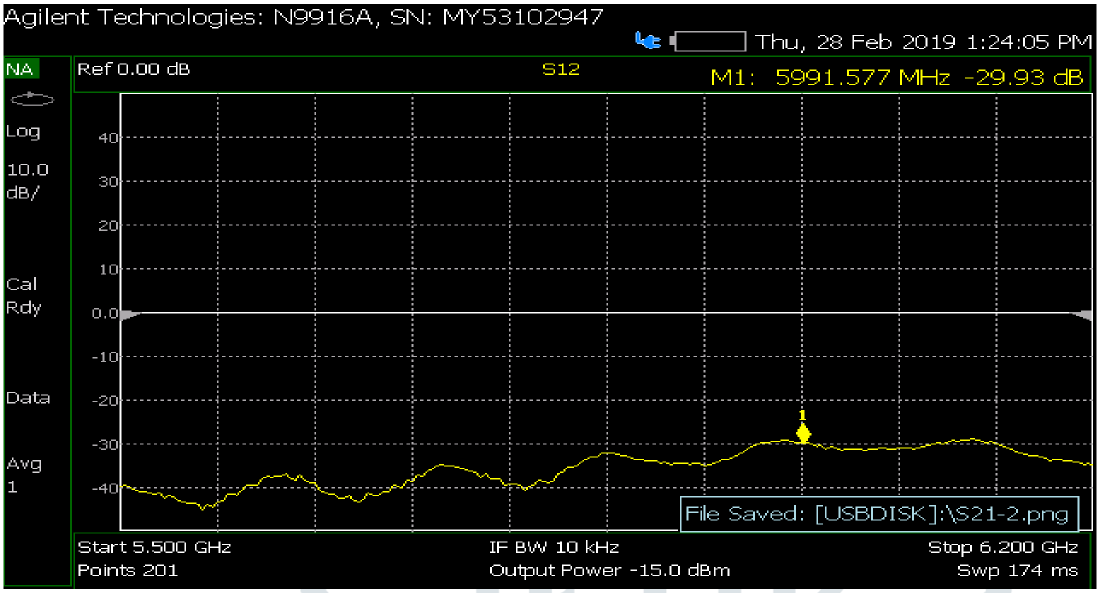

Fig. Measured Mutual coupling (S12) of fabricated microstrip antenna with TVS-EBG Structure.

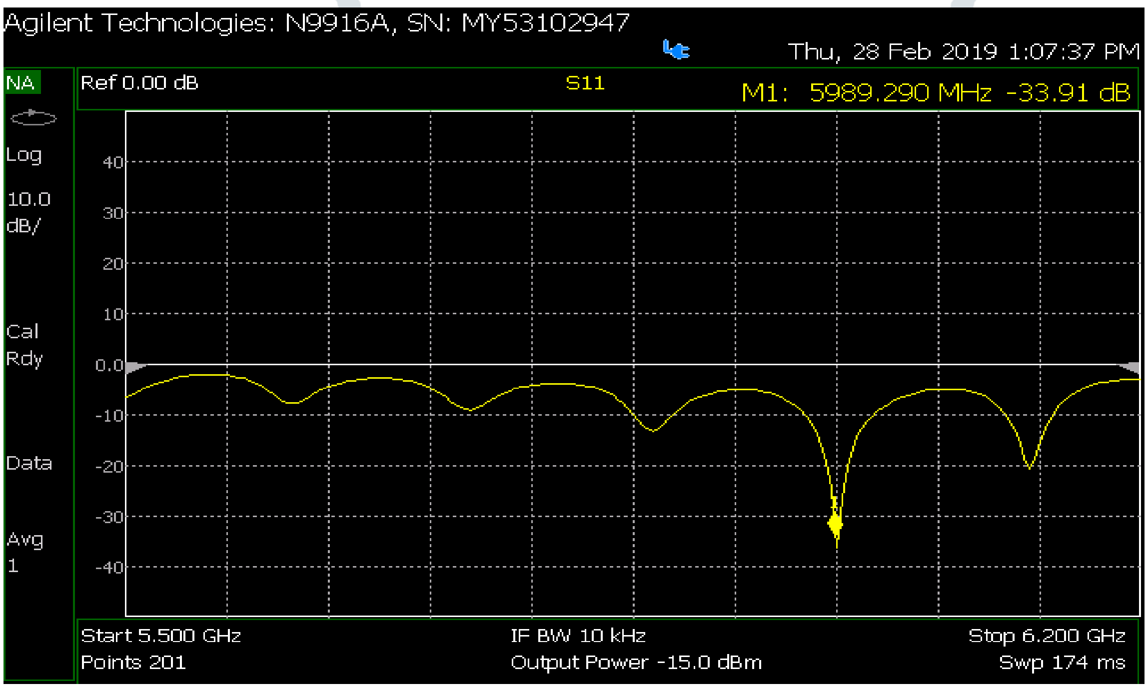

Fig. Measured S11 curve of fabricated microstrip antenna with TVS-EBG Structure for bandwidth calculation.

From above curve bandwidth extends from 5.97GHz to 6.01GHz.(For 5.99 GHz dip) and 5.85GHz to 5.87GHz(for 5.8GHz dip).

Comparison of Results with Base paper:

Sr. No.	Antenna Type	Measured Results		Measured Results(Base Paper)	
		Fo(GHz)	S12(dB)	Fo(GHz)	S12(dB)
1.	Microstrip patch antenna with TVS-EBG Structure.	5.80GHz	-37.85 dB	5.81GHz	-30.14 dB
		5.99GHz	-29.93dB		

From measured results of base paper for without TVS-EBG structure a strong mutual coupling of -23.13 dB occurs at 5.81 GHz between two patch antennas. When they have inserted two columns of the TVS-EBG between two patch antennas, a 7.01 dB mutual coupling reduction is obtained at 5.81 GHz.

In our case with insertion of two columns of TVS-EBG we have obtained 14.72dB mutual coupling reduction at 5.80GHz as compared to without TVS-EBG structure from base paper. And 7.71dB more mutual coupling reduction at 5.80 GHz as compared to with TVS-EBG structure from base paper. This Comparison proves the capability of the TVS-EBG structure to reduce the mutual coupling.

5. CONCLUSION

Reduction of mutual coupling of patch antenna array at 5.80 GHz frequency using TVS-EBG has been presented. Presented structure for patch array has implemented by inserting two rows of EBG structure between two patch antennas to reduce the mutual coupling. Periodic structures help in the reduction of mutual coupling using their ability of suppressing surface waves propagation in a given frequency range. Experimental results shows that the mutual coupling reduction of 14.72 dB is achieved using TVS-EBG structure. Presented mutual coupling reduction in patch antenna is very useful in IOT application where compactness is highly desirable.

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