

## Study of Compact 2×1 Microstrip Antenna Array Loaded with EBG Structure

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### Abstract

In this paper the design of two element microstrip antenna array (TEMAA) without and with Electromagnetic Band Gap (EBG) structure integrated in the ground plane and on the surface is demonstrated. The TEMAA designed at a frequency of 6 GHz is resonating at a frequency of 5.53 GHz with a return loss of -21.23 dB. With the introduction of EBG, the mutual coupling of TEMAA is reduced from -17.83 dB to -49.89 dB respectively. The front to back ratio of the modified antenna array is enhanced to 7.08 dB. The antenna arrays have been designed using Mentor Graphics IE3D simulation software and the measured results have been obtained using vector network analyzer. The antenna arrays designed operate in the frequency range of 1-7 GHz.

**Keywords-** Electromagnetic Band Gap Structure, Front to Back Ratio, Mutual Coupling, Return Loss.

### Introduction

An antenna is defined as an electrical device that transmits and receives electromagnetic waves. An antenna is an integral part of every person's life and can be used for a variety of applications. It is a key component of most of the communication systems. The radiation properties of an antenna can be varied by changing the dimensions of the geometry of the antenna or by incorporating new structures in the antenna or by making necessary changes in the antenna structure. Some of the radiation properties of an antenna are directivity, gain, half power beam width, beam width between first nulls, radiation resistance etc. Proper design of an antenna is very much desired in attaining the objectives of the researcher. [1-4]

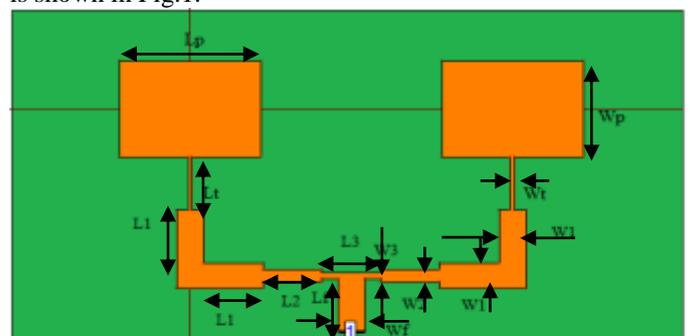
In the year 1953, scientist Deschamps invented a new class of antennas called microstrip antennas. With the recent advancements in technology towards designing low profile antennas, these antennas have received huge appreciation from researchers in fulfilling their aims and objectives due to the numerous advantages. Over the past few decades these antennas have proved to be excellent radiators in various fields of applications. In its simplest form a microstrip antenna consists of a dielectric substrate embedded between the radiating patch and ground plane. The radiating patch is available in a variety of shapes like square, rectangular, circular etc. [5-7]

Microstrip antenna arrays suffer from the serious drawback of very high mutual coupling between the

individual antenna elements. The problem of mutual coupling arises due to the excitation of surface waves in the dielectric substrate of the antenna array. This demerit can be overcome by increasing the distance between the antenna elements. However, this increases the area occupied by the microstrip antenna array. Mutual coupling can also be decreased by decreasing the substrate thickness, employing EBG structures, metamaterials etc. Many researchers have obtained appreciable improvement in the performance of microstrip antenna arrays by employing EBG structures. These structures are periodic in nature which assist or stop the propagation of electromagnetic band gap structures in a particular band of frequencies for any incident angle or polarization state. EBG structures have attracted many researchers because of their unique properties. [8-14]

### Configuration of Microstrip Antenna Array

Initially the conventional TEMAA is designed at 6 GHz. The antenna array is designed using FR-4 glass epoxy substrate which has a dielectric constant of 4.2 and loss tangent of 0.0245. This antenna array is made up of two similar rectangular radiating patches. The TEMAA is placed on the dielectric substrate FR-4 glass epoxy with a dielectric constant of 4.2. The length and width of the finite ground plane are 115.6 and 62.7 mm respectively. Corporate feeding technique is employed to design the conventional TEMAA. This feeding technique employs the feed of 50Ω transmission line. Additionally, it uses transmission lines of 70 and 100Ω respectively. The separation between the two antenna array elements is 20.81 mm. The schematic of the conventional TEMAA is shown in Fig.1.



**Fig.1. Schematic of conventional TEMAA.**

Table I summarizes the parameter values of conventional two element antenna array.

TABLE I. Parameter values of TEMAA.

Parameter	Value(mm)
Length of the patch (Lp)	15.73
Width of the patch (Wp)	11.76
Length of the quarter wave transformer (Lt)	6.47
Width of the quarter wave transformer (Wt)	0.47
Length of the 50Ω line (L1)	6.52
Width of the 50Ω line (W1)	3.05
Length of the coupler	3.05
Width of the coupler	3.05
Length of the 70Ω line (L2)	6.54
Width of the 70Ω line (W2)	1.62
Length of the 100Ω line (L3)	6.56
Width of the 100Ω line (W3)	0.70
Length of the feed line (Lf)	6.52
Width of the feed line (Wf)	3.05

**EBG STRUCTURE DESIGN**

In the design of the modified antenna array, two EBG's are used. The first EBG is the swastika slot type embedded in the ground plane of TEMAA. The second EBG is the square patch type incorporated on the surface of TEMAA in between the two radiating patches. The unit cells of both the EBG's and their dimensions are depicted in Fig.2. The left schematic depicts the unit cell of the EBG used in ground plane and the right schematic depicts that of the EBG used on the surface

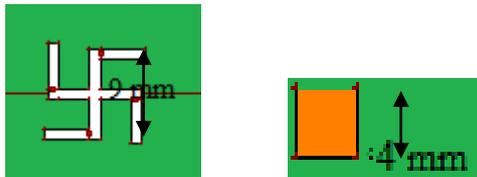


Fig.2. Schematic of the structure of unit cell of EBG's employed.

Figs.3 and 4 show the schematic of the EBG's employed to enhance the performance of TEMAA. The EBG structure used in the ground plane of TEMAA is a matrix of 4 rows and 7 columns of swastika slots depicted in Fig.3. The distance between the two adjacent unit cells of this EBG structure is  $S = 8.7$  mm along x-axis and y-axis.

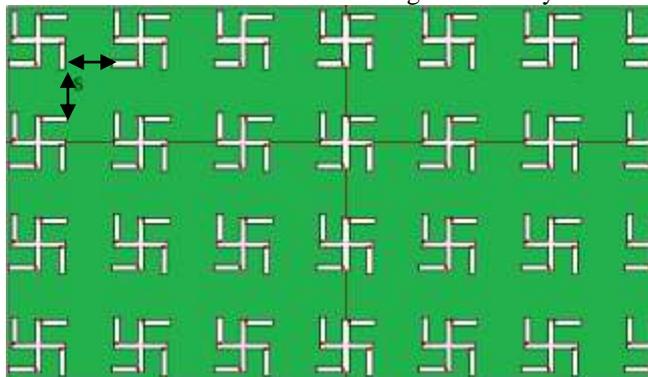


Fig.3. Schematic of the swastik slot EBG structure.

The EBG structure used on the surface of TEMAA is a matrix of 5 rows and 3 columns of square patch as depicted in Fig.4. The unit cells of this EBG structure are repeated after every  $S = 1$ mm along x-axis and y-axis.

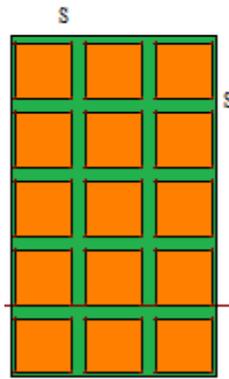


Fig.4. Schematic of the square patch EBG structure.

**ANTENNA ARRAY DESIGN WITH EBG**

To examine the effect of EBG on the TEMAA, the swastika slot EBG structure and square patch EBG structure are integrated in the ground plane and on the surface of TEMAA as shown in Fig.5. Using this schematic, bandwidth (%), return loss, virtual size reduction (%) can be evaluated.

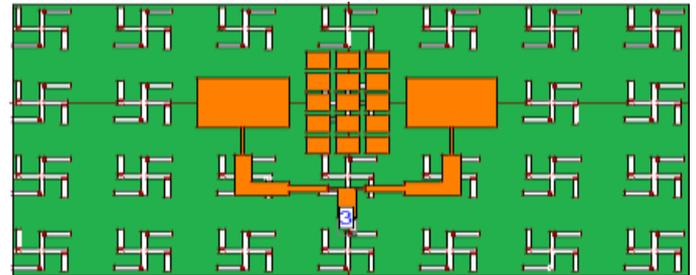


Fig.5. Schematic of TEMAA with EBG structures in the ground plane and on the surface.

The parameter mutual coupling can be measured by feeding the individual antenna elements separately. Fig.6. depicts the schematic of TEMAA with the EBG structures incorporated in the ground plane and on the surface. It is assumed that both the antennas are fed with the same amount of power. The distance between the antenna elements is maintained constant as in Fig.1.

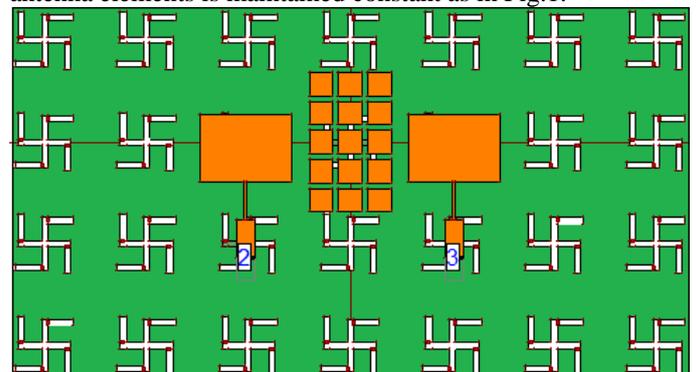


Fig.6. Schematic of TEMAA with EBG structures in the ground plane and on the surface for the determination of mutual coupling.

**PHOTOGRAPHS OF FABRICATED ANTENNAS**

The antenna arrays discussed in section III are fabricated using FR-4 glass epoxy as the substrate material. The

photographs of the fabricated antennas are depicted in Figs. 7, 8, 9 and 10.

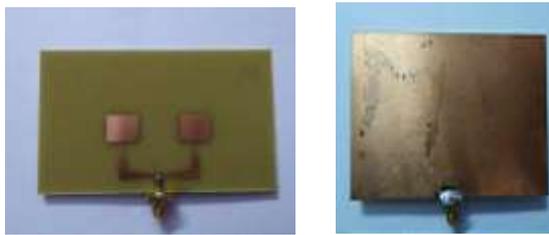


Fig.7. Photograph of TEMAA.  
(a) Front view (b) Back view

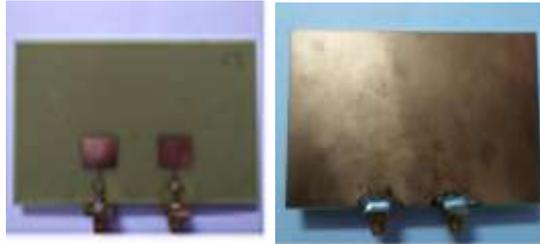


Fig.8. Photograph of TEMAA arrangement for mutual coupling measurement.  
(a) Front view (b) Back view.

Fig.9. Photograph of TEMAA with EBG.  
(a) Front view (b) Rear view.

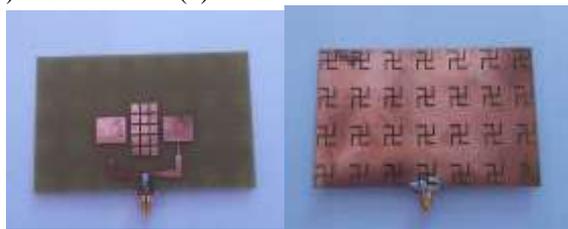
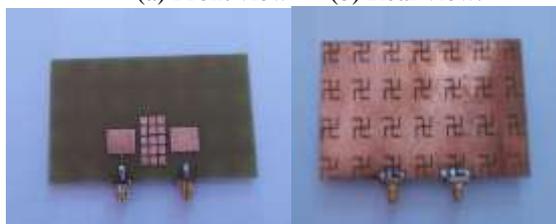


Fig.10. Photograph of TEMAA with EBG for mutual coupling measurement.  
(a) Front view (b) Rear view.



### Results and Discussion

The results of the fabricated antenna arrays are taken over a frequency range of 1-7 GHz. Fig.11 shows the plots of return loss and mutual coupling versus frequency.

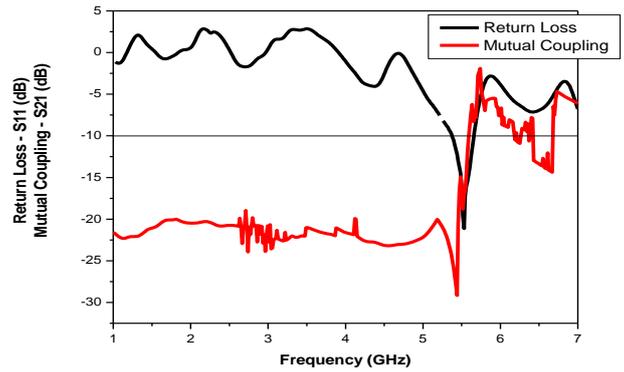


Fig.11. Plot of Return Loss and Mutual Coupling versus frequency of TEMAA.

The return loss plot shown in Fig.11 depicts that TEMAA is resonating at 5.53 GHz with a return loss of -21.23 dB. The bandwidth measured is equal to 130 MHz. The bandwidth (%) is 2.35%. From Fig.10, the value of mutual coupling measured at the resonant frequency of 5.53 GHz is equal to -17.83 dB. As can be seen from Fig.11, the graphs of return loss and mutual coupling are overlapping at the resonant frequency of 5.53 GHz which means there is disturbance in the transmission of information between the transmitting and receiving antennas.

The study of performance of TEMAA with the introduction of swastik slot EBG structure in the ground plane and square patch EBG structure on the surface is carried out. There is an improved performance of TEMAA as discussed in the following paragraph. Fig.12 shows the plots of return loss and mutual coupling of the modified antenna array.

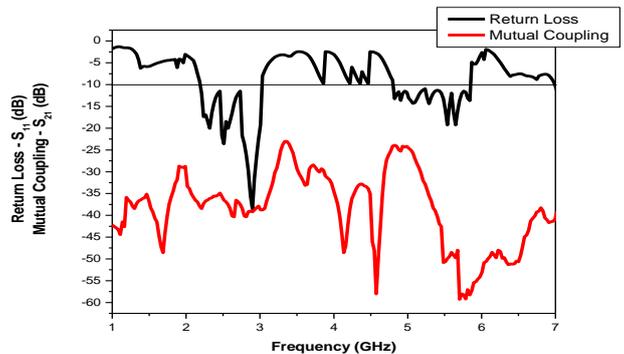
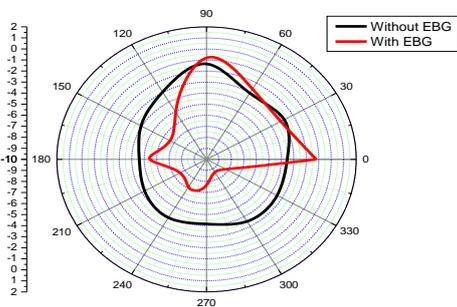


Fig.12. Plot of Return Loss and Mutual Coupling versus Frequency of TEMAA with EBG structures.

In the presence of EBG structures, the antenna array is resonating at 2.89 and 5.53 GHz respectively. The return loss of the modified antenna array at the fundamental resonant frequency of 2.89 GHz is -38.28 dB. The bandwidths measured for the two resonant frequencies are 837 and 1053 MHz respectively. The overall bandwidth (%) is equal to 48%. Thus we see that the bandwidth is enhanced by 45.65 %. Further, the mutual coupling measured at the frequency of 5.53 GHz is -49.89 dB. There is a huge decrease in the mutual coupling

value with the integration of TEMAA with the EBG structures. Moreover, from Fig.12, we can also see that the return loss and mutual coupling plots are no more overlapping at the resonant frequency of 5.53 GHz. This shows that the interference between the transmitting and receiving antennas has been minimized. This demonstrates that the TEMAA is transmitting and receiving information with better efficiency.

With the EBG structures, the antenna array is resonating at a fundamental resonant frequency of 2.89 GHz compared to 5.53 GHz without the EBG structures, thus producing a miniaturization of 47.73%. The radiation pattern of the proposed antenna arrays are plotted and studied in Fig.13. The radiation patterns of TEMAA without and with EBG structures are studied at the resonant frequency of 5.53 GHz.



**Fig.13. Plot of radiation patterns of TEMAA without and with EBG.**

The radiation plot of an antenna provides the data regarding the amount of power radiated from 0° to 360°. At the angle of 90° the forward power is measured and at 270° the backward power is measured. In the absence of EBG's, the TEMAA is radiating the forward power and backward power of -1.31 and -4.18 dB respectively. On the other hand, the TEMAA with EBG is radiating the forward power and backward power of -0.75 and -7.83 dB respectively. We see that with the introduction of EBG structures in the ground and on the surface, there is a remarkable decrease in the back lobe power from -4.18 dB to -7.83 dB respectively.

The parameter Front to Back ratio is calculated from the information provided by the radiation plots. It is determined by using the formula

$$\text{Front to Back ratio (dB)} = \text{Forward power radiated (dB)} - \text{Backward power radiated (dB)} \tag{1}$$

The front to Back ratio calculated without and with EBG structures are 2.87 and 7.08 dB respectively. The modified antenna array has greater front to back ratio compared to its counterpart, which implies the modified antenna array is radiating better in the desired direction than in the undesired direction.

**Summary of Measured Results**

Table II provides the summary of the measured results.

**Conclusion**

This paper demonstrates the effectiveness of employing

Electromagnetic Band Gap structures in improving the performance of a two element microstrip antenna array. Thus these structures have proved to be very useful tools in reducing the mutual coupling as well as in the miniaturization of the antenna array. The antenna arrays have been successfully designed and fabricated. A virtual size reduction of 47.73 % has been achieved. The antenna array with EBG structures is exhibiting good radiation characteristics. This shows that the performance of two element antenna array is improved by loading the EBG's in the ground plane and on the surface.

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Type of Antenna	Resonant Frequency (GHz)	Return Loss (dB)	Band Width (MHz)	Band Width (%)	Mutual Coupling (dB)
Without EBG	5.53	-21.23	130	2.35	-17.83
With EBG's	2.89 5.53	-38.14 -19.29	837 1053	48	-49.89

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