International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Available at http://inpressco.com/category/ijcet

Research Article

A Compact Efficient MIMO Antenna with EBG Structure

Arun Kumar[a*] and Taimoor Khan[b]

[a]Department of ECE, Trident ET Group of Institutions, Ghaziabad-201003
[b]Department of ECE, Delhi Technological University, Delhi

Accepted 5 July 2013, Available online 01 August 2013, **Vol.3, No.3 (August 2013)**

Abstract

A compact efficient multiple-input- multiple-output (MIMO) antenna with EBG structure is presented. The MIMO antenna consists of two symmetric monopoles and an EBG (electromagnetic band gap) plane which is present at an air gap of 0.4 mm above the ground plane. This EBG surfaces offer a mechanism to improve antenna performance, reduce antenna size and reduce antenna to antenna coupling on platforms. In this paper, we also introduced the comparison of performance parameters of the proposed MIMO antenna with EBG structure and referred MIMO antenna. The concept of air gap is also used with EBG and to collectively enhance the impedance bandwidth, increases the gain, increases the efficiency and reduces the effective size of the antenna. A high bandwidth with S11≤ -10 dB and S21 ≤ -18 dB from 2.303 - 6.738 GHz is achieved. The analysis has been done by using IE3D software based on method of moments (MOM).

Keywords: *Multiple-input multiple-output (MIMO) antenna, S-parameter (S_{11} & S_{21}), Directivity, Gain, Antenna Efficiency, Radiation Efficiency, EBG and Air gap.*

1. Introduction

Now-a- days, there is a demand to increase the data rate of existing wireless communication systems. The application of diversity techniques, most commonly assuming two antennas (commonly known as MIMO antenna(Qing-Xin Chu *et al*, 2012)) in a mobile terminal , can enhance the data rate and reliability without sacrificing additional spectrum or transmitted power in rich scattering environments (T. Bolin *et al*, 2005). When these two or more antennas can be used at both transmitter and receiver are called Multiple-input and multiple-output (MIMO) antenna or system. Theoretical and experimental investigations have revealed substantial improvements in channel capacity and reliability when multiple transmitter and receiver antennas are deployed. A critical point is to arrange, these compact MIMO antenna elements without impairing antenna performance and system requirements (Youngki Lee *et al*, 2012). When a multiple-input multiple-output (MIMO) antenna is applied in a multifunctional portable device, good performance parameters are demanded. As we know that the MIMO systems which consists of two or more monopole antennas have the advantages of low cost, easy fabrication, and good performance (Cheng Yang, *et al*, 2012). But these performance parameters of MIMO antenna are not good enough to increase the performance of the portable device. However, the design of a compact efficient MIMO antenna with good performance parameters is an open issue.

In this paper, a compact efficient MIMO antenna with EBG structure is proposed. The electromagnetic band gap (EBG) structures between the substrate and the ground plane of referred MIMO antenna is inserted and its effect on the performance parameters of the MIMO antenna are studied . These structures (EBG) consist of uniformly distributed periodic metallic, dielectric or composite structures that exhibit pass and stop bands in their frequency response. Essentially the behaviour of the EBG structure is based on the interactions between adjacent cells and therefore the larger the number of cells, the more effective the structure (R.B. Waterhouse , *et al*, 2000). When these structures are introduced at the ground level some radiation will occur in the reverse side of MIMO antenna also. This creates back lobe in the opposite side. This EBG plane is used at the distance from the ground plane, which creates an air gap between the substrate and ground plane. When this EBG plane is placed at an air gap of 0.4 mm above the ground plane, all the parameters of the MIMO antennas have been increased much further (N. S. Raghava , *et al*, 2006). Hence, the MIMO antenna performance parameters such as radiation efficiency, antenna efficiency, directive gain (K. Payandehjoo , *et al*, 2009) are improved. As we have discussed above how EBG structure is used to enhance the performance of referred MIMO antenna. In this proposed paper the effect of air-gap with reference to EBG on the performance parameters of the MIMO antenna are also

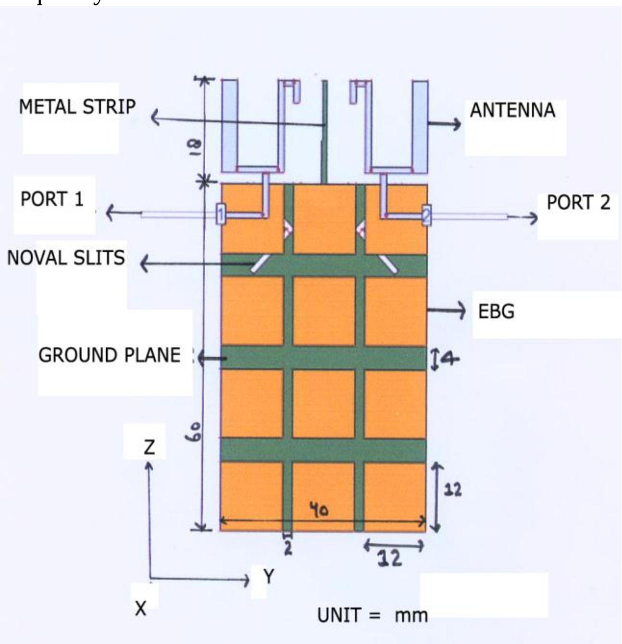
*Corresponding author: Arun Kumar

studied. This air-gap technique collectively enhances the impedance bandwidth, increases the gain, increases the efficiency and reduces the effective size of the antenna. This air-gap helps in order to achieve tunable resonant frequency characteristics.

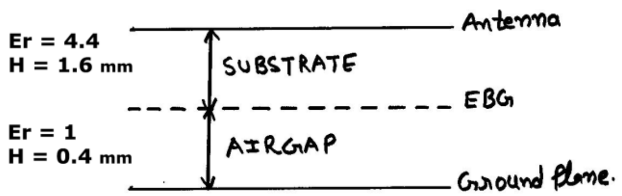
The proposed Compact Efficient MIMO antenna with EBG structure consist of two dual-branch monopoles and an EBG surface which at an air gap of 0.4 mm above the ground plane and the compact sizes of the monopole , the ground plane (L*W), EBG cells, gap between EBG cells on width sides and gap between EBG cells on length sides are 18mm* 15 mm , 60mm* 40 mm , 12mm*12 mm, 2 mm and 4 mm, respectively. A high bandwidth with $S_{11} \leq -10$ dB and $S_{21} \leq -18$ dB from 2.303 to 6.738 GHz is achieved, which covers 2.4/5.2/5.8-GHz WLAN, 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1–4.8 GHz) operation.

2. Proposed MIMO Antenna With EBG Structure

The geometry of the proposed MIMO antenna with EBG is designed by using IE3D software (Zeland), which is illustrated in Fig. 1. The MIMO antenna is printed on the upper part of a partially grounded FR4 substrate with dimensions 78mm*40mm*1.6mm^3 and relative permittivity 4.4. And an EBG structure is inserted at an air-gap of 0.4mm above the ground plane. On the back surface of the substrate, the main rectangular ground plane of 40 mm in width and 60 mm in length is printed. The compact sizes of the monopole , the ground plane (L*W), EBG cells, gap between EBG patches on width sides and gap between EBG patches on length sides are 18mm* 15 mm, 60mm* 40 mm, 12mm*12 mm, 2 mm and 4 mm, respectively. EBG is of like Mushroom-type and each slit is coupled fed by a 50 ohm microstrip line. The geometry of proposed antenna is simulated on the meshing frequency of 7 GHz.



(a) Top-view



(b) Side-view

Fig 1: MIMO Antenna with EBG structure.

3. Working Mechanism of Proposed Antenna

The proposed MIMO antenna with EBG structure shown in Fig. 1 has been simulated and studied to a good agreement using IE3D software. From the calculated graphs and tables we can say that the performance parameters of MIMO with EBG structure shows much improvement as compare to refer MIMO antenna. Between 3-3.5 GHz and above 6 GHz frequency, the performance parameters of proposed antenna show great improvement.

4. Simulated Results and Comparison

Performance Parameters of Proposed Antenna

(i) S-parameters – As we know that it describe the input-output relationship between ports (or terminals) in an electrical system. If S_{11} = -10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power. Fig 2 depicts the return loss (S_{11}) and (S_{21}) characteristics of the proposed antenna and the referred MIMO antenna with frequency respectively. It also shows a high bandwidth with $S_{11} \leq -10$ dB and $S_{21} \leq -18$ dB from 2.303 to 6.738 GHz covering the following bands: 2.4/5.2/5.8-GHz WLAN, 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1–4.8 GHz) operation.

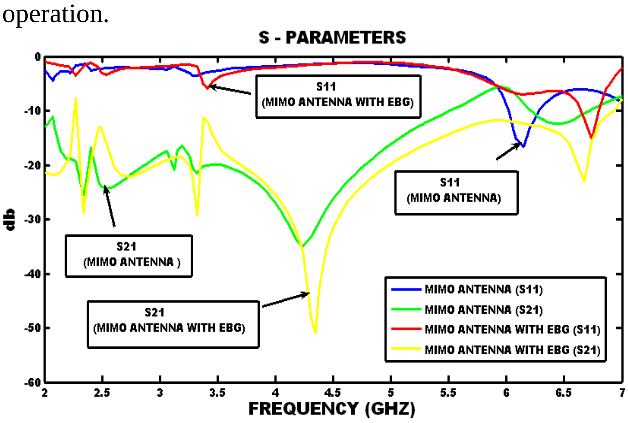


Fig 2: S-parameters (S_{11} and S_{21}) vs. Frequency

The above graph shows the comparison of S_{11} and S_{21} characteristics of MIMO antenna with EBG and the referred MIMO antenna(Qing-Xin Chu *et al*, 2012). The proposed antenna worked in various frequency bands which is shown by fine frequency dips in the above graphs. The values of S_{11} and S_{21} characteristics against these frequencies dip are shown in the below table.

(ii) Directivity - As we know that it is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction. Fig. 3 depicts the variations of antenna directivity characteristics of the proposed antenna and the referred MIMO antenna with frequency respectively.

From the below graph, it is calculated that the directivity of the proposed antenna is above 6.6 dBi over a frequency band 3-3.5 GHz and 6 GHz, respectively. Also the Directivity (D) of proposed MIMO antenna with EBG structure is increased by 0.487% against the referred MIMO antenna and by 0.487 % against the MIMO antenna with Air gap respectively over a frequency band of 3-3.5 GHz.

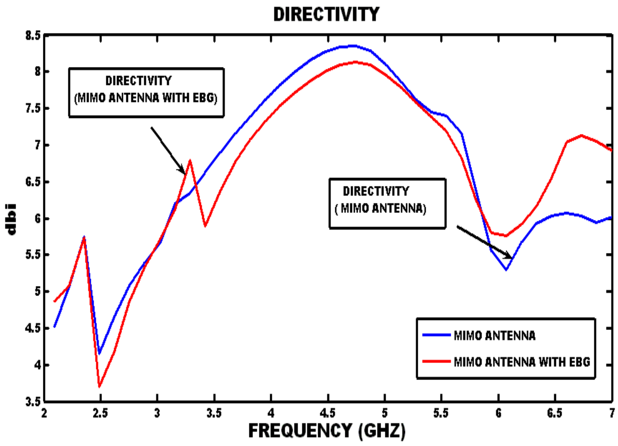


Fig 3: Directivity vs. Frequency

(iii) Gain - The gain is an actual quantity, which is always less than the directivity. We are only interested in the maximum gain, which is the gain in the direction in which the antenna is radiating most of the power. Fig 4 depicts the variations of antenna gain characteristics of the proposed antenna and the referred MIMO antenna with frequency respectively.

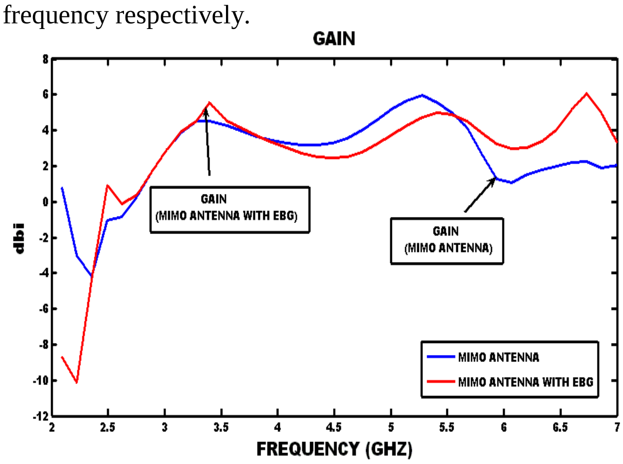


Fig 4: Gain vs. Frequency

The proposed antenna has a gain above 5 dBi over a frequency band 3-3.5 GHz and 6.5 GHz respectively which we have calculated from the above graph. And also the Gain (G) of proposed antenna is increased by 12.88% against the referred MIMO antenna and by 5.583 % against the MIMO antenna with Air gap respectively over a frequency band of 3-3.5 GHz.

(iv) Efficiency - The antenna efficiency (or radiation efficiency) can be written as the ratio of the radiated power to the input power of the antenna. Fig 5(a) depicts the variations of antenna efficiency characteristics of the proposed antenna and the referred MIMO antenna with frequency respectively. The proposed antenna has an antenna efficiency of 83.16 % and 74.92 % over a frequency band 3-3.5GHz and 6 GHz, respectively which is calculated from the below graph.

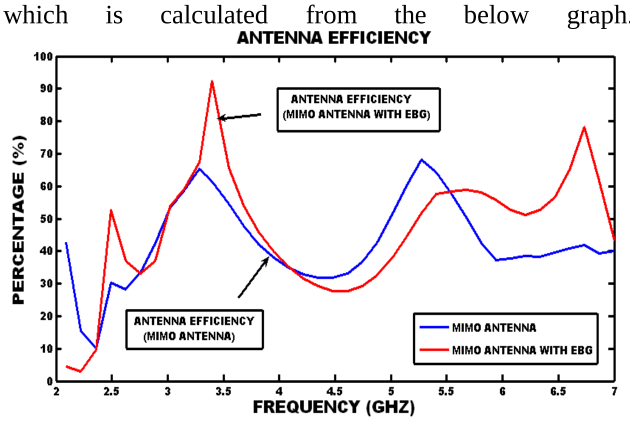


Fig 5(a) Antenna Efficiency vs. Frequency

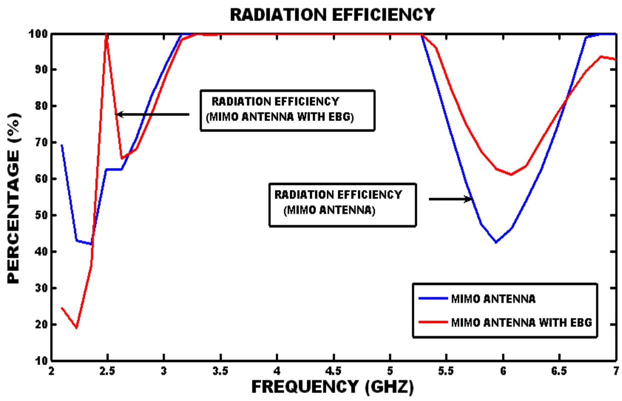


Fig 5(b) Radiation Efficiency vs. Frequency

Fig 5(b) depicts variations of radiation efficiency characteristics with frequency. The proposed antenna has a radiation efficiency of 100% over both frequency band 3-3.5 GHz and 6 GHz, respectively which cover 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1–4.8 GHz) operation. And in reference to the other antenna's (MIMO antenna and MIMO antenna with Air gap) the radiation efficiency (RE) of proposed antenna is same (100 %) over a frequency band of 3- 3.5 GHz.

(A) MIMO Antenna with EBG Structure

Table 1 show the variations of different performance parameters (directivity, gain, antenna efficiency, radiation efficiency) with respect to frequency and we have noted these variations from the above graphs.

Table 1: MIMO Antenna with EBG Structure

S. No.	f (GHz)	S_{11} (dB)	D (dBi)	G (dBi)	AE (%)	RE (%)
1	2.303	-3.096	5.215	-3.115	15.04	34.91
2	2.504	-3.294	3.750	1.218	57.63	86.34
3	**3.388**	**-5.785**	**6.596**	**5.125**	**83.16**	**100**
4	6.137	-6.948	5.839	2.981	51.78	61.99
5	**6.738**	**-14.246**	**7.187**	**5.936**	**74.92**	**81.15**

The above table of proposed antenna shows a high bandwidth with $S_{11} \leq$ -10 dB and $S_{21} \leq -18$ dB from 2.303-6.738 GHz covering the following bands: 2.4/5.2/5.8-GHz WLAN, 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1–4.8 GHz) operation. In above table the bold portion shows much improvement in performance parameters over frequency band 3 – 3.5 GHz and above 6 GHz when compared to the referred MIMO antenna and the MIMO antenna with air gap.

(B) MIMO Antenna with Air-Gap OF 0.01 mm from Ground Plate

This table show the readings or variations of different performance parameters (directivity, gain, antenna efficiency, radiation efficiency) with respect to frequency and we have noted these variations from the graphs for our own interest which we get after simulation of MIMO antenna with air gap (0.01mm) geometry. This geometry is simulated to check whether the performance parameters of referred MIMO antenna are increased or not. The results shows slight improvements in all the parameters.

Table2: MIMO Antenna with Air-gap

S. No.	f(GHz)	S_{11}(dB)	D(dBi)	G(dBi)	AE (%)	RE (%)
1	2.11	-4.981	4.637	2.923	55.14	68.78
2	2.249	-3.424	5.129	-2.906	15.96	42.48
3	2.431	-2.471	4.758	-2.206	44.9	88.62
4	3.154	-2.536	5.857	3.61	60.61	96.45
5	**3.326**	**-3.306**	**6.564**	**4.854**	**64.7**	**100**
6	6.143	-14.991	5.457	1.341	38.9	51.48

The above table of MIMO antenna with air gap shows a high bandwidth with $S_{11} \leq$ -10dB and $S_{21} \leq -18$ dB from 2.110 to 6.143 GHz covering the following bands: 2.4/5.2/5.8-GHz WLAN, 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1-4.8 GHz) operation. In above table the bold portion shows the improvement in performance parameters of the MIMO antenna with air gap over frequency band 3-3.5 GHZ when compared to the referred MIMO antenna.

(C) MIMO Antenna

Table 3 show the readings or variations of different performance parameters with respect to frequency and we have noted these variations from the above graphs.
The below table of MIMO antenna shows a high bandwidth with $S_{11} \leq$ -10 dB and $S_{21} \leq$ -18 dB from 2.114 to 6.137 GHz covering the following bands: 2.4/5.2/5.8-GHz WLAN, 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1-4.8 GHz) operation. In above table the bold portion shows the best performance parameters over frequency band 3-3.5 GHz.

Antenna efficiency (AE) of MIMO antenna with EBG is increased by 28.61% against the referred MIMO antenna and 28.53 % against the MIMO antenna with Air gap respectively over a frequency band of 3-3.5 GHz.

Table3: MIMO Antenna

S. No.	f (GHz)	S_{11} (dB)	D (dBi)	G (dBi)	AE (%)	RE (%)
1	2.114	-11.430	4.733	-2.301	23.43	54.25
2	2.249	-3.389	5.288	-3.118	14.68	41.77
3	2.413	-2.481	3.847	0.887	51.25	96.51
4	3.099	-2.361	6.034	3.077	51.06	97.81
5	**3.321**	**-3.479**	**6.423**	**4.540**	**64.66**	**100**
6	6.137	-16.834	5.449	1.270	38.20	49.73

From the above tables we can say that between 3 to 3.5 GHz and above 6 GHz frequency, the performance parameters of MIMO with EBG show great improvement compare to the other two antennas (MIMO antenna with air-gap and referred MIMO antenna).

Conclusion

A compact efficient MIMO antenna with EBG structure has been investigated and also the comparison of performance parameters of the proposed antenna with the MIMO antenna with Air gap and the MIMO antenna (Qing-Xin Chu *et al*, 2012) are studied. A high bandwidth with $S_{11} \leq -10$dB and $S_{21} \leq -18$dB from 2.303 to 6.738 GHz is achieved, which covers 2.4/5.2/5.8-GHz WLAN, 2.5/3.5/5.5-GHz Wi-MAX and the lower UWB band (3.1–4.8GHz) operation. The comparison of calculated results from the graphs and tables shows that the performance parameters of the proposed antenna are increasing to a great extent. The MIMO antenna with air gap shows slight improvement in the performance parameters when compared to the referred MIMO antenna. As we have also seen in this paper that EBG techniques are used to enhance the impedance bandwidth, increase gain, increase efficiency and reduces the effective size of the antenna.

References

Qing-Xin Chu, Tian-Gui Huang, Jian-Feng Li (2012), Compact wideband MIMO antenna with two novel bent slits, *IEEE Trans on Antennas and Propag*, Vol. 60, No. 2.

T. Bolin, A. Derneryd, G. Kristensson, V. Plicanic, and Z. Ying (2005), Two-antenna receive diversity performance in indoor environment, *Electron Lett,* Vol. 41, No. 2, pp. 1205–1206.

Youngki Lee, Deukhyeon Ga and Jaehoon Choi (2012), Design of a MIMO Antenna with Improved Isolation Using MNG Metamaterial, *International Journal of Antennas and Propagation*, Article ID 864306 ,7 pages, doi:10.1155/2012/864306.

Cheng Yang, Yuan Yao, Junsheng Yu and Xiaodong Chen (2012), Novel Compact Multiband MIMO Antenna for Mobile Terminal, *International Journal of Antennas and Propagation,* Article ID 691681, 9 pages, doi:10.1155/2012/69168.1

R.B. Waterhouse and D. Novak (June 2000), A Small Electromagnetic Band-gap Structure, *IEEE Proceedings-International Microwave Symposium*.

N. S. Raghava and Asok De (2006), Photonic Band-gap Stacked Rectangular Microstrip Antenna for Road Vehicle Communication, *IEEE Antennas and Wireless Propagation Letters*, Vol. 5, pp. 421-423.

K. Payandehjoo and R. Abhari (2009), Employing EBG Structures in Multiantenna Systems for Improving Isolation and Diversity Gain, *IEEE Antennas and Wireless Propagation Letters*, Vol. 8, pp. 1162-1165.

Zeland IE3D 14.1 software which work on method of moments (MOM).