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Design of EBG Structure for Mutual Coupling Reduction in Patch Antenna Array

Mr. M. B. Kadu*
Research Scholar, Symbiosis International University,
Lavale, Pune, India
mahesh.kadu@gmail.com

Dr. Neela Rayavarapu
Professor, Symbiosis Institute of Technology, Symbiosis
International University, Lavale, Pune, India
neela.rayavarapu@sitpune.edu.in

Dr. R. P. Labade
Head Department of Electronics and Telecommunication
Amrutvahini College of Engineering
Sangamner,India
rplabade@gmail.com

Abstract— **In this work a microstrip patch antenna array is designed to resonate at 2.4 GHz frequency. The FR4 material having dielectric constant (ϵr) of 4.4 is used as a substrate of height 1.6mm to design antenna array. The two elements in array structure are kept at a distance of 0.2λ from each other. Further to reduction in mutual coupling between two elements of array is achieved by designing an Electromagnetic Band Gap structure. A mutual coupling reduction of 10 dB is obtained using proposed EBG Structure. HFSS simulation software is used to optimize the proposed antenna array with EBG.**

Keywords-Antenna Array , Mutual Cou[pling , EBG.

I. INTRODUCTION

With the advancement in wireless communication technology need is felt for more data rate for each application. Moreover multiple applications are introduced in wireless gadgets such as mobile phone, laptop etc each requiring an antenna for communication. Also it is required to execute each application simultaneously. So the current focus is on designing multiple antenna system that will meet the needs of wireless transmission and reception of data. Since wireless gadgets are becoming smaller and smaller the antenna which is an inseparable part of these devices has to also reduce its size. Designers are trying to meet both these aspects by designing compact wireless system. In these compact designs mutual coupling between antenna array elements is a major hurdle.

Antenna diversity techniques such as spatial and polarization diversity are being employed by designers to increase isolation between elements [1]. Some designers are focusing on increasing isolation by reducing surface wave currents and ground currents. They have successfully implemented certain techniques like Electromagnetic Band Gap structures, slits in ground plane, T shaped neutralizer, placing metallic plates between elements to combat issue of increasing isolation between ports [2]-[9].

II. MUTUAL COUPLING REDUCTION TECHNIQUES

Different isolation enhancement techniques are successfully implemented by researchers. Among them defective ground structure is more popular owing to its simple design and implementation [2]. Sectored patch technique is employed where isolation requirements are not so stringent [5]. Electromagnetic band gap structures offer a great increase in isolation between elements but are complex to design and analyze, also space available for EBG structure in a MAS system is a major design issue [6]. Metamaterials can also enhance isolation between radiating elements [8]. A microstrip open stub helps to improve isolation when used in MAS. Mutual coupling between elements can be reduced by loading antennas with shorting posts or shorting pins. All the techniques discussed in this paper are aimed to combat surface wave and ground plane currents in a multiple antenna system. The challenge for a researcher is to design a Multiple Antenna System with enhanced isolation in a given space for a wireless communication system. Alam, Md. Shahidul, Norbahiah Misran, BaharudinYatim, and Mohammad Tariqul Islam showed that an EBG structure has some special features that are not seen in nature. Broadly, they defined it as “artificial effectively homogeneous electromagnetic structures with unusual properties not readily available in nature”. In EBGs metallic elements are arranged periodically in either of one, two or three dimensions. Designed structure creates multiple band gaps as band gap is created is also controlled by each element resonating in EBG structure. The interaction between macroscopic and microscopic resonances each individual element structure decides the band gap formation in EBG. The periodicity results in the creation of the Bragg resonance, whereas the microresonance is created because of features of each element. Band gap achieves maximum width when these two resonances meet. Dominance of each stop band depends on the structure of EBG and wave polarized in a array

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structure. All other frequencies except frequencies at the stop band are passed by EBG structure [10].

III. ANTENNA ARRAY DESIGN

Rectangular shaped microstrip patch antenna element is designed to resonate at frequency f_r = 2.4 GHz. Dielectric substrate of FR-4 material is used for design of single element. The dielectric constant of this substrate is ε_r = 4.4 and having height h = 1.6mm.The overall dimensions of the rectangular microstrip antenna are calculated from transmission line formulae.

Further a two element microstrip patch antenna array is designed with distance between two elements equal to 0.2λ as shown in Fig 1.

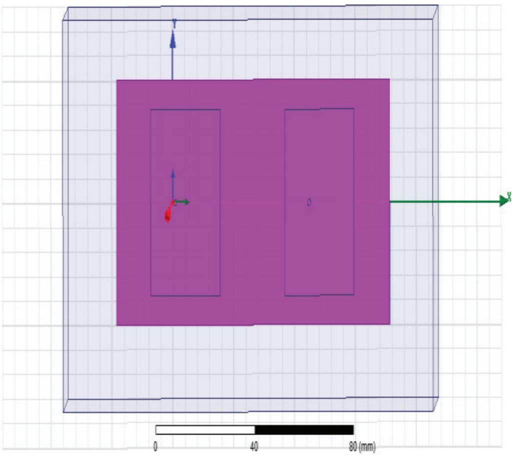

Fig. 1. Geometry of the two element Rectangular MSA Array with spacing of λ/5 between two elements

The overall dimensions of single element rectangular patch antenna are exhibited in Table I.

Table I

Dimensions of rectangular patch antenna

Resonant Frequency	2.4GHz
Width of Patch	38mm
Length of Patch	28mm
Width of Substrate	48 mm
Length of Substrate	38mm
Feed Position	(6,0)
Width of ground plane	48 mm
Length of ground plane	38mm

IV. DESIGN OF ANTENNA ARRAY WITH EBG STRUCTURE

A. *Design of Single EBG structure*

The conventional mushroom like EBG structure is designed as shown in Fig 2.It has a ground plane with a dielectric and metallic patch with connecting vias.

The overall dimensions are obtained as W= 0.12λ_{GHz}, g= 0.02 λ_{GHz}, h= 0.04 λ_{GHz}, ε_r=4.4 and the via radius is 0.005 λ_{GHz}.

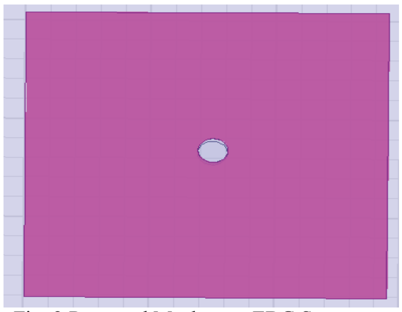

Fig. 2.Proposed Mushroom EBG Structure.

B. *Antenna Array with EBG structure*

Three EBG structures separated by a gap of .25mm are placed in between two patch antenna elements of array. The final optimized design of antenna array with EBG is shown in Fig 3.

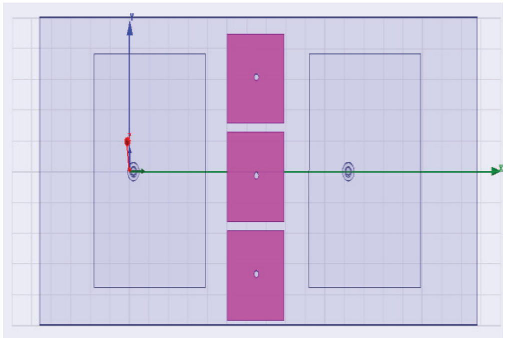

Fig. 3 Three element Square EBG Structure with spacing =0.02λ = 0.25 mm.

V. RESULTS AND DISCUSSION

A. *Return Loss for First rectangular patch antenna(S11)*

As shown in Fig 4 return loss value for first patch element in a array i.e S11 is about -13.0dB at 2.4 GHZ frequency .

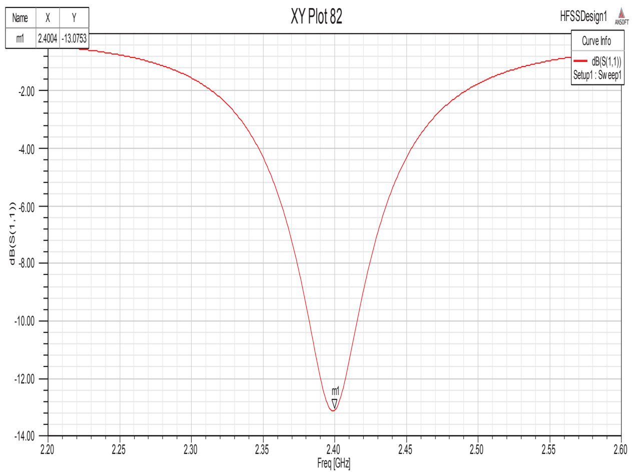

Fig. 4. Graph of RL Vs frequency of antenna(S11)

B. Return Loss for Second rectangular patch antenna(S22)

As shown in Fig 5 return loss value for first patch element in a array i.e S11 is about -13.0dB at 2.4 GHZ frequency.

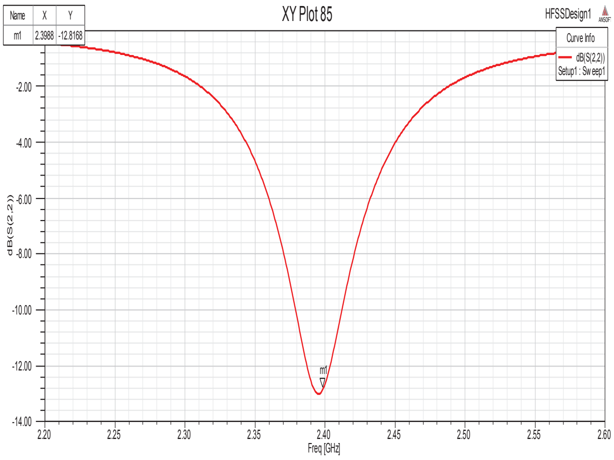

Fig.5. Graph of RL Vs frequency of antenna(S22)

C. Measurement of mutual coupling between two Rectangualr patch elements without EBG

Mutual Coupling value obtained from simulation is about -23.0 dB shown in Fig 6, which is due to surface current coupling between two patch elements.

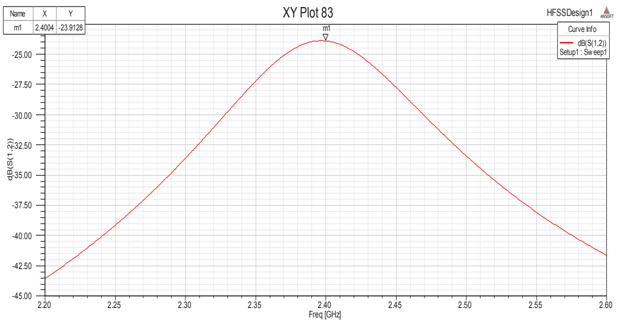

Fig. 6. Mutual coupling parameter between two array elements without

D. Measurement of mutual coupling between two Rectangualr patch elements with EBG

Fig 7 shows that mutual coupling between two elements used in array structure is below -33 dB below value of mutual coupling is obtained due to EBG structure acting as a Band Stop Filter at 2.4 GHz frequency.

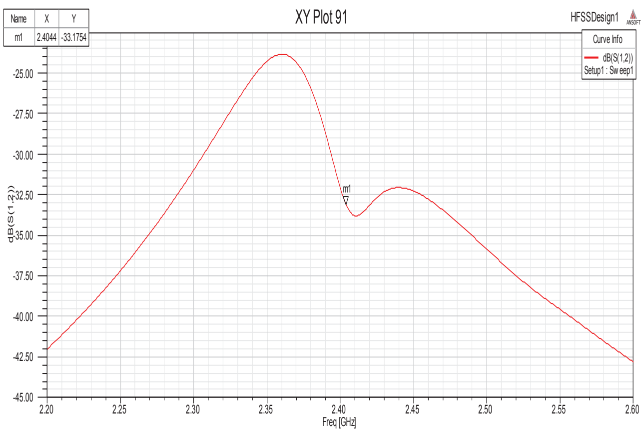

Fig. 7 Mutual coupling parameter between two array elements with EBG.

V. CONCLUSION

A single Rectangular Microstrip Patch Antenna was designed and optimised using Transmission line Formulae to resonate at 2.4 GHz(ISM band) frequency. Rectangular Microstrip Patch Antenna Array was designed and simulated using HFSS simulation software. Mutual Coupling value obtained from simulation was -23.0 dB. Further a Electromagnetic Band gap structure was designed for Rectangular Microstrip Patch Antenna Array which has reduced mutual coupling to -10 dB showcasing S12= -33.0 dB.

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