PERFORMANCE ENHANCEMENT OF RMPA BY UNDERNEATH 2D-EBG GROUND PLANE

Kunapareddy Koteswara Rao[1], Pasumarthy Nageswara Rao[2], Vangala Sumalatha[3]
Department of ECE, Asst. Professor , Matrusri Engineering College,,Hyderabad.
Department of ECE, Professor ,Vardhaman College of Engineering, Hyderabad |
Department of ECE, H.O.D, Jawaharlal Nehru Technological University Anantapur (JNTUA)

***Abstract*—**The radiation characteristics of Rectangular Microstrip Patch Antenna (RMPA) placed over two dimensional Electromagnetic Band Gap (2D-EBG) ground plane is studied. The complete model is designed in numerical 3D-EM (electromagnetic) simulation software. The results obtained are compared with results of conventional RMPA over conducting ground. The dimensions of 2DEBG are considered such that it can operate within ISM band, and RMPA is made to operate within the ISM band gap. The first part of this paper contains characterization of surface properties of 2DEBG. The 2DEBG is resonating at 2.5GHz with a FBG (forbidden band gap) of 1.5GHz, in phase reflection band gap (AMC) of 41MHz and a high impedance of 3540 ohms. The high surface impedance property of helps achieve RMPA miniaturization. The property of in-phase reflection band helps to enhance the gain upto 3.5dB, when compared with the conventional arrangement. Due to surface wave band gap property, smoother radiation pattern, improvement in the radiation efficiency and an operating band width of 3% has been achieved.

***Index Terms*— EBG (Electromagnetic band gap), EM(Electromagnetic) Waves, AMC (Artificial Magnetic Conductor)**

I. INTRODUCTION

The growth of wireless communication marketis challenging the RF engineers to fulfill the increasing needs of end user. The challenges include in designing of compact size, wide-band, high gain, power efficient, cost effective, multipurpose system design. In literature, various techniques were proposed to sustain the bandwidth of an antenna at adequate level with a miniaturized antenna operating in compact multisystem environment. The methodologies include, slotted patches, shorting pin [1]. Metamaterials, EBG [2, 3], Double negative materials [4, 5], Left handed materials [6-8].

The EBGs are periodic structures and can be easily fabricated using conventional PCB technology. EBG structures are exhibiting FBG and AMC properties and have useful application in antenna engineering. The FBG property helps to achieve better gain, efficiency, lower side and back lobe levels, and better isolation between array elements [9-11]. Its structure consists of capacitive patches that are connected to a conducting ground plane by means of metal stubs. The stubs pass through a dielectric material. This forces the tangential magnetic fields impinging on its surface to become zero & hence named as Artificial Magnetic Conductor (AMC) [12-14]. The AMC property helps to design low volume antennas [15-17]. Numerous forms of EBG structures were fabricated and applied for antennas, to diminish the size of antenna and improve its bandwidth and gain [18-24].

II. DESIGN PROCEDURE

The structure of conventional microstrip patch antenna consists metallic patch on a top surface of dielectric substrate, treated as a radiator or receiver of EM energy, backedby a conducting metal surface resembled as ground. The patch antenna radiate radio waves in front surface direction due to ground conductor. The directivity of respective antenna depends on the size of ground conductor, as ground size reduces the directivity reduces because of leakage of radio waves to sides and the rear.

The architecture of 2D-EBG consists square patches printed over the top face of FR4 dielectric, while other side consists of conducting ground plane. The conducting stubs electrically shorts the ground plane with patches. Three unusual properties these 2D-EBGs are exhibiting, such as (i) high surface impedance, (ii) in-phase reflection and (iii) surface wave suppression band. In this paper, RMPA with edge feeding is placed over the 2DEBG ground and its radiation characteristics are studied.

First part of the paper contains determination of EM properties of 2D-EBG. Later, comparative analysis of RMPA radiation characteristics with and without 2DEBG ground is performed and results obtained are presented. The complete structure is designed& analyzed using simulation software named as HFSS.

III. 2D-EBG DESIGN:

The 2D-EBG structure can be visualized as resonating structure due to its lumped inductance L and capacitance C in parallel combination. The inductances are developed due to vertical stubs and capacitances are formed due to fringing fields between adjacent patches. The resonating frequency of 2DEBG can be given as $w_0 = \frac{1}{\sqrt{LC}}$ where capacitance C is given as

$$C \approx \frac{w(\varepsilon_1 + \varepsilon_2)}{\pi} \cosh^{-1}\left(\frac{a}{g}\right) \qquad [1]$$

Inductance L is given as L = µt, where t is thickness, µ is permeability of a medium.

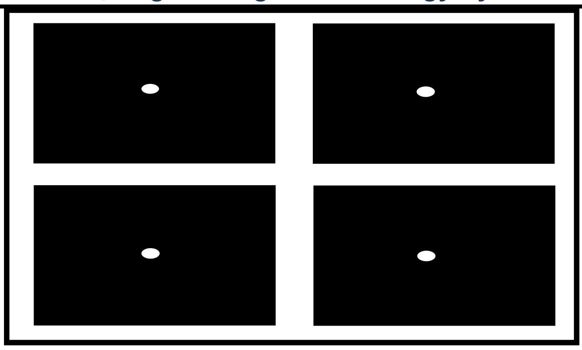


Fig 1: Periodic array of 2DEBG unit cells

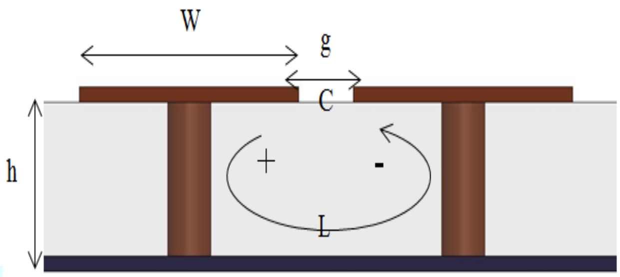


Fig 2: Cross sectional view

W: the patch width,g: the gap width between patches,h: the substrate thickness, ε_r : The substrate permittivity, r: the via radius.

Fig 1: Shows the top view of periodic array of 2DEBG unit cells. This consists of double sided FR4 substrate with dielectric constant of 4.4 and loss tangent of 0.009. Its top face is etched out so as to form a lattice of square patches. Its bottom face consists of planar conducting surface. Top square patches are shorted to bottom conducting surface with the help of conducting stub or via that passes through the dielectric medium from top to bottom. The stub or via is placed exactly at the center of each unit cell. Fig 2: shows the cross sectional view of 2DEBG unit

IV. CHARACTERIZATION OF 2DEBG:

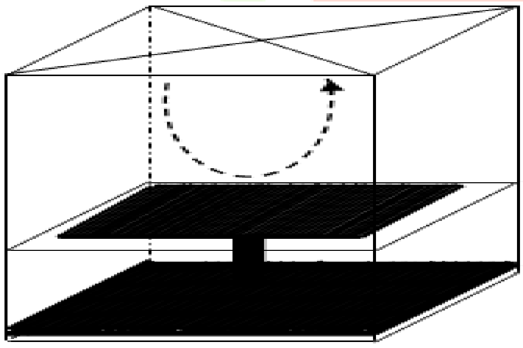


Fig 3: Schematic diagram used to measure propagation characteristics

1. REFLECTION CHARACTERISTICS

Fig 4: Displays Graph of reflection phase, drawn between scattering (S11 in dB) parameter verses frequency for incident TEM wave for fig 3. Here the reflection characteristics vary from +180 degree to -180 degree. The range between + 90 degree to -90 degree is considered as AMC band. During this band magnitude of reflection co-efficient is +1. Proposed model exhibiting AMC band of 41MHz.

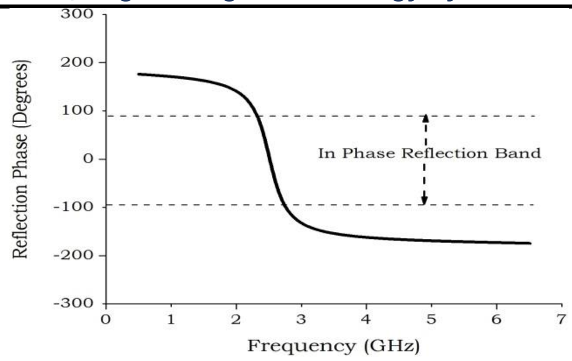


Fig 4: Graph of reflection phase

2. High Impedance Characteristics

Fig 5:Reveals the High impedance curve of fig 3. Practical high impedance surfaces are usually low loss. Proposed model a high impedance of 3540 ohms.

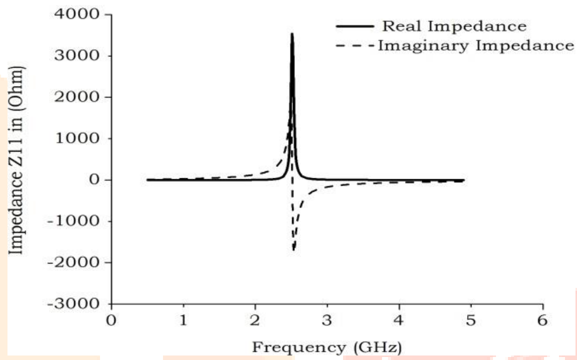


Fig 5: High impedance curve

3. Dispersion Characteristics

Fig 7: Represents Schematic diagram for FBG measurement in numerical simulation tool.This also contains periodic arrangement on its side walls topped by PML layer. The setup will give stop band characteristics of fig 6 by applying periodic boundaries with perfect matched layer over the top.

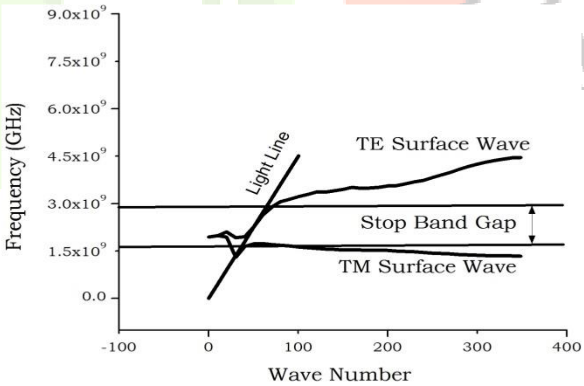
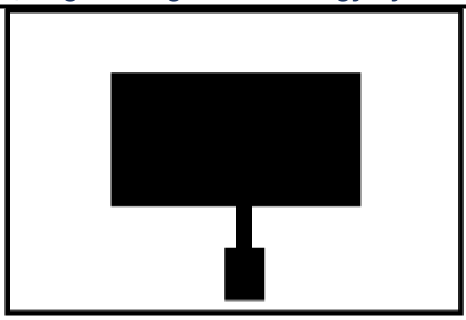


Fig 7: Graph of dispersion curves

The gap between TE and TM waves is known as FBG. Present design,exhibiting FBG of 1.5GHz that is varying from 1.5GHz to 3GHz.

V. Conventional RMPA Design:

Fig 8: shows conventional design of RMPA contains FR4 substrate, sandwiched between a rectangular patch radiator and planar ground. The dimensions of patch are 33.3X27.6 mm², which make the antenna to operate at 2.5GHz.



VI. MINIATURED RMPA DESIGN:

Fig 9:Shows the miniatured Patch antenna with 2DEBG ground. The planar ground shown in figure 8 is replaced by 2DEBG ground. Due to high surface impedance of 2DEBG, with lower volume the antenna can resonate at 2.5GHz. The patch dimensions are 29.4 X 24 mm².

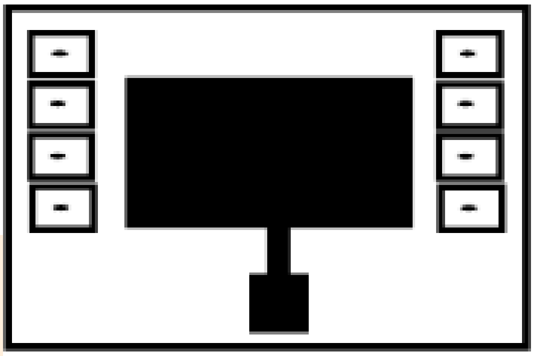


Fig 9: Miniature size Patch antenna surrounded by 2DEBG

Fig 10: shows the Return loss characteristics of conventional patch antennafor fig 8, Fig 11 shows the Return Loss for characteristics for proposed antenna for fig 9. The bandwidth due to conventional structure is 57.8MHz, where as 2DEBG ground is 121.5MHz. So we can conclude that the band width of patch is doubled due to 2D-EBG ground.

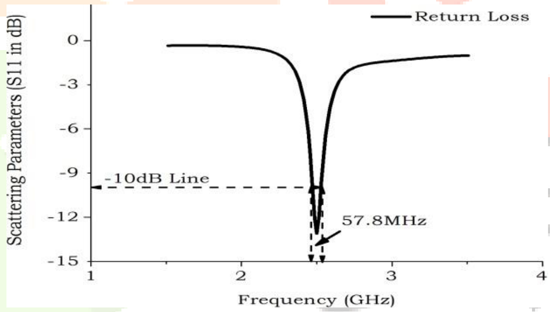


Fig 10: Return loss of Conventional patch antenna over FR4 substrate

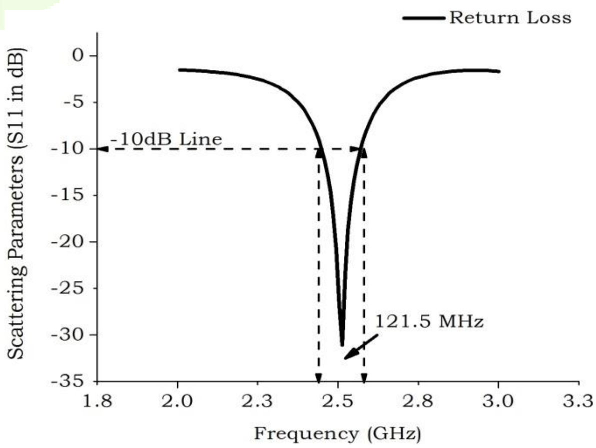


Fig 11: Return Loss of patch antenna surrounded by 2DEBG

Fig 12 shows the gain of the conventional patch antenna for fig 8, Fig 13 shows the gain of antenna surrounded by 2DEBG structure for fig 9. Due to AMC property of 2DEBG, Ground reflected waves are added in phase with the radiated wave in forward direction resulting an improvement in gain is achieved. The gain due to conventional design is 2.35dB, whereas 2DEBG ground is 5.72dB, hence gain improvement is achieved.

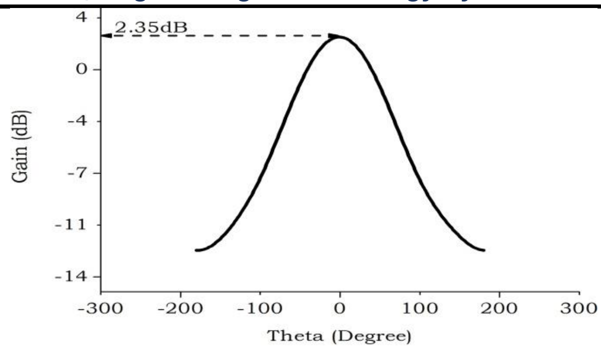


Fig 12: Gain of Conventional patch antenna over FR4 substrate

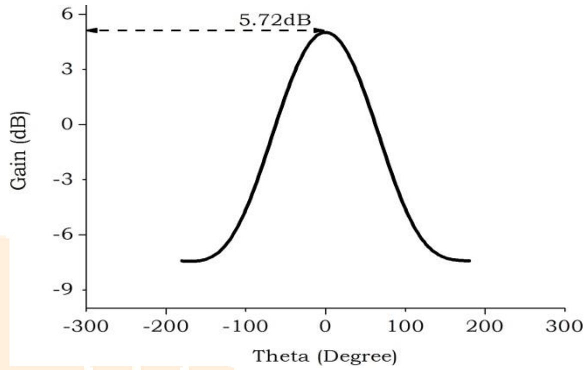


Fig 13: Gain of antenna surrounded by 2DEBG

V. CONCLUSION:

The performance of RMPA with and without the EBG ground is investigated. An enhancement in band width of 3%, and gain upto 3.5dB is achieved by 2DEBG ground antenna as compared with the conventional microstrip patch antenna. The proposed 2DEBG is exhibiting FBG of 1.5GHz, AMC of 41MHz and a high impedance of 3540 ohms at the resonating frequency of 2.5GHz.

REFERENCES

[1] K.-L. Wong, Compact and Broadband Microstrip Antennas. New York: Wiley, 2002.

[2] D. Sievenpiper, L. Zhang, R. F. J. Broas, N. G. Alexopolous, and E. Yablonovitch, “High-impedance electromagnetic surfaces with a forbidden

frequency,” IEEE Trans. Microw. Theory Tech., vol. 47, no. 11, pp. 2059–2074, Nov. 1999.

[3] F.-R. Yang, K.-P. Ma, Y. Qian, and T. Itoh, “A uniplanar compact photonic-bandgap (UC-PBG) structure and its applications for microwave circuit,” IEEE Trans. Microw. Theory Tech., vol. 47, no. 8, pp. 1509–1514, Aug. 1999.

[4] V. Veselago, “The electrodynamics of substances with simultaneously negative values of " and _,” Soviet Phys. Uspekhi, vol. 10, no. 4, pp. 509–514, 1968.

[5] R. A. Shelby,D. R. Smith, and S. Schultz, “Experimental verification of a negative index of refraction,” Science, vol. 292, no. 5514, pp. 77–79, Apr. 2001.

[6] C. Caloz and T. Itoh, “Transmission line approach of left-handed (LH) materials and microstrip implementation of an artificial LH transmission line,” IEEE Trans. Antennas Propag., vol. 52, no. 5, pp. 1159–1166, May 2004.

[7] A. Lai, C. Caloz, and T. Itoh, “Composite right/left-handed transmission line metamaterials,” IEEE Microw. Mag., vol. 5, no. 3, pp. 34–50, Sep. 2004.

[8] G. V. Eleftheriades, A. K. Iyer, and P. C. Kremer, “Planar negative refractive

index media using periodically L-C loaded transmission lines,” IEEE Trans. Microw. Theory Tech., vol. 50, no. 12, pp. 2702–2712, Dec. 2002.

[9] R. Gonzalo, P. De Maagt, and M. Sorolla, “Enhanced patch-antenna performance by suppressing surface waves using photonic-bandgap substrates,” IEEE Trans. Microw. Theory Tech., vol. 47, no. 11, pp. 2131–2138, Nov. 1999.

[10] J. S. Colburn and Y. Rahmat-Samii, “Patch antennason externally perforated high dielectric constant substrates,” IEEE Trans. Antennas Propag., vol. 47, no. 12, pp. 1785–1794, Dec. 1999.

[11] F. Yang and Y. Rahmat-Samii, “Microstrip antennas integrated with electromagnetic band-gap (EBG) structures: A low mutual coupling design for array applications,” IEEE Trans. Antennas Propag., vol. 51, no. 10, pp. 2936–2946, Oct. 2003.

[12] Z. Li and Y. Rahmat-Samii, “PBG, PMC and PEC ground planes: A case study of dipole antennas,” in Proc. IEEE Antennas Propag. Soc. Int. Symp. Dig., Jul. 2000, vol. 2, pp. 674–677.

[13] D. J. Kern, D. H. Werner, A. Monorchio, L. Lanuzza, and M. J. Wilhelm, “The design synthesis of multiband artificial magnetic conductors using high impedance frequency selective surfaces,” IEEE Trans. Antennas Propag., vol. 53, no. 1, pp. 8–17, Jan. 2005.

[14] N. Christopoulos, G. Goussetis, A. P. Feresidis, and J. C. Vardaxoglou, “Metamaterials with multiband AMC and EBG properties,” in Proc. Eur. Microw. Conf., Oct. 2005, vol. 1, pp. 77–79.

[15] F. Yang and Y. Rahmat-Samii, “Reflection phase characterizations of the EBG ground plane for low profile wire antenna applications,” IEEE Trans. Antennas Propag., vol. 51, no. 10, pp. 2691–2703, Oct. 2003.

[16] J. Bell and M. Iskander, “A low-profile archimedean spiral antenna using an EBG ground plane,” IEEE Antennas Wireless Propag. Lett., vol. 3, pp. 223–226, 2004.

[17] A. P. Feresidis, G. Goussetis, S. Wang, and J. C. Vardaxoglou, “Artificial magnetic conductor surfaces and their application to low-profile high-gain planar antennas,” IEEE Trans. Antennas Propag., vol. 53, no. 1, pp. 209–215, Jan. 2005.

[18] S. Pioch and J.-M. Laheurte, “Size reduction of microstrip antennas by means of periodic metallic patterns,” Electron. Lett., vol. 39, no. 13, pp. 959–961, Jun. 2003.

[19] S. Pioch and J.-M. Laheurte, “Parametric study of compact flat antennas based on periodic patterns,” Microw. Opt. Tech. Lett., vol. 40, no. 4, pp. 311–314, Jan. 2004.

[20] M. Ermutlu, C. Simovski, M. Karkkainen, P. Ikonen, S. Tretyakov, and A. Sochava, “Miniaturization of patch antennas with new artificial magnetic layers,” in Proc. IEEE Int.Workshop Antenna Technol.: Small Antennas Novel Metamaterials (IWAT), March 2005, pp. 87–90.

[21] K. Z. Rajab, R. Mittra, and M. T. Lanagan, “Size reduction of microstrip antennas using metamaterials,” in Proc. IEEE Antennas Propag. Soc. Int. Symp. Dig., Jul. 2005, vol. 2B, pp. 296–299.

[22] H. Yang and J. Liang, “Analysis of a proximity coupled patch antenna on metalized EBG substrates,” in IEEE Antennas Propag. Soc. Int. Symp., Albuquerque, NM, Jul. 2006, pp. 2287–2290.

[23] H. Mosallaei and K. Sarabandi, “Antenna miniaturization and bandwidth enhancement using a reactive impedance substrate,” IEEE Trans.Antennas Propag., vol. 52, no. 9, pp. 2403–2414, Sep. 2004.

[24] H. Mosallaei and K. Sarabandi, “Design and modeling of patch antenna printed on magneto-dielectric embedded-circuit metasubstrate,” IEEE Trans. Antennas Propag., vol. 55, no. 1, pp. 45–52, Jan. 2007.