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Design of 3D-EBG for L band Applications

Dr.Jammi Ashok
School of Electrical and Computer Engineering, IOT, Hawassa University, Hawassa, Ethiopia.

N.L.Pratap
Lecturer, Department of ECE, IOT, Harmaya University,Ethiopia.

Estifanos Yohanes
Head, School of Electrical and Computer Engineering, IOT, Hawassa University, Hawassa, Ethiopia.

Abstract – Three dimensional electromagnetic band gap structures is proposed in present paper. This 3DEBG exhibits universal band gaps, therefore do not allow propagation states in any direction. In order to understand it's operating characteristics, its surface properties are such as (i) surface wave band gap (ii) In phase Reflection (iii) Impedance and (iv) Transmission co-efficient are measured with the help of electromagnetic simulation software. The FEM based simulation software results are presented with detailed description. The proposed structure is operating at 1.9GHz and exhibiting with a surface wave suppression band gap of 240MHz and Inphase reflection band gap of 50MHz.

Index Terms — Reflection Coefficient; Transmission Coefficient; surface band gap.

1. INTRODUCTION

A three dimensional electromagnetic band gap structures are exhibiting two prime characteristics, such as PMC [1] (Perfect Magnetic Conductor) and surface suppression band gaps[2-3]. They can play key role in many microwave applications. The EBGs are available in one, two and three dimensional configurations. Present paper is concentrating on three dimensional electromagnetic band gap structure [4].

These structures can be analyzed using either effective medium model or structural models. In order to use effective medium model (EMM) the 3DEBG parameters need to be represented into its electrical equivalent and finally all the parameters are simplified to one single parameter. For high complex structures, applying of EMM very tedious. On the other hand it does not considers substrate permittivity effects and periodicity of elements, so it fails to give exact band gaps. Hence in this paper we are adopting structural model which uses numerical technique of Finite Element Method (FEM). This method has ability to determine multiple band gaps[5] also, if existed in the structure. This method considers all the parameters so as to determine its complete properties.

2. STRUCTURAL MODEL OF 3D-EBG

The architecture of 3D-EBG consists of planar conducting ground plane, multi-dielectric substrates arranged in ascending order with respect to permittivity, square conducting patches are arranged in three dimensional and conducting via are shorting the metal patches to ground. This arrangement is shown in figure 1.

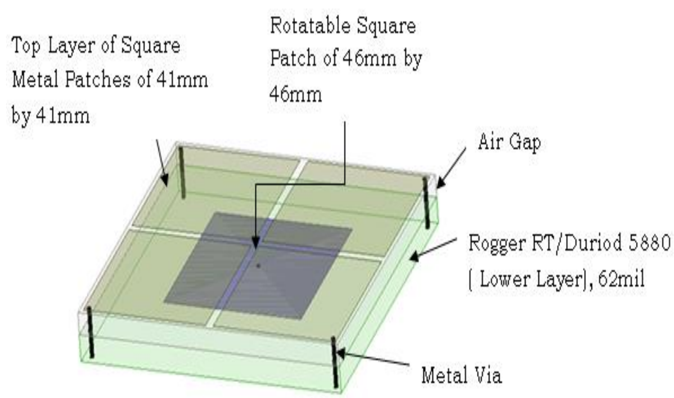

Fig 1. Structural model

The proposal can be fabricated with the help of multi-layer PCB technology [6-7]. The inductive nature inside the structure is produced by the introduction of this via and capacitive nature is produced in gap between patches due to fringing electric fields.

3. DISPERSION DIAGRAM

We start our analysis first with a prime characteristic known as band gap. This can be obtained by calculating the dispersion or β-ω or k-ω diagram. This diagram presents surface wave band gap and leaky waves or radiative wave[9] properties. To obtain dispersion characteristics a unit cell should placed in air box its sides are applied with periodic boundaries. On the top of air box a perfect matched layer is placed.

Figure 2 shows the top view and cross section of a typical 3D-EBG unit cell in parallel-plate environment. A square cell of width(w), and gap(g) so period is a = 2X(w+g), is considered. The reduced Brillouin triangle Γ-X-M is included as well.

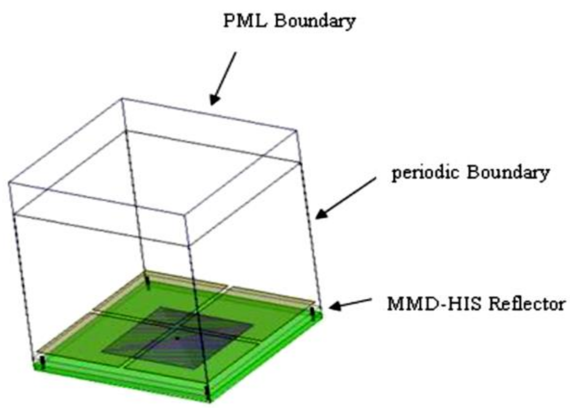

Fig 2. Unit cell Model

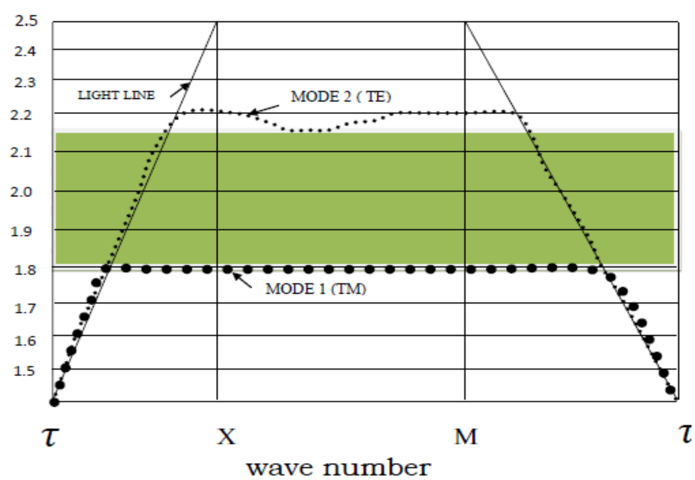

Fig 3. dispersion diagram

The figure 3 is showing a dispersion diagram for 3DEBG unit cell. The lowest line in the graph (bellow to highlighted region) is called TM surface wave. Up to certain frequency range TM band moves in parallel with light line, later it becomes very flat suddenly. The upper line in the graph is called as TE surface wave. The surface wave band gap or forbidden band gap region can be defined as the range of frequencies that are spread from the TM band edge to a point where TE band crosses the light line. The TM waves are always lying below the light line so they cannot be radiative. But the TE waves are crossing the light at some intervals so they radiate.

4. REFLECTION CHARACTERISTICS

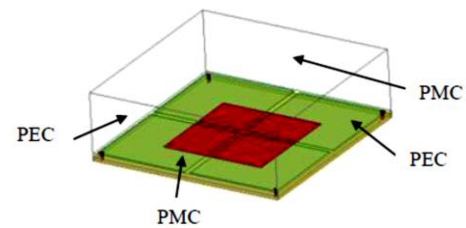

Fig 4. Periodic boundaries

In figure 2 the PML (perfect matched layer) is replaced with floquet port, where it will illuminate waves normal to 3DEBG surface and observes the reflected waves shown in figure 4. Figure 5 is showing the reflection phase characteristics of 3DEBG structure versus frequency.

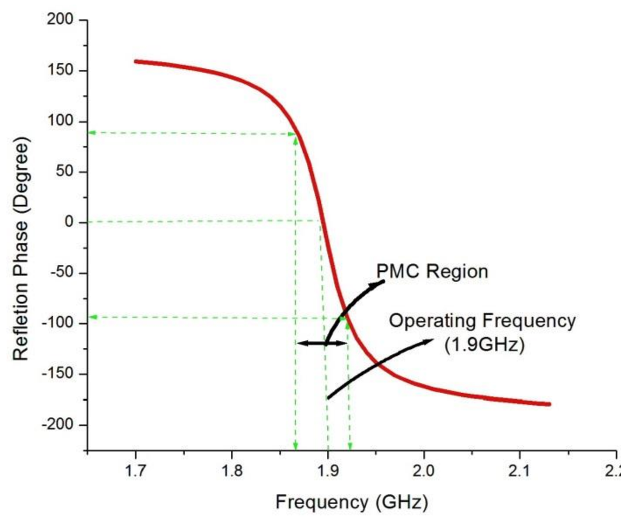

Fig 5. Reflection Characteristics of 3D-EBG

At lower and higher frequencies this structure reflects with a $+180^0$ and -180^0 phase shift. As the frequency increases the phase slops downward and crosses through zero degree point frequency at this point is considered as operating frequency. The region between +87.92 degree to –176 degree shown in Figure 5 functions like surface wave suppression band gap. A region that exist between $+90^0$ to -90^0 functions like Perfect Magnetic Conductor (PMC). There exist so many techniques to make both surface band gap and reflection band gap are identical. Any structure that is operating with in this region can improve its results. The region before and after to highlighted region functions like ordinary reflector.

5. IMPEDANCE CHARACTERISTICS

The impedance characteristics of 3D-EBG structure are also abnormal. Here the reactive impedance is dominating the real impedance of structure hence these can be called a artificially high impedance surfaces. This is because of engineered architecture that develops lumped inductance and capacitance within the structure shown in figure 7. The magnitude of red colored(developed due to lumped inductance and capacitance) line is dominating the green colored line (indicating real impedance due to conducting mediums in structure).

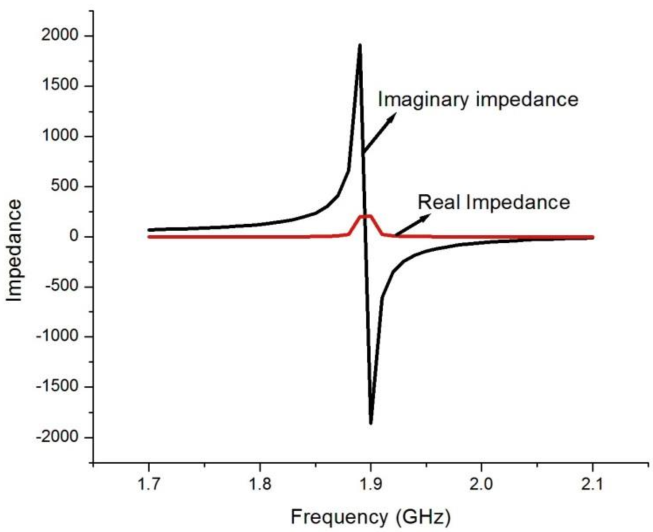

Fig 7. Impedance Characteristics

6. TRANSMISSION CHARACTERISTICS (S21)

The band rejection range or surface wave suppression band gap of 3DEBG can be determined with the help of transmission characteristics. The scattering parameter techniques are easy to calculate and are obtained from power transfer and reflection between designated ports on the structure. To demonstrate this, two micro strip patch antennas of individual feed co-axially, are considered. Both are operating in stop band region as described in dispersion diagram. One column of multi-Layer Multi Dielectric High Impedance Surface is incorporated between them. A minimum transmission coefficient level of -60dB is observed. This clearly indicates that 3DEBG blocks the transmission of power between antennas[12]. So mutual coupling problem can be almost eliminated. In present problem it was observed that band gap range is equal to minimum transmission co-efficient level range at -60dB. From S21 parameters curve by knowing lower (F_L) and upper (F_U) corner frequencies, the operating frequency f_0, fractional band width delta BW, and absolute band width are possible to define.

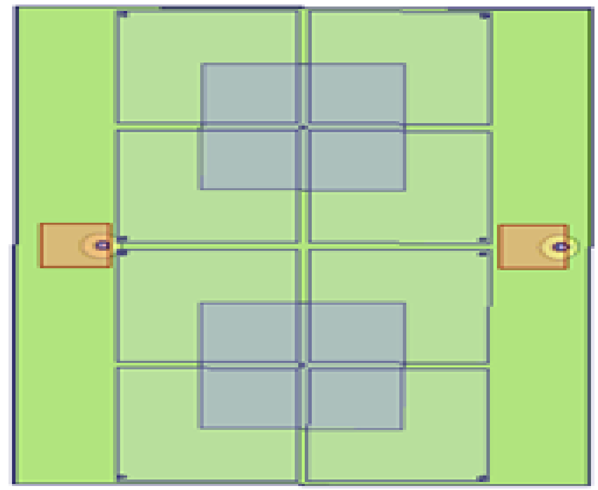

Fig 8. S21 Measurement setup

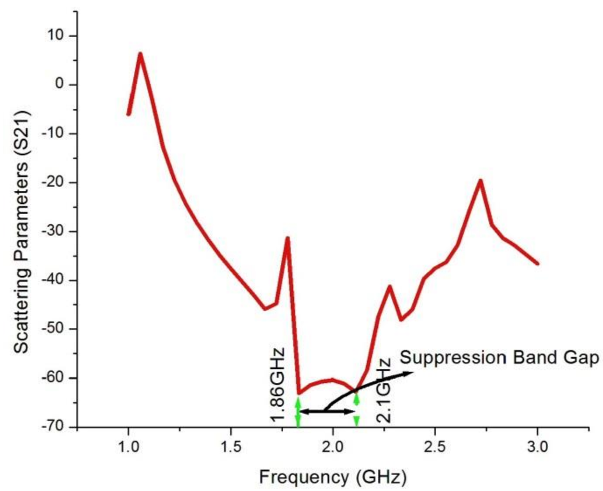

Fig 9. Magnitude of S21

7. CONCLUSION

The 3D EBG is designed in Ansoft HFSS v13 software and three key parameters such as surface band gap, reflection co-efficient, impedance of 3DEBG structure are analyzed using finite element method. The stop band ranges from 1.86GHz to 2.1GHz. (i.e -87.96degree to 176degree), in this range TM surface waves are always non radiative and TE surface waves are radiative at some place. The microwave devices that are operating within this region is placed over 3DEBG can enhance the performance characteristics. The operating point of structure is at 1.9GHz. The transmission coefficient level is at -60dB.

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Authors

Dr Jammi Ashok is currently working as a Professor at Hawassa University, Hawassa, Ethiopia. He is having Experience in sophisticated research techniques and technologies: applications of pattern classification, Neural networks, Image Processing, data mining and data ware housing. He received outstanding scientist award by international research foundation and best paper award in International Conference of Systemic, Cybernetics and Informatics (ICSCI – 2012) organized by Pentagram Research Centre, Hyderabad. He also got selected for UWA excellence award for 2015. He possesses good knowledge and skill of various Programming languages and expertise in lab and research, data collection/analysis.

He has more than 85 refereed international journal and conference papers to his credit and presented papers internationally. He was given live interviews on carrier guidance for some television channels in India and Editorial board member of many international peer reviewed journals. He is a regular reviewer of many international peer reviewed scientific journals and conferences and Member of Board of studies for some reputed universities in India. He has given around 20 guest lectures and attended as Resource person for organizing workshops outside.