ENHANCEMENT OF BANDWIDTH AND MINIMIZATION OF SURFACE WAVES IN MICROSTRIP PATCH ANTENNA USING EBG SUBSTRATE

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Abstract – *The main aim of this paper is to enhance the bandwidth of the microstrip patch antenna and reduce surface waves excitation by introducing ebg structures on the substrate of the microstrip patch antenna. Microstrip patch antennas became very popular due to the ease of their analysis on the printed circuit boards in mobile and wireless communication. One of the key drawbacks is their narrow bandwidth. In order to achieve wider bandwidth, a relatively thick substrate must be used. However, the antenna substrate supports tightly bound surface waves which represent a loss mechanism in the antenna. This paper gives a study about increasing the antenna parameters of microstrip patch antenna especially bandwidth without any surface wave excitation.*

Key Words:**1. Microstrip Patch Antenna, 2. Surface Waves, 3. Ebg substrate, 4. Bandwidth**

1. INTRODUCTION

In today's world microstrip patch antennas became very powerful in the field of wireless communications and also in military applications. The performance and characteristics of microstrip patch antennas mainly depends upon the patch and also the dielectric material which is also called as substrate onto which the patch is printed. They provide an alternative solution for the compactness, easy fabrication, robustness and conformality in the field of communications. Apart from all these pro patch antennas suffers from in built cons. One of the most major drawbacks present in microstrip patch antenna is their bandwidth. The range of frequencies over which the antenna will be able to operate is very less. The excitation of the surface waves between conductor-dielectric or dielectric- dielectric medium when we increase the thickness of the substrate in order to increase its bandwidth leads to radiation losses in antenna. This surface wave causes ripples in radiation patterns, back radiation, gain drop and lower polarization purity, because it is scattered othe surfaces.

1.1 Microstrip Patch Antenna

The basic structure of microstrip patch antenna consists of a ground plane say copper and then you find dielectric material whose dielectric constant is say εr and a patch is printed on the other side. If the shape of the patch is rectangle then it is called Rectangular microstrip patch antenna.

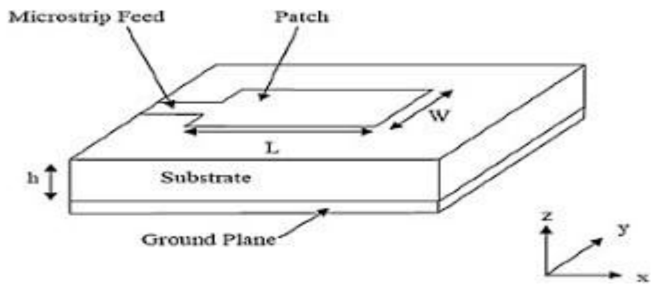

Fig -1: Microstrip patch antenna

The beginning point of the microstrip patch antenna was in 1953 where it was observed that there was a radiation going on from microstrip integrated circuit board. But, it was two decades later in 1974, when Manson had proposed how to practically use this MIC(microstrip integrated circuit) as antenna, then a revolution happened in the field of communications. Moving aside from the history and coming back to the discussion on physical dimensions of the microstrip patch antenna. The length (L) of the patch is usually used to determine the resonant frequency of the antenna. The width (W) of the antenna is completely responsible forits radiation. Substrates used: Alumina, Glass epoxy, Teflon, Air, Foam. The refractive index of the substrate used can be determined using their dielectric constant.

Table 1: Parameters guidelines to design the effective Microstrip patch antenna.

PARAMETERS	MICROSTRIP PATCH ANTENNA
Dielectric constant (εr)	Small
Thickness of the substrate (h)	Large
Width(w)	Generally large
Radiation	Maximum

More the width of the microstrip patch antenna, more is its radiation efficiency. The gain of the microstrip patch antenna is about 30db which is very low. So, in order to provide a solution for all the disadvantages of microstrip patch antenna, electromagnetic band gap materials are mounted on the surface of the substrate which exhibit some selectiveness in supporting surface waves excitation and also plays a key role in bandwidth enhancement. We'll discuss in detail about electromagnetic bandgap materials and how they are mounted on the substrate in the next pages.

2. Literature Survey

1. Research Paper on: "EBG ANTENNAS: THEIR DESIGN AND PERFORMANCE ANALYSIS FOR WIRELESS APPLICATIONS"

The paper clearly explains about the microstrip patch antenna, their disadvantages and it also explains about the electromagnetic band gap materials which is used as superstrate to overcome the limitations of microstrip patch antenna. Firstly, it explains in detail about the ebg materials, negative refractive index materials, surface wave currents, design procedure of rectangular patch and ebg structure, parameters involved in design procedure. Lastly, simulation results were displayed and compared with conventional microstrip patch antenna parameters. The paper gave me a knowledge on electromagnetic band gap materials and how they are reducing the surface waves excitation.

2. Research Paper on: "EBG STRUCTURES AND ITS RECENT ADVANCES IN MICROWAVE ANTENNA"

The paper is divided into three sections. Here, in the first section the paper only deals with the basics of microstrip patch antenna and in the second section, the theory of EBG structure is introduced with its corresponding bandgap features. In third section, the recent advances done by various researchers has been discussed. In second section, the paper explains in detail about the ebg structures and its types namely (1) three dimensional volumetric structures (2) two-dimensional planar surfaces, and (3) one dimensional transmission lines. It explains in detail about the design consideration, the parameters involved in it. In the third section it involves the recent advances in the field of ebg materials and their use as substrate in microstrip patch antenna. In this section, it deals with various ebg structures like (1) Stack EBG structure (2) Fork like EBG structure (3) Hexagonal shape EBG structure. Lastly, the paper concluded that the proper utilizations of EBG structures could enhance the performance of less profile antennas.

3. Research Paper on: "SURFACE WAVES MINIMISATION IN MICROSTRIP PATCH ANTENNA USING EBG SUBSTRATE"

This paper mainly deals with surface waves minimization in microstrip patch antenna in order to enhance the band width of the antenna. The II section of the paper deals with the ebg structures and their properties. The paper explains the comparison of E-plane and H-plane radiation patterns with conventional microstrip patch antennas and that of microstrip patch antennas embedded with ebg materials. It also deals with reduction of mutual coupling present in conventional substrate. This paper mainly dealt with the design of patch antenna within the band gap of ebg materials so as to reduce and suppress the surface waves excitation. The design procedure of 2x2 microstrip patch antenna array considering mutual coupling between individual antenna elements in both E-plane and H-plane and reducing it. Then it explained about the reduction of return losses and minimization of back lobes when we introduced a ebg substrate on the ground plane of microstrip patch antenna

4. Research paper on: "IMPLEMENTATION OF EBG CONFIGURATION FOR ASYMMETRIC MICROSTRIP ANTENNA TO IMPROVE RADIATION PROPERTIES"

This paper deals with the procedure of embedding circular ebg configuration along the edges of miniaturized half microstrip antenna has been achieved. The size was reduced to about 52.77% without any ebg configurations used as superstrate on microstrip patch antenna and overall size was reduced to about 21.69% with EBG configuration embedded on it. It was also observed that the size reduction affected the gain and bandwidth of microstrip patch antenna. The proposed method in this paper increased the gain by about 4.45db at 2.49 GHz with a bandwidth of 60 M Hertz.

5. Research paper on: "DESIGN AND DEVELOPMENT OF MICROSTRIP PATCH ANTENNA USING EBG STRUCTURES FOR S- BAND COMMUNICATION"

This paper deals with the design and implementation of microstrip patch antenna for s- band communication. The paper explains us about the design and development of compact patch antenna loaded with double L shaped ebg structures and also the use of FR4 substrate of thickness 1.6mm. It also discusses about the geometrical parameters of the ebg antenna. The transmission coefficient of ebg antenna and also the surface wave impedance is calculated and shown pictorially in the graph. If you want to go through these papers, the reference links of all these papers are placed in the reference section.

3. EBG (Electro Magnetic Band Gap) Materials

Ebg materials are artificially engineered materials which you cannot found directly existing in nature. The arrangement of dielectric materials and metallic conductors are periodic in the ebg structures. The dimension of the ebg structures are very small when compared to the wavelength of the light due to which they have certain effect on electromagnetic wave propagation. They are also called by the names, frequency selective surfaces, high impedance surfaces. When the dielectric constant of the substrate is greater than the 0.1 surface waves are produced. Surface waves causes end fire radiation along with coupling between various elements of an array. Surface waves incident on the ground plane gets reflected back which again hits the dielectric-air interface and the process is continued till the end of the antenna. In case, if there is another antenna placed as an array the surface wave gets coupled on to it. The ebg structures are designed in such a way that they are selective to surface wave currents, different from conventional metallic conductors. Strong surface waves of sufficient strength, which propagate on the metal ground plane will reach the edge and propagated into free space. This creates a multi-path interference. In contrast the HIS (high impedance surfaces) suppresses the propagation of surface waves.

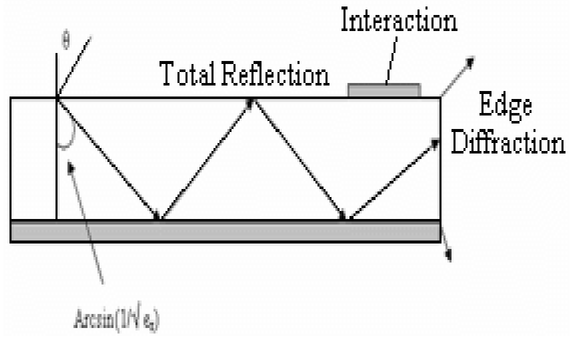

Fig -2: Propagation of surface waves in microstrip patch antenna.

Solution to the surface waves suppression and reduction are given below. One method is to make the substrate periodically loaded so that the surface wave dispersion diagram presents a forbidden frequency range (stop band or band gap) about the antenna operating frequency. Because the surface waves cannot propagate along the substrate, an increase amount of radiating power couples to the space waves. The ebg structures are divided into three types namely (1) three-dimensional volumetric structures, (2) two-dimensional planar surfaces, and (3) one dimensional transmission lines.

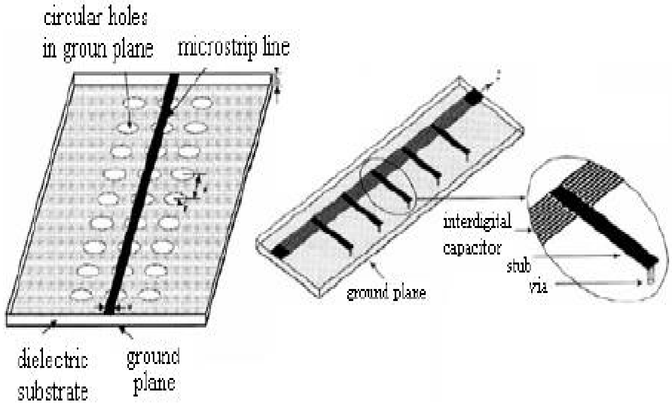

Fig -3: One dimensional Ebg transmission lines.

In order to make the ebg structures frequency selective surface, they must satisfy the following conditions. (1) They must have the capability to interact with parallel plate wave guide method. (2) The parameters must be known for the antenna to operate at its resonant frequency.

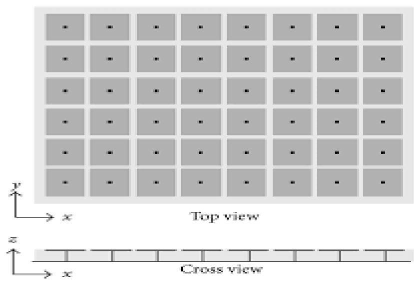

Fig -4: Mushroom type Ebg structures.

The typical ebg antenna consists of four parts namely ground plane at the bottom, a dielectric substrate, metal patches which repeats over regular intervals on the surface of the substrate, and a radiating element called Type equation here.patch above the dielectric substrate. 'W' in fig 5(a) represents the width of the patch placed on the dielectric substrate, 'g' represents the distance(gap) in between the two metal patches placed over the dielectric substrate. 'h' represents the substrate thickness and vias radius is represented by 'r'. Vias is a wire like substance used to join the metal patches present over the substrate to the ground plane. When the periodicity i.e., the sum of width of the patch and the gap width between two patches (W+g) is small compared to the wavelength of the light then the working mechanism of this ebg structure can be explained by using an equivalent lumped lc model shown in fig 5(c). As you can see in fig 5(c) the capacitance results from the gap between the metal patches placed over the dielectric material and inductance results from the current travelling along the adjacent patches. The structure is designed at resonant frequency which is equal to 2.49 GHz. The substrate on which the metallic patches are arranged periodically is known as FR4 substrate. The thickness of the FR4 substrate is nearly equal to 1.6mm. As the capacitance is determined by the gap present in between the two metallic patches, I can undoubtedly say that the capacitance decreases as the size of the metallic patches increases further.

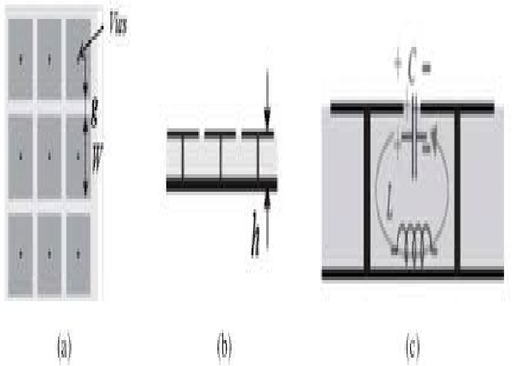

Fig -5: (a) top view (b) cross view (c) lumped lc crystal analysis.

The impedance of the parallel resonant L-C circuit shown in fig 4(c) can be given by the formula:

$$z = \frac{j\omega L}{1 - \omega^2 LC}$$

The resonant frequency, capacitance and inductance values are given by the following formulas:

$$\omega = \frac{1}{\sqrt{LC}}$$

$$C = \mathcal{E}_0 \mathcal{E}_r \frac{\omega^2}{h}$$

$$L = 0.2 * h \left[\ln \frac{2h}{r} - 0.75\right]$$

Here ω is the resonant frequency, C is the capacitance and L is the inductance value.

Ebg structures designed at resonant frequency provide a stop band to the excitation of surface waves and eradicate them which in turn increases the bandwidth of the patch antenna.

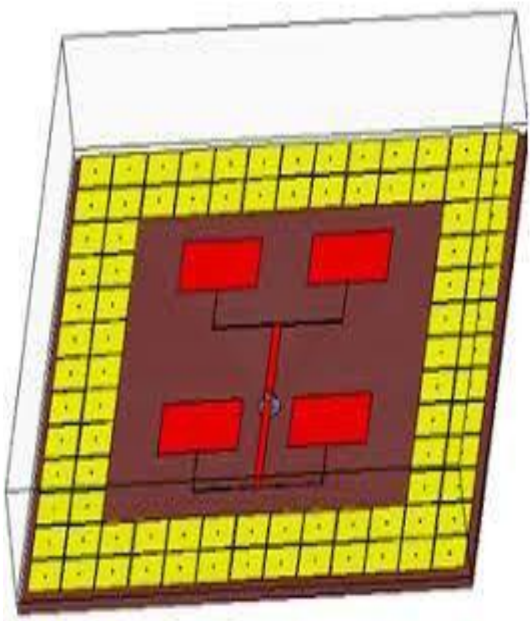

Fig -6: Microstrip patch antenna with ebg structure.

4. SIMULATION RESULTS

Simulation is carried out successfully at resonant frequency which is equal to 2.49GHz. Here we are using HFSS (high frequency structure simulator) to minimize the time in the process of calculation and to design certain antenna structures. Hence, it is observed that antenna with conventional substrate provides gain of 2.83dB and bandwidth of about 60MHz with voltage wave standing ratio (VSWR) of 1.1. After embedding ebg substrates with microstrip patch antenna it is realized that it provides a gain of about 4.51dB at a bandwidth of 67.5MHz with VSWR equal to 1.75.

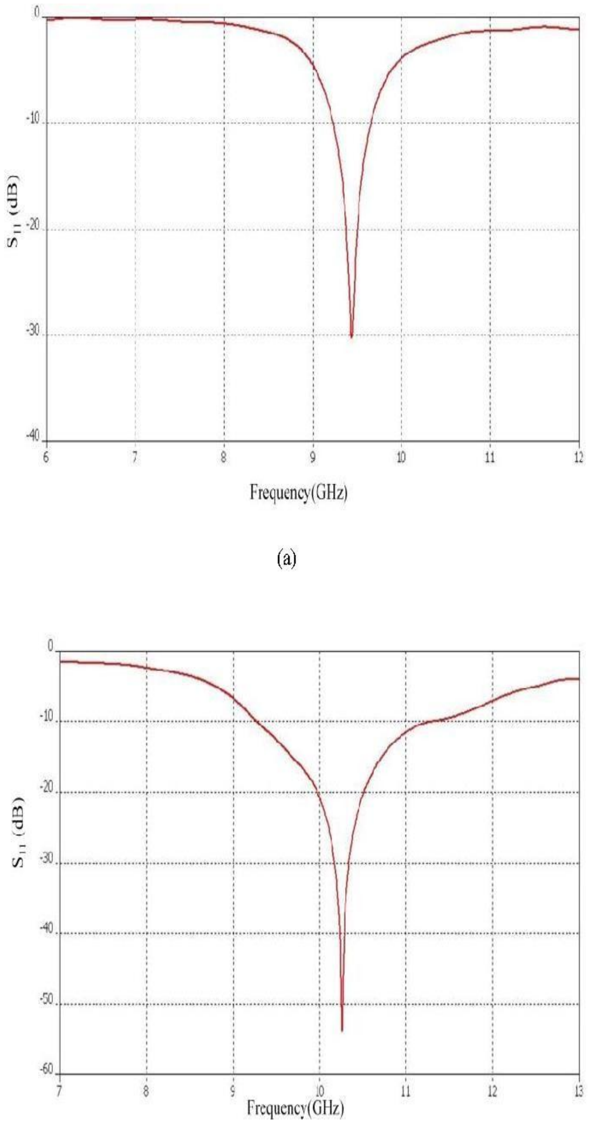

Chart -1: Comparison of bandwidth between microstrip patch antenna with conventional substrate to that of microstrip patch antenna with ebg substrate.

Table -2: Comparison of antenna parameters between micro strip patch antenna embedded with conventional substrate and ebg substrate.

S.no.	Antenna parameters	Patch with conventional substrate	Patch with ebg substrate
1.	Peak directivity (dB)	4.0344	5.1049
2.	Peak gain(dB)	3.4535	4.5814
3.	Peak Gain(dB)	2.83	4.81
4.	Bandwidth (MHz)	60MHz	67.5MHz
5.	Radiated power	0.81145W	0.89486W
6.	Voltage wave standing ratio (VSWR)	1.1	1.75

5. CONCLUSION

In this paper the basics of microstrip patch antenna, problems arising in it, introduction to the ebg materials and how they are embedded in the microstrip patch antenna and how those periodically arranged substrate materials helped in increasing the bandwidth, gain and decreasing surface waves is clearly explained. High Frequency Structure Simulator (HFSS) is used for the easy designing of ebg antenna in order to reduce the time and complexity in calculating resonant frequency, bandwidth, gain etc. Finally, reduction in surface waves and increase in bandwidth and gain of micro strip patch antenna was reported.

6. REFERENCES

[1] C. A. Balanis Antenna Theory: Analysis and Design, 3rd ed, 811-876, Wiley India Edition 2012.

[2] K. F. lee, K. M. Luk, Miccrostrip patch Antennas, Imperial college Press'',2011

[3] R Er-Rebyiy, J Zbitou, A Tajmouati… - 2017 International …, 2017 - ieeexplore.ieee.org

[4] A. Y. I. Ashyap et al.: Overview of EBG Integrated Wearable Antennas.

[5] Naveen Jaglan, Samir Dev Gupta "Design and Analysis of Performance Enhanced Microstrip Patch Antenna with EBG Substrate" International Journal of Microwave and Optical Technology (IJMOT), Volume 10, Number 2, pp 79-88, March 2015.

[6] Shinde J. P., Shinde P. N., " M-shape electromagnetic-bandgap structures for enhancement in antenna performance," Int. J. of Electronics and Communications, vol. 70, issue 6, pp. 842 - 849, 2016.

[7] S.M. Shakil Hassan, Md. Nurunnabi Mollah, "Identical performance from distinct conventional electromagnetic bandgap structures", IET Microw. Antennas Propag., vol. 10, issue 12, pp. 1251–1258, 2016.

[8] Bhuvaneswari B., Malathi K., Shrivastav A.K., "Effect of placing mushroom electromagnetic bandgap structures at the inset feedline of microstrip patches," IET Microw. Antennas Propag., vol. 6, issue. 13, pp. 1487–1497, 2012.

[9] Khan M. U., Said Sharawi M., Mittra R., "Microstrip patch antenna miniaturisation techniques: a review," IET Microw. Antennas Propag., vol. 9, issue 9, pp. 913–922, 2015.

[10] Progress In Electromagnetics Research B, Vol. 10, 55–74, 2008

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