Design and Characterization of Microstrip Patch Antenna with EBG Periodic Structures for C Band Applications

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Abstract--- This paper reveals about the design and characterization of Electromagnetic Band Gap (EBG) structures designed for various antenna applications. These structures which include the materials for deploying various innovative structures and shapes that finds many applications in industry and military as well. Generally these structures involve a substrate of metallic patches (i.e cells) acquires the dimensions which are normally less than its operating wavelength (λ) compared with that of microstrip antenna which finally enhances efficiency and bandwidth of the designed antenna which placed on a modified ground surface. In reality there is less discussion on the optimized design and on its performance for certain confront external conditions, while the maximum literatures focus only on EBG structured computational aspects. The design of antenna includes the set of octagonal slots in the substrate together with ground plane and the patch. Concept of Optimetrics is introduced for finding the parameters of patch desired to resonate the antenna at required frequency. The design provides S_{11} of -21.09dB which is better than the conventional patch antenna structures. The structure proposed is resonating at 6.9 GHz which comes under the category of C Band frequency range.

Key words: EBG, Octagonal Slots, Conventional Patch Antennas, C-Band frequency range

1. Introduction

It is known that to transmit the information from source to destination (long distance) we use antennas generally. These play a unique role in wireless communication .The source of information to these antennas can be originated are of speech may be from an individual else systems numerical data.

Microstrip Patch (MSP) antenna's are likely designed by a conducting patch of regular geometry placed on a dielectric substrate of desired material together arranged on a ground plane. Radiating patch likely to be conventional shapes like square, rectangular, triangular, circular and elliptical usually of copper material[1,2]. The preference to these antenna usage is gradually increased because of its low cost, low profile and also can be easy printed based circuit directly[3].

Upon introducing periodic EBG structures that became lucrative in antenna engineering. The parameters which are not optimized with the conventional patch antennas that can be enhanced by initializing periodic EBG structures[4,5]. Most of the analysts prefer the slotted type antenna designs for efficient communication. The added advantage for the selected structures are due to its low cost, low profile, compactness and ease in fabrication. These features diverted the attention of analysts and also become competent in all aspects such as achieving high gain, broad covered bandwidth, directiveness etc.

While propagating the electromagnetic energy through the medium, depending upon the design structures a part of energy is reflected back towards the edges which are unable to radiate termed as surface waves. The performance of the antennas is degraded due to these surface waves. To overcome these defects the antennas are promoted to new era by introducing periodic EBG structures which are equivalent to a magnetic surface resulting in a very high surface impedance.

By appropriate design of these structures the surface waves can be suppressed at desired frequency levels, hence can be regarded as frequency selectors[6,7]. On the other hand the mutual coupling in the radiators can also be minimized. These structures are categorized into three geometrical configurations detailed as one dimensional which are used in filtering application, second one being the two dimensional which are formed by square patches named as mushroom type and the third category as three / multy dimensional formed by laying metallic strips in both vertical and horizontal layers.

The design and characterization of proposed antenna is detailed in section II. In section III the details of EBG structure is précised. And the antenna analysis together with simulation results are deliberated in section IV. Finally the article is concluded in section V.

2. Proposed antenna design

The antenna which is proposed in the article is desired to operate at resonant frequency of 6.9 GHz of C band range[8]. The substrate considered of octagonal slots suitable for FR4 material having a loss tangent of 0.02[9,10].The design flow of antenna process may become slow and also complicated due to the involvement of large parameters like continuous, discrete or in some cases both. The design parameters together with scattering and radiation issues can be evaluated by using the concept of optimization[11,12]. This concept plays a key role in modern electromagnetic theory now a days. The antenna design proposal specified in the paper is suitable for C-band applications by using optimization technique with HFSS[13].

Optimization is a process of detecting a superior or most acceptable design structure among the various possibilities [14]. The parameterization may be applied at all modeling stages i.e for geometry (size, shape, orientation etc.), materials (lossless, complex etc.), boundaries and solution setup. The optimized design model is further investigated to resonate at desired frequency. The dimensions of all the parameters after final investigation are used to construct the proposed antenna are listed in table 1.

Design Parameters	**Label**	**Value (mm)**
Width of the substrate	W_s	21
Length of the substrate	L_s	22
Height of the substrate	H_s	1
Width of the patch	W_p	13
Length of the patch	L_p	10.7
Width of the feed	W_f	0.9
Length of the feed	L_f	7

Table 1 Dimensions of proposed antenna

The schematic representation of antenna includes the ground plane, substrate and patch as shown in Fig 1.

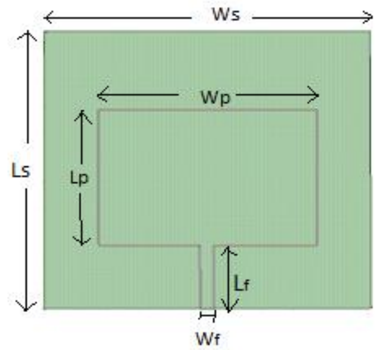


Fig1. Geometrical representation of proposed antenna

Fig 2 represents the geometrical structure of four EBG arrays placed at a gap of 1mm in its width and 2mm gap along the length. Each element in an array has an octagonal slot accommodated in a cell of rectangular shape having dimensions 10mmX10mm. The radii of inner and outer octagonal are of 2.5mm and 3mm. The thickness between these two octagonals is 0.7mm and the gap maintained within these complementary rings is of 0.5mm[15]. Fig 3 depicts the combination of both rectangular patch antenna placed on array of EBG Structured octagonal slots.

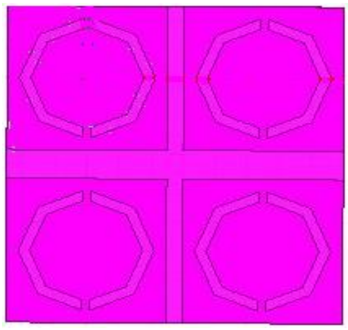


Fig2. Geometrical structure of EBG Array

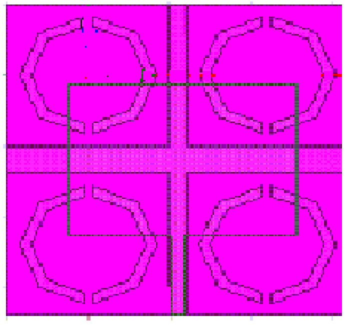


Fig3. Proposed EBG Array schematic antenna representation

3. Antenna analysis and experimental results

The simulated results of proposed antenna are short listed. It is known that (Radio Frequency) RF energy travels through the medium from source to destination. Return loss and VSWR are the important metrics related to the antenna performance. Return loss is a metric that illustrate the ratio against the proportion of RF waves received by the antenna towards the transmitted one. Using the concept of Optimetrics the return losses for various lengths of Patch are recorded as shown in fig 4.a. It is clearly shows that return loss for length 12mm is -26.3384 dB, for length 13mm is -21.0902 dB, for length 14mm is -16.5761 dB. It is also found that the antenna designed is resonating at 6.93 GHz with good return loss of -21.09 dB.

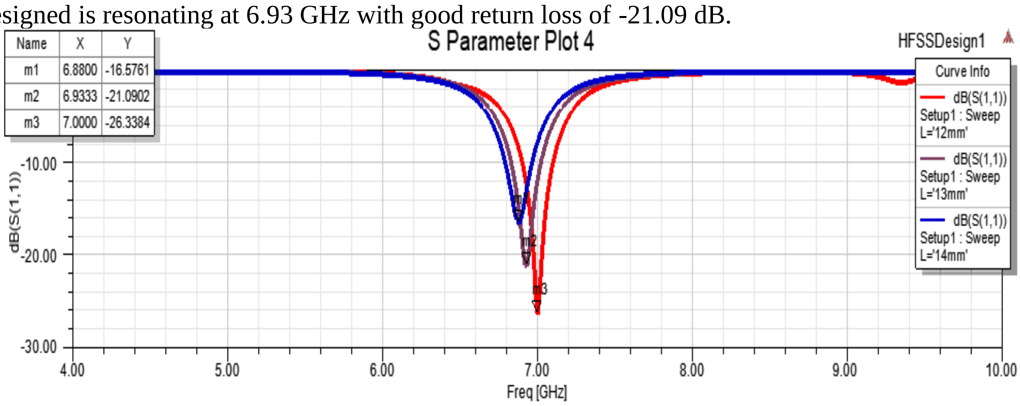


Fig (4a) return losses plot

VSWR (voltage standing wave ratio) is another metric which is basically an alternative approach of return loss. VSWR is the ratio of forward to the reflected radio waves which are propagating simultaneously those emerged within the medium of transmission. The details of VSWR is achieved of 1.42 which is shown in Fig 4b. A 3D radiation pattern measurement with a gain and directivity is shown in Fig4(c-d) with the values 4.94dB and 6.8dB. Similarly the 3D plots relative to same gain and directivity are shown in fig4 (e-f).

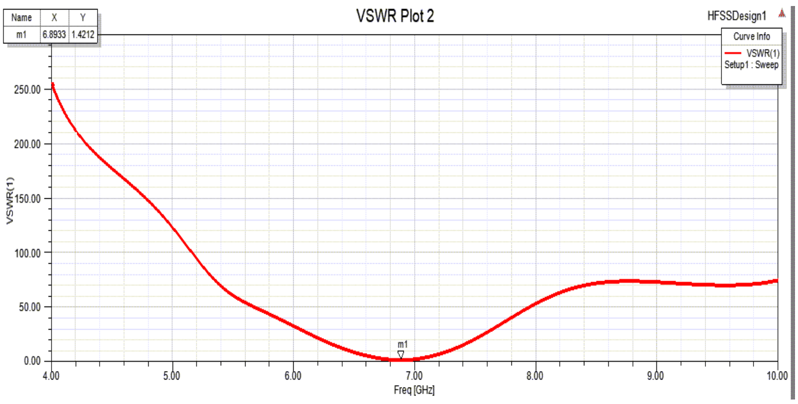


Fig (4b) VSWR plot

Name	Theta	Ang	Mag
m1	0.0000	0.0000	4.9445

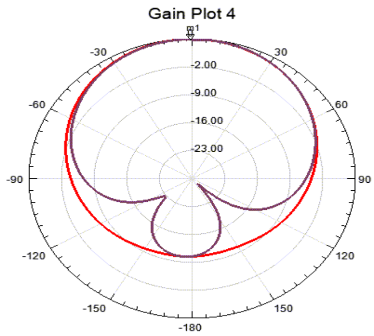


Fig (4c) Gain plot

Name	Theta	Ang	Mag
m1	0.0000	0.0000	6.8056

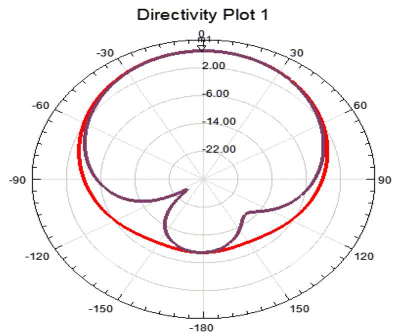
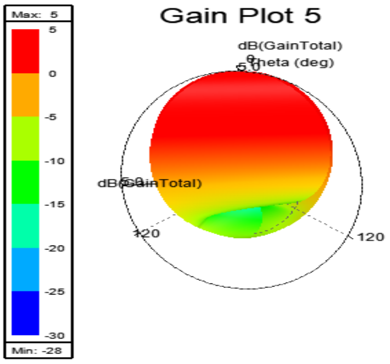


Fig (4d) Directivity plot



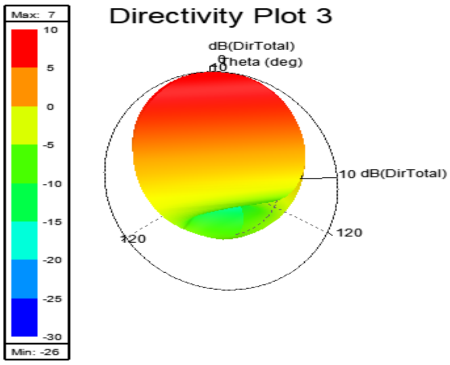


Fig (4e) 3D-gain plot **Fig (4f) 3D-Directivity plot**

The details of polarization effects are also discussed in the article. The proposed antenna is worked out for linear polarization. At phi=0 whatever the transmitting antenna does radiates and the same is received by receiving antenna at phi=0 then these are said to be copolarized with each other, nevertheless if the receiving antenna receives at phi=90 then it is said to be cross polarized. Fig 5a shows the copole and crosspole representation with values obtained as 4.8 and -41.45. Generally the copole value will be much higher than crosspole for achieving better polarization[16].

Name	Theta	Ang	Mag
m1	0.0000	0.0000	4.8023
m2	14.0000	14.0000	-41.4551

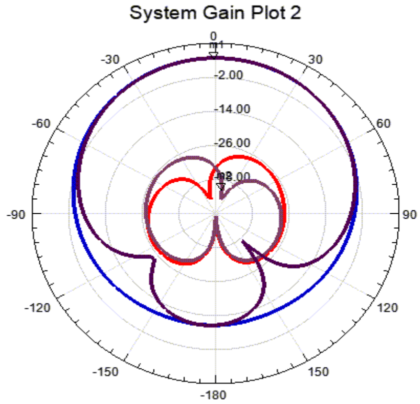


Fig (5a) Copole and Crosspole plot

The fields (current) carrying out through the proposed antenna is observed to be maximum at the center and minimum as it moves outwards shown in Fig 5b. The (HPBW) Half Power Beamwidth is a parameter which is detailed as an angular separation of radiation pattern magnitude decreased by 50% (or -3 dB) with respect to the peak of its main beam. Fig 5c shows the details of measuring HPBW at phi = 0^0 and phi = 90^0 when resonating at 6.9 GHz. The above discussion shows a successful study of parametric analysis for designing an antenna.

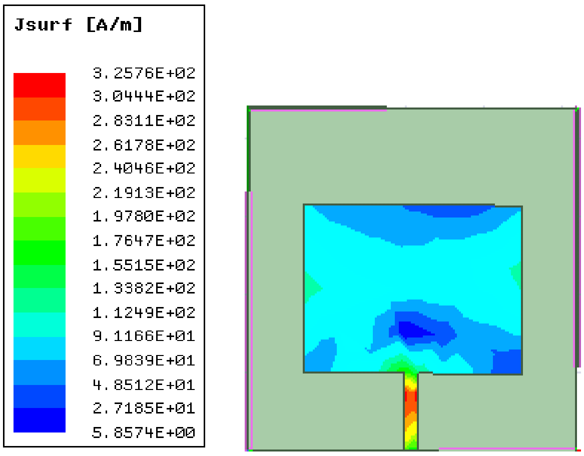


Fig (5b) Fields (Current) of Antenna plot

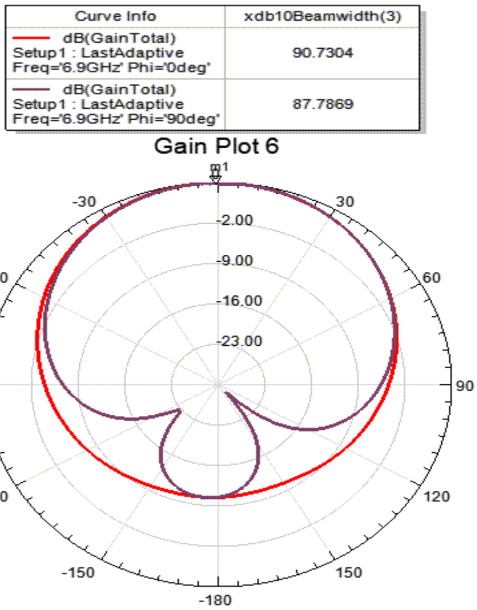


Fig (5c) Half Power Beam Width (HPBW) plot

4. Conclusion

Based on the concept of optimization a compact octagonal slot shaped EBG array antenna is proposed in this paper which is suitable for C-band applications provided with HFSS. The Effective usage of optimization technique leads to a smart design of antennas in the future. Such an antenna design gives the gain more than 4.94 dB and directivity of 6.8 dB. A good bandwidth is also achieved about 250 MHz when resonating at 6.9 GHz. This can be further improved by varying the radii and gap between the octagonal split slots. The radiation efficiency ‘η’ of 72% to 73% is achieved that shows the applicability of the radiator at desired frequency.

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