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Wideband High Gain Antenna Array with Electromagnetic Band Gap Structures for Mutual Coupling Reduction

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Abstract:
Simple techniques for minimizing the drawbacks of the patch antenna and antenna arrays are been proposed in this communication. The limitations in a basic patch antenna like gain, bandwidth along with mutual coupling effects which are observed in microstrip antenna array are been addressed in this paper. The space in between the ground and substrate layers is increased to enhance the gain and a meandered rectangular patch is considered to enhance the bandwidth. Electromagnetic band gap (EBG) structures are been proposed to minimize the mutual coupling. Basic patch antenna elements are be excited using a Coax feed. From the simulated S parameters results the operating frequency of the proposed antenna ranges 1.30GHz to 1.39GHz with a bandwidth of 89MHz and a return loss value of 15.47dB is observed at the center frequency of 1.35GHz. Proposed antenna is having a gain 8.37dB at 1.35GHz. Low loss RT Duroid 5880 with a depth of 1.574mm and a dielectric constant of 2.2 has been used as substrate for the proposed antenna. For designing the antenna parameters and analyzing the performance of the antenna Ansys HFSS tool has been used.

Keywords:*Air Cavity, Mutual Coupling, EBG.*

I. INTRODUCTION

The unique abilities of the patch antennas like low profile and ease of fabrication have made them most significant in modern communication systems. Apart from their unique physical characteristics there are some limitations in microstrip in terms of their gain and bandwidth[1]. Due to this low gain and low bandwidth it is difficult to use microstrip antennas in some specific applications where high gain and bandwidth are necessary.

Many researchers have proposed number of techniques to overcome the limitations of microstrip antennas and these techniques are been implemented successfully. One of the conventional technique to enhance gain is to use a low dielectric constant substrate and for bandwidth enhancement the conventional method is to extend the depth of the substrate[2].

But there is a limitation for substrate thickness, we cannot go on increasing it to increase the bandwidth, the relationship between the substrate thickness and bandwidth is not completely linear, initially it is linear but after some time it is having non linear relationship. The increase in the substrate thickness will increase the feed probe length and it will inturn increase the inductance on the antenna which will result in reduction of the impedance bandwidth of antenna[3]. Substrates with low dielectric constant are generally high in price.

Proposed is an air cavity backed meandered rectangular patch antenna which can overcome the limitations of the conventional patch antenna. Air will not have any material losses which are observed in normal substrates and it is having a very low dielectric constant of value one. So by introducing a air space in between the substrate and the ground layers we can make the combination of ground, air cavity and substrate will result in a very low effective dielectric constant and this will enhance the gain of the antenna[4]. The air space will enlarge the distance between the substrate and the ground layers which will result in bandwidth enhancement.

The inductance effect of the feed probe on the antenna increases with increase in probe length but by using a air cavity the inductance effect of the probe will be very low on the antenna. A meandered patch is been used as a radiating element, the meandered structure will produce inductance which will cancel the inductance generated by the probe. The air space can be replaced with a foam layer which is a non radiating material so the antenna radiation characteristics are not been effected and it will also provide some additional physical strength to the antenna[5].

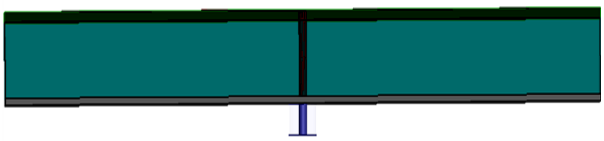
Design of Antenna arrays with minimum inter element spacing has become a challenging task to antenna design engineers, this is necessary to meet the compact size requirements of the modern communication systems. The effects of mutual coupling will be high if the inter element spacing is less and mutual coupling will effect the antenna performance. So to reduce these effects Electromagnetic bandgap structures are been proposed.

The proposed work in this paper is to design a high gain wideband microstrip antenna and then develop an antenna array with a low mutual coupling and high isolation. A periodic EBG structure has been considered which will reduce coupling and improve isolation in antenna array.

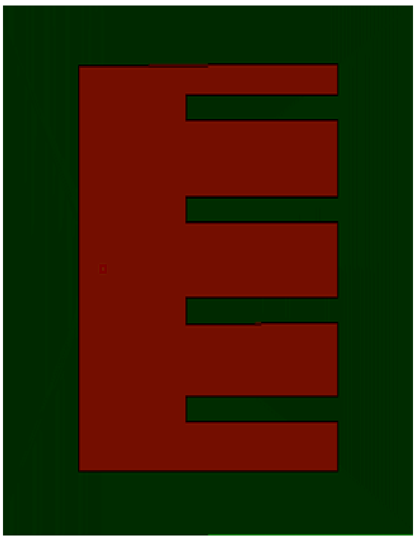
II. ANTENNA DESIGN

In Figure 1 we can see the geometrical configuration of proposed meandered rectangular patch antenna, it comprises of a thick aluminum plate as ground plane, a low dielectric constant RT Duroid 5880 substrate, a E shaped meandered rectangular patch and a air gap in between the substrate and ground layers. The antenna is excited by a Coax feed. The height of the air cavity is 12mm and the thickness of the ground is 1mm. The depth of the substrate is about 1.574mm with a relative permitivity of 2.2. For simulation purpose the air cavity has been filled with non radiating ROHACELL foam material.

The ground plane and the substrate are having equal dimensions of 145mm in terms of length and width and the radiating patch is having a dimension of 88.75mm×110mm, four slots each with a dimension of 52mm×7mm are etched on the patch, these slots are etched at equal distance from each other. The feed is positioned at the center of the patch nearer to the opposite side of the slotted edge.



(a) Side View



(b) Top View

Figure 1. Proposed patch antenna

III. RESULT AND ANALYSIS

Various Antenna parameters are simulated and analyzed by using Ansys HFSS software. S_{11} characteristics of the proposed meandered patch antenna is presented in the Figure 2.Observed a return loss value of-15.47dB at the resonating frequency of 1.35GHz. Aimpedance bandwidth of 89 MHz which comes to be 6.7% of bandwidth is

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observed and it is covering the frequency range from 1.30GHz to 1.39GHz. A VSWR of 1.4 is observed at the resonating frequency of 1.35GHz as shown in Figure 3. The complete impedance bandwidth is having a VSWR value of less than 2. The obtained results depicts that the impedance matching of the antenna with the coax feed is close to 50Ω.

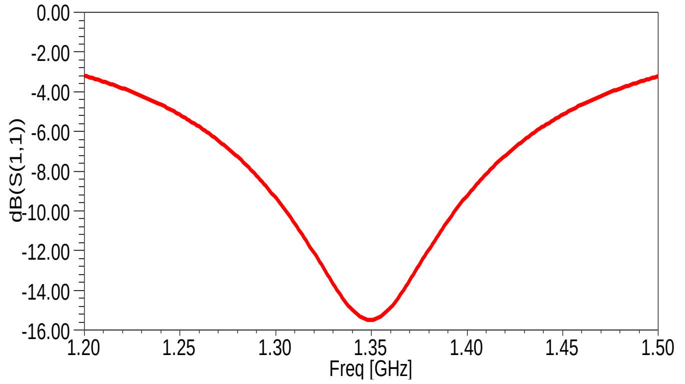


Figure 2. Return loss

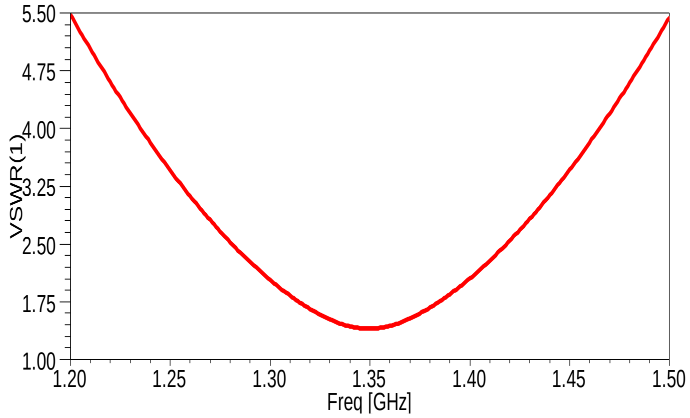
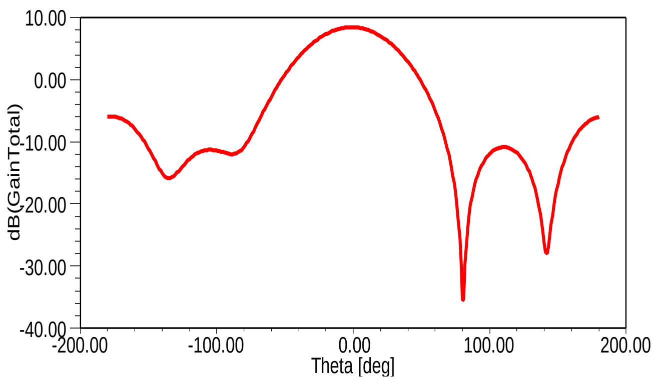
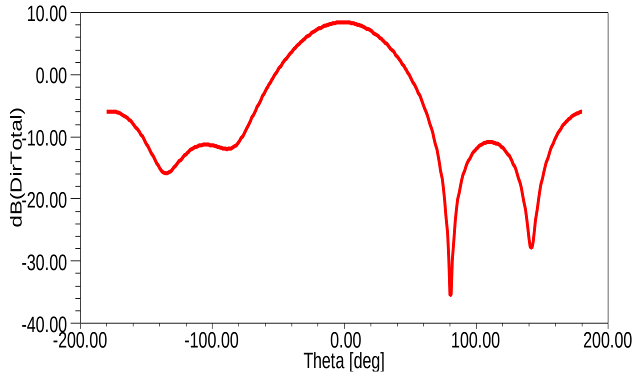


Figure 3. VSWR

The air space introduced between the aluminium ground and the substrate is the key contributor for the enhanced gain.



(a) Gain



(b) Directivity

Figure 4. Gain and Directivity at 1.35 GHz.

Antenna operating frequency range varies depending upon the height of the air cavity. So the height of the air cavity is optimized so that the proposed antenna will radiate at 1.35GHz. Figure4 aboveshows the simulated plots of gain and directivity.Observed a gain 8.37dB and directivity of 8.39dB at the resonating frequency of 1.35GHz.

Figure 5 shows the scattering parameters of the meandered patch at the resonating frequency of 1.35GHz, from the plot it can be observed that the radiation is maximum at both the edges for the operating frequency of 1.35GHz. The radiation at the meandered edge will generate inductance which is in opposite direction to the inductance generated by the long feed probe and cancels it.

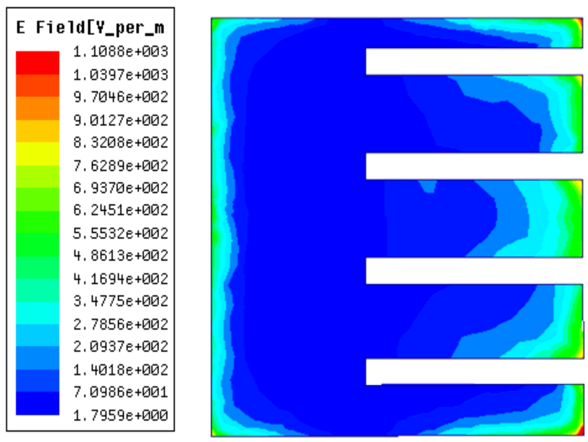
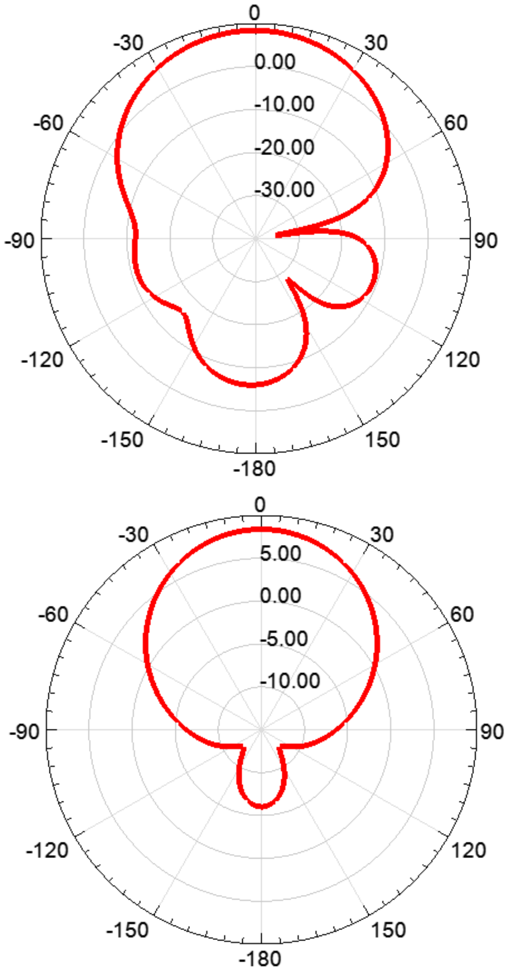


Figure 5. Current distribution at 1.35GHz

The radiation characteristicsof the antenna at the resonating frequencyof 1.35GHz are shown in Figure6 below, The Elevation plane is depicted Figure 6(a) and the Azimuthal plane is depicted in figure 6(b). Observed a Half power beamwidth values of 63º and 67º for the Elevation plane and Azimuthal planerespectively at the resonating frequency of 1.35GHz. The radiation patterns of the proposed meandered rectangular patch antenna are having broadside characteristics when compared to the patterns of aconventional microstrip patch antenna[6]-[8].



(a) Elevation Plane (b) Azimuthal plane

Figure 6. At 1.35GHz

Figure 7 below shows the antenna array structure of the meandered rectangular patch antenna.

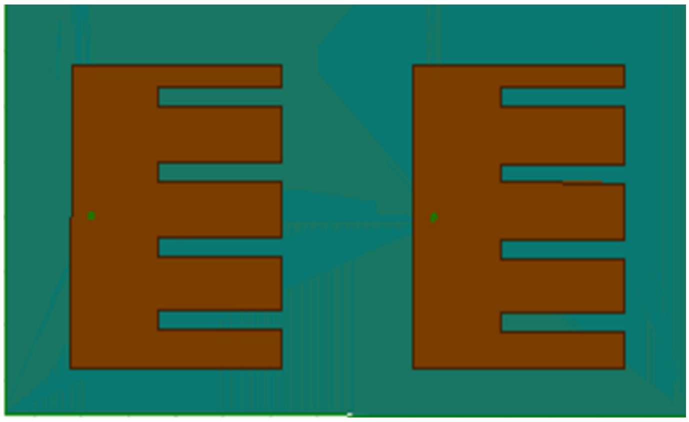


Figure 7. Proposed patch antenna array

Figure 8 below shows the mutual coupling plot of the antenna array in between the two ports exciting the two radiating elements.

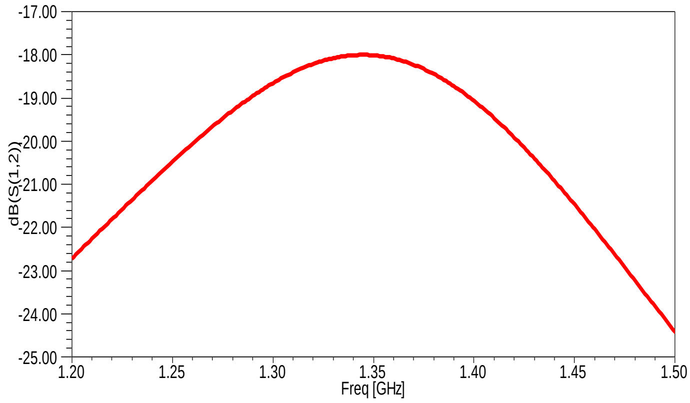


Figure 8. Mutual Coupling of the antenna array

Geometry of the single unit cell of the proposed EBG structure is shown in the Figure 9. The basic characteristic of the EBG structure is to absorb the surface currents generated by the antenna elements so that they will not effect the performance of the other radiating elements [9-10]. The center square is having a side length 0.325mm the two strip lines passing through the center square are of 1.65mm*0.115mm. The four squares in the four quadrants are having a side length of 0.425mm.

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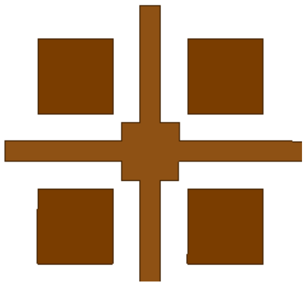

Figure 9. Unit cell of EBG structure

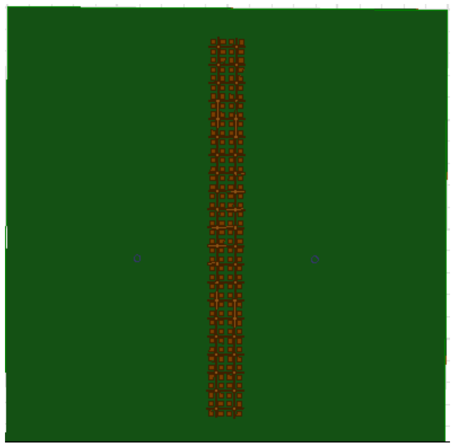

Figure 10. Proposed EBG structure

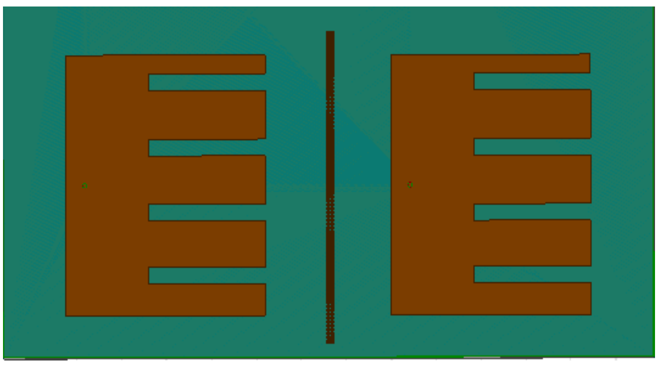

Figure 11. Proposed Antenna Array with EBG

Figure 10 and 11 above presents the combination of EBG structures into the proposed array. Figure 12 below shows the mutual coupling plot of the antenna array integrated with the proposed EBG structure. Here we can observe that by integrating the proposed EBG structure to the antenna array the mutual coupling of the antenna array has reduced by -20dB i.e from -17.77dB to -38.54dB.

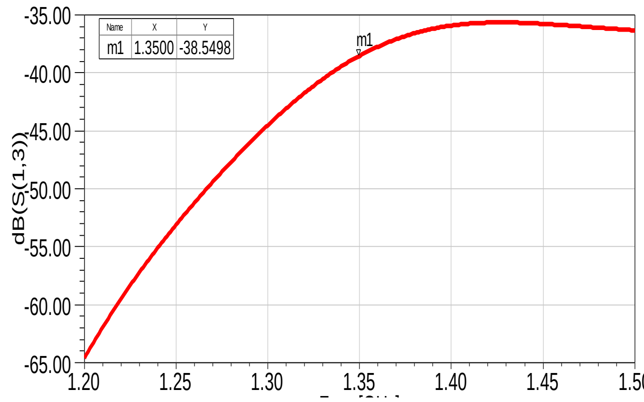

Figure 12. Mutual Coupling of the antenna array with EBG

IV. CONCLUSION

Simple techniques to overcome the limitations of conventional microstrip patch antenna are been proposed in this paper, the limitations of low gain,low bandwidth and mutual coupling for microstrip antenna and microstrip antenna array are been investigated successfully. A air cavity backed meandered rectangular patch antenna with a coax fed is presented and for mutual coupling analysis a basic two element array is considered. The air space is introduced in between the substrate and ground layers to enhance the gain and a meandered rectangular patch is considered to enhance the bandwidth. The proposed EBG structure has demonstrated that the mutual coupling can be reduced in a considerable range by integrating the EBG in antenna array. From the simulated S parameters results the operating frequency of the proposed antenna ranges 1.30GHz to 1.39GHz with a bandwidth of 89MHz and a return loss value of 15.47dB at the center frequency of 1.35GHz. The gain of the antenna at the center frequency of 1.35GHz is 8.37dB with a mutual coupling reduction of -20dB with the introduction of EBG structure. The proposed antenna is having a dimension of 145mm×145mm×14.5mm and is best suitable for the L band applications.

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