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Design of EBG Superstrate to Improve the Performance of Patch Antenna

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Abstract: The frequency selective surface (FSS) properties of a planar EBG unit cell due to meander variations are studied. The meander EBG unit cell has meander line inductors and inter digitated capacitors to provide FSS characteristics. A 13 X 13 array of the EBG is used as a superstrate for a patch antenna operating at 10.8GHz to increase its directivity. The radiation characteristics of the patch antenna with and without FSS superstrates are simulated and analyzed. The patch antenna accompanied with the FSS superstrate shows 5dB improvement in directivity with a smooth radiation pattern at 10.8GHz.
Index terms: Directivity, Electromagnetic Band Gap (EBG), Frequency Selective Surface (FSS), Patch antenna, Superstrate

I. INTRODUCTION

The wireless communication systems require highly directive antennas with compact and cost effective geometric structure. Microstrip antenna is one of the most popular low profile printed antenna. Microstrip antennas have several well-known advantages over other antenna structures, that includes low-profile, light weight, low cost of production, robust nature and compatibility with microwave monolithic integrated circuits (MMICs) and optoelectronic integrated circuits (OEICs). Because of these merits microstrip patch antenna have been utilized in mobile communication base stations, space borne satellite communication systems, and even mobile communication handset terminals. Despite the previously mentioned features, Microstrip patch antenna suffers from poor radiation efficiency, narrow bandwidth etc.

Electromagnetic Band Gap technology has become a significant breakthrough in the Radio frequency and microwave applications due to their unique band gap characteristics at certain frequency ranges. EBGs are periodic arrangements of dielectric or metallic elements in one, two, or three dimensional manners. EBG structures are periodic in nature, which can be formed by drilling, cuffing, and etching on the metal or dielectric substrates. They may be formed in the ground plane or over the substrate or as a superstrate.

II. DESIGN OF PATCH ANTENNA

For designing a Microstrip patch antenna, the operating frequency and a dielectric medium has to be selected for which the antenna has to be designed.

The width of the Micro strip patch antenna is given by equation as:

$$w = \frac{C_0}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

The value of the effective dielectric is calculated using the following equation:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{w}]^{\frac{-1}{2}}$$

Due to fringing, electrically the size of the antenna is increased by an amount of (ΔL). The fringing E-fields on the edge of the microstrip antenna add up in phase and produce the radiation of the microstrip antenna. Therefore, the actual increase in length (ΔL) of the patch is to be calculated using the following equation:

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{w}{h} + 0.8)}$$

Where 'h'= height of the substrate.

The length (L) of the patch is now to be calculated using the below mentioned equation:

$$L=\frac{1}{2fr\sqrt{\mu_o \varepsilon_o \epsilon_{reff}}}-2\Delta L$$

The length of a ground plane (L_g) and the width of a ground plane (W_g) are calculated using the following equations:

$$L_g = 6h + L$$

$$W_g = 6h + W$$

The figure of the patch antenna designed for 10.8GHz using the above equations is given below:

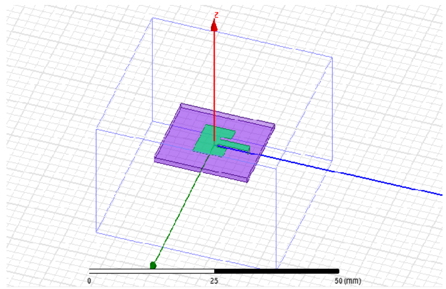

Fig.1.Design of Patch antenna

III. DESIGN OF MEANDERED ELECTROMAGNETIC BANDGAP STRUCTURES (EBG) AND IT'S ANALYSIS

A Frequency Selective Surface is any thin repetitive surface designed to reflect, transmit or absorb Electromagnetic fields based on frequency of the field. Three FSS unit cell structures (Structure A, Structure B and Structure C) are designed and its FSS characteristics are analysed using ANSYSS HFSS solver (version 16.2). The unit cell structures are as follows:

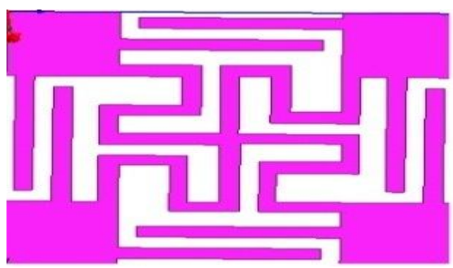

Fig.2.Schematic of the unit cell- Structure A

The unit cell showed in Fig.1 has a dimension of 3.51 X 3.51 mm^2 and the gap between each meander is 0.15mm. FSS properties of structure A has been analysed by placing it over a layer of FR4 epoxy. Floquet ports are placed above and below the unit cell at some arbitrary distance for the purpose of analysis.

A. The Unit Cell Analysis of Structure A is as Follows

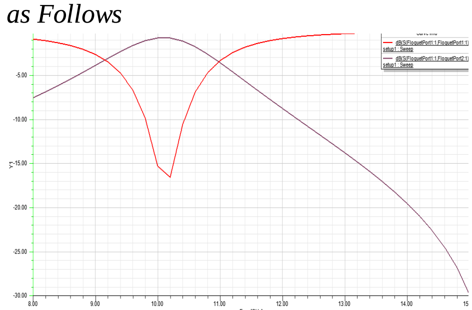

Fig.3.Reflection and Transmission co-efficient for Structure A unit cell

On analyzing Structure A's unit cell it is found that resonant frequency is obtained near the solution frequency of 10.8GHz with a return loss of -16dB and has zero degree reflection phase at 10.8GHz.

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Structure B is obtained from structure A by changing the inductance and keeping the capacitance same. The introduction of meander lines results in lowering of resonant frequency. The meander spacing increases the resonant frequency decreases.

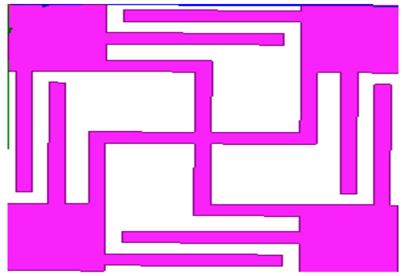

Fig.4.Schematic of the unit cell- Structure B

B. The Unit Cell Analysis of Structure B is as follows

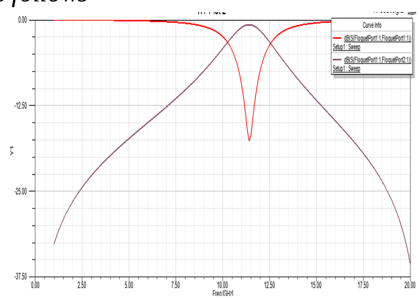

Fig.5. Reflection and Transmission co-efficient for Structure B unit cell

On comparing Structure B's unit cell with Structure A it is found that the resonant frequency has shifted towards the right from solution frequency and there is a decrease in return loss.
Structure C is also obtained from Structure A by keeping the inductance same and changing the capacitance

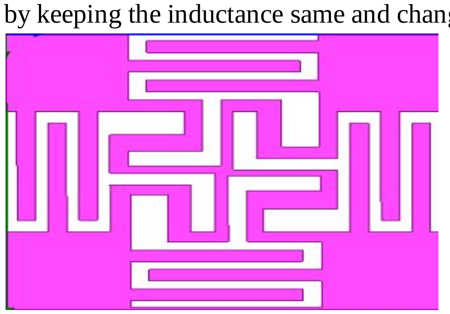

Fig.6.Schematic of the unit cell- Structure C

C. The Unit Cell Analysis of Structure C is as Follows

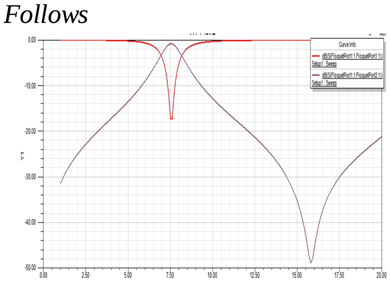

Fig.7.Reflection and Transmission co-efficient for Structure C unit cell

The unit cell analysis of Structure C implies that there is a shift of resonant frequency towards left from the solution frequency and return loss has increased. On comparing the three unit cell structures, Structure A is found to be more optimum than the other structures since resonant frequency is near the solution frequency. So, Structure A is used in the Superstrate arrangement as a 13 X

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13 array.

IV. INTEGERATION OF EBG SUPERSTRATE WITH MICROSTRIP PATCH ANTENNA

A Micro strip patch antenna operating at 10.8GHz is designed using HFSS software. Structure A is used in the Superstrate arrangement as a 13 X 13 array at a distance of about 14.5mm and it is analysed. The results are then compared with a microstrip patch antenna working at 10.8GHz without superstrate.

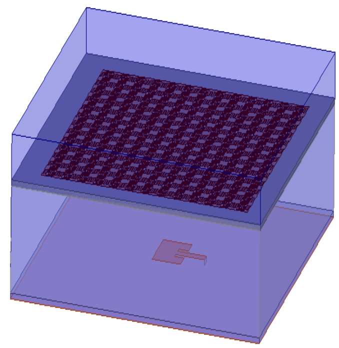

Fig.8.Design of patch antenna with superstrate operating at 10.8GHz

A. The Return Loss Plot of the Patch Antenna Designed With and Without Superstrate are as Follows

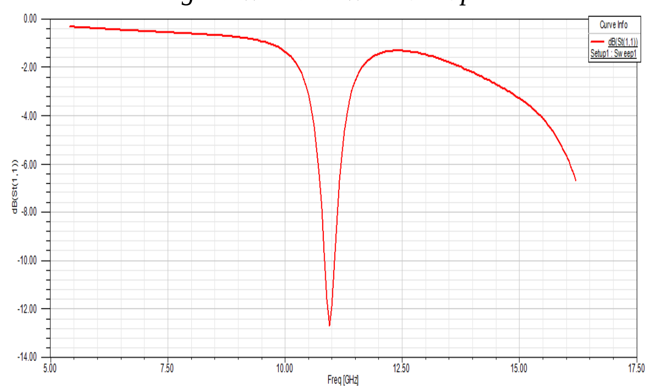

Fig.9.1.Return Loss of Patch antenna without superstrate

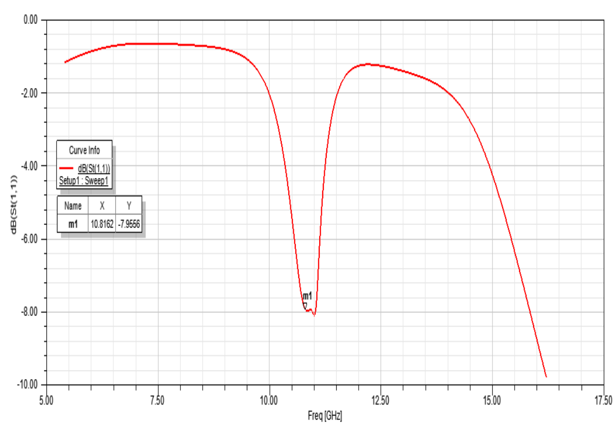

Fig.9.2. Return Loss plot of Patch antenna with superstrate

The resonant frequency of the patch antenna is slightly lower because of the use of superstrate. The simulated directivity from HFSS software for an antenna with operating frequency of 10.8GHz with the use of superstrate is found to produce better directivity when compared with directivity results of a microstrip patch antenna without superstrate.

V. COMPARISON OF RADIATION PATTERN

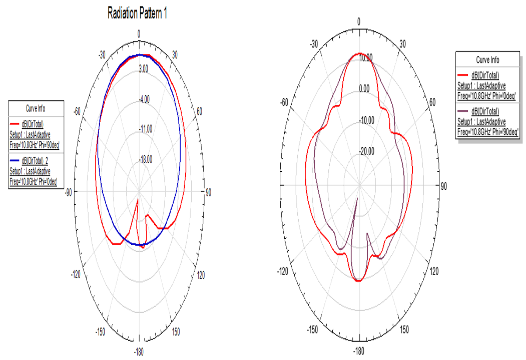

Fig.10. Simulated radiation pattern of the patch antenna with superstrate and without superstrate operating at 10.8GHz

From the Radiation pattern of the patch antenna it is seen that the antenna with superstrate shows improvement in the directivity as compared to the reference antenna without any superstrate. On calculating it is found that antenna without superstrate has a directivity of 7.08dB whereas antenna with a superstrate provides a directivity of about 12.008dB.

VI. CONCLUSION

The FSS characteristics of the proposed unit cell are studied using simulation. On analyzing Structure A is the best. It is found that with proposed EBG superstrate in microstrip patch antenna with the superstrate the directivity is enhanced by about 4.928dB.

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