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Design & Simulation of Rectangular & Circular Patch Antenna with Electromagnetic Band Gap Substrates

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Abstract: -
This paper presents the design and simulation of rectangular & circular patch antenna with Electromagnetic Band Gap Substrates (EBG) substrate using High Frequency Structure Simulator (HFSS). The two different configurations of broadband micro strip patch antenna, multi stacked rectangular patch antenna & multi stacked circular patch antenna are analyzed. Return Loss & Gain are performance parameter. The substrate used in these two configurations is RT Duroid having dielectric constant 2.2. The result calculated is return loss of rectangular patch & circular patch with EBG substrates are -13.98 dB & -43.4437 dB and gain of rectangular patch & circular patch with EBG substrates are 5.7478 dB & 10.4954 dB respectively.

Keywords *–Rectangular Patch, Circular Patch, High Frequency Structured Simulator (HFSS*).

Introduction

Microstrip antenna is an ideal choice for wireless communication due to low profile, light weight, low cost, simplicity of manufacturing and easy integration to circuit. However, conventional microstrip patch antenna suffers from very narrow bandwidth [1], typically about 5% bandwidth with respect to central frequency.

In high performance aircraft, spacecraft, satellite, and missile applications, where size,
weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low-profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications that have similar specifications. To meet these requirements, microstrip antennas [2] can be used. These antennas are low profile, conformable to planar and non planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and when the particular patch shape and mode are selected, they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed.

II. Antenna Design

In this section, structure of patch antennas are discussed, EBG rectangular patch, EBG Circular patch are simulated by HFSS software in order to decrease return loss and increase gain.

A. Rectangular Patch Antenna

A Rectangular patch antenna is designed and simulated here. Dimensions given in fig.1 of patch are calculated using [3] and optimized dimensions are L=21.388mm, W=20.388mm. Substrate with dielectric constant 2.2 and height 1.588 mm, x=3.126 mm. Patch is designed for operating frequency 10.5 GHz. Dimension of ground plate is calculated using following equation

$$Wg = 6h + w$$

$$Lg = 6h + L$$

For designing the rectangular patch following calculations is done with help of given equations [9]

$$W = \frac{V_0}{2f_r}\sqrt{\frac{2}{\varepsilon_{r+1}}}$$

V_0 = free space velocity of light

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\left[1 + 12\frac{h}{w}\right]^{1/2}$$

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

$$L = \frac{\lambda}{2} - 2\Delta L$$

$$L_{eff} = L + 2\Delta L$$

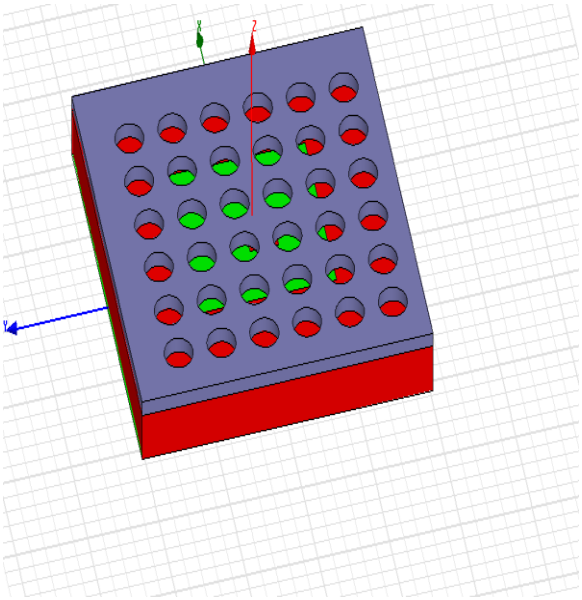

Fig 1. Top and Side view of rectangular patch antenna

After Simulation return loss is obtained -13.98 db with gain 5.7478 db. Frequency Vs Return Loss plot & radiation pattern is shown in fig. 2 & fig. 3 respectively.

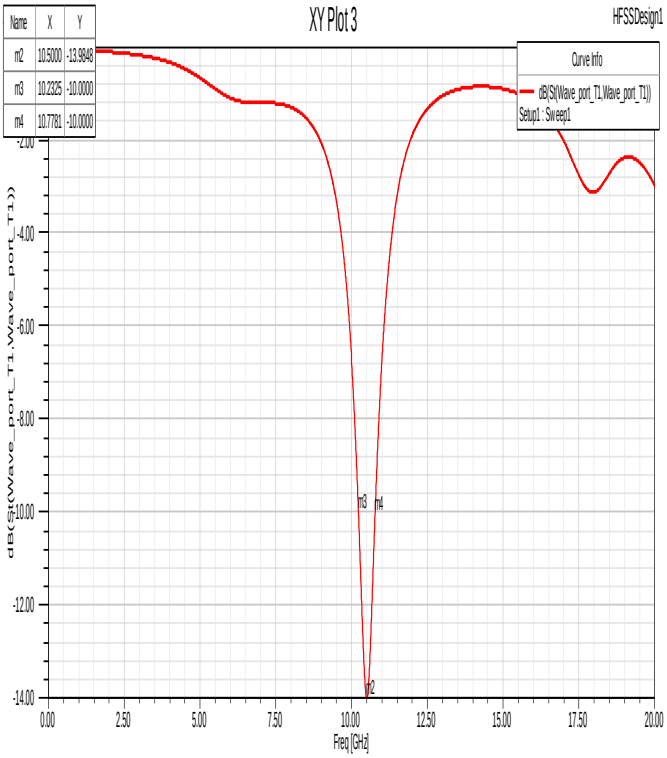

Fig 2.Frequency Vs return loss plot for rectangular patch antenna

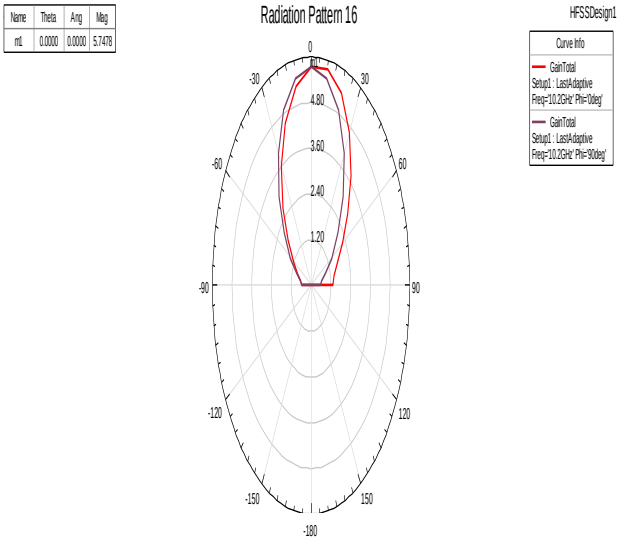

Fig 3. Radiation Pattern for rectangular patch antenna

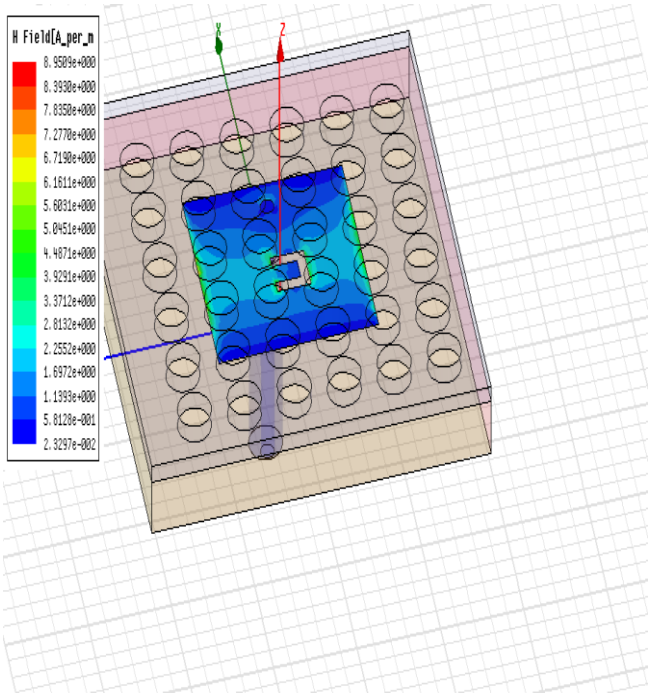

Fig. 4 Magnetic Field distribution for rectangular patch antenna

Electric field & magnetic field also play very important role to design patch antenna. The distribution of magnetic field is given in fig 4. Maximum magnetic field is 5.6031 A/m

B. Circular Patch Antenna

A circular patch antenna is designed and simulated here. Dimensions given in fig. 5 of patch are calculated using [3] and optimized dimensions are a = 30mm. Substrate with dielectric constant 2.2 and height 1.588 mm, x=4.8 mm. Patch is designed for operating frequency 10.5 GHz. Dimension of patch is calculated using given equations

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_{rF}}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}}$$

$$F = \frac{8.791 \times 10^{9}}{f_{r\sqrt{\varepsilon_r}}}$$

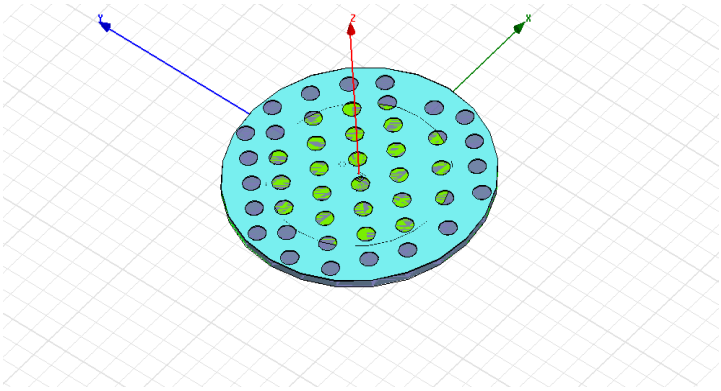

Fig. 5 Top and Side view of Circular patch antenna

After Simulation return loss is obtained -43.4437 db with gain 10.4954 db. Frequency Vs Return Loss plot & radiation pattern is shown in fig. 6 & fig. 7 respectively.

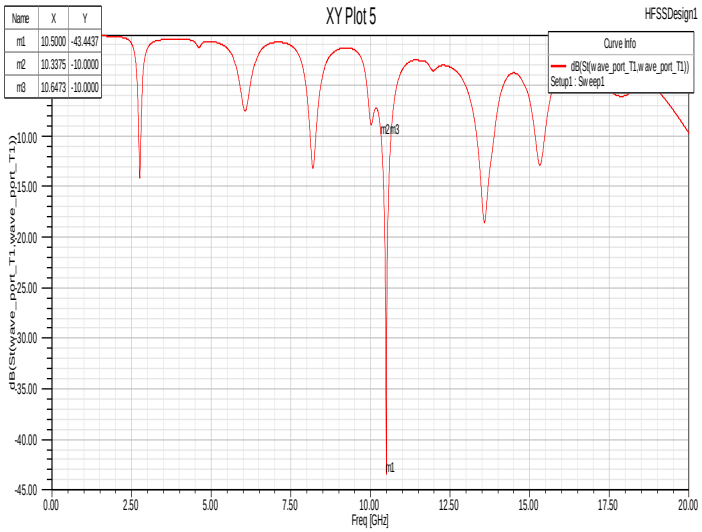

Fig 6.Frequency Vs return loss plot for Circular patch antenna

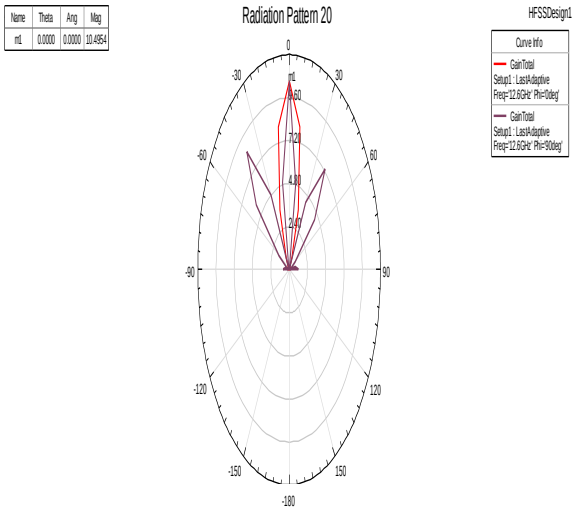

Fig.7 Radiation Pattern for Circular patch antenna

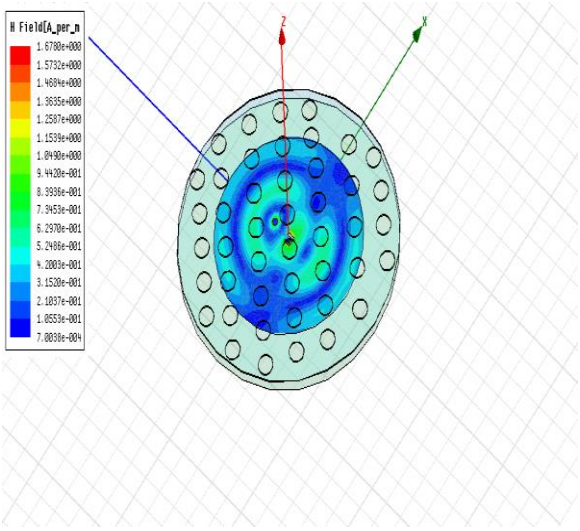

Fig.8 Magnetic Field distribution for circular patch antenna

Electric field & magnetic field also play very important role to design patch antenna. The distribution of magnetic field is given in fig 8. Maximum magnetic field is 1.1534 A/m

III. Comparative Analysis

In this section, comparative of two configurations is shown in tabular form. Return loss and bandwidth is compared in table 1.

Sr. No	Parameters	Rectangular Patch	Circular Patch
1.	Return Loss	-13.98	-43.4437
2.	Resonant Frequency(f_0)	10.5	10.5
3.	Lower cutoff Frequency(f_L)	10.2325	10.3374
4.	Upper Cutoff Frequency(f_H)	10.7781	10.6473
5.	Bandwidth	0.5456	0.3099
6.	Gain	5.7478	10.4954

Table 1.Comparative analysis of different configurations of Antenna

IV. Conclusion

After Simulation, it is found that Circular patch with c slot antenna has low return loss with high gain and bandwidth. Simulated return loss is -43.4437 db with gain 10.495 db.

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