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Design and Analysis of Microstrip Patch Antenna for X Band for 8 Ghz for Different Substrate Material FR4, Rogers 5880 and Arlon 255

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Abstract - Microstrip Patch antenna is emerging in the field of wireless communication and its application in the field of radar communication, space applications, and military applications because of low weight, simple to built and low cost. Due to the advanced technology in electronics world, the size miniaturization and performance enhancement are key requirements for communication systems. The proposed antenna is of 8 GHz for different materials FR4, Rogers 5880 and Arlon255.The substrate material is with specifications, FR4 dielectric constant is 4.3 and loss tangent is 0.002, rogers whose approximately permittivity is 2.2 and loss tangent is 0.0009 and arlon255 dielectric constant is 2.55 and loss tangent is 0.00913 are considered. The dimensions are measured HFSS software is used for the design of software. Different parameters of MPAs are measured 3D gain, radiation pattern, VSWR, return loss, gain, radiation efficiency, half power beam width, bandwidth. The best performance in terms of gain revealed by criteria analysis is of arlon255. The microstrip line edge feeding method is used in this antenna for feeding patch.

Keywords: *Microstrip patch antenna, 8 GHz, X band, Arlon255, FR4, Rogers 5880 substrate material.*

1. Introduction

The presented rectangular patch antennas with different substrate materials are designed mainly to cover 8 Ghz of frequency with high gain, better VSWR, high radiation efficiency, and radiation pattern. There has been interest growing in the design of pattern reconfiguration with reasonable and simple configurations that can be used for radar, wireless, military and satellite communication [1]. An MPA comprises three layers, ground, substrate, and patch. The patch of the antenna comprises conducting material copper (Cu) or Gold (Au). The MPAs provide good directional patterns [2]. The microstrip patch antenna comes in various shapes like rectangular, elliptical, triangular, circular, dipole, square, etc [3]. The substrate material in the microstrip patch antenna is placed between the radiating patch on the top and the ground at the bottom [4]. The polarized flexible antennas can be useful for satellite communications and high-resolution polar metric synthetic aperture radars. There are some transmit diversity scheme that helps to improve the data rate, and the capacity of wireless schemes [5,6,7]. The feedline photoetching and radiating are done on the dielectric substrate [8]. The resonant length of the microstrip patch antenna is approximately λo/2. For many applications, its too large [9]. Different techniques are employed to reduce the height of resonant length of patch. The fringing effect at the patch field increases when there is a low value of dielectric constant and thus radiated power also increases [10]. There are many ways to improve microstrip patch antennas for example by varying dielectric substrate, change in the shape of the patch, by introduction of superstrate, removal of substrate and the combination of different methods. A thin patch is to be selected so that t << λo (where t is the patch thickness). The range between 2.2 ≤ εr ≤ 12 is defined for substrate material [11]. MPAs are the best miniaturized structures that are considered nowadays so that can easily work for to communication devices.

2. Microstrip Line Edge Feed Method

Feeding is one of the main steps in a microstrip patch antenna, which establishes a connection between the transmitter and receiver for communication process. Enormous feedline techniques are introduced. External edge feeding is provided via feedline. The design is made in such a way that width of the feed element is less than the radiating patch [12]. There is a direct connection between the conducting strip and the microstrip patch's edge. The size of the conducting strip is smaller in width than a patch. To provide a planar structure, this arrangement has an advantage that the feed can be etched on the same substrate. A quarter wave impedance transformer which is written as λ/4 impedance transformer having 70-80 ohms' impedance.

3. Research Methodology

For Designing an antenna and calculating its various parameters, there are various steps.

The Proposed microstrip patch antenna is designed using FR4 substrate, arlon255, and rogers5880. Having dielectric permittivity. The width of the patch is calculated by this given formula. Equation (1-7) is used for designing the proposed antenna.

$$w = \frac{c}{2fc}\sqrt{\frac{2}{1+\varepsilon_r}} \ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where

c = velocity of light in air 3 x 10 ^{8} m/s

fc = Frequency of antenna 8 GHz.

The dielectric constant of the substrate

Effective dielectric constant as specified by Hammersted and Jensen [13],

$$\varepsilon_{eff} = \frac{1+\varepsilon_r}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-1/2} \ldots \text{(2)}$$

Where

ε reff = effective dielectric constant

ε_r is dielectric constant of substrate

h is height of dielectric substrate

W is width of the patch

Owing to the effect of fringing fields, the fringing fields along the length of the patch, there is extension of ΔL on both sides of the patch,

The extension length (ΔL) is determined by

$$\Delta L = 0.412h\frac{(\varepsilon_r + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon_r - 0.258)(\frac{w}{h} + 0.8)} \quad \text{(3)}$$

The effective dielectric length of antenna

$$L_{eff} = c/2fr\sqrt{\varepsilon reff} \ldots\ldots \text{(4)}$$

Length of patch

$$L = L_{eff} - 2\Delta L \ldots\ldots \text{(5)}$$

Ground plane length is given by

Lg= 6h +L……… (6)

Ground plane width is given by

Wg = 6h + W……. (7)

The microstrip patch antenna dimensions depend on desired resonant frequency and the relative permittivity of the substrate material.

4. Geometry and structure of microstrip patch antenna

The rectangular patch antenna has been analyzed with specified to work with X band at 8 GHz with different substrates which shows the parameters such as VSWR, return loss, 3D gain, bandwidth, and the Half power beam width. Fig 1 shows the design of the microstrip patch antenna of Rogers5880 substrate material, fig 2 shows design **of** FR4 substrate material, fig 3 shows the design of the microstrip patch antenna of Arlon255 substrate material for 8 GHz. Table I shows all substrate materials design parameters.

Table I. Design Parameters for all substrate materials patch antennas

Parameter	**Rogers 5880**	**FR4**	**Arlon 255**
Length of Ground (mm)	49.7	46.7	46.7
Width of Ground (mm)	26	25	25
Length of patch (mm)	11.8	8.3	10.95
Width of patch (mm)	15	12	15
Substrate length (mm)	49.7	46.7	46.7
Substrate width (mm)	26	25	25

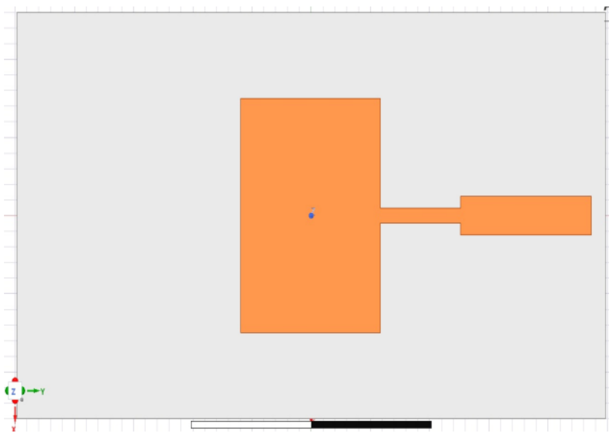

Fig.1 Pictorial representeation of Rogers 5880 for 8 GHz

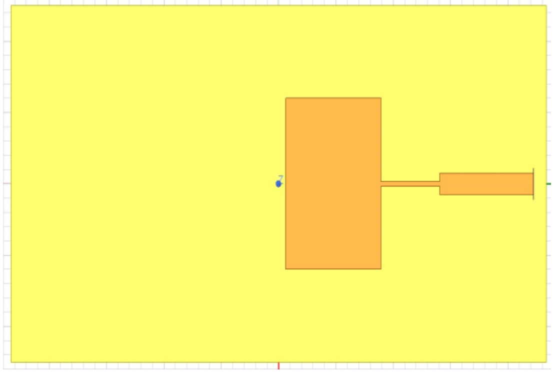

Fig. 2 Pictorial representation of fr4 for 8 GHz

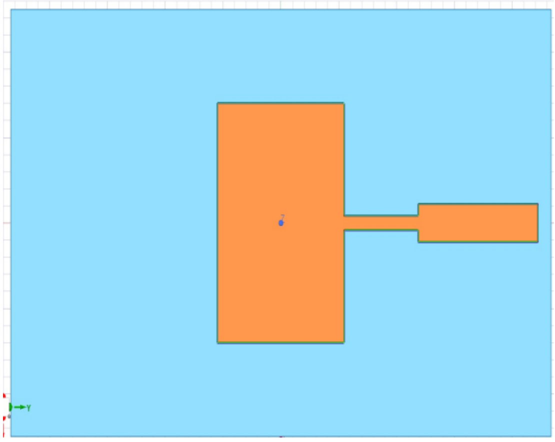

Fig.3 Pictorial representation of Arlon 255 for 8 GHz

5. Flowchart for the design of the the Microstrip Patch antenna

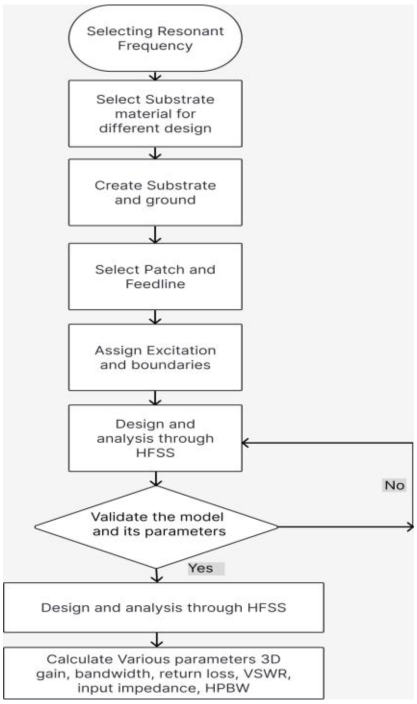

Fig. 4 Flowchart for the design of microstrip patch antenna

6. Simulated and measurement result

This section discusses results for different substrates Rogers 5880, FR-4 and Arlon255 with dielectric constants of 4.3, 2.2, 2.55 respectively. Fig 4 shows the flowchart for the design of the microstrip patch antenna. Calculation of different parameters VSWR, return loss (S parameters), gain, bandwidth, half power beam width, and analyzed radiation efficiency should be analysed. Our main purpose of this analysis is to utilize the performance of the designed antenna to achieve the desired resonance.

a) VSWR: The measure of how a transmission line is matched to the impedance of the connected equipment is called VSWR. It signifies the efficiency of power transfer between the source and the load [14]. At 50 ohms, the VSWR is determined by how well the antenna is matched to its characteristic impedance for a microstrip patch antenna. A high VSWR value indicates that the antenna is not matched correctly and it gives poor performance. Below there is the calculation for different substrates. For 8 GHz, Rogers's 5880 VSWR value is 1.6, FR4 VSWR is 1.1, Arlon255 is 1.7. Fig 5 shows the VSWR of rogers 5880, fig 6 shows the VSWR for FR4 and fig 7 represents a graph of VSWR for Arlon 255 for 8 GHz.

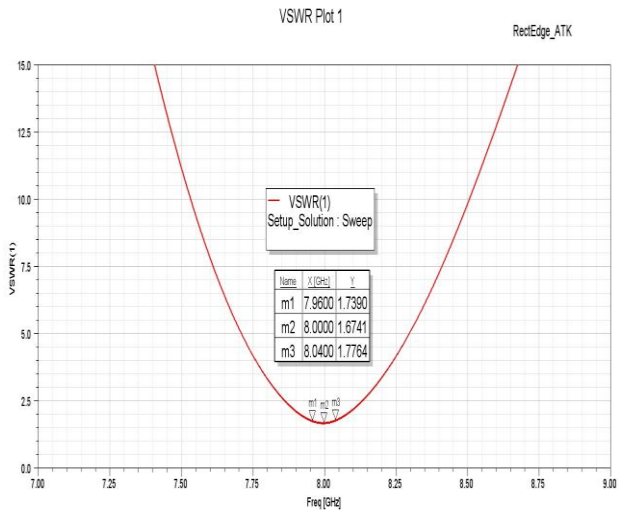

Fig 5. Graphical representation of VSWR for Rogers 5880 for 8 GHz

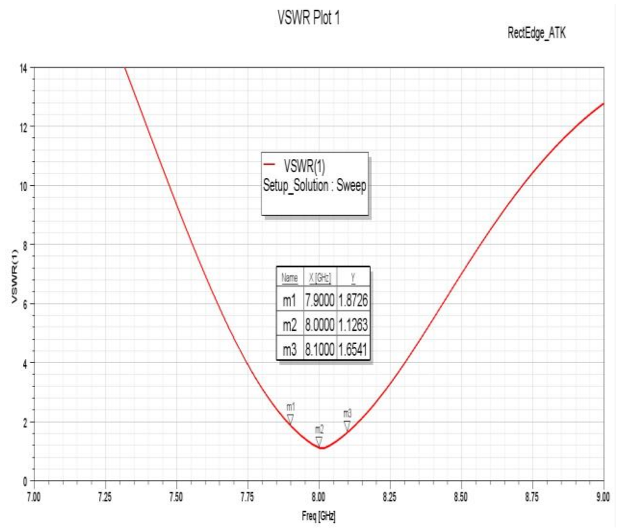

Fig 6. Graphical representation of VSWR for fr-4 for 8 GHz

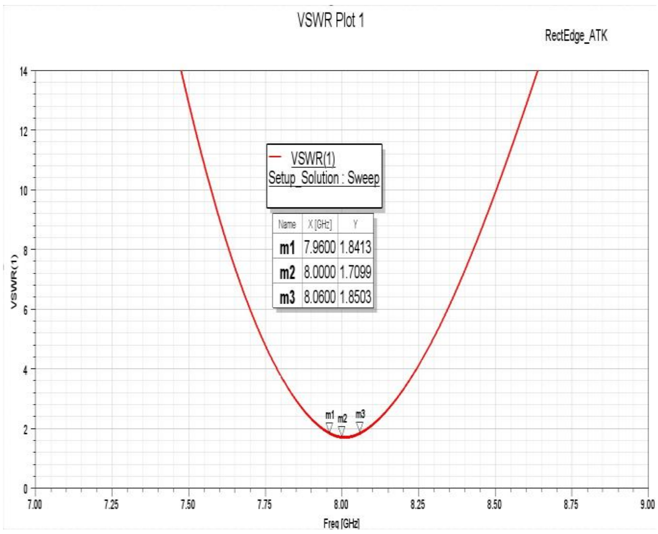

Fig 7. Graphical representation of VSWR for Arlon 255 for 8 GHz

b) Bandwidth: It refers to the range of frequencies over which the antenna can operate effectively with acceptable performance. It is typically characterized by its impedance bandwidth and its radiation pattern. The bandwidth of FR4 substrate for the given performance. The bandwidth for 8GHz for Fr4 is 200MHz, rogers 5880 is 120MHz and Arlon 255 is 120MHz.

c) S parameters: The input-output relationship between ports (or terminals) is called S parameters. There are two S parameters in a 2-port device, S11, called reflection coefficient or return loss. It gives the quantity of power reflected to the source compared to the power that was incident on the antenna. The smaller the S11 magnitude, the greater the return loss and vice versa [14]. Fig 8 shows the graphical image of the return loss for Rogers 5880, fig 9 shows the return loss for FR4, fig 10 shows return loss for Arlon 255 for 8 GHz. The return loss for Rogers 5880 is -11.9dB, the return loss for Fr4 is -11.9dB and Arlon 255 is -11.63dB for 8 GHz.

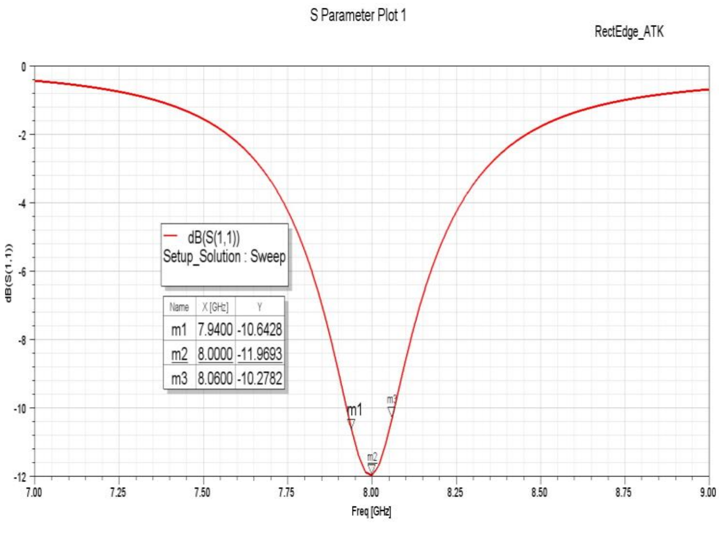

Fig 8. Graphical representation of return loss for Rogers 5880 for 8 GHz

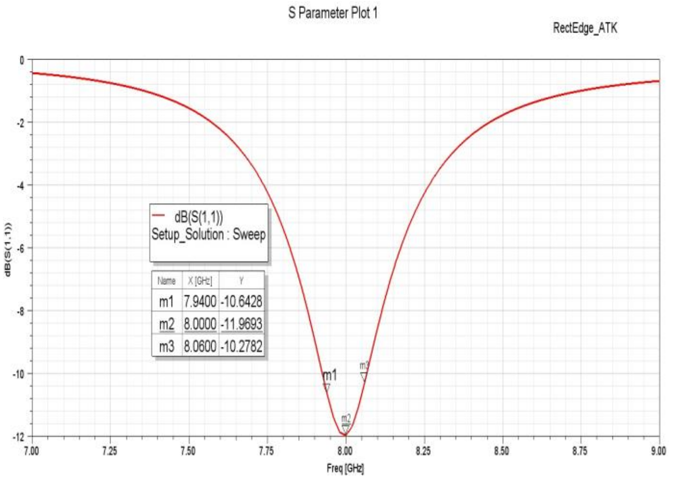

Fig 9. Graphical representation of return loss for Fr4 for 8 GHz

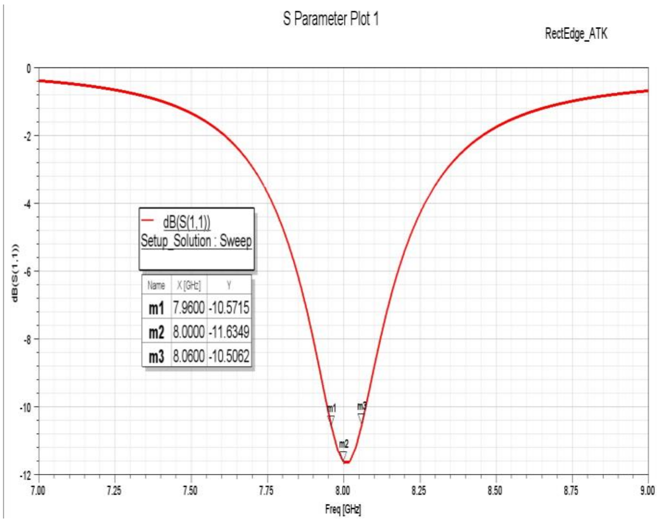

Fig 10. Graphical representation of return loss for Arlon 255 for 8 GHz

S21 also called transmission coefficient is the representation of the S parameter that represents the power transferred from the input port to the output port of the antenna. Calculation of amount of power is radiated by the antenna and is available at its output. The power transferred from port 1 to port 2.

d) Input impedance: It is also measured by the Smith chart, which indicates that it is a constructed measurement tool used by electrical engineers to solve problems related to RF transmission lines and matching devices. How well and antenna efficiently transfers EM energy to and from the feedline or transmission medium. Various factors affect the input impedance like feed type, patch geometry, and operating frequency.

The input impedance of an antenna is represented at its terminal of microstrip patch antenna.

Zin = Rin + jXin

Zin is the antenna impedance at its terminal

Rin is the antenna resistance

Xin (imaginary part) is the antenna reactance and shows the power accumulated in the near field of the microstrip patch antenna.

e) 3d Gain plot

The gain of the patch antenna is defined as the measurement of the ability to focus energy in a particular direction. It is expressed in decibels (dBi). Gain for Rogers 5880 is 6.90 dBi, FR4 is 4.54 dBi, and Arlon 255 is 6.95 dBi. Fig 11 shows of Rogers 5880 gain, fig 12 shows Fr4 gain and Fig 13 Arlon 255 gain.

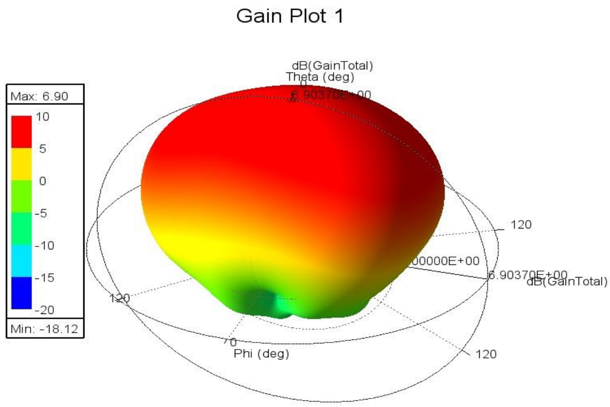

Fig 11. Pictorial representation of gain of Rogers 5880 for 8 GHz

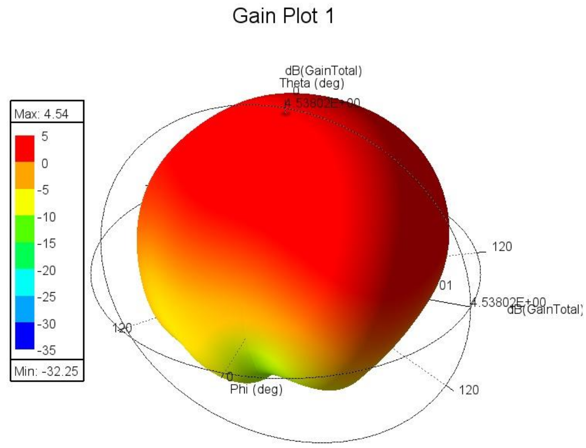

Fig 12. Pictorial representation of gain for Fr4 for 8 GHz

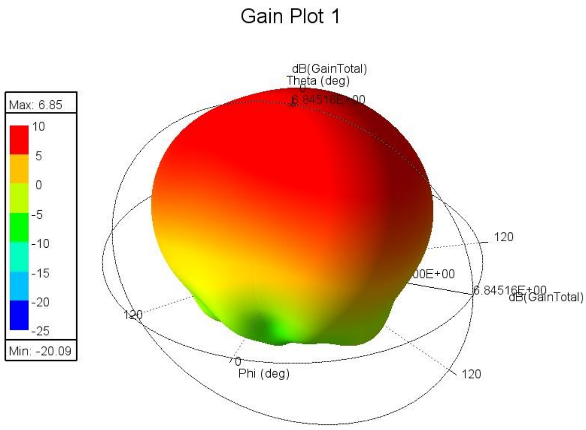

Fig 13. Pictorial representation of gain of Arlon 255 for 8 GHz

f) Half Power beam width: Beam width is the angular width (in degrees) measured on the antenna's major lobe of an antenna radiation pattern at half power points. It is a crucial parameter because it indicates the coverage area of the antenna and is related to the directivity of the antenna. Wider beam width is suitable for applications requiring wider coverage. It is broadened by both the horizontal and vertical currents. Half power beam width is angular separation where magnitude of radiation pattern reduced by 50 % (-3dB). Fig 4 shows the pictorial representation of parameters of microstrip patch antenna. It is the angle where the relative power is more than 50 % of the peak powerwhich comes under effective radiated field of the antenna.

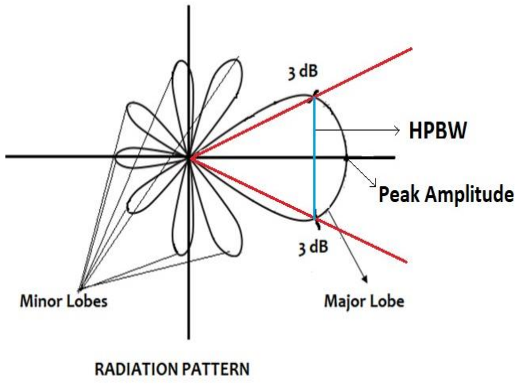

Fig 14. Pictorial representation parameters of microstrip patch antenna

g). Radiation Pattern: By Simply slicing trough the 3Dradiation pattern, the azimuth and elevation plane patterns are derived. The azimuth plane is obtained by slicing through the x-z plane, and the elevation plane pattern is formed by cutting through the y-z plane. The Elevation gain radiation pattern is pretty much uniform, yet it presents zero gain for low incidence angles [15]. Fig 15, pictorial representation of Azimuth and Elevation for Roger 5880 for 8 GHz, fig 15 shows pictorial representation of Azimuth and Elevation for Roger 5880 for 8 GHz, fig 17 shows Pictorial representation of Azimuth and Elevation for Fr4 for 8 GHz, Fig 18, Pictorial representation of azimuth and elevation for Arlon 255 for 8 GHz. Table II. Shows comparison for parameters for 8 GHz.

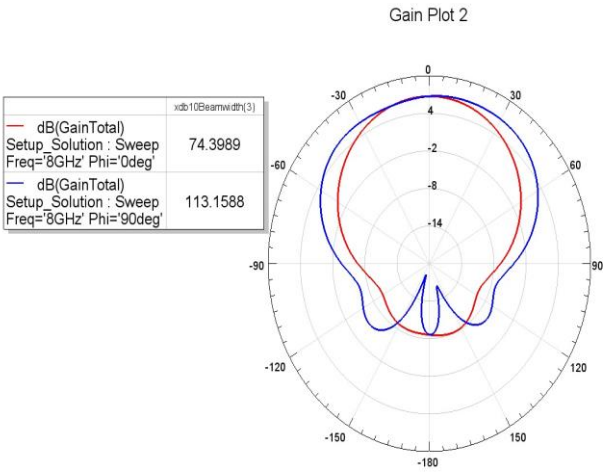

Fig 15. Pictorial representation of azimuth and elevation for Roger 5880 for 8 GHz

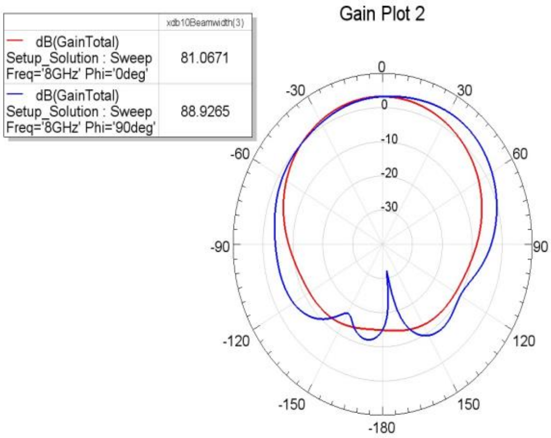

Fig 16. Pictorial representation of Azimuth and Elevation for FR4 for 8 GHz

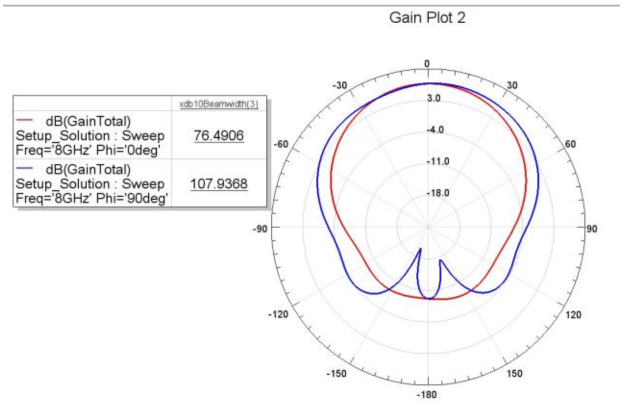

Fig 17. Pictorial representation of azimuth and elevation for Arlon 255 for 8 GHz

Table II. Comparison for parameters for 8 GHz

Parameters	FR4	Arlon 255	Rogers 5880
3D gain(dBi)	4.54	6.84	6.90
Radiation Pattern(Elevation (Elv) & Azimuth (Azi)	81 & 88	76 & 107	74 & 113
Bandwidth (MHz)	200	120	120
VSWR	1.1	1.7	1.6
Return Loss	-11.9	-11.9	-11.6

Future work

In future work, microstrip patch antenna array should be developed. There could be different topics about microstrip antennas. New designs will be investigated for several space and wireless communication applications. To enhance the performance, efficiency and capability of a miniaturized microstrip patch antenna. Designing and operating of wideband and multiband antennas can operate at multiple frequencies. For different resonant frequencies the microstrip patch antenna designing will be performed.

7. Conclusion

A rectangular patch antenna is studied, designed and simulated with three different substrate materials, Rogers 5880, FR4, Arlon 255.Their radiation pattern and parameters with different substrates material are compared. A proper selection of feeding technique is also important because of its effect on bandwidth, half power beam

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width, S parameter, VSWR, radiation efficiency. The radiation efficiency of three different designs is more than 90%. Anechoic chamber is a device where echoes or reflections of either sound or EM waves are stopped. All the far filed radiation pattern measurements are carried out in fully anechoic measurements. It is fully understood now in good harmony. Vector network analyzer are used for the measurements of bandwidth and return loss. It is observed that the simulated and measured results are in a good agreement.

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