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Design of Microstrip Patch Antenna for C-Band Radar Applications

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ABSTRACT

The development of microstrip antenna has great importance in radar applications. Because Microstrip antennas are light in weight, smaller in size and length, low cost. Radars has been widely used for various purposes such as military, identifying targets and monitoring weather. In this project we propose an antenna structure which may be used in weather forecasting radar applications. It is proposed to design a small sized, low profile Rectangular patch antenna, which is operated at frequency of C-Band (4-8 GHz) suitable for radar applications.The proposed antenna is designed and simulated by modifying the dimensions with different substrates like FR4 Epoxy, Duroid etc. The design of this antenna is to improve parameters like VSWR and Return loss. For the simulation of the above antenna HFSS (High Frequency Structure Simulator) software is used.

KEYWORDS: HFSS, Microstrip Patch Antenna, C-Band, VSWR, Return Loss, Reflection Coefficient.

1. INTRODUCTION

An antenna is a metallic structure capable of transmitting and receiving electromagnetic waves. An antenna is a component of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves, according to the official IEEE definition. An antenna is required for every component of a radio, whether it's a receiver or a transmitter, and it can be built-in or external. It radiates electromagnetic energy that serves as a transition between a transmission line and air to broadcast or receive electromagnetic (e.g., TV or radio) waves.

In radio systems, a variety of antennas are used for specialized applications with distinct characteristics. One of the dynamic and planar oriented antennas was the Microstrip Patch antenna. [1] A micro strip or patch antenna is a low-profile antenna with several advantages over other antennas, including its compact weight, low cost, and ease of integration with supporting electronics. While the antenna's structure might be three-dimensional (wrapped around an object, for example), the elements are normally flat, hence the term planar antenna.

Radar is currently one of the most cutting-edge technologies. This technology has the potential to replace the human eye's ability to monitor objects at a distance. Radar is an electromagnetic wave technology that can be used to detect, measure distances, and map things. [2]

An antenna system is an integral component of a radar system. As a result, this study will examine the fabrication of antennas for radar applications using various dielecric substrates such as FR4 Epoxy / Rogers 4350. The modelling procedure was carried out using the High Frequency Structure Simulator (HFSS) programme. Microstrip technology is utilised to create an antenna that is small in size, light in weight, easy to fabricate, and low in cost. Aside from that, when it comes to the synthesis of radar-suitable aperture fields. [3]

2. DESIGN EQUATIONS

2.1 Calculation of the height (h): This is the height of the antenna's dielectric substrate, which the metallic patch is put on. The formula is used to compute the height of a microstrip antenna's dielectric substrate. [4]

$$h = \frac{0.3C}{2\pi f\sqrt{\varepsilon_r}}$$

2.2 Calculation of the width (W) of the patch: The formula used to determine the width of the patch is given as [4]

$$w = \frac{C}{2f\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Where, c is the velocity of light = 3.0×10^8 m/s

f is the frequency of operation.

2.3 Calculation of the effective dielectric constant (ε_{eff}): The formula used to determine the effective dielectric constant is given as [4]

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

Where h and w are the patch's height and width, respectively.

2.4 Calculation of the effective length of the patch (L_{eff}) : The formula to determine the effective length of the patch is given as [4]

$$L_{eff} = \frac{C}{2f\sqrt{\varepsilon_{eff}}}$$

2.5 Calculation of the length extension (ΔL): The length extension is the extra length along the breadth of the object as a result of fringing fields, which is computed using the formula [4]

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

The effective length (L_{eff}) and twice the length extension (L) can be used to calculate the patch's actual length (ΔL)

$L = L_{eff} — 2\Delta L$

2.6 Calculation of length of ground plane: The ground plane's length is computed using the formula [4]

$$L_g = L + 6h$$

2.7 Calculation of width of the ground plane: The ground plane's width is computed using the formula [4]

$$W_g = w + 6h$$

2.8 Calculation of reflection coefficient (□): The reflection coefficient, which specifies the power reflected from the antenna, determines the VSWR.

VSWR equals maximum voltage/minimum voltage.

As a result, the VSWR reflection coefficient is calculated as

$$|\ \square\ | = \frac{VSWR-1}{VSWR+1}$$

3. DESIGN PARAMETERS

3.1 Design of Microstrip patch antenna using coaxial feed with FR4 Epoxy substrate:

On a FR4 Epoxy substrate with a dielectric constant of 4.4, the antenna illustrated in Fig. 1.1 is simulated. The substrate has a thickness of 1.6mm. The antenna's operational frequency is 6 GHz, and it receives its feed through coaxial cable.

L_p=11.33mm,W_p=15.21mm,L_s=20.93mm,

W_s=24.81mm, X=2.89mm, Y=2.59mm.

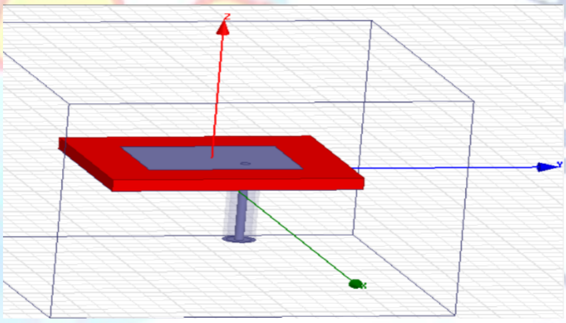

Fig. 1.1: Microstrip patch antenna using coaxial feed with FR-4 Epoxy substrate

4. SIMULATION RESULTS

VSWR:

The Voltage Standing Wave Ratio (VSWR) is a measurement of the mismatch between an antenna and the feed line to which it is connected. Another name for this is the Standing Wave Ratio (SWR). VSWR has a range of values from 1 to infinity. A VSWR of less than 2 is considered acceptable for most antenna applications. The antenna can be described as "good match." When someone says the antenna is poorly matched, they usually mean the VSWR is greater than 2 for the desired frequency.

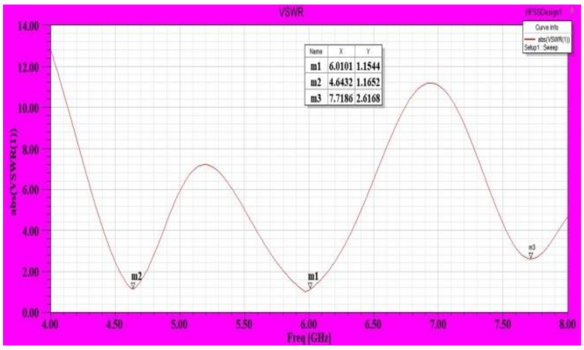

Fig. 1.2: VSWR of the antenna

Return Loss:

It is the quantity of energy reflected from a signal that has been conveyed. It's frequently communicated in positive decibels. The greater the number, the lower the amount of energy reflected. The negative value of return loss is represented by the S11 parameter.

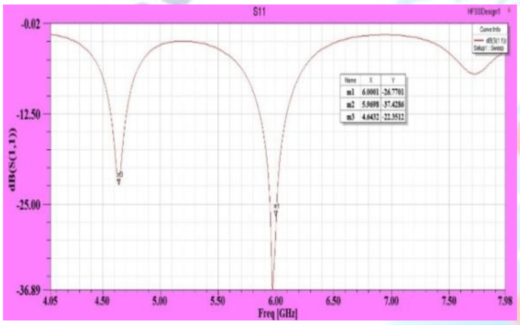

Fig. 1.3: S11 of the antenna

Gain:

The ratio of directional intensity to the radiation intensity that is obtained if the antenna's power was emitted isotropically gives the gain of the antenna. It communicates about the strength of the transmitting signal.

3D Polar Plot:

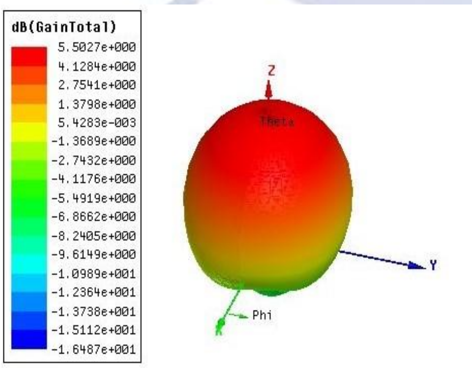

Fig. 1.4: 3-D Polar Plot of the antenna

This polar plot shows the 3-D radiation pattern of designed antenna in which gain obtained for 6 GHz frequency is 5.5 dB.

Radiation Pattern:

The radiation pattern, often known as the antenna pattern, is a graphical depiction of the antenna's radiation qualities as a function of space. The antenna's pattern, in other words, explains how the antenna radiates energy into space (or how it receives energy). This pattern shows how power or energy radiates in different directions with respect to elevation and azimuthal angles.

Here in the Fig. 1.5 the radiation is maximum at 0^0 is 14.7db which shows radiation beam is narrow that is likely to radiate more power in single direction.

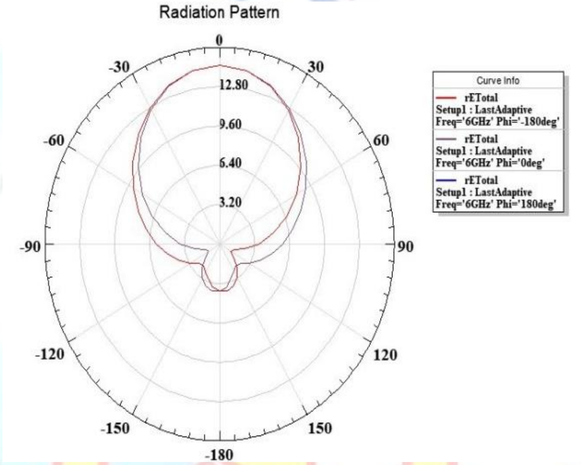

Fig. 1.5: Radiation Pattern of the antenna

3.2 Design of Microstrip patch antenna using line feed with FR4 Epoxy substrate:

On a FR4 Epoxy substrate with a dielectric constant of 4.4, the antenna illustrated in Fig. 2.1 is simulated. The substrate has a thickness of 1.6mm. The antenna's operational frequency is 6 GHz, and it receives its feed through line cable.

L_p=11.33mm,W_p=15.21mm,L_s=20.93mm W_s=24.81mm.

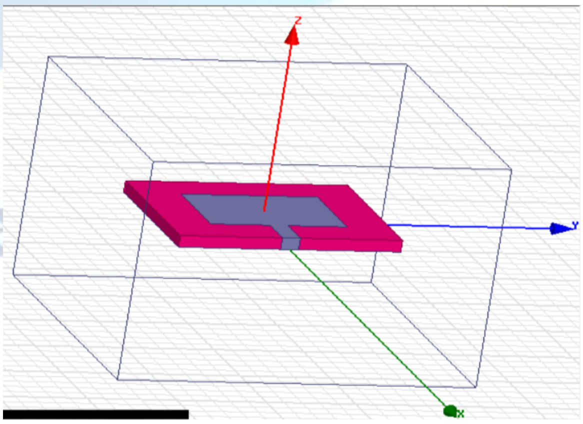

Fig. 2.1: Microstrip patch antenna using line feed with FR4 Epoxy substrate

SIMULATION RESULTS

VSWR:

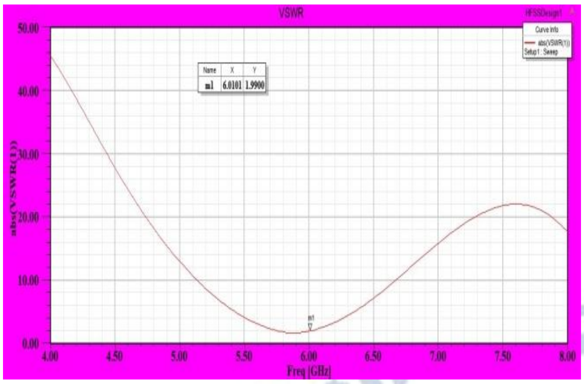

Fig. 2.2: VSWR of the antenna

For this designed microstrip antenna Fig. 2.2 shows that VSWR obtained at 6 GHz is 1.99 which results that maximum power is transmitted to the destination.

Return Loss:

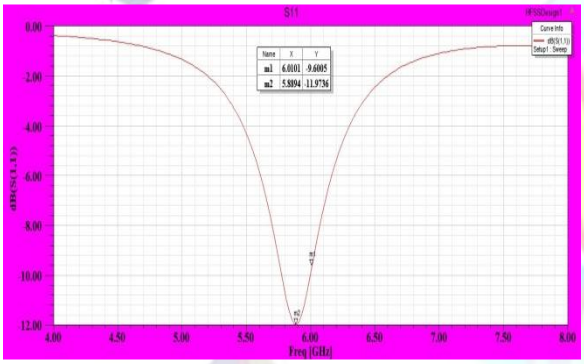

Fig. 2.3: S11 of the antenna

Fig. 2.3 shows that S11 at 6GHz frequency is -9.6 db which shows that it is not a good value since it is above -10db.

3D Polar Plot:

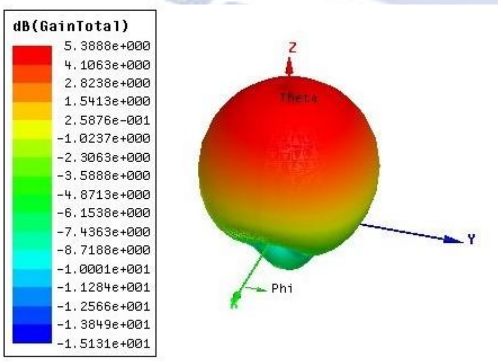

Fig. 2.4: 3-D polar plot of the antenna

Fig. 2.4 shows the 3-D radiation pattern of 5.38db for the 6GHz operating frequency of the line fed antenna.

Radiation Pattern:

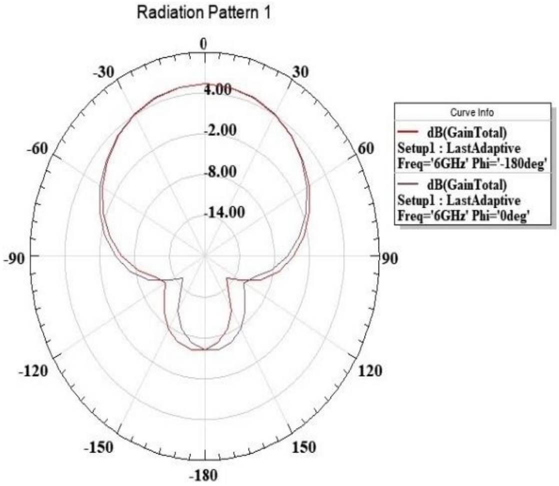

Fig. 2.5 Radiation Pattern of the antenna

Fig. 2.5 shows the radiation pattern maximum at 0^0 of 5.8dB.

5. COMPARISION OF RESULTS

Table: Comparison of antennas with different feeds and substrates

Substrate	Type of Feed	VSWR	S11 (dB)	Gain (dB)
FR-4 Epoxy	Coaxial	1.15	-26.7	5.5
	Line	1.9	-9.6	5.38
Rogers 4350	Coaxial	2.8	-6	7.06
	Line	3.39	-5.27	6.94
Duroid 6010	Coaxial	5.17	-3.39	6.66
	Line	6.3	-2.76	5.42

Antennas using other substrates such as Rogers 4350 whose dielectric constant is 4.4 and Duroid whose dielectric constant is 10.7 are designed and their parameters such as VSWR, Return Loss, 3D Polar Plot, Radiation Pattern are studied. Their values were mentioned in the above table.

6. CONCLUSION

From the analysis of the antennas with different feeds using different substrates, it is concluded that the antenna with FR-4 epoxy substrate using coaxial feed shows good results while operating at C-Band frequency of 6 GHz. HFSS simulation software was used to analyze the features of the proposed microstrip patch antenna. Though gain of the antenna which is 5.5dB shows less value that may impact on the strength of the transmission signal, VSWR of 1.15 and return loss value of -27.6dB are in good level which helps in decrease in power or radiation loss. The reflection coefficient of 0.059 which is very small indicates that the only small amount of signal is reflecting back due to impedance mismatch. And also FR-4 epoxy substrate have many industrial uses that is, it is resistant to moisture that shows relative-ness to temperature which helps the antenna to operate for weather monitoring applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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