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Performance analysis of frequency on various substrate in microstrip patch antenna

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Abstract
In this work design and simulation of various patch antennas were carried out with the help of advanced designed system (ADS) software. Initially micro strip feed single patch antennas were designed at 900 MHz and 10 GHz frequencies on Fr-4 and Rogers-5880 substrate. The antenna parameters such as return loss, directivity, gain, efficiency, 2-D radiation pattern were obtained. Based on the result inference obtained is antenna designed on Rogers's substrate at 10 GHz frequency gives the better results like higher gain, efficiency and reduced area. Above all the main advantage is the size is greatly reduced which gives the answer why arrays developed on Rogers?

Keywords: return loss, gain, efficiency, E-field, H-field, substrate (Fr-4 and Rogers-5880) and frequency

1. Introduction
Antennas are key components of any wireless communication system. The principle involved in this is when we give some input current or voltage an electric field is created from which magnetic field are produced and finally EM wave propagates into space. The receiving antenna is responsible for the reciprocal process i.e., that of turning an electromagnetic wave into a signal or voltage at its turning that can subsequently be processed by the receiver [4]. The radiation and receiving characteristics of antenna can be shaped by synthesizing certain equivalent source distributions. Before it is difficult to control continuous aperture currents or fields, discrete configurations are often used, leading to the concept of antenna array. Putting the elements of an antenna array in a certain pattern and adjusting the amplitude and phase of the individual antenna elements appropriately allow for the synthesis of arbitrary aperture source.

Micro strip antenna was born of Micro strip circuit technology and inherited many characteristics such as low radiating efficiency and narrow bandwidth that are undesirable for a radiator. However, they offered many describable features in terms of size, low profile, ease of integration with circuits and forming arrays consequently, research has been conducted to improve their performance as radiators. Modern mobile communication system is increasingly employing phased array at base stations to expand the base station customer capacity and reduce interference among adjacent stations in the wireless industry, such antenna is typically referred to as smart or adaptive antenna, reflector, horn and microstrip array antenna are widely used in microwave applications.

In this work, the different type of rectangular microstrip patch antenna arrays are designed and simulated at 10 GHz frequency for x-band planar, low–profile rectenna applications.

2. Design of rectangular microstrip patch antenna
2.1. Transmission line model
Transmission line model is the easiest of all. It gives good physical insight, but is less accurate and is more difficult to model coupling [4]. Because of the finite length and width of the patch, the fields at the patches undergo fringing. Since some of the waves traveling the substrate and some in air, an effective dielectric constant ε_{reff} is introduced to account for fringing and the wave propagation in the line [4]. Geometry of the microstrip antenna is shown in fig. 1.

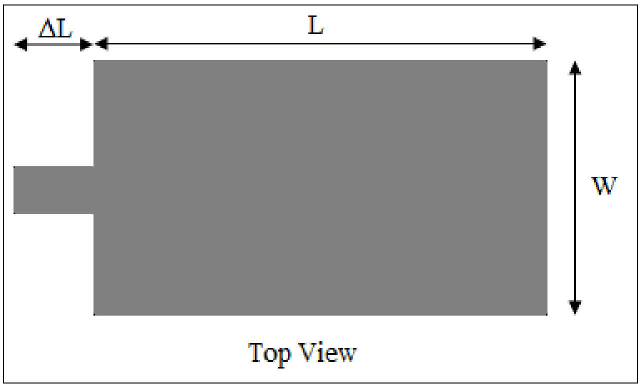

Fig 1: Top view of microstrip

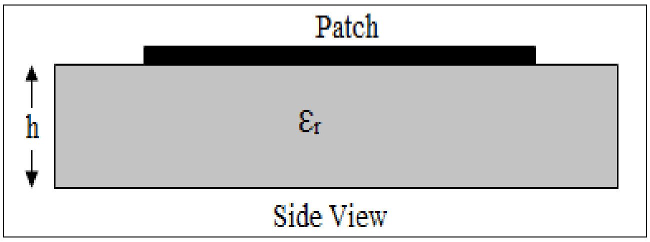

Fig 2: Geometry of the microstrip patch antenna

2.2. Design specifications

The antenna must be effectively designed to exhibit as high gain as possible at the frequency of operation, and at the same time should be compact to allow space minimization. As the gain of the antenna increases, dimension of the antenna would increase. Furthermore, increasing the gain of the antenna increases the efficiency of the receiver. Then, there is a trade-off between the gain, dimension and efficiency of the rectifier. Based on the application an antenna is designed. The proposed topology of the antenna is designed at 10 GHz. The design specifications of edge feed rectangular microstrip patch antenna is shown in table 1. The antenna is designed on a Rogers 5880 substrate. Rogers 5880 is a glass microfiber reinforced ptfe composites are designed for exacting strip line and microstrip circuit applications.

Table 1: Rectangular microstrip patch antenna design specifications

Frequency	**10 GHz**
Substrate	Rogers 5880
Dielectric constant	2.2
Loss tangent	0.0004
Substrate height	10 mil
Conductor thickness	17 µm

The antenna performance can be varied by changing different properties like length, feeding methods, size, arrays, introducing notch, varying substrate and so on. In this paper we mainly focus on the commonly used substrates like FR-4 and Rogers. Rogers have distinct nature of low loss and uniform electrical and absorption properties which find major usage as substrates in antenna. It was replaced by Fr4 as the cost of using RT-duroid 5870 exceeds this project's budget. Fr4 in comparison has a higher dielectric constant which results in a smaller patch size but the high tangent loss will result in lower gain. This is not desirable but as the budget does not allow using RT- duroid 5870. But FR-4 cannot be used at high frequency and arrays because of its cost and high dielectric loss properties. This is because fr4 does not have a very constant dielectric constant which limits usage to frequencies to 1 GHz or so. After analyzing the dielectric constant graph and some survey, it was decided that 4.7 was the value to use. This value might not be entirely true but nevertheless provide us with a start value to work with.

2.3. Single microstrip patch antenna design

The objective of this part is to design a single microstrip patch antenna which consists of patch, quarter wave transformer and feedline.

There are many shapes of patch antenna like circular, square, rectangular, etc. But rectangular patch is used mainly for simple calculation of length, width and simple design. Since a 50ω surface mount adapter connector is going to be used to connect the feedline to the coaxial cable, the feedline will be a 50ω feedline. The feedline will be feed to the patch through a matching network which is a quarter-wave transformer. Fig. 1. shows the patch antenna with quarter-wave transformer. Following calculations are based on the transmission line model. The length and width of the patch are calculated using equations (1) and (2).

$$L = 0.49\frac{\lambda}{\sqrt{\varepsilon_r}} \qquad (1)$$

$$w = \sqrt{90\,\frac{\frac{\varepsilon_r{}^2}{\varepsilon_r - 1}}{Z_a}} \qquad (2)$$

$$Z_1 = \sqrt{Z_0 R_{in}} \qquad (3)$$

The impedance of the quarter wave line is calculated using equation (3). Z_1 is the transformer characteristic impedance. Z_0 is the characteristic impedance of the transmission line and r_{in} is the edge resistance at resonance [4]. The obtained values for the parameters are illustrated in the table 2 and Fig. 3.

Table 2: Dimensions of rectangular patch antenna

	Patch
Width w	13.3 mm
Length l	Length l
λ/4 transformer	
Width w	**0.214085 mm**
Length l	5.690830 mm
50Ω feedline	
Width w	0.761088 mm
Length l	5.47985 mm

In this work we mainly concentrate on designing microstrip patch antenna arrays. The steps involved are calculation of dielectric constant of substrate, calculation of dimensions, making design, simulation using Ads and then testing the properties.

3. Microstrip patch antenna

Microstrip patch antenna ate famous for its low weight aircraft applications. It consists of substrate of dielectric above which a strip of conductor is made and then offset, edge, or center feed is given to excite the antenna. These antennas are inexpensive to fabricate using printed circuit board etching, which makes them very useful for integrated active antennas in which circuit functions are integrated with the antenna to produce compact transceivers. Microstrip antennas can be in various shapes and configurations but for this work only a rectangular patch microstrip antenna is selected. The basic antenna element is a thin conductor of dimensions l x w on a dielectric substrate of permittivity (εr), loss tangent (tanD) and thickness (h) backed by a conducting ground plane.

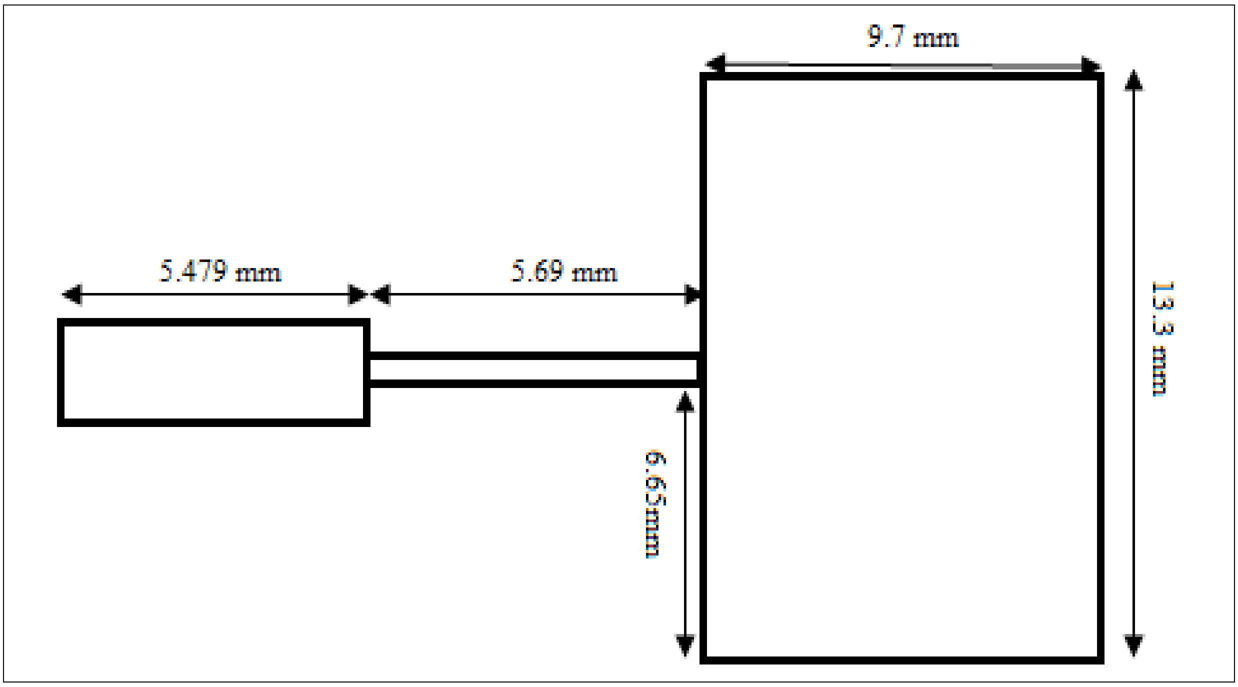

Fig 3: Single patch antenna design layout

4. E & H-field pattern

A Radiation Pattern defines the radiation of power radiated by an antenna as the function of the direction away from the antenna. It is called as far field. E-plane and H-plane are reference planes for polarized waveguides antennas and other microwave apparatus-field have the direction of maximum radiation. It determines orientation of micro and radio waves & H- pattern at various frequencies are given below.

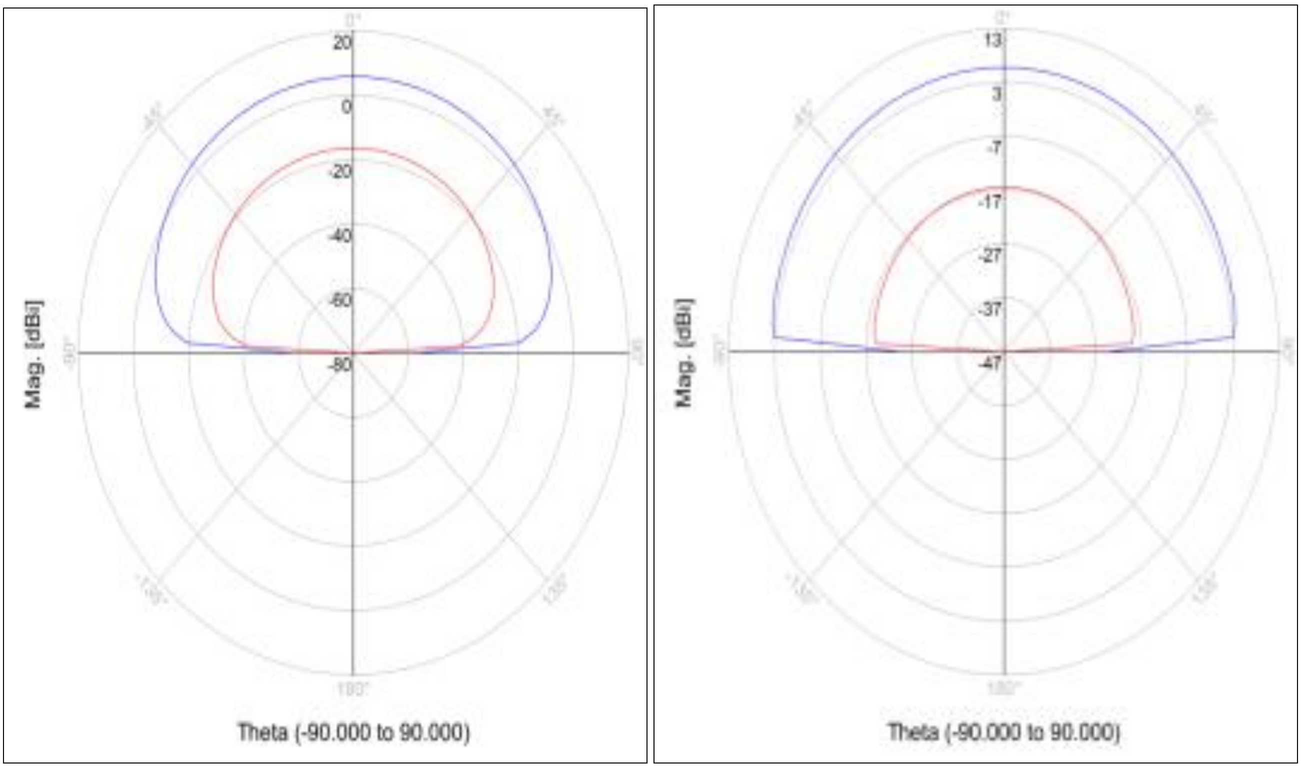

Fig 4: E & H- Field of 900 MHz antenna on fr-4 substrate

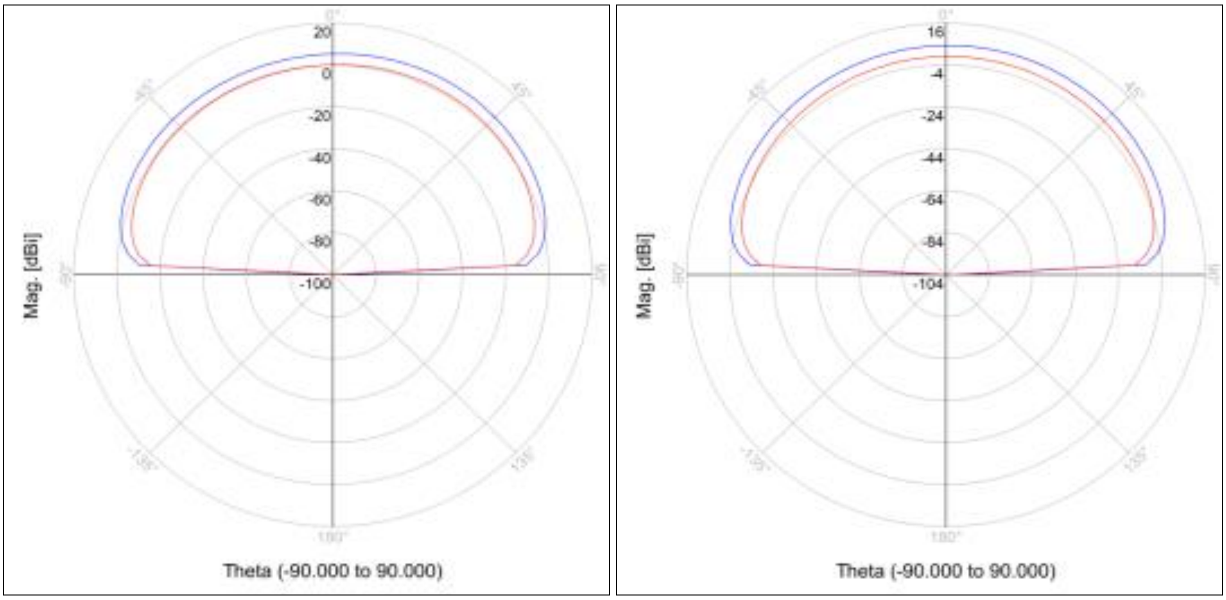

Fig 5: E & H- Field of 10 GHz antenna on fr-4 substrate

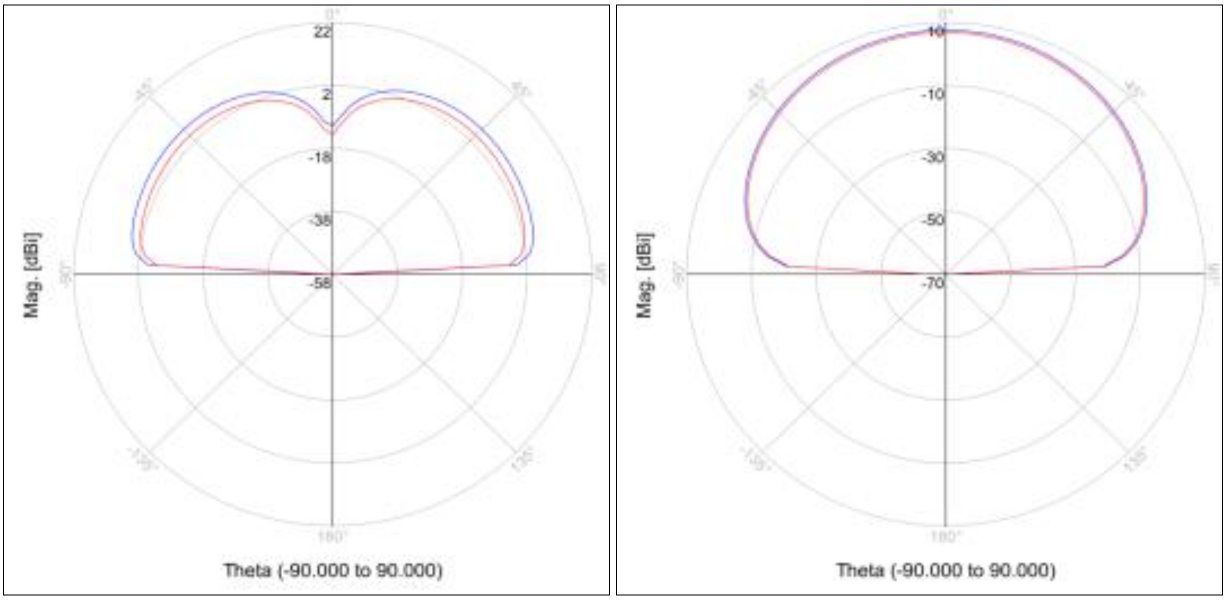

Fig 6: E & H- Field of 900 MHz antenna on rogers-5880 substrate

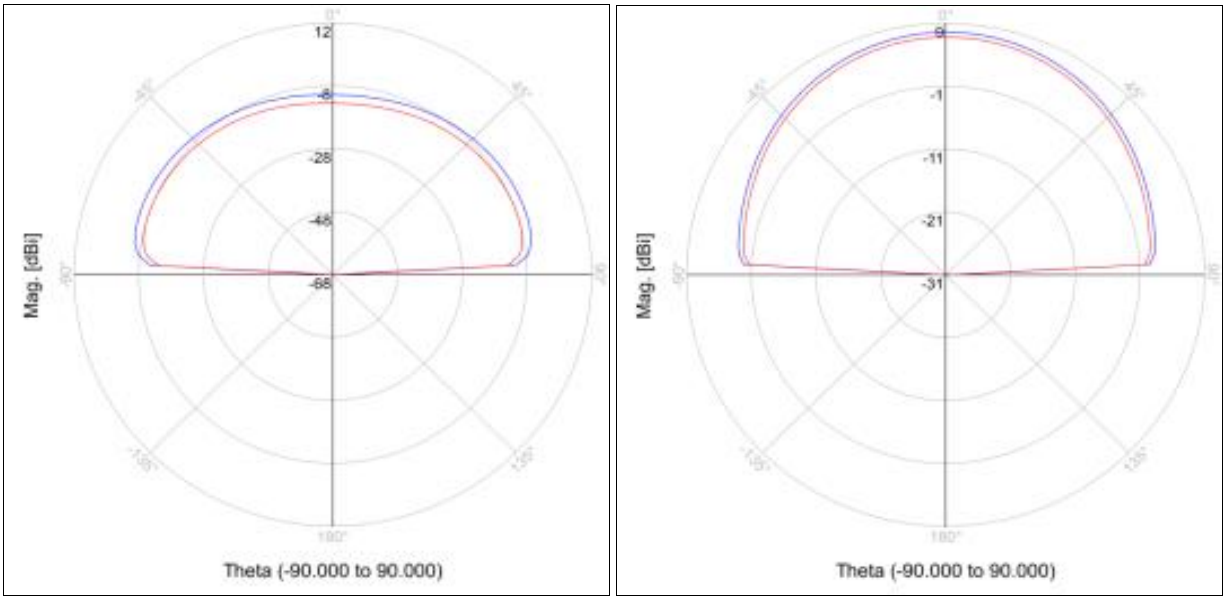

Fig 7: E & H- Field of 10GHz antenna on rogers-5880 substrate

Return losses

It is the loss of power in reflected signal due to discontinuity in a transmission line or in any communication links. This can be matched with a terminating load or devices. It includes both Standing Wave Ratio (SWR) and Reflection coefficient (Γ).

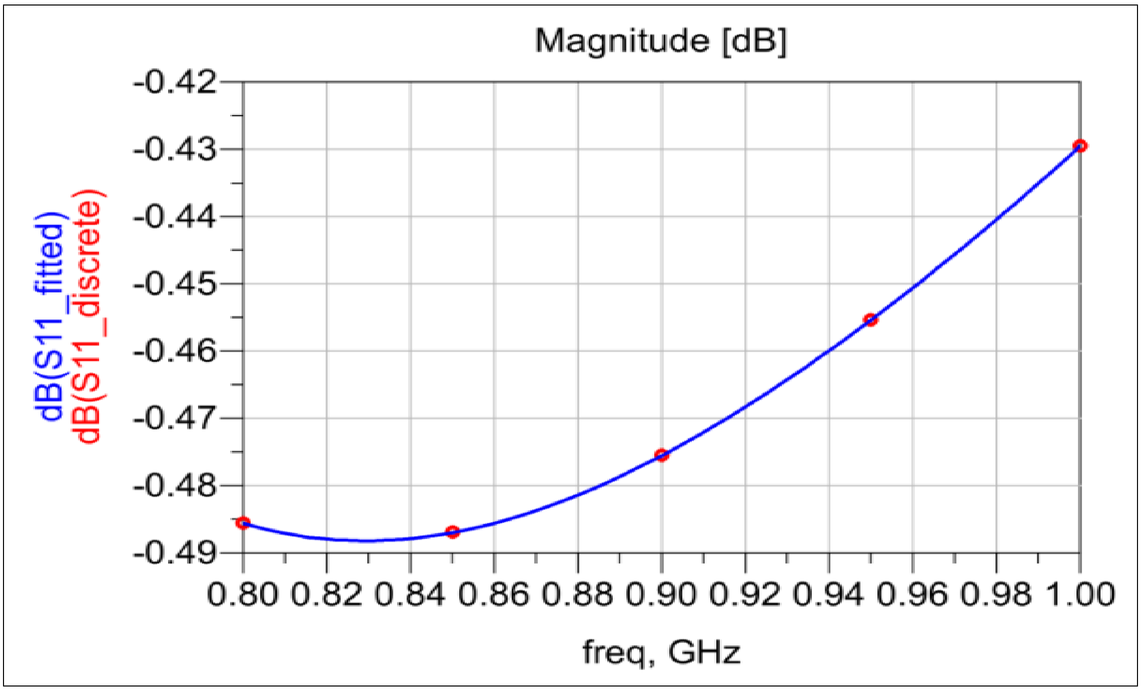

Fig 8: Return loss of 900 MHz patch antenna on fr-4 substrate

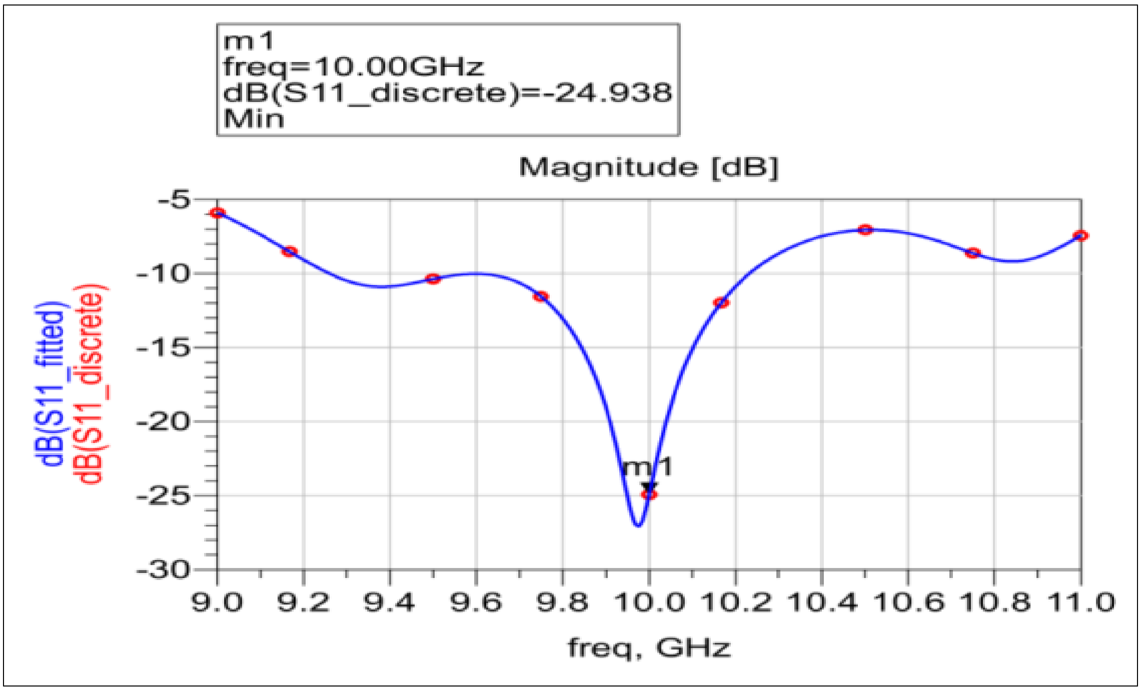

Fig 9: Return loss of 10 GHz patch antenna on fr-4 substrate

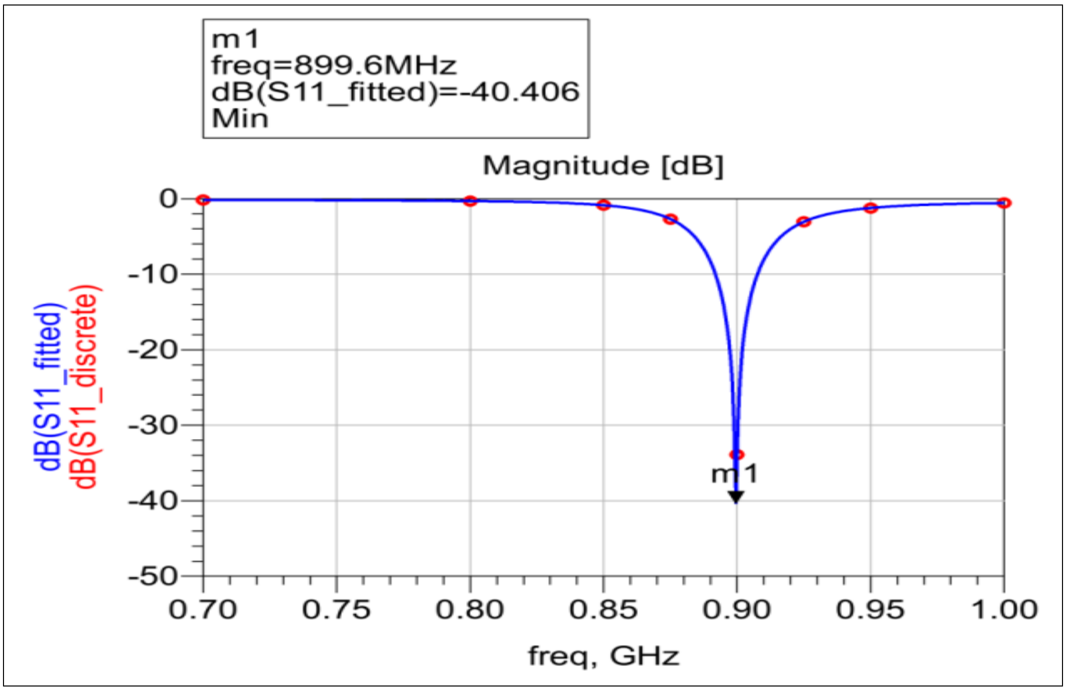

Fig 10: Return loss of 900 MHz patch antenna on rogers-5880 substrate

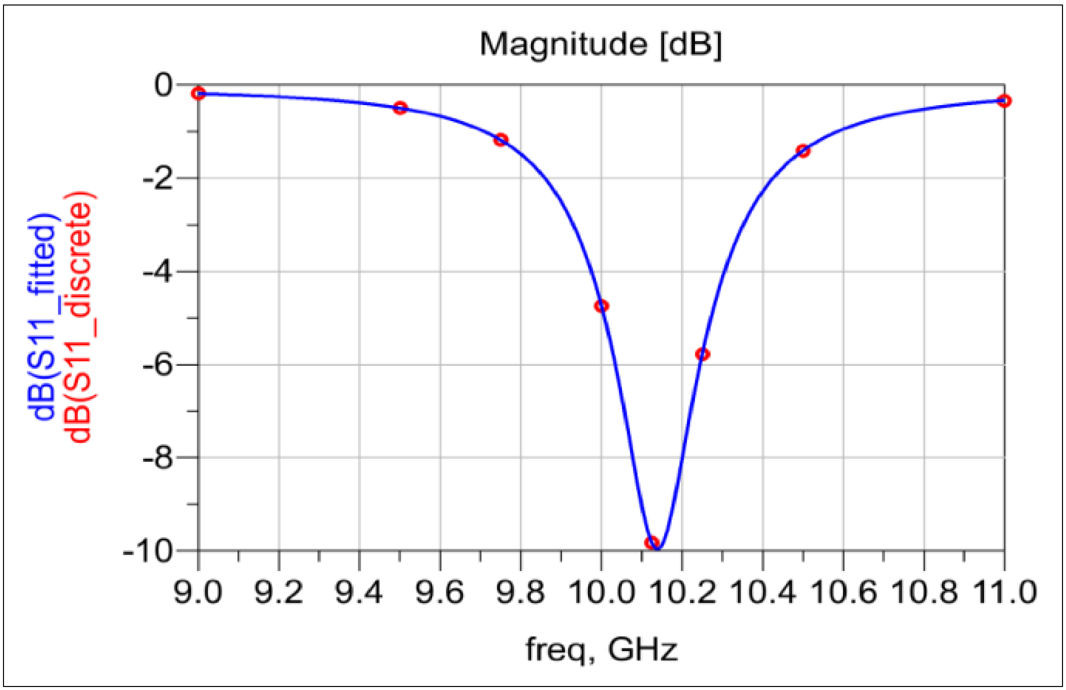

Fig 11: Return loss of 10 GHz patch antenna on rogers-5880 substrate

5. Comparison of various parameters

Table 3: Comparison of various parameters

Antenna parameter	Rogers-5880 10 GHz	Fr-4 10 GHz	Rogers-5880 900 MHz	Fr-4 900 MHz
Gain (dB)	6.77	1.24	4.4	16.5
Directivity (dB)	7.55	6.43	7.1	5.6
Efficiency (%)	85.53	30.28	62.22	32
Return loss (dB)	-24.93	-10	-40.46	-0.47

7. Result and Conclusion

In this work design and simulation of the single patch antennas and arrays have been carried out using ads software. The antenna parameters like return loss, gain, directivity, efficiency, 2d radiation pattern of E and H-plane have been obtained for 900 MHz and 10 GHz patch antennas on fr-4 and rogers-5880 substrates. Fr-4 dielectric produces more dielectric losses for 10 GHz frequency. For lower frequency, efficiency is low because of conduction loss.

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