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Ultra Wideband (UWB) Hexagon Shape Planar Microstrip Slot Antenna

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Abstract: In this paper ultra wideband (UWB) hexagon shape planar microstrip slot antenna is presented that can find applications in wireless communications. The antenna is fed by a 50 Ω microstrip line and printed on a dielectric Roger4003 substrate of dimension (15mm X 15 mm) permittivity εr = 3.5 and height h = 1.6 mm. Combination of the hexagon shape slot, feed line are used to obtain 124% (2.65–11.30 GHz) impedance bandwidth which exceeds the UWB requirement of 110% (3.10–10.60 GHz). The optimization on the planar hexagonal microstrip has been presented to accomplish an ultra wide 10 dB return loss bandwidth. A ground plane of 50 mm 80 mm size is used which is similar to wireless cards for several portable wireless communication devices. Moreover, in comparison with a simple rectangular shaped antenna, the proposed design enhances the bandwidth and improves input return loss. Better than 10 dB return loss, 93.45 % radiation efficiency has been achieved in the range 3.1 to 12 GHz. The parameters, which affect the performance of the antenna in terms of its frequency domain and time domain characteristics, are investigated. Finally, experimental verification of the fabricated antenna for its impedance bandwidth is carried out, which shows agreement with the simulated data.

Keywords: Directional patterns, finite ground plane, microstrip line feed, microstrip slot antenna, omni-directional patterns, ultra wideband (UWB).

1. INTRODUCTION

The Federal Communications Commission (FCC) has allocated the frequency spectrum from 3.1 GHz to 10.6 GHz as the ultra wideband (UWB) in the year 2002. Since then the UWB technology has progressed a lot and is still emerging. It has created increased interest in the UWB antennas, as well. The UWB wireless communication antennas are special due to very short and low-power impulse signals, which are transmitted efficiently with less distortion. Planar forms of the UWB antennas an also be integrated between the radio frequency (RF) front end circuitry and the radiating structure. One way of implementing planar forms of the antenna is using the microstrip technology, which is widely used in wireless applications. An MSA in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. However, other shapes, such as the square, circular, triangular, semicircular, sectoral, and annular ring shapes are also used.

Microstrip antennas are popular because of its low profile, small size, lightweight, low cost, high efficiency and economical fabrication features [1], [2]. One form of the microstrip antennas is the microstrip slot antenna, which radiates omni-directional radiation patterns. Microstrip slot antennas fed by a microstrip line have shown wideband and ultra wideband performances [3], [4].

2. ANTENNA GEOMETRY AND SIMULATION RESULTS

Antenna Geometry:

Fig. 1 illustrates the evolution of the proposed Microstrip Antenna on the Roger4003 substrate. Fig. 1(a)

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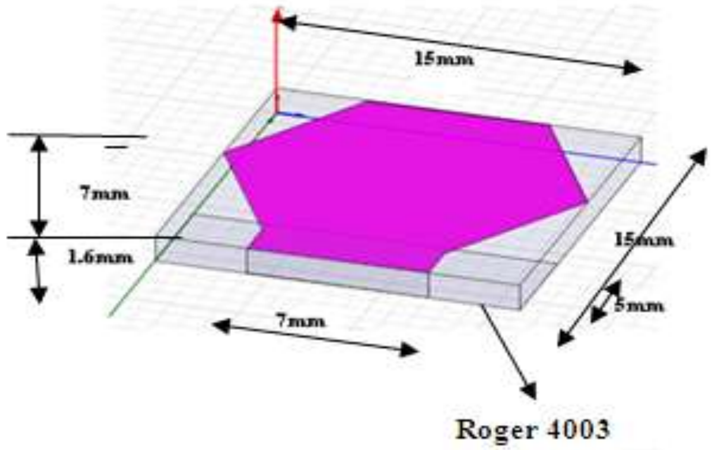


Fig.1: The proposed Hexagonal Microstrip antenna (a) Simulation Model

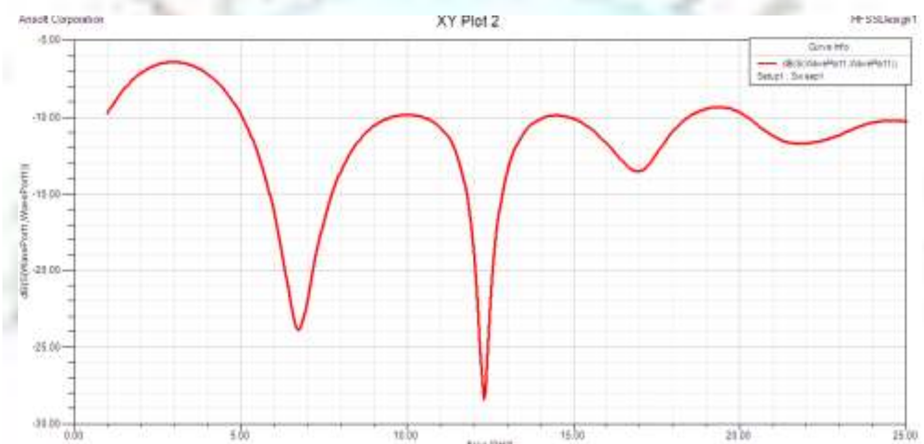


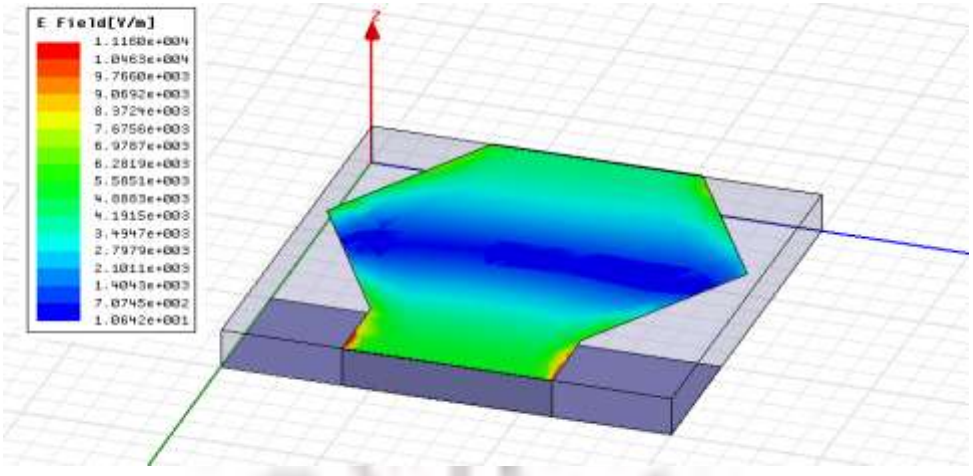
Fig.2: The reflection coefficient (S11, dB) versus frequency (GHz) plot for the antenna design

From the simulations & measurements the optimized dimension are 15 mm x 15 mm (l x b) thickness of 1.6mm. The offset feeding strip is generally 1.6 mm thick. In this design of antenna structure we are using a rectangular structure which acts as a wave port to provide the feed to the antenna. It should be noted that the designed structure of a microstrip antenna was fed by a microstrip feeding technique. The excitation source of 50 ohm internal resistance is between the end of the feeding strip & ground plane. The internal resistance has been considered because in the measurement of the small antennas the RF cable usually affects the performance of antenna under test.

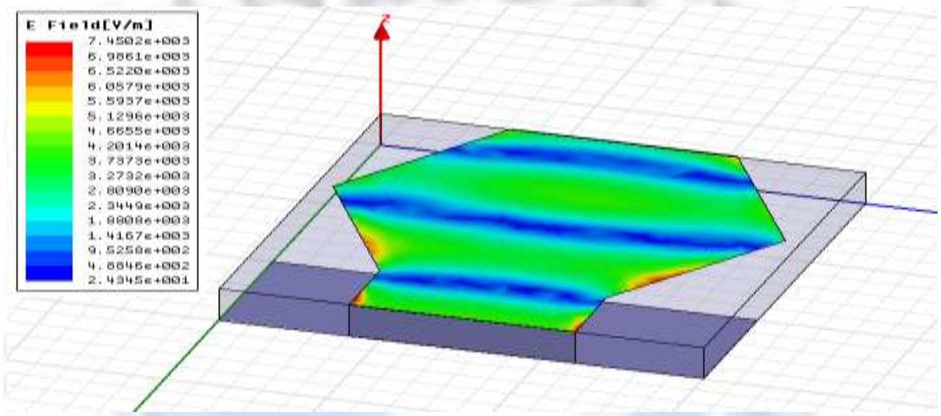
Fig.1 (a) shows the microstrip antenna with Hexagonal structure and finite system ground plane. However the Efficiency Vs Frequency characteristics of microstrip antenna vary for the different frequency of simulation. However the Efficiency characteristics of the microstrip antenna design may vary for the different frequency of simulation / solution frequency.
In order to further reduce the overall size of the microstrip hexagonal structure a rectangular slot can be cut at the Hexagonal radiator. As an example the microstrip antenna fabricated on a Roger4003, εr=3.38 & 1.6 mm in thickness. The position of feed point to the antenna structure can be varied to vary the result.

It should be noted that in the simulation process the microstrip antenna design structure was feed by a microstrip feeding and close to the edge of the Roger4003 substrate. The excitation source with a 50 ohm internal resistance is provided without any RF feeding cables.

At 5 GHz



At 15 GHz



At 25 GHz

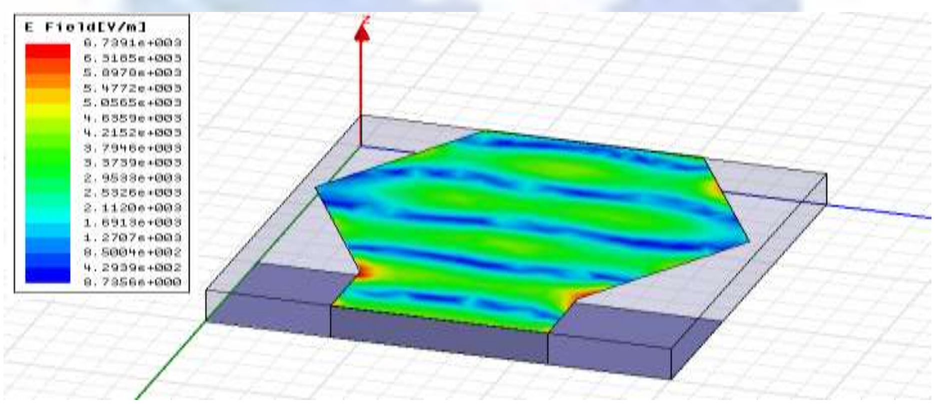


Fig.3: illustrates the simulated current distributions on the antenna at (a) 5GHz (b) 10 GHz (c) 15GHz (d) 20 GHz (e) 25GHz

At 5 GHz, it can be observed that the majority of the electric currents is concentrated except around the central portion of the radiator while the currents at the central portion of the radiator as well as the ground plane are very weak Thus, the effects of the ground plane and RF cable on the antenna performance at the lower frequencies can be suppressed greatly. At higher frequencies, most of the electric currents are distributed on the feeding strip, the junction of the hexagonal radiator, and the top strip. As a result, the currents on the ground plane are stronger than those at 5 GHz. Consequently, the feed gap greatly affects the impedance matching. At 25 GHz the field distribution are stronger as compared to 5 GHz.

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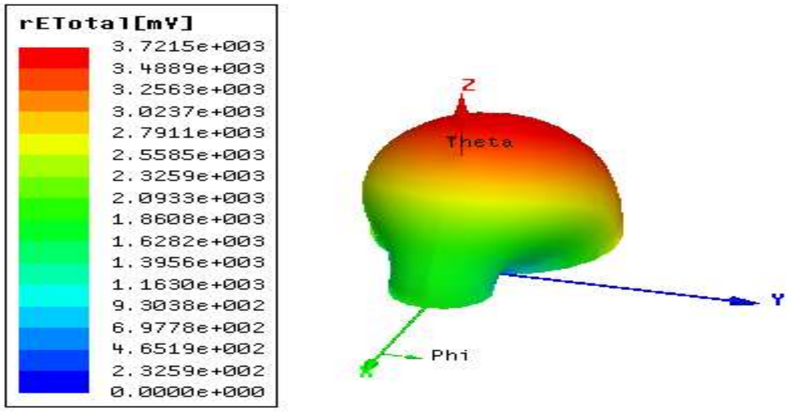
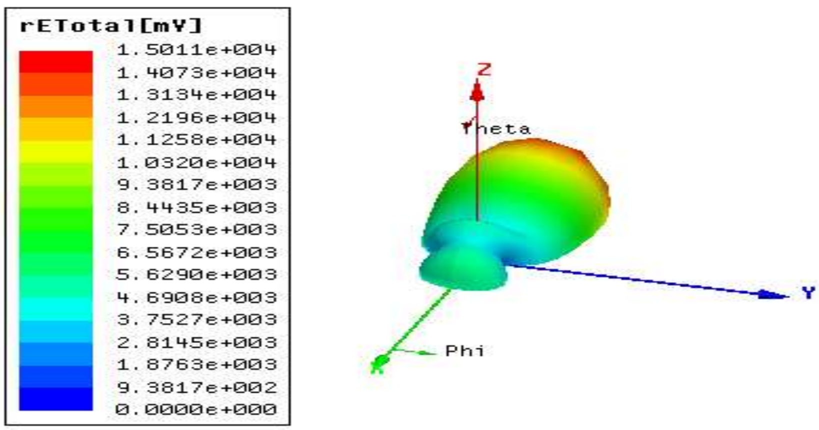
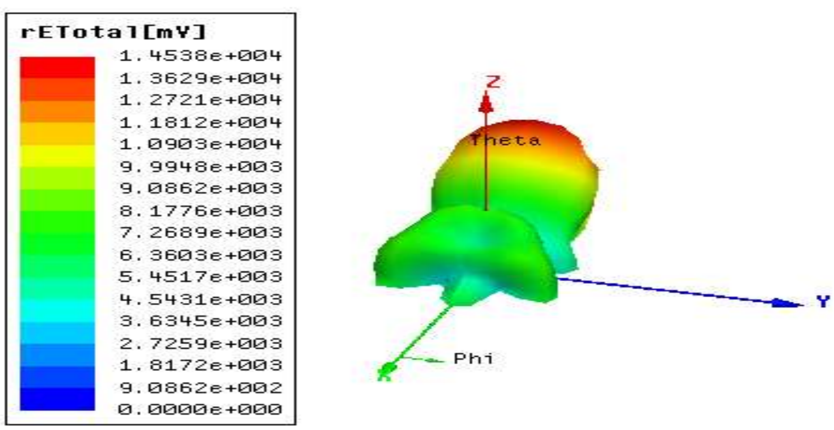
At 5 GHz



At 15 GHz



At 25 GHZ



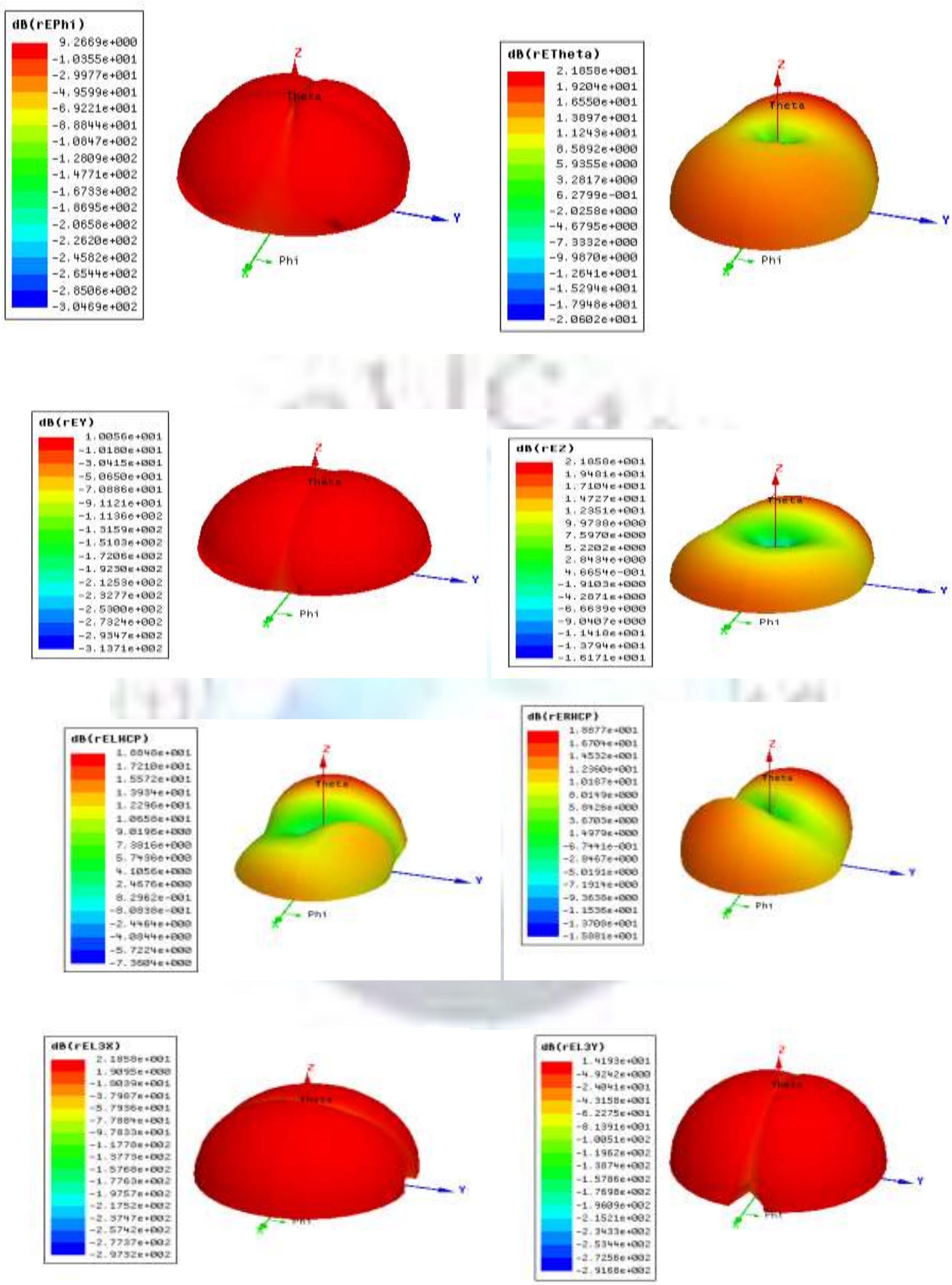


Fig.4: illustrates the effect of the different radiation pattern of Microstrip antenna

This work is to design a small antenna suitable to be used in mobile devices, where a three-dimensional (3-D) omni-directional radiation and high radiation efficiency are desirable. The 3-D radiation patterns for total radiated electric fields were measured at frequencies of 5, 10, 15, 20and 25 GHz , where the red colour indicates the stronger radiated E-fields and the blue colour the weaker ones. It is seen from the figure that the radiation at 3,5, and 6 GHz is almost 3-D omni-directional, which is unlike a typical monopole/dipole antenna. because the x and y–components of the electric currents on the antenna are both strong as shown in Fig. 4(a). The radiation is slightly weak along the –y and –x axis directions. At the higher frequency of 25 GHz, the radiation has become more directional with a deep dip in the x-y -plane and- y axis direction due to the electrically larger size of the antenna. Such 3-D omni-directional radiation performance is conducive to the applications of the antennas in mobile devices. With the measured 3-D radiation patterns, the radiation efficiency can be attained. The measured radiation efficiency varies from 60.14 % at 3 GHz to 93.45% at 7 GHz. The microstrip antenna substrate is enclosed in a radiation box. The radiation box of the antenna is generally larger in dimension (lxb) and it is approximate four times larger in height. The antenna structures are then assigned with the analysis set-up which encloses solution frequency, start & stop frequency of simulations, step size, Max. no. of passes etc..

The directivity of the microstrip antenna can also be calculated with the following mathematical relationship:

$D= 0.2\ W +6.6 +10 \log(\frac{1.6}{\sqrt{\varepsilon_r}})$

The gain of the antenna structure can be calculated as the mathematical derivation:

$\text{Gain} = 4\pi.\frac{U}{P_{acc}}$

U: Radiation intensity in W

P_{acc} . : Accepted Power in w

Furthermore the efficiency of the antenna structure in its symmetrical form can be estimated. The efficiency of the microstrip antenna can be expressed in terms of the peak directivity & peak realized gain of the antenna.

$\text{Efficiency} = \frac{\text{Peak Realized Gain}}{\text{Peak Directivity}} * 100$

Frequency Vs Efficiency Graph:

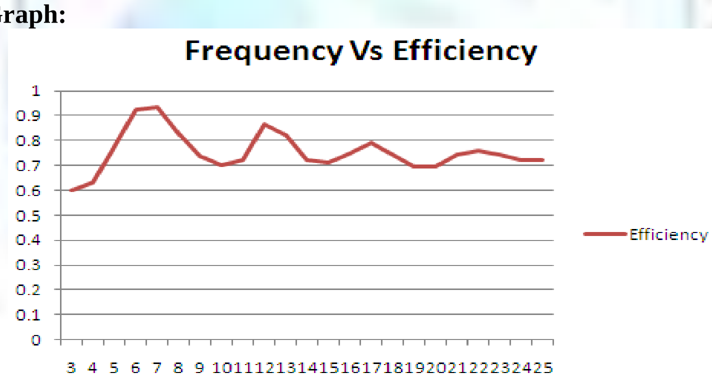


Fig.6: The frequency (GHz) versus efficiency plot for the Microstrip antenna design

From the above graph of Frequency Vs Efficiency it has been observed that the max. efficiency of antenna i.e. (93.45 %) obtained at 7at GHz.

Frequency Vs Peak Realized Gain Graph:

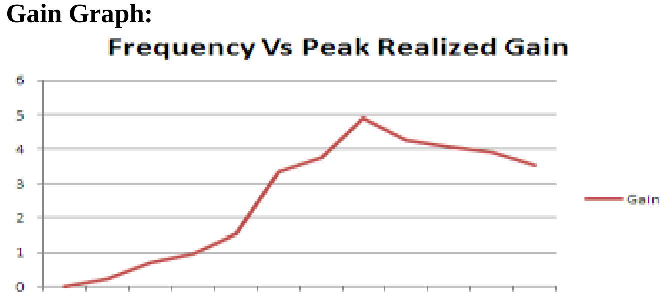


Fig.7: The frequency (GHz) versus Gain plot for the Microstrip antenna design

From the above Graph of Frequency Vs Gain it has been observed that the max. gain of microstrip antenna i.e. 5 obtained at 17 GHz.

Effect of Substrate Material (FR4) on S Parameter:

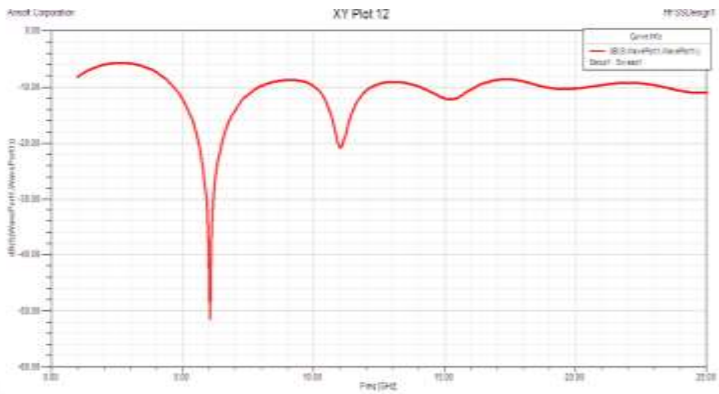


Fig.8: The reflection coefficient (S11, dB) versus frequency (GHz) plot with FR4 as a substrate material for the Microstrip antenna design

Effect of Substrate Material (FR4) on Efficiency & Peak Realized Gain:

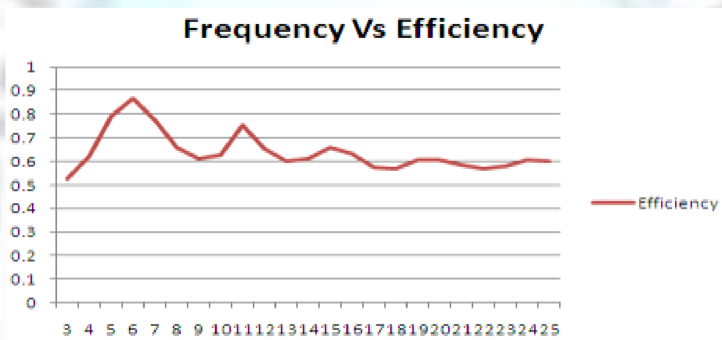


Fig.9: The frequency (GHz) versus efficiency plot with FR4 as a substrate for the Microstrip antenna design

In this design of antenna we are taking two substrates to calculate their effect on efficiency, realized gain & calculation of S11 parameter. With the use of Roger 4003 as substrate the max. efficiency of antenna 93.45% has been obtained whereas the use of FR4 as a substrate there is a reduction in efficiency i.e. 86.49% .With FR4 as substrate there are also reduction in lobe size in the calculation of S11 parameter. With the use of Roger4003 the max. peak realized gain of 5 has been obtained whereas the use of FR4 as a substrate reduces the max. peak realized gain to 3.4.

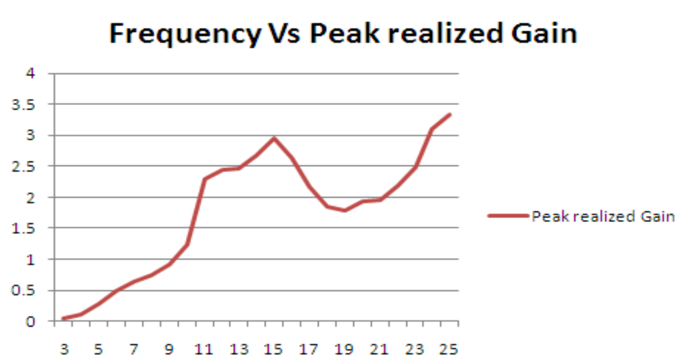


Fig.10: The frequency (GHz) versus Gain plot with FR4 as a substrate for the Microstrip antenna design

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Effect of Ground Size on performance:

At 5 mm

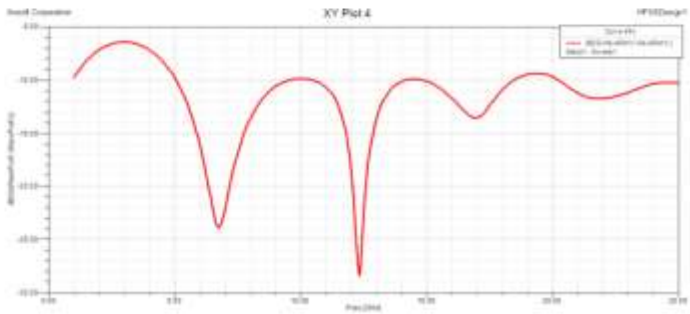

Fig.11: The reflection coefficient (S11, dB) versus frequency (GHz) plot with Ground size of 5 mm for the Microstrip antenna design

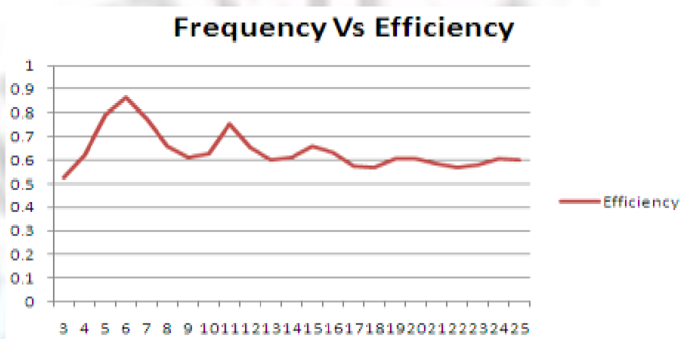

Fig. 12: The frequency (GHz) versus efficiency plot with Ground size of 5 mm for the Microstrip antenna design.

At 9 mm

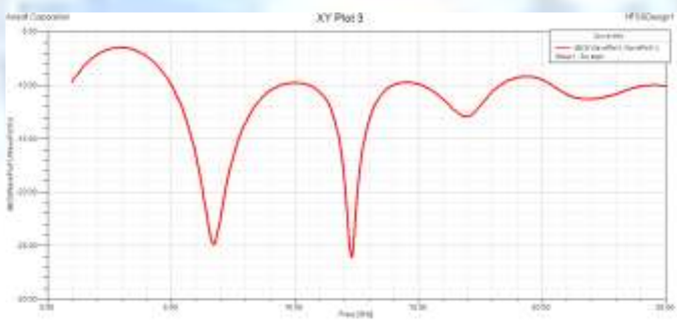

Fig.13: The reflection coefficient (S11, dB) versus frequency (GHz) plot with Ground size of 5 mm for the Microstrip antenna design

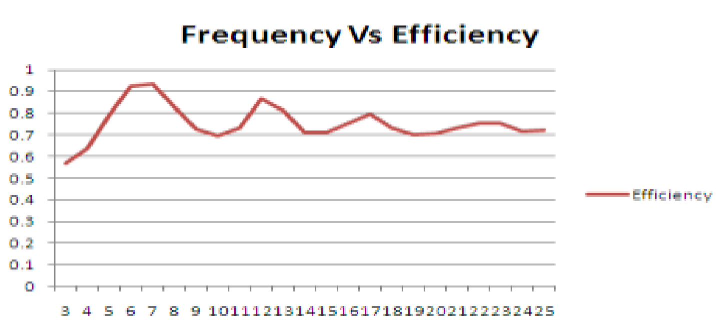

Fig.14: The frequency (GHz) versus efficiency plot with Ground size of 5 mm for the Microstrip antenna design

In this design variation of ground size has a little effect on the efficiency. The S parameter value of first lobe is 23 with ground size of 5mm whereas it increases to 25 with a ground of 9 mm.

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