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SIMULATION OF A MICROSTRIP PATCH ANTENNA AT 2.8GHZ

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ABSTRACT

A microstrip antenna consists of a sandwich of two parallel conducting layers separated by a single dielectric substrate. The patch conductors are normally of copper and gold. The lower conductors function as a ground plane and the upper conductors may be a simple patch of any desired shape. The dielectric constant of the substrate should be low in order to enhance the fringing fields which are responsible for most of the radiations from the patch. The shapes of the patch are rectangular, triangular, square, circular, elliptical, hexagonal etc.

KEYWORDS : Microstripantena Patch, Antenna

A patch antenna is a metal patch suspended over a ground plane. Assembly is contained in a plastic radome which protects the structure from damage. It was first proposed by G A Deschamps in 1953. The proposed concept of microstrip antennas to transmit radio frequency signals could not gain much ground till late 1970s. Further researches by Robert E Munson and others who used the then available low-loss soft substrate materials enhanced its utility prospects. Further the development of the PCB, microwave techniques, and many kinds of low attenuating media materials made the use of microstrip antenna more practical.

R E Munson worked on a new class of antenna using microstrips to form the feed networks and radiators in 1974. It was limited to small bandwidths phased arrays. This work was further improved by S A Long and M D Walton in 1979. In 1984, Y Suzuki and T Chiba performed a computer simulation for a random structured microstrip antenna. In between, a lot of researches were performed for various shapes and wide band frequencies for MSAs. In 2001, Chattopadhyay et al improved the characteristics if a microstrip antenna with variable air gap and varying aspect ratio (Kraus et al., 2006).

The invention of radiation from microstrip resonators has brought an extensive revolution during the last two decades in the design and application of microstrip antennas for aerospace vehicles and satellites. Their light weights and miniature size are appreciable features besides low cost, planner configuration and compatibility. Low gain and narrow bandwidth of microstrip antennas are being compensated by the incorporation of integrated active devices such as MESFET, GUNN Diodes with patches. Thus they have omni-field of applications in satellite communication, high speed vehicles, missiles, tanks and various strategic defence equipments.

An antenna mounted on space shuttles/missiles generates electro-acoustic waves in addition to RF waves during its voyage through the atmosphere. At speeds above 10 mach, the character of air in shock waves around a space vehicle has different physical and chemical properties from stationary air. At altitudes corresponding to the region of re-entry, the important decomposition product is nitric oxide which ionizes readily due to excessive heat generated and releases a dense cloud of electrons. Depending upon the density of electrons and frequency of RF waves, the ionization barrier reflects and refracts the incident wave. The actual point at which this occurs is called quasi-electrical or plasma frequency below which no propagation occurs.

A 110GHz system would sustain a communication link through a plasma sheath opaque to the usual communication wavelengths. Thus the surrounding plasma medium modifies the permittivity of medium and hence the radiation pattern of the antenna. The resonant frequency of the microstrip antennas depend on the medium in which it is operating, through the effective permittivity and the velocity of propagation of RF wave in the medium.

Advantages

The major advantages of the microstrip antennas are:

1. Compact Planer Structure
2. Miniature Size

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Table 1: Mach Number and Critical Frequency of a Vehicle Re-entering From Orbits

Altitude (Kms.)	Mach Number	Critical Frequency (GHz)
36.576	22	110
30.480	22	110
24.384	22	110
21.336	20	80
18.288	18	60
15.240	14	25

3. Light Weight
4. Low Fabrication Cost
5. Integrability with feeding network and devices
6. Compatibility with MMIC technology
7. Multiple polarization possibility with simple changes in the feed position
8. Low scattering cross-section

Disadvantages

1. Very narrow bandwidth
2. Low gain due to half space only
3. Poor end-fire radiation
4. Low power handling capacity
5. Bandwidth variation with substrate thickness

Applications

1. RADARs and altimeters
2. Satellites and space communication
3. High speed space shuttles
4. Tanks and missiles telemetry
5. Biomedical applications
6. Feed elements for complex antennas
7. Remote sensing and navigation

Rectangular Microstrip Antenna

Figure 1 illustrates the basic structure of the rectangular microstrip antenna, by far the most popular type of microstrip antennas. The ground plane and dielectric underneath are shown in figure. The dimension L is universally taken to mean the long dimension, which causes resonance at half-wavelength frequency. The radiating edges are at the ends of the L-dimension of the rectangle which sets up the single polarization. Radiation that occurs at the ends of the W-dimension is far less and is referred to as the cross-polarization.

Figure 2 illustrates the side view of figure and is an attempt to show the distribution of the E-field under the patch. Due to the half-wave nature of the patch, the fields under the L-edges are of opposite polarity and when the field lines curve out and finally propagate out into the direction normal to the substrate they are in the same

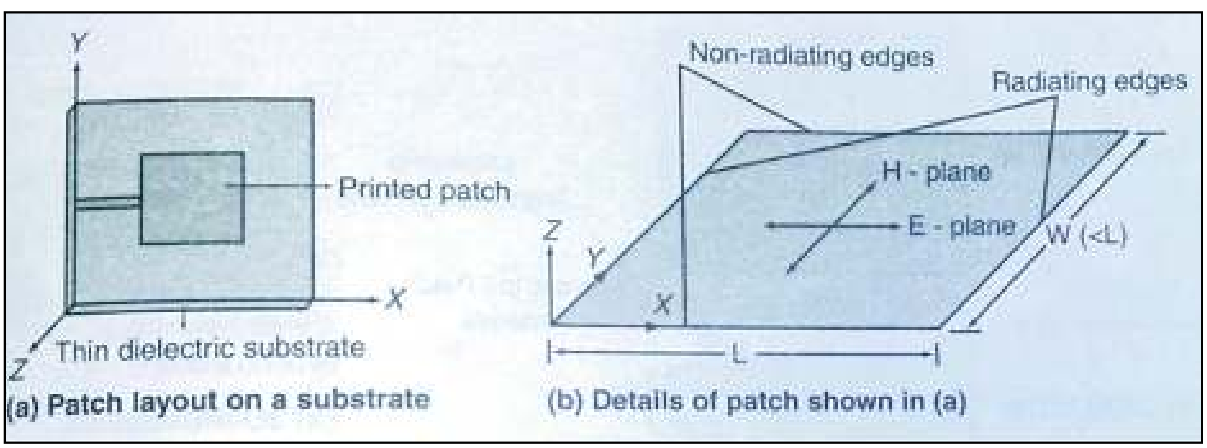


Figure1 : Basic Structure of a Rectangular Microstrip Antenna

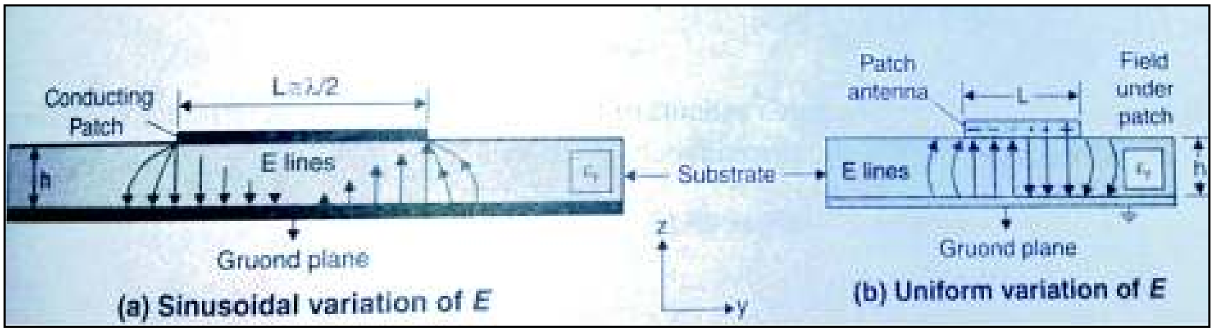


Figure 2 : Patch Antenna With E Field Distribution

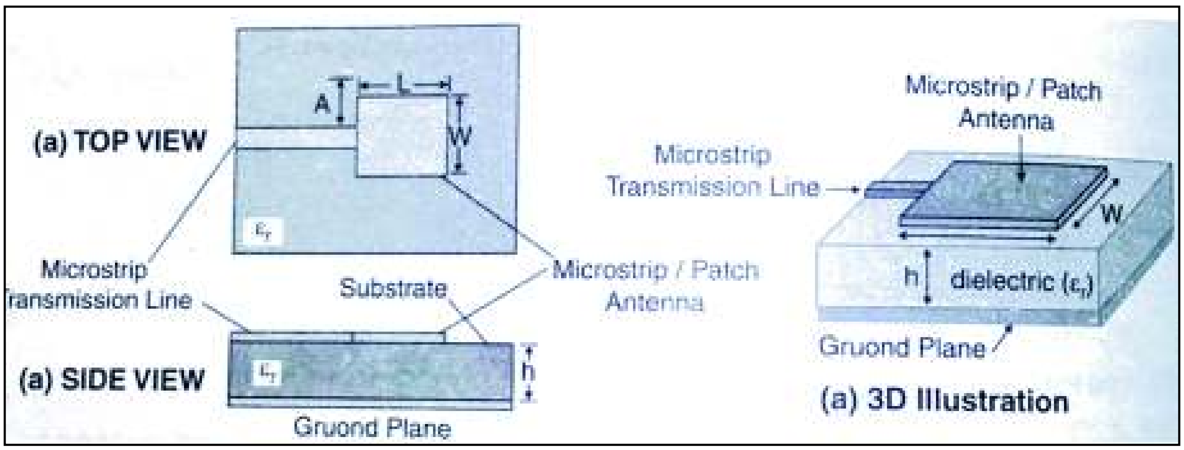


Figure 3 : Geometry of a Microstrip Antenna

direction. In the far field perpendicular to the substrate, the radiation from the two sides adds up because the fields are in phase. It can be seen that in the directions of off-bore-sight the intensity drops as the fields of the two edges go farther and farther and out of phase. At two angles, the fields exactly cancel. Thus, the microstrip antenna radiation intensity depends on the direction it is viewed from as it has gain and directivity.

For effective radiation from a microstrip antenna, the structure needs to be a half-wavelength resonator with a thicker dielectric material of low dielectric constant under the patch but the height still needs to be a fraction of the wavelength.

The rectangular shape is the simplest and most widely used configuration for fabrication of microstrip antennas. Consider the microstrip antenna shown in figure 3, fed by a microstrip transmission line. The microstrip antenna, transmission line and ground plane are made of a high-conductivity metal. The patch is of length L, width W, and sitting on the top of a dielectric substrate of thickness h with permittivity εr. The thickness of the ground plane or of the microstrip is not critically important. Typically, the height h is much smaller than the wavelength of operation.

The frequency of operation of the patch antenna is in general determined by the length L. The critical or centre frequency fc can be approximately given by

$$f_c \cong \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \quad (1)$$

Where c is the velocity of light, ε0 and μ0 are the permittivity and permeability of the free space respectively and εr is the permittivity of the dielectric substrate. As an example, a patch antenna with dimensions L = 1.56cm and W = 1.25cm is mounted on a substrate with εr = 2.2 and h = 0.795mm having critical frequency of 4.37GHz from (1).

According to, the frequency of operation of patch antenna also depends on W along with the length L and the governing equation can be given by

$$f_r = \frac{c}{2\sqrt{\varepsilon_{r,eff}}}[\{\frac{n}{L+2\Delta L}\}^2 + \{\frac{m}{W+2\Delta W}\}^2]^{1/2} \quad (2)$$

Where
$$\varepsilon_{r,eff} = \frac{4\varepsilon_{re}\varepsilon_{r,dyn}}{(\sqrt{\varepsilon_{re}}+\sqrt{\varepsilon_{r,dyn}})^2} \qquad (3)$$

The expression for dominant mode is given by

$$f_{r,nm} = \frac{c}{2(L+2\Delta L)\sqrt{\varepsilon_{r,eff}}} \qquad (4)$$

In the above equations, ΔL and ΔW are the incremental length and width which account for the fringing of field at the respective edges. The other symbols have their usual meanings. It is to be noted that fringing length ΔL is also dependent on W.

The width of the antenna controls the input impedance. For a square patch fed in the manner above, the input impedance will be of the order of 300 ohms. By increasing the width the impedance can be reduced. However, to decrease the input impedance to 50 ohms, often a very wide patch is required. The width further controls the radiation pattern. The normalized pattern of the antenna can be obtained by plotting the field E_θ and $E_\varnothing$ which is approximately given as

$$E_\theta = \frac{\sin[(kw\sin\theta\sin\varnothing)/2]}{[(kw\sin\theta\sin\varnothing)/2]}\cos\left[\left(\frac{kL}{2}\right)\sin\theta\cos\varnothing\right]\cos\varnothing \qquad (5)$$

$$E_\varnothing = -\frac{\sin[(kw\sin\theta\sin\varnothing)/2]}{[(kw\sin\theta\sin\varnothing)/2]}\cos\left[\left(\frac{kL}{2}\right)\sin\theta\cos\varnothing\right]\sin\varnothing \qquad (6)$$

The net magnitude of electric field at any point is a function of θ and Ø and is given by

$$E(\theta,\varnothing) = \sqrt{(E_\theta^2 + E_\varnothing^2)} \qquad (7)$$

In view of (4), (5) and (6), the radiation patterns obtained for a specific case of W=L=λ/2 in θ=0 and Ø =90 planes are illustrated in figure 4.

Normally the directivity of the patch is below 10dB and the field for centre-fed rectangular patches is linearly polarized.

Characteristics of Microstrip Antenna

Radiation Pattern

In figure 4a and 4b, two radiation patterns in Ø = 0 (in azimuth), and Ø = 90 (in elevation) are shown. Another

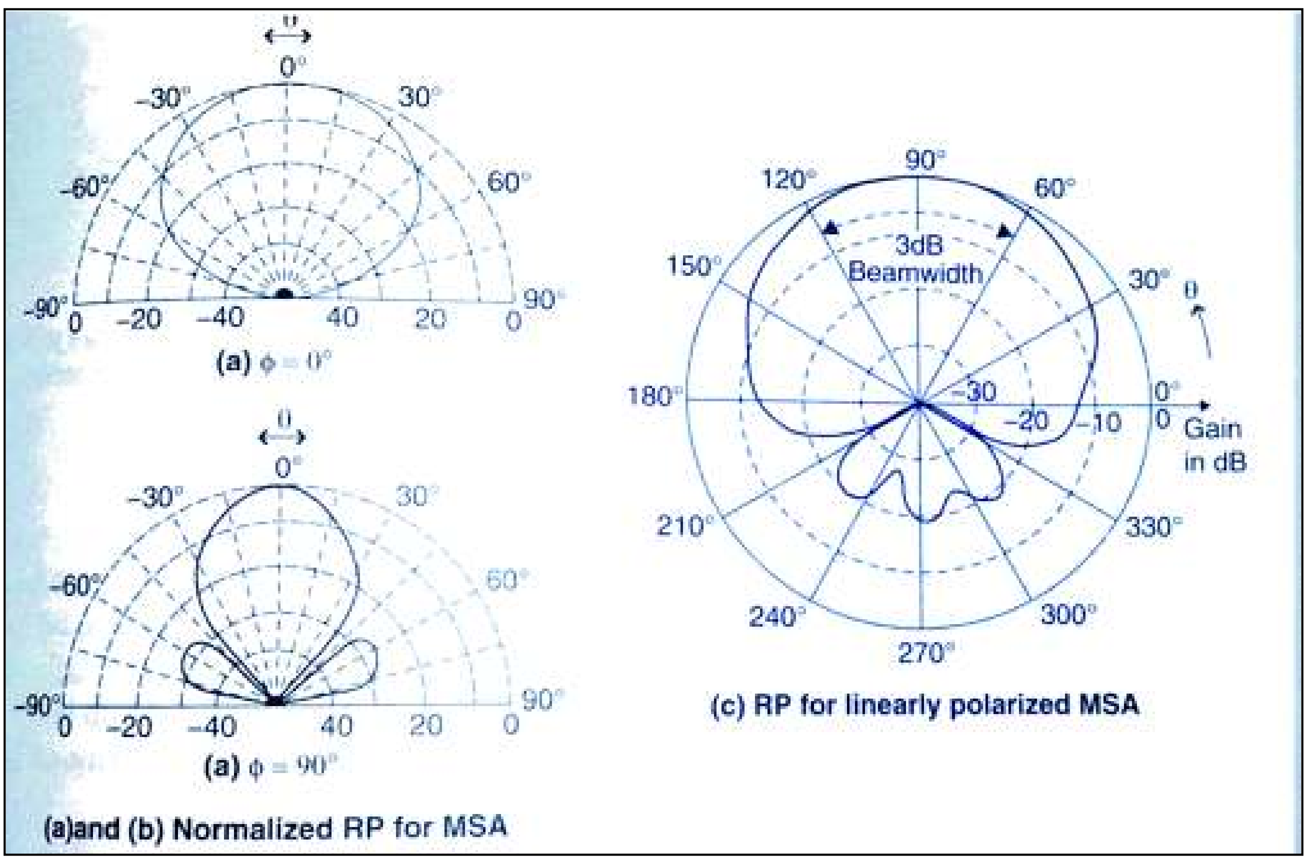


Figure 4 : Radiations Patterns of MSA

typical radiation pattern for a linearly polarized patch antenna is shown in figure 4c. This figure shows a cross section in a horizontal plane. The pattern in the vertical plane is similar though not identical. The scale is logarithmic, so the power radiated at 180 is about 15 dB less than power in the centre of the beam, i.e. at 90. The beam width is about 65 and the gain is about 9 dBi. An infinitely large ground would prevent any back radiation, but the real antenna has a fairly small ground plane, and the power in the backward direction is only about 20 dB down from that in the main beam.

To understand the radiation process in microstrip antenna, consider the view of a patch antenna, shown in figure 3. In connection with the inset feed, it was mentioned the in and end-fed case, the current will be low at the ends and high in the centre of the antenna. The above statement can further be remodelled for the assumed sinusoidal current distribution that the current will be zero at the ends of the patch and maximum at the centre of the half wave patch. Since the patch is a conductor, the voltage and current are out of the phase. Voltage will be maximum at the end of the patch and minimum at its mid point. Thus the field underneath the patch will resemble that of figure. This figure roughly displays fringing of the field around the edges. This fringing field near the surface of the patch is in the y direction. It is the fringing field that is responsible for radiation. It is to be noted that smaller the εr, more bowed is the fringing field as it extends farther away from the patch. Therefore, use of a substrate with smaller εr yields better radiation. Also, in the location where no power is to be radiated, a high value of εr is to be used. Such a selection allows more tight coupling of the field with less fringing and hence less radiation. This is one of the trade-off in patch antenna design. It needs to be further mentioned that in an end-fed antenna, since there is low current at the feed, the impedance has to be high.

Beam Width

Figure 4 illustrates different radiation patterns for an MSA. It can be noted that MSA's generally have a very wide beam width, both in azimuth and elevation.

Directivity

In view of the cavity model of an MSA, the simplified expression for directivity D for $TM_{1,0}$ mode can be written as

$$D = \frac{2h^2 E_0^2 W'^2 K_0^2}{P_r \pi \eta_0} \tag{8}$$

where h is the thickness of the substrate, Pr is the radiated power, W'= W+h, η0 = 120π, K0 is the wave number and E0 is the magnitude of the z-directed electric field intensity inside the cavity given by

$$E_z = E_0 cos\frac{m\pi x}{L} cos\frac{n\pi y}{W} \tag{9}$$

Here L is the length of the patch along the x-axis and W is the width of the patch along y-axis.

Gain

Gain of a rectangular microstrip patch antenna with air dielectric is roughly estimated between 7-9dB in view of the following counts:

Gain of the patch form the directivity relative to the vertical axis is normally about 2 dB, provided the length of the patch is half a wavelength.

If the patch is of a square shape the pattern in the horizontal plane will be directional. Such a patch is equivalent to a pair of dipoles separated by half wavelength.

If the addition of the ground plane cuts off most or all radiation behind the antenna, the power averaged over all directions is reduced by a factor of 2 and thus the gain is increased by 3 dB.

Bandwidth

The impedance bandwidth of a patch antenna is strongly influenced by the spacing between the patch and the ground plane. As the patch is moved closer to the ground plane, less energy is radiated and more energy is stored in the patch capacitance and inductance: that is, the quality factor Q of the antenna increases and impedance bandwidth decreases.

A patch printed onto a dielectric board is often more convenient to fabricate and is a bit smaller, but the volume of the antenna is decreased. The bandwidth decreases with the increase of Q roughly in proportion to the dielectric constant of the substrate. Real patch antennas often use ground planes only modestly larger than the patch, which also reduces performance. The feed structure also affects the bandwidth.

The volume standing ratio 'S' is an important parameter to be accounted, particularly at the input and under resonance conditions. If Q0 is the unloaded radiation quality factor it is related to the bandwidth by the following relation:

$$Bandwidth = \frac{S-1}{Q_0\sqrt{S}} \quad (3)$$

Quality Factor

Microstrip patch antennas have a very high quality factor. The quality factor Q represents the losses associated with the antenna. A large Q leads to narrow bandwidth, and a low efficiency Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, a large fraction of the total power delivered by the source transforms into a surface wave. This transformation amounts to an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. The surface waves can be minimized by using photonic band-gap structures. Problems of low gain and low power handling capacity can be overcome by employing array configuration.

Efficiency

The total loss factor for an MSA can be given by

$$L_T = L_c + L_d + L_r \quad (4)$$

where, L_r is the loss in radiation, L_c is the loss in the conductor and L_d is the loss in dielectric. The loss in the conductor and dielectric substrate results in the reduction of radiation efficiency which is given by

$$\eta = \frac{P_r}{P_c + P_d + P_r} \quad (5)$$

where, P_r is the radiated power, P_c is the power dissipated due to conductor loss, and P_d is the power dissipated due to the dielectric.

Return Loss

The return loss is defined as the ratio of the Fourier transform of the incident pulse and the reflected signal. It is an important parameter to reckon with. Figure 5a illustrates the variation of the return loss with two resonance frequencies.

As an example, consider a square patch antenna fed at the end as before. Though the MSAs operate at much higher frequencies and are of much smaller size, but for a moment assume that the antenna dimensions are L = W = 1.5m and h = 3cm with air as substrate. Such an antenna will be resonant at 100 MHz. When matched to a 200-ohm load, the magnitude of the return loss will be as shown in figure 5b. This figure leads to the following important conclusions.

1. The bandwidth of a patch antenna, in general, is very small. The bandwidth of rectangular patch antennas is typically of the order of 3%.

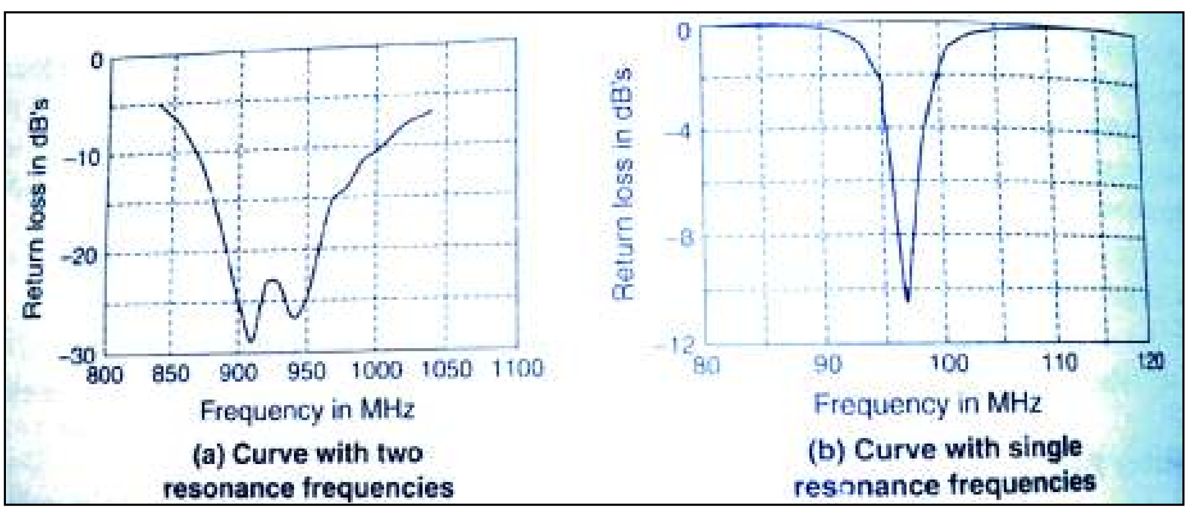


Figure 5 : Variation of Returns Loss With Frequency

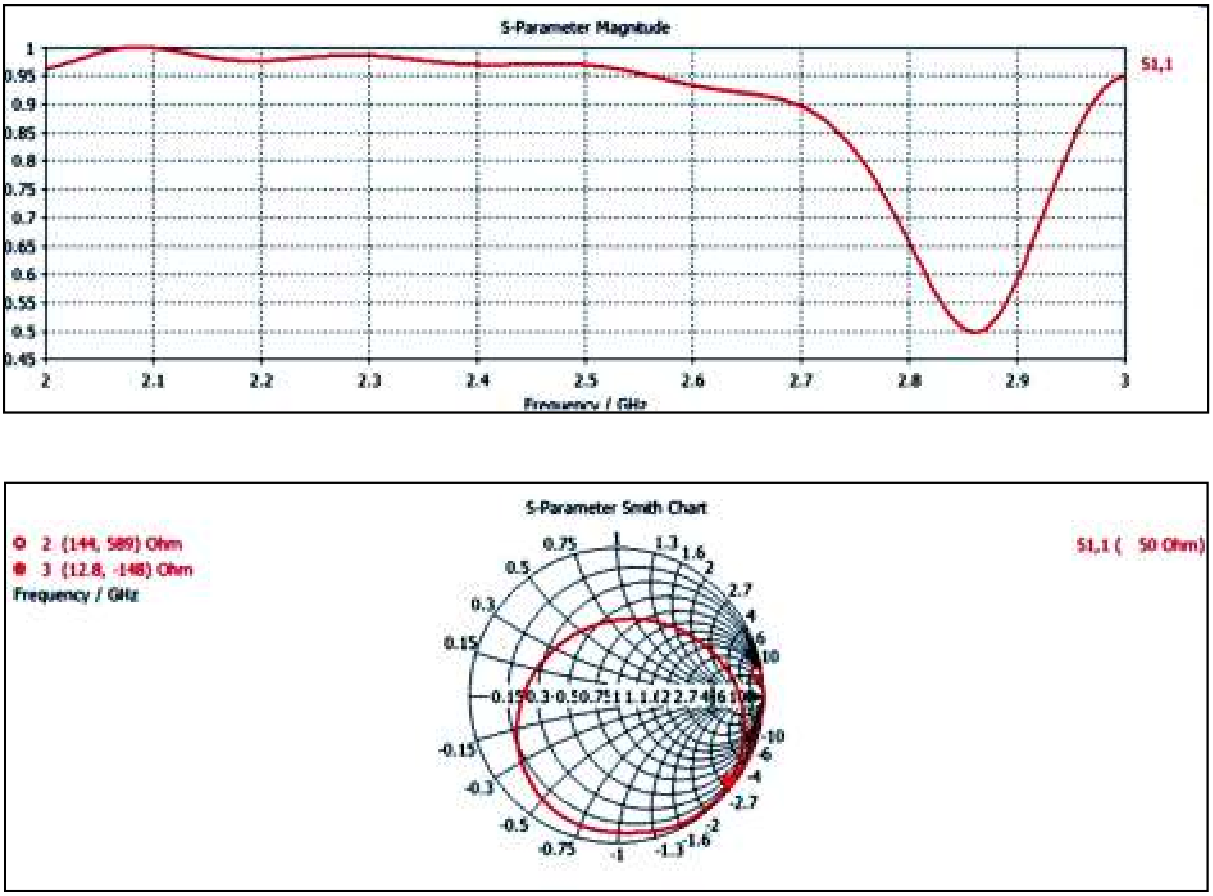


Figure 6 : Simulation Result 1

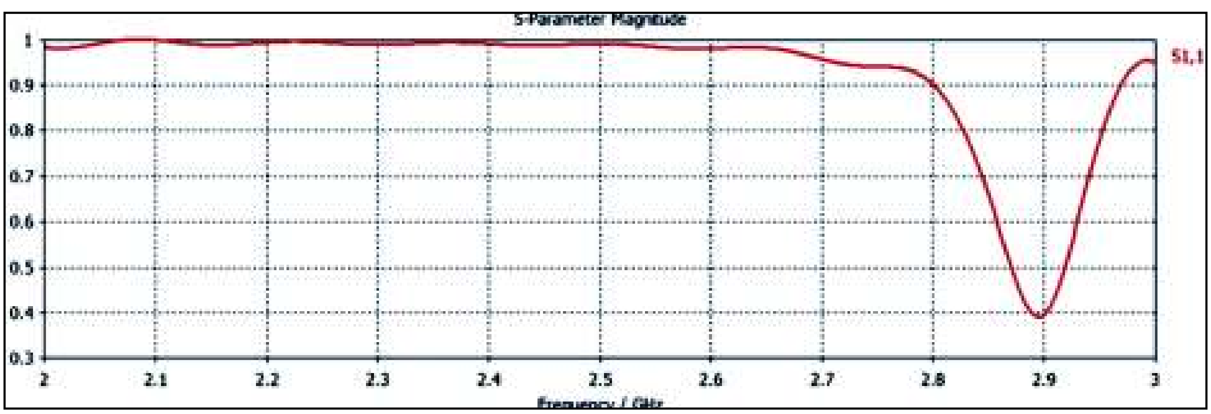


Figure 7 : Simulation Result 2

2. The antenna designed to operate at 100MHz is resonant at nearly 96MHz. This shift is due to fringing fields around the antenna, which makes the patch appear a littl0e longer. Thus, when a patch is designed it is customary to trim the length by 2-4% to achieve resonance at the desired frequency.

Analysis and Simulation

In this work, a microstrip patch antenna with dimensions L = 24.67mm, W = 32.23mm and h = 1.56mm, ΔL = 0.4124mm, εr, eff = 4.5 is simulated in CST Microwave Studio version 2010.03 Apr 13 2010. Frequency of operation is chosen as 2.8GHz.

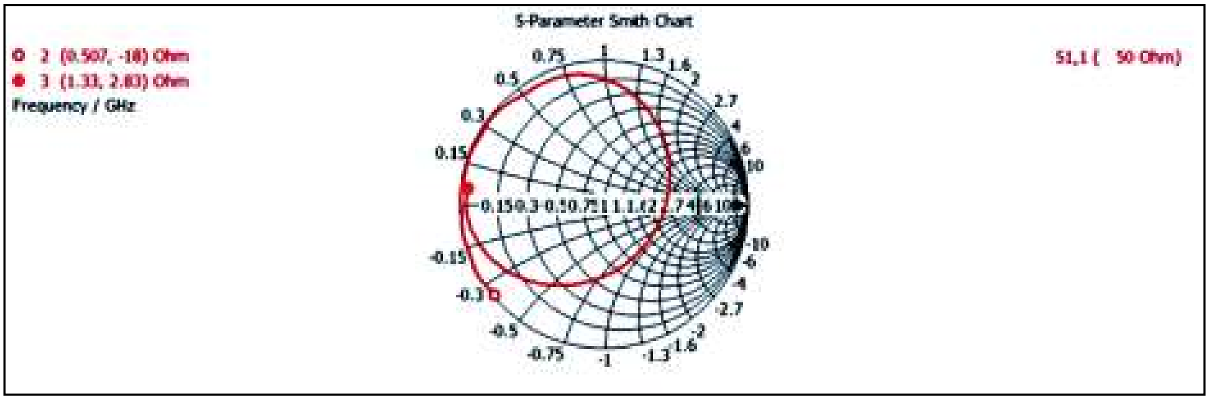
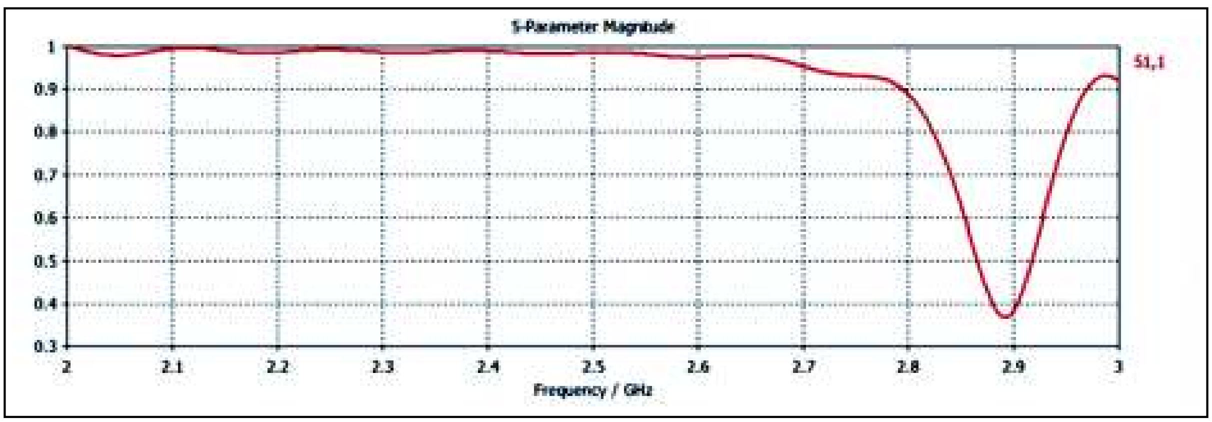


Figure 7 : Simulation Result 2



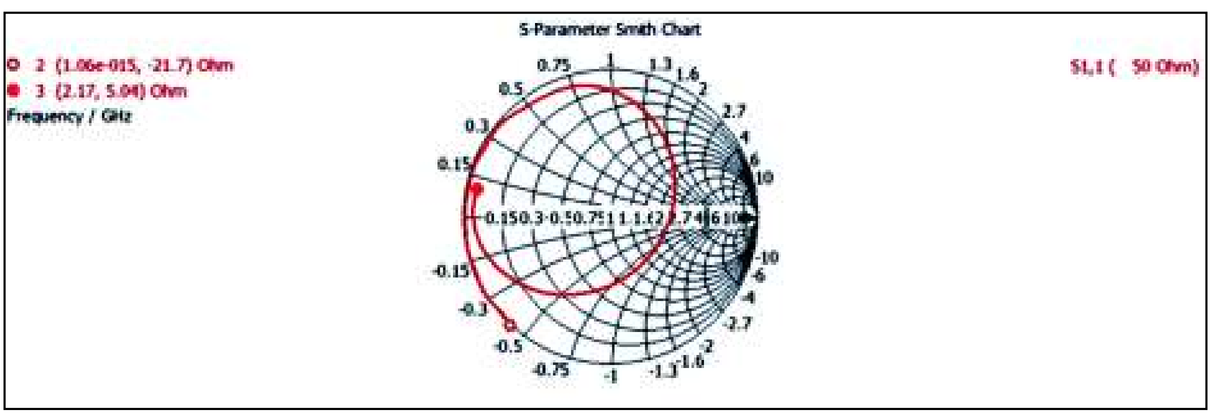
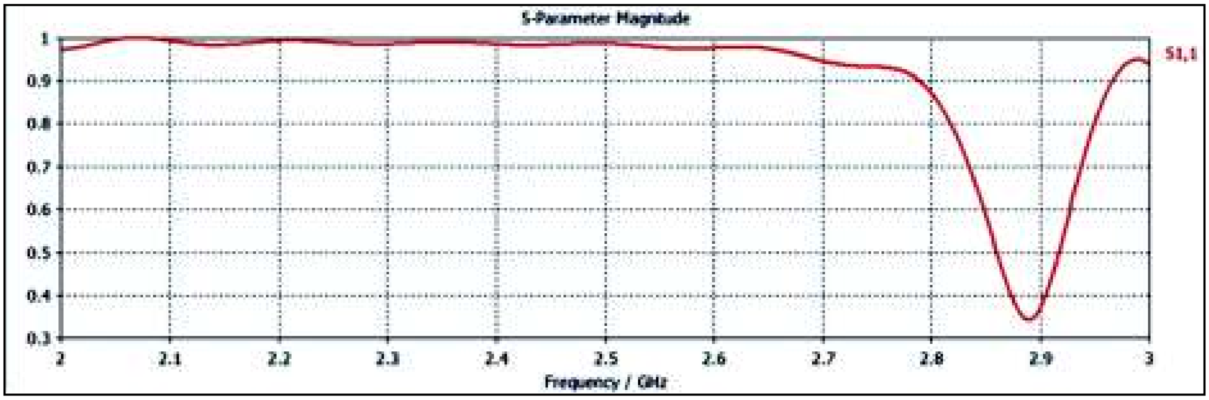


Figure 8 : Simulation Result 3



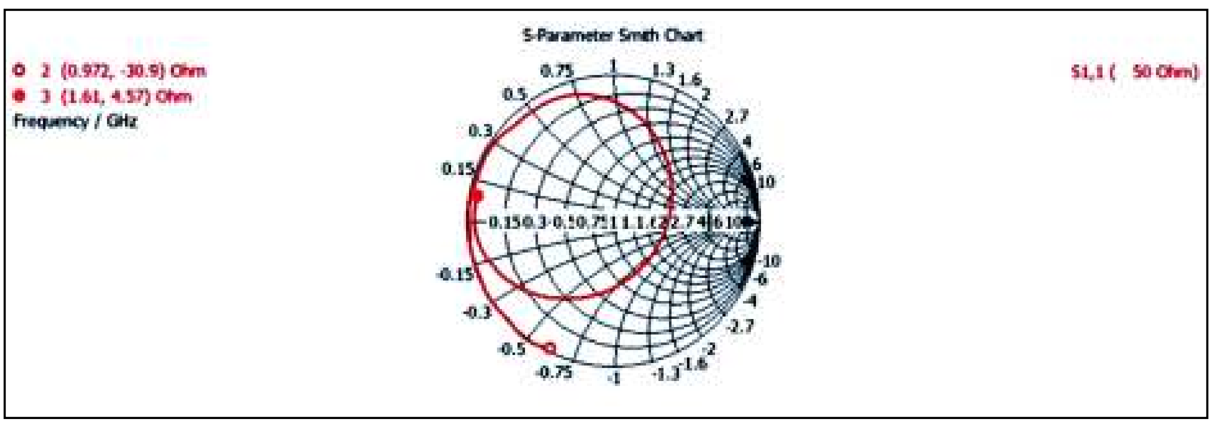
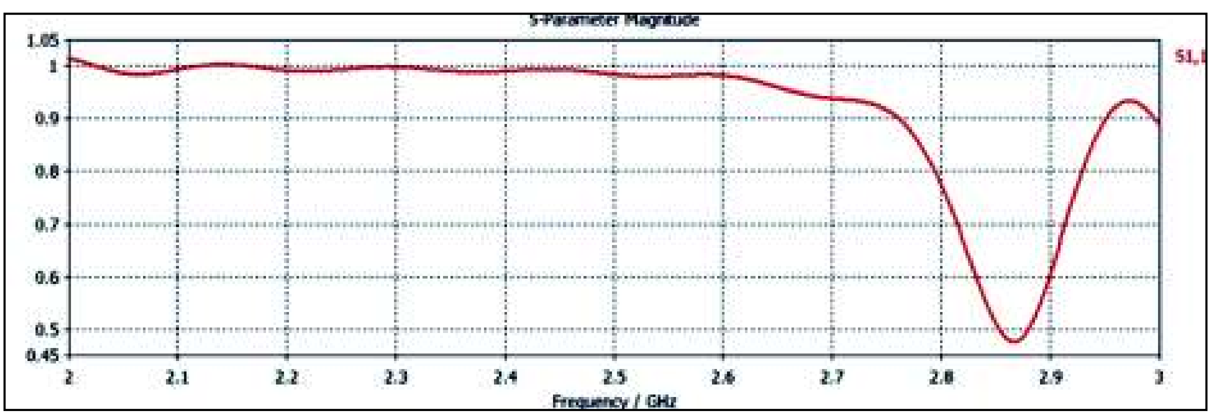


Figure 9 : Simulation Result 4



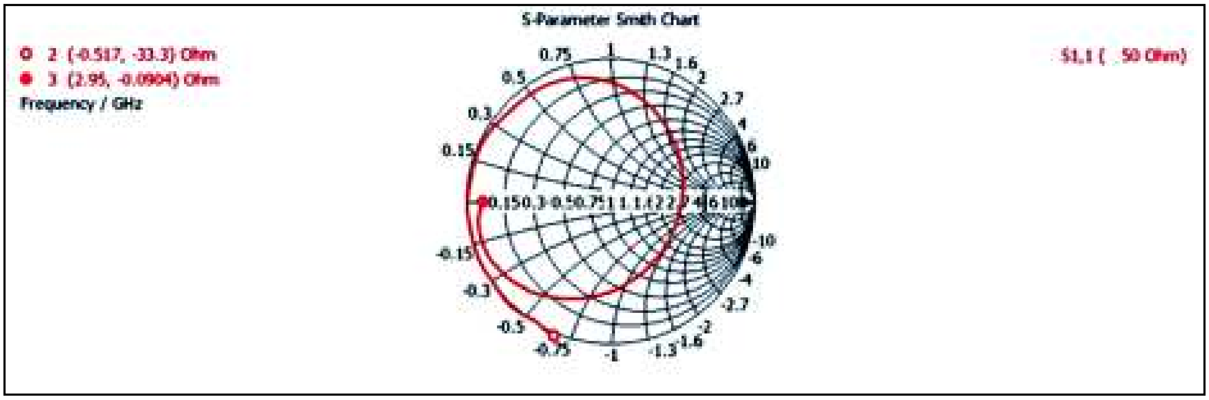
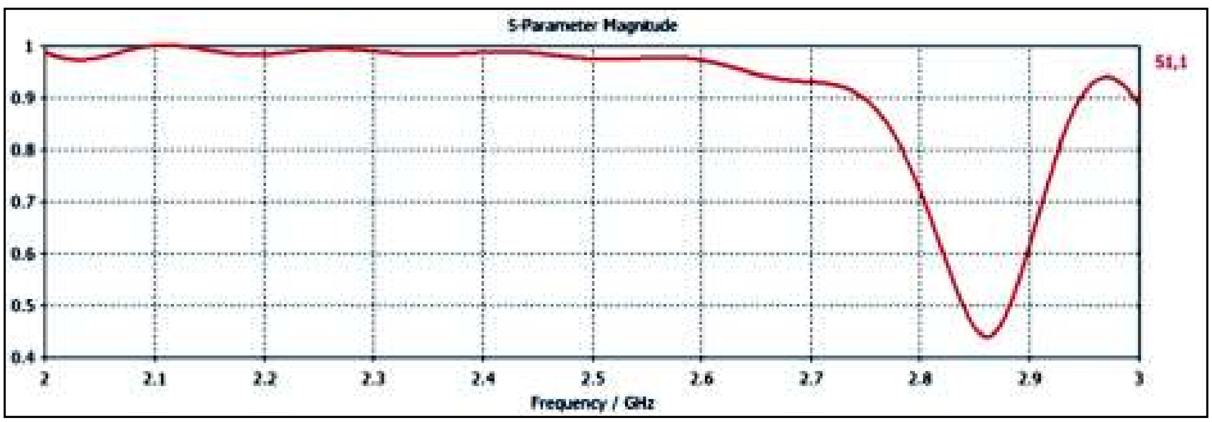


Figure 10 : Simulation Result 5



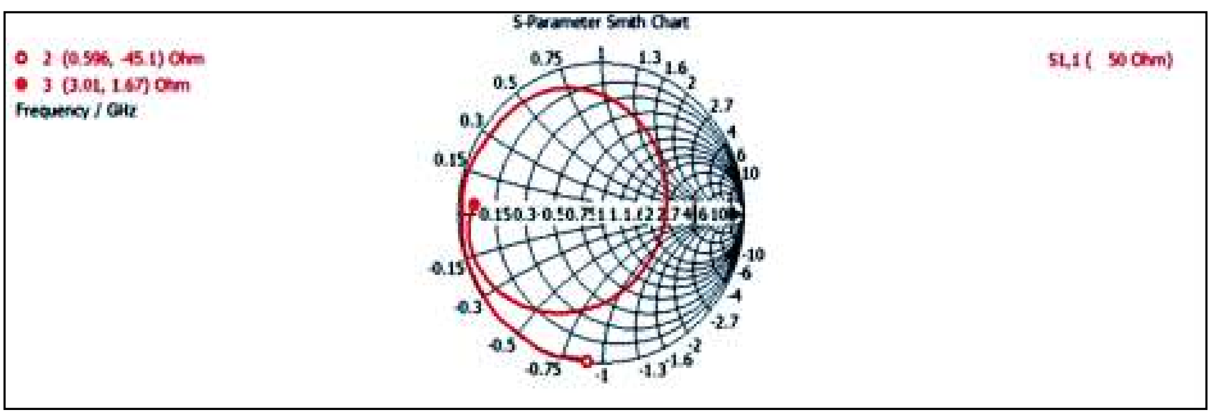
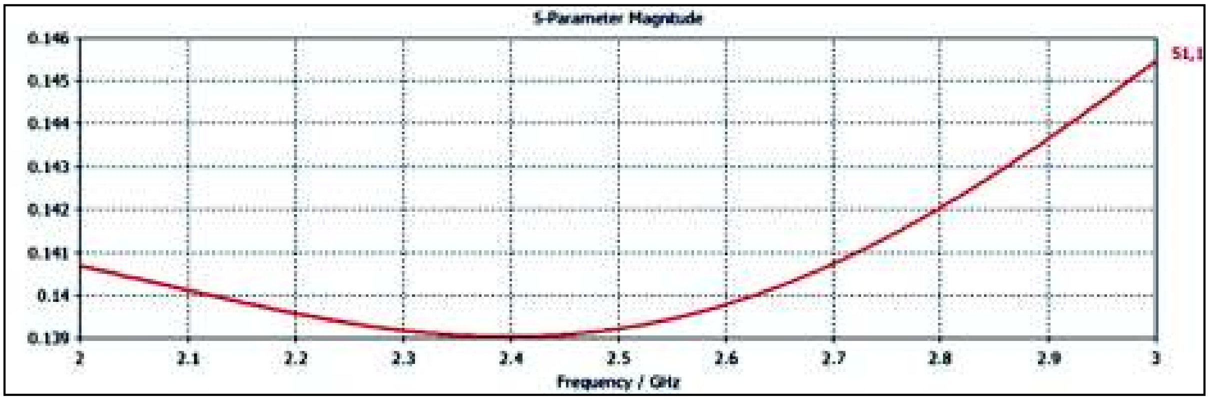


Figure 11 : Ssimulation Result 6



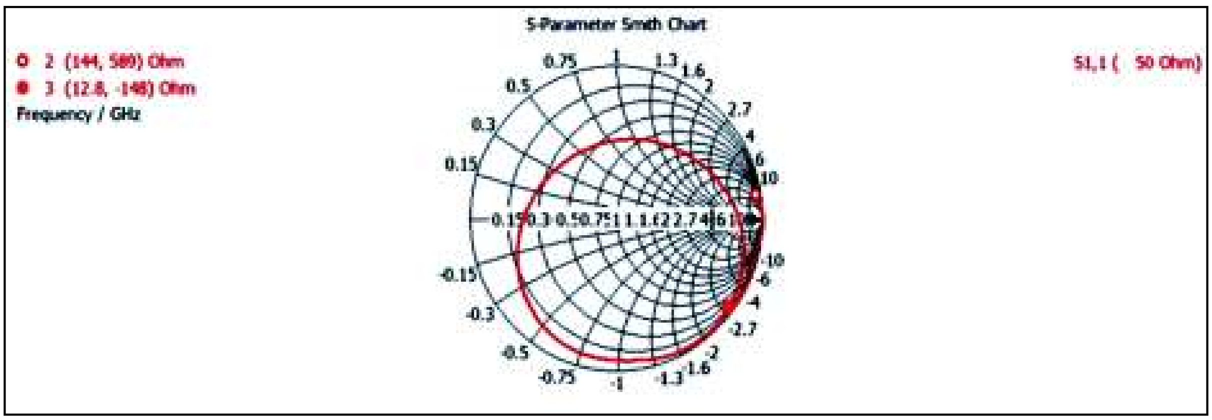


Figure 12 : Simulation result 7

REFERENCES

Munson R. E., 1974. Conformal Microstrip Antennas and Microstrip Phased Arrays". IEEE Transactions on Antennas and Propagation, AP-**22**, 74-78.

Long S. A., Walton, M. D., 1979. "A Dual Frequency Stacked Microstrip Antenna", IEEE Transactions on Antennas and Propagation, AP-**27**, 137-149.

Suzuki Y., and Chiba T., 1984. "Computer Analysis Method for Arbitrarily Shaped Microstrip Antenna with Multiterminals", AP-32, No. 6, 585-590, ibid..

Chattopadhyay, S., Biswas, M., Siddiqui, J. Y. and Guha, D., 2009. "Rectangular Microstrips with variable air gap and varying aspect ratio: Improved formulation and experiments", Microwave and Optical Technology Letters, **51** :169-173.

Kraus John D., Marhefka Ronald J., Khans and Ahmad S,, 2006. Antennas and Wave Propagation, TMH Education Private Limited, India.