CHAPTER FIVE

COMPACT TUNABLE AND DUAL FREQUENCY MICROSTRIP PATCH ANTENNA

Tunable and dual band microstrip patch antennas are very useful where wide band response is difficult to obtain over the required frequency range. In this chapter, tunable and dual band microstrip patch antenna will be analyzed.

5.1 INTRODUCTION

In multichannel applications a low instantaneous bandwidth is needed over a large frequency range. Tunable antenna gives an alternative to a wideband antenna, in which an antenna with a small band width is tuned over a large frequency range. Dual frequency operations can be achieved by utilizing the multiresonance characteristics of narrow strips positioned along radiating corners (edges) and non radiating corners (edges) of fed printed patch and are parasitically coupled. Dual frequency operation can also be obtained by using meandering method (or defective ground) to the finite metallic ground plane of a patch antenna design. In some wireless applications, the system requires to be work within two frequency bands that are far apart. Here dual frequency antenna rather than broadband antenna is used. If the antenna operates only at two spot frequencies, then it is known as a dual frequency antenna. Compact microstrip antennas capable of dual-polarized radiation are very suitable for applications in wireless communication systems that demand frequency reuse or polarization diversity [74].

All the proposed tunable and dual frequency antenna designs are simulated using IE3D software based on MoM and its radiation characteristics are analyzed for optimization of various practical tunable and dual band applications of wireless communication system. These tunable and dual band microstrip patch antennas are designed in place of broadband antennas for various multichannel applications of wireless communication, mobile communication, WLAN, WiMax systems in S-band (2 to 4 GHz) and C-band (4 to 8 GHz).

5.2 DUAL FREQUENCY MICROSTRIP PATCH ANTENNA DESIGN-1

In the antenna design-1, dual band operation is achieved by utilizing the square slot cut of 15 mm length at the center of the patch. In dual frequency antenna design-1, when feed is given at the suitable position on the patch, there is an enhancement of bandwidth and decrement in the operating frequencies as the square slot cut length increases. The antenna gives better radiation characteristics as compared to a rectangular micro strip antenna of same design specification without square slot cut and the square slot cut of 5 mm and 10 mm.

Figure 5.1 shows the rectangular micro strip patch antenna design-1. The patch is printed on inexpensive FR4 having dielectric constant (€r) of 4.4, loss tangent tan δ = 0.02 and height 1.6 mm. The coaxial probe feed having 50-ohm impedance is used for feeding the patch. This rectangular microstrip patch antenna is designed for the application of wireless communication system, which gives dual frequency, with lower operating frequency f_1 = 1.06 GHz with BW= 20 MHz (1.88%), and higher operating frequency f_2 = 1.38 GHz with BW= 40 MHz (2.89%) in the frequency range of 0.8 GHz to 1.6 GHz, This antenna has a ratio of the two operating frequencies of about 1.3. length of patch L = 47 mm**,** width of patch W = 62 mm, with a square slot cut of 15 mm * 15 mm (L*W) at coordinates {(16,23.5), (16,38.5), (31,38.5), (31,23.5), (16,23.5)}, feed point location = (37, 45). Figure 5.2 shows the graph between return loss (in dB) and frequency (in GHz) for antenna design-1; the impedance bandwidth is taken from the 10-dB return loss. Figure 5.3 and Figure 5.4 shows the radiation pattern (2-D elevation pattern) for antenna design-1 at lower operating frequency f_1 = 1.06 GHz and higher operating frequency f_2 = 1.38 GHz respectively. Figure 5.5 shows the impedance loci for antenna design-1. At lower and higher operating frequencies, the simulated input impedance of antenna is in good agreement with the 50 ohms impedance.

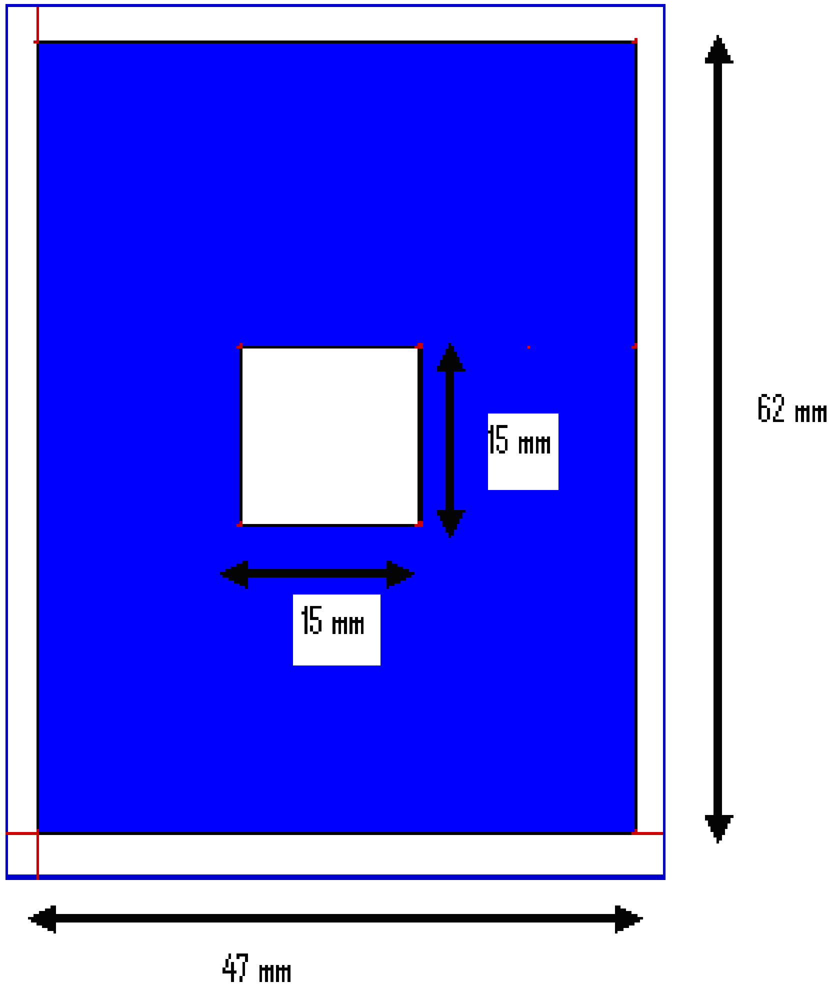

Figure 5.1 Dual-frequency rectangular microstrip

antenna with square slot cut at the center

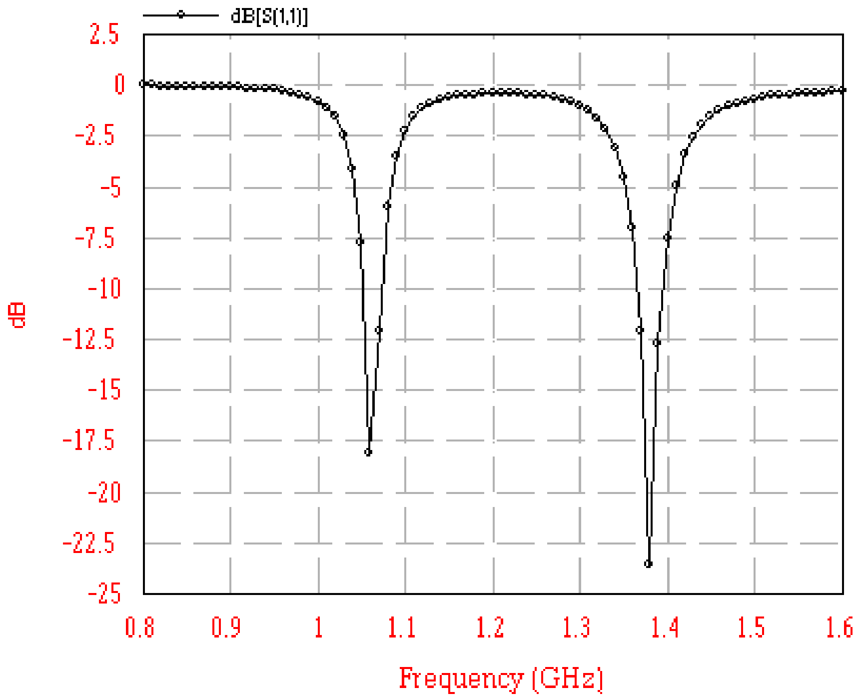

Figure 5.2 Graph between return loss and frequency for antenna design-1

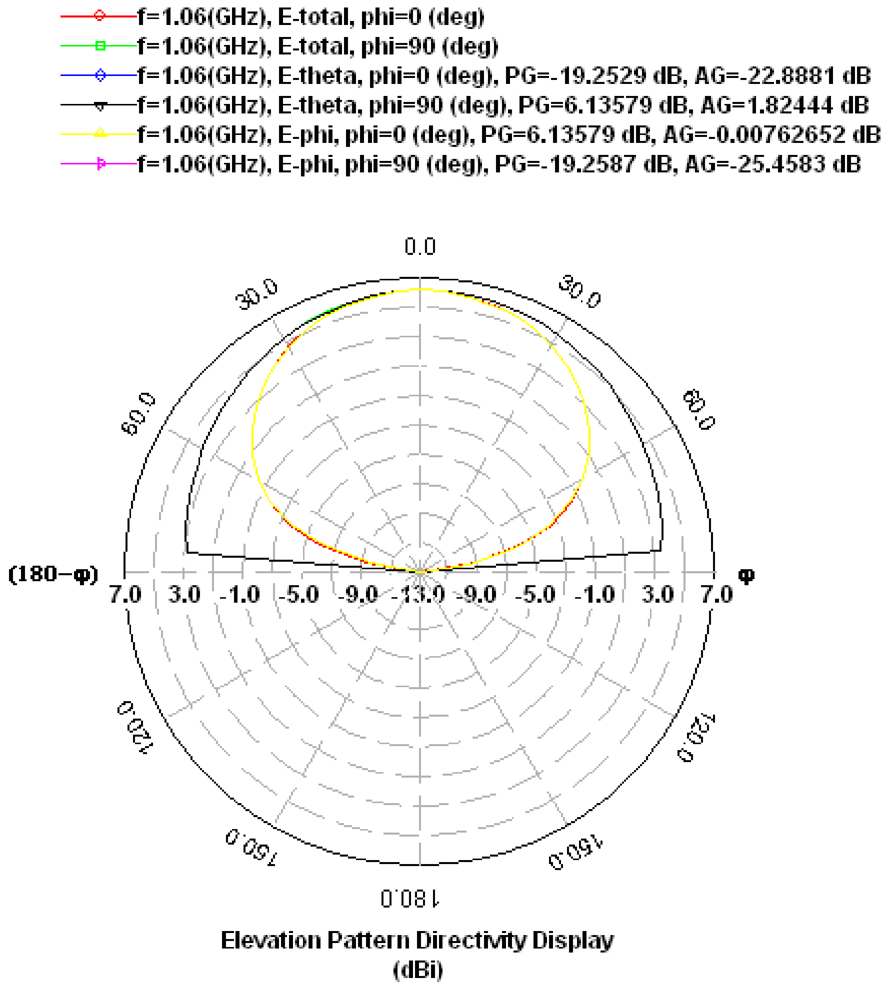

Figure 5.3 Radiation pattern for antenna design-1

at lower resonance frequency f_1 = 1.06 GHz

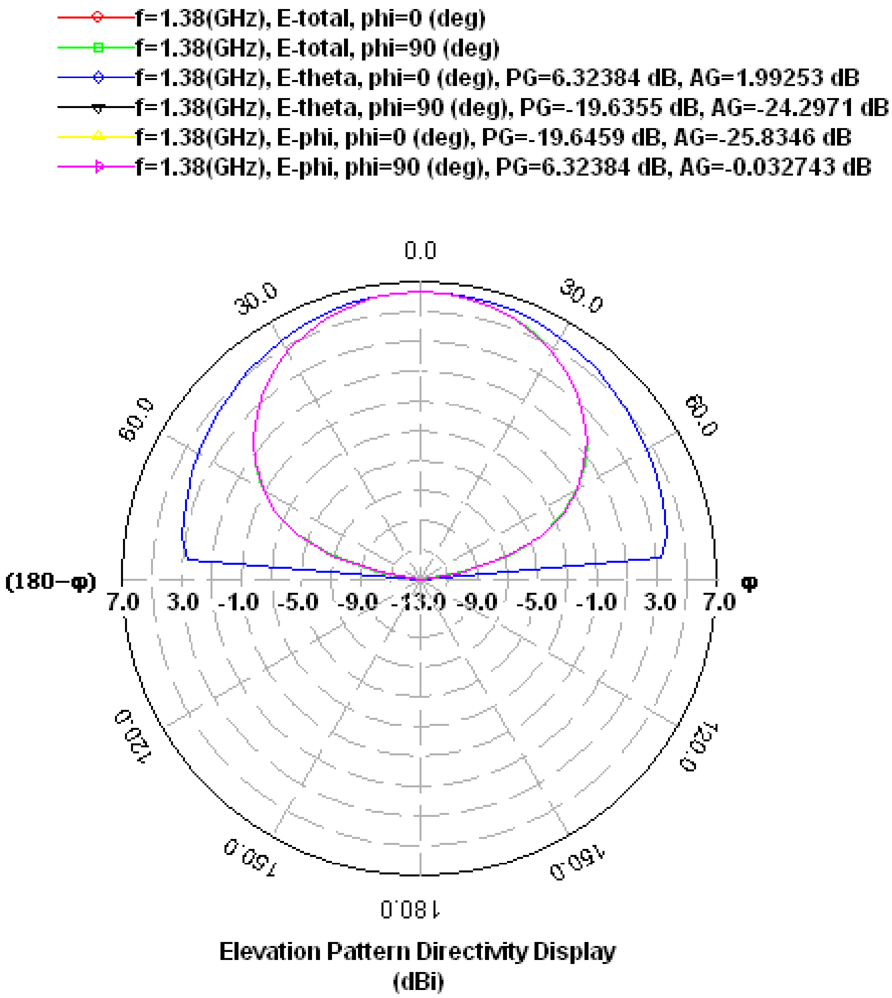

Figure 5.4 Radiation pattern for antenna design-1

at higher resonance frequency $f_2 = 1.38$ GHz

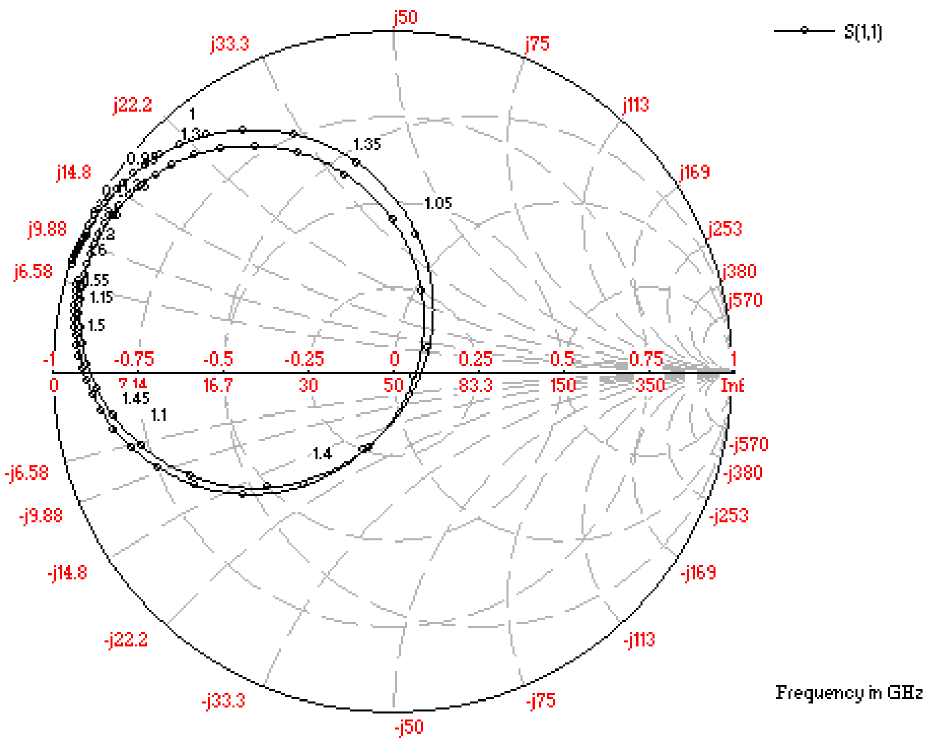

Figure 5.5 Impedance loci for antenna design-1

Table 5.1: Dual-Frequency performance of antenna design-1

Square slot length (mm)	**Feed point location (mm)**	**f_1(GHz), BW (MHz, %)**	**f_2(GHz), BW (MHz, %)**	**f_2 / f_1**
0	37,45	1.15,1.73	1.49,1.34	1.295
5	37,45	1.14,1.75	1.48,2.02	1.298
10	37,45	1.11,1.8	1.43,2.09	1.288
15	37,45	1.06,1.88	1.38,2.89	1.301

Table 5.1 shows the change in operating frequency (in GHz) and bandwidth (MHz, %) with change in length of square slot (in mm) at the center of the rectangular micro strip patch antenna. For a square slot cut with 15 mm length, antenna gives lower operating frequency f_1 = 1.06 GHz with **BW= 20 MHz (1.88%)** and higher operating frequency f_2 = 1.38 GHz with **BW= 40 MHz (2.89%)** in the frequency range of 0.8 GHz to 1.6 GHz. In dual frequency antenna design-1, there is an enhancement of band width with decrement in the operating frequencies, and the antenna is compact and tuned in the frequency range of 1.06 to 1.38 GHz and gives better radiation characteristics as compared to a rectangular microstrip antenna of same design specification without square slot cut and the square slot cut of 5 mm and 10mm.

5.3 DUAL FREQUENCY MICROSTRIP PATCH ANTENNA DESIGN-2

In the antenna design-2, dual frequency operation is achieved by utilizing the multiresonance characteristics of narrow strips, multiresonator with square cut corner of 5 mm and three gap coupled parasitic patches are placed along the non radiating edge of fed rectangular microstrip antenna with the gaps between the patches are equal to 1 mm. In the dual frequency antenna design-2, bandwidths have been improved and the multiresonator antenna gives satisfactory result as compared to a rectangular microstrip antenna of same design specification without multiresonator.

Figure 5.6 presents the gap coupled multiresonator rectangular microstrip patch with square cut corner antenna design-2. In the antenna design-2, three gap coupled parasitic patches (narrow strips multiresonator) are positioned along the non radiating corners of one rectangular feed patch to increase the band width by given an air gap of 1 mm between each parasitic patch. This rectangular patch antenna is designed for the application of wireless communication system, which gives dual frequency, with lower resonance frequency f_1 = 1.52 GHz with **BW= 80 MHz (5.2%)**, and higher resonance frequency f_2 = 2.25 GHz with **BW= 70 MHz (3.11%)**, within the frequency range from 0.5 GHz to 2.5 GHz, with step of frequency selected to be 0.01 GHz, patch length L = 47 mm**,** patch width W = 62 mm, feed point positions = (40, 32), square cut corner = 5 mm. The patch is printed on inexpensive FR4 having dielectric constant (Єr) of 4.4, loss tangent tan δ = 0.02 and height 1.6 mm. The coaxial probe feed having 50-ohm impedance is used for feeding the patch. Figure 5.7 shows the graph between return loss (in dB) and frequency (in GHz) for antenna design-2; the impedance bandwidth is taken from the 10-dB return loss. Figure 5.8 and Figure 5.9 shows the radiation pattern (2-D elevation pattern) for antenna design-2 at lower resonance frequency f_1 = 1.52 GHz and higher resonance frequency f_2 = 2.25 GHz respectively. Figure 5.10 shows the impedance loci for antenna design-2. At lower and higher operating frequencies, the simulated input impedance of antenna design-2 is near to be matched with 50 ohm impedance.

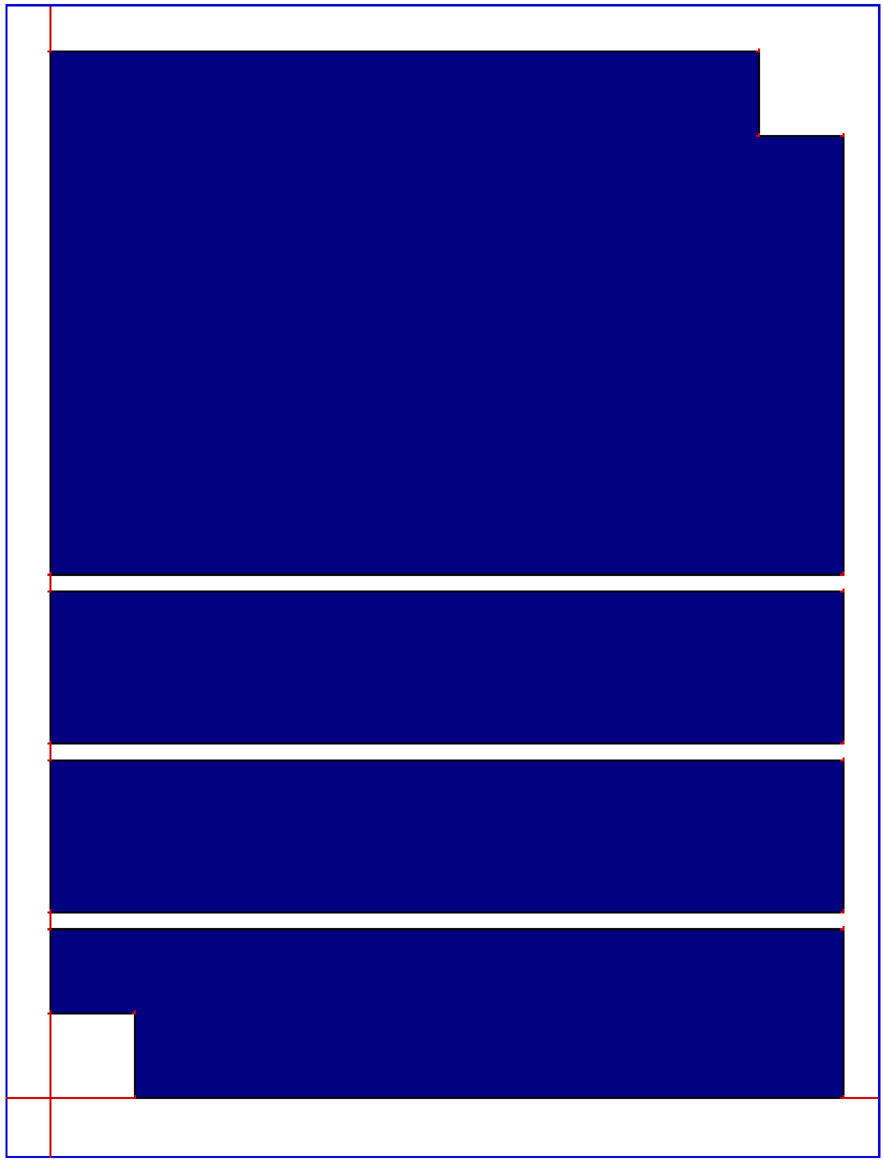

Figure 5.6 Gap-coupled multiresonator rectangular microstrip antenna with square cut corner of antenna design-2

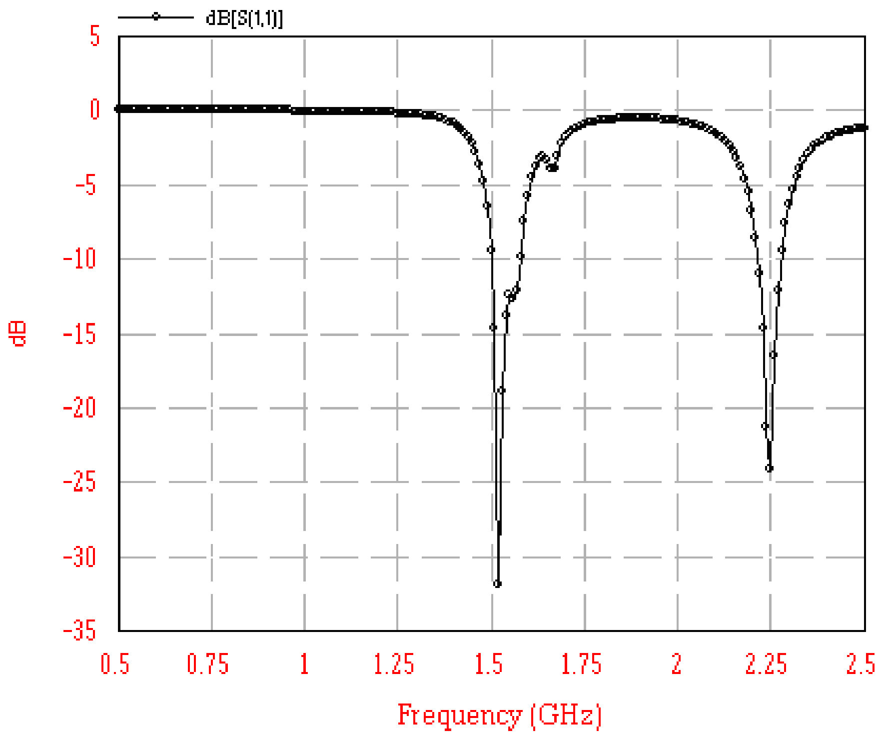

Figure 5.7 Graph between return loss and frequency for antenna design-2

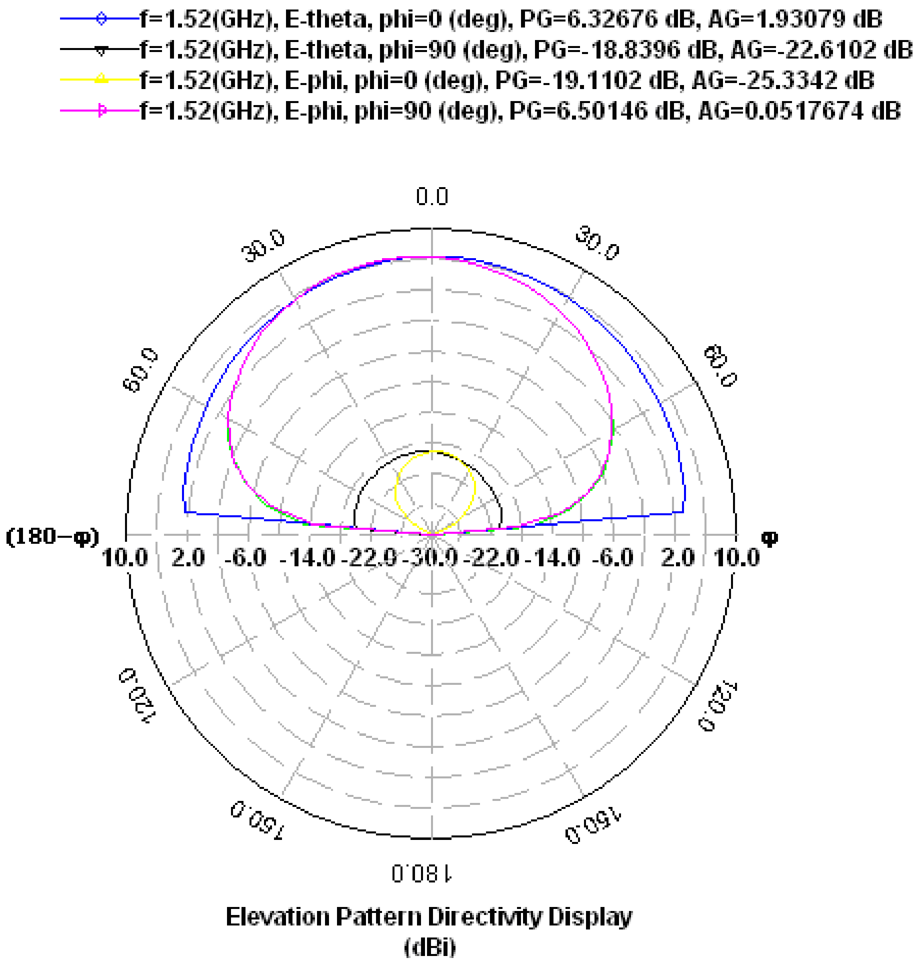

Figure 5.8 Radiation pattern for antenna design-2

at lower resonance frequency f_1 = 1.52 GHz

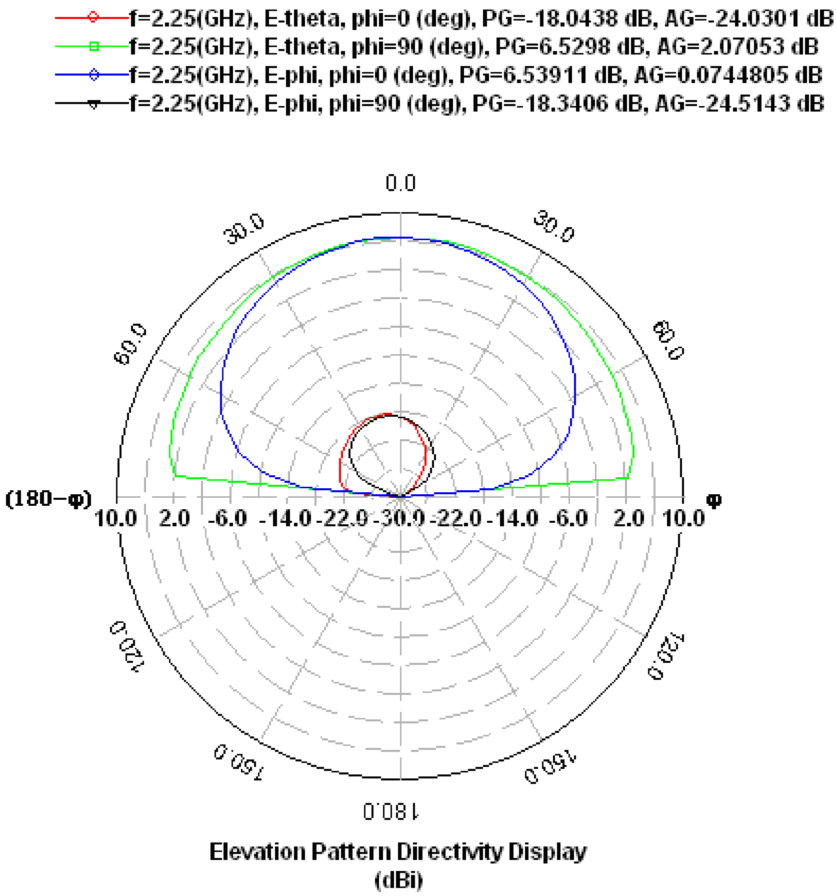

Figure 5.9 Radiation pattern for antenna design-2

at higher resonance frequency $f_2 = 2.25$ GHz

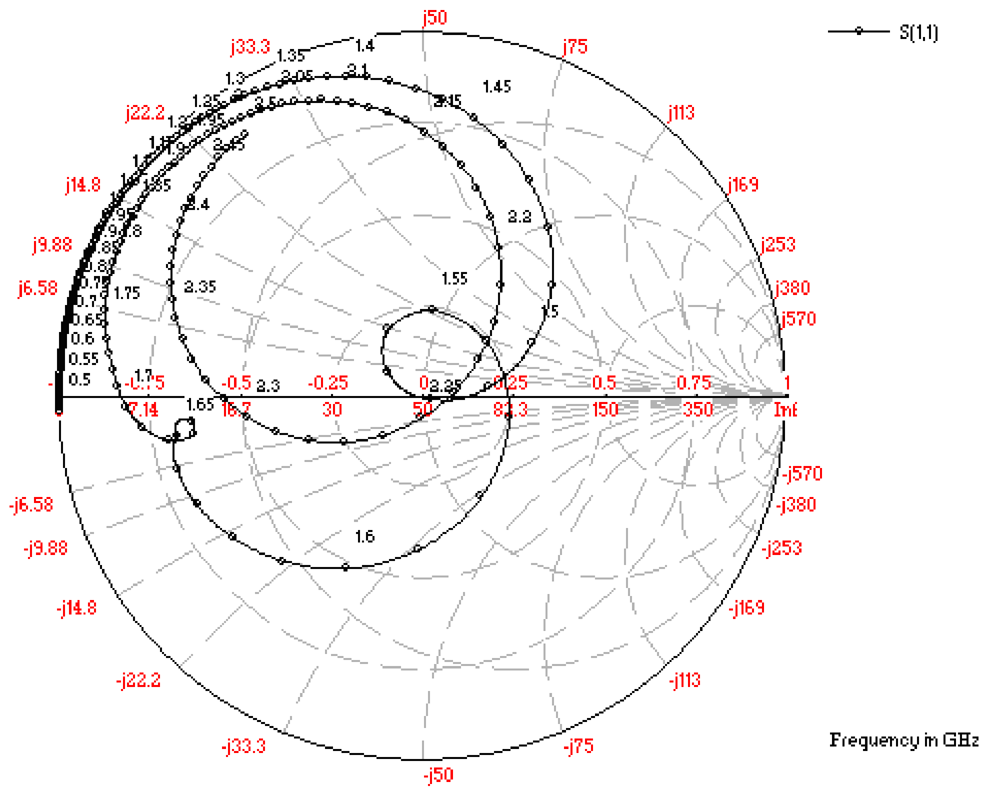

Figure 5.10 Impedance loci for antenna design-2

5.4 DUAL FREQUENCY MICROSTRIP PATCH ANTENNA DESIGN-3

In the patch antenna design-3, dual frequency modified square microstrip patch antenna with wideband is achieved by corner cut and inserting slits inside the edges of the radiating patch having slot loaded finite ground plane. In this dual band modified square microstrip patch antenna design-3, there is an improvement of bandwidths and the antenna gives very good radiation characteristics.

Figure 5.11 presents the front view of modified square microstrip patch antenna with slot loaded finite ground plane. Antenna is designed for different applications of wireless communication in S-band and C-band for lower operating frequency = 3.21 GHz and higher operating frequency = 4.03 GHz, within the frequency range 2.5 GHz to 5 GHz, with step of frequency selected to be 0.01 GHz, In this modified square patch antenna design, patch length L = 30 mm**,** patch width W = 30 mm with slot loaded and corner cut finite ground plane of the dimension L = 45 mm and W = 45 mm and square slot of dimensions 10 mm × 10 mm at the centre position, feed point positions at the patch is (11.825, -12.375). The patch is printed on inexpensive FR4 having dielectric constant (Єr) of 4.4, loss tangent tan δ = 0.02 and height 1.6 mm. The coaxial probe feed having 50-ohm impedance is used for feeding the patch. Figure 5.12 shows the back view of modified square microstrip patch antenna with slot loaded and corner cut finite ground plane. Figure 5.13 shows the graph between return loss (in dB) and frequency (in GHz) for antenna design-3; the impedance bandwidth is taken from the 10-dB return loss. Figure 5.14 shows the graph between VSWR and frequency (in GHz) for antenna design-3. Figure 5.15 shows the graph between directivity (in dBi) and frequency (in GHz) for the proposed antenna design. Figure 5.16 and Figure 5.17 shows the radiation pattern (2-D elevation pattern) for antenna design-3 at lower (3.21 GHz) and higher resonance frequency (4.03 GHz) respectively. Figure 5.18 shows the graph between efficiency (antenna and radiating, in %) and frequency (in GHz) for antenna design-3, antenna and radiating efficiency both are coming between 80-90 % at both lower and higher operating frequencies. Figure 5.19 shows the impedance loci for antenna design-3. At lower and higher operating frequencies, the simulated input impedance of antenna design-3 is near to be matched with 50 ohm impedance. For antenna design-3, the obtained impedance bandwidths for lower and higher operating frequencies are **15.58 %** (500 MHz) and **27.8 %** (1120 MHz) respectively.

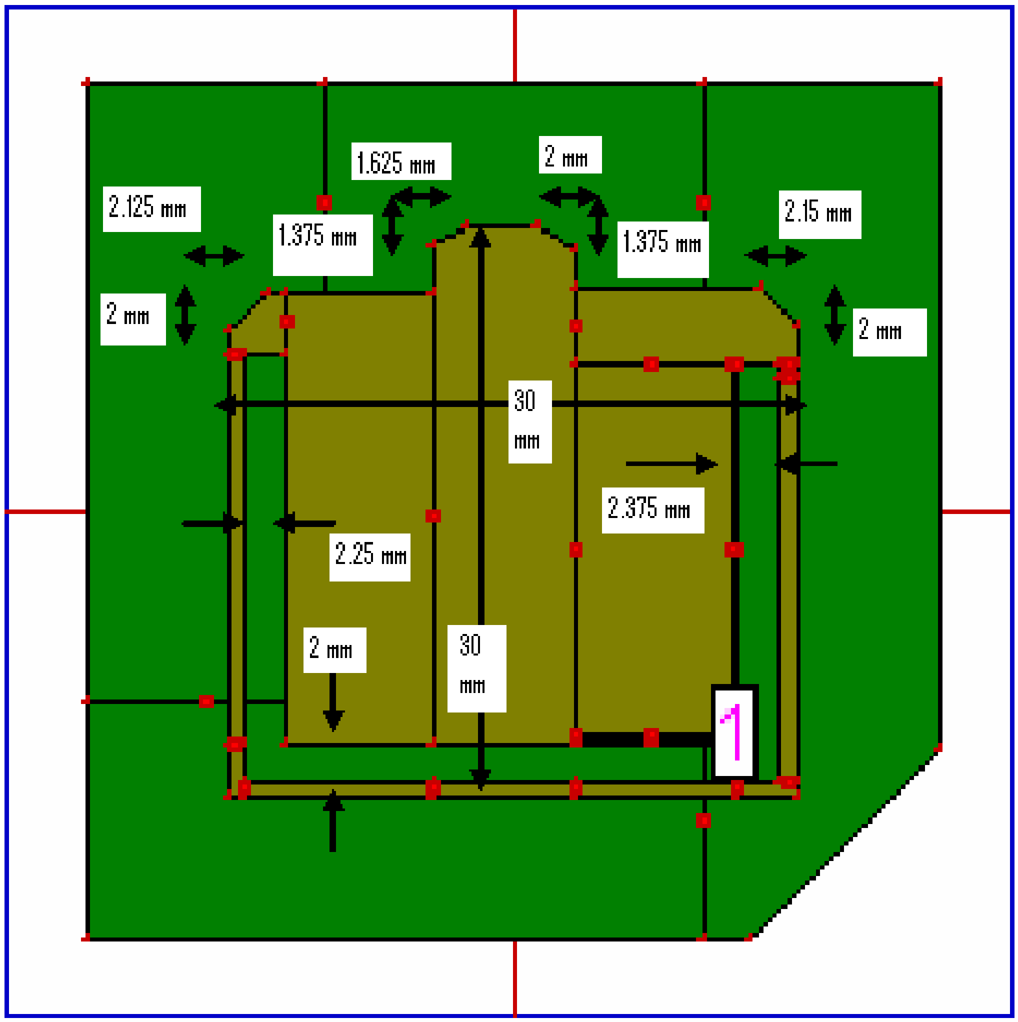

Figure 5.11 Front view of modified square MSA

with slot loaded and corner cut finite ground

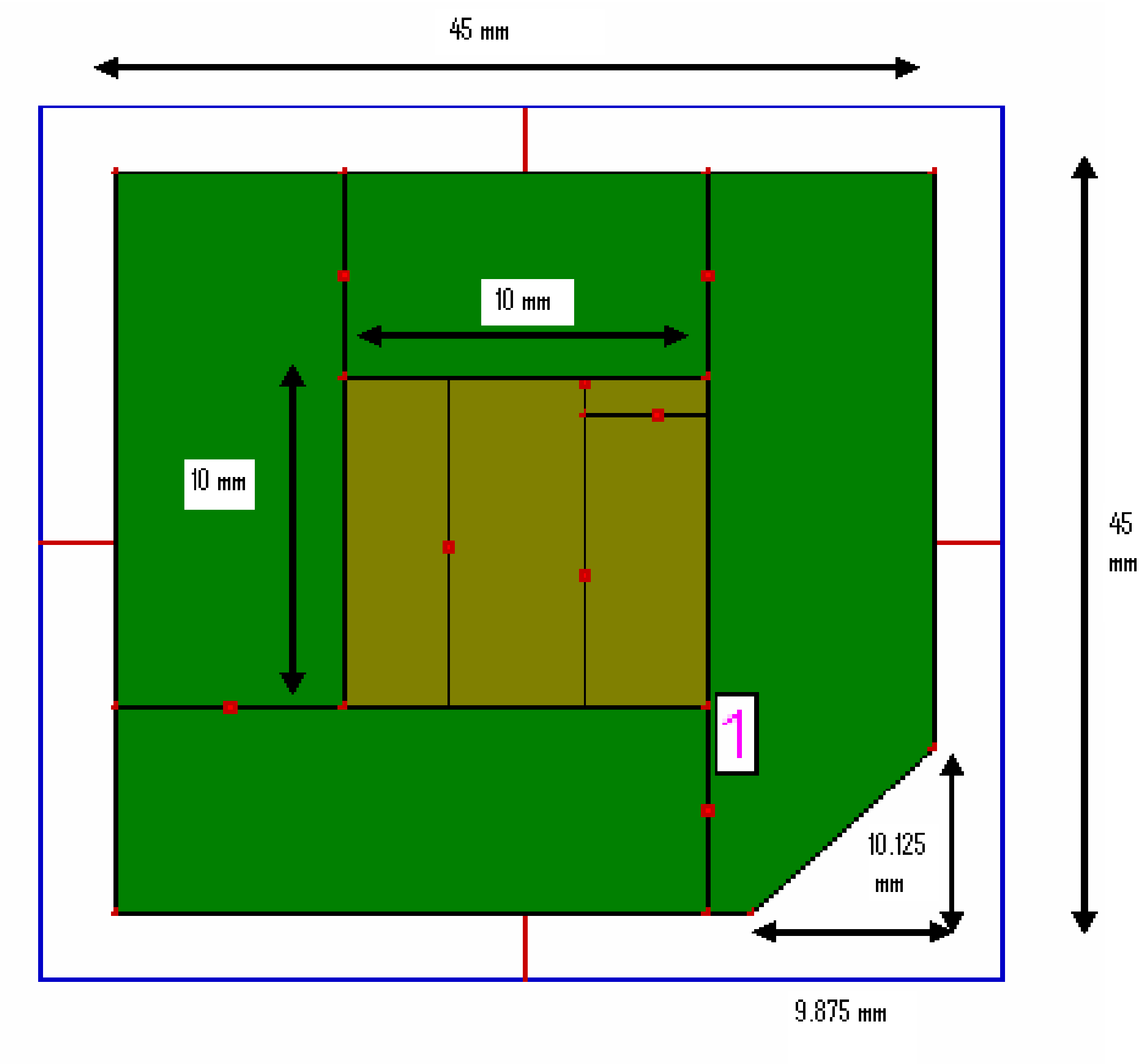

Figure 5.12 Back view of modified square MSA

with slot loaded and corner cut finite ground

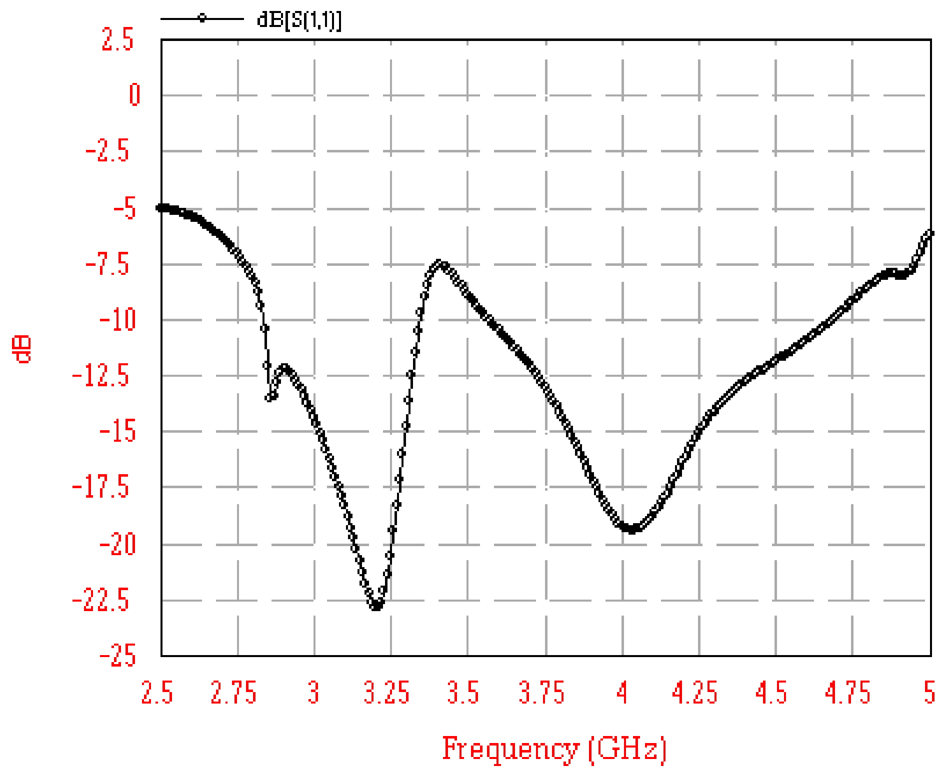

Figure 5.13 Graph between return loss and frequency for antenna design-3

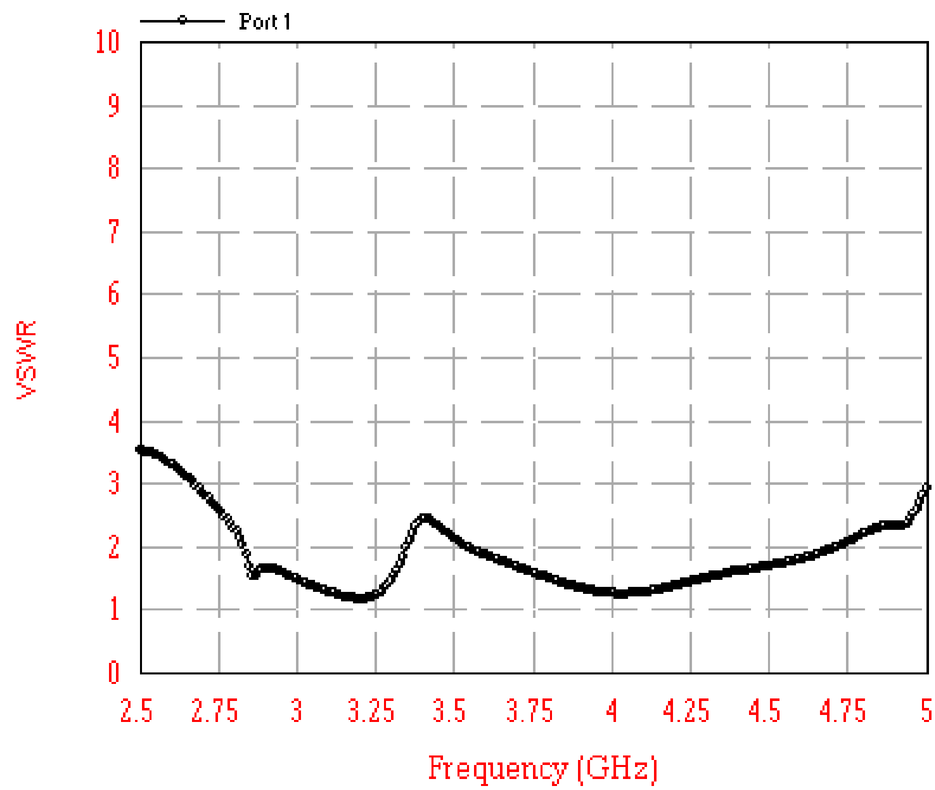

Figure 5.14 Graph between VSWR and frequency for antenna design-3

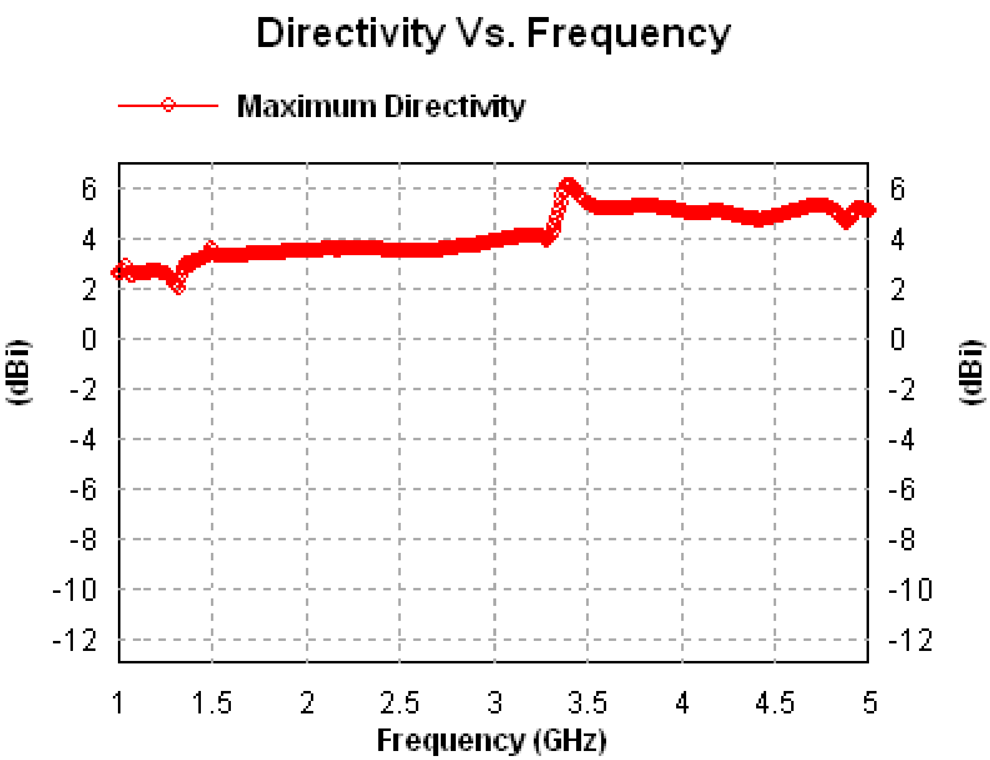

Figure 5.15 Graph between directivity and frequency for antenna design-3

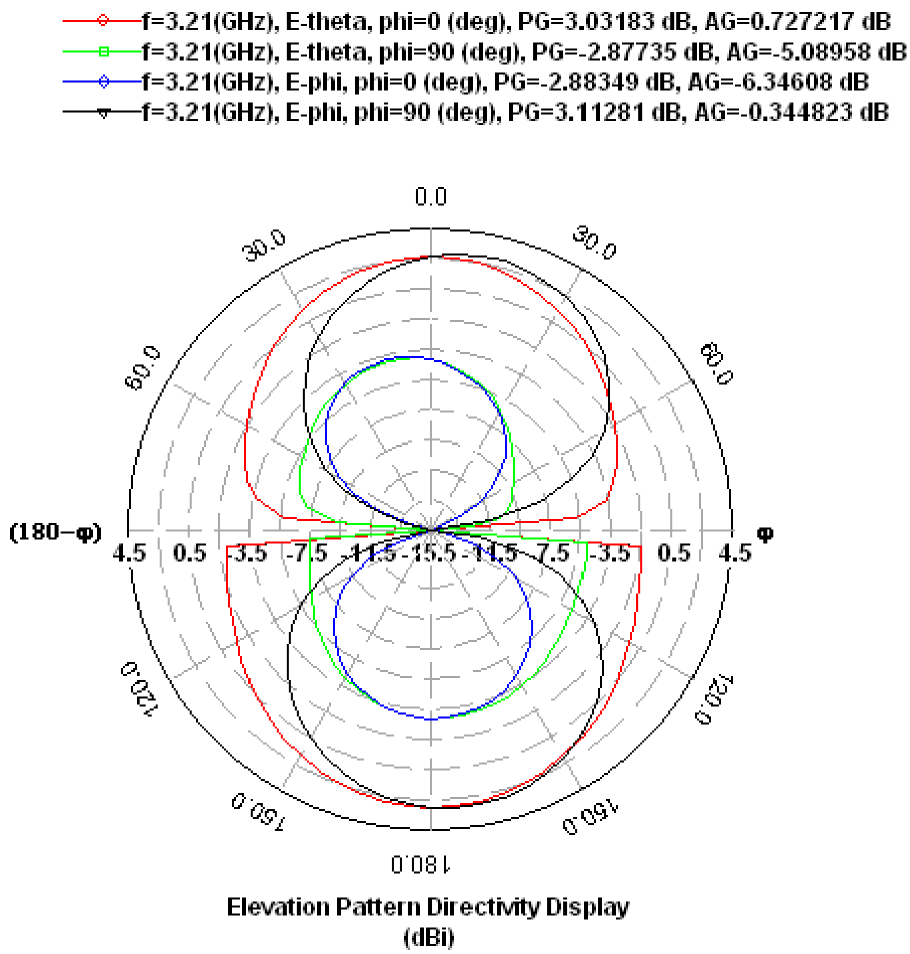

Figure 5.16 Radiation pattern for antenna design-3

at lower resonance frequency f_1 = 3.21 GHz

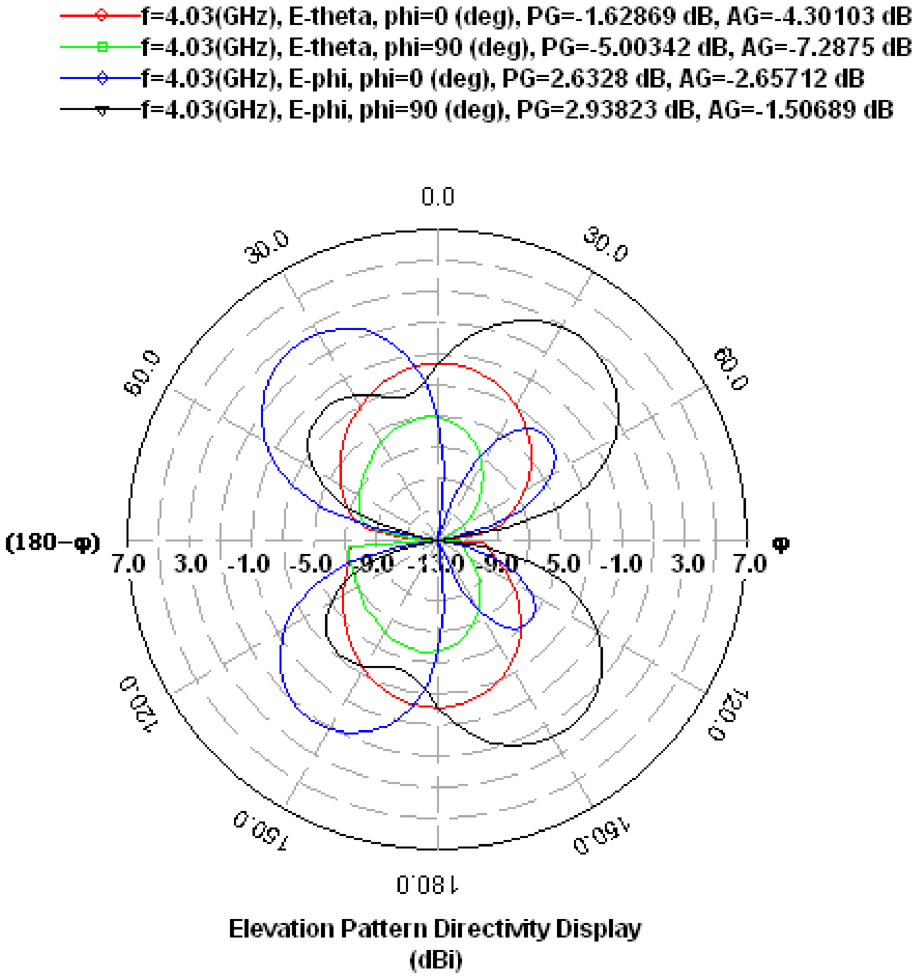

Figure 5.17 Radiation pattern for antenna design-3

at higher resonance frequency f_2 = 4.03 GHz

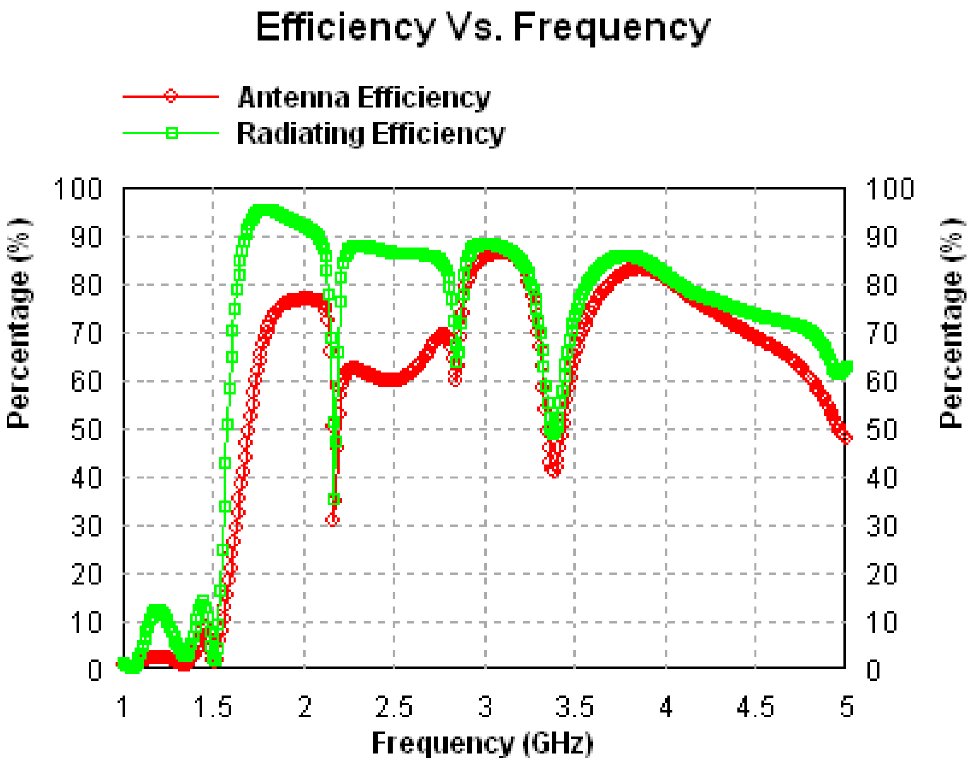

Figure 5.18 Graph between efficiency and frequency for antenna design-3

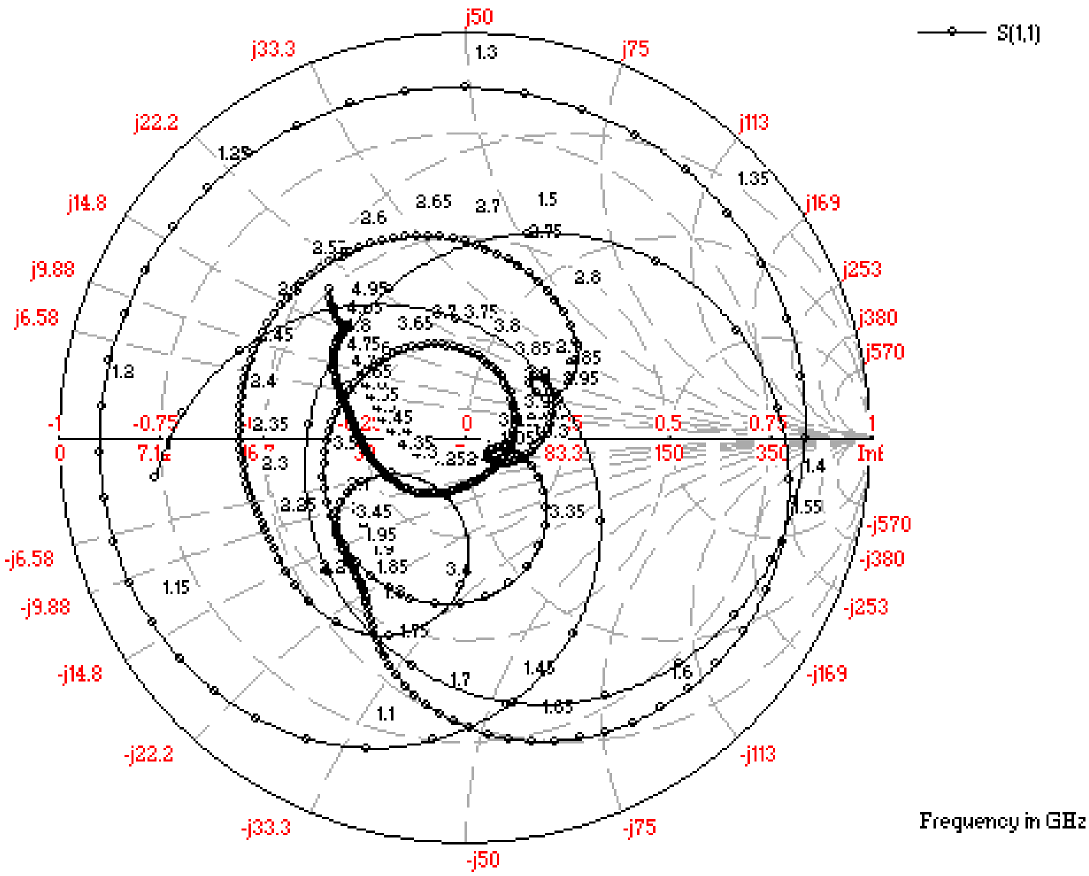

Figure 5.19 Impedance loci for antenna design-3

5.5 DUAL FREQUENCY MICROSTRIP PATCH ANTENNA DESIGN-4

In the patch antenna design-4, dual frequency modified square microstrip patch antenna with wideband is achieved by corner cut and inserting slits inside the edges of the radiating patch having slot loaded finite ground plane. In this dual frequency modified square microstrip patch antenna design-4, there is an improvement of bandwidths and the antenna gives very good radiation characteristics as compared to a rectangular microstrip antenna of same design parameters without modifications.

Figure 5.20 presents the front view of modified square microstrip patch antenna with slot loaded finite ground plane. Antenna is designed for different applications of wireless communication in S-band and C-band for lower operating frequency = 3.16 and higher operating frequency = 4.21 GHz, within the frequency range 2 GHz to 5 GHz, with step of frequency selected to be 0.01 GHz, In this proposed modified square patch antenna design, patch length L = 30 mm**,** patch width W = 30 mm with slot loaded finite ground plane of the dimension L = 45 mm and W = 45 mm and square slot of dimensions 10 mm × 10 mm at the centre position, feed point positions at the patch is (-10.775, -12). The patch is printed on inexpensive FR4 having dielectric constant (€r) of 4.4, loss tangent tan δ = 0.02 and height 1.6 mm. The coaxial probe feed having 50-ohm impedance is used for feeding the patch. Figure 5.21 shows the back view of modified square microstrip patch antenna with slot loaded finite ground plane. Figure 5.22 shows the graph between return loss (in dB) and frequency (in GHz) for antenna design-4; the impedance bandwidth is taken from the 10-dB return loss. Figure 5.23 shows the graph between VSWR and frequency (in GHz) for antenna design-4. Figure 5.24 shows the graph between directivity (in dBi) and frequency (in GHz) for antenna design-4. Figure 5.25 and Figure 5.26 shows the radiation pattern (2-D elevation pattern) for antenna design-4 at lower (3.16 GHz) and higher resonance frequency (4.21 GHz) respectively. Figure 5.27 shows the graph between efficiency (antenna and radiating, in %) and frequency (in GHz) for antenna design-4, antenna and radiating efficiency both are coming between 80-90 % at both lower and higher operating frequencies. Figure 5.28 shows the impedance loci for antenna design-4. At lower and higher operating frequencies, the simulated input impedance of antenna design-4 is near to be matched with 50 ohm impedance. For antenna design-4, the obtained impedance bandwidths for lower and higher operating frequencies are **14.24 %** (450 MHz) and **28.74 %** (1210 MHz) respectively.

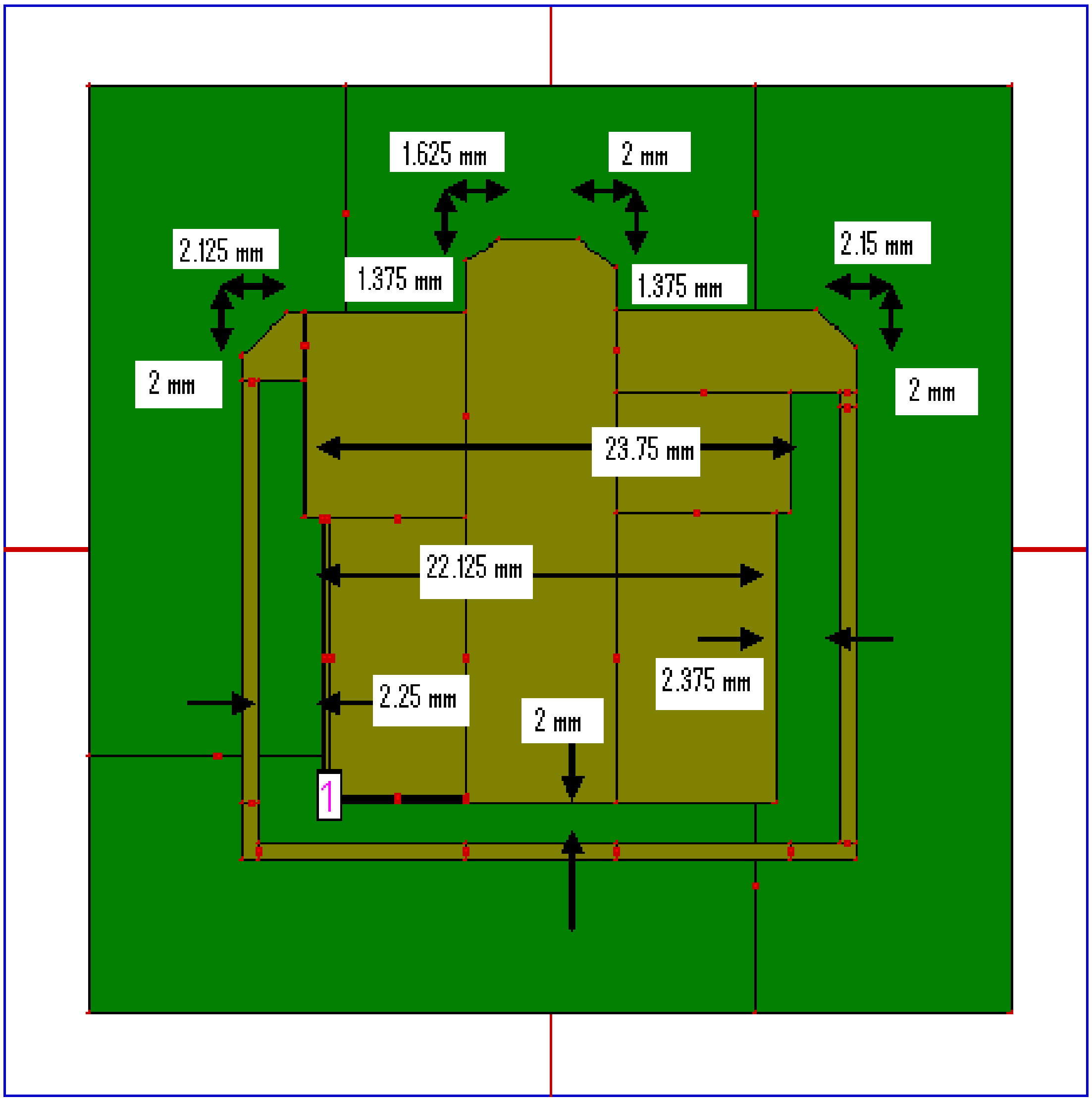

Figure 5.20 Front view of modified square microstrip

patch antenna with slot loaded finite ground

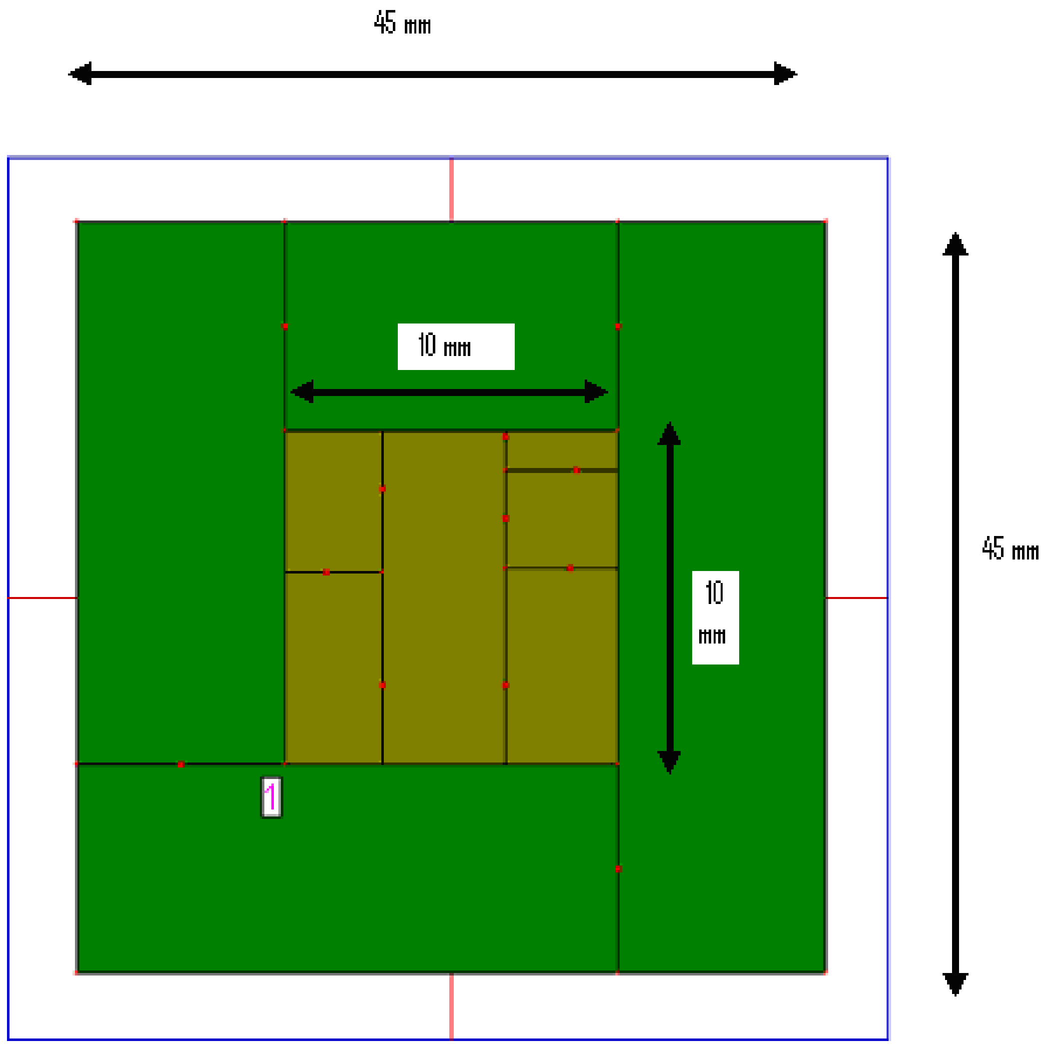

Figure 5.21 Back view of modified square microstrip

patch antenna with slot loaded finite ground

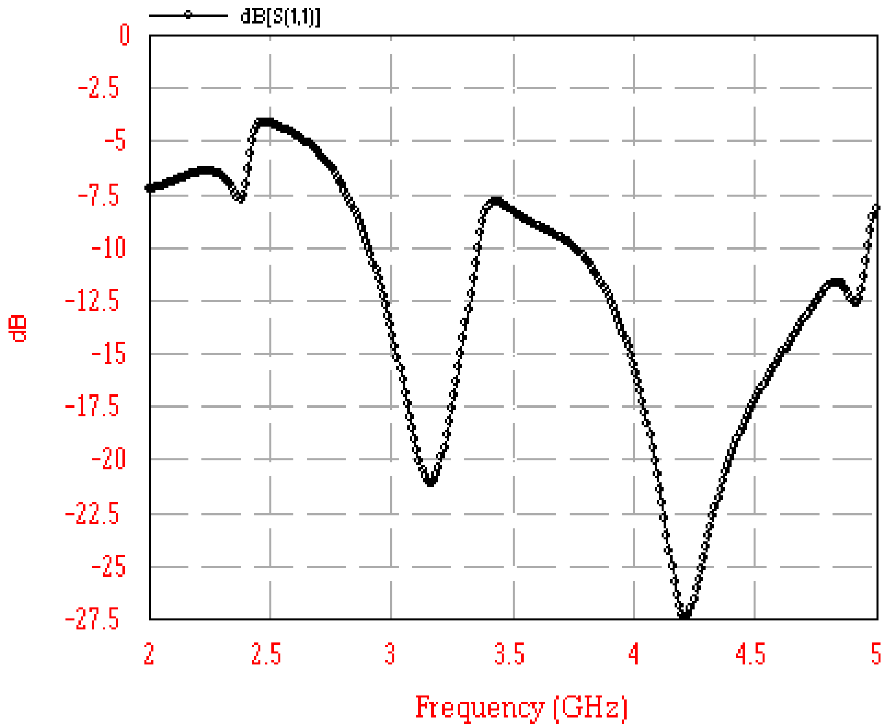

Figure 5.22 Graph between return loss and frequency for antenna design-4

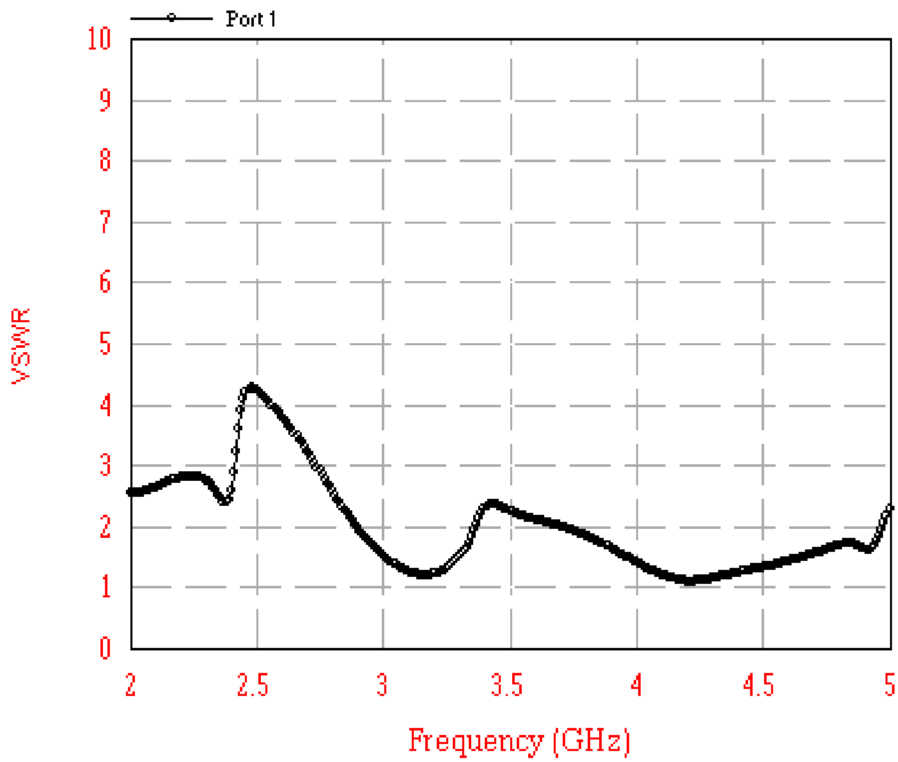

Figure 5.23 Graph between VSWR and frequency for antenna design-4

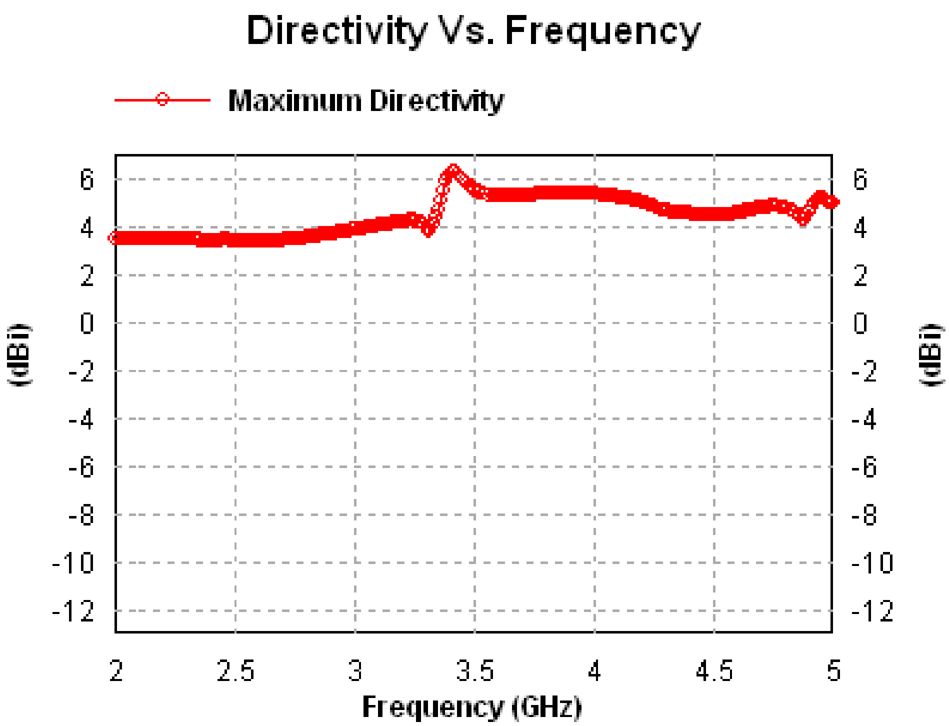

Figure 5.24 Graph between directivity and frequency for antenna design-4

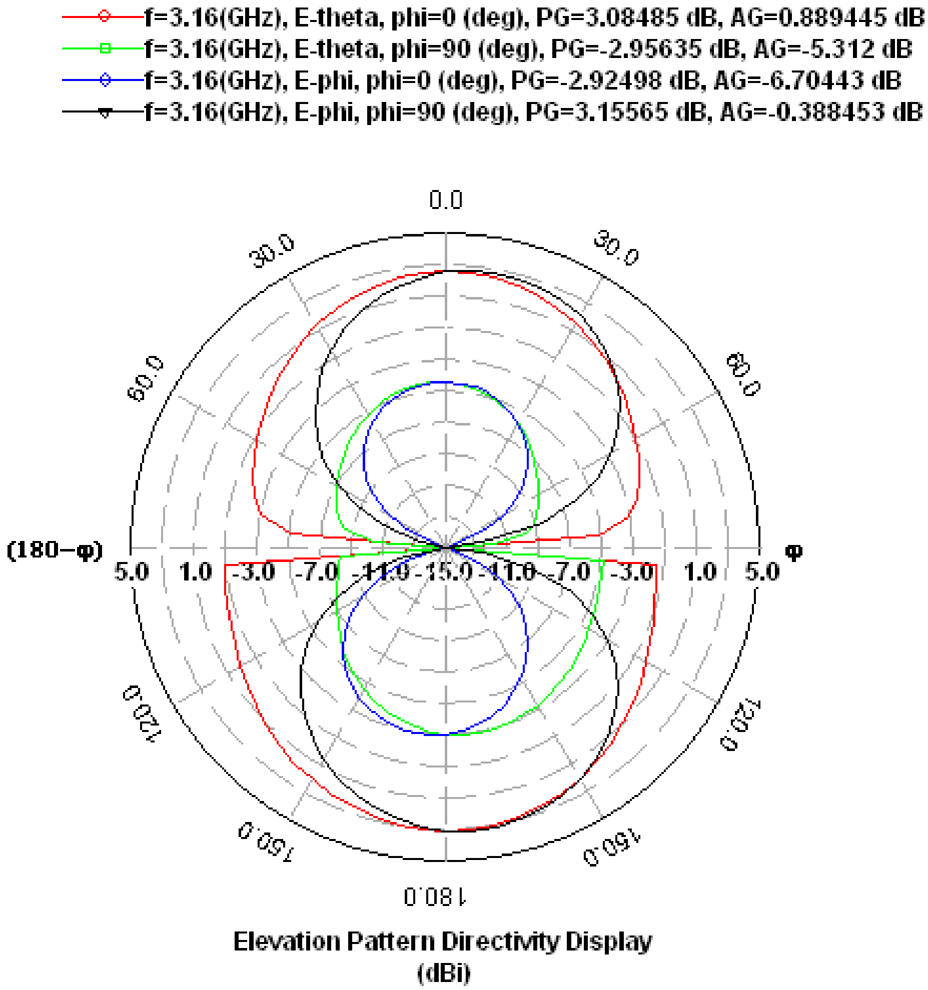

Figure 5.25 Radiation pattern for antenna design-4

at lower resonance frequency f_1 = 3.16 GHz.

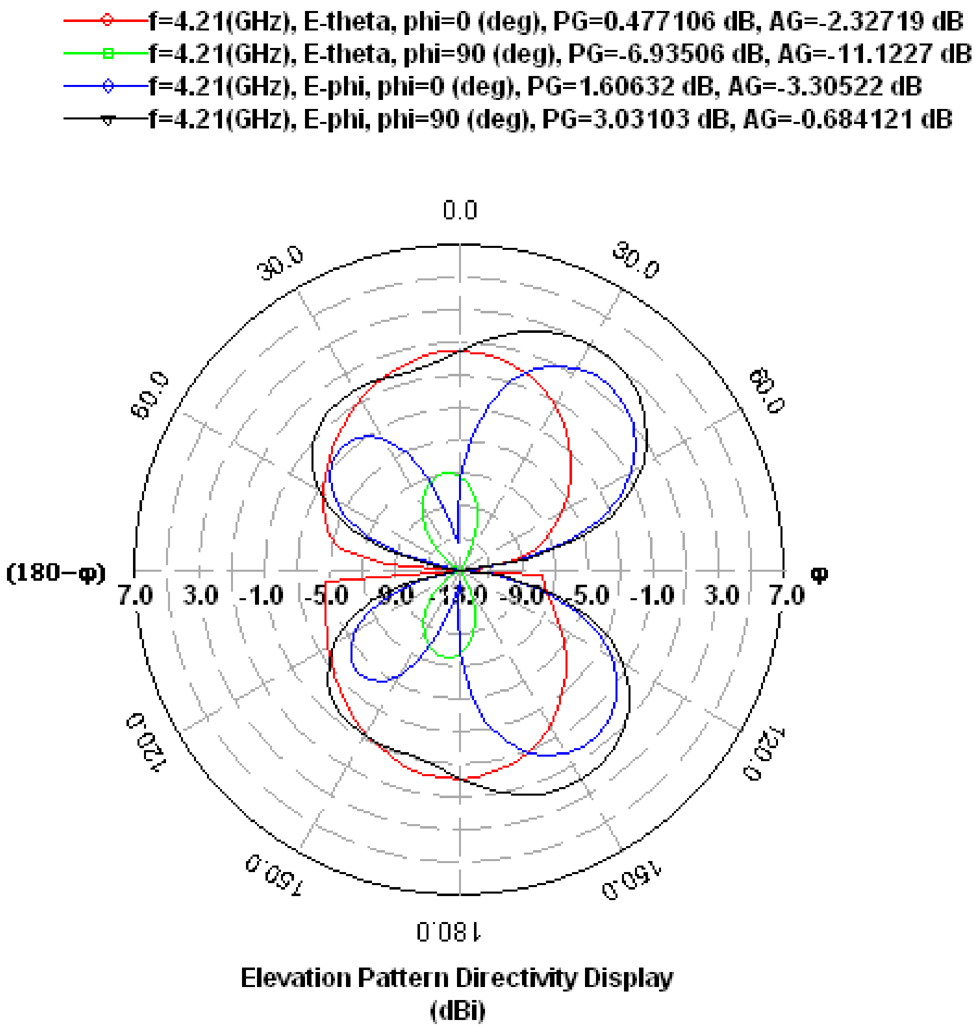

Figure 5.26 Radiation pattern for antenna design-4

at higher resonance frequency $f_2 = 4.21$ GHz

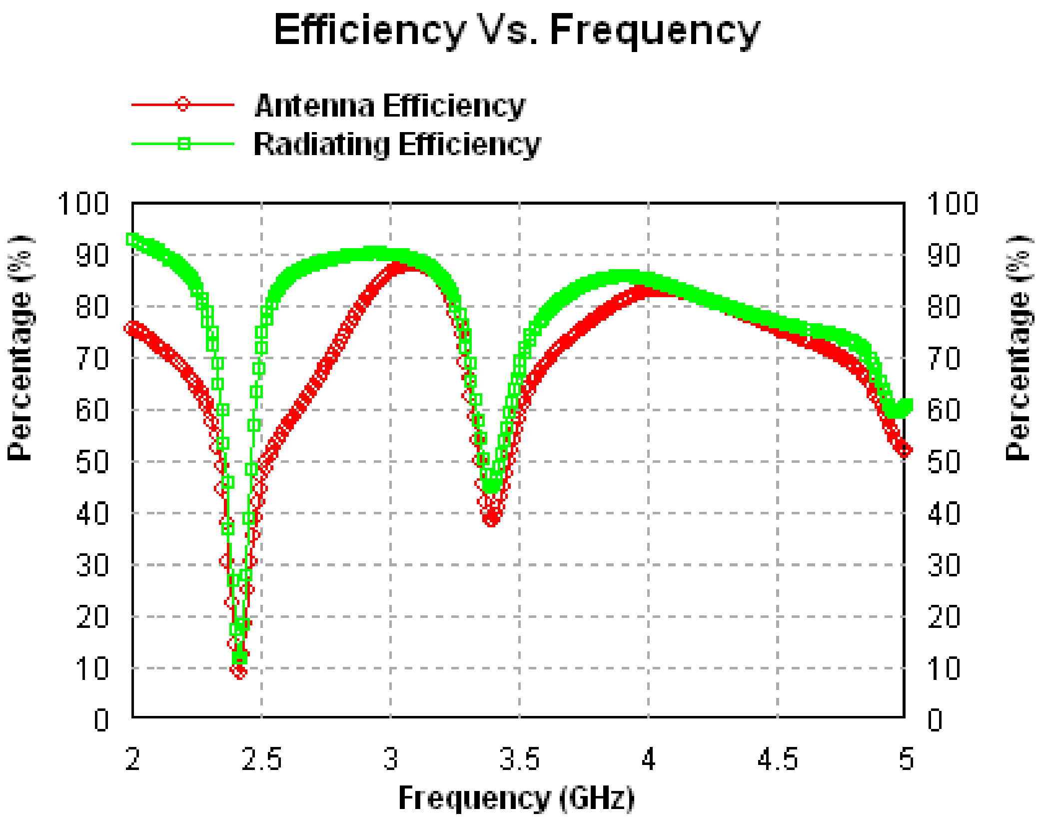

Figure 5.27 Graph between efficiency and frequency for antenna design-4

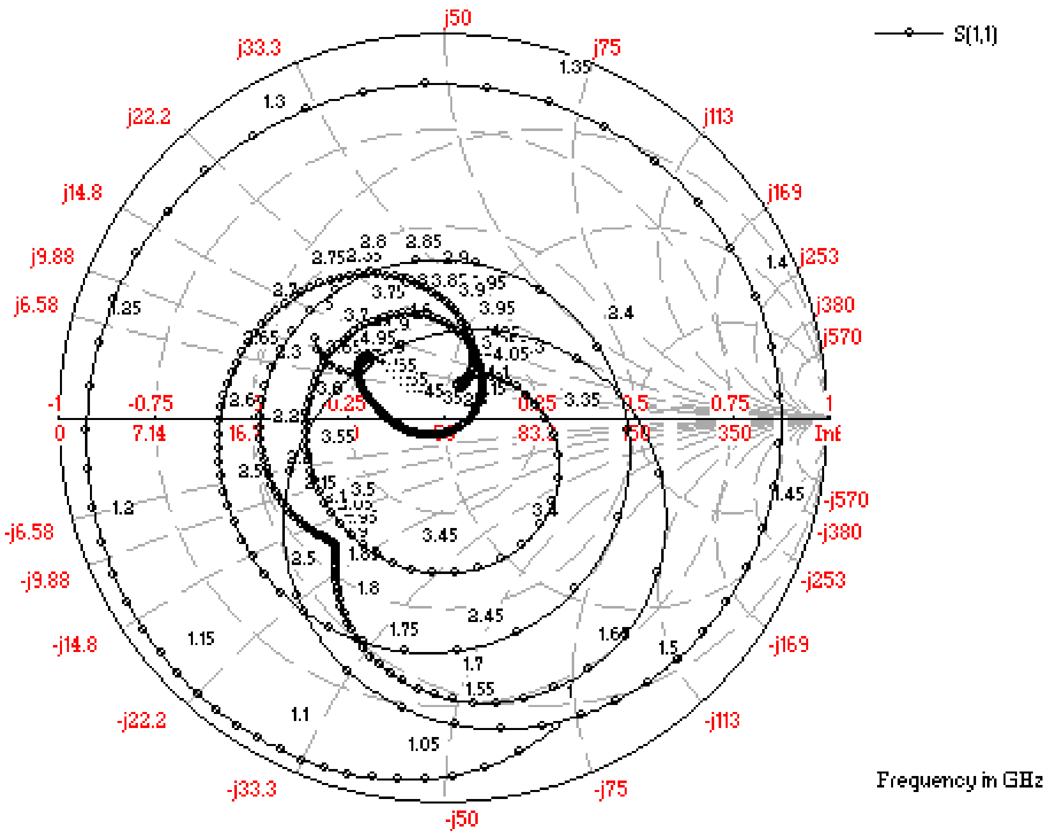

Figure 5.28 Impedance loci for antenna design-4

5.6 CONCLUSION

In this chapter, tunable and dual band microstrip patch antennas have been analyzed. Tunable antennas provide an alternative to a wideband antenna, in which an antenna with a small band width is tuned over a large frequency range.

In the next chapter, compact modified wideband microstrip antenna with increased substrate height will be analyzed.