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Design Microstrip Patch Antenna with EMI Rejection Characteristics for Ultra-wide Band Applications

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Abstract

In this paper design both planner Ultra-wide band and Ultra-wide band antenna with two rejection bands are presented. The antenna consist of a rectangular patch on FR-4 substrate with 50 ohm feed line. The rectangular patch with partial ground having the simulated bandwidth of 7.03GHz range from 3.38 GHz to 10.42GHz. The rejection bands are the WIMAX and WLAN achieved by inserting the stub and slot in the patch and ground. The Rejection bands ranges from 3.24 GHz to 3.83GHz for WIMAX and 5.1 GHz to 5.9 GHz for WLAN. The simulated bandwidth of proposed antenna is 12.56 GHz ranges from 2.88 GHz to 15.44GHz.The proposed antenna having good radiation pattern and gain.

Keywords: Stub, slot, UWB, Patch, Band rejection, HFSS

INTRODUCTION

Earlier systems were narrowband, long range systems but in order to extend the use of available spectrum we are now using broadband systems. One of the main problems in Ultra-wide band system is the interference of narrow bands such as WIMAX and WLAN within the band. The frequency range of WIMAX is from 3.3GHz to 3.8GHz whereas for WLAN it is from 5.1GHz to 5.825 GHz. It is essential to minimize the interference from Ultra-wide band spectrum. As investigated in many research papers different techniques such as antenna design with different types of slot, parasitic strips coupled with radiating patch, ground plane, feed line and two monopoles of same size and a strip to achieve wide bandwidth with band notch characteristic. The aim of my project is to increase percentage bandwidth up to 120% with rejection in WIMAX and WLAN frequency range nearly close to 3.3 to 3.8 GHZ and 5.15 GHz to 5.825 GHz. To achieve this aim, Stub technique and slot insertion technique is used.

The Paper consists of three antenna geometry. One antenna geometry is to reject the WIMAX band. For this L shaped stub is coupled with the patch. The L-stub in the patch effects the current distribution in the patch which helps to reject certain band from the spectrum. In the second geometry is to reject the WLAN frequency band from the Ultra-wide band spectrum. For this a U slot of proper size is inserting in the ground plane at proper location. In both design the partial ground geometry is used for proper impedance matching and to increase the bandwidth of antenna. Both design effects on the quality factor of antenna. As quality factor is directly proportional to the energy stored beneath the patch and inversely proportional to the bandwidth. As the size of ground changed from full the impedance matching improves and bandwidth is also increases due to less energy stored beneath the patch and ground.

In the third antenna design both L-stub and U-slot are used in the single geometry. In this design ground plane further defected to increase. The proposed antenna has a bandwidth of 12.56 GHz ranging from 2.88GHz – 15.44 GHz .WIMAX frequency band is rejected in the range from 3.24GHz to 3.83GHz and WLAN band is rejected in the range from 5.1 GHz - 5.9 GHz. Percentage bandwidth of antenna is 137 %. VSWR graph of proposed antenna which is less than 2 for entire operating bandwidth except the range 3.24GHz to 3.83 GHz and 5.15 GHz - 5.9 GHz. Simulated results of proposed antenna such as Return Loss, VSWR, and Radiation pattern have satisfactory values within desired frequency band.

ANTENNA DESIGN EQUATION

The effective length of the patch Leff now become

$$L_{eff} = L + 2\Delta L \quad (1)$$

$$\Delta L = 0.412h \frac{\varepsilon_{reff}+0.3}{\varepsilon_{reff}-0.258} \left(\frac{W/_{h}+0.264}{W/_{h}+0.813} \right) \quad (2)$$

For a given resonant frequency fo, the effective length is

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

For a rectangular microstrip patch antenna, the resonance frequency for any TM mn mode is given by James and Hall as:

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{reff}}} \left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2 \right]^{0.5} \quad (4)$$

Where m and n are modes along L and W respectively.

The width W is

$$W = \frac{C}{2f_0} \left(\frac{\varepsilon_r + 1}{2} \right)^{-0.5} \quad (5)$$

Where fo = Resonant frequency

C =speed of light in free-space

ANTENNA DESIGN

A. UWB rectangular Antenna

A simple microstrip rectangular patch antenna is designed with low cost FR4 epoxy dielectric substrate with relative permittivity ε_r = 4.4 and thickness h = 1.6 mm as shown in Figure 1.1. In order to fulfill the requirements of a portable device, a microstrip feed line is designed for 50 ohm characteristic impedance with 2.85 mm width. Microstrip feed line width is calculated by transmission line calculator.

The partial ground plane shows better return loss compared to full ground plane because the antenna is transformed from patch type to monopole type by the partial ground plane.

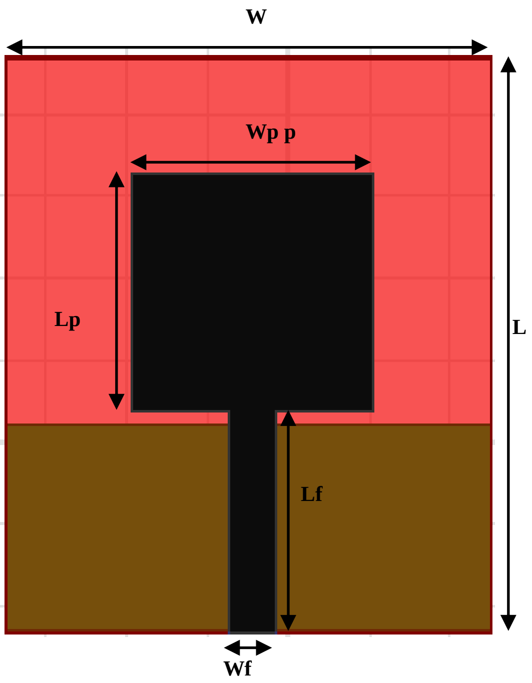

Figure 1.1. Microstrip patch antenna with partial ground plane

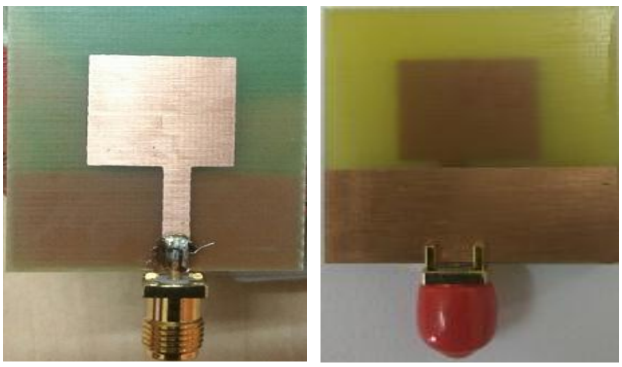

Figure 1.2. Fabricated Microstrip patch antenna with partial ground plane

Reducing the ground plane length up to the point where the patch edge is just above the ground plane thereby providing no distance for distribution of electric and magnetic field energies which in turn results in no impedance matching between the transmission line and the patch. On further reducing the ground plane length such that distance is created between the patch edge and the ground plane. Length of ground plane is decreased from 35 mm to below the edge of the patch as 13.5 mm and the required bandwidth is obtained.

Table 1

S.No	Dimensions of microstrip patch antenna		
	Parameter	***Symbol***	***Dimension(mm)***
1	Substrate width,	W	30
2	Substrate length,	L	35
3	Patch width,	Wp	15
4	Patch length,	Lp	14.5
5	Feedline width,	Wf	2.85
6	Feedline length,	Lf	13.5
7	Ground plane length,	Lg	12.5

B. Microstrip patch Antenna for WIMAX rejection

The antenna with partial ground plane is able to achieve wide frequency range from 3.3 GHz to 10.42 GHz. But WIMAX frequency range from 3.3 GHz to 3.8 GHz exists in this wide frequency range and causes interference to WPAN devices. Many approaches are discussed above to reject this frequency band and stop the function of the antenna in this particular frequency range. So design an antenna with compact size, light weight and broadband width is an important issue. One of the techniques is design an antenna with Stub insertion. In this design methodology, antenna is designed initially with one L-Stub. For this first a rectangular slot cut from the patch then after L-shaped stub insert in the patch and coupled to the patch. The stub insertion effect the current direction in the patch. The size and position of the stub is very important to reject particular band from the spectrum. The size of patch and ground is same as antenna with partial ground. Two corners square also cut from the patch and ground plane to improve the bandwidth of the antenna. The size of the corner slots are 2 x2 mm. The geometry of the antenna is shown in figure 1.2.

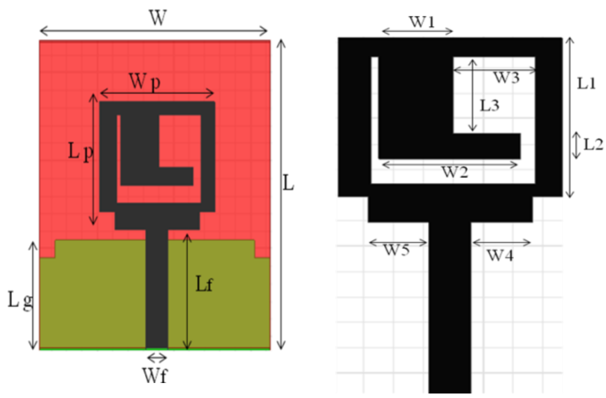

Figure 1.3. Microstrip patch antenna with L stub for WIMAX rejection

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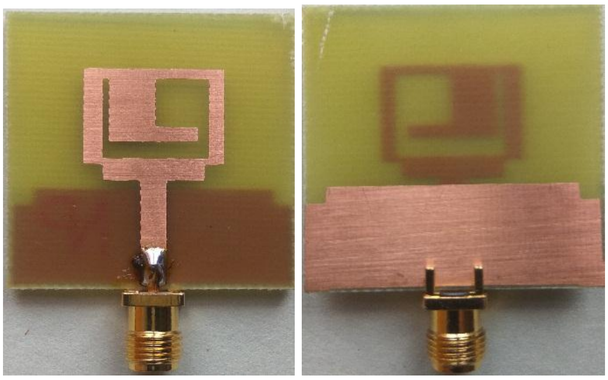

Figure 1.3. Fabricated Microstrip patch antenna with L stub for WIMAX rejection

TABLE II

S.No	Dimensions of microstrip patch antenna		
	Parameter	***Symbol***	***Dimension(mm)***
1	Substrate width,	W	30
2	Substrate length,	L	35
3	Patch width,	Wp	15
4	Patch length,	Lp	14.5
5	Feedline width,	Wf	2.85
6	Feedline length,	Lf	13.5
7	Ground plane length,	Lg	12.5
8	Stub length	L1	12.5
9		L2	2
10		L3	6
11	Stub Width	W1	5
12		W2	9
13		W3	5.5
14		W4	4.05
15		W5	4.1

C. Microstrip patch Antenna for WLAN rejection

The antenna with partial ground plane is able to achieve wide frequency range from 3.3 GHz to 10.42 GHz. But WLAN frequency range from 5.1 GHz to 5.812 GHz exists in this wide frequency range and causes interference to WPAN devices. Many approaches are discussed above to reject this frequency band and stop the function of the antenna in this particular frequency range.

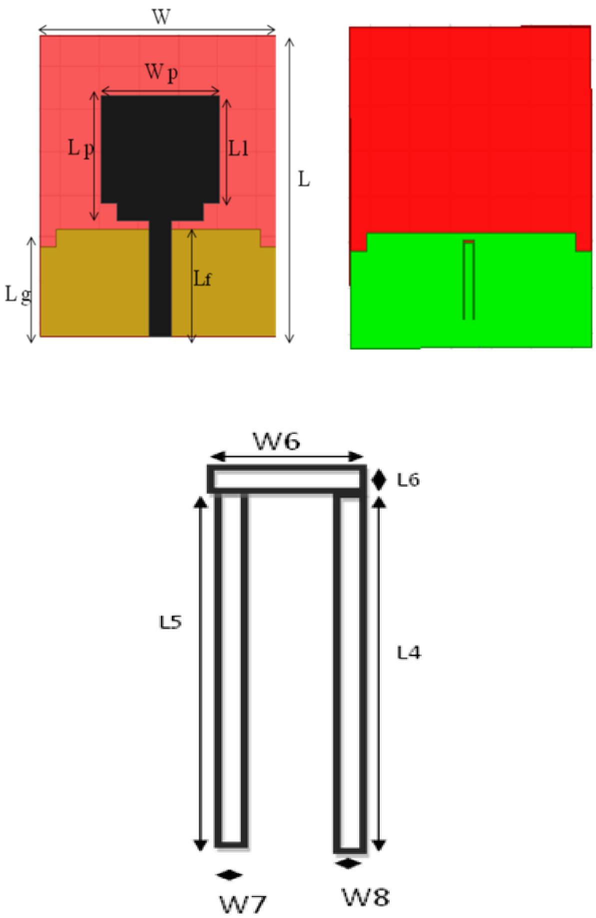

Figure 1.4. Microstrip patch antenna with U slot for WLAN rejection

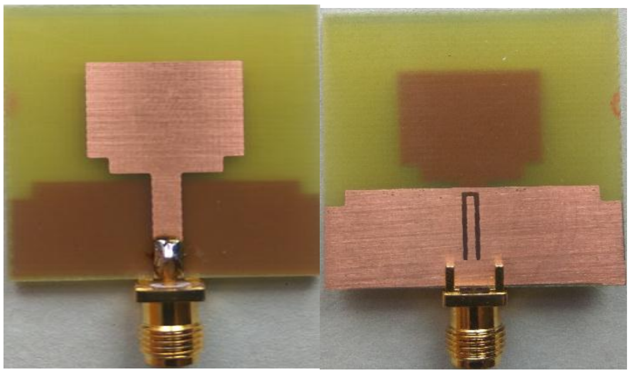

Figure 1.5. Fabricated Microstrip patch antenna with U slot for WLAN rejection

So design an microstrip patch antenna with small/compact size, light weight and good band width is an important issue. One of the techniques is design an antenna with Slot insertion in the ground plane. For this u slot of proper length is cut from ground plane at proper location. The size and position of the slot is very important to reject particular band from the spectrum. The geometry of the antenna is shown in figure 1.3.

TABLE III

S.No	Dimensions of microstrip patch antenna		
	Parameter	***Symbol***	***Dimension(mm)***
1	Substrate width,	W	30
2	Substrate length,	L	35
3	Patch width,	Wp	15
4	Patch length,	Lp	14.5
5	Feedline width,	Wf	2.85
6	Feedline length,	Lf	13.5
7	Ground plane length,	Lg	12.5
8	Length	L1	12.5
9	Slot length	L4	9.5
10		L5	9.5
11		L6	0.25
12	Slot Width	W6	1.5
13		W7	0.25
14		W8	0.25

D. Microstrip patch Antenna for WIMAX and WLAN rejection

The antenna with partial ground plane is able to achieve wide frequency range from 3.3 GHz to 10.42 GHz. But from the simulation graph it is clear that the narrow frequency bands WIMAX and WLAN is not removed from the spectrum. The techniques to remove WIMAX and WLAN are already discussed above. In this antenna geometry both techniques are used together. The size of substrate and ground is same as above structure.

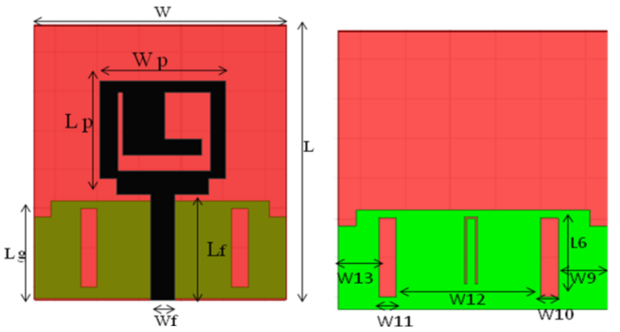

Figure 1.6. Proposed Microstrip patch antenna for WIMAX and WLAN rejection

There are some changes in the ground geometry. In the ground plane two rectangular slits is also removed to improve the directivity and bandwidth of antenna. The band main reason of altering the ground plane is to decrease the value of Q factor which increase the antenna bandwidth. The proposed antenna having a bandwidth 12.56GHz from 2.88GHz to 15.44GHz.The percentage bandwidth is 137% which more than the targeted bandwidth of dissertation. The Proposed antenna structure is given in the figure 1.7.

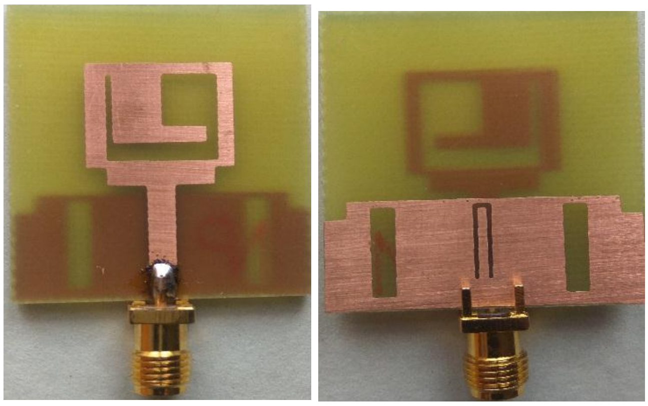

Figure 1.7. Fabricated Microstrip patch antenna for WIMAX and WLAN rejection

TABLE IV

S.No.	Dimensions of Proposed microstrip patch antenna		
	Parameter	***Symbol***	***Dimension(mm)***
1	Substrate width,	W	30
2	Substrate length,	L	35
3	Patch width,	Wp	15
4	Patch length,	Lp	14.5
5	Feedline width,	Wf	2.85
6	Feedline length,	Lf	13.5
7	Ground plane length,	Lg	12.5
8	Rectangular Slot length	L6	12.5
9	Width from corner	W9	5.5
10	Width of rectangular slots	W10,W11	2
11	Distance between rectangular slots	W12	16
12	Width from corner	W13	4.4

SIMULATION RESULTS

HFSS software used for simulation. HFSS is stands for high frequency structure simulator. It is electromagnetic (EM) field simulator for arbitrary three dimensional design modeling with high performance capability that takes lead among all well known Microsoft Windows graphical user interface. It employs the Finite Element Method (FEM), adaptive meshing, and impressive graphics to give us better performance and insight to our entire 3D EM problem Ansoft HFSS can be used to calculate parameters such as Return Loss, VSWR Parameters, Resonant Frequency, and Radiation Pattern.

The simulated and measured result of return loss and VSWR of optimized rectangular microstrip patch antenna is presented in Figure 1.8 (a) and 1.8(b) respectively. According to figure 1.8(a) the simulated antenna has broadband characteristic i.e. frequency band of 3.55 GHz – 11 GHz and bandwidth of 7.5 GHz at -10 dB level. The antenna has resonating frequencies at 4.84 GHz with S11 – 16.99dB and 10.06 GHz with S11 – 13.88dB and VSWR is obtained below 2. Figure 1.8. (b) shows the simulated VSWR of the microstrip patch antenna having partial ground plane as a function of frequency. VSWR of

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antenna in the entire bandwidth range from 3.55 GHz to 11GHz is well within desired 2:1 VSWR ratio.

The simulated and measured result of return loss and simulated result of VSWR of the microstrip patch antenna with L-stub is presented in Figure 1.10 (a) and 1.10 (b) respectively. From the Figure 1.10 (a), the proposed antenna has a bandwidth of 8.63 GHz ranging from 2.88 GHz – 15.2 GHz and WIMAX band is rejected in the range from 3.25 GHz – 3.83GHz.The percentage bandwidth of antenna is to 136%. The presence of L-stub caused a band notch in frequency range of 3.24 GHz to 3.87 GHz. VSWR graph of proposed antenna which is less than 2 for entire operating bandwidth except the range 3.24GHz - 3.87 GHz. The antenna has impedance matching at resonance frequencies 3.116 GHz with S11 -20.93 dB, 4.256 GHz with S11 -20.69dB and 7.905 GHz with S11 -33.68 dB using microstrip line feed.

The simulated and measured result of return loss and simulated result of VSWR of the microstrip patch antenna with U-slot is presented in Figure 1.12 (a) and 1.12 (b) respectively. From the Figure 1.12 (a), the proposed antenna has a bandwidth of 11.98 GHz ranging from 3.37 GHz – 15.35 GHz and WLAN band is rejected in the range from 5.1 GHz – 5.83GHz. The percentage bandwidth of antenna is to 127%. The presence of U- Slot caused a band notch in frequency range of 5.1 GHz to 5.83 GHz. VSWR graph of proposed antenna which is less than 2 for entire operating bandwidth except the range 5.1 GHz - 5.83 GHz. The antenna has impedance matching at resonance frequencies 4.08 GHz with S11 -34.99 dB and 8 GHz with S11 -31.27 dB using microstrip line feed.

The simulated result of return loss and VSWR of the microstrip patch antenna for WIMAX and WLAN rejection is presented in Figure 1.14 (a) and 1.14 (b) respectively. From the Figure 1.14 (a), the proposed antenna has a bandwidth of 12.56 GHz ranging from 2.88 GHz – 15.44 GHz. The percentage bandwidth of antenna is to 137%. From Figure 1.14(a) and 1.14(b) it is clear that for above geometry both WIMAX and WLAN rejected from the antenna spectrum. The antenna having a good impedance matching at frequencies 3.12GHz, 4.24GHz and 8.72 GHz with S11parmeter of -17.89dB, -32.39dB and -22.83dB. The radiation pattern or gain pattern is shown in Figure 1.16, 1.17and 1.17

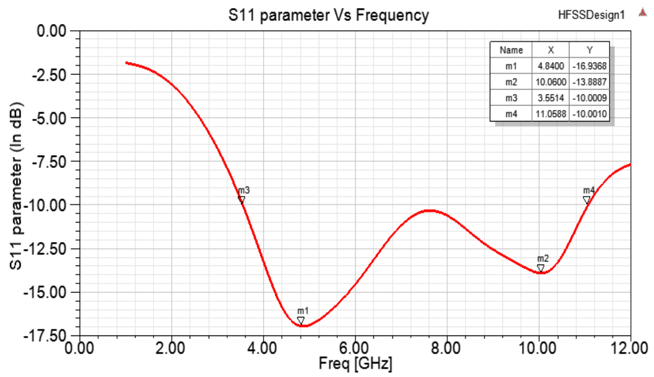


Figure 1.8. (a) S11 parameter variation w.r.t frequency for partial ground microstrip patch antenna

The bandwidth of the antenna can be said to be those range of frequencies over which the return loss is greater than - 10 dB (corresponds to a VSWR of 2). The bandwidth of the proposed patch antenna is 12.56 GHz. The maximum gain of 8.5dBi is at frequency 3.12GHz. This gain variation is at Phi = 0 deg and theta = 0 deg. The Value of Gain Varies from 9dBi to 11dBi in the frequency range 2.88GHz to 15.44GHz. The value of gain at 4.24GHz is 5.34dBi.

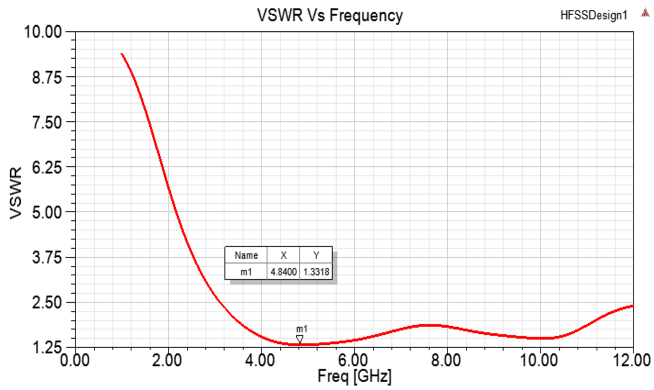
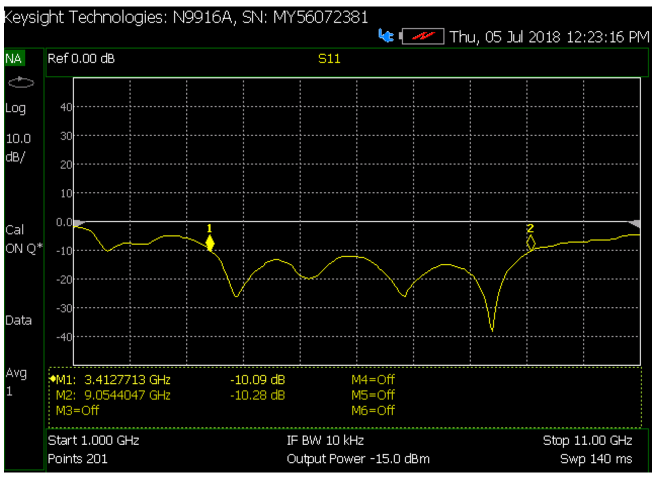
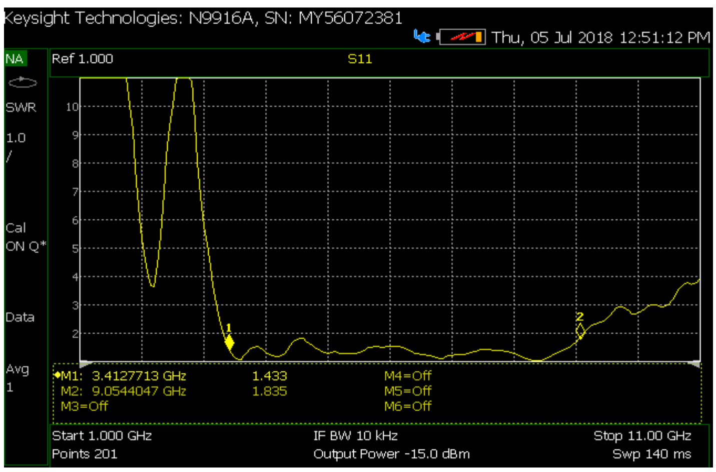


Figure 1.8. (b) VSWR variation w.r.t frequency for partial ground microstrip patch antenna





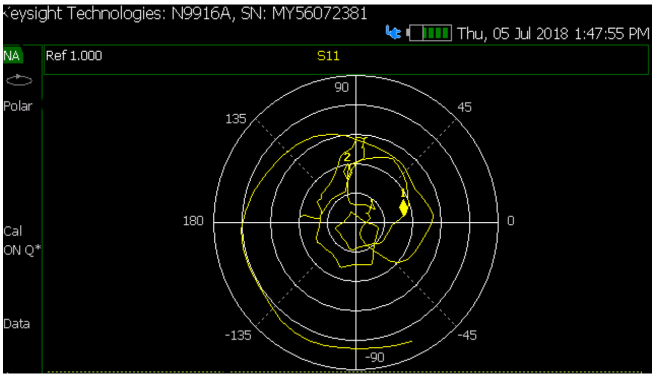


Figure 1.9. VNA Measured Result for partial ground structure

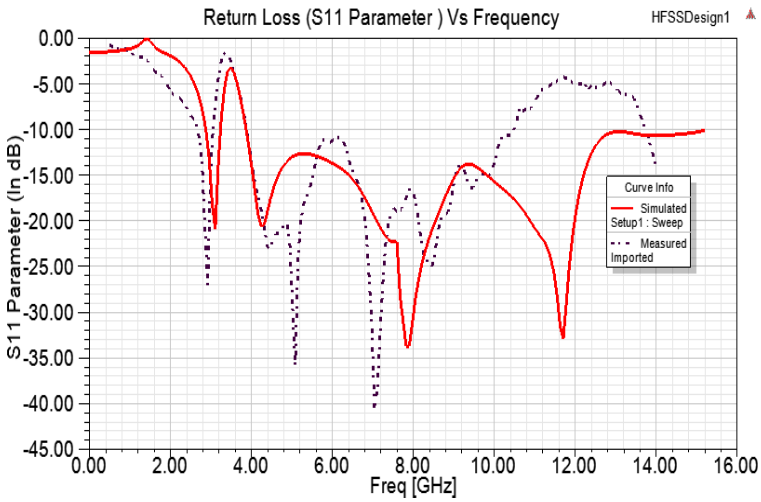


Figure 1.10. (a) S11 parameter variation w.r.t frequency with WIMAX rejection

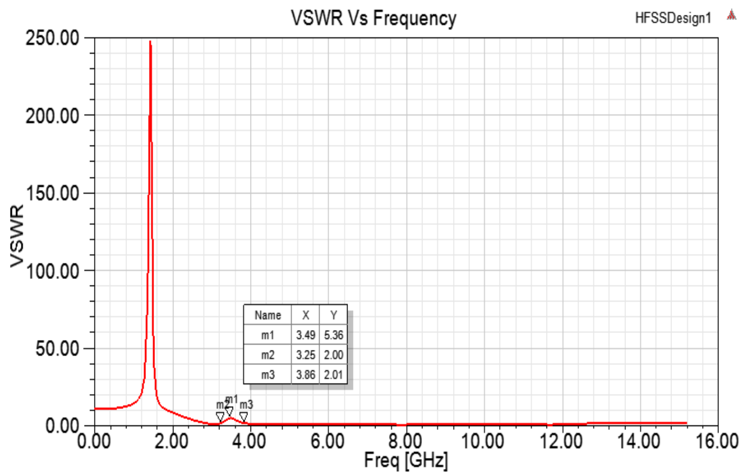


Figure 1.10. (b) VSWR variation w.r.t frequency with WIMAX rejection

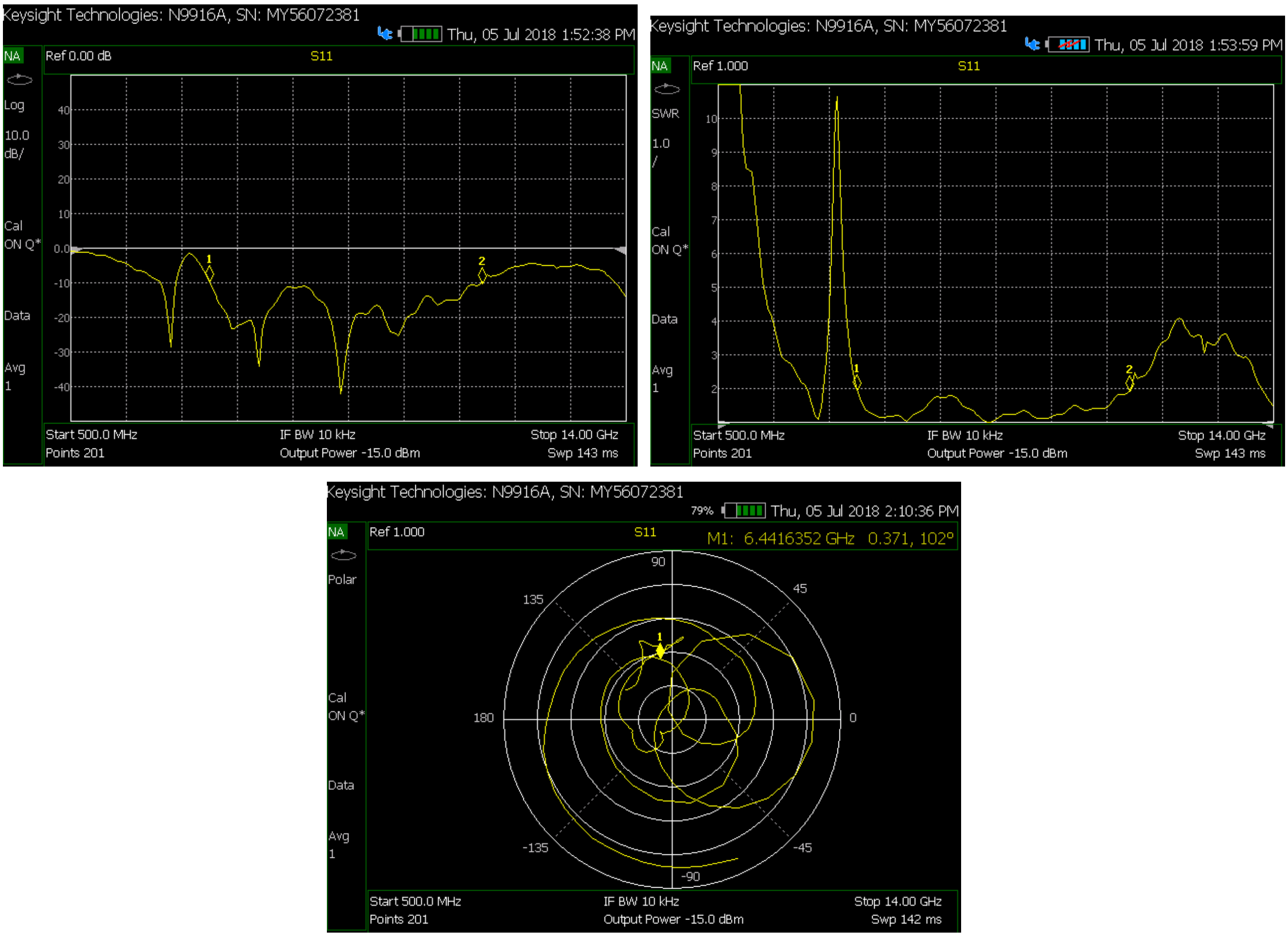


Figure 1.11. VNA Measured Result for WIMAX rejection MSA

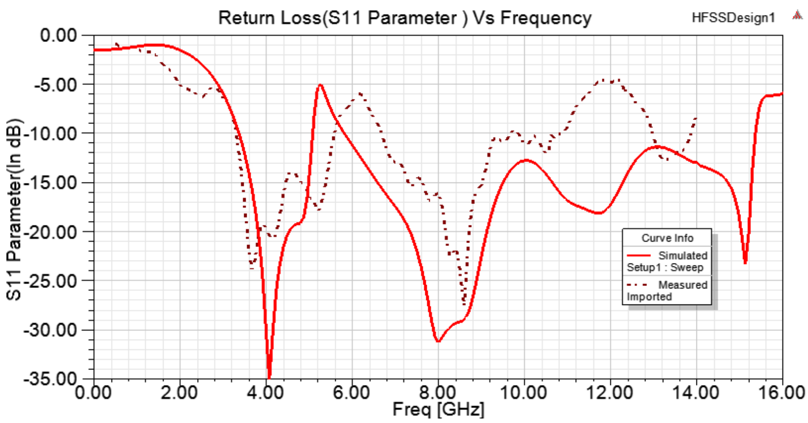


Figure 1.12. (a) S11 parameter variation w.r.t frequency with WLAN rejection

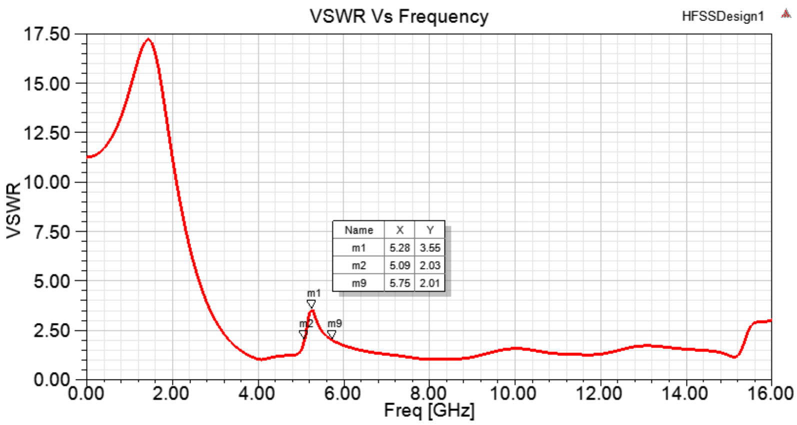


Figure 1.12. (b) VSWR variation w.r.t frequency with WLAN rejection

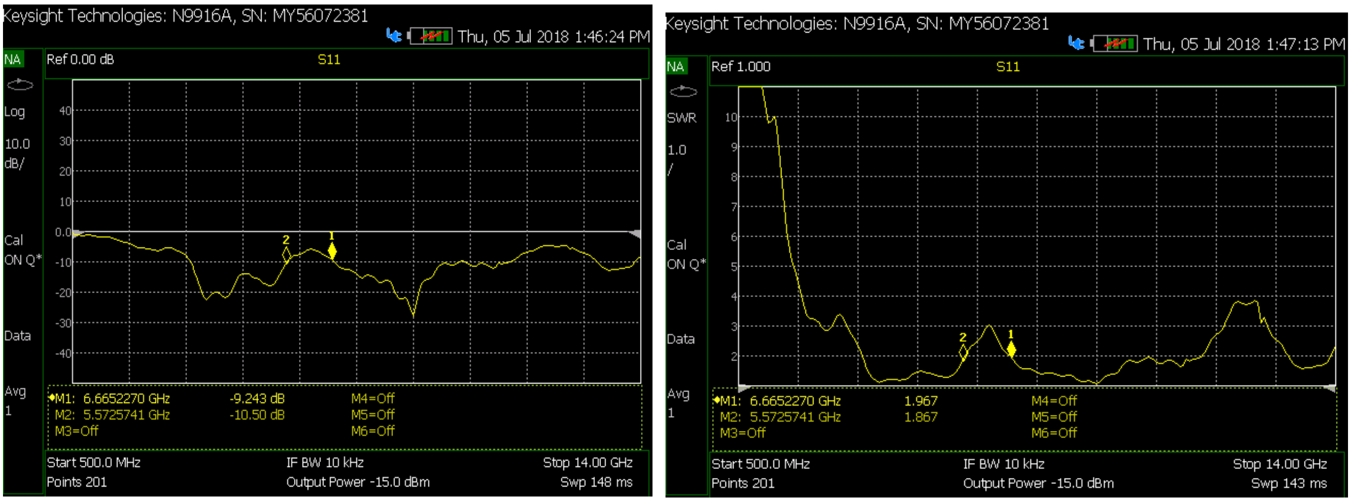


Figure 1.13. VNA Measured Result for WLAN rejection MSA

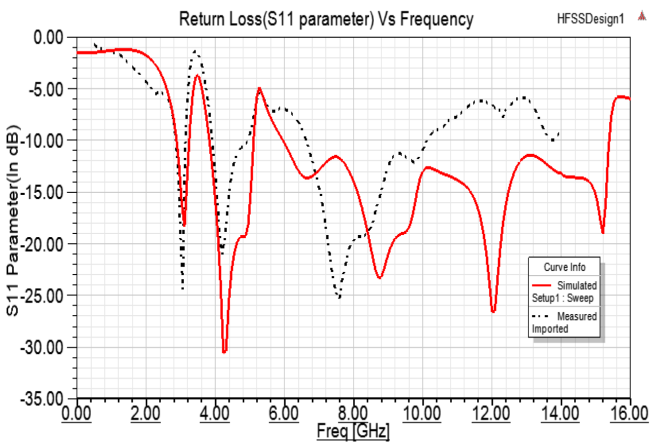


Figure 1.14. (a) S11 variation w.r.t frequency for Proposed antenna

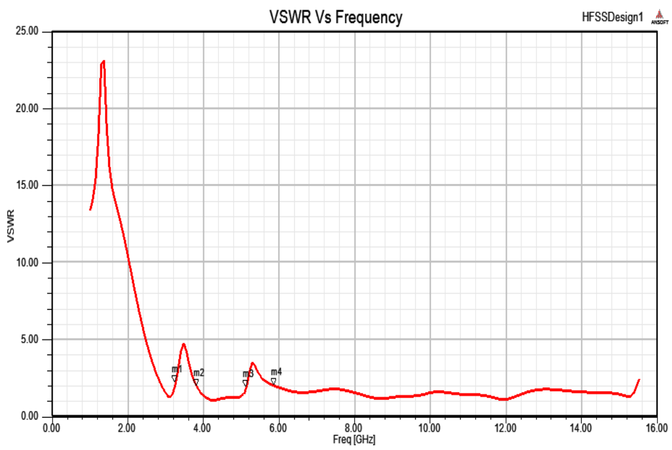


Figure 1.14. (b) VSWR w.r.t frequency for Proposed antenna

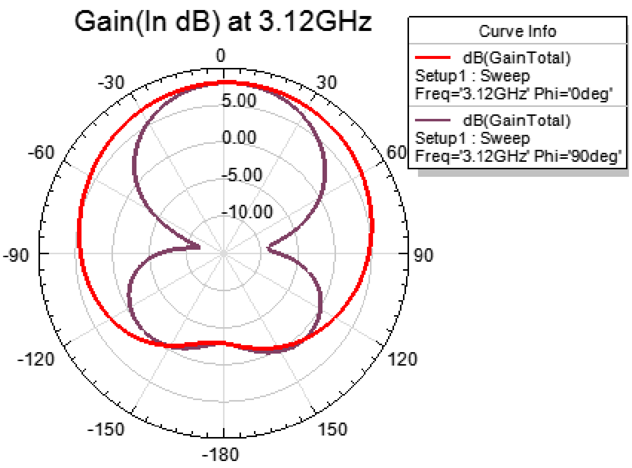


Figure 1.15. Radiation pattern at 3.12GHz for Proposed antenna

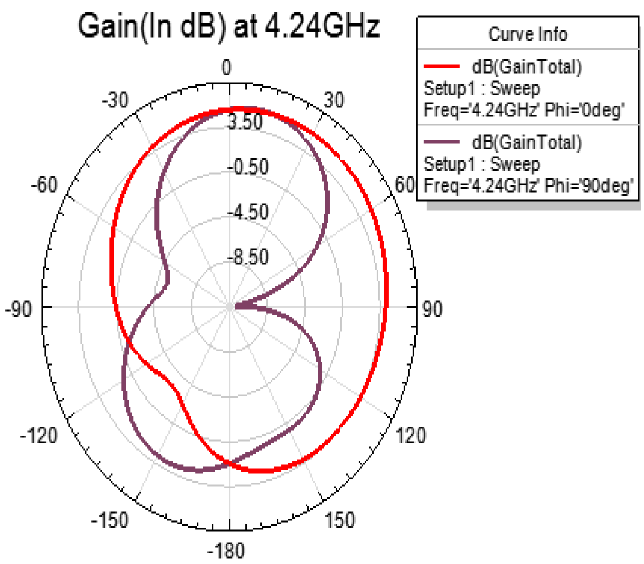


Figure 1.16. Radiation pattern at 4.24GHz for proposed antenna

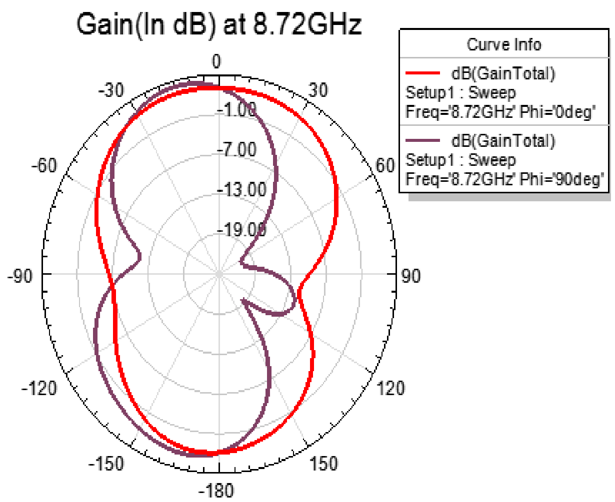


Figure 1.17. Radiation pattern at 8.72GHz for proposed antenna

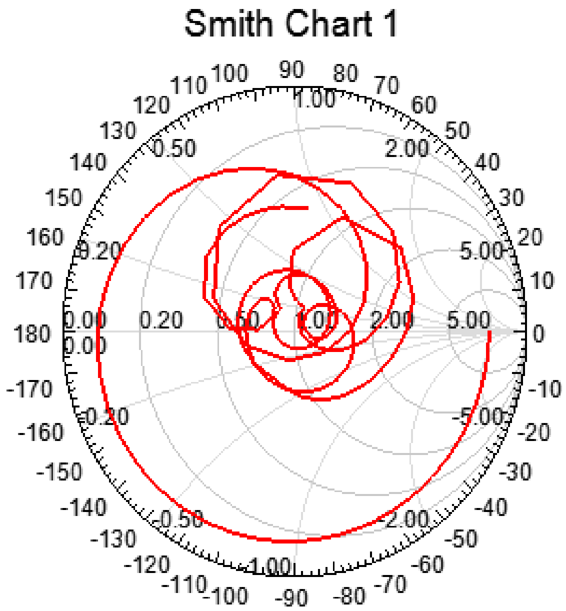


Figure 1.18. Smith Chart for proposed antenna

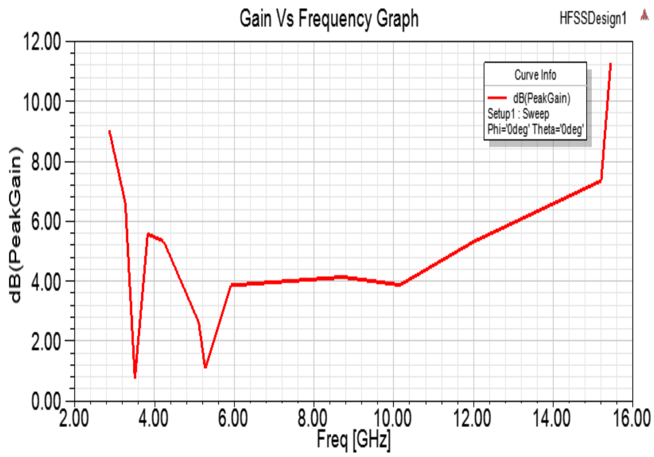


Figure 1.19. Gain Vs Frequency for proposed antenna

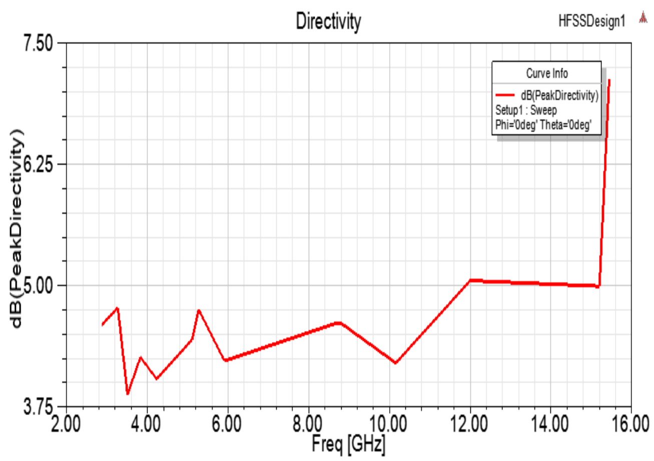


Figure 1.20. Directivity Vs Frequency for proposed antenna

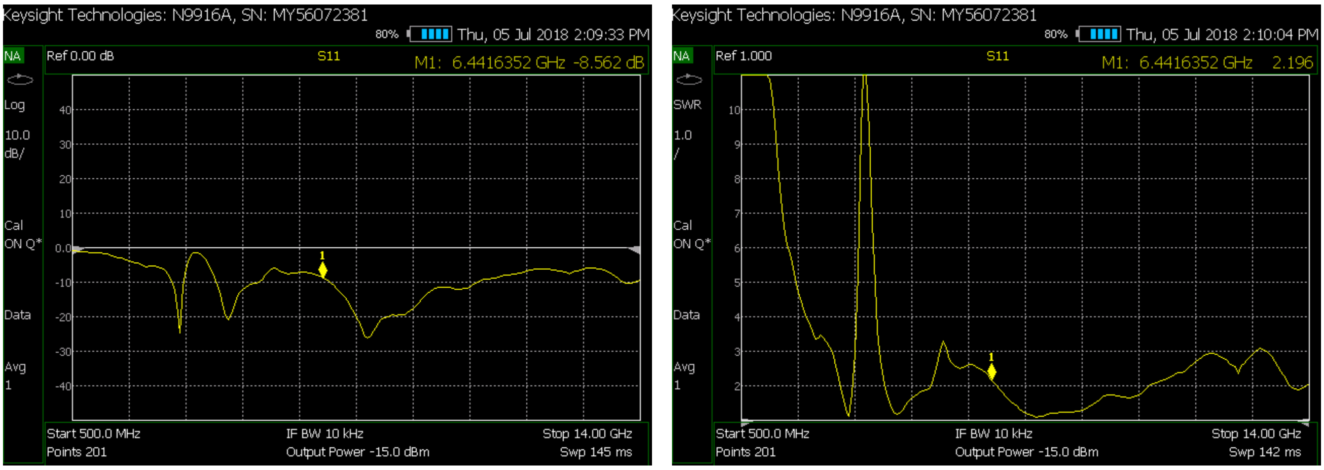


Figure 1.21. VNA Measured Result for Proposed MSA

CONCLUSION AND FUTURE SCOPE

The proposed antenna has a bandwidth of 12.56 GHz ranging from 2.88GHz – 15.44GHz .WIMAX frequency band is rejected in the range from 3.24GHz to 3.8GHz and WLAN band is rejected in the range from 5.1 GHz - 5.9 GHz. Percentage bandwidth of antenna is to 137 %. VSWR graph of proposed antenna which is less than 2 for entire operating bandwidth except the range 3.24GHz to 3.8GHz and 5.15 GHz - 5.83 GHz. Simulated results of proposed antenna such as Return Loss, VSWR, and Radiation pattern have satisfactory values within desired frequency band. For use of meta material and low dielectric constant material such as RT Duroid for more improvement in bandwidth.

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