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A Novel Microstrip Patch Antenna With Multiband Characteristic

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***Abstract*—** a novel Microstrip patch antenna with hash shaped slotted ground plane and Π + U slotted patch is presented. Hash shaped slot in ground plane provides the multiple resonances. Proposed antenna provides wide bandwidth and reduced return loss. In this paper large bandwidth is achieved by introducing slots in ground plane and conducting patch. Designed antenna cover the WLAN 5.2 GHz (5.15-5.35 GHz) band. Performance parameters Return loss, bandwidth, gain, directivity, and voltage standing wave ratio (VSWR) have been analyzed for Simple Rectangular Patch Antenna and for Proposed multiband Microstrip Patch Antenna by using Finite element method based High Frequency Structure Simulator software (HFSS).

Keywords- *DGS, HFSS Software, Microstrip Patch antenna, return loss, VSWR.*

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1. Introduction

Rapid development in wireless communication devices increase the demand of antenna which operate at more than one frequency [8]. Dual frequency behavior is required in mobile and satellite communication [10]. Microstrip patch antenna is widely employed because of its numerous advantages such as low profile, low cost, ease of fabrication. Narrow bandwidth [7] and low gain are the main limitation of microstrip patch antenna. In literature various techniques have been studied to improve the bandwidth of microstrip patch antenna such as increasing substrate thickness, using low dielectric substrates , stacking geometry, shorting pins , cutting slots and slits in radiating patch and embedding slots in ground plane. Rectangular and circular patches are preferred because of ease of analysis [1]. Defected Ground Structure is studied to improve the basic characteristics of conventional microstrip patch antenna [5].

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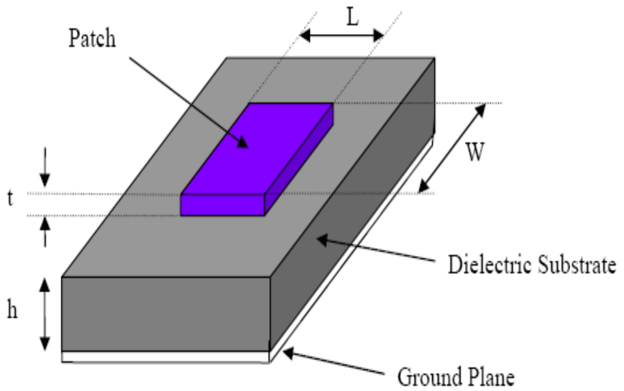

Figure 1 Basic Rectangular Microstrip Patch Antenna

Slits and slots in the patch increase the length of the path of current hence resonant frequency is lowered and dual frequency operation is achieved [3]. Microstrip Patch Antenna in its simplest configuration consists of a radiating patch on one side of dielectric substrate which has a ground plane on other side [1-2]. Most preferred method to feed microstrip antenna are microstrip line feed, coaxial feed, aperture coupled feed, and proximity coupled feed. Proposed antenna is designed by using Microstrip line inset feed [6].

2. Design Specifications

Three main components for designing of microstrip antenna are resonant frequency, dielectric material and height of substrate. The proposed antenna is designed for 5.2 GHz frequency. For the designing of antenna FR4 epoxy is used having dielectric constant 4.4 with 0.02 loss tangent and height 1.5748 mm. High dielectric constant is used for size reduction. Transmission line model design equations are used for calculation of length and width of patch and ground plane. Substrate dimensions are same as ground plane. Antenna is designed with Patch width W=17.55 mm and length L= 13.21 mm.

Width of the patch is calculated by formula given below -

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

C = $3*10^8$ m/s, Dielectric constant ϵ_r = 4.4, Resonant frequency f_r = 5.2 GHz
After calculation Patch width W = 17.55 mm.

Effective dielectric constant calculation (ϵ_{reff})

$$\epsilon_{reff} = \frac{\mathcal{E}_r+1}{2} + \frac{\mathcal{E}_r-1}{2}\left(1+12\frac{h}{w}\right)^{-\frac{1}{2}}$$

Substitute ϵ_r = 4.4. h = 1.5748 mm, W = 17.55 mm

Effective dielectric constant ϵ_{reff} = 3.879

Length extension calculation

$$\Delta L = 0.412h\,\frac{\epsilon_{reff}+0.3 \quad \left(\frac{W}{h}+0.264\right)}{\epsilon_{reff}-0.258 \quad \left(\frac{W}{h}+0.8\right)}$$

Put ϵ_{reff} = 3.879, h = 1.5748 mm, W = 17.55 mm

Obtained length extension ΔL = 0.718 mm

Effective length calculation

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$$L_{eff} = \frac{C}{2f_r\sqrt{\epsilon_{reff}}}$$

$C = 3*10^8$ m/s, fr = 5.2 GHz
L_{eff} = 14.64 mm

Actual length calculation

$$L = L_{eff} - 2\Delta L$$

L_{eff} = 14.64 mm, ΔL = 0.718 mm
L= 13.20 mm

Ground plane dimensions are calculate by

$$W_g = 6h + W$$
$$L_g = 6h + l$$

3. DESIGN AND SIMULATION

Inset feed Simple Rectangular Patch Antenna is designed with the specifications discussed above but length of patch is reduced to enhance the performance parameters. The designed antenna has Patch length L=12.95 mm and Width W= 17.55 mm. Ground plane dimensions are W_g = 27 mm and L_g = 22.88 mm.

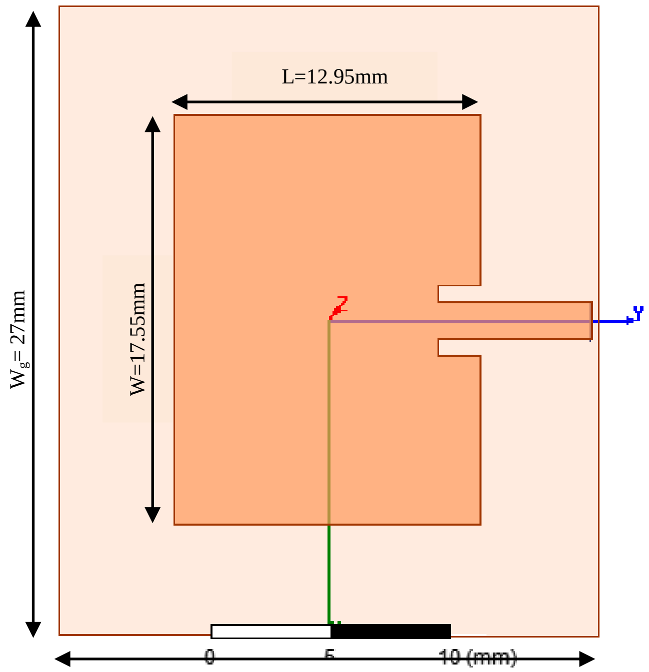

Figure 2 Simple Rectangular Microstrip Patch Antenna

Return loss versus frequency graph is shown in below figure 3. Antenna resonates at three frequencies 5.24 GHz, 7.70 GHz and 10.38 GHz with return loss -27.26 dB, -10.38 dB and -11.42 dB respectively. It is observed from figure 3 that bandwidth at 5.24 GHz is 244 MHz (5.1122-5.3569 GHz). It covers the WLAN frequency range 5.15-5.35 GHz. Figure 4 and 5 shows the 3D polar plot for Gain 5.03 dB and directivity 6.62 dB at fundamental frequency 5.24 GHz.

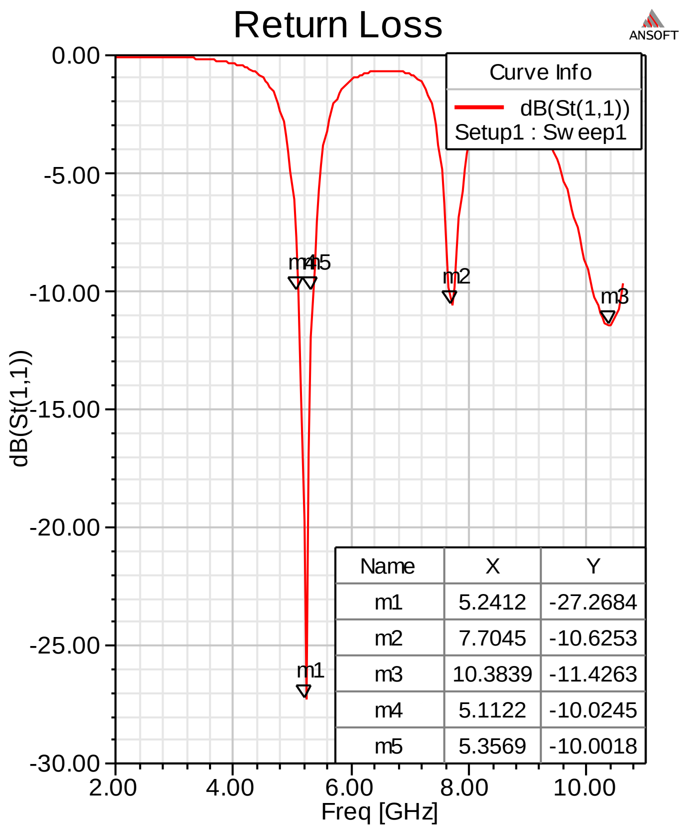

Figure 3 Return Loss of Simple Rectangular Microstrip Patch Antenna

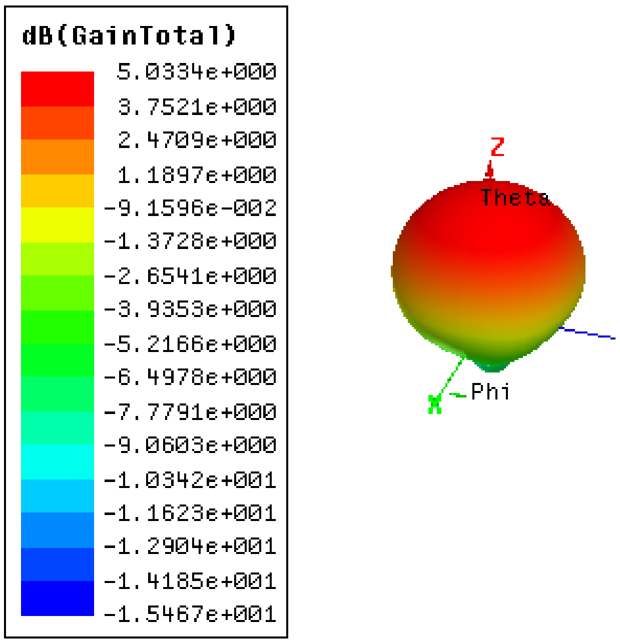

Figure 4 3D Polar Plot for Gain of Simple Rectangular Microstrip Patch Antenna

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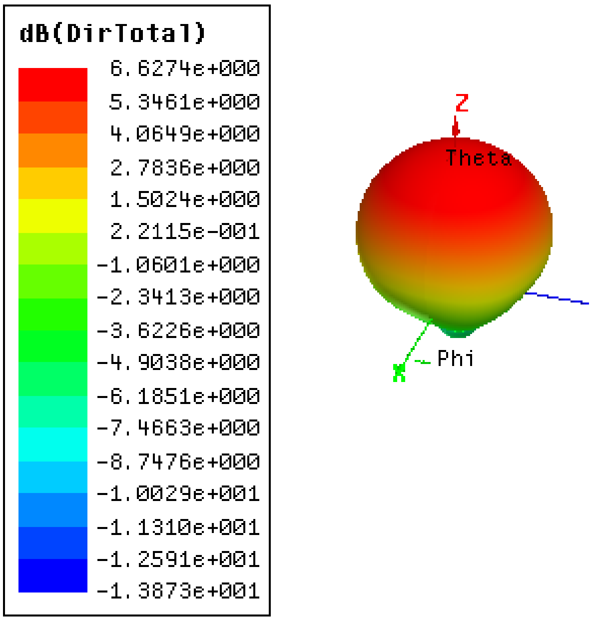

Figure 5 3D Polar plot for Directivity of Simple Rectangular Microstrip Patch Antenna

Figure 6 indicates VSWR (voltage standing wave ratio) of Simple Rectangular Microstrip Patch Antenna. Value of VSWR lies between 1 and 2 for all resonant frequencies.

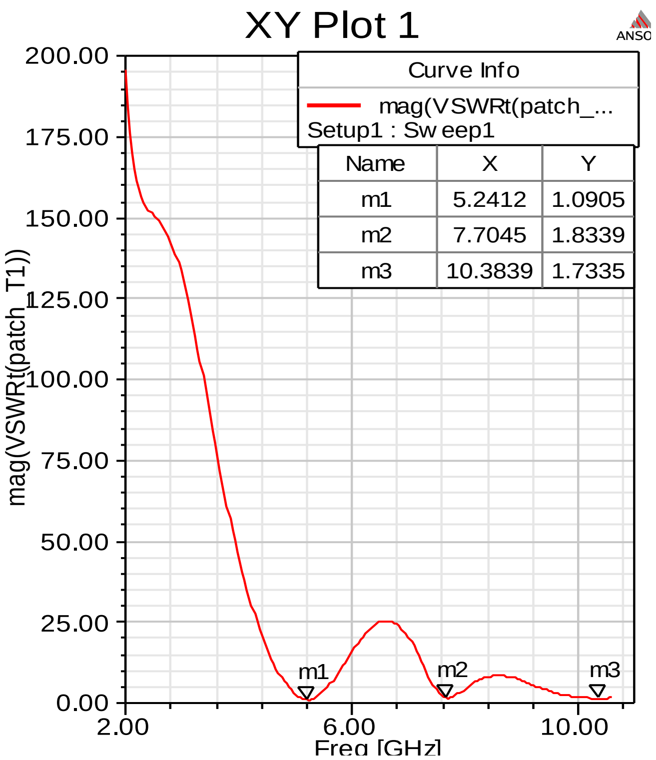

Figure 6 VSWR for Simple Rectangular Patch Antenna

3.1 Slotted patch and Hash shaped DGS structure in ground plane

Proposed Antenna is designed by cutting hash shaped slot in ground plane and Π and U shaped slot in patch as shown in figure 7. Large bandwidth and reduced return loss is achieved by cutting multiple slots on ground plane and in patch. Slot width is kept small 0.1mm. Proposed antenna is designed with same dimensions as discussed in section 2.

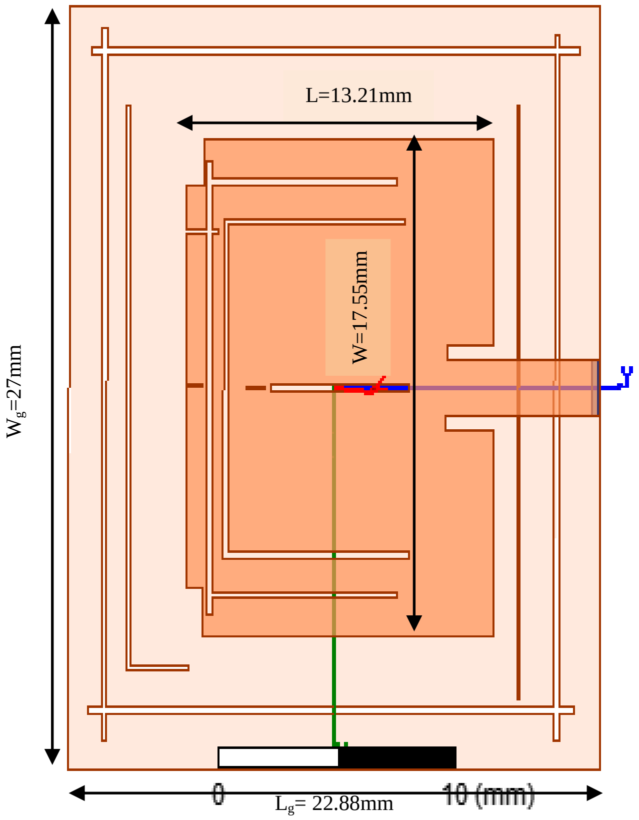

Figure 7 Hash shaped DGS and Π+U Slotted Patch

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Fundamental resonant frequency is lowered from 5.4261 GHz to 5.23 GHz by cutting slots .The proposed antenna resonates at multiple frequencies and has large bandwidth 540 MHz (5.1699-5.7105 GHz) at fundamental resonant frequency 5.2 GHz as shown in figure 8. Figure 8 depicts the return loss of the designed antenna. With the combination of slots in patch and DGS structure multi-frequency resonance is obtained. Designed antenna resonates at 5.2 GHz, 5.58 GHz, 6.06 GHz, 8.0 GHz, 9.77 GHz, and 10.51 GHz with return loss of -30.07dB, -15.04 dB, -12.68 dB, -24.93 dB, -11.17 dB, -14.54 dB as shown in figure 3. Antenna has minimum return loss -30.07 dB at fundamental frequency 5.24GHz. 4.91 dB gain is obtained at 5.58 GHz with directivity of 6.36 dB. 3.44 dB gain and 5.46 dB directivity are at 6.06 GHz. At 8 GHz 3.09 dB gain and 5.46 dB directivity is observed. Value of gain is 4.01 dB for 9.77 GHz with 5.80 dB directivity and 10.51 GHz has 3.29 dB gain and 5.80 dB directivity.

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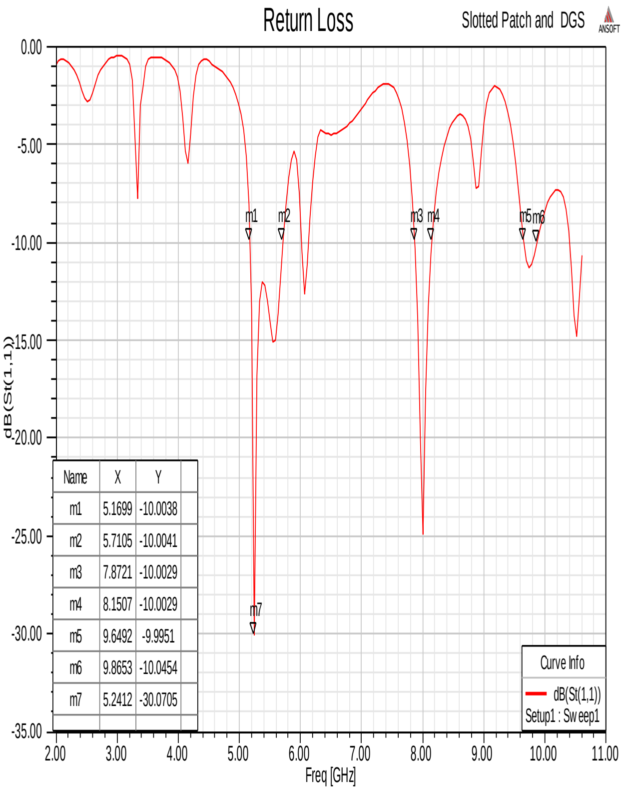

Figure 8 Return Loss of Proposed Antenna

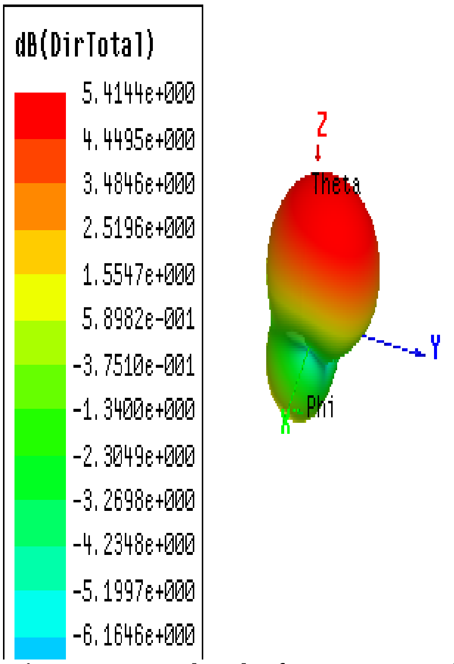

Figure 10 3D Polar Plot for Directivity of Proposed Antenna

Figure 9 and 10 represents the 3D polar plot for gain and directivity for proposed antenna at 5.24 GHz frequency.

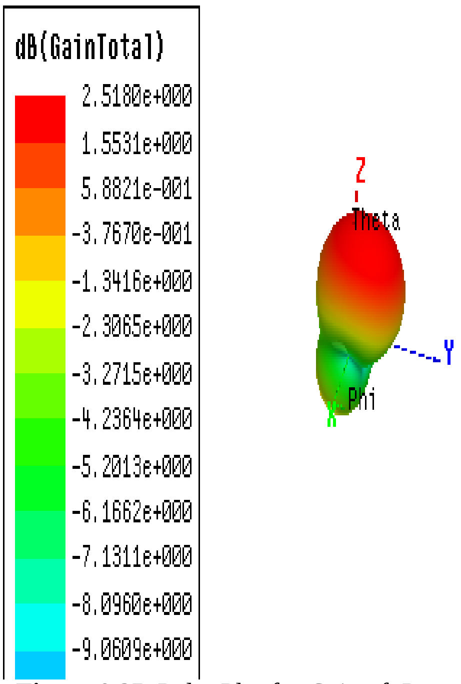

Figure 9 3D Polar Plot for Gain of Proposed Antenna

Figure 6 shows the VSWR for proposed multiband antenna. Minimum VSWR is achieved 1.06 at 5.2 GHz and 1.12 at 8.00 GHz. Voltage standing wave ratio indicates the impedance matching of antenna. For perfect matching VSWR should unity.

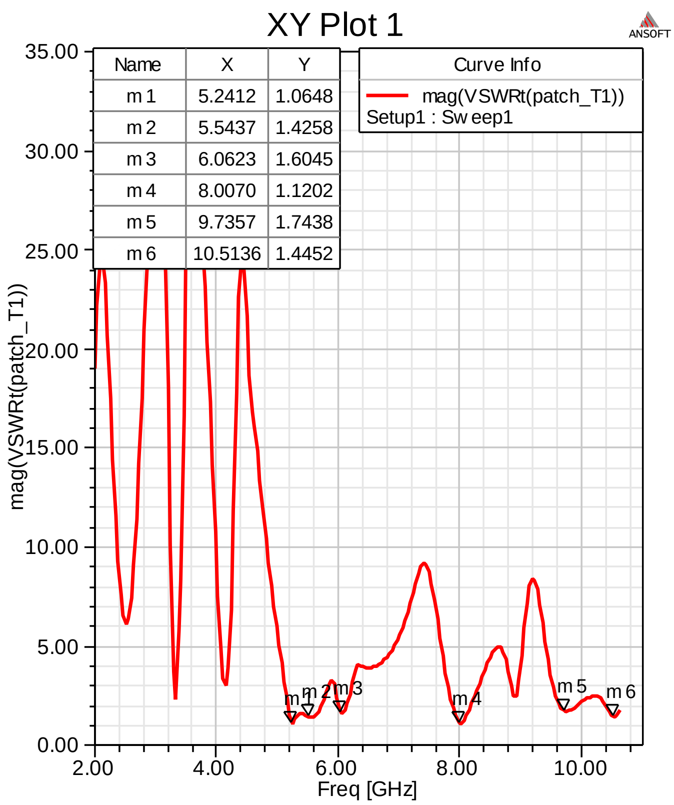

Figure 11 VSWR of Proposed Antenna

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3.2 Effect of Changing Feed Width and Inset Gap

By changing feed width and inset gap of Feed line in Proposed Design results are analyzed. When feed width and inset gap is reduced then it has minimum return loss -34.21 dB at 5.2 GHz (5.16-5.69 GHz) with a gain 2.46 dB and directivity 5.36 dB. Antenna resonates at six different frequencies as shown in figure.

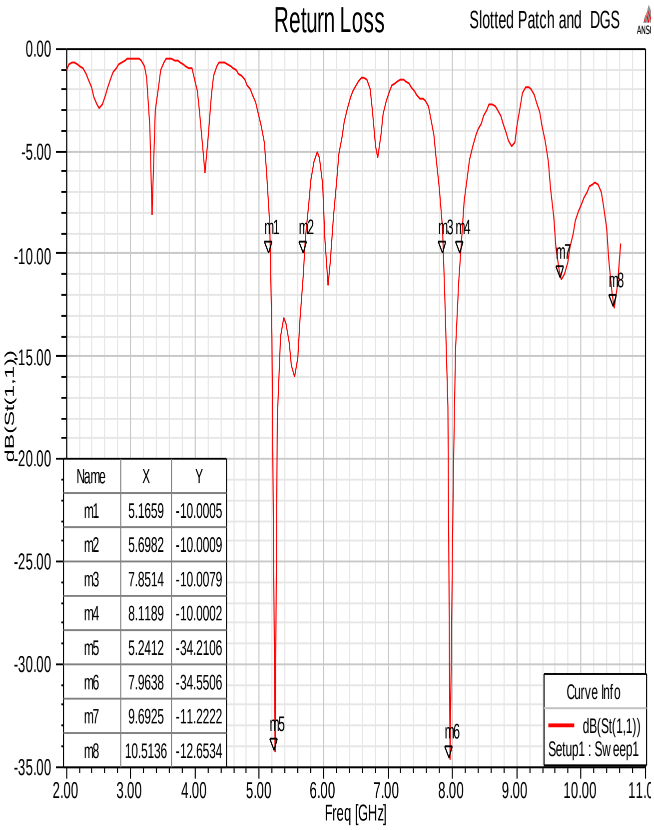

Figure 12 Return Loss of Proposed Antenna with Change in Feed Width and Inset Gap

4. Conclusion

Proposed antenna is designed by introducing multiple slots in Patch and Ground Plane. Better return loss, directivity and VSWR is achived because of these slots. Antenna has a wide bandwidth at 5.24 GHz (5.16-5.71 GHz) which covers the WLAN frequency band 5.15-5.35 GHz. Designed antenna resonates at six different frequencies. Results are analyzed by changing the width of feed line and inset gap and observed that impedance matching is good because it has minimum value of reflection coefficient -34.21 dB at 5.24GHz . It covers the C band and X band and used for satellite and radar communication. Designed antenna is better in terms of bandwidth and return loss.

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