Design of Microstrip Patch Antenna by Introducing Defected Ground Structure

Harpreet Kaur
Student
ECE Department, BGIET, Sangrur, India

Monika Aggarwal
Associate Professor
ECE Department, BGIET, Sangrur, India

ABSTRACT
This paper proposes a novel Inset Feed Microstrip patch antenna with Z and F shape defect in ground plane. Initially simple inset feed rectangular Patch Antenna is designed and results are analyzed. Further this design is modified by etching Z and F shaped defect on ground plane. Defected Ground Structure is studied to enhance the performance parameters of microstrip patch antenna. Proposed antenna provides wide bandwidth and reduced return loss. 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 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

1. INTRODUCTION
Wireless communication is the fastest growing field in communication industry. Antenna is an important element in wireless system. Handheld devices in wireless communication raise the demand of compact and multiband antenna. Microstrip antenna because of its small size employed in wireless communication. Microstrip patch antenna is widely used because of its numerous advantages such as low profile, low cost, ease of fabrication [1]. Narrow bandwidth and low gain are the main limitation of microstrip patch antenna [2]. 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. Defected Ground Structure is studied to improve the basic characteristics of conventional microstrip patch antenna [9]. An antenna with multiband characteristics and high bandwidth is required for wireless applications. Different feeding techniques are available to excite microstrip patch antenna. In wireless communication an antenna to cover more than one frequency band is required to support more applications with single antenna. Different techniques to achieve multiband operation are like Probe Compensation (L-shaped probe), Parasitic Patches, Direct-Coupled Patches, Slot and Slit loaded patches (U or V- shaped slots and E patch, U-Shaped Slit, Stacked Patches, Patch with parasitic strip and the use of Electromagnetic Band Gap (EBG) structures[9]. Most of these methods require complex feeding techniques and complex structures like more layers and parasitic structures. In order to avoid the complexity of structure, an inset feed rectangular Microstrip Patch antenna is designed by embedding slots in ground plane to obtain multiband characteristics.

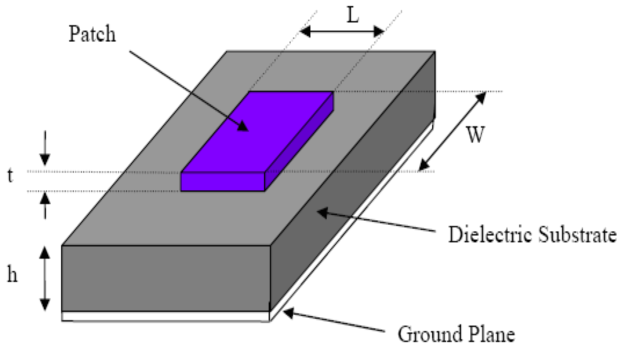

Fig 1: Basic Microstrip Patch Antenna

2. ANTENNA DESIGN
Three main components for designing of microstrip antenna are resonant frequency, dielectric material and substrate height. The proposed antenna resonates at 5.2 GHz frequency. For the designing of antenna FR4 epoxy is used having dielectric constant 4.4 with 0.02 loss tangent. High dielectric constant is used for size reduction. Width and length is calculated by using transmission line model equations.

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 = 17.55mm.

Effective dielectric constant calculation (ϵ_{reff})

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

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

Effective dielectric constant ϵ_{reff} = 3.879

Length extension calculation

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

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

Obtained length extension $\Delta L = 0.718$mm

Effective length calculation

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

$C = 3* 10^8$ m/s, $f_r = 5.2$GHz

$L_{eff} = 14.64$mm

Actual length calculation

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

$L_{eff} = 14.64$mm, $\Delta L = 0.718$ mm

$L = 13.20$mm

Ground plane dimensions are calculated by
Transmission line model is suitable for infinite ground planes but practically we should have finite ground plane. If we take the size of ground plane is greater than the patch dimensions by six times the substrate height similar results can be obtained as with infinite ground plane. Therefore length and width of ground is given

$W_g = 6h + W$

$L_g = 6h + L$

3. SIMULATION RESULTS

3.1 Inset feed Simple Rectangular Microstrip Patch Antenna

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

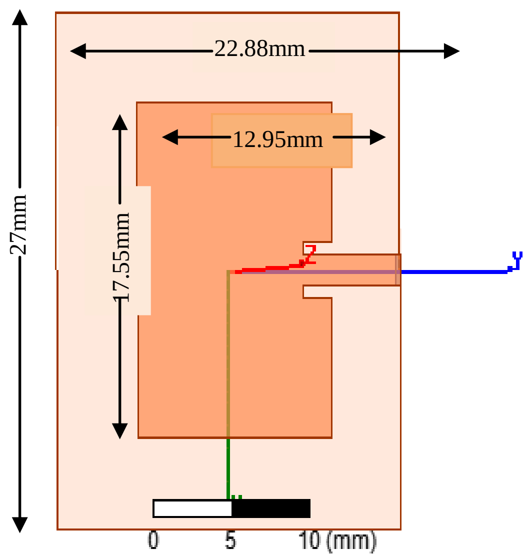

Fig 2: Geometry of Simple Rectangular Microstrip Patch Antenna

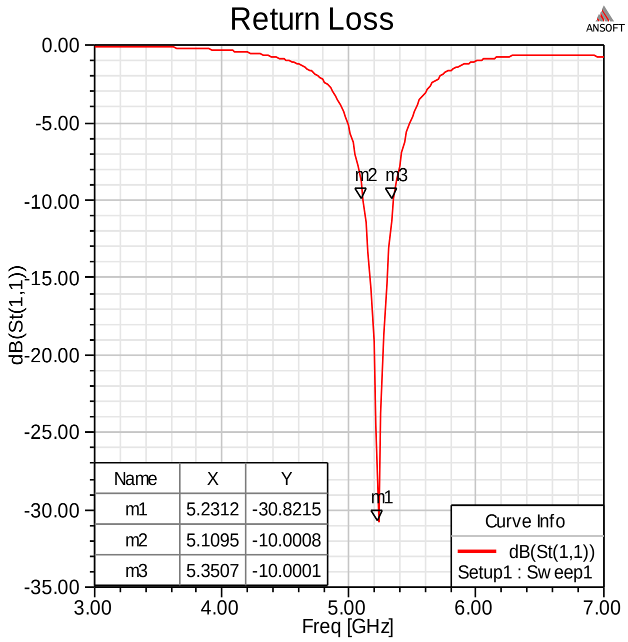

Fig 3: Return Loss of Simple Rectangular Microstrip Patch Antenna

Return loss versus frequency graph is shown in figure 3. Antenna resonates at 5.23 GHz with return loss -30.82 dB. Bandwidth of antenna can be calculated from return loss graph. It is observed from figure 3 that bandwidth at 5.23GHz is 241 MHz (5.1095-5.3507 GHz) It covers the WLAN frequency range 5.15-5.35 GHz.

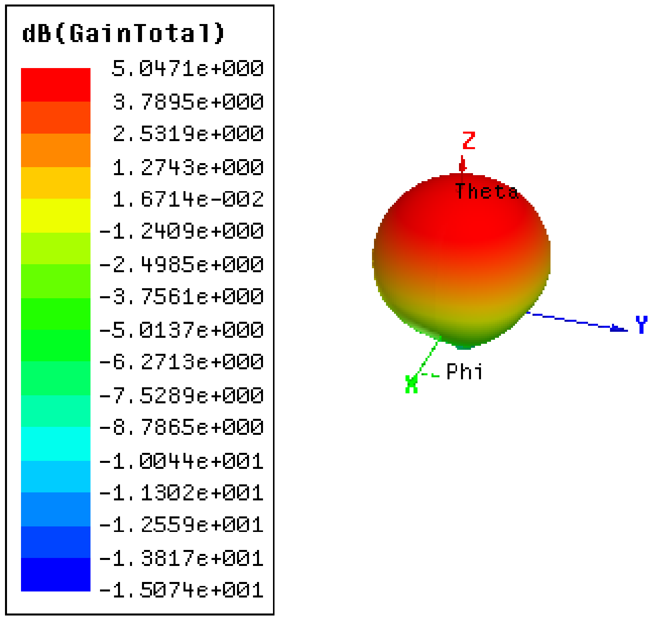

Fig 4: 3D Polar Plot for Gain of Simple Rectangular Microstrip Patch Antenna

Figure 4 and 5 shows the 3D polar plot for Gain 5.04 dB and directivity 6.62 dB at resonant frequency 5.23 GHz.

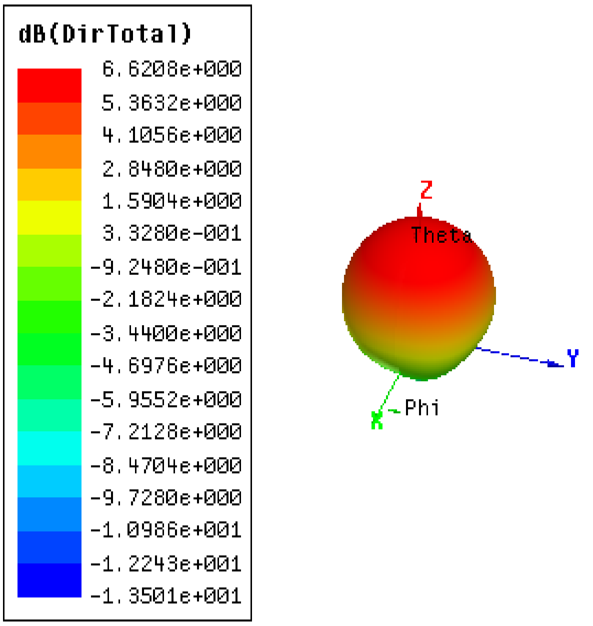

Fig 5: 3D Polar Plot for Directivity of Simple Rectangular Microstrip Patch Antenna

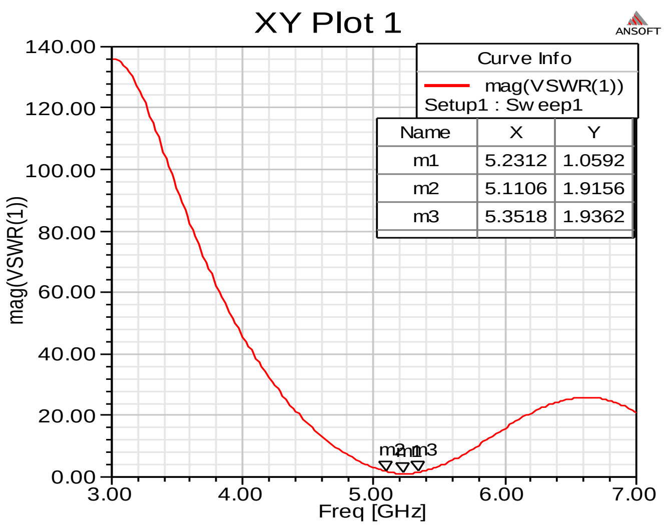

Fig 6: VSWR of Simple Rectangular Microstrip Patch Antenna

VSWR plot for inset feed simple rectangular Microstrip patch antenna is shown in figure 6. The value of VSWR is 1.05 at 5.23GHz.

3.2 Z and F shaped Defected Ground Structure

In proposed design Z and F shaped defect is etched on the ground plane to achieve multiband characteristics. Geometry of proposed design is shown in figure 7. In DGS defect on the ground plane is etched intentionally, size and shape of the defect can be varied according to design requirement.

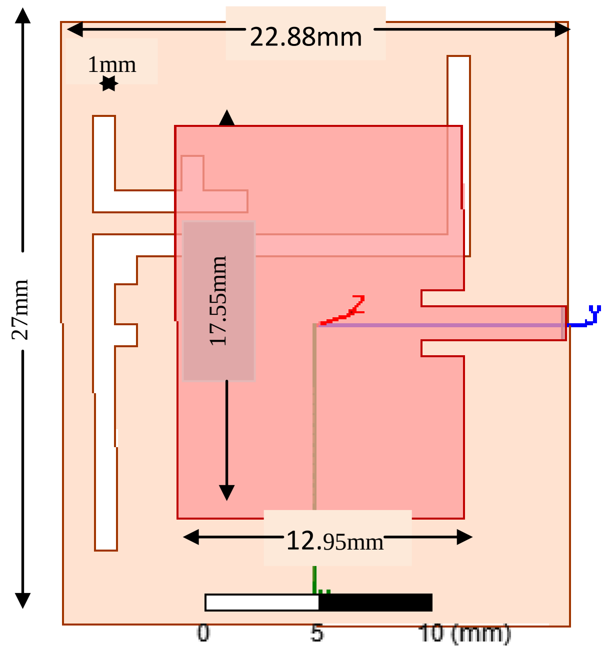

Fig 7: Z and F slot DGS antenna

Figure 8 depicts the return loss of the designed antenna after DGS structure. It is observed from return loss versus frequency graph that designed antenna resonates at multiple frequencies by etching Z and F shaped slots on ground plane. Designed antenna resonates at 5.2 GHz, 5.60 GHz, 10.44 GHz, and 11.52 GHz with return loss of -40.16 dB, -23.57 dB, -43.75 dB, -20.50 dB, as shown in figure 8. Antenna has highest return loss -40.16 dB at fundamental frequency 5.24 GHz. The proposed antenna resonates at multiple frequencies and has large bandwidth 555 MHz (5.1067-5.6624 GHz) at resonant frequency 5.2 GHz as shown in figure 2. Percentage bandwidth of antenna is 10.32%. It has 1.696 GHz (10.1036-11.80 GHz) bandwidth at 10.39 GHz.

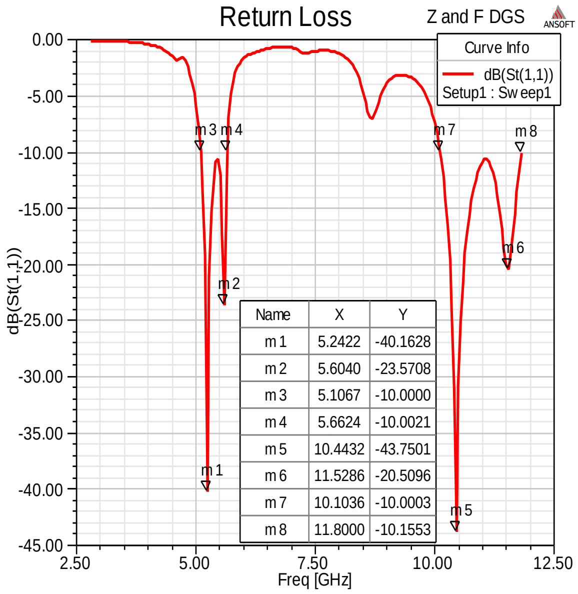

Fig 8: Return loss of Z and F slot DGS Antenna

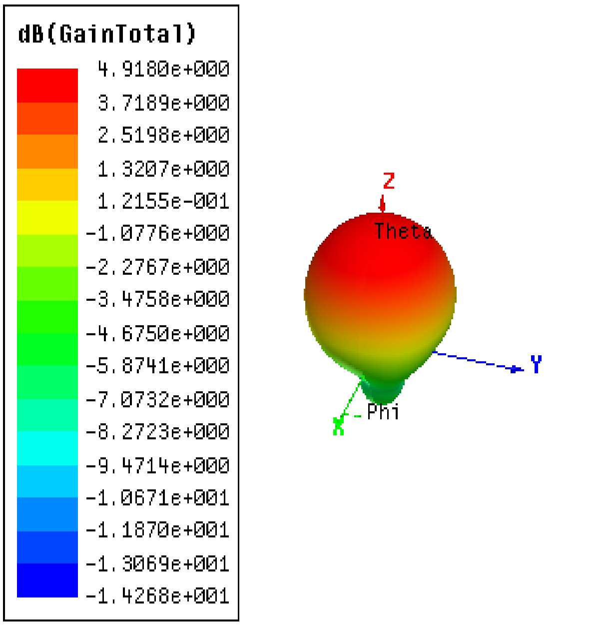

Fig 9: 3D Polar plot for gain of Z and F slot DGS Antenna

Above figures 9 shows the 3D polar plot for gain at 5.24 GHz. Designed antenna has 4.91 dB gain .It has 6.45 dB directivity at 5.24 GHz as shown in figure 10.

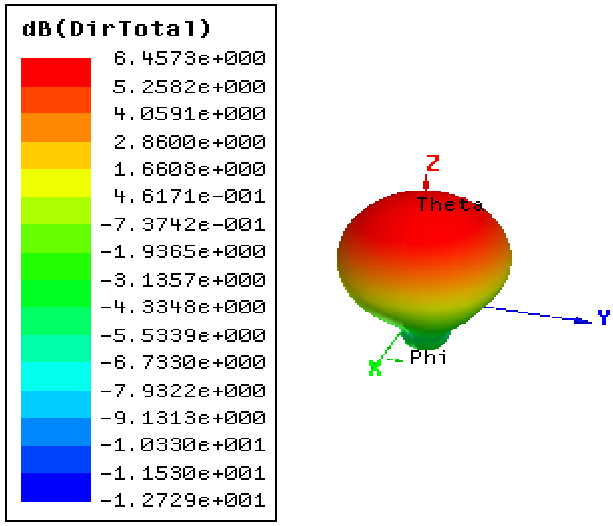

Fig 10: 3D Polar plot for directivity of DGS Antenna

Figure 11 shows the VSWR (Voltage standing wave ratio) for proposed multiband antenna. Voltage standing wave ratio indicates the impedance matching of antenna. The value of VSWR should lie between 1 and 2. Minimum VSWR is achieved 1.01 at 5.24 GHz, 1.14 at 5.60 GHz, 1.01 at 10.44 GHz and 1.20 at 11.52 GHz.

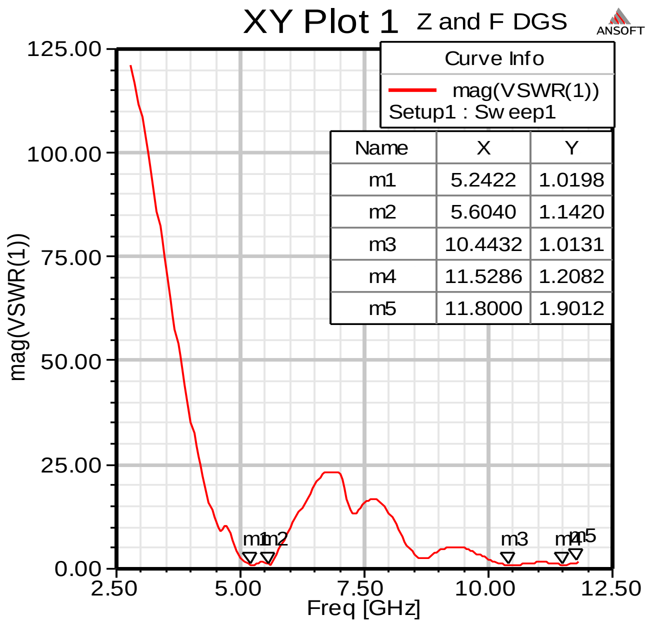

Fig 11: VSWR Plot of Z and F slot DGS Antenna

4. CONCLUSION

Proposed antenna is designed by etching slots in Ground Plane. Better return loss, directivity and VSWR is achived because of the Defected Ground Structure. Antenna has wide bandwidth at 5.24 GHz (5.1067-5.6624 GHz) which is WLAN frequency band. Designed antenna resonates at four different frequencies. 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. It has minimum return loss -40.74 dB and bandwidth 555 MHz (5.1067-5.6624 GHz) at 5.24 GHz. In future return loss, bandwidth and gain can be improved by introducing new shapes slots in patch and ground plane.

5. REFERENCES

[1] Gajera,H.R., and Anoop,C.N., 2011, "The study on Bandwidth enhancement of Rectangular Microstrip Patch Antenna for Wireless Application", Inteernational Journal of Electronics & Communication Technology,Vol. 2, Issue 4, ISSN: 2230-7109 (Online) ISSN: 2230-9543(Print), pp.171-174.

[2] Kaur, J., and Khanna, R., 2013, "Co-axial Fed Rectangular Microstrip Patch Antenna for 5.2 GHz WLAN Application", *Universal Journal of Electrical and Electronic Engineering,* pp. 94-98.

[3] Kumar, G., and Ray, K.P., "Broadband microstrip antennas", Artech House.

[4] Matin, M.A., and Sayeed, A.I., 2010, "A design rule for inset-fed rectangular microstrip patch antenna", *Wseas Transactions on Communications*, , Vol. 9**,** Issue 1, ISSN: 1109-2742.

[5] Nawale, P.A., and Zope, R.G., 2014, "Design and Improvement of Microstrip Patch Antenna Parameters Using Defected Ground Structure", *International Journal of Engineering Research and Applications,* Vol. 4, Issue 6, ISSN: 2248-9622, pp. 123-129.

[6] Patel, J.M., Patel, S.K., Thakkar, F.N., 2013, "Defected Ground Structure Multiband Microstrip Patch Antenna using Complementary Split Ring Resonator", *International Journal of Emerging Trends in Electrical and Electronics,* , Vol. 3, Issue 2, ISSN: 2320-9569, pp. 14-19.

[7] Singh, G., and Kaur, J., 2014, "Design a multiband Rectangular ring antenna Using DGS for WLAN, WiMAX Applications", *International Journal of Advanced Research in Computer and Communication Engineering,* Vol. 3, Issue 6, ISSN (Online): 2278-1021

[8] Weng, L.H., Guo, Y. C., Shi, X. W., and Chen, X. Q., 2008, *"*An Overview On Defected Ground Structure", *Progress in Electromagnetics Research B, Vol. 7, pp. 173–189.*