Design of Compact E-Shaped Slot Multiband Antenna Wireless Systems

Disha Mahulia[1], Sudesh Gupta[2]

[1]M Tech Scholar, Department of Electronics and Communication, TIT & Science, Bhopal
[2]Research Guide and Head, Department of Electronics and Communication, TIT & Science, Bhopal

---

Abstract - *A Novel Design for E Slotted Antenna is designed which resonates for 1.2, 2.5, 3.5 and 6.75 GHz frequncies application for Wireless Systems like WiFi/WLAN, WiMAX, LTE, ISM GNSS Applications with Total Bandwidth of 2990 MHz. The E-shaped slot structure has been etched in the patch, and the 50 microstrip line feed is etched with the ground on the same face of the substrate as CPW monopole. An additional circular patch attached to the ground on the reverse side of the antenna for multibandoperation. The antenna structure has been modeled and its performance has been evaluated using a FEM based electromagnetic simulator, Ansys HFSS results show that, the proposed antenna offers good return loss response (for S_{11} less than ¡10 dB) at the four bands.*

Key Words: CPW-fed Microstrip Antenna, Multiband Antenna, E Slotted Antenna Designing, Compact Antenna, circular ground antenna etc.

1. INTRODUCTION

The application of the E-shaped structure in patch antenna design has been first presented in [1]; in an attempt to overcome the narrow band and the large size of the conventional microstrip patch antennas. Since then, this structure had attracted antenna designers in their efforts to produce antennas with reduced size and multiband performance for different applications. The conventional E-shaped patch antenna has been used to design wideband antennas. Various U ,L F-shaped patch antennas with tapered, corrugated, and trapezoidal slots have been reported in the literature [6-8]. Many variants of the E-shaped patch structure have been proposed to produce reduced size and wideband antennas [9-12]. Patch antennas with half E-shaped and folded E-shaped structures have been also reported [9, 10, 13-15]. Moreover, the E-shaped structures have been used together with other slot structures to produce antennas with enhanced bandwidths [15-17]. For dual band antenna applications, E-shaped patch structures have been successfully verified as reported in [17, 18].As a slot, the E-shaped structure has drawn less attention from antenna designers; to name a few [19, 20]. In [19], the E-shaped slot structure has been applied to build a complementary part of an multiband antenna to produce the 3 GHz band-notch. In the other work [20], two printed wide-slot antennas constituting of both E-shaped patch and E-shaped slot with rounded corners and fed by CPW and microstrip line and circular ground have been presented..

2. ANTENNA DESIGN

In general, the bandwidth of a microstrip patch antenna is not very wide because it has only one resonance mode. Thus, to design a wideband radiator, two or more resonant parts with each part operating at its own resonance is essential, and the overlapping of these multiple resonances mode may lead to multiband or Wideband operations.

After the selection of three parameters based on application, i.e. frequency of operation, height of substrate and permittivity of dielectric material, next step is to calculate width and length of the patch.

Step 1: Calculation of Width (W)

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad 1$$

where, μ_0 is the free permeability, ε_0 is the free space permittivity and ε_r is relative permittivity.

Step 2: Calculation of Effective Dielectric Coefficient (ε_{reff}) the effective dielectric constant is

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{1/2} \qquad 2$$

Step 3: Calculation of Effective Length (Leff)

The effective length is

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad 3$$

Step 4: Calculation of Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{rff}-0.258)(\frac{W}{h}+0.8)} \qquad 4$$

Step 5: Calculation of Length of Patch (L)

The actual length of radiating patch is obtained by

$$L = L_{eff} - 2\Delta L \qquad 5$$

Step 6: Calculation of Ground Dimensions (Lg, Wg)

$$L_g = 6h + L\ ,\ W_g = 6h + W \qquad 6$$

Therefore, the geometry of the proposed E-shaped slot antenna structure is shown in Figure 1(a). The slot has been constructed, in the form of E-shape, on the patch plane side of a dielectric substrate.

In order to achieve multiband operation, a circular ground structure of radius 8.1 mm has been made in the opposite plane of the patch and placed on the feed side of the rectangular microstripand ground planes. The dielectric substrate is supposed to be the FR4 with a relative dielectric constant of 4.4 and thickness of 1.6 mm. For design convenience, the proposed antenna is fed by a 50- microstrip line printed on the same side of the substrate. The microstrip line, with a width of 3.0mm is placed on the centreline of the combined slot structure (x-axis). Figure 1(b) shows the antenna layout with respect to coordinate system.

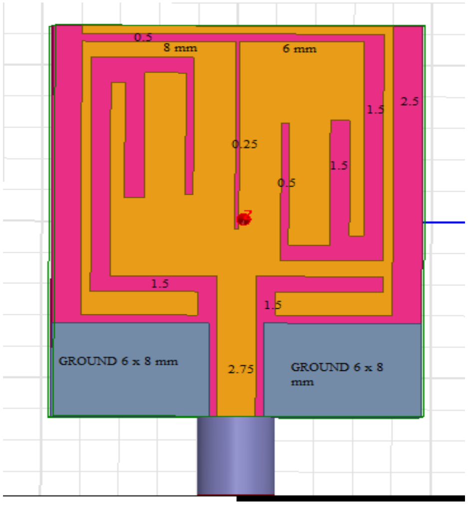

Fig. 1 (a).The proposed multiband antenna (top).

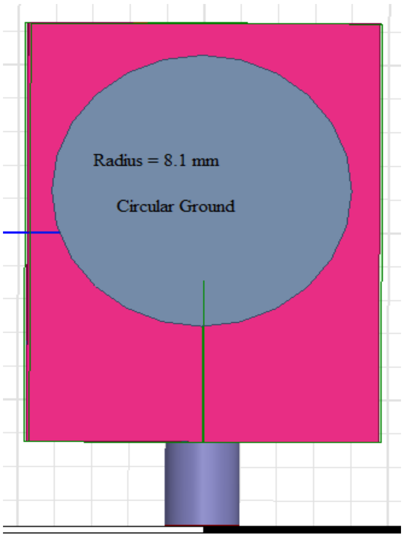

Fig 1(b). circular ground geometry (bottom)

To study the operating principle and the relationship between resonant frequencies and important parameters of the antenna, the simulated return loss is plotted at the sample frequencies of 1.2, 2.5, 3.5 and 6.75 which is shown in Fig. 2.

Therefore, it can be understood that the 2.4-/2.5-GHz WLAN resonance occurs due to the middle and right side of the patch. For the it is observed that the resonance occurs due to E-shaped slot on the left-hand side of the patch. The third (highest) 6.75 GHz resonant mode of the antenna, due to the circle at ground. This clearly indicates the importance of the embedded circle in ground plane on the proposed antenna resonance.Moreover, at this frequency, a strong current distribution is noticed on the finite ground plane around the circular strip. Further analysis shows that the circular strip on the ground plane improves the impedance matching and the bandwidth of the mode; it does contribute to the fourth resonance.

3. SIMULATION AND RESULTS

The electromagnetic waves solver, Ansoft HFSS, is used to investigate and optimize the proposed antennas configuration. Fig. 2, shows the simulated return loss of the proposed antenna. HFSS solver was used to measure the performance of the proposed antenna such as impedance bandwidth, VSWR, and gain. Fig. 2 shows the effect of radius R of the circular patch beneath the radiator and gap-coupled with ground plane on return loss of the antenna. Results show that the radius R influences the antenna performance significantly. By increasing the radius to 7.9 mm, all modes are excited, and bandwidth and impedance matching are improved considerably. Further increasing the radius from 7.9 to 8.1 mm, all the frequency bands shift toward the lower frequency. According to this, the optimal value of radius (R) of the circular patch beneath the radiator is chosen as 8.1 mm

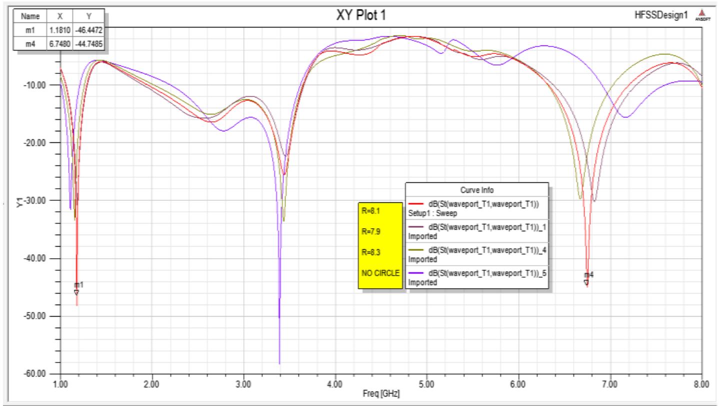

Fig.2 Return Loss for different values of R=8.1, 7.9, 8.3mm and no circle at ground.

Design	Frequency	Return Loss (dB)	Bandwidth	Applications
E Slotted (Proposed Antenna)	1.2 GHz	-50	220 MHz	GNSS,WIMAX, LTE,WIFI/WLAN and ISM
	2.5 GHz	-18	1770 MHz	
	3.5 GHz	-26		
	6.75 GHz	-46	1000 MHz	

The coaxial probe feed used is designed to have a length of 5 mm; feed consists of 2 concentric cylinders of 1.5 mm and 3 mm respectively. A frequency range of 1-8 GHz is selected and step size of 0.001 selected over this range to obtain accurate results. The center frequency is selected as the one at which the return loss is minimum.

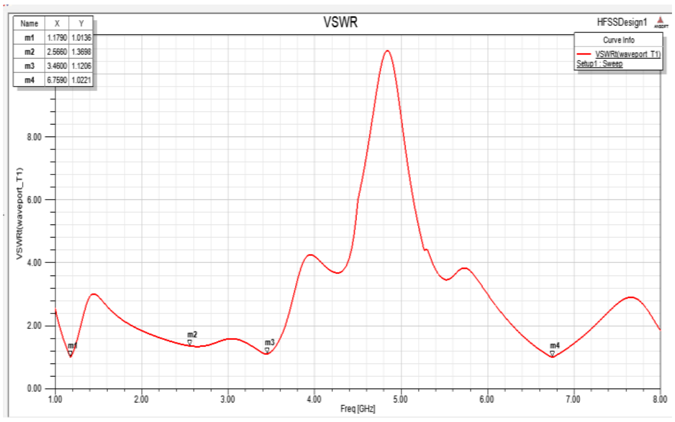

Fig.3 VSWR for proposed design.

It is found that the antenna has nearly good omni directional radiation patterns at all frequencies in the E-plane (xy -plane) and the H-plane (xz-plane). This pattern is suitable for application in most wireless communication equipment, as expected. The simulated radiation patterns for the proposed multiband base structure microstrip antenna are plotted in Fig. 5 where the principle plane is shown at the frequencies. With the obtained gain pattern for E plane and H Plane, the antenna has radiation pattern of omnidirectional which has wide variety of application in mobile communication.

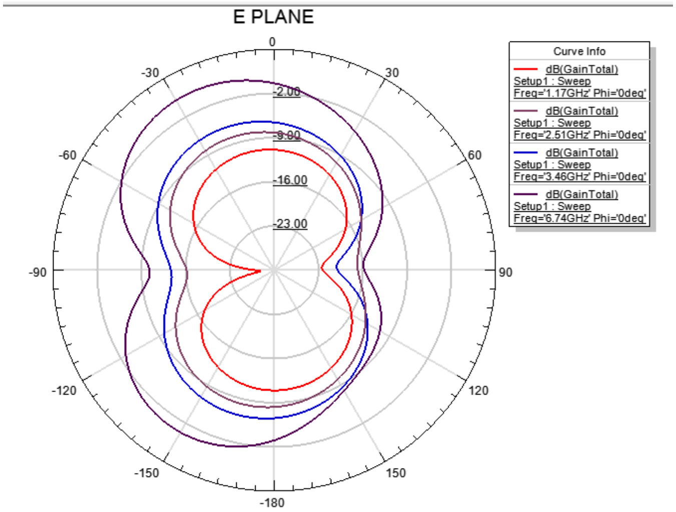

Fig. 4. (a) E plane 2D radiation pattern

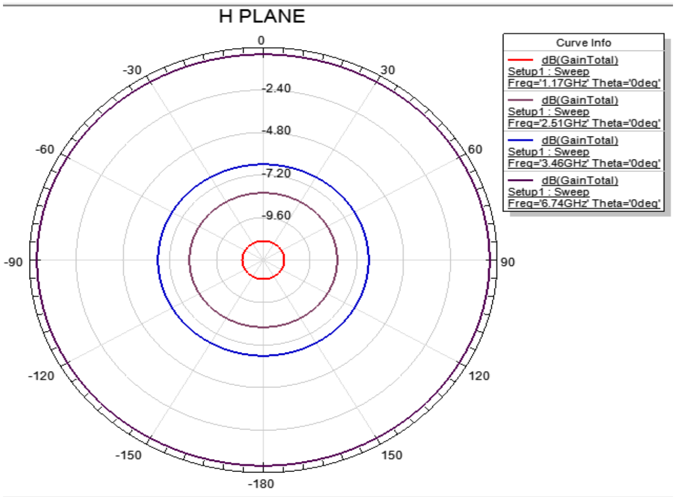

Fig. 4. (b) H Plane 2D radiation pattern

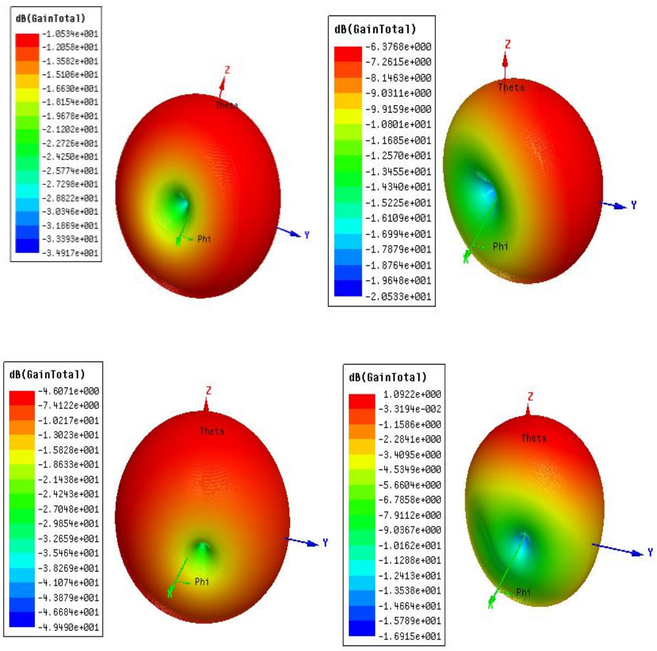

Fig 5. 3D Radition Pattern at 1.2, 2.5, 3.5 and 6.75 GHz resonating frequencies.

4. CONCLUSIONS

An optimal microstrip-fed monopole antenna with two E-shaped slot radiators is successfully proposed, simulated, for WLAN/WiMAX operation. The proposed antenna features compact size, good multiband operating bandwidth, and stable radiation patterns indicating that it can be good candidate forWLAN/WiMAX applications. A Novel Design for E Slotted Antenna is designed which resonates for 1.2, 2.5, 3.5 and 6.75 GHz frequncies application for Wireless Systems like WiFi/WLAN, WiMAX, LTE, ISM GNSS Applications with Total Bandwidth of 2990 MHz. The overall size of the proposed antenna is only 19 mm × 25 mm.

REFERENCES

[1] W. Hu, Y.-Z. Yin, P. Fei, and X. Yang, “Compact triband square-slot antenna with symmetrical L-strips for WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 10, no. pp. 462–465, May 2011.

[2] L. Dang, Z. Y. Lei, Y. J. Xie, G. L. Ning, and J. Fan, “A compact microstrip slot triple-band antenna for WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 9, pp. 1178–1181, Dec. 2010.

[3] C.-M. Wu, C.-N. Chiu, and C.-K. Hsu, “A new non-uniform meandered and fork-type grounded antenna or triple-band WLAN applications,” IEEE Antenna Wireless Propag. Lett., vol. 5, no. 1, pp. 346–349, Dec. 2006.

[4] L. Peng, C.-L. Ruan, and X.-H.Wu., “Design and operation of dual/tripleband asymmetric M-shaped microstrip patch antennas,” IEEE Trans. Antennas Propag., vol. 9, pp. 1069–1072, Dec. 2010.

[5] A. Kunwar, A. K. Gautam, and B. K. Kanaujia, “Inverted L-slot tripleband antenna with defected ground structure for WLAN and WiMAX applications,” Int. J. Microw. Wireless Technol., Feb. 2, 2016, doi: 10.1017/S1759078715001105

[6] H. Zhai, Z. Ma, Y. Han, and C. Liang., “A compact printed antenna for triple-band WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 12, pp. 65–69, Jan. 2013.

[7] R. Karimian, H. Oraizi, S. Fakhte, and M. Farahani, “Novel F-shaped quad-band printed slot antenna for WLAN andWiMAX MIMOsystems,” IEEE Antennas Wireless Propag. Lett., vol. 12, pp. 405–408, Mar. 2013.

[8] H. Chen, X. Yang, Y. Z. Yin, S. T. Fan, and J. J. Wu, “Triband planar monopole antenna with compact radiator for WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 12, pp. 1440–1443, Oct. 2013.

[9] X. Li, X.-W. Shi, W. Hu, P. Fei, and J.-F. Yu, “Compact triband ACS-fed monopole antenna employing open-ended slots for wireless communication,” IEEE Trans. Antennas Propag., vol. 12, pp. 388–391, Mar. 2013.

[10] H. Huang, Y. Liu, S. Zhang, and S. Gong, “Multiband metamaterialloaded monopole antenna for WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 14, pp. 662–665, Feb. 2015.

[11] C. Zhou, G. Wang, J. Liang, Y. Wang, and B. Zong, “Broadband antenna employing simplified MTLs for WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 14, pp. 595–598, Apr. 2014.

[12] S. Joshi, A. K. Gautam, and R. Upadhyay, “Frequency agile triple band microstrip antenna for WLAN/WiMAX application,” Int. J. Future Comput. Commun., vol. 3, pp. 258–261, 2014.

[13] P. Liu, Y. Zou, B. Xie, X. Liu, and B. Sun, “Compact CPW-fed triband printed antenna with meandering split-ring slot forWLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 1242–1245, Nov. 2012.

[14] C.-M. Peng, I.-F. Chen, and J.-W. Yeh, “Printed broadband asymmetric dual-loop antenna for WLAN/WiMAX applications,” IEEE Antennas Wireless Propag. Lett., vol. 12, pp. 898–901, Jul. 2013.

[15] C. A. Balanis, Antenna Theory Analysis and Design, 3rd ed. Hoboken, NJ, USA: Wiley, 2005.

[16] Anil Kumar Gautam, Lalit Kumar, Binod Kumar Kanaujia, and Karumudi Rambabu, "Design of Compact F-Shaped Slot Triple-Band Antenna for WLAN/WiMAX Applications", IEEE Transactions On Antennas And Propagation, Vol. 64, No. 3, March 2016