Pakistan Journal of Science, 71 (4 Suppl.): 2019, Page 115-118
ISSN: 2411-0930

SEMI-CIRCLE ANTENNA FOR IEEE 802.11b NETWORK APPLICATIONS

Q. Awais[1, *], M.N. Khan[2], T. Zahid[3], M.A. Hafeez[1], K. Mehboob [1], H. Farooq[5], W. Ali [5] and M. Farasat[4]

[1] Department of Electrical Engineering, Chenab College of Engineering and Technology, Gujranwala, Pakistan
[2]Department of Electrical Engineering, University of Lahore, Pakistan
[3]Department of Electrical Engineering, Riphah International University, Lahore, Pakistan
[4]Department of Electrical and Data Engineering, University of Technology, Sydney
[5]Department of Electrical Engineering. RCET, University of Engineering and Technology, Lahore, Pakistan
[*]Corresponding author's E-mail: qasim.awais@yahoo.com,

ABSTRACT: In this paper a novel compact wideband antenna is designed and implemented for WLAN (2.45G Hz) applications. The proposed design has 50 Ω symmetrical CPW feed line with semi-circular ground structures that is tuned at 1.6 GHz to 2.9 GHz range. Maximum current density is measured to be 7.76 A/m^2 along the feed line with omnidirectional like and three directional radiation patterns at H-plane and E-plane respectively. The reduced size of this device makes is suitable for handheld electronics and wireless sensor network applications. Maximum simulated gain of 7.9 dB and measured gain of 5.1 dB is achieved at designated frequency band.

Keywords: CPW antenna, Wideband, Wireless communications, WLAN 2.45 GHz

INTRODUCTION

Modern wireless communication has witnessed revolution in last decade as data rate has been improved from few kilobits per second to giga bits per second. Wide deployment of novel WIFI, WIMAX and 5 G system has enabled the concept of cloud computing where memory storage and processing power in remotely administered. All these technologies are heavily dependent on the performance of antenna devices which have wide bandwidth and better gain to support high data rates. However, conventional microstrip antenna has narrow bandwidth which is great hinderance to attain speedy communications (Ali *et al.*, 2012; Nornikman *et al.*, 2013)

With the increasing number of wireless devices, it is challenge to design antenna that can cover all frequency bands and reduce interference from adjacent spectrum of frequencies. Traditionally, band pass filters have been used to isolate antenna from frequency interferences but it adds more complexity (Hu *et al.,* 2013; Lu *et al.*, 2010). Wideband antenna provides such benefits due to its transmission efficiency and super wide characteristics. Size reduction is another requirement for WLAN antenna for small electronics systems. Mostly reported wideband antennas (Awais *et al.,* 2018; Shen and Law, 2011; Squadrito *et al.,* 2018; Elwi, 2018) have dimensions of 52 x 42 mm^2, 124 x 120 mm^2, 150 x 150 mm^2 and 60 x 60 mm^2. The proposed antenna is smaller is size with dimensions of 40 x 42mm^2 with simulated and measured gain of 7.9 dB and 5.1 dB respectively. Main features of proposed design are simplicity, reduced size, radiation efficiency, better gain and good impedance matching at 2.45 GHz band. In later parts of this paper design analysis, results and conclusion is presented.

MATERIALS AND METHODS

To achieve broadband this antenna is designed with semi-circle ground planes. Various techniques such as u-slots, complementary split ring resonators, bow-tie designs, defected ground structures and embedded slits have been implemented in literature for bandwidth enhancement (Subbarao and Raghavan*,* 2011; Awais *et al.,* 2018). In this design absolute bandwidth of 1GHz – 3GHz and 3.9 GHz – 5.1 GHz is measured. Fractional bandwidth of 34 % is measured at VSWR <2 along the resonant frequency band. The geometry of this design and the fabricated antenna is shown in Figure 1.

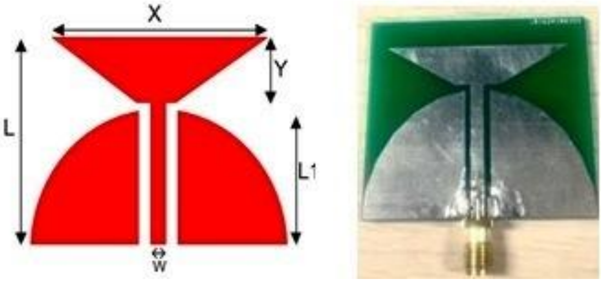

Figure 1: Geometry of fabricated antenna and its prototype

Substrate dimensions of this design are 40 mm x 50 mm x 1.6mm. The optimized major dimensions are “X=42 mm”, “Y=8.2 mm”, “L=40 mm”, “L1=25 mm” and “W=2.6 mm”. Lumped port excitation is used at feed in the HFSS and parametric analysis is performed to optimize the design parameters for “X”, “Y”, “L1”, “L” and feed width “W”. Above mentioned bandwidth and gain enhancement technique has advantages of lumped port loading in radiator which reduces design complexity. Multi-port designs and asymmetric coplanar waveguide antennas are subject to certain restrictions of impedance matching at different frequencies and interferences. To ensure the efficiency and practicality of design, substrate thickness and feed structure are designed by using following expressions (3).

$$Z_0 = \frac{30}{\sqrt{\varepsilon_{eff}}}\frac{K(k_0^{'})}{K(k_0)} \quad (1)$$

$$\varepsilon_{eff} = 1 + \frac{\varepsilon_r - 1}{2}\frac{K(k_1)K(k_0^{'})}{K(k_1^{'})K(k_0)} \quad (2)$$

$$G = 2s + W \quad (3)$$

$$k_0 = \frac{w}{G} \quad (4)$$

$$k_0^{'} = \sqrt{1 - k_0^{2}} \quad (5)$$

$$k_1 = \frac{sh(\pi w / 4h)}{sh(\pi G / 4h)} \quad (6)$$

$$k_1^{'} = \sqrt{1 - k_1^{2}} \quad (7)$$

Here,” h”, “ε_r”, “ε_{eff}”, “W” and “s” is the thickness of the dielectric substrate, the substrate relative permittivity, the effective dielectric constant of the substrate, the width of CPW-fed wire, the gap between CPW-fed line and the ground respectively. K(k_0), K(k_1), K($k_0^{'}$), K($k_1^{'}$) are the first complete elliptic integral function and its complement functions. We can calculate the width “W” and gap width “s” of the CPW signal line by using the above expressions.

RESULTS AND DISCUSSIONS

By varying the “X” parameter smaller bandwidth is calculated at smaller antenna size as it emits limited radiations and by increasing the gap between the antenna feed, the bandwidth of antenna decreases due to changing coupling capacitance between the radiator and coplanar grounds. The reflection coefficient of the designed antenna with respective VSWR is shown in Figure 2. This novel design has shown three major resonant frequencies at 1.4 GHz, 2.45 GHz and 4.5 GHz but as we can see that only 1.6 GHz and 2.45 GHz are tuned to accommodate WLAN band effective functionality, as at 4.5 GHz VSWR value overshoots to 4.1.

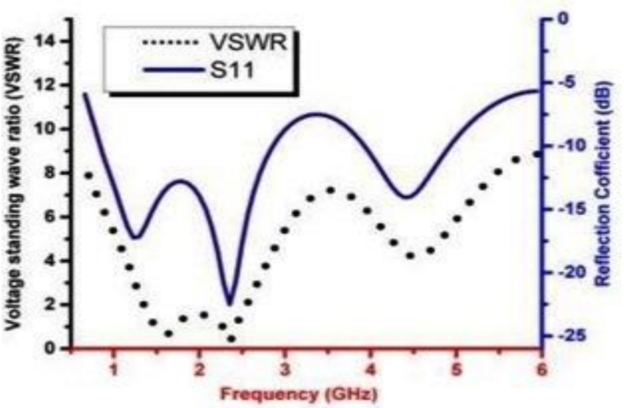

Figure 2: Reflection coefficient and VSWR of proposed antenna

The input impedance for real and imaginary parts is shown in Figure 3. Huge variations in real and imaginary impedance is observed at 4 GHz and 7 GHz which implies the functionality of EM waves dispersion at the feed for these frequencies. The real part is calculated to be 50.141 Ω and the imaginary part is calculated to be 0.036 Ω at 2.45 GHz. It is duly noted that impedance is quite constant from 1.6 GHz to 2.9 GHz that explains the smooth matching at these bands.

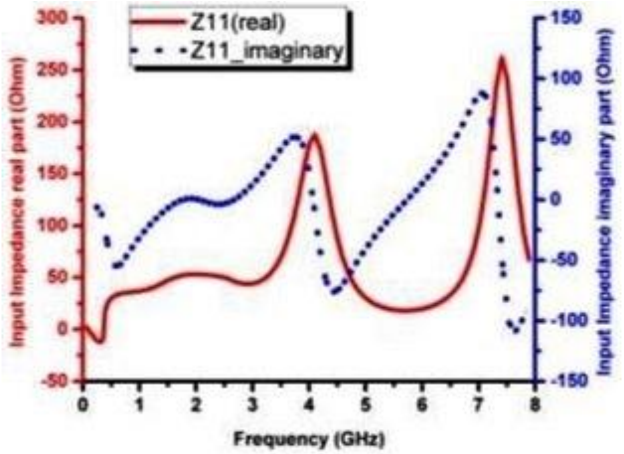

Figure 3: Real and imaginary parts of Input impedance of semicircular design.

The current distribution of this design is illustrated in Figure 4. Maximum current at the bottom and top of radiator feed line is observed. Majority area has 2.37 A/m^2 surface current density and maximum current density is calculated to be 7.76 A/m^2. Ground planes radiate symmetrical radiations along with feed line, as going away from the feed line, surface current density is reduced slowly and overall low current distribution is calculated at the edges of this design.

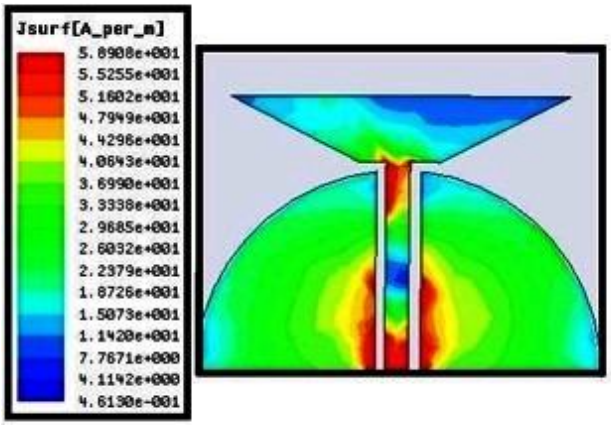

Figure 4: Surface current distribution of semicircular design

Simulated and measured radiation pattern for H-Plane and E-Plane is shown in Figure 5 (a), (b). Blue lines represent simulated values and dashed red line represents measured values. The two-dimensional broad radiation pattern is measured at H-Plane covering most of 360^0 except weak coverage from 60^0 to 150^0. This design is circularly polarized therefore the orientation of the device is not a big issue in practical applications.

While 3-dimensional radiation pattern is observed at E-Plane covering major radiation angles of 30^0, 170^0 and -80^0. Major lobe is measured between 0^0 and 30^0 which implies that maximum gain is available in this direction and gain reduces in supplementary dimension accordingly. Simulated and measured values are in great agreement that justifies the fabrication process and overall measuring efficiency.

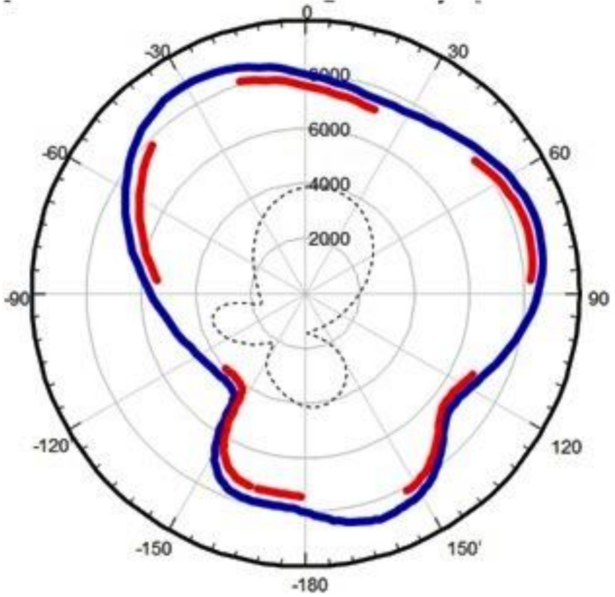

Figure 5(a): Radiation pattern at H-plane

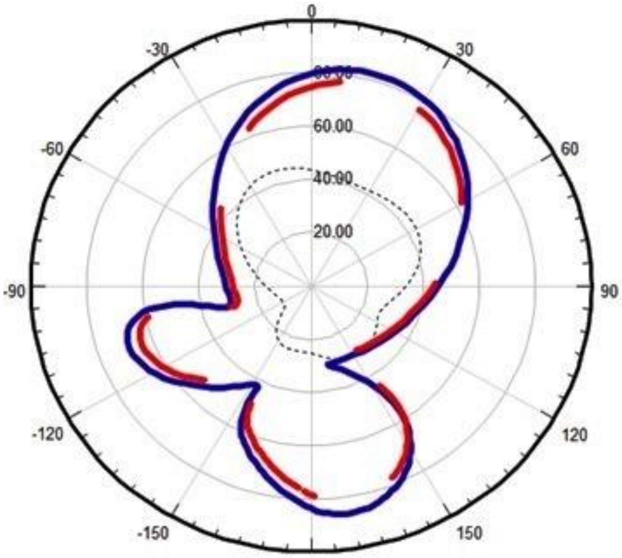

Figure 5(b): Radiation pattern at E-plane

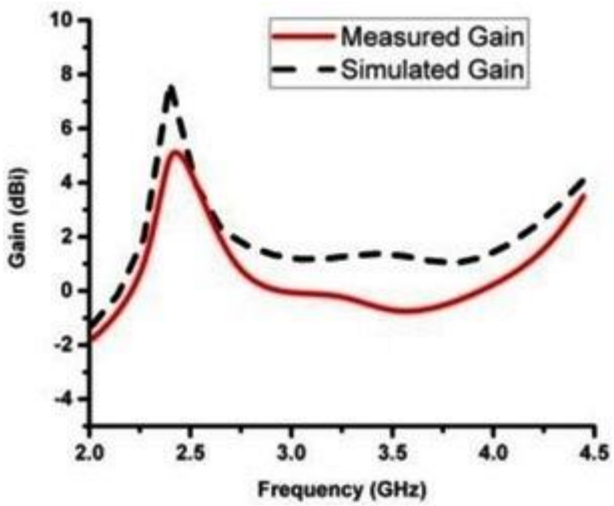

Figure 6: Simulated and measured gain of semicircular CPW antenna

Finally, comparison of simulated and measured gain for this antenna is illustrated in Figure 6. Antenna gain is measured from 2 GHz to 4.5 GHz. Simulated gain has a peak value of 7.9 dB and measured peak gain value is observed to be 5.1 dB which is impressive as we compare it with most antennas published in the literature. While analyzing the gain plot we see that 1 dB to 2 dB gain is simulated at frequencies from 2.7 GHz to 4 GHz but the measured values lag the simulated values between 0 dB and -1dB. Moreover, from the S_{11} plot, we see that simulated reflection coefficient for 2.45 GHz band has peak values from 1.6 GHz to 3 GHz that is justified from the gain plot as at these frequencies maximum gain is measured.

Resonant frequency of 2.45 GHz lies at the major lobe in a radiation pattern that resulted in the improved overall gain. Consequently, this antenna is suitable for RF energy harvesting applications due to enhanced gain and bandwidth as a common characteristic. The third resonant band can be easily tuned to match the impedance when desired as this design shown the dynamic reconfigurability by varying the "X" parameter as mentioned earlier.

Conclusion: In this article a compact wideband antenna is tested and analyzed. The proposed design initially has three resonance bands at 1.4 GHz, 2.45 GHz and 4.5 GHz which can be tuned separately. Excellent impedance matching with real part of 50.141 Ω and imaginary 0.036 Ω is observed at 2.45 GHz. Simplistic design with improved radiation efficiency is the main features of this antenna. Further, maximum gain of 5.1 dB is measured at the WLAN band that is adequate for high data rate applications. The top of antenna uses bow-tie like structure which is straight forward technique to improve the overall bandwidth of system. The measured and simulated radiation patterns are omnidirectional in nature and provide the basis for wide deployment of this device for WLAN applications.

REFERENCES

Awais, Q., Y. Jin, H.T. Chattha, M. Jamil, H. Qiang and B.A. Khawaja (2018). A compact rectenna system with high conversion efficiency for wireless energy harvesting. IEEE Access, 6, 35857-35866.

Ali, M.T., N. Nordin, N. Ya'acob and M.M. Tan (2012). Design of wideband microstrip patch antenna using L-probe fed at 2.6 GHz. In 2012 International Conference on Computer and Communication Engineering (ICCCE) (pp. 961-965). IEEE.

Awais, Q., H. T. Chattha, M. Jamil, Y. Jin, F. A. Tahir and M. U. Rehman (2018). A novel dual ultrawideband CPW-fed printed antenna for Internet of Things (IoT) applications. Wireless Communications and Mobile Computing, 2018.

Daniel, R.S., R. Pandeeswari and S. Raghavan (2017). Multiband monopole antenna loaded with Complementary Split Ring Resonator and C-shaped slots. AEU-International Journal of Electronics and Communications, 75, 8-14.

Elwi, T.A. (2018). A miniaturized folded antenna array for MIMO applications. Wireless Personal Communications, 98(2), 1871-1883.

Hu, S., Y. Wu, Y. Zhang and H. Zhou (2013). Design of a CPW-fed ultra wide band antenna. Open Journal of Antennas and Propagation, 1(02), 18.

Lu, W.J., Y. Cheng and H.B. Zhu (2010). Design concept of a novel balanced ultra-wideband (UWB) antenna. In 2010 IEEE International Conference on Ultra-Wideband (Vol. 1, pp. 1-4). IEEE.

Nornikman, H., F. Malek, N. Saudin, M.M. Shukor, N.A. Zainuddin, M.A. Aziz, B.H. Ahmad and M.A. Othman (2013). Design of rectangular stacked patch antenna with four L-shaped slots and CPW-fed for WiMAX application. In 2013 3rd International Conference on Instrumentation, Communications, Information Technology and Biomedical Engineering (ICICI-BME) (pp. 39-43). IEEE.

Shen, Y. and C.L. Law (2011). A microstrip-fed quasi-spiral circularly polarized ultra-wideband antenna. In 2011 IEEE International Symposium on Antennas and Propagation (APSURSI) (pp. 1463-1466). IEEE.

Squadrito, P., S. Zhang and G.F. Pedersen (2018). Wideband or dual-band low-profile circular patch antenna with high-gain and sidelobe suppression. IEEE Transactions on Antennas and Propagation, 66(6), 3166-3171.

Subbarao, A. and S. Raghavan (2011). A novel pot shaped CPW-fed slot antenna for Ultra wideband applications. In 2011 International Conference on Emerging Trends in Electrical and Computer Technology (pp. 1119-1122). IEEE.