Pakistan Journal of Science, 71 (4 Suppl.): 2019, Page 106-110
ISSN: 2411-0930

DESIGN AND ANALYSIS OF CPW RECTANGULAR ANTENNA WITH SLOTS FOR 2.45 GHz Applications

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

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

ABSTRACT: In this paper stacked antenna with symmetrical slots has been implemented on FR4 substrate with the overall size of 760 mm^2. The height of stack antenna is optimized at 10 mm which resulted in 30.04% bandwidth enhancement. Gain of < 2.5 dB is achieved without stack and with the addition of stack gain is increased to 4.8 dB. Primarily the antenna is resonant at two band of 2.4 GHz and 4.3 GHz which is further improved for WLAN 2.45 GHz band by adjusting feed width parametric analysis. Omnidirectional like radiation patterns for E and H planes have been achieved with stable gain.

Keywords: Stacked antenna, Gain enhancement, Coplanar wave guide, 2.45 GHz

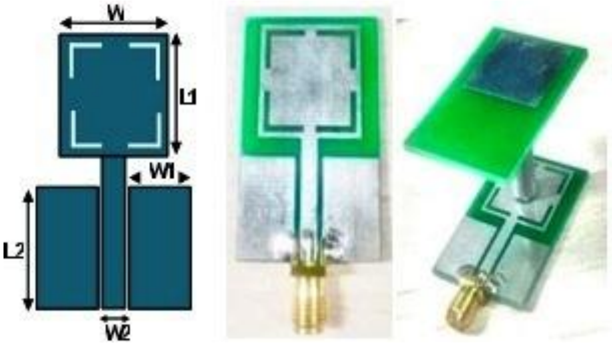
INTRODUCTION

Microstrip antennas have attained significant focus due to the benefits of low cost, small profile and ease of fabrication in modern communication systems. These devices are integral part of smart hand-held electronics, bluetooth devices and satellite systems due to their compact size. Traditionally high efficiency is achieved using horn antennas with low loss PTFE based substrates but these have huge size and bulky structure which makes them unsuitable for compact devices. Further, spill over efficiency is reduced by removing unwanted radiations. Coplanar waveguide (CPW) feed offers these desirables with minimal cost and light weight characteristics. Besides profound advantages, microstrip antennas have inherently narrow bandwidth and reduced gain which requires significant attention to attain acceptable efficiency.

Different techniques have been investigated to cater the narrow bandwidth including the addition of parasitic patches (Santosa *et al.,* 2018), using asymmetrical feed system (Wu *et al*., 2018) and to design array of antennas (Khan *et al.,* 2018; Zhu *et al.,* 2018; Alibakhshikenari *et al.,* 2018; Lin *et al.,* 2018). Etching different kind of slots in microstrip antennas have been implemented in (Rahman *et al.,* 2018; Saraswat and Harish, 2018; Midya *et al.,* 2018) which resulted in 21% bandwidth increase (Rahman *et al.,* 2018; Khan *et al.*, 2016). Recent developments have proved that stacking the microstrip antenna results in wideband characteristics with improved directivity (Yang *et al.,* 2018; Yan *et al.,* 2018; Lee *et al.,* 2018). We have designed and implemented dual band CPW antenna with wideband behavior using stacked antenna technique which is resonant at 2.45 GHz and 4.3 GHz. Symmetrical CPW feed mechanism is adopted with square shape antenna having identical slots on the corners. Same sized stack is designed and tested for numerous height distances. Later parts of this paper discuss about the design procedure of antenna, parametric analysis, results and finally conclusion is presented.

MATERIALS AND METHODS

Design geometry for first measured and tested antenna is shown in Figure 1 (a). Fabricated radiator with and without stack is depicted in Figure 1 (b).



(a) (b)

Figure 1 (a): Geometry of tested antenna, (b): Fabricated antenna with and without stack

The substrate of 760 mm^2 is chosen with "W", "W1"," W2"," L1" and "L2" equal to 19.3 mm, 10.7 mm, 2.8 mm, 19.3 mm and 15.2 mm respectively. The Broadband operation of the antenna is acquired by simultaneously adjusting the dimensions of the antenna through simulation software Ansoft HFSS 16.0. The width and length of antenna is calculated using transmission line model, design equations are expressed as following (Zhu *et al.,* 2018).

$$W = \frac{C}{fr}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

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

$$L_{eff} = \frac{C}{2fr\sqrt{\varepsilon_{eff}}} \qquad (3)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{-1}{2}} \qquad (4)$$

$$\Delta L = 0.421h\frac{(\varepsilon_{eff}+0.8)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.264)(\frac{W}{h}+0.8)} \qquad (5)$$

In above equations, “W”, “L”, “ΔL”, “ε_{reff}“ and “fr” represent width, length, fractional length, effective relative permittivity and resonance frequency respectively. The actual length is calculated by considering the fringing effect of radio waves on the substrate. Maximum dispersion of EM waves with respect to length is expressed in last equation. The gap between the antenna and stack is varied to different height and at 10 mm height better gain and wide bandwidth are measured.

Effect of feed width variation: The impedance matching is performed by varying the coplanar waveguide feed width and by controlling the gap in between adjacent grounds. Two resonance bands are observed at 2.45 GHz and 4.3 GHz with overall absolute bandwidth from 1 GHz to 5.2 GHz. The reflection coefficient of – 29.75 dB and -31.12 dB is measured at 2.45 GHz and 4.3 GHz respectively. In the first stage, the antenna is designed without stack and afterward, stack is loaded on the antenna to enhance the gain characteristics of the radiator. As effective RF energy harvesting can be attained by maximum radiation efficiency and gain over all the major directions. Therefore, gain is mainly dependent on the radiation pattern of the antenna as unidirectional or bidirectional antennas have higher gain as compared to the omnidirectional designs as more and more energy is concentrated in direction of interest. Reflection coefficient of the antenna without stack is shown in Figure 2.

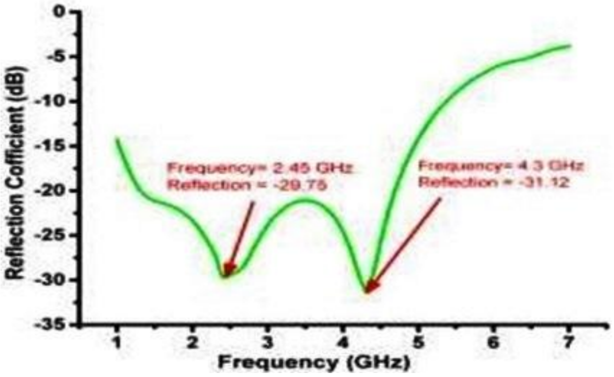


Figure 2: Reflection coefficient of antenna without stack

In above design it is observed that this design meets the requirements of efficient return loss at -10 dB, bandwidth of more than 4 GHz, the efficiency of 74 % and gain is less than 2.5 dB. The effect of feed line width along with feed gap is shown in Figure 3.

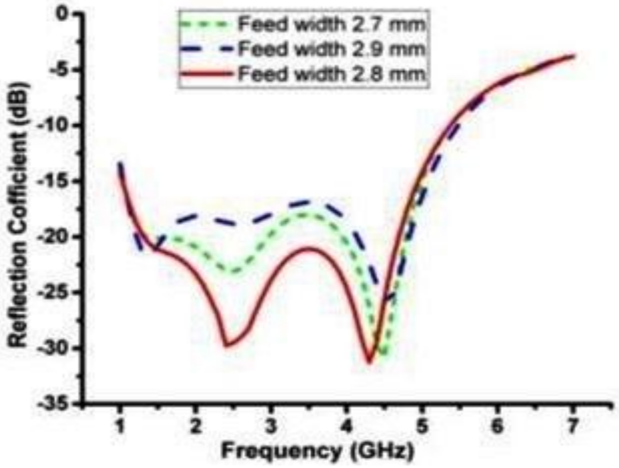


Figure 3: The effect of feed width variation on reflection coefficient

At feed width of 2.9 mm, only one effective resonant band is realized with acceptable VSWR. Feed width of 2.7 mm results in the creation of second resonance frequency at 2.45 GHz which is further stabilized by optimizing feed width to 2.8 mm. The relation of voltage standing wave ratio against frequency is plotted in Figure 4. That implies that excellent impedance matching is achieved at 2.45 GHz and 4.3 GHz. The value of VSWR at 2.45 GHz is measured to be 0.61 which is well below the threshold value to 2. It is clearly understood that this design is capable of operating from 1.2 GHz to 4.7 GHz with slight notch band at 3.5 GHz.

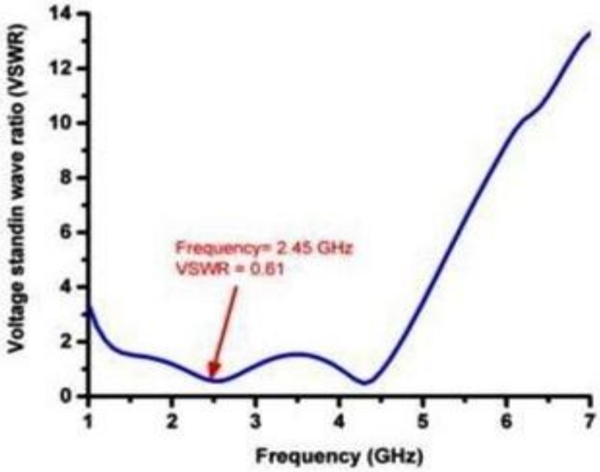


Figure 4: VSWR Vs Frequency plot for unstacked design.

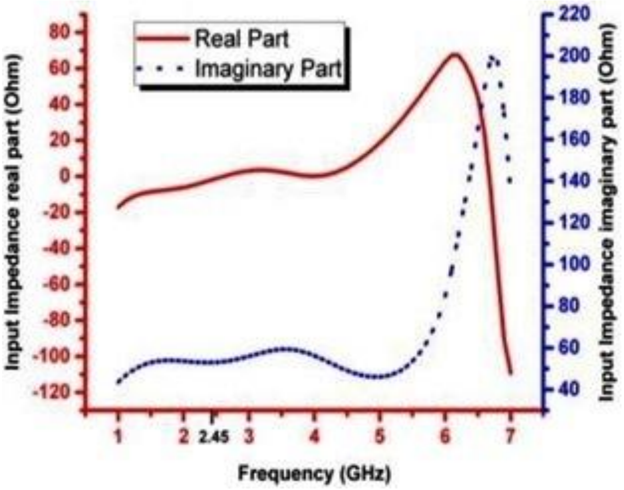


Figure 5(a): Measured input impedance.

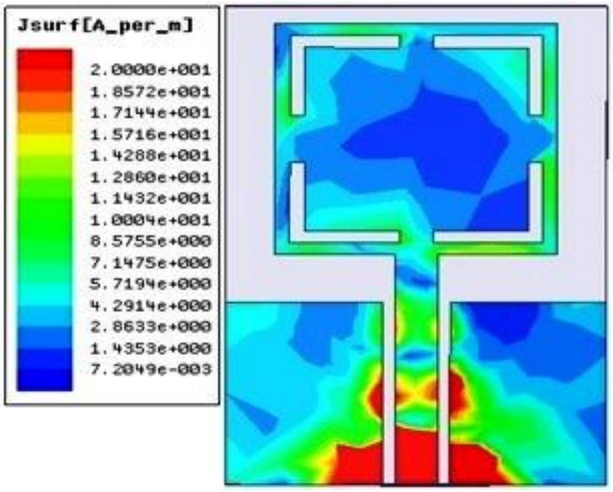


Figure 5(b): Simulated surface current density

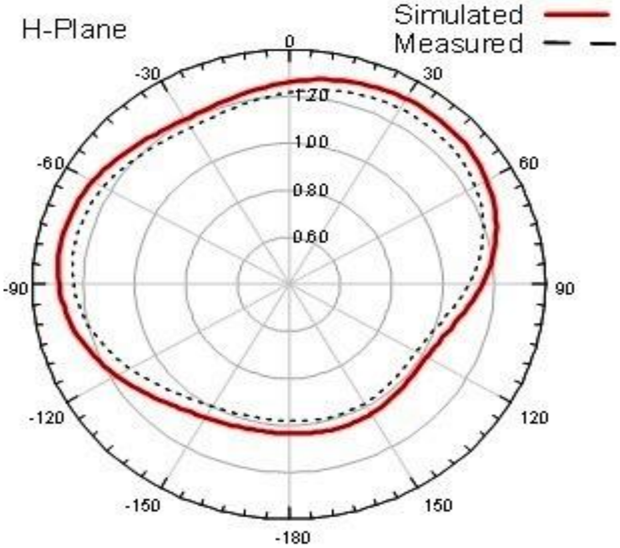


Figure 6(a): Simulated Vs Measured radiation pattern at H-plane.

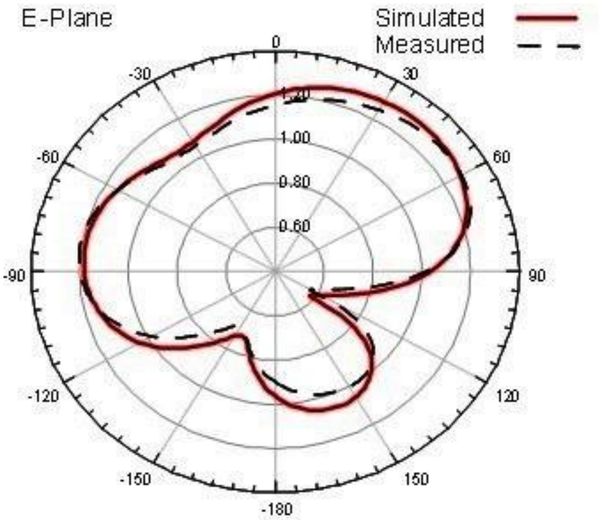


Figure 6(b): Simulated Vs Measured radiation pattern at H-plane

The input impedance of this antenna is set to standard 50 Ω and the measured values for Z_{11} are plotted in Figure 5 (a). The real part of Z_{11} is found to be 49.8 Ω and imaginary part of Z_{11} is calculated as 0.0023 Ω at the targeted resonant frequency of 2.45 GHz. At 4.3 GHz, impedance is calculated to be 50.01+j0.006 Ω which implies that this antenna is well matched at WLAN band and future expected 5G band. It is anticipated that 5G band may be licensed at 4 GHz – 5GHz although different frequencies are allotted in different reigns. The resonance frequency of this design can easily be configured according to the demands due to flexible ultra-wideband characteristics.

Current distributions at 2.45 GHz is shown in Figure 5 (b) that implies better current dispersion at feed line and at adjacent ground structures. 1st order quarter wavelength radio waves are incident at feed line effectively and overall improved current distribution is measured along the symmetrical slots in the radiator. At all frequencies and phases maximum surface current is distributed at feed line and relatively low current concentration at the center of the rectangular patch is a common characteristic.

RESULTS AND DISCUSSION

The measured radiation pattern of antenna with embedded stack at E-plane is shown in Figure 6 (a). The two-dimensional radiation pattern is simulated and measured at 2.45 GHz with a small lobe at 150^0. Simulation and measured results are in good accordance and antenna is feasible for RF energy harvesting as it covers most of the radiation angles for receiving electromagnetic radiations

Figure 6 (b) shows the simulated and measured radiation of this novel design at H-plane and omnidirectional radiation is observed at this plane which covers almost 360^0 orientations for good radiation efficiency. It is confirmed that stacked enhance the bandwidth of CPW designs and improve the overall gain. The gain of this antenna is < 2.5 dB without stack at WLAN frequency and with stack gain is greatly improved to 4.8 dB.

The bandwidth improvement due to added stack in this coplanar design is shown in Figure 7. Absolute bandwidth is increased from 4.2 GHz to 5.3 GHz (1 GHz – 6.3 GHz) which is a super wide antenna to harness ambient electromagnetic energy for the Internet of things (IoT) and wireless sensor network (WSN) applications specifically with compact dimensions.

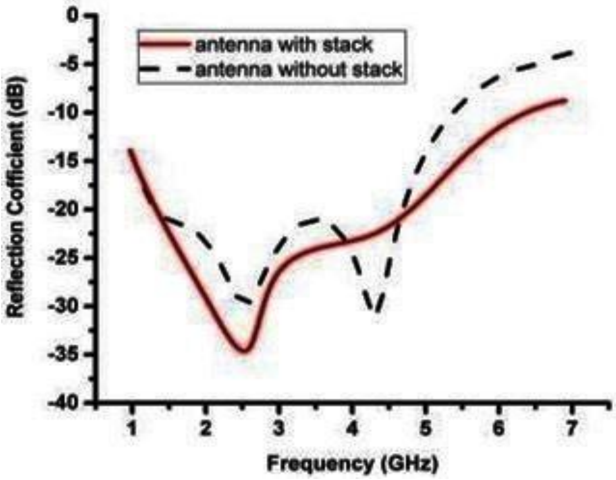


Figure 7: Enhanced antenna bandwidth comparison due to added stack

Increase in the bandwidth of 30.04 % is due to stacked patch which is based on phenomenon of trapping more and more EM waves at the resonant band which consequently improve the antenna gain. But the incursion of the stack, the antenna may become bulky in some area constrained applications where compact devices are desired. Apart from stack this antenna also shows the acceptable quality of service parameters at a designated frequency of 2.45 GHz as discussed above.

Conclusion: In this paper, stacked antenna with enhanced bandwidth is proposed and implemented for WLAN 2.45 GHz applications. 1 GHz – 6.3 GHz bandwidth range is achieved with the addition of stack over antenna and gain in improved from 2.5 dB to 4.8 dB respectively. Extensive analysis of feed width effect is presented and variation of stack height is simulated and measured in iterative process. Antenna stack height of 10 mm is observed to be optimum for WLAN band and feed width of 2.8 mm produced desired antenna characteristics. Symmetrical L-shape slots have been introduced in design to further enhance current distributions at designated band. Small size, light weight and low-cost fabrication makes it suitable for WLAN and future 5G applications.

REFERENCES

Alibakhshikenari, M., B.S. Virdee, C.H. See, R. Abd-Alhameed, A.H. Ali, F. Falcone and E. Limiti (2018). Study on isolation improvement between closely-packed patch antenna arrays based on fractal metamaterial electromagnetic bandgap structures. IET Microwaves, Antennas & Propagation, 12(14), 2241-2247.

Chen, H.M., Y.F. Lin, C.H. Chen, C.Y. Pan and Y.S. Cai (2014). Miniature folded patch GPS antenna for vehicle communication devices. IEEE transactions on antennas and propagation, 63(5), 1891-1898.

Khan, M.N., S.O. Gilani, M. Jamil, A. Rafay, Q. Awais, B.A. Khawaja, M. Uzair and A.W. Malik (2018). Maximizing throughput of hybrid FSO-RF communication system: An algorithm. IEEE Access, 6, 30039-30048.

Khan, M., S.K. Hasnain and M. Jamil (2016). Digital Signal Processing: A Breadth-first Approach. Stylus Publishing, LLC.

Lee, H.J., E.S. Li, H. Jin, C.Y. Li and K.S. Chin (2018). 60 GHz wideband LTCC microstrip patch antenna array with parasitic surrounding stacked patches. IET Microwaves, Antennas & Propagation, 13(1), 35-41.

Lin, W., S.L. Chen, R.W. Ziolkowski and Y.J. Guo (2018). Reconfigurable, wideband, low-profile, circularly polarized antenna and array enabled by an artificial magnetic conductor ground. IEEE Transactions on Antennas and Propagation, 66(3), 1564-1569.

Midya, M., S. Bhattacharjee and M. Mitra (2018). Pair of grounded L strips loaded broadband circularly polarised square slot antenna with enhanced axial ratio bandwidth. Electronics Letters, 54(15), 917-918.

Rahman, M., M.J. Naghshvarian, S. Mirjavadi and A. Hamouda (2018). Bandwidth enhancement and frequency scanning array antenna using novel UWB filter integration technique for OFDM UWB radar applications in wireless vital signs monitoring. Sensors, 18(9), 3155.

Santosa, C.E., J.T. Sri Sumantyo, K. Urata, C.M. Yam, K. Ito and S. Gao (2018). Development of a low profile wide-bandwidth circularly polarized microstrip antenna for C-band airborne CP-SAR sensor. Progress In Electromagnetics Research C, 81, 77-88.

Saraswat, K. and A.R. Harish (2018). Analysis of wideband circularly polarized ring slot antenna using characteristics mode for bandwidth enhancement. International Journal of RF and Microwave Computer-Aided Engineering, 28(2), e21186.

Wu, Q.S., X. Zhang and L. Zhu (2018). A wideband circularly polarized patch antenna with enhanced axial ratio bandwidth via co-design of feeding network. IEEE Transactions on Antennas and Propagation, 66(10), 4996-5003.

Yang, X., L. Ge and J. Wang (2018). A differentially driven dual-polarized high-gain stacked patch antenna. IEEE Antennas and Wireless Propagation Letters, 17(7), 1181-1185.

Yan, N., K. Ma and H. Zhang (2018). A novel substrate-integrated suspended line stacked-patch antenna array for WLAN. IEEE Transactions on Antennas and Propagation, 66(7), 3491-3499.

Zhu, S., H. Liu, Z. Chen and P. Wen (2018). A compact gain-enhanced Vivaldi antenna array with suppressed mutual coupling for 5G mmWave application. IEEE Antennas and Wireless Propagation Letters, 17(5), 776-779.