Open Journal of Antennas and Propagation, 2019, 7, 13-21
http://www.scirp.org/journal/ojapr
ISSN Online: 2329-8413
ISSN Print: 2329-8421

Parallel Notch and H Shape Slot Loaded Compact Antenna for X and Ku Band Applications

Nagendra P. Yadav, Guozhen Hu, Zhengpeng Yao

School of Electrical and Electronics Information Engineering, Hubei Polytechnic University, NO.16 North Guilin Road, Huangshi, Hubei, China
Email: 202075@hbpu.edu.cn, huguozhen@hbpu.edu.cn

How to cite this paper: Yadav, N.P., Hu, G.Z. and Yao, Z.P. (2019) Parallel Notch and H Shape Slot Loaded Compact Antenna for X and Ku Band Applications. *Open Journal of Antennas and Propagation*, **7**, 13-21.
https://doi.org/10.4236/ojapr.2019.72002

Received: May 17, 2019
Accepted: June 24, 2019
Published: June 27, 2019

Abstract

This paper represents parallel notch, H-shape slot loaded single layer patch antenna in X, and Ku bands for wideband applications. The design has made on low-cost material of Rogers R03003 substrate having dielectric constant of 3.0 with thickness of 1.6.0 mm. The proposed scheme and probe feeding technique provide designed antenna to operate in two different frequencies range in X and Ku band (10.60 GHz to 15.91 GHz). The antenna resonates at 11.37 GHz for X band and another three resonates at 12.13 GHz, 13.14 GHz and 14.66 GHz for Ku band with maximum gain of 9.20 dBi respectively. The simulation results have been obtained 40.01% impedance bandwidth with return loss (−10 dB) or $VSWR \leq 2$. The proposed antenna is simple in structure compared to the regular single layer patch antennas. It is highly suitable for satellite and RADAR communications system. Designing and simulation of this antenna have been done by IE3D software version 12.0, which is based on MOM method.

Keywords

Patch Antenna, H-Slot Antenna, Radio Frequency, Compact Antenna, Bandwidth and Method of Moment (MOM)

1. Introduction

Exhaustive research has been carried out to develop the bandwidth-enhancement techniques by keeping the size of the patch antenna as small as possible. In recent years, with the wider applications of microstrip antennas, many researchers had found many methods, which can improve the bandwidth. The coaxial feed technique is used for the analysis of this antenna because it occupies less space and has low spurious radiation by using Teflon connector. The method of moment (MOM) is used to discuss the electromagnetic radiation characteristics of the microstrip antenna. The simulator tool computes most of the useful quantities of interest such as radiation pattern, input impedance, etc. [1]. Microstrip Patch Antennas (MPA) is one of the promising candidates and has been found extensive applications in satellite communication application systems due to their advantages such as low profile, low-cost fabrication and ease of integration with feed network [2]. However, narrow bandwidth and low gain are the major weakness of the patch antenna. The recent technologies used to improve the performance of the MPA include the reactive loading [3], aperture coupling [4], increasing the substrate thickness [5], using more than one layer of resonator [6] [7] [8], and proximity feeding techniques [9] [10]. Simultaneously, the MPA needs to have small and compact configuration to accomplish the severe size constraints of some critical application such as mobile, Vehicle, cellular handsets, Bluetooth devices etc.

In this paper, the design of X-band and Ku band E-shape notch and H-shape slot loaded rectangular patch antenna at single layer with Co-axial feeding technique has been proposed. The H shape-cutting slot is chosen such that proposed antenna reduced the size and exhibit the wide bandwidth characteristics. Further, the variation of return loss for H shape horizontal side stripes length (W_n) and vertical length (W_2) has studied to obtain the maximum bandwidth. Simultaneously, the variation of return lost for parallel notch length (L_s) and notch width (W_s). Radiation pattern characteristics and the gain of the proposed antenna are also calculated. This antenna has improved the bandwidth and gain with reduced the size which are the advantages over the earlier reported paper [11]. In this paper, mainly I have used compact and reduced size of antenna, which results, is best in comparisons to previously published papers by using the method of reducing the size of the antenna by co-axial feeding technique. It is an extended work of published paper [12]. The proposed antenna can be used in wireless communication, satellite communication and for X, Ku band application.

2. Antenna Design and Structure

a) Parallel notch and H-slot loaded rectangular microstrip patch antenna

The proposed configuration of the antenna is shown in **Figure 1**. The antenna design consists of a single layer of thickness of 1.6 mm. The dielectric materials Rogers R03003's dielectric constant is 3.0. The H-shape slot loaded, E-shaped antenna is formed by inserting [13] the coordinate or by removing the inserted points from the rectangular patch of suitable dimension. Two parallel notches in rectangular patch, two vertical slots and one horizontal slot in H-shape are incorporated inside the rectangular patch antenna to perturb the surface current path. The probe is feed at point (−8.925, 2.125) as shown in **Figure 1**. The fabricated PCB antenna can be shown in **Figure 1(b)**.

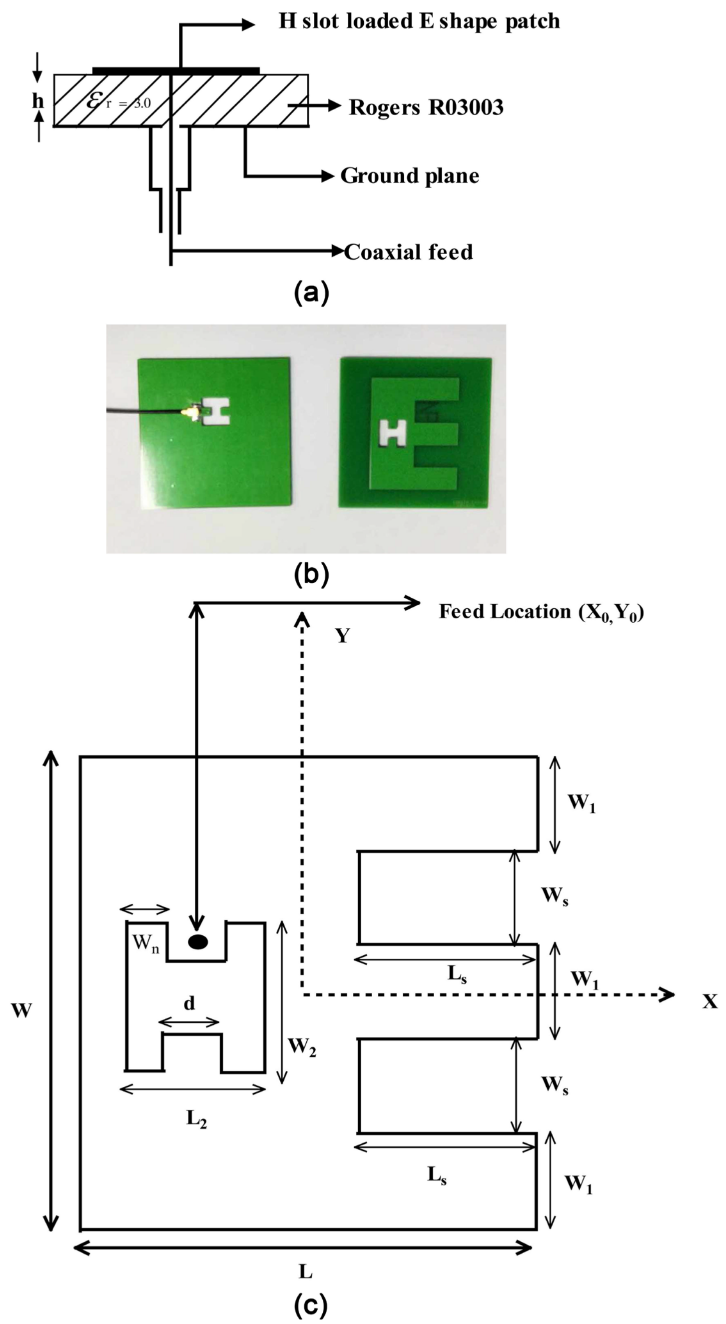

Figure 1. (a) Top view and (b) Prototype antenna (c) Side view geometry of the proposed antenna.

The E-shaped is simpler in construction. The two parallel notches have the same length L_s and same width W_s. The separation [14] [15] of the two notches is W_1. There are thus only three parameters (L_s, W_s, W_1) for the notches used here. Similarly, the H-shape slot is simpler in cut in same patch. The two vertical slots have the same length W_2, same side stripes width W_n and one horizontal slot length L_2. The separation [15] of the two slots is d. In this way, the four parameters are obtained in H-shape, *i.e.*, W_2, W_n, *and* L_2, *d*. A probe feeds a point (−8.925, 2.125) located for good excitation of the proposed antenna over a wide bandwidth. The current distribution of the proposed antenna is given in Figure 2.

b) ***Design Equation***

Because of the fringing effects, electrically the patch of the antenna looks larger than its physical dimensions the enlargement on L is given by [10]:

$$\Delta L = \frac{0.412h\left(\varepsilon_{reff} + 0.3\right)\left(Wh^{-1} + 0.264\right)}{\left[\left(\varepsilon_{reff} - 0.258\right)\left(Wh^{-1} + 0.8\right)\right]} \tag{1}$$

where the effective (relative) permittivity is,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12hW^{-1}}} \tag{2}$$

This is related to the ratio of *h/W*. The larger the *h/W*, the smaller the effective permittivity [16] [17] is. The effective length of the patch is given by:

$$L_{eff} = L + 2\Delta l \tag{3}$$

The resonant frequency for the TM_{100} mode is:

$$f_r = \frac{1}{\left[2L_{eff}\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0 \mu_0}\right]} \tag{4}$$

$$f_r = \frac{1}{\left[2\left(L + 2\Delta L\right)\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0 \mu_0}\right]} \tag{5}$$

An optimized width for an efficient radiator is,

$$W = \frac{1}{\left(2 f_r \sqrt{\varepsilon \mu_0}\right) \times \sqrt{\frac{2}{\varepsilon_r + 1}}} \tag{6}$$

c) ***Design Procedure***

If the substrate parameter (ε_r and *h*) and the operating frequency (f_r) are known then we can easily calculate the dimensions of the patch antenna using above simplified equation following design procedure to design the antenna:

Step 1: Using Equation (6) to find out the patch width W.

Step 2: Calculate the effective permittivity using the Equation (2)

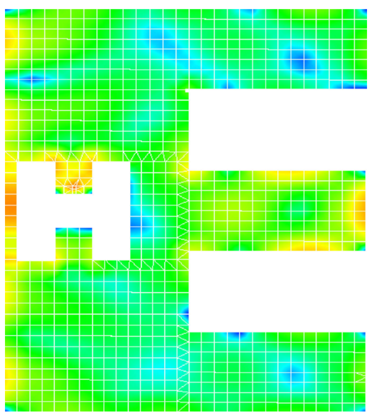

Figure 2. Current distribution at centre frequency (13.25 GHz) of the designed antenna.

Step 3: Compute the extension of the length using the Equation (1)

Step 4: Determine the length L by solving the equation for L giving the solution.

From Equation (6), (f_r) is the resonance frequency at which the rectangular microstrip antenna is to be designed. The radiating edge *W*, patch width is usually kept such that it lies within the range for efficient radiation. The ratio gives good performance according to the side lobe appearances. The actual value of resonance frequency is slightly less than because fringing effect causes the effective distance between the radiating edges of the patch to be slightly greater than *L*. By using the above equations, we can find the values of actual length of the patch as:

$$L=\left[\frac{1}{\left(2f_r\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}\right)}\right]-2\Delta L \tag{7}$$

Whole dimensions of the prescribed Antenna are given in Table 1.

The most sensitive parameters are found to be the thickness of substrate, shape and size of slots; notches are selected for the parametric study. To accurately understand the influence of these parameters on its impedance bandwidth, only one parameter at a time was varied, while others were kept constant.

3. Results and Discussion

We first show simulation results to illustrate the main features of the method.

The microstrip patch antenna structure is studied and simulated by using IE3D simulation software which is MOM (Method of Moment) based simulation software. As part of the simulation, it is observed that the return loss of the microstrip patch antenna is almost −25 dB, which is quite good when compared to normal antenna structures. Different simulated results are seen by using the

Table 1. Optimized dimensions of the Antenna (Unit: mm)

Frequency	10 - 17 GHz
W	37.21 mm
W_1	7.44 mm
W_s	7.44 mm
L	28.89 mm
L_s	14.44 mm
L_1	14.44 mm
W_2	9.0 mm
W_n	3.0 mm
L_2	9.0 mm
d	3.0 mm
Dielectric (ε_r)	3.0
Thickness (h)	1.6 mm, 2.0 mm

IE3D results like the return loss, radiation pattern, VSWR, and gain vs. frequency.

Figure 3, it is observed from the analysis of the return loss versus frequency that, the return loss of the designed microstrip patch antenna is −20 dB at the frequency of 13.16 GHz with a frequency band 11.0 GHz to 15.0 GHz, when the substrate height will increases up to from 1.6 mm to 2.0 mm, which result shown in Figure 4, it is observed from the analysis of the return loss versus frequency that, the return loss of the designed microstrip patch antenna is near about −25 dB at the frequency of 13.25 GHz with a frequency band 10.60 GHz to 15.91 GHz. Similar configuration in terms of VSWR versus frequency of the designed

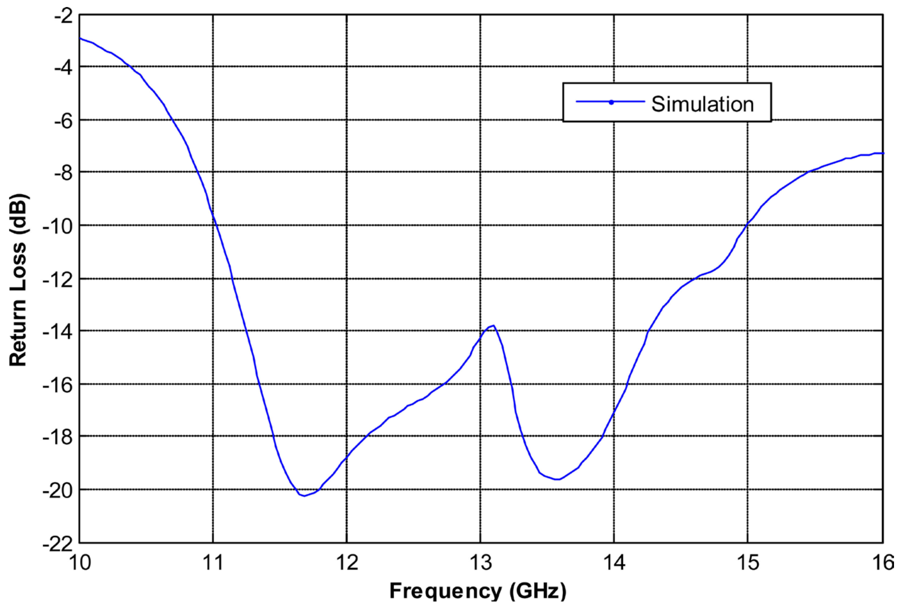

Figure 3. Comparative plot between Return loss and Frequency of the proposed antenna the substrate height at 1.6 mm.

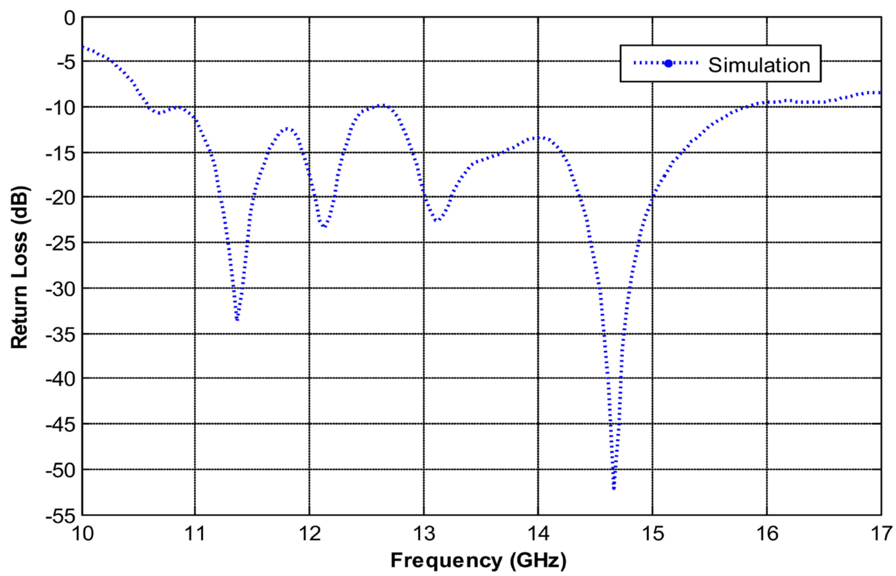

Figure 4. Comparative plot between Return loss and Frequency of the proposed antenna the substrate height at 2.0 mm.

antenna is shown in (**Figure 5** & **Figure 6**), Which shows that it is very useful for the vehicle antennas and it comes in range of X and Ku band which is used in satellite communications. It shows the impedance bandwidth of 40.01% enhancement, which is quite justifiable.

The antenna gain over the BW is shown in **Figure 7**. The antenna shows a gain of more than 7 dBi over the BW with peak gain of more than 9 dBi.

The above study shows the influence of size and shape of notches, slots and thickness of substrate on the impedance bandwidth. Wideband and UWB can

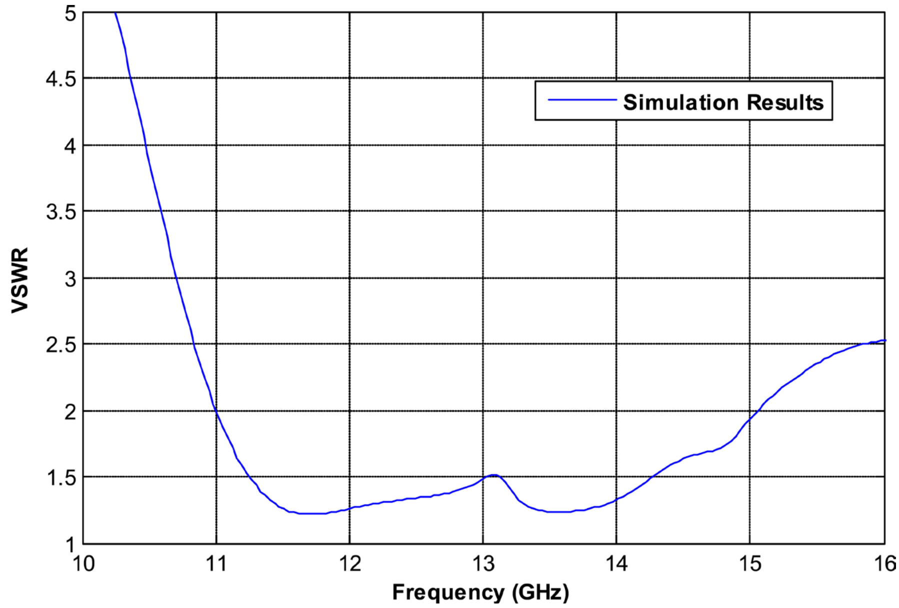

Figure 5. Comparative plot between VSWR and Frequency of the proposed antenna the substrate height at 1.6 mm.

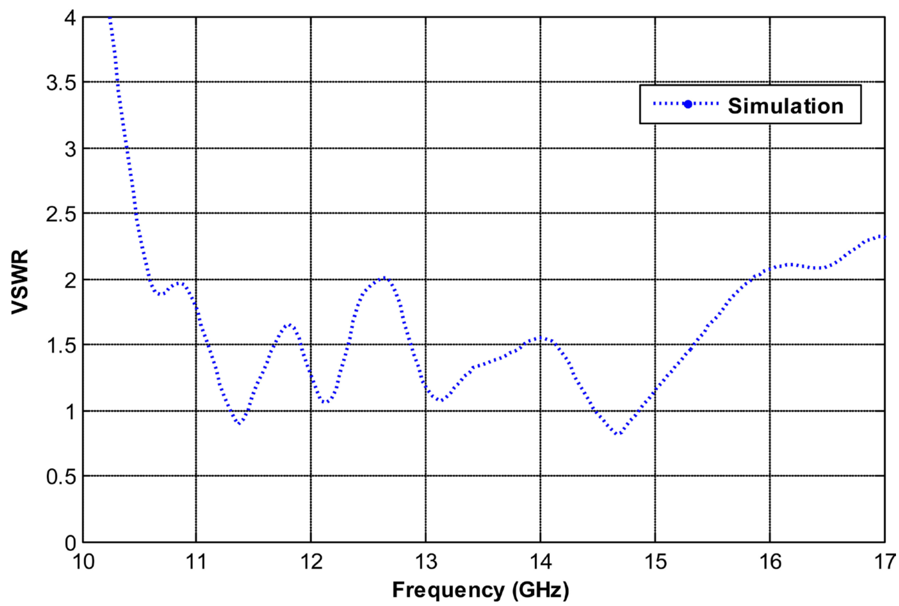

Figure 6. Comparative plot between VSWR and Frequency of the proposed antenna the substrate height at 2.0 mm.

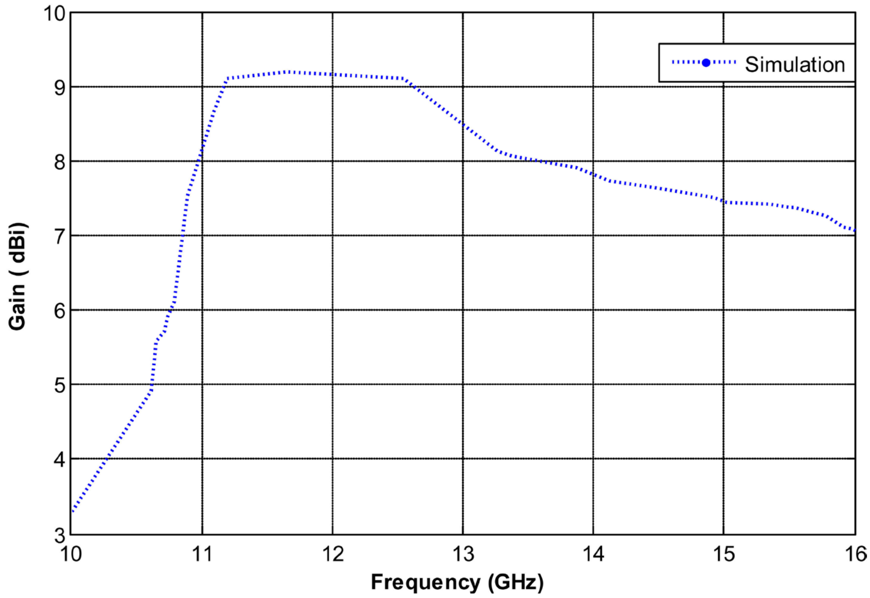

Figure 7. Gain versus frequency of the proposed antenna.

be easily achieved with monopole antenna using thick substrate and microstrip line-fed technique. However, our proposed antenna provides a wideband (10.60 - 15.91 GHz) with a thin microwave substrate and using coaxial probe-fed technique without monopole concept. At the same time gain of the antenna is also, high (9.2 dBi). Here lays the novelty of the research work.

4. Conclusion

The main concern of the paper is to study the wideband and high gain with simple and reduced size patch antenna. Initially, the single element rectangular microstrip antenna is designed to operate at frequency 13.25 GHz. This antenna structure provides a good amount of gain and the directivity along with that, this antenna structure works in two frequency bands as shown in the return loss and VSWR curve and provides good bandwidth. Present antenna is designed to meet the requirement for wide bandwidth with compact size. The proposed antenna is working in X and Ku- frequency band and can be used for satellite and RADAR communication system where simple wideband high gain antennas are desired.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Goswami, K., Dubey A., Tripathi, G.C. and Singh, B. (2011) Design and Analysis of Rectangular Microstrip Antenna with PBG Structure for Enhancement of Bandwidth. *Global Journal of Research Engineering*, **11**, 22-28.

[2] Ramadan, A., Kabalan, K.Y., El-Hajj, A., Khoury, S. and Al-Husseini, M. (2009) A Reconfigurable U-Koch Microstrip Antenna for Wireless Applications. *Progress in*

Electromagnetic Research, **93**, 355-367. https://doi.org/10.2528/PIER09050605

[3] Ojaroud, N., Ojaroudi, M. and Ghadimi,N. (2013) Dual Band Notched Small Monopole Antenna with Novel W-Shaped Conductor Backed Plane and Novel T-Shaped Slot for UWB Applications. *IET Microwave, Antennas and Propagation,* **7**, 8. https://doi.org/10.1049/iet-map.2012.0180

[4] Hsu, C.-K. and Chung, S.-J. (2014) Compact Antenna with U-Shaped Open-End Slot Structure for Multi-Band Handset Application. *IEEE Transactions on Antennas and Propagation*, **62**, 929-932. https://doi.org/10.1109/TAP.2013.2289996

[5] Ansari, J.A., Singh, P., Dubey, S.K., Khan, R.U. and Vishvakarma, B.R. (2008) Analysis of Slot-Loaded Stacked Disk Patch Antenna. *Microwave and Optical Technology Letters*, **50**, 2625-2629. https://doi.org/10.1002/mop.23738

[6] Lee, R.Q., Lee K.F. and Bobinchak, J. (1987) Characteristics of a Two-Layer Electromagnetically Coupled Rectangular Patch Antenna. *Electronics Letters*, **23**, 1070-1072. https://doi.org/10.1049/el:19870748

[7] Mak, C.L., Luke, K.M. and Lee, K.F. (1999) Wideband L-Strip Fed Microstrip Antenna. *IEEE Antennas and Propagation Society International Symposium*, 1999 *Digest*. Orlando, FL, 1216-1219.

[8] Ansari, J.A., Yadav, N.P. and Singh, P. Analysis of Disk Patch Antenna with Parasitic Elements in Single and Multilayer Structures. *Microwave and Optical Technology Letters*, **52**, 865-870. https://doi.org/10.1002/mop.25076

[9] Yadav, N.P. and Vishwakarma, B.R. (2013) L-Strip Feed Circular Disk Dual Resonator Patches Antenna for Wireless Communication. *Wireless Personal Communications*, **68**, 795-807. https://doi.org/10.1002/mop.25076

[10] Lo, T.K., Ho, C.O., Hwang, Y., Lam, E.K.W. and Lee, B. (1997) Miniature Aperture Coupled Microstrip Antenna of Very High Permittivity. *Electronics Letters*, *33*, 9-10. https://doi.org/10.1049/el:19970053

[11] Mok, W.C., Wong, S.H., Luk, K.M. and Lee, K.F. (2013) "Single Layer Single Patch Dual Band and Triple Band Patch Antennas. *IEEE Transaction on Antennas and Propagation*, **61**, 4341-4344. https://doi.org/10.1109/TAP.2013.2260516

[12] Yadav, N.P. (2015) Single-Layer Single Patch Four Band E-Shape Notch and Symmetrically H-Slot Loaded Compact Rectangular Patch Antenna for X-Band Applications. *International Journal of Advances in Electrical and Electronics Engineering*, **3**, 130-137.

[13] (2008) IE3D Simulation Software, Zeland, Version 14.05.

[14] Yang, F., Zhang, X.-X., Ye, X. and Rahmat-Sammi, Y. (2001) Wide-Band E-Shaped Patch Antennas for Wireless Communication. *IEEE Transaction on Antennas and Propagation*, **49**, 1094-1100. https://doi.org/10.1109/8.933489

[15] Ang, B.-K. and Chung, B.-K. (2007) A Wideband E-Shaped Microstrip Patch Antennas for 5 - 6 GHz Wireless Communications. *Progress in Electromagnetic Research*, **75**, 97-407. https://doi.org/10.2528/PIER07061909

[16] Balanis, C.A. (2005) Antenna Theory, Analysis and Design. 2nd Edition, John Wiley & Sons, New York.

[17] Johnson, R.C. (1993) Antenna Engineering Handbook. 3rd Edition, MGH, New York, NY.