MULTIBAND COMPACT MICROSTRIP PATCH ANTENNA FOR WIRELESS COMMUNICATION APPLICATIONS

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Abstract

In this paper, a multiband compact microstrip patch antenna for different communication frequencies has been presented. The proposed design of the microstrip patch antenna consists of a slotted patch, a quarter-wave feed line, and a ground with a cross-edge slot. The antenna can operate from 2.1 GHz to 3.4 GHz with a bandwidth of 1.3 GHz; this band corresponds to applications such as Mobile WiMax (2110 MHz-2200 MHz, 2300 MHz-2400 MHz, 2500 MHz-2690 MHz), Bluetooth (2400 MHz-2497 MHz), and RFiD. (2400 MHz -2483 MHz). The higher band, 4.7 GHz to 7.4 GHz, covers C-band, WLAN, and sub-6GHz 5G applications and has a gain factor of about 2.15 dB. The antenna is fabricated, and measurements of the radiation pattern and return loss are made. The comparison of observed results with those from simulations reveals excellent symmetry. Furthermore, the 70× 40 mm2 size of the proposed antenna makes it appropriate for use in lower 5G bands.

Keywords: Microstrip antenna, Multi band, patch antenna, RFiD, Sub- 6 GHz, Wi-Max, WLAN.

1. INTRODUCTION

Multi-band microstrip patch antennas (MPAs) have drawn a lot of interest in light of the quick growth of mobile communication systems because to its many benefits, including low profile, lightweight, cheap cost, superior performance, ease of manufacturing, low cost, and multi-band operation. As a result, they have long had a central role in research on antennas and wireless propagation. They have an intrinsic constraint of a small impedance bandwidth (almost 5%) when constructed on thin substrates.

The demand for mobile terminals with a variety of functionalities has surged due to the rapid development of wireless communications. Nowadays, it's practically a must for any Smartphone to integrate a variety of services, such as coverage of several cellular frequencies, the ability to use navigation and positioning, and the availability of Wi-Fi. Thus, in order to support all of these services, mobile terminals must operate at several frequencies. Moreover, portable gadgets must be lightweight, small, cheap, and compact in order to be mobile and flexible.

Antennas are a crucial component of any communication equipment that uses wireless technology and are essential to ensuring that the device complies with operational frequency, size, weight, and cost requirements. The mobile terminal becomes larger when each service has its own specialized antenna, which also increases the weight and price of the device.

A highly desirable solution to this issue has been the use of a single low-profile antenna that can operate in several bands at the many needed communication frequencies [1]-[4]. The universal mobile telecommunications system (UMTS), long-term evolution (LTE), Bluetooth, Worldwide interoperability for microwave access (WiMAX), and wireless local area network (WLAN) bands can all operate simultaneously on a multi-band microstrip antenna. In recent years, various designs of multi-band patch antennas have been proposed in the literature. Liu, Xiao et al [5]. Presents a novel multiband patch antenna design that can operate at three different frequencies. The antenna is composed of a rectangular patch with two inverted L-shaped slots, a T-shaped feed line, and a ground plane. Islam, Misran et el. [6] presents a compact multiband patch antenna with a novel E-shaped feed line. The antenna operates at three different frequencies, and the bandwidths are increased by using a slotted ground plane. Malhat, Safwat et el. [7] presents a compact multiband patch antenna with a T-shaped feed line. The antenna is designed to operate at four different frequencies, and the bandwidths are enhanced by using a slotted ground plane. Jiang and Xu [8] presents a multiband patch antenna with a slit ring resonator. The antenna is designed to operate at four different frequencies, and the bandwidths are increased by using a meandered ground plane. Islam and Ali [9] present the design and analysis of a dual-band patch antenna for WLAN applications. Abbosh and Bialkowski [10] proposes a multiband patch antenna design that can operate in the frequency bands of 900 MHz, 1.8 GHz, and 2.4 GHz. Das, Bahera and Patnaik [11] proposes a multiband microstrip patch antenna design that can operate in the frequency bands of 2.4 GHz, 5.2 GHz, and 5.8 GHz for wireless communication systems. Vishwakarma and Srivastava [12] presents a multiband stacked patch antenna design that can operate in the frequency bands of 2.4 GHz, 3.5 GHz, and 5.8 GHz for WLAN and WiMAX applications. Samsuzzaman and Islam [13] proposes a multiband fractal patch antenna design that can operate in the frequency bands of 1.8 GHz, 2.4 GHz, and 5.8 GHz for wireless communication systems. Singh, Kumar, and Gupta [14] proposes a multiband printed monopole antenna design that can operate in the frequency bands of 2.4 GHz, 5.2 GHz, and 5.8 GHz for wireless communication systems.

So, the multi-band patch antennas have been widely studied and proposed for various applications such as WLAN, Wi-Fi, and WiMAX. The design of these antennas is challenging due to the requirement of good impedance matching, radiation pattern, and gain over multiple frequency bands. However, the research conducted in this area has shown that it is possible to design compact, lightweight, and low-profile multi-band patch antennas with good performance characteristics, this inspires us to further study and make an antenna that can cover most of the mobile communications bands.

2. DESIGN METHODOLOGY OF THE ANTENNA

This section describes the process that demonstrates how the suggested antenna is created step-by-step to obtain the appropriate frequency band. To get multiband characteristics, four distinct micro strip antennas were constructed and simulated using the ANSYS HFSS software.

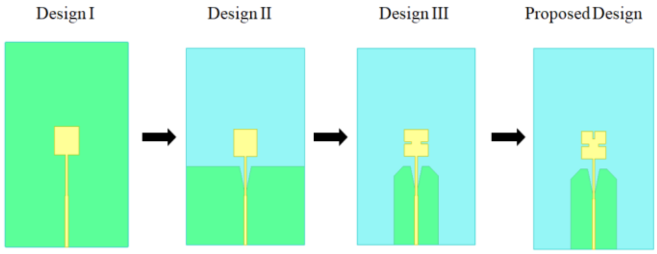


Figure 1: *Different phases of the proposed antenna geometry*

2.1 Basic Rectangular Patch Antenna Design (Design I)

The antenna was designed using the middle frequency of the UWB band, 6 GHz, as the resonant frequency. The model of antenna has been developed using the resonant frequency (f), dielectric constant (ε_r), and dielectric height (h) formulas from [15].The equations provided in [16] have been taken into consideration when designing the classic Rectangular patch antenna (RPA) with dielectric constant (ε_r), resonant frequency (f), and dielectric height (h). Equations (1) to (3) have been used to calculate the length of patch (L_p), width of the patch (W_p) and width of the feed line (W_f). The antenna has been designed and modeled in FEM-based electromagnetic software named Ansys HFSS after all the parameters have been calculated. Some of the parameter values have been tuned to ensure the intended performances. The optimum parameter value for the traditional RPA is displayed in table 1 and the model using the parameters obtained is illustrated in Fig. 1 (Design I).

$$\frac{c}{2f\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

$$= \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1+12\frac{h}{Wp}\right]^{\frac{1}{2}} \tag{2}$$

$$\frac{0.412h(\varepsilon_{reff}+0.3)(\frac{W_p}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W_p}{h}+0.8)} \tag{3}$$

$$= \frac{c}{2f\sqrt{\varepsilon_{reff}}} \tag{4}$$

$$L_{eff} + 2\Delta L \tag{5}$$

For a rectangular Microstrip patch antenna, the resonance frequency for any TMmn mode is given as [17]:

$$f = \frac{c}{\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L_p}\right)^2 + \left(\frac{n}{W_p}\right)^2\right]^{\frac{1}{2}} \tag{6}$$

Where,

h = dielectric substrate height
W_p = patch width
ε_r = substrate dielectric constant
ε_{reff} = dielectric constant effective

The S11 [dB] of the design I is as illustrated in Fig. 2. It shows the antenna does not radiate in the given frequency range. So more modification are desired in the design and geometry of antenna.

2.2 Rectangular Patch Antenna with Partial Ground (Design II)

In this iteration, more than half of the ground is removed while keeping the patch size constant, and simulation is performed, but the result shows no improvement. To improve the performance, a triangular slot is removed along the microstrip feed line. The antenna began to resonate around 4 GHz and 5.5-6.5 GHz as a result of this modification. Many applications use frequencies ranging from 2.1 GHz to 3 GHz, so this is one of the approximate desired bands. Because the desired frequency band is not obtained in this design, hence, additional modifications are required.

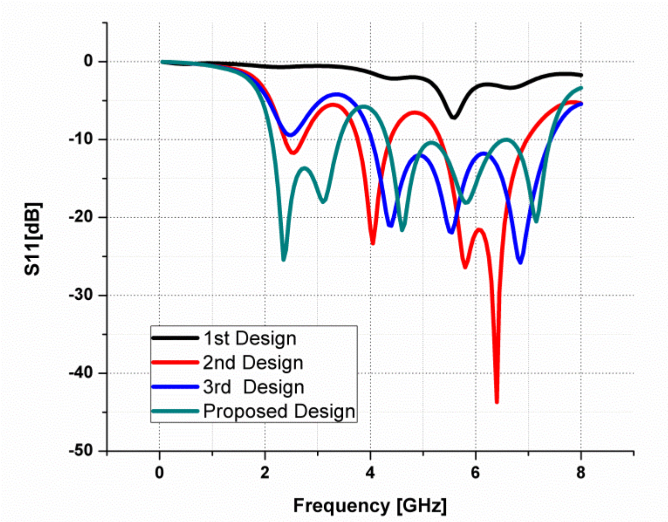


Figure 2: *Comparison of S11 (dB) for the different design under study*

2.3 Slot loaded Patch antenna with small partial ground (Design III)

To achieve the desired frequency band, the ground is reduced further while leaving the triangular slot along the micro stripe line intact. This step yields superior results than design II as shown in Fig. 2. Two 1mm by 3mm slots are introduced along the width of the rectangular patch to improve the design even further. Because of the slots and the removal of the ground, the antenna begins to radiate in a wide band ranging from 4 GHz to 8 GHz. Still, the desired lower band operation is not observed, so more design changes are required.

2.4 Slot loaded (Notched) Patch along width and length with partial ground (Proposed design).

The rejection of a single band frequency was achieved by eliminating a slot from the radiating patch. Fig.4 depicts the suggested patch antenna geometry, whereas Fig. 3. Depicts the S11. Which shows that the slot has enhanced antenna bandwidth as well. The slot dimensions can be changed to control the notched band (length and width). It also shows that the rejected band has a bandwidth ranging from 3.4 GHz to 4.3 GHz. The band-notched feature is obtained by using the stopband's centre frequency, which specifies the dimension of the slot and may be represented as [18],

$$F_n = \frac{c}{4\, L_{slot}\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{7}$$

$$L_{slot} = l_s + w_s \tag{8}$$

Where,
l_s = slot length
w_s = Slot width

The notched can be controlled by changing the value of l_s and w_s.

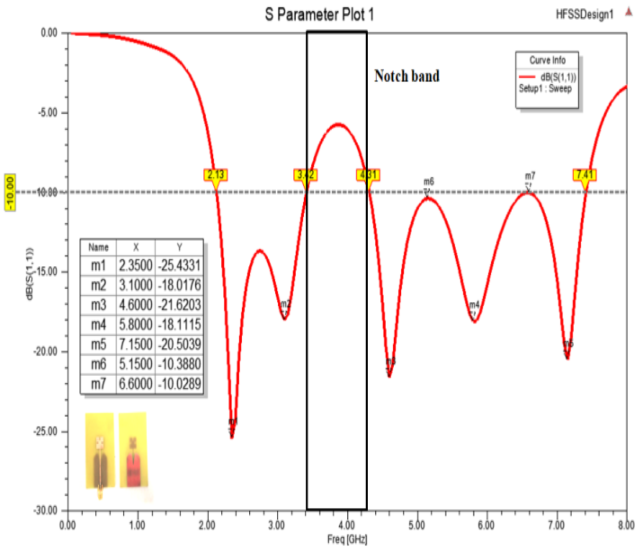
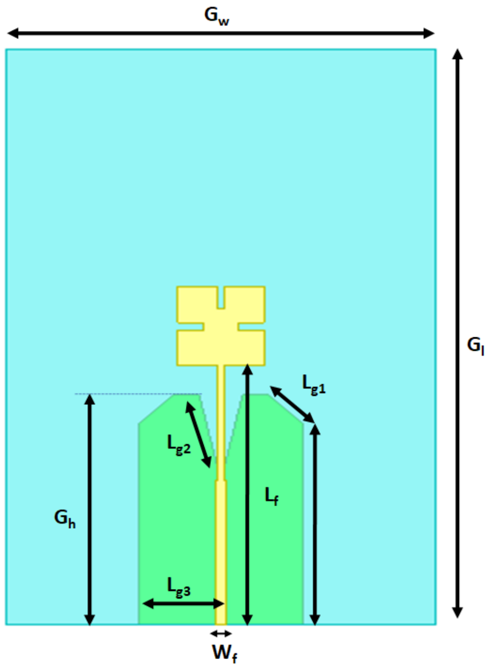


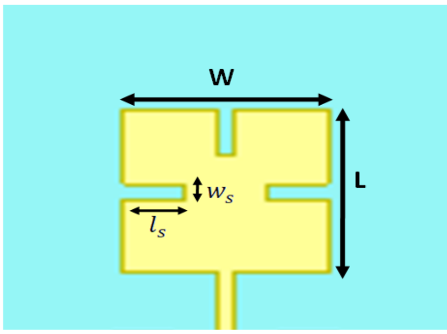
Figure 3: *S11 (dB) graph for proposed design demonstrating notch band.*

Table 1: *Physical Parameters and dimensions of proposed design*

Parameter	Dimensions (mm)
Patch width (W)	11
Patch Length (L)	10.3
Width of Feed line (W_f)	1.34
Length of Feed line(L_f)	36
Ground Length (G_l)	48
Ground width (G_w)	38
Slot width (w_s)	1
Slot Length (l_s)	3
Length of ground Arm (Lg1)	4
Length of ground slot (Lg2)	12
Half Length of ground (Lg3)	9.5



(A)



(B)

Figure 4.: *Design and parameter of the for proposed antenna design (A)Top view showing parameters of ground and substrate geometry (B) Top View Showing parameters of radiating patch.*

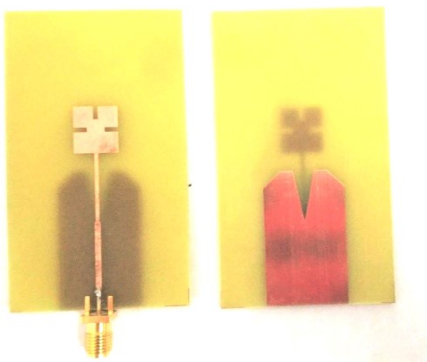


Figure 5: *Fabricated design of proposed antenna with top and bottom view.*

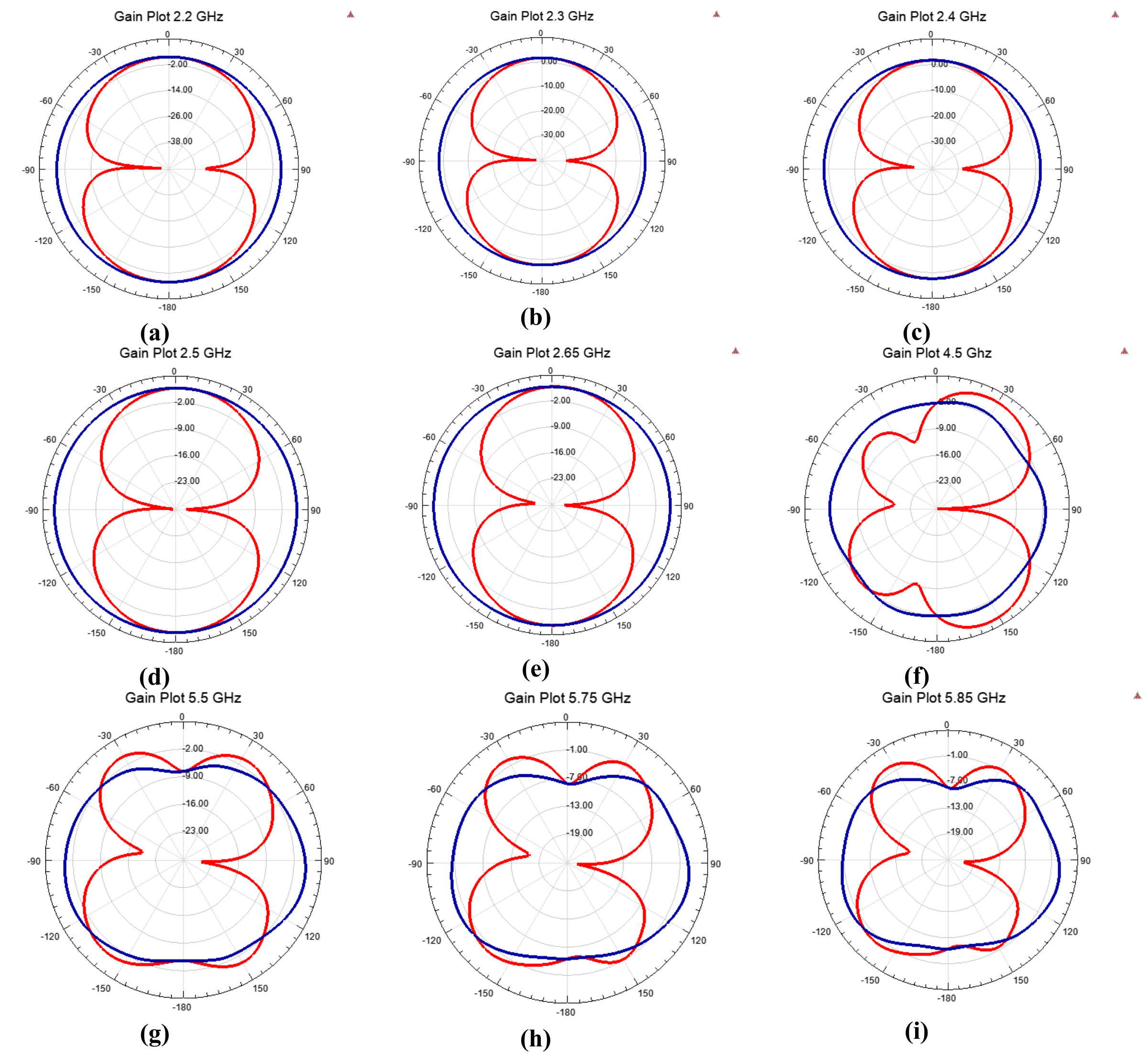


Figure 6: *Radiation pattern of proposed antenna at various frequencies (a)2.2 GHz (b) 2.3 GHz (c) 2.4 GHz (d) 2.5 GHZ (e)2.65 GHz (f)4.5 GHZ(g)5.5 GHz (h)5.75 GHz (i) 5.85 GHz.*

3. RESULTS AND DISCUSSION

After getting results in desired bands it was decided to fabricate the proposed design. The antenna is fabricated on FR4 substrate having loss tangent of 0.001 and permittivity of 4.4. The thickness of FR4 used is 1.6 mm. the fabricated antenna is as shown in Fig 5.

3.1 Comparison of Simulation and Measured S_{11}

The S11 plot of the all four simulated design was compared in Fig 2. It shows that the proposed antenna resonates from 2.13 GHz to 3.42 GHz, having minimum s11 at 2.35 GHz, which is -25.4 dB and at 3.15 GHz it is -17 dB. Further it resonates from 4.32 GHz to 7.41 GHz having three minima at 4.65 GHz, 5.85 GHz and 7.15 GHz.

The comparison of measured result and simulated results are shown in Fig 6. The results shows excellent match at every band. Slight mismatch and slight shift in frequency is observed in measured result, which may be due to the fabrication error and mismatch at excitation port.

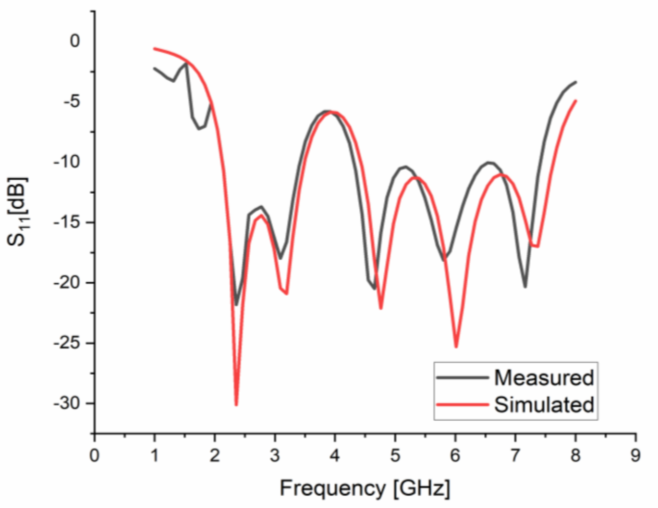


Figure 7: *Comparison of S11 [dB] parameter of proposed antenna with simulated one*

3.2 Radiation Pattern Comparison

The proposed antenna's radiation pattern has been analyzed at various frequencies, ranging from 2.2 GHz to 5.85 GHz, as shown in Fig. X. The results indicate that the radiation pattern remains almost constant in the lower band, 2.1 GHz to 3.1 GHz, with a bi-directional pattern in the elevation plane and an omni-directional pattern in the azimuth plane. This pattern is essential for mobile communication applications. In the higher band, the radiation pattern slightly deteriorates in the azimuth plane from perfect omni-directionality. However, there is no significant variation in the radiation pattern beyond the 5 GHz band, and it remains approximately omni-directional in the azimuth plane.

3.3 Comparison with existing literature

Table 2 provides a comparison of the proposed antenna and a few different UWB antennas. In comparison to the references, it is concluded that the suggested antenna has a compact structure and good notched-band properties.

Table 2: *Comparison of proposed antenna with existing literature*

Ref.	Freq. band (GHz)	Notch band	Application	Dimension	Notch band
[15]	3.1-10.6	3.2-3.8 4.8-6.2	WiMAX, WLAN	30 *30	Dual band
[18]	2.4-5.9	4.2- 4.8	Wifi, WLAN, Wimax	45* 40	Single Band
[19]	2-10	5.10-6.10	UWB	47*37	Single band
[20]	3-11	5-6	UWB	50*41	Single band
[21]	3.5-7.5	5.05-6.17	UWB	49*53	Single band

[22]	3.1-10.6	5-6	UWB	40*35	Single band
This work	2.13-7.14	3.42-4.31	Wifi, Bluetooth, WLAN, Wimax	48*38	Single Band

4. CONCLUSION

In conclusion, the analysis and design of a multiband compact microstrip patch antenna that is appropriate for various wireless communication systems and can function in a wide range of frequencies have been described. Through extensive simulation, optimization and measurement, we have determined that the proposed design provides the best performance, with a gain of 2.15 dB and multi-band operation at 2.11-3.43GHz and 4.30-7.32GHz. The fabricated antenna was tested in ELARC lab V.V. Nagar-Anand, and the simulated and measured results showed excellent agreement. Compared to other multiband and wideband antennas, the proposed antenna is cost-effective, compact, and covers almost all the applications of S-band and C-band. Furthermore, it is suitable for sub-6 GHz 5G applications. Overall, the proposed antenna design offers a promising solution for wireless communication systems operating in a wide range of frequencies.

References

[1] Ali, M., Hayes, G., Hwang, H.-S., & Sadler, R. (2003). Design of a multiband internal antenna for third-generation mobile phone handsets. *IEEE Transactions on Antennas and Propagation*, 51(7):1452-1461.

[2] Liao, W. J., Chang, S. H., & Li, L. K. (2010). A compact planar multi-band antenna for integrated mobile devices. *Progress In Electromagnetics Research*, 109:1-16.

[3] Falade, O., Ur Rehman, M., Gao, Y., Chen, X., & Parini, C. (2012). Single feed stacked patch circular polarized antenna for triple-band GPS receivers. *IEEE Transactions on Antennas and Propagation*, 60(10): 4479-4484.

[4] Zhang, T., Li, R., Jin, G., Wei, G., & Tentzeris, M. (2011). A novel multiband planar antenna for GSM/UMTS/LTE/Zigbee/RFID mobile devices. *IEEE Transactions on Antennas and Propagation*, 59(11):4209-4214.

[5] Liu, Y., Xiao, S., & Yin, Y. (2009). Design and analysis of a novel multiband patch antenna. *Progress in Electromagnetics Research* 93:61-74.

[6] Islam, S. S., Islam, M. T., & Misran, N. (2013). A compact multiband patch antenna with a novel E-shaped feed line. *Microwave and Optical Technology Letters*, 55(3): 530-533.

[7] El-Azem Malhat, H. A., Safwat, A. M. E., & Ibrahem, S. M. M. (2014). A compact multiband patch antenna using a T-shaped feed line. *International Journal of Electronics and Communications*, 68(5):390-396.

[8] Jiang, J., & Xu, Y. (2013). Design of a multiband patch antenna with a slit ring resonator. *IEEE Antennas and Wireless Propagation Letters*, 12:1398-1401.

[9] Islam, T., & Ali, M. (2011). Design and analysis of a compact dual-band patch antenna for WLAN applications. *IEEE Transactions on Antennas and Propagation*, 59(5):1702-1706.

[10] Abbosh, M., & Bialkowski, M. E. (2008). Design and optimization of a multiband patch antenna for wireless communication systems. *IEEE Transactions on Antennas and Propagation*, 56(7), 1868-1876.

[11] Das, S., Behera, S. K., & Patnaik, A. (2014). Multiband microstrip patch antenna for

wireless communication systems. *International Journal of Electronics and Communication Engineering & Technology*, 5(3):66-71.

[12] Vishwakarma, R. K., & Srivastava, D. K. (2014). Design and analysis of multiband stacked patch antenna for WLAN and WiMAX applications. *International Journal of Antennas and Propagation*, 2014, Article ID 739139

[13] Samsuzzaman, S., & Islam, M. T. (2012). Design and analysis of a multiband fractal patch antenna for wireless communication systems. *Progress In Electromagnetics Research*, 132:523-536.

[14] Singh, S. P., Kumar, P., & Gupta, K. C. (2011). Design and analysis of a multiband printed monopole antenna for wireless communication systems. *Microwave and Optical Technology Letters*, 53(11):2639-2643.

[15] Zheng, Z.-A., & Chu, Q.-X. (2009). A compact dual-band printed monopole antenna for WLAN applications. *Progress In Electromagnetics Research*, 11:83-91.

[16] Islam, M. S., Ibrahimy, M. I., Motakabber, S. M. A., Hossain, A. K. M. Z., & Azam, S. M. K. (2019). Design of a Compact UWB Antenna with Dual Notched Bands for WLAN and WiMAX Applications. *Bulletin of Electrical Engineering and Informatics*, 8(2):586-596.

[17] Ye, L.-H., & Chu, Q.-X. (2010). Dual-band monopole antenna with a parasitic strip for *WLAN applications. Electronics Letters*, 46(5): 325-326.

[18] Sun, J.-S., & Huang, S.-Y. (2013). Broadband printed planar monopole antenna for wireless terminal devices applications. Microwave and Optical Technology Letters: 55(1), 79-82.

[19] Zhang, K., Li, Y., & Long, Y. (2010). Band-Notched UWB Printed Monopole Antenna with a Novel Segmented Circular Patch. *IEEE Antennas and Wireless Propagation Letters*, 9:1209-1212.

[20] Ahmed, O., & Sebak, A.-R. (2008). A Printed Monopole Antenna With Two Steps and a Circular Slot for UWB Applications. *IEEE Antennas and Wireless Propagation Letters*, 7:411-413.

[21] Jang, J.-W., & Hwang, H.-Y. (2009). An Improved Band-Rejection UWB Antenna With Resonant Patches and a Slot. *IEEE Antennas and Wireless Propagation Letters*, 8:299-302.

[22] Komjani, M. Y. N. (2011). A Compact Band-Notched UWB Planar Monopole Antenna with Parasitic Elements. *Progress In Electromagnetics Research Letters*, 24:129-138. doi:10.2528/PIERL11043002