Bulletin of Electrical Engineering and Informatics
Vol. 10, No. 4, August 2021, pp. 2072~2078
ISSN: 2302-9285, DOI: 10.11591/eei.v10i4.2935

Design compact microstrap patch antenna with T-shaped 5G application

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Article Info

Article history:

Received Mar 1, 2021
Revised May 30, 2021
Accepted Jun 23, 2021

Keywords:

Microstrap patch antenna
T-shaped slot 5G
Wireless communications

ABSTRACT

This paper is presents a microstrap patch with a T-shaped rectangular antenna workings; the T-shaped patch operating at 3.6 GHz resonating frequency range for 5G application (from 2.9 to 4.4 GHz) repectively. The overall size of the proposed antenna is 22×24×0.25 mm^3; the feeding technique using a 50 Ω feed line to the antenna. The proposed antenna is printed on compact Rogers RT 588 lz substrate having permittivity (εr) 2.00, loss tangent (tan δ) 0.0021, with thikness 0.2 mm. The proposed antenna introducesmany advantages like small size, low profile, and simpler structure. The characteristics such as radiation pattern, reflection coefficient, gain, current distribution, and radiation efficiency are respectively presented and discussed, using CST microwave study in simulating and analysing. Introducing a slot with a rectangular T-shaped patch antenna achieved lower frequency with 98.474% radiation efficiency and peak gain of the proposed antenna at 2.52 dB. The fractional bandwidth is 42.81% (2.90 GHz to 4.48 GHz) with a resonant frequency of 3.6 GHz and return loss at 28.76 dB. This frequency band attributessuited 5 G mobile application.

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1. INTRODUCTION

The cellular services explosive growth calls for higher capacity and faster data speeds. A new spectrum with fifth generation (5G) technology and more bandwidth (BW). Many countries employ N78 (3.3-3.8 GHz) band for the new 5G radio in 6 GHz sub-band. Antennas were required in the 3.5 GHz range for the past worldwide interoperability for microwave access (WiMAX) network. With the advent of 5G, the 3.5GHz band experienced rapid growth. Many large scale 5G networks experiments are being successfully conducted around the world. In the past few decades, researchers have been studying to improve the radiative performance of communication antennas. The microstrip patch antenna is disused in [1], [2]. Therefore, the development of wireless networks is crucial because 5G technology uses high-frequency bands and wide signal bandwidth to increase the transmission bit rate, thus providing better coverage with less power consumption [3], [4]. Be developed in the wireless 4G and 5G communication generation to meet the required performance. Wireless communication is amultiple systems convergencein wireless access technologies [5], [6]. Thus 3.5 GHz band has broad application prospects in 5G implementation [7]. In wireless communications system, one of the main goal is focoues on the next generation through some required must achive are highe data rate application and service such as image in local coverage network, web browsing, wireless teleconference and multimedia. This major challenge factor for next generations [8]. For most mobile data where internal traffic is generated, antenna distributionplays an increasingly significant role in indoor wireless communication systems. In addition, toprovide better communication services, many frequency bands are designed and commercially used in different communications systems such as 4G WiMAX and wireless local area network (WLAN). Therefore, a capable broadband distribution antenna is required in simultaneously meeting multiple service frequency bands [9]. The microstrip (MSA) antenna withmany advantages, such as small size, low cost, and easy integration with active circuits;suitable for multi-band design and dual-polarisation antennas [10], [11], are widely used in printed circuits. Main drawback ofmicrostrip patch antenna is itsnarrow bandwidth. Therefore, many techniques have been used to increase the bandwidth [12]-[14].

Microstrip patch antennas have been used in wireless and communication systems, but their gain and power handling ability are small [15]. Wong in [16], Baudha and Kumar [17], methods such as U-shaped and rectangular segmentation have been proposed to improve the bandwidth of microstrip antennas. Many frequency bands have narrowband applications [18], [19] like 3.3 GHz to 3.7 GHz for WiMAX [20], lower frequency band (4.5-5.5 GHz) for 5G applications [21], 5.15 GHz to 5.35 GHz, and 5.725 to 5.825 GHz for WLAN [22]. Antenna bandwidth can also be enhanced through using two pairs of quarter wavelengths (λ/4) microstrip line resonators, paired close to the rectangular patch antenna [23], [24]. The T-shaped patch antenna is optimised to have a rectangular hole and can be directly inserted into the 50 Ω microstrip line using the following method, the IE3D emulator optimized bandwidth at 2.45 GHz by changing each of the four parameters while keeping the other three constants [25].

In this paper, compact size antenna with techini T-shape microstrip patch antenna using material Rogers RT/588 lz substrate having permittivity (εr) 2.00, loss tangent (tan δ) 0.0021, with thikness 0.25 mm, parasitic radiator has been analysed, designed, and fabricated for frequency band from 2.9 GHz to 4.4 GHz, of 5G application. The substrate matxerial choice greatly influences the bandwidth and patch antenna size. Decreasing the dielectric constant will increase both the bandwidth and antenna size while increasing the dielectric constant increases the bandwidth, efficiency, and antenna size.

2. ANTENNA CONFIGURATION

The design microstrap patch by useing CST softwer, in designing a rectangular microstrip patch antenna, the calculations for width and length of the rectangle patch is as follows [26].

$$W=\frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

The speed of light in free space is (c) (3 x 108 m/s), εr isthe dielectric constant of the substrate, while fr is the design antenna frequency, the correction width is W, and the effective dielectric constant εreff, is given in [26].

$$\varepsilon reff=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \tag{2}$$

Where the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is a function of the effective dielectric constant ε reff and the width-to-height ratio (W/h), and the normalized extension of the length, is

$$\frac{\Delta L}{h}=0.412\,\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{3}$$

Thus, the actual length of the patch can be calculated as [26].

$$L=\frac{c}{2f_r\sqrt{\varepsilon_{reff}}}-2\Delta L \quad (4)$$

The rectangular microstrip patch, length and width of the ground plane can then be calculated as

$$Lg=6h+L \quad (5)$$

$$Wg=6h+W \quad (6)$$

3. DESIGN OF T-SHAPE MICROSTRIP ANTENNA

A miniaturised T-shaped microstrip structure as shown in Figure 1, is presented to enhance the antenna performance. The designed T-shaped microstrip patch antenna was fabricatedon the R/Duroid 5880 LZ with a dielectric substrate constant of 0.0021 and 3.6 GHz in design frequency. The dielectric height of the substrate is 0.254 mm. This proposed microstrip is used for 5G application. The microwave studio program CST is used as the main program to design and simulatethe antenna. One of the main issues that must be carefully considered in any design processes is the choice of materials. The thickness of the material can also play a decisive role in small tapesprompting for a careful selection during designing the antenna. In designing the microstrip arc structure, Roger’s RT/Duroid 5880 LZ is used as raw materials. These materials were chosen because they are cheap and readily available.

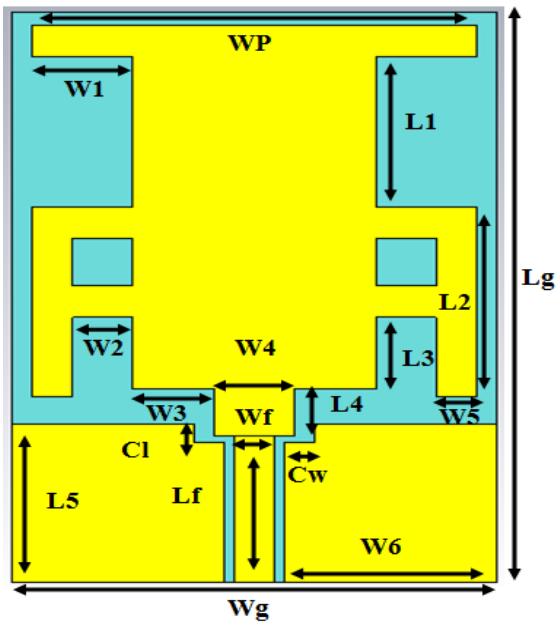


Figure 1. The geometry of the proposed T-shape microstrap patch antenna

4. ANTENNA STRUCTURE

The dimensions of the proposed microstrip antenna were calculated by applying (1-6). The simple rectangular microstrip patch antenna is excited by 50 ohms impedance microstrip line to get better impedance matching and the dimension of the feed line microstrip patch is 9.20 mm long and 2 mm wide; excitation was created using a 3.6 GHz resonance frequency. The T-shape microstrip patch antenna was designed following the specification parameters shown in Table 1. The maximum bandwidth of the T-shape microstrip patch is 2.9 to 4.4 at 3.6 GHz resonating frequency with return loss (S11) is-28.809 dB. Inserting edge pieces into the design makes the resonating Hulk works in a band operation. Strings in the slot will enhance the antenna gain. The tapered ground is inserted into the rear of the chassis to improve the bandwidth and feeder. Matching the proper impedance will make the design resonate in enhanced performance of the antenna design parameters. The structure of the designed antenna with the optimised dimensions is shown in Figure 1.

Table 1. The specification of antenna design

Parameters	Value
Design frequency (f_r)	3.6 GHz
Dielectric constant (ε_r)	2
Height of the substrate (h)	0.25 mm
angent (tan δ)	0.02
Width of the T- shape patch (Wp)	22 mm
The ground plane width (Wg)	24 mm
The ground plane length (Lg)	36 mm
The feed line strip length of (Lf)	9.2 mm
The feed line strip width (Lw)	2 mm
Width of the edge cut (Cw)	1.5 mm
Length of the edge cut (Cl)	1.2 mm

The microstrip patch antenna length and width are 22 mm and 34 mm, respectively. The overall size of the proposed microstrip patch antenna ground plane is 24×36×0.25 mm^3. Shown in Table 1 and Table 2 are the specification parameters of the T-shaped rectangular patch antenna. These different parameters keep the other parameters separately stable. The strings in the slot will enhance the antenna gain. The ground is inserted into the rear of the chassis to improve the bandwidth and feeder. Two rectangular T-shaped in the patch antenna with diminutive 5×2 mm and 12×2 mm were designed with horizontal and vertical arms of the rectangular T-shaped patch antenna, respectively. The simulation resultsin the return loss at resonant frequency 3.6 GHz and the matching of the return loss (S11) is-28 dB. The maximum bandwidth of 1.5 GHz is observed at 3.6 GHz and VSWR of the structure is shown in Figure 2.

Table 2. T-shape patch antenna parameters

Parameters	Value
W1	5 mm
W2	3 mm
W3	4 mm
W4	3.5 mm
W5	2 mm
W6	10.5 mm
L1	9.5 mm
L2	12 mm
L3	4.5 mm
L4	3 mm
L5	10 mm

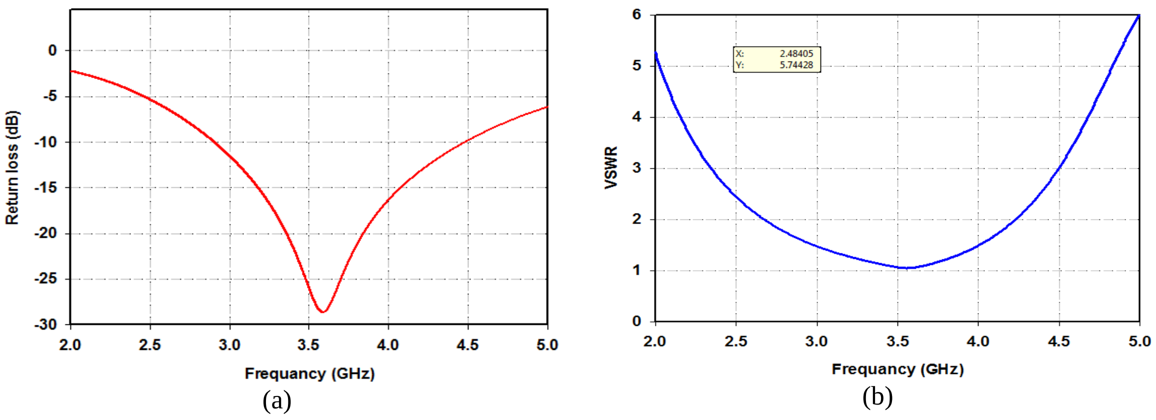


Figure 2. These figures are; (a) return loss for proposed antenna, (b) VSWR plot

5. RESULT AND DISCUSSION

The simulation and fabrication results in the T-shape patch antenna incorporating RT/Duroid 5880LZ materials as the substrate with a thickness of 0.25 mm and loss tangent (tan δ) 0.02. It can be seen in Figure 3 that the antenna was matched in the (S11) at about -28.76 dB for the simulation while the measurement (S11) was about -20.4 dB, respectively. The bandwidth (BW) of T-shape microstrip patch antenna wassimulated from 2.90 GHz to 4.48 GHz, at 42.81% efficiency, meanwhile, the measured bandwidth is from 3. 27 GHz to 4.22 GH. Four parameters of the T-shape microstrip patch antenna was found enhanced; simulated and analysed using CST Microwave studio at the resonant frequency of 3.6 GHz. The performance indicators such as return loss (simulated and measured). The proposed antenna gain is 2.52 dB and the antenna efficiency is 98.474% at 3.6 GHz resonant frequency, respectively. While bandwidth is 42.81% (2.90 GHz to 4.48 GHz) with a resonant frequency of 3.6 GHz and return loss -28.76 dB. Comparsion return loss between simulated and measured, gain, radaion pattern directivity, and surface current distribution of the proposed T-shape patch antenna are plotted for this frequency range of 2-5 GHz in Figures 3-9.

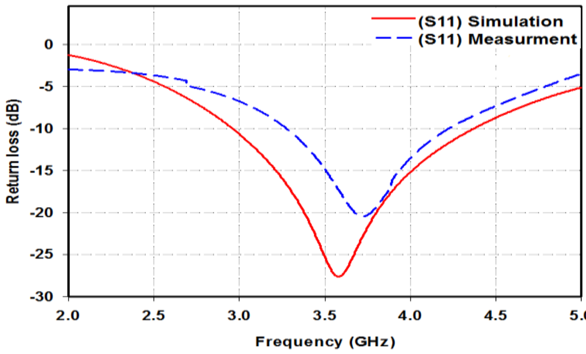
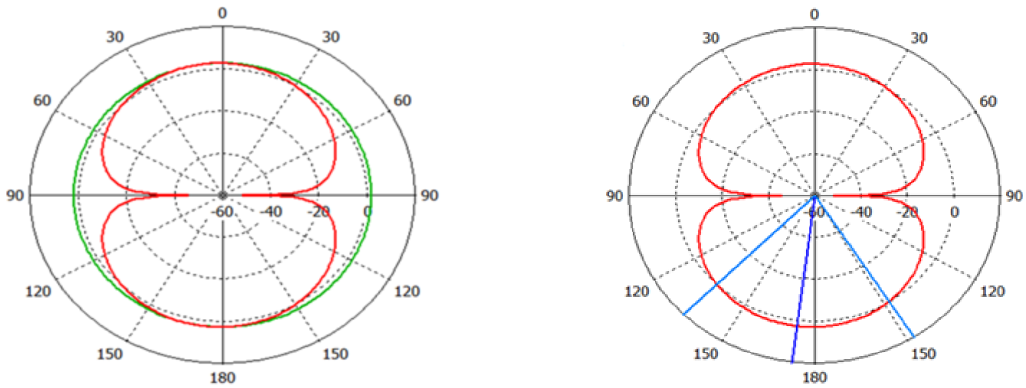


Figure 3. The comparison (S11) for simulated and measured return loss of T-shape patch antenna



(a) (b)

Figure 4. Radiation pattern characteristic for both, (a) phi=0º at 3.6 GHz, (b) 90º at 3.6 GHz

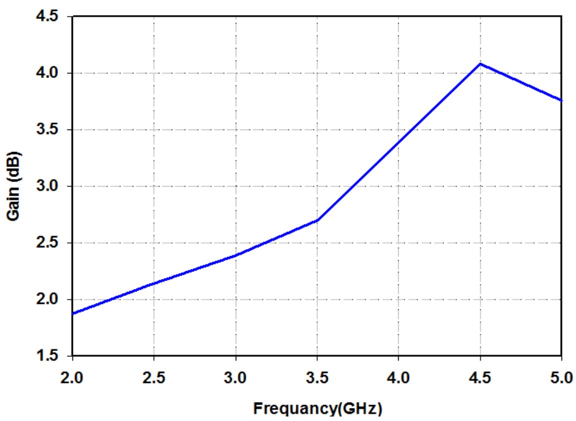


Figure 5. Realized gain of the proposed antenna

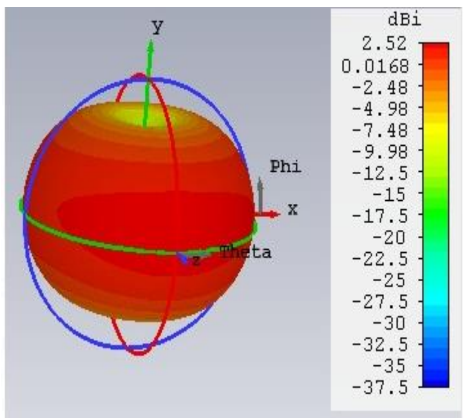


Figure 6. 3-D plot of the gain characteristics

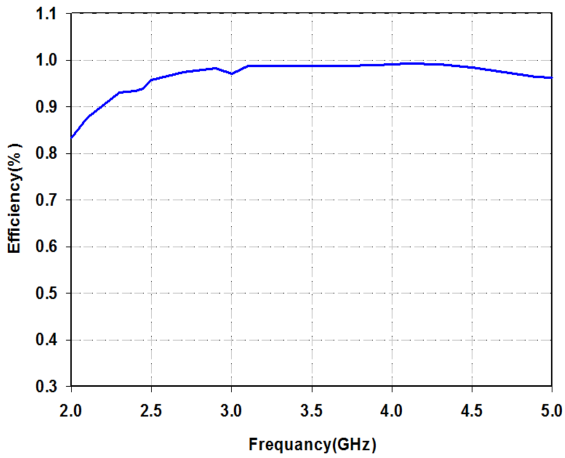


Figure 7. Radiation efficiency of the proposed antenna

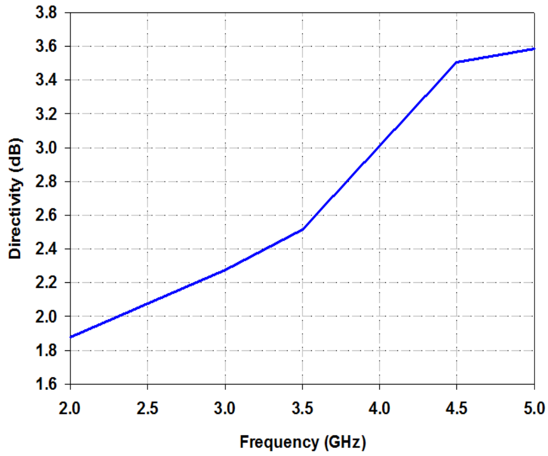


Figure 8. Directivity of the proposed antenna

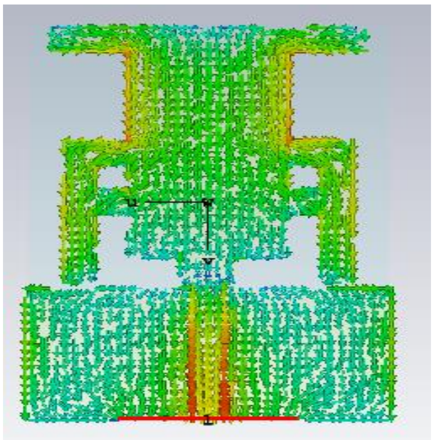


Figure 9. The graph of surface current distribution for proposed antenna

6. CONCLUSION

In this proposed, compact T-shape microstrip antenna is proposed for 5G wireless communication system. The proposed microstrip patch antenna was simulated and printed by using R/Duriod 5880 LZ, with an overall size of the microstrip patch antenna was 22×24×0.25mm^3. Designing T-shape microstrip patch is done to overcome the narrow bandwidth limitation of the conventional microstrip patch antenna. This structure provides the best impedance matching at different frequencies and thus has stable radiation characteristics at different frequencies. Introducing a rectangular T-shaped aperture at ground level can improve the bandwidth of the low-frequency band. The optimize antenna's fractional bandwidth is 42.81% (2.90 GHz to 4.48 GHz) with a resonant frequency of 3.6 GHz and return loss -28.76 dB. The proposed antenna gain is 2.52 dB and the antenna efficiency is 98.474% at 3.6 GHz resonant frequency. This type of structure is more suitable for a long term information technology due to the direction of their development. This feature has improved the proposed architecture making it suitable for various wireless communications such as 5G mobile applications.

REFERENCES

[1] M. M. Ciydem and E. A. Miran, "Dual-Polarization Wideband Sub-6 GHz Suspended Patch Antenna for 5G Base Station," in *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 7, pp. 1142-1146, July 2020, doi: 10.1109/LAWP.2020.2991967.
[2] F. Zhu, *et al.*, "Ultra-wideband dual-polarized patch antenna with four capacitively coupled feeds," *IEEE Transactions on antennas and propagation*, vol. 62, no. 5, pp. 2440-2449, 2014, doi: 10.1109/TAP.2014.2308524.
[3] A. S. B. Mohammed, S. Kamal, Z. A. Ahmad, and U. Ullah, "Microstrip Patch Antenna: A Review and the Current State of the Art," *Journal of Advanced Applied Scientific Research*, vol. 11, no. 7, pp. 510-524, 2019.
[4] A. A. Abdulbari, S. K. A. Rahim, M. Z. A. Abd Aziz, K. G. Tan, N. K. Noordin, and M. Z. M. Nor, "New design of

wideband microstrip branch line coupler using T-shape and open stub for 5G application," *International Journal of Electrical and Computer Engineering*, vol. 11, no. 2, pp. 1346-1355, April 2021, doi: 10.11591/ijece.v11i2.pp1346-1355.
[5] H. Hao, D. Hui, and D. Lau, "Material advancement in technological development for the 5G wireless communications," *Nanotechnology Reviews*, vol. 9, no. 1, pp. 683-699, 2020, doi: 10.1515/ntrev-2020-0054.
[6] R. Chávez-Santiago, *et al.*, "5G: The Convergence of Wireless Communications," *Wirel. Pers. Commun.*, vol. 83, no. 3, pp. 1617-1642, 2015, doi: 10.1007/s11277-015-2467-2.
[7] Q. C. Li, H. Niu, A. T. Papathanassiou, and G. Wu, "5G Network Capacity," *IEEE Vehicular Technology Magazineno*, vol. 9, no. 1, pp. 71-78, March 2014.
[8] G. A. Hussain and L. Audah, "BCH codes in UFMC: A new contender candidate for 5G communication systems," *Bulletin of Electrical Engineering and Informatics*, vol. 10, no. 2, pp. 904-910, April 2021, doi: 10.11591/eei.v10i2.2080.
[9] A. A. Abdulbari, Z. Zakaria, S. K. A. Rahim, Y. M. Hussein, M. M. Jawad, and A. M. Hamzah, "Design and development broadband monopole antenna for in-door application," *Telkomnika (Telecommunication, Computing, Electronics and Control)*, vol. 18, no. 1, pp. 51-56, February 2020, doi: 10.12928/TELKOMNIKA.v18i1.13171.
[10] B. Cheng, Z. Du, and D. Huang, "A Broadband Low-Profile Multimode," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 7, pp. 1332-1336, 2019.
[11] A. K. Jassim and R. H. Thaher, "Design and analysis of broadband elliptical microstrip patch antenna for wireless communication," *Telkomnika (Telecommunication, Computing, Electronics and Control*, vol. 16, no. 6, pp. 2492-2499, December 2018, doi: 10.12928/TELKOMNIKA.v16i6.9246.
[12] J. U. Yoo and H. W. Son, "A Simple Compact Wideband Microstrip Antenna Consisting of Three Staggered Patches," *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 12, pp. 2038-2042, 2020, doi: 10.1109/LAWP.2020.3021491.
[13] T. Huynh and K. F. Lee, "Single-layer single-patch wideband microstrip antenna," *Electronics letters*, vol. 31, no. 16, pp. 1310-1312, 1995, doi: 10.1049/el:19950950.
[14] D. Sun, W. Dou, L. You, X. Yan, and R. Shen, "A broadband proximity-coupled stacked microstrip antenna with cavity-backed configuration," *IEEE Antennas and wireless propagation letters*, vol. 10, pp. 1055-1058, 2011, doi: 10.1109/LAWP.2011.2169389.
[15] Y. M. Hussein, *et al.*, "Substrate integrate waveguide and microstrip antennas at 28 ghz," *Bulletin of Electrical Engineering and Informatics*, vol. 9, no. 6, pp. 2462-2468, December 2020, doi: 10.11591/eei.v9i6.2190.
[16] Kin-Lu Wong, "Compact and Broadband Microstrip Antennas," John Wiley & Sons, New York, vol. 3, 2002.
[17] S. Baudha and V. D. Kumar, "Miniaturized Dual Broadband Printed Slot Antenna With Parasitic Slot And Patch," *Microwave and Optical Technology Letters*, vol. 55, no. 11, pp. 2562-2568, 2014, doi: 10.1002/mop.
[18] S. Bhunia, D. Sarkar, S. Biswas, P. P. Sarkar, and B. Gupta, "Reduced Size Small Dual And Multi-Frequency Microstrip Antennas," *Microwave and Optical Technology Letters*, vol. 50, no. 4, pp. 961-965, February 2008, doi: 10.1002/mop.
[19] L. Asadpor and M. Rezvani, "Compact UWB CPW-fed monopole antenna with variable triple-band-notched property," *IETE Journal of Research*, pp. 1-9, December 2018, doi: 10.1049/el.2010.2772.
[20] M. M. H. Mahfuz, S. Islam, and I. Rafiqul, "Design of UWB microstrip patch antenna with variable band notched characteristics," *TELKOMNIKA Telecommunication, Computing, Electronics and Control*, vol. 19, no. 2, pp. 357-363, April 2021, doi: 10.12928/TELKOMNIKA.v19i2.18147.
[21] "Final report by 5G taskforce NFCP," in *Malaysia, submitted to MCMC, Cyberjaya, Malaysia on 15 Oct," 2019*. [Online]. Available: https//www.nfcp.my/5G-Task-Force/5GMedia, 2019.
[22] M. A. Salamin, W. A. E. Ali, S. Das, and A. Zugari, "Design and investigation of a multi-functional antenna with variable wideband / notched UWB behavior for WLAN/X-band/UWB and Ku-band applications," *International Journal of Electronics and Communications (AEÜ)*, vol. 111, p. 152895, November 2019, doi: 10.1016/j.aeue.2019.152895.
[23] J. Zhang, L. Zhu, Q. Wu, N. Liu, and W. Wu, "A Compact Microstrip-Fed Patch Antenna With Enhanced Bandwidth and Harmonic Suppression," in *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 12, pp. 5030-5037, Dec. 2016, doi: 10.1109/TAP.2016.2618539.
[24] A. M. Hamzah, L. Audah, N. Alkhafaji, H. J. Mohammed, and A. A. Abdulbari, "Substrate Integrated Waveguide SIW Technology-based Miniaturization and Performance Enhancement of Antennas," *International Journal of Advanced Science and Technology*, vol. 29, no. 6, pp. 1739-1754, 2020.
[25] R. Kumar and V. D. K. Srivastava, "Bandwidth enhancement of a slot loaded T-shape patch antenna," *Journal of Computational Electronics*, vol. 18, no. 1, pp. 204-209, March 2019, doi: 10.1007/s10825-018-1277-7.
[26] K. V Rop, D. Konditi, and H. A. Ouma, "Parameter optimization in design of a rectangular microstrip patch antenna using adaptive neuro-fuzzy inference system technique," *International Journal on "Technical and Physical Problems of Engineering" (IJTPE)*, vol. 4, no. 12, pp. 16-23, September 2012.