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Design and development broadband monopole antenna for in-door application

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ABSTRACT

This paper describes the broadband monopole antenna refers to a signal wideband of the frequencies, which can be divided the signal into channels of the frequency bins. Aim this paper to design and development broadband monopole antenna. The monopole antenna was designed by adding slot to the radiated patch antenna with a single feed line, which reduced the size and the design complexity. A rectangular patch antenna was presented using feed line to decrease the ground plane with a suitable gap distance. The broadband monopole antenna was designed with a frequency range of 800 MHz – 3 GHz, with Bandwidth 0.66 (dB), reflection coefficients and return loss. The frequency-dependent characteristic impedance was included. It can be used in various broadband applications in used commercially for various communication systems such as 4G (LTE), WiMAX and WLAN (LTE), remote sensing, biomedical, and mobile wireless. Apart from that, this technology is environment-friendly; an antenna which consists of reception and transmission. The antenna is simulated by using computer simulation (CST) software; using FR-4 substrate of 4.4 permittivity thickness 1.6 mm and loss tangent of 0.025. The measurement result is accepted with simulation result, proving the acceptable broadband operation for this proposed structure.

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1. INTRODUCTION

Today, mobile phone users are reaping the benefits from the tremendous growth in the demand for high-speed and broad-band data services such as high-speed browsing, high definition videos, and video calls [1–4]. According to statistics more than 80% of mobile data traffic comes from domestic environment, such as the commercial buildings and airports. Therefore, internally distributed antenna systems, (IDAS) have become even more sought after to provide, wireless communication coverage in high-traffic areas [5–8]. IDAS is a broadband network connected to a common source via a coaxial cable to improve coverage. Several vertically polarized antenna designs are proposed for IDAS and discussed in the open literature [9-11].

The evolution of a multi-polar MIMO antenna system with two multi-purpose components for AP wireless applications in the range of 2.3–9 GHz was studied. The proposed system included single pole antennas with a wide-angle microstrip antenna having a common radiate element and a ground plane due to alternative coupling. New parasitic elements were introduced to increase isolation between the ports. Expected bandwidth coverage for Wi-Fi and LTE applications [12–14].

With rapid development of modern mobile wireless industry, the request for broadband services and high-speed data services are increasing [15]. For most mobile data, as traffic are generated in internal environment, distributed antennas play an increasingly important role in internal wireless communication systems. In addition, in order to provide better telecommunication services, more frequency bands have been designed and used commercially for various communication systems such as 4G WiMAX and WLAN. Therefore, there is a need for broadband distribution antennas that can cover multiple service ranges simultaneously [5, 16, 17]. This paper discusses the a broadband antenna with double casing load for indoor mobile, communications system [10]. The purpose is to cover wider frequency bands (698–960 and 1710–2300 MHz in [18], 800-1100 and 1700-2580 MHz in [19]), but the bandwidth are still not wide enough to be used in LTE applications in the unlicensed spectrum of LTE-U and LTE, LAA applications [20, 21].

Diversity in current LTE systems is typically limited to two antennas per radio, enough to ensure that, if an antenna is in an RF vacuum, the other antenna is not normally available, providing better performance in a multi-track environment. Antenna diversity with LTE is used to defend against multiple pathways, reduce interruptions, and improve the quality and the reliability of communication links [13, 22–25]. Dual broadband antenna for internal LTE terminals. The antenna consists of three separate radiated elements a rectangular upper plate with two U-shaped slots, two long rectangular openings to cover the upper range of 1700–2700 MHz, and two low-reflective L-Shaped components used to cover the low frequency range of 800–960 MHz. The proposed antenna is expected to be applied directly to all portable and wireless systems, including 2G, 3G, 4G LTE, and Wi-Fi [26]. With the development of hand-held devices, rapid development has emerged, and device appearances must be attractive and compact. The antenna can be described as a device that converts the electromagnetic wave in the antenna into radiation in an unlimited medium [27]. Due to the exponential growth of wireless systems, mobile phone antennas should be smaller and widely supported for LTE systems for wide area network (WWAN) as its performance is at least 100 MB/s in 100 high data rate links with 50 Mbps in transmission [28].

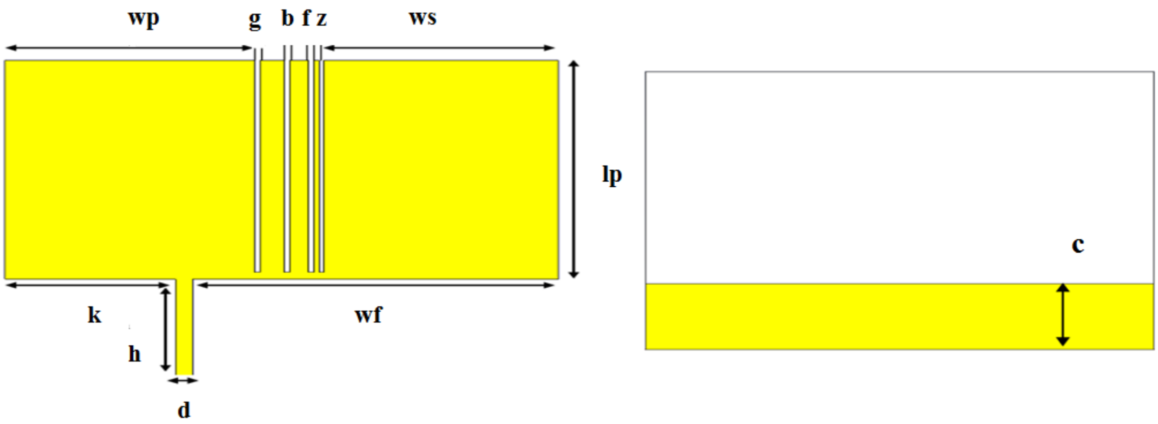
In recent years, internal antenna technology has been growing due to the evolution of wireless communications such as WiFi, WiMAX, 3G, 4G, LTE, and WLAN. In addition to the rapid growth in the number of wireless terminals in buildings, airports, and conference rooms, researchers also need antennas to meet the requirements for internal antennas such as high performance (gain, efficiency), effective data rates, broadband, and one-way [29]. The proposed broadband bandwidth are sufficient for all mobile system services, namely, GSM/UMTS LTE, including LTE bands 42-43 (3400–3800 MHz) and LTE-U/LTE-LAA (5150–5850 MHz). The proposed antenna is characterised by four conditions of annular antenna [30, 31]. Monopole antennas ideally give omnidirectional patterns [32]. The condition of not stimulating anything other than placing the first higher order complicates the feeding process of the traditional, microstrip LWA [33]. Characterization of simulation using CST Microwave Studio; analysis and comparison of results [34, 35].

In this paper, the broadband monopole antenna was designed with the operating frequency band from 800 MHz to 3 GHz. These frequencies are chosen for the applications of 4G LTE indoor buildings. The main objective, of this paper is to provide the highest possible antenna gain. Finally, the proposed antenna was fabricated and tested and do comparisons between the results. For future work to provide as high as possible of the antenna gain, the gain and bandwidth (BW) can be increased through many techniques. The most common technique is the doing monopole, stack, adding a slot.

2. ANTENNA CONFIGURATIONN

Figure 1 (a) shows the geometric dimensions of broadband monopole antenna at the frequency range of 800 MHz – 3 GHz for LTE applications. The back view for monopole antenna is shown in Figure 1 (b). Figure 2 shows the integrated fabricated antenna, fed and printed on an FR4. The substrate and copper of dielectric constant, ε_r = 4.4 with thickness, hs = 1.6 mm, where the length and the width of the substrate = 99.53 mm, and the length of the substrate = 84.35 mm. The length and the width for copper, ws = 99.53 mm, ls = 84.73 mm, ht = 0.035, loss tangent of 0.02, with transmission line driven by 50 Ω.

The centre frequency for the antenna was at 2 GHz. The patch antenna is becoming increasingly, useful because it can be printed directly onto a circuit board. Microstrip antenna is also becoming more widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. In parametric studies on patch antennas, the slots resulted in patch antennas resonating at a significantly lowered frequency [36]. The microstrip line is used as the feed antenna structure, and the coupling method is well known in terms of reducing the size of small antennas in mobile communications [37]. Microstrip antennas have the key advantages of being low-profile, easy to manufacture, lightweight, and have been widely used in wireless applications [38]. An antenna radiation scheme is essential for many communication applications, such as wireless communications and radar [39, 40]. In table 1 the explain the dimension for monopole antenna.



(a) (b)

Figure 1. (a) Geometric dimensions of broadband monopole antenna at frequency 800 MHz to 3 GHz for LTE application, (b) Back view for broadband monopole antenna

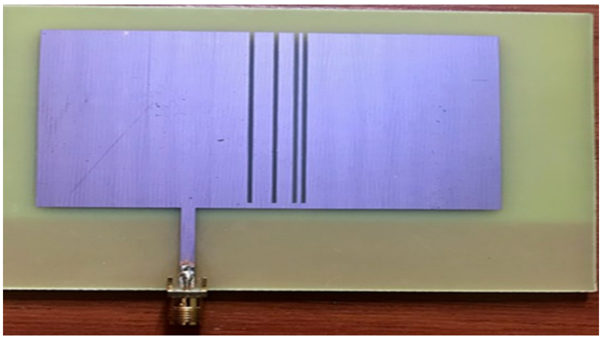


Figure 2. Fabricated antenna

Table 1. Antenna parametric

Parameter	Value (mm)
wp	34.30
g	0.70
b	3.30
f	2.65
z	0.75
ws	32.20
lp	52.81
wf	50.25
d	2.35
h	23.54
k	23.40
c	20.09

3. RESULTS AND ANALYSIS

The design antenna was simulated using CST simulation software to obtain the results. The monopole antenna results were analysed in terms of reflection coefficient, bandwidth, resonant frequency, gain, and directivity and radiation pattern at the frequency range of 800 MHz – 3 GHz. The results were discussed, and comparison was done to observe the antenna performance, in both simulation and measurement mode. The antenna parameters were first obtained through simulation, followed by measurement. The measure of return loss during antenna design or investigation is a powerful performance tool. An antenna is not able to accept RF energy hence, it is unable to radiate. In the resonant frequency of simulation, the broadband monopole antenna at 800 MHz and 3 GHz gave a reflection coefficient of -20 dB. On the other hand, the measurement results of the broadband monopole antenna at 804 MHz and 3 GHz gave reflection coefficients of -15.651 dB and -10 dB. The measurement result of the broad-band monopole antenna resonant frequency (804 MHz) had shifted 0.4% from 800 MHz. However, the simulation results of the monopole antenna achieved better reflection coefficients (-20 dB and -10 dB) at 800 MHz and 3 GHz compared to the measurement method where the monopole antenna only achieved reflection coefficients (-15.651 dB and -20 dB) at 804 MHz and 3 GHz. The comparison results are shown in Table 2. The broadband monopole antenna has two gains in frequency 2 GHz as shown in Figure 3, and frequency 2.8 GHz shown in Figure 4. Simulation process whereas the gain in measurement process is dB. Both processes provided different gains due to power loss in the FR4 board as mentioned previously. This table explains simulation results for reflection coefficients, bandwidth, and return loss. Figure 5 as compared between simulation and measured result for the broadband monopole antenna.

Table 2. Comparison simulation and measurement broadband monopole antenna

Antenna parameters	Simulation broadband monopole-antenna		Measurement broadband monopole antenna	
Resonant frequency	800 MHz	3 GHz	804 MHz	3 GHz
Reflection coefficient RL (dB)	-20 dB	-10 dB	-15.651 dB	-20 dB
Bandwidth, BW (%)	0.66		0.75	

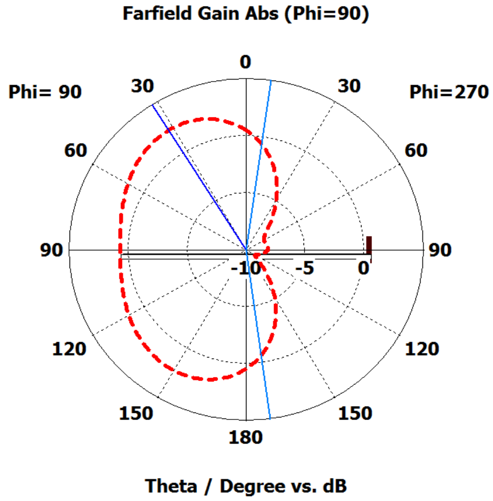


Figure 3. Radiation pattern for 1st band 2 GHz for monopole antenna

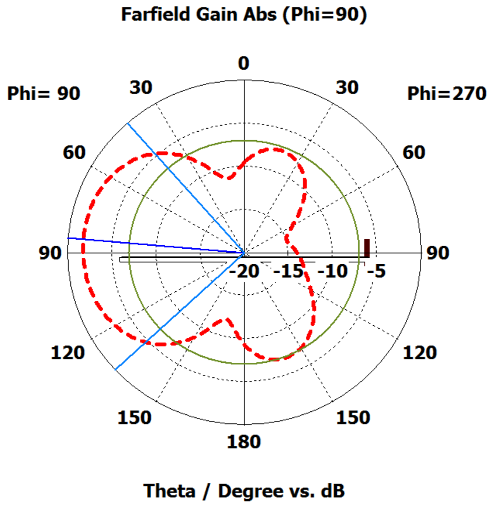


Figure 4. Radiation pattern for 2.8 GHz for monopole antenna

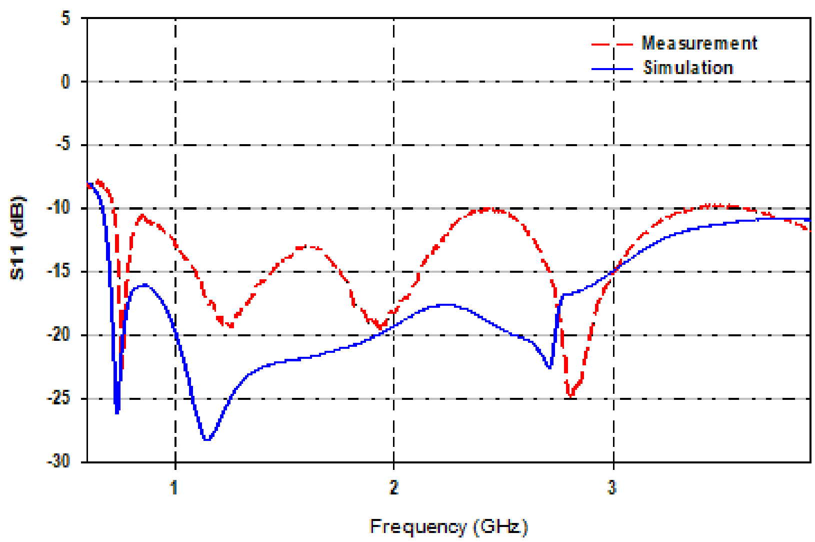


Figure 5. Comparison of simulation results with measurement for monopole antenna

4. CONCLUSION

This paper discusses the design and the development of short-range communication devices using the broadband monopole antenna. Short-range communication systems that served to transmit and receive at these frequency bands were chosen from 800 MHz to 3 GHz. Hence, these frequencies are chosen for 4G LTE applications for in-door buildings. Furthermore, the response of the design was optimized in order to get appropriate outputs of S-parameter and gain. The result of the antenna seemed to be inconsistent with the original hypothesis since the frequency resulting through the lap measurement test is somehow begin shifted to a different frequency with a different return loss. With that, the gain received also is different through calculation compared to the simulation. The difference in the results between the simulation and measurement is due to some factors that many have been contributed starting from the fabrication process such as the soldering process, measurement process, and the FR4 tolerance.

REFERENCES

[1] Attiah M. L., Md Isa A. A., Zakaria Z., Abdulhameed M. K., Mohsen M. K., Dinar A. M., "Hybrid multi-independent mmWave MNOs assessment utilising spectrum sharing paradigm for 5G networks," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 3, pp. 1101–1109, 2019.

[2] Attiah M. L., Isa A. A. M., Zakaria Z., Abdulhameed M. K., Mohsen M. K., Ali I., "A survey of mmWave user association mechanisms and spectrum sharing approaches: an overview, open issues and challenges, future research trends," *Wireless Networks*. pp. 1-28, 2019.

[3] Attiah M. L., Ismail M., Nordin R., Abdullah N. F., "Coverage probability optimisation by utilizing flexible hybrid mmwave spectrum slicing-sharing access strategy for 5G cellular systems," *Journal of Telecommunication, Electronic and Computer Engineering*," vol. 10, no. 2, pp. 91–98, 2018.

[4] Attiah M. L., Md Isa A. A., Zakaria Z., Abdullah N. F., Ismail M., Nordin R., "Adaptive multi-state millimeter wave cell selection scheme for 5G communications," *International Journal of Electrical and Computer Engineering (IJECE),* vol. 8, no. 5, pp. 2967–2978, 2018.

[5] Zuo S. L., Yin Y. Z., Zhang Z. Y., Song K., "Enhanced bandwidth of low-profile sleeve monopole antenna for indoor base station application," *Electron Letters*. vol. 46, no. 24, 2010.

[6] Wu Q., Ding X., Chen A., "A broadband dipole antenna for multiservice indoor distributed antenna system (MS-IDAS)," *IEEE Antennas and Wireless Propagation Letters,* vol. 14, no. c, pp. 839–842, 2015.

[7] Eshaghzadeh Torbati H., "The Role of Environmental Graphic in the Identification of Urban Public Spaces," *Civil Engineering Journal*, vol. 4, no. 8, pp. 1949–1954, 2018.

[8] Moayedi M., Kheyroddin R., Shieh I., "Determining the Role of Pedestrian-Orientation, Concerning the Public Places: Improvement of Urban Social Capital Quality," *Civil Engineering Journal*, vol. 5, no. 4, pp. 901–912, 2019.

[9] Abdulhameed M. K., Isa M. S. M., Z. Zakaria, Ibrahim I. M., M. K. Mohsin A. M., "Novel design of triple-band EBG," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 4, pp. 1683–1691, 2019.

[10] Zhang Z. Y., Fu G., Wu W. J., Lei J., Gong S. X., "A wideband dual-sleeve monopole antenna for indoor base station application," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 45–48, 2011.

[11] Zhou L., Jiao Y., Qi Y., Weng Z., Lu L., "Wideband ceiling-mount omnidirectional antenna for indoor distributed antenna systems," *IEEE Antennas and Wireless Propagation Letters*, vol. 13, pp. 836–839, 2014.

[12] Moradikordalivand A., Rahman T. A., Evizal, Fadoul M. M., "Evolution Process of a Wideband Dual Polarized MIMO antenna System for Wireless Access Point Applications," *7th International Symposium on Telecommunications (IST'2014)*, pp. 266–269, 2014.

[13] Mohsen M. K., Isa M. S. M., Rahman T. A., Abdulhameed M. K., Isa A. A. M., Zin M. S. I. M., et al., "Novel design and implementation of MIMO antenna for LTE application," *Journal of Telecommunication, Electronic and Computer Engineering,"* vol. 10, no. 2–8, pp. 43–49, 2018.

[14] Abdulhameed M. K., Isa M. S. M., Ibrahim I. M., Zin M. S. I. M., Zakaria Z. M. M., "Review of Radiation Pattern Control Characteristics for The Microstrip Antenna Based On Electromagnetic Band Gap (EBG)," *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, vol. 10, no. 3, pp. 129–140, 2018.

[15] Mustafa Emad Hameed, Masrullizam Mat Ibrahim, Nurulfajar Abd Manap MLA., "Comparative study of several operation modes of AES algorithm for encryption ECG biomedical signal," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 9, no. 6, 2019.

[16] Kim K. H., Kim J. U., Park S. O., "An ultrawide-band double discone antenna with the tapered cylindrical wires," *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 10, pp. 3403–3406, 2005.

[17] Javadi K., Komjani N., "Investigation into Low SAR PIFA Antenna and Design a Very Low SAR U-slot Antenna using Frequency Selective Surface for cell-phones and Wearable Applications," *Italian Journal of Science & Engineering*, vol. 1, no. 3, pp. 145–57, 2017.

[18] Zheng M., Wang H., Hao Y., "Internal hexa-band folded monopole dipole loop antenna with four resonances for mobile device," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 6, pp. 2880–2885, 2012.

[19] Wong K. L., Chen M. T., "Small-size LTE/WWAN printed loop antenna with an inductively coupled branch strip for bandwidth enhancement in the tablet computer," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 12, pp. 6144–6151, 2013.

[20] Qualcomm, "Making the Best Use of Unlicensed Spectrum for 1000x," White Pap, pp. 1–15, 2015.

[21] Zhang R., Wang M., Cai L. X., Zheng Z., Shen X., Xie L. L., "LTE-unlicensed: the future of spectrum aggregation for cellular networks," *IEEE Wireless Communications*, vol. 22, no. 3, pp. 150–159, 2015.

[22] Abdulhameed M. K., Isa M. S. M., Ibrahim I. M. M. M., "Improvement of Microstrip Antenna Performance on Thick and High Permittivity Substrate with Electromagnetic Band Gap," *Journal of Advanced Research in Dynamical and Control Systems,* vol. 10, no. 4, pp. 661–669, 2018.
[23] Rao P. V. V. K., Vishnu C., Reddy V., Tejaswini K., Babu B. V. V. R., Babu K. J., "A Wideband H Shape Dielectric Resonator Antenna for Wireless MIMO Systems," *International Journal of Engineering and Innovative Technology (IJEIT),* vol. 1, no. 3, pp. 64–66, 2012.
[24] Gamil Y., Abdul Rahman I., "Identification of Causes and Effects of Poor Communication in Construction Industry: A Theoretical Review," *Emerging Science Journal*, vol. 1, no. 4, pp. 239–246, 2017.
[25] Astaneh A. A., Gheisari S., "Review and Comparison of Routing Metrics in Cognitive Radio Networks," *Emerging Science Journal*, vol. 2, no. 4, pp. 191–201, 2018.
[26] Tai M. I., "Development of Dual Band Dual Polarized Patch Antenna System for Indoor Application," *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 4, no. 5, pp. 229–233, 2017.
[27] Nanthini N., Dinesh V., Vijayalakshmi J., Dhivya K. T., "A Survey on Design of Multiband Monopole Antenna for Wireless Applications," *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 1, no. 12, pp. 949–954, 2013.
[28] Luo J., Gong S. X., Duan P., Mou C., Long M., "Small-Size Wideband Monopole Antenna with Crlh-Tl for Lte Mobile Phone," *Progress in Electromagnetics Research C*, vol. 50, pp. 171–179, 2014.
[29] Yu L., Song J., Gao Y., He K., Gao F., "Low-Profile Dual-Polarized Omnidirectional Antenna for Broadband Indoor Distributed Antenna System," *Progress in Electromagnetics Research Letters*, vol. 67, no. 10, pp. 39–45, 2017.
[30] Xu H., Huang Y., Cheng Y., Xu Q., Wang H., Zhou H., et al., "A Compact and Low-Profile Loop Antenna with Six Resonant Modes for LTE Smartphone," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 9, pp. 3743–3751, 2016.
[31] Omidi A., Karami R., Emadi P. S., Moradi H., "Design of the Low Noise Amplifier Circuit in Band L for Improve the Gain and Circuit Stability," *Emerging Science Journal*, vol. 1, no. 4, pp. 192–200, 2017.
[32] Üstüner F., Aydemir E., Güleç E., Ilarslan M., Çelebi M., Demirel E., "Antenna radiation pattern measurement using an unmanned aerial vehicle (UAV)," *2014 XXXIth URSI General Assembly and Scientific Symposium (URSI GASS)*, pp. 1–4, 2014.
[33] Mohsen M. K., Isa M. S. M., Zakaria Z., Isa A. A. M., Abdulhameed M. K., Attiah M. L., "Electronically controlled radiation pattern leaky wave antenna array for (C band) application," *TELKOMNIKA Telecommunication Computing Electronics and Control,* vol. 17, no. 2, pp. 573-579, 2019.
[34] Ezio Biglieri, Robert Calderbank, Anthony Constantinides, et. al., "MIMO Wireless Communications," Cambridge University Press, 2007.
[35] Lu Y. C., Chan Y. C., Li H. J., Lin Y. C., Lo S. C., Chuang G. C. H., "Design and system performances of a dual-band 4-Port MIMO antenna for LTE applications," *IEEE International Symposium on Antennas and Propagation (APSURSI),* pp. 2227–2230, 2011.
[36] Paracha K. N., Abdul Rahim S. K., Soh P. J., Chatha H. T., Misran M. H., Lokman A. H., "A dual band stub-loaded AMC design for the gain enhancement of a planar monopole antenna," *Microwave and Optical Technology Letters*, vol. 60, no. 9, pp. 2108–2112, 2018.
[37] Jungho Ahn., Seunghwan Kim., Joonho Byun., Austin S. Kim., Youngsik Kim., "Compact PCB-embedded GPS antennas loaded with a coupling strip and lumped elements for mobile phones," *Microwave and Optical Technology Letters*, vol. 55, no. 2, pp. 363-366, 2013.
[38] Azman A., Abd Aziz M. Z. A., Suaid M. K., Salleh A., Nornikman H., Malek F., "CPW-FED compact monopole antenna for dual-band WLAN/WiMAX applications," *I4CT 2015-2015 2nd Int Conf Comput Commun Control Technol Art Proceeding,* vol. August, pp. 485–488, 2015.
[39] Abdulhameed M. K., Isa M. S. M., Ibrahim I. M., Zakaria Z., Mohsen M. K., "Mushroom-Like EBG to Improve Patch Antenna Performance for C-Band Satellite Application," *International Journal of Electrical and Computer Engineering (IJECE),* vol. 8, no. 5, pp. 3875–3881, 2018.
[40] Abdulhameed M. K., Isa M. S. M., Zakaria Z., Mohsen M. K., "Controlling the Radiation Pattern of Patch Antenna Using Switchable EBG," *TELKOMNIKA Telecommunication Computing Electronics and Control,* vol. 16, no. 5, pp. 2014–2022, 2018.