A Review and Analysis Micro-Strip Patch Antenna for 3.5 GHz

Received: 2 June 2022; Accepted: 14 June 2022 *Review Article*

Ali Abozied
aliradar@yahoo.com

Abdelaziz Al-dawi
azizedowi@gmail.com

***Abstract*— In recent years, there has been a lot of interest in microstrip patch antennas owing to their small volumes, low profiles, effective integration, low prices, and outstanding performance. With the continual growth of wireless communication services and therefore the constant shrinking of communication equipment, this antenna is planned to be used for WiMAX and wireless communications. However, these antennas have disadvantages like low gain, low power operation, and slim bandwidth, among others. The first drawbacks of those antennas are their restricted band performance as well as their high cost. Technological advancements within telecommunications are accelerating, particularly with the arrival of fifth-generation technology, which offers the advantages of quick knowledge transmission speeds and really low latency. In 2015, the World Radio Conference (WRC) urged frequencies for 5G communication technologies, one of which is 3.5 GHz. A variety of analysis articles were collected and studied, and for the frequency of 3.5 GHz, many forms and substrate materials with dynamical relative permittivity were devised for microstrip patch antennas. The simulated results show that these antennas will simply offer dual-and tri-band operation, as well as nearly as good dipole-like and spatial relation radiation properties, stable gain, and high radiation efficiency, indicating that the planned antennas are candidates for WiMAX and wireless communications. The urged antennas have come back with losses starting from -32 decibels to -30.8 dB. The results are obtained through the use of the PC simulation applications standards CST and ADS.**

Keywords—microstrip antenna, WiMAX, wireless communications,5G,3.5 GHz

I. INTRODUCTION

Nowadays, no person can deny it has a cell package and wi-fi conversation capabilities to perform more than one capability at an equal time. Rapid advancements in wireless communication offerings have resulted in a massive mission in antenna design. Microstrip antennas have several blessings, that embody being tiny in size, swish models for digital circuits, lower electricity exhaustion, excessive-performance, lower be valued, mechanistic sturdiness, and twin hesitation packages. However, microstrip antennas have the hazards of slender information measure and poor performance because of numerous losses. The layout of lightweight, low-cost, excessive bandwidth antennas is significant for wi-fi gadgets thus one will transmit images, speech, and statistics in numerous frequency bands at a similar time. The patch antenna construct appears to own been planned by Deschamps within the early 1950s. some years later, a antenna patent was issued through Gutton and Bassinet. within the 1970s, thin, surface-suited antennas were made for army packages, together with missiles and space shuttles.

Patch antennas for twin and multi-frequency band operation are getting progressively common and wide utilized in a range of applications, including cell phones, satellites, radars. And missile guidance. additionally refers to high-speed properties among PCs, laptops, mobile phones, associate in alternative devices in an atmosphere wherever wireless statistics offerings have advanced and continue to grow with the usage of various technologies, together with 2G and 3G. The result of such numerous technologies on the usage of frequency bands in one-of-a-kind technologies can need to occupy one-of-a-kind frequency allocations, comprehensive of WLAN/WiMAX and wi-fi spoken communication structures, inclusive of Worldwide ability for Microwave Access (WiMAX), wi-fi close neck of the woods network (WLAN) and C-Band, that have perceptibly appealing and are loosely used. Hence, the decision for low-profile antennas with compact size and multiband operation overlaying the bands of these applications, additionally to omnidirectional insurance and simple flat systems, is in pressing need. The layout and checking out of the 5G spoken communication gizmo devolve on the data of the propagation channels, and a large frame of channel measurements is consequently required. Currently, 5G cell structures are broadening their spectrum to guide an excessive information rate. At the globe world Communication Conference (WRC) in 2015, the 5G possibility frequency bands below vi rate were broadly speaking mentioned.

This paper is targeted at the publishing channel characterizations within the 3.55 GHz band. The antenna should be sufficiently little to suit any small speech gadgets from new technology. The goal is to own a high advantage and performance to make sure that the foremost records switches in any wi-fi communication space antenna are the amount one requirement. once birth out any microstrip patch antenna, several improvement ways are used, and twin feed. Wide information measure antennas are applied for a huge type of community frequencies, that are larger inexperienced for a few distance space implementations. With a twin-feed antenna, section distinction is simple to maintain the foremost common issue in wi-fi communication is the orientation of receivers and transmitters. Multiband operation and antenna length miniaturization could also be performed by utilizing the noted options of self-similarity and area filling.

II. LITERATURE REVIEW

A. Microstrip antenna Consists of two rectangular with square-shaped

Results acquired Comparison among the traditional antenna and the proposed antennas: Simulation outcomes of going back loss (S11) for each traditional and proposed antennas, the directivity of the traditional antenna changed into 7.03dBi and VSWR of 1.7, even as the proposed antennas (double and unmarried square-formed metamaterial unit cell antenna) are 5.51dBi and 5.26dBi, 1.2 and 1.0, respectively. Hence, the lower back and aspect lobes of the proposed antennas had been rising, as a result decreasing the directivity

of the antennas. The microstrip patch antennas with square-formed metamaterial unit cells have a progressed bandwidth and length discount in comparison to the traditional microstrip patch antennas. The overall performance of the square-formed split-ring metamaterial unite and cargo cell antenna may be similarly progressed with a made-over configuration. Hence, those performances are nicely ideal for WIMAX applications.

B. 3.5 GHz Microstrip Transmission Line

In this paper, a microstrip transmission line includes metal strapline and floor plane among a dielectric medium known as the substrate is located of 3.5 GHz is efficiently designed in CST microwave Studio software program to satisfy function Impedance of 50.03 Ohms, Also S–parameters The fee of going back loss S11 = 12 dB and S21 = 0.5 dB at 3GHz frequency. As properly because the dielectric substrate G-10 of εr = 4.8 is used to acquire bandwidth from three GHz to five GHz. The designed microstrip transmission line is used to feed numerous varieties of antennas in preference to a coaxial feed and is likewise used for the transmission of records in the microwave, cellular cell smart phone antennas, and Wi-Fi antennas.

C. Rectangular Patch Microstrip Antenna 5G

There are a few variations among the simulation and the dimension effects, however, the parameters are taken into consideration properly enough, as it's far glad the favored parameters. Because the bandwidth is reduced via way of means of a full-size amount. The effects of this study are that the VSWR is elevated via way of means of 0.242, the impedance is elevated via way of means of 15.256 Ω, and the benefit is elevated via way of means of three dB, and the go back loss is modified to -17.436 dB. The VSWR, go back loss, and benefit is glad the favored parameters. Finally, the simulation and the dimension effects display that the antenna is according to the favored parameters. It is predicted that hopefully, the antenna is beneficial for 5G applications.

D. Design Broadband Microstrip Antenna

Classic wideband microstrip dipole antenna layout that may be utilized in WiMAX packages (masking the bands 2.4–2.5 GHz and 2.5–3.5 GHz) is introduced. A wideband microstrip dipole antenna layout with overall performance withinside the 2.36-3.67 GHz range, which may be utilized in packages masking WiMAX bands, is introduced. Relating to withinside the layout, asymmetrical bent loading factors are delivered close to the feed of the fifty-two mm (~λ/2) lengthy microstrip dipole antenna element. the bandwidth of a fashionable microstrip dipole antenna with 10%ndwidth may be improved to 43%. As an end result of those additions, there has been no deterioration withinside the radiation sample function of the antenna. The proposed broadband antenna has a non-directional sample and a directional advantage of 2.36 dBi. The calculated overall radiation performance of the layout on the applicable frequency is -0.428 dB. Thanks to those studies, it's been determined that the applicable broadband function is acquired through combining unique bands.

E. T-shaped Design compact microstrip patch antenna

A T-shape microstrip is proposed. microstrip patch antenna becomes simulated and printed with the help of victimization the employment of R/Duriod 5880 LZ, with a typical length of the antenna changing into 22×24×0.25mm3 planning T-form is completed to beat the information measure difficulty of the normal antenna. This form offers wonderful resistance matching at exceptional frequencies and thus has sturdy radiation traits at exceptional frequencies. Introducing a sq. T-formed aperture at the ground stage will enhance the bandwidth of the lower-frequency.

The optimized antenna partial bandwidth is 42.81% with a resonant hesitance of 3.6 GHz and a go-back loss of -28.76 dB. the antenna performance is 98.474% at a 3.6 GHz resonant frequency. This characteristic has advanced the planned structure creating it applicable for varied wi-fi communications alongside 5G cellular applications.

F. 3.5 GHz Circular Patch Antenna Using Open-Ring Artificial Dielectric

This case describes the characteristics of a 3.5 GHz circular antenna and the usage of a synthetic open ring. The acrylic herbal dielectric fabric substrate has been changed by placing a skinny conductor strip on the pinnacle of the substrate to boom the permittivity of the acrylic. From the S11 the antenna has a canter of 3.5 GHz the go-back lack of 26.46 dB. At the equal time, the ensuing bandwidth is 194.7 MHz at a go-back lack of 10 dB. From those consequences, the synthetic microstrip antenna has a much broader bandwidth and a more go-back loss than traditional microstrip antennas.

The consequences display that the proposed antenna has a much broader bandwidth of 16.1 MHz or 8.94percentand a better go-back loss on the center frequency of 1.32. dB or five.25% better than traditional antennas. The consequences display that the proposed antenna has a much broader bandwidth of 16.1 MHz or 8.94%, a better benefit of 0.05 dBi or 0.78%, and a better go-back loss on the canter frequency of 1.32 dB or five.25% better than traditional antennas.

The synthetic antenna has a patch vicinity measurement of 11% smaller than traditional antennas and a substrate vicinity of 32.08% smaller than traditional microstrip antennas. The relative permittivity of acrylic multiplied from 3.4 to 3.82 or 12.24%. From those consequences, the open-ring synthetic dielectric can enhance traditional antennas characteristics and might miniaturize antenna dimensions.

G. Circle Patch Microstrip Antenna for Frequency 3.5 GHz

From the simulation, it changed located that the circle antenna with a radius of 16.94 mm, the width of the feeder channel is 4.92 mm and an insert feed with a period of thirteen mm and a width of 1.3 mm can produce an antenna with a go back loss of -26,385 and VSWR of 1.0989. The use of insect feeds on an antenna can have an effect on the overall performance of the antenna. Total antenna radiation performance changed into acquired for -0.6489dB and benefit changed into acquired in 3504 frequency GHz at 7.64 dBi. Although the microstrip antenna has small dimensions it nevertheless profits little bandwidth, the bandwidth of this observation changed into attained at three,504 GHz frequency most effective via way of means of 72 MHz This bandwidth is just too small if it's far used to seize records from many channels.

H. An Ultra-Wideband Microstrip Patch Antenna for Mobile WiMAX at 3.5 GHz

An ultra-wideband antenna is designed for the cause of mobile WiMAX operations. The proposed antenna covers the complete band of the IEEE 802.16e-2005 fashionable band of the 3.4-3.8GHz spectrum. Though the proposed antenna has a low gain, it has pretty appropriate VSWR, directivity, efficiency, HPBW, and really low SAR which display the

suitability of the antenna for cellular WiMAX programs over an extensive variety of frequencies. the VSWR cost of the proposed antenna and the minimal cost of the VSWR is 1.45 at 3.38 GHz. The cost of VSWR varies from 2 between 3.2 GHz to 3.9 GHz because the proposed antenna is an ultra-wideband antenna. also, the S-parameter curve of the proposed antenna. The minimal go-back lack of the antenna is -14.655 dB at 3.381 GHz. The go-back loss cost varies past -10 dB from 3.2 GHz to 3.9 GHz because the antenna is an ultra-wideband antenna.

İ. Microstrip Patch Antenna Different Dielectric Substrate-based for 5G

The analysis of the implications and therefore the assessment among substrate substances FR-4, RT-5880, and TLC-30 had been appreciably studied. The intention of the projected antenna styles become to realize high overall performance in phrases of advantage and information measure at a similar time as keeping a reflection constant below -10dB. All the proposed antennas finished top overall performance (better profits and bandwidth ⩾a hundred MHz) at the same time as assembly the mirrored image coefficient and VSWR for Design-1, 2 and three had were 1.078, 1.48, and 1.259, severally at 3.5 GHz. furthermore, Design-1,2, and 3 have a performance of 60.13%, 61.51%, and 75.70% on the popular frequency for Design-1, 2, and 3. consistent with the ITU needs for 5G cell report widget packages, the VSWR is far under 2. This indicated that TLC-30 is going to be the fantabulous need for 5G packages. Additional analysis may want to be achieved to reinforce the performance of the antennas, in special, to enhance the profits and information measure at a similar time as having a smaller antenna dimension.

J. 3.5 GHz A Small Patch Antenna for 5G

For paper, tiny low compact antenna has been designed to be used at 3.5 Gc for 5Gapplication. The antenna features a bodily length of 25.2 X45 millimeter it's a go-back loss of -30dB at 3.5 GHz. The antenna profit is 5.01 dB. As it' so much recognized that the resonant frequency and therefore the go-back loss could also be calculated from the S11 curve of the patch antenna respectively. this means that the antenna has a completely low go-back loss while it operates at a 3.5 GHz frequency. which method an amazing amount of the sign may be transmitted through the antenna features a terribly excessive performance of 96.67%.

K. Circular Slotted Rectangular Microstrip Patch Antenna

The designed antenna can be a converting type of rectangular patch antenna that encompass three identical round slots inside the patched ground. The projected antenna has completely unique operative frequencies of 2.592 and three.338 gigacycle, and with the assistance of exploitation writing the antenna with slots, the information diploma of the antenna is stepped forward with the resource of the usage of 50.9% and 39.5% at the one's resonance frequencies, respectively. The numerical evaluation of the deliberate antenna corresponds to mirrored image coefficients, directive gain, ground cutting-edge, and radiation designs examined with the resource of the usage of victimization Central Time Microwave Studio.38 price and ten sound unit information diploma is 1.32 GHz. Gain values are variable amongst 2.06 decibel and 2.24 dB a number of the operative bands. The projected antenna has attempted to be geared up to supply home the bacon immoderate standard overall performance and is suitable for wireless conversation systems.

L. Twin Feed Φ- form Patch Antenna 5G Applications

A twin feed Φ- kind patch antenna is meant with the assist of victimization the employment of HFSS software. The Antennas are extensively talking utilized antennas due to their lightweight, the price is low, and simplicity of fabrication. The nonconductor substrate utilized is FR4 Epoxy. The go-returned loss of twin-feed Φ-fashioned patch antenna below -10 decibel is -21.2 dB. The dual-Feed Φ-Shaped Patch Antenna well-known shows a resistance statistics degree of three. Three to three. Eight gigahertz the antenna is matched to the road even as the VSWR really well worth is small. And it is now no longer up to 2 dB that's 1.51. The Simulated and VSWR for dual Feed Φ-Shaped Patch Antenna. and gain of dual Feed Φ-Shaped Patch Antenna is 4. 41 dB. And is suitable for 5G applications.

M. High Gain & Directivity Microstrip Patch Antenna at 3.5 GHz

The current status of the work includes the design process for a microstrip patch antenna at a resonant frequency of 3.55 GHz suitable for WLAN applications, satellite communications, and WiMAX applications. The results show an improved bandwidth, the gain is high and the parameters S11 define the transmission power and thus the reflection at the antenna. In order to get the maximum radiation, the reflection must be as low as possible to make the antenna more efficient. Graphical results in order to show the efficiency increase and the wide radiation patterns, detailed experimental studies can be carried out at a later date to find a design method for symmetrical gain antennas.

N. MIMO Compact Short Microstrip Antenna

A four-detail shorting pin-loaded patch antenna is designed on the sub 6 GHz 5G band The antenna is resonating at 3.41 GHz with back the loss of S11 of -37.65 dB at port 1, S22of -29.12 dB at 3.44 GHz, S33 of -42dB at 3.405 GHz, and S44 of -23 dB at 3.445 GHz. with a bandwidth of about one hundred MHz on the middle frequency. the benefit and radiation performance of the proposed four detail antenna is accelerated as compared to two-detail and unit-detail antennas. that is appropriate for cell handsets. From the above results, it's far clean that the proposed antenna reveals ok gain and compactness, appropriate for employees' cell devices. The configuration may be prolonged for the bottom station antenna with the aid of using growing the wide variety of elements. Also, antenna configuration may be incorporated into the layout device for 5G communication.

O. Rectangular Microstrip Antenna 1x2 Array for 5G.

Stops end result of the format of a square 1x2 array and single patch microstrip antenna with a frequency of 3.5 GHz, then the perception that can be taken is for the 1x2 array microstrip antenna to deliver a pass returned loss cost of -12.6 dB, VSWR 1.6, gain 5.5 dB, bandwidth 66.5 MHz on microstrip antenna single patch produces a pass returned loss cost of -37.8 dB, VSWR 1, gain 5.5 dB, bandwidth 73.2MHz

P. Slotted Two- C Shaped Microstrip Patch at 3.5 GHz for WiMAX.

for the duration of this paper, a slot C-shaped microstrip patch antenna became designed and simulated to radiate withinside the center band of the WiMAX frequency variety

of 3.2-3.8 GHz. The go back loss is -32.30 dB and has a VSWR = 1.07 at a resonant frequency of 3.5GHz

Q. Antenna from Flexible Textile with Transparent Conductive for WiMAX Communication

A bendy and optically apparent simply cloth patch antenna for wireless communications modified into studied with the motive of being blanketed into OLED devices, similarly to slight or flexible displays. This way, the equal device is ready with every mild and communications function. The substrate uses a microstrip line for Wireless communique systems WiMAX strolling at 3.5 GHz. We have confirmed that antenna format techniques perform properly even for material substrates such as apparent conductive fabric blanketed with polyester. The antenna is well-known for omnidirectional radiation coverage with a gain of 1.07 dB at 3.5 GHz the only drawback is reducing the gain at higher frequencies.

R. Design a C-Shaped Compact microstrip antenna

Although it's been suggested that a patch antenna has a narrow bandwidth, on this examination an antenna with a much wider bandwidth than an ordinary patch antenna has been designed for 4G systems. In order to widen the antenna bandwidth, a round kind slot is added. Afterward, the antenna has been fabricated, and go back loss is measured, VSWR end result could be very good and good gain. in addition to simulated in HFSS. Simulation consequences suggest that the 3-D radiation styles withinside the 3.45–3.55 GHz variety are acceptable, specified for 4G (WiMAX).

S. Microstrip Patch Antennas Compact Dual-band and Tri-band.

The article introduces the design of three compact multiband microstrip antennas, Ant.1, Ant.2, and Ant.Ant.1 and Ant.3 are useful for the dual-band, while Ant.2 is useful to use as a TRI band antenna.2/5.8) WLAN and C-band.Ant.1 covers the WiMAX band 3.55 GHz and WLAN band 4.80GHz Ant.2 covers the 3.55GHz WiMAX band, 5.40GHz Wi-Fi band, and C7 band.25 GHz, while Ant.3 covers the WiMAX 3.62 GHz band and the WLAN 5 band.10 GHz The designed antennas are easy to manufacture and compact in size (21 × 21 × 1.6 mm3). In addition, the simulated radiation pattern of these antennas shows that the designed antennas have omnidirectional radiation, making them suitable for use in portable and wireless devices.

T. Design Circular Patch Antenna Based Miniature for 5G Mobile Communication

In the paper, for 5G communication for 3.5 GHz new technology cell terminals, a miniature round new microstrip antenna layout primarily based totally on the patch detail is introduced. A miniature antenna structure (frequency 3.5GHz) turned into received with the DGS withinside the shape of CSRR (Complementary Split Ring Resonator) generated withinside the floor plane. Developed antenna layout. Radiation detail stepped microstrip-line located on CSRR-DGS (defected floor structure), it turned into created with a fed round patch, the proposed CSRR-DGS-primarily based totally miniature antenna Numerical evaluation outcomes of the layout are given. Proposed CSRR-DGS is primarily based on a totally miniature layout 3.5 It is well-known shows S11<-10 dB overall performance withinside the GHz-centered, 3.46-3.53 GHz working band.

TABLE I. COMPARATIVE ANALYSIS DEFFRENT ANTENNA DESIGN FOR 5G, WI-MAIX AND COMMUNICATION

Paper	Type of antenna used or materials used	Technology used	Features/ advantages
[1] [3][15]	Two rectangular with square-shaped and Antenna 1x2 Array	bandwidth and length discount in comparison. simulation and the measurement	nicely ideal for WIMAX useful for 5G applications
[2]	metallic strapline and ground plane	used to feed various types of antennas	mobile phone antennas, Wi-Fi antennas.
[4]	Broadband Microstrip Antenna	two asymmetrical bent loading elements are added near the feed of the 52 mm	used in applications covering WLAN/WiMAX
[5].	microstrip patch antenna-shaped compact	using R/Duriod 5880 LZ, with an overall size	various communications such as 5G
[6] [7] [11]	Circular Patch Antenna Using Open-Ring Artificial Dielectric	The acrylic natural dielectric material substrate	wireless communications and covering WLAN/WiMAX
[8]	Ultra-Wideband Microstrip Patch Antenna	the complete band of the IEEE 802.16e-2005 fashionable	mobile WiMAX operations because the antenna is an ultra-wideband
[9]	Microstrip Patch Antenna Dielectric Substrate	assessment among substrate substances FR-4, RT-5880, and TLC-30	good for gain top performance in phrases and bandwidth the first-class for 5G
[10]	Small Patch Antenna	antenna has a bodily length of 25.2 X45 mm	very excessive performance of 96.67%. used for 5G Application.
[12]	Twin Feed Φ-Shaped Antenna	The dielectric substrate used is FR4 Epoxy	for 5G applications
[13]	High Gain & Directivity	design method for symmetrical gain antennas.	WLAN, WiMAX, and satellite communications
[14]	Compact Short Antenna	MIMO	5G communication.
[16] [18]	Two- C Shaped Microstrip	Slotted Two- C Shaped a narrow bandwidth	for WiMAX. for 4G (WiMAX). Good gain.
[17] [19]	Antenna Flexible Textile Antennas Compact Dual-band and Tri-band.	Flexible Textile with Transparent Conductive Integrated and three compact multi-band antennas	for WiMAX and Wireless Communication Systems

Recommended miniature CSRR-DGS-primarily based totally microstrip layout has antenna systems that may be utilized in 3.5 GHz five G applications. Considered to be an alternative. On the opposite hand, standards, it's far aimed to growing the bandwidth to cowl the range.

CONTRUBITION OF THE AUTHORS

The contributions of the authors to the article are equal.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

STATEMENT OF RESEARCH AND PUBLICATION ETHICS

Research and publication ethics were observed in this study.

REFERENCES

[1] A. A. Abdulbari et al., "Design compact microstrap patch antenna with T-shaped 5G application," Bulletin of Electrical Engineering and Informatics, vol. 10, no. 4, pp. 2072-2078, 2021.

[2] N. K. Ashish Kumar, Nitesh, "Design of Microstrip Patch Antenna for High Gain & Directivity at 3.5 GHz by Simulation studies using ADS," IJETT Journal, vol. 55 Number-1, p. 3, 2018.

[3] A. Bah and G. Gucuyetkin, "Design of microstrip patch antenna for wimax applications," Int J Electric Electron Data Commun, vol. 6, no. 6, 2020.

[4] N. Engin and Z. Erman, "Düzce Üniversitesi Bilim ve Teknoloji Dergisi," Düzce Üniversitesi Bilim ve Teknol Derg, vol. 4, pp. 293-304, 2016.

[5] N. Ferdous, G. C. Hock, S. H. A. Hamid, M. N. A. Raman, T. S. Kiong, and M. Ismail, "Design of a small patch antenna at 3.5 GHz for 5G application," in IOP Conference Series: Earth and Environmental Science, 2019, vol. 268, no. 1: IOP Publishing, p. 012152.

[6] G. Immadi, M. V. Narayana, A. Navya, and P. Anusha, "Dual Feed Φ-Shaped Patch Antenna For 5G Applications," NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| NVEO, pp. 1540-1549, 2021.

[7] A. Irfansyah, B. Harianto, and N. Pambudiyatno, "Design of Rectangular Microstrip Antenna 1x2 Array for 5G Communication," in Journal of Physics: Conference Series, 2021, vol. 2117, no. 1: IOP Publishing, p. 012028.

[8] A. Kazdağ, M. H. Uçar, and G. Çakır, "5G Mobil Haberleşme Uygulamaları için CSRR-DGS Tabanlı Minyatür Dairesel Yama Anten Tasarımı."

[9] S. E. B. KESKİN and C. GÜLER, "DESIGN OF CIRCULAR SLOTTED RECTANGULAR MICROSTRIP PATCH ANTENNA WITH DUAL-RESONANCE FOR WLAN/WIMAX APPLICATIONS," Mühendislik Bilimleri ve Tasarım Dergisi, vol. 9, no. 4, pp. 1296-1301, 2021.

[10] A. Kumari, A. Pal, and D. Kumar, "3.5 GHz microstrip transmission line design for microwave ICs," Int. J. Sci. Res. Rev, vol. 7, no. 04, pp. 651-654, 2019.

[11] M. K. M. Masal and M. S. Kale, "Design of Slotted Two-C Shaped Microstrip Patch Radiating at 3.5 GHz for WiMax Applications," Change, vol. 3, no. 2.21, p. 3.49, 2018.

[12] S. Murugan, "Compact MIMO Shorted Microstrip Antenna for 5G Applications," MECS International Journal of Wireless and Microwave Technologies, vol. 11, no. 1, 2021.

[13] D. K. Naji, "Design of compact dual-band and tri-band microstrip patch antennas," International Journal of Electromagnetics and Applications, vol. 8, no. 1, pp. 26-34, 2018.

[14] D. Paragya and H. Siswono, "3.5 GHz rectangular patch microstrip antenna with defected ground structure for 5G," ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, vol. 8, no. 1, p. 31, 2020.

[15] M. A. Rahman, S. Sobhan, and M. Hossain, "Design and Performance Analysis of An Ultra-Wideband Microstrip Patch Antenna for Mobile WiMAX applications at 3.5 GHz Band including Human Interaction."

[16] Y. N. Rahmawati and H. Ludiyati, "The Characteristic of a 3.5 GHz Circular Patch Antenna Using Open-Ring Artificial Dielectric," in 2nd International Seminar of Science and Applied Technology (ISSAT 2021), 2021: Atlantis Press, pp. 387-393.

[17] N. Ramli, S. K. Noor, T. Khalifa, and N. Abd Rahman, "Design and performance analysis of different dielectric substrate based microstrip patch antenna for 5G applications," Design and Performance, vol. 11, no. 8, 2020.

[18] S. Sekkal, L. Canale, and A. Asselman, "Flexible textile antenna design with transparent conductive fabric integrated in OLED for WiMAX wireless communication systems," in 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), 2020: IEEE, pp. 1-4.

[19] W. Wildan, D. A. Cahyasiwi, S. Alam, M. A. Zakariya, and H. Ramza, "Circle Microstrip Antenna Simulation for Frequency 3.5 GHz," Akta Teknik Elektro, vol. 1, no. 1, pp. 1-4, 2021.