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Triple-Band Wireless Applications using a C-Shaped Slotted Patch Antenna Designed and Analyzed Using a DGS Structure

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ABSTRACT

With a permittivity (ε_0) of 4.3 (FR4) and dimensions of 35×43×1 mm^3, the author of this article makes a small patch antenna that is sandwiched between a radiating patch and defected ground structure (DGS) plane. The C-shaped antenna is connected to the coaxial cable connection using a microstrip feedline, and the input impedance (50Ω) is matched. The DGS-based antenna was designed to resonate between the bands of frequencies 13.18 - 15.82 GHz (Ku-band), 16.97 - 19.65 GHz (K-Band) and 22.64 - 24.95 GHz (Ka-Band) at resonance frequencies of 14.15 GHz, 18.45 GHz and 23.88 GHz respectively. The voltage standing wave ratio (VSWR) at resonance frequencies of 14.15 GHz, 18.45 GHz and 23.88 GHz is found 1.02, 1.10 and 1.45 respectively, which is less than two (VSWR<2). This patch antenna is being deliberate because it has a low VSWR at each of the three resonance frequencies and has a large bandwidth at −10 dB. For wireless communications, this design is appropriate for triple band operations. Computer simulated tool (CST) software has been used to simulate the electromagnetics properties of the proposed antenna. Proposed antenna provides a triple band with appropriate Gain, VSWR, return loss, and radiation pattern for wireless applications. According to parametric study, this design is suitable for Ka-band, K-band, and Ku-band for wireless applications.

Keywords: C-shaped, Triple-band, Ka-band, K-band, and Ku-band.

1.0 Introduction

In the past several decades, satellite and wireless communication have made remarkable advancements, and they have already had a big influence on daily life. There are several communications and local area network applications that call for a way to send and receive electromagnetic waves. Due to the flexibility of microstrip patch antenna (MPA) technology, a broad variety of designs and techniques to meet this demand have been developed [1-5]. There is a rising demand for small mobile phone. Smaller mobile phones are starting to become available. Compact handset demand will rise along with overall demand. The antenna size is one of the most important factors in portable communication systems. The MPA is often utilized due to its low volume and low profile. The design parameters of MPA are mostly controlled by the resonance's length and width of radiating patch. The 5G generation of mobile technology, can operate at extremely high speeds with very little delay and very high reliability [6-11].

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The 5G new radio interface is positioned to satisfy the more stringent requirements for the very varied usage scenarios of 2020 and beyond, including explosive increases in connectivity and traffic density and volume. To accommodate such a diverse range of usage scenarios and requirements, enough 5G spectrum availability is necessary [12-15].

An antenna works like a transducer. It transforms electrical signals into electromagnetic waves and vice versa. It is a component of both the transmitter and the receiver circuits. This work offers a revolutionary millimeter wave antenna design that can be used for a number of purposes, such as cellular communications and transfer the large amounts of data quickly [15-20].

In the sections below, the design and assessment processes for the antenna is discussed. In part 2, the utilized design approaches and suggested antenna configurations are discussed; in section 3, the optimization and parametric analysis of the proposed antenna are covered. Section 4 finishes with a discussion of the future direction of this study after analyzing its performances and making a thorough comparison with other published works.

2.0 Design Analysis

Figure 1 illustrates the development of asymmetric configurations of antenna that have been created and studied. The proposed antenna design, inner and outer curve has a diameter of 17.96 mm and 15.96 mm. Angular displacement between these two curves is 23.52 degrees as shown in Fig.1. The steps for calculating geometric design parameters are shown below.

Design Step-1: Calculation of the radiating patch width (*W*):

The radiating patch width of the microstrip antenna based on DGS structure is given below in equation1:

$$\mathrm{W} = \frac{\mathbf{c}}{\mathbf{2fo}\sqrt{\frac{\mathbf{\epsilon r+1}}{\mathbf{2}}}} \tag{1}$$

Design Step-2: Calculation of effective dielectric constant (ε_{reff}**):**

The effective dielectric constant is given in equation 2:

$$\mathcal{E}\mathrm{reff.} = \frac{\boldsymbol{\epsilon r+1}}{\mathbf{2}} + \frac{\boldsymbol{\epsilon r+1}}{\mathbf{2}}\sqrt{1+12\frac{\boldsymbol{h}}{\boldsymbol{w}}} \tag{2}$$

Design Step-3: Calculation of the effective radiating patch length (L_{eff}**):**

The effective length (L_{eff}) of radiating patch of antenna is given in equation 3 and L_{eff} of patch depends on the electromagnetics wave travelling with speed of light (c), operating frequency (f_0), and effective relative permittivity (ε_{reff}) of substrate materials:

$$Leff = \frac{c}{2fo\sqrt{\mathcal{E}\mathrm{reff.}}} \tag{3}$$

Design Step-4: Calculation of the length extension of radiating patch ($\triangle L$**):**

The length extension of radiating patch is given in equation 4, and its depends on physical parameters of the effective relative permittivity (ε_{reff}) of substrate materials, width (w), and thickness (h) of substrate.

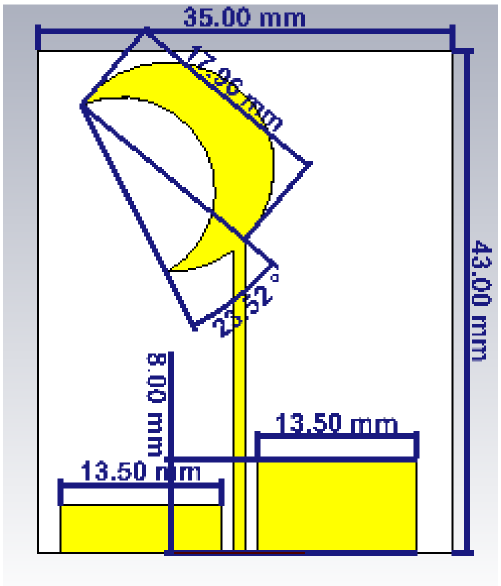
$$\triangle L = 0.412h\frac{(\mathcal{E}\mathrm{reff}+0.3)(\frac{w}{h}+0.264)}{(\mathcal{E}\mathrm{reff}-0.258)(\frac{w}{h}+0.8)} \tag{4}$$

Design Step-5: Calculation of actual length of radiating patch (L):

The actual length is obtained by as per equation 5:

$$L = Leff - 2.\triangle L \tag{5}$$

Figure 1: C-Shaped slotted with DGS-structure of suggested antenna



3.0 Parametric Study and Result Analysis

The electromagnetic wave (EM) simulator CST V.17 simulates the suggested antenna design using the Finite Integration Technique (FIT) in the antenna template transient mode. Results of the suggested antenna have been attained and have demonstrated good agreement between typical and simulated results in CST in terms of return loss, VSWR, impedance bandwidth (IBW), radiation pattern, directivity, and gain electrical parameters of antenna. The optimal value of several electrical parameters of proposed antenna are listed in Table 1.

Table 1: Result Analysis

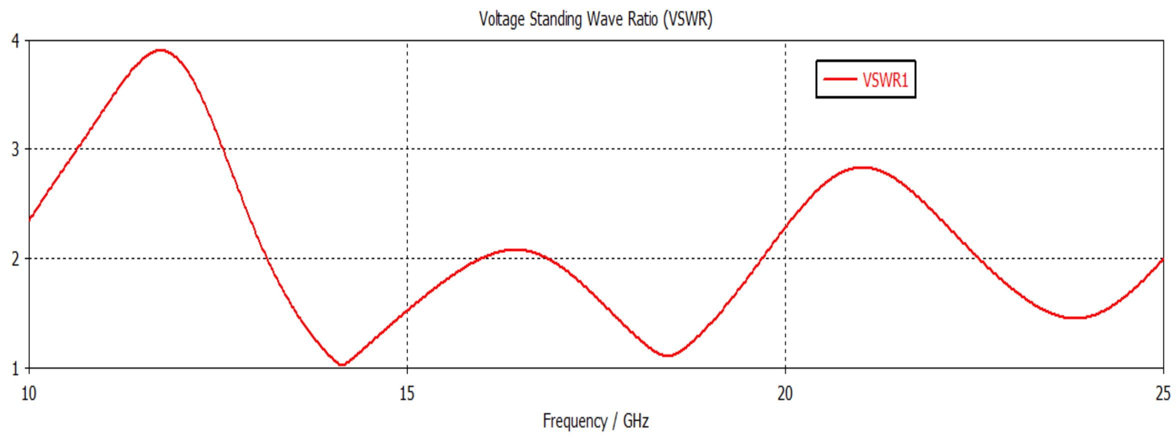
Antenna Geometry (mm^3)	VSWR (< 2)	Resonance frequency (f_r) in GHz	Antenna Bandwidth (GHz)	S_{11} Parameter (dB)	Number of Bands
35×43×1 mm^3	1.02	f_{r1} = 14.15	13.18-15.82	−40	Triple
	1.10	f_{r2} = 18.45	16.97-19.65	−26	
	1.45	f_{r3} = 23.88	22.64-24.95	−15	

The suggested patch antenna's VSWR graph is shown in Fig. 2. Fig. 3 displays the return loss, whereas Fig. 4 and 5 indicate directivity, antenna's gain, and Fig. 6 depicts the radiation pattern.

3.1 VSWR

The electrical radio frequency (RF) signal transmission system, the VSWR is the ratio of transmitted to reflected voltage standing waves of antenna is called VSWR. It measures how well RF power is transmitted from the power source, along a transmission line, and into the load. The resonance frequencies of the suggested antenna are 14.15 GHz, 18.45 GHz, and 23.88 GHz at VSWRs of 1.02, 1.10, and 1.45, respectively, as shown in Fig. 2.

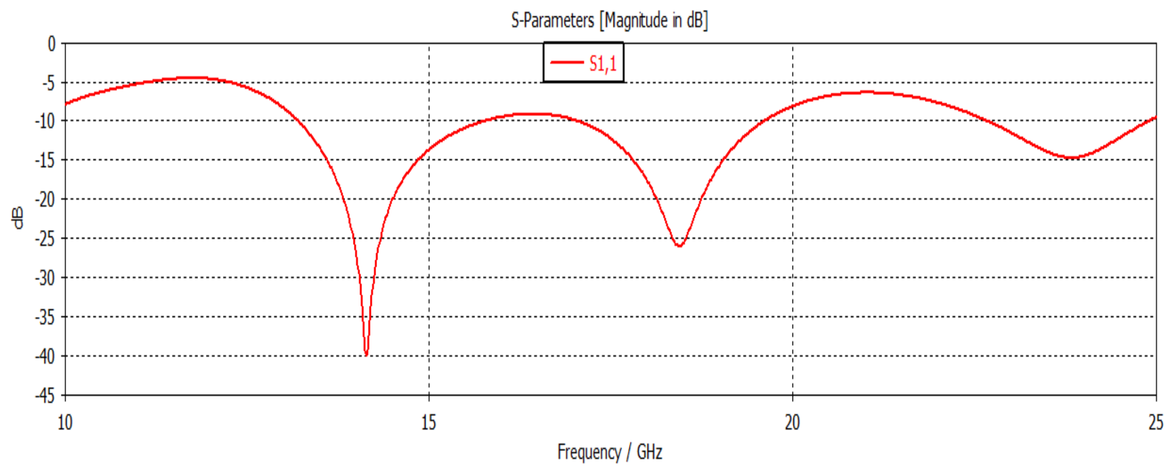
Figure 2: VSWR of the Suggested Antenna



3.2 Reflection coefficient (return loss)

Reflection coefficient is the ratio of reflected power to transmitted power, measured in decibels (dB). The resonance frequencies of suggested antenna are 14.15 GHz, 18.45 GHz, and 23.88 GHz at the return loss is −40 dB, −26 dB, and −15 dB respectively as shown in Fig. 3.

Figure 3: Return Loss of the suggested Antenna

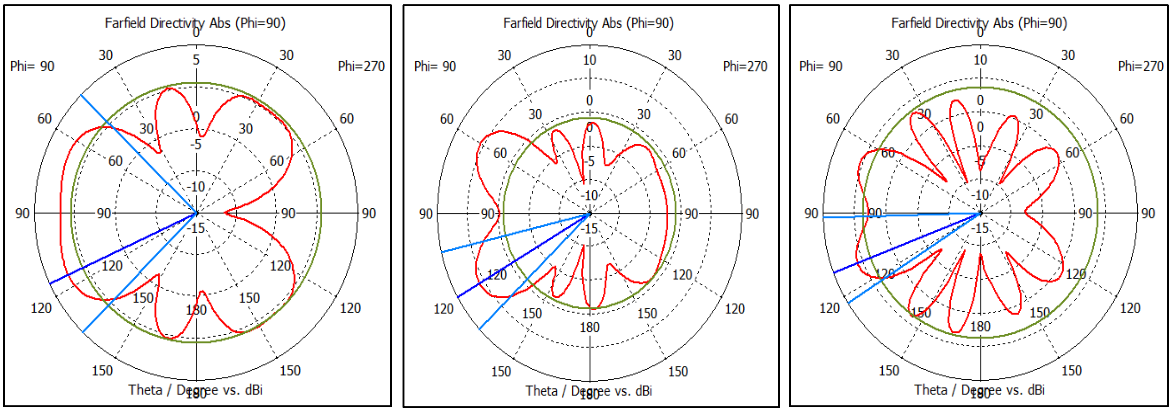


3.3 Directivilty

It is measured in relation to the concentration of energy emitted in a certain direction by the transmitting antenna. The primary lobe's directivity magnitude at 14.15 GHz is 2.42 dBi. According to

Figure 4: The Major Lobe Magnitude of Directivity is 5.82 and 5.81 dBi, Respectively, for Resonance Frequencies of 18.45 and 23.88 GHz

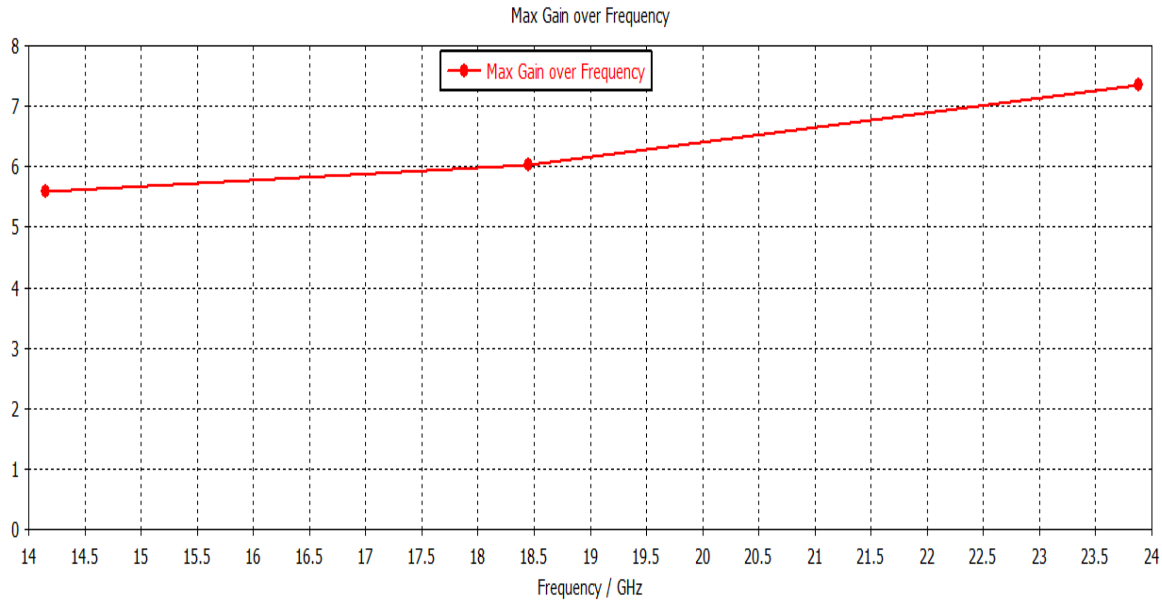
(a) (b) (c)



3.4 Gain

Antenna gain is the quantity of power that an isotropic source transmits in the direction of the peak radiation. As shown in Fig. 5, the gain is 5.7 dB, 6.02 dB, and 7.3 dB at resonance frequencies of 14.15 GHz, 18.45 GHz, and 23.88 GHz, respectively.

Figure 5: Gain of the Suggested Antenna

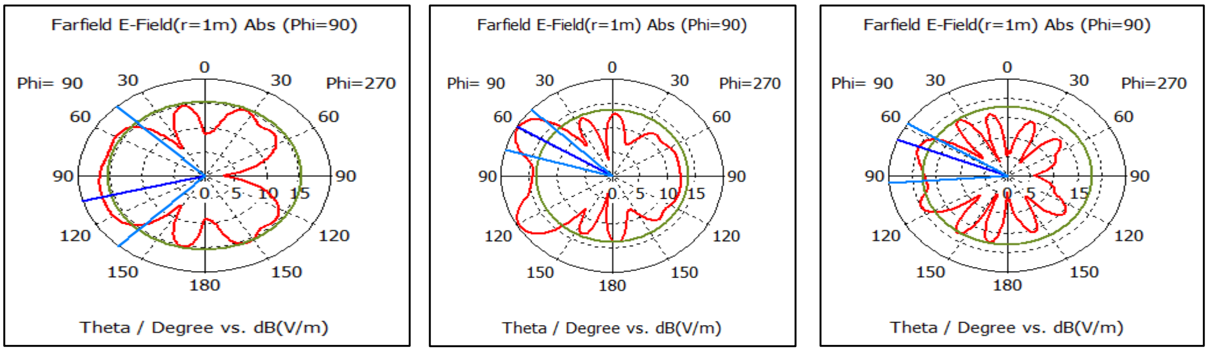


3.5 Radiation pattern

Voltage and electric field are related; a higher E-field striking an antenna will result in a greater voltage differential between the antenna's terminals. As shown in Fig. 6, the major lobe magnitude of the E-field is 16.7 dB (V/m), 19.7 dB (V/m), and 20.1 dB (V/m) at resonance frequencies of 14.15 GHz, 18.45 GHz, and 23.88 GHz, respectively.

Figure 6: Radiation Pattern of Suggested Antenna
(a) 14.15 GHz, (b) 18.45 GHz, and (c) 23.88 GHz

(a) (b) (c)



4.0 Conclusion

A unique and effective microstrip patch antenna based on DGS is constructed to deliver the necessary results. The suggested antenna is small in size and has triple bands, which resonate at three resonance frequencies of 14.15 GHz, 18.45 GHz and 23.88 GHz. This design is perfectly suitable for Ka-Band, K-band and Ku-band for wireless applications. The third band is also suitable for 5G wireless applications. This C-shaped slotted design gives the desired results for various wireless applications.

This unique design has three frequency bands 13.18-15.82 GHz, 16.97-19.65 GHz and 22.64-24.96 GHz, by reducing the size of the antenna and taking a material with different dielectric materials, the range of frequency band will be increased, which will increase the range of resonance frequencies in higher bands, it can have used in more upcoming wireless applications.

References

1. Anupam Kumar Yadav, Sandeep Singh and Suman Lata Dhar "Tri-Shul Shaped microstrip patch antenna for X-band wireless applications" International Journal of Scientific Research in Engineering and Management, ISSN: 2582-3930, Volume: 06 Issue: 09 | September – 2022. DOI: 10.55041/IJSREM16299,
2. Anupam Kumar Yadav, Sandeep Singh and Suman Lata Dhar "B-shaped Microstrip Patch Antenna for frequency range of 5-6.5GHz" International Journal of Innovative Research in Advanced Engineering, ISSN: 2349-2163, August 2022, Volume 9, Issue 8, pp 356-360. https://doi.org/10.26562/ijirae.2022.v0908.36,
3. Anupam Kumar Yadav, Suman Lata Dhar, and Sandeep Singh "Review on microstrip patch antenna for wireless applications" International journal of creative research and thoughts. ISSN:2320-2882 Volume-10, issue-7 July 2022, PP 78-86
4. Anupam Kumar Yadav, Sandeep Singh "Compact Dual Band PIFA gap coupled Antenna for Wireless Applications using CSSRR" book chapter published in "Recent Developments in Engineering and Technology's 818912881-7, March 2022.
5. Anupam Kumar Yadav, Awadhesh Dwivedi" Result Comparison between I and + Sign Slotted Micro Strip Patch Antennas for Wi-Max applications"-International Journal of Innovative Research in Technology, ISSN: 2349-6002 Volume-8, Issue-5, (Oct 2021), PP 679-682

6. Anupam Kumar Yadav, Awadhesh Dwivedi, Namrata Yadav" Performance comparison between I slotted and U slotted shaped microstrip patch antennas"- Journal of Engineering Science, ISSN: 0377-9254 Volume-11, Issue-5, (May 2020), PP 329-332,
7. Anupam Kumar Yadav, Awadhesh Dwivedi, "Result Comparison of Slotted I Sign Shaped Microstrip Patch Antenna with Rectangular Patch Antenna for Wi-Max Frequency" IJESR/June 2019/ Vol-9/Issue-6/18-22, 2019.
8. Anupam Kumar Yadav, Vijay Kumar 'L-Shaped Micro stripped Patch Antenna for Frequency Range of 3 - 3.5 GHz" IJESR/ICRIT 2018/ Special Issue/Article No-57/356-361, 2018.
9. Anupam Kumar Yadav, Suaib Mohammad 'Design of H Shape Slotted Micro Strip Patch Antenna for Wi-Max Applications" IJESR/ICRIT-IV/ Special Issue/ Article No-40/219-222, 2018.
10. Anupam Kumar Yadav, "Design of Slotted I Sign Shaped Microstrip Patch Antenna for Wi-Max Frequency of 3.5 GHz" IJESR/ICRIT-IV/ Special Issue/ Article No-39/213-218 ', 2018.
11. Anupam Kumar Yadav, "A Review of Genetic And K- Means (GAK) Algorithm for Data Clustering" IJESR/ICRIT 2018/ Special Issue/Article No-7/29-34
12. Anupam Kumar Yadav, "Design of U-slotted microstrip patch antenna for wi-max Frequency range of 3 to 3.5ghz, IJESR/ICRIT 2018/ Special Issue/Article No-53/330-334
13. Anupam Kumar Yadav, V.K. Pandey "Slotted Dumbbell Shaped Microstrip Patch Antenna for Wi-Max Frequency band of 3.4-3.69GHZ"-International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249-8958 Volume-2, Issue-6, (August 2013), PP 170-172, www.ijeat.org.
14. Anupam Kumar Yadav, Sabyasachi Mukherjee "Collision Avoidance Approach for Performance Optimization in Packet Switched Network" International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Issue 3, Volume 2 (March 2015).
15. Anupam Kumar Yadav, Sabyasachi Mukhopadhyay, Pradip Kumar Yadava "Performance Comparison between U Slotted and Dumbbell Slotted Shaped Rectangular Patch Antenna" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 4, April 2015.
16. Anupam Kumar Yadav, Sandeep Singh and Suman Lata, "Design and Investigation of a Double-Damru (Pellet Drum)-Shaped CPW-Fed Microstrip Patch Antenna for 5G Wireless Communications" Journal of electronics Materials (JEM)-Scopus Indexed DOI: 10.1007/s11664-023-10413-x
17. Anupam Kumar Yadav, Sandeep Singh and Suman Lata "Investigating the |S11| Parameter of CPW-Fed Antennas for Wi-MAX and WLAN Applications" Journal of electronics Materials (JEM)-Scopus Indexed. DOI: 10.1007/s11664-023-10413-x
18. Anupam Kumar Yadav, Sandeep Singh and Suman Lata "Design and Parametric Analysis of a Triple Band Waxing Crescent Moon Shaped Slotted Microstrip Patch Antenna for 5G Wireless Communications" International Journal of Scientific Research in Engineering and Management. ISSN: 2582-3930. Volume: 06 Issue: 11 | 2022.
19. Anupam Kumar Yadav, Sandeep Singh and Suman Lata Dhar "Tri-Shul Shaped microstrip patch antenna for X-band wireless applications" International Journal of Scientific Research in Engineering and Management, ISSN: 2582-3930, Volume: 06 Issue: 09 | September – 2022. DOI:10.55041/IJSREM16299,
20. Anupam Kumar Yadav, Sandeep Singh and Suman Lata "Design and Analysis of CPW-Fed Antenna for Quad-Band Wireless Applications" Journal of electronics Materials (JEM)- Scopus Indexed. DOI: 10.1007/s11664-023-10413-x