©2025 Published in 11th International Symposium on Intelligent Technologies in Engineering and Science 16-18 May 2025 (ISITES2025 Diyarbakır - Turkey)

Microstrip Antennas in Modern Wireless Communication: Applications and Innovative Designs

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Abstract

This paper presents a wideband circular microstrip antenna designed for mobile phones to meet the increasing demand for antennas that support multiple communication generations, including 2G, 3G, 4G, and 5G. The proposed antenna operates within a frequency range of 1.15 GHz to 6.5 GHz, effectively covering the various communication bands across these generations. It demonstrates a gain of up to -6.2 dB, an efficiency of 90%, a voltage standing wave ratio (VSWR) below 1.5, and a return loss (S11) reaching -40 dB, with a bandwidth of 5.35 GHz. The antenna, designed on an FR4 substrate with dimensions of 68 × 83 × 1.6 mm³, offers reliable performance across wide frequency ranges.

Key words: circular Microstrip,wide band width, G2 G3 G4, mobile, Gain.

1. Introduction

With the rapid advancement of mobile communications technology from 2G to 5G, the way individuals communicate, and access information has changed dramatically. Provide fast and efficient communication over wide frequency ranges with every generation of mobile devices. Consequently, the demand for antennas compatible with different communication generations has increased dramatically. Modern mobile devices must be high performance and lightweight devices that can meet communication standards. An antenna is key to facilitating high speed data transmission in different frequency bands. Signals must be transmitted and received efficiently to support telephony, data, and multimedia services. The challenge is to design antennas that can operate efficiently over multiple generations of communication without sacrificing performance or size. Wideband and multiband antennas capable of handling multiple frequencies in a single subsystem have emerged as important solutions to meet these requirements.

Many research works have been planned to optimize the wideband antennas for mobile devices. For example, Shandal et al. [1]. propose a small antenna design over a partial ground plane. The antenna with dimensions of 20×18 mm² is mounted on FR4 substrate and operates at 4.5–9.3 GHz frequency. The antenna fed by a microstrip line has simulated return loss values of -33 and -41 dB, respectively. Another study proposed by the same authors [2], one compact antenna with a fractal circular patch microstrip resonator with a pentagon slot design was realized. This work made possible operating in a frequency band: 4.5-9.3 GHz, and advanced integration with small-sized antennas. Awad and Abdelazeez [3] have presented the two rejected bands ultra-wideband antenna designs along with planar UWB antennas. The feeding of the antenna is given with a 50 Ω feed line, and the patch itself is rectangular on an FR4 substrate. The simulated bandwidth attains a return loss of about 10 dB, and it falls from 3.42 to 11.7 GHz. Gaid et al. [4] proposed two small multiband microstrip patch antennas for 5G wireless communication. These low-profile antennas can be easily integrated into mobile devices. They are operating at 28 GHz, 45 GHz, and 60 GHz frequency ranges. Chauhan et al. [5] developed a high gain model of the microstrip antenna for 5G mobile communication. The study shows that with a center frequency of 38 GHz, this antenna works excellently with good directivity and minimum return loss. An et al. [6] have proposed a novel low-profile microstrip antenna for 5G applications with a constant gain within the wide bandwidth. It achieves an average gain of 5 dBi and impedance bandwidth of 58.3% from 2.84 to 5.17 GHz, which gives constant gain with four resonant modes for bandwidth enhancement. A novel single-layer and small microstrip antenna integrated with filtering function was proposed by Yang et al. [7]. The antenna is of wide bandwidth, high selectivity, high gain, and low profile. With the addition of four parasitic strips, one additional resonance point was achieved to improve the selectivity of the high-band edge. The measured impedance bandwidth is 20.1% with a frequency range from 2.19 to 2.68 GHz while the average gain of the antenna is over 9.5 dBi. Yulianto La Elo et al. [8] proposed a wideband microstrip antenna covering a frequency range of 850-2300 MHz with bandwidth 1707.64 MHz for 4G/LTE. The proposed antenna can be used for 4G/LTE applications as this antenna offers omnidirectional radiations and peak gain 4.47 dB using parasitic elements on FR4 substrate. Zaharis et al.[9] aimed to design a new wideband log-periodic antenna (LPA) using an improved particle swarm optimization (PSO) method with velocity mutation (PSOvm). The LPA geometry consists of wire dipoles arranged according to an exponential rule, optimized to operate in the 790–6000 MHz frequency range. The resulting antenna achieves gain flatness below 2 dB, and a standing wave ratio below 2, making it suitable for covering a wide range of wireless services. Ojaroudi Parchin et al.[10] In, a tri-band MIMO antenna array for a 5G mobile handset was proposed. The array consisted of eight identical PIFA elements placed along the edges of the mainboard of the handset; the overall dimensions were 150×75 mm². The frequency ranges covered are 2.5-2.7 GHz, 3.4-3.75 GHz and 5.6-6 GHz which correspond to LTE bands 41, 42/43 and 47, respectively. The array realizes better than 15 dB return loss across these bands and provides dual-polarized radiation with good efficiency and gain results appropriate for multi-mode 5G applications.

In this paper, we present a study that tries to further develop the functionality and performance of mobile communication antennas. We have proposed an antenna design that has given considerable bandwidth and efficiency gains over earlier studies, as illustrated by Table 1. The antenna results will now illustrate how the proposed design meets the requirements of modern communication standards. This antenna closes an important gap in the market: a high-performance, small product able to integrate several generations of communication seamlessly for use in contemporary applications.

These six sections are organized as follows: In section II, Material and Method will be described in detail about the development of the antenna, including materials used, simulation technique, and physical construction. The section III. Results shows the main performance metrics of the antenna confirmed by simulation, mainly on return loss, efficiency, and impedance matching. Discussion IV. The results analysis, discussion about their limits, and underlines about benefits are performed. Summarizing the results in the section V. Conclusion and delineating the next steps toward improvement of the antenna's design should be done in the VI. Future Work section.

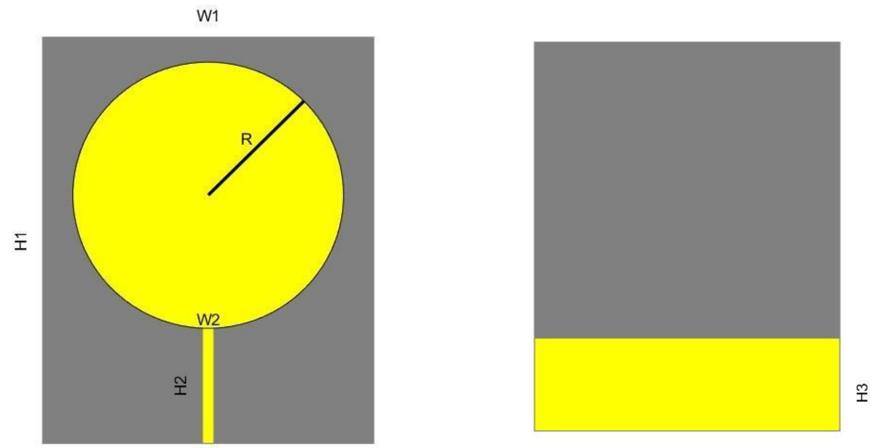
Table 1. Comparison of Antenna Designs Based on Frequency Range, Bandwidth, and Advantages

Study	Frequency Range (GHz)	Bandwidth (GHz)	Advantages of our study compared to each study
Shandal et al.	4.5 – 9.3	4.8	Wider frequency coverage
Awad and Abdelazeez	3.42 – 11.7	8.28	Higher efficiency
Gaid et al.	28, 45, 60	Multiband	Coverage for multiple generations
Chauhan et al.	38	-	Higher efficiency, wider coverage
An et al.	2.84 – 5.17	2.33	Wider bandwidth
Yang et al.	2.19 – 2.68	0.49	Wider bandwidth
Yulianto La Elo et al.	0.85 – 2.3	1.70764	Wider frequency coverage
Zaharis et al.	0.79 – 6.0	5.21	Higher efficiency, lower return loss (-40 dB vs. VSWR < 2)
Ojaroudi Parchin et al.	2.5 – 2.7, 3.4 – 3.75, 5.6 – 6.0	Multiband	Wider coverage for all generations
This study	1.15 – 6.5	5.35	-

2. Materials and Method

Owing to their small size, lightweight, and simple structure, microstrip antennas have recently become more and more popular for a range of communication applications [11]. Within this project, one circular microstrip patch antenna was designed by considering the wide frequency range to be able to support 2G, 3G, 4G, and 5G communication protocols [12]. The design process of the antenna is presented within this section.

The one-sided dielectric substrate of microstrip antenna contains a ground plane and on the other side, it contains a radiating patch and feed line as shown in Figure 1 [13]. Patch is available in several shapes such as elliptical, circular, and rectangular with all of them having some special characteristics [14]. When the requirement is for compact dimensions and omnidirectional radiation pattern, patch is normally used in circular shape [15]. The resonance frequency of a circular microstrip antenna is determined mainly by the operating wavelength, patch radius, and substrate properties.



(a) (b)

Figure-1: (a) The Top View of the Antenna in the Simulator. (b) The Bottom View of the Antenna in the Simulator.

Table 2. The measurements of the antenna

parameter	*mm*
W1	68
W2	2
H1	83
H2	24
H3	20
R	28
h (Thickness)	1.6

Antenna simulation has also been performed using the CST software. This antenna has three layers: ground, patch, and substrate. FR4 material substrate of 1.6 mm was used, as it is easily available and economical. A partial ground plane antenna has been opted for; that is, the ground does not completely cover the substrate for optimization purposes of the antenna. The final dimensions of the antenna are given in Table 2 and Figure 1. The intention of this design is due to the rapid increase in demand for low-cost wideband antennas for various applications in communications. Thus, this design will be effective, low-cost, and easy to fabricate with extremely high-quality results.

3. Results

The main performance characteristics of the circular microstrip antenna, inclusive of return loss, efficiency, gain, and impedance matching, are shown in the results from the CST simulation, confirming the suitability of the device in mobile communication.

Figure 2 presents the analysis of S11 of the antenna with simulated results between 0 and 7 GHz. From this, the antenna shows it can provide the bandwidth to cover several mobile applications.

Precisely, the antenna achieves -40.11 dB at 1.89 GHz and -30.93 dB at 4.95 GHz, operating from 1.15 GHz up to 6.5 GHz with a return loss less than -10 dB.

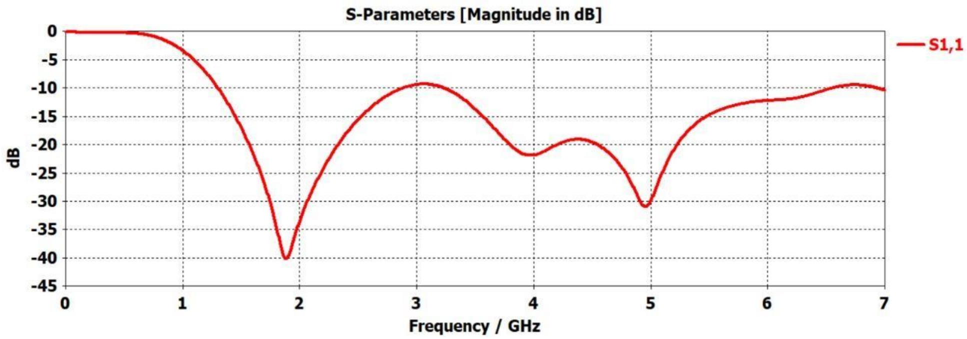


Figure-2: S11-parameters

Figure 3 shows that the VSWR of the antenna remains below 1.5, which indicates an acceptable impedance matching. In addition, the reflection coefficient (Z11) as depicted in Figure 4 highlighted a performance of 62 ohms, indicating that the major portion of the input power is successfully radiated.

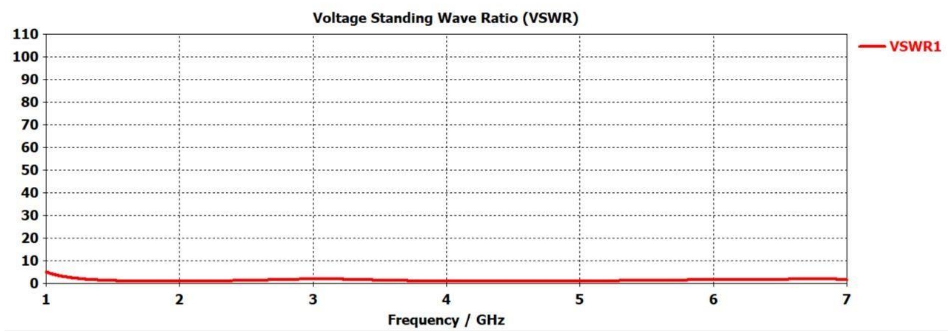


Figure-3: VSWR

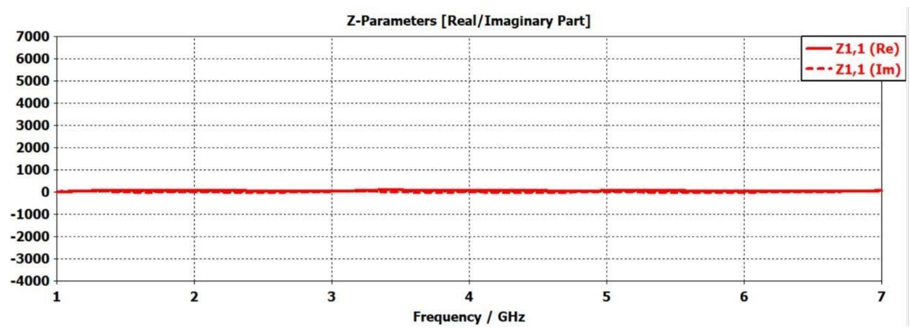
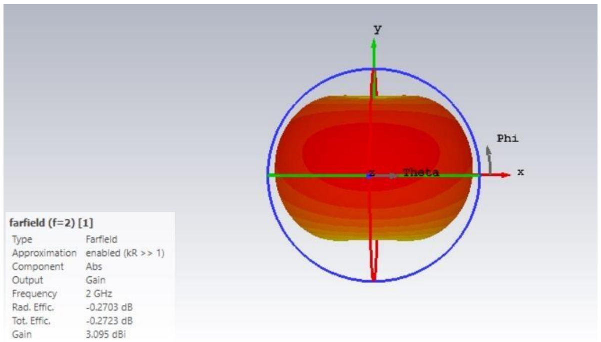
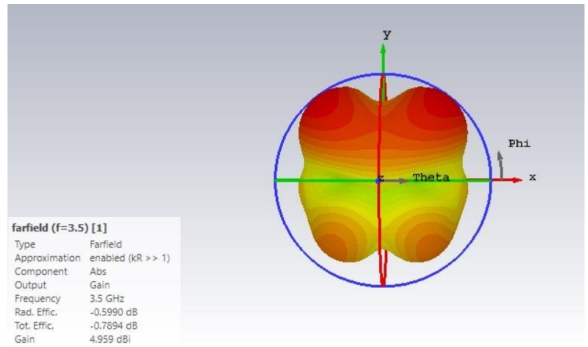


Figure-4: Z11 Parameter

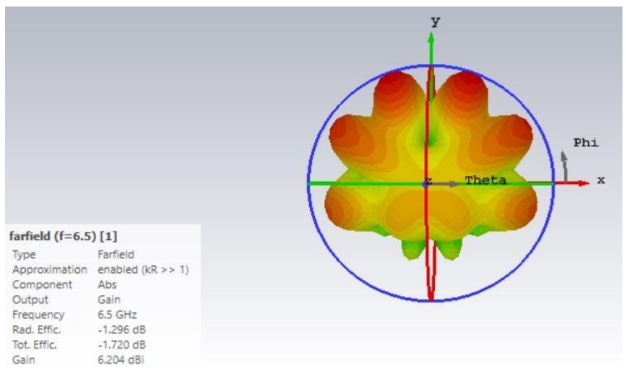
The antenna in Figure 5 has a gain of 3.095 dB, 4.959 dB, and 6.204 dB at 2 GHz, 3.5 GHz, and 6 GHz, respectively. This gain is within the standard range of microstrip patch antennas, between 3 dBi and 5 dBi. Such a value of gain guarantees reliable connectivity across various standards of communication and efficient data transmission between mobile devices.



(a)



(b)



(c)

Figure-5: (a) The Gain at 2 GHz. (b) The Gain at 3.5 GHz. (c) The Gain at 6 GHz.

Figure 6 shows that the radiation efficiency stays between 80% and 90% over frequencies from 1.15 to 6.5 GHz. That is a good deal, since dependable communication can be achieved by antennas operating at efficiency rates higher than 75%.

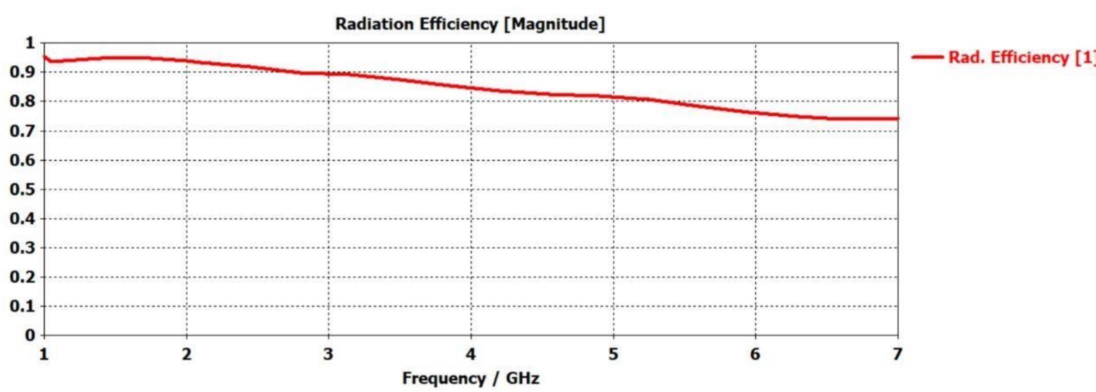


Figure-6: Radiation Efficiency

4. Discussion

In this range of radiation efficiency between 80% and 90%, most of the input power is being radiated hence saving the power losses and ensuring efficient coverage. It is optimum in mobile applications to achieve such a wide frequency range with an efficiency of more than 75% since this ensures constant and reliable communication at low power consumption.

The gains at 2 GHz, 3.5 GHz, and 6 GHz are 3.095 dB, 4.959 dB, and 6.204 dB, respectively-a gain range which agrees with the expected antenna gain range for microstrip patch antennas. It is claimed that these gains will provide enough signal power for a range of communication standards-from 5G high-speed data transfer up to conventional mobile telephony.

Besides, the Voltage Standing Wave Ratio being below 1.5 depicts excellent impedance matching in the frequency of operation. Because of the low VSWR, the magnitude of the reflection of power will be very minimal, hence increasing the overall antenna efficiency. Probably the antenna will radiate most of the input power efficiently because of the reflection coefficient Z11 which is 62 ohms close to the ideal impedance of 50 ohms.

Ultimately, performance metrics of this antenna-including large operational bandwidth, excellent efficiency, sufficient gain, and acceptable impedance matching-make it a feasible option to be integrated into modern mobile communication systems. In that respect, the design meets the requirements for support of various communication standards while preserving necessary performance for reliable data transfer and high-quality signal integrity.

Conclusions

Based on the work presented here, we have designed a wideband circular microstrip antenna suitable for 2G, 3G, 5G, and 4G in different mobile communication purposes. Hence, an operating frequency from 1.15 GHz to 6.5 GHz allows the proposed antenna to serve almost all the communication bands that state-of-the-art mobile terminals require with a maximum bandwidth of 5.35 GHz.

Measurements of performance confirm that the antenna works at a return loss less than -10 dB for efficient transmission and reception. The radiation efficiency is within the range of 80% to 90%, which means it has the capability to radiate most of the input power with very little loss. The maximum gain of 6.204 dB is at different frequencies, hence explaining that this antenna will be able to maintain its good connectivity within a wide range of spectrums in frequency during communication protocols. A reflection coefficient Z11 of 62 ohms, close to the ideal impedance of 50 ohms and with less than a VSWR of 1.5, ensures excellent impedance matching, critical for power transfer.

These results, taken together, reassure that the developed antenna can indeed meet the ever-increasing demand for high performance from a tiny package which supports multiple generations of mobile communication. The invention will meet the growing demand for reliable data transfer and high-quality signals, which is significant in the fast-emerging field of mobile communications.

Further integration techniques and design optimization of the antenna will be done under future studies with regards to optimum performance in practical realization.

References

[1] S. A. Shandal, Y. S. Mezaal, M. F. Mosleh, and M. A. Kadim, "Miniaturized wideband microstrip antenna for recent wireless applications," *Adv. Electromagn.*, vol. 7, no. 5, pp. 7–13, 2018, doi: 10.7716/aem.v7i5.806.

[2] M. Aboud Kadhim, M. F. Mosleh, and S. A. Shandal, "Wideband Square Sierpinski Fractal Microstrip Patch Antenna for Various Wireless Applications," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 518, no. 4, 2019, doi: 10.1088/1757-899X/518/4/042001.

[3] N. M. Awad and M. K. Abdelazeez, "Multislot microstrip antenna for ultra-wide band applications," *J. King Saud Univ. - Eng. Sci.*, vol. 30, no. 1, pp. 38–45, 2018, doi: 10.1016/j.jksues.2015.12.003.

[4] A. A. Hamzah and H. Bayomi, *Text steganography with high embedding capacity using arabic calligraphy*, vol. 1073. 2020. doi: 10.1007/978-3-030-33582-3_13.

[5] B. Chauhan, S. Vijay, and S. C. Gupta, "Millimeter-Wave Mobile Communications Microstrip Antenna for 5G - A Future Antenna," *Int. J. Comput. Appl.*, vol. 99, no. 19, pp. 15–18, 2014, doi: 10.5120/17481-8303.

[6] W. An, Y. Li, H. Fu, J. Ma, W. Chen, and B. Feng, "Low-Profile and Wideband Microstrip Antenna with Stable Gain for 5G Wireless Applications," *IEEE Antennas Wirel. Propag. Lett.*, vol. 17, no. 4, pp. 621–624, 2018, doi: 10.1109/LAWP.2018.2806369.

[7] S. Sun *et al.*, "Investigation of Prediction Accuracy, Sensitivity, and Parameter Stability of Large-Scale Propagation Path Loss Models for 5G Wireless Communications," *IEEE Trans. Veh. Technol.*, vol. 65, no. 5, pp. 2843–2860, 2016, doi: 10.1109/TVT.2016.2543139.

[8] Y. La Elo, F. Y. Zulkifli, and E. T. Rahardjo, "Design of wideband microstrip antenna with parasitic element for 4G/LTE application," *QiR 2017 - 2017 15th Int. Conf. Qual. Res. Int. Symp. Electr. Comput. Eng.*, vol. 2017-December, pp. 110–113, 2017, doi: 10.1109/QIR.2017.8168463.

[9] Z. D. Zaharis *et al.*, "Exponential Log-Periodic Antenna Design Using Improved Particle Swarm Optimization with Velocity Mutation," *IEEE Trans. Magn.*, vol. 53, no. 6, pp. 1–4, 2017, doi: 10.1109/TMAG.2017.2660061.

[10] N. Ojaroudi Parchin, H. Jahanbakhsh Basherlou, and R. A. Abd-Alhameed, "Design of Multi-Mode Antenna Array for Use in Next-Generation Mobile Handsets," *Sensors (Basel).*, vol. 20, no. 9, 2020, doi: 10.3390/s20092447.

[11] D. M. Pozar, "Microstrip Antennas," *Proc. IEEE*, vol. 80, no. 1, pp. 79–91, 1992, doi: 10.1109/5.119568.

[12] N. W. Septiani *et al.*, "No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title," *J. Sisfokom (Sistem Inf. dan Komputer)*, vol. 2, no. 2, pp. 39–43, 2017, [Online]. Available: http://ansitea.blogspot.com

[13] R. A. SMITH, "Antennas. John D. Kraus. New York: McGraw-Hill, 1950. 553 pp. $8.00,"

Science, vol. 113, no. 2927. pp. 131–131, 1951. doi: 10.1126/science.113.2927.131.
[14] C. A. Balanis, "[ENG_C.A.Balanis]_Antenna.Theory.Analysis.and.Design_2ed_(Wiley_1997).pdf." p. 249, 1997.
[15] T. Addepalli and V. R. Anitha, "A very compact and closely spaced circular shaped UWB MIMO antenna with improved isolation," *AEU - Int. J. Electron. Commun.*, vol. 114, p. 153016, 2020, doi: 10.1016/j.aeue.2019.153016.