

TEXTILE MICROSTRIP ANTENNA ON NYLON SUBSTRATE WITH ENHANCED BANDWIDTH FOR 5G AND WBAN APPLICATIONS

Vanvisa CHUTCHAVONG[†] Wanchalerm CHANWATTANAPONG[†] Chawalit RAKLUEA^{‡,*}

Norakamon WONGSIN[‡] Thinnawat JANGJING[‡] Paitoon RAKLUEA[‡]

Nipont TANGTHONG[‡] Maleeya TANGJITJETSADA[□]

[†]School of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand

[‡]Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Pathum Thani 12110, Thailand

[□] Faculty of Engineering and Architecture, Rajamangala University of Technology Suvarnabhumi,

Nonthaburi 11000, Thailand

E-mail: [†]{vanvisa.ch, 62601025}@kmitl.ac.th, [‡]{chawalit, norakamon, thinnawat_j, paitoon_r}@rmutt.ac.th,
[‡]nipont.t@en.rmutt.ac.th [□]maleeya.t@rmutsb.ac.th

Abstract The textile antenna for 5G communication presented in this article is designed using circular conductors with triangular grooves and teardrop-shaped holes on the conductor sheet. The proposed antenna is fed by a microstrip line, while impedance matching is achieved through a trapezoidal ground plane. CST Microwave Studio was used to analyze the antenna. A prototype was fabricated on a nylon fabric substrate measuring 80×70 mm², with a relative dielectric constant of 2.2042 and a thickness of 0.537 mm. The proposed antenna operates across an impedance bandwidth of 2.25–7.00 GHz. It exhibits an average gain of approximately 2.35 dBi, with an omnidirectional radiation pattern in the X–Z plane and a bidirectional pattern in the Y–Z plane.

Keyword Textile antenna, 5G Communication, Nylon fabric substrate

1. INTRODUCTION

Antennas are fundamental components of wireless communication. They transmit and receive electromagnetic waves through the air. Currently, many different types of antennas are used, depending on their application and adaptability. However, the majority are fabricated of metal because of its strong signal propagation qualities. However, their shortcomings include being hefty, stiff, and inflexible, making them unsuitable for wearable electronic devices. Textile antennas have been developed because they are lightweight, flexible, bendable, and easily attachable to other materials [1]. They are compatible with Wireless Body Area Networks (WBANs), which are gaining popularity globally and influencing daily activities. As a result, research has been conducted on the design and development of textile antennas for various wireless applications, including WLAN communication

[2]–[3] and ISM communication [4]. Currently, 5G wireless technology provides advantages such as of higher data rates, lower latency, and wider bandwidth [5]. Much research has been conducted to develop antennas for 5G communications, particularly in the sub-6GHz band, which has been used in many applications due to its balance between coverage and capacity. In the past, there has been research on textile antennas for various 5G communication applications. Such as textile antennas for millimeter wave communication [6]; multi-band textile antennas that can be used in various applications, including high-frequency 5G communication [7]; antenna with a denim substrate that can operate in the 5G frequency range of 3.02 GHz–4.5 GHz [8]; textile antennas with a biodegradable substrate operating in the 3.25 GHz–3.8 GHz frequency range [9]; and star-shaped textile antennas operating in the 3.43 GHz–3.56 GHz frequency range [10]. The

*Corresponding author

aforementioned examples demonstrate that there has been a significant amount of development of textile antennas for 5G frequencies; however, the majority of them are built to support frequencies in the 3 GHz - 4 GHz range or are specifically developed for narrow band, multi-frequencies.

In this paper, a wideband 5G communication textile antenna is designed using nylon, which has strong, resilient, and flexible properties [11]. It is widely employed in a variety of industries, including the manufacture of garments, ropes, socks, sports equipment, and even machine parts. The proposed antenna is constructed with a circular conductor as a propagating component, which is upgraded to obtain a wide frequency range by drilling a teardrop shape and a triangle groove on the conducting sheet. A microstrip line is used to feed the signal, which is impedance matched to a trapezoidal ground plane. The antenna characteristics are examined using CST Microwave Studio software.

2. ANTENNA DESIGN

This section describes the design and geometry of a textile antenna for 5G communication in the 2.6 GHz - 5.9 GHz frequency spectrum, which use a nylon fabric substrate. The parameters of substrate were measured using a Vector Network Analyzer model E8363B, which obtained a substrate thickness (h) of 0.537 mm, a relative dielectric constant for a polycarbonate substrate (ϵ_r) of 2.2042, a conductor material thickness (tk) of 0.068, and a dielectric loss tangent ($\tan \delta$) of 0.00892. The input signal was a 42.72 Ω matched microstrip line.

Fig.1 shows the geometry of propose antenna. The development sequence of a textile antenna for 5G communication can be described as follows. First, a circular propagation region is designed to obtain wide bandwidth [12], and matching is accomplished by placing a ground plane behind the microstrip line. Next, the enhancement of the propagation region to achieve the antenna's intended operating frequency range. A teardrop-shaped hole is drilled inside the circular conductor, and a triangular hole is drilled on the same conductor. The last improved signal matching by

eliminating the ground on both sides, giving it the appearance of a trapezoid.

After designing the antenna components, CST Microwave Studio simulates their operation, and the size of each component is adjusted to achieve the best response. The optimal propagation and ground plane parameters are shown in Table 1.

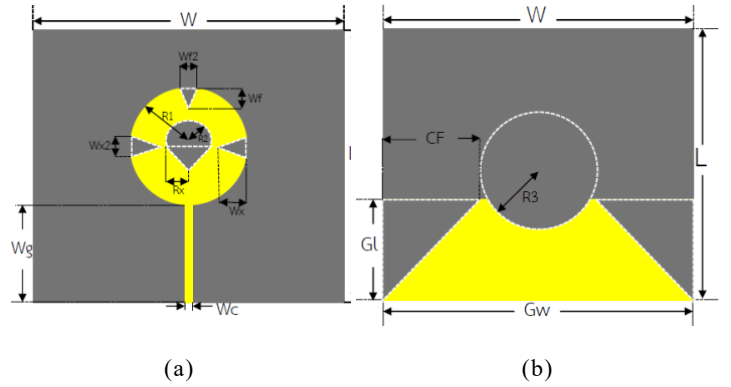


Fig.1. Geometry of the proposed antenna (a) front and (b) back

Table 1. The optimize parameters of proposed antenna

Parameter	W	L	h	tk	Wg
Values(mm)	7	8	0.537	0.068	20.5
Parameter	Wt	R1	R2	Rx	Gw
Values(mm)	2	10.5	4	4	80
Parameter	Gl	R3	Wx	Wf	CF
Values(mm)	26	11.5	5.4	4.2	2.6

Fig. 2 depicts the simulation results for the planned antenna using the optimal parameters. It can be seen that the antenna has a reflection coefficient of less than -10 dB throughout the 2.4 GHz to 6.3 GHz band. That is, the suggested antenna has a functioning frequency range that covers the 5G communication frequency band.

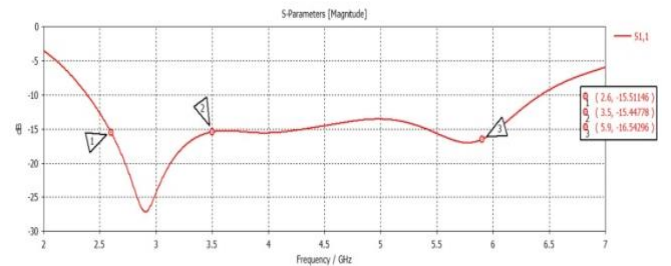


Fig.2. Simulated S_{11} result of the proposed antenna with the optimal parameters.

3. RESULTS AND DISCUSSION

The optimal antenna parameters were established based on the design. This was used to produce a prototype antenna, as shown in Fig. 3. The antenna's characteristics were evaluated using an Agilent PNA Network Analyzer Model 8720c.

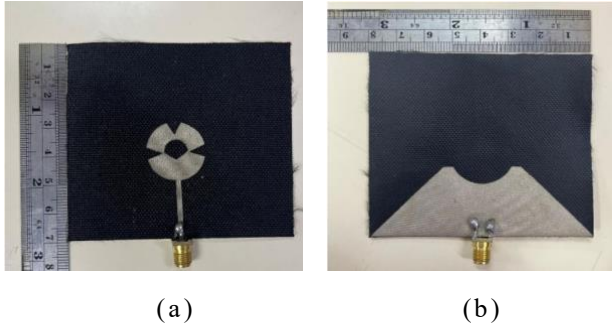


Fig.3. The prototype of proposed antenna (a) front and (b) back

The parameters were measured, and discussed are as follow.

3.1. REFLECTION COEFFICIENT ($|S_{11}|$)

A comparison of simulated and measured reflection coefficient ($|S_{11}|$) data is displayed in Fig. 4. The results are consistent. The simulated reflection coefficients have a frequency response in the range of 2.4 GHz - 6.3GHz, while the measured reflection coefficients have a frequency response in the range of 2.25 GHz – 7 GHz. It observed that the actual antenna provides a slightly wider operating bandwidth than the design, which could be attributed to the antenna fabrication.

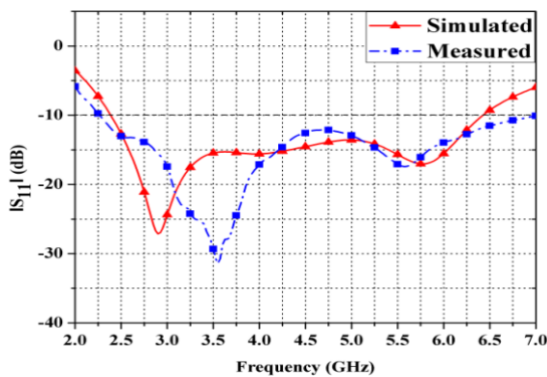


Fig.4. The simulated and measured results of the reflection coefficient of the proposed antenna

3.2. RADIATION PATTERN FORMATTING

This section presents the results of the radiation pattern examinations in three frequency bands, such as 2.6 GHz, 3.5 GHz, and 5.9 GHz. Co-polarization and cross-polarization studies were carried out in each frequency range.

Fig. 5 – Fig.7 show the corresponding radiation patterns of the measured and simulated results. In the X-Z plane, the antenna is omnidirectional across all three frequencies. Furthermore, the Y-Z plane displays a bidirectional pattern at all three frequencies, with the highest radiation pattern occurring at 0° and 180° at 2.6 GHz, while the peak radiation pattern shifts as frequency increases. That is, at 3.5 GHz, the peak radiation pattern is at 195° and 345° , whereas at 5.9 GHz, it is at 210° and 330° . Furthermore, if the frequency increases, the cross polarization also becomes larger.

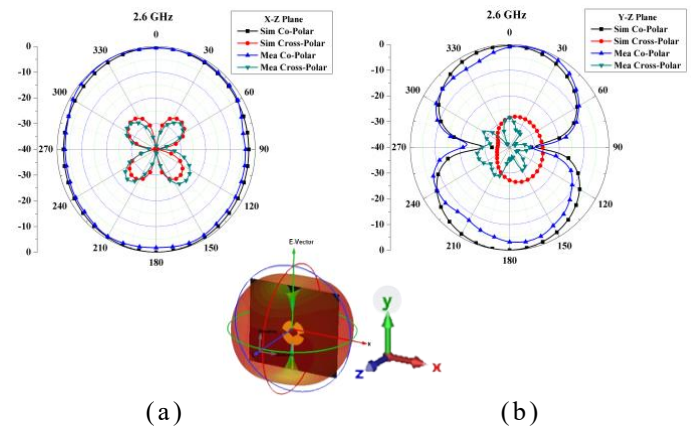


Fig.5. The radiation pattern at 2.6 GHz in (a) X-Z plane and (b) Y-Z plane

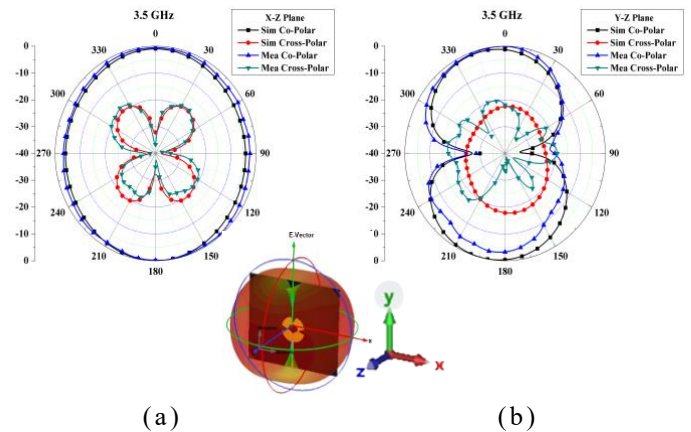


Fig.6. The radiation pattern at 3.5 GHz in (a) X-Z plane and (b) Y-Z plane

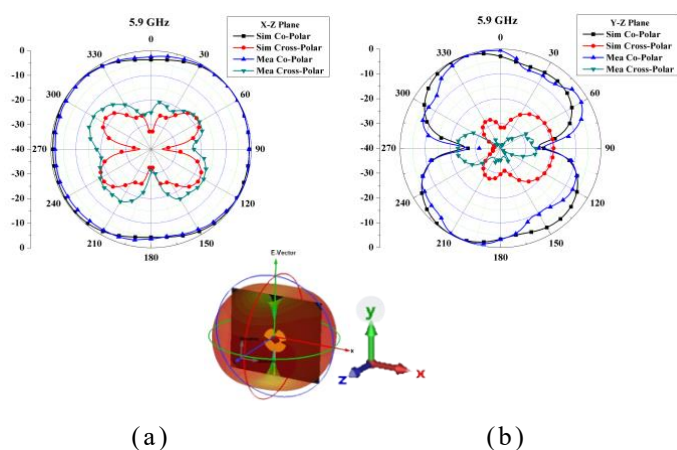


Fig.7. The radiation pattern at 5.9 GHz in (a) X-Z plane and (b) Y-Z plane

3.3. GAIN

Fig. 8 consider the antenna gains in the 5G frequency range from 2.6 GHz to 5.9 GHz. The antenna gain measurement results are compatible with the simulation results. The actual antenna gain is around 0.5 dBi less than the simulation results. The suggested antenna has an average gain of 2.35 dBi.

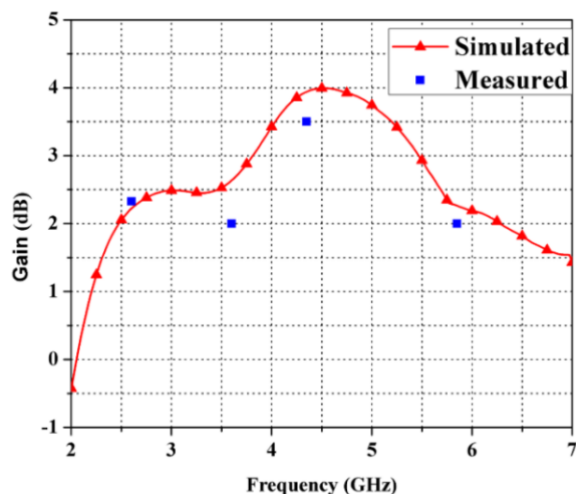


Fig.8. Simulated and measured gains of the proposed antenna.

4. CONCLUSION

This paper presented a nylon-substrate antenna with a circular radiating conductor. The introduction of teardrop-shaped holes and triangular grooves on the conducting plate enhanced its impedance bandwidth, while

impedance matching was achieved using a trapezoidal ground plane. The antenna, fed by a microstrip transmission line, measures 80×70 mm² and maintains an impedance match better than -10 dB across the entire 2.25–7.00 GHz frequency band. It demonstrates omnidirectional radiation patterns in the X–Z plane, bidirectional patterns in the Y–Z plane, and an average gain of 2.35 dBi. These results confirm that the proposed textile antenna is well-suited for 5G communication applications and has potential for broader use in other wireless communication systems. Moreover, the nylon textile substrate makes the antenna compact, lightweight, flexible, and easily integrated into fabrics, supporting its suitability for Wireless Body Area Networks (WBANs).

References

- [1] Rafiq M, Imran A, Rasheed A, Zaman S uz. A review on the manufacturing techniques for textile based antennas. *Journal of Engineered Fibers and Fabrics*. 2024;19. doi:10.1177/15589250241226585
- [2] W. Chaihongsa and C. Phongcharoenpanich, "Performance of textile antenna using two layers of strip line and round-off circular path," *2015 IEEE Conference on Antenna Measurements & Applications (CAMA)*, Chiang Mai, Thailand, 2015, pp. 1-3, doi: 10.1109/CAMA.2015.7428167.
- [3] S. Sankaralingam and B. Gupta, "A textile antenna for WLAN applications," *2009 International Conference on Emerging Trends in Electronic and Photonic Devices & Systems*, Varanasi, India, 2009, pp. 391-394, doi: 10.1109/ELECTRO.2009.5441084.
- [4] S. K. Mishra, S. Shukla and V. Mishra, "Design of dual band textile antenna for ISM bands using fractal geometry," *2015 International Conference on Signal Processing and Communication (ICSC)*, Noida, India, 2015, pp. 161-165, doi: 10.1109/ICSPCom.2015.7150640.
- [5] Z. S. Attarbashi, A. E. Altaieb, A. H. Mohd Aman, A. Hassan Abdalla Hashim and S. Eker, "A Review of 5G Technology: Architecture and Challenges," *2022 IEEE 8th International Conference on Computing, Engineering and Design (ICCED)*, Sukabumi, Indonesia, 2022, pp. 1-4, doi: 10.1109/ICCED56140.2022.10010607.
- [6] Wissem, E. M., Sfar, I., Osman, L., & Ribero, J.-M. (2021). A Textile EBG-Based Antenna for Future 5G-IoT Millimeter-Wave Applications. *Electronics*, 10(2), 154. <https://doi.org/10.3390/electronics10020154>

- [7] H. Bhaldar, S. K. Gowre, M. M. Mathpati, M. S. Ustad, A. A. Jadhav and P. Mankal, "Multiband Microstrip Textile Antenna for WiFi/WiMAX/5G Communication," *2021 IEEE 4th International Conference on Computing, Power and Communication Technologies (GUCON)*, Kuala Lumpur, Malaysia, 2021, pp. 1-10, doi: 10.1109/GUCON50781.2021.9573799.
- [8] M. S. Singh, S. Roy, S. Ghosh and A. Sarkhel, "Wearable textile based MIMO antenna for 5G Application," *2021 IEEE Indian Conference on Antennas and Propagation (InCAP)*, Jaipur, Rajasthan, India, India, 2021, pp. 159-162, doi: 10.1109/InCAP52216.2021.9726301.
- [9] O. Thompson, S. Alkaraki, Q. H. Abbasi, S. F. Jilani and D. A. Evans, "A Bio-degradable Textile-Based Graphene Antenna for the 5G Smart Wearables," *2022 16th European Conference on Antennas and Propagation (EuCAP)*, Madrid, Spain, 2022, pp. 1-4, doi: 10.23919/EuCAP53622.2022.9769657.
- [10] G. Martins, P. Pinho and C. Loss, "Textile Star-Shaped Supershaped Patch Antenna for 5G Applications," *2022 16th European Conference on Antennas and Propagation (EuCAP)*, Madrid, Spain, 2022, pp. 1-4, doi: 10.23919/EuCAP53622.2022.9769069.
- [11] Vagholkar, Parth. (2016). Nylon (Chemistry, Properties and Uses). *International Journal of Scientific Research*. 5. 349-351.
- [12] P. Cao, Y. Huang and J. Zhang, "A UWB monopole antenna for GPR application," *2012 6th European Conference on Antennas and Propagation (EUCAP)*, Prague, Czech Republic, 2012, pp. 2837-2840, doi: 10.1109/EuCAP.2012.6206443.