# Design of Multiband MIMO Antenna for 5G Applications

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This study introduces a new antenna design that combines a bow-tie slot antenna with four Linear Tapered Slot Antennas (LTSAs) on a single aperture, supporting multiple frequency bands for 5G applications. The design uses a coplanar waveguide transmission line to feed the bow-tie slot antenna, and a MIMO configuration is applied to the LTSAs in the mm-wave band. The antenna shows a bi-directional radiation pattern in the microwave range with a maximum gain of 6.70 dB, and an end-fire radiation pattern for each LTSA in the mm-wave band. The design effectively covers several microwave bands and the n258 band in the mm-wave range, covering both lower and higher 5G frequency bands. With its compact and efficient structure, this antenna is a promising solution for multi-band applications, making it suitable for various wireless communication systems. Its versatility and performance make it a strong candidate for future 5G technologies.

**Keyword:** Linear Tapered Slot Antennas; Bow-Tie Slot Antennas; Coplanar waveguide; Bi-directional; MIMO Antenna.

**Introduction:**

The growing demand for high-speed, low-latency, and broadband communication systems in technologies like 5G, IoT, and next-generation radar has increased the need for bow-tie slot antennas. Their flat design and compatibility with printed circuit boards (PCBs) make them ideal for compact and integrated systems. These antennas are also less affected by fabrication errors and can be made from various materials, including flexible substrates for wearable and biomedical applications. In military and defense fields, bow-tie slot antennas are commonly used in ground-penetrating radar (GPR) and stealth communication, due to their ultra-wideband (UWB) capabilities.

Various bow-tie antenna designs have been explored in the literature. Compared to traditional microstrip antennas, the designs presented in [1], [2], and [3] offer a broader frequency range and exhibit either uni-directional or bi-directional radiation patterns. To further improve bandwidth, two small metal conductors are incorporated within the bow-tie slot antenna, as shown in [4]. The effect of rounding the corners on antenna performance is discussed in [5], where it is found that rounded corners improve return loss. For dual- or triple-band operation, tuning stubs are introduced in [6], [7], while [8], and [9] explore methods to enhance spectral efficiency.

MIMO antennas play a key role in extending the range and capacity of wireless communication, MIMO antennas play a crucial role. By receiving synchronized inputs and transmitting multiple data streams, MIMO technology improves bandwidth, spectral efficiency, and signal reliability. The integration of sub-6 GHz and millimeter-wave (mm-wave) technologies has become essential in the developing 5G communication systems. As the miniaturization of communication terminals and base stations grows, there is a rising demand for compact dual-band antennas that operate in both sub-6 GHz and mm-wave frequencies [10], [11]. To meet the increasing demand for high data rates and efficient spectrum use, MIMO technology has been incorporated into mm-wave antenna systems. Traditionally, dual-band functionality is achieved by using separate antennas for different frequencies, which simplifies MIMO implementation. However, such MIMO antenna configurations tend to occupy a lot of space. To address this, researchers have explored structure reuse techniques for creating dual-band antennas [12].

The proposed antenna aims to design and develop a multiband MIMO antenna for 5G applications, improving performance metrics such as gain and bandwidth while reducing interference. The novelty lies in its innovative design, offering a unique solution that provides a compact and efficient antenna, enabling high-speed data transmission and reliable communication, thereby bringing new insights and advancements to the field of antenna design and 5G technology. To take advantage of both the sub-6 GHz microwave band and the mm-wave band of 5G, our proposed design integrates a bow-tie slot antenna for the microwave range and four longitudinally tapered slot antennas (LTSAs) for the mm-wave range. The LTSAs are placed along the substrate's edges, radiating in an end-fire pattern to form a four-element MIMO array. Since the bow-tie slot antenna has bi-directional radiation, covering both the upper and lower hemispheres, the side space is effectively utilized for embedding the LTSAs. This design provides coverage for both the sub-6 GHz and mm-wave bands, enhancing the system's performance for 5G applications.

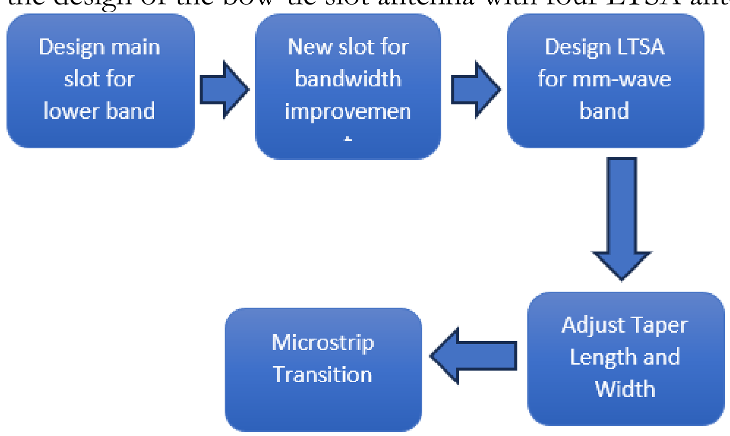
The rest of the paper is organized as follows: Section II describes the structure of the proposed antenna, while Section III presents a parametric study. Section IV analyzes the impact of supporting surfaces beneath the antenna. Section V covers fabrication and radiation field measurements, and Section VI concludes the paper.

**Methodology:**

The bow-tie slot antenna is fabricated on a Rogers RO4003C substrate with a thickness of 0.2 mm ($\varepsilon r = 3.38$ and $\tan \delta = 0.0027$). The dimensions of the proposed antenna are 120 mm × 60 mm. It consists of two right-angle triangle slots with rounded corners, as shown in Figure 1. These right-angle triangles are fed by a coplanar waveguide transmission line connected via an SMA (Sub Miniature Version A) connector. An additional slot is placed between the arms of the right-angle triangles, helping the antenna to resonate at another frequency, covering a band around 5.6 GHz. The arm of the right-angle triangle slot antenna that is perpendicular to the feeding line has a length (L) of 20.8 mm. The width of all the slots is the same which is uniform and denoted by W, which is 5 mm.

The antenna is fed by a coplanar waveguide which is connected through an SMA conductor with a characteristic impedance of 50 **Ω**. A quarter wavelength transformer is placed between the antenna and the CPW feed line. The length of the longer side of the quarter-wavelength transformer is 29.5 mm and the shorter side is 19.1 mm. The width of the quarter-wavelength transformer is 2 mm with a spacing of 4 mm between the slots. Figure. 1 shows the model of the bow-tie slot antenna which is fed by the CPW feed line.

The total length(U) of the LTSA slot antenna is 17 mm and its width (d) is 3mm. The LTSA is fed by a microstrip feed line and has a circular transition in both the microstrip and slotted LTSA. The geometry of a single-element LTSA is shown in Figure. 2. The bow-tie antenna is excited by a CPW feed line while the LTSA antennas are excited through the microstrip feed line. Table 1 lists all the values used for both antennas. The following is the flow diagram for the design of the bow-tie slot antenna with four LTSA antennas.




Flow of study diagram

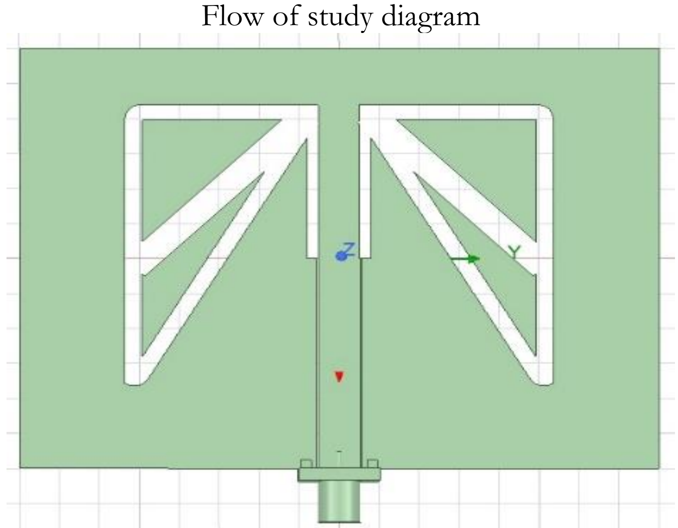


**Figure. 1.** Bow-Tie Slot Antenna with Co-Planar Waveguide Fed Line

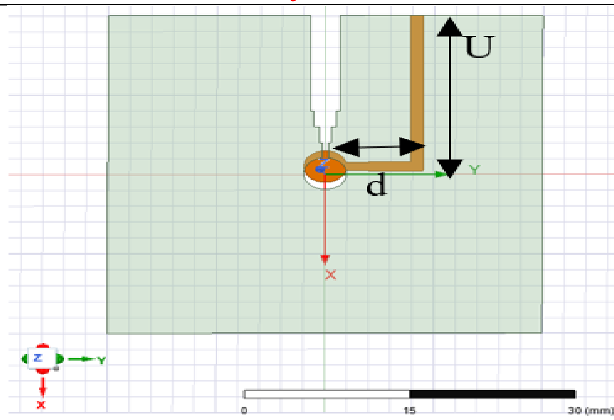



**Figure. 2.** Single Element of Linear Tapered Slot Antenna

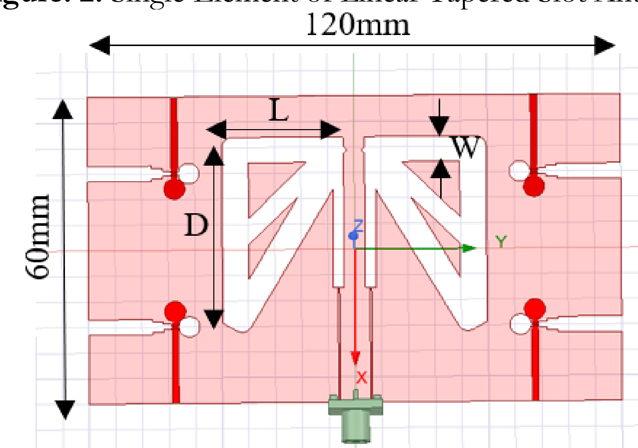



**Figure.3.**Final Model of Bow-Tie Antenna with 4 Linear Tapered Slot Antennas

**Table 1.** Parametric List of Bow-Tie Slot Antenna with 4 LTSA Antennas

| Variables | Value(mm) |
|---|---|
| L | 20.8 |
| W | 5 |
| D | 34.37 |
| U | 17 |
| D | 3 |
| R | 2 |

**Table 2.** Comparison Between Antennas Presented in Introduction

| Ref. | Size | Max Gain | Bandwidth | MIMO Capability |
|---|---|---|---|---|
| 1. | 52mm × 46mm | 6.5 dB | 15.84 GHz | No |
| 2. | 20.5mm × 25mm | 4.39 dB | 2.85 GHz | No |
| 4. | 30mm × 26mm | -- | 12.9 GHz | No |
| 5. | 70mm × 80mm | 8.5 dB | 12 GHz | No |
| This work | 60mm × 120mm | 6.7 dB | 8.5 GHz | Yes |

**Results:**

The combined model of the proposed antenna which includes the bow-tie antenna and four LTSAs, is shown in Figure. 3. Figure. 4 presents the S-parameters of the proposed antenna. From the results, it is evident that the bow-tie antenna resonates at 2.45 GHz and covers the frequency range from 3.4 GHz to 5.8 GHz. The resonance points are influenced by changes in the arm length of the bow-tie antenna. As the arm length increases, the resonance shifts toward the lower frequency. The primary radiators in the proposed antenna are the horizontal and diagonal arms. The first and third resonances are affected by the lengths of these arms. The quarter-wavelength transformer, placed in the middle resonance region, is installed between the bow-tie antenna and CPW feed line. The performance of the slot bow-tie antenna also depends on the width (W) of the antenna. If the width increases, the resonance shifts to higher frequencies, and vice versa. The result demonstrates that the antenna successfully covers several standard bands in the microwave range.

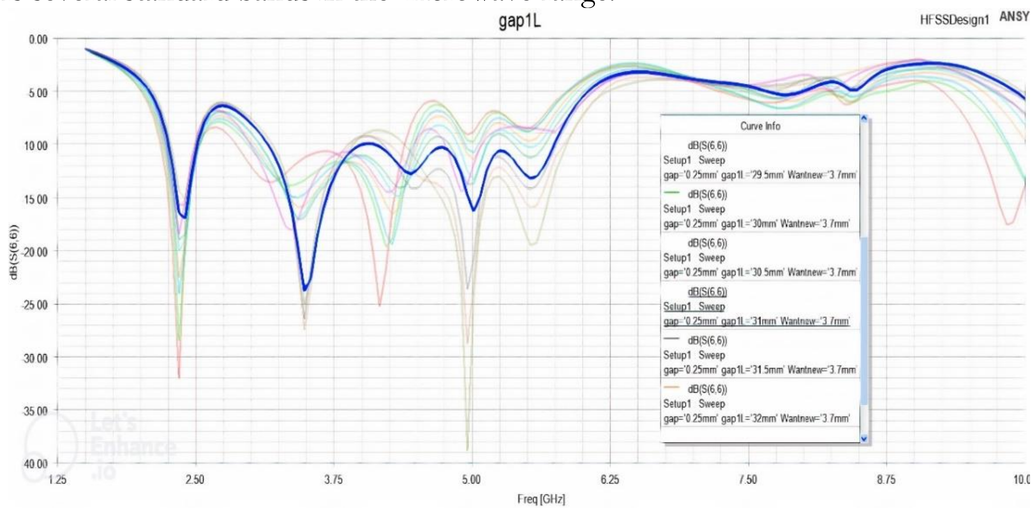



**Figure. 4. S-Parameter of Bow-tie slot antenna**

**Discussion:**

Figure 5 shows the S-parameters of the same structure when operating in the mm-wave band. The bow-tie antenna connected to port 1 is not excited as it operates within the microwave bands. The four LTSAs are excited through individual ports. Four microstrip ports are used to excite the antennas. Figure 5 displays the simulated S-parameter for port 2. Where it can be observed that the LTSA covers the frequency range between 25 GHz and 27.5 GHz which corresponds to the n258 band. This band is designated for high-capacity, short-range communications, commonly used in dense urban environments and fixed wireless access (FWA) applications.

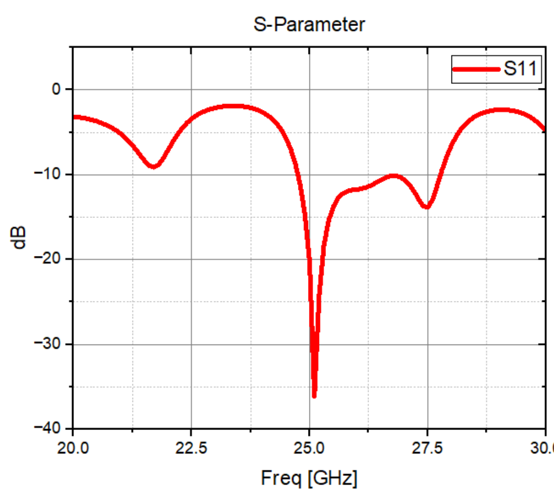



**Figure. 5.** Improved S-parameter at milli-meter wave band

Figure. 6 shows the main plot of the system at ϴ = 90 degrees and φ = 0 degrees, illustrating the end-fire radiation pattern of the single LTSA antenna system in the YZ plane. The radiation pattern is symmetrical, radiating equally in both upper and lower hemispheres. When the two right LTSA antennas are excited, the end-fire radiation pattern appears on the right side. Similarly, when the two left LTSA antennas are excited, the end-fire pattern is directed in the opposite directions.

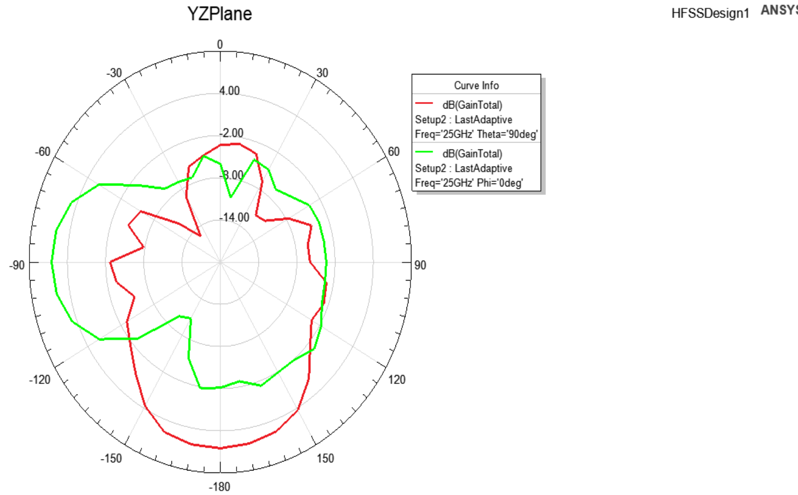



**Figure. 6.** Radiation Pattern at 25 GHz

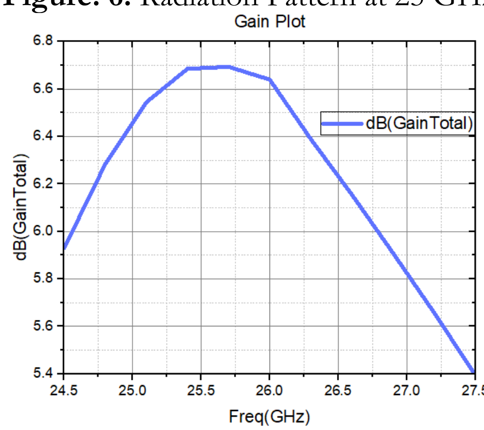



**Figure. 7.** Gain vs Frequency at milli meter wave band

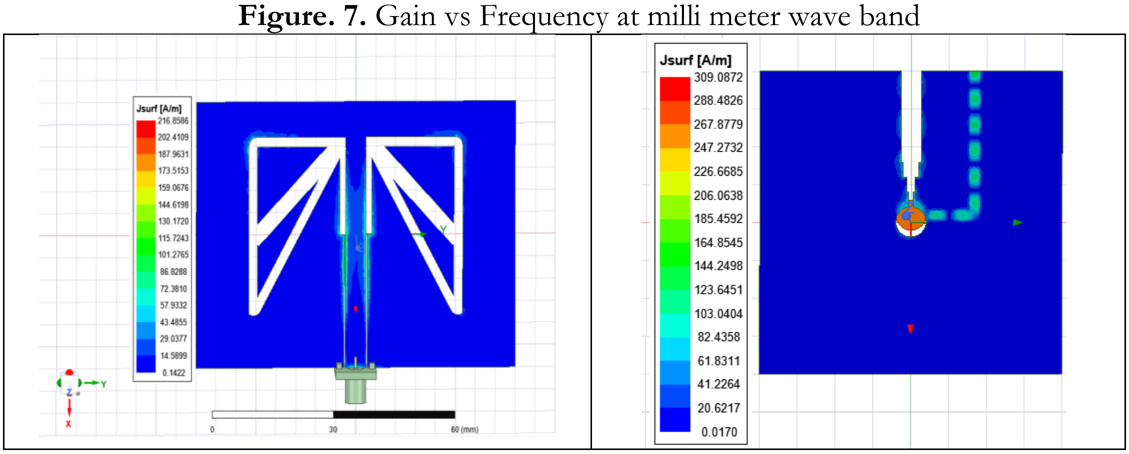



**Figure.8.** (a) Current Distribution of bow-tie slot Antenna (b) Current Distribution of Linear Tapered Slot Antenna

Figure. 7 shows the gain plot in the millimeter-wave band, with a maximum gain of 6.7 dB at 26 GHz. Figure. 8 presents the current distribution of the bow-tie slot antenna and a single MIMO antenna at 25 GHz. Both figures indicate that the antennas are properly excited. Figure. 9 shows the isolation between MIMO ports, demonstrating that the isolation is better than -22dB across the entire frequency range. Figure. 10 displays the Envelope Correlation Coefficient (ECC) of the MIMO array with the graph showing an ECC value better than 0.01. This indicates that the antenna is well-suited for MIMO applications.

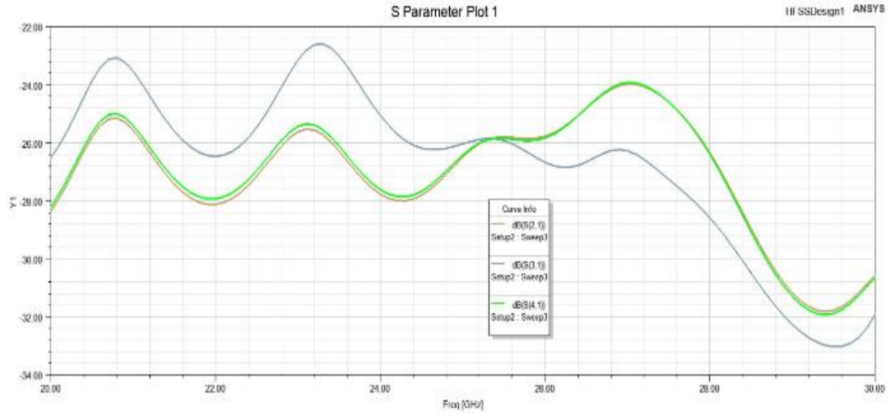



**Figure. 9.** Isolation between MIMO ports

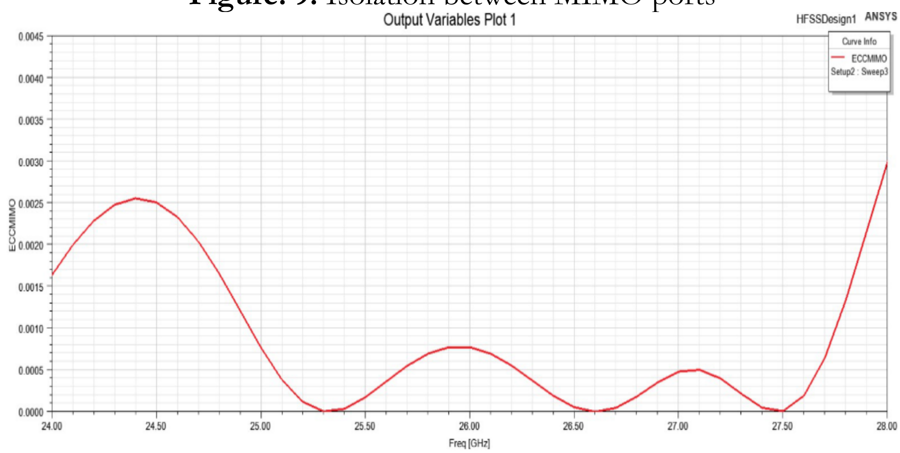



**Figure. 10.** Envelope Correlation Coefficient of MIMO Array

**Conclusion:**

The proposed antennas, which include four LTSA antennas and bow-tie slot antennas operate effectively in both the microwave and millimeter-wave ranges covering several standard frequency bands. In the microwave range the antenna radiates bidirectionally, while in the millimeter-waves range, it radiates in the end-fire direction, with LTSA covering a quadrant in the azimuth plane. The maximum gain of 6.70 dB is achieved in the microwave range. The LTSA antennas are arranged in a MIMO configuration, enhancing the reliability and spectral efficiency of the system. The antennas cover the sub-6GHz range, including the n79 and n96 bands, the Wi-Fi band in the microwave range, and the n258 band in the millimeter-wave range.

**References:**

[1] R. M. J. Yeo, Y. Lee, "Wideband slot antennas for wireless communications," *IEEE Proc. Microw. Antennas Propag*, vol. 151, no. 4, pp. 351–355, 2004, doi: https://doi.org/10.1049/ip-map:20040627.

[2] E. A. Soliman, S. Brebels, P. Delmotte, G. A. E. Vandenbosch, and E. Beyne, "Bow-tie slot antenna fed by CPW," *Electron. Lett.*, vol. 35, no. 7, pp. 514–515, Apr. 1999, doi: 10.1049/EL:19990399.

[3] C. S. Abdelnasser Eldek, Atef Elsherbeni, "Characteristics of Bow-Tie Slot Antenna with Tapered Tuning Stubs for Wideband Operation," *Prog. Electromagn. Res.*, vol. 49, pp. 53–69, 2004, doi: 10.2528/PIER04021301.

[4] L. P. Yan-Lin Chen, Cheng-Li Ruan, "A Novel Ultra-Wideband Bow-Tie Slot Antenna in Wireless Communication Systems," *Prog. Electromagn. Res. Lett.*, vol. 1, pp. 101–108, 2008, doi: 10.2528/PIERL07112302.

[5] S. W. Qu and C. L. Ruan, "Effect of round corners on bowtie antennas," *Prog.*

*Electromagn. Res.*, vol. 57, pp. 179–195, 2006, doi: 10.2528/PIER05072103.

[6] Lin-Chuan Tsai, "A Dual-Band Bow-Tie-Shaped CPW-Fed Slot Antenna for WLAN Applications," *Prog. Electromagn. Res. Lett.*, vol. 47, pp. 167–171, 2014, doi: 10.2528/PIERC14011002.

[7] J. H. Yoon and Y. C. Lee, "Modified bow-tie slot antenna for the 2.4/5.2/5.8 GHz WLAN bands with a rectangular tuning stub," *Microw. Opt. Technol. Lett.*, vol. 53, no. 1, pp. 126–130, Jan. 2011, doi: 10.1002/MOP.25647.

[8] S. Soltani, P. Lotfi, and R. D. Murch, "A Port and Frequency Reconfigurable MIMO Slot Antenna for WLAN Applications," *IEEE Trans. Antennas Propag.*, vol. 64, no. 4, pp. 1209–1217, Apr. 2016, doi: 10.1109/TAP.2016.2522470.

[9] K. Ding, C. Gao, D. Qu, and Q. Yin, "Compact Broadband MIMO Antenna with Parasitic Strip," *IEEE Antennas Wirel. Propag. Lett.*, vol. 16, pp. 2349–2353, Jun. 2017, doi: 10.1109/LAWP.2017.2718035.

[10] N. K. Niamat Hussain, Anees Abbas, Sang-Myeong Park, Seong Gyoon Park, "A Compact Tri-Band Antenna Based on Inverted-L Stubs for Smart Devices," *Comput. Mater. Contin.*, vol. 70, no. 2, pp. 3321–3331, 2022, doi: https://doi.org/10.32604/cmc.2022.020688.

[11] H. T. Chattha, M. K. Ishfaq, B. A. Khawaja, A. Sharif, and N. Sheriff, "Compact Multiport MIMO Antenna System for 5G IoT and Cellular Handheld Applications," *IEEE Antennas Wirel. Propag. Lett.*, vol. 20, no. 11, pp. 2136–2140, Nov. 2021, doi: 10.1109/LAWP.2021.3059419.

[12] Y. Yao, X. Cheng, C. Wang, J. Yu, and X. Chen, "Wideband Circularly Polarized Antipodal Curvedly Tapered Slot Antenna Array for 5G Applications," *IEEE J. Sel. Areas Commun.*, vol. 35, no. 7, pp. 1539–1549, Jul. 2017, doi: 10.1109/JSAC.2017.2699101.