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REGULAR ARTICLE

Design and Development of Four Element Multiband MIMO Microstrip Antenna for LTE/5G Applications

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A multiband Multiple Input Multiple Output (MIMO) antenna with four elements has been designed for LTE and 5G applications. The antenna consists of four planar elements with inset feeding, ensuring compactness and efficiency. It is constructed on an FR-4 substrate with a dielectric constant of 4.4, a thickness of 1.6 mm, and overall dimensions of 150 × 150 × 1.6 mm³. The design supports multiple frequency bands, operating at 2.4 GHz, 3.7 GHz, and 4.5 GHz, with |S11| ≤ – 10 dB. These bands correspond to LTE band 40 (2300-2400 MHz), LTE band 43 (3600-3800 MHz), and the 5G mid-band (4500-4900 MHz), ensuring broad coverage for modern wireless communication systems. The antenna exhibits excellent pattern diversity, providing robust signal reception and transmission with minimal interference. It achieves low Envelope Correlation Coefficient (ECC), ensuring efficient MIMO performance with minimal signal degradation. Additionally, the design maintains good gain, directivity, and over 33 dB isolation between ports, reducing cross-channel interference and improving overall system performance. The results confirm the antenna's high efficiency and suitability for LTE/5G applications. Moreover, the structure is simple to fabricate, making it a practical choice for modern wireless communication systems that demand high performance, compactness, and cost-effective manufacturing.

Keywords: LTE bands, Multiband LTE bands, Multiband, MIMO.

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1. INTRODUCTION

High-speed wireless communication demands efficient antenna designs, driving the adoption of MIMO technology [1]. LTE, operating between 400 MHz and 4 GHz, incorporates MIMO to enhance network efficiency and data rates [2]. Multiband MIMO antennas are crucial for modern wireless applications, ensuring compactness and high performance [3]. MIMO utilizes multiple input ports at both the transmitter and receiver to improve throughput and minimize transmission errors [4]. However, achieving high isolation between radiating elements while maintaining a low Envelope Correlation Coefficient (ECC) remains a significant challenge [5]. This study presents a four-element multiband MIMO antenna designed for LTE, 5G, and Wi-Fi applications [6]. The proposed antenna features inset feeding and symmetrically arranged planar elements, ensuring high isolation and omnidirectional radiation [7]. It covers key frequency bands for LTE, 5G, and Wi-Fi, ensuring versatile functionality [8]. The substrate and ground have the same dimensions to simplify fabrication and minimize alignment errors [12]. Performance metrics include a return loss of – 10 dB and isolation of – 15 dB. Key contributions of this work include the design of a compact four-element multiband MIMO antenna, high isolation and low ECC for improved signal quality, simple fabrication with a shared substrate and ground, and optimized return loss and isolation performance, ensuring reliable wireless communication across multiple frequency bands.

2. ANTENNA CONFIGURATION

The proposed 4-element multiband MIMO antenna design is illustrated in Figure 1. The antenna consists of four rectangular planar radiating elements with the following dimensions: patch length (P_L) = 29.4 mm and patch width (P_W) = 38 mm. The element is driven using an inset feeding technique, where the feed width (F_W) is 3 mm, the feeding gap (F_G) is 1.5 mm, and the feeding length (F_L) is 24.8 mm. These antennas are placed on material of substrate have FR4 relative permittivity of 4.4, a loss tangent of 0.02, and density of 1.6 mm. The substrate dimensions are given as S_L (length) = 150 mm, S_W (width) = 150 mm, and S_H = (height) = 1.6 mm. The ground plane has dimensions of 150 mm × 150 mm. To achieve better impedance matching the antennas are optimized. And they are symmetrically placed to

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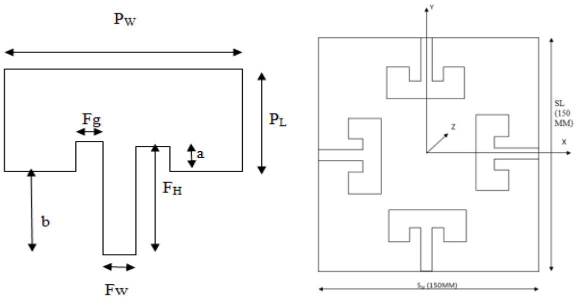
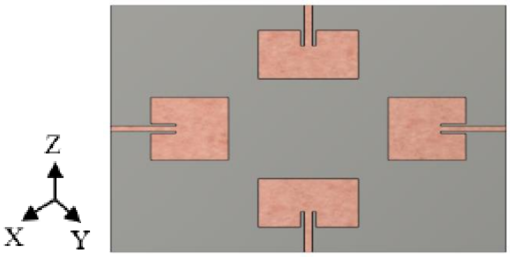
obtain a bandwidth with |S11| ≤ – 10 dB, ensuring good isolation and a low Envelope Correlation Coefficient (ECC). The optimized parameters for the 4-port antenna system are presented in Table1.

Table 1 – Parameters of Antenna

Antenna Parameters	Measurements (mm)
S_L	150
S_W	150
S_H	1.6
P_L	29.4
P_W	38
F_W	3
F_ g	1.5
F_L	24.8
a	9.5
b	15.3
F_H	24.8



(a)



(b)

Fig. 1 – Proposed antenna Geometry: (a) patch view with dimensions (b) four port view

3. DESIGNIG METHODOLOGY AND STUDY

The proposed antenna design followed a step-by-step approach, starting with a single-element analysis, progressing to a two-element configuration, and culminating in a four-element design. Performance insights guided optimization, fabrication, and final testing.

3.1 Single Antenna

A single-element antenna (60 × 60 × 1.6 mm³) was initially studied, with a patch size of $L = 29.4$ mm and $W = 38$ mm.

Simulations guided the development of a four-element design, achieving a – 22 dB reflection coefficient (Figure. 2). The 3D radiation pattern (Figure. 3) showed strong efficiency and gain. The antenna exhibited |*S*11| ≤ – 10 dB at 2.4 GHz, covering LTE Band 40 (2300–2400 MHz). It provided a 2.98 dB gain and a 58.7 MHz bandwidth in LTE/4G Band 40, making it ideal for LTE and Wi-Fi applications.

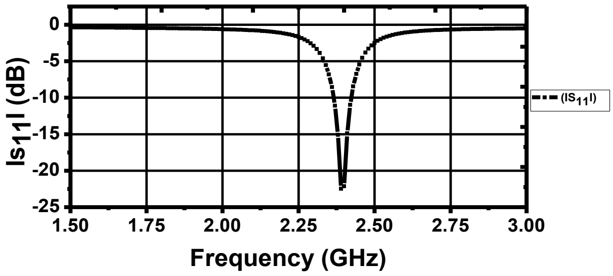


Fig. 2 – *S*-Parameter: Reflection coefficient

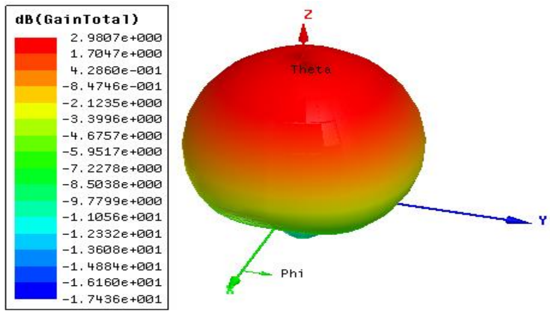


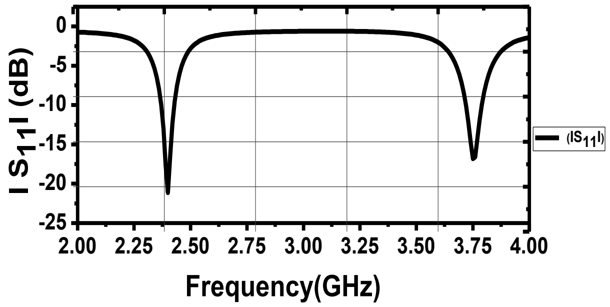
Fig. 3 – Radiation of 3D at 2.4 GHz

3.2 Two Antennas

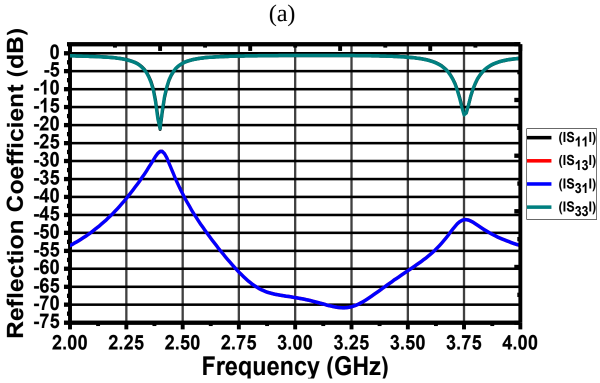
The two-element MIMO microstrip antenna (150 × 60 × 1.6 mm³) features symmetrically placed patches, 60.6 mm apart. It operates at 2.4 GHz and 3.7 GHz with bandwidths of 62.3 MHz and 75.4 MHz, respectively, covering LTE Bands 40 and 43. The single-element variant achieves 2.9 dB gain and 58 MHz bandwidth.

Fig. 4- Two radiators Geometry with distance 60.6mm

The geometry of the two radiators, spaced 60.6 mm apart, is illustrated in Figure 4. The isolation and reflection coefficient in Figure 5 show bandwidth improvement with |*S*11| ≤ – 10 dB, covering two LTE bands. Isolation ranges from 27 dB to 46 dB, achieved using two patches. The 3D radiation pattern (Figure 6) confirms peak radiation along the X-axis. With ECC of 0.0001 at 2.4 GHz and 3.7 GHz, minimal mutual coupling ensures efficient performance. Simulated parameters are listed in Table 2.

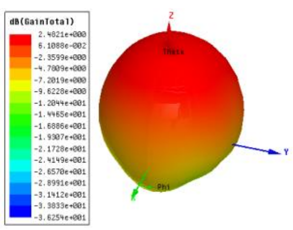


(a)

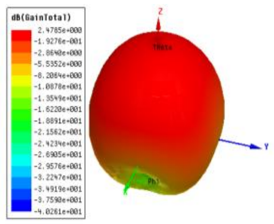


(b)

Fig. 5 – *S*-Parameters: (a) Reflection coefficient, (b) Isolation



(a)



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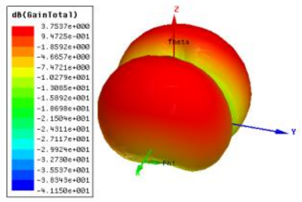


(c)

Fig. 6 – Radiation pattern 3D at 2.4 GHz: (a) Port-1, (b) Port-2 (c) Port 1 and 2

Table 2 – Simulated Measurement parameters at port1 and 2

Antenna Parameters	Frequency 2.4GHZ	3.7GHz
Covered bandwidth (GHZ)	2.3619-2.3696	3.7211-3.7603
Isolation (dB)	– 27.32	– 46.3058
Return loss (dB)	– 20.14	– 16.6
Gain (dB)	2.47	3.75
ECC	< 0.0001	< 0.0001

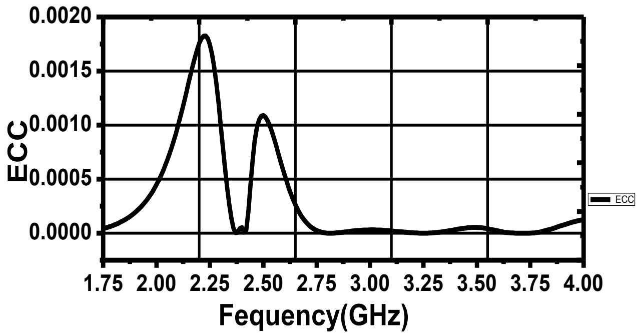


Fig. 7 – ECC at port 1, 2

If operating on both ports, the peak power is observed only on the X-axis. Instead of 4 ports [10], Dual bands with excellent isolation and enhanced ECC were achieved using only two ports, as illustrated in Figure 7. The envelope correlation coefficient at ports 1 and 2 is less than 0.0001

3.3 Four Antennas

The four-element antenna operates at 2.4, 3.7, and 4.5 GHz, ensuring optimal LTE and 5G performance. It offers – 25.05 to – 33.18 dB isolation, with *S*-parameters shown in Figure 8.

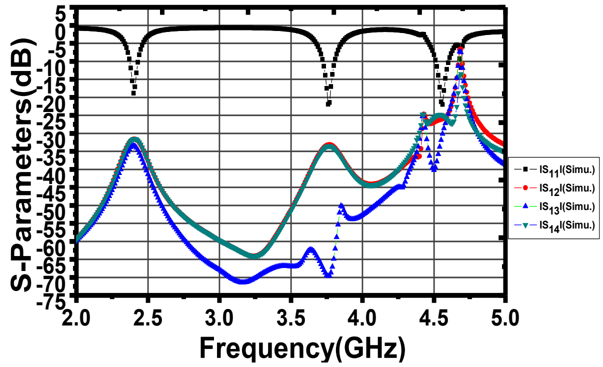


Fig. 8 – *S*-Parameter of four antennas system

Table 3 – Simulated values of port 1, 2, 3 and 4

Antenna Measurements	Operating Frequency 2.4GHz	3.7GHz	4.5GHz
Covered bandwidth (GHZ)	2.3763-2.4349	3.723-3.8101	4.5173-4.6044
Isolation (dB)	– 31.72	– 33.18	– 21.92
Return loss(dB)	– 18.12	– 21.92	– 21.96
Gain (dB)	1.74	3.61	6.3
ECC	< 0.001	< 0.001	< 0.001

The simulated values of the multi-band antenna are in Table 3. ECC, derived from S-parameters, is crucial for MIMO performance, as lower ECC enhances diversity gain by reducing port correlation.

$$\rho = \frac{|S_{11}*S_{12}+S_{21}*S_{22}|^2}{(1-(|S_{11}|^2+|S_{22}|^2))(1-(|S_{22}|^2+|S_{12}|^2))} \quad (1)$$

$$G_{app} = 10 * \sqrt{1-|\rho|^2} \quad (2)$$

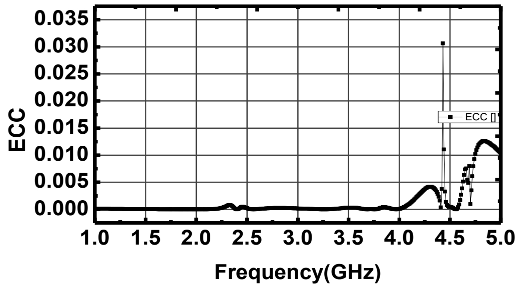
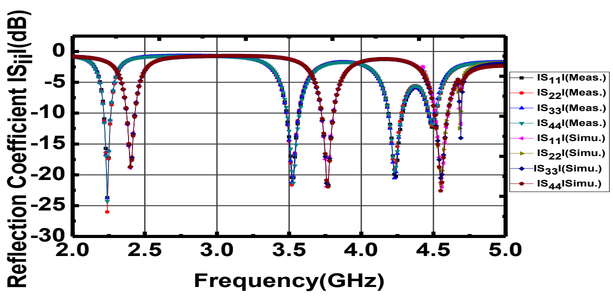


Fig. 9 – ECC at port1, 2, 3 and 4

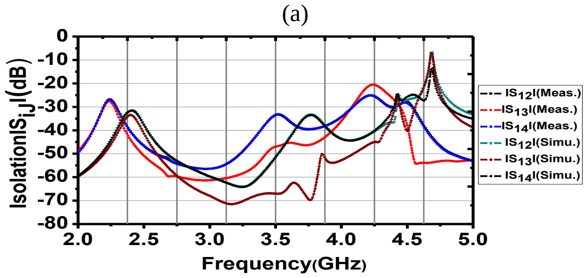
The correlation coefficient and diversity gain are inversely related, as shown in Equation (1 & 2). Lower correlation enhances diversity performance. The presented multi-band antenna exhibits excellent MIMO characteristics, with ρ between 0 and 0.001 and diversity gain below 9.999 within the operating band, as shown in Figures 9 and 12. This makes it highly suitable for MIMO applications in LTE, 5G, and Wi-Fi bands.

4. MEASURED RESULTS AND DISCUSSION

The MIMO system prototype is shown in Figure 11. Simulated and measured S-parameters (Figure 10) show strong correlation at 2.3, 3.5, and 4.3 GHz, covering LTE bands with bandwidths of 58.6 MHz, 87.1 MHz, and 87.1 MHz. Isolation exceeds 21 dB due to optimal element positioning, reducing mutual coupling. ECC (Figure 13) remains below 0.001, and diversity gain (Figure 12) reaches 9.999 dB, ensuring efficient MIMO performance with good port isolation across the operating frequency range.



(a)



(b)

Fig. 10 – *S*-parameters of presented MIMO (a) Reflection coefficient (b) Isolation

(a) (b)

Fig. 11 – Fabricated model of proposed antenna: (a) Front view, (b)Back view

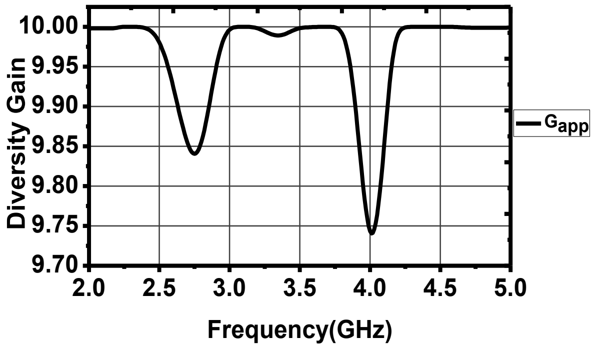


Fig. 12 – The measured diversity gain of proposed MIMO

Figure 12 compares measured and simulated 2D patterns, while Figure 13 shows 3D radiation patterns. At 2.4 GHz, radiation emits in all directions, while at 3.7 GHz, it radiates on four sides.

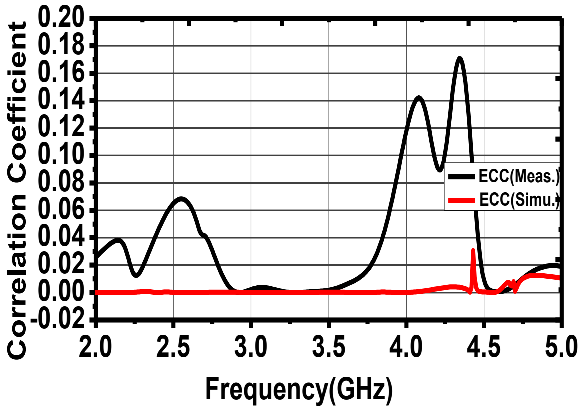
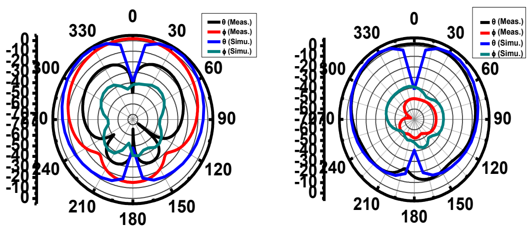
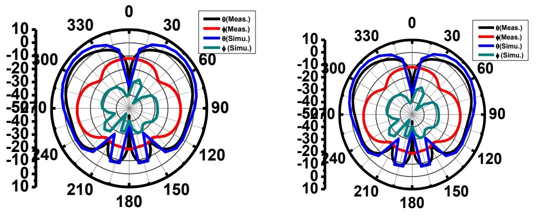


Fig. 13 – Comparison of measured and simulated ECC



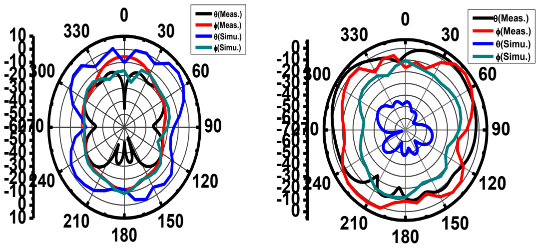
E- plane *H*- Plane

(a)



E- Plane *H*-Plane

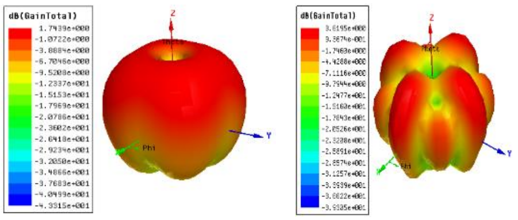
(b)



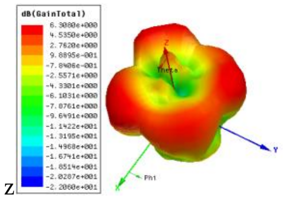
E-Plane *H*-Plane

(c)

Fig. 14 – Radiation pattern at (a) 2.4 GHz, (b) 3.7 GHz (c) 4.5 GHz



(a) (b)



(c)

Fig. 15 – 3D radiation pattern at: (a) 2.4 GHz, (b) 3.7 GHz (c) 3.5 GHz

The comparison of the measured and simulated ECC of the presented MIMO is shown in Figure 13. The correlation between ports is very less. The 3D radiation patterns show that the peak power is more concentrated in the *X*-axis and *X*-axis along with in the *Y*-axis and *Y*-directions. Table 4 and 5 shows the performance estimation of the proposed multi-band MIMO antenna with other existing MIMO antennas based on MIMO characteristics, antenna parameters, and antenna size.

Table 4 – Performance Estimation

Ref.	Size mm³	B.W. (GHz)	Iso. (dB)	Gain (dB)
[11]	70 × 40 × 1.035	40 dB (5.9 GHz-6.3 GHz) 20 dB(4.4 GHz-4.6 GHz)	– 40 – 20	4.046 2.2
[10]	125 × 128 × 1.6	1.8 GHz 2.6 GHz	< – 17 < – 30	3.96 3.22
P.D.	150 × 150 × 1.6	(2.3763-2.4349) 58.6 MHz at 2.4 GHz (3.723-3.8101) 87.1 MHz at 3.7 GHz 4.5173-4.6044 87.1 MHz at 4.5 GHz	< – 31 < – 33 < – 21	1.74 3.61 6.3

B.W. – Bandwidth, Iso. – Isolation

Table 5 – Performance Estimation of MIMO

Ref.	Size mm³	ρ	G_{app} (dB)
[11]	70 × 40 × 1.035	0.003	9.9
[10]	125 × 128 × 1.6	0.04	9.9
P.D.	150 × 150 × 1.6	0.001 (s) 0.01(m) 0.00(s) 0.01(m) 0.001(s) 0.02(m)	9.999 9.999 9.999

5. CONCLUSION

In this research paper, a four-element symmetric antenna for LTE/5G/Wi-Fi applications is developed and studied. A presented multi-band antenna is fabricated and measured by insertion feeding. The measured bandwidth is 58.6 MHz, 87.1 MHz, and 87.1 MHz at 2.3 GHz, 3.5 MHz, and 4.3 MHz respectively permitting to the measured results with > 21.98 dB isolation under working band. As per the simulation, the same band was also achieved at 2.4 GHz, 3.7 GHz, and 3.5 GHz. Therefore, both the simulated and measured values have good agreement. The designed antenna allows easy fabrication and feeding with good MIMO characteristics. The ρ of presented MIMO is < 0.01 and Gapp is nearly 9.99 dB in under working frequency band. The results and functioning of the presented multi-band antenna validate that it should be a suitable contender for LTE/5G/Wi-Fi applications in addition to *S* and *C* bands.

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Проектування та розробка чотириелементної багатодіапазонної мікросмужкової антени MIMO для застосувань LTE/5G

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Для застосувань LTE та 5G розроблено багатодіапазонну антену MIMO (Multiple Input Multiple Output) з чотирма елементами. Антена складається з чотирьох планарних елементів з вбудованим живленням, що забезпечує компактність та ефективність. Вона виготовлена на підкладці FR-4 з діелектричною проникністю 4,4, товщиною 1,6 мм та загальними розмірами 150 × 150 × 1,6 мм³. Конструкція підтримує кілька частотних діапазонів, що працюють на частотах 2,4 ГГц, 3,7 ГГц та 4,5 ГГц, з |S11| ≤ –10 дБ. Ці діапазони відповідають діапазону LTE 40 (2300-2400 МГц), діапазону LTE 43 (3600-3800 МГц) та середньому діапазону 5G (4500-4900 МГц), що забезпечує широке покриття для сучасних систем бездротового зв'язку. Антена демонструє чудове рознесення діаграм спрямованості, забезпечуючи стабільний прийом і передачу сигналу з мінімальними перешкодами. Вона досягає низького коефіцієнта кореляції обвідної (ECC), що забезпечує ефективну роботу MIMO з мінімальним погіршенням сигналу. Крім того, конструкція підтримує хороший коефіцієнт посилення, спрямованість та ізоляцію між портами понад 33 дБ, що зменшує міжканальні перешкоди та покращує загальну продуктивність системи. Результати підтверджують високу ефективність антени та її придатність для застосувань LTE/5G. Крім того, конструкція проста у виготовленні, що робить її практичним вибором для сучасних систем бездротового зв'язку, які вимагають високої продуктивності, компактності та економічно ефективного виробництва.

Ключові слова: Діапазони LTE, Багатодіапазонні діапазони LTE, MIMO.