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Dualband Microstrip Elliptic Patch 1x4 MIMO Antenna Design for 5G System Device

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***Abstract*— This paper presents a dual-band antenna for the 5G system communication device. The Multiple Input Multiple Output (MIMO) antenna can potentially boost the capacity and transmission rates to a new level in a communication system. The MIMO 1x4 elliptic patch is designed at 24 GHz and 27.8 GHz. The performance of this antenna is shown in terms of return loss and gain from the simulated S11 results, a single patch antenna provides -16.364 dB at 24 GHz and -35.44 dB at 27.86 GHz. While for the MIMO 1x4 patch, the simulated S11 of -15.563 dB and -21.889 dB are achieved at both 24 GHz and 27.8 GHz, respectively. It has a gain value of 9.04 dBi at 24 GHz and a gain value of 6.56 dBi at 27.8 GHz. These gains are higher than the gain obtained with a single element. According to the simulation, the proposed antenna achieves the required 5G parameters for the single patch and the MIMO 1x4 patch configuration.**

Keywords— Elliptic Patch, 5G Antenna, Dual band, MIMO Antenna.

I. INTRODUCTION

The growth of telecommunication has drastically forced people to make a new communication system that is faster and better. Converged 5G networking is emerging as an important research area in next-generation access architectures. An improvement that 5G brings is the improvement in wireless technology, this includes a cellular system. The purpose of 5G is to provide the connection to another device through a communication system. 5G applies many new technologies to improve the information transmission rate. One of the most important technologies is MIMO. The advantages of MIMO technology have included higher spectral efficiency, more signal stability, and greater channel capacity. How to improve the isolation of channels and how to control the reflection loss of antennas are all problems that need to be solved [1].

The issue concerning the MIMO antenna systems is the mutual coupling between the constituent element antennas. Since the 3.5 GHz-band (3400–3600 MHz) and 5 GHz-band (4800–5000 MHz) spectra have been identified for 5G mobile communications, developing compact dual-band MIMO antenna systems with high element isolations is of great necessity [2].

The system demands a higher data rate and low latency networks to fulfill the user demands [3]. Critical aspects of 5G research are high bandwidths available to end-user (e.g. 1 Gb/s to mobile devices and 10 Gb/s to fixed premises, residential or Small and Medium Sizes Enterprises(SMEs)), latency (with a target of 1 ms delays), lower energy consumption, and higher security [4].

The mm-wave higher frequency ranges from 24.25 GHz to 27.5 GHz have been considered for 5G cellular networks. Exploring such higher frequencies will allow the usability of large bandwidths and channel capacities. The increase in omnidirectional path loss due to the higher frequencies of mm-wave transmissions can be completely compensated through suitable beamforming and directional transmissions [5].

To achieve precise beam steering, considerably more power amplifiers with lower power output (P_{OUT}) requirements are needed to be integrated into the frontend modules (FEM) for the massive-MIMO type of 5G systems to be implemented [6].

For practical application, a microstrip antenna can be completely printed on a common substrate and assembled within a short period. Because of its advantages such as low fabrication cost, high production efficiency, and high manufacturing accuracy, etc., since its invention, the microstrip antenna (printed on the substrate) is widely used today. However, most of the microstrip antennas are planar structures and cannot be applied in three-dimensional (3D) construction [7].

This paper proposes a dual-band 1x4 MIMO antenna with an elliptic patch. The design works at 24 GHz and 27.8 GHz. The 24.25 GHz - 29.5 GHz and 37 GHz -43.5 GHz ranges are the most promising frequencies for the early development of 5G millimeter-wave systems and it is recommended that at

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least 400 MHz of contiguous spectrum per network be assigned for each frequencies waves [8].

Some company like AT&T and T-Mobile have also decided to try the 24 GHz bands since the auction that is held are bought highly by both of company and received many positive responses for the possibility of the 24 GHz band. As such, it is also attracting interest for the high-capacity wireless communications, it is useful for 5G's future networking integration [9]. The MIMO 1x4 antenna elements are composed of four single-elliptic patch antennas. A simple microstrip feeding line feeds the antenna. The proposed antenna shows the simulated gain is higher than 5 dBi as required.

II. Design of 24 GHz and 27.8 GHz Dual Band antenna

A. *Single Elliptic Patch Antenna*

Fig. 1 shows the geometry of a single element of the antenna. The substrate is fully grounded with a patch size of 8 mm x 3.5 mm. The design used a single elliptic patch antenna for better bandwidth and gain value for the antenna in 5G implementation. The single elliptic patch is used to build a MIMO antenna. The antenna used Rogers RO3210 (lossy) as a dielectric substrate having relative permittivity = 10.8 and a thickness = 0.64 mm. The initial dimension is listed in Table I below.

TABLE I. Antenna Parameter

No	Parameter	Dimension	Value (mm)
1	vr	Elliptic patch vertical radius	3.5
2	ur	Elliptic patch horizontal radius	8
3	ws	Substrate and ground width	25
4	Ls	Substrate and ground length	26.8
5	st	Substrate thickness	0.64
6	pt	Ground and patch thickness	0.035
7	wf	Feedline width	0.6
8	Lf	Feedline length	12.5
9	L1	Inset feed 1 length	2.85
10	W1	Inset feed 1 width	0.5
11	L2	Inset feed 2 length	2.85
12	W2	Inset feed 2 width	0.5
13	us	Elliptic slot horizontal radius	5
14	vs	Elliptic slot vertical radius	1.2

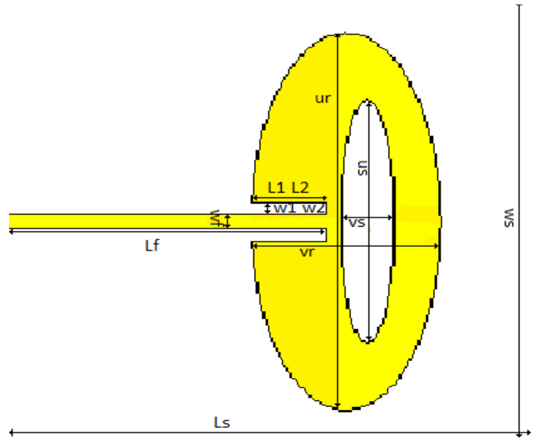

Fig. 1. The geometry of a single elliptic patch antenna.

B. *Design of 1x4 MIMO Elliptic Patch*

The MIMO 1x4 elliptic patch antenna is proposed. The design is composed of four single elliptic patch antennas to meet the expected result as required. They are arranged symmetrically in four pairs of loops. The geometry including critical dimensions of the designed 4-element MIMO antenna system is illustrated in Fig. 2. The distance between each antenna is 10 mm. Four ports were fed by the microstrip feed line. Each elliptic patch size is equal to the previous patch size that it used.

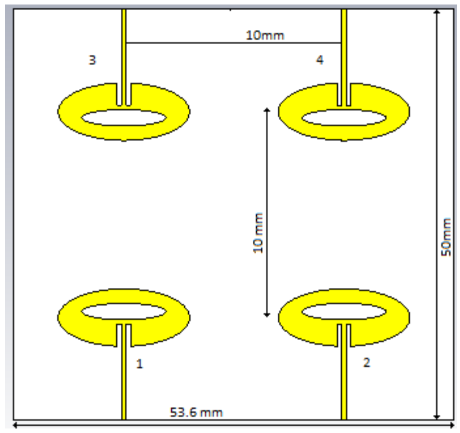

Fig. 2. The geometry of four single elliptic patch antennas.

III. Simulated Result

In this section, the S-parameters and radiation patterns are addressed and discussed from the single to the final form of the MIMO antenna design. CST Microwave Studio software is used in this simulation.

A. *Single Elliptic Patch*

Optimization has been done to the size of the antenna to obtain the desired frequency. The elliptic slot horizontal radius was optimized from 5 mm to 5.4 mm. The characterization was performed every 0.5 mm. Fig. 3 shows the simulated S11 results for each of the characterization. It is known that the optimized radius is obtained for 5.4 mm that close to the desired frequency.

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Fig. 4 shows the simulated S11 of the optimized single element. The simulated S11 are -16.364 dB at 24 GHz and -35.44 dB at 27.8 GHz concerning -10 dB. The bandwidth obtained is 495 MHz and 334 MHz at 24 GHz and at 27.8 GHz, respectively.

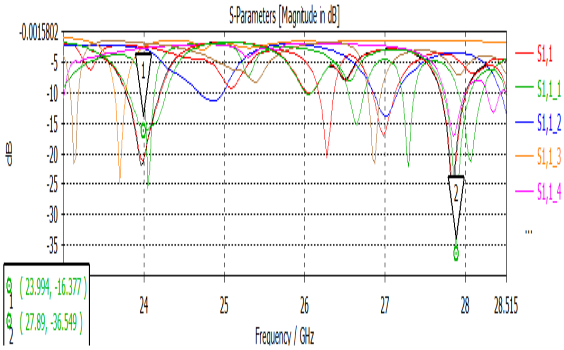

Fig. 3. The simulated S11 characterization on a single elliptic patch.

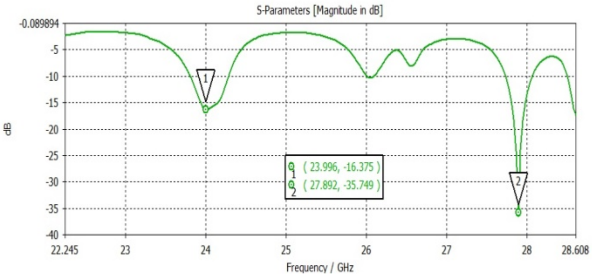

Fig. 4. The simulated S11 of optimized single patch elliptic circular antenna

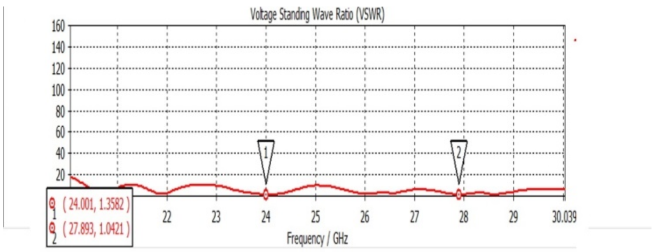

Fig. 5. The simulated VSWR of the optimized single elliptic patch antenna.

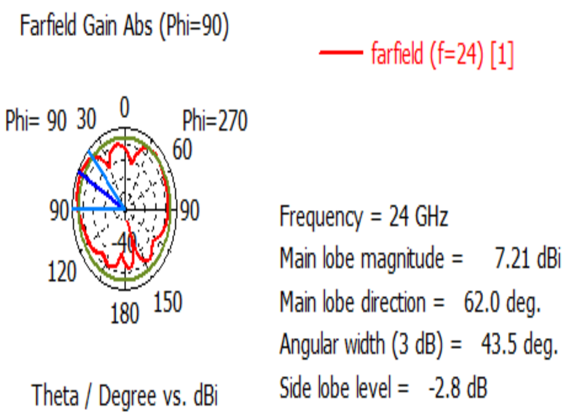

Fig. 6. The simulated radiation pattern of the E and H plane of the single elliptic patch antenna at 24 GHz.

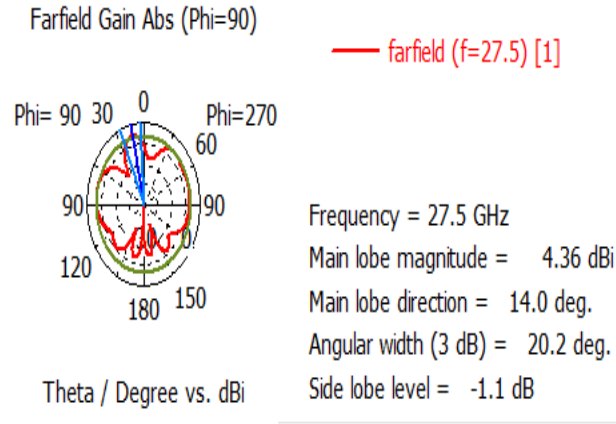

Fig. 7. The simulated radiation pattern of the E and H plane of the single elliptic patch antenna at 27.8 GHz.

Fig. 5 shows the simulated Voltage Standing Wave Ratio (VSWR) of the optimized single element. The simulated VSWR of the 24 GHz resulted in a value of 1.3582 and of the 27.8 GHz resulted in a value of 1.0421. The nearly omnidirectional radiation pattern is achieved with the gain antenna of 7.21 dBi for 24 GHz and 4.36 dBi for 27.8 GHz as shown in Fig. 6 and Fig. 7, respectively.

B. 1x4 MiMO Elliptic Patch

As shown in Fig. 8, the 1x4 MIMO antenna performs sufficient bandwidth to cover both frequencies, 24 GHz and 27.8 GHz. The simulated S11 of -15.563 dB and -21.889 dB are achieved at both 24 GHz and 27.8 GHz Also, the isolation between each port is lower than -30 dB.

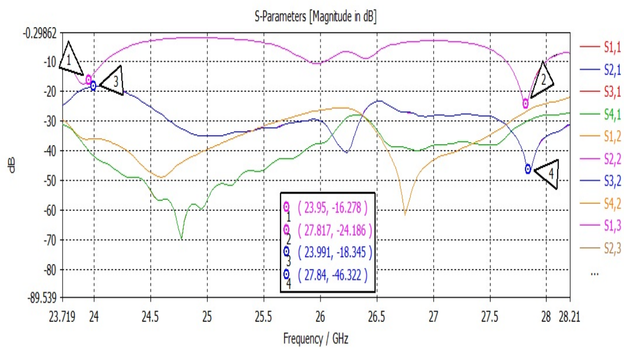

Fig. 8. The simulated S-parameters of the 1x4 MIMO elliptic patch antenna.

The VSWR at 24 GHz is 1.4385 and at 27.8 GHz is 1.1777 as shown in Fig. 9 with a bandwidth value of 328 MHz and 345 MHz. The small bandwidth obtained is due to the MIMO system characteristic used in the antenna design. The radiation pattern of this antenna is nearly omnidirectional which meets the 5G requirements. The gain value resulted at the 24 GHz is 9.04 dBi with a low sidelobe of -3.5 dB. For the 27.8 GHz, the resulted gain value is 6.56 dBi with a low sidelobe of -1.4 dB. Both gain values are shown in Fig. 10 and Fig. 11, respectively. It shows that the MIMO system will potentially boost the system to meet the requirement for 5G's communication device.

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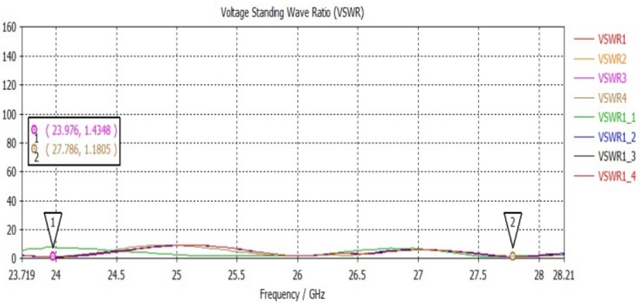

Fig. 9. The simulated VSWR of 1x4 MIMO elliptic patch antenna.

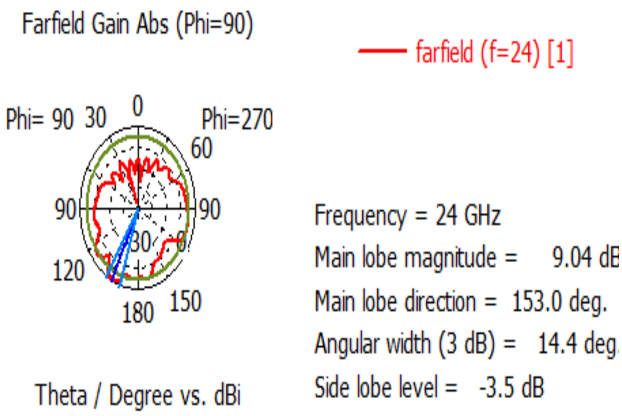

Fig. 10. The simulated radiation pattern of the E and H plane at 24 GHz

TABLE II COMPARISON OF THE PROPOSED ANTENNA WITH THE EXISTING PAPER.

Reference	Freq (GHz)	S11 (dB)	Gain (dBi)
This paper	24 and 27.8	- 15.563 and -21.889	9.04 and 6.56
[10]	30	-33.307	6.6
[11]	3.5 and 26	- 21.417 and - 10.819	9,176 and 7.3
[12]	32.56	<-25	6.13
[13]	60	-29.899	9.66
[14]	28 and 38	< -10	8.4 and 6.1
[15]	28 and 38	Both <-25	12.6 and 13

Table II lists the comparison between the proposed antenna with the existing references. It shows that our designed antenna has an acceptable performance. It has a higher gain compared to the existing ones with the same frequency range (24/27 GHz). MIMO antenna with multi-feed technology is simpler in structure. The dual-band operation is obtained using a simple and well-known technique which is the technique of inserting a slit opening into the radiating element. The proposed antenna system presents a nearly omnidirectional radiation pattern at the two working bands.

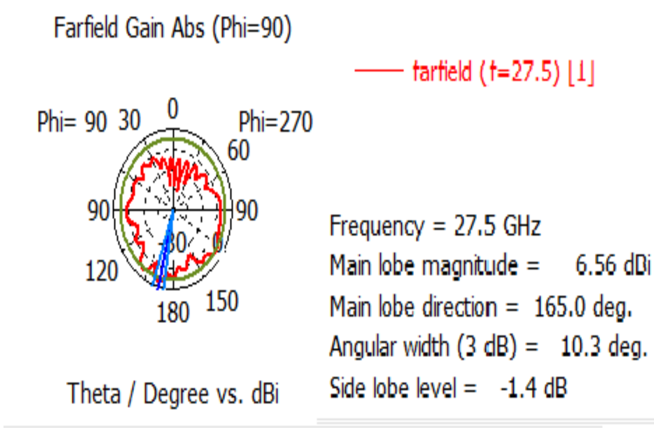

Fig. 11. The simulated radiation pattern of the E and H plane at 27.8 GHz

IV. Conclusion

In this paper, a new 1x4 MIMO elliptic patch antenna has been designed. The S11 of -15.563dB and -21.889 dB are achieved at both 24 GHz and 27.8 GHz. The bandwidth obtained is 331 MHz for 24 GHz and 359 MHz for 27.8 GHz. The radiation pattern is nearly omnidirectional with a gain value of 9.04 dBi with a low sidelobe of -3.5 dB at the 24 GHz and a gain value of 6.56 dBi with a low sidelobe of -1.4 dB at the 27.8 GHz. Our proposed antenna uses four patch elements and four ports. The antenna is designed using Rogers RO3210 (lossy) dielectric substrate having relative permittivity = 10.8 and a thickness of 0.64 mm. This design meets the requirements for the 5G communication systems. The 5G requires the antenna with MIMO capability, and good S11 value (<-10 dB). Most 5G antennas have a gain ≥5dBi.

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