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Design and Performance Evaluation of a 2×1 MIMO Microstrip Antenna Using a Truncated-Corner Rectangular Patch for 2.3–2.4 GHz LTE Applications

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Abstract

Multiple-input multiple-output (MIMO) technology is widely used to improve data throughput, spectral efficiency, and communication reliability in Long-Term Evolution (LTE) wireless systems. Integrating MIMO technology with microstrip antennas offers several advantages, including compact dimensions, low weight, a low-profile structure, and low manufacturing cost. However, conventional microstrip antennas generally exhibit limited bandwidth, relatively low gain, and reduced radiation efficiency; therefore, optimization techniques are required to improve their overall performance. This study presents the design, simulation, fabrication, and performance evaluation of a 2×1 MIMO microstrip antenna operating in the 2.3–2.4 GHz LTE band using a truncated-corner rectangular-patch technique. The antenna was designed using CST Studio Suite 2019 and fabricated on an FR-4 substrate with a relative permittivity of 4.3 and a thickness of 1.6 mm. The design process included dimensional calculation, parametric optimization, fabrication, and experimental measurement using a vector network analyzer. The optimized simulation produced a return loss of −15.306 dB at 2.4 GHz, a bandwidth of 989.1 MHz, a voltage standing-wave ratio (VSWR) of 1.414, a gain of 2.291 dBi, and a unidirectional radiation pattern. Measurements of the fabricated antenna produced return-loss values of −10.61 dB at 2.3 GHz and −12.39 dB at 2.4 GHz, with VSWR values of 1.648 and 1.633, respectively. Although differences were observed between the simulated and measured results, the fabricated antenna satisfied the basic operating requirements for the targeted LTE band. The findings demonstrate that the truncated-corner rectangular-patch technique can improve impedance matching and radiation performance while maintaining compact dimensions suitable for LTE communication applications.

Keywords

MIMO antenna, microstrip antenna, LTE, truncated corner, return loss, VSWR, bandwidth, gain, radiation pattern

I. Introduction

Long-Term Evolution (LTE) is one of the most widely adopted wireless communication standards for high-speed mobile data services. LTE was developed as a fourth-generation (4G) technology to overcome the limitations of previous cellular generations by providing higher data rates, lower latency, and improved spectral efficiency. Under ideal operating conditions, LTE networks can support downlink rates of up to 300 Mbps and uplink rates of up to 75 Mbps.

The increasing demand for multimedia applications, cloud services, Internet of Things (IoT) devices, and high-definition video transmission requires communication systems that can deliver high throughput while maintaining reliable connectivity. One of the most effective approaches to improving LTE performance is the implementation of MIMO technology.

MIMO systems use multiple transmitting and receiving antenna elements simultaneously to increase channel capacity, mitigate multipath fading, and improve communication reliability. By exploiting spatial diversity, MIMO can enhance system performance without requiring additional bandwidth or transmission power.

Among the antenna types used for LTE applications, microstrip antennas have attracted substantial attention because of their compact size, low profile, light weight, ease of fabrication, and low production cost. These characteristics make them suitable for portable devices, wireless communication systems, repeaters, and base-station applications.

Despite these advantages, conventional microstrip antennas have several limitations, including narrow bandwidth, low gain, and relatively low radiation efficiency. Various optimization techniques have therefore been developed. The truncated-corner rectangular-patch method modifies the patch geometry by removing portions of its corners, which can improve impedance matching, polarization characteristics, and radiation performance.

Previous studies have demonstrated that array configurations can increase antenna gain. The truncated-corner technique provides an alternative approach for improving directivity and reducing polarization-mismatch losses. Accordingly, this study focuses on the design and performance evaluation of a 2×1 MIMO microstrip antenna with truncated-corner rectangular patches for operation in the 2.3–2.4 GHz LTE band.

II. Methodology

A. Antenna Design

The antenna was designed using CST Studio Suite 2019. The design procedure comprised seven stages: (1) a literature review of MIMO antennas and relevant performance parameters; (2) determination of the initial antenna dimensions and design specifications; (3) selection of the operating frequency, element dimensions, and inter-element spacing; (4) electromagnetic simulation and iterative optimization until the target specifications were achieved; (5) transfer of the optimized design to Eagle software and fabrication of the antenna; (6) measurement of the fabricated prototype using a vector network analyzer; and (7) comparison and analysis of the simulated and measured results.

B. Antenna Dimensions

The antenna has overall dimensions of 100 × 55 mm², two patch elements, two slots, and two ports in a 2×1 MIMO configuration. It is designed for operation from 2.3 to 2.4 GHz and uses an FR-4 substrate with a thickness of 1.6 mm and a relative permittivity of 4.3. The antenna geometry is shown in Figure 1.

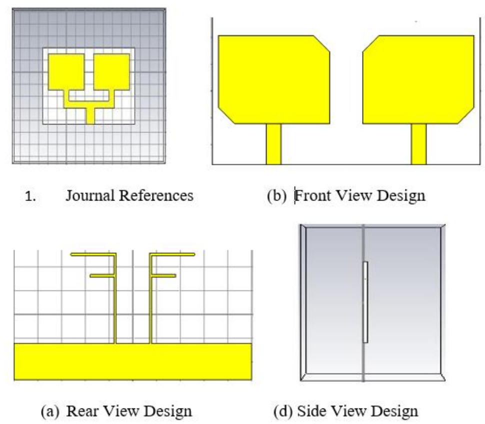

Figure 1. Antenna design and geometry.

Figure 1 presents the reference geometry and the modified truncated-corner design. The principal dimensional differences are summarized in Table 1.

Table 1. Comparison of the reference and modified antenna dimensions.

Parameter	Reference design	Modified design
Substrate/ground-plane size	100 × 55 mm²	100 × 55 mm²
Substrate thickness	1.6 mm	1.6 mm
Ground-plane thickness	0.035 mm	0.035 mm
Corner geometry	No corner truncation	6 mm truncated corners
Feed-line length	16 mm	15.29 mm

C. Antenna Fabrication and Measurement

After the optimized design met the specified simulation targets, the antenna was fabricated and measured. The measured return loss, VSWR, and impedance bandwidth were then compared with the simulation results. Differences between the two datasets were evaluated in relation to fabrication tolerances, etching quality, connector installation, and soldering quality.

III. Results and Discussion

A. Parametric Study

A parametric study was conducted to determine the dimensions that produced the most suitable antenna response. Selected dimensions were systematically increased or decreased, and the resulting changes in return loss, VSWR, bandwidth, and gain were evaluated.

1) Feed-Line Length

The feed-line length was evaluated at 11.29, 13.29, and 15.29 mm. The 11.29 and 13.29 mm configurations produced less favorable return-loss and VSWR characteristics, whereas a feed-line length of

15.29 mm produced the best impedance response among the evaluated configurations.

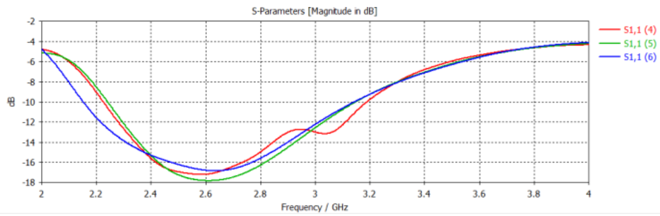

Figure 2. Simulated S11 response for different feed-line dimensions.

2) Ground-Plane Length

Ground-plane lengths of 41, 40, and 38 mm were evaluated. The 38 mm configuration provided the most favorable combined performance in terms of return loss, bandwidth, VSWR, and gain.

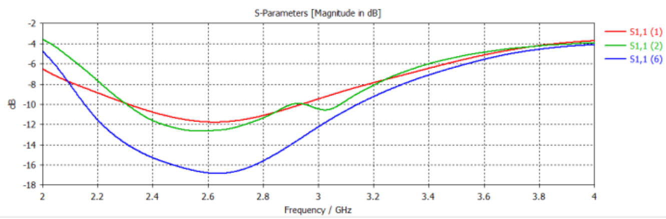

Figure 3. Simulated S11 response for different ground-plane lengths.

B. Return Loss

Return loss represents the ratio of reflected power to incident power and is commonly used to assess impedance matching. An antenna is generally considered adequately matched when S11 is ≤ −10 dB. In the optimized simulation, the return-loss values were −13.867 dB at 2.3 GHz and −15.306 dB at 2.4 GHz. The fabricated antenna produced measured values of −10.61 dB at 2.3 GHz and −12.39 dB at 2.4 GHz. Thus, both the simulated and measured antennas satisfied the −10 dB criterion throughout the targeted operating frequencies, although the simulation results showed better matching.

The discrepancy between simulation and measurement may be attributed to dimensional inaccuracies during cutting and etching, uneven copper surfaces, substrate-property tolerances, connector losses, and imperfect soldering between the feed line and connector.

C. VSWR

VSWR describes the degree of mismatch between an antenna and its feed line. A VSWR value of 1 represents ideal matching, while values ≤ 2 are generally acceptable. The fabricated antenna produced VSWR values of 1.648 at 2.3 GHz and 1.633 at 2.4 GHz. The corresponding optimized simulation values were 1.508 and 1.414. Therefore, the simulated antenna achieved better matching, but the measured values remained within the acceptable limit.

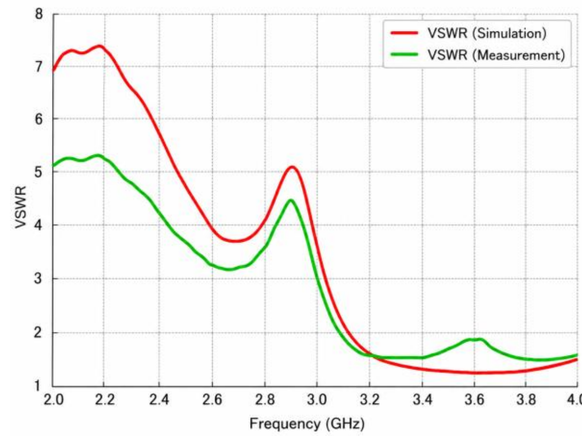

Figure 4. Comparison of simulated and measured VSWR.

D. Bandwidth

The impedance bandwidth was determined from the frequency range over which S11 remained below −10 dB. The optimized simulation produced a bandwidth of 989.1 MHz, whereas the fabricated antenna produced a measured bandwidth of 680 MHz. The smaller measured bandwidth is likely related to fabrication tolerances, etching inaccuracies, substrate variations, and connector and soldering effects. Nevertheless, the measured bandwidth fully covers the intended 2.3–2.4 GHz LTE band.

E. Gain

Antenna gain indicates the ability of an antenna to concentrate radiated power in a particular direction. At the targeted 2.3–2.4 GHz frequencies, the simulated peak gain was 2.291 dBi, as shown in Figure 5.

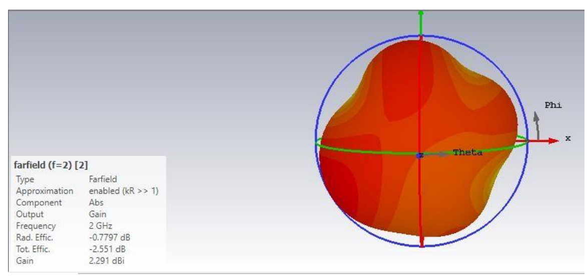

Figure 5. Simulated three-dimensional gain pattern.

F. Radiation Pattern

The simulated radiation pattern was unidirectional within the targeted band, indicating that most of the radiated energy was concentrated in one principal direction. The polar radiation pattern is shown in Figure 6.

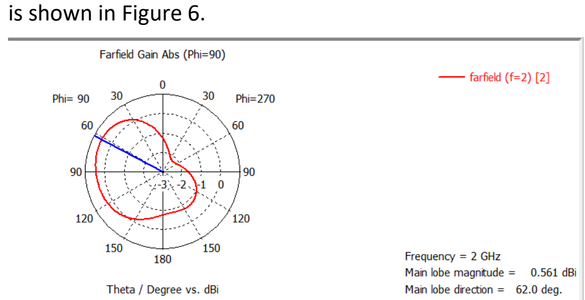

Figure 6. Simulated polar radiation pattern.

G. Overall Performance Comparison

Table 2. Comparison of simulated and measured antenna performance.

No.	Parameter	Simulation	Measurement
1	Return loss (dB)	≤ −10	≤ −10
2	Bandwidth (MHz)	989.1	680
3	VSWR at 2.4 GHz	1.414	1.633
4	Gain (dBi)	2.291	Not measured
5	Radiation pattern	Unidirectional	Not measured

Table 2 shows that the optimized simulation generally produced better results than the fabricated prototype. However, the measured return loss, VSWR, and bandwidth still met the basic requirements for operation in the intended LTE frequency band. Experimental gain and radiation-pattern measurements were not reported and should be included in future validation work.

IV. Conclusion

A 2×1 MIMO microstrip antenna using truncated-corner rectangular patches was successfully designed, simulated, fabricated, and evaluated for operation in the 2.3–2.4 GHz LTE band. The optimized simulation achieved return-loss values of −13.867 dB at 2.3 GHz and −15.306 dB at 2.4 GHz, a VSWR of 1.414 at 2.4 GHz, an impedance bandwidth of 989.1 MHz, a peak gain of 2.291 dBi, and a unidirectional radiation pattern. The fabricated prototype achieved return-loss values of −10.61 and −12.39 dB and VSWR values of 1.648 and 1.633 at 2.3 and 2.4 GHz, respectively, with a measured bandwidth of 680 MHz. Although the measured performance was lower than the simulated performance, the prototype covered the target band and satisfied the commonly accepted return-loss and VSWR criteria. The observed differences were most likely caused by fabrication tolerances, substrate variations, connector losses, and soldering quality. Future work should include experimental measurements of gain, radiation pattern, inter-port isolation, envelope correlation coefficient, diversity gain, and other MIMO-specific performance parameters.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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