

Multiband Printed Slot Meander Patch Antenna for MIMO Implementation in 4G Handheld Devices

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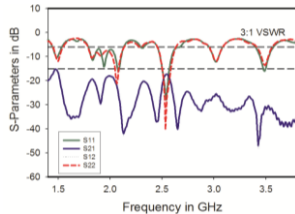
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Graphical abstract



Abstract

This paper presents a Low-profile slot meander patch antennas. The antenna is a multiple communication bands for handheld devices and implements multiple-input–multiple-output (MIMO) technique. The proposed model covers LTE band-11 1.5 GHz Lower (1427.9 - 1452.9, 1475.9 - 1500.9), LTE band-2 PCS 1900 (1930 -1990, 1850 -1910), LTE band-7 2.6 GHz (2620-2690, 2500- 2570), and LTE band-22 3.5 GHz (3510-3590, 3410-3490) with dB matching criterion (VSWR 3:1). An isolation less than -15 dB has been obtained between two typical slot meander patch antennas. The isolation is achieved as a result of using CPW feeding mechanism and inserted CLL network isolator. This dual-feed (2-elements) planar antenna is fabricated and measured. The result of this small size structured MIMO antenna system shows a good radiation characteristics and small mutual coupling which is promising for MIMO applications in compact portable devices.

Keywords: Slot meander patch; CLL network isolator; MIMO; 4G LTE antenna; multiband antenna

Abstrak

Kertas ini membentangkan antenna tampalan lubang yang berlekuk-lekuk serta berprofil rendah. Antena ini mempunyai kepelbagai an frekuensi komunikasi untuk kegunaan alat mudah alih menggunakan teknik pelbagai masukan dan keluaran (MIMO). Antena yang dicadangkan yang dicadangkan meliputi LTE-11 band 1.5 GHz Rendah (1427,9-1452,9, 1475,9-1500,9), LTE band-2 PCS 1900 (1930 -1990, 1850 -1910), LTE band-7 2.6 GHz (2620-2690, 2500 - 2570), dan LTE-22 band 3.5 GHz (3510-3590, 3410-3490) dengan padanan kriteria (VSWR 3:1) dalam unit dB. Pengasingan yang kurang daripada -15 dB telah diperolehi di antara dua antenna tampalan lubang yang berlekuk-lekuk. Pengasingan telah dicapai dengan menggunakan mekanisme suapan CPW dan memasukkan rangkaian pengasing CLL. Dua suapan (2-unsur) antenna satah ini telah direka dan diukur. Keputusan antenna MIMO yang berstruktur kecil ini menunjukkan sifat radiasi yang baik dan gandingan penhubung yang kecil serta menjanjikan untuk kegunaan aplikasi MIMO dalam peranti mudah alih yang kompak.

Kata kunci: Slot berluk patch; CLL rangkaian isolator; MIMO; 4G LTE antena; antenna pelbagai jalur

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1.0 INTRODUCTION

MIMO techniques are considered as a solution to the problem of low data rates and improve the channel bandwidth. Additionally, it addresses the problem of multipath fading [1]. MIMO design comprise of more than one antenna elements in transmitter and receiver terminals in order to improve the channel capacity in a high multipath environment [2]. Lately, there is a high interest in an increased extension of MIMO techniques to small size mobile platforms (e.g., laptop computers, PC cards, mobile phones) [2]. However, these MIMO techniques use spatial diversity of spaced out the elements of MIMO system, and the overall size of the MIMO antenna system is usually exceeds the standard sizes due to the complexity of physical structure as well as the diversity

requirement. Therefore, the size reduction issue has become more challenging factor in communications systems. In order to achieve MIMO gain, at least 0.3λ distance must separate the MIMO antenna elements (where λ is the wavelength of LTE frequency range 0.7~3.8 GHz) and this separating distance is bigger comparing to the standard size of hand-held device. As a result, and in order to attain a good MIMO performance in a limited- size MIMO antenna an isolation technique must be adopted. Adding to the broad bandwidth advantage, Co-Planar Wave Gide(CPW)fedantennas present a smaller mutual coupling between nearby lines and easy integration with solid-state active devices [3-6]. Therefore, we used CPW-fed in designing the proposed MIMO antenna system. In order to enhance the antennas isolation a Capacitor Coil-Coil (CLL) network isolator

is placed between the two slot meander patch antennas [6,7]. The obtained result shows an isolation less than -15 dB over all the covered bands.

2.0 ANTENNA DESIGN

The detailed design of the proposed MIMO antenna is demonstrated in Figure 1. The antenna composes of two parallel elements with separation of $d=28$ mm nearly $0.14\lambda_0$ at 1.5 GHz and is printed on the upper part of a partially grounded FR-4 substrate with dimensions $100 \times 60 \times 1.6$ mm³ and dielectric 4.4. Due to the symmetrical structures of the two elements of the proposed MIMO antenna system we only discuss the element number 1. The element number 1 (Figure 1(c)) is a simple printed planar meandered patch scattered with one continuous 1 mm width meandered slot. The slot distributes the meandered patch to two parallel meandered lines connected at their edges. The meander lines' widths are 1 mm, and their thickness is 0.035 mm. The meander patch shrink's length is 21 mm, and is equivalent to the wavelength of the lowest frequency, 1.42 GHz. The optimized design parameters for the elements of the proposed MIMO antenna system are shown in Figure 1 (c). In this paper, the CLL network structure (shown in Figure 2) is applied to enhance the isolation between the MIMO antenna elements.

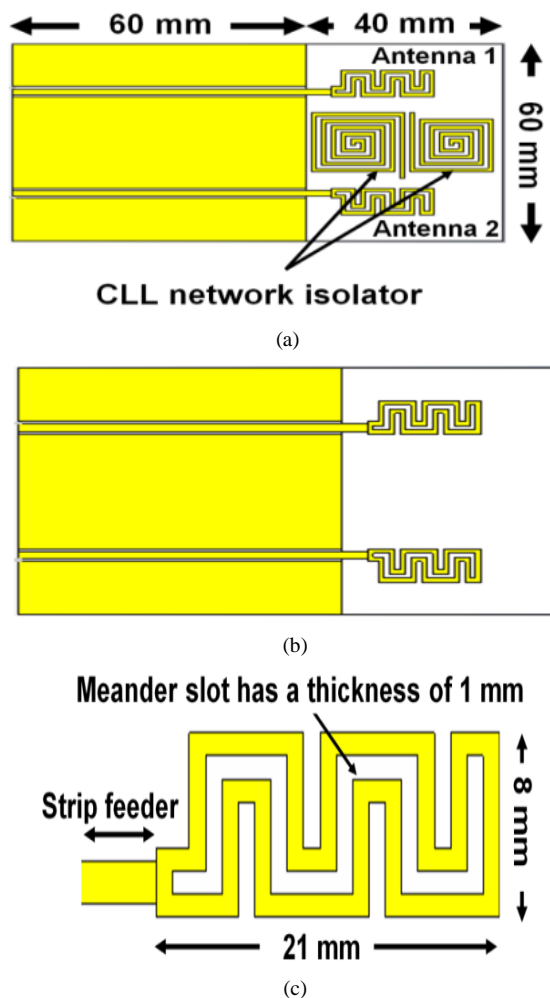


Figure 1 MIMO antenna system design; (a) with CLL network, (b) without CLL network, and (c) the element antenna geometrical design

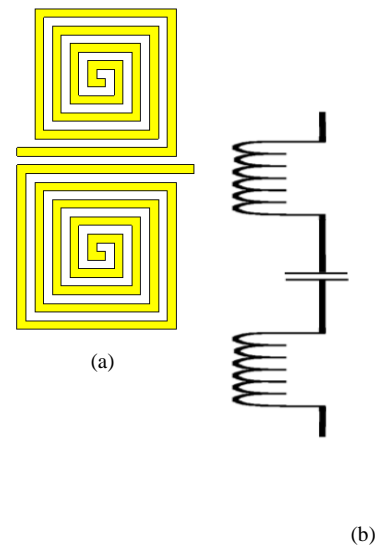


Figure 2 (a) the designed isolation CLL network and (b) the equivalent CLL network

3.0 DISCUSSION AND RESULT

We used CST microwave studio software in simulating the proposed design of the MIMO antenna as shown in Figure 1. In order to measure the fabricated antenna return loss (for verifying the simulation results) the Agilent Technologies vector network analyzer E5071C is used. Our antenna measurement system features 8 m long x 5 m wide x 5 m height tapered anechoic chamber, scanner and an automated data acquisition system. The anechoic chamber (AFI industries-RF SHIELDING & ANECHOIC system and NSI antenna measurement system software) provides an RF proof environment where both the antenna and measurement devices are isolated from outside interference and stray field. Figure 3 depicts the photos of the fabricated MIMO antenna. A small shift between the simulated and measured S-parameters is obtained (as can be seen in Figure 4) as a result of the good agreement between simulation and fabrication. By etching the meander slot over the meander patch, the impedance matching is improved and four-separated bands are obtained. The lower band of 7.3% with $|S_{11}| \leq -6$ dB (3:1 VSWR) and $|S_{21}| \leq -15$ dB from 1.42 to 1.55 GHz covers LTE band-11 1.5 GHz Lower (1427.9 - 1452.9, 1475.9 - 1500.9). The second band of 7.6% with $|S_{11}| \leq -6$ dB and $|S_{21}| \leq -17.5$ dB from 1.8 to 2.1 GHz covers LTE band-2 PCS 1900 (1930 -1990, 1850 -1910). The third band of 1.1% with $|S_{11}| \leq -6$ dB and $|S_{21}| \leq -17$ dB from 2.4 to 2.7 GHz covers LTE band-7 2.6 GHz (2620-2690, 2500- 2570). The upper band or band four of 0.57% with $|S_{11}| \leq -6$ dB and $|S_{21}| \leq -30$ dB from 3.4 to 3.6 GHz covers LTE band-22 3.5 GHz (3510-3590, 3410-3490).

CLL network structure is also applied to enhance the isolation between the MIMO antenna elements. As stated above the proposed MIMO antenna (with two parallel elements) has four bands. There is noticeable isolation improvement particularly for the second band, where the isolation of the antenna - without applying CLL network structure as in Figure 1 (b) - is more than -15 dB as shown in Figure 5 (a). As a result of inserting of the CLL as in Figure 1 (a) there is an improvement of the lower band isolation to less than -15 dB as shown in Figure 5 (b). The accepted value of the isolation over the first, third and

the fourth bands – without applying CLL network structure – is due to the applied CPW feeding structure.

Furthermore, the antenna has a good radiation characteristics and acceptable gain and efficiency over all the covered bands. The Measured and simulated E and H planes of the MIMO antenna at 1.5, 2.0, 2.6, and 3.5 GHz are shown in

Figure 6. While the antenna measured efficiency and gain are shown in Figure 7.

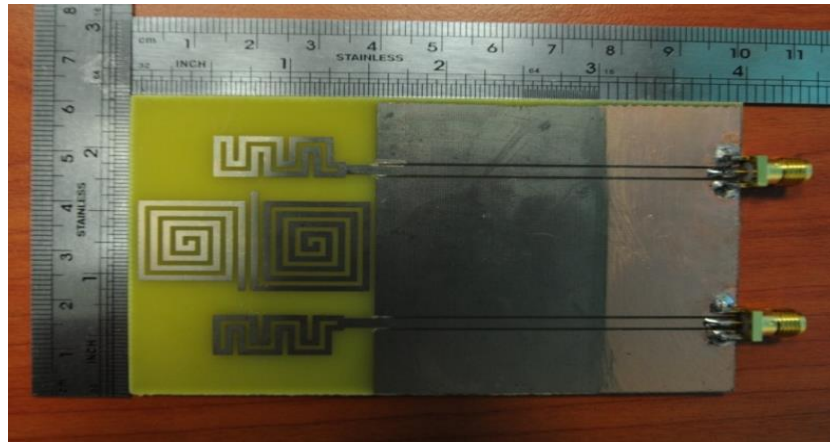


Figure 3 The photo of the proposed antenna prototype

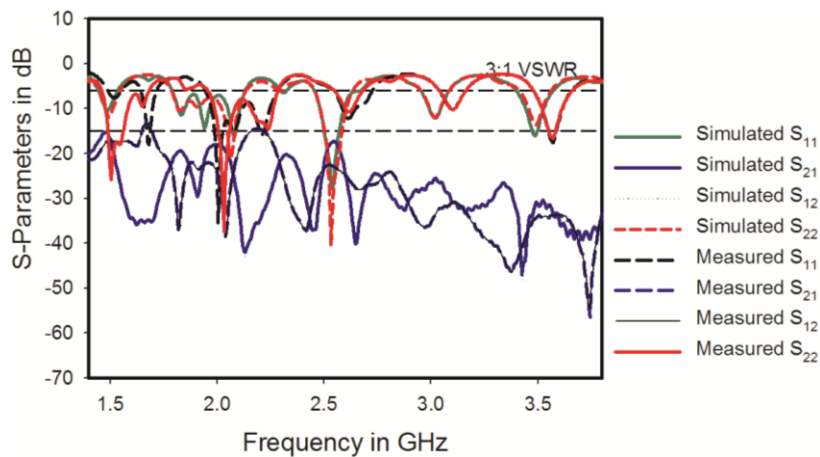


Figure 4 The Measured and simulated S-parameters of the proposed MIMO antenna system

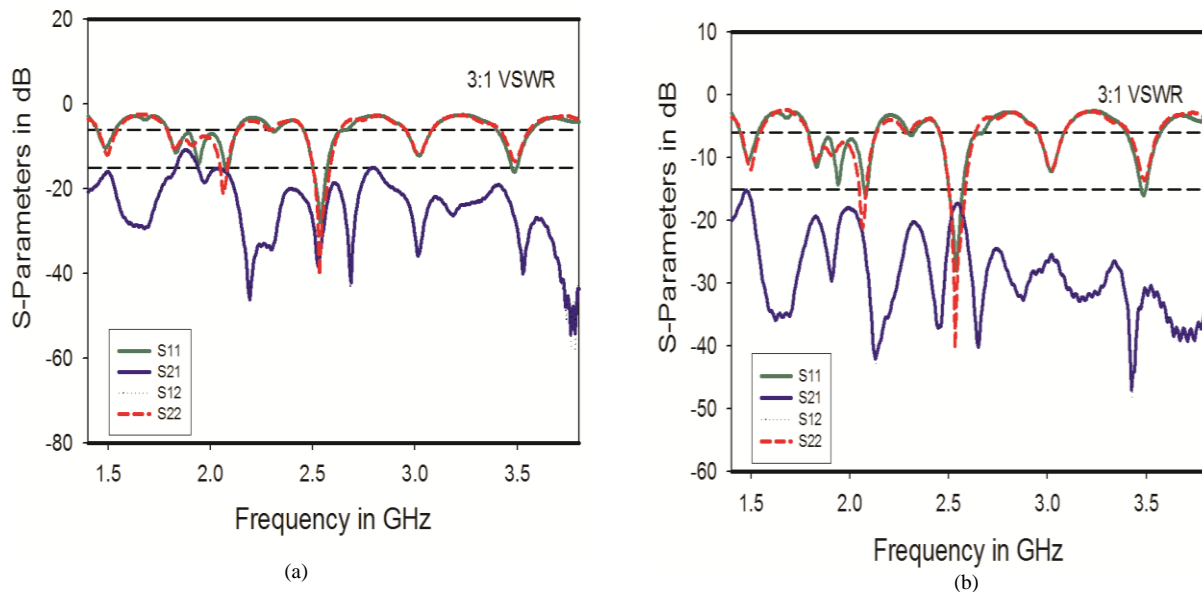


Figure 5 S-Parameters of the MIMO antenna system (a) without CLL network and (b) with CLL network

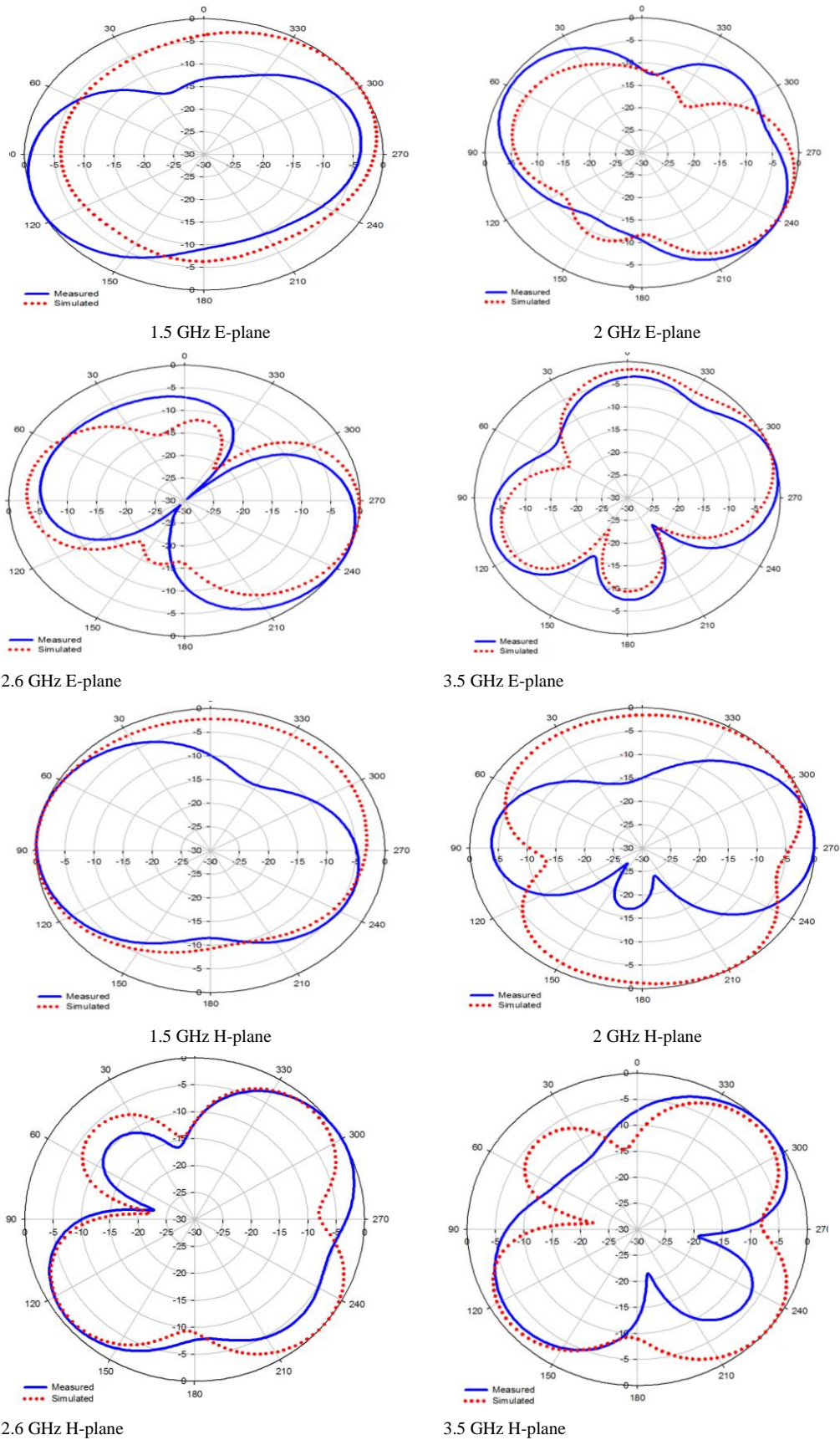


Figure 6 The Measured and simulated E and H planes of the MIMO antenna at 1.5, 2.0, 2.6, and 3.5GHz

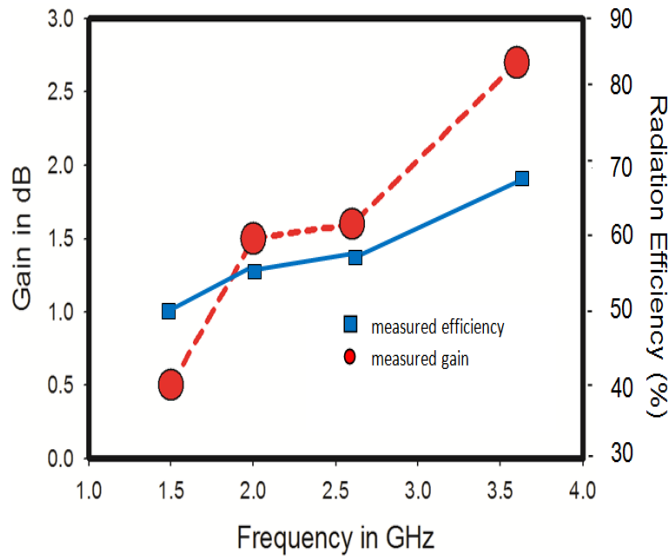


Figure 7 The efficiency and gain of the MIMO antenna at 1.5, 2.0, 2.6, and 3.5 GHz

4.0 MIMO SYSTEM PERFORMANCE

The literature has shown that MIMO system performance is a critical issue and requires essential parameters to investigate such as Envelop Correlation Coefficient (ECC). The ECC between antenna elements is one of the most important parameters, which is related to spectral efficiency and may degrade systems' performance [8]. One of the appropriate methods of calculating the ECC is S-parameters method which needs the values of scattering parameters obtained from the antenna elements [9,10]. In general, to achieve MIMO diversity gain the ECC value must be equal to or lower than 0.5 (envelope correlation always leads to high diversity gain). For dual-element antenna system, a simple formula can be used to calculate ECC as shown in the equation (1).

The calculated result of the proposed antenna is exhibited in Table 1. It shows that the desired operation bands of the proposed antenna have an ECC less than 0.4, meaning that the antenna has good diversity gain.

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

Table 1 The calculated ECC value at frequencies 1.5, 2.0, 2.6, and 3.5GHz

Entry	Frequency In GHz	ρ_e
1	1.5	0.40
2	2	0.23
3	2.6	0.20
4	3.5	0.14

5.0 CONCLUSION

A compact four-band MIMO antenna has been achieved. The design of this model is a simple planner printed antenna and it consists of two parallel meander patch elements with meander slot. The lower band of 7.3% with $|S_{11}| \leq -6$ and $|S_{21}| \leq -15$ from 1.42 to 1.55 GHz covers LTE band-11 1.5 GHz Lower (1427.9 - 1452.9, 1475.9 - 1500.9). The second band of 7.6% with $|S_{11}| \leq -6$ and $|S_{21}| \leq -17.5$ from 1.8 to 2.1 GHz covers LTE band-2 PCS 1900 (1930 -1990, 1850 -1910). The third band of 1.1% with $|S_{11}| \leq -6$ and $|S_{21}| \leq -17$ from 2.4 to 2.7 GHz covers LTE band-7 2.6 GHz (2620-2690, 2500- 2570). The upper band or band four of 0.57% with $|S_{11}| \leq -6$ and $|S_{21}| \leq -30$ from 3.4 to 3.6 GHz covers LTE band-22 3.5 GHz (3510-3590, 3410-3490). The proposed MIMO antenna has good characteristics of the nearby conducting elements, and the diversity performance of the antenna. All results obtained from this study indicated that the proposed antenna operate as a hand held MIMO antenna device that can provide spatial and pattern diversity to combat multipath fading.

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