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Compact V-shaped MIMO Antenna for LTE and 5G Communications

***Abstract**. A new small V-shaped MIMO antenna with dimensions of the antenna 21 × 24 × 0.8 mm within the bands of (4.4-4.9) and (5.15-5.925) GHz was designed, and the fabrication and measurement outcomes derived from the use of the MIMO prototype revealed that the fractal MIMO antenna. The small and simple fractal antenna demonstrated high isolation of less than -18.5 dB and envelope correlation coefficient less than 0.05. These attributes are suitable for mobile, which is being introduced into Japanese markets.*

Streszczenie.** Zaprezentowano nową mał antenę MIMO w kształcie V o wymiarach 21 × 24 × 0.8 mm na pasmo 4.4-4.9 i 5.1-5.925 GHz. Przedstawiono projekt, wykonanie I badania anteny. **Kompaktowa antena MIMO w kształcie V do LTE I 5G komunikacji

Keywords: 5G band, Envelope correlation coefficient (ECC), Fractal antenna, MIMO antenna
Słowa kluczowe: antena MIMO, pasmo 5G, kształt V

Introduction

Over the past three decades, improvements in cellular communications standards have dramatically altered the construction of antennas. Two main parts are included in this development. First, it is the interest of users, which consists mainly of ergonomic and aesthetic considerations, and secondly, the introduction of different spectra in line with evolving regulatory standards. Antenna design is one of the many difficult requirements for mobile system designers. The rapid growth of mobile wireless systems requires about 5G multi-band, broadband, or even broadband antennas to cover the interoperability of mobile services and reduce system complexity[1]–[5].

Additional demands for portable antennas include small size, ease of integration into the portable chassis, and coexistence with and support for MIMO systems. MIMO is one of the key elements that support 5G technology in achieving better bandwidth compared to 4G and LTE-Advance (LTE-A) systems. This technology provides additional system capacity while increasing the number of antenna elements, without the need for additional frequency or power spectrum. A high-performance MIMO system requires high isolation for each element and a low envelope correlation coefficient between them. However, this needs to be spaced between items, which is difficult to find in mobile devices as it is ideally designed to be compact.Antenna design. The focus on smart device miniaturization would require less space for antenna design, and consequently, this will affect the close association between isolation and bandwidth in the MIMO antenna system[6]–[9]. As such, this paper attempted to solve the above-mentioned issues with a high isolation printed on two-element arrays operating in the centre frequencies of 4.65 GHz and 5.5375 GHz in the bands of (4.4-4.9) and (5.15-5.925) GHz

Antenna Design and Analysis

1. Antenna Design

Table1 displays all the dimensions of the proposed MIMO antenna. Each radiating element of the two-element MIMO antenna held a symmetrical monopole antenna fed by a 50 Ω microstrip line. This proposed MIMO antenna includes two separate ports with a distance of 7mm monopoles printed on a 24 × 21 mm FR-4 substrate, as exhibited inFig. 1. To obtain high isolation, neutralization lines were inserted between the two separated antennae of the patch plane and using defected ground structure to the inserted slot on the ground plane. This complemented the two vertical lines of the patch plane, with a width of W1 = 3mm and length of L1=21mm, a vertical line of width g9 = 1mm and length g10 = 21mm on the ground plane, and a slot of length (g4+g3+g4+g3)= 6.68mm, as shown in Fig.1.

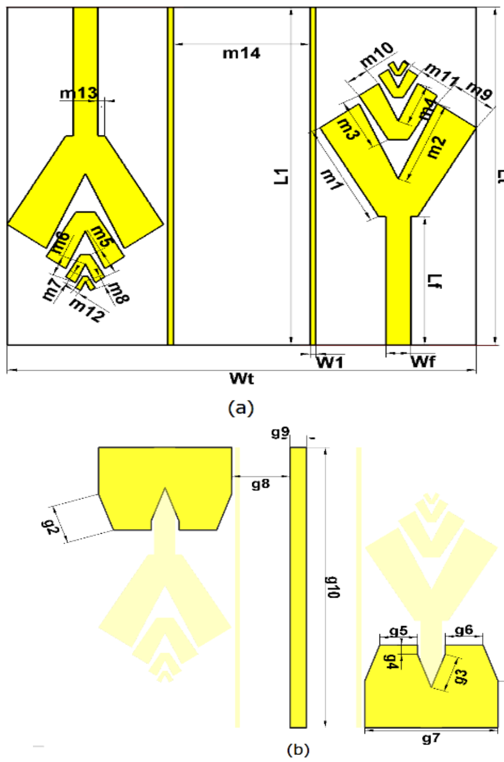

Fig. 1: Proposed design geometry of fractal V- shaped MIMO antenna (a) Front View (b) Back View

Table 1: Parameters and dimensions of the fractal Siperpinki MIMO antenna

parameter	value	parameter	value	parameter	value
Lf	8	m5	1.57	m12	0.31
Wf	1.27	m6	1.27	m13	0.37
W1	3	m7	0.78	m14	7
m1	6.26	m8	0.63	g1	3.5
m2	5.08	m9	2.5	g2	2.85
m3	3.13	m10	1.25	g3	2.68
m4	2.54	m11	0.63	g4	0.7
g5	2.27	g6	2.27	g7	8
g8	3.5	g9	1	g10	21
L1	21	Lt	21	Wt	24

2. Antenna Parametric analysis

The simulated results to 1st iteration and 4th iteration are exhibited in Fig2. The difference in results of the proposed MIMO antenna used in the 5G applications, suggests the influence of the adding V-shaped, to generate various bands of LTE and 5G. By fixing the other radiation elements, and changing the width of the centre line S1= 4.3 mm, the results of the MIMO antenna will be changed. In 1st iteration, the solid curve represents the return losses of the antenna when the width of the centre line S1 is at 3.35 mm. There is one operating band as observed (4.4 - 4.85) GHz with a return loss of 29.5 dB and the isolation value of -19.75 as shown in Fig.2-a.

In Fig.2-b represented the 4th iteration, observed that the result of the operating band (4.4 - 4.9) GHz with a return loss of -33 dB and the isolation value of -19.5 as shown in Fig.2-b. By changing the width of the centre line S1=4.3 mm when 1st iteration, the simulation result operating obtained one band (5.12-5.97) GHz with a return loss of -30 dB and the isolation value of -20 dB as shown in Fig.2-c. while, when using 4th iteration changed the operating band to (5.15-5.925) GHz, changed the value of isolation -21 dB with the return loss value of -58dB, as shown in Fig.2-d.

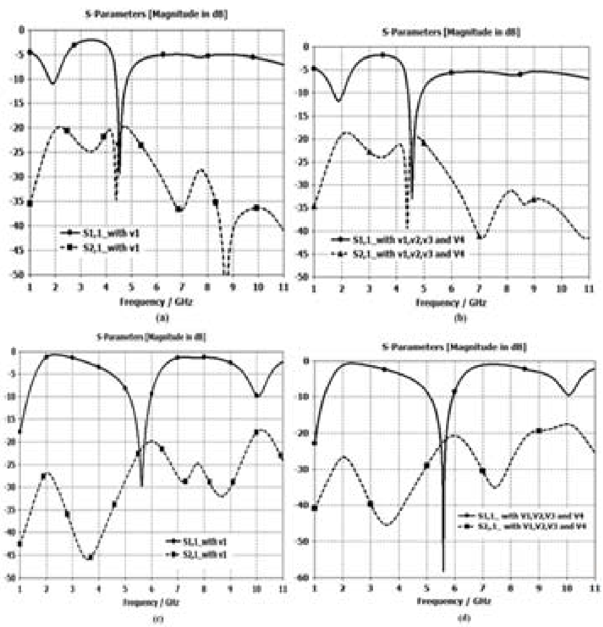

Fig. 2: S-parameters of the Siperpinki MIMO Antenna of (a) 1st iteration at S1=3.35 mm (b) 4th iteration at S1=3.35 mm (c) 1st iteration at S1=4.3 mm and (d) 4th iteration at S1=3.35 mm.

Performances MIMO antenna

1. Isolation technique

As mentioned earlier, adoption of the hybrid techniques (NL with DGS) for the proposed antenna structure increases the isolation between the elements. To scrutinize the effect of this hybrid technique on the coupling reduction, Fig.3 (a) shows MIMO antenna with and without this technique, when S1 parameter is set at 4.3 mm. As can be seen in the Fig.3, existence of the isolation technique decreased the bandwidth at lower frequency edge to about 2.667 GHz. However, noticeable effect was seen on S21 curve; that is, the isolation between the elements. As can be seen, by the addition of hybrid technique, significant reduction was obtained in S21 curve. Fig.3 (b), shows MIMO antenna with and without hybrid technique, when S1 parameter is set at 3.35 mm. As shown, the existence of the hybrid technique increased the isolation and decreased the bandwidth at lower frequency edge to about 1.663 GHz.

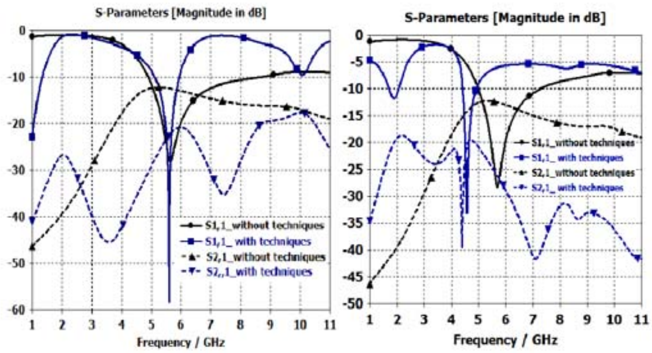

Fig. 3: A comparison with/without isolation technique of the fractal siperpinki MIMO antenna.(a) When parameter S1 = 4.3 mm (b) When parameter S1 = 3.35 mm

As it was stated already, the width of the S1 highly influences the isolation between elements, it was expected that any changes in the S1 parameter would influence the performance of proposed MIMO antenna. The effect of changing the length of S1, from 4.3 mm to 3.35 mm with a step of around 1 mm, is shown in Fig. 3 (b). As it is clearly seen, the best bandwidth and highest isolation was achieved when S1= 4.3 mm and 3.35 mm. Moreover, the surface current distribution, shown in Fig. 4, confirms the obtained results. In antenna-1, when rectangular slot with triangular base was embedded from the top edge of the ground plate, the surface current was mostly concentrated around the slots in opposite directions. The opposite alignment of the current around the embedded slots realized the notched functionality. Similar behavior was also observed for antenna-2.

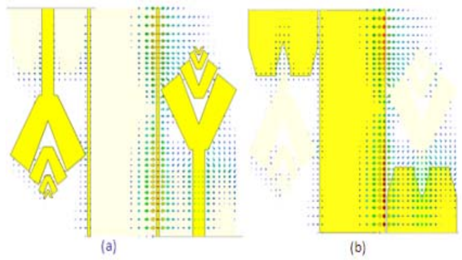

Fig. 4: Simulated current densities with port-1 of the siperpinki MIMOantenna of (a) Front (b) Back view.

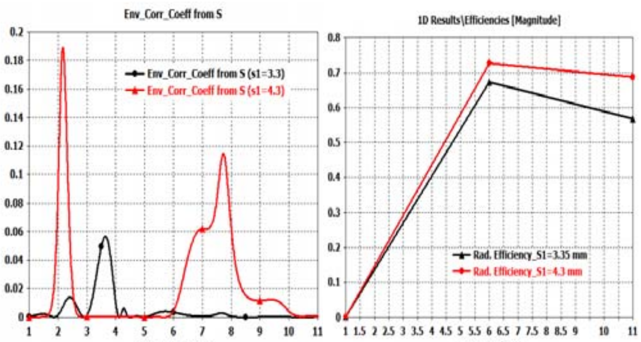

Fig.5: the fractal siperpinki MIMO antenna of (a) ECC (b) Efficiency

ECC and Efficiency

Fig. 5(a) shows the ECC of the MIMO antenna with port-1. The minimum ECC obtained was 0.0036 and 0.00 for the two bands (4.4 - 4.9 GHz and 5.15 - 5.925 GHz) when changing S1. Apart from this, the proposed antenna achieved a higher level of efficiency, 50 – 57%, and 56 - 67% on 4.4 - 4.9 GHz and 5.15 - 5.925 GHz operating bands, respectively. The antenna efficiency was observed to be above 50% in all operating bands, as shown in Fig.5(b).

Prototype and Measurement result

By fabricating a mobile antenna prototype for the band of (4.4-4.9) GHz with a centre frequency of 4.85 GHz from an inexpensive FR4 dielectric with overall dimensions of 21 × 24 × 0.8 mm3, as shown in Fig.6, the simulated and measured reflection and transmission coefficients demonstrated by the two representative antennae (antenna-1 and antenna- 2) in Fig.7, were therefore implied to have a similar level of performance.

Fig. 6: A photograph of the fabricated Siperpinki MIMO antenna

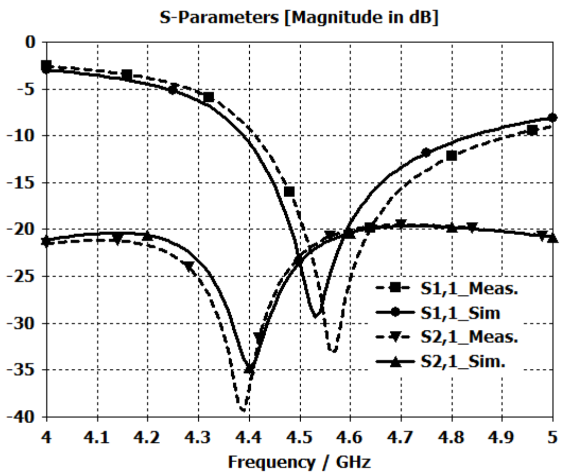

Fig. 7: Simulated and Measured of the Siperpinki MIMO antenna at (4.4-4.9) band

The normalized gains of the proposed Vicsek fractal MIMO antenna at centre frequency (4.65) GHz and are depicted in Fig. 8 for both simulation and measurement cases. From this Fig. 8, it can be noticed that the antenna has an Omni-directional pattern in both simulation and measurement cases, which means that our antenna is convenient for required applications. Also, the Measured and simulated S-parameters demonstrated by the two representative MIMO antenna in Fig. 8, were therefore implied to have a similar level of performance.

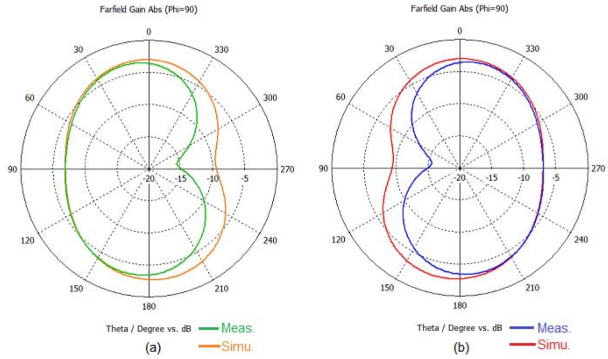

Fig. 8: Normalized simulated and measured gain of the proposed Vicsek fractal MIMO antenna at centre frequency (4.65) GHz. (a) Gain of port1 (b) Gain of port2

Validation of the Proposed Antenna

Table 2 shows, the comparison of findings between this research works with other research work. The proposed antenna is compared with several selected types of research. The comparison was based on important characteristics, such as a number of ports, isolation, efficiency, envelope correlation coefficient, material, bandwidth and size. This V-shaped MIMO antenna is the best for LTE and 5G communications propose for several reasons.

The first reason is the fact that Fractal Siperpinki MIMO Antenna has two operating bands that cover all required frequencies for LTE and 5G communications (4.4-4.9 or 5.15-5.925). The second reason is high isolation and very small size. The Third reason is envelope correlation coefficient properties at some operating bands for Fractal Siperpinki MIMO Antenna that has is less than 0.0036 and equal zero of the first and second bands respectively. The fourth reason is a small size, which provided the possibility of using the proposed MIMO antenna for mobile LTE and 5G communications devices. The Fifth reason is that fact that side from being low cost, ease of fabrications and use of commercial FR-4 substrate, the antennas examined in this study can be adopted for the purpose for which that has designed.

Table 2: Comparisons between the proposed of MIMO antennas and previous related antennas

Ref.	BW (GHz),	Size (mm^2)	Isolation	ECC	Efficiency (%)
[7]	4.4 - 4.99	31 × 31	< -20	< 0.002	(56 - 59)
[8]	3.7 - 4.2	26 × 46	< -20	< 0.0056	(78 - 87)
[3]	4.7 - 5	24 × 21	< -18.5	< 0.016	> 70
[10]	5.1 - 6	40 × 60	< -20	< 0.1	(70 - 81)
[11]	5.6 - 5.95	56 × 38	< -25	< 0.002	> 95
[12]	5.6 - 5.93	137 × 77	< -18	< 0.05	> 73
[13]	3.4 - 3.8	75 × 150	< -15	< 0.1	(65 - 80)
[14]	5.15-5.85	24 × 28	< -16	< 0.15	> 60
[15]	5.6 - 5.9	54 × 30	< -20	< 0.05	= 45
[16]	4.03 - 5.4	105 × 50	< -27	< 0.05	(65 - 68)
This work	4.4-4.9 or 5.15-5.925	24 × 21	< -21	= 0	(56-67)

Conclusion

A mobile phone with a two-element antenna design was proposed for the use of LTE and 5G MIMO communications. This job involved the simulation and fabrication of a novel fractal MIMO antenna for the bands ranges of (4.4-4.9) GHz and (5.15-5.925) GHz. The different bands were controlled by way of the application of decoupling hybrid technique (neutralizationlines and defected ground structure). Besides enhancing the isolation between the antenna elements, the ECC between the signals received by the MIMO antenna ports was sufficiently reduced to meet the specifications for 5G applications.

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