

# Characterization of Low-Cost UWB MIMO antenna model for K/Ka/Q/U/V bands Applications

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**Abstract.** A dual-element and a four elements low-cost multiple-input-multiple-output (MIMO) antenna are introduced in this paper. It achieves a bandwidth (BW) of 25 GHz (22-45 GHz) and 35 GHz (22- 60 GHz) respectively, and the VSWR is less than 2 for both configurations. The proposed antennas average isolation of 20 dB over the entire operating band, and a peak realized gain of 7.6 dBi for the dual element antenna and 7.59 dBi for the four-element antenna, which are suitable for ultra-wideband at K/Ka/Q/U/V bands Applications.

**Index Terms**—dual element MIMO antenna, four element MIMO antenna, ultra-wideband antenna, patch antenna.

## 1 Introduction

Ultra-wideband (UWB) technology has attracted much attention in the last years, Due to its outstanding advantages of low power and high data rate, is regarded as a good choice in several wireless communications, such as imaging systems, ranging, and satellite communication. Multiple-input-multiple-output (MIMO) technology is another promising technology [1], which can play an essential role in wireless communication systems to meet the requirements of omnidirectional characteristics, more bandwidth and higher data rate [2], UWB-MIMO can make full use of their advantages and provide more big data rate [1]. On the other hand, some techniques of development for UWB antennas have been introduced in [3]. A UWB crescent-shaped monopole antenna for a 5G millimeter-wave test frequency band has been proposed in [4]. Ref. [5] applied a Genetic algorithm to design an Ultra-wideband.

Others work to design a compact MIMO antenna. Ref [6] used a 6-elements MIMO system with EBG structure in the form of a square spiral cell. a compact microstrip four-port dual MIMO antenna for the Sub-6G band is discussed in [7].

Another challenge to combine a UWB technology and MIMO antenna which can be applied to wireless systems, for example, ref [8] based on split-ring resonator (SRR) and complementary split-ring resonator (CSRR). A parasitic unit decoupling was used to prove UWB-MIMO in ref.[ 9]

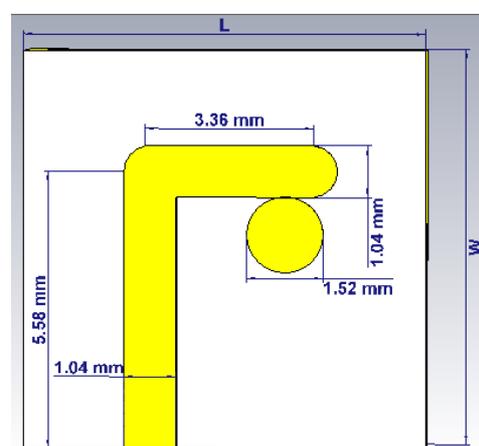
With a small profile, low-cost structure, two configurations of UWB-MIMO antenna which the first model of dual-element cover 22GHz-45 GHz UWB and the second of four elements covers 22 GHz- 60 GHz UWB are studied in this article.

Simulation is achieved using the Finite Integration Technique (FIT) based computer simulation technology microwave studio (CST MWS) .

## 2 The primary structure antenna

Fig. 1 (a) and (b) show the geometry of the primary proposed antenna on CST Microwave and HFSS respectively. The proposed model consists of a new configuration radiating patch inspired from the L-shaped antenna cited in [10]. The UWB is achieved by inverting the L-shaped radiating element and modifying the 50  $\Omega$  coaxial cable position.

The S11 result depicted in Fig. 1 operates from 22 GHz to 45 GHz that appeared in K, Ka and Q bands technology. The major advantage of this structure antenna is resumed in its small size, low-cost profile, and good results.



(a)

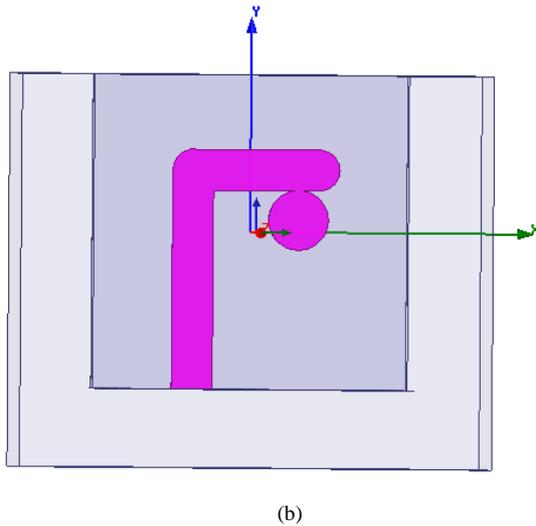


Fig1. Primary structure antenna, (a) on CST Microwave, (b) on HFSS.

Fig. 2 (a) shows the variation effect of the length (L) of the proposed structure on the reflection coefficient results. The simulated S11 result obtained with L=W=10mm operates from 22 GHz to 45 GHz that appeared in K, Ka, and Q bands applications. On the other hand, fig.2 (b) shows the comparison between the simulation on CST Microwave and the other on HFSS, the both obtained S11 results obtained with L=10mm indicates good conformity in the desired frequency bands. Thus, the mismatch in Fig.2 (b) curves is related to the high losses of the used substrate at high frequency bands.

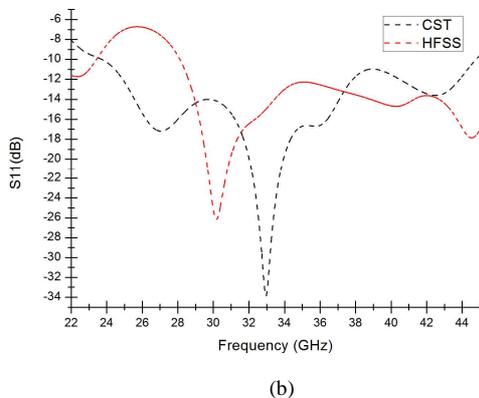
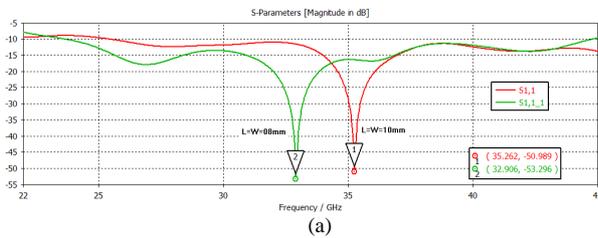


Fig2. (a) The S11 result of the primary structure, (a) comparison on CST with two different dimension of antenna, (b) comparison result, CST Microwave and HFSS.

To determine the bandwidth of an antenna, two relationships should be mentioned: a return loss of -10

dB corresponds to a VSWR less than 2. In fig .2 and fig.3 we can inspect those last conditions.

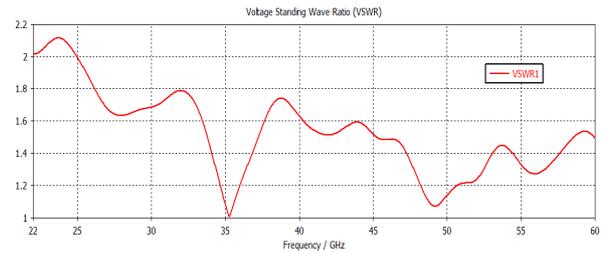


Fig3. VSWR of the proposed antenna

Fig. 4 shows the current distribution on the surface of the radiating element at 33 GHz. The maximum current concentrated in the center of the patch can be produced due to the inclined shape of the patch depending on the port excitation.

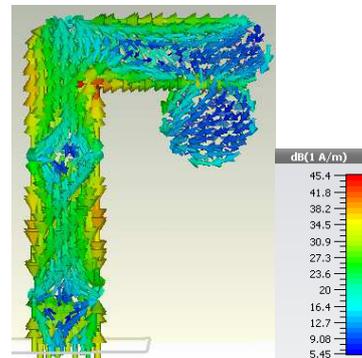
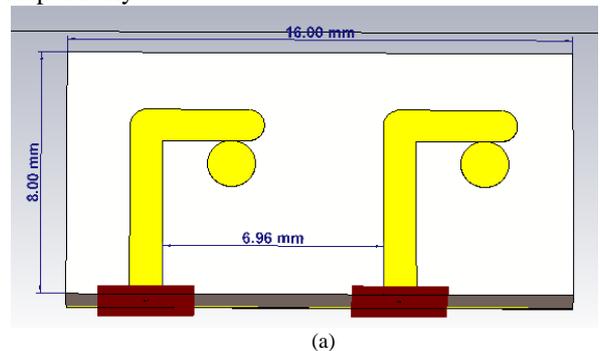


Fig4. The current distribution on the surface of the primary element antenna at 33 GHz.

### 3 UWB-MIMO structure

#### 3.1 First configuration of dual elements MIMO antenna

In this suggestion, and for the first 1X2 MIMO configuration, the substrate size is increased up to 16x08 mm, and the two radiating elements are studied in two configurations as seen in Fig.5 (a) and (b), respectively.



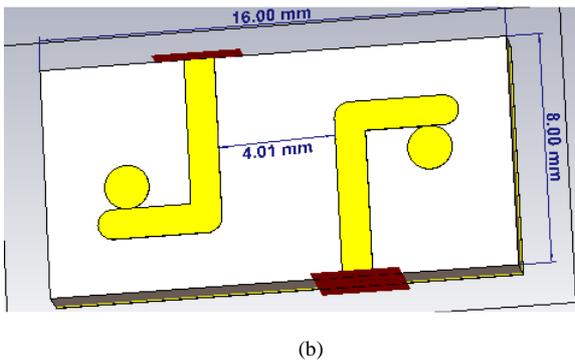


Fig.5. The proposed MIMO 1X2 antenna, (a) of the first MIMO antenna model, and (b) the second MIMO antenna model.

The simulated  $S_{ij}$  of the MIMO configurations shown in fig. 5 is depicted in Fig.6 (a) and (b) respectively. Both  $S_{11}$  results of the proposed configurations cover the band assigned for UWB applications that operates from 25 GHz to 45 GHz. On the other hand, the isolation between the radiating elements is greater than 20 dB over the entire operating frequency, as depicted in fig.6. (b). The proposed dual-radiating element can be used for the K, Ka and Q technologies.

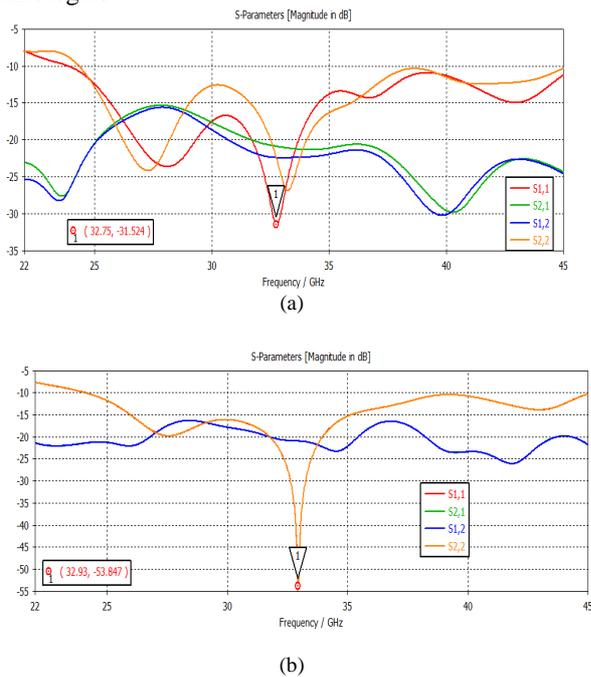


Fig.6. Simulated  $S_{ij}$  result of the proposed antenna vs. Frequency; (a) of the first MIMO configuration and (b) of the second MIMO configuration.

Fig. 7 shows the variation gain in dBi vs frequency from 22 GHz to 45 GHz of both 1X2 MIMO configurations antenna, that the maximum gain is 5.1 dBi at 32 GHz for the first configuration and 4.6 dBi from 39.6 GHz to 33.4 GHz for the second configuration. Both proposed configurations suggest good gain characteristics.

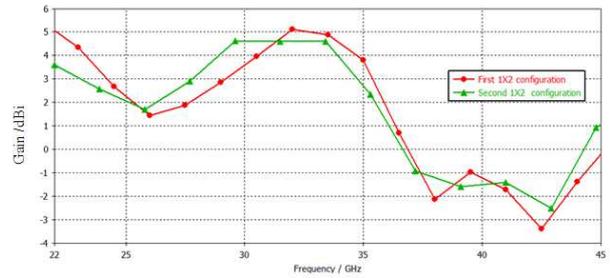


Fig.7. Simulated gain results of the proposed (a) and (b) 1X2 MIMO antenna.

### 3.2 second configuration of four elements MIMO antenna

In this step, the last 2X2 configurations are showed in fig.8 (a) and (b) of 2X2 in order to achieve the UWB from 22 GHz to 60 GHz and covers K, Ka, Q, U and V bands Applications. The global size of this model is 16X16 mm, with four 50  $\Omega$  feeding cables exiting the antenna.

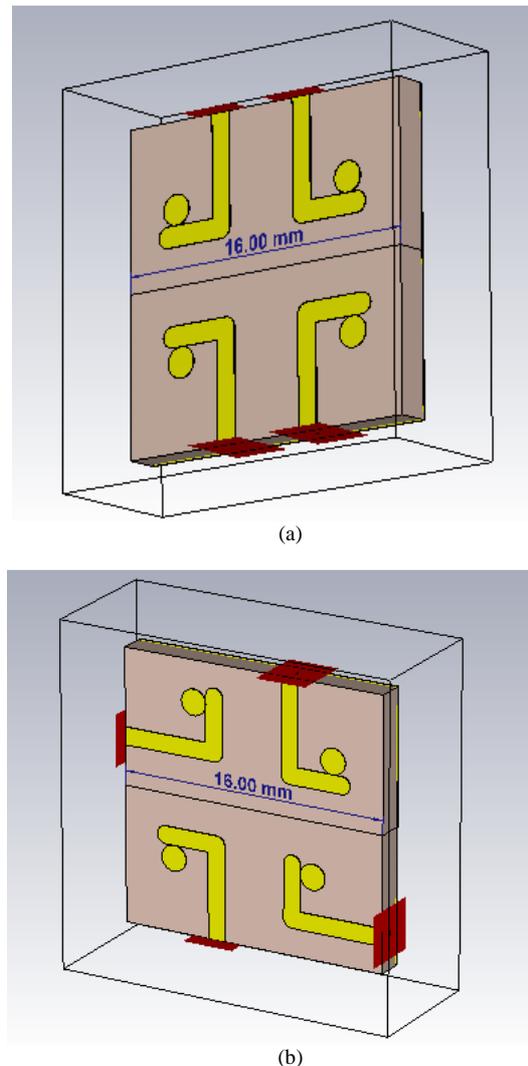


Fig.8. The proposed MIMO 2X2 antenna, (a) the first MIMO model and (b) the second MIMO model.

Fig. 9 (a) and (b) show the simulated characteristics  $S_{ij}$  of the four radiating elements MIMO antenna. The obtained  $S_{11}$  reveals a good performance from 25 GHz

to 60 GHz for both configurations (a) and (b). Otherwise, the isolation in Fig. 9 (a) indicates better performance compared to Fig. 9 (b). Fig. 10 shows the VSWR variation of the configuration fig 8 (b) which is less than 2.

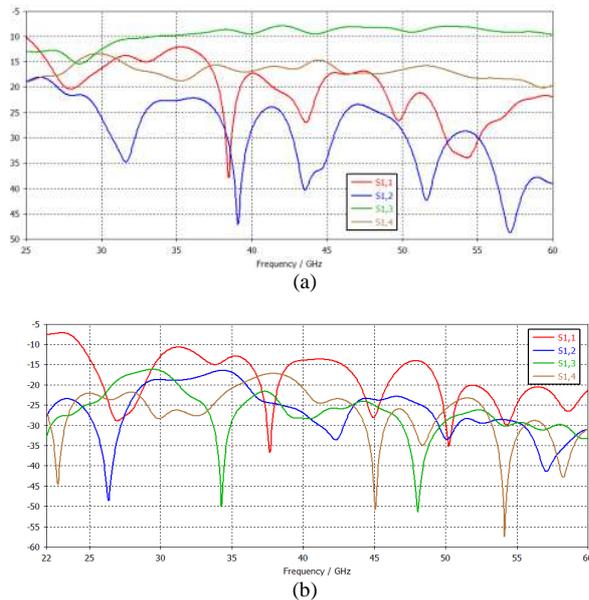


Fig9. Simulated  $S_{ij}$  result of the proposed MIMO 2X2 antenna vs. Frequency; (a) the first MIMO antenna model and (b) of the second MIMO antenna model.

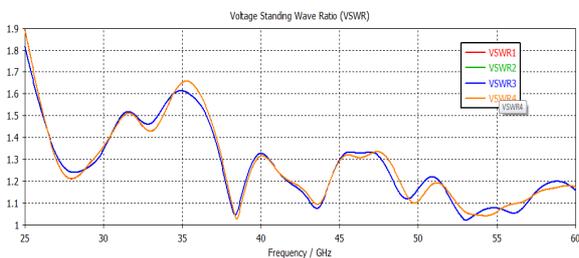


Fig10. Simulated VSWR of the first proposed MIMO 2X2 antenna .

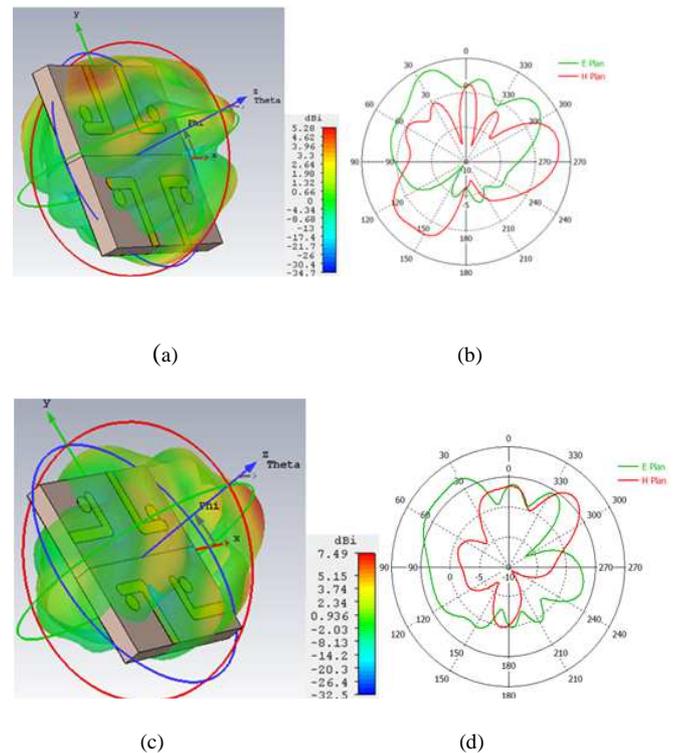


Fig11. Simulated radiation patterns at 38 GHz and 37.4 GHz of the proposed MIMO 2X2 antenna, (a) 3D, (b) polar radiation, (c) 3D, (d) polar radiation of first and second configurations.

Fig. 11 (a), Fig. 11 (b), Fig. 11 (c) and Fig. 11 (d) show the simulated far-field 3D and both polar radiation patterns E-plane and H-plane of the 2X2 MIMO configuration proposed in Fig. 8 (a) and of the second 2X2 MIMO configuration proposed in Fig. 8 (b) at 38 GHz and 37.4 GHz respectively. The main beam in E-Plan of Fig. 11 (b) deviates from the z-axis by  $24^\circ$  for 4.26 dBi of gain with a 3-dB beamwidth of  $66.6^\circ$ . And the main beam in E-Plan of Fig. 11 (d) deviates from the z-axis by  $33^\circ$  for 6.91 dBi of gain with a 3-dB beamwidth of  $66.3^\circ$ . For H-Plan, the main beam of Fig. 11 (b) deviates from the z-axis by  $282^\circ$  for 3.51 dBi of gain with a 3-dB beamwidth of  $52.5^\circ$ . And, the main beam in H-Plan of Fig. 11 (d) deviates from the z-axis by  $316^\circ$  for 6.15 dBi of gain with a 3-dB beamwidth of  $31.2^\circ$ . In the present patterns, the radiation patterns of Fig. 11 (d) for the second 2X2 MIMO configuration dominate. The full-wave simulation was carried out using CST software. These results in Fig. 11 (a), and Fig. 11 (d) are simulated at 37.4 GHz and 38 GHz giving a maximum gain of 7.59 dBi and 5.25 dBi respectively.

**Table 1.** Performance comparisons between the proposed and some previously reported MIMO antennas.

Ref.	Bandwidth (GHz)	Applications	Antenna size (mm <sup>2</sup> )	Configuration	Average isolation	Max Gain	
[11]	From 2.4 to 11	Automotive applications	24X29	1X2	15	2 dBi	
[12]	From 2.1 to 20	WiMAX and military/radar applications	37X40	2X2		5.8 dB	
[13]	From 2.6 to 4.2 and from 5.11 to 10	5G and X band	35X25	1X2	-	10 dBi	
This Work	1X2 config (a)	from 25 to 45	K,Ka,Q bands	16X08	1X2	20	5.1 dBi
	1X2 config (b)	from 22 to 45	K,Ka,Q bands	16X08	1X2	20	7.6 dBi
	2X2 config (a)	from 22 to 60	K,Ka,Q,U,V bands	16X16	2X2	20	5.28 dBi
	2X2 config (b)	from 22 to 60	K,Ka,Q,U,V bands	16X16	2X2	20	7.49 dBi

In order to evaluate the usefulness and advantages of this work, the performance of the simulated prototype is outlined in Table 1 to compare with the previously reported antennas. These common approaches are based on MIMO technology and UWB antennas. The comparison focuses on the bandwidth, antenna size, maximum gain, configuration, and application bands. In [11], the antenna mentioned has a small size and good average isolation, but low gain. It can be seen in [12] that although the antenna has a WB, there is still a large size. Ref [13] appeared as a low dual-band. However, compared with this work, the scheme of the proposed antenna is low cost, cited, for example, single substrate layer, and small size. The comparisons show, too, that the proposed antenna model has achieved a good performance in UWB and gain value.

## Conclusions

With very compact size, a dual element MIMO antenna for K, Ka, Q bands and another four-element MIMO antenna for K, Ka, Q, U, V bands with average isolation of 20 dB are designed, analyzed, and discussed. The results demonstrate that the proposed dual-element MIMO antenna operates from 22 GHz to 45 GHz, and the other four elements MIMO antenna operates from 22 GHz to 60 GHz. Moreover, other characteristics such as good gain value, and acceptable far-field radiation patterns, make both proposed configurations of MIMO antenna suitable for several wireless communication systems like 5 G and satellite communications systems.

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