Wideband MIMO antenna with enhanced isolation for wireless communication application

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Abstract: A wideband multiple input multiple output (MIMO) antenna with enhanced isolation for wireless communication application is presented in this article. The proposed antenna operates in a wide frequency range of 1.92–6.1 GHz, and is suitable for WiMAX, IEEE 802.11a/b/n/g, UMTS, LTE-2300 and LTE-2500 wireless communications. The MIMO antenna structure of the proposed antenna consists of two identical radiators with a small size of $35 \times 36$ mm$^2$ and a novel H-shaped parasitic element, which is connected to the ground plane of the proposed antenna. The H-shaped parasitic element helps in enhancing antenna isolation performance between the two antenna ports. The overall performance of the proposed antenna in terms of $S$-parameters, radiation pattern, gain, and envelope correlation coefficient is investigated and verified through the measurements. The measured results show that the proposed antenna has attractive properties such as compact size, the low mutual coupling of less than $-15.4$ dB, and a low envelope correlation coefficient of less than 0.14 across the whole operating frequency band. These attractive properties make the proposed antenna a good candidate for wireless communication application.

Keywords: MIMO, wideband, high isolation

Classification: Microwave and millimeter-wave devices, circuits, and modules

References

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1 Introduction

Multiple-input-multiple-output (MIMO) as a wireless technology, can increase the channel capacity effectively. MIMO technology has become an essential technique in most wireless standards such as wireless local area network (WLAN), and worldwide interoperability for microwave access (WiMAX) [1, 2, 3, 4, 5]. The MIMO systems are able to simultaneously transmit multiple signals through spatially parallel channels between isolated multiple antennas. In a MIMO system, data throughput is substantially increased by the introduction of spatial multiplexing gain and diversity gain. Owing to these superior features, recently emerged mobile communication standards relating to long-term evolution (LTE), worldwide interoperability for microwave access (WiMAX) and IEEE 802.11a/b/n/g for wireless local area networks (WLANs) have been incorporated into MIMO technologies and adapted to handheld mobile applications.

Recently, various MIMO antennas for UWB or WLAN/WiMAX applications have been reported [6, 7, 8, 9, 10]. However, there are some limitations in their designs. In [7], the antenna only operates a frequency range of 1.79–3.77 GHz, which is not suitable for WLAN/WiMAX applications. A bandwidth of 51.6% (2.30–3.90 GHz) is achieved in [8], which is not suitable for long-term evolution (LTE) applications. In [9] and [10], the MIMO antennas are suitable for UWB
applications, covering the bandwidth of 3–10.6 GHz. According to the author’s knowledge, by using some certain techniques, a low-frequency operating band can be achieved from previous designs.

In this paper, a wideband MIMO antenna with enhanced isolation for IEEE 802.11a/b/n/g, WiMAX, UMTS, LTE-2300 and LTE-2500 wireless communication applications is proposed. The proposed antenna covers the whole three WiMAX bands (2.30–2.36, 2.50–2.90 and 3.3–3.8 GHz), the WLAN bands (2.40–2.485, 5.15–5.35, 5.725–5.825 GHz), the UMTS band (1.92–2170 GHz), and the LTE bands (2300–2400 and 2500–2690 GHz). The antenna consists of two identical symmetrical radiating elements. To mitigate the mutual coupling, a novel H-shaped parasitic element is added to the ground plane. The antenna is designed by using a computer-based simulation software namely CST. The details of the antenna design, simulation and measurement results are presented and discussed. The optimized physical parameters of the proposed MIMO antenna are given below.

2 Antenna design and analyze

2.1 Antenna configuration

The configuration of the proposed MIMO antenna is shown in Fig. 1. The antenna is designed on a 1.6 mm-thick FR4 substrate with a relative permittivity of 4.6 and a loss tangent of 0.02, and the overall dimension is only $35 \times 36$ mm$^2$. The UWB slot antenna presented in [9] is used as a reference, but the decoupling mechanism is different, which employs the orthogonal polarization as the decoupling method and requires a larger antenna area. The proposed MIMO antenna consists of two rectangular antenna elements, denoted as Antenna 1 and Antenna 2. The two
antenna elements are placed in parallel and each antenna element is fed by a 50-Ω microstrip line. To obtain a larger bandwidth, a pair of defected ground structures (DGSs) are etched. Moreover, another DGS is etched on the ground between the two ports and an H-shaped parasitic element is added at the same time to further improve the isolation. Finally, the physical parameters of the proposed antenna are optimized as follows: \( W = 36 \text{ mm}, \ L = 35 \text{ mm}, \ l_1 = 12 \text{ mm}, \ l_2 = 5 \text{ mm}, \ l_3 = 15.5 \text{ mm}, \ l_4 = 14 \text{ mm}, \ l_5 = 15 \text{ mm}, \ l_6 = 9 \text{ mm}, \ l_7 = 2 \text{ mm}, \ l_8 = 7 \text{ mm}, \ w_1 = 2 \text{ mm}, \ w_2 = 8.5 \text{ mm}, \ w_3 = 0.5 \text{ mm}, \ w_4 = 12 \text{ mm}, \ w_5 = 0.5 \text{ mm}, \ L_f = 16.5 \text{ mm}, \ w_f = 3 \text{ mm}, \ w_{\text{gap}} = 6 \text{ mm}.

2.2 Design process and parameters optimization

The design process of the proposed MIMO antenna (denoted as Ant 4) is demonstrated as shown in Fig. 2, including Ant 1 to Ant 4. Fig. 3 shows the correspond-

Fig. 2. Evolution process of the proposed MIMO antenna.

Fig. 3. Simulated S-parameters of the four antenna configurations.
ing simulated S-parameters of the four types of antenna configurations. One can observe that when the main radiator of Ant 1 is consist of a rectangular patch and a T-shaped stub, only a single resonance mode at 4.93 GHz is generated; Ant 2 is realized by adding a pair of defected ground structures (denoted as DGS 1) to Ant 1, the reflection coefficient less than $-10$ dB of Ant 2 covers from 2.3 GHz to 6.1 GHz, but the mutual coupling of Ant 2 is just lower than $-7$ dB across the whole operating band; Ant 3 is realized by adding a defected ground structure (denoted as DGS 2) to Ant 2 between the two antenna ports, the reflection

Fig. 4. Simulated surface current distributions of the four antenna configurations.
The coefficient of Ant 3 is almost unchanged (2.18 GHz to 6.1 GHz), but the isolation shows a bit better than Ant 2; Finally, the proposed MIMO antenna (Ant 4) is obtained by adding an H-shaped parasitic element to Ant 3. As can be seen from Fig. 3(b), the mutual coupling level (S21) is improved greatly, and the reflection coefficient less than −10 dB of Ant 4 covers from 2.19 GHz to 6.1 GHz.

To further understand the operation mechanism of the proposed MIMO antenna, Fig. 4 shows the corresponding simulated surface current distributions of the four types of antenna configurations (Only Port 1 is excited while Port 2 is terminated with a matching load). As can be seen from Fig. 4(a), the first antenna model Ant 1, the currents are mainly concentrating at the T-shaped stub, so that the resonance mode of Ant 1 is mainly contributed by the T-shaped stub; for the second antenna model Ant 2, as a pair of defected ground structures (denoted as DGS 1) are etched, the impedance bandwidth is improved largely, the lower resonance mode at 2.4 GHz is contributed by the narrow gap between the long side of the main radiator (þy direction) and the DGS 1, the higher resonance mode at 5.5 GHz is mainly contributed by the gap between the short side of the main radiator (−x direction) and the DGS 1 as well the T-shaped stub; for the third antenna model Ant 3, the surface current distribution is similar to Ant 2, one obvious difference is that part of the currents are blocked by the DGS 2, resulting a small increase in isolation and impedance bandwidth; for the fourth antenna model Ant 4, the surface current distribution is similar to Ant 2 and Ant 3, but most of the currents are blocked by the H-shaped parasitic element, which improves
the isolation greatly by blocking the currents between the two antenna ports, while the impedance bandwidth is almost kept unchanged.

Fig. 5 shows the simulated S-parameters when tuning the parameter $w_{\text{gap}}$. As can be seen, it is clear that increasing the $w_{\text{gap}}$ from 3 mm to 9 mm with a step increment of 3 mm can vary the isolation greatly while the reflection coefficients are kept unchanged, the optimal isolation is obtained when $w_{\text{gap}}$ is set to 6 mm.

Fig. 6 depicts the simulated S-parameters when tuning the parameter $l_6$. One can observe that increasing the $l_6$ from 4 mm to 12 mm with a step increment of 4 mm can vary the reflection coefficients of the higher resonant frequencies (4.7 GHz–5.5 GHz) while the lower resonant frequencies are almost kept unchanged; Furthermore, the optimal mutual coupling level ($S_{21}$) less than $-15.2$ dB is obtained over the whole bands when $l_6$ is set to 8 mm.

![Illustration of the prototyped MIMO antenna](image)

**Fig. 7.** Illustration of the prototyped MIMO antenna

![Simulated and measured S-parameters](image)

**Fig. 8.** Simulated and measured S-parameters.

### 2.3 Fabrication and measurement

The proposed antenna has been fabricated and measured, and its photograph is shown in Fig. 7. The antenna elements are fed through 50 ohms SMA. The S-parameters of the proposed antenna were measured by means of a vector network analyzer, employing a coaxial cable at the desired antenna port and connecting the others to 50-Ω load.

The simulated and measured S-parameter plots are presented in Fig. 8. It could be seen that the measured S-parameters are consistent with the simulated results.
The discrepancies between the simulated and measured results may be attributed to the variations in the geometry, and mismatch of feed probe in the fabrication process. The proposed prototyped MIMO antenna operates over a frequency range of about 1.92–6.1 GHz with a measured mutual coupling level \( (S_{21}) \) less than \(-15.4\) dB.

![Graph showing ECC and gain against frequency.](image)

**Fig. 9.** Measured ECC and gain against frequency.

The measured peak gain of the proposed antenna across the whole desired band is depicted in Fig. 9. It can be seen that the minimum gain is about 2.7 dBi at 1.92 GHz, and the maximum gain is about 3.8 dBi at 6.1 GHz. Therefore, the proposed antenna exhibits stable gains across the operating bands, which is suitable for practical applications. Fig. 9 also contains the envelope correlation coefficient (ECC) which is an important parameter to evaluate the diversity characteristic of a MIMO system. The envelope correlation coefficient can be calculated from measured complex radiation pattern as [11]:

\[
ECC = \frac{\left| \iiint_{4\pi} [E_1(\theta, \phi) \ast E_2(\theta, \phi)] d\Omega \right|^2}{\iint_{4\pi} |E_1(\theta, \phi)|^2 d\Omega \iint_{4\pi} |E_2(\theta, \phi)|^2 d\Omega}
\]  

where \( E_i(\theta, \phi) \) is the complex 3D radiated field pattern for Antenna \( i \) \((i = 1, 2)\) and \( \ast \) denotes the Hermitian product. In general, the lower the ECC level, the higher the diversity. As can be seen from Fig. 9, the maximum ECC lower than 0.14 across the whole operating band, and the ECC maintained at 0.06 over most of the operating band, which means that the antenna design has a good diversity.

![Diagram showing measured radiation patterns.](image)

**Fig. 10.** Measured radiation patterns: (a) \(xoz\)-plane, (b) \(xoy\)-plane.
Fig. 10 shows the measured two-dimensional radiation patterns of the proposed antenna for three frequencies of 2.4, 3.5, 5.5 GHz. The radiation patterns are similar to each other, and nearly omnidirectional radiation patterns in the $xoz$-plane, and a dipole-like radiation pattern in the $xoy$-plane. Besides, performances comparison with several existing antennas in references are listed in Table I, it reveals that the proposed MIMO antenna does exhibit some advantages in gain, mutual coupling, bandwidth and ECC.

| Table I. Comparison of the proposed antenna and references |
|----------------------------------------------------------|
| [4]  | [7]  | [12] | This work |
| Size (mm$^3$) | 30 x 40 x 0.8 | 10 x 17.7 x 1.6 | 25 x 40 x 1.6 | 35 x 36 x 1.6 |
| Frequency (GHz) | 3.1–10.6 | 1.79–3.77 | 3.1–5.15 | 1.92–6.1 |
| Mutual coupling (dB) | <-18 | <-13 | <-26 | <-15.4 |
| Minimum gain (dBi) | 1.8 | 2.86 | 1.5 | 2.7 |
| ECC | <0.06 | <0.16 | <0.1 | <0.14 |

3 Conclusion

A wideband multiple input multiple output (MIMO) antenna with enhanced isolation for wireless communication application is presented. The MIMO antenna structure consists of two identical radiators with a small size of 35 x 36 mm$^2$ and a novel H-shaped parasitic element is connected to the ground plane. By using this H-shaped parasitic element, a better isolation performance has been achieved between the two antenna ports. The measured radiation pattern of the antenna shows nearly omnidirectional radiation and good gain variation as well. Moreover, the antenna elements have excellent ECC values. Consequently, the results obtained show that the proposed antenna has attractive properties due to being a compact size, the low mutual coupling of less than $-15.4$ dB, and a low envelope correlation coefficient of less than 0.14 across the whole operating frequency band, making it a good candidate for wireless communication application.