A Compact Wideband Open-Slot MIMO Antenna With Parasitic Strips

Hongfei Liu, Long Zhang, Yejun He*, Wenting Li and Sai-Wai Wong
Guangdong Engineering Research Center of Base Station Antennas and Propagation
Shenzhen Key Laboratory of Antennas and Propagation
College of Electronics and Information Engineering, Shenzhen University, 518060, China
Email: 2335743998@qq.com, long.zhang@szu.edu.cn, heyejun@126.com*, 525645594@qq.com, wongsaiwai@ieee.org

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***Abstract*—This paper presents a compact wideband open-slot MIMO antenna which includes six identical units corresponding to six directional beams on the XOY plane. Each unit consists of a pair of open-slot structures and a parasitic strip. The open-slot structure works in low frequencies while the parasitic strip resonates like a dipole mode in high frequencies. By introducing two isolation slits on both sides of each unit, the resonant frequency of the open-slot structure moves to higher frequency, thus effectively extending the bandwidth of the antenna, the isolation between ports has also been greatly improved. The simulated and measured results show that the proposed antenna provides the impedance bandwidth of 36.4% between 2.7 GHz and 3.9 GHz for $|S11| <$ -10 dB, the gain of higher than 4 dBi and the front-to-back ratio (FBR) of higher than 11 dB, and the isolation between ports of higher than 20 dB.**

***Index Terms*—MIMO, wideband, open-slot structure, compact.**

I. Introduction

In communication system, the beam-switching antennas are usually adopted to reduce the channel interference and signal fading and ensure the communication quality. Compared with adaptive antennas, beam-switching antennas can obtain the expected beam in a simpler way with low algorithm complexity and cost. Therefore, beam-switching antennas have been widely used in many fields such as military radar, mobile communication and short-distance communication. Some researchers have designed various beam-switching antennas using different principles[1-4]. In order to further increase channel capacity, we focus on wideband antennas with beam switching function.

Open-slot antennas have attracted more and more attention because of their simple structures, low profile, wide bandwidth and directional property. In order to further expand the bandwidth of the open-slot antenna, T-shaped and L-shaped open slots are proposed in [5]. Compared with rectangular open-slot antenna, L-shaped and T-shaped open-slot antennas are easier to excite more resonant modes and obtain wider impedance bandwidth. Scholars have also proposed a series of methods to improve the directional radiation characteristics of open-slot antennas, so that slot antennas can meet the application of strong directional radiation characteristics. In [6], a pair of open-slot antennas with the same opening direction are placed horizontally so that the back radiation of the front open-slot antenna and the forward radiation of the rear open-slot antenna offset each other by using a feed-source with a phase difference of 90°, which weakened the back radiation of the antenna, and then achieved a high FBR. A wideband quasi-yagi antenna proposed in [7] adopts a trapezoidal connection structure and etches a pair of holes on the ground, which has the characteristics of wide band and unidirectional radiation.

The designed compact wideband open-slot MIMO antenna in this paper has the following structures and advantages. Firstly, a parasitic strip is placed at the opposite end of the open slots, which introduces a dipole mode and improves the bandwidth of the antenna. At low frequency, the parasitic strip also acts as a director to improve the FBR of the antenna. Secondly, a pair of open-slot structures are introduced to stabilize the antenna pattern. Finally, slotting on both sides of the open-slot structure improves the isolation between antenna ports. The antenna chassis is a hexagonal structure to achieve beam switching.

II. Antenna Design

A. Antenna Structure

The perspective view of the proposed antenna is shown in Fig. 1, which consists of six identical units. The feed lines are on the top layer and the bottom layer is radiation patch. The middle layer between the top layer and bottom layer of the proposed antenna is RO4003 substrate with the thickness of 0.508 mm. The physical dimensions of the antenna are shown in Table 1. The energy is coupled to the open-slot structures in the way of common mode fed by the Wilkinson power dividers. A parasitic strip is at the opposite of the open-slot structures, and two slits are distributed on both sides of each unit.

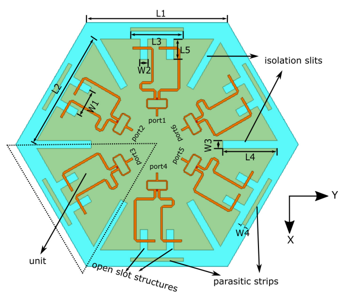


Fig. 1. Configuration of the Proposed Antenna.

TABLE I
PHYSICAL DIMENSIONS OF THE PROPOSED ANTENNA

Parameters	L1	L2	L3	L4	L5	W1	W2	W3	W4
Dimensions (mm)	75	65	28	30	11	14	4	4	2

B. *Antenna Analysis*

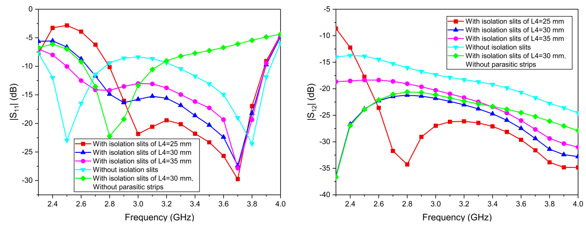
The open-slot structure evolves from the narrow-slot structure. By cutting the half-wavelength narrow-slot antenna along the symmetrical position of the center, the open-slot antenna retains the original resonance characteristics. The slot length of the open-slot antenna is only half of the length of the narrow slot, which is about a quarter of the wavelength. Due to the reduced restriction of current, the open-slot antenna is easier to generate displacement current and radiate electromagnetic waves. Compared with the narrow-slot antenna, the open-slot antenna has a lower Q value, and it is more easily to obtain a wide antenna impedance bandwidth.

The proposed antenna mainly focuses on how to further expand the antenna bandwidth. There are many ways to improve the bandwidth of the antenna, such as changing the feeding mode, introducing the gradient structure, adding new resonant modes, etc. Due to its simple principle and easy combination with other antennas, it is very convenient to introduce the dipole mode at the end of the open-slot structure in this design. On the other hand, the introduced dipole can also increase the gain of the open-slot mode, and reduce the back lobe, just act as a director which is similar to the principle of Yagi antenna.

Open-slot antenna has natural directional radiation properties. However, the gain of open-slot antenna is often not very high, and the back lobe is very large. At the same time, the asymmetry of the antenna feed also causes the asymmetry of the radiation pattern. Therefore, single open-slot antenna often can not meet the requirements of some specific applications. To overcome the shortcomings of the above single open-slot antenna, this design uses a pair of open-slot antennas, which can effectively improve the antenna gain, reduce the back lobe of the pattern, and make the antenna pattern more symmetrical.

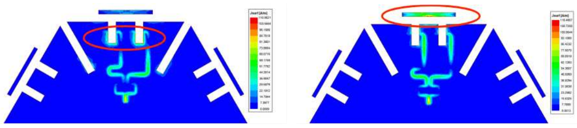
The other key characteristic in this design is to improve the isolation between ports. The ground current is an important reason for the deterioration of the isolation of ports, thus an effective method to improve the isolation of ports is to slot on the ground. Obviously, this design is also suitable for slotting on both sides of the open-slot structure.

Based on the above analysis, Fig. 2 shows the influence of parasitic strips and isolation slits on the antenna bandwidth. Compared with and without parasitic strips, it can be clearly seen that the antenna with parasitic strips introduces a new resonant mode at high frequencies, which can be called the dipole mode. It should be pointed out that new added slits play the role of improving the isolation, and the resonant frequency with the open-slot antenna is higher than that without the open-slot antenna. Moreover, as the length of the open slot increases, the resonant frequency increases less and less, and the isolation also deteriorated. Fig. 3 shows the current distribution describing the operating modes of the antenna. The current distribution of the antenna operating at 2.9 GHz is near the open slots (Open-slot mode). The current distribution of the antenna at 3.7 GHz is near the parasitics (Dipole mode).



(a) (b)

Fig. 2. The influence of parasitic strips and slits on the antenna bandwidth and isolation.



(a) (b)

Fig. 3. Antenna current distribution when port 1 is excited (only the upper part of the antenna is shown). (a) 2.9 GHz (b) 3.7 GHz

III. SIMULATION AND MEASUREMENT RESULTS

The antenna was optimized using the ANSYS Electronics Desktop to achieve an acceptable tradeoff among FBR, bandwidth and isolation. The simulated and measured S parameters of the proposed antenna are shown in Fig. 4. Good agreement between the simulation and measurement results is observed. where the relative bandwidth of 36.4% between 2.7-3.9 GHz for $|S11| <$ -10 dB is obtained, the isolation between adjacent ports of the antenna is less than -20 dB, and the isolation between non-adjacent ports is less than -30 dB.

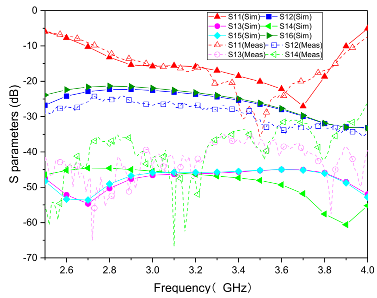


Fig. 4. Simulated and measured Scattering parameters of the proposed antenna.

The simulated and measured realized gain and FBR versus frequency are plotted in Fig. 5. Discrepancies between the simulated and measured results is due to the fact that far field measurement equipment error and SMA connector welding factors. In the frequency range of 2.7 GHz to 3.9 GHz, the gain of the proposed antenna is more than 4 dBi, and the FBR is more than 11 dB. Fig. 5 also shows the gain and FBR of the proposed antenna with parasitic strips are improved.

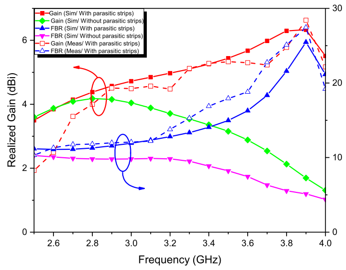


Fig. 5. Simulated and measured realized gain and FBR of the proposed antenna.

Fig. 6 shows the simulated and measured radiation patterns of the proposed antenna at port 1 in 2.9 GHz and 3.7 GHz. The difference of cross-polarization between simulation and measurement results is mainly due to the limitation of measurement equipment. It can be seen that the proposed antenna has very low cross-polarization at both 2.9 GHz and 3.7 GHz. The half-power beamwidth of the antenna in horizontal plane (XOY) is almost 80° at 2.9 GHz and 3.7 GHz. In the vertical plane (XOZ or YOZ), the half-power beamwidth of 180° at 2.9 GHz is wider than that of 153° at 3.7 GHz. The gains of the proposed antenna at 2.9 GHz and 3.7 GHz are 4.8 dBi and 6 dBi, respectively. The FBRs of the proposed antenna at 2.9 GHz and 3.7 GHz are 11.5 dB and 18 dB, respectively. Fig. 7 shows the simulated radition patterns of the proposed antenna at six ports in 3.3 GHz, and the corresponding half-power beamwidth of six ports can cover the XOY plane. A prototype of the proposed antenna is shown in Fig.8.

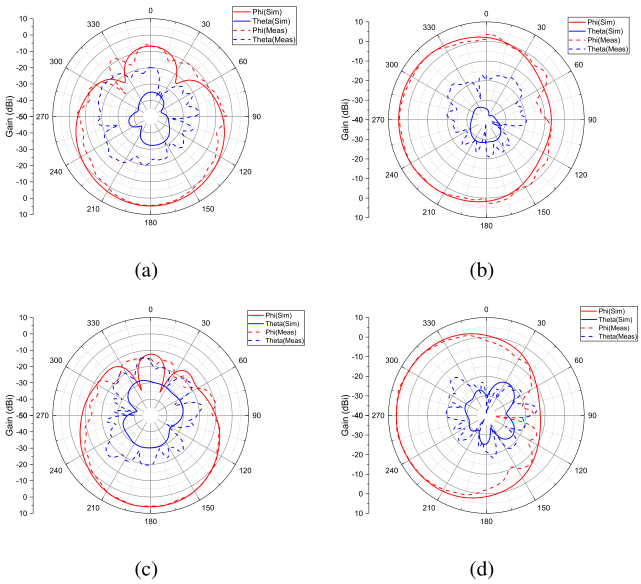


Fig. 6. Simulated and measured radiation patterns of the proposed antenna at port 1. (a) 2.9 GHz, XOY plane. (b) 2.9 GHz, XOZ plane. (c) 3.7 GHz, XOY plane. (d) 3.7 GHz, XOZ plane.

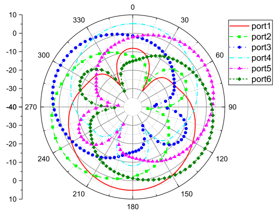


Fig. 7. Simulated and measured radiation patterns of the proposed antenna at six ports in 3.3 GHz (XOY plane).

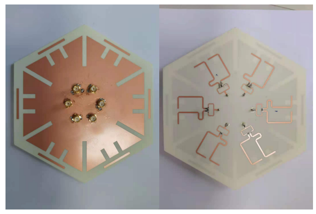


Fig. 8. A prototype of the designed antenna.

IV. Conclusion

A compact wideband open-slot MIMO antenna was presented to achieve beam switching. By introducing parasitic strips, a dipole mode is added to the antenna to extend the antenna bandwidth and improve the antenna's FBR. The improvement of isolation is realized by slotting adjacent units. The effect of isolation-slit length on bandwidth and isolation is also analyzed. Simulation and measurement results show that for the beam-switched antenna, the bandwidth of 36.4% between 2.7 GHz and 3.9 GHz for $|S11| < $ -10 dB is achieved, the gain is more than 4 dBi, the FBR is up to 11 dB, and the isolation of each port reaches 20 dB. Obviously, the proposed antenna has a wide bandwidth, high isolation, low cross polarization, good FBR and high gain, which can meet the requirements of related wireless applications.

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