A Novel Metal Ground Plane Design Methodology for Optimizing MIMO Antenna Isolation

Long-lin Ji, Yu-feng Shih and Yi-shang Huang
Micro-Star International Co., Ltd
No.69, Lide St., Zhonghe Dist., New Taipei City 235, Taiwan

Abstract—Based on the electric platform designs such as All-in-one (AIO) PC, laptop and tablet PC, this article propose a quickly procedure to optimize the isolation of MIMO antennas even though the antenna structure is unknown. With two 50ohm loads as feeding sources, a simplified procedure to optimize the central slotted ground plan was introduced to achieve minimal isolation. Taking a 2.4GHz PIFA antenna system for example, similar trends between real case and simulation were observed, so the feasibility of this proposed method was verified and work well.

I. INTRODUCTION

As time progresses, wireless local area network (WLAN) technology continuously develops and wireless technology keep improving from IEEE802.11a/b/g with single-input single-output (SISO) technology to IEEE802.11n/ac with multiple-input multiple-output (MIMO). However, it is difficult to achieve optimal MIMO antenna placement, because of slim and light trends. Modern small devices don’t have enough space for antennas and the adjacent MIMO antennas were coupled and interference with each other. Besides, the common noise also cause signal loss and reduce the transmission rate. Hence, it is important to achieve optimal MIMO antennas and improve isolation of the MIMO antenna in a limited space.

The traditional methods usually utilize simply spatial diversity, such as the spacing between two planar inverted-F antennas (PIFAs) is required to be at least greater than half the free-space wavelength above a common ground plane [1]. Otherwise, Electromagnetic band-gap structures (EBGs) have been investigated to increase the isolation as well in [2]. Other techniques have been presented to enhance the isolation between the MIMO antennas such as a coupling element [3], the defected ground structures (DGS) [4] and the inserted ground slot or T-shaped slot [5]. Recently, a compact T-shaped open-ended ground slot with a chip capacitor between two closely packed PIFA is proposed for isolation improvement and size reduction [6], [7].

Nevertheless, almost all of the previous methods are based on double layer printed circuit board (PCB) design. In this paper, the major consider is the situation that realistic antenna systems as shows in Fig. 1 and Fig. 2, the antenna grounds are attached to metal chassis or aluminium foil. This kind of antenna ground is not only practical but complicated relatively. This paper will introduce a quick method to find out an appropriate slot size to achieve optimal isolation for the pre-design of ground metal parts in electric devices.

Fig. 1 WLAN antenna attached on chassis in AIO

Fig. 2 WLAN antenna attached on aluminium foil at the panel part of laptop

To simplify the case, a system with two PIFA antennas shown as Fig.3 is described as an example. Both of the antennas are attached on the 118mm x 69mm copper foil plate, and all of antennas and copper foil are stuck on a plastic sheet with a dielectric constant of 2.4 and a thickness of 2.2mm. Owing to improve the isolation property among different ground slot designs, a ground slot is set in the center of copper foil.

Fig. 3 Geometry of PIFA antennas with common ground structure
I. METHODOLOGY OF SLOT OPTIMIZATION

During actual system development process, the electrical parameters and mechanical sizes of materials are modified frequently, such as antennas, plastic parts, LCD, webcam and cables. If we want to design a suitable slot on the ground plane to improve isolation after every parts are all decided, it will become an impossible mission because of extra cost of modification and the time pressure to market. Thus, an effective methodology is presented to simplify the design of slot on the metal ground plane and is shown as Fig. 6.

First of all, because the slot has acted as a band-stop filter [6], the main filtering characteristic of slot is dominated by the current distribution on the ground plane, the influence of different antennas are assuming to be ignored. Consequently, two MIMO antennas were changed to SMA feeding structure consist of 50ohm load and shorting pin to ground plane as Fig. 5 shows. The measurements of S-parameter were done with the SMA outputs connected to port1 and port2 of a vector network analyser (VNA) via coaxial cables as the setup of Fig. 4. The 50 ohm load between centre pin and outside metal plays the role of a broadband matching circuit. The positions of 50ohm loads are suggested to be as near the feeding point of PIFA antenna as possible. The advantage of this exchange is that we can ignore the antenna structure and various components in the real system, thus we can focus on the design of ground slot, since the leakage surface current is coupled to adjacent antenna through common ground plane, not antenna. Afterward, the length of slot is set as a quarter of wavelength at the beginning [8], and then the optimal width of slot can be fine-tuned and obtained through checking the minimal S21 within the working range from 2.4GHz to 2.45GHz.

The next step is to fine-tune the length of slot to acquire a more accurate resonant frequency. Finally, after applying this optimal slot size on the ground plane, the corresponding antenna characteristics may shift slightly and should be adjusted again to get better antenna performance. Finally, the slot optimization for isolation enhancement is completed if all the steps are finished.

![Fig. 4 Measurement setup of slot optimization](image)

![Fig. 5 Detail view of SMA connector feeding with 50ohm load](image)

![Fig. 6 Optimization methodology of slot for isolation improvement](image)

II. CHARACTERISTIC ANALYSIS OF GROUND SLOT

A. Simulation of isolation with 50ohm loads

The simulation of proposed method is simulated as Fig. 7 and the excitation of port1 and port2 were both 50ohm resistive source. The locations of both 50ohm resistors are near the feeding points of PIFA antennas, and the transmission loss of two ports was considered as the indicator of isolation.

![Fig. 7 Simulated ground structure with 50 ohm loads (Unit: mm)](image)

The length of slot is a quarter of operation wave length at 2.45GHz which is 30.6mm [8]. As shown in Fig. 8, a resonant
frequency is observed due to the slot, and it will move toward lower frequency as long as the width of slot becomes larger. Besides, the isolation at 2.45GHz can be significantly reduced about 30dB if the slot width is set to 17mm.

Furthermore, by applying fixed slot width of 17mm, the influence of slot length can be observed as Fig. 9. The resonant frequency will move toward lower frequency while the slot length is getting larger. The best slot length is determined to 30mm as the simulation results of Fig. 8 and the minimal transmission loss occurs as well.

It is obvious that the optimal slot (w=17mm, l=30mm) on the ground cause less coupling noise to the adjacent antenna in Fig. 9 and the slot performs as a band-stop filter between two antennas.

![Fig. 8 Simulated S-parameters with slot length 30.6mm](image)

**Fig. 8** Simulated S-parameters with slot length 30.6mm

![Fig. 9 Simulated S-parameters with optimal slot width 17mm](image)

**Fig. 9** Simulated S-parameters with optimal slot width 17mm

**B. Simulation of isolation with PIFA antennas**

In order to verify the antenna performance with optimal slot size, structure with two PIFA antennas as mentioned in Fig. 3 was simulated. Fig. 10 shows the simulated S-parameter, and it is found that the slot on the ground contributes to more than 20dB isolation reduction over the working WLAN band. By observing S11, the resonant frequency of antenna is moving toward the lower frequency with a central slotted ground plane.

![Fig. 10 Simulated S-parameter of PIFA antenna system](image)

**Fig. 10** Simulated S-parameter of PIFA antenna system

**C. Surface current distribution**

To better understand how the ground slot improves isolation, the survey of surface current is presented in this section. The scale of surface current has been set as logarithm scale because the level of surface currents on the ground plane is much smaller than the exciting source.

If the source is excited to the PIFA antenna on the left side, a strong coupling current also can be found in Fig. 11 (a). Furthermore, if the slot has introduced on the ground, a good band-stop filter characteristic can be seen in Fig. 11 (b), and the surface current on the right side become very small. Hence, for a common ground MIMO antenna system, the isolation can be decreased significantly, if the ground slot has been designed well.

![Fig. 11 Surface current distribution with PIFA antennas](image)

**Fig. 11** Surface current distribution with PIFA antennas
III. Simulation and Measurement Results

A prototype of antenna system was fabricated as Fig. 4, and the feeding structure are SAM connectors with 50ohm loads. As shown in Fig. 12, the measured resonant frequencies of S21 matched quite well with the simulation one, and the minimal isolation can reaches the level of about -80dB.

The configuration of investigated antenna system is depicted as Fig. 13, and it can be seen that a good correlation between simulation and real case in Fig. 14, and hence this optimization procedure can be evaluated to work well.

In this work, we investigated an efficient and low cost method for MIMO antenna isolation optimization even though the structure is complicated and with unknown materials. By applying a pair of SMA with 50ohms loads and shorting pins, the optimal slot on common ground structure can be obtained easily step by step.

Since the resonant frequency of S21 is dominated by width and length of slot, thus the isolation between two antennas can be reduced more than 20dB by applying optimal slot size in this study. Furthermore, this method is supposed to be extending to more complicated structure such as multi-antenna system during design stage in the future.

IV. Conclusion

The authors would like to thank I-Fong Chen professor of Jinwen University of Science and Technology for technical support about simulation and measurement.

REFERENCES


Fig. 12 S-parameter measured by SMA connector with 50ohm load & shorting pin when a proposed slot is in common ground plane

Fig. 13 Photograph of 2.45GHz PIFA antenna system with optimal slot size

Fig. 14 S-parameter simulated and measured with original PIFA antennas