A Compact MIMO Planar Inverted-F Antenna

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Abstract. In this work, a compact MIMO antenna is designed as a planar inverted F-antenna (PIFA) which can be used for smallest smartphones. The proposed antenna will cover the GSM frequency range of 900MHz and 1800MHz. Those dual bands are attained with high gain up to 4.7dB. Simulation and experimental results have been presented.

1. Introduction

Recently, the microstrip antenna technology has been rapidly developing [1-3]. In fact, the demand for microstrip antennas will expand even further in personal communication systems (PCS), direct broadcast televisions (DBS), mobile satellite communications, wireless local area network (WLANS) and also intelligent vehicle highway systems are known as IVHS [1]. The development of microstrip antennas has been driven by system requirements for antennas that have the characteristic such as low profile, low weight, planar configuration, low cost, easy integrality into arrays and any more.

The main point of microstrip antenna was introduced by G. A Deshamps in 1950s [4]. A multiple of antenna has been designed and implemented for 2 × 2 MIMO handset applications [5]. The proposed antenna for this paper is planar inverted-F antenna which is suitable with its characteristic that has resonance at λ/4 whereas it can be reduce the overall space of the antenna [6].

The most important factor to improve the performance of the antenna is the role of ground plane. For an instant, the ground plane has to be used to lower the frequency operation and used as a radiating part. But, the disadvantage of the ground plane when its radiating part is the effect of the user’s hand is likely to reduce the antenna performance. This will be happening when the antenna is fitted inside the smartphones [7-8]. Besides, the ground plane also plays an important role in the radiation process. Hence, there are some strategies which add intelligence in the ground plane have appeared in order to increase the number of operating bands and make the antenna compact and small.
2. Antennas Design Configuration

A detailed of the proposed antenna structure will be presented in two categories as a single inverted antenna and MIMO antennas as follows:

A. Single Antenna Design

The design of Planar Inverted F-Antenna begins with the calculation of the dimension or antenna design specifications where the antenna consists of a main radiator with an irregular shape, shorting walls, a rectangular slot, and also the ground plane. FR4 is the material used for substrate with 4.4 of dielectric constant, 0.02 of a loss tangent and 1.57mm height of substrate. While the size of the ground plane of PIFA is $40 \times 40$mm. This PIFA antenna must have very small of size and physically thin. Figure 1 (a) and Figure 1 (b) shows the front and side view of the single PIFA antenna respectively.

![Figure 1](a) Front view and (b) side view of single PIFA antenna.

B. MIMO Configuration Antenna Design

MIMO configuration is applied by placing the second one of single antenna at the PCB. The positioning and placement of the two antennas are varied. However, this position should not use more than allowed space of $65 \times 100$ mm PCB board. In recent research, the researchers remind that the optimum configuration possible in the space provided is a configuration of the first antenna placed vertically at the top left corner and the other one of single antenna are placed at the bottom right corner in horizontal. Figure 2 shows the front view of MIMO configuration.

Two materials were identified in designing the antenna that can compact in smartphones. The ground with dimension of $21mm \times 40mm$ and upper patch layer used copper as a material while FR4 is a material for the substrate of the antenna with the dimension of FR4 is $100mm \times 40 mm \times 1.54mm$. This is because copper is the best materials that made from high conductivity metal. This antenna is fed by 50 Ohm coaxial probe feeding structure. Upper patch of the proposed antenna is demonstrated in Figure 3 by referring the design model in the CST microwave software. These copper plates must be measure same as the model design in order to ensure the simulation result is exactly same with the measurement result. Furthermore, the ground plane also will be measured by referred the design model precisely. Figure 4 shows the antenna prototype after the fabrication process done.
3. Result and Discussion

Figure 5 indicates the obtained reflection coefficient in the case of ground plane length; GP is adjustable with five different lengths. It can be seen that S11 at 63mm represents the best result among the others which is -26.4 dB. However, the others length is slightly same. Moreover, 63mm length of the ground plane is not exactly match at 0.9GHz and 1.8GHz frequency bands whereas 78mm length of ground plane shows more accurate result with -10.7dB return loss, which meets the requirement of the design which is less than -6 dB. Table I shows the obtained values frequency drop and gain based on size of ground plane at different size. Besides that, the length of the certain part of antenna design is measured and simulated one by one in order to get the accurate drop of frequency needed for GSM. The frequency required for this research is GSM900GHz and GSM1800GHz.
Figure 5. Reflection coefficient S11 with different GP length.

Table 1. Different size of ground plane

| Length (mm) | Frequency Drop (GHz) | Gain (dB) |
|-------------|----------------------|-----------|
| GP=78       | 0.920, 1.801         | 1.847, 4.592 |
| GP=73       | 0.941, 1.810         | 1.770, 4.486 |
| GP=68       | 0.949, 1.817         | 1.859, 4.443 |
| GP=63       | 0.954, 1.825         | 1.984, 4.383 |
| GP=58       | 0.962, 1.828         | 2.598, 4.387 |

Figure 6 shows the reflection coefficient at five lengths of Y1 as shown in Figure 2. Five different lengths of the proposed design are selected as 27.5mm, 28.5mm, 29.5mm, 30.5mm, and 31.5mm separately. However, the length at 27.5mm shows -10.7dB of reflection coefficient at frequency drop 0.94GHz. In contrast, the tuning size of X1 is needed to improve the proposed antenna gain as shown in Figure 7. Several size of X1 which are 10.0mm, 10.5mm, 11.0mm, 9.5mm, and 9.0mm are chosen and optimized whereas the obtained result indicate best result at 10.0mm length of X1. Figure 8 shows the observed result for MIMO configuration at different Y1 length. For desired frequency at 1.8Ghz, the selected Y1 length has no much affect which mean the five values of this frequency is slightly same but at 0.9GHz, the graph shows too much different in aspect of frequency drop.
Figure 6. Reflection coefficient S11 with different Y length

Figure 7. Reflection coefficient S11 with different X length

Figure 8. MIMO reflection coefficient S11 with different Y length

Figure 9 (a) and (b) show the far field view of single antenna of PIFA with operating at frequency 0.8GHz and 1.9GHz respectively with a different value gain and directivity. Gain of antenna is a most important parameter which it describes the amount of power been transmitted in the direction of peak radiation. Gain is a measurement of the ability of the antenna to direct the input power into radiation in a particular direction and it’s measured at the peak radiation intensity. Based on that figure, the gain values are 1.847dB and 4.592dB is obtained for the frequency 0.9GHz and 1.8GHz respectively.

Figure 10 (a) and (b) show the gain proposed MIMO antenna. The achieved gain values are 2.434dB for frequency 0.9GHz and 4.224dB for frequency 1.8GHz. The simulated and measured
result is shown in Figure 11. It can be seen that the lower frequency is slightly shifted due to fabrication process as well as the high frequency showed some ripple in the measured result but still can be accepted in the range as needed for mobile applications which is indicated at threshold value of -6 dB.

![Figure 9](image1.png)

**Figure 9.** 3D polarization for farfield for gain for (a) 0.9GHz and (b) 1.8GHz

![Figure 10](image2.png)

**Figure 10.** 3D polarization for farfield for directivity for (a) 0.9GHz and (b) 1.8GHz
4. Conclusion

A compact planar inverted F-antenna antenna for smartphone applications is designed and fabricated. The antenna configuration is capable to operate at two operating frequency bands which are 900MHz and 1800 MHz. This paper starts by designing a single antenna followed by MIMO antenna. Dual bands with high gain up to 4.7 dB are achieved.

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