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# A COMPACT MIMO ANTENNA FOR SMART PHONE APPLICATION AT 900 MHz AND 1800 MHz

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## ABSTRACT

This paper presents a design of compact Multiple Input Multiple Output (MIMO) of Planar Inverted F-Antenna (PIFA) involving parameters which may affect the characteristics of PIFA. The proposed antenna consists of two ports with one patches operates at GSM frequencies which is 0.9 GHz and 1.8 GHz. The single antenna is fabricated on an inexpensive FR4 a dielectric constant of $\varepsilon = 4.3$, with thickness of substrate that is 1.54 mm and the thickness of patch is 0.035 mm. The simulated result represents that the proposed antenna obtained the reflection coefficient as needed which is at least ≤ -6 dB for single antenna design and also for MIMO configuration of antenna. Simulation by using CST Microwave Studio program and measurement on the final prototype antenna were carried out and compared. A MIMO system characteristic of a two port MIMO antenna is performed. A two port antenna for mobile applications is designed, the antenna shows good in frequency drop, radiation pattern and reflection coefficient.

**Keywords:** MIMO antenna, PIFA, compact antenna.

## INTRODUCTION

MIMO known as Multiple Input Multiple Output used multiple of antennas at the transmitter and receiver in order to enhance the performance in the communication system. This multiple of antenna use the same hardware to process the radio signal. MIMO will be operated when two or more data signals transmitted at the same time to use the same radio channel. There are four types of multiple antenna which are SISO, SIMO and MISO [1]. SISO (single input, single output) means when the transmitter and the receiver of the radio system that has one antenna for both sides. While SIMO (single input, multiple output) have multiple antennas at the receiver and one antenna at the transmitter. Next, as the transmitter have multiple of antenna and only have one antenna at the receiver is known as MISO (multiple input, single output). MIMO can be divided into two major categories which are spatial diversity and spatial multiplexing [2]. Diversity also can improve the quality of bit-error rate (BER) in the communication system.

MIMO is a radio antenna technology that efficiently uses a multiple of the antenna at the transmitter and receiver to enable a variety of signal path to carry the data. Choosing separate paths for each antenna is the way in order to enable multiple signal paths to be used.

Planar Inverted-F antenna (PIFA) is a rectangular antenna that charge by a feed probe. Nowadays, PIFA is the most popular antenna used in smart phones because its own characteristics such as good performance, low profile, easy to fabricate and relatively low specific absorption rate or known as SAR [3]. Because of the side view of this type of antenna and its air dielectric approximate to the letter F with its face down, it is called an inverted-F antenna. Besides that, there are the most important reasons why this kind of antenna used in smart phones. It is due the size of the antenna that can be hidden in the smart phone housing if compared to other antennas.

A digital mobile telephony systemm that widely used in Europe and other parts of the world is Global System for Mobile (GSM) communication. It can be operated in two frequency band either 900Mhz or 1800 MHz. GSM will operate to compute and compress the received data. Besides, it will send down a channel with two other streams of user data on its own time slot. The spectrum frequency for GSM1800 and GSM900 are shown in Figure-1 [4].


**Figure-1.** Spectrum frequency for mobile 1800 [4].

The proposed antenna manage to operate for dual frequencies of 900 MHz and 1800 MHz in a single compact antenna. It is used as the MIMO antenna is Planar inverted F-antenna (PIFA) due to its own characteristic that can be integrated into the smallest smartphones nowadays. Moreover, small backward radiation is one of the advantages of PIFA in order to reduce the specific absorption rate or known as SAR that can degrade the antenna performance in handset application.

## ANTENNA DESIGN

In this research, 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

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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 40x40mm. This PIFA antenna must have very small of size and physically thin. Figure-2 and Figure-3 show the front and side view of the single PIFA antenna respectively.

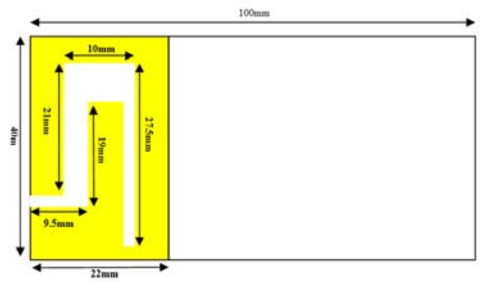


**Figure-2.** Front view measurement of single PIFA antenna.

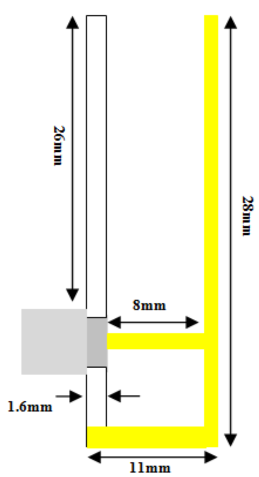


**Figure-3.** Side view measurement of single PIFA antenna.

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 65x100 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-4 shows the front view design of MIMO configuration.

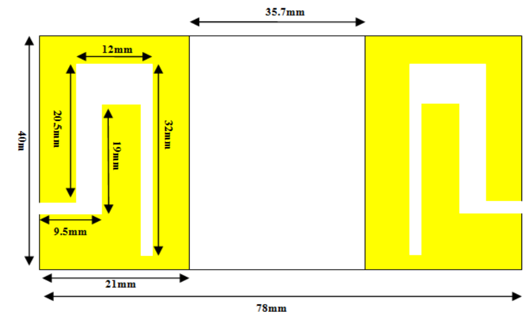


**Figure-4.** Front view of MIMO antenna.

In this project, two materials were identified in designing the antenna that can compact in smartphones. The fabrication process is a process before the measurement process occurs. The ground with dimension of 21 mm x 40 mm 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 100 mm x 40 mm x 1.54 mm. 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. Figure-5 below shows the geometrical of the three layer of the single antenna while Table-1 indicates the specification parameter for single PIFA.

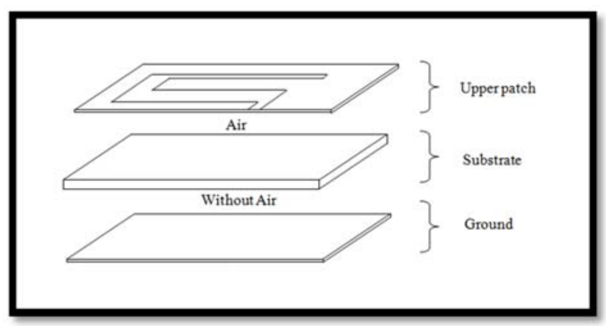


**Figure-5.** Geometrical of three layer of the antenna design

**Table-1.** Specification of parameter for single PIFA.

| Shape | Rectangular |
|---|---|
| Frequency of operation | GSM900<br>GSM1800 |
| Dielectric constant of the substrate | 4.3 |
| Height of dielectric substrate | 1.54mm |
| Feeding method | Coaxial probe |
| Gain | (0 - 5)dB |

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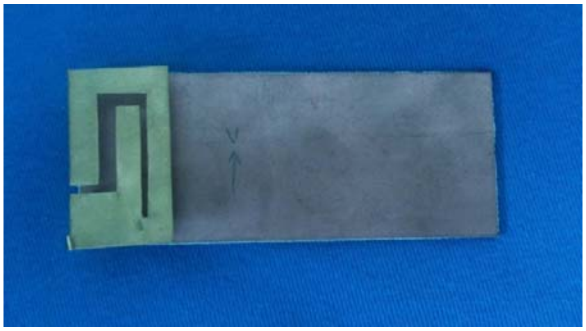

**Figure-6.** The fabricated antenna.

The PIFA is fabricated by referring the design model in the CST microwave software as shown in Figure-6. 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 refered to the design model precisely.

## RESULTS AND DISCUSSIONS

Generally measurement process is measured using network analyzer in order to get the result waveform that must be same when doing the simulation process. The network analyzer has two port which are support the frequency from 300kHz up to 20GHz. Then, one of the port is connected to antenna under test (AUT) and the result of reflection coefficient will appears directly. The measurement setup can be expressed as Figure-7 and Figure-8 shows the antenna under test setup.

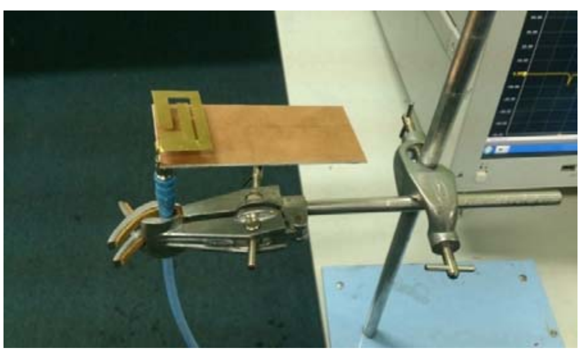

**Figure-7.** Reflection coefficient measurement setup.

The measurements of radiation pattern was measured in anechoic chamber as shown in Figure-8 using vector network analyzer as equipment for testing the AUT. Port 1 of VNA is connected to the horn antenna as the transmitter while the other port of VNA is connected to the AUT as the receiver.

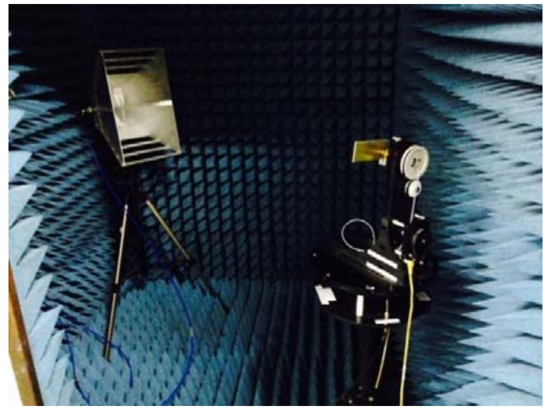

**Figure-8.** Anechoic chamber setup.

This results are categorized into three parts which are simulation results of a single PIFA antenna, the simulation results of MIMO antenna, result of measurement for single antenna and discussion in a parametric study. Parametric study is done on PIFA for better understanding the antenna behavior to improve the antenna performance in term of operating frequency and gain. S11 or refelction coefficient represents how much power is reflected from the antenna, and hence is known as the reflection coefficient. A good performance of the antenna should indicate a refelction coefficient of less than -10dB, but the refelction coefficient for mobile applications of less than -6dB is acceptable.

Figure-9 below indicates the result obtain when the length of ground plane, GP is adjustable with a five different length. The S11 result for 63mm present the best result among the others which is reflection coefficient for this length is -26.4 dB. While the others length is slightly same. However, 63mm length of the ground plane is not the best result in the frequency drop which is its frequency drop not exactly at 0.9GHz and 1.8GHz. Therefore, 78mm length of ground plane shows the accurate result in frequency drop and the reflection coefficient of this length is acceptable where the S11 is -10.7dB, which meets the requirement of the design which is less than -6 dB.

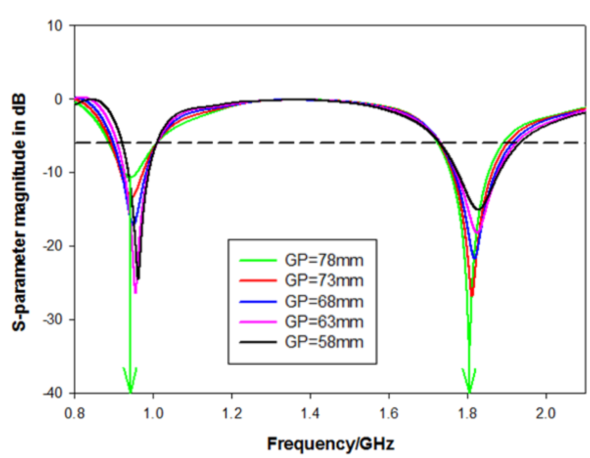


**Figure-9.** S11 results for variance of GP of single PIFA.

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Figure-10 shows the reflection coefficient result in five lengths of Y1 (slotted length). Five different lengths of 27.5mm, 28.5mm, 29.5mm, 30.5mm and 31.5mm are investigated. However for the 27.5mm length Y1 shows the needed result in aspect of reflection coefficient and also the frequency drop which is 0.94GHz and 1.8GHz respectively while the reflection coefficient of this selected length is -10.7dB.

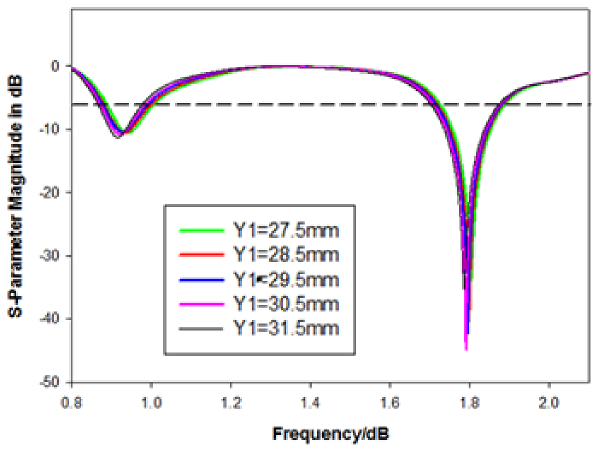


**Figure-10.** S11 result for various Y1 of single PIFA.

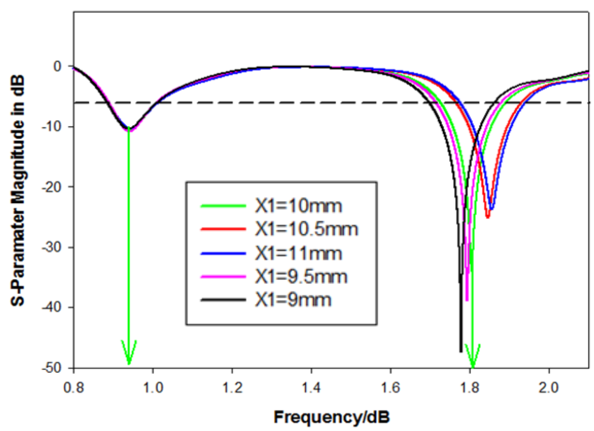


**Figure-11.** S11 result for various X1of single PIFA.

The tuning size of X1 is needed in order to improve the frequency drop of desired antenna. There are also five measurement need to be considered to improve the gain and also frequency drop of each required frequency. The measurement are when X1 is 10.0mm, 10.5mm, 11.0mm, 9.5mm, and 9.0mm as in Figure-11. Based on Figure-11, the 10.0mm length of X1 shows the best result for frequency drop and gain among others value of measurement.

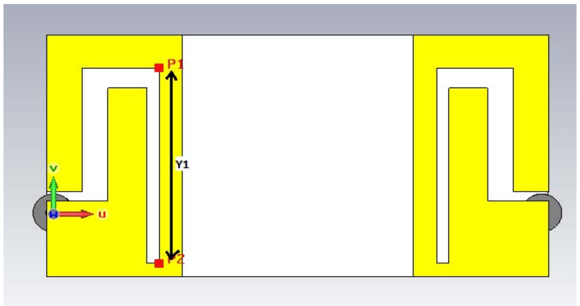


**Figure-12.** MIMO antenna structure.

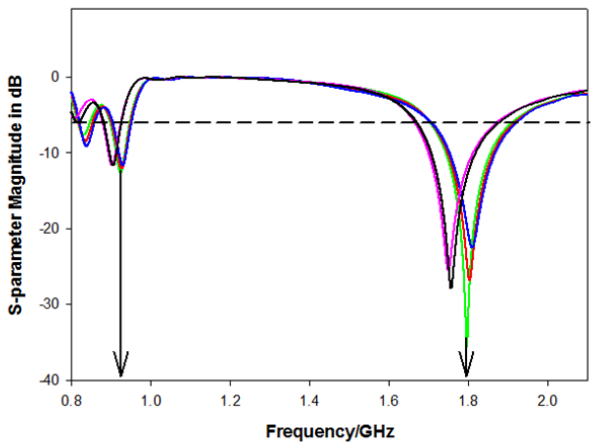


**Figure-13.** S11 result for various X2of MIMO PIFA.

Figure-12 above indicates the placement of the two PIFA antenna so as the MIMO configuration required. X2 is the length where the different result of S11 was collected. There are five different length of X2 considered in order to get the frequency drop needed by GSM.

Hence, Figure-13 shows the result obtain in five different value of X2. When the value changed to X2=45mm, the frequency drop for 0.9GHz is accurate but the other frequency is not drop at accurate frequency. When X2=35.7mm, the frequency drop at nearest at desired frequency which is 0.92GHZ and 1.8GHz respectively. The return loss for X=45mm is -12.6dB for 0.92Ghz and -35.2dB for 1.8Ghz.

The result below shows the five measurement of Y1 for MIMO configuration. There are 32.5mm, 30.5mm, 30.0mm, 28.5mm and 27mm. While doing this research, measurement of Y1 somewhat play the role in getting the desired result. For desired frequency 1.8Ghz, the measurement of Y1 not much effected which mean the five values of this frequency is slightly same but for 0.9GHz, the graph is shows too much different in aspect of frequency drop.

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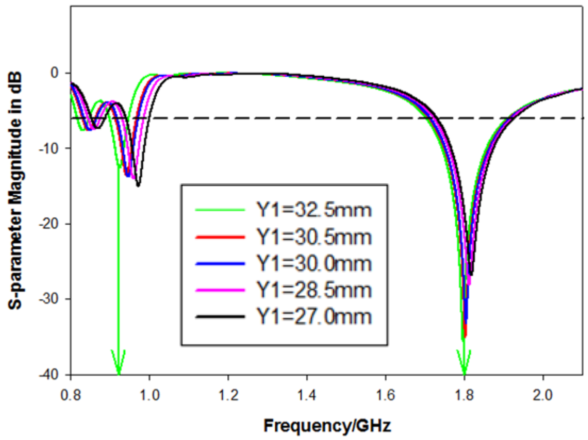



**Figure-14.** S11 result for various Y1of MIMO PIFA.

The result of reflection coefficient can be compared in two situations which is in simulation result and measurement. Figure-15 indicates two results in one graph where the result can differentiate each other. The reflection coeeficient in this two situations shows a little bit different in the frequency drop but the result for reflection coefficient is still in the range as needed for mobile applications.

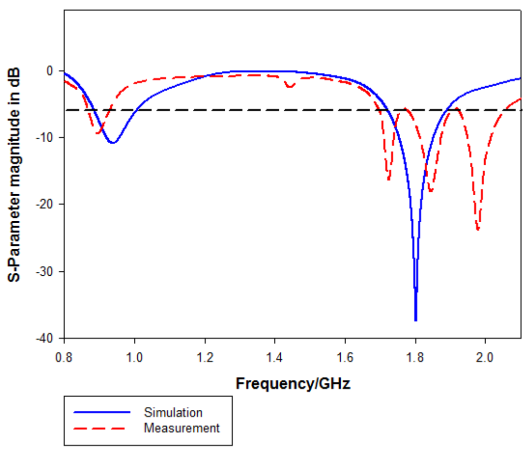
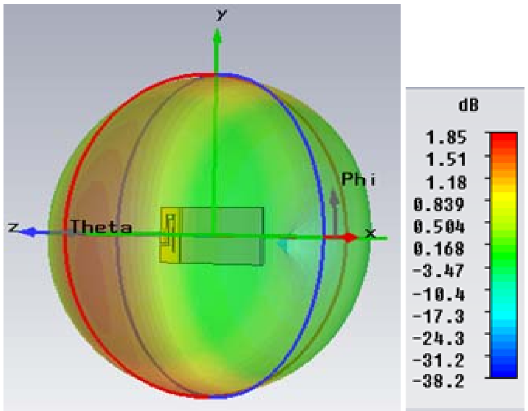
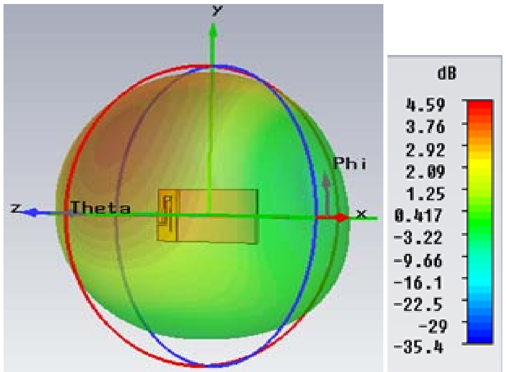



**Figure-15.** Comparison result of S11 in simulation and measurement.

Figures 16 (a) and (b) below shows 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 its 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.




(a)




(b)

**Figure-16.** 3D polarization for farfield for gain for (a) 0.9GHz and (b) 1.8GHz.

Figure-17. (a) and (b) below show the values of gain of MIMO configuration for this project. The gain values are 2.434dB for frequency 0.9GHz and 4.224dB for frequency 1.8GHz.

## CONCLUSIONS

The goal of this project is to design a compact MIMO antenna for smartphone applications that can overcome the problem of existing antenna in smartphones in aspects of data capacity and speed performance. This configuration of the antenna is capable to operate at two operating frequency which is 900MHz and 1800Mhz. There is some objective of this project that has been achieved such as to identify all the method of antenna that can increase the gain of the antenna used in the smart phone and also be able to do some simulation of a single antenna that can be integrated into the selected smart phone. The simulation result was compared by adjusting the several sizes of the antenna in order to achieve the best result. Besides, the size of the ground plane also affected the simulation result. For the measurement result, reflection coefficient was compared between simulation result and measurement result.

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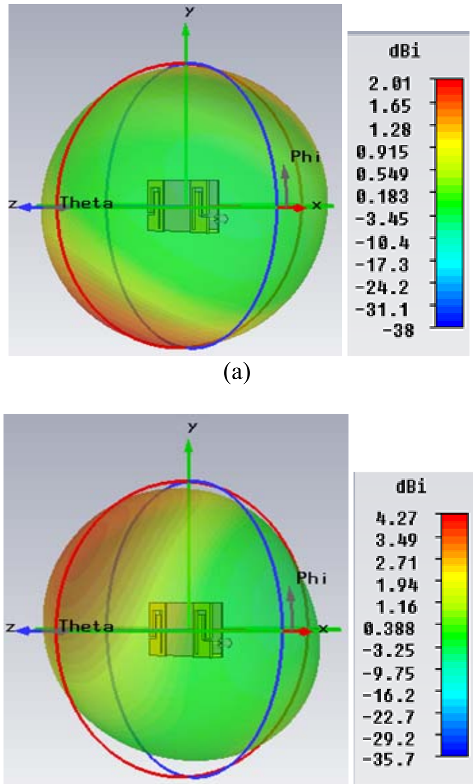

(a)

(b)

**Figure-17.** 3D polarization for farfield of gain for MIMO configuration at frequency (a) 0.9GHz and (b) 1.8GHz.

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