The Effect of Back-Slit Ground-Plane to Microstrip Patch Antenna for 4G Mobile Phones Application

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ABSTRACT - **In this project, a rectangular patch antenna with back slits slots on the ground plane is proposed and investigated. This proposed antenna is named as rectangular back-slits patch antenna that will have return loss, S1, 1 lower than -20dB and voltage standing wave ratio, VSWR less than 1.5 respectively. This proposed antenna provides bidirectional-polarization pattern and operating at frequency of 2.6 GHz which is for 4G mobile phones application that will cover spectrum band of 900 Mhz to 1800 Mhz in LTE technology. The gain and directivity for this proposed antenna are 1.559dB and 5.378dBi. The substrate used is FR4 lossy which have dielectric constant of 5.0 and thickness of 1.6mm.Details of the antenna design and simulation are prepared and discussed.**

Keywords-Rectangular patch antenna, slits, low loss.

I. INTRODUCTION

LTE is term used to describe 4G technology for wireless communication of high-speed data for mobile phones that having operating frequency at 2.6 Ghz. The network is based on GSM/EDGE and UMTS/HSPA technologies where it increases the data capacity and speed using new modulation techniques.4G offers high speed uplink packet access (HSUPA) and high speed downlink packet access (HSDPA) and now being used by smart phone's applications widely. As mobile phone is one of the wireless communication devices, antenna is the most important device that every mobile phone should have in order to transmit and receive the signal from or to any data terminals. The function of the antenna is to convert radio signal or electromagnetic wave into electricity.

So, for mobile phones application, microstrip antenna can be said as the most suitable antenna to be used in term of its size, cost, easy manufacturing and fabricating as well. However, there are some limitations of this microstrip antenna that need to be considered and overcome to make sure that this microstrip antenna can be used efficiently in any applications. High loss is part of the microstrip antenna's limitation. In order to solve this high loss limitation of microstrip antenna, a few methods should be apply like varying the antenna's geometries and parameters which is a common method that have been adopted in designing any type of antenna. Other than that method, construction of slit slots on the ground-plane is another method that is applicable to produce the required performance of the antenna. This slots antenna is one of the conventional patch antennas which comprise a slot in the grounded substrate. Slot antennas are generally bidirectional radiators; that is, they radiate on both sides of the slot. [1]

Microstrip slot antennas (MSAs) also have the advantage of being able to produce bidirectional and unidirectional radiation patterns with larger bandwidth. [2] Since mobile-phone is a portable device, bidirectional-polarized antenna is needed to make sure that the antenna can received and transmit signal not just in a specific direction as it is not a static devices. Strip and slot combinations offer an additional degree of freedom in the design of microstrip antennas. A combination of strip conductors and slots emerged along the sides of a microstrip feed can produce circularly polarized radiation. [3, 4]

So, for this project, a printed "I" slot antenna which is called rectangular back-slits patch antenna is introduced and discussed. The "I" slit is constructed on the ground plane in order to meet the desired performances of mobile phones antenna. This proposed antenna operates at 2.6 Ghz and having return loss less than -20dB. It also produces voltage standing wave ratio (VSWR) of lower than 1.5 besides having bidirectional-polarization pattern.

Objectives

The objective for this project is to design an antenna for 4G mobile phones application that can operates at 2.6 GHz besides having good performance in term of its loss and standing wave ratio. Then, to make comparison of simulation results between proposed antenna and microstrip patch antenna without back-slits.

Scopes of Project

The scopes of this project are to design, fabricate and testing the proposed antenna which was designed for 4G mobile phones application that operates at 2.6 GHz frequency. The proposed antenna was designed to provide low return loss and voltage standing wave ratio besides having bidirectional-polarized radiation pattern. The simulation results of the proposed antenna is then compared with the microstrip patch antenna without back-slits to prove that this rectangular back-slits patch antenna have better performances than microstrip patch antenna without back-slits.

METHODOLOGY

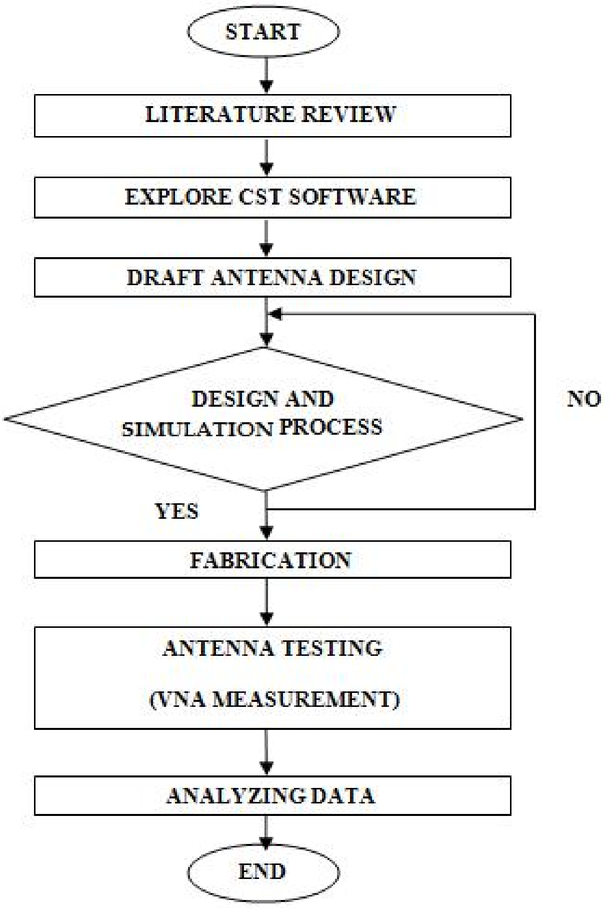

Figure 1: Flow Chart of Project

This project started with some literature review about the desired performance of an antenna that applicable for mobile phone, operating frequency and also frequency band that is used for 4G. The reference sources are taken from journals that had been published in the internet and some books that related with this proposed antenna. The software used for designing this rectangular back-slit antenna is CST Microwave Studio where all the functions need to be explored before designing process begin. The geometry and parameters of the proposed antenna also should be roughly drafted before running the design and simulation process .The dimensions, material used for ground plane, substrate and gap space material have to be set in the CST software during the design process. The center or resonant frequency for the proposed antenna also been set for the antenna design to 2.6 Ghz. During the design and simulation process, some of the dimensions or parameters of the antenna have to be changed several times until the desired results obtained. The simulations results were observed in E-field, H-field and Far-field for 1D, 2D and 3D fields as to analyze the S1,1 (dB), VSWR and radiation pattern results which generated by using transient time domain solver with 1 waveguide port. The simulations results will observed and analyzed to determine whether the antenna already meet the desired specifications or not. If not, the dimensions of the antenna will be changed until the best results obtained. When the best results obtained, the designed antenna will be fabricated to produce the antenna hardware. The antenna design will have to be converted to DXF file before being printed on the FR4 substrate to remain the absolute dimension of the designed antenna. The hardware (antenna) that was fabricated is then tested in the lab to measure the performances of the antenna by using the Vector Network Analyzer Machine (VNA). Finally, the experimental results and readings of the antenna will be recorded and discussed to conclude whether the objectives of this project are successful achieved or not.

II. ANTENNA GEOMETRY

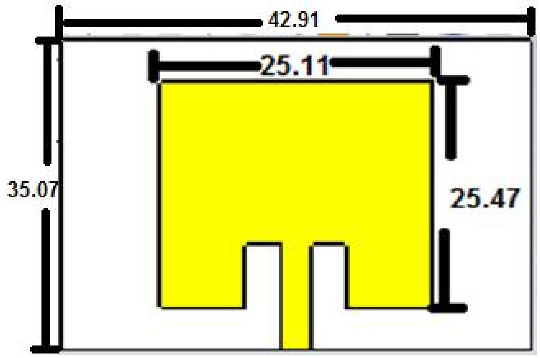

Figure 2(a): Front View of Proposed Antenna

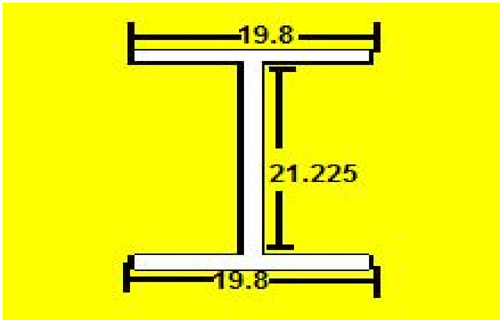

Figure 2(b): Back View of Proposed Antenna

The geometry and parameter of proposed antenna are shown in Figure 2 (a) and (b). Figure 2 (a) shows the front view of the antenna while Figure 2 (b) represents the antenna geometry at the back-side of the antenna where the "I" slits slot is constructed on the ground plane of the antenna. The entire dimensions are in millimeter (mm).

TABLE 1: INTERNAL DESIGN SPECIFICATIONS OF RECTANGULAR BACK-SLITS PATCH ANTENNA

Dimension	Value (mm)
Substrate thickness (FR 4)	1.6
Dielectric constant (FR 4)	5.0
Copper thickness	0.035
Return Loss	< 20dB
VSWR	< 1.5

A. Equations

For this antenna design, the dimension of rectangular patch antenna followed the equations below. The dielectric constant *(εr)* for the substrate used is 5.0 with thickness *(d)* of 1.6mm and operating frequency *(fr)* at 2.6Ghz. The matching impedance is set to 50Ω.

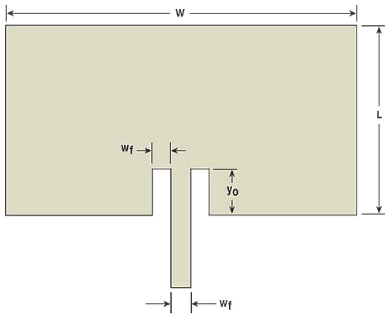

Figure 3: Rectangular Patch

Patch Dimension:

Width,

$$W = \frac{1}{2f_r\sqrt{\varepsilon_o \mu_o}}\sqrt{2/(\varepsilon_r + 1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where the Effective Dielectric Constant (ε_{reff}) and ΔL are;

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12\,{}^{d}/_{W}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\Delta L = 0.412d\left(\varepsilon_{reff} + 0.3\right)\left({}^{W}/_{d} + 0.264\right)/\left(\varepsilon_{reff} - 0.258\right)\left({}^{W}/_{d} + 0.8\right) \quad \ldots\ldots(3)$$

Length,

$$L = \frac{1}{2\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_o \mu_o}} - 2\Delta L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Ground Plane Dimension:

$$L_g = 6h + L$$
$$W_g = 6h + W \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Recessed Distance:

$$Z_a = 90\,\frac{{\varepsilon_r}^2}{\varepsilon_r - 1}\left(\frac{L}{W}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$Z_T = \sqrt{50 \times Z_a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$Y_o = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_T}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

III. RESULTS AND DISSCUSSION

A. Return Loss in dB

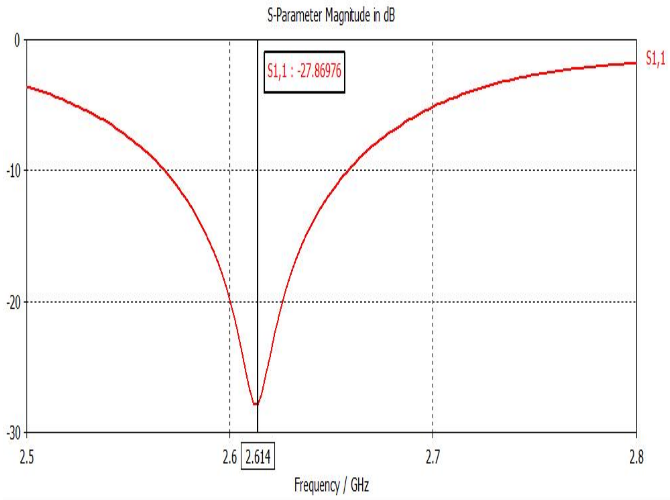

Figure 3(a): Return Loss of Proposed Antenna

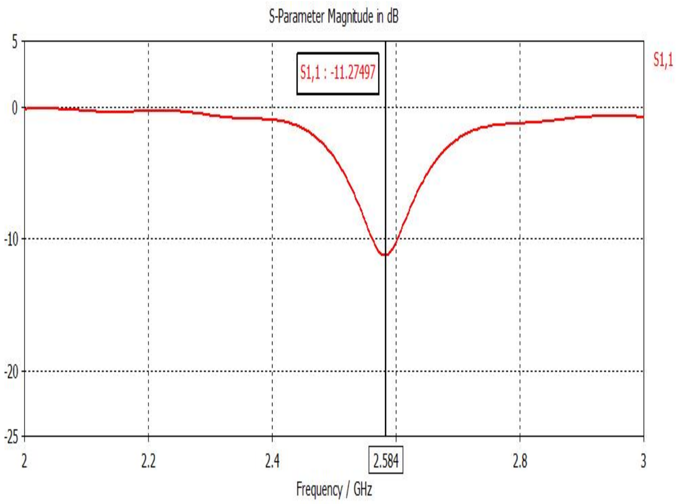

Figure 2(b): Return Loss of Microstrip Patch without Back-Slits

S1, 1 is a term used to represents the return loss in dB and at what frequency the antenna best radiates or resonates. Return loss is one of the fundamental for antenna performance where it indicates the reflected power or losses. The lower the return loss, the better and more efficient the antenna would be. When the return loss is low enough, it means there are only a little power will be reflected or absorbed as losses. In the other word, the power is transmitted well to the antenna. So, by referring to the results above, it shows that Figure 3 (a) which is simulated result for the rectangular back-slits patch antenna shows better S1, 1 result where the frequency radiates at the desired operating frequency which is at 2.6 Ghz and the return loss is at -27.87dB compared to the microstrip patch antenna without back-slits for Figure 3(b), its operating frequency was occurred at 2.58 GHz and returns loss at -11.27dB.

B. VSWR

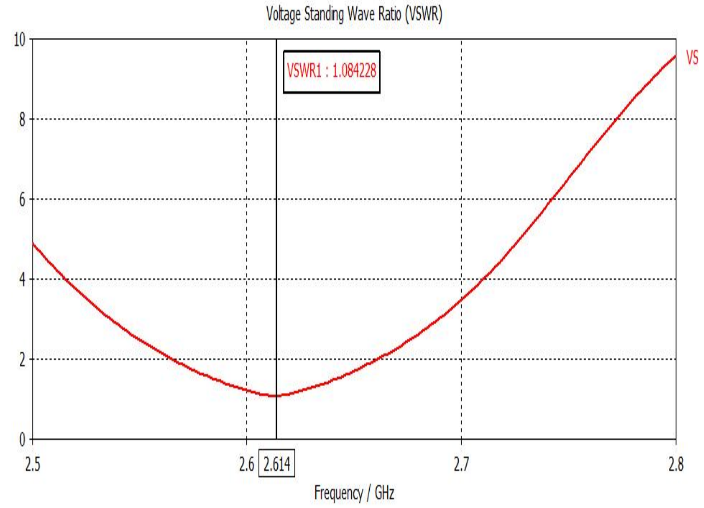

Figure 4(a): VSWR for Proposed Antenna

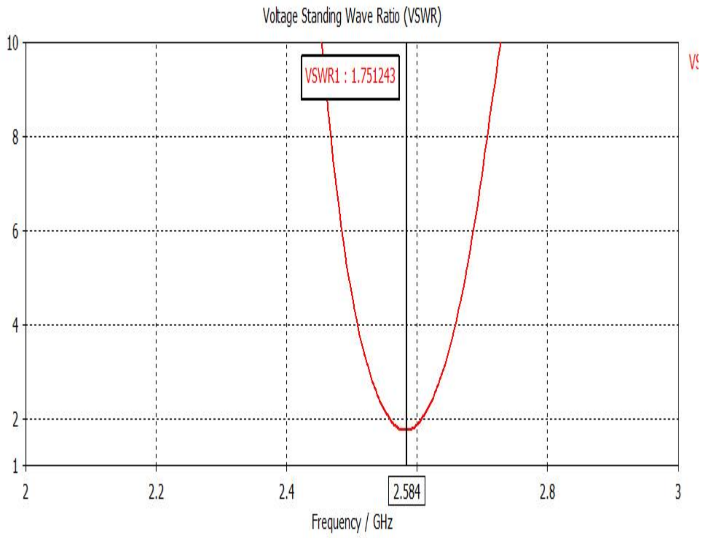

Figure 4(b): VSWR for Microstrip Patch Antenna without Back-Slits

VSWR is the voltage standing wave ratio which describes how well the antenna is matched to the transmission line it is connected to. VSWR is a function of reflection coefficient which determines how much power reflected from the antenna where smaller VSWR means more power delivered to the antenna which is better for an antenna performance. The minimum value for VSWR is 1.0 where it indicates that there is no power reflected from the antenna. From the simulations results of the above, Figure 4 (a) is showing the VSWR for the proposed antenna where the value is 1.08 while for Figure 4 (b), VSWR for microstrip patch antenna without back-slits is 1.75. So, it shows that the proposed antenna is having better performance than microstrip patch antenna where only 8% of the power is reflected from the antenna compared to 75% of the microstrip patch antenna without back-slits.

C. RADIATION PATTERN

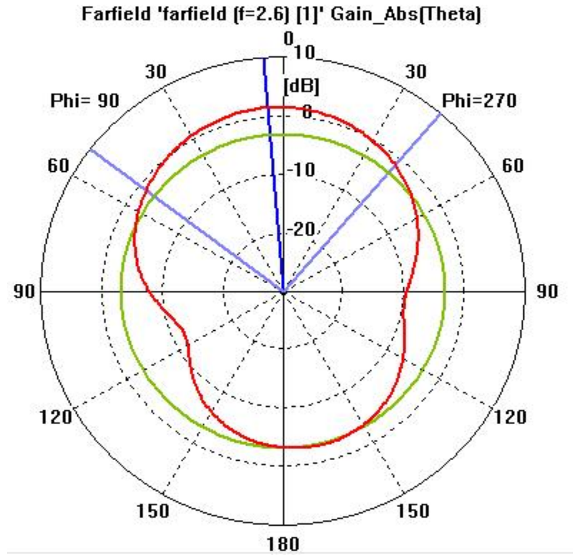

Figure 5(a): Radiation Pattern for Proposed Antenna

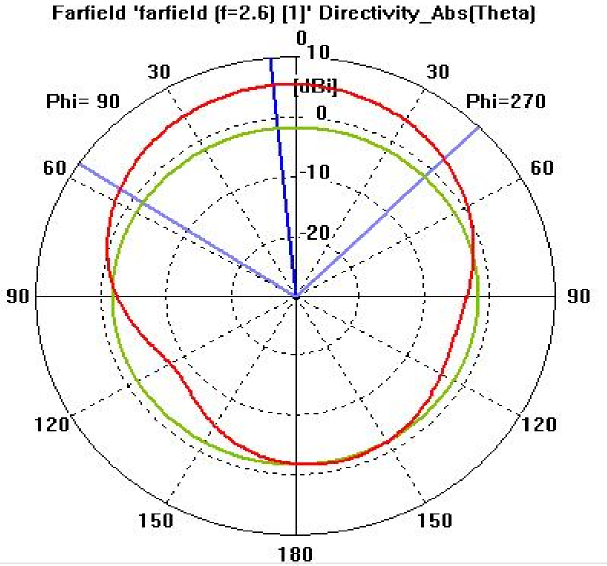

Figure 3(b): Radiation Pattern for Microstrip Patch Antenna without Back-Slits.

Figure 5 (a) shows the radiation pattern for the proposed antenna where it produced bidirectional-polarization pattern with directivity of 5.378 dBi and gain of 1.559 dB. While Figure 5 (b), the microsrtip patch antenna without back-slits has produce almost omnidirectional pattern, with directivity of 5.503 dBi and gain of 1.086 dB. From both radiation patterns, it was clearly proven that the slits slot of the proposed antenna has caused this bidirectional-polarization pattern. The radiations from both sides of the slot not just produce this bidirectional pattern, but also decreasing the directivity of the antenna. However, the gain of this proposed antenna is still better than the microstrip antenna without back-slits even though the value is quite small.

D. SIMULATION AND MEASUREMENT RESULT

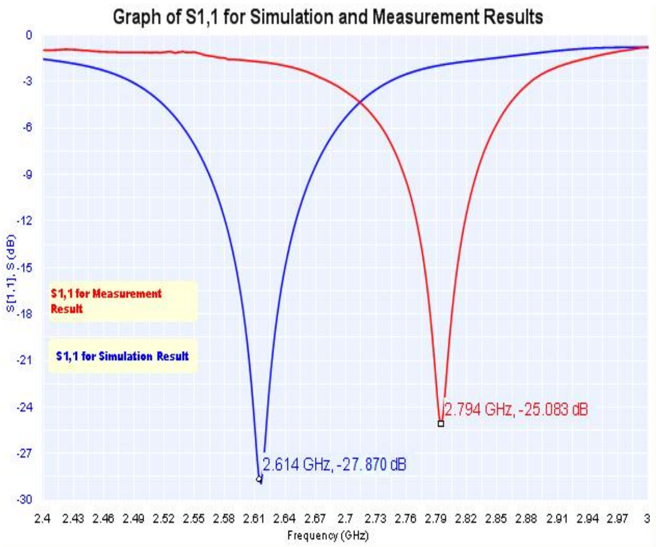

Figure 4 : S1, 1 for Simulation and Measurement Results

Figure 6 shows the S1,1 graph for simulation and measurement results of the rectangular back-slits patch antenna. After the proposed antenna hardware been tested using Vector Network Analyzer Machine (VNA) to get the measurement result, the graph obtained shows that the operating frequency has shifted around 7.69% which is from 2.6 Ghz to 2.80 Ghz. The return loss has also increase about 10.0% which is from -27.870 dB to -25.083 dB. These unequality results could be caused by a few factors especially during the fabrication process. During the fabrication process, the subsrate may be oxcidized due to long exposure to the environment which may effect its performances and the dimension of the proposed antenna may fluctuated a bit from its acual design dimension while fabricating. The connector that is used to connect the antenna port could also be the factor. The power may be dissipated from the port and may be absorbed as losses by the connector during the test.

IV. CONCLUSION

The objectives for this project were achieved where the rectangular back-slits patch antenna for 4G mobile phones was successfully designed. The frequency resonated at the desired value by the simulation result and the return loss was obtained less than -20dB by simulation and measurement result as well. The voltage standing wave ratio, VSWR was also meeting the required value which is below than 1.5 and by referring to the comparison results between rectangular back-slits patch antenna and microstrip antenna without back-slits, it can be said that this proposed antenna is having better performances than the microstrip patch antenna without back-slits. Therefore, with all the results obtained, this final year project can be concluded as successful completed.

V. RECOMMENDATION

Even though all the objectives for this project have successfully achieved, the gain and directivity of this proposed antenna is quite small where it contributes to low efficiency. Therefore, it is recommended to use substrate with low in dielectric constant because higher dielectric constant usually supports a larger amount of surface wave that can affect the gain and directivity of an antenna. Other than that, well fabricating process also needs to beware in remaining the good measurement results when the antenna hardware being tested using VNA machine. The dimension of hardware antenna must exactly the same as in the design to minimize the shifted frequency and the return loss as well.

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