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Gain Enhancement of Rectangular Microstrip Patch Antenna Using T-Probe Fed for Mobile and Radio Wireless Communication Applications

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ABSTRACT

This paper presents an enhancement of gain for square microstrip patch antenna using a T-probe feeding technique. Air is used as a substrate in the proposed design. The thickness of the air-filled substrate, h_2 = 12mm is selected with dielectric constant, $\varepsilon_0 = 1$. The air-filled substrate is sandwiched between superstrate and a ground of aluminum plane, which supported by a silicon spacer for each corner of the rectangular dimension. The patch is fed by the T-shaped probe which is placed on the 1mm thickness of an aluminum plate. It is fed by a standard SubMiniature version A (SMA) connector to connect cable dielectric to the interface without air gap. The simulation and optimization based on Computer Simulation Technology (CST) Microwave simulator and Vector Network Analyser (VNA) are used for the return loss, S_{11} analysis. The reliability of the designed antenna was analyzed, such as bandwidth, gain, S_{11}, Voltage Standing Width Ratio (VSWR) and radiation pattern. From the simulation result, the S_{11} obtained is -39.08dB and the measurement value is -10.8dB at 2.4GHz frequency. Both S_{11} are necessary for mobile and radio wireless communication applications. The VSWR simulation is 1.024, where the result is acceptable since the ratio fulfill the standard of VSWR < 2.
KEYWORDS: air filled substrate, CST, VSWR, SMA connector, VNA.

INTRODUCTION

Antenna is one of the important elements in the Radio Frequency (RF) system for receiving or transmitting the radio wave signals from and into the air medium. Without a proper antenna design, the signal generated by the RF system will not be transmitted and no signal will be detected at the receiver. The best choice of antenna type for mobile and radio wireless communication applications is microstrip patch antenna.

Microstrip antenna is also known as printed circuit antenna or patch antenna. When a low profile antenna is requested, the microstrip antenna is the best choice to use. This type of antenna has several advantages of low cost and weight, reproducibility, design flexibility and ease of installation [1]. The radiating elements together with feed lines are easily photo etched on a thin dielectric sheet on a ground plane. The element can be in square, rectangular, round etc. form, where it excites through one or more feed points from the edge of back through the ground plane. One of its principal disadvantages, it has a narrow bandwidth. Extensive researches have been devoted to the bandwidth problem in recent years. Many techniques have been suggested and implemented to achieve the wide band characteristics [2, 3].

Worldwide Interoperability for Microwave Access (WIMAX) is a telecommunication technology that provides a wireless transmission of data using a variety of transmission modes from point to multi point links. The technology is based on IEEE 802.16 standard. The WIMAX standard specifies 2GHz to 11GHz as a usable operating frequency range for modulation and channel access etc. [4].

Recently, a novel feeding technique for the thick substrate patch antenna which employing L or T shape probe has been reported in [5]. The use of T-probe feeding is essential with the utilization of air filled or foam substrate to achieve a wireless communication application. The dielectric constant of the substrate usually ranges between $2.2 \leq \varepsilon r \leq 12$. The thick substrates which the dielectric constant is in lower range is the most desirable for the antenna performance. It provides a better efficiency, larger bandwidth and offer loosely bound fields for the radiation into the space, but with expanding of larger element size [1].

In the paper, the proposed antenna is introduced at 2.4GHz resonant frequency for mobile and radio wireless communication applications. A square microstrip patch antenna with a T-probe feeding technique was constructed and analyzed. The T-probe feeding method is essential with the utilization of air-filled or foam substrate to achieve mobile and radio wireless communication characteristics. These methods are proven to overcome a problem occurs in conventional microstrip patch antenna due to narrow bandwidth.

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METHODOLOGY

The procedures of designing and analyzing the square microstrip patch antenna using T-probe fed is summarized in Figure 1. Firstly, the proposed antenna is designed by using a CST software to meet the standard design requirements. Then, the process is continued to the next stage, which is a fabrication step. However, before fabricating the antenna, the design needs to be transferred to AUTOCAD layout. After the fabrication, a Vector Network Analyzer (VNA) is used to measure the performance of the antenna. Lastly, the simulation and measured results are compared for validation purpose. It is to ensure both meet the requirements for 2.4GHz resonant frequency with return loss, $S_{11} \leq -10$dB range for mobile and radio wireless communication applications.

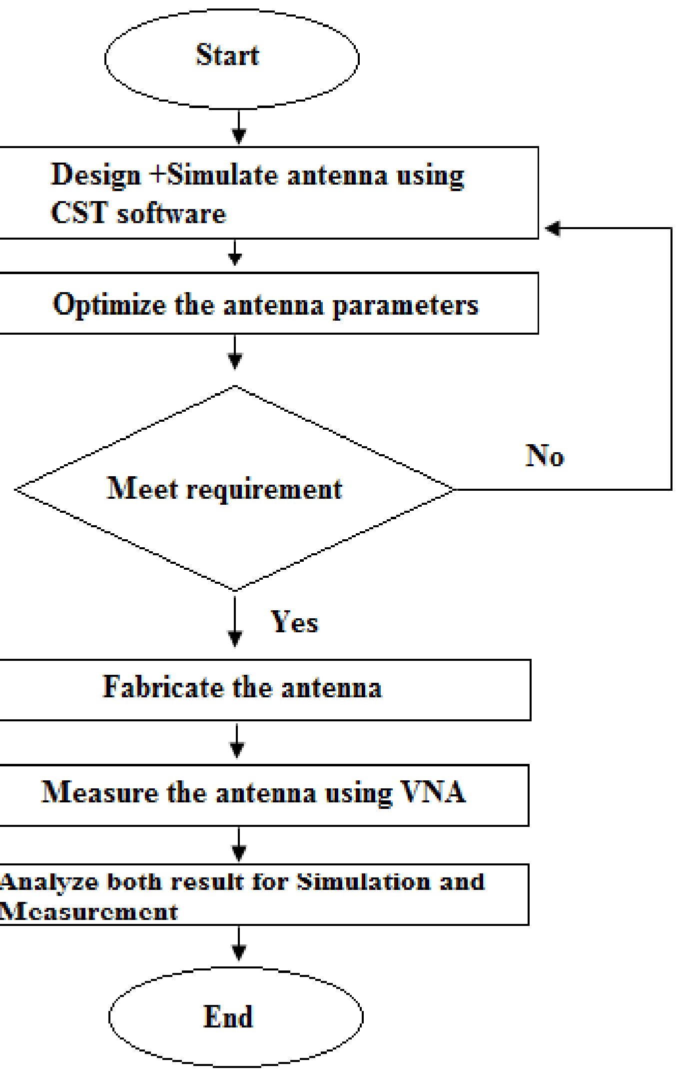

Figure 1: The design flowchart of proposed square microstrip patch antenna

Antenna Design

The microstrip patch antenna is tuned to operate around 2.4GHz. In Figure 2, the dimension of square patch antenna is designed by using a CST software, after optimizing the given length, Lp_1 and width, Wp_1. It is supported by a superstrate with Flame Retardant-4 (FR-4) lossless material with thickness, h_1 = 1.6mm and relative permittivity, εr = 4.7. The superstrate square dimension is Wss x Lss.

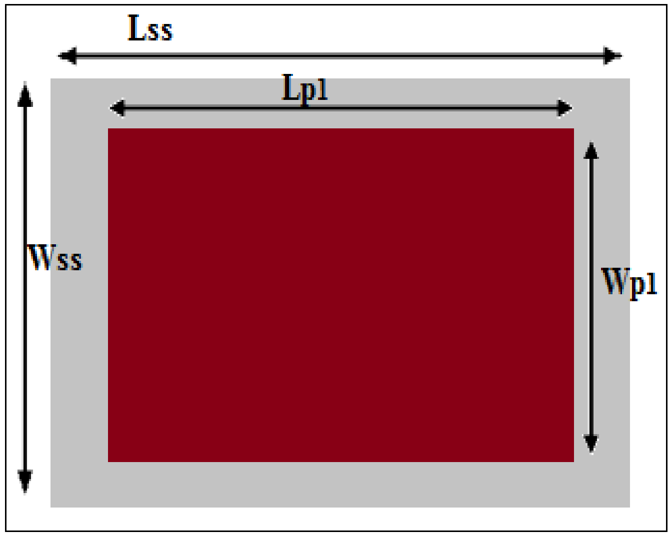

Figure 2: The dimension of proposed square patch with superstrate

Based on Figure 3, the air is used as a substrate in this proposed design. The thickness of the air-filled substrate, h_2 is presented with ε_0 = 1. The air-filled substrate is sandwiched between superstrate and a ground aluminium plane supported by placing silicon spacer for each corner of square dimension. The patch is fed by a T-shaped probe with vertical length, L_V and horizontal length, L_H. The probe with thickness of h_4 is placed in the middle on the 1 mm thickness of aluminum plate. It is fed by a standard SMA connector to takes cable dielectric to the interface without air gaps. The SMA connector design is according to specification in [7] using Teflon. So, the feed can be placed at any desired location inside the patch in order to match with its input impedance.

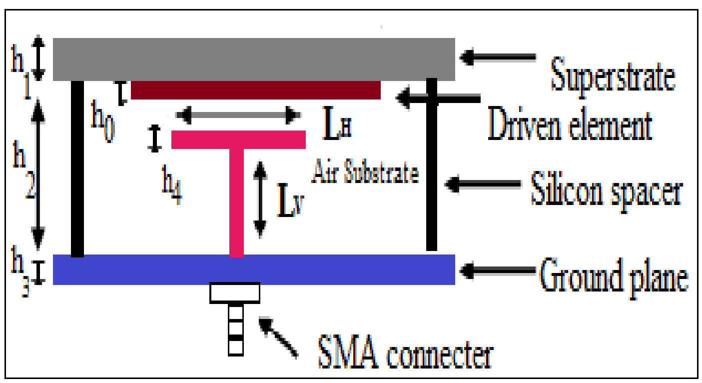

Figure 3: The side view of square microstrip antenna design

The design specifications for the square patch antenna is shown in Table 1.

Table 1: Design specification for rectangle patch antenna

Center frequency, f_0	**2.4 GHz**
Substrate	Air substrate
Dielectric constant, ε_0	1
Substrate height, h_2	12mm
Superstrate	FR-4
Dielectric constant, εr	4.7
Superstrate height, h_1	1.6mm

PARAMETRIC STUDY

A conventional square microstrip patch antenna is firstly designed and altered to obtain required specification parameters at 2.4GHz frequency. This design is used as a benchmark to design a first of antenna structure for mobile and radio wireless communication applications. S_{11} is measured at the input of the antenna in decibel (dB) unit. Thus, in order to design a well perform antenna, the return loss should be equal or less than -10dB. The smaller the value of return loss, the accurate it will perform. This is to ensure more than half of power is transmitted to the destination.

Parametric study is based on the effects of various dimension parameters of patch and thickness of the air-filled substrate. In Figure 4, the dimensions of the patch, Lp x Wp are varied to obtain the required parameters which resulted 42.94mm^2. The results resonate at 2.4GHz and S_{11} at -39.02dB. It can be concluded that the varied dimension of the patch by increasing its dimension will decrease the resonant frequency.

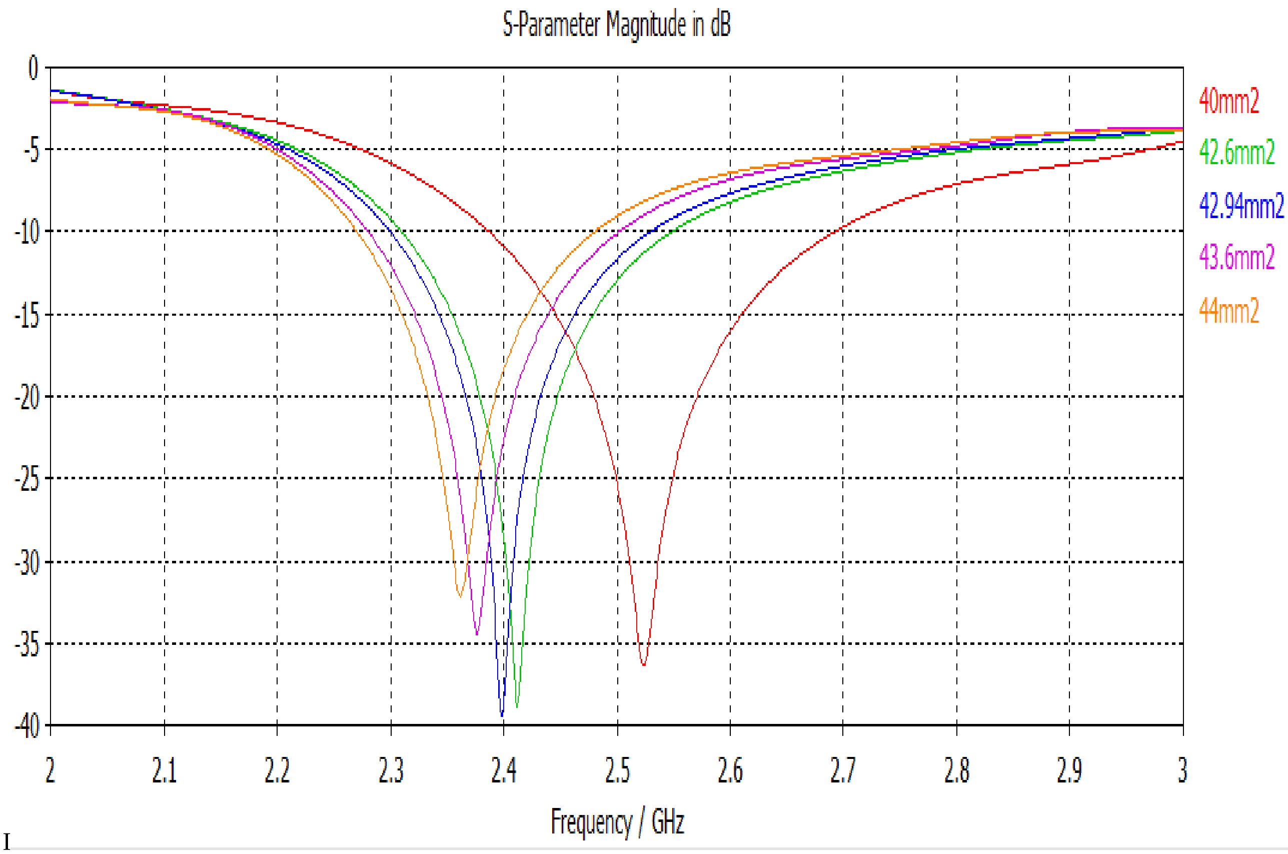

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Figure 4: Varied dimension of antenna patch

In Figure 5, it shows a variation of the resonant frequency which depends on the width of the patch. The patch antenna width, W is given by (1) [11].

$$W = \frac{c}{2f_r}\frac{1}{\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

From Figure 5, the resonant frequency and S_{11} are depending on the width of the antenna, where the result is 21.47mm.

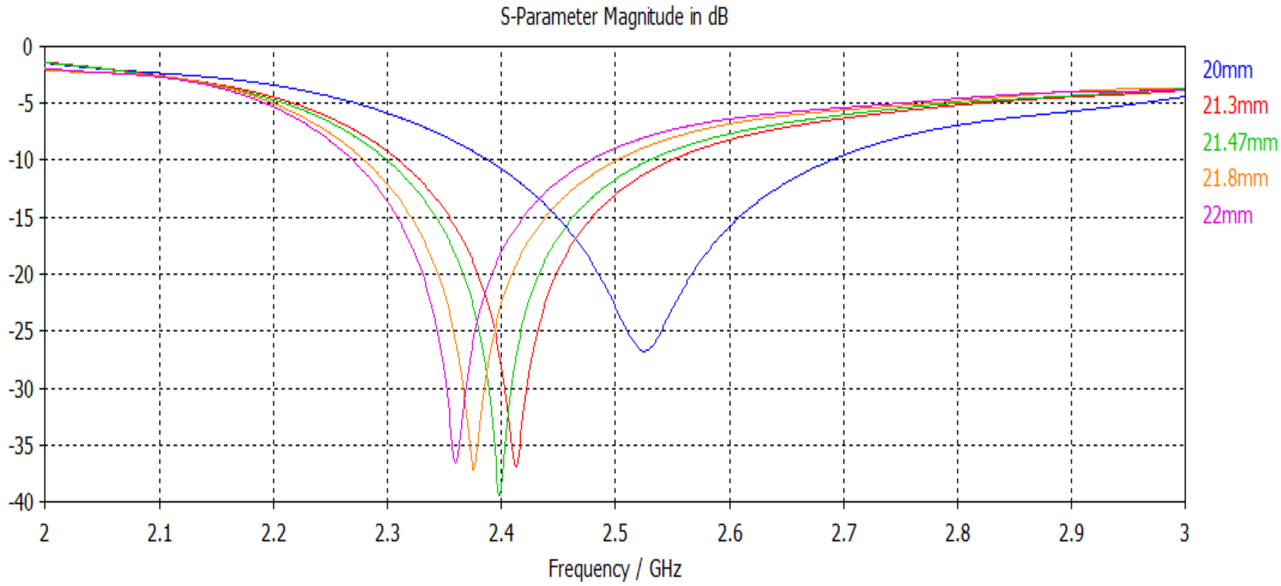


Figure 5: Varied width of antenna patch

Figure 6 shows the return loss result when it varied the thickness of the air-filled substrate, h_2. The variation is from 11mm to 13mm by increasing 0.5mm per time. The optimized substrate thickness of 12mm is used as a reference model. When the thickness is equal to 11mm and 11.5mm, the curve shifted upward to the right, while as for 12.5mm and 13mm, the curve shifted upward to the left. The variation of air substrate thickness is an ideal solution to gain a wider bandwidth. Since the material is in loose form, a better radiation will penetrate the radiating elements. So, the thickness of the substrate is designed accordingly to ensure the signal from the T-probe fed to the patch will radiate for transmitter to receive the signal. The thickness with 12mm air-filled substrate is a good design which obtains the smaller S_{11}, which is -39.08dB.

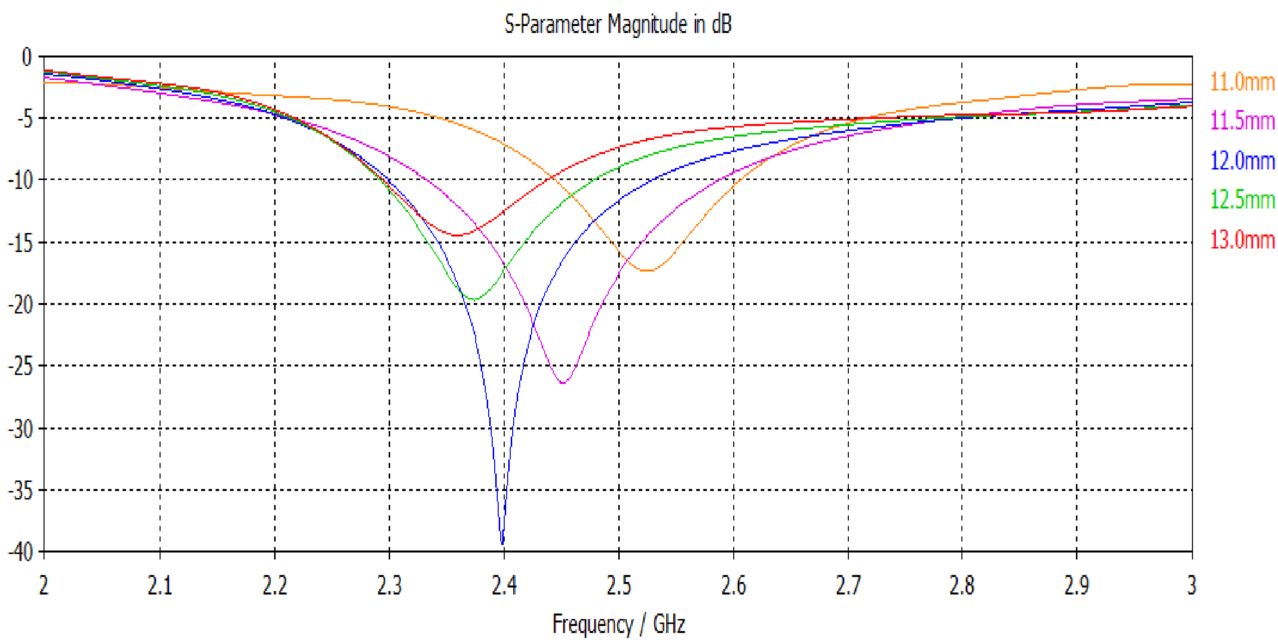


Figure 6: Varied thickness of the air-filled substrate

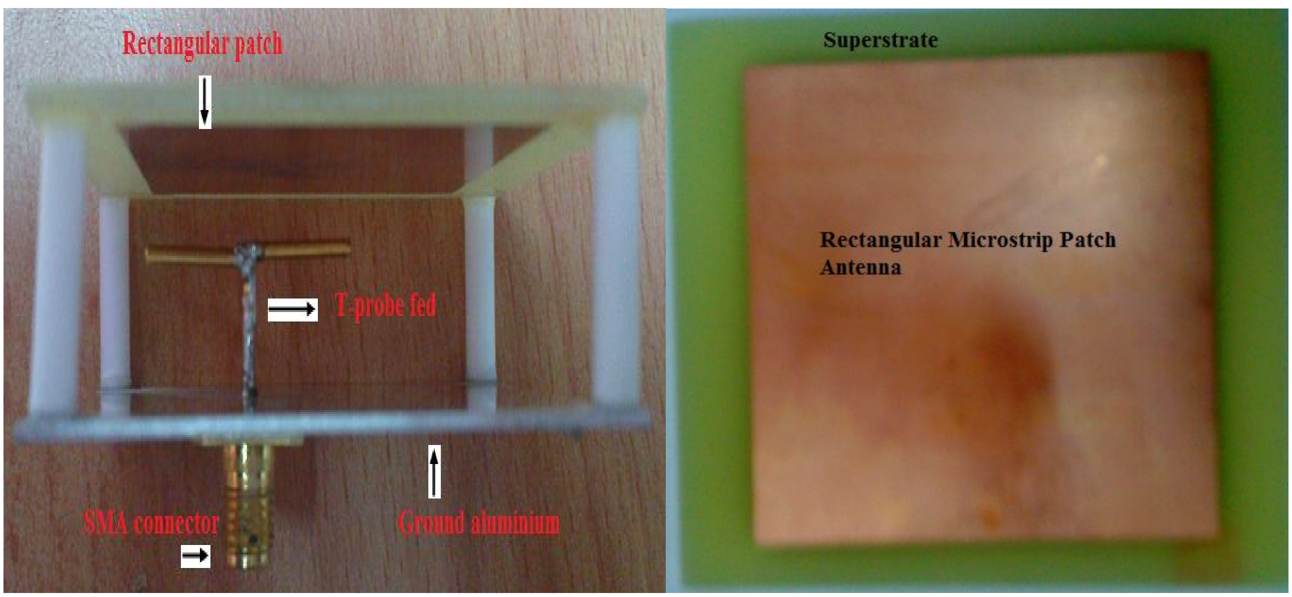
A design for proposed antenna to resonate at 2.4GHz and return loss less than -10dB for square patch antenna is summarized in Table 2.

Table 2: Summarize of square patch antenna design using t-probe fed

Microstrip Square Patch Antenna Dimensions (mm)	
Patch	
Width,W_{p1}	42.94
Length,L_{p1}	42.94
Thickness,h_0	0.035
Superstrate	
Width,Wss	52.2
Lenght,Lss	57.8
Thickness,h_1	1.6
T-probe	
Vertical lenght,Lv	10
Horizontal Lenght,L_H	20
Radius,h_4	0.25

RESULTS AND DISCUSSION

The simulation and measurement results of the square microstrip antenna using T-probe fed were compared and analyzed. The simulation and optimization are done by applying CST software and Vector Network Analyzer (VNA) for return loss measurement. The optimization from design obtain the line impedance is 50 ohms that is ideal for feeding width is required to obtain a 50 ohms line impedence [11]. Figure 7 (a) and (b) show the actual fabrication structure of the proposed antenna using T-probe fed.



(a) (b)

Figure 7: Actual structure of square patch antenna with T-probe fed (a) side view (b) square patch

Figure 8 shows the differences between simulation and measurement of square microstrip patch antenna design. From the simulation result, the S_{11} parameter obtained is -39.08dB at 2.4GHz resonant frequency. Meanwhile, the measurement result is -10.8dB, which resonates at 2.6GHz frequency. Both S_{11} are necessary for mobile and radio wireless communication applications. Notice that, the measurement of return loss is inaccurate due to losses introduced by the dielectric, the mismatch between the source and antenna. The differences occur due to human error such as in fabrication, soldering and measurement process, environmental effect and equipment error.

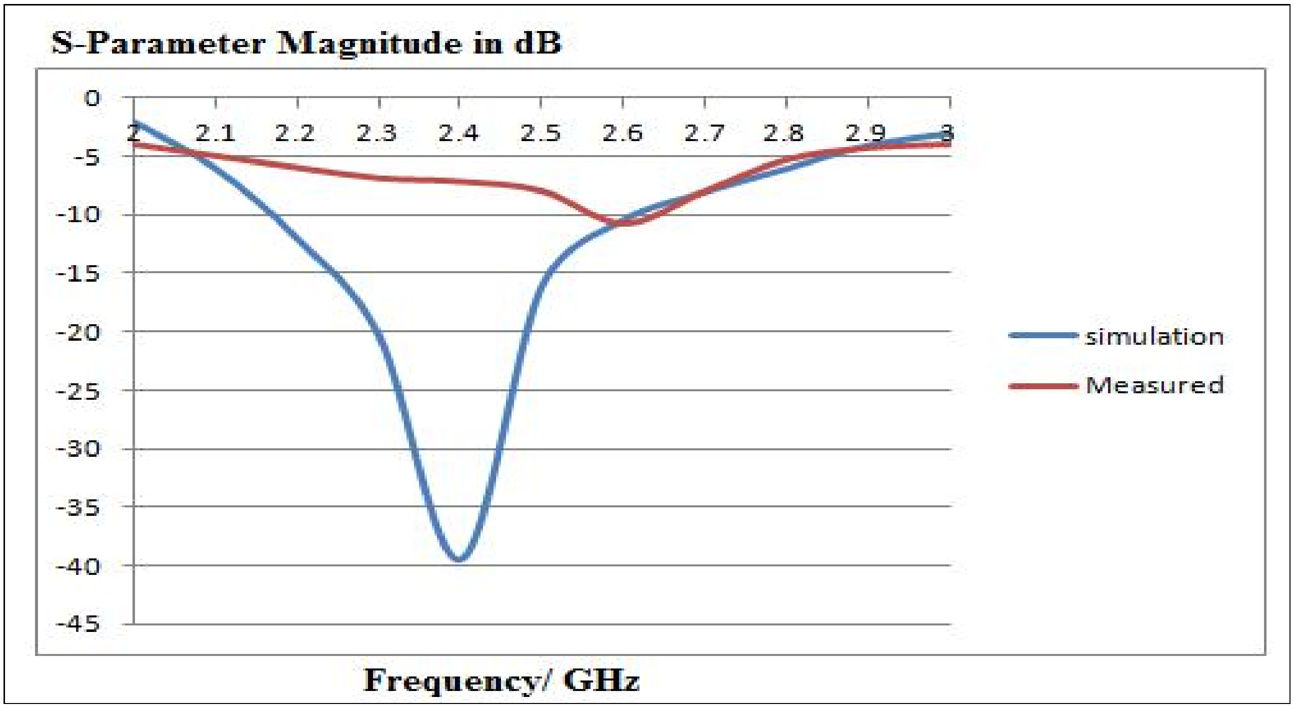


Figure 8: S_{11} versus frequency

Next parameter that needs to be considered is Voltage Standing Wave Ratio (VSWR). VSWR is a measurement of how well the antenna matched to the line impedance. VSWR ratio indicates how much power is reflected back or transferred into a cable. A perfect matched antenna would have a VSWR of 1:1 [8]. This ratio indicates the perfectly matched antenna design for power transferred into the cable. Minimum VSWR is 1.0 which is ideal transmitted signal where no power will reflected back from the antenna [10]. Figure 9 shows the VSWR simulation result where it satisfies the standard ratio of VSWR < 2. At its most optimum frequency of 2.4GHz, the VSWR simulation is 1.024.

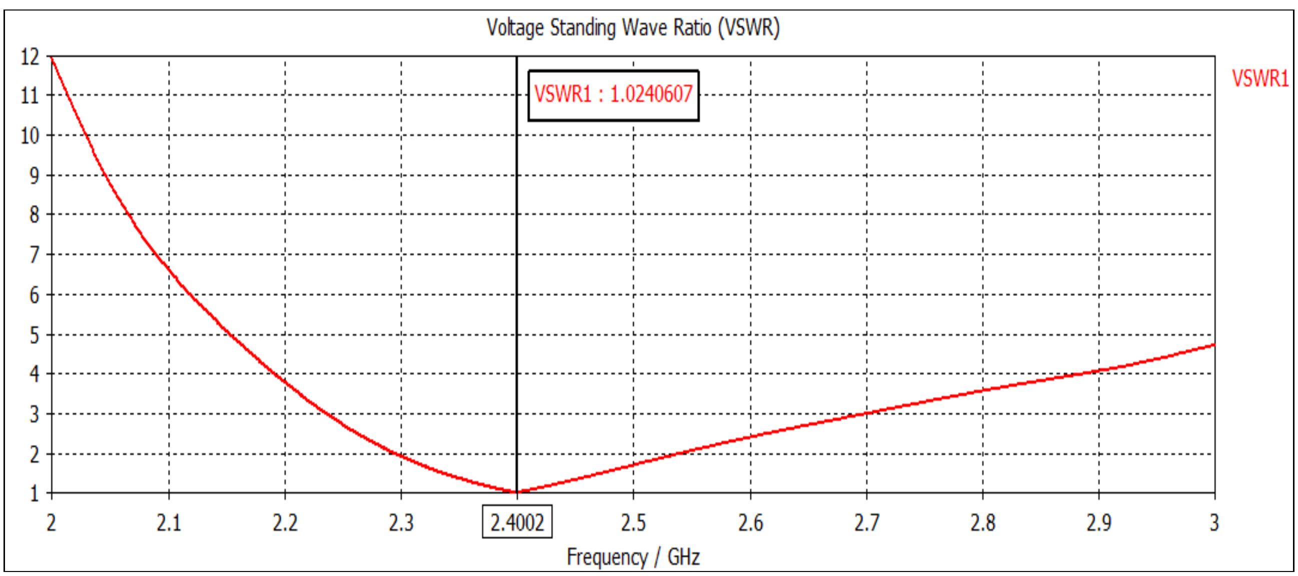


Figure 9: VSWR versus frequency

For the third parameter for antenna design is radiation pattern. Antenna's radiation pattern is also considered as an important parameter in order to determine the antenna's performance. The radiation pattern describes the relative strength of the radiated field in the various directions from the antenna at a constant distance [9]. From Figure 10, the radiation pattern results at 2.4GHz with a main lobe magnitude of 7.7dB and -6.1dB for the side lobe magnitude. And the result of angular width (3dB) is equal to 51.0^{0}. The major lobe depicts the greatest amount of signal radiated by antenna, while the minor lobe illustrates the least amount of radiation.

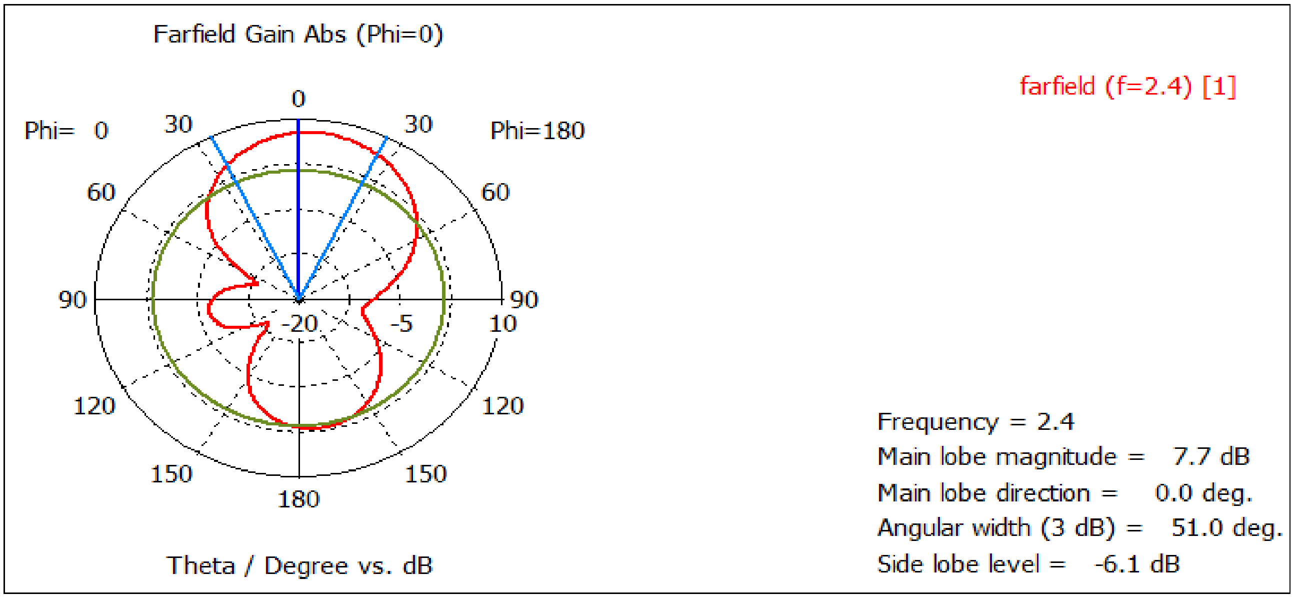


Figure 10: The radiation pattern

The last parameter is the gain, as shown in Figure 11.It indicates that the gain measured at its most optimum 2.4GHz frequency is 7.681dB. The obtained gain is acceptable for the antenna performance analysis.

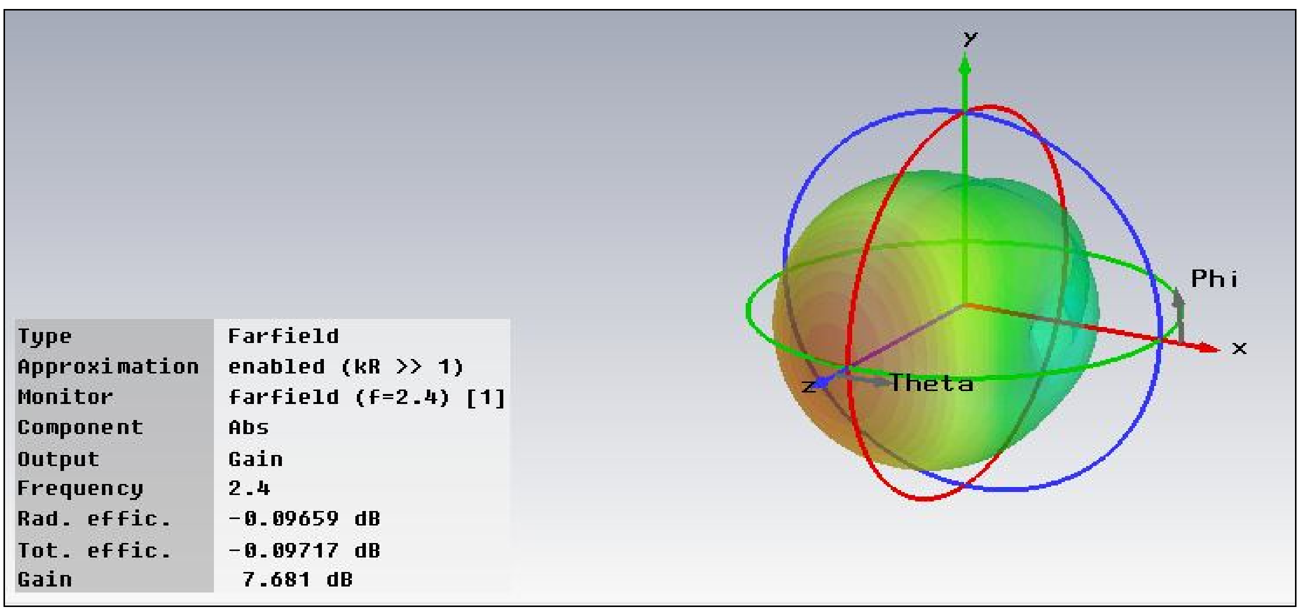


Figure 11: The simulation gain

CONCLUSION

In the paper, the major objective of the research is to design an antenna that meets the requirements of 2.4GHz frequency for mobile and radio wireless communication applications. The utilization of T-probe fed technique for feeding line with a thick air-filled substrate contributes in bandwidth enhancement. From the simulation result, the parameter obtained is -39.08dB, which resonates at frequency of 2.4GHz. Meanwhile, the measurement result is -10.8dB at 2.6GHz resonant frequency. Both return losses are required for mobile and radio wireless communication applications. The VSWR simulation is 1.024, which satisfies the value of VSWR<2 ratio standard. The designed antenna has potential to resonate at frequency 2.4GHz for mobile and radio wireless communication applications.

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