Investigation on Integration Square Loop Antenna with The SMD LED

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Abstract – **This paper present an investigation on integration square loop antenna with the Surface Mount Device (SMD) Light Emitting Diode (LED). The parameters of the antenna will be determined by using basic square antenna equations. The antenna is designed by using CST Microwave Studio 2013 and fabricated on the FR-4 substrate. The data for experimental is taken by using Vector Network Analyzer (VNA) to get the return loss value and the radiation pattern is captured in a chamber room. The performances of the integrated antenna were investigated in term of the return loss, resonant frequency, gain, radiation pattern and VSWR. Both result from simulation and measurement are compared and analysed. The integrated LED also affected the performance of the antenna by shifting the frequency to the lower frequency and the return loss also change to deeper value. It is verified that LED is acts like a bridge on the antenna and it has the inductance characteristic.**

Keyword: Surface Mount Device (SMD), Light Emitting Diode (LED), Wireless Fidelity (Wi-Fi), Computer Simulation Technology (CST), Vector Network Analyzer (VNA).

I. INTRODUCTION

An antenna is a transducer that transmits and receives electromagnetic waves. But, it can operate as a receiver or transmitter only and it depends on the application. In other words, the antennas convert electromagnetic radiation into electric current, or vice versa. There are many types of antenna and each type of the antenna is depends on the application itself [1-2]. Most of antenna in communication system used Microstrip Antenna which has a lot of advantages compared to the other antenna such as it is inexpensive and easy to design [3-4]. For simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common [5-6]. Therefore, square shape is chosen as a design in this research. There are various parameters used to evaluate the operation of the antenna such as bandwidth, gain, return loss, VSWR and radiation pattern [7].

Plasma antenna is introduced as a multifunction antenna which it can radiate waves and produced light at the same time [8]. However, the fluorescent lamp used is have several disadvantages such as it is consuming higher energy and produced heat[9]. This research will improve the Plasma antenna by using LED as a light source to replace the Fluorescent lamp. LED is a semiconductor diode that is allowed current to flow in one direction. In a PN junction, the P side contains positive charge or also known as holes which are the absence of electrons. The N side contains negative charge or electrons. The electrons move from the N area toward the P area and holes move vice versa after forward voltage is used. The light is emitted when an electron combines with holes [10-11]. LEDs require 2 to 4 volts of direct current in the range from 1 to 50 mili-amperes and require a specific electrical polarity where voltage in reverse polarity can destroy them. Silicone resin is a material which is commonly used as SMD LED encapsulant, because of the thermal and photo stability, lower internal stress. But poor adhesion and high gas or moisture permeability are disadvantages of silicone resin [12]. Therefore, this research proposes to design a multifunction antenna that can be used to radiate waves and produce light without affecting the performance of the antenna. LED is used as the lighting source for this paper.

II. METHODOLOGY

This project starts with design a square loop antenna by using CST Microwave Studio 2013 and the simulation results are obtained. Then, the suitable design is fabricated on the FR-4 board which has a parameter as shown in Table 1. The measurement result is obtained and then the results will be compared with the simulation results. All the collected data will be analysed and translated into S_{11} graph and radiation pattern. The step above will be repeated after the LED is integrated with the antenna. The conclusion is made based on the results obtained.

TABLE 1: SUBSTRATE PROPERTIES

Properties	FR-4
Dielectric constant, εr	4.3
Thickness	1.6mm
Copper Thickness	0.035mm

A. *Square Loop Antenna Design*

The antenna is designed to operate at 2.2GHz frequency and it must suitable for the LED to be connected parallel. The designed process starts with the simple square formula to get the size of the antenna and then it designed in CST. In order to get the desired frequency, the design is optimized in term of the location of the feed point, length of the patch and the width of the patch. The performance of the antenna is evaluated from the return loss, frequency and the gain of the antenna. The parasitic loop is added at the outer loop antenna to increase the gain[13]. Figure 1 shows the square loop antenna with the parasitic loop. Parasitic loop added has two functions as the element to increase the gain and as the connection to the negative polarity of LED. Figure 2 shows the fabricated square loop antenna.

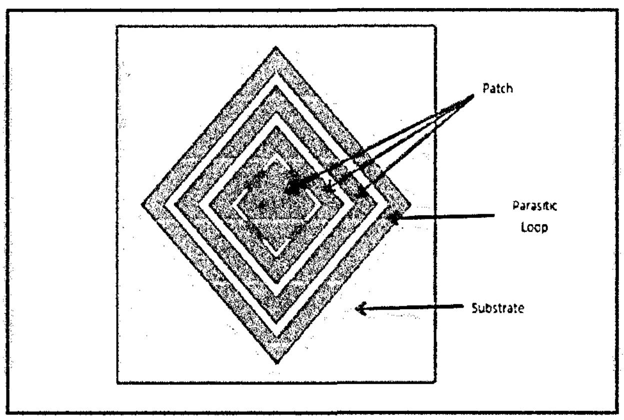

Figure 1: The Square Loop Antenna

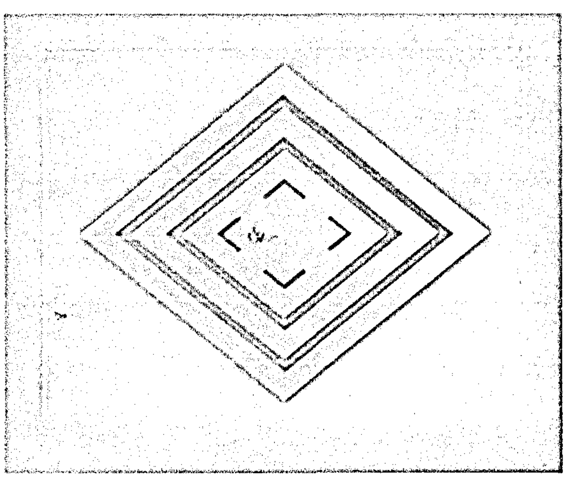

Figure 2: The Fabricated Square Loop Antenna.

B. *Integration of an Antenna with LED*

In the simulation by using CST software, LED is placed by PEC with 5mm X 5mm area and thickness 0.02mm. Five SMD 5050 LEDs are used to be placed on the antenna as shown in figure 3. The white LED is added one by one. Once it is integrated with the antenna, the data for return loss and the radiation pattern are taken in two conditions which are 'OFF' mode and 'ON' mode. The same step is repeated for another four LED. The first three LED is placed counter clockwise while the fourth and fifth LED is putted symmetrically with the other LED. The location of the LED on the antenna is shown in figure 4. Two jumpers are added on the antenna to connect the DC supply.

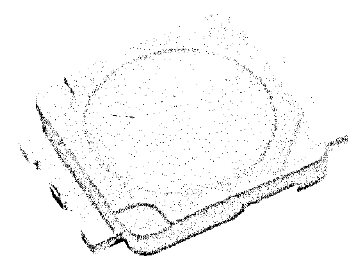

Figure 3: SMD 5050 LED.

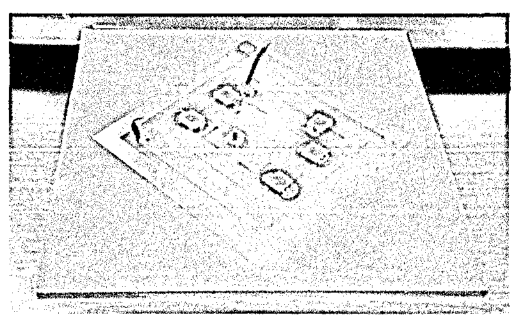

Figure 4: LED on the Square Loop Antenna.

III. RESULTS AND DISCUSSION

The data are obtained from the simulation by using CST Microwave Studio 2013 and the measurement data is taken by using two different equipments which return loss is measured by using VNA while radiation pattern is measured in a chamber. Both simulation and measurement data will be compared for the antenna before it integrated with the LED. The performance of the antenna will be evaluated from the both data. In section A, there will be a discussion on the results of Square Loop Antenna and the section B will be discussing the results of Integrated Square Loop Antenna with LED.

A. Square Loop Antenna

TABLE 2: RSULTS FOR SIMULATION AND MEASUREMENT

	Simulation	Fabrication
Frequency (GHz)	2.22	2.3
Return Loss (dB)	-39.11	-19.43
Gain (dB)	3.755	-
VSWR	1.11	1.23

For a simulation results, return loss is -39.11dB at 2.22GHz frequency. However, the measurement result is slightly different from the simulation results where the return loss is -19.43 at the 2.3GHz. It is different about 0.08GHz from the result obtained in simulation. There are several factors that lead to the different results. The fabrication error occurs during the fabrication process, the quantity of the chemical used during the etching process can affect the dielectric of the board. Besides that, the equipment used to measure the data and the surrounding interference also cause the measurement results to be different. Figure 5 shows the S-Parameter result for both simulation and measurement.

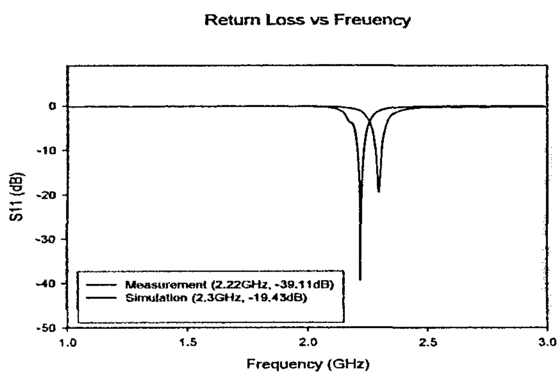

Figure 5: Return Loss vs Frequency Graph for Simulation and Measurement

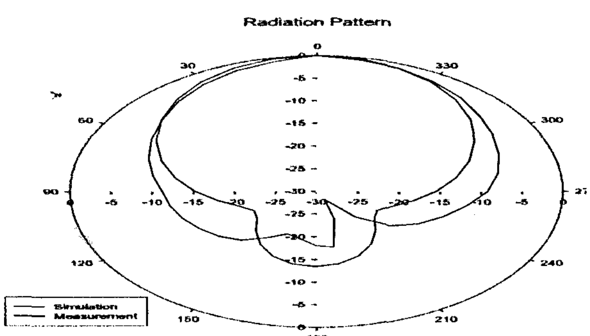

Figure 6: Radiation Pattern for Simulation and Measurement

According to figure 6, the radiation pattern for both simulation and measurement is slightly different. It is because of the surrounding interference during the measurement process in the chamber room.

B. The Integrated Square Loop Antenna with LED

In this section, there are five LEDs used as parasitic element. The data for each LED is measured by using VNA to measure return loss and the Chamber room used to capture the radiation pattern. The LED is on "ON" mode during the process of capturing the radiation pattern. The result of the integrated antenna is compared to the measurement result of square loop antenna. 3 Volts DC supply is used during the measurement.

S-PARAMETER

1 LED

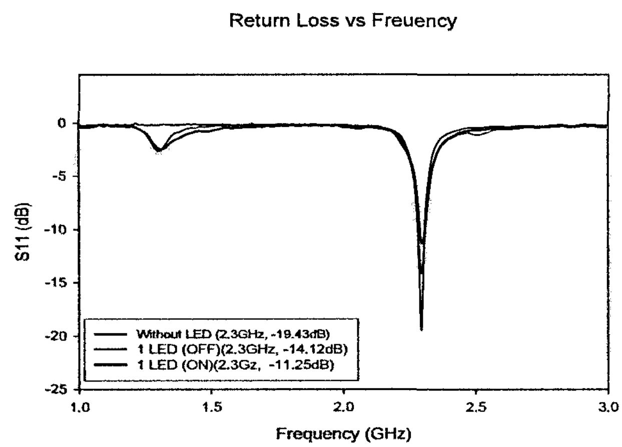

Figure 7: Return Loss vs Frequency for 1 LED

2 LED

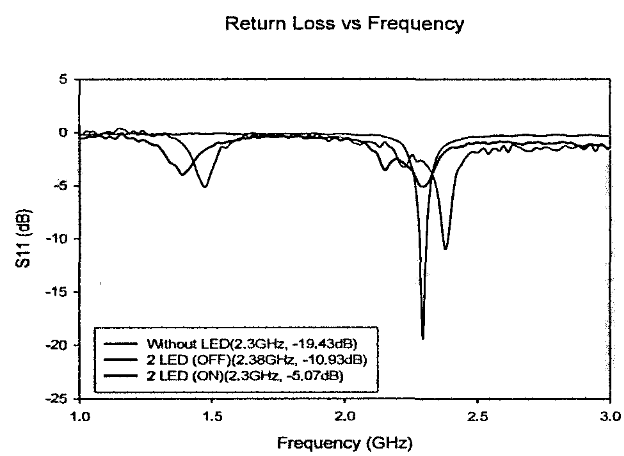

Figure 8: The Return Loss vs Frequency for 2 LED

3 LED

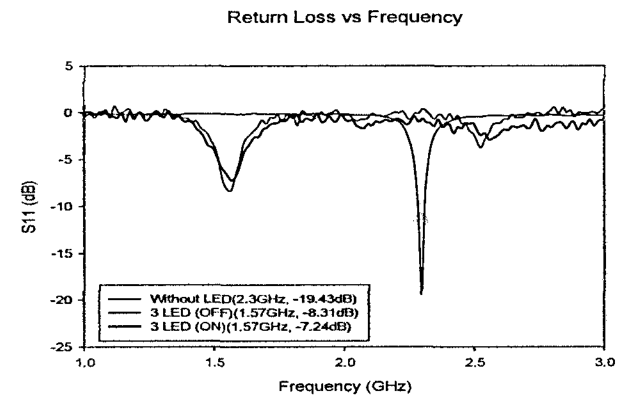

Figure 9: Return Loss vs Frequency for 3 LED

4 LED

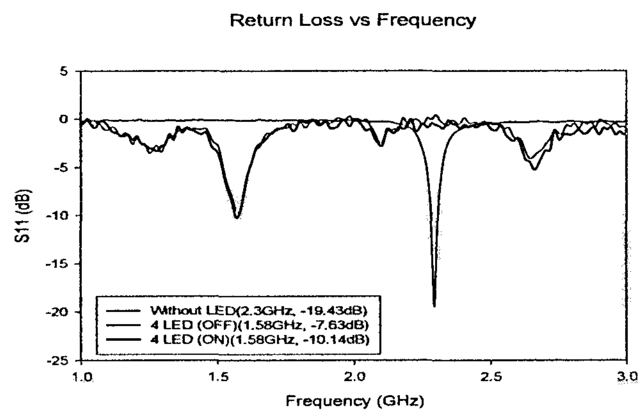

Figure 10: Return Loss vs Frequency for 4 LED

5 LED

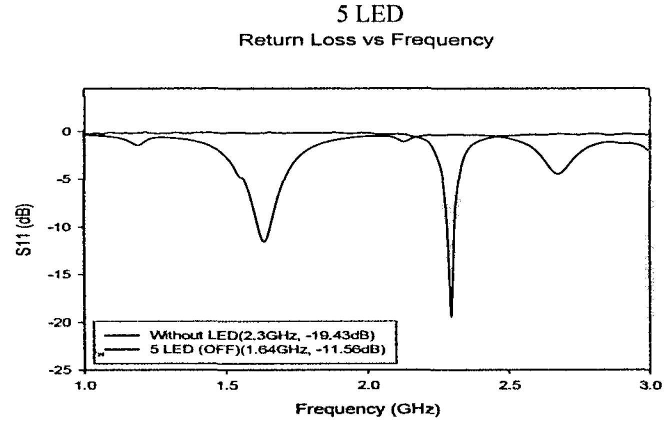

Figure 11: Return Loss vs Frequency for 5 LED

Figure 7 to Figure 11 shows the changes of return loss when the parasitic LED is placed on the antenna one by one. By comparing each of the return loss graphs, the new resonant frequency is starting to occur when there are the existing of the LED on the antenna. As the quantity of the LED is increased, the return loss is also changed to -11.56 dB. The resonant frequency is shifted to the lower frequency as the number of LED is increased. This result is satisfied with the antenna theory which is stated that the bigger of the antenna size, the frequency will decrease[14]. As the LED is connected in between inner loop and the outer loop, the antenna size is *increased because the LED has served as the bridge. The LED* is also considered to have an inductance characteristic[15]. That is why the frequency tends to shift to the higher frequency when the number of LED is increasing. The location of the LED itself also gives effect to the value of return loss the location of first, second and third led is placed counter clockwise, the value of S_{11} is increasing slowly but, when LED fourth and fifth is placed symmetrically to LED first and second, the S_{11} value approaching -10dB. There are no different for "ON" mode and "OFF" mode. Table 3 shows the result of the integrated square loop antenna.

TABLE 3: RESULTS OF INTEGRATED SQUARE LOOP ANTENNA

No of LED	Frequency (GHz)		Return Loss (dB)	
	OFF	ON	OFF	ON
1	2.3	2.3	-14.12	11.25
2	2.38	2.3	-10.93	-5.07
3	1.57	1.57	-8.31	-7.24
4	1.58	1.58	-7.63	-10.14
5	1.64	-	-11.56	-

RADIATION PATTERN

Figure 12 to Figure 17 show the radiation pattern of the integrated antenna with the increment number of LED. There are slightly different at the pattern capture for each LED. However, the radiation of the LED is approaching to the omnidirectional radiation pattern as the number of LED increase. According to the theoretical of microstrip antenna, the radiation pattern do not have back lobe[16]. However, with the existing of the LED, the radiation pattern is starting to become an omnidirectional. This is because after the LED is placed, the antenna is becoming a slotted antenna[17].

LED 1

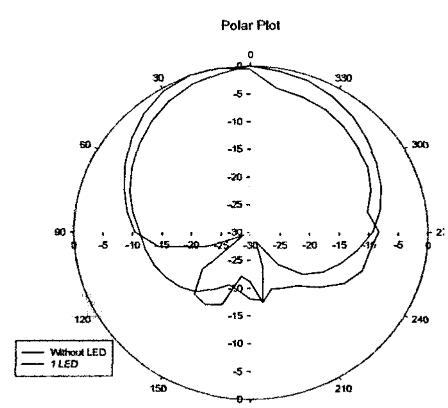

Figure 12: The Radiation Pattern for 1 LED

2 LED

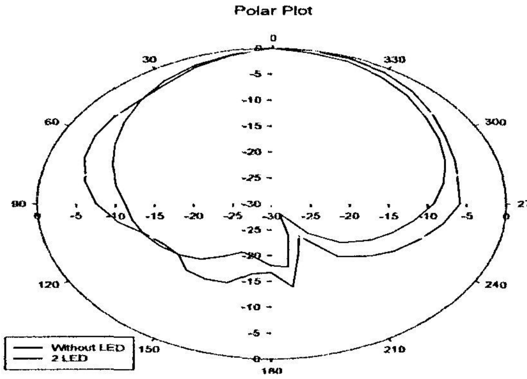

Figure 13: The Radiation Pattern for 2 LED

3 LED

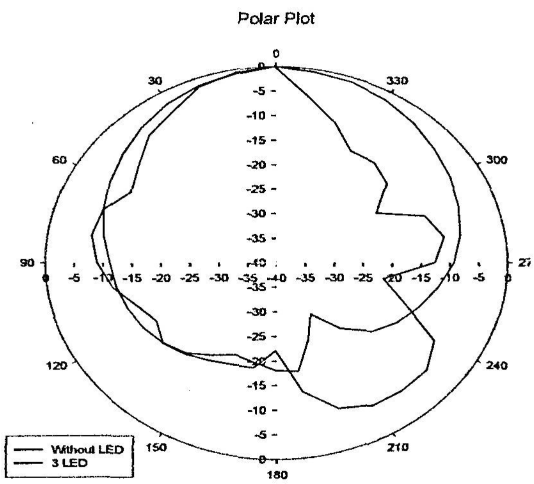

Figure 14: Radiation Pattern for 3 LED

4 LED

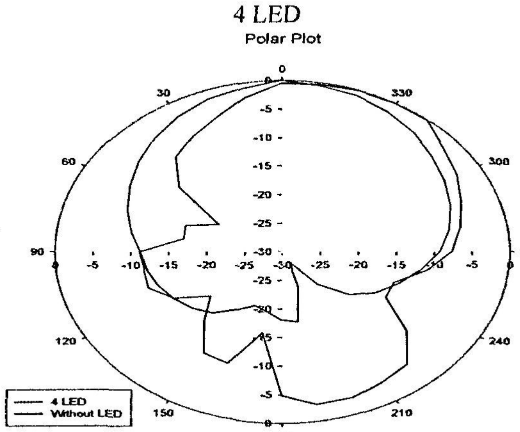

Figure 15: Radiation Pattern for 4 LED

5 LED

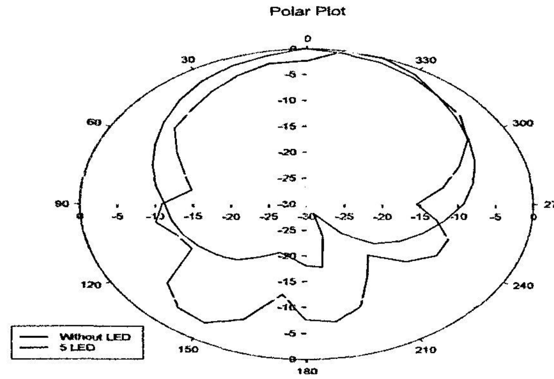

Figure 16: Radiation Pattern for 5 LED

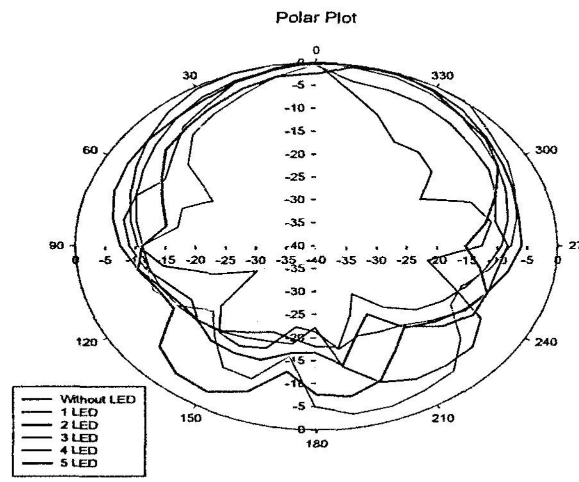

Figure 17: Radiation Pattern for all LED

IV. CONCLUSION

This research is investigating the effect of LED for the antenna. It is affecting the performance of the antenna by shifting the resonant frequency to the lower frequency. Besides that, the return loss also tends to be deeper along the shifted frequency. For this design, the LED serves as a bridge on the antenna. There are a few factors that need to be considered when placing the LED on the antenna such as the location of the LED, the connection of the LED and the process of placing the LED on the antenna because it will affect the return loss and the matching system between feeding and radiating patch. The location of the LED also will give effect to the radiation pattern as the increment of the LED will change the radiation pattern to omnidirectional. At this time, the antenna and the LED will act as slot antenna.

For a future research, different material of LED can be used as a parasitic element and the effect of the material can be investigated. Besides that, the jumper used to connect the DC supply to the LED can be replaced with other connecter. As the technology development, the application of the antenna can be reconfigurable for another application. The bandwidth and the gain of the antenna also can be improved in future research by adding a different parasitic element or applying a different method on enhancing a bandwidth of a microstrip antenna.

V. ACKNOWLEDGEMENT

The author of this paper like to thanks all the members of the Antenna Research Group for the support and guidance that have been given to finish the project and the facilities provided throughout the project.

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