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PCB/Microstrip Antenna Design and Simulation

Aaron Don M. Africa, Francis Xavier Asuncion, Raymund Miguel Francisco A. Munchua, Janos Lance Tiberio, Joshua Vincent Ligayo, Raine Mattheus Manuel

Department of Electronics and Communications Engineering
De La Salle University, Manila
2401 Taft Ave., Malate, Manila 1004,
Philippines, aaron.africa@dlsu.edu.ph

ABSTRACT

The paper will give insights on the different types of printed circuit board (PCB) antennas. The study will also explain why the PCB antenna is continuously being developed. The paper will also explain how PCB antennas work. This research aims to create and simulate a working Printed circuit board antenna design. The study will be implemented using MATLAB and its toolboxes. The simulation will focus on the practicality of a PCB antenna and will show how it functions. The design of the PCB antenna will show the basic implementation of a smartphone antenna. The data that will be gathered will show how a smartphone antenna works in the real world. Through the data and results presented in the paper, the concept of how the signal transmission works within smartphones and how data is being sent and received will be explained. The study will give insights on how to improve upon current PCB antennas and what factors should be worked on to make more accurate, efficient and cost-efficient.

Key words: Printed circuit board antenna, frequency, wireless communication, data transfer, transmission lines.

1. INTRODUCTION

In today's modern world, wireless systems have been a big part of electronics, especially the ones being used every day by consumers. Before the development of portable and thin devices like smartphones, similar communication devices used big antennas in order to transmit and receive information. The same goes for the old models of televisions (TV), they used to have big antennas on top of them or at least connected to them that would serve as the receiver for different TV programs to watch. Basically, antennas back in the days, antennas were bigger and more visible than what antennas have in-store today. This, of course, does not include the big ones used for long-distance communications [1, 2].

Today, microstrip antennas or printed circuit board (PCB) antennas are antennas found inside a device that is fabricated using microstrip on a PCB [3]. These antennas are mostly used in microwave frequency applications with frequencies between 300 MHz and 300 GHz. Applications of this frequency range varies from telecom, cellular access, space communication, GPS, and many more [4]. Smartphones today use PCB antennas known as the Inverted-F antenna, which is also used in wireless local area network hardware (WLAN) and other portable wireless communication devices [5]. A popular application of PCB antennas today is the RFID system used in physical cards that contain information.

PCB antennas today are in demand and are good antennas for small wireless devices. Its design varies with its integration with the rest of the electronic circuit it supports. The performance and consistency it provides depend on its foundation. These antennas can be fabricated with different transmission line technologies. Depending on the application, different transmission lines can be combined within the PCB antenna. [6,7]

Designing a PCB antenna involves choosing an integrated circuit (IC) that would meet the requirements of the design, choosing a type of antenna design, and finally designing the layout before testing the antenna. [8, 9]

2. BACKGROUND OF THE STUDY

With the continuing emergence of smartphones in the industry, a lot of companies are developing different features that make their device stand out from the rest [10,11]. Different aspects from a smartphone are in continuous development but one integral part of a phone will always be there, its microstrip antenna or printed circuit board antenna. The microstrip antenna is a miniature version of common antennas. It is made to fit inside a compact space like a smartphone or any other handheld device. The microstrip antenna has many different functions inside a smartphone. The most basic concept is that it performs the sending and receiving of data. A more specific application would be text messaging, phone calls, web browsing, GPS location, and file transferring.

The development in microstrip antennas continues to grow. With different factors that are being focused on there are a lot

of reasons why phone antennas are continuously being researched on. Since the data being transmitted from a data source is evolving, the receiver of smartphones should also be developed. For example with the continuing evolution of the generations of wireless communications, from the first generation of wireless communication which was analog to the second generation which was already digital to the third and fourth generation that constantly showed improvements and the currently underdevelopment fifth generation of wireless communication, it is easy to see that wireless communication is still developing. Phone antennas are continuously being worked on to cater to the frequency of the data that it will receive [12,13,14].

It is also worth taking into consideration that another reason for the further development of the PCB antenna is for better accuracy, efficiency, practicality, and cost. With the demands of smartphones being as fast and as efficient as possible, a key part in its functionality comes from the data it receives, the data that passes through the PCB antenna [15, 16].

3. STATEMENT OF THE PROBLEM

The desire for the best possible wireless communication speed and quality in wireless communication devices used by consumers becomes stronger as new technology is introduced. Of course, consumers also desire to have the products as cheap and as simplistic as possible. Because antennas are critical parts in wireless communication, its design and integration to the whole system's circuit is the foundation for a good wireless communication device[17,18].

Today, cellular communication is a daily driver of many. Because people grow more reliant to smartphones every day, they often use their cellular network for communication and also for internet communication, which requires the use of cellular data for accessing the web [19,20]. How well the phone will be able to communicate wirelessly in order to get the best signal and network quality not only depends on the carrier where the consumer is subscribed but also the device's capability. Because of PCB antenna's consistency and good performance, the design and improvement of current PCB antennas, especially Inverted-F antennas found inside the phone, would play a big role in the phone's quality because majority of a phone's activity usage is dependent on the cellular network and other wireless communication sources such as wireless fidelity or Wi-Fi [21].

4. SIGNIFICANCE OF THE STUDY

Because the demand from the consumers and engineers for better quality and speed of wireless communication is growing fast, the development of new antenna designs that would be both goods in performance, efficiency, and practical is a must for research and development. For consumers, the development of new antennas, specifically PCB antennas for this research paper, means the advance of wireless communication technology in terms of speed and quality. For engineers, new designs can help build a new foundation to future wireless communication systems such as cellular communications through the use of PCB antennas found on phones. Of course, these are not only limited to cellular applications but also portable wireless applications like RFIDs used in identification cards, toll gate payments like the ETC here in the Philippines, and many more [22, 23, 24].

5. DESCRIPTION OF THE SYSTEM

The Antenna design that was created in MATLAB is a Log Periodic Antenna encased in FR4 dielectric material. The dimensions of the antenna are as follows:

The board length is 0.03658 m, the board width is 0.02437 m, the height is 0.0016m, the strip line width is 0.001185m, the feed length is 0.0065m, Each arm length is varied and are 0.00405m, 0.004501m, 0.005002m, 0.005557m, 0.006175m, 0.006861m, 0.007623m, and 0.008471m. The Arm widths are also varying and are as follows 0.00088m, 0.00098m, 0.00109m, 0.00121m, 0.00134m, 0.00149m, 0.00166m, and 0.00185m. Lastly the Arm spacing is 0.0027m, 0.003m, 0.00333m, 0.0037m, 0.00411m, 0.00457m, and 0.00508m. The antenna has a resonant frequency of 2.45 GHz[25, 26].

6. METHODOLOGY

For this research paper, MATLAB's Antenna Toolbox was used to design an antenna and test its properties. With the MATLAB Antenna Toolbox, designing, analyzing, and visualizing antenna elements and antenna arrays was possible. The students used the toolbox to create a basic PCB antenna with certain properties. These properties can be seen using some of the features offered in the antenna toolbox of MATLAB. The properties observed in this research paper of the antenna are the minimum and maximum gains, frequency operation, azimuth, elevation, and impedance.

7. REVIEW OF RELATED LITERATURE

A Basic Rectangular Microstrip Patch Antenna Design and Analysis for Exposure System is a journal article written by Rahul Dev Mishra and Pramod Kumar Singhal in 2016. The purpose of the research conducted was to design and analyze a microstrip antenna for exposure systems. The authors discussed the characteristics of a microstrip antenna as introductory information to the antenna model that they were designing. The design of the microstrip antenna is rectangular and was designed using CST software. The article also included the fabrication of the rectangular microstrip antenna. The process started with a simulation of the design. After multiple simulations, the actual fabrication of the antenna model was done by screen printing, etching, and drilling for the SMA port connection. After completing the construction of the antenna model, they tested the physical model of the rectangular microstrip antenna that they designed. They used a spectrum analyzer to test the rectangular antenna. The authors provided the parameters, such as the return loss,

average power, and radiation patterns, from the actual testing of the antenna model. They also compared both the simulation and the actual testing of the designed rectangular microstrip antenna.

Dual-Band Spline-Shaped PCB Antenna for Wi-Fi Applications is a journal article by Leonardo Lizzi, Federico Viani, and Andrea Massa in 2011[27]. The paper discussed wireless communication systems for local area networks and its continuous development. It also discussed the functions and structure of a dual-band PCB antenna designed for applications in WI-FI. It also provided information on the antenna which was designed to be functional for WI-FI bands and reliable impedance which matches frequencies centered at specific values of frequencies. The structure of the antenna was modeled geometrically to a spline curve and a partial metallic ground plane. The effectiveness of the antenna model and the prototype were tested through simulations and experimental measurements. Results collected were both electrical parameters and radiation patterns. The results from the tests were validated theoretically and experimentally. From the results obtained, it can be concluded that the designed antenna model is an effective model because it displays a VSWR below 2 in both WI-FI bands specified in the study.

Low-cost PCB antenna for UWB applications is a journal article conducted by Low, Z. N., Cheong, J. H., and Law, C. L. The article contains a design of a low cost double-sided PCB antenna. They designed an antenna that has return loss of more than 10 db [28]. They explained that antennas are important components when it comes to the performance of an ultra wide-band system also known as UWB. Development of antennas tends to focus on small antennas to be more feasible on manufacturing and integrate on system board. The article presented a good group delay result and the antenna's impulse response. Their case study was to present a small antenna that can produce minimal distortion and wide bandwidth. Their design of the antenna is shaped like a knight's helm.

8. THEORETICAL CONSIDERATIONS

The basic construction of a printed circuit board antenna or PCB antenna (figure 1)consists of limitations [29]. The construction of a PCB antenna can be varied to improve its functionality and performance in different conditions. The loop antenna is one variation to the basic PCB antenna. The loop is a PCB board copper in the form of a closed-loop. It is connected to the terminal of the transmitter or the receiver. It is ideal for short-range communications but is generally inefficient. Another type of PCB antenna variation is the patch antenna. The patch is attached on the back of the PCB on a ground plane. It has a strong radiation perpendicular to the patch. Patch antennas are used to increase the beam width and increase the gain of wide local area network antennas. The inverted-F antenna is commonly used in wireless devices such as mobile phones. Its function is to greatly increase the bandwidth of the antenna because most digital wireless devices require such wide bandwidths. Another PCB antenna variation is the Meander line. The ideal structure of this type of antenna is shorter in length due to the capacitors. The size of the antenna is decreased, as well as its bandwidth, efficiency, and radiation resistance. [30] The last type of PCB antenna is the Slot which is commonly used in aircraft radars. The slot antenna is oriented horizontally and has a vertical electrical field polarization. The slot is center-fed and has high impedance. The properties of antenna is shown in figure 2.

9. DATA AND RESULTS

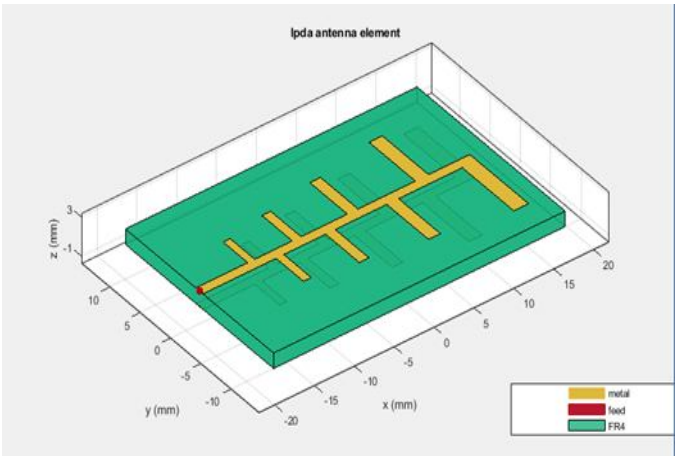

Figure 1: PCB Antenna Design

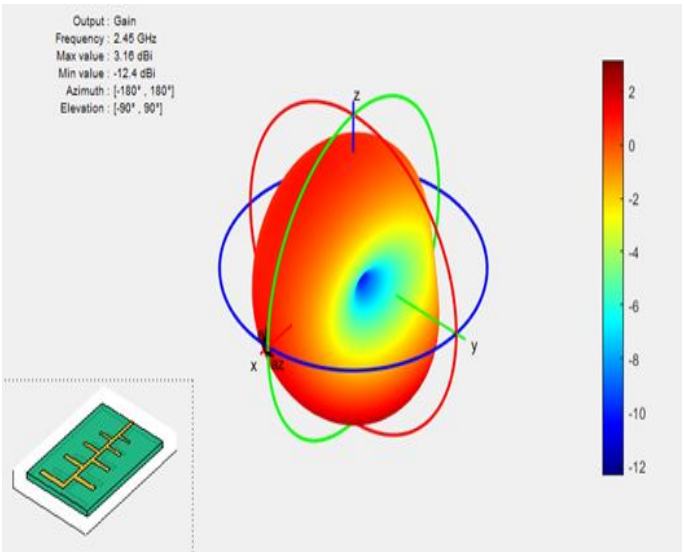

Figure 2: Antenna Properties

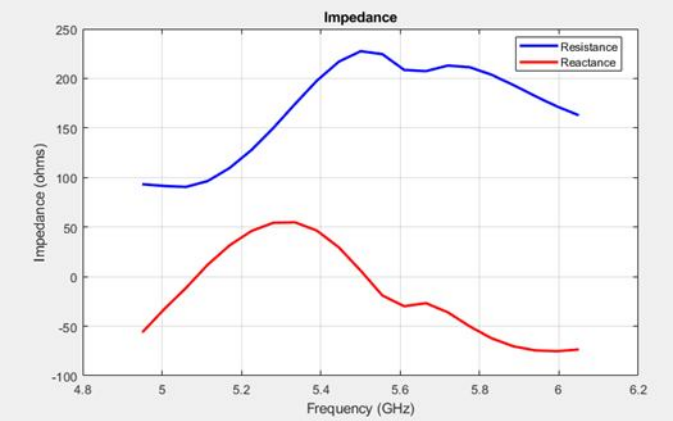

Figure 3: Antenna Impedance

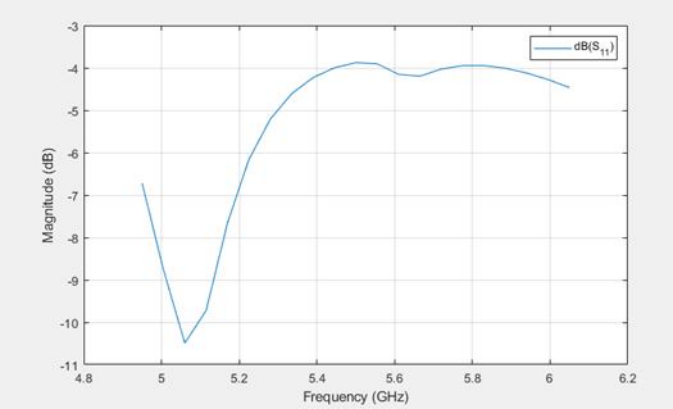

Figure 4: Antenna Gain

MATLAB Code

```
antennaObject = lpda;
antennaObject.Substrate.Name = 'FR4';
antennaObject.Substrate.EpsilonR = 4.8;
antennaObject.Substrate.LossTangent = 0.026;
antennaObject.Substrate.Thickness = 0.0016;

plotFrequency = 2450000000;

freqRange = (4950:55:6050) * 1e6;

figure;

show(antennaObject)

figure;
pattern(antennaObject, plotFrequency)

figure;
impedance(antennaObject, freqRange)

figure;
s = sparameters(antennaObject, freqRange);
rfplot(s)
```

Here the antenna is generated using the lpda or Log-periodic antenna variable which is a set variable in the matlab antenna toolbox. The dimensions are specified, and the dielectric substrate is set to be FR4. The resonant frequency is also specified which is 2.45 GHz for Wifi application. The plot for the 3dimensional gain of the antenna along its effective range is generated along with the impedance graph, which is seen to have peak resistance and lowest reactance at its resonant frequency. The 2d graph for the gain is also shown.

10. ANALYSIS OF DATA

Small design of a PCB antenna is a great product that can be feasible to signal transmission applications. MATLAB was used to create the measurements of each parameter that is suited on antenna design of PCB. This design is feasible when it comes to manufacturing it as it involves minimal materials and it is easier to integrate it into the system board. The antenna design was a simple rectangular shaped PCB that produces an impedance and reactance output. These outputs were closely related to each other as shown in Figure 3. The impedance of the antenna decrease to the point of around 5.1 GHz and eventually it increases rapidly. The code of the MATLAB as shown before this section is a code that sets the parameters of the antenna. It also shows the plot of the impedance and reactance with respect to the frequency. The impedance and reactance of the PCB and antenna are important as it shows how the performance of the PCB antenna affects its signal transmission and how well will the signal from that PCB antenna transmit and receive. The benefits of designing a small PCB design of the antenna is it is small which it is efficient and inexpensive. It requires less materials in order to manufacture it. It can produce greater bandwidth to provide greater range of frequency to transmit and receive signals.

11. CONCLUSION

A PCB antenna is a design that applies signal transmission using PCB. This design was developed using simulation such as MATLAB and other software tools. The results of the simulation proved that PCB designed antenna is useful and effective as the parameters that were measured satisfies the problem that was given. The researchers were able to implement antenna design using MATLAB. The results of the MATLAB was successful as it satisfies the condition of the given problem. Figures 3 and 4 were the plots of the parameters of the PCB antenna. It shows the impedance and reactance of the design with respect to its frequency.

Antenna design is important in the transmission of signal because antennas are the major component which can channel signals between the transmitter and receiver. Basically, they are the bridge when it comes to transmitting signal. Without antennas, signals cannot travel from one location to other destined location.

12. RECOMMENDATION

The researchers designed a printed circuit board antenna. The PCB antenna was a generic design that implemented an antenna design within a PCB. The properties of the PCB antenna is intended for simulation purposes only. They did not subject the PCB antenna to an actual circuit within the compact spaces of a mobile phone or any other handheld device. For future studies, the researchers recommend testing the simulated PCB antenna to an actual system. The researchers would also suggest changing some parameters in the experimentation. Parameters like dimensions and resonant frequency can be changed to see if there will be any effect on the antenna property, antenna gain, and the antenna impedance.

The researchers would also recommend studying on different types of antennas. The one used in the study was the most common type of logic-periodic antenna (LP), the logic-periodic dipole array antenna. Future researches can include different types of antennas like the yagi antenna. For future studies, the researchers would suggest looking for the best types of antennas within a smartphone. Since there are a lot of antennas in a smartphone, the researchers suggest looking for and simulating antennas for 2G/3G mobile antenna, 4G mobile antenna, GPS antenna, WiFi antenna, NFC antenna Bluetooth antenna and 5G mobile antenna in future studies. The researchers would also suggest studying and simulating microstrip antennas, planar inverted-F antennas, and printed antennas, the most commonly used antennas in mobile devices.

The researchers designed the PCB antenna using the FR4. They must take into account the dielectric constant at higher frequencies as FR4 is not advised for 1GHz and above frequencies. Other researches can improve upon the dielectric material used within the antenna. Different dielectric substrates like E glass, Fused Quartz, Teflon and foam can be researched on to find the best dielectric substrate for the antenna [30]. The database configuration of the system are based on the studies of [31,32,33,34,35]. The program structures follow the studies of [36,37,38].

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