AN ANALYSIS OF SIGLE-LAYER DIFFERENTIAL CPW-FED NOTCHED-BAND TAPERED-SLOT UWB ANTENNA

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This Report Is Submitted In Partial Fulfillment of Requirement for the Bachelor Degree of Electronic Engineering (Telecommunication Electronics)

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

June 2015

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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Tajuk Projek : An Analysis of Singe-Layer Differential CPW-Fed Notched-Band Tapered-Slot UWB Antenna

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Special dedication:

To my beloved family and my highly dedicated supervisor.

ACKNOWLEDGEMENT

First of all, I would like to express my deepest appreciation to my supervisor, Dr Azlishah bin Othman who had giving me guidance in completing this final year project. Besides that, I would like to thank other lectures and post graduate students of Faculty of Electronic and Computer Engineering for their cooperation, valuable information, suggestion and guidance in helping me to complete this final year project.

Furthermore, I would like to thank my family for their cooperation, non-stop encouragement, and full support throughout my four years course of study. Finally, I would like to thank all my coursemates who have been contributing with helps and guidance directly and indirectly.

ABSTRACT

Ultrawideband (UWB) system operates from 3.1GHz to 10.6GHz as been released by the Federal Communications Commissions (FCC). However, there are some existing wireless communication system partially overlap with UWB system such as WLAN, RFID and radar system. In order to avoid signal interference at certain frequencies, notch-band characteristic is needed to be applied at UWB antenna. Therefore, this project is conducted by designing and analyzing two UWB antennas which one antenna consists of notch-band characteristic to avoid overlapping. The notch-band characteristic can be achieved by applying resonators to the antennas. These antennas are then analyzed in term of the bandwidth and the gain. The notch-band characteristic is studied too in this project.

ABSTRAK

Sistem komunikasi Ultrawideband (UWB) beroperasi dari frekuensi 3.1 GHz hingga 10.6 GHz seperti yang telah ditetapkan oleh Suruhanjaya Komunikasi Persekutuan. Walaubagaimanapun, terdapat beberapa lagi sistem komunikasi tanpa wayar yang bertindih dengan sistem UWB seperti WLAN, Sistem Pengenalan Frekuensi Radio (RFID), dan sistem radar. Bagi mengelak gangguan isyarat pada frekuensi tertentu, sifat 'notch band' adalah diperlukan untuk diaplikasikan ke antena UWB. Sehubungan dengan itu,projek ini dilaksanakan dengan mereka dan menganalisa dua antena UWB di mana salah satu darinya mempunyai sifat notch band yang bertujuan untuk mengelak pertindihan sistem. Sifat 'notch-band' boleh dicapai dengan mengaplikasikan resonator kepada antena tersebut. Antena yang telah direka ini kemudiannya akan di analisa menggunakan dapatan dan lebar jalur yang telah diperolehi. Sifat "notch-band" juga akan di kaji dalam projek ini.

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UWB	-	ULTRAWIDE BAND
CPW	-	COPLANAR WAVEGUIDE
FCC	-	FEDERAL COMMUNICATION COMMISSIONS
VSWR	-	VOLTAGE STANDING WAVE RATIO
WLAN	-	WIRELESS LOCAL AREA NETWORK

CHAPTER I

INTRODUCTION

1.1 Project Summary

This project is started by designing two CPW antennas that operate in the ultra-wideband range of frequencies from 3.1 GHz to 10.6 GHz. The designed antennas then will be simulated. The design and simulation processes are done by using CST (Computer Simulation Technology) software. These 2 antennas then will be compared from one to another in term of the antennas performance before one antenna is proposed and fabricated. The comparison of these antennas is made by analyzing the value of the s-parameters and the antennas' gain.

1.2 Project Introduction

Antenna is a transducer that is designed for the usage of transmitting and receiving data in electromagnetic waves. Antennas have the ability to convert electrical power into radio waves and convert the radio waves back to electrical power in order to complete a communication system. These processes may occur in the transmitter and the receiver.

In a transmission process, a radio transmitter supplies an electric current oscillating at radio frequency to the antenna's terminals before the antenna radiates the energy from the current as electromagnetic waves. In reception, an antenna intercepts some of the power of an electromagnetic wave to produce a tiny voltage at its terminals before the voltage is applied to a receiver for the amplification process. The antennas are widely used for most systems and components that are connected wirelessly such as cell phones, walkie-talkie, and satellite communication systems.

Antennas consist of metallic conductors that are connected to the receiver electrically through the transmission line. The transmitter forces an oscillating current of electrons through the antenna thus creating an oscillating magnetic field around the antenna elements. This process encourages the charge of the electrons to create an oscillating electric field along the elements.

Antennas can be categorized into two types which are the omnidirectional and the directional according to its application. Omnidirectional is a weak directional antenna that will receive or transmit waves and data in all direction. The omnidirectional antenna is used at low frequency and low power applications. The example of the omnidirectional antenna is the whip antenna. The directional antenna operates differently compared to the omnidirectional as it is intended to maximize its coupling electromagnetic field in its direction. The directional antenna will receive and transmit radio waves and data in particular direction and this category of antenna operates in high frequencies

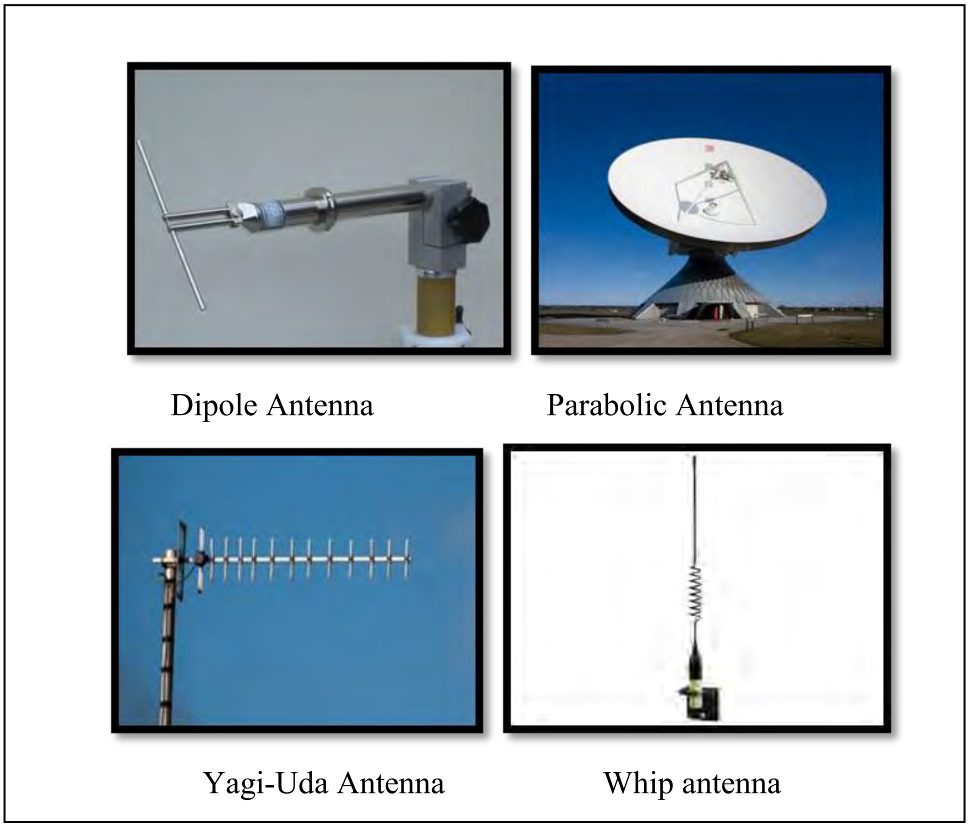

Figure 1.1: Types of Antenna

Nowadays, basic antennas such as dipole and vertical design are rarely used as the technology grows rapidly. Moreover, there are many types of antenna that has been developed to improve the performance in term of the directivity and the gain of the antenna.

Microstrip antenna is an antenna that is developed to overcome problems facing by antennas that had been developed before. Microstrip is light in term of weight, can produce high gain, and simpler to design and construct. These advantages make microstrip antenna a popular choice for certain application such as medical application. Microstrip antennas have the ability to produce high gain value, wide bandwidth, and good efficiency. This type of antenna consists of a feeding network that plays the role to distribute the voltages into one point. Other than that, impedance matching provides efficiency to the antenna as the connection between the antenna and cable may have some mismatch. Therefore, to overcome this mismatch is by producing impedance matching techniques for antennas. The performance of a microstrip antenna is depending on the antenna's parameters such as dielectric parameters, height, length, thickness, and frequency. These parameters can be optimized to improve the performance of the particular antenna. Microstrip patch array antennas consist of a very thin metallic strip that is patched on ground plane according to particular designs. The performance of a microstrip antenna can be obtained by analysing the dimension of frequency, directivity, r efficiency, return loss, and the standing wave ratio.

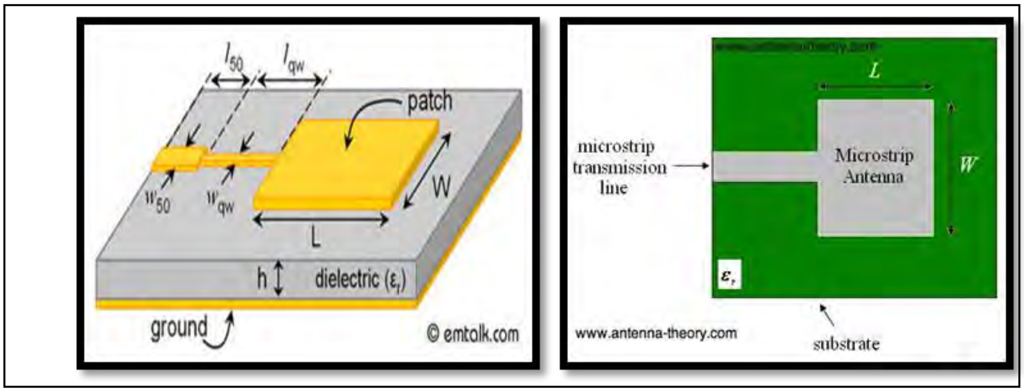

Figure 1.2: Example of Microstrip Antennas

Resonant frequency is the tendency of a system to oscillate with greater amplitude at some frequencies. At these frequencies, small periodic forces can produce large amplitude oscillations since this system has stored energy. This phenomenon may occur at all types of waves and can have some small amount loss called damping.

The gain of an antenna is the main criteria used to determine the antenna's performance. The plot of the gain as a function of direction is called radiation pattern. The efficiency of an antenna in transmitting and receiving data can be obtained by analysing this radiation pattern. This ratio is usually expressed in decibels and the units are referred to as "decibels-isotropic" (dBi). The effective length of an antenna can be obtained after determining the antenna gain. The effective length is proportional to the square root of the antenna's gain for particular frequencies and radiation resistance. This technique is very useful for the optimization process to improve the antenna performance.

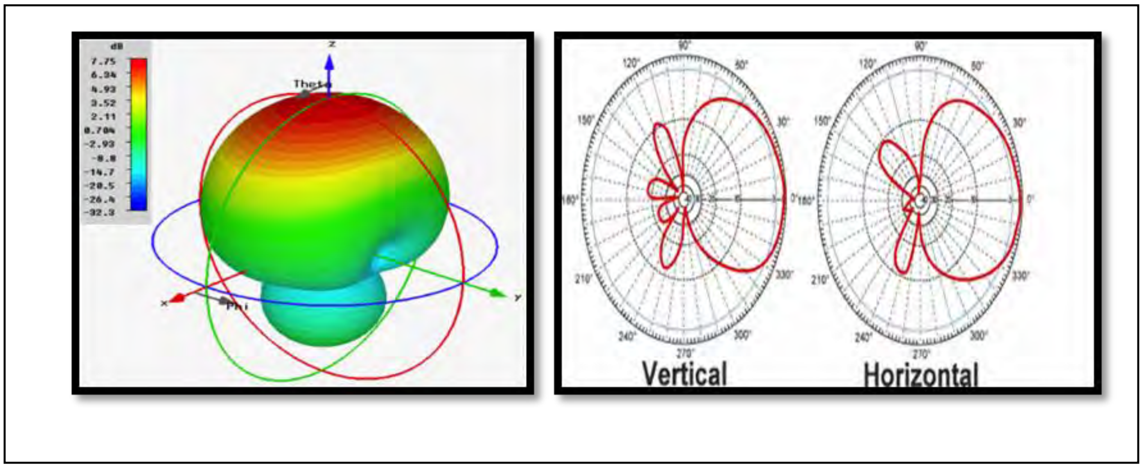

Figure 1.3: Example of the Gain in Radiation Pattern of a Microstrip Patch Antenna

Bandwidth is another fundamental parameter for an antenna. Bandwidth describes the range of frequencies over which an antenna can properly radiate or receive wave energy. The desired bandwidth is one of the parameter that is needed to be decided before an antenna is designed. IEEE defines bandwidth as "*The range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard.*" However, in practise, bandwidth is normally determined by measuring characteristics such as SWR and S-parameters over certain range of interested frequencies.

Return loss is the loss of signal power resulting from the reflection caused by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. The return loss is usually expressed as a ratio in decibels (dB).

$$RL(dB) = 10_{log}\frac{Pi}{Pr} \quad (1.1)$$

Where RL (dB) is the return loss in dB, Pi is the incident power and Pr is the reflected power. Return loss is related to both standing wave ratio (SWR) and reflection coefficient. Increasing in return loss is corresponding to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in lower insertion loss. Return loss is used in modern practise in preference to SWR because it has better resolution for small values of reflected wave.

Ultra-wideband is a radio technology which may be used at a very low energy level for short-range, high-bandwidth communications using a large portion of the radio spectrum. Similar to spread spectrum, UWB communications transmit in a manner which does not interfere with conventional narrowband and carrier wave used in the same frequency band. Ultra-wideband is a technology for transmitting information spread over a large bandwidth (>500 MHz); this should, in theory and under the right circumstances, be able to share spectrum with other users. Regulatory settings by the Federal Communications Commission (FCC) in the United States intend to provide an efficient use of radio bandwidth while enabling high-data-rate personal area network (PAN) wireless connectivity; longer-range, low-data-rate applications; and radar and imaging systems. Ultra-wideband (UWB) signals operate from 3.1GHz to 10.6GHz as been released by the Federal Communications Commission (FCC).

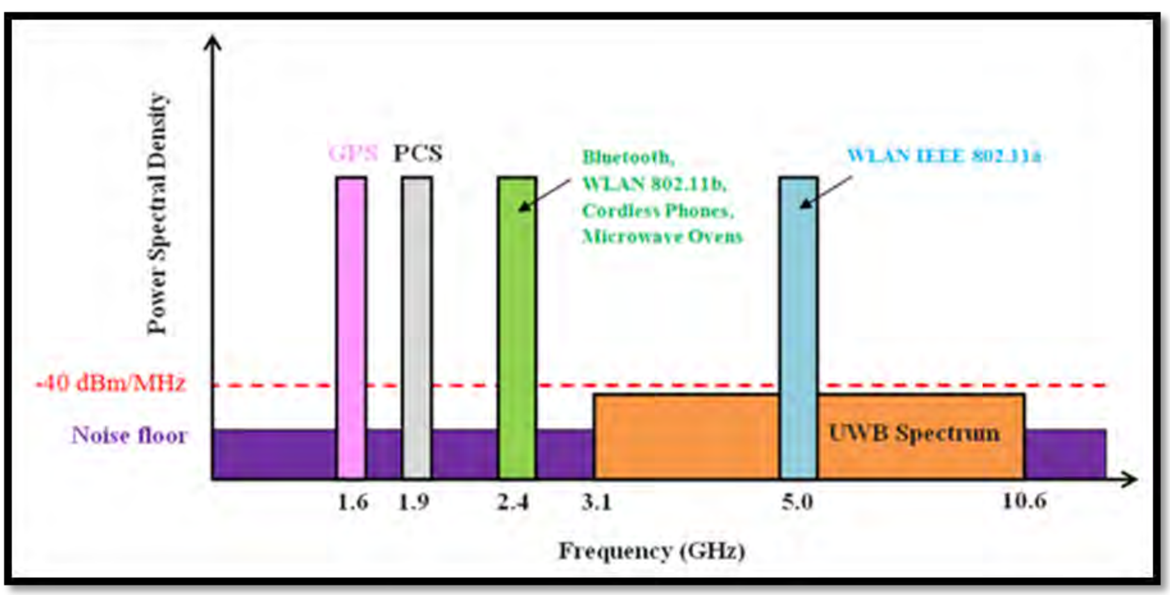

Figure 1.4: UWB versus other radio communication systems

Plenty types of antennas have been designed for single-ended signal operation in recent years. However, differential signal operation has been widely used in the radio frequency systems. When single-ended antennas are integrated with differential circuits, baluns are needed to transform differential signals into single-ended signal, which cause energy loss and decreases the efficiency of the system. Thus, differential antennas are more suitable for differential signal operation due to the direct integration with differential circuits. An antenna is said to be single layer when the patches and the feeding network are placed on the same layer.

Coplanar waveguide is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals. On a smaller scale, coplanar waveguide transmission lines are also built into monolithic microwave integrated circuits. Conventional coplanar waveguide (CPW) consists of a single conducting track printed onto a dielectric substrate, together with a pair of return conductors, one to either side of the track. All three conductors are on the same side of the substrate, and hence are coplanar. The return conductors are separated from the central track by a small gap, which has an unvarying width along the length of the line. Away from the central conductor, the return conductors usually extend to an indefinite but large distance, so that each is notionally a semi-infinite plane. Conductor-backed coplanar waveguide (CBCPW) is a common variant which has a ground plane covering the entire back-face of the substrate. The ground-plane serves as a third return conductor. The electromagnetic wave carried by a coplanar waveguide exists partly in the dielectric substrate, and partly in the air above it. In general, the dielectric constant of the substrate will be different (and greater) than that of the air, so that the wave is travelling in an inhomogeneous medium. In consequence CPW will not support a true TEM wave; at non-zero frequencies, both the E and H fields will have longitudinal components.

A feedline is used to feed the radio waves to the rest of the antenna structure, or in receiving antennas collect the incoming radio waves, convert them to electric currents and transmit them to the receiver. There are many different methods of feeding and four most popular methods are microstrip line feed, coaxial probe, aperture coupling and proximity coupling. Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be considered as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.

Coaxial feeding is feeding method in which that the inner conductor of the coaxial is attached to the radiation patch of the antenna while the outer conductor is connected to the ground plane. Aperture coupling consist of two different substrate separated by a ground plane. On the bottom side of lower substrate there is a microstrip feed line whose energy is coupled to the patch through a slot on the ground plane separating two substrates. This arrangement allows independent optimization of the feed mechanism and the radiating element. Normally top substrate uses a thick low dielectric constant substrate while for the bottom substrate; it is the high dielectric substrate. The ground plane, which is in the middle, isolates the feed from radiation element and minimizes interference of spurious radiation for pattern formation and polarization purity. Proximity coupling has the largest bandwidth, has low spurious radiation. However fabrication is difficult. Length of feeding stub and width-to-length ratio of patch is used to control the match.

Notch function characteristic has been developed for the communication system to avoid signal interferences at certain frequencies. This function characteristic is clearly needed for UWB communication. As been released by the Federal Communications Commission (FCC), UWB signals operate from 3.1GHz to 10.6GHz. Within that range, some existing wireless communication system partially overlaps with UWB system. The communication system, WLAN operates at 5.15GHz – 5.825 GHz thus allowing UWB and WLAN to overlap, producing signals interference at the frequencies. Therefore, antennas that can be operated from 3.1GHz to 10.6GHz and have sharp and controllable notch from 5.15GHz to 5.825 GHz characteristic are needed for the UWB communication system. The notch function characteristic can be developed for an antenna by undergoing several techniques. For example, addition of a pair of stubs and slits can be added to the patch of an antenna to develop a controllable notch characteristic. This notch characteristic operates similarly to the band stop filter that passes most frequencies unaltered, but attenuates those in a specific range to very low levels.

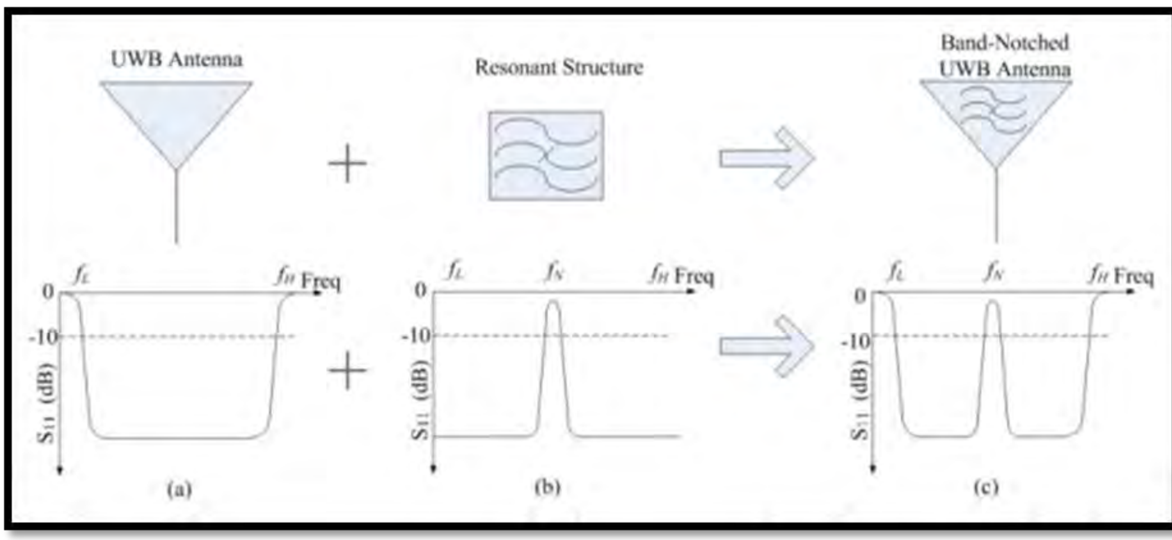

Figure 1.5: Basic design concept for band-notched UWB antenna

The main limitation of microstrip antennas is that this type of antenna radiates efficiently at narrow frequencies and cannot operate at high power. On the other hand, a large dimension of patch will create higher order modes that will allow radiation or interference at other frequencies. This additional mode allows the intentional design of multi band patch array antennas. CPW patch array antenna also has low impedance bandwidth, low gain, excitation of surface waves but still sufficient to some applications.

Besides that, due to small separation between the radiating patch and its ground plane, microstrip antennas can only handle low radio frequency power.

The antennas can be used successfully if the frequencies are in range of electromagnetic spectrum. Electromagnetic spectrum covers from the lowest to the higher frequencies. The lower frequencies are normally used in radio communication while the higher frequencies are used in short wavelength communication. Electromagnetic spectrum consists of radio wave, microwave, infrared, visible light, ultraviolet, X-ray, and gamma ray.

1.3 Problem Statement

Ultrawide Band (UWB) signals operate from 3.1GHz to 10.6GHz as been released by the Federal Communications Comission (FCC). However, there are some existing wireless communication system partially overlap with UWB system. The communication system, WLAN operates at 5.15GHz – 5.825 GHz thus allowing UWB and WLAN to overlap, causing signals interference at the frequencies. Therefore, an antenna that can be operated from 3.1GHz to 10.6GHz and have sharp and controllable notch from 5.15GHz to 5.825 GHz characteristic is needed.

1.4 Objectives

This project has three objectives. The first objective is to design a single-layer differential CPW-FED notched-band tapered-slot UWB antenna. An antenna that operates within ultra-wideband (UWB) range of frequencies which operates from 3.1 GHz to 10.6 GHz is needed in this project. The second objective of this project is to achieve a notch-band characteristic to avoid an operating band that operates at 5.15GHz