DESIGN OF MICROSTRIP ULTRA WIDE BAND ANTENNA WITH TWO NOTCH FILTERS FOR WIRELESS COMMUNICATION

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ABSTRACT

This research develops a small size UWB patch antenna with two notch filters. U-shaped and J-shaped slots are loaded in the patch of the antenna for WiMAX and WLAN frequency band rejection. The antenna is simulated using the commercially available CST Microwave Studio software. The slots dimensions are systematically calculatedand optimized to achieve the desired band rejection responses. A multi-state reconfigurable UWB circular patch antenna with two notch filters. The two notch filters can be implemented using U-shaped and J-shaped slots embedded on the patch for WiMAX and WLAN frequency bands rejection. In order to add reconfigurable characteristics to the patch antenna, two copper strips are putted on the slots to represent the ON and OFF switching status of an ideal Pin diode. By using this simple switching technique, the current distribution of the patch changes and enables the antenna to have four modes of operation. The achieved results demonstrate that the antenna can function over the entire UWB working frequency range (3.1 GHz to 10.6 GHz) in one of the switching configurations. On the other hand, it rejects one or both WiMAX (3.13 – 3.7 GHz) and WLAN (5.15-5.85 GHz) frequency bands in the other three switching configurations. The antenna is simulated using electromagnetic simulation software CST Studio Suite. The obtained results were experimentally validated and good agreement was observed.

ABSTRAK

Penyelidikan ini dijalankan dengan tujuan untuk membuat satu UWB antenna yang dilengkapi dengan dua penapis notch. U-shaped dan J-shaped dilekatkan kepada penampal antenna untuk penghapus band frekuensi WiMax dan WLAN. Simulasi dijalankan dengan menggunakan perisian CST Microwave Studio untuk melihat simulasi antenna. Dimensi ruang simpanan dikira dan di optimumkan dikira secara sistematik dalam usaha untuk mendapatkan tindakan balas daripada penghapus frekuensi band. Satu konfigurasi pelbagai keadaan untuk UWB dilengkapi dengan antenna yang mempunyai dua penapis notch. Penapis notch ini boleh diimplementasikan dengan menggunakan ruangan U-shaped dan juga J-shaped yang dibenamkan kedalam patch penghapus band frekuensi untuk WiMAX dan juga WLAN. Cara untuk menambhbaik kepembolehgunaan rekonfigurasi untuk antenna, dua keeping plat kuprum diletakkan didalam ruangan bagi mewakili keadaan pensuison ON dan jga OFF untuk diod pin ideal. Dengan menggunakan kaedah pensuisan mudah, cara penghantaran patch yang terkini diubah dan membolehkan antenna beroperasi dalam empat (4) mod operasi. Keputusan dicapai setelah antenna bole berfungsi sepenuhnya berbanding dengan jarak frekuensi bergerak UWB (3.1 GHz ke 10.6 GHz) didalam satu konfigurasi pensuisan. Dalam pada masa yang sama, patch akan menolak dan memberhentikan operasi diantara WiMax (3.13-3.7GHz) manakala untuk WLAN (5.15-5.85 GHz) berfungis pada tiga konfigurasi pensuisan) . Antenna di simulasi dengan menggunakan perisian simulasi electromagnetic CST Studio Suit. Data yang diperolehi amat baik untuk tujuan pemerhatian dan persetujuuan telah direkodkan.

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LIST OF ABBREVIATIONS

λ	Free space wavelength
c	Speed of light
ε_r	Dielectric constant
D	Directivity
G	Gain
E	Efficiency
W	Substrate Width
r	Patch Readies
Wg	Ground Plane Width
Wf	Feed Line Width
t	Patch Thickness
L	Substrate Length
L_p	Patch length
L_g	Ground Plane length
Lf	Feed Line length
h	Substrate thickness
L_{eff}	Effective length
PCB	Printed circuit board
SWR	Standing wave ratio
VSWR	Voltage standing wave ratio
RL	Return loss
RCHP	Right hand circular polarization
LHCP	Left hand circular polarization
HPBW	Half power beamwidth
dB	Decibel
Z_{in}	Input impedance

Z_o	Characteristic impedance
S_{11}	Return loss or Reflection Coefficient (dB)
Γ	Reflection coefficient
R_{in}	Antenna resistance
X_{in}	Antenna reactance
f	Operating frequency
f_H	Upper frequency
f_L	Lower resonant frequency
f_c	Center frequency
UWB	Ultra Wide Band
FCC	Federal Communications Commission
LDR	Low Data Rate
HDR	High Data Rate
EMI	Electromagnetic Interference
WLAN	Wireless local Area Network
WiMAX	Worldwide Interoperability for Microwave Access
FSS	Frequency Selective Surface
CST	MICROWAVE STUDIO
MSA	Microstrip Antenna
MMIC	Monolithic Microwave Integrate Circuit
CPW	Co-Planar Waveguide
PEC	Perfectly Electrically Conducting
RL	Return Loss
FBW	Fractional Bandwidth
BW	Bandwidth

CHAPTER 1

INTRODUCTION

1.1 Introduction

Ultra Wide Band (UWB) technology is the basis of different methods of wireless communications. In 1886, Heinrich Hertz verified Maxwell's equation and came up with the first spark gap transmitter. In 1896, the first UWB communications system was set up in London to connect two post offices, which were more than a mile apart [1]. A contemporary UWB system was introduced in 1960 when the U.S. armed forces made use of pulse transmissions to conceal imaging, radar and stealth communication [2].

According to the Shannon-Hartley theorem, the main benefit of the UWB system is that it is channel capacity corresponds to the bandwidth. The UWB can handle a large capacity of hundreds of Mbps because of it is ultra-wide frequency bandwidth. In addition, UWB systems function at exceedingly low levels of power transmission. Hence, it is able to offer an extremely safe and dependable communications system because the low energy density makes accidental detection rather difficult. Finally, the impulse radio UWB is cheap and simple because of the basically baseband character of the signal transmission [3, 4]. In February, 2002, Part 15 of the rules concerning unlicensed radios was revised to incorporate the operation of UWB devices. A bandwidth of 7.5 GHz. from 3.1 GHz to 10.6 GHz, was also allocated by the Federal Communications Commission (FCC) to UWB applications. Based on the FCC's decision, any signal that takes up at least 500 MHz of the spectrum can be employed in UWB systems. Thus, UWB is no longer confined to impulse radios alone, but also includes any technology that utilizes 500 MHz of the spectrum and fulfills all the other prerequisites for UWB. Since impulse radio-based UWB systems deliver pulses of energy, they are able to transmit data at a more rapid rate compared to narrowband frequency carriers.

Generally, the pulses have very brief intervals, characteristically a few nanoseconds (billionths of a second), that produce an ultra-wideband frequency spectrum [3]. There are numerous applications for UWB, among which are Low Data Rate (LDR) applications, such as very simple transmitters that forbid the excessive use of energy, thus enabling the battery to last longer. This is used primarily in low data rate networks such as those employed in military systems, which are hard to detect and are also exceptionally good at clogging resistance. UWB is also employed in High Data Rate (HDR) applications such as internet access and multimedia services, location-based services, home networking and home electronics [5].

1.2 Problem Statement

Some UWB applications get rid of unwanted frequency bands by means of discrete band-stop filters in order to overcome the problem of electromagnetic interference (EMI). However, the use of such filters will undoubtedly increase the complexity or limitations of the UWB systems. Therefore, a small UWB antenna with numerous notched bands is required, for which several approaches have been putted forward and demonstrated.

Earlier research has approached the subject area in a number of different ways. The following provides a summary of the considerations. Cutting different shaped slots in the radiation patch or the ground plane is the most common approach, such as U-shaped [6], C-shaped [7], L-shaped [8], pi-shaped [9], and H-shaped slots [10].

Introducing parasitic strips near the radiation patch or the ground plane has been attempted [11,12]. Other methods have been used to obtain the band notched properties. For example, by embedding a pair of T-shaped stubs inside an elliptical slot in the radiation patch, a notched band around 5.5 GHz is obtained [13], a complementary split-ring resonator is inserted near the feed line, to generate notched bands [14], or the band notched function is obtained using a coupled C-shaped parasitic structure [15]. Each notch structure can achieve only one rejected band. Therefore, to yield multiply notched bands, multiple or various notch structures are required.

1.3 Aim and Objectives

The main aim of this project is to design a microstrip UWB antenna. In this study, an innovative planar microstrip UWB antenna with enhanced dual band rejection is proposed.

I. To design band notched characteristics at 3.4 GHz by using a J-shaped notch filter.
II. To determine a filter in the form of a U-shaped slot in the patch, that will reject strong bands with a frequency at 5.5 GHz.
III. To develop multifunctional capabilities by two copper strips are embed on the two notch structures antenna, those are used to represent the ON and OFF switching states of an ideal PIN diode for WiMAX and WLAN bands.

1.4 Project Scopes

The project scopes focusing on the follows:

1. The frequency operation of this antenna is from 3.1 GHz to 10.6 GHz, which is UWB frequency of wireless application.
2. To design this type of antenna with two bandstop filters at WIMAX and WLAN frequency that can reduce the interference with UWB.
3. The antenna had been simulated by using CST Microwave Studio.
4. Microstrip patch antenna had been tested by using Network Analyzer after fabrication.

1.5 Project Organization

Chapter 1: provides an overview of the introductory chapter that defines the importance of this research respectively, the state of the problem, project objectives and scope of the study. The introduction of UWB technology, the challenges in UWB antenna design, the UWB notched band characteristics and the current issues are also highlighted.

Chapter 2: introduces a review of literature related the UWB history and definition of UWB signal with some international standardization on it. The literature review examined the comprehensive background of other related research works and the fundamental antenna parameters that should be considered in designing UWB antenna.

Chapter 3: we present the methodology of the design the proposed UWB antenna. The calculation for the parameters and the antenna damnation and the simulation and fabrication steps are described.

Chapter 4: presents the results and discussion. Simulated and measured results are compared by using CST microwave studio and MATLAB.

Chapter 5: concludes this research and furnishes recommendations for any future work.

CHAPTER 2

LETRCHARE REVIEW

2.1 Introduction

The microstrip antenna is now an established type of antenna that is confidently prescribed by designers universal, principally when low profile radiators are required. The printed antenna has now reached an age of maturity where many well-tried techniques can be relied upon and there are few mysteries about it is performance. With increasing requirements for personal and mobile communications, the demand for a low profile and smaller antennas has brought the MSA to the forefront. In useful UWB applications, patch antennas that can be directly printed onto printed circuit boards (PCBs) are the most promising applicant. Such as PCB antenna has a low manufacturing cost, a low profile and can be easily integrated with other parts of monolithic microwave integrate circuit (MMIC) for a transceiver [16] [17].

2.2 Microstrip Antenna

Microstrip antennas can be divided into two basic types of structure, namely microstrip slot and patch antenna, the slot antennas can be fed by slot line, microstrip line and coplanar waveguide CPW [18]. Microstrip UWB antennas are simplest form consist of a radiating patch etching one side of a dielectric substrate and a partial ground plane on the other side if the antenna is fed by microstrip transmission line or on the same side in the case of coplanar waveguide (CPW) feeding [17].

The patch is generally made of conducting material such as copper or gold and can take any possible profile. The feed lines and the radiating patch are usually photos etched on the dielectric substrate. However, such a configuration leads to a larger antenna size [19].

Microstrip Antenna (MSAs) has the attractive features of easy fabrication, conformability to mounting hosts, light weight and low profile. However, microstrip antennas inherently have a narrow bandwidth and bandwidth enhancement is usually demanded practical applications. In addition, applications in present-day mobile communication systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile unit is. Therefore, size decrease and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas. Some approaches have been developed for bandwidth enhancement. Among those common ones, one is to increase the height of the dielectric substrate while the other is to decrease the substrate dielectric constant. Certainly, the latter will induce the matching circuit is to be impractical due to excessively wide line designed [20].

To satisfy such requirements, various types of planar antennas have been developed for UWB communications over the last few years. Also, several bandwidth enhancement techniques have been reported, to improve the impedance bandwidth of these antennas, much significant progress in the design of compact microstrip antennas with dual-polarized circularly polarized, broadband, dual frequency and gain-enhanced operations have been reported over the past several years [20].

2.2.1 Microstrip Patch

The typical geometry of a microstrip patch antenna consists of radiating metallic patch and a larger ground plane etched on either side of a substrate having a fixed dielectric constant and thickness [21] is given by the Figure 2.1.

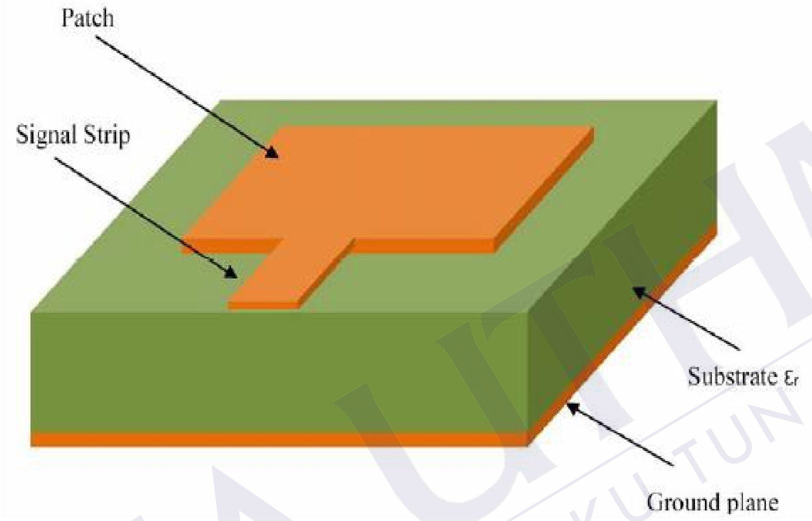


Figure 2.1: Structure of a microstrip patch antenna.

The length of the patch is typically about one-half of the dielectric wavelength corresponding to the resonant frequency, where the return loss value is the minimum at the resonant frequency [21].

Often microstrip antennas are also referred to as patch antennas performance. The propagating elements and the feed lines are usually photos etched on the dielectric substrate. The radiating patch may be circular, square, triangular, rectangular, elliptical, or any other configuration [22], as illustrated in Figure 2.2.

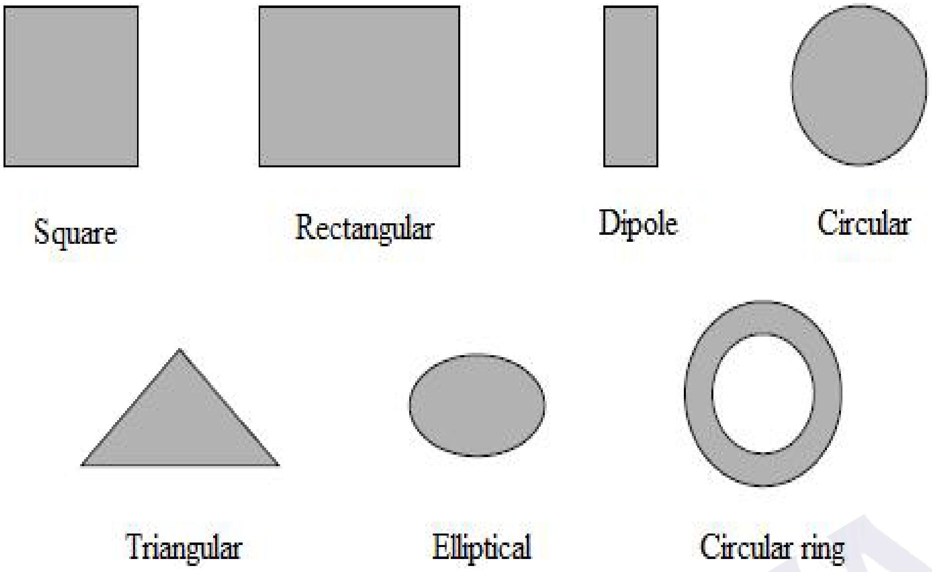


Figure 2.2: Common shapes of microstrip patch elements.

For a rectangular patch, the length L of the element is usually$\lambda_0/3 < L < \lambda_0/2$. And the patch which is selected to be very thin ($t << \lambda_0$), where (t) is the patch thickness, λ_0 is the free-space wavelength and the height (h) of the dielectric substrate ($h << \lambda_0$, usually $0.003\lambda_0 \leq h \leq 0.05\ \lambda_0$) [23].

The microstrip patch is designed so that it is maximum pattern is normal to the patch. Because, the dimensions of the patch are finite along the length and width and the fields undergo fringing at the edges of the patch. The quantity of fringing is a function of the dimensions of the patch and the height of the substrate. Fringing makes the microstrip line look wider electrically compared to it is objective dimensions. While, some of the waves pass through in the substrate and some in the air, an effective dielectric constant ε_{reff} is introduced to account for fringing [23].

Therefore, the radiation of a microstrip antenna is generated by the fringing field between the patch and the ground plane. The minimum size of the ground plane is therefore related to the thickness of the dielectric substrate. Generally a $\lambda_0/4$ extension from the edge of the patch, is required for the ground plane [24]. There are numerous substrates that can be used to the design of microstrip antennas and their dielectric constants are usually in the range of $2.2 \leq \varepsilon_r \leq 12$. The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide bigger bandwidth, better efficiency, loosely bound fields for radiation into space, although at the expense of bigger element dimension. Greater losses, they are less efficient and have relatively smaller bandwidths [23]. Since microstrip antennas are often integrated with other microwave, a compromise should be reached between good antenna performance and circuit design [23].

2.2.2 Microstrip Antenna Advantages and Disadvantages

The microstrip antenna (MSA) has proved to be an excellent radiator for many applications because of it is several advantages, but it also has some disadvantages. The important advantages are:

i. Low profile and lightweight, $t \ll 0.03\lambda_0$ and it is usually made from perfectly electrically conducting (PEC).
ii. Conformability to surfaces of substrates, it may be of a planar or nonplanar surface, which can completely conform to the surface of the dielectric substrate it is attached to.
iii. Low cost: It is fabricated using an inexpensive printed circuit technique. The substrate is usually the most costing portion
iv. Integration with other circuit is: It is simple to completely integrate a microstrip patch antenna on a printed-circuit board (PCB) with other planar circuit is.
v. Versatility: amicrostrip patch antenna is very versatile in terms of impedance, resonant frequency, radiation pattern, polarization and operating mode [25].
vi. They permit both linear and circular polarization.
vii. They can make compact for use in special mobile communication [26].
viii. However, microstrip patch antennas in their basic forms suffer from some drawbacks, such as narrow impedance bandwidth (typically of

around 1%), poor polarization, low radiation efficiency, poor scan performance, and low gain [25].

2.3 Basic Antenna Parameters

An antenna is a device that converts a guided electromagnetic wave on a transmission line to a plane wave propagating in free space. Thus, one side of an antenna appears as an electrical circuit component, although the other side provides an interface with a propagating plane wave. Antennas are inherently bi-directional; they can be used for both transmitting and receiving functions. The following are short notes of some of the antenna parameters that have to be taken into consideration when designing an antenna.

2.3.1 Input Impedance (Zi)

For an efficient transport of energy, the impedance of the radio and of the transmission cable connecting them should be similar. Typically designed the impedance 50 Ω for transceivers and their transmission lines are. If the antenna has an impedance different from 50Ω. Then, there is a mismatch and an impedance matching circuit is required [18]. Antenna impedance relates the voltage to the current at the input to the antenna. An antenna with the real input impedance (zero imaginary part) is said to be resonant.

2.3.2 Reflection Coefficient (Γ) and Characteristic Impedance (Zo)

When considering higher frequency applications, a prominent phenomenon that must be taken into account is the idea of reflection that occurs in microwave transmission lines [18]. Every transmission line has a resistance associated with it, and this resistance comes about because of the construction of the transmission line. This is called characteristic impedance of the transmission line Z_o. The standard performance impedance value is 50Ω. On the other hand, when the transmission line is terminated with an arbitrary load Z_L not equivalent to it is performance impedance ($Z_L \neq Z_o$), a reflected wave will occur.

A reflection coefficient (Γ) is defined to give a measure of this experience. It is obtained by normalizing the amplitude of the reflected wave V_o^-, to the amplitude of the incident wave, V_o^+, and is given as [18]:

$$\Gamma = \frac{V_o^-}{V_o^+} = \frac{Z_L - Z_o}{Z_L + Z_o} \tag{2.1}$$

2.3.3 Return Loss *(RL)*

The Return Loss is a parameter that indicates the amount of a power that is lost in a load and does not return as a reflection. The same as explained in the preceding section, waves are reflected leading to the formation of standing waves, at what time the transmitter and antenna impedance do not match. Therefore, the RL is a parameter similar to the VSWR to indicate how well the matching between the transmitter and antenna has taken place. The RL is given by [27]:

$$RL = -20\log_{10}|\Gamma| \ (dB) \tag{2.2}$$

For perfect matching between the transmitter and the antenna, $\Gamma = 0$ and RL = ∞ which means no power would be reflected back, whereas a $\Gamma = 1$ has a RL = 0 dB, which implies that all incident power is reflected. For practical applications, a VSWR of 2 is acceptable since this corresponds to a return loss of -9.54 dB.

$$RL\ (in\ dB) = 20\log_{10}\frac{VSWR-1}{VSWR+1} \tag{2.3}$$

2.3.4 Voltage Standing Wave Ratio *(VSWR)*

In order for the antenna to operate efficiently, maximum transfer of power must take place between the antenna and the transmitter. Highest power transfer can catch place only when the impedance of the antenna (Zin) is matched to that of the transmitter (Zs).

If the condition for matching is not satisfied, then some of the power may be reflected back and this leads to the creation of the standing waves, which can be characterized by a parameter called the Voltage Standing Wave Ratio (VSWR). The VSWR can express as [18]:

$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+S_{11}}{1-S_{11}} \tag{2.4}$$

The VSWR expresses the degree of match between the transmission line and the antenna. While, the VSWR is 1 to 1 (1:1) the match is ideal and all the energy transferred to the antenna prior to being radiated. An antenna system, it is reflection coefficient is also it is S_{11}. Moreover, for an antenna to be reasonably functional, a minimum VSWR ≤ 2 is required.

2.3.5 Radiation Pattern

The radiation pattern is defined as the power radiated or received by an antenna in a function of the angular position and radial distance from the antenna. It explains how an antenna directs the energy it radiates. The Figure 2.3 shows a radiation pattern of a generic directional antenna. A main lobe and several minor lobes they represent the pattern. With all antennas (except monopoles and dipoles), side lobe and back lobes can be obtained, and they are always undesirable because they represent the wasted energy for transmitting antennas and the potential noise sources for receiving antennas.

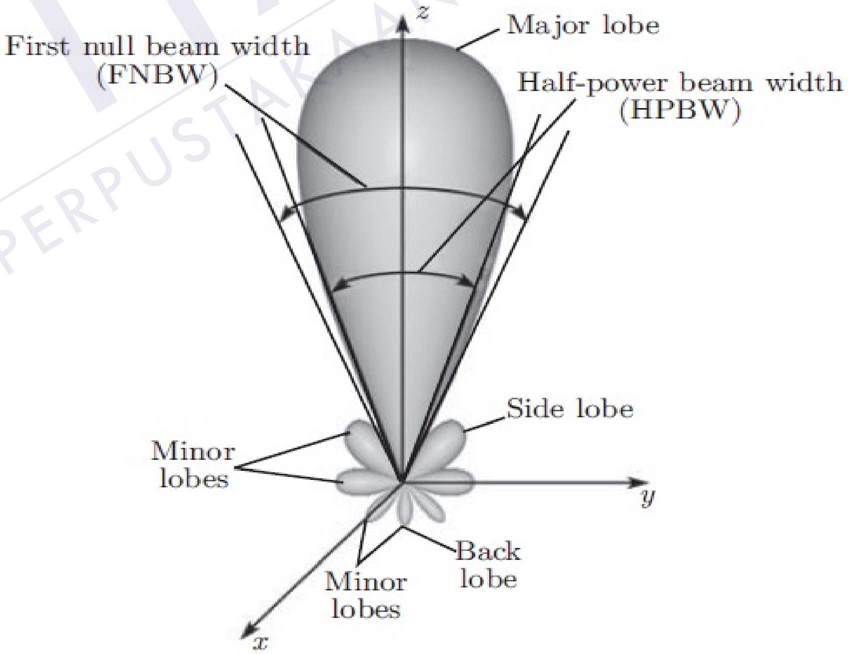


Figure 2.3: Radiation pattern of a generic directional antenna [19].

The figure above illiterate the follows:

i. HPBW:

The half power beamwidth can be defined as the angle subtended by the half-power points of the main lobe. In a plane containing the direction of the maximum of a beam, the angle between the directions in which the radiation intensity is one-half the maximum value of the beam.

ii. Major Lobe or Main Lobe is the radiation lobe containing the direction of maximum radiation.

iii. Minor Lobes:

All the lobes other than the main lobes are called the minor lobes. These lobes represent the radiation in undesired directions. The minor lobes levels usually expressed as a ratio of the power density in the lobe in a question to that of the major lobe. This ratio is called as the side lobe level (expressed in decibels).

iv. Back Lobe:

This is opposite the main lobe the minor lobe diametrically.

v. Side Lobes:

These are the minor lobes adjacent to the main lobe and are separated by various nulls. Generally, side lobes are the largest among the minor lobes. In the majority wireless systems, minor lobes are undesired. Therefore, a good antenna design should minimize the minor lobes.

2.3.6 Directivity

Directivity is the ability of an antenna to focus energy in a particular direction when transmitting or to receive energy better from a particular direction when receiving [19]. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the required direction. On the other hand, in a dynamic system where the antenna must radiate equally in all directions, the transceiver is not fixed, and this is known as an omni-directional antenna.

$$D = \frac{U}{U_o} = \frac{4\pi U}{P_{rad}} \qquad (2.5)$$

Where U is radiation intensity and P_{rad} is radiated power.

2.3.7 Gain

Gain is not a quantity which can be defined in terms of a physical quantity such as the Watt or the Ohm, but it is a dimensionless ratio [19]:

$$G = \frac{4\pi U}{P_{\text{in (lossless isotropic source)}}} \text{ (dimensionless)} \qquad (2.6)$$

$$= e_r \cdot D \quad (where\ 0 \le e_r \le 1)$$

The gain is given in reference to a standard antenna. The isotropic antenna and the resonant half-wave dipole antenna are the two most common reference antennas. The radiates are equally well in all directions for the isotropic antenna. Actual isotropic antennas do not exist, but they provide useful and simple theoretical antenna patterns with which to compare real antennas. Generally, the real antenna will radiate more energy in some directions than in others. While, it cannot create energy, the overall power radiated is the same as an isotropic antenna. Therefore, in other directions it must radiate as less as energy.

The gain of an antenna in a given direction is the amount of energy radiated in that direction compared to the energy an isotropic antenna would radiate in the same direction when driven with the same input power.

Usually, we are only interested in the maximum gain, which is the maximum value in a certain direction that the antenna is radiating most of the power. The resonant half-wave dipole can be a useful standard for comparing to other antennas at one frequency or over a very narrow band of frequencies. When compare the dipole to an antenna over a range of frequencies requires different lengths for number of dipoles. The method of measuring gain by comparing the antenna under test against a known standard antenna, which has a calibrated gain, is technically known as gain transfer technique.

2.3.8 Bandwidth (BW)

The bandwidth of an antenna is pass on to the band of frequencies over which the antenna can operate fittingly.

The antenna bandwidth is the number of Hz for which the antenna will exhibit a $VSWR \leq 2$ or $RL \leq -10$ dB. Moreover, the bandwidth can also be explained in terms of percentage of the center frequency of the bandwidth.

The bandwidth of an antenna can also be defined as the percentage of the frequency difference over the center frequency [20]. In this case, it is called the fractional bandwidth (FBW) and can be written as:

$$FBW(\%) = \left[\frac{f_H - f_L}{f_C} \right] \times 100 \tag{2.7}$$

Where f_H is the highest frequency in the band, f_L is the lowest one in the band while f_C is the center frequency in the band.

2.3.9 Polarization

Polarization is defined as the orientation of the electric field of an electromagnetic wave so it describes the time-varying direction and the relative magnitude of the electric field vector. In other words, the position and the direction of the electric field with reference to the earth's surface or ground determine the wave polarization. Polarization is in general represented by an ellipse. There are three classifications of antenna polarization: linear (vertical or horizontal), elliptical and circular. Linear and circular polarizations are special cases of elliptical polarizationas illustrated in Figure 2.4 are linear (horizontal or vertical) polarization and circular (right hand or left hand) polarization.

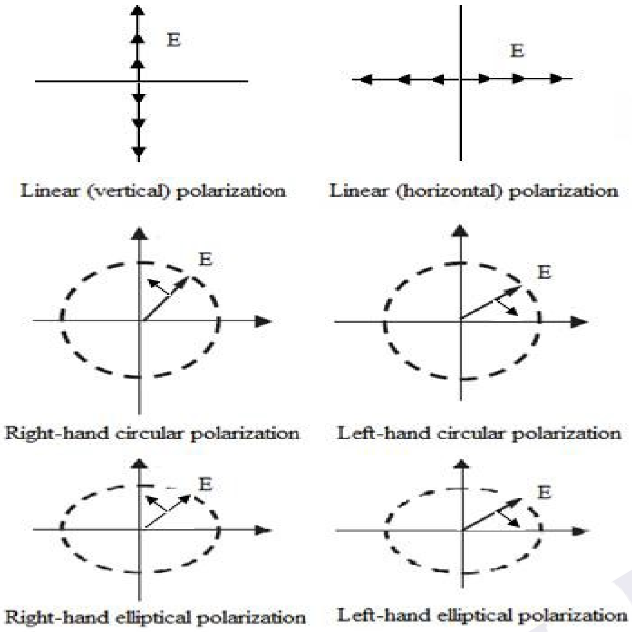


Figure 2.4 some wave polarization states.

If the path of the electric field vector is back and forth along a line, it is said to be linearly polarized. A circularly polarized wave has the electric field vector remains constant in length but rotates around in a circular path on three damnation. In addition, the left hand circular polarized wave is one in which the wave rotates counterclockwise whereas right-hand circular polarized wave exhibit is clockwise motion.

2.4 Feeding Techniques

The way to transfer energy efficiently from the transmission system to the antenna is the feed techniques. The propose of the feeding structure directly governs the surface waves, impedance matching, spurious radiation, operating modes and geometry patch The feeding structure thus plays a vital role in widening the impedance bandwidth and enhancing radiation performance [24].

2.4.1 Microstrip-Line Feed

The microstrip feed line is connected directly to the edge of the patch antenna [23]. This feed understanding has the benefit is that it can be etched on the same substrate, so the total structure remains planar. As illustrated in Figure 2.5, it is usually of much smaller width compared to the patch, simple to match and easy to fabricate by controlling the inset position [23].

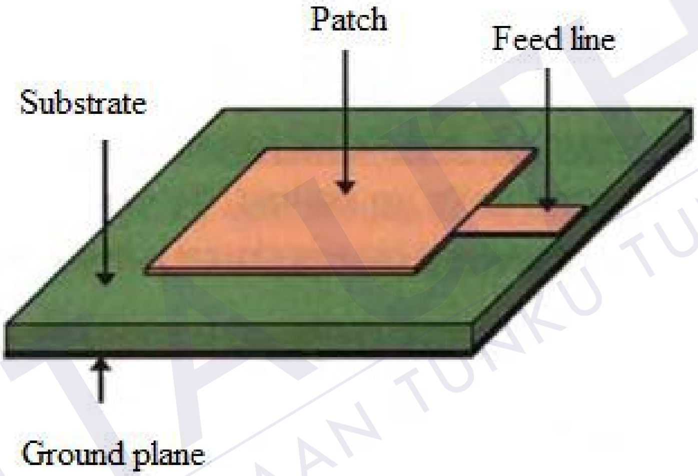


Figure 2.5: Microstrip line feed.

2.4.2 Coaxial-Line Feed

Coaxial-line feed or probe feed, is a very familiar technique used for feeding microstrip patch antennas this days, where the internal conductor of the coaxial is extended through the dielectric and attached to the radiation patch antenna, although the outer conductor is connected to the ground plane [23], as seen in Figure 2.6. The major benefit of this feed is that it can be putted at any desired location inside the patch to match with it is input impedance of the patch [25]. It is also easy to fabricate, and it has low spurious radiation. The disadvantages are that it also has narrow bandwidth and is more difficult to model [28].

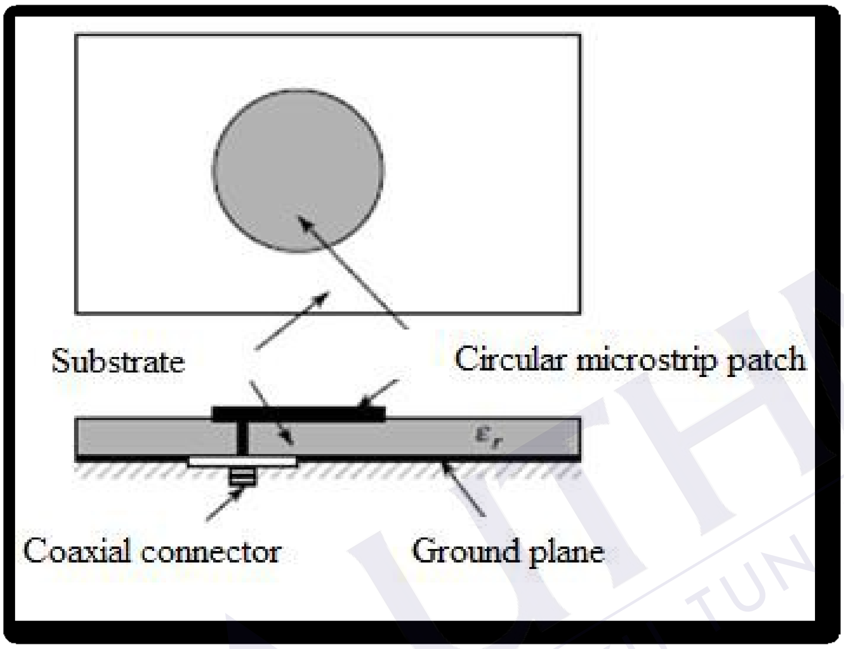


Figure 2.6: Coaxial (Probe) feed.

2.4.3 Aperture Coupled Feed

The aperture-coupled structure is very popular feeding configuration in microstrip patch antennas, consists of two substrates separated by a ground plane. Moreover, the lower substrate can see on the bottom side. There is a microstrip feed line whose energy is attached to the patch during a slot on the ground plane separating, the two substrates for this design as shown in Figure 2.7(a). A high dielectric material is used for the bottom substrate and a thick low dielectric constant material for the top substrate. The ground plane between the substrates also isolates the feed from the radiating element and minimizes the interference of spurious radiation for pattern formation and polarization purity. The disadvantage of this feeding technique is that it is not easy to fabricate and it has a narrow band. On the other hand, it is somewhat easier to model and has a moderate spurious radiation [23].

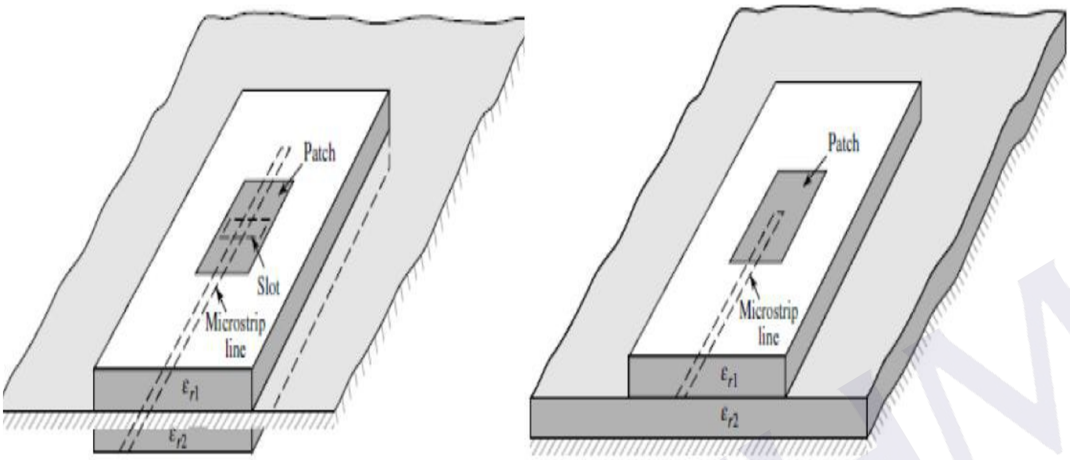


Figure 2.7 (a): Aperture-coupled feed (b): Proximity-coupled feed.

2.4.4 Proximity Coupled Feed

This kind of feeding technique is recognized as electromagnetic coupling. The feeding line is putted between the ground plane and the patch, which is separated by two dielectric media [25] as shown in Figure 2.7 b [23]. Energy is transferred by means of the electromagnetic coupling between the patch and the feeding line [24]. The advantages of this feeding configuration include the elimination of spurious feed-network radiation; and the increase in the bandwidth due to the increase in the overall substrate thickness. The main inconveniences of this feeding technique are that it is difficult to be fabricated because of the two layers needed to be aligned properly [25].

2.4.5 Co-planar Waveguide (CPW) Feed

Another feeding technique is based on the co-planar waveguide (CPW). This technique is a very suitable for microstrip patch antenna design and has been widely used [24]. The co-planar waveguide consists of a central signal strip bounded by twin lateral ground strips separated by a small gap. The entire structure can be printed on the single side of a substrate [26].

Recently, several CPW-fed monopole antennas have been introduced for UWB applications because of their characteristics of wide impedance bandwidth, compact and simple structure, low cost and unidirectional radiation pattern [23]. In addition, CPW-feed offers a less dispersion at a higher frequency, a broader matching, no via, an easy fabrication and integration with monolithic microwave integrated circuit is MMIC [29]. A typical monopole fed by the CPW feeding is given in Figure 2.8.

Figure 2.8: Co-planar waveguide (CPW) feed.

2.5 Band-notched UWB antenna and design

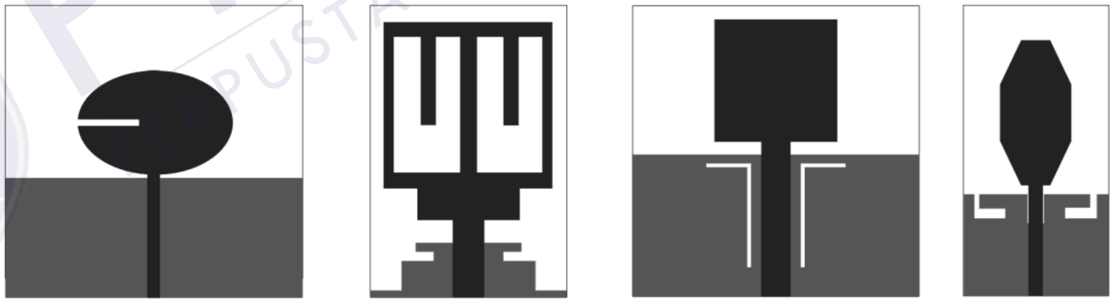
The Federal Communication Commission released the frequency band 3.1~10.6 GHz for the UWB system in 2002. However, along with the UWB operating bandwidth, there are some narrowband wireless providers, these narrowband occupy some of the frequency bands in the UWB operation frequency. The famous narrowband we known is wireless local area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN operating in 5.15~5.35 GHz and 5.725~5.825 GHz bands. Apart from WLAN, in some Asian countries and European, world interoperability for microwave access (WiMAX) service from 3.3 to 3.6 GHz also shares range with the UWB bandwidth. The interference can cause between the UWB system and these narrowband on communication systems.

To solve this difficulty, one way is to use filters to notch out the interfering frequency. On the other hand, the use of an extra filter will result in increasing the complexity of the UWB system and also the addition loss, size and weight for the UWB trans-receivers. For that reason, various UWB antennas with notched functions have been investigated to overcome this electromagnetic interference. In conclusion, the existing band-notched techniques, that can be organized into the following categories: bandstop transmission, embedding slot, parasitic stub, line, and hybrid techniques.

2.5.1 Embedding Slot

Between a variety of proposed techniques on the design band notched UWB antenna. The simple way is to etch slots on the ground plane or radiation patch. So far, a lot of shapes of embedding slots were considered, and some representatives are shown in Figure 2.9. Kim al. [30] proposed a CPW-fed planar UWB antenna with a hexagonal radiating element. When applying a V-shaped thin slot with a length of λc/4 (λc is the wavelength of notched frequency) on the hexagonal radiating element, the frequency band-notched is shaped, where the fractional bandwidth is approximately 8~10%. Chung et al. [32-33] introduced the printed UWB monopole antenna by inserting an inverted U-shaped, rectangular slot or Π-shaped. The current is concentrated around the edges of the slot and is oppositely directed between the interior and the notched band. This guides to the desired high attenuation near the notched band. In a notched printed monopole antenna is provided by using two modified U-shaped slots [34]. The U-shaped slot perturbs the resonant response and acts as a half-wave resonant configuration. Moreover, the desired high attenuation near the notched frequency can be produced. [35, 36] established a pair of inverted L-shaped slots around the antenna line on the ground plane; a frequency notched response can also be achieved.

(a) V-shaped slot (b) inverted U-shaped slot (c) inverted Π-shaped slot



(d) rectangular slot (e) double U-shaped slots (f) double L-shaped slots

Figure 2.9: Notched-band designs with various slots on patch or ground [30-36].

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