

# A WEARABLE CIRCULAR POLARIZED ANTENNA

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To my beloved parents,



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## ABSTRACT

Recently, wearable electronic applications have arising in the commercial market. There has been growing use of textile antennas for wearable electronic and body centric applications such as health care, GPS and fire fighter personal communications. The use of circularly polarized antennas presents an attractive solution to achieve this polarization match which allows for more flexibility in the angle between transmitting and receiving antennas the new generation of textile has the capability to conduct electricity and at the same time as wearable. Microstrip patch antennas represent one family of compact antennas that offer a conformal nature and the capability of ready integration with communication system's printed circuitry. In this project, a circular polarized (CP) textile antenna is designed and simulated at 1.5 GHz. circular polarization (CP) textile antenna is designed for Global Positioning System (GPS) application. The truncated rectangular patch antenna is having a full ground plane from Shieldite and felt as a substrate. The proposed antenna operates at 1.5 GHz with a good bandwidth from 1.5 to 1.52 GHz. The optimized chamfer has been made at two edges of a rectangular patch in order to produce a Circular Polarization with a good axial ratio (AR) bandwidth of 1.5 GHz to 1.52 GHz, moreover I made bending different way such concave, convex and degree last compare result in reflection coefficient. This manuscript also presents the analytical performances of CP textile antenna under bending condition that suitable for the on-body antenna applications.

## ABSTRAK

Baru-baru ini, aplikasi elektronik yang boleh dipakai muncul di pasaran komersial. Terdapat penggunaan antena tekstil yang semakin meningkat untuk aplikasi elektronik dan badan yang boleh dipakai seperti komunikasi kesihatan, GPS dan komunikasi peribadi pemadam kebakaran. Penggunaan antena terpolarisasi bulat memberikan penyelesaian yang menarik untuk mencapai padanan polarisasi ini yang memungkinkan lebih banyak fleksibiliti dalam sudut antara antena pemancar dan penerimaan generasi baru tekstil mempunyai keupayaan untuk mengalirkan elektrik dan pada masa yang sama boleh dipakai. Antena patch mikrostrip mewakili satu keluarga antena padat yang menawarkan sifat konformal dan kemampuan penyatuan siap dengan litar bercetak sistem komunikasi. Dalam projek ini, antena tekstil polarisasi bulat (CP) dirancang dan disimulasikan pada 1.5 GHz. antena tekstil polarisasi pekeliling (CP) dirancang untuk aplikasi Sistem Penentuan Lokasi Global (GPS). Antena tampalan segi empat tepat terpotong mempunyai bidang tanah penuh dari Shieldiet dan dirasakan sebagai substrat. Antena yang dicadangkan beroperasi pada 1.5 GHz dengan lebar jalur yang baik dari 1.5 hingga 1.52 GHz. Chamfer yang dioptimumkan telah dibuat pada dua tepi tampalan segi empat tepat untuk menghasilkan Polarisasi Pekeliling dengan lebar jalur nisbah paksi (AR) yang baik dari 1.5 GHz hingga 1.52 GHz. Naskah ini juga menyajikan persembahan analitik antena tekstil CP dalam keadaan lenturan yang sesuai untuk aplikasi antena badan.

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## LIST OF ABBREVIATIONS

CP	Circular Polarization
WLAN	Wireless Local Area Network
GPS	Global Positioning System
LHCP	Left Hand Circular Polarization
RHCP	Right Hand Circular Polarization
dB	Decibels
CST	Computer Simulation Software
BW	Bandwidth
GHz	Giga Hertz
IEEE	Institute of Electrical and Electronic Engineers
AR	Axial Ratio
LP	Patch length
WP	Patch width
WS	Substrate width
LS	Substrate length
Fo	Resonant frequency
C	Speed of light
S11	Return Loss
VSWR	Voltage standing wave ratio
S11	Return Loss
F	Frequency
$\lambda$	Wave Length

## CHAPTER 1

### INTRODUCTION

#### 1.1 Background

One of the fastest developing wireless technologies currently is Wireless Body Area Network (WBAN), which offers countless new applications for both professional and leisure activities. Typical applications may include smart clothing for fire-fighters and rescue workers, military and space personnel, health and activity monitoring for outdoor enthusiast like hikers and cyclists. Battery life is often a concern and limiting factor in wireless communication systems; moreover, antenna performance plays an essential role in battery consumption. Hence, it is sensible to pay extra attention in antenna design to achieve an optimal performance.

In such communication systems where the antenna is not only receiving but also transmitting, especially when an adaptive power control is present, an under-performing antenna may increase power consumption and hence shorten the battery life remarkably. Sometime unnecessary losses might still occur when the polarizations of the transmitting and receiving antennas are not matched. It follows from the reciprocity theorem that a transmitter antenna behaves the same as an identical receiving antenna and vice versa. Fortunately, power losses due to polarization mismatch can be avoided by employing circularly polarized antennas. The polarization type is independent on the mutual orientation of the transmitting and receiving antennas and is relatively easy to implement in wearable applications as the size of the antenna is not as strictly limited than in handheld devices.

There are mainly two cases when circularly polarized antennas are, if not essential, at least necessary to consider in wearable communication systems. The first is in satellite systems that are used for navigation and communication. Since satellite antennas often transmit circularly polarized waves, by employing circularly polarized receiving antenna, 3 dB better power level can be achieved compared with linearly polarized antennas.

The second case where circularly polarized antennas are beneficial includes off-body communication systems in which the power level is very low and the user is moving and hence the orientation of transmitting and receiving antennas varies. If polarizations of both transmitting and receiving antennas are close to linear, the connection might be totally lost when a user moves in such a position where one antenna's orientation is perpendicular with respect to the other from a polarization perspective. As usual, there is no such thing as a free lunch. Circular polarization is sensitive to distortion due to undesired reflections and hence a system employing circularly polarized antennas is at its best in a line of sight connection. This usually is the case in satellite communication systems; however, it has been shown that Global Positioning System (GPS), for example, may also operate in multipath environment with linearly polarized antennas [7]

On the other hand, a circularly polarized receiving antenna is blind to reflected, interfering signals because the handedness of the circular polarization is often changed in reflection. Another downside is that designing a circularly polarized antenna may be more challenging compared with a design process in which the polarization preference/requirement is ignored. Depending on the structure and the chosen antenna topology, generating a circularly polarized wave may require a special feeding technique. Furthermore, additional measurements are needed in order to ensure circularly polarized operation over the bandwidth and coverage angle under consideration.

As depicted in Fig. 1.1, if the antenna beam is very narrow, the line-of sight connection may be possible only when the antenna's bore-sight is almost perpendicular to the satellite antenna. By placing several antennas around the user's clothing, probability for line of sight communication can be increased. The wider the coverage angle, the fewer antennas are needed for full coverage.

Polarization of an antenna is defined by the orientation of the electric field component of the electromagnetic plane wave transmitted by the antenna with respect to the earth's surface. Polarization of a plane wave is said to be linear, elliptical, or circular depending on the pattern in which the electric field vector of the wave traces while propagating. As the electric field of a propagating plane wave is always oriented perpendicular to the propagation direction, the shape of the polarization pattern can be seen when observing the wave from the xy-plane as the wave is travelling along the z-axis. On the other hand, when the plane wave is linearly polarized, the electric field vector is oscillating along a line in xy-plane. The direction of this line depends on the position of the antenna. However, either horizontal or vertical position is usually considered. In the case where the electric field vector of the plane wave is rotating and traces out a circle, the wave is said to be circularly polarized. The electric field has now two perpendicular components, which have equal magnitude and  $90^\circ$  phase difference. The most common polarization type, however, is elliptical polarization [2][3].

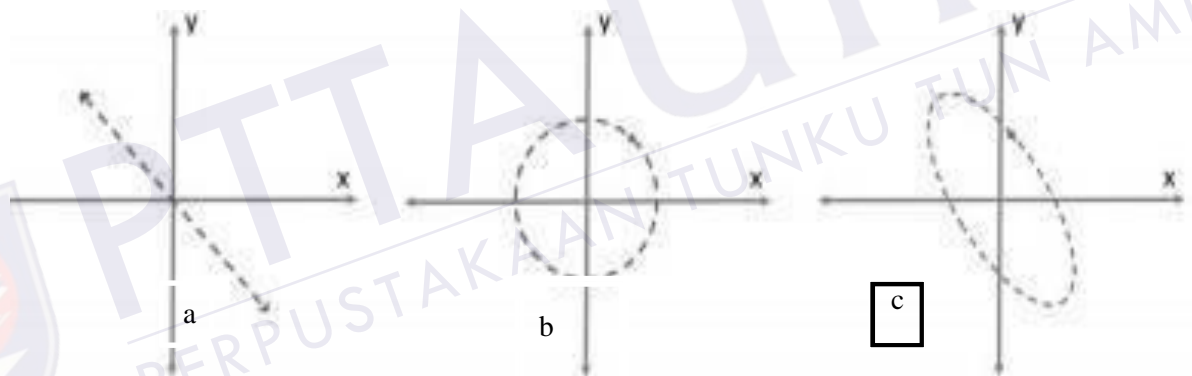


Figure 1.1: The three polarization types: linear, circular and elliptical

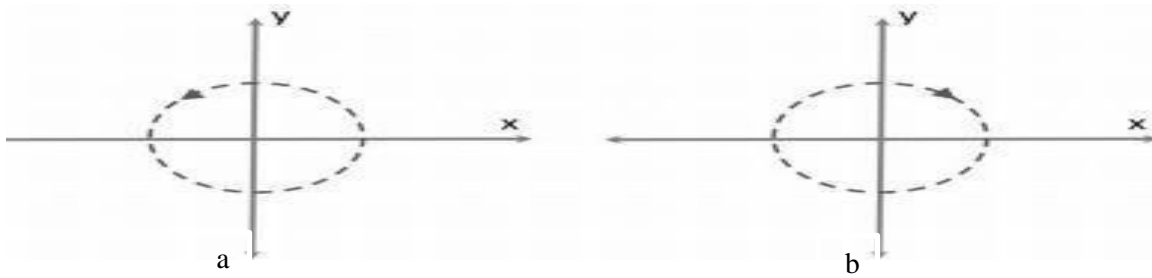


Figure 1.2: Left- hand and right –hand circular polarization

When applying a circularly polarized antenna into a communication system, it is essential to account for the direction in which the electric field vector is rotating. By convention, when the thumb is pointing in the direction of wave propagation, the curled fingers show the direction, and the polarization is referred as right-hand circular polarization (RHCP) when the rotation is counter clockwise, while it is a left- hand circular polarization (LHCP) when the rotation is clockwise. Figure 1.2 shows the two rotation directions when the wave is travelling perpendicularly through the paper, moving away from the observer.

The desirable handedness depends on the system in which the antenna is to be applied in. The satellites in GPS system, for example, utilize RHCP waves. The handedness of circularly polarized plane wave can be determined by measuring both LHCP and RHCP gains of the antenna. When the antenna is circularly polarized, either LHCP or RHCP gain is remarkably greater than the other.



The difference between these two gains also indicates the purity of the circular polarization. The greater the difference, the better the purity. If LHCP and RHCP gain values are equal, the wave is linearly polarized. In the case of wearable antennas, especially circularly polarized ones, it is important to take into consideration all possible operational circumstances which may have an effect on the antenna performance. Hence, RHCP and LHCP gain.

Measurements need to be repeated for each situation/position, such as bending in different directions. It should also be noted that antenna gain measurement alone does not take into account the handedness of circular polarization. It is often advisable to investigate the direction of antenna gain as well, especially in the case where line-of-sight communication is desirable. Maximum gain presented over a frequency range without angle information shows the maximum gain value from the three-dimensional perspective, but it does not give information about the direction. If the pattern changes in shape at different frequencies, the direction of the maximum gain may vary significantly. Furthermore, and as explained below, the direction of circular polarization may vary too.



## 1.2 Problem Statement

Antenna polarization is an important parameter to determine the radiated fields produced by an antenna, evaluated in the far field. If the transmitted signal is horizontal polarization, the receiving antenna must also have the same polarization which is horizontal polarization and as well as vertical otherwise it might cause a mismatch.

The disadvantage of the linear polarization is there will be a high loss of the receiving signal if polarization is mismatched. Thus, a circularly polarized Microstrip patch antenna is used to overcome the problem of high loss. When the antenna was designed as a circularly polarized, it will give flexibility in the angle of the antenna during transmitting and receiving process where it will reduce the effect of multipath reflections, unstable weather condition, and also give mobility to both transmitter and receiver. For a far field transmission, the signal might experience losses and attenuates due to multipath and long-distance transmission which changed their original polarization.

Thus, even though both transmitter and receiver have same polarization, there is some possibility the signal might lose. Since that antenna is a wearable, which the material is flexible in terms of bending degree and radius. This analysis is needed to be done in order to monitor / analyse the effect of the bending antenna condition to its performance.

### **1.3 Objective**

The objectives of this project are

- a) To design a wearable circular polarized antenna working at 1.5 GHz.
- b) To analyse the performance of antenna with different degree and radius of bending condition.

### **1.4 Scope of the Project**

The scope of this project is to design and develop a wearable circular polarized antenna at 1.5GHz that suitable GPS band. The CST Microwave Studio will be used in the simulation and optimization of the design. The preferred results in this stage will be examined such as S11 and performance is analyzed in terms of bending antenna affect, In types of bending affect which is concave, convex and degree with radius of 10 to 125 mm of cylindrical bending technique has been investigated. For the verification of the proposed design, it will be analysing and measured. Finally, project aims to produce results in terms of S11, Axial ratio, gain, and radiation pattern for both simulation and effect of bending different concave, covex and degree.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This chapter provides an overview of the microstrip patch antennas, antenna properties, polarization, summary of previous researches on designing wearable circular polarized antenna.

#### **2.2 Microstrip Patch Antenna**

Microstrip patch antennas have been very promising antennas, especially in the telecommunication field. They are easy to design, implement, and cheap to manufacture. They are very compact with the mobile phones design profile. In the past decade, the performance of these antennas has proven its promising future in the field of mobile communication and the distributed antennas field. Furthermore, it is much easier to implement a single patch antenna in a mobile device than multiple patch antennas. The very basic form of the microstrip patch is two conducting materials in between them there is a dielectric material known as substrate.

The two conducting materials operate as a ground plane and a patch or a radiating element, as indicated in Figure 2.1. Once the upper patch is excited with an electromagnetic signal, considering the operating frequencies of the patch, an electromagnetic signal is de-latched normal to the surface of the patch, creating a microstrip patch antenna. As the researches and developments of these antennas increase,

different and various shapes, structures, feeding methodologies, materials, fabrication methods and principles were used.

In this studies, microstrip patch antenna for GSM and ISM is explored along with the possibilities to combine the operation frequency bands of the cellular mobile networks and the local networks in one compact, easy to fabricate antenna.

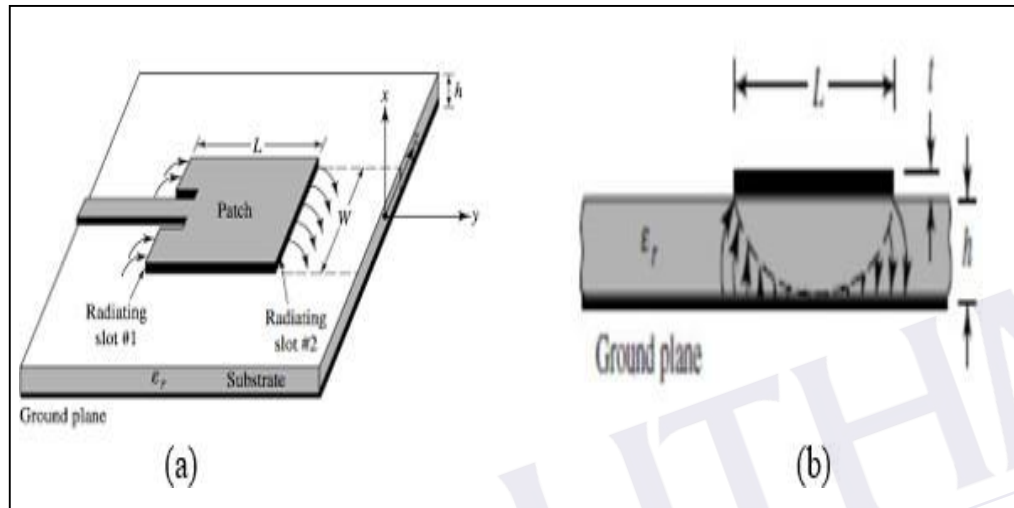


Figure 2.1: Microstrip patch antenna (a) radiating element, (b) side view, ground plane [9].

### 2.2.1 Different Types of Microstrip Patch Antennas

Microstrip patch antennas can be classified based on their physical parameters. Different types of patches have different purposes. There is square, rectangular, circular, dipole, printed and elliptical configurations. Some of the configurations are shown in Figure 2.2. There are different slots in patch antenna configuration such as A-slot, U-slot, H-slot, E-slot patch antennas. They are used for different frequency bands.

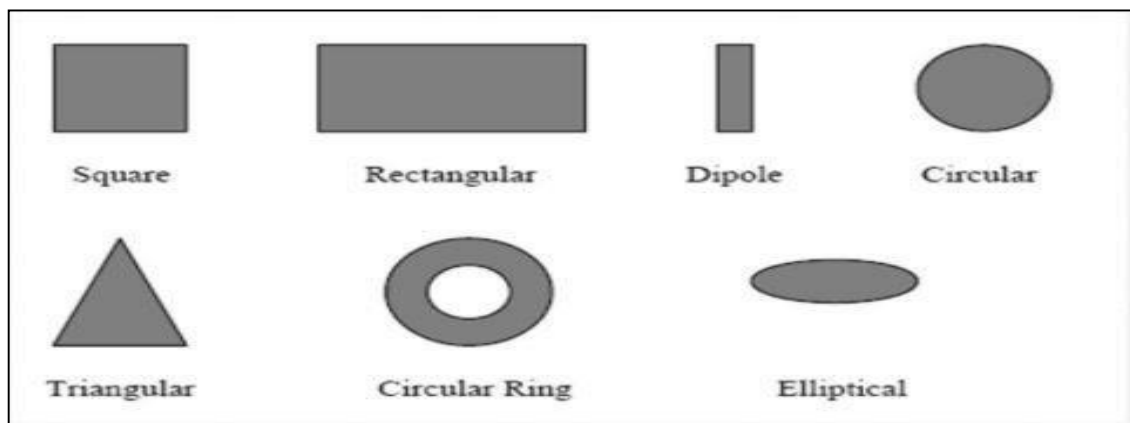


Figure 2.2: Different shapes of microstrip patch antenna [10]

### 2.2.2 Advantages and Disadvantages of Microstrip Antennas

Microstrip patch antennas are increasing in popularity for the use in wireless applications due to their low-profile structure. Therefore, they are extremely compatible with embedded antennas in handheld wireless devices such as cellular phones, pagers (used for messaging only) etc. The telemetry and communication antennas on missiles need to be thin and conformal and are often go hand in hand with microstrip patch antennas. Another area where they have been used successfully is in GSM and ISM applications [11]. Some of the major advantages of microstrip patch antennas are:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of multiple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from drawbacks compared to conventional antennas. Some of their major disadvantages are:

- Narrow bandwidth
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Low power handling capacity.
- Surface wave excitation

## 2.3 Polarization

Polarization is one of the fundamental factors and important design consideration. Both RF antennas and electromagnetic waves are said to have polarization. By antenna, polarization understands the radiated fields generated by the antenna. These generated fields are the properties of electromagnetic wave. This wave looks into the matter of time-varying direction and magnitude of the electric field vector. Antenna polarization needs to be matched with the radiated field orientation to receive the maximum field intensity to the electromagnetic wave.

If the polarization of the receiving and transmitting sides does not match each other, there will be polarization mismatch and power loss. So, in order to avoid power loss, polarization needs to be in the same direction. The Polarization Loss Factor is also known as polarization efficiency, antenna mismatch or antenna receiving. All of these names refer to the same concept. Antenna polarization can be divided into three: linear, circular and elliptical. When the electric and magnetic fields of the antenna is traveling in a single or same direction that indicates they are perpendicular to each other, it is considered linear polarization. If the electric field parallels to the earth, then it is horizontally polarized. On the other hand, when the electric field is perpendicular to the earth, it is vertically polarized [12].

When choosing an antenna, some criteria are needed for consideration. Antenna polarization is one of the important issues, which needs to be considered. Most communications systems use antennas with vertical, horizontal or circular polarization.

### 2.3.1 Linear Polarization

Understanding the difference between polarization and how to maximize their benefit is very important to the antenna designer. A linearly polarized antenna radiates only in one plane containing the direction of propagation, the plane of propagation is always horizontal or vertical for the linearly polarized antenna. There are two forms of linear polarization: vertical, where the electric field is perpendicular to the Earth's

surface, and horizontal, where the electric field is parallel to the Earth's surface. Both directions can be used simultaneously on the same frequency.

Linear polarization comprises both Horizontal and Vertical components, as shown in Figure 2.3, which are exactly “in phase”, and have the same frequency as stated above. This means there is always a component in both the horizontal and the vertical plane for each frequency in the spectrum. How we tune or extract the energy from the wave establishes the operational mode [13].

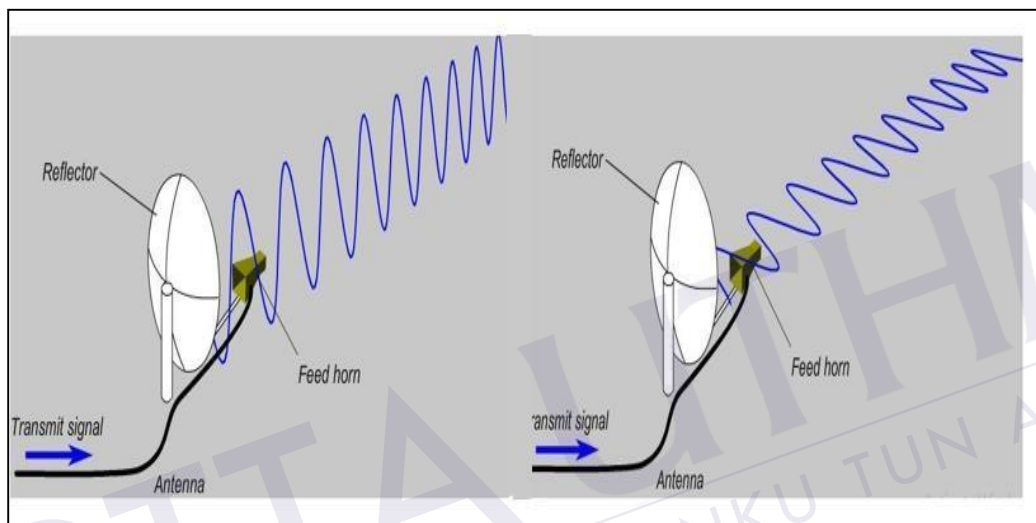


Figure 2.3: Linear, vertical polarization (left) & horizontal polarization (right) [13].

### 2.3.2 Circular Polarization

Circular polarization involves the plane of polarization rotating in a corkscrew pattern, making one complete revolution during each wavelength. The circularly polarized wave will radiate energy in the horizontal, vertical plane and every plane in between. There are two directions of propagation that come with circular polarization: Right-Hand-Circular (RHC) and Left-Hand-Circular (LHC), as depicted in Figure 2.4. If the wave rotates clockwise to the direction of propagation, it is called right-hand circular polarization (RHCP) otherwise, it is called left-hand circular polarization [12].

Circularly polarized radiation can be generated by exciting two near degenerate linearly polarized orthogonal patch modes with equal amplitude excitation and  $90^\circ$  phase difference. The sign of the relative phase determines the



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