WEARABLE MICROSTRIP PATCH ANTENNA FOR ELDERLY HEALTHYCARE MONITORING

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In the name of Allah, the Most Gracious, and Most Merciful

In the name of Allah, Most Gracious, Most Merciful. All praises be to Allah for blessing me and giving me the strength to complete this project.

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ABSTRACT

Recently, there is a growing demand of healthcare monitoring for elder people. Therefore, wearable antennas become the best solution to monitor elderly's body. Fabric is considered the most suitable material for body wearable applications due to its flexibility this type of antenna textile or fabric based which has the characteristics of wearable microstrip patch antenna such as light weighted, easily attached to the body of senior person and low cost. A wearable microstrip patch antenna operating at single frequency 2.45 GHz had been designed. Therefore, the geometry of the patch antenna is 51 mm (L) × 56 mm (W) while the ground plane and substrate dimensions are 73 mm (L) × 73 mm (W). The substrate material used for this project is felt with a height of 1.1 mm and dielectric constant of 1.38 and copper for radiating element. The simulated return loss S11 of the microstrip patch antenna is -34.011 dB at 2.45 GHz, while the measured S11 is -19.507 dB at 2.44 GHz. In conclusion, the simulated SAR confirms that the antenna is wearable, with 0.4755 W/kg at 2.45 GHz. Furthermore, the bending effect of the antenna with radius from 36 to 126 mm and its SAR was analysed. The SAR value of the antenna was tested, based on flat and bended antenna to show the radiation effect on the human body phantom. The bended SAR value shows 0.702 W/kg at 2.45 GHz. The SAR values of both antennas are safe according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP), European standard. The standard safe level is 2 W/kg for any 10 grams of tissue. The antenna performance was measured using Vector Network Analyzer. The simulated and measured results shown a good agreement only on the frequency but shows different results on the return loss.

ABSTRAK

Baru-baru ini, terdapat permintaan pemantauan penjagaan kesihatan untuk orang tua yang semakin meningkat. Oleh itu, antena yang boleh dipakai menjadi penyelesaian terbaik untuk memantau tubuh orang tua. Fabrik dianggap sebagai bahan yang paling sesuai untuk aplikasi yang boleh dipakai oleh badan kerana fleksibiliti antena jenis tekstil atau fabrik yang mempunyai ciri-ciri antena microstrip patch yang boleh dipakai seperti ringan, mudah melekat pada badan orang tua dan kos rendah. Microstrip patch antena yang boleh dipakai yang beroperasi pada frekuensi tunggal 2.45 GHz telah direkabentuk. Oleh itu, geometri patch antena adalah 51 mm (L) × 56 mm (W) sementara dimensi permukaan tanah dan substrat adalah 73 mm (L) × 73 mm (W). Bahan substrat yang digunakan untuk projek ini adalah felt dengan ketinggian 1.1 mm dan pemalar dielektrik 1.38 dan tembaga untuk elemen memancar. Simulasi kehilangan kembali S11 antena patch mikrostrip adalah -34.011 dB pada 2.45 GHz, sementara S11 yang diukur adalah -19.507 dB pada 2.44 GHz. SAR yang disimulasikan mengesahkan bahawa antena boleh dipakai, di mana 0.4755 W / kg pada 2.45 GHz. Selain itu, kesan bengkokan antena dengan radius dari 36 hingga 126 mm and nilai SAR telah dianalisis. Nilai SAR antenna telah diuji berdasarkan antena rata dan bengkok untuk menunjukkan kesan radiasi ke atas badan manusia. Nilai SAR terbengkok adalah 0.702 W/kg pada 2.45 GHz. Nilai SAR kedua-dua antena adalah selamat berdasarkan piawaian Eropah ICNIRP. Piawaian untuk aras selamat adalah 2 W/kg untuk setiap 10 gram tisu. Antena diukur menggunakan Vector Network Analyzer. Hasil simulasi dan pengukuran menunjukkan kesepakatan yang baik hanya pada frekuensi tetapi menunjukkan hasil yang berbeza pada kehilangan kembali.

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LIST OF SYMBOLS AND ABBREVIATIONS

PLF	-	Polarization loss factor
D	-	Directivity
E	-	Efficiency
f	-	Operating frequency
f_C	-	Centre frequency
f_H	-	Upper frequency
G	-	Gain
h	-	Substrate thickness
L	-	Length
ε_{reff}	-	Effective relative permittivity
R_{in}	-	Antenna Resistance
S_{11}	-	Return loss or reflection loss (dB)
W	-	Width
P_{in}	-	Input Impedance
ε_r	-	Dielectric Constant
ΔL	-	Extended length due to fringing field effect
VSWR	-	Voltage standing wave ratio
Γ	-	Reflection coefficient

CHAPTER 1

INTRODUCTION

1.1 Background study

A good healthcare device should be developed for our senior citizens to ease the struggle and make it enjoyable their journey of life and to keep on track their condition every time.

Wearable microstrip patch antenna is the perfect way to provide cheap cost-effective remote healthcare monitoring to obtain readings of body parameters, such as blood pressure blood sugar and heart rate [1].

This project is presented to improve healthcare monitoring and help elderly patients in medical treatments by designing a single band wearable antenna. this type of antenna will be developed to oversee the elder health problems and their conditions. by attaching the antenna to the elderly's body, the medical services will be able to notice the problem without examining. therefore, this will make it easy to fight against health issues also more comfortable the senior's way of living.

Fabric material such as textile or fabric are considered the most suitable material for wearable microstrip patch antenna applications due to its flexibility and characteristics. In particularly they are light weighted, which can be easily attached to the body of senior person and has low cost [2].

1.2 Problem statement

In order to improve healthcare quality, largely for those who lack access to traditional health monitoring such as elderly people, Telemedicine solutions has been introduced. Which needs that the observing must not influence elder regular habits. To achieve that demand the electronic component such as antenna which is important by carrying out the monitoring of the senior's daily routine. For that purpose, a practical solution will be to employ wearable antennas that can be fully integrated with clothes and to be used for remotely transmitting and receiving the sensors data.

wearable antennas such as wired antenna, flexible substrate antenna and film antenna are explored in making the antenna more flexible. However, telehealth applications still require to be comfortable with the wearable microstrip patch antenna when involved in a certain body movement and position. In this case, material selection to fabricate the microstrip patch antenna is one of the important factors, therefore in this project different materials will be investigated and compared such as Fleece fabric, Cordura and Felt for the substrate, while the radiating element will be copper respectfully due to their flexibility, light weight and ability to conform to the curvature of human body. Also, the materials will be analysed in terms of their performance and return loss.

1.3 Objectives

The objectives of this project are:

i. to design wearable antenna for elderly healthcare monitoring.
ii. to simulate and fabricate the wearable antenna.
iii. To verify the wearable antenna using CST.
iv. to compare the simulated result and the measured result.

1.4 Scope of study

This project is divided into some major phases:

i. The wearable antenna operates at 2.45 GHz for ISM band.
ii. CST software is used to design and simulate the wearable microstrip patch antenna.
iii. The antenna is fabricated and then tested by using Vector Network Analyzer
iv. The measured result and the simulated result obtained from CST software will be compared.

1.5 Organization of thesis

Chapter 1 describes the motivation for doing this project. The objectives are stated, and the organization of the thesis is shown in this chapter.

Chapter 2 gives an overview of this project and introduction for wearable antenna is given. Particularly, the introduction to microstrip patch antenna and its characteristics are to discuss in this chapter.

Chapter 3 contains the design methodology of the project. The design overview and all the tools and modules used in this project are discussed including antenna design parameter and calculation involved.

Chapter 4 focuses on the simulation and testing results. Also, the main characteristics, such as return loss, radiation pattern and gain are investigated.

Chapter 5 concludes the thesis and gives some recommendations for future work and improvement of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a literature review of the related work on wearable antenna and will interduce the concept of microstrip patch antenna, including the wireless body area network (WBANs). Furthermore, this chapter also describes details of microstrip patch antenna.

2.2 Theoretical review

The first antenna for compact applications was distributed in the last 4 decades. In recent research for wearable antenna design, including planar dipoles, monopoles, planar inverted-Fs (PIFAs). Microstrip antennas are flat and can be mounted on a printed circuit board (PCB). This made them a realistic type of antenna due to their low cost and fast fabricating. In [3], Salonen explored the concept of the planar inverted-F antenna (PIFA) as a wearable antenna intended to be mounted on the clothing sleeve. PIFAs are like quarter wave monopole antennas, which are parallel to the ground plane.

Figure 2.1 shows microstrip antenna placed on the shoulder. The ground plane formed as a shield for human body so the radiation will not radiate to the body. In other words, the ground plane was acting as a radiation reflector [4].

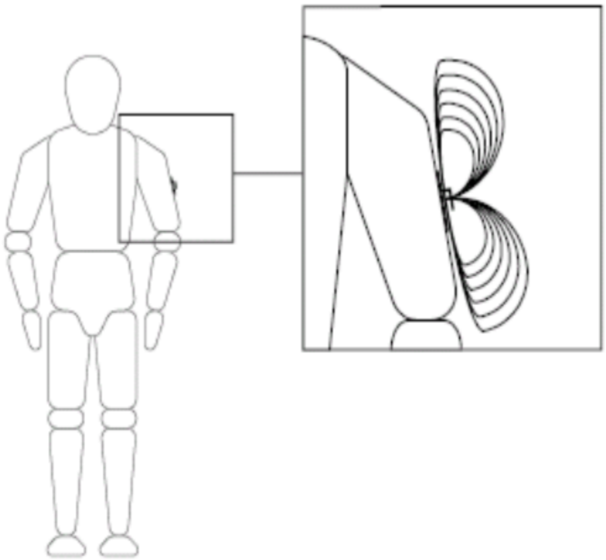


Figure 2.1: Planar Inverted F antenna (PIFA) [15]

2.3 Microstrip patch antenna

Microstrip patch antenna are a class of planar antennas and has many advantages over traditional microwave antennas and have been used on one side of the dielectric substrate in many practical applications. Usually, patches are made of conductive materials such as copper or gold and may take the shape that is possible [11]. As shown in Figure 2.2, the four basic components are the microstrip antenna (metallic patch, dielectric substratum, ground plane and power structure), where L is the patch length, W is the fill width, h is the dielectric substrate height, and εr is the relative permittivity of the substrate.

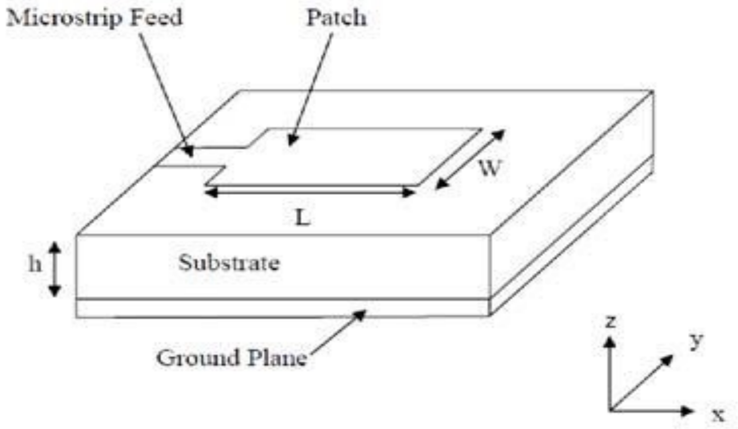


Figure 2.2: Basic microstrip antenna [13]

The typical structure of the microstrip antenna where W stands for the patch width, L for the patch length, the patch thickness of t, and the substrate height of h are shown. For good antenna performance, a good dielectric constant with a tiny dielectric constant is necessary. This offers greater efficiency, higher bandwidth and more radiation. Nevertheless, larger antenna sizes are produced to accomplish this. A growing dielectric constant is used to get a small antenna, which means a compact design, which reduces the bandwidth more effectively [17].

Microstrip patch antenna contains a thin metal plate on a dielectric substrate. Figure 2.3 shows the state of the microstrip patch antenna, which is rectangular, striped, circular triangular, or any mix of shapes. every one of them has its various features and is chosen to address specific issues. rectangular squares, circles are the most well-known structure to analyze [12].

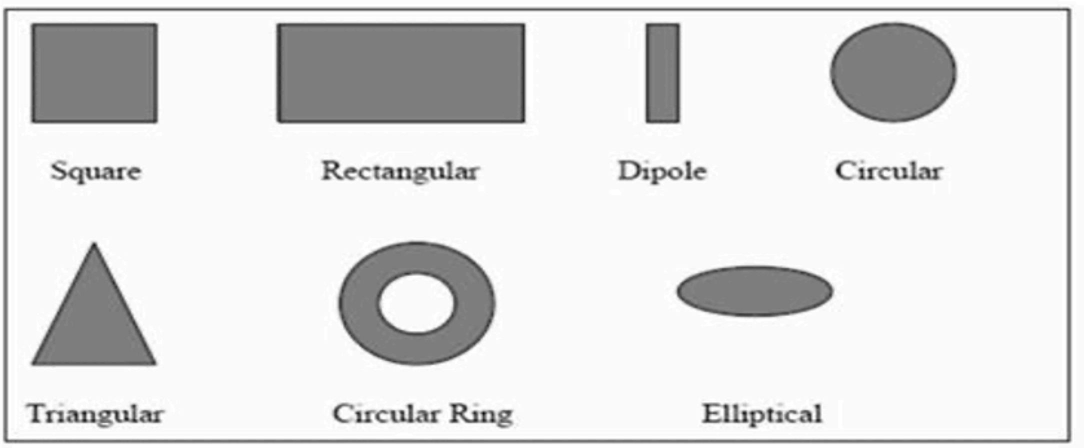


Figure 2.3: The shapes of microstrip antenna [12]

2.3.1 Advantages and disadvantages of microstrip patch antenna

Advantages of microstrip patch antennas such as low profile, which can also be made conformal to a shaped surface. Also, microstrip patch antenna has low weight, low radar cross-section and can be designed for dual or multi-frequency operations.

Other advantages microstrip patch antennas have thin profile and light weight. Also, allow both linear and circular polarization.

There are a few drawbacks related with microstrip patch antenna. Initially, the low gain and also low efficiency, therefore, these drawbacks can make the antenna to not achieve half of the bandwidth.

Microstrip patch antennas have also these disadvantages such as huge ohmic loss, the most part it occurs is in the dielectric substrate and the metal conductor, also microstrip patch antennas have low power handling capacity.

2.3.2 Antenna efficiency

Efficiency means that the antenna and the transmission line must be aligned to prevent any loss; otherwise, it will cause a reflection at the input terminals and will be considered a loss of reflection. Radiation efficiency matched by the impedance mismatch loss is the total antenna performance.

2.3.3 Gain

The gain of the antenna in a particular direction is more compared to isotropic antenna radiation in all directions for providing a better performance. It means the ratio of the radiation intensity, in a given direction, to the total power acknowledged by the antenna.

2.3.4 Polarization

Polarization of the antenna is a very important factor to consider when selecting an antenna. It is important to know the difference between these types of polarization.

Polarization is a singular electromagnetic frequency wave that represents the electric field [27]. There are three types of polarization alongside how current moves within the antenna: linear polarization, circular polarization, or elliptical polarization. As the current passes along one axis, polarization is called linear, and if two orthogonal currents with a 180-degree phase offset are formed on the antenna.

2.3.5 Feeding techniques

Techniques for feeding are divided into two groups. Contacting and non-contacting is the other [4]. There are four kinds of feeding methods and they are coaxial probe, microstrip line, coupling aperture and coupling proximity. The following Figure 2.4, Figure 2.5, Figure 2.6 and Figure 2.7 show the four feed lines.

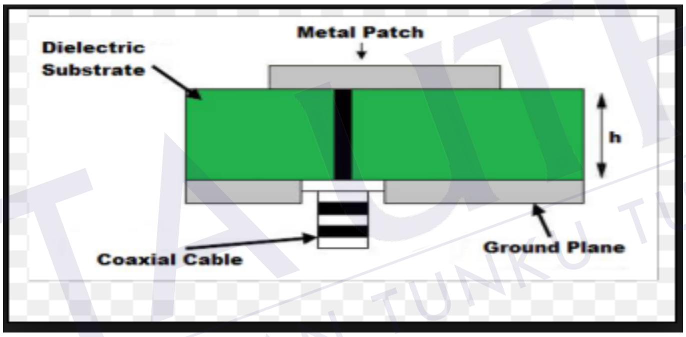


Figure 2.4 Coaxial probe feed patch antenna [6]

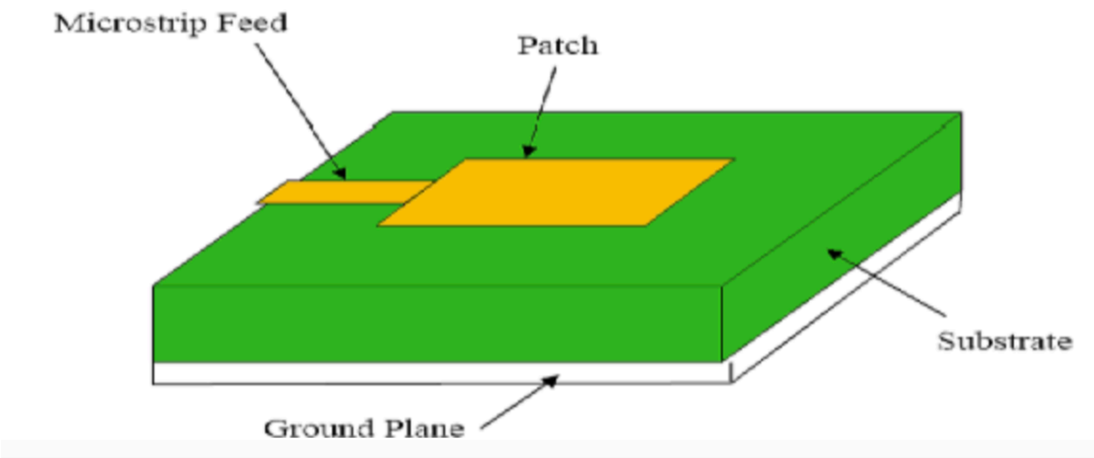


Figure 2.5: Direct microstrip feed line [6]

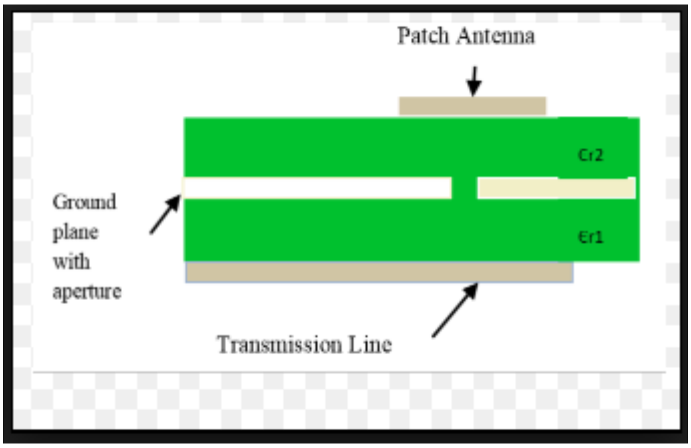


Figure 2.6: Aperture coupling [6]

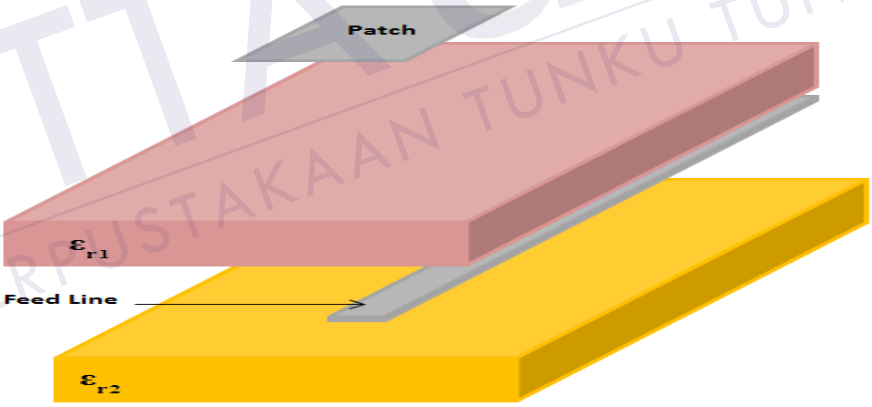


Figure 2.7: Aperture coupling [6]

2.4 Wireless body area networks (WBANs)

Wireless body area networks (WBANs) are in an early stage of growth to serve healthcare applications, but provide useful surveillance, diagnostic or therapeutic contributions. They cover the collection of medical real-time data obtained from various sensors with safe communication of data and low power consumption. Due to the increasing interest in the use of this form of network, a number of articles have recently been published dealing with various aspects of these systems [16].

To pick the most helpful options for healthcare, WBAN issues for medical monitoring purposes. Wireless communication protocols, frequency bands, data bandwidth, transmission distance, authentication methods, power consumption and mobility are the most important features considered in the study [16].

2.5 Wearable antenna

The characteristics of wearable antenna are lightweight, and low-cost portable and ability for wireless sensors and communications, wearable antennas have gained a lot of attention in recent years. When used on various parts of the human body, these antennas must be compliant, so they must be fitted with flexible materials and built with a low-profile structure [24].

In our everyday lives, wearable devices have different uses. They are not restricted to wristwatches, fitness bands, virtual reality glasses, but many medical uses are also covered. Wearables are used in the healthcare system to monitor the vital health conditions of patients. They have a glucose monitoring system to track the sugar level of the patient; heart rate monitoring; blood pressure; and body temperature monitoring [26] as shown in Figure 2.8.

Figure 2.8: Microstrip patch antenna attached on chest [26]

2.6 Substrates

Substrate is layer between the patch and the ground. Depending on the requirements of the antenna. The effect of dielectric constant εr on radiation efficiency is needed when selecting the dielectric material for the substrate. If a high dielectric constant material is chosen, the size of the antenna can be reduced at the same time as the radiation efficiency is also reduced. The size must be small when the antenna is used as an implantable device for WBAN networks, and its efficiency should be high [23].

Table 2.1 shows that the materials of fleece with the thickness of 2.55 mm and permittivity of 1.17 also the tangent which is 0.0035. Cordura with the thickness of 0.57 mm and permittivity of 1.90 also the tangent which is 0.0098. Felt with the thickness of 1.1 mm and permittivity of 1.38 also the tangent which is 0.023. Cotton with the thickness of 0.88 mm and permittivity of 1.60 also the tangent which is 0.0040. Polyester with the thickness of 0.5 mm and permittivity of 1.90 also the tangent which is 0.0045. Silk with the thickness of 0.58 mm and permittivity of 1.75 also the tangent which is 0.012 [27].

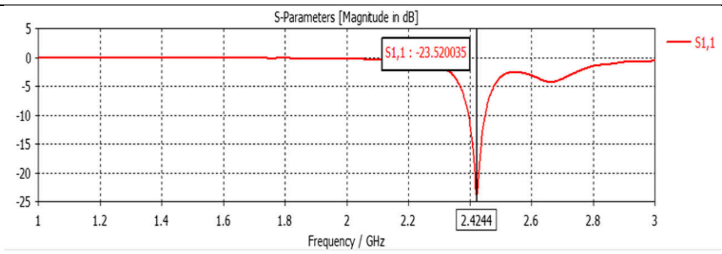
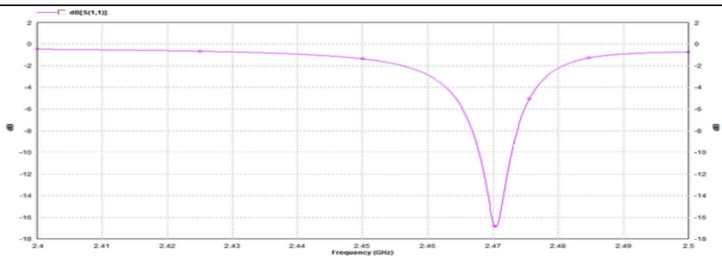
Table 2.1: Fabric materials [22]

Materials	**Thickness (mm)**	**Permittivity**	**Tangent**
Fleece	2.55	1.17	0.0035
Cordura	0.57	1.90	0.0098
Felt	1.1	1.38	0.023
Cotton	0.88	1.60	0.0400
100% Polyester	0.5	1.90	0.0045
Silk	0.58	1.75	0.012

2.7 Summary of related work

Table 2.2 shows the previous research done by researchers and it showed that S11 simulated produced great results and enhances the performance of the antenna at the specified resonate frequency.

Table 2.2: Summary of related work

Author	Title	Frequency	Result
Ameena Benu Mustafa, Tamilselvi Rajendran. (2019) [23]	An effective design of wearable antenna	2.42 GHz	
Wahiba Grabssi, Sarah Izza. (2018) [13]	microstrip patch antenna for medical applications	2.47 GHz	 *Figure3.b: simulated return loss at 2.47 GHz*

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