

**A 2X1 WEARABLE PERIODICAL ARRAY ANTENNA FOR IEEE
standards P802.11 ay/D4.O APPLICATIONS**

Submitted in partial fulfilment of the requirements of the award of
Bachelor of Engineering Degree in Electronics and Communication Engineering

By

S. ALLEN (Reg. No. 37130019)



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION
ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

APRIL 2021



SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with "A" grade by NAAC
piaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119
www.sathyabama.ac.in



DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **S. ALLEN (37130019)** and **P. BARANNATH (37130048)** who carried out the project entitled "**A 2X1 WEARABLE PERIODICAL ARRAY ANTENNA FOR IEEE standards P802.11 ay/D4.O APPLICATIONS**" under our supervision from September 2019 to April 2021.

Internal Guide

Dr.M. SUGADEV, M.Tech., Ph.D.,

Head of the Department

Dr. T. RAVI, M.E., Ph.D.,

Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I, **S. ALLEN (37130019)** hereby declare that the Project Report entitled “**A 2X1 WEARABLE PERIODICAL ARRAY ANTENNA FOR IEEE standards P802.11ay/D4.O APPLICATIONS**” done by us under the guidance of **Dr. M. SUGADEV, M.Tech., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

1)

2)

DATE:

SIGNATURE OF THE CANDIDATES

PLACE :

ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr.N.M. NANDHITHA, M.E., Ph.D., Dean, School of Electrical and Electronics Engineering** and **Dr. T. RAVI, M.E., Ph.D. Head of the Department, Department of Electronics and Communication Engineering** for providing us necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our Project Guide **Dr. M.SUGADEV, M.Tech., Ph.D. Assistant Professor, Department of Electronics and Communication Engineering** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of the project work.

We wish to express our thanks to all teaching and Non-teaching staff members of the **Department of Electronics and Communication Engineering** who were helpful in many ways for the completion of the project.

We express our gratitude to our parents for their constant encouragement and support for the completion of the project

ABSTRACT

Nowadays RF and wireless communication systems are widely used in day-to-day activities of human being and industrial applications. WLAN, Wi-Fi, WiMAX, ISM are some applications in which antenna plays an important role. Microstrip patch antennas are widely used to cater the requirements of today's communication system. This report aims to present a review on various configuration and techniques of microstrip patch antennas used in wireless communication systems. RF communication systems are playing potential role in day-to-day human activity. These systems are used to assist in distribution or collection of large data or to make home entertainment system more convenient. The microstrip patch antenna is found to be suitable candidate.

CHAPTER-1

INTRODUCTION

INTRODUCTION

Wireless communications, nowadays, depend on antenna as an essential component. Without the antenna, it would be virtually impossible to have any form of wireless communication. Instead, the communications would be achieved by clumsily connecting wires between every transmitter and receiver. The world would be proliferated by an abundance of wires, and the range of available communications would be very limited to say the least.

The history of the antenna is a relatively young one. Started in 1842, when Joseph Henry used vertical wires on the roof of his house to detect lightning flashes. Later on, in 1864, James Clerk Maxwell presented the equations that form the basis for antenna technology and microwave engineering. In 1885, Thomas Edison patented a communications system that utilized top-loaded, vertical antennas for telegraphy. Two years later, Heinrich Hertz introduced a Hertzian dipole to experimentally validate Maxwell's equation in regard that electromagnetic waves propagate through the air. Guglielmo Marconi, in 1898, developed radio commercially and pioneering transcontinental communications.

In 19th century, antennas have been used for lot of applications. The need for radar during the major wars of the 20th century sparked the creation of large reflectors, lenses, dipole and waveguide slot arrays. The antenna has been an essential component of the television set since the 1930's. The proliferation of antennas in today's world is also quite evident. Satellites in orbital space relay information about the weather, in addition to news of important social and political events around the globe. Radar, an application of antennas, allows air traffic controllers to track and safely guide aircraft to their destinations around the world. More recently, antennas serve as vital

components on pagers and cellular phones, devices central to a wireless revolution. Also large radio astronomy antennas are constantly searching the sky looking for other forms of intelligent life in the universe. This sampling of antenna topologies and applications is by no means inclusive; it serves to demonstrate the wide variety and uses of antennas in practical life.

ANTENNA PARAMETERS

Antenna is a metallic structure designed for radiating and receiving electromagnetic energy. It acts as a transitional structure between the guiding device (e.g. waveguide, transmission line) and the free space. There are several critical parameters that affect an antennas performance and can be adjusted during the design process. These are impedance, gain, aperture or radiation pattern, polarization, efficiency and bandwidth.

In this chapter the principles and characteristics of antennas and its performance parameters are examined.

Electromagnetic Radiation

Electromagnetic radiation includes radio waves, microwaves, infrared radiation, visible light, ultraviolet waves, X-rays, and gamma rays. Together they make up the electromagnetic spectrum. They all move at the speed of light $c = 3 \times 10^8 \text{ m / s}$. The only difference between them is their wavelength $\lambda (m)$ (the distance a wave travels during one complete cycle [vibration]), which is also directly related to the amount of energy the waves carry.

The shorter the wavelength, the higher the energy. Figure 1.1 lists the electromagnetic spectrum components according to wavelength and frequency $f (Hz)$ (the number of complete cycles per second). Radio waves are very long compared to the rest of the electromagnetic spectrum. The radio spectrum is divided up into a

number of bands based on their wavelength and usability for communication purposes. They extend from the Very Low Frequency *VL**F* portion of the spectrum through the Low (*LF*), Medium (*MF*), High (*HF*), Very High (*VHF*), Ultra High (*UHF*), and Super High (*SHF*) to the Extra High Frequency (*EHF*) range as depicted in the illustration below.

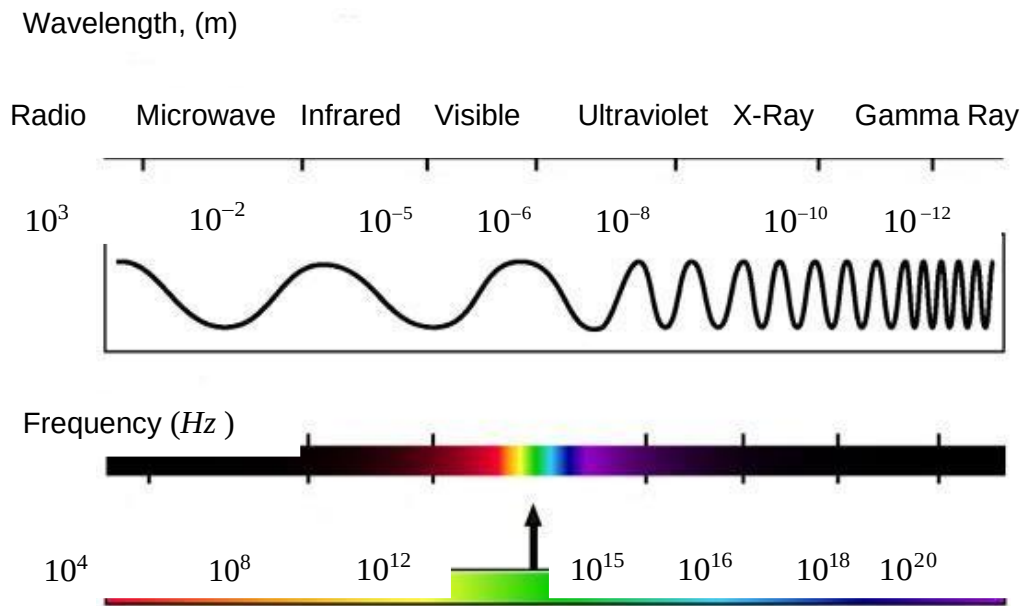


Figure 1.1 Electromagnetic Spectrum.

Above the (*EHF*) band comes infrared radiation and then visible light. Table 1.1 below, presents the electromagnetic spectrum and applications.

Table 1.1 Electromagnetic Spectrum and Some Applications.

Band	Frequency	Wavelength	Applications
VLF	3 - 30 kHz	100 km - 10 km	Long range navigation and marine radio
LF	30 - 300 kHz	10 km - 1 km	Aeronautical and marine navigation

MF	300 kHz - 3 MHz	1 km - 100 m	AM radio and radio telecommunication
HF	3 - 30 MHz	100 m - 10 m	Amateur radio bands, NRC time signal
VHF	30 - 300 MHz	10 m - 1 m	TV, FM, cordless phones
HFU	300 MHz - 3 GHz	1 m - 10 cm	UHF TV, satellite, air traffic radar, etc
SHF	3 - 30 GHz	10 cm - 1 cm	Mostly satellite TV and other satellites
EHF	30 - 300 GHz	1 cm - 1 mm	Remote sensing and other satellites

Radio waves propagate much like surface water waves. They travel near the Earth's surface and also radiate sky ward at various angles to the Earth's surface. As the radio waves travel, their energy spreads over an ever-increasing surface area. A typical radio wave has two components, a crest (top portion) and a trough (bottom portion). These components travel outward from the transmitter, one after the other, at a consistent velocity. The distance between successive wave crests is called a wavelength and is commonly denoted by λ as shown in Figure 1.2.

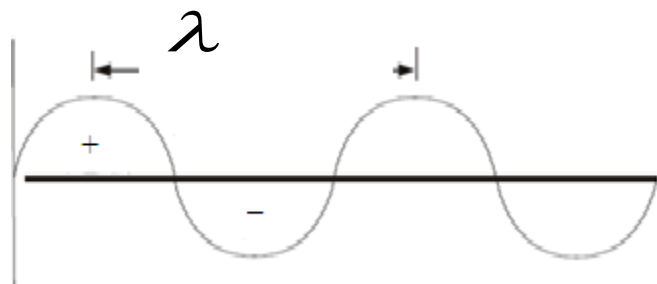


Figure 1.2 Radio Wave.

Frequency is measured and stated in hertz (Hz) . Frequency has an inverse relationship to the concept of [wavelength](#); simply, frequency is inversely proportional to wavelength λ [2]. The frequency f is defined as:

$$f = \frac{c}{\lambda}. \quad (1.1)$$

ANTENNA RADIATION

A conducting wire radiates mainly because of time-varying current or an acceleration (or deceleration) of charge. If there is no motion of charges in a wire, no radiation takes place, since no flow of current occurs. Radiation will not occur even if charges are moving with uniform velocity along a straight wire. However, charges moving with uniform velocity along a curved or bent wire will produce radiation. If the charge is oscillating with time, then radiation occurs even along a straight wire.

The radiation from an antenna can be explained with the help of Figure 1.3 which shows a voltage source connected to a two conductor transmission line. When a sinusoidal voltage is applied across the transmission line, an electric field is created which is sinusoidal in nature and these results in the creation of electric lines of force which are tangential to the electric field. The magnitude of the electric field is indicated by the bunching of the electric lines of force. The free electrons on the conductors are forcibly displaced by the electric lines of force and the movement of these charges causes the flow of current which in turn leads to the creation of a magnetic field. Due to the time varying electric and magnetic fields, electromagnetic waves are created and these travel between the conductors. As these waves approach open space, free space waves are formed by connecting the open ends of the electric lines.

Since the sinusoidal source continuously creates the electric disturbance, electromagnetic waves are created continuously and these travel through the transmission line, and radiated into the free space. Inside the transmission line and the

antenna, the electromagnetic waves are sustained due to the charges, but as soon as they enter the free space, they form closed loops and are radiated.

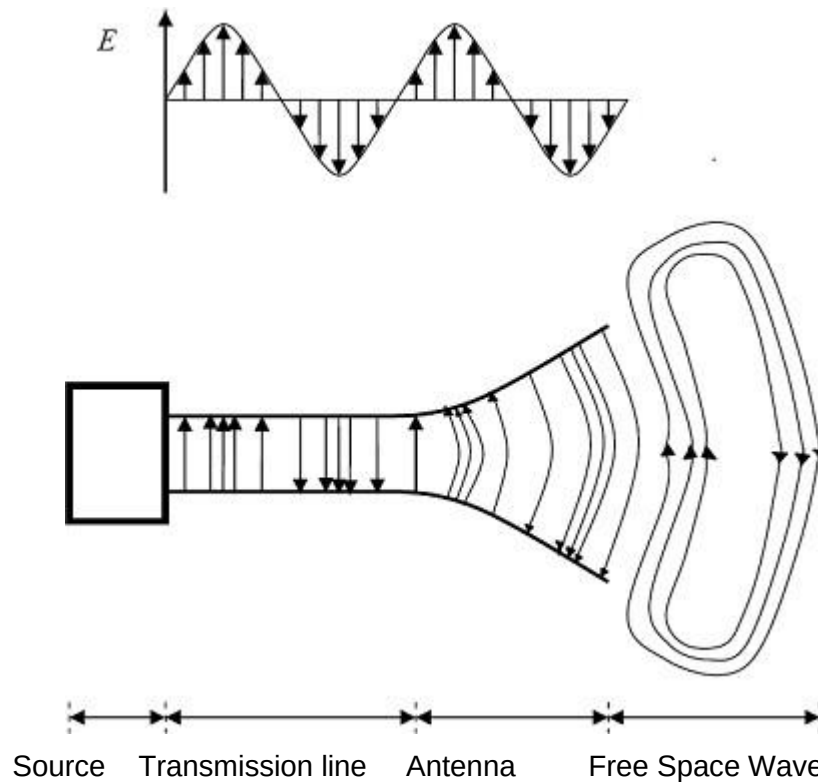


Figure 1.3 Radiations From an Antenna.

NEAR AND FAR FIELD REGIONS

The field patterns, associated with an antenna, change with distance and are associated with two types of energy: radiating energy and reactive energy. Hence, the space surrounding an antenna can be divided into three regions.

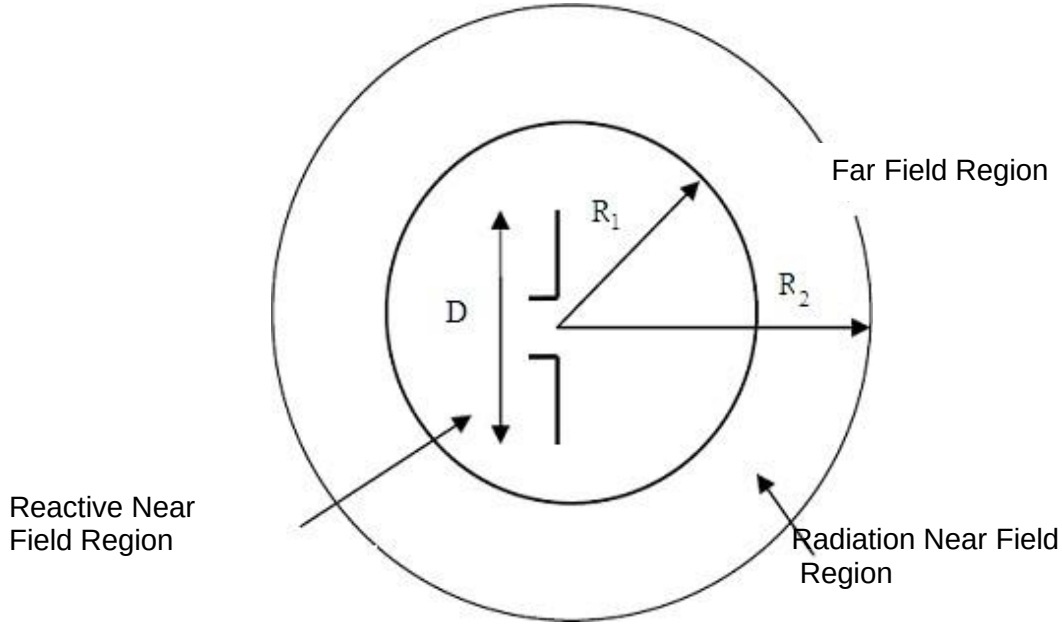


Figure 1.4 Field Regions Around an Antenna.

The three regions shown in Figure 1.4 are:

- Reactive near-field region: In this region, the reactive field dominates. The reactive energy oscillates towards and away from the antenna, thus appearing as reactance. In this region, energy is only stored and no energy is dissipated. The outermost boundary for this region is at a distance

$$R_1 = 0.62 \sqrt{\frac{D^3}{\lambda}}, \quad (1.2)$$

where R_1 is the distance from the antenna surface, D is the largest dimension of the antenna and λ is the wavelength. Radiating near-field region (Fresnel region). It is the region which lies between the reactive near-field region and the far field region. Reactive fields are smaller in this field as compared to the reactive near-field region and the radiation fields dominate. In this region, the angular field distribution is a function of the distance from the antenna. The outermost boundary for this region is at a distance

$$R_2 = \frac{2D^2}{\lambda}, \quad (1.3)$$

where R_2 is the distance from the antenna surface.

- Far-field region (Fraunhofer region): The region beyond $R_2 = \frac{2D^2}{\lambda}$ is the far field region.

In this region, the reactive fields are absent and only the radiation fields exist. The angular field distribution is not dependent on the distance from the antenna in this region and the power density varies as the inverse square of the radial distance in this region.

BASIC ANTENNA PARAMETERS

The performance of an antenna can be gauged from a number of parameters. Certain critical parameters are briefly discussed below.

Radiation Pattern

The radiation pattern of an antenna is a plot of the far-field radiation properties of an antenna as a function of the spatial coordinates which are specified by the elevation angle θ and the azimuth angle φ .

More specifically, it is a plot of the power radiated from an antenna per unit solid angle which is nothing but the radiation intensity [3]. Let us consider the case of an isotropic antenna. An isotropic antenna is one which radiates equally in all directions.

If the total power radiated by the isotropic antenna is P , then the power is spread over a sphere of radius r , so that the power density S at this distance in any direction is given by

$$S = \frac{P}{4\pi r^2} \text{ (Watts /m}^2\text{)}, \quad (1.4)$$

and the radiation intensity for this isotropic antenna U_i can be written as

$$U_i = r^2 S = \frac{P}{4\pi} \text{ (Watts)}. \quad (1.5)$$

An isotropic antenna is not possible to realize in practice and is used only for

comparison purposes. A more practical type is the directional antenna which radiates more power in some directions and less power in other directions. A special case of the directional antenna is the omnidirectional antenna whose radiation pattern may be constant in one plane (e.g., E -plane) and varies in an orthogonal plane (e.g., H -plane). The radiation pattern plot of a generic directional antenna is shown in Figure 1.5.

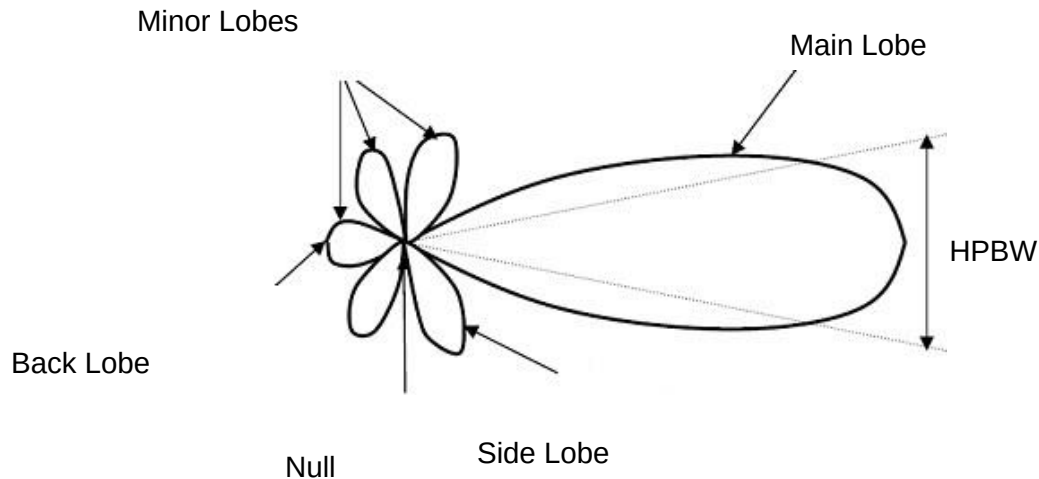


Figure 1.5 Radiation Pattern of a Directional Antenna [3].

Figure 1.5, the half power beam width (HPBW) can be defined as the angle subtended by the half power points of the main lobe, main lobe is the radiation lobe containing the direction of maximum radiation, and minor lobe is all the lobes other than the main lobe. These lobes represent the radiation in undesired directions. The level of minor lobes is usually expressed as a ratio of the power density in the lobe in question to that of the major lobe.

This ratio is called as the side lobe level (expressed in decibels). Back lobe is the minor lobe diametrically opposite the main lobe; side lobes are the minor lobes adjacent to the main lobe and are separated by various nulls. Side lobes are generally the largest among the minor lobes. In most wireless systems, minor lobes are undesired. Hence a good antenna design should minimize the minor lobes [3].

Polarization

Polarization of a radiated wave is defined as the property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric field vector [3]. The polarization of an antenna refers to the polarization of the electric field vector of the radiated wave. In other words, the position and direction of the electric field with reference to the earth's surface or ground determines the wave polarization.

The most common types of polarization include the linear (horizontal or vertical) and circular (right hand polarization or the left hand polarization). If the path of the electric field vector is back and forth along a line, it is said to be linearly polarized. Figure 1.6 shows a linearly polarized wave. In a circularly polarized wave, the electric field vector remains constant in length but rotates around in a circular path.

A left hand circular polarized wave is one in which the wave rotates counterclockwise whereas right hand circular polarized wave exhibits clockwise motion as shown in Figure 1.7.

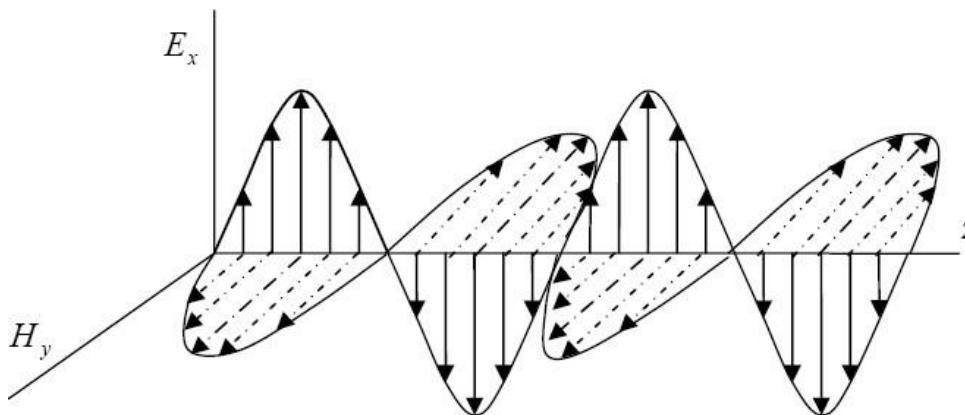


Figure 1.6 Linearly (Vertically) Polarized Wave [3].

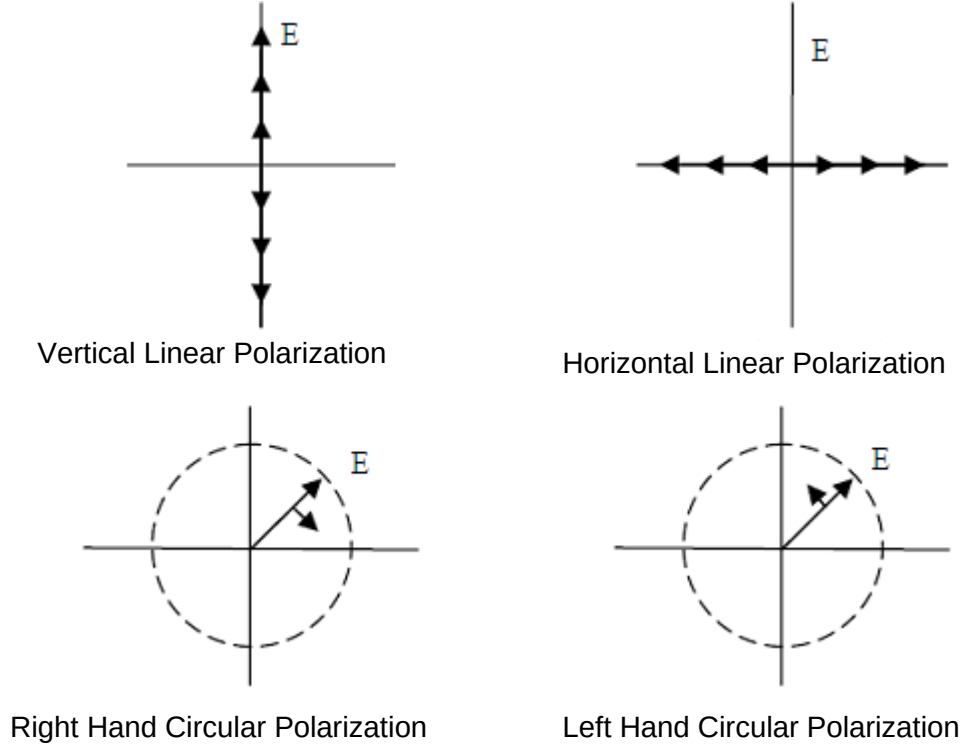


Figure 1.7 Commonly Used Polarization Schemes [3].

Directivity

The directivity of an antenna is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions [4]. In other words, the directivity (D) of a nonisotropic source is equal to the ratio of its radiation intensity in a given direction, to an isotropic source:

$$D = \frac{U}{U_i} = \frac{4\pi U}{P}, \quad (1.6)$$

where U is the radiation intensity of the antenna, U_i is the radiation intensity of an isotropic source and P is the total power radiated. The maximum directivity ($D_{\max}$) is defined by [3]:

$$D_{\max} = \frac{U_{\max}}{U_i} = \frac{4\pi U_{\max}}{P}, \quad (1.7)$$

where $U_{\max}$ is the maximum radiation intensity and P is the total radiated power. Directivity is a dimensionless quantity, since it is the ratio of two radiation intensities. Hence, it is generally expressed in dB .

The directivity of an antenna can be easily estimated from the radiation pattern of the antenna. An antenna that has a narrow main lobe would have better directivity, than the one which has a broad main lobe, hence it is called more directive [3].

Antenna Efficiency

The antenna efficiency is a parameter which takes into account the amount of losses at the terminals of the antenna within the structure of the antenna. The types of losses are given as follows:

- Reflections because of mismatch between the transmitter and the antenna.
- $I^2 R$ losses (conduction and dielectric) .

The total antenna efficiency can be written as

$$e_t = e_r e_c e_d , \quad (1.8)$$

$$e_r = 1 - |\Gamma|^2 , \quad (1.9)$$

where e_r is reflection (mismatch) efficiency, e_c is conduction efficiency and e_d is dielectric efficiency. Since e_c and e_d are difficult to separate, they are lumped together to form the antenna radiation efficiency e_{cd} which is given by

$$e_{cd} = e_c e_d = \frac{R_r}{R_L} , \quad (1.10)$$

which is simply defined as the ratio of the power delivered to the radiation resistance (R_r) to the power delivered to (R_L) .

Antenna Gain

Antenna gain is a parameter which is closely related to the directivity of the antenna. The directivity is how much an antenna concentrates energy in one direction in preference to radiation in other directions. Hence, if the antenna is 100% efficient, then the directivity would be equal to the antenna gain and the antenna would be an isotropic radiator.

Since all antennas will radiate more in some direction than in others, therefore the gain is the amount of power that can be achieved in one direction at the expense of the power lost in the others [5]. The gain is always related to the main lobe and is specified in the direction of maximum radiation. Antenna gain can be calculated by using the following expression:

$$G(\theta, \phi) = e_{cd} D(\theta, \phi) \quad (1.11)$$

or

$$G = \frac{4\pi}{BW_\phi BW_\theta} \quad (1.12)$$

where (BW_ϕ) is the azimuth beam width and (BW_θ) is the elevation beam width. The bandwidth of an antenna, is the range of usable frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard.

The bandwidth can be the range of frequencies on either side of the center frequency where the antenna characteristics like input impedance, radiation pattern, beamwidth, polarization, side lobe level or gain, are close to those values which have been obtained at the center frequency.

The bandwidth of a broadband antenna can be defined as the ratio of the upper to lower frequencies of acceptable operation. The bandwidth of a narrowband antenna can be defined as the percentage of the frequency difference over the center frequency [3].

Front-to-Back Ratio

It is often useful to compare the front-to-back ratio of directional antennas. This is the ratio of the maximum directivity of an antenna to its directivity in the opposite direction. For example, when the radiation pattern is plotted on a relative dB scale, the front-to-back ratio is the difference in dB between the level of the maximum radiation in the forward direction and the level of radiation at 180° . This number is meaningless for an omnidirectional antenna, but it gives one an idea of the amount of power directed forward on a very directional antenna. Front to back can be described by F/B [6].

Input Impedance

The input impedance of an antenna is defined, as the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point [3]. Hence, the impedance (Z_{in}) at the terminals of antenna is defined by:

$$Z_{in} = R_{in} + j X_{in} \quad (1.13)$$

where R_{in} is the antenna resistance and X_{in} is the antenna reactance. Further, the imaginary part (X_{in}), represents the power stored in the near field of the antenna. Reactance is the imaginary part of electrical impedance, a measure of opposition to a sinusoidal alternating current. Reactance arises from the presence of inductance and capacitance within a circuit [7].

The resistive part R_{in} , consists of two components, the radiation resistance R_r and the loss resistance R_L . The power associated with the radiation resistance is the power actually radiated by the antenna, while the power dissipated in the loss resistance is lost as heat in the antenna itself due to dielectric or conducting losses [3].

Wearable MSPA

In this report in chapter 4 involves the detail study on Wearable microstrip patch antenna (WMSPA) by simulating and fabricating it by placing all the simulated electromagnetic parameter results by analyzing the simulated WMSPA in ANSYS EM suite version 20 and tested the fabricated MSPA in Vector Network Analyzer and obtained the measured results. In recent years the process of wireless communication are increasing day by day and the MSPA plays the prominent role in this modern era of the wireless communication and in wearable MSPA is a good choice. In this letter now going to get into the 5G wireless communication till the early 2020 there are only two promising spectrum for 5G wireless communication one is mm waves other is Sub-6 GHz at present the other promising spectrum is added (i.e) Sub-7 GHz by the International Telecom Union-Radio communication (ITU-R) & added to IEEE P 802.11 standards for 5G communications. In this letter the proposed wearable MSPA is going to work efficiently in the both Sub-6 & Sub-7 GHz frequency bands according to the IEEE P802.11 ax/ay/D4.0 and also ITUn 77, 79 standard applications [14, 18]. The proposed simulated & fabricated wearable MSPA in this letter resonated at 3.74 GHz & 5.3 GHz frequency with good return loss. As mentioned previous that “wearable” so here the dielectric material used in this MSPA is cotton with low dielectric constant and in recent years the wearable MSPA is blooming into modern wireless communication technologies and also received the significant attention of the researchers. This wearable MSPA plays a prominent role in the field of military & medical applications. The electrical and the mechanical properties of the substrate material are considered carefully in designing of the wearable MSPA. Due to their foldable, stretchable & bendable properties these wearable MSPA is need excessively in this modern innovative era. To achieve the goal and to satisfy the IEEE norms the proposed design is implemented with various techniques and various optimization were carried out during simulation process. In this letter a deep study on techniques like array & Split Ring Resonator (SRR) are taken into an account. In MSPA array technique is nothing but it is a group of radiating patch placed on the single dielectric material. In recent years array

techniques in microstrip patch antenna plays a vital role and also attracted the attention of the researchers in this field of designing MSPA. By implementing the array technique can achieve long range in transmission of information with high data rates and high gain can be obtained so the working efficiency of the antenna is very high this achievements is due to the steering of the arrays so the proposed wearable MSPA in this letter also obtained very high range of working efficiency in transmission and all the simulated results proofs are discussed in upcoming sections. The SRR is implemented to load the MSPA array and this Split Ring Resonator is implemented in the ground plane of the proposed design in this letter and this technique is referred as meta-material by adding capacitance in it. This type of structures in the ground plane is also called as “man made structure”. When compared to other technique the combination of array patch & CSRR in ground shows the high performance rate and this CSRR shows a good potential to improve the mutual coupling between the array elements.

CHAPTER-2

Literature Survey

A Compact Wearable 2.45 GHz Antenna for WBAN Applications is simulated by Abi T Zerith M (2020), a compact flexible and wearable meandered structure microstrip patch antenna to resonate at 2.45 GHz frequency (ISM band) has been proposed. The proposed antenna substrate is designed using polydimethylsiloxane (PDMS) substrate with a dielectric constant of 2.71, loss tangent of 0.0134 and thickness of 1mm. the designed antenna are analyzed and validated using finite element method based Ansys HFSS (High Frequency Simulator Software) software. The simulation results show that the antenna has a gain of 1.9 dB, -26.82 dB return loss, 100 MHz bandwidth (2.4 GHz – 2.5 GHz) based on $|S_{11}| \leq -10$ dB, a directivity of 2.1 and 92% radiation efficiency. The compact size and high flexibility of the proposed antenna makes it suitable for Wireless Body Area Network (WBAN) applications.

Wearable dual-band antenna with harmonic suppression for application in medical communication systems is simulated and fabricated by Farzad Khajeh-Khalili (2020), a wearable dual-band antenna (WDBA) with harmonic suppression capability is presented for application in wireless medical/communication systems such as industrials, scientific, and medical (ISM) bands (0.9–1 GHz and 2.4–2.48 GHz). The dimensions of the proposed antenna are $60 \times 60 \times 2$ mm³. The maximum simulated gain at 1 GHz and 2.4 GHz are equal to 2.23 dB and 2.38 dB, respectively. Finally, to prove the simulations, the proposed WDBA was fabricated and its parameters were measured. The results of the measurement are in good proportion to the simulated results.

A Review on Recent Advances in Wearable Antenna Technologies and simulated & fabricated the antenna by Sarmad N. Mahmood¹ (2020), The proposed antenna was constructed at (2.45) GHz and (5.8) GHz ISM band utilizing denim as antenna substrate and copper tape as a radiation part. Using denim, a dielectric constant of (1.54) was realized based on a simple method with return loss., the proposed antenna realized maximum gain value specified by (6.34 and 4.7) dB at (2.45 and 5.8)

GHz.

A.J. Pascual (2019) explained about a unit cell design for antenna arrays efficiently matched to uni travelling carrier photodiodes. The optimized algorithm is used to find the optimization geometry of the unit cell from the given source impedance by knowing the two quantities of input impedance and radiation efficiency. The matching efficiency of the antenna can be increased at the cost of bandwidth and to get a 3dB power drop with relative bandwidth of 50%.

M. Sugadev (2017) explained about the antenna design with corporate feed based metamaterial antenna for wireless application. Coplanar waveguide fed antennas provide impedance matching for border frequency range. Along with CPW feed the design uses two annular rings for radiating layer and also uses split ring resonator elements for achieving metamaterial property. The antenna resonates in 2.8GHz and 4.8 GHz with a maximum gain of 5.53dB and with an impedance bandwidth of 450MHz. The CPW method of feeding is used to provide good impedance matching and omni directional patterns.

Adel Y.I. Ashyap (2017) Explained about an antenna with low profile electromagnetic band gap structure which is based on a textile wearable antenna for medical application. The main reason for the use of EBG is to reduce the radiation intensity in to the human tissues up to 13db. There are some negative aspects to demonstrate the EBG antenna designs such as electrically large, poor front to back ratio, semi flexible and rigid. The evolution of specific absorption rate is carried to validate the performance of the antenna when placed near to a human body. The structure of the designed antenna is compact in size and has a dimension of $54 \times 54 \times 1.6 \text{ mm}^3$ and obtained 8.5% impedance bandwidth ranging from 2.33 – 2.4 GHz with a power gain of 6.79dBi. The EBG structure can be analyzed by two methods such as reflection phase and suspended line method. The reflection phase can be analyzed with one unit cell to achieve 0 phase shift whereas suspended line is used to get band reject filter.

An UWB Metamaterial Antenna for Wlan Application has been discussed by U. Surender (2015). The antenna structure has an inverted T slotted on the radiating layer is and designed to operate in range from 3.1GHz to 10.6GHz and it has exactly resonated in 5.5GHz for WL:AN Application. Metamaterials antennas are used to enhance the performance of antenna in miniaturized sizes. The antenna is designed in Fr4 dielectric medium with a height of 1.6mm and having a length and width of 25mm and 21mm. The return loss obtained is -28dB in 5.5 GHz with a max gain of 3.6dB.

Quad Band U-Slot Microstrip Antenna for C,X and Ku Band Wireless Applications has been proposed by M.Sugadev (2105). A Quad band Microstrip patch antenna to target frequencies spanning over C,X and Ku Band by making a U slot in the patch by obtaining a return loss below -22db and Voltage standing wave ratio below 1.5 at all resonating frequencies of 5.8GHz, 8.25GHz, 9.85GHz and 13.95GHz. The bandwidth achieved in all resonating frequencies are found to be 5.2 – 5.5GHz, 7.7-8.5GHz, 9.75-10GHz and 13.75 – 14.10GHz and the efficiency of the antenna is 95%.U slot parameters are used to achieve wide bandwidth and the coaxial fed rectangular patch antenna is printed on Rogers RT/Duroid substrate with thickness of 3.175mm and permittivity of 2.2. The Length and width of the antenna is 67 x 74mm.

A triple-band antenna array for next generation wireless and satellite based applications has been proposed by Asghar A. Razzaqi (2014). The antenna is designed and simulated using Agilent ADS Momentum using FR4 substrate with a thickness of 1.66mm. The triple band of 1x2 and 1x4 microstrip patch antenna array are designed for next generation wireless and satellite application by achieving a triple band in 3.6GHz, 5.2GHz and 6.7GHz and the main patch of the antenna is designed for 3.6GHz. The 1x2 array achieved gain of 7.75, 7.7 and 9.4 in dBi with bandwidths of 1.67%, 1.06% and 1.65% and for 1x4 array are 10.2, 8.2 and 10 are the gains in dBi with bandwidth of 1.67%, 1.45% and 1.05%. This antenna array can be used for advanced antenna beam steering systems.

A Compact Multiple slot Microstrip antenna for modern mobile communication has been proposed by M.Sugadev (2016). A triple band patch antenna is designed by etching slots in the radiating patch in the shapes of L and M to get the resonating frequencies at 3.6GHz, 5.6GHz and 7.9GHz. Transmission line of 50 Ohm Impedance is used to design in FR4 epoxy resin material with return loss less than -10db and VSWR below 2 in all the three frequency bands and the gain 0.826dB.

A. Yadav, et al.,[2019] This work displays a structure of 2×1 microstrip patch array antenna for 5G C-band passage applications. The array utilizes the component of rectangular microstrip antenna with U opening on parasitic patch for 5G C Band (3.4 – 3.8 GHz) application. A microstrip feed arrange is utilized to bolster the antenna array is likewise actualized in the plan. The antenna is two layered antenna array and low profile is a decent up-and-comer of antenna for 5G C band passageway applications. the paper shows consequences of examination, for example, return misfortune, efficiencies, radiation design, and so forth of both single component and array antenna.

Ahmed Khidre et al., (2013) proposed a wideband dual-beam U-Slot microstrip antenna in which a coaxial-fed rectangular patch is printed over a RT Duroid substrate and a U-slot is cut on the patch's surface. The other side of the substrate is coated with metal, which is the ground plane of the antenna. The antenna has 11.3% bandwidth (5.17–5.81 GHz) and exhibit dual radiation beams and single resonant frequency of 2.4 GHz [9]. Realized gain of the forward beam is 7.92 dBi at the center frequency, whereas it is 5.94 dBi for the backward beam. The difference between both beam's maxima is less than 2 dBi across the entire bandwidth.

Amit Kumar Gupta et al., (2012) proposed a dual E-shaped antenna designed by cutting four notches in the rectangular shaped micro strip antenna [10]. It is observed that the antenna operates in three different frequency bands with bandwidths of 6.55%, 7.012% and 34.60% of resonant frequency. The bandwidth of the antenna is between 1 to 5 GHz with a gain of 6dBi.

Design of multiband antenna is more efficient that a single antenna can be used for multiple number of applications. The Design of elliptical shaped multiband antenna for

applications in wireless communication has been proposed by HaydarM.Al-Tamimi (2019). Many various types of patch antennas are used for many wireless communications by which they differ in shape of antenna elements like circular, elliptical, rectangular etc., The antenna is designed with a resonating frequency of 7.5GHz the height of the substrate used is 1.5mm. The Dimensions of the antenna is $103.4 \times 96.56 \text{ mm}^2$ and the multi resonance frequency varies from 3.2-11.5 GHz. The Multiband frequencies are 3.6GHz, 4.25GHz, 4.75GHz, 5.3GHz, 6.96GHz, 8.2GHz, 9.55GHz and 11.15GHz with return loss of above -10db.

ToukoTcheutouStephaneBorel (2019) explained about the design of rectangular patch array antenna for satellite communication. Small sized patch array antenna is used widely in satellite communication because of its advantages when compared to conventional antennas. A linear 2x2 array antenna is designed with exactly resonators in 12GHz with a bandwidth of 693.2MHz with thickness of 1.6mm. The efficiency of the antenna designed is equal to 83% since the gain and directivity obtained are 8.98db and 10.83db respectively. This antenna is designed in High Frequency Structure Simulator software for satellite communication, X band application and Ku band application. One of the significant advantages of array antenna is that direction of maximum radiation can be used for beam scanning. $40 \times 30 \text{ mm}^2$ are the dimensions of the array antenna designed for satellite communication.

X. Yang, et al., A minimal patch antenna exhibit with high segregation by utilizing two decoupling structures including a column of fractal uniplanar conservative electromagnetic bandgap (UC-EBG) structure and three cross openings is proposed. Reenacted results show that critical improvement in interelement disconnection of 13 dB is acquired by setting the proposed fractal UC-EBG structure between the two emanating patches. Additionally, three cross spaces carved on the ground plane are acquainted with further stifle the common coupling. The plan is anything but difficult to be produced without the execution of metal vias, and a progressively minimized cluster with the edge-to-edge separation of $0.22 \lambda_0$ can be encouraged by a line of fractal UC EBG, which can be very much applied in the patch antenna exhibit.

A multi-slotted antenna for LTE/5G Sub-6 GHz wireless communication applications proposed by Rezaul Azim, (2020), presents a low-profile multi-slotted patch antenna for long term evolution (LTE) and fifth-generation (5G) communication applications. The studied antenna comprised of a stepped patch and a ground plane. The dimension of the presented antenna is 20 mm x 30 mm. The studied antenna achieved an operating band from 1.341 to 3.834 GHz and fails to cover the entire mid 5G band. In, a low-profile microstrip antenna was presented for 5G applications.

A compact triple slotted Rectangular Microstrip Patch Antenna with Metamaterial ground for Sub-6 GHz/5G communication is simulated and fabricated by Vinoth M (2020), The antenna design is optimized in steps to achieve a compact antenna with high performance by Different RMPA architectures to realize an antenna to operate in sub-6 GHz for 5G communications. The modified RPA with a Triple Slotted in patch without altering the dimension resonates at 3.5 GHz with good return loss performance of -30.77 dB and gain of 5 dB. The dimension of compact TSRMPA with MTM ground is 30.2 x 36.4 mm. These antennas are investigated using High Frequency Structural Simulator (HFSS) software. Finally, good concurrence between simulated and tested result is presented to prove the functioning of proposed antenna design.

A 24 GHz microstrip antenna array with large space and narrow beamwidth is simulated & fabricated by Yongtao Jia (2019), A microstrip antenna array with large space and narrow beamwidth working at 24 GHz is presented Rogers 4350 is adopted as dielectric substrate with a dielectric constant of 3.66 (loss tangent = 0.004) and a thickness of 0.254 mm. The synthesis method of series-fed microstrip antenna arrays is presented. Finally, a 12 × 8 mm wave antenna array working at 24 GHz with the maximum gain and sidelobe of 22.26 and -23.5 dB. The simulated and measured results are presented and discussed. Through processing and testing, it is proved that the antenna array has good performance and can be applied to 24 GHz automotive collision avoidance radar or 24 GHz perimeter security radar.

Improvement of Circular Shaped Microstrip Patch Antenna Performances Using Triangular and Pentagonal Shaped Patches is simulated & designed by Md. Arifur

Rahman (2020), A triangular and pentagonal shaped micristrip patch antenna with coaxial probe feed have been designed in this paper to increase the performances of a circular shaped microstrip parch antenna. FR4_epoxy substrate material with dielectric constant 4.4 is used to design the antenna. A comparative study have been made among the circular, triangular and pentagonal shaped patches. The antenna is designed using ansoft HFSS software. The overall dimensions of coaxial probe feed triangular and pentagonal shaped patches are 30 mm x 30mm.

CHAPTER – 3

Proposed Methodology

The proposed methodology

The methodology to be proposed in this particular design is Array techniques in patch of the antenna & Split Ring Resonator (SRR) in the ground plane of the antenna and designing in Transmission Line model.

Hardware required:

- Substrate Material (Cotton material)
- SMA connector (50 Ohm impedance)
- Copper (for patch and ground)
- Vector Network Analyzer.

SUBSTRATE MATERIAL

Cotton based substrates materials are not preferred for the most PCB applications till date. But in recent days the wearable MSPA is taken into the picture and this material is also very low in cost and has excellent mechanical properties, making it ideal for a wide range of electronic component applications. As more and more microwave systems aimed at consumer markets are developed, there is a considerable interest in minimising the cost of these systems. Substantial cost savings could be realized by using Cotton in place of costly PTFE based substrates for microwave circuits and antennas. This paper describes a programmed of work which has been undertaken at ERA Technology, as part of its Membership Research Programme, to evaluate the characteristics of this material at microwave frequencies between 1 GHz and 15 GHz. It is concluded that the use of cotton is unlikely to be viable for antenna feeding structures due to its high losses. However, for high density microwave circuits where path lengths are short and for broadband antenna elements, where losses and absolute dielectric constant values are less

critical, the material could be used in place of more conventional microwave substrate materials, offering significant cost savings. To provide the high-speed network environment in order to cope with a large volume of data, a multilayer PCB that can transfer digital signals at high speed in the high frequency domain is needed. The cotton substrate is applicable to network equipment with low dielectric loss and low permittivity.

SMA CONNECTOR

The SMA connector is a semi-precision sub-miniature RF and microwave connector that is extensively used, especially for RF connections within electronic systems for frequencies up to 18 GHz and sometimes more. The SMA connector comes in a variety of formats, male, female, straight, right-angled, bulkhead fitting and many more enabling it to meet most requirements. Its sub-miniature size also enables it to be used, even within relatively small items of electronic equipment.

Although now well established, the SMA connector is likely to see its use extended as many new RF systems see their operating frequencies extending well into the microwave region. SMA connectors are designed to have a constant 50-ohm impedance across the connector. The SMA connectors were originally designed and specified for operation up to 18 GHz, although some versions have top frequencies of 12.4 GHz, some less and some are specified up to 24 or 26.5 GHz. The higher frequency top limits may need to operate with a higher return loss. The SMA connector uses a 1/4-inch diameter, 36-thread-per-inch threaded barrel.

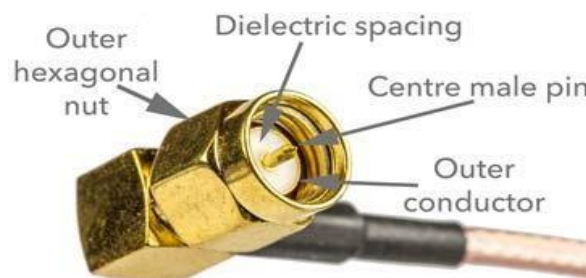


Fig 3.1 SMA Connector

VECTOR NETWORK ANALYSER:

A Vector Network Analyzer contains both a source, used to generate a known stimulus signal, and a set of receivers, used to determine changes to this stimulus caused by the device-under-test or DUT.

The stimulus signal is injected into the DUT and the Vector Network Analyzer measures both the signal that's reflected from the input side, as well as the signal that passes through to the output side of the DUT. The Vector Network Analyzer receivers measure the resulting signals and compare them to the known stimulus signal. The measured results are then processed by either an internal or external PC and sent to a display.

Vector Network Analyzer's perform two types of measurements – transmission and reflection. Transmission measurements pass the Vector Network Analyzer stimulus signal through the device under test, which is then measured by the Vector Network Analyzer receivers on the other side. The most common transmission S-parameter measurements are S_{21} and S_{12} (S_{xy} for greater than 2-ports). Swept power measurements are a form of transmission measurement. Some other examples of transmission measurements include gain, insertion loss/ phase, electrical length/delay and group delay. Comparatively, reflection measurements measure the part of the VNA stimulus signal that is incident upon the DUT, but does not pass through it. Instead, the reflection measurement measures the signal that travels back toward the source due to reflections.

Software

The antennas can be designed and simulated using software. Various software available in market are Magus, Cosmol, IE3D, Sonnet, HFSS, FEKO, CST Microwave studio, SEMCAD, efield, XFDTD, EXPIRE, WIPL-ProGEMS. Here we have chosen HFSS where it is convenient for the user. ANSOFT HFSS software is an industrial standard for simulating 3-D full-wave electromagnetic fields. It provides good-standard accuracy. The computer technology have made it an essential tool for engineers who are

designing high-frequency and high-speed electronic components.

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS to design high-frequency, high-speed electronics found in communications systems, radar systems, advanced driver assistance systems (ADAS), satellites, internet-of-things (IoT) products and other high-speed RF and digital devices.

HFSS (High Frequency Structure Simulator) employs versatile solvers and an intuitive GUI to give you unparalleled performance plus deep insight into all your 3D EM problems. Through integration with Ansys thermal, structural and fluid dynamics tools, HFSS provides a powerful and complete Metaphysics analysis of electronic products, ensuring their thermal and structural reliability. HFSS is synonymous with gold standard accuracy and reliability for tackling 3D EM challenges by virtue of its automatic adaptive meshing technique and sophisticated solvers, which can be accelerated through high performance computing (HPC) technology.

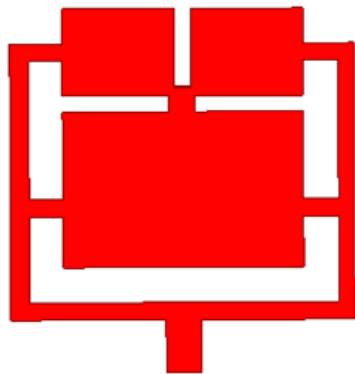
The proposed wearable microstrip patch antenna is simulated using the ANSYS EM suite version 20 which is described above in detail and in the next part the simulated WMSPA is placed and given some detailisation on the design and done analysis in the proposed design.

Antenna Design

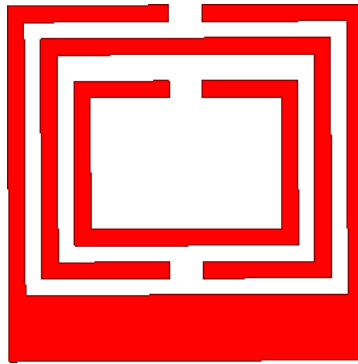
The footprint of the studied 2X1 wearable periodical array antenna for IEEE standards P802.11 ay/D4.0 applications is displayed in Fig 4.2. Here in this section the analyzing process of proposed wearable MSPA is taken into account. The below figure represents as A & B the first image is top view of the WMSPA and the next image is bottom view or ground plane of the WMSPA. The substrate material of the WMSPA plays the important role in wearability so the radiating patch of the proposed WMSPA is built on the cotton substrate material with the dielectric constant of 2.17 and this antenna is fed with the strip line feeding technique and a 50 ohm feed line is

imprinted along with the patch of the proposed WMSPA. To match the impedance of the WMSPA the feeding technique plays the prominent role. To connect the feed of the MSPA the 50 ohm SMA connector introduced into this design. The dimension of the proposed wearable MSPA is $21 \times 21 \times 1.6 \text{ mm}^3$ and its just only 2.1 cm in width & length from this analysis the compactness is achieved. A split-ring resonator (SRR) is an artificially produced structure common to meta materials. Their purpose is to produce the desired magnetic susceptibility (magnetic response) in various types of meta materials up to 200 terahertz. These media create the necessary strong magnetic coupling to an applied electromagnetic field, not otherwise available in conventional materials. For example, an effect such as negative permeability is produced with a periodic array of split ring resonators. A single cell SRR has a pair of enclosed loops with splits in them at opposite ends. The loops are made of nonmagnetic metal like copper and have a small gap between them. The loops can be concentric, or square, and gapped as needed. A magnetic flux penetrating the metal rings will induce rotating currents in the rings, which produce their own flux to enhance or oppose the incident field (depending on the SRRs resonant properties). This field pattern is dipolar. The small gaps between the rings produces large capacitance values which lower the resonating frequency. Hence the dimensions of the structure are small compared to the resonant wavelength. This results in low radioactive losses, and very high quality factors. Metamaterials are artificially engineered structures that exhibit unique properties such as having negative values of permittivity and permeability simultaneously in a specific frequency band, resulting in negative values of index of refraction.^{1–3} These structures usually operate at resonance and their resonant frequencies depend highly on the geometry of the structure. Metamaterials have been demonstrated in a wide range of frequencies, spanning from GHz to optical frequencies⁴ for various applications such as cloaking,^{5,6} super lenses,^{7,8} sub-diffraction focusing,⁹ perfect absorption,¹⁰ and biosensing.^{11–16} Split-ring resonators (SRR) are among the basic building blocks to realize metamaterials.¹⁷ SRRs are thin metallic rings or square loops with a split on top of a dielectric substrate. SRRs are one of the first metamaterial-based microwave resonators whose geometries are smaller than the wavelength of exciting electromagnetic waves.¹⁸ So far, different designs have

been introduced in the field of metamaterials and the most conventional ones are circular and rectangular split-ring resonators. These are investigated regarding different performance parameters such as sensitivity for sensing applications. The total antenna design is simulated using the ANSYS HFSS EM software version 20 and this simulated design is also fabricated and tested in standard testing environment using Vector Network Analyzer and also obtained the results similar to the simulated results and the proofs also discussed in the next section.



(A)



(B)

Surface	Lg	Wg
Patch	21mm	21mm
Ground	21mm	21mm

(C)

Fig.3.2 Represent the footprint of proposed MSPA (A) Top view (B) Bottom view (C) Dimension Table

CHAPTER- 4

RESULT ANALYSIS

In this section various electromagnetic parameters are analyzed for the proposed 2X1 wearable periodical array MSPA by placing all the obtained simulated results with the help of ANSYS EM suite version 20. The performances are observed and it is shown next in this letter.

4.1 Return Loss

The S_{11} parameter plot of the 2X1 wearable periodical array MSPA has been given in the fig 2. From the simulated results below it observed that the proposed wearable MSPA is resonated at 3.74 GHz with bandwidth of 3.67 GHz-3.78GHz & at 5.3 GHz with bandwidth of 4.17GHz-5.41GHz and with the corresponding return loss at -14 dB for Sub-6 GHz applications & -22.7 dB for Sub-7 GHz applications. From the analysis the proposed MSPA transmits the data in the both reported applications with low reflections.

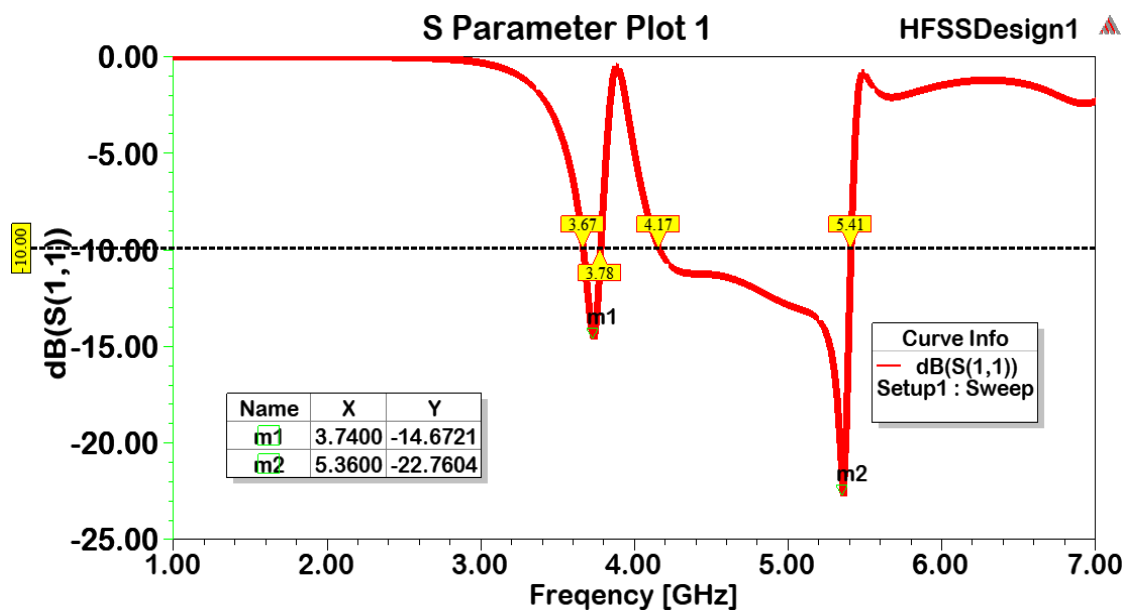


Fig 4.1 Represent the VSWR plot of the proposed wearable MSPA

VSWR

As we know that S_{11} parameter is directly proportional to the VSWR so the proposed MSPA has a direct impact on the VSWR due to the decrease in the reflection coefficient in the proposed MSPA in this letter. From the analysis of presented simulated result in figure 4 all the reported frequency bands falls near unity so its performance rate is also high.

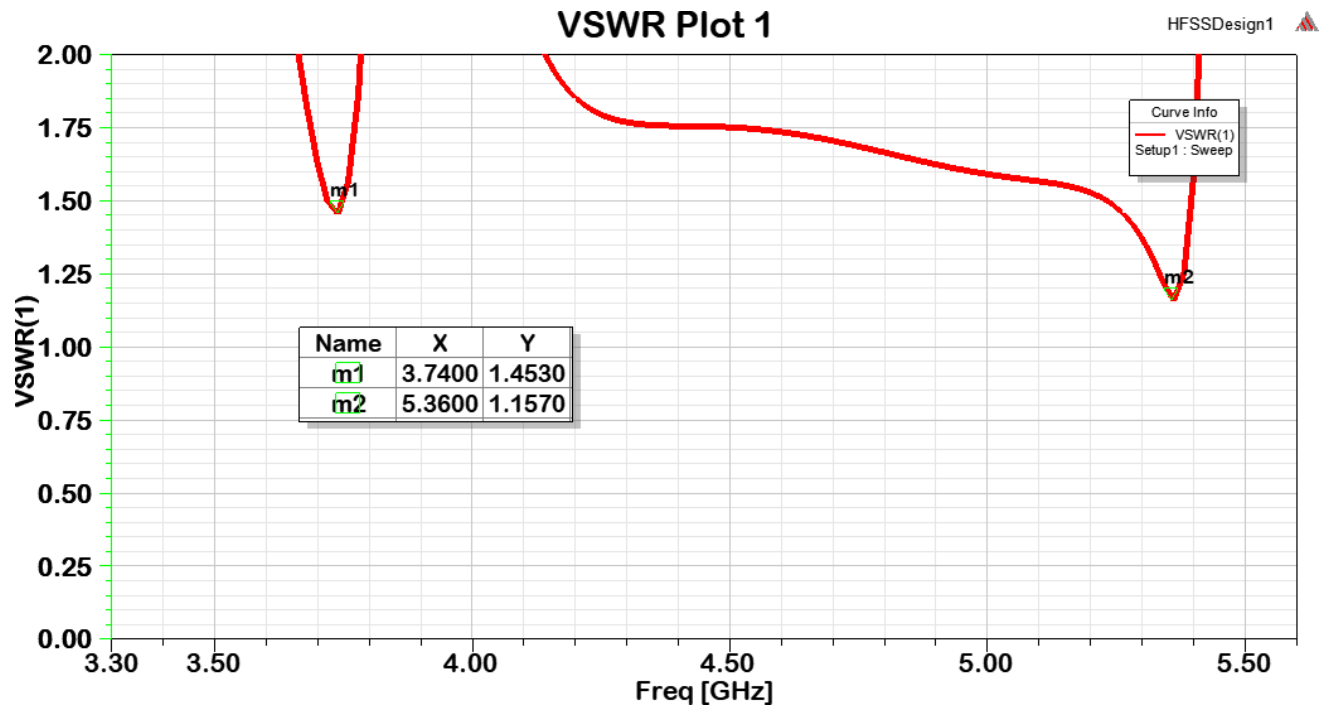


Fig 4.2 Represent the VSWR plot of the proposed wearable MSPA

Impedance Plot

The below figure represented the impedance plot graph for the 2X1 wearable periodical array MSPA for the proposed designs. The term impedance in the patch antenna relates input voltage and current to the antenna. The Y parameters, Z parameters, reflection coefficient for the proposed 2X1 wearable periodical array MSPA design is plotted in the smith chart and analyzed and this MSPA provides good impedance matching.

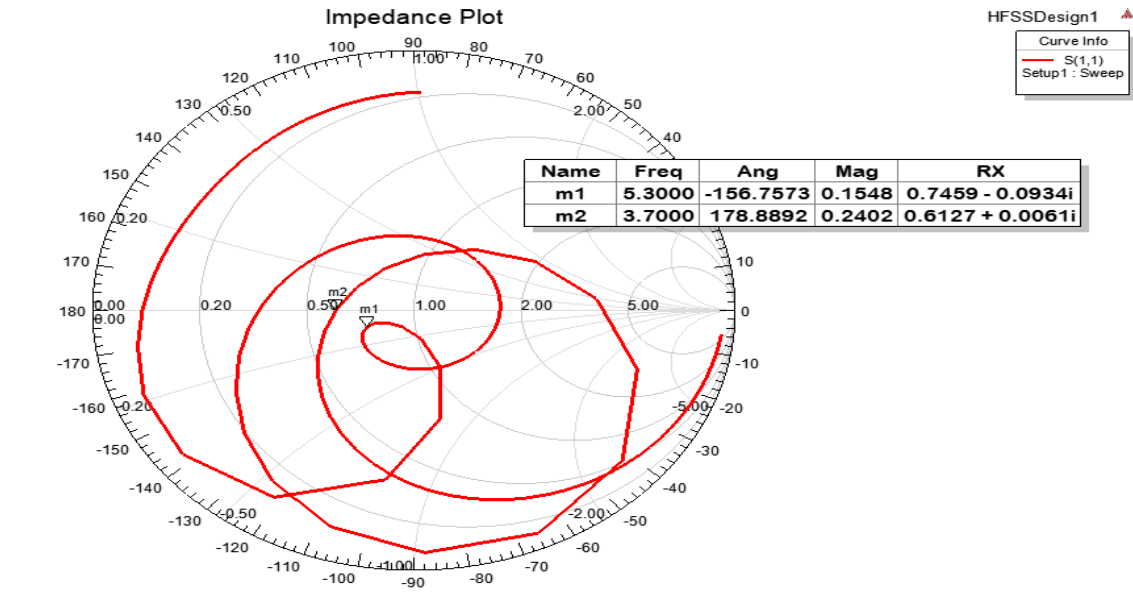


Fig 4.3 Represent the Impedance plot of the proposed wearable MSPA

Gain & Directivity

The gain & directivity of the proposed 2X1 wearable periodical array MSPA is represented in 3D polar plot in the fig. 6. From the obtained simulated result the gain for the resonated Sub-6 & Sub-7 GHz frequency is 4.6 dB and this value is considered as the maximum gain of the proposed wearable MSPA. Gain should be positive and this parameter illustrates the capabilities of the MSPA to focus energy in particular direction. From the obtained simulated result the Directivity for the resonated Sub-6 & Sub-7 GHz frequency is 4.2 dB and this value is considered as the maximum directivity of the proposed wearable MSPA.

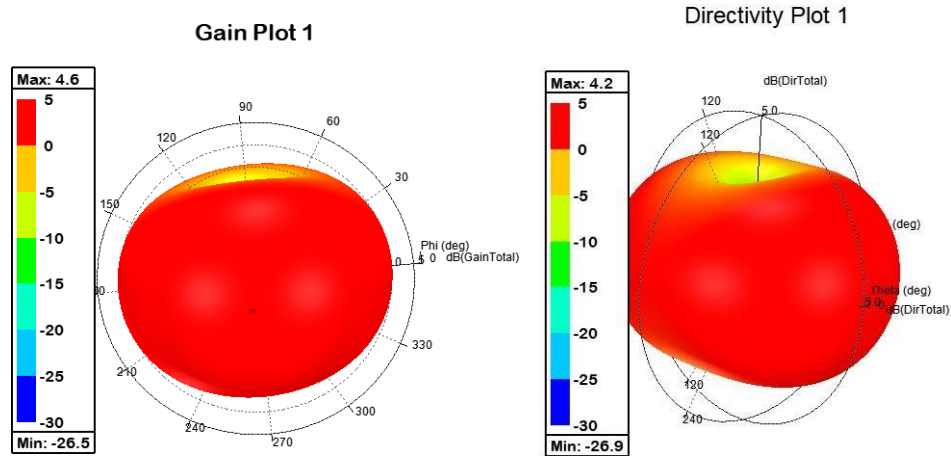


Fig 4.4 Represent the Gain & Directivity of the proposed wearable MSPA

Radiation Efficiency

In this scenario the efficiency of the proposed 2X1 wearable periodical array MSPA can be calculated as we know the simulated value for the gain & directivity and the formula used here we used is $\text{Efficiency} = \text{Gain} / \text{Directivity}$ so according to the formula the efficiency rate of the proposed MSPA is exactly 109%, so considered it as the 100 percent efficiency as here calculated the efficiency the simulated proposed WMSPA is also analyzed in the EM suite and obtained the result. From analysis the radiation efficiency of the proposed WMSPA at resonated frequency is similar to calculated value.

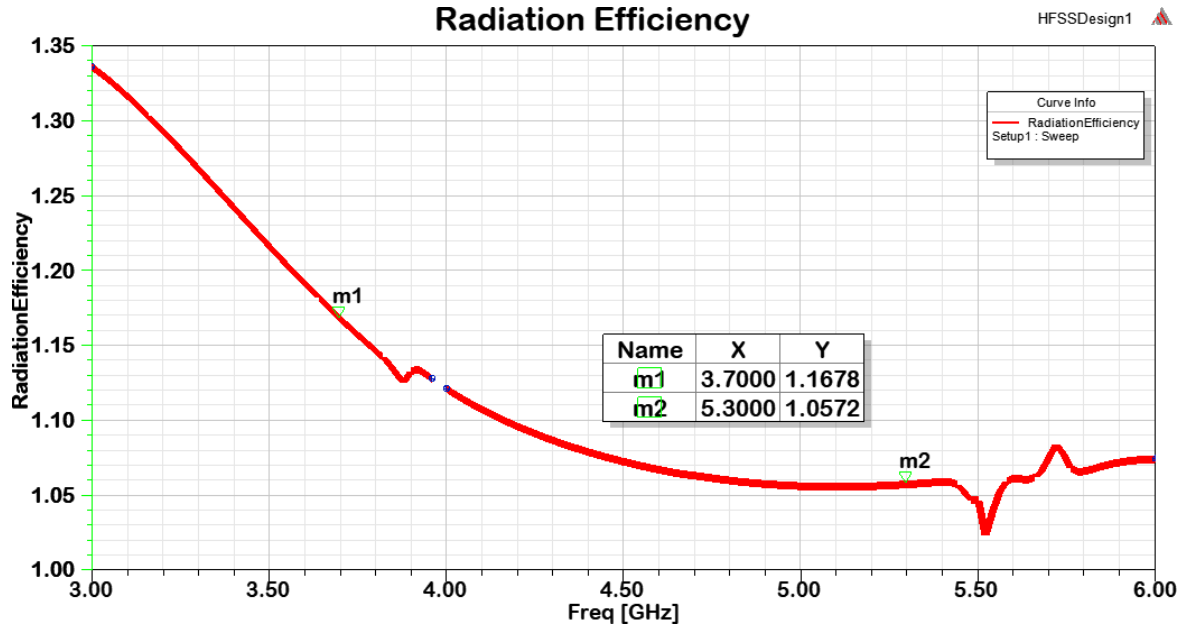
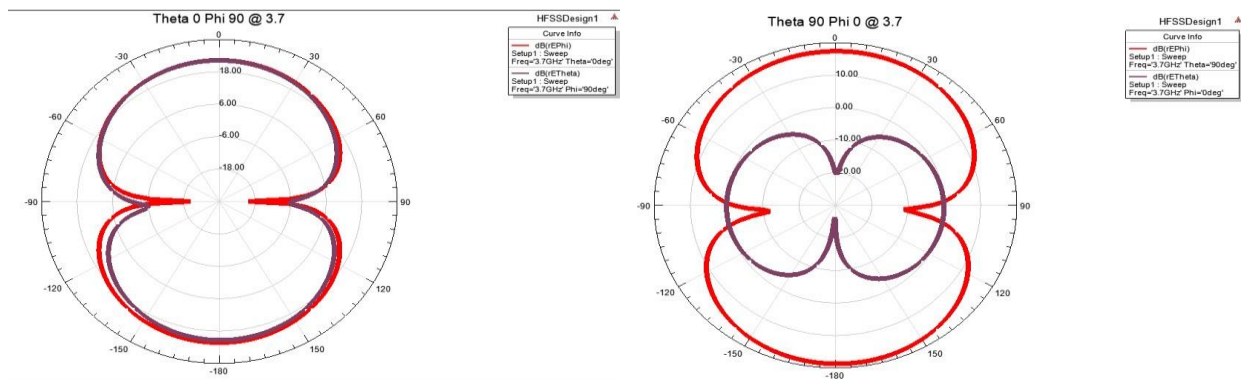


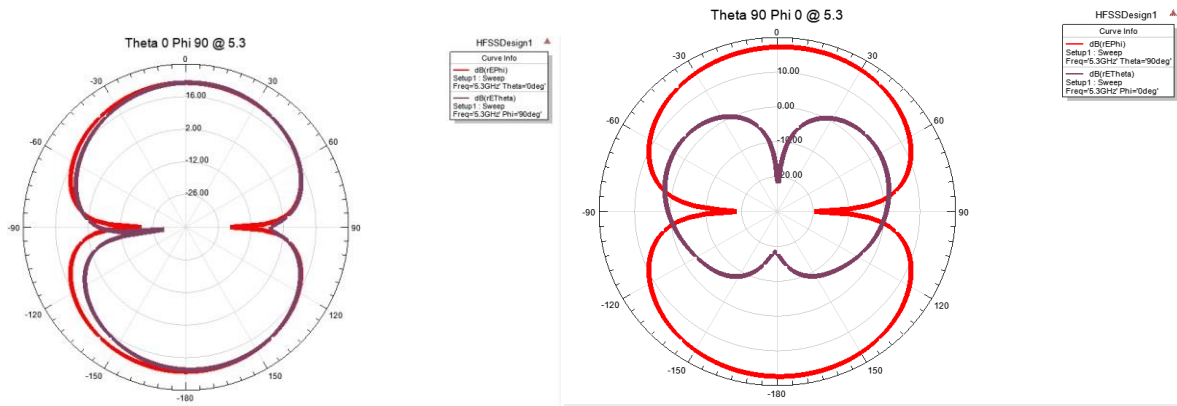
Fig 4.5 Represent the Radiation Efficiency of the proposed wearable MSPA

Radiation Pattern

The 2D radiation pattern of the strip line feed 2X1 wearable periodical array MSPA is represented in fig 7 for the resonated frequency at 3.74 GHz & 5.3 GHz in zero & ninety degree and this obtained result is analyzed using the HFSS v₂₀ EM suite. From analysis of the below figure the proposed MSPA provides linear polarization in zero degree and co-polarization in ninety degree for the reported frequency bands above and it is presented in the figure 8 (A) & (B).



(A)



(B)

Figure 4.6 Represent the Radiation pattern (A) For 3.7GHz (B) 5.3 GHz

SAR

As the proposed MSPA is going to act as the wearable one then it is going to have the close contact with the human body, in this criteria the most important parameter namely Specific Absorption Rate (SAR) for the proposed 2X1 wearable periodical array MSPA have to be analyzed the radiation of this WMSPA is “zero” so there is no harm full radiation for the human beings.

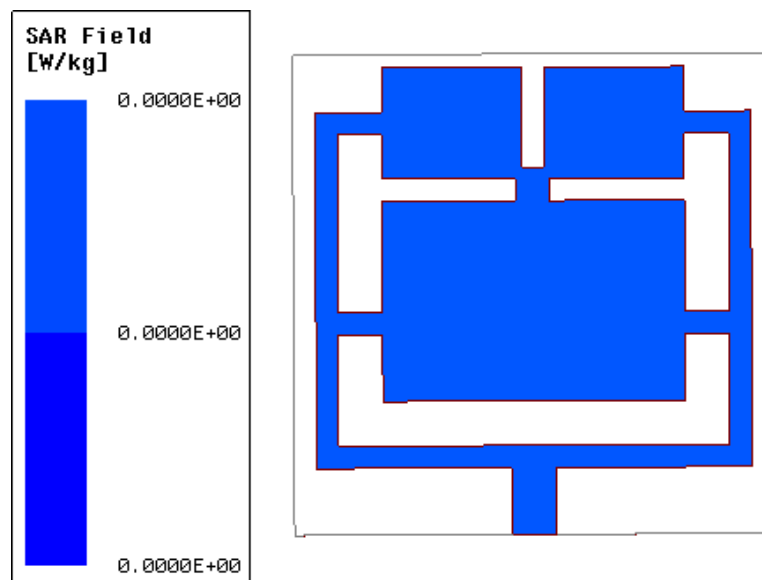


Fig 4.7 Represent the SAR for the proposed antenna

FBR

The FBR of the proposed 2X1 wearable periodical array MSPA is represented in 2D plot in the fig. 5.8. From the analysis of obtained simulated results the proposed value in the graph is acceptable range, so the proposed MSPA in this letter will work most efficiently in backward & forward direction and this is due to the methods & techniques implemented to design this MSPA.

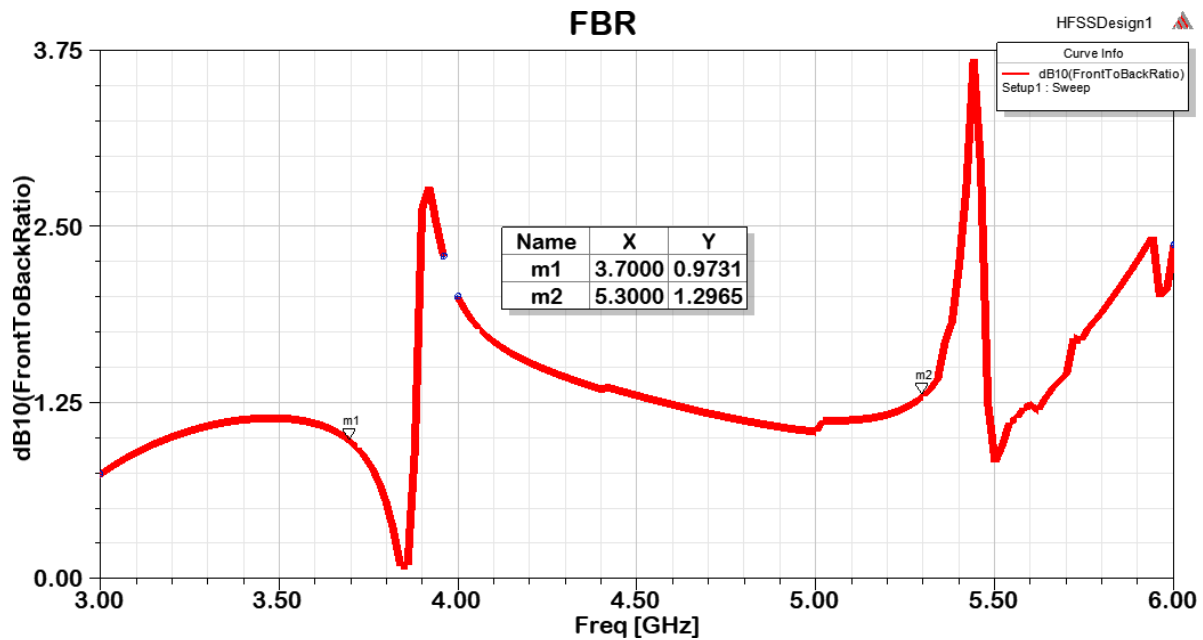
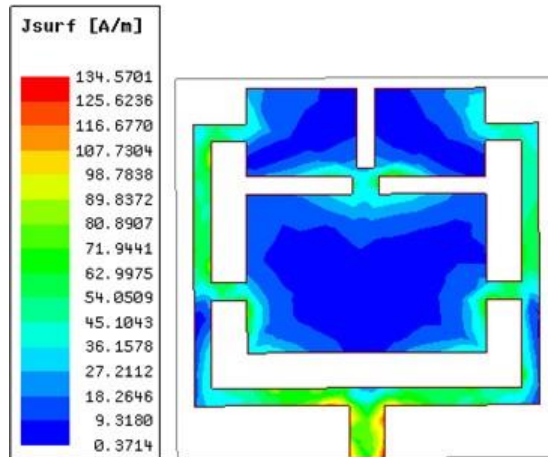


Figure 4.8 Represent the FBR of the proposed wearable MSPA in 2D plot

Surface Current

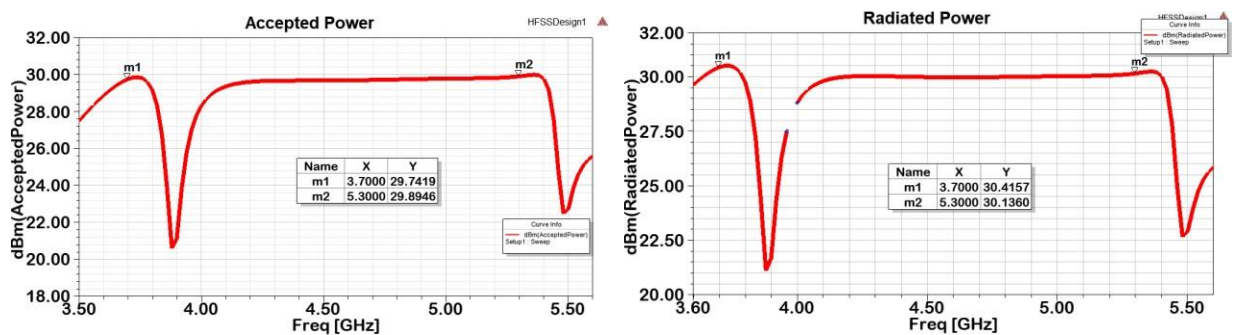
The figure 5.9 illustrates the simulated Surface Current Distribution for the proposed MSPA at reported frequencies in this letter. From the analysis of the obtained results the surface current in the proposed MSPA is distributed evenly in the overall region.



**Figure 4.9 Represent the Surface current distribution of the proposed wearable
MSPA**

Power

In this scenario the one of the important parameter of the proposed WMSPA have to be analyzed that is the power consumption range of the proposed WMSPA and it also analyzed in the EM suite. From the obtained result the power consumption range of the proposed WMSPA is simulated in dBm the values are nearer to the 30 dBm, so the power consumption range of the proposed WMSPA is less than the 1watt.



**Figure 4.10 Represent the Power consumption of the proposed
WMSPA**

The below table represents the simulated parameter results for the proposed WMSPA

for resonated frequency is tabulated in clear manner.

Parameters	3.7 GHz	5.3 GHz
S Parameter	-14.6 dB	-22.7 dB
VSWR	1.45	1.15
Gain	4.6 dB	4.6 dB
Directivity	4.2 dB	4.2 dB
Radiation Efficiency	1.16	1.05
FBR	0.97 dB10	1.27 dB10
Accepted Power	29.74 dBm	29.8 dBm
Radiated Power	30.4 dBm	30.1 dBm

The proposed WMSPA is fabricated on cotton dielectric material and under gone with wet etching process while in the fabrication. The scattering parameter of the proposed WMSPA is measured using the Anritsu Vector Network Analyzer (VNA). Figure 11 presents the snap shot of the fabricated piece, as this fabricated WMSPA testing process is carried out in the VNA and the measured result is also placed in the fig 12 in the comparative manner. From the analysis both simulated and the measured results are in good agreement so the proposed WMSPA will work most efficiently in real time.

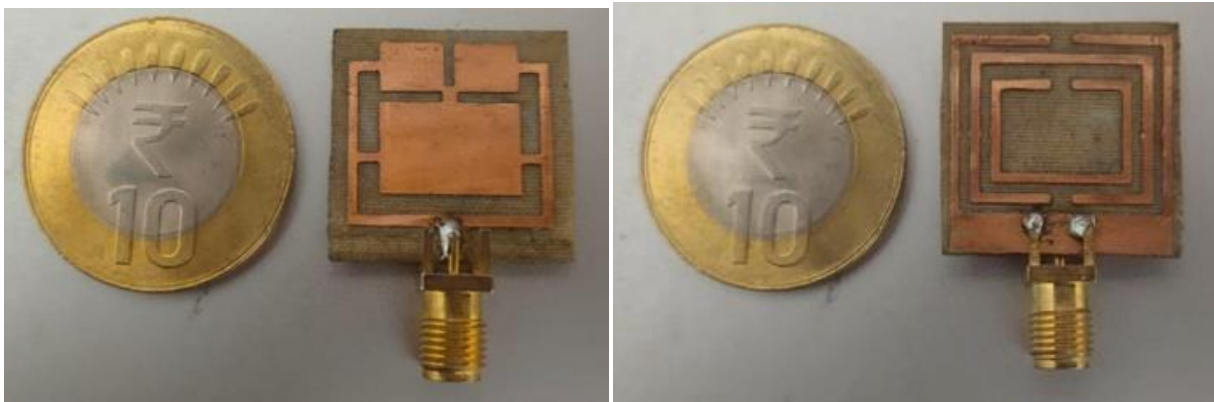


Fig 4.11 Represent the Snap shot of the fabricated image for proposed WMSPA

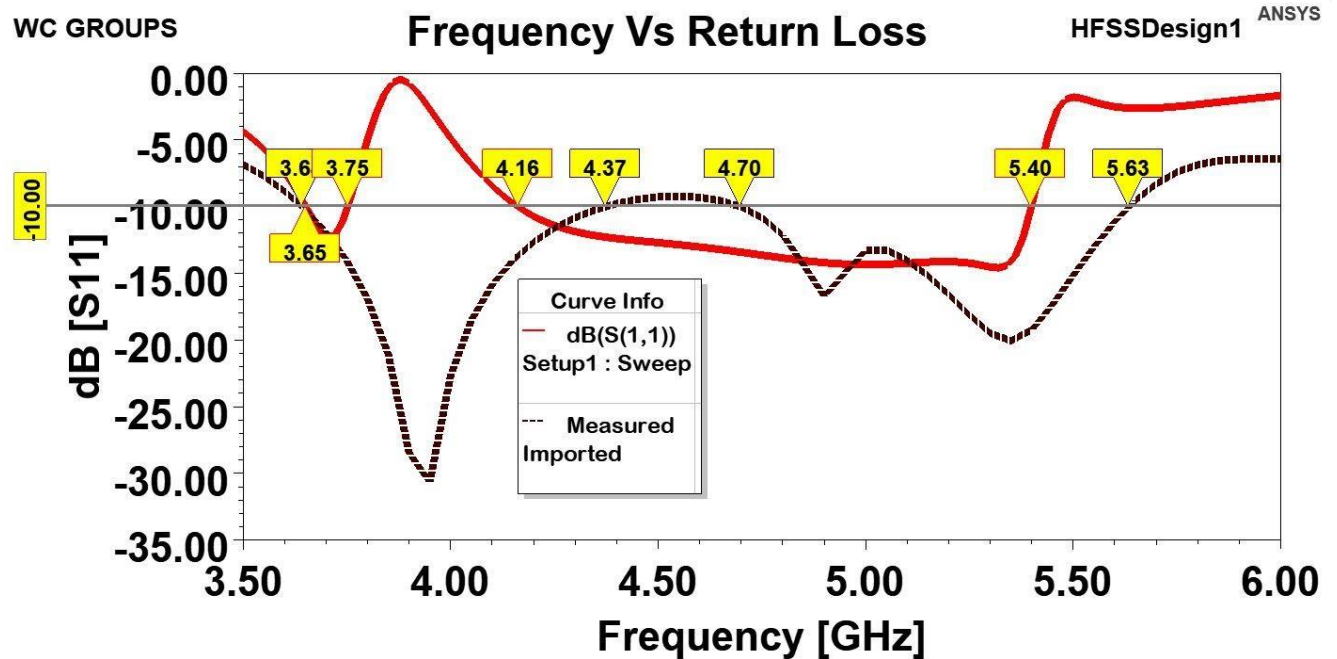


Figure 4.12 Represent the Simulated & measured comparative result graph for proposed WMSPA

Frequency	Simulated	Tested
Sub-6 GHz	-14.6 dB	-32 db
Sub-7 GHz	-22.7 dB	-21 dB

The presented WMSPA is initially simulated in various substrate materials to find the better performance and to have good quality in real time. The substrate material taken for the comparison is FR4, Glass, Distilled water, Diamond and in cotton and found better obtained results in cotton substrate material.

Substrate Material	Dielectric Constant	Resonated Frequency	Simulated Return Loss	Simulated Gain

Cotton	2.17	3.7 GHz, 5.3 GHz	-14 dB, -22 dB	4.6 dB
FR4	4.4	3.52 GHz	-25.73 dB	1 dB
Glass	5.7	3.2 GHz	-8 dB	2.18 dB
Distilled water	78.5	4.9 GHz	-12 dB	3.8 dB
Diamond	16.5	5.7 GHz	-11 dB	1.5 dB

CHAPTER - 5

CONCLUSION

A low profile 2X1 wearable periodical array MSPA is designed using the cotton dielectric material is discussed and analyzed the simulated electromagnetic parameters in this letter and the substrate material used in this proposed MSPA will have high flexibility which is really suitable for the wearable scenario in IEEE P802.11 ax / ay/D 4.O standard applications i,e in Sub-6 & Sub-7 GHz frequency bands (5G wireless communication) with low signal deviation. The simulation of the proposed MSPA is carried out using ANSYS HFSS EM suite version 20 and took a detail investigation on all the simulated parameters. From investigation the proposed methodology shows the better performance rate. The presented fabricated 2X1 wearable periodical array MSPA will show's a great performance in real time with the very high efficiency rate in the reported 5G frequency bands in the letter with zero SAR rating.

Reference

- [1] Sarmad N. Mahmood, Asnor J. Ishak¹, Tale Saeidi, Hussein Alsariera, Sameer Alani, Alyani Ismail, and AzuraChe Soh, Recent Advances in Wearable Antenna Technologies: A Review, Progress In Electromagnetics Research B, Vol. 89, 1–27, 2020.
- [2] Shahid M. Ali, Cheab Sovuthy , Muhammad A. Imran, Soeung Socheatra, Qammer H. Abbas, Zuhairiah Zainal Abidin, Recent Advances of Wearable Antennas in Materials, Fabrication Methods, Designs, and Their Applications: State-of-the-Art, Micromachines 2020, 11, 888; doi:10.3390/mi11100888.
- [3] Mariam El Gharbi, Raúl Fernández-García, Saida Ahyoud, Ignacio Gil, A Review of Flexible Wearable Antenna Sensors: Design, Fabrication Methods, and Applications, Materials 2020, 13, 3781; doi:10.3390/ma13173781.
- [4] Raviteja, G.V. 2019. A 2x2 Millimeter-Wave Microstrip Antenna Array for 5G Applications. European Journal of Engineering and Technology Research. 4, 10 (Oct. 2019), 55-58. DOI: <https://doi.org/10.24018/ejers.2019.4.10.1581>.
- [5] Farzad Khajeh-Khalili, Fatemeh Haghshenas, Ali Shahriari, Wearable dual-band antenna with harmonic suppression for application in medical communication systems, AEU - International Journal of Electronics and Communications, Volume 126, 2020, <https://doi.org/10.1016/j.aeue.2020.153396>.
- [6] You, X., Wang, CX., Huang, J. et al. Towards 6G wireless communication networks: vision, enabling technologies, and new paradigm shifts. Sci. China Inf. Sci. 64, 110301 (2021). <https://doi.org/10.1007/s11432-020-2955-6>.
- [7] Garg, R., Mishra, G., Purohit, N., & Kesari, V. (2015). Beam-steering in a three-element circular antenna-array. International Journal of Microwave and Wireless Technologies, 7(1), 45-51. doi:10.1017/S1759078714000312.

- [8] Nabil, M., Faisal, M.M.A. Design, Simulation and Analysis of a High Gain Small Size Array Antenna for 5G Wireless Communication. *Wireless Pers Commun* 116, 2761–2776 (2021). <https://doi.org/10.1007/s11277-020-07819-9>.
- [9] El Sayed Ahmad, A., Thevenot, M., Menudier, C., Koubeissi, M., Arnaud, E., & Monédière, T. (2011). Design of a coupled antenna array for mobile HyperLAN2 applications. *International Journal of Microwave and Wireless Technologies*, 3(6), 609-614. doi:10.1017/S1759078711000602.
- [10] Chirag Arora, Shyam Sundar Pattnaik, and Rudra Narayan Baral, "SRR Inspired Microstrip Patch Antenna Array," *Progress In Electromagnetics Research C*, Vol. 58, 89-96, 2015. doi:10.2528/PIERC15052501.
- [11] Md. Arifur Rahman, Md. Abdullah-Al-Mamun, Sham Datto, Md. Shamim Anower, Improvement of Circular Shaped Microstrip Patch Antenna Performances Using Triangular and Pentagonal Shaped Patches, *American Journal of Engineering Research (AJER)*, Volume-9, Issue-1, pp-215-219, www.ajer.org.
- [12] Ramamohan B., Usha S., Ananth P., Lalitha V.S., Jaswanth S. (2021) Design of Dumbbell-Shaped MIMO Antenna for Wearable Applications. In: Sekhar G.C., Behera H.S., Nayak J., Naik B., Pelusi D. (eds) *Intelligent Computing in Control and Communication. Lecture Notes in Electrical Engineering*, vol 702. Springer, Singapore. https://doi.org/10.1007/978-981-15-8439-8_24.
- [13] Vojnović, N.M., Savić, S.V., Ilić, M.M. et al. Performance Analysis of Low-Cost Printed Antenna Array Elements for 5G LOS-MIMO Arrays at 60 GHz. *Wireless Pers Commun* 111, 2641–2658 (2020). <https://doi.org/10.1007/s11277-019-07007-4>.
- [14] Yongtao Jia, Ying Liu, Yu Zhang, A 24 GHz microstrip antenna array with large space and narrow beamwidth, *Microwave and Optical Technology Letters* Volume 62, Issue 4 p. 1615-1620, <https://doi.org/10.1002/mop.32190>.
- [15] Jain V., Dhaliwal B.S. (2020) Design of Wearable Antennas for Body Area Networks. In: Pant M., Sharma T., Verma O., Singla R., Sikander A. (eds) *Soft*

Computing: Theories and Applications. Advances in Intelligent Systems and Computing, vol 1053. Springer, Singapore. https://doi.org/10.1007/978-981-15-0751-9_84

- [16] Zahraa A. Jawad et al, A High Efficiency Antenna Array for Wireless Communication Systems, 2020 IOP Conf. Ser.: Mater. Sci. Eng. <https://doi.org/10.1088/1757-899X/932/1/012089>.
- [17] Hasan, M.R., Goodbody, C., Nguyen, T.T. et al. Double-sided bowtie antenna array for Ku/K band applications and performance study of controlling ground plane. Microsyst Technol 26, 2703–2713 (2020). <https://doi.org/10.1007/s00542-020-04815-8>.
- [18] Chakraborty, S., Rahman, M.A., Hossain, M.A. et al., A 4-element MIMO antenna with orthogonal circular polarization for sub-6 GHz 5G cellular applications. SN Appl. Sci. 2, 1180 (2020). <https://doi.org/10.1007/s42452-020-2957-z>.
- [19] Kushwaha R., Chauhan R.K. (2019) Dual Band Slotted Patch Microstrip Antenna Array Design for K Band Application. In: Verma S., Tomar R., Chaurasia B., Singh V., Abawajy J. (eds) Communication, Networks and Computing. CNC 2018. Communications in Computer and Information Science, vol 839. Springer, Singapore. https://doi.org/10.1007/978-981-13-2372-0_56.
- [20] A–zen Bayraktar, Dilek Uzer, S. Sinan GÃ¼ltek, Rabia Top, Usage of T-Resonator Method at Determination of Dielectric Constant of Fabric Materials for Wearable Antenna Designs, Materials Today: Proceedings, Volume 18, Part 5, 2019, Pages 1796-1802, <https://doi.org/10.1016/j.matpr.2019.06.666>.