University of Mohamed Khider Biskra
faculty of sciences and Technologies
Department of Electrical and Engineering

MASTER'S DEGREE

Sciences et Technologies
Field: Telecommunication
Option: Network and Telecommunication

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Presented by:
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DESIGN AND SIMULATION OF USB DONGLE ANTENNA

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Favorable opinion of the supervisor:
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Summarize (English and Arabic)

Our project is to design and simulate a monopole patch antenna with coupled branch strips for USB dongle using that response the demand of the wireless communication. Therefore, our study is based on the miniaturization of the monopole antenna that will improve the performance to obtain a dual frequency it can be suitable for WLAN applications, and properly for a Wi-Fi connection. Two techniques are introduced for enhancing and miniaturizing the antenna; the first one is miniaturized the Micro-strip monopole patch antenna with a coupled branch strips in the patch and the second one is changing the material of the substrate to enhancing the parameters. The obtained results are by using the HFSS simulation program.

Keywords: USB dongle, Micro-strip, Monopole, Wi-Fi, WLAN**,** HFSS

مشروعنا هو تصميم و محاكات هوائي مطبوع أحادي القطب مصمم بشرائط متماثة ل USB dongle antenna الذي يستجيب لطلب الإتصالات اللاسلكية. لذلك دراستنا تعتمد على تصغير الهوئي أحادي القطب لتحسين الآداء لكي يصبح ذو نطاق مزدوج حيث يمكن أن يشع في WLAN ، و نستطيع أن نسخدمها في اتصال Wi- Fi ,تم تقديم تقنيتين لتحسين و تصغير الهوائي; الأولى هي تصغير الهوائي المطبوع أحادي القطب بشرائط مزدوجة تكون في الصفيحة و الثانية هي تغيير مادة العازل المستخدم لكي نحسن النتائج. النتائج تم الحصول عليها بإستخدام البرنامج المحاكيHFSS.

كلمات مفتاحية: WLAN، Wi-Fi ، هوائي مطبوع، USB dongle antenna، HFSS

Dedication

This thesis dedicated to:

My daughter Tameni because I was encouraged to graduate for her.

My great parents for their endless love.

My beloved brothers and sisters.

My husband for his encouragement.

My country Algeria.

And all the readers.

Acknowledgments

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)، -سورة المجادلة: الآية 11-

الحمد لله الذي بفضله تتم الصالحات

I wish to express my deepest gratitude to my supervisor Mr. Ameid Sofiane for his guidance, advice, criticism and encouragements and insight throughout the research.

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I like to express my sincere gratitude to Mohamed Khider University and all the teachers in the department of electrical engineering for all the considerate guidance.

Last and not the least, I must thank my parents for their support and encouragement throughout my pursuit for education. I hope this achievement will fulfill the dream they envisioned for me.

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1G: **F**irst **G**eneration

2G: **S**econd **G**eneration

3G: **T**hird **G**eneration

3GPP: **3**rd **G**eneration **P**artnership **P**roject

4G: **F**ourth **G**eneration

5G: **F**ifth **G**eneration

CN: **C**ore **N**etwork

CAT: **A**ir **T**ransport **C**ompany

CRLH: **C**omposite **R**ight/**L**eft **H**anded

D-AMPS: **d**igital **a**dvanced **m**obile **p**hone **s**ervice

FDD: **F**requency **D**ivision **D**uplex

GSM: **G**lobal **S**ystem **M**obile

GAN: **G**lobal **A**rea **N**etwork

HSPA: **H**igh **S**peed **P**acket **A**ccess

IEEE: **I**nstitute of **E**lectrical and **E**lectronics **E**ngineers

LTE: **L**ong **T**erm **E**volution

LLP: **L**iquide **C**rystal **P**olymer

MPA: **M**icrostrip **P**atch **A**ntenna

Manet: **M**obile **A**d hoc **NET**work

MIMO: ***M**ultiple-**I**nput **M**ultiple-**O**utput*

NASA: **N**ational **A**eronautics and **S**pace **A**dministration

OFDM: **O**rthogonal **F**requency **D**ivision **M**ultiplexing

OFDMA: **O**rthogonal **F**requency **D**ivision **M**ultiple **A**ccess

OAI: ***O**pen **A**rchives **I**nitiative*

PCS: **P**ersonal **C**ommunication **S**ervice

PIFA : **P**lanar **I**nverted-**F** **A**ntennas

PARR : **P**eak to **A**verage **P**ower **R**atio

RFID : **R**adio **F**réquence **I**dentification

RAN : **R**adio **A**ccess **N**etwork

SCFDMA : **S**ingle **C**arrier **F**requency **D**ivision **M**ultiple **A**ccess

SLC: **S**mart **L**ink **C**ommunication

TDD: **T**ime **D**ivision **D**uplex

UMTS: **U**niversal **M**obile **T**elecommunication **S**ystem

USB: **U**niversal **S**erial **B**us

UWB: **U**ltra **W**ide**B**and

VoIP: **V**oice **Over** **I**nternet **P**rotocol

VSWR: **V**oltage **S**tanding **W**ave **R**atio

VPNs: **V**irtual **P**rivate **N**etwork

WiFi: **Wi**reless **Fi**delity

WiMAX: **W**orldwide **I**nteroperability for **M**icrowave **A**ccess

WLAN: **W**ireless **L**ocal **A**rea **N**etwork

WMAN: **W**ireless **M**etropolitan **A**rea Network

WPAN: **W**ireless **P**ersonal **A**rea **N**etwork

WUSB: **W**ireless **U**niversal **S**erial **B**us

Contents

General introduction

General introduction

Nowadays, wireless technology is very important thing in our lives because he covered most of the human needs which have appeared in many areas in our life. Wireless networking is a method by which homes, Telecommunications network and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. Admin telecommunications networks are generally implemented and administered using Radio communication. This implementation takes place at the physical level (layer) of the OSI model network structure. The most important component in wireless communication is the antenna which is responsible of transmitting and receiving the electromagnetic waves. The development of the wireless technology depends on the performance of the antenna. We can apply the antenna in a lot of uses of the wireless network like mobility, remote control devices, USB dongle…

There are many types of antennas and the most used nowadays is the micro-strip patch antenna for its many benefits like easy fabrication and low cost. The types of applications of MPAs are restricted by the antennas, inherently narrow bandwidth (BW). Accordingly, increasing the BW of the MPA has been a primary goal of research in the field. This is reflected in the large number of papers on the subject published in journals and conference proceedings. In fact, several dual band MPA configurations have been reported in the last few decades. Therefore, we want to design a dual band micro-strip patch antenna in our project.

The remarkable progress in mobile communication systems has proportionally led to the advancement of the antenna systems in the recent decade. The typical mobile communication system has rapidly evolved, emerging from analogue systems to integrated digital systems fully capable of multimedia transmission over several frequency bands. It has become feasible to bring together numerous different applications operating at different channels within only one single wireless device.

Thesis's objective

The objective of this project is to design and simulate monopole patch antenna with coupled branch strips for the USB Dongle using. All this study and design is with the use of the 3D design program and electromagnetic simulator which is the high frequency structure simulator (HFSS)version 15.

Thesis outline

This thesis is divided into three chapters organized as follows:

The first chapter: an introduction to the wireless technologies (WPAN, WLAN, WMAN) and his benefits. Also, we introduce the antenna and its basics parameters like frequency, bandwidth, antenna impedance, VSWR, RL, smith chart and impedance matching, Radiation Pattern, Directivity, gain, efficiency and polarization.

The second chapter: an overview of the micro-strip antenna (definition, advantages and disadvantages, application, feeding techniques) and the fundamental theories of the working context of the MPA concerning the miniaturization and the enhancement techniques to obtain a good result that we can use it in the applications of USB dongle antenna.

The last chapter: a monopole patch antenna design was modeled and simulated by using the HFSS v15 simulator. The design of the miniaturized monopole antenna for the USB dongle antenna were achieved using the coupled branch strips technique in the patch. And we will enhance the parameters by changing the material of the substrate.

Finally, we conclude our study with a general conclusion, perspectives.

Chapter I: Wireless Networks and Antenna Fundamentals Proprieties

1.1 Introduction

Wireless networks have been a crucial part of communication in the last few decades and a truly revolutionary paradigm shift, enabling multimedia communications between people and devices from any location. It brings fundamental changes to data networking, telecommunication, and is making integrated networks. It has made the network portable because of digital modulation, adaptive modulation, information compression, wireless access and multiplexing. It supports exciting applications such as sensor networks, smart homes, telemedicine, and automated highways. Early users of wireless technology primarily have been the military, emergency services, and law enforcement organizations. As the society moves toward information centricity, the need to have information accessible at anytime and anywhere takes on a new dimension. With the rapid growth of mobile telephony and networks, the vision of a mobile information society (introduced by Nokia) is slowly becoming a reality. It is common to see people communicating via their mobile phones and devices. With today’s networks and coverage, it is possible for a user to have connectivity almost anywhere.

In this first chapter, we will talk about the wireless networks, we will give some historic development and their types. Also, because the antenna has made great progress in the wireless networks, it becomes a big player in the communication due to its characteristic, an overview about its basics and parameters will be giving.

1.2 Wireless Networks

1.2.1 The benefits of wireless network

Wireless networking is potentially a quick, easy and economical alternative that works between nodes and is executed without the use of wires around our home or office. It also opens possibilities for connecting buildings, which are up to several kilometers apart. It offers consistent and effectual keys to a number of instant applications therefore at present it is used under numerous diverse platforms such as health care, education, finance, hospitality, airport, and retail. The usage of wireless network increases day by day, because it has significant impact on the world. Therefore, its uses have appreciably grown-up. The benefits of wireless networks are summarized as below:

• User can move about and get access to the wireless network while working at an outdoor location.

• User can send information over the world using satellites and other signals through wireless networks. [1]

1.2.2 History

The first professional wireless network was developed under the brand Alohanet in 1969 at the University of Hawaii and became operational in June 1971. The first commercial wireless network was the Waveland product family, developed by NCR in 1986.

- 1973 – Ethernet 802.3
- 1991 – 2G cell phone network
- June 1997 – 802-11 Wi-Fi protocol first release
- 1999 – 803-11 voip integration [2]

1.2.3 Types of wireless networks

a. Wireless PAN

Wireless Personal Area Network (WPANs) connect devices within a relatively small area, that is generally within a person's reach. For example, both Bleutooth radio and invisible infrared light provides a WPAN for interconnecting a headset to a laptop. ZigBee also supports WPAN applications. Wi-Fi PANs are becoming commonplace (2010) as equipment designers start to integrate Wi-Fi into a variety of consumer electronic devices. Intel "My WiFi" and windows 7 “virtual Wi Fi” capabilities have made Wi-Fi PANs simpler and easier to set up and configure.

b. Wireless LAN

A Wireless Local Area Network (WLAN) links two or more devices over a short distance using a wireless distribution method, usually providing a connection through an access point for internet access. The use of spread-spectrum or OFDM technologies may allow users to move around within a local coverage area, and remain connected to the network.

Products using the IEEE_802.11 WLAN standards are marketed under the Wi-Fi brand name. Fixed wireless technology implements Point-to-point links between computers or networks at two distant locations, often using dedicated Microwave or modulated Laser light beams over Line-of-sight propagation paths. It is often used in cities to connect networks in two or more buildings without installing a wired link. To connect to Wi-Fi using a mobile device, one can use a device like a wireless Router or the private Hotspot capability of another mobile device.

c. Wireless ad hoc network

A wireless ad hoc network, also known as a wireless mesh network or mobile ad hoc network

(MANET), is a wireless network made up of radio nodes organized in a mesh topology. Each node forwards messages on behalf of the other nodes and each node performs routing. Ad hoc networks can "self-heal", automatically re-routing around a node that has lost power. Various network layer protocols are needed to realize ad hoc mobile networks, such as Distance Sequenced Distance Vector routing, Associativity Based Routing, ad hoc on-demand Distance vector routing protocol and Dynamic Source Routing. [2]

d. Wireless MAN

Wireless Metropolitan area network are a type of wireless network that connects several wireless LANs.

WIMAX is a type of Wireless MAN and is described by the IEEE 802.16 standard.

e. Wireless WAN

Are wireless networks that typically cover large areas, such as between neigh boring towns and cities, or city and suburb. These networks can be used to connect branch offices of business or as a public Internet access system. The wireless connections between access points are usually Point-to-point Microwave transmission using Parabolic dish on the 2.4 GHz and 5.8 GHz band, rather than Omnidirectional antenna used with smaller networks. A typical system contains base station

gateways, access points and wireless bridging relays. Other configurations are mesh systems where each access point acts as a relay also. When combined with renewable energy systems such as photovoltaic solar panels or wind systems they can be standalone systems.

f. Cellular network

A cellular network or mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location Transceiver known as a Cell site or Base station. In a cellular network, each cell characteristically uses a different set of radio frequencies from all their immediate neighboring cells to avoid any interference.

When joined these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, Pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

Although originally intended for cell phones, with the development of Smartphone Cellular network routinely carry data in addition to telephone conversations:

- Global System for Mobile Communications (GSM): The GSM network is divided into three major systems: the switching system, the base station system, and the operation and support system. The cell phone connects to the base system station which then connects to the operation and support station; it then connects to the switching station where the call is transferred to where it needs to go. GSM is the most common standard and is used for most cell phones.

- Personal Communications Service (PCS): PCS is a radio band that can be used by mobile phones in North America and South Asia. Sprint happened to be the first service to set up a PCS.

- D-AMPS: Digital Advanced Mobile Phone Service, an upgraded version of AMPS, is being phased out due to advancement in technology. The newer GSM networks are replacing the older system. [2]

g. Private LTE/5G networks

Private LTE/5G networks use licensed, shared or unlicensed wireless spectrum thanks to LTE or 5G cellular network base stations, small cells and other radio access network (RAN)

infrastructure to transmit voice and data to edge devices (smartphones, embedded modules, routers and gateways.

3GPP defines 5G private networks as non-public networks that typically employ a smaller-scale deployment to meet an organization's needs for reliability, accessibility, and maintainability.

h. Open source

Open-source private networks are based on a collaborative, community-driven software that relies on peer review and production to use, modify and share the source code.

OAI provides an open-source software using talent from around the world to build wireless cellular Radio Access Network (RAN) and Core Network (CN) technologies.

Fire cell provides the world's first open source 4G and 5G private network solutions. They are a strategic member of OAI.

i. Global Area Network

A Global area network (GAN) is a network used for supporting mobile across an arbitrary number of wireless LANs, satellite coverage areas, etc. The key challenge in mobile communications is handing off user communications from one local coverage area to the next. In IEEE Project 802, this involves a succession of terrestrial Wireless LAN.

j. Space Network

Space networks are networks used for communication between spacecraft, usually in the vicinity of the Earth. The example of this is NASA's Space Network. [2]

1.2.4 Antennas applications in some types of Wireless networks

i. WLAN

A major development in antenna technology is the WLAN applications and will continue to grow in the foreseeable future. In the evolution of the Wireless LAN (WLAN) communications (Figure 1.1), different frequency bands have been allocated with the release of newly developed standards. Under IEEE 802.11n standard, it is required to include the MIMO techniques, which implies that more than one antenna has to be equipped in one device. Enhancements to 802.11n are under development as part of the newer released IEEE 802.11ac. With newer wireless technologies, the selection of operating frequencies is widening, and allocated frequency bands are getting lower which creates demand for more antenna area and volume on the device, especially with handheld and portable devices. Therefore, physical size has taken an increased importance in antenna design. It is a growing trend in antenna engineering to design compact antennas or antenna arrays that can operate at multiple commercial frequency bands including

GSM, UMTS, WLAN and WiMAX applications. Size reduction, adequate bandwidth, multimode operation etc. are the essential design consideration for practical applications. IEEE 802.11 WLAN: IEEE 802.11 work group started its standardization activities in 1991. It published the first standard specification in 1997 and operating at the unlicensed band of 2.4 GHz at speeds of 1 and 2 Mbps. in 1999, the IEEE 802.11a standard was updated and operating on the 5 GHz (5.15-5.35 and 5.725-5.825) and provide a transmission rate up to 54 Mbps. In the same year, the standard was approved that resulted in 802.11b and operating at

2.4 GHz and provides 11 Mbps of data rate. In 2003, the standard 802.11g was recognized because of inconsistency band between 802.11b and 802.11a. More then, another standard IEEE 802.11n, which underpins up to 600 Mbps, is being standardized. IEEE 802.11 WLAN, or WIFI, is likely the most generally broadband wireless, giving the most data rate transmission among standard based wireless technologies. The most typical applications of the 802.11 WLAN include Internet access of portable devices in various networking environments.

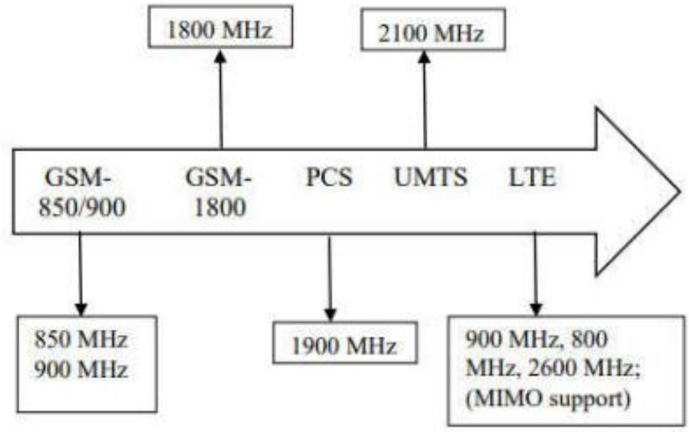


Figure 1. 1. The evolution of WLAN standards

ii. WiMax

WiMAX stands for Worldwide Interoperability for Microwave Access, a telecommunication technology based on Wireless MAN standard (802.16). WiMAX provides wireless data transmission using different transmission modes, from point-to-point to complete cell access. The standard was created in 2001 by the collaboration of Intel and Alvarion companies and ratified by the IEEE under the name IEEE802.16. WiMAX is an appropriate solution for e-learning platforms when the trainee location is isolated. One of the main concerns is related to security. Currently there are no efficient solutions to prevent the attacks at the physical layer of a WiMAX network but, despite of all issues and threats, WiMAX is a secure network that provides: strong user authentication

- Access control.
- Data privacy.
- Data integrity.
- Using sophisticated authentication and encryption technology.

WiMAX technology will be used in Romania on a large scale soon. This will help the e-learning solutions and that will lead to a better education system in Romania. 1.2.3 LTE, an abbreviation for Long-Term Evolution, commonly marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements. The standard is developed by the 3GPP (3rd Generation

Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9. Although marketed as a 4G wireless service, LTE (as specified in the 3GPP Release 8 and 9 document series) does not satisfy the technical requirements the 3GPP consortium has adopted for its new standard generation, and which were originally set forth by the ITU-R organization in its IMT-Advanced specification. However, due to marketing pressures and the significant advancements that WiMAX, HSPA+ and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies. The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT Advanced. To differentiate LTE Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as True 4G. Orthogonal frequency division multiple access (OFDMA) is the multiple access method used in the LTE downlink. The LTE uplink is based on the single-carrier frequency division multiple access (SDFDMA) mode. This mode is similar to OFDMA but has the advantage SC-FDMA that signals exhibit a lower peak-to-average power ratio (PAPR). LTE has two different duplex modes for separating the transmission directions from the user is the base station and back: frequency division duplex (FDD) and time division duplex (TDD). In the case of FDD, the downlink and uplink are transmitted using different frequencies. In TDD, the downlink and the uplink are on the same frequency and the separation occurs in the time domain, so that each direction in a call is assigned to specific timeslots. This paper describes the details of the LTE TDD (TD-LTE) technology and highlights any differences from the LTE FDD technology. Special characteristics and specific challenges to be faced during network planning are also described. Frequency bands The TDD duplex mode is used for transmissions in unpaired frequency bands. This means that the TDD bands already defined for UMTS can also be used for LTE TDD.

1.2.6 Performance Comparison among WLAN, WiMAX, Cellular, ZigBee, MobileFi and Bluetooth

The table below gives a few differences between Bluetooth, WiFi, WiMAX, cellular, ZigBee and MobileFi

Wireless technology	Data transmission rate	Distance coverage (approximate)	Frequency	Nodes per network	Security	Potential application in SG
WLAN	From 1 Mbps to 54 Mbps	100 m to more	2.4 GHz and 5.8 GHz	> 1000	WEP, AES	1. Substation automation 2. Monitoring and controlling
WiMAX	70 Mbps	Up to 48 Km	2.3, 2.5 and 3.5 GHz	NA*	Extensible authentication protocol	1. AMR 2. Real-time pricing
ZigBee	20–250 kbps	30–100 m(7km, LOS[44])	868 MHz, 915 MHz and 2.4 GHz	65000	128-bit AES	1. WSN 2. Smart home/home area network
Cellular	240 kbps	10–50 km	824- 894 MHz/ 1900 MHz	NA	Proprietary	1. SCADA 2. Remote monitoring
MobileFi	20 Mbps	Vehicular standard	Below 3.5 GHz	NA	Proprietary	1. Broadband communication 2. Plug-in electric vehicle 3. SCADA
Bluetooth	750 kbps	1-100 m	2.4 GHz	7	E0 stream cipher	1. Online monitoring 2. Substation automation

Table 1. 1. Comparison among WLAN, WiMAX, Cellular, ZigBee, MobileFi and Bluetooth [4]

1.3 Antenna Fundamentals Proprieties

1.3.1 Definition of Antenna

An antenna is a metallic structure that captures and/or transmits radio electromagnetic waves. Antennas come in all shapes and sizes from little ones that can be found on your roof to watch TV to big ones that capture signals from satellites millions of miles away. [5]

The antennas that Space Communications and Navigation uses are a special bowl-shaped antenna that focuses signals at a single point called a parabolic antenna. The bowl shape is what allows the antennas to both capture and transmit electromagnetic waves. Electromagnetic Waves (EM) are made up of Electric Fields (E-field) measured by Newtons/Coulomb [N/C] and Magnetic fields (H-field) measured in Amps/Meter[A/m] which both of them are a vector quantity (in every point in space they have magnitude and a direction). The spatial variation (EM vary with space) and the temporal (time) variation (EM vary with time) are given in figures I.2 and I.3. [6]

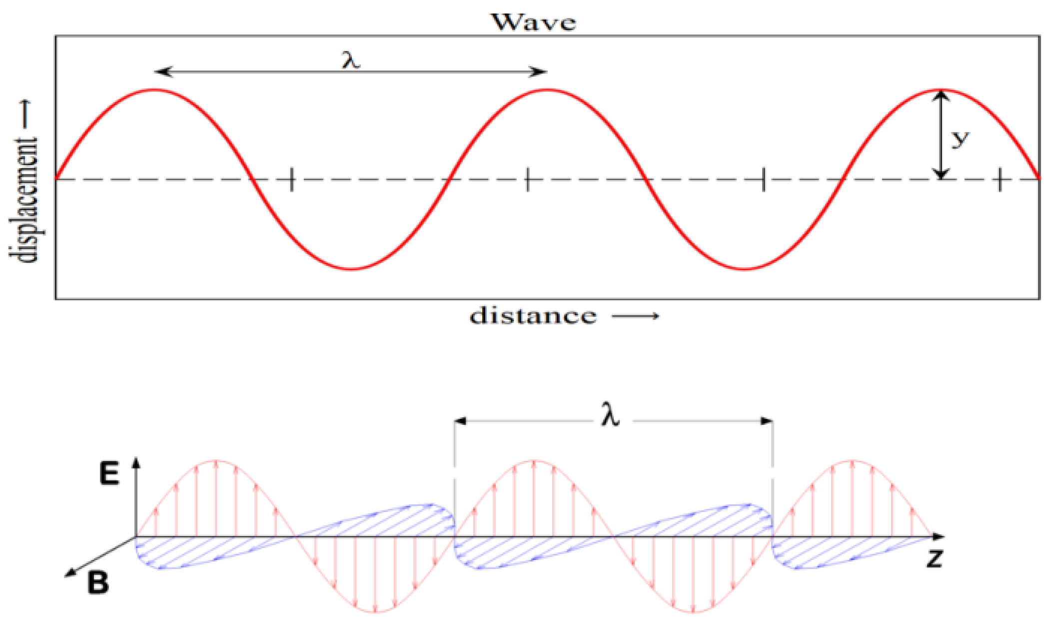


Figure 1. 2. The spatial variation of EM wave [7][8]

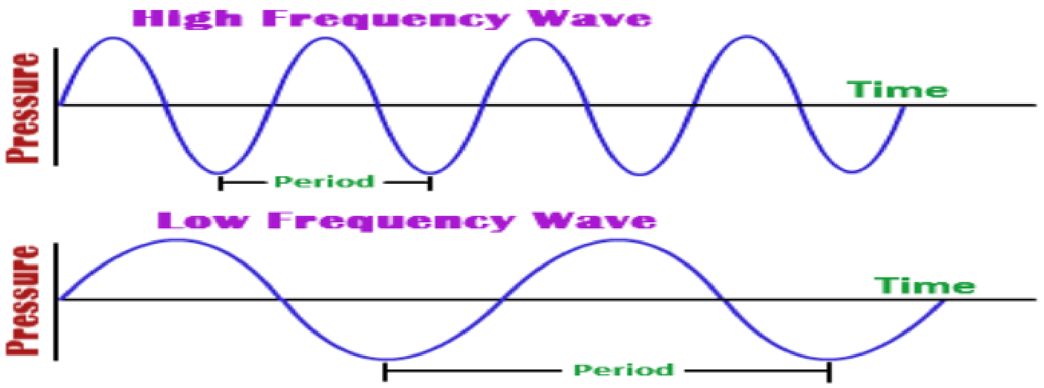


Figure 1. 3. The temporal variation[9]

Most fundamentally, an antenna is a way of converting the guided waves present in a waveguide, feeder cable or transmission line into radiating waves travelling in free space, or vice versa. Figure I.4 shows how the fields trapped in the transmission line travel in one dimension towards the antenna, which converts them into radiating waves, carrying power away from the transmitter in three dimensions into free space. The art of antenna design is to ensure that this process takes place as efficiently as possible, with the antenna radiating as much power from the transmitter into useful directions, particularly the direction of the intended receiver, as can practically be achieved.[10]

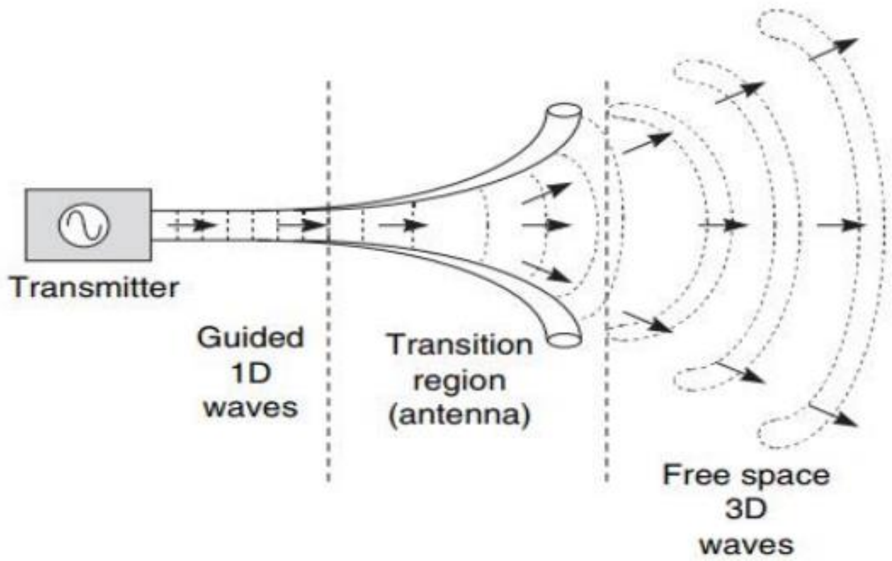


Figure 1. 4. The antenna as a transition region between guided and propagation waves [11]

1.3.2 Antenna types

There are several types of antennas, and each literature work has its own classification of antennas. Some of the common types of antennas are mentioned below:

- **Wire Antennas**
  - Short dipole Antenna
  - Dipole Antenna
  - Half-Wave dipole
  - Broadband dipoles
  - Monopole Antenna
  - Folded dipole Antenna (Figure 1.5)
  - Loop Antenna
  - Cloverleaf Antenna
- **Travelling wave Antennas**
  - Helical Antennas
  - Yagi-Uda Antenna
  - Spiral Antennas (Figure 1.6)
- **Reflector Antennas** (Figure 1.7)
  - Corner reflector
  - Parabolic reflector (dish Antenna)
- **Microstrip Antennas** (Figure 1.8)
  - Rectangular Microstrip (Patch) Antennas
  - Planar inverted-F Antennas (PIFA)
- **Log-Periodic Antennas**
  - Bow Tie Antennas
  - Log-Periodic Antennas (Figure 1.9)
  - Log-Periodic dipole array
- **Aperture Antennas**
  - Slot Antenna
  - Cavity-backed slot Antenna
  - Inverted-F Antenna
  - Slotted Waveguide Antenna
  - Horn Antenna (Figure 1.10)
  - Vivaldi Antenna
  - Telescopes
- **Other Antennas**
  - NFC Antennas
  - Fractal Antennas (Figure 1.11)
  - Wearable Antennas [11]

Figure 1. 5, Folded dipole antenna

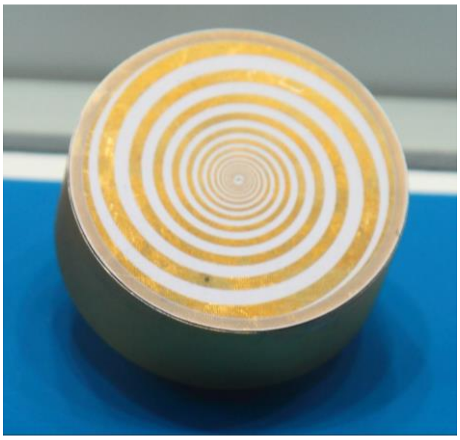


Figure 1. 6. Spiral antenna

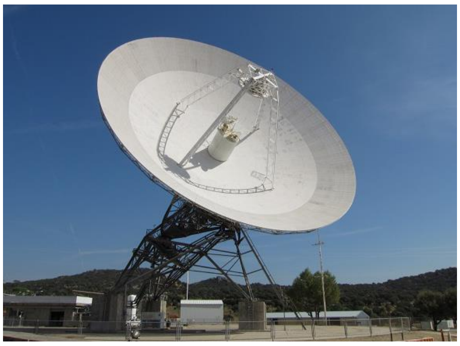


Figure 1. 7. Reflector antenna

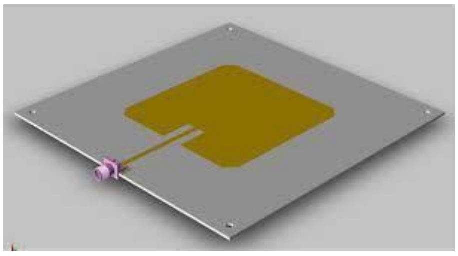


Figure 1. 8. Microstrip antenna

Figure 1. 9. Log-periodic antenna

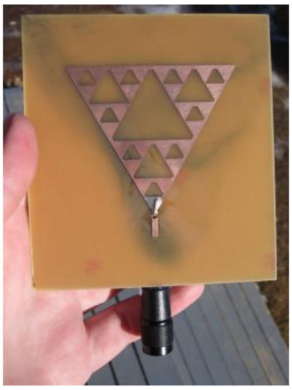


Figure 1. 10. Fractal antenna

Figure 1. 11. Horn antenna

1.3.3 General antenna characteristics

a. <u>Radiation Density</u>

The simplest imaginable antenna is the isotropic radiator, which does not exist in practice, but makes an excellent theoretical model. An isotropic radiator, which is a dimensionless point in space, generates waves with spherical wave fronts that are radiated uniformly in all directions. When the ideally matched transmitter power PS is applied to it, then at distance r this gives rise to the radiation density: $S = PS/4\pi r\ 2$ (1.1)

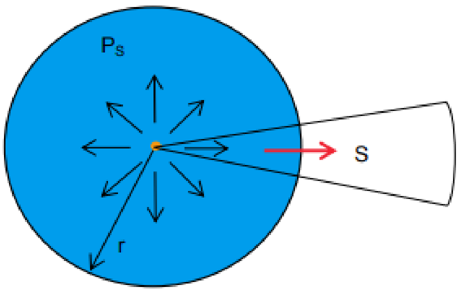


Figure 1. 12. The isotropic radiator in homogenous space

The radiation density (often also known as the power density) can also be determined in the far field as the product of electric and magnetic field strength in accordance with **$S = E \cdot \mathrm{H}$ (1.2)**

b. <u>Radiation pattern</u>

The three-dimensional radiation behavior of antennas is described by their radiation pattern (normally in the far field). As explained before, only an isotropic radiator would exhibit the same radiation in every spatial direction, but this radiator cannot be implemented for any specified polarization and is therefore mainly suitable as a model and comparison standard. Dipoles and monopoles possess directivity. An electrically short dipole in free space has a three-dimensional radiation pattern shown in Figure (1.6) with nulls in the direction of the antenna's axis. [11]

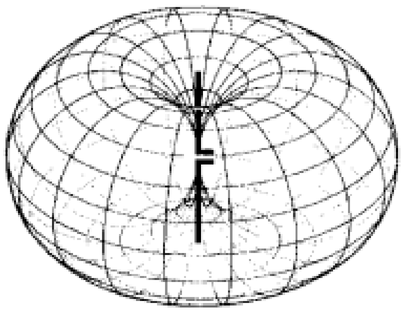


Figure 1. 13. Three-dimensional radiation of a dipole antenna

While the radiation pattern is three-dimensional, it is common however to describe this behavior with two planar patterns, also called the principal plane patterns. They can be obtained from the spatial radiation characteristics by looking at a cut plane - usually through the origin and the maximum of radiation. Spherical coordinates as shown in Figure (1.8) are commonly used to describe a location in the three-dimensional space. The horizontal pattern (see Figure 1.9) shows the field strength as a function of the azimuth angle ϕ with a fixed ϑ (usually ϑ = 90°). The vertical pattern (Figure 1.7) shows the field strength as a function of ϑ for a fixed ϕ (usually ϕ = +/- 90 ° or 0°/180°). [11]

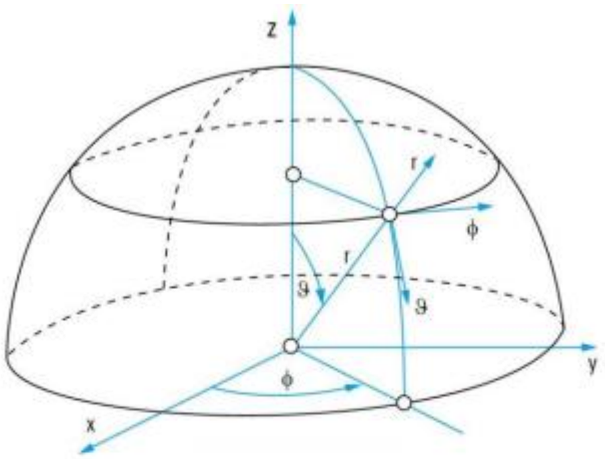


Figure 1. 14. Explanation of spherical coordinates

Characterizing an antenna's radiation behavior with the two principal plane patterns is adequate for antennas with a well-behaved pattern - meaning that not much information is lost when just the two planes are shown. In literature or datasheets, the terms azimuth pattern or elevation pattern are also frequently found. The term azimuth describes the reference to "the horizon" or "the horizontal" whereas the term elevation describes the reference to "the vertical". If these two terms are used to describe antenna radiation patterns, they assume that during the measurement the antenna is mounted in the orientation in which it will be normally used. Another common designation for the two principal plane patterns is E-plane pattern and H-plane pattern. They depend directly on the orientation of the antenna's radiators. [11]

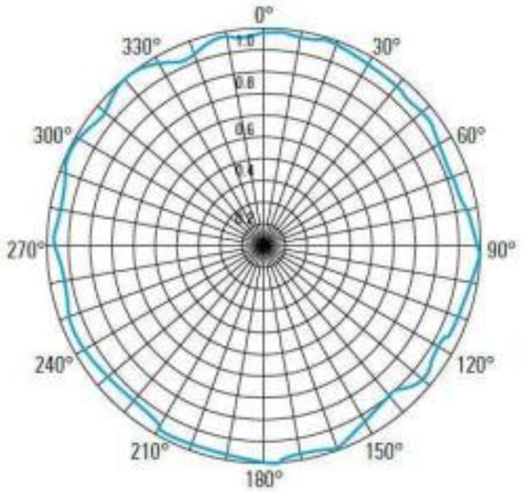


Figure 1. 15. Horizontal pattern of a dipole antenna [11]

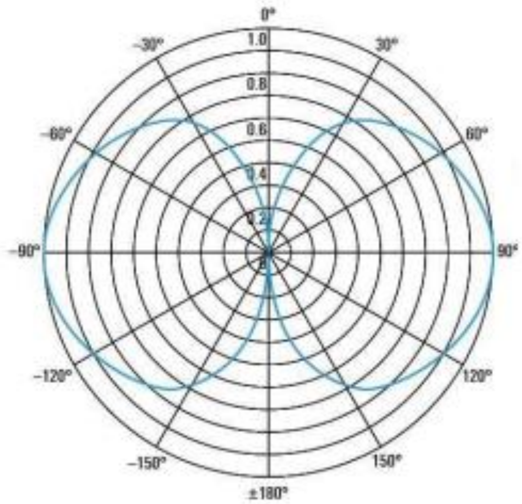


Figure 1. 16. Vertical pattern of a dipole antenna [11]

c. Directivity

The directivity factor D is defined as the ratio of the radiation intensity U obtained in the main direction of radiation to the radiation intensity Fi that would be generated by a loss-free isotropic radiator with the same radiated power P_{rad}.

$$\boldsymbol{D = \frac{U}{U_0} = \frac{4\pi\, U}{P_{rad}}} \qquad \textbf{(1.3)}$$

Where:

D: directivity

U: radiation intensity
U_0: radiation intensity of isotropic source
P_{rad}: total radiated power

d. Gain

Corresponding to the directivity factor, the gain G is the ratio of the radiation intensity Fmax obtained in the main direction of radiation to the radiation intensity Fi0, that would be generated by a loss-free isotropic radiator with the same input power Pt0. [11]

$$G = 4\pi \frac{U}{P_0} \qquad (1.4)$$

Where P_0 is the power input in the antenna and U is radiation intensity

e. Practical Gain

While the gain definition assumes ideal matching between the antenna and the connected cable and receiver or transmitter, in practice this is rarely the case. So what is measured in a non-ideally matched setup is called the practical gain of an antenna. The gain can be determined from the practical gain with the following formula:

$$G = Gpra \frac{1}{1-|r|\ 2} \qquad (1.5)$$

Where the amount of mismatch is expressed by the magnitude of the reflection coefficient r [11]

f. Effective Area

The effective area Aw of an antenna is a parameter specially defined for receiving antennas. It is a measure for the maximum received power Pr that an antenna can pick up from a plane wave of the power density

$$S: P_{r\,max} = S \cdot A_w \qquad (1.6)$$

Although the effective area of an antenna can well be conceived as a real area perpendicular to the direction of propagation of the incident wave, it is not necessarily identical with the geometrical area Ag of the antenna. The relationship between the effective and the geometrical areas is described by the aperture efficiency q:

$$q = \frac{A_w}{A_g} \qquad (1.7)$$

The effective area of an antenna can be converted to the gain and vice versa by means of the formula:

$$AW = \frac{\lambda^2}{4\pi}G \qquad (1.8)$$

g. Input Impedance

One of the most significant parameters of an antenna is its input impedance:

$$Z_{in} = R_{in} + jX_{in} \qquad (1.9)$$

Where: Z_{in}: antenna impedance

R_{in}: antenna resistance
X_{in}: antenna reactance

This is the impedance present at the antenna feed point. Its real part R_{in} can be split up into the radiation resistance R_R and the loss resistance:

$$R_{in} = R_R + R_L \qquad (1.10)$$

Where R_L is the loss resistance

It should be noted however that the radiation resistance, being the quotient of the radiated power and the square of the RMS value of the antenna current, is spatially dependent. This applies also to the

antenna current itself. Consequently, when specifying the radiation resistance, its location on the antenna needs to be indicated.

Quite commonly the antenna feed point is specified, and equally often the current maximum. The two points coincide for some, but by no means for all types of antenna. The imaginary part X_{in} of the input impedance disappears if the antenna is operated at resonance. Electrically very short linear antennas

have capacitive impedance values ($X_{in} < 0$), whereas electrically too long linear antennas can be recognized by their inductive imaginary part ($X_{in} > 0$). [11]

h. VSWR

In order for the antenna to operate efficiently, maximum transfer of power must take place between the transmission line and the antenna. Maximum power transfer can only take place when the impedance of the antenna is matched to that of the transmitter. If the matching condition is not satisfied, some of the power will be reflected and this leads to the creation of standing waves, which can be characterized by voltage standing wave ratio (VSWR). The parameter can be expressed by formula I.9. VSWR is a real number that is always greater than or equal to 1. A VSWR of 1 indicates no mismatch loss (the antenna is perfectly matched). Higher values of VSWR indicate more mismatch loss. The VSWR is a function of the Γ (the reflection coefficient) describes the power reflected from the antenna. If the reflection is given by Γ, then the VSWR is defined by the formula (1.13) [11][12][13].

$$\boldsymbol{\Gamma} = \frac{V_r}{V_i} = \frac{Z_A - Z_s}{Z_A - Z_s} \qquad \textbf{(1.11)}$$

$$\boldsymbol{VSWR} = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad \textbf{(1.12)}$$

Where:

Γ: is the reflection coefficient.
$\boldsymbol{Vr}$: is amplitude of reflected wave.
$\boldsymbol{Vi}$: is amplitude of incident wave. A practical antenna design must have an input impedance equal to 50Ω or 75Ω and most radio equipment is built for this impedance

i. Frequency

The frequency (written f) is simply the number of complete cycles the wave completes (viewed as a function of time) in one second (two hundred cycles per second is written 200Hz or 200 "Hertz").

Mathematically this is written as: $$f = \frac{1}{T} \qquad \textbf{(1.13)}$$

Basically, the frequency is just a measure of how fast the wave is oscillating and since all EM waves travel at the same speed, the faster is oscillates the shorter the wavelength. And a longer wavelength implies a slower frequency [11]

Mathematically this is written as: $$f = \frac{c}{\lambda} \qquad \textbf{(1.14)}$$

Where f, T, c, λ are represent:
f: frequency in Hertz
T: periodic wave in second
c: speed of Light in meters/second
λ: wave lenght in meters

j. Bandwidth

The bandwidth of an antenna is defined as the range of usable frequencies within which the performance of the antenna with respect to some characteristics conforms to a specified standard. The parameter most commonly considered here is the impedance match (i.e., VSWR < 1.5) - but other parameters like gain or side lobe suppression may serve as a bandwidth criteria here, too. For broadband antennas, the ratio of the highest and lowest usable frequencies is determined. A ratio of 2:1 is called an octave - a ratio of 10:1 is a decade.

$$BW = \frac{f_H}{f_L} \qquad (1.15)$$

Where: f_H is the highest usable frequency and f_L is the lowest usable frequency.

An antenna is said to be broadband when BW is equal or greater than 2. There exists also a different definition of bandwidth which is valid only for narrowband antennas:

$$BW\ \% = \left(\frac{f_H - f_L}{f_c}\right) \times 100 \qquad (1.16)$$

Where: f_c is the center frequency. Values here can range from 0 to 200% - in practice this definition is only used up to about 100%.

k. Return Loss

The Return Loss is a parameter which indicates the amount of energy lost to the load when the impedance of the transmitter and the antenna are not equal. From where RL is a parameter similar to VSWR that can be thought of as a measure of how close the actual input/output impedance of the network is to the antenna impedance value [23][25].

$$RL = 10\log10 \left|\frac{1}{\Gamma^2}\right| = -20 log_{10}|\Gamma|\ \mathrm{dB} \qquad (1.17)$$

For a perfect match between the transmitter and the antenna, **Γ** = **0** and **RL = -** ∞ means that there will be no reflected energy; while that **Γ** = **1** and **RL = 0 dB** which implies that all the incident power is reflected. For a two-port device there are four S parameters S11, S21, S12, and S22. The S11 and S22 are simply the forward and reverse reflection coefficients, with the opposite port terminated in Z_0 (usually 50 ohms.); S21 and S12 are simply the forward and reverse gains assuming a Z_0 source and load (again usually 50ohms). [12][14]

1.4 Conclusion

Because of the human needs for the wireless devices like PC's, cell phones etc… in order to communicate between them and sending files and messages by using wireless technologies like Bluetooth, WiFi, WiMAX. So, we talk about all the wireless networks, and we focused on the WLAN and WiMAX technology for its many features recently like its high speed and large distance converged. To improve all these technologies in wireless devices like mobile phone we need an antenna that can radiate and pick up the frequencies of this wireless networks. Therefore, we took about the antenna basics, and we choose the microstrip Patch antenna exactly the Microstrip Monopole antenna in our study for its easy fabrication and low cost which we will explain more in the second chapter.

Chapter II: Overview about microstrip patch antenna and miniaturization technique

2.1 Introduction

Nowadays, Microstrip Patch antenna can be found in everyday objects of all kinds because of his advantages and better prospects. They are lighter in weight, low volume, low cost, low profile, easy of fabrication and the important advantage is very smaller in the size.

the applications of the MPA are in various fields of the communications such as in Mobile and satellite communication, global positioning system, telemedicine, RFID, WIMAX, USB dongle antenna and radar applications…

In this chapter, we will start by detailing the microstrip patch antenna (definition and basics, geometry, characteristics, feeding techniques, the application of MPA, advantages and disadvantages, substrate of the antenna). After that we will explain the dipole and monopole antenna to obtain omnidirectional pattern, and we will talk a little bit about the USB dongle antenna because of his great demand for application in the wireless local area network. Also, in the recent years, increasing progress in communication system rises the demand to achieve miniaturization of patch and enhance the performance, we will use the technique miniaturization to have a good result that we can use it in WUSB dongle antenna

2.2 Microstrip Patch Antenna

Antenna is a transducer designed to transmit or receive electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications. Microstrip antennas in its simplest configuration are shown in Figure 2.1. It consists of a radiating patch on one side of dielectric substrate (Єr≤10), which has a ground plane on other side.

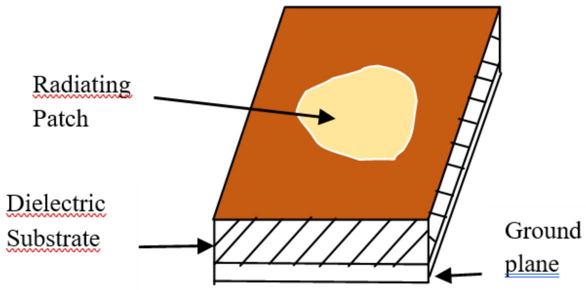


Figure 2. 1. Microstrip antenna configuration

Microstrip antennas are characterized by a larger number of physical parameters than are conventional microwave antennas. They can be designed to have many geometrical shapes and dimensions .[15]

All microstrip antennas can be divided into four basic categories:

A. Microstrip patch antenna
B. Microstrip dipoles and monopoles
C. Printed slot antennas
D. Microstrip travelling wave antennas

A microstrip patch antenna (MPA) consists of a conducting patch of any planar or nonplanar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semi hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array. Many microstrip patch antennas have been studied to date. An exhaustive list of the geometries along with their salient features is available [16].

However, other shapes such as the square, circular, triangular, semicircular, annular and square ring shapes shown in figure 2.2 The rectangular and circular patches are the basic and most used microstrip antennas. These patches are used for the simplest and the most demanding applications. Rectangular geometries are separable in nature and their analysis is also simple. The circular patch antenna has the advantage of their radiation pattern being symmetric. A rectangular microstrip patch antenna in its simplest form is shown in Figure 2.3 [17]

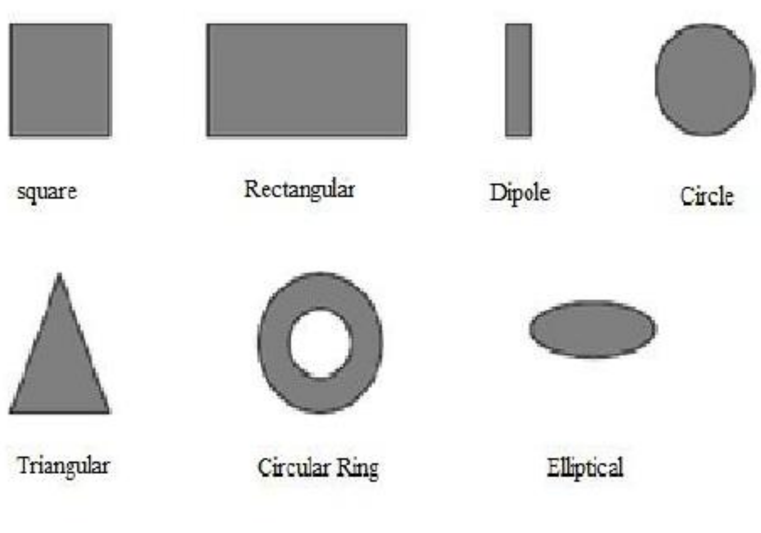


Figure 2. 2. Representative shapes of microstrip patch antenna [18]

Consider the microstrip antenna shown in Figure ground plane are made of high conductivity metal (typically copper). The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity ε_r. The thickness of the ground plane of the microstrip is not critically important. Typically, the height h is much smaller than the wavelength of operation but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded.

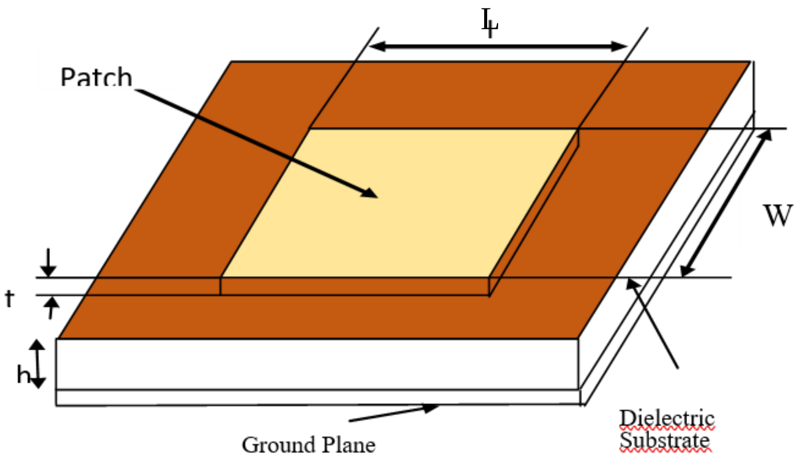


Figure 2. 3. Structure of rectangular microstrip patch antenna

2.2.1 Antenna Geometry

The material with dielectric constant is used as a backplane conductor to form a microstrip antenna and the heart of a micro-strip patch antenna is the upper conductor. The patch of finite dimensions can be an open-ended transmission line of length and width. The amplitude of surface currents becomes significant when the signal frequency is close to resonance by taking only the fundamental mode into account. The resonant frequency can be calculated by the formula [19][20].

$$\boldsymbol{fr} = \boldsymbol{c}\ (\boldsymbol{L}+2\boldsymbol{\Delta L})\ \boldsymbol{\varepsilon_{eff}} \qquad (2.1)$$

Where:

ΔL is the equivalent length extension that financial records for the fringing fields at the two open ends

$\boldsymbol{\varepsilon_{eff}}$ is the effective relative permittivity. A micro-strip structure is not homogeneous because the electromagnetic field extends over the two media air and dielectric [20].

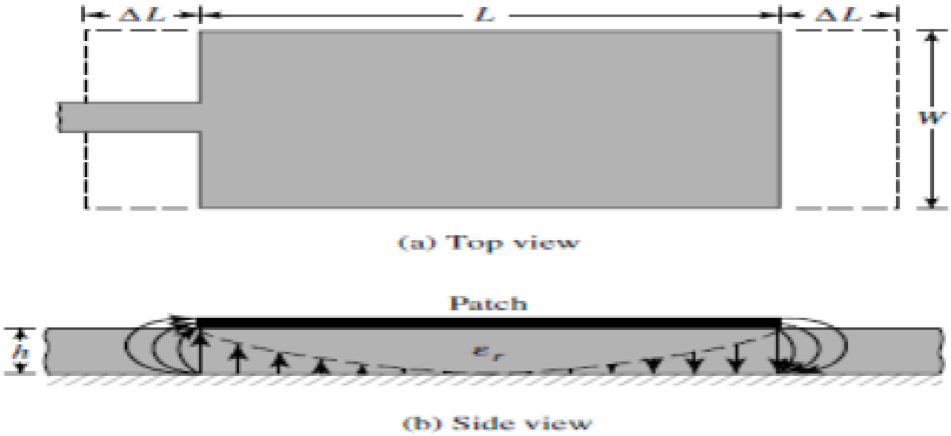


Figure 2. 4. (a) Top view Physical of rectangular MPA, (b) side view of effective lengths of rectangular MPA [21]

The dimensions of the MSA are giving by analytical formulae [21][20][22]:

a) Width of metallic patch (W):

$$\mathbf{W} = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad \textbf{(2.2)}$$

$$\mathbf{W} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad \textbf{(2.3)}$$

Where: **c:** free space velocity of light εr: Dielectric constant of substrate

b) Effective dielectric constant is calculated from:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} + \left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right) \qquad \textbf{(2.4)}$$

c) Length of metallic patch (L):

$$\mathbf{L} = L_{eff} - 2\Delta\mathbf{L} \qquad \textbf{(2.5)}$$

Where: $$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \qquad \textbf{(2.6)}$$

d) Calculation of Length Extension:

$$\frac{\Delta\mathbf{L}}{h} = \frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}+0.258)(\frac{W}{h}+0.8)} \qquad \textbf{(2.7)}$$

e) Length and width of Ground plane (Wg, Lg):

$$\mathbf{Wg} = \mathbf{6h} + \mathbf{W} \qquad \textbf{(2.8)}$$
$$\mathbf{Lg} = \mathbf{6h} + \mathbf{L} \qquad \textbf{(2.10)}$$

f) Feed line length (Lf):

$$\mathbf{Lf} = \frac{\lambda_g}{4} \qquad \textbf{(2.11)}$$

where $\boldsymbol{\lambda}\mathbf{g} = \boldsymbol{\lambda}\frac{\lambda}{\sqrt{\varepsilon_{eff}}}$, **λg** is a guided wave **length** **(2.12)**

2.2.2 The characteristics of microstrip patch antennas

We compared the characteristics of 3 types of MPA: microstrip patch antennas, microstrip slot antennas and printed dipole antennas are in table2.1 below:

Sr. No.	Characteristics	Microstrip Patch Antenna	Microstrip Slot Antenna	Printed Dipole antenna
1.	Profile	Thin	Thin	Thin
2.	Fabrication	Very easy	easy	easy
3.	Polarization	Both linear and circular	Both linear and circular	Linear
4.	Dual-Frequency operation	Possible	Possible	Possible
5.	Shape flexibility	Any shape	Mostly rectangular and circular shapes	Rectangular and triangular
6.	Spurious radiation	Exists	Exists	Exists
7.	Bandwidth	2-50%	5-30%	-30%

Table 2. 1. Comparison the characteristics of 3types of MPA

2.2.3 Feeding techniques

A feedline is used to excite to radiate by direct or indirect contact. There are many different techniques of feeding, and four most popular techniques are coaxial probe feed, microstrip line, aperture coupling and proximity coupling. [23]

Coaxial probe feeding is feeding method in which that the inner conductor of the coaxial is attached to the radiation patch of the antenna while the outer conductor is connected to the ground plane. Advantages of coaxial feeding is easy of fabrication, easy to match, low spurious radiation and its disadvantages is narrow bandwidth, Difficult to model specially for thick substrate.[24]

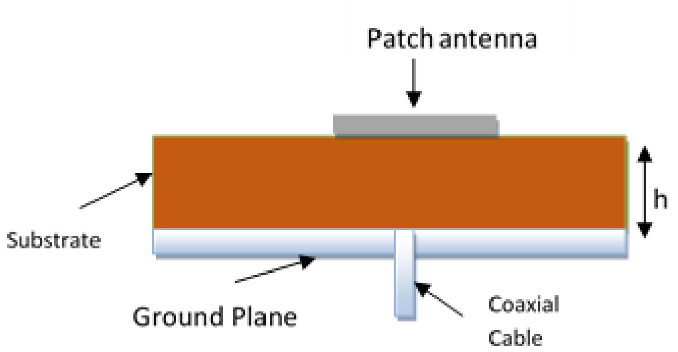


Figure 2. 5. Coaxial probe feed patch antenna

Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However, the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.[24]

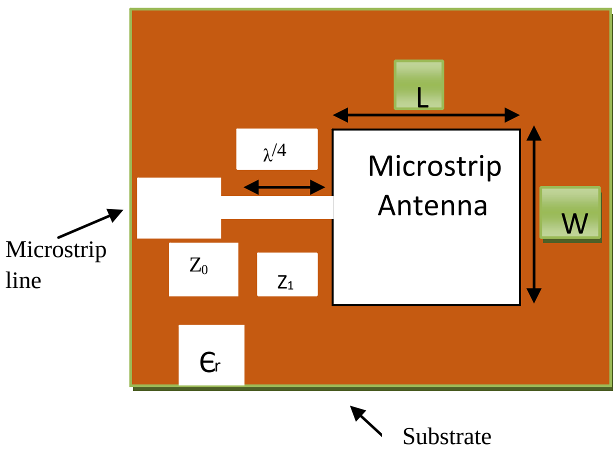


Figure 2. 6. Microstrip line feed patch antenna

Aperture coupled feed consist of two different substrates separated by a ground plane. On the bottom side of lower substrate there is a microstrip feed line whose energy is coupled to the patch through a slot on the ground plane separating two substrates. This arrangement allows independent optimization of the feed mechanism and the radiating element. Normally top substrate uses a thick low dielectric constant substrate

while for the bottom substrate; it is the high dielectric substrate. The ground plane, which is in the middle, isolates the feed from radiation element and minimizes interference of spurious radiation for pattern formation and polarization purity. Advantages is allowing independent optimization of feed mechanism element.[24]

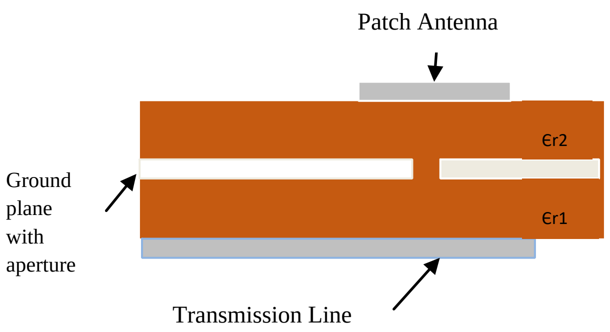


Figure 2. 7. Aperture coupled feed patch antenna

Proximity coupling has the largest bandwidth, has low spurious radiation. However, fabrication is difficult. Length of feeding stub and width-to-length ratio of patch is used to control the match. Its coupling mechanism is capacitive in nature.[24]

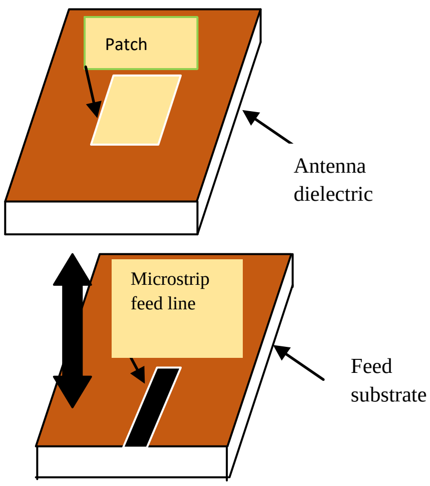


Figure 2. 8. Proximity coupled microstrip patch antenna

The major disadvantage of this feeding technique is that it is difficult to fabricate because of the two dielectric layers that need proper alignment. Also, there is increase in overall thickness of the antenna.

In the wide range of antenna models there are different structures of Microstrip antennas, but overall, we have four basic parts in the antenna. [25]

They are:

- The patch
- Dielectric Substrate
- Ground Plane
- Feed Line

2.2.4 The application of MPA

The Microstrip patch antennas are well known for their performance and their robust design, fabrication and their extent usage. The advantages of this Microstrip patch antenna are to overcome their de-merits such as easy to design, light weight etc., the applications are in the various fields.

Some of these applications are mentioned it as below:

- Mobile and satellite communication application
- Global Positioning System
- Worldwide Interoperability for Microwave Access (WiMax)
- Radio Frequency Identification (RFID)
- Radar Application
- Rectenna Application
- Telemedicine Application
- Medicinal applications of patch

2.2.5 advantages and disadvantages

Microstrip patch antenna has several advantages over conventional microwave antenna with one similarity of frequency range from 100 MHz to 100 GHz same in both types. The various advantage and disadvantage are given in table 2.2. [24]

Sr. No.	Advantage	Disadvantage
1.	Low weight	Low efficiency
2.	Low profile	Low gain
3.	Thin profile	Large ohmic loss in the feed structure of arrays
4.	Required no cavity backing	Low power handling capacity

5.	Linear and circulation polarization	Excitation of surface waves
6.	Capable of dual and triple frequency operation	Polarization purity is difficult to achieve
7.	Feed lines and matching network can be fabricated simultaneously	Complex feed structures require high performance arrays

Table 2. 2. Advantages and disadvantages of MPA

2.2.6 substrate and Comparison on Various Substrates of Antenna

Substrates use in microstrip patch antenna varies from 2.2≤Ɛ≤12. Lower the permittivity of dielectric material larger the size of the antenna but it achieves better efficiency and larger

bandwidth. The Ɛr is limited by radio frequency or microwave circuit connected to antennas. When substrate of higher dielectric constants was used than the performance result degrades. Air with least dielectric constant of 1 shows least return loss of -22.6449 whereas Benzocyclobutane with dielectric constant of 2.6 return loss is -18.1248 [26] With the use of Duroid 6010 which is counted among the higher dielectric constant substrate i.e., 10.7 used in phased array 1×4 at 1.35 GHz. It showed optimized results.[27] A nylon fabric is a substrate considered among medium dielectric constant with dielectric constant 3.6. Work has been done to demonstrate the antenna fabricated using nylon fabric. antenna resonates at 989 MHz it results in return loss of -35.42dB, directivity of 6.72dB, Gain of 6.11dB. Fractal shaped microstrip patch antenna is also implemented using the foam substrate. It reduced the size of the antenna up to 84%. RT-Duroid substrate is costlier than LCP (liquid crystal polymer) but RT-Duroid gives better performance in term of gain, directivity and bandwidth [28]

Comparison on Various Substrates of Antenna:

Substrates	*Ɛr*	*Loss tangent*	*Resonance frequency*	*Return Loss*	*Gain*
Benzocyclobutane	2.6	0	2.04GHz	-18.124	5.5
Duroid 6010	10.7	0.0060	2.455	-9.449	4.02
Roger 4350	3.48	0.004	2.586GHz	-25.29	4.62
Foam	1.05	0	454MHz	-16.732	2.73
FR-4	4.4	0.018	5.8GHz	-14.73	9.8

Substrates	*Size Reduction*	*Bandwidth*	*Efficiency*
Benzocyclobutane	Medium	medium	96.51
Duroid 6010	Lowest	minimum	93.51
Roger 4350	Medium	medium	99.66
Foam	Highest	maximum	61
FR-4	Medium	medium	99.60

Table 2. 3. Comparison on Various Substrates of Antenna

2.2.7 Dipole and Monopole Antennas

a) Dipole Antennas

The dipole antenna has been developed by Heinrich Rudolph Hertz around 1886 and remains the most widely used antenna. It owns two identical (same length) and symmetrical metal wires, and its feeding device is connected at the center of the dipole for example connected to the two adjacent wires ends. The dipole working results of a standing wave phenomenon depending on its length. The antenna fundamental mode occurs when the whole antenna is a half-wavelength long [29]. A general-purpose dipole antenna (long thin wire antenna) with height h1 = h2 = L/2, where L is the total length of the antenna is shown in figure 2.9 [30].

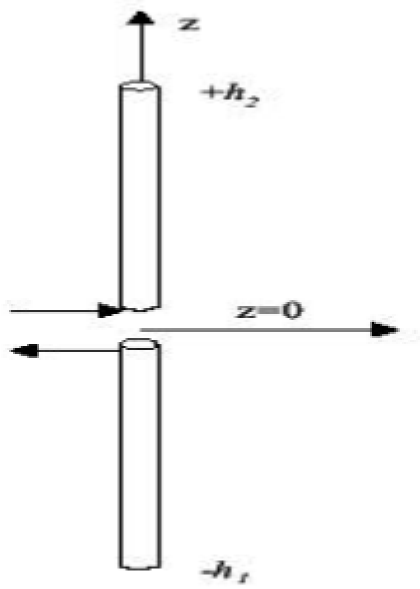


Figure 2. 9. Thin Linear Antenna of Total Length h2 + h1 [30]

The current of the center fed antenna of length L at any point z on the antenna is [30]:

$$I(z) = I_0 \sin[\frac{2\pi}{\lambda}(\frac{L}{2} - |z|)] \quad \textbf{(2.13)}$$

The peak value of the current *I*0 is not reached along the dipole unless the length is greater than half a wavelength as shown in figure 2.10 [11].

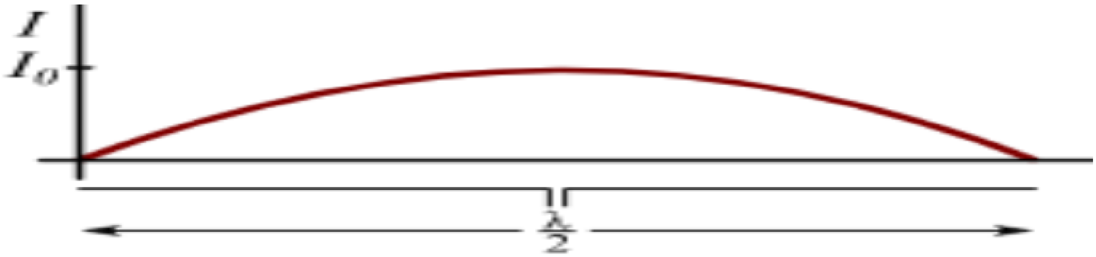


Figure 2. 10. Current distributions on finite-length dipole antennas [51]

If the dipole antenna's length becomes slightly less than λ/2 the antenna has zero imaginary component to the impedance (reactance X=0), and the antenna is said to be resonant. If the dipole antenna's length becomes close to one wavelength, the input impedance (given by Z=V/I) becomes infinite and the current at the terminals is zero. The dipole antenna is an example of an omnidirectional antenna (figure 2.11) [11].

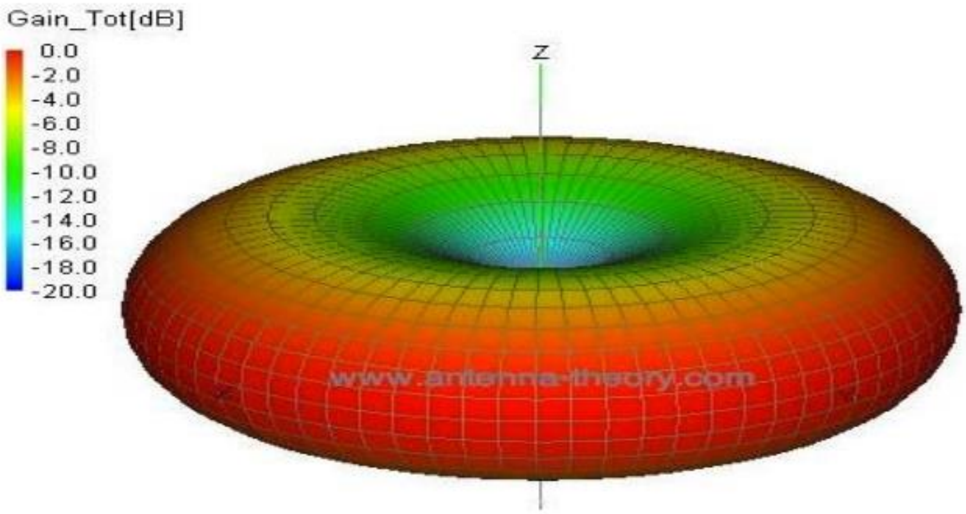


Figure 2. 11. Normalized 3d radiation pattern for the dipole antenna [16]

b) Monopole Antennas

A monopole antenna is one half of a dipole antenna, almost always mounted above some sort of ground plane. A quarter-wave monopole antenna excited by a source at its base as shown in figure 2.12 exhibits the same radiation pattern in the region above the ground as a half-wave dipole in free space. This is because, from image theory, the conducting plane can be replaced with the image of a λ/4 monopole. However, the monopole can only radiate above the ground plane. Hence the λ/4 monopole radiates only half as much power as the dipole [30].

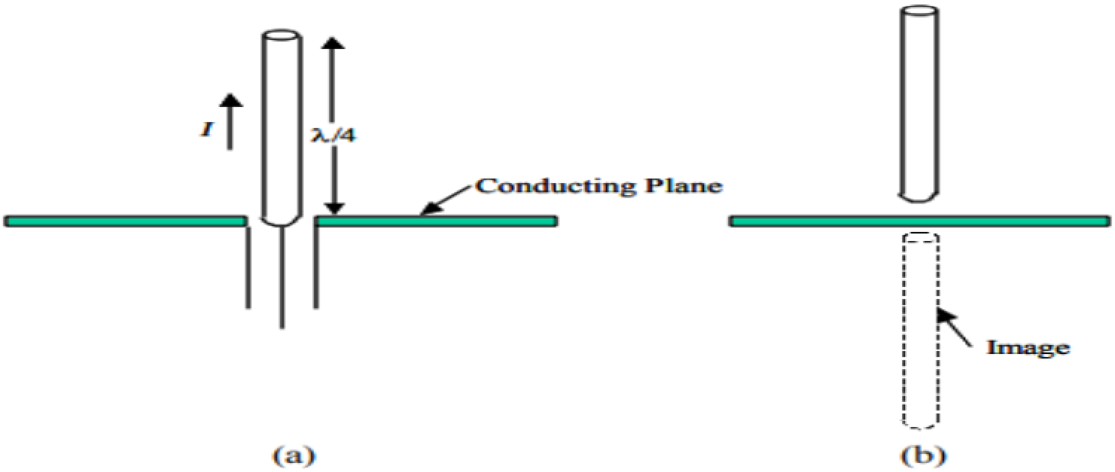


Figure 2. 12. Quarter-Wave Monopole Antenna. (b) Equivalent Half-Wave Dipole Antenna [30]

The radiation pattern of monopole antennas, above a ground plane is also known from the dipole result and still omnidirectional as shown in his figure II.12. The only change that needs to be noted is that the impedance of a monopole antenna is one half of that of a full dipole antenna. The directivity of a monopole antenna is twice the directivity of a dipole antenna of twice the length. Monopole antennas are half the size of their dipole counterparts, and hence

are attractive when a smaller antenna is needed. Therefore, it presents a 3 dB gain higher than the dipole antenna. Also, antennas on older cell phones were typically monopole antennas. The first mobile phones were using this kind of antennas to receive the Global System for Mobile Communications (GSM) which is presented in figure 2.13 [11][29].

Figure 2. 13. Monopole antenna integrated in cell mobile phone [19]

2.3 USB dongle antenna

Wireless USB dongle has compact size and can be conveniently used in Wi-Fi and internet systems. The major challenges while designing an UWB antenna includes ultra-wideband performance and stability of the antenna and to make sure that the design is compatible with electronic applications. In terms of practical applications, bandwidth enhancement and size reduction are the major design issues. The Universal Serial Bus (USB) technology has several applications in electronics and mobile market. Wireless USB (WUSB) is a promising application among the UWB wireless connection system. The presence of cable in USB technology was the major constraint but with the advent of WUSB various devices such as scanner, digital camera etc can be connected directly to the PC. Therefore, in other words Ultra-wideband (UWB) helped unwiring of USB devices [32][33].

Figure 2. 14. USB dongle antenna

2.4 Ansys HFSS software:

HFSS (high-frequency structure simulator), is a commercial Finite element method solver for electromagnetic (EM) structures from Ansys that offers multiple state-of-the-art solver technologies. Each solver in ANSYS HFSS is an automated solution processor for which the user dictates the geometry, properties of the material and the required range of solution frequencies.

Engineers use Ansys HFSS primarily to design and simulate high-speed, high-frequency electronics in radar systems, communication systems, satellites, ADAS, microchips, printed circuit boards, IoT products, and other digital devices and RF devices. The solver has also been used to simulate the electromagnetic behavior of objects such as automobiles and aircraft. ANSYS HFSS allows system and circuit designers to simulate EM issues such as losses due to attenuation, coupling, radiation and reflection.

The benefits of simulating a circuit's high frequency behavior with high accuracy on a computer reduces the final testing and verification effort of the system as well as mitigating the necessity of building costly multiple prototypes, saving both time and money in product development.

HFSS captures and simulates objects in 3D, accounting for materials composition and shapes/geometries of each object. HFSS is one of several commercial tools used for Antenna design, and the design of complex Radio frequency Electronic circuit elements including filters, transmission lines, and packaging.

Figure 2. 15. HFSS logo

2.5 Technique of miniaturized monopole patch antenna with coupled branch strips

Many techniques have been developed to reduce the size of the patch antennas, such as employing high dielectric substrate, loading shorting pins or shorting walls, loading resistive or reactive components, extending current paths by meandering patch edges, etching slots into the patch or applying a folded patch, composite right/left-handed (CRLH) metamaterial structures. In addition, miniaturized the patch antenna with coupled branch strips have also been applied to reduce the size of patch antennas, this technique will make a little space between each strip that will miniaturize the antenna and his performance will be better than the performance of the simple size of the antenna.

We will make a simple example with this compact monopole antenna for the dual-band WLAN/WiMAX. The basic configuration of the proposed antenna is fed by a strip line and was printed on one side of a 1.0-mm-thick FR4 substrate that was used herein, with a 4.4 relative permittivity, whereas the other side of the substrate was printed on a ground plane. In this design, the total size of the substrate is 37*40 mm^2. The size of the proposed antenna is 37 *24 mm^2. The ground size was optimized for good impedance matching. The ground size of the proposed antenna is 37 *15 mm^2. In this design, two branch strips were added to the end of the monopole to provide different surface current paths and to produce dual resonant modes. To achieve dual- and wideband operation. [31]

The design of the MPA is shown in figure (2.15)

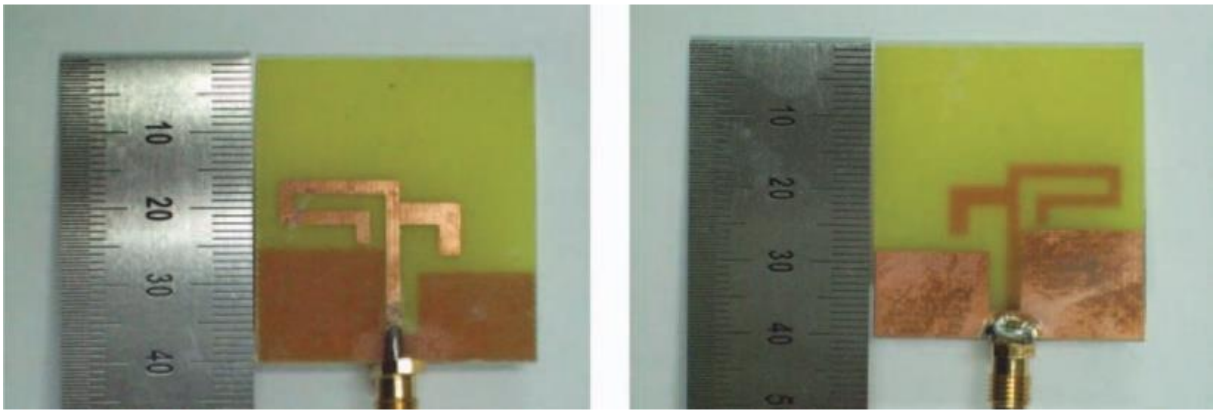


Figure 2. 16. (Left) front view of the prototype of the compact monopole antenna with two strips, (Right) back view of the compact monopole antenna with a ground [31]

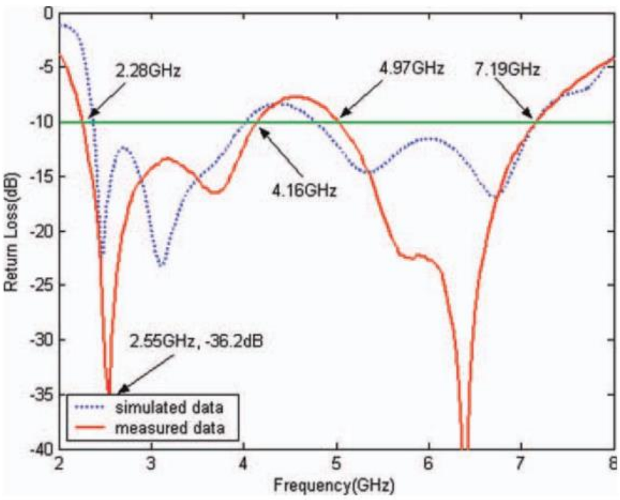


Figure 2. 17. Simulated Return Loss of the proposed antenna [31]

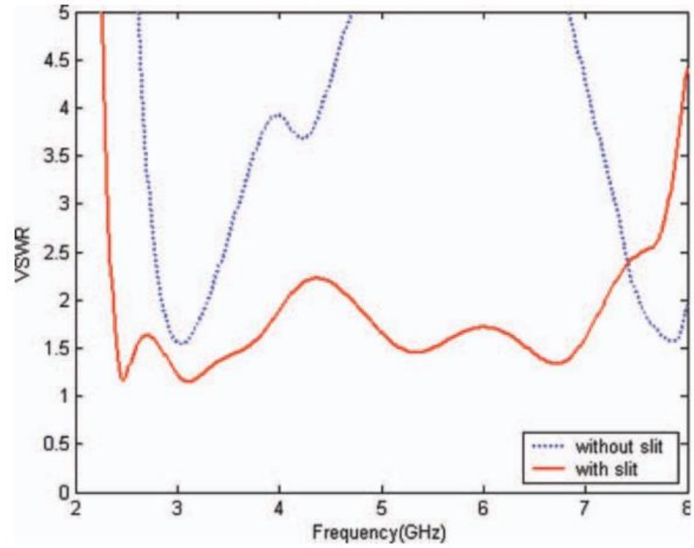


Figure 2. 18. Simulated VSWR of the proposed antenna with and without a rectangular slit in the ground plane [31]

Effect of One Branch Strip (L6): Figure (2.18) illustrates the VSWR for different values of L6. It can be seen in the figure that the impedance bandwidth did not greatly change when L6 was changed from 0.0 to 4.0 mm. It can be seen in the figure, however, that the impedance bandwidth greatly changed and worsened in the higher frequency band when L6 was 4.0 mm. This may have occurred because of the effect of the ground plane when L6 became 3.0 mm and when the gap between the branch strip and the ground plane became 0 mm. To design good dual-band for USB dongle antenna using L6 was set at 2.0 mm. [31]

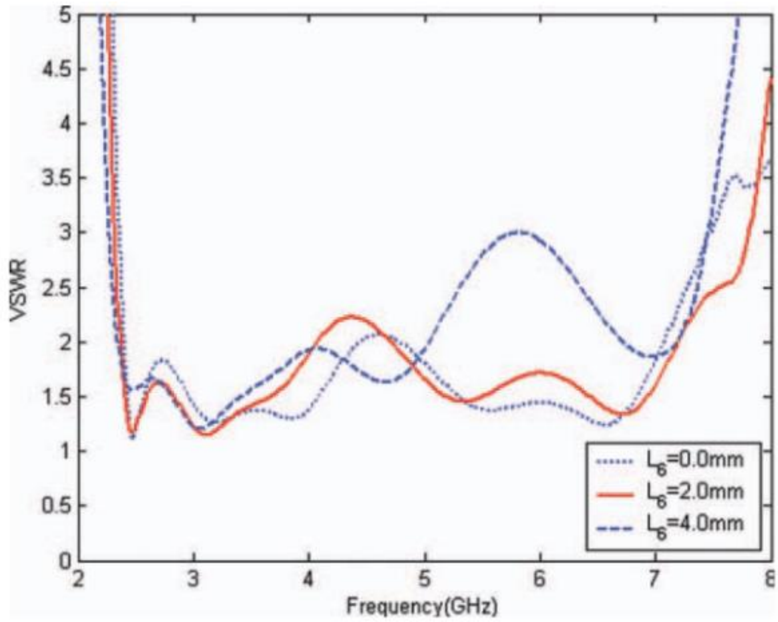


Figure 2. 19. Simulated VSWR of the proposed antenna with different values [31]

2.6 Conclusion

In this chapter we present an overview about micro-strip patch antenna to more understand its performance in wireless network which is used in several applications. Also, we define a dipole and a monopole antenna to obtain a omnidirectional antenna which is demanded in cell phone applications. Finally, we explained miniaturization techniques with reducing the size of the strips in order to use this technique for enhancing and miniaturized the patch antenna and to have a results that we can use it in USB dongle antenna.

Chapter III: Design and simulation

3.1 Introduction

With rapid development in mobile communication, several wireless systems integrated in a single portable device has become a major new trend. Thus, the great demands in antenna design include low-profile, lightweight, easy fabrication.

In this study, we designed a miniaturized monopole patch antenna with a lot of coupled branch strips gives us a dual band antenna was operate in (2.76Ghz–5.04Ghz) its for WLAN applications and connecting wifi, also we can use it in the applications of USB dongle antenna, and two other frequencies (3.14Ghz and 6.3Ghz) for other applications. Through proper selection of the dimensions of the coupled branch strips and suitable arrangement, the desired frequency characteristics of the antenna can be achieved. Details of the design and experimental results are presented and discussed as follows.

Finally, We will do some variation in the strips to know the importance of the strip's dimensions in the performance of the antenna, and we will try to enhance the performance of the MPA by changing the substrate properties.

3.2 Monopole patch antenna design

The proposed antenna is composed of monopole antenna with 3 branch strips and an L shape coupled branch strip on the bottom surface as shown in figure (3.1):

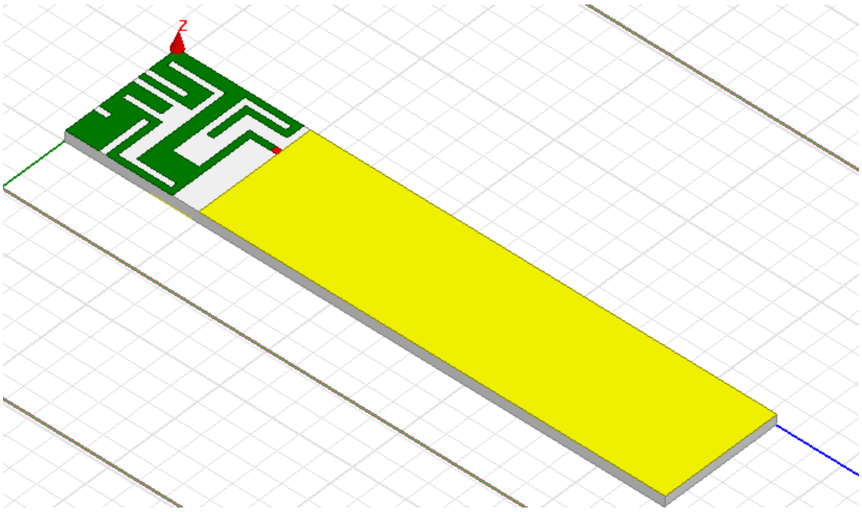


Figure 3. 1. The design of the miniaturized monopole patch antenna

This monopole patch antenna occupying an area of 10 *10 mm^2 which is printed on a low-cost FR4 substrate of 45*10 mm^2 and his thickness 0.8mm and a ground plane of 35 *10 mm^2

The tables below outline the geometry of the MPA:

L1	L2	L3	L4+L7	L5+L13
2	0.5	4.5	2.5	1
L6+L8+L16+L15	**L9**	**L11+L14**	**L12**	
3	4	3.5	4.5	

Table 3. 1. Dimentions of the lenghts of the patch

W1	W2+W3	W4+W10	W5+W7+W8+W9+W12	W6+W18
7	4	2.5	0.5	3
W11+W13	**W14+W16**	**W15**	**W17**	
1	2	8	1.5	

Table 3. 2. Dimensions of the widths of the patch

Lg1	Lg2	Lg3
1	3	2
W1g	**W2g**	**W3g**
8	6	2

Table 3. 3. Dimensions of the widths and lengths of the L shape patch

In figure 3.2 all geometry dimensions of the designed antenna are depicted in detail, Where the Upper view of the patch is shown in figure 3.2(a). and the figure 3.2(b) present the bottom view with the L shape strip.

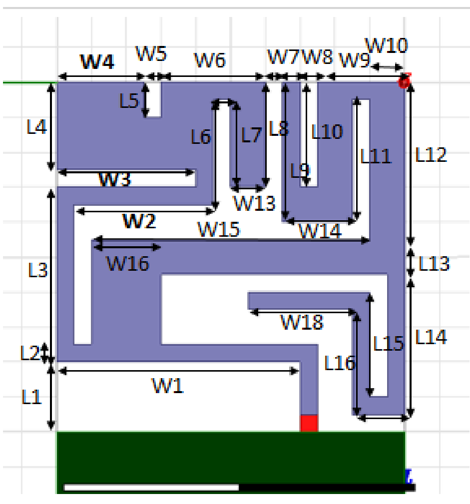


Figure (a)

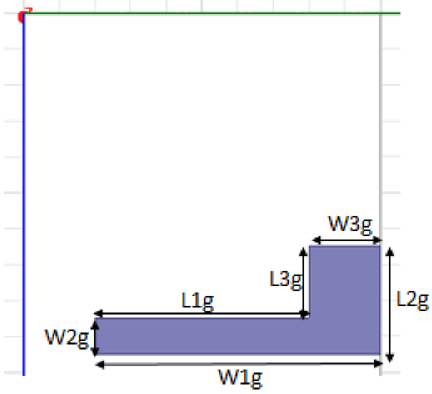


Figure (b)

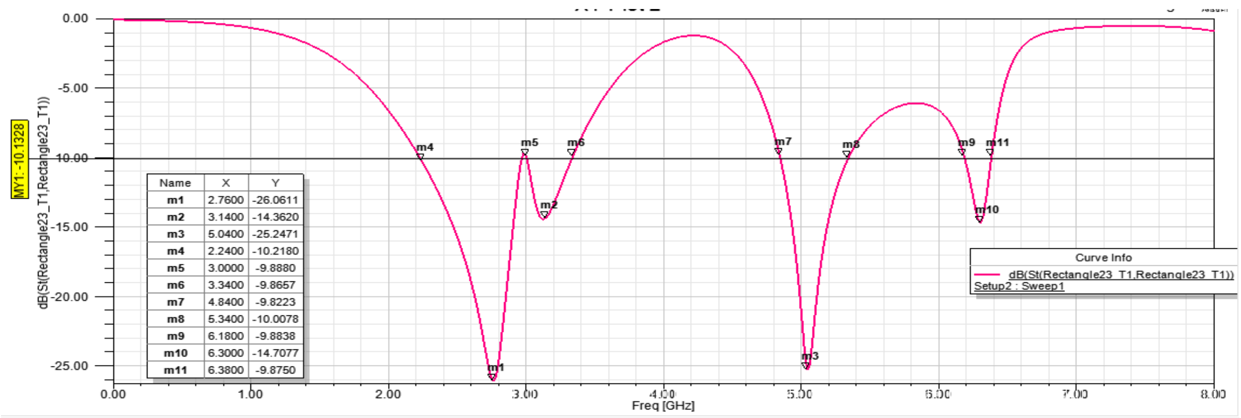
Figure 3. 2. (a) front view of the geometry with dimensions of the patch antenna design, (b) back view of the geometry with dimensions for the ground design

3.3 The results

PART ONE

Results of the miniaturized monopole antenna with coupled strips

A. Return Loss



Name	X	Y
m1	2.7600	-26.0611
m2	3.1400	-14.3620
m3	5.0400	-25.2471
m4	2.2400	-10.2180
m5	3.0000	-9.8880
m6	3.3400	-9.8657
m7	4.8400	-9.8223
m8	5.3400	-10.0078
m9	6.1800	-9.8838
m10	6.3000	-14.7077
m11	6.3800	-9.8750

Figure 3. 3. Return Loss of the miniaturized monopole patch antenna with coupled branch strips

- A bandwidth of 9.42% between 2.24Ghz and 3Ghz with a return loss of -26.06Db of the frequency 2.76Ghz.
- Second bandwidth of 10.82% between 3Ghz and 3.34Ghz with a return loss -14.36dB of the frequency 3.14Ghz.
- We can see that this antenna resonates at frequency of 5.04Ghz in the bandwidth of
- 10% with a return loss of -25.24dB.
- Also, this antenna shows resonance at frequency of 6.3Ghz in the bandwidth of
- 3.17% with a return loss of -14.70dB.

B. Smith chart

The figure 3.4 describes the change in impedance with frequency. It shows that the four resonant frequencies is well matched.

Name	Freq	Ang	Mag	RX
m1	[illegible]	[illegible]	[illegible]	21.8601 - 0.6378i
m2	3.1200	-0.8019	0.9886	70.0905 - 85.3386i
m3	2.7200	0.0814	0.9991	639.2725 + 998.2587i
m4	3.2200	-1.4928	0.9993	1.9590 - 76.7095i

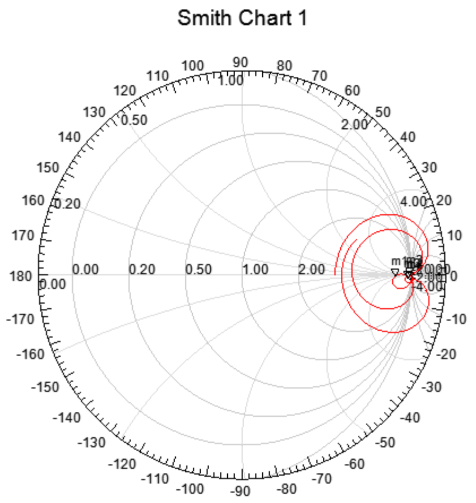
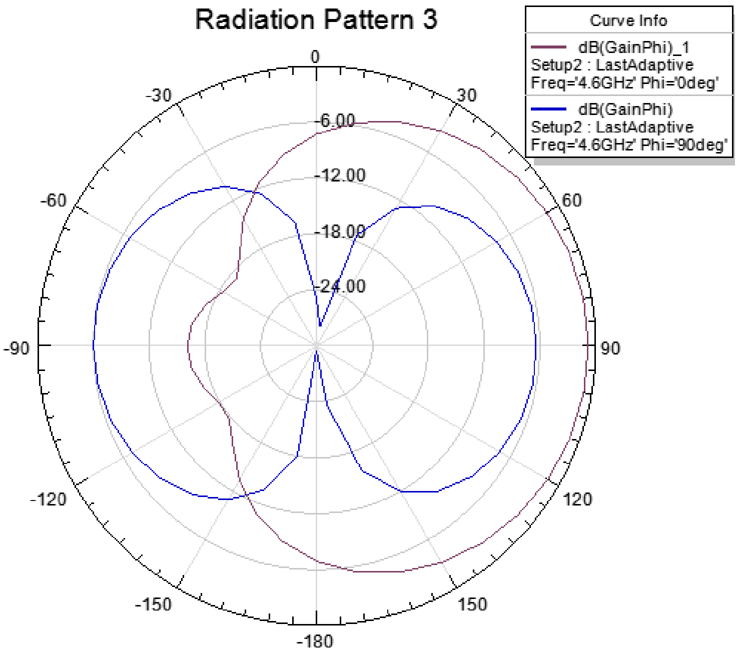


Figure 3. 4. Smith chart for the miniaturized monopole antenna

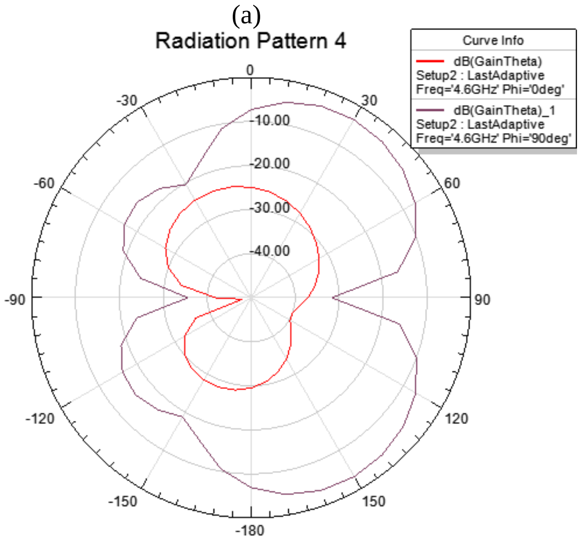
C. Radiation pattern

We've got Gain Theta to represent the E-plane when the Cross-polarization is at 0 deg and Co-polarization is at 90 deg.

Gain phi represent the H-plane when theCross- polarization is at 90 deg and Col-polarization is at 0 deg. As shown in Figure 3.5



(a)



(b)

Figure 3. 5. (a) GainPhi for φ = 0 and φ = 90 degrees at 4.6 GHz.
(b) GainTheta for φ = 0 and φ = 90 degrees at 4.6 GHz.

A. Total gain

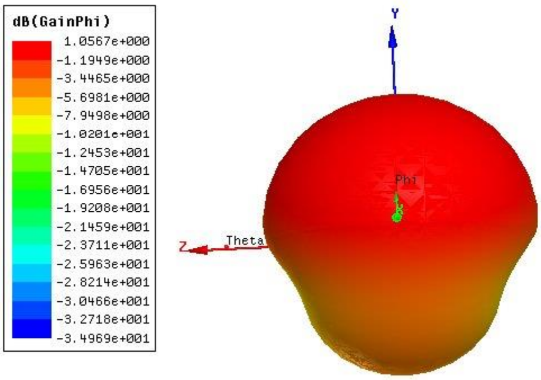


Figure 3. 6. The up side of the gain total of the miniaturized MPA

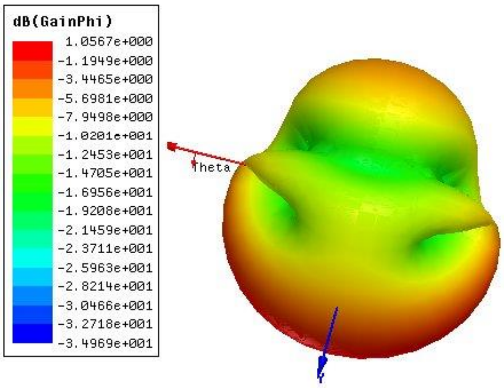


Figure 3. 7. The back side of the gain total of the miniaturized MPA

B. Effects of the strip Lengths and widths:

E.1) Width of parameter W18:

The figure 3.11 below shows the effect of variation in (W18). It indicates that the effect of parameter (W18) is generally on the low resonance frequency. When we increase the variable the resonance frequency decreases.

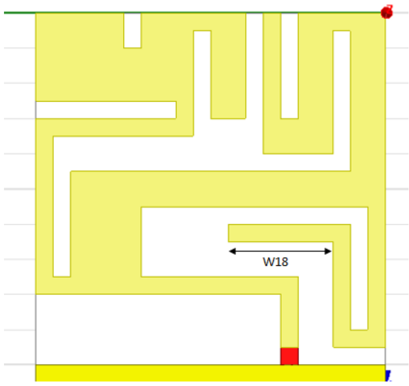


Figure 3. 8. A miniaturized monopole antenna with strip variation width W18

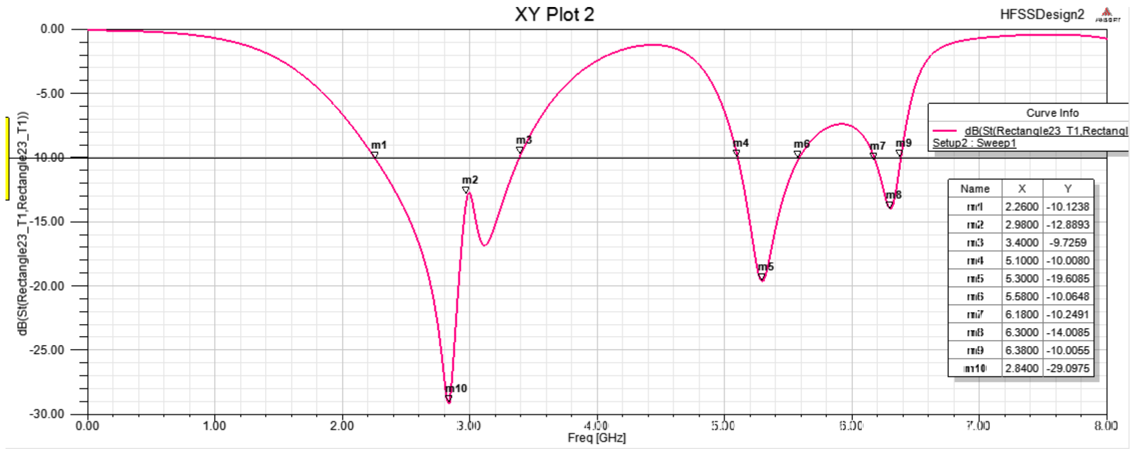


Figure 3. 9. Return loss of the effect variation W18=2

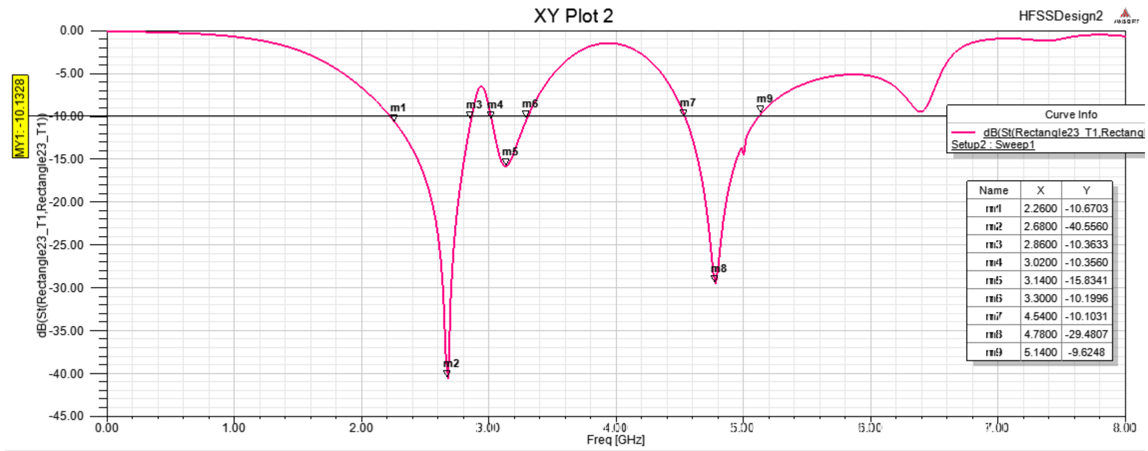


Figure 3. 10. Return loss of the effect variation W18=4

W18	F(Ghz)	BW%	S11(dB)	F(Ghz)	BW%	S11(dB)	F(Ghz)	BW%	S11(dB)	F(Ghz)	BW %	S11(dB)
2mm	2.68	22.38 %	-40.55	3.14	8.91%	-15.83	4.78	12.55 %	-29.48	6.4	0	-10.95
3mm	2.76	9.42%	-26.06	3.14	10.82 %	-14.36	3.04	10%	-25.24	6.4	3.17 %	-14.7
4mm	2.68	22.38 %	-40.55	3.14	8.91%	-15.83	4.78	12.55 %	-29.48	6.4	0	-10.95

Table 3. 4. Results of the variation in W18

E.2) Length of parameter L8:

The figure 3.11 below shows the effect of variation in (L8). When we increase the variable the resonance frequency decreases.

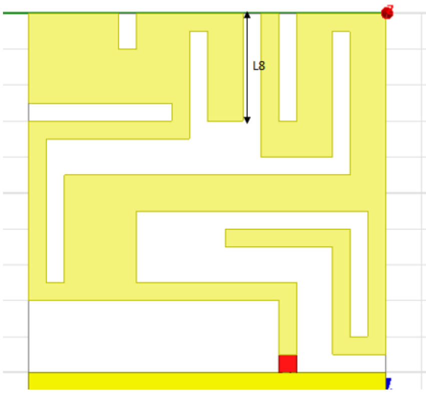


Figure 3. 11. A miniaturized monopole antenna with strip variation length L8

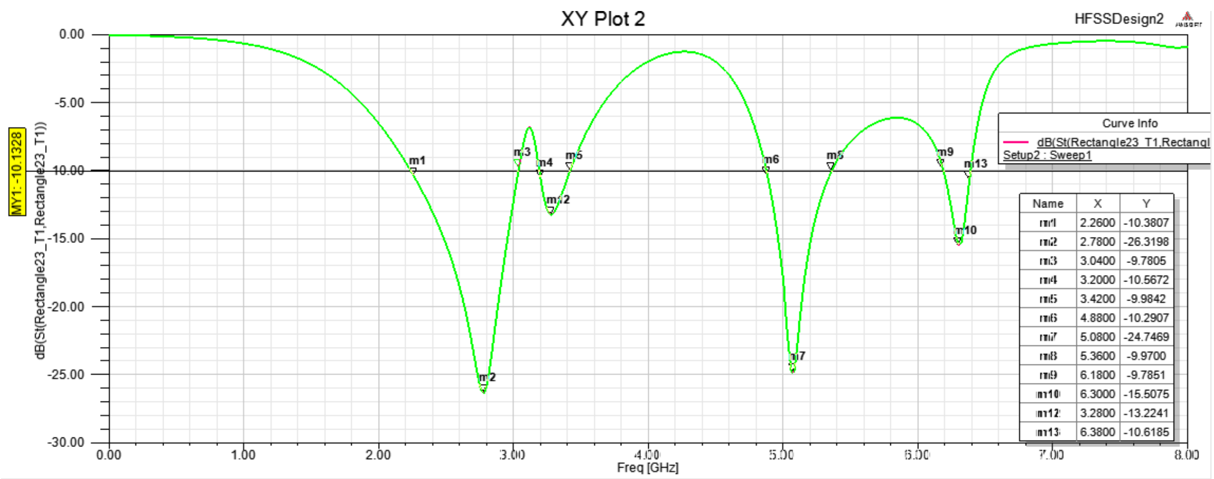


Figure 3. 12. Return loss of the effect variation in L8=2

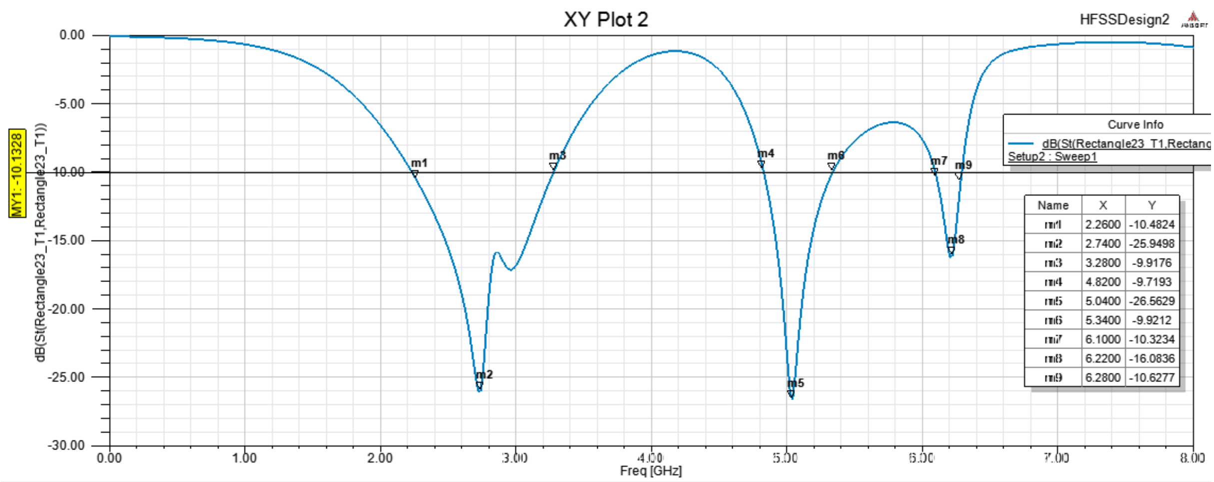


Figure 3. 13. Return loss of the effect variation L8=4

L8	F(Ghz)	BW %	S11(dB)	F(Ghz)	BW %	S11(dB)	F(Ghz)	BW %	S11(dB)	F(Ghz)	BW %	S11(dB)
2mm	2.78	28.05 %	-26.31	3.28	6.7%	-13.22	5.08	9.4%	-24.74	6.3	3.1%	-15.05
3mm	2.76	9.42 %	-26.06	3.14	10.82 %	-14.36	5.04	10%	-25.24	6.3	3.17 %	-14.7
4mm	2.74	37.22 %	-25.94	3	0	-15.4	5.04	10.3 %	-26.56	6.22	2.9%	-16.08

Table 3. 5. Results of the variation in L8

E.3) Width of parameter W3g:

The figure (3.14) below shows the effect of variation in (W3g)

When we increase the variable the resonance frequency decreases.

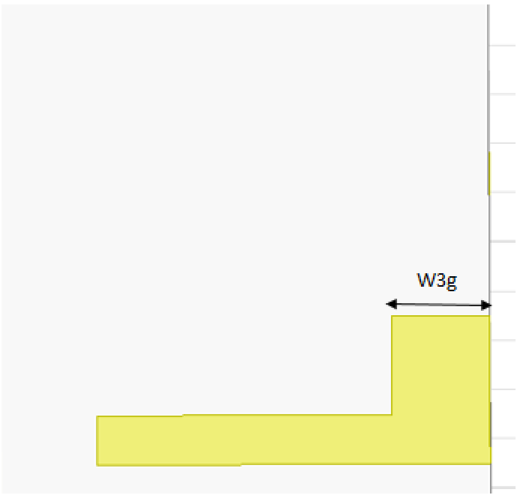


Figure 3. 14. A miniaturized monopole antenna with strip variation width (W3g)

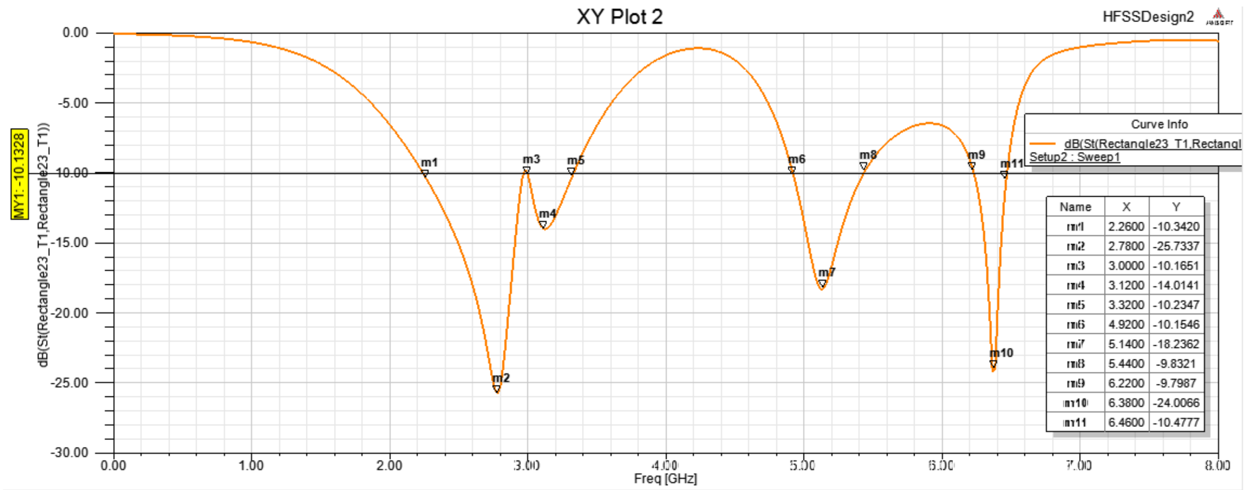


Figure 3. 15. Return loss of the effect variation W3g=1

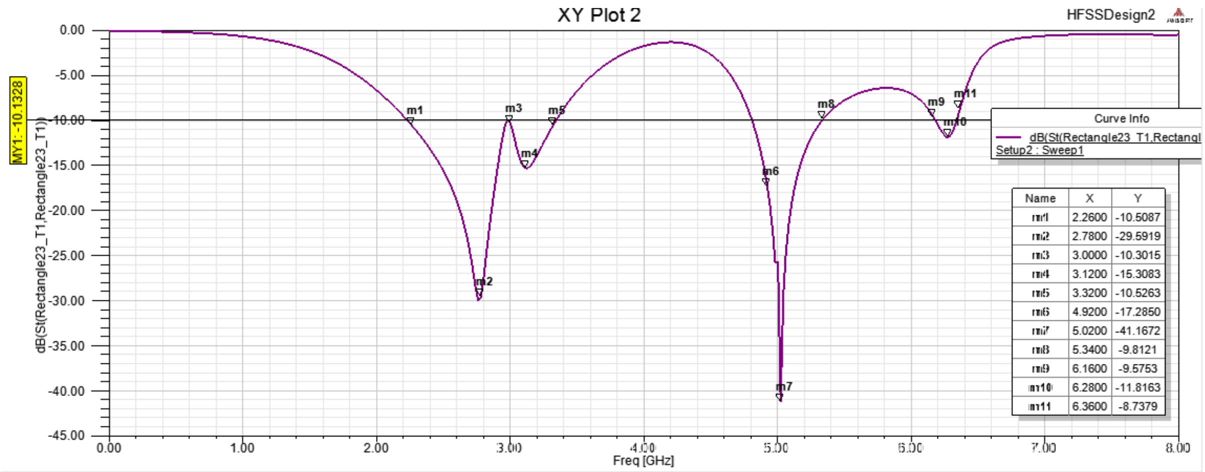


Figure 3. 16. Return loss of the effect variation W3g=3

W3g	F(Ghz)	BW %	S11(dB)	F(Ghz)	BW %	S11(dB)	F(Ghz)	BW %	S11(dB)	F(Ghz)	BW %	S11(dB)
1mm	2.78	8.6%	-25.73	3.12	10.25 %	-14.01	5.14	10.11 %	-18.23	6.38	3.76 %	-24
2mm	2.76	9.42 %	-26.06	3.14	10.82 %	-14.36	5.04	10%	-25.24	6.3	3.17 %	-14.7
3mm	2.78	8.6%	-29.6	3.12	10.25 %	-15.3	5.02	10.75 %	-41.16	6.28	3.18 %	-11.81

Table 3. 6. Results of the variation in W3g

PART TWO

Enhancing the performance of the MPA by changing the material of the substrate

The dielectric constant influences the geometry of the antenna (Width and Length) as well as in the frequency. That's why we will compare between the FR4 material with dielectric constant 4.4 and the Rogers RO4350 material with a 3.66 dielectric constant to know who gives the best results.

We have the results of the FR4 epoxy now we will simulate with the Rogers RO4350:

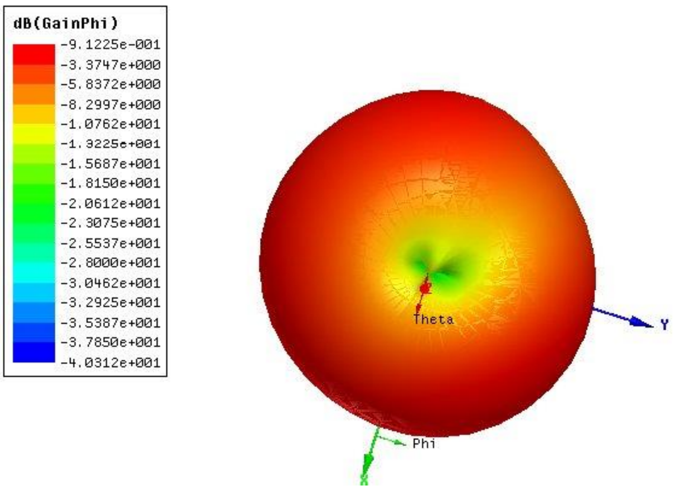


Figure 3. 17. The upside of the gain total of the miniaturized MPA with substrate Rogers 4530

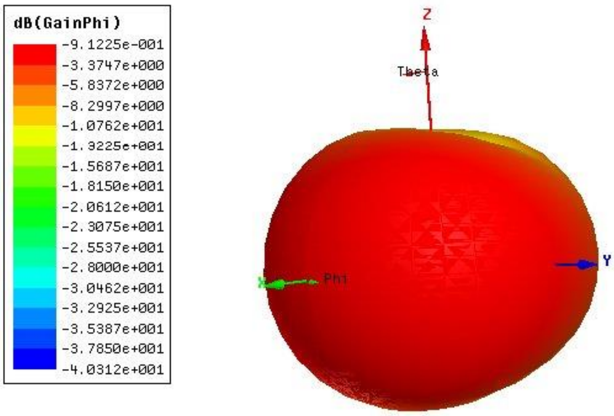


Figure 3. 18. The back side of the gain total of the miniaturized MPA with substrate Rogers 4530

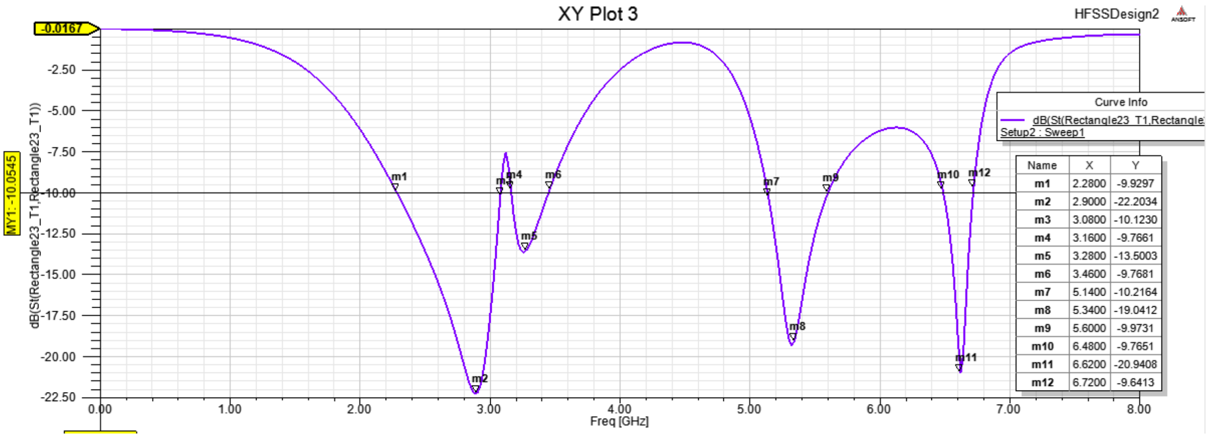


Figure 3. 19. Return Loss of the miniaturized monopole antenna with the subtract Rogers RO4350

Material of subtract	**F(Ghz)**	**BW %**	**S11(dB)**	**F(Ghz)**	**BW %**	**S11(dB)**	**F(Ghz)**	**BW %**	**S11(dB)**	**F(Ghz)**	**BW %**	**S11(dB)**
Rogers RO4350	2.9	27.58 %	-22.2	3.28	9.4%	-13.5	5.34	8.67 %	-19.04	6.62	3.62 %	-20.94
FR4 epoxy	2.76	9.42 %	-26.06	3.14	10.82 %	-14.36	5.04	10%	-25.24	6.3	3.17 %	-14.7

Table 3. 7. Results of subtract Rogers RO4350 and FR4 epoxy

3.4 Conclusion

In this chapter we have presented the designed and simulated monopole patch antenna with coupled branch strips for the USB Dongle using.

Firstly, when we designed the proposed miniaturized antenna, we found four frequencies, we obtained a dual frequency that operated in 2.76Ghz and 5.04Ghz respectively, it can be suitable for WLAN applications and properly for a WiFi connection. two other frequency pics at 3.14Ghz and 6.3Ghz.

In the second stage, by making changes in width and length of some strips antenna parameters, we have observed that when we reduced the size of those strips we found good results in the Return Loss, so in frequencies and amplitude, of the proposed monopole patch antenna.

Finally, we have changed the material type of the antenna substrate in order to enhance the performance of the proposed antenna, and we have obtained an enhancement especially in the frequency and in the gain pattern results.

The obtained results make the proposed antenna suitable for using as an USB Dongle antenna for the WLAN network connections.

General conclusion and Perspectives

General conclusion

Rapid development has increased the need for the cost effective and several wireless technologies for the same devices. Therefore, we started our project by defining WPAN, WLAN and WMAN found in Bluetooth and WiFi in our mobile phones.

For this purpose, we present in this project the conception design and simulation of a monopole patch antenna with the technique coupled branch strips in the patch that occupying an area of 10x10mm^2 which is printed on a low-cost FR4 substrate of 45x10mm^2 and his thickness 0.8mm and a ground plane of 35x10mm^2. Then an effective study of the size parameters effect on antenna results such return loss and gain are presented.

for the first design antenna we obtain four frequencies, where to frequencies occur a dual band capability of the proposed antenna operates in 2.76Ghz and 5.04Ghz, this bands allow the using of the proposed antenna to be used as USB dongle for connecting to WLAN networks such Wi-Fi connection.

Then, we make a study on some antenna design parameters such as the width and length of selected strips of the patch to observe his effects in the antenna properties results. We observe that when we reduced the strips we found good results in the Return Loss of the patch antenna better than the first results.

We conclude our study by changing the subtract material from the FR-4 to ROGERS 4350 for the purpose to further enhance the performance of the proposed patch antenna, and we found enhancement in the results especially in the frequencies amplitudes and in the gain pattern.

Perspectives

Through the work on this project some perspectives are observed:

- The investigation with different coupled branch strips in the patch and the ground.

- design a new antenna with different substrate properties further to enhance antenna properties and make it more suitable for other frequency Bands.

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