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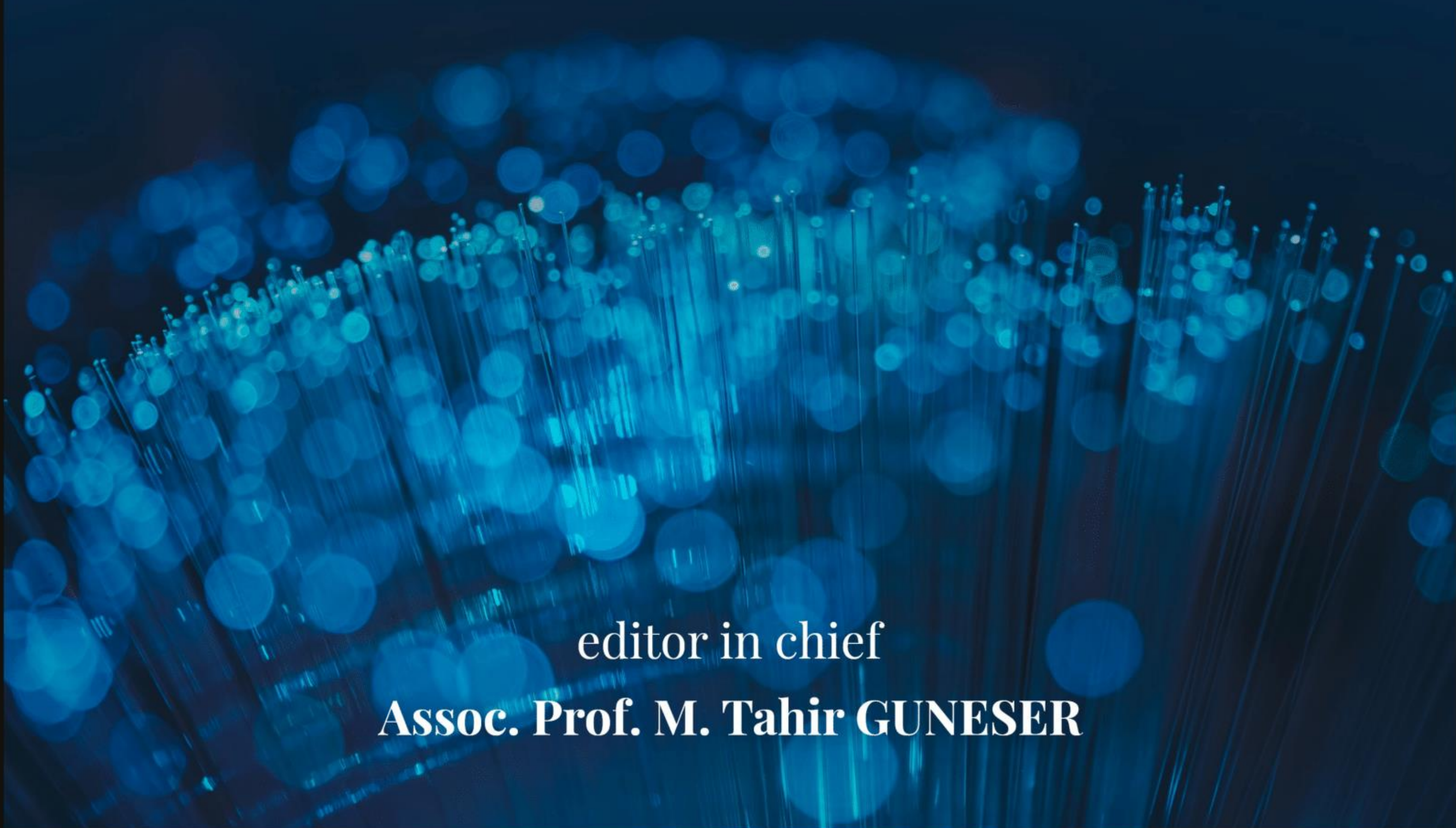
JOMCOM

Journal of Millimeterwave Communication, Optimization and Modelling



editor in chief

Assoc. Prof. M. Tahir GUNESER

CONTENT

About the Journal

Journal of Millimeterwave Communication, Optimization and Modelling (JOMCOM) is an international on-line and refereed journal published 2 times a year (June and December) in English. Journal of Millimeterwave Communication, Optimization and Modelling (JOMCOM) published its first issue in 2021 and has been publishing since 2021. Manuscripts in JOMCOM Journal reviewed of at least 2 referees among the referees who have at least doctorate level in their field.

Journal of Millimeterwave Communication, Optimization and Modelling (JOMCOM) is an international online journal that is published 2 times in a year in English.

The purpose of JOMCOM is publishing the scientific research in various fields of communication.

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Aims & Scope

Communication Technologies: Journal of Millimeter-wave Communication, Optimization and Modelling (JOMCOM) publishes original research and review articles in Communication Technologies, Innovative Technologies, and Systems in the broad field of Information-Communication Technology. Purpose of JOMCOM; To create value in the field by publishing original studies that will contribute to the literature in wireless communication sciences and be a resource for academia and industrial application whole over the world. Besides, JOMCOM aims to bring the valuable work of researchers working in Communication studies to a broader audience at home and abroad. Readership of JOMCOM; valuable representatives of the wireless communication area, especially those who do academic studies in it, and those who do academic studies about modelling and system design and other interested parties. Since JOMCOM will appeal to a broader audience in article submissions, it prioritizes studies prepared in English.

Optimization and Modelling: Journal of Millimeter-wave Communication, Optimization and Modelling (JOMCOM), within the scope of Wireless Communication Sciences, publishes articles on communication theory and techniques, systems and networks, applications, development and regulatory policies, standards, and management techniques. It also reports experiences and experiments, best practices and solutions, lessons learned, and case studies. Additional studies on System Design, Modelling and Optimization. Subject areas of interest covered in the journal include the following but are not limited to:

5G-6G Technologies

Circuits for Optical Communication Systems

Antenna Design

Communication Design Materials

Fiber Optic Communication

Innovative Designs for Communications

Integrated Circuits for Communications

Optimization Methods on Engineering

Realization of Antenna Systems

Realization of Microwave, Radar, and Sonar Systems

RF Circuits

System Design

Visible Light Communication

Wireless Communication

Designing a Heating and Cooling System in the Ground

Received: 12 April 2022; Accepted:13 June 2022 *Research Article*

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***Abstract*—The primary objective of this research is to describe and validate an essential ground heating and cooling system design. This experiment established that this system could sustain a room temp of 25°C. Applications/uniqueness: The breakthrough lies in utilizing the earth's constant ground temperatures as a refrigerant in a cooling system that does not rely on a heat pump to provide cooling and heating. This system can be tweaked or enhanced to match an individual's unique needs. This technique can be utilized in businesses wherever air cooling is not permitted to replace air coolers.**

***Keywords*—cooling system, heat source, ground temperature, air cooler, temperature**

I. INTRODUCTION

Earth-linked heat transfer generators are a type of underground heat exchanger capable of collecting and dispersing the temperature of the ground. The ground's temperature is practically constant underground, making it an excellent location for heating or cooling air or fluid in the home, agriculture, or industry. This document discusses our ground energy demonstration in detail and alternative energy sources that could be employed in place of existing heating and cooling systems[1]. Ground energy is a huge source of free, or almost free, energy from the ground. The ground air-cooling method is often deemed to be the highly energy-efficient type of air-cooling system offered today. [2] Additionally, an evaporative cooler and air-cooling system can be used in conjunction with a Ground Combined Heat Exchanger. It is a far more affordable alternative that also consumes less energy. It is a form of renewable energy in which heat is transported from the ground or earth to the surrounding air (Full Of Atmosphere air in the neutral state). A critical truth that everyone is aware of is that while the temperature of the surrounding air varies with the seasons, the earth's temperature remains constant throughout the year, regardless of where you are globally (roughly around 200-250C). A more sensible option would be to link the heat sink to the ground, enabling the use of a ground-coupled heat exchanger to maintain a constant temperature with the heat sink (Earth) (ambient air). In contrast to variable ambient air, most land-based systems maintain a constant temperature for both the land and the earth. It minimizes power consumption, as most systems need energy solely to maintain a steady temperature throughout the year [5]. While ambient air consumption varies according to operation load, it also exhibits an inverse connection with power usage. As is the case throughout the year, summer increases the workload because of the additional energy required to transfer heat from a building to a cooled already and hot heat source.

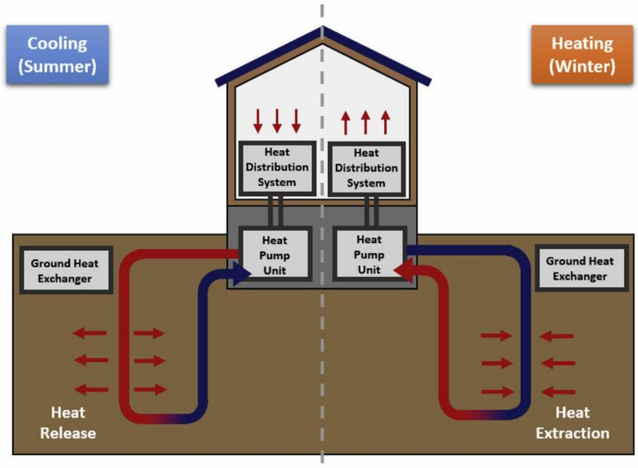

Fig. 1. Graph of Ground Heating coupled with Cooling Usage

The workload and energy consumption are reduced in the winter due to the lower temperature of the heat sink. When considering electricity consumption, using the earth or ground as a heat sink is a more cost-effective choice than ambient air. The earth's temperature is limited in its expansion and contraction throughout the year due to the same temperature of the earth and water 4-5 feet beneath the surface. This feature allows the system to function well in virtually any place at any time of year. Hot air is circulated through a ground heat pump when ground energy systems create heat. They cool by using an air-to-liquid exchange to circulate warm air. The bulk of ground-based chilling systems work by transferring heat from the surface to a 20-foot-deep (6-meter) location many feet below ground. Water is heated and absorbed into the ground as it travels under the ground's surface via a ground loop. After that, the water is allowed to ascend to the surface, where it cools and helps keep the surface temperature stable. Earth systems can frequently lower even the most intense heat sources due to the density of the ground under them. Ground energy is suited for green data centres, other industrial settings, and even households, as it is sourced from the earth's core heat. Ground cooling uses almost no energy, emits no carbon, and relies on the water already existing in the confined environment.

II. OPERATIONAL PRINCIPLES

The earth cooling and heating system are based on the notion that the ground maintains a continuous temp during the year at a depth below the earth's surface. The temperature usually is between 20 and 25 degrees Celsius, though this might fluctuate based on geological and geographical variables [3]. The soil's conductivity, thermal inertia, and a range of other parameters such as the soil's water holding capacity and depth determine the rate of heat transmission amongst the ground cooling and heating system and the earth [4]. While the efficiency of ground-source heat pumps and cooling systems may obtain up to 6 times the amount of heat energy consumed by electrical energy, evaporative air coolers and air-conditioning systems are less efficient, as they cannot extract this level of heat energy.

The system is comprised of the following components: an air stream (4), a water basin (2), cooling loops (3), a water drain (5), a fan (6), an ac superior motor (6), and High-Density Polyethylene Pipes pipelines (1). This operation entails extracting water from the reservoir (2) or tank (3) and transferring it to the cooling system through copper tube loops before cooling coils (5) in the cooling section. Following that, the cooling unit extracts or suctions hot air from the surrounding environment. It is composed of an outside shell, air leaks (4), capillary heat pipe coils or cooling coils (5), an excellent ac motor (6), and a fan (6). Air is channelled from the heat exchanger inside the unit to the cooling water loop and then exits the unit. It does so by heating the water in the loop, forcing it to rise. As the water rises, it transfers its heat to the copper tubing outside the unit, which is then convectively transmitted to the outside air. After turning on the cool water, hot water is now being discharged from the cooling unit via High-Density Polyethylene Pipes.

(1) Down to the ocean's bottom, Extremes of temperature are more pronounced near the ground, as it absorbs half of the sunlight that the earth receives. As a result, temperatures at a depth of 4 to 5 feet stay relatively constant throughout the year, in contrast to temperatures above the surface, which are substantially lower. A network of High-Density Polyethylene Pipes has been installed over 600 feet below the earth's surface.

(2) Grounded looping conduct heat away from hot water and act as a heat sink, cooling or returning the water to its initial level. The cold water from the water cooler then streams through the High-Density Polyethylene Pipes (1) and into the water tank (2), where it is collected, and the cycle begins again, chilling the room. While soil contributes to winter heating, it can also be used as an inside heater due to its warmth.

III. EXPERIMENTAL METHODS

The purpose of this article is to layout and test ground-based heating than a cooling method for practicality. To precisely measure the effectiveness of this system, we use a standard bedroom measuring 12 feet on each side, ten feet tall, and 10 feet long. A room with a 1200 ft3 should be refilled with new air every hour, as estimated by multiplying the room's volume by the formula (room volume) divided by the number of times every hour that new air should be placed in the room 60 meters. A regular air adjustment per period for just a room is assessed to be 6 using the air exchange index. It suggests that the Cubic Feet Per Minute value for the 1200 ft3 room is 120. Following that, we need to determine the amount of cooling coil required for the stated room, which we determined using the following data: This machine can generate up to 120 cubic feet per minute of airflow. The water pump has a maximum pumping capacity of 0.23 kg/s, the outside air temp is 45°C, and the ideal room temp is 25°C. After that, the thermobarometer is used to analyze the particular volume and air moisture of air at the system's input and output, respectfully. We calculated these statistics and concluded that the system's entrance and departure are constantly enthalpies. These measurements were used to calculate the low humidity flowrate and the ground water mass flow rates. These data suggest that once each of these computations is complete, this system's cooling load be established. To determine the required surface area for convective heat transfer, we shall examine cooling coil sizing.

Flow rate of the air dry in mass volume

$$(Ma *) = V */V1Ma *$$
$$= 0.055/0.8 = 0.06875 Kg/s$$

Mass flow rate of condensate water

$$(Ma *) = V */V1Ma *$$
$$= 0.055/0.8 = 0.06875 Kg/s$$

$$Load\ of\ Cooling\ (Q *) = Ma * \times (h2 - h1) + (Mw * \times hw)$$
$$Q * = [0.062 \times (76.08 - 125.37)] + (0.00065 \times 102.85)$$
$$= 2.8 KW = 2.8 KJ/s$$

Cooling loop give vent to temp.

$$F1 = Q * /(M * \times Cp)$$
$$= Tin + F1$$
$$= 27 + 2.8/(0.25 \times 4.2)$$
$$= 29.6^{0}C$$

Let's apply the approach we used for calculating heat transfer for heat exchange below to measure cooling coils, which will provide us with the heating coils contact area that will be in touch with air for the proper cooling capacity.

TABLE I. FACTORS AND PRINCIPLES

S. No	Factors	Principles
1.	Thermal mass flow rate (M*), also referred to as cooling water volume flow rate	0.25 Kg/s
2.	The temperature of the Upstream Side	30 °C
3.	Detailed Temperature Capacity of Water (Cp)	4.5 KJ/Kg K
4.	The temperature of Heat exchanger Water	47 °C
5.	Heat content (hw = hf at 25ºC)	105.73 KJ/Kg

TABLE II.

Acreage	Air Gets In	Air Get Out
Particular Humidity (W)	W1 = 0.033	W2 = 0.025
Specialized Volume (V1)	0.8 m3/s (low Humidity)	
Relative Humidity (RH)	51%	100%
Air Temp. (T)	44 °C	26 °C
Heat content (h)	h1 = (1.006 × 45) + 0.033 × [(1.84 × 45)	
Air Capacity Stream Ratio (V*)	+ 2501] = 125.36 KJ/Kg	h2 = (1.006 × 25) + 0.025 × [(1.84 × 25) + 2501] = 76.09 KJ/Kg

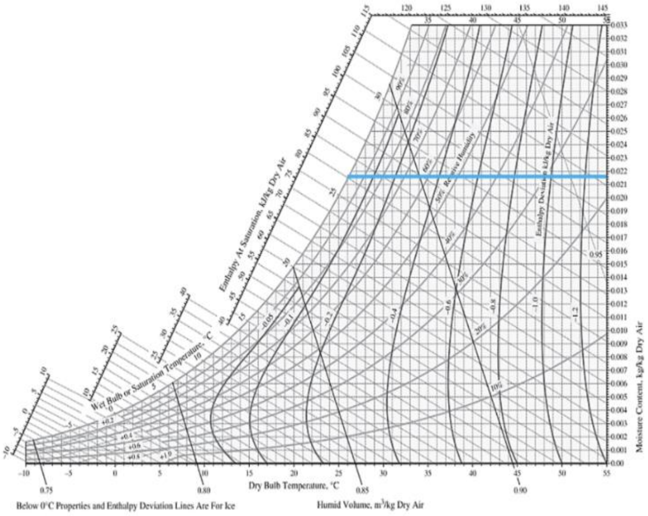

Fig. 2. Chart of Psychrometric

$$Q = h \times As \times (Ts - T\infty)$$

Where

Q = Heat created or cooling capacity

H= When copper is utilized as a method, it is the global heat transmit coefficient among air and water.

As =Convective heat spread occurs at a surface area. Ts = As's surface temperature

T = The high temperature of the water is symbolized by the letter.

$$2900 = 13.15 \times As \times (46 - 23)$$

$$As = 2900/266 = 11.01\, m2 = 119.12\, ft2$$

If any cooling loop has a 12 ft2 effective face area, the cooling element will require 9.89 or approximately 10 coils of the correct features stacked together to create a 119.04 ft2 effective surface area

IV. CONCLUSION

Based on the data, we determined that this system could maintain an appropriate room temperature of 25°C using water as a refrigerant for a cooling load of a room. However, there has been a major rise in the treatment of copper in the construction of cooling coils, making this system more expensive to build. This technology is more expensive than a traditional air cooler, but it uses substantially less energy and is more durable. Additives like nanoparticles could improve the effectiveness of this system in the future, and the cooling and heating might also utilize them in businesses where air coolers and the air coolers are not feasible to build.

CONTRUBITION OF THE AUTHORS

The contributions of the authors to the article are equal.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

STATEMENT OF RESEARCH AND PUBLICATION ETHICS

Research and publication ethics were observed in this study

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A Broadband Millimeter Wave Microstrip Antenna for 5G Communication Systems

Received: 13 April 2022; Accepted: 13 June 2022 **Research Article**

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Abstract— **Every day, more and more people throughout the globe own portable wireless gadgets. Larger data transfers and faster data speeds have been necessitated by this growth. In recent years, millimeter wave frequencies have been used for 5th Generation (5G) communication networks throughout the globe because of this demand. Studies have made use of the millimeter wave frequency, which has lately garnered the attention of microstrip antenna designers. Broad frequency coverage and fast data transmission rates are two of millimeter wave microstrip antennas' most significant advantages. High data transmission speeds will be possible because to this advantage, which will allow a large number of users to connect at once.**

Keywords— broadband, millimeter wave, microstrip antenna, 5G, communication systems

I. Introduction

Today, wireless communication tools have become an indispensable daily necessity for people. People can choose and use different types of mobile services according to their needs. In parallel with developing technology and needs, expectations from wireless systems are increasing. While the number of users on the previously developed wireless networks was limited to a certain number, the user and usage area increased over time. Over time, automatic aircraft, machines, autonomous transportation vehicles, smart networks, smart homes, cities, mobile services are desired to be turned into remotely controllable systems. In addition, low cost, high data capacity and high data transfer rate are expected from these wireless systems.

The foundations of wireless communication systems date back to the 1980s. The 1st generation communication system was named AMPS (Advanced Mobile Phone Service) in 1983. With the 2nd Generation (2G) communication system, the transition from the Analog system to the Digital system was achieved in 1997. After 1999, 3rd Generation (3G) standards were announced by ITU (International Telecommunication Union). With the 3rd Generation communication system using 5 MHz bandwidth, the transition from a voice-centered system to a data-centered system has been achieved. As of 2013, WIMAX (Worldwide Inoperability For Microwave) and LTE (Long Term Evolution) systems have been developed. These systems include high speed data and voice transfer feature. These systems, which are similar to each other, offer a bandwidth of 20 MHz. LTE and WIMAX standards, which are two different 4G technologies developed, were completed in 2011 and are used by networks [1].

Today, the interest of portable wireless system developers has turned towards the wireless communication technology called 5G technology. The expectations that 5G systems must meet are much higher speed, greater multi-data transfer. More bandwidth is needed for this. Before 5G systems, bandwidths below 6 GHz were used [2]. Due to the limited bandwidth here, frequency bands above 6 GHz have been defined by ITU (International Telecommunication Union). With the bandwidth it provides within these bands, the millimeter wave (mm wave) bandwidth is very attractive. A millimeter wave bandwidth of 24 GHz and above has been deemed suitable for 5G systems [3].

II. 5TH Generation (5G) Systems

5G technology is not just an advanced version of broadband networks. This technology comes with possibilities that can serve in many branches. Thanks to this newly developed technology, it will be possible for users to stay connected to networks with high reliability and low latency in public transportation vehicles such as high-speed trains in areas with high mobility. In addition, 5G technology comes with many advantages such as more data capacity, lower data latency, more mobility and data reliability [4]. The reduction in energy consumption offered by 5G technology to telecom technology will be one of the most important contributions of 5G technology. In addition, for the use of increasingly widespread software-based network services, 5G technology will provide very important services in this sector thanks to data security and speed [5].

5G can be named as a new type of network designed to connect almost all devices. We can give examples of machines, transportation vehicles, generations and many vehicles.

Fig. 1. Frequency ranges allocated by country and targeted for operation: dark lines are licensed light lines unlicensed bands [9].

In addition, 5G communication technology aims to provide ultra-low latency, much higher data rates, security, network capacity width and the experience of connecting a much larger number of users to the network at the same time [6].

With the development of 5G technology, the coverage areas will expand, and the waiting times for users will be shortened thanks to the increased data transfer rate. In this way, increasing internet demands will be met much more quickly. 5G will help to provide innovative usage services in many areas such as remote control in the industrial field, healthcare, agricultural technologies [7].

It is recommended that WRC-19 (agenda item 1.13) support the work in the 24.5–27.5 GHz and 37.0–43.5 GHz bands and that the technical conditions for 5G be made suitable. In Figure 1, the frequency ranges allocated by countries and targeted to work as of December 2020 are shown. Generally speaking, countries work in the 24-30 GHz band for 5G technology. Considering that the investments will increase at these frequencies, the studies to be carried out in these intervals are gaining value day by day [8].

III. Millimeter Wave Technology

Requirements such as very high data transfer rates, low bit error rate, fast video and audio streaming, and much less interference from sound are expected from wireless systems that have grown with great momentum in recent years. The carrier spectrum frequency, which varies in the 700 MHz and 2.6 GHz bands, is insufficient for high quality data transfer and low delay times, which are the requirements of today's communication systems [10]. With the increase in the number of users around the world and the increasing number of mobile phones, with the transition to smart phones and tablets, the average data transfer rates and the need for new spectrums have led to new searches to increase system capacities [11]. With the 5G vision that has been developing since 2018, targets such as data rate at multigigabit per second, reduction of delay times below 1 ms, capacity increase in the amount of devices falling into a certain area have been the source of interest for many researches in this field [12]. Interest in carrier frequencies above 6 GHz is increasing day by day. Although not all of these needs can be met at the same time, some of the needs should be met to a certain extent and a systematic development should be allowed. Research and development activities have started to make 5G millimeter wave frequencies ready for use by 2020. Along with IMT-2020, the requirements for 5G networks, devices and services have been published by the ITU [2].

Looking at recent history, mobile communication is one of the best technology innovations. Mobile communication has become indispensable thanks to the development of technological tools and the relationship between them. Together with portable mobile data provider devices such as smart phones, e-books, netbooks, it has become an important part of life for five billion people and continues to grow with an unprecedented development [13].

The bandwidth needed to meet the requirements of 5G systems is higher. Since the spectrum width below 6 GHz is not sufficient for 5G systems, frequencies above 6Ghz are shown as candidate frequency bands for 5G systems by ITU. Millimeter waveband has been one of the most attractive candidates with the unlicensed broadband range it provides. The wavelength of the millimeter wave frequency is approximately between 1 mm and 10 mm. Millimeter-wave rays have wavelengths that are smaller than microwave rays and larger than x-rays and infrared rays.

The spectrum region of millimeter waves corresponds to the frequency range of 30 to 300 GHz. The high frequency and propagation patterns of millimeter waves have made them attractive for radar and communication systems [4].

One of the factors to be considered in the millimeter wave frequency band is atmospheric factors. Effects such as fog, rain, oxygen absorption and water vapor can cause weakening of the signals. It can also affect polarization in signals and cause depolarization or multidirectional propagation. The variation of millimeter wave signals between 1 and 1000 GHz according to moist air and dry air is seen in Figure 2 depending on the frequency. At distances up to 1 km, the atmosphere effect can be neglected as it is below 0.5 dB up to 50 GHz. While the effect of oxygen absorption increases between 50 and 70 GHz, it increases at 60 GHz and reaches a maximum value of 15dB. Adverse weather conditions and oxygen absorption have little effect on millimeter wave couplings at distances up to about 100 m [14].

IV. Microstrip Antennas

The foundations of microstrip antennas date back to the 1950s. The first microstrip antenna was designed by Deschamps in 1953. Guttom and Bassiniot produced a patented flat microstrip antenna in 1955. Munson worked on microstrip antennas in 1974 and designed the first ratic Microstrip antenna. Howell worked on basic rectangular and circular microstrip antennas in 1975 and the first circular and rectangular microstrip antennas were designed by Howell in 1975. Microstrip patch antennas are basically placed on a dielectric base. It consists of a radiant metal patch on one surface and an earthen ground on the other. The radiating surface can be in strip, rectangular, triangular, circular and other geometric forms. Microstrip antennas are inexpensive components with their simple physical geometry. The metal patch can be made of conductive material, usually silver, copper or gold. Microstrip antennas were initially used in applications such as airplanes, space shuttles, satellites and missiles. Following this, the need for smaller profile microstrip antennas in commercial and institutional applications such as wireless communication has increased day by day. Especially the need for commercial areas has increased the interest in microstrip antennas. This need has brought with it many scientific studies on microstrip antennas. When their small structures are integrated into planar and non-planar surfaces, their robust structure is one of the most important advantages. They are easy to manufacture thanks to their simple structure. It is possible to obtain a versatile structure in terms of polarization, radiation pattern and impedance when the ideal mode radiant structure is designed with various geometric combinations on the dielectric material.

In recent years, with the increasing interest and need for the 5G system, millimeter wave frequencies have been focused on. With these studies, the tendency towards thin substrates and lower dielectric coefficients in substrate selection has increased. The production and design of microstrip antennas, which are getting smaller and smaller, becomes more difficult in terms of cost and production due to sensitive substrate material and very small designs.

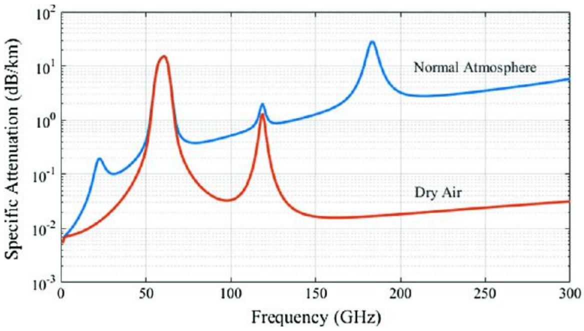

Fig. 2. Attenuation graph of millimeter wave signals compared to dry and humid air in standard conditions.

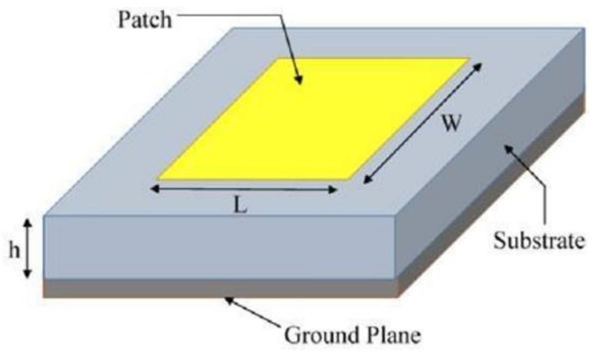

Fig. 3. Microstrip antenna structure.

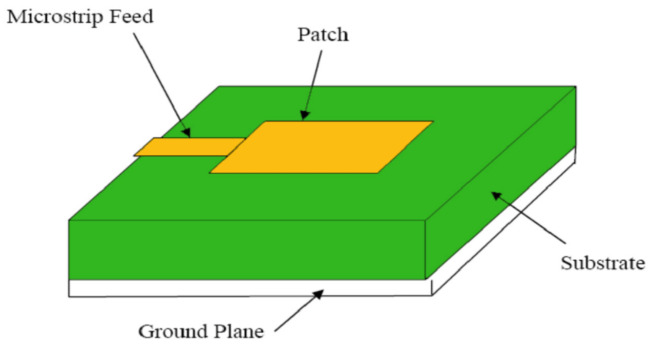

Fig. 4. Microstrip planar line-shaped feeding.

As seen in Figure 3, microstrip antennas are composed of a thin substrate material with a low dielectric coefficient, a conductive patch radiating on one surface of this material, and a ground plane on the other surface of the material.

Basically, antenna size criteria,

- Metal patch thickness $t \ll \lambda_o$
- Substrate thickness, patch-soil length $h \ll \lambda_o$, $0.003\ \lambda_o \leqslant h \leqslant 0.05\ \lambda_o$
- L patch length $\lambda_o/3 < L < \lambda_o/2$
- The dielectric material constant is expressed as ε_r $2.2 \leqslant \varepsilon_r \leqslant 12$.

In microstrip antennas, radiation is generally provided by electric fields called fringing from the ground plane and patch edges. For this reason, the designed patch and ground plane greatly affect the antenna performance. In addition, the dielectric coefficient and quality of the selected substrate material are also important. As the dielectric constant approaches 2,2, the losses in the electric fields will decrease and the performance will increase [15].

Microstrip antennas have several advantages. Their low weight and volume expands their usage areas. In addition, thanks to their thin profile, they provide ease of integration in vehicles in the automotive and defense sectors. It is advantageous in terms of production cost and can be produced easily. They can be easily integrated into microwave circuits. Such advantages have made the field of microstrip antennas attractive to scientists in terms of study area [16].

A. *Microstrip Antenna Feed Types*

While designing a microstrip antenna, the most suitable feeding technique and circuit for the designed antenna should be designed accordingly. The feeding mechanism has an important value on the working conditions of the antenna. Microstrip antennas are commonly fed by four different feeding techniques. These are microstrip planar line feed, coaxial feed, aperture coupled feed, and proximity coupled feed.

1) Microstrip planar line-shaped feeding: As seen in Figure 4, the most preferred feeding method of microstrip antennas is the microstrip planar line shaped feeding type. The patch line and the supply line are positioned on the same plane. This provides convenience in terms of production. In microstrip feed, it consists of a sliver line whose width adjacent to the patch is much smaller than the patch width. The microstrip line is very easy to manufacture, adjust and design the strip according to the antenna. As the substrate thickness increases, the surface thickness and unwanted radiation may increase, which can reduce the bandwidth by approximately 5% [17].

2) Coaxial supply: As can be seen in Figure 5, a coaxial line is used in coaxial feed, unlike the microstrip planar line feed. This line consists of inner and outer conductors. While the outer conductor is connected to the antenna ground, the inner conductor passing through the coaxial line is connected to the radiating plane with a hole drilled in the substrate material. The feeding point can be connected to the radiation plane from a desired point. This point can be determined with the simulations to be made in such a way as to achieve the best impedance match. It is a frequently used method due to its ease of use and high efficiency. One of its most important disadvantages is its narrow bandwidth. As the substrate thickness increases, since the inner line length will increase in coaxial feeding, it may have a reducing effect on the bandwidth and difficulties may occur in coaxial feeding [17].

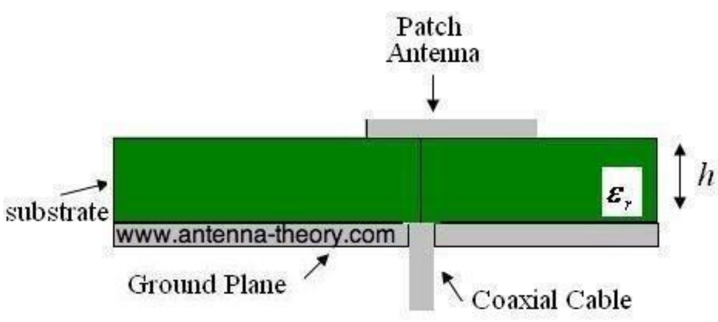

Fig. 5. Coaxial feed.

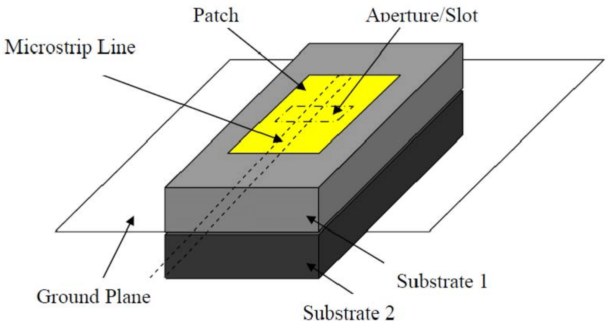

Fig. 6. Aperture coupled feed.

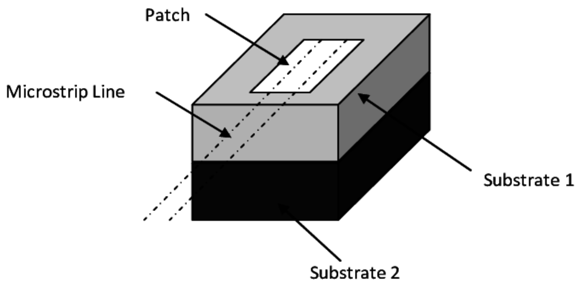

Fig. 7. Proximity coupled feed.

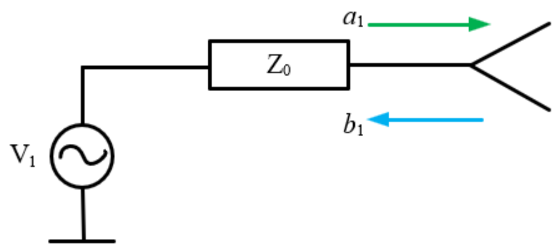

Fig. 8. System consisting of a single antenna.

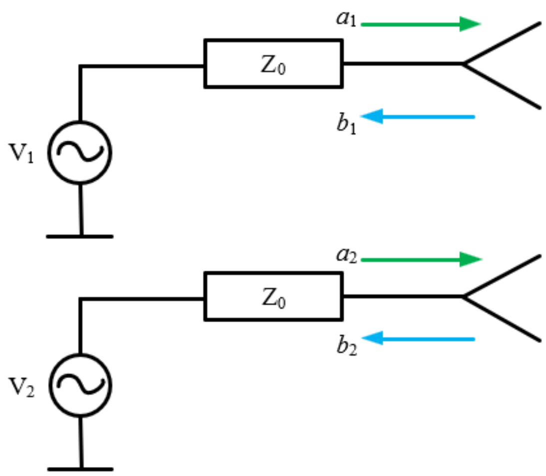

Fig. 9. System consisting of two antennas.

3) Aperture coupled feed: As seen in Figure 6, the aperture coupled feed has two substrates separated by the ground plane. At the bottom of the underlying substrate is the microstrip line, which transmits its energy to the radiant patch through the gap above the ground plane. This structure ensures that the radiant patch and the supply element are independent, protecting the radiant patch and the radiation leaking from the supply line. Material with high dielectric constant is used in the substrate in the lower part, and material with low dielectric constant is used in the substrate in the upper part [17].

4) Proximity coupled feed: In the proximity-coupled feed, as in the aperture-coupled feed, substrate material with two different dielectric coefficients added on top of each other is used. In this type of feeding, patch and soil planes are located on the outer parts of the substrate materials. The feeding line is positioned to be between these two sub-stones. In proximity-coupled feeding, the substrate thicknesses must be set at appropriate thicknesses to achieve impedance matching. The dimensions of the microstrip patch are important parameters that need to be optimized for impedance matching, such as the length of the transmission line. The most important challenge of proximity and aperture coupled feeds is the production difficulties in their position relative to each other due to the use of different substrates.

V. Antenna Performance Parameters

A. S-Parameters

S-Parameters are one of the most important parameters that allow us to obtain information about the radiation performance of antennas and impedance matching. The S-parameters show the relationships between the input and output signals provided by the ports in an electrical system in terms of supplied electricity. The S-parameter we need to examine in a single port antenna system is S11. S11 is expressed as the reflection coefficient. When we look at this value, we can see how much energy is reflected to the antenna through the port. In an ideal antenna, it is desired that all power is transmitted from the antenna and no reflected signals are formed. However, it is inevitable that there will be some reflected signals in the antennas, even if it is undesirable. The reference S11 value in antennas is -10 dB and below. At a value of -10 dB, the power of the signal given to the antenna radiates at the rate of 90%, so it is reflected back at the rate of 10%.

$$S11 = b1 \,/\, a1 \tag{1}$$

As seen in the figure, the S11 value in a single-element antenna system is the ratio of the signal value reflected back from the antenna to the signal going to the antenna.

In antennas with two antennas or more multiple ports, there is a common interaction between the antennas. A two-antenna system is shown in Figure 9. When we look at the parameters of this antenna, the parameter S11 represents the return loss of the first antenna. Likewise, the parameter S22 expresses the return loss of the second antenna. Other S-parameters are those that evaluate the mutual interaction between antenna pairs S12 and S21. S12 examines the effect of radiation from the second antenna on the first antenna. S12 is the ratio of the signal returning from the first antenna to the signal going to the second antenna. S21, on the other hand, examines the effect of radiation from the first antenna on the second antenna. S21 is the ratio of the signal returning from the second antenna to the signal going to the first antenna. Interaction between antennas is inevitable. The aim is to make the necessary adjustments and reduce the interaction below the -10dB level. Its parameters are generally specified in dB (decibels) and are calculated using the equation below.

$$|Sxy|dB = 20log10|Sxy| \tag{2}$$

$$S11 = b1 \,/\, a1 \quad (3)$$

$$S12 = b1 \,/\, a2 \quad (4)$$

$$S21 = b2 \,/\, a1 \quad (5)$$

$$S22 = b2 \,/\, a2 \quad (6)$$

B. Impedance Bandwidth

The impedance bandwidth can be found by examining the graph depending on the S11 and frequency values of that antenna. The acceptable S11 parameter in an antenna is below -10dB. As seen in Figure 10, the first frequency point where S11 value falls below -10dB on the graph is defined as the lower frequency value (f_{low}), and the first frequency point where it exceeds 10dB after the lower frequency value is defined as the upper frequency value (f_{up}). As given in Equation 7, the bandwidth (BW) consists of the difference between the upper and lower frequency values. Percentage bandwidth is given in Equation 8. If the percent bandwidth is over 20%, these antennas are referred to as ultra-wideband antennas.

$$BW = f\mathrm{up} - f\mathrm{low} \quad (7)$$

$$BW(\%) = BW \,/\, f\mathrm{center} \times 100 \quad (8)$$

C. Directionality

The directivity of an antenna is calculated as the ratio of the radiation intensity of the antenna to the radiation intensity of the isotropic antenna. The directionality is also the ratio of the radiant intensity to the total radiant power (P_{rad})(W) multiplied by 4π [15].

$$\text{Directionality } (D_0) = U_{max} \,/\, U_{\mathrm{isotropic}} = 4\pi U \,/\, P_{rad} \quad (9)$$

D. Yield

As given in the equation, the efficiency of the antenna is obtained by dividing the radiant power (radiant) converted into electromagnetic wave by the power entering the antenna (input).

$$\text{Yield } (E) = P_{\mathrm{radiant}} \,/\, P_{\mathrm{input}} \quad (10)$$

E. Gain

The gain of the antenna is defined as the ratio of the radiation intensity in a specified direction to the radiant power emanating from an omnidirectional (isotropic) source and is denoted by G. The gain value, like directivity and efficiency, is unitless. As given in Equation 11, the gain of the antenna is equal to the product of the directivity and the efficiency.

$$\text{The gain value } (G) = E \times D_0 \quad (11)$$

F. Radiation Pattern

The radiation pattern is the graph showing the change of the electromagnetic field strength emitted by the antenna according to the angle values at a certain distance, formed by the antenna at a specified distance.

VI. MILLIMETER WAVE ANTENNA DESIGNS PROPOSED IN THE LITERATURE

In recent years, the excessive increase in the number of wireless devices has brought demands for data size and data transfer speed. With this need, the orientation towards 5G technology in wireless communication tools has increased to a great extent and it is aimed to use millimeter wave frequencies in these devices. 5G technology, which includes millimeter wave frequencies, promises that many devices will be connected to each other at high speed with much larger data. With this need, the interest in antennas operating at millimeter wave frequency has increased intensely. As the operating frequency increases, antennas naturally become smaller. For this reason, designing very small-sized antennas suitable for targeted millimeter wave frequencies by using antenna modification methods has become a very important research topic. Some millimeter wave antennas proposed in the literature are presented below. In the study presented by Ahmad et al. [18] in Figure 11, a millimeter wave antenna was designed for 5G communication systems. The dimensions of the antenna with resonant frequencies of 29.5 and 30.5 GHz are 4.8x5x0.508 $mm3$. Although it has a relatively small antenna structure, it is quite low in terms of the bandwidth it provides. The proposed antenna and S-parameters are shown in Figure 11.

In the study presented by Shahjehan et al. [19] in Figure 12, a millimeter wave antenna was designed for 5G communication requests. The antenna maximum bandwidth is 5.5 GHz and 8.67 GHz at these points, with resonant frequencies of 37 and 54 GHz. The antenna dimensions are 7.2x5x.0.787 $mm3$. Although it has a relatively small antenna structure, it is low in terms of the bandwidth it provides. The proposed antenna and S-parameters are shown in Figure 12.

In the study presented by Qayyum et al. [20] in Figure 13, a microstrip antenna operating in the 28 GHz (27.6–28.55 GHz, 3.10%) resonant frequency range was designed for 5G communication systems. It has been observed that the resonance frequency range of the antenna designed with the dimensions of 7.23x7.23 $mm2$ is quite low. Antenna structure is given in Figure 13.

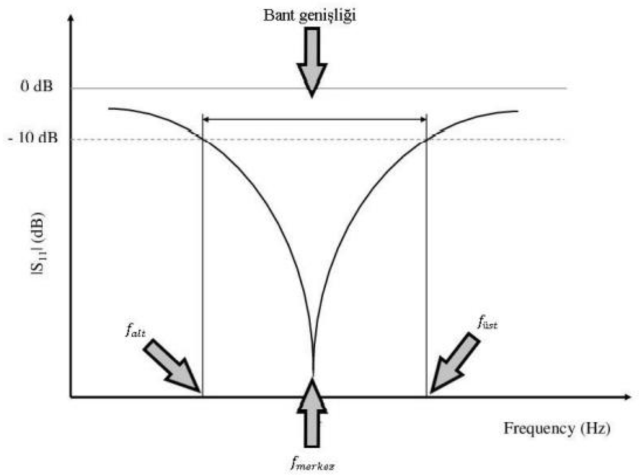

Fig. 10. Display of impedance bandwidth of an antenna.

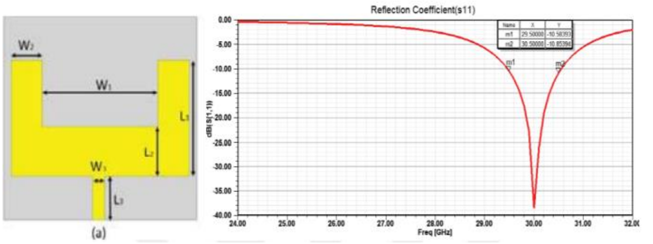

Fig. 11. Millimeter wave antenna geometry and S11 parameter (Ahmad et al., 2020).

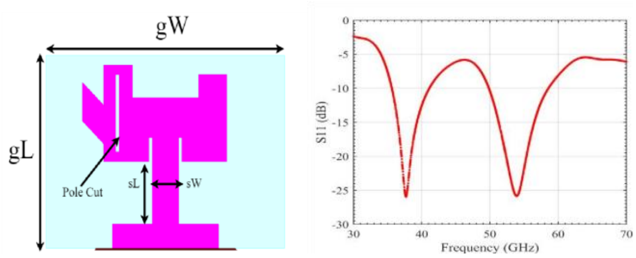

Fig. 12. Millimeter wave antenna geometry and S11 parameters (Zeeshan et al., 2019)..

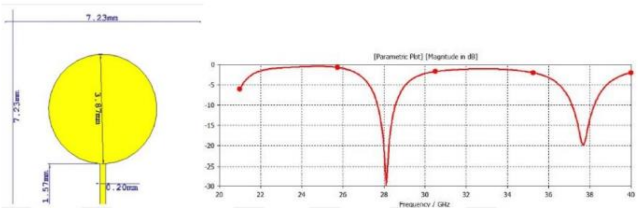

Fig. 13. Millimeter wave antenna geometry and S11 parameters (Qayyum et al., 2020).

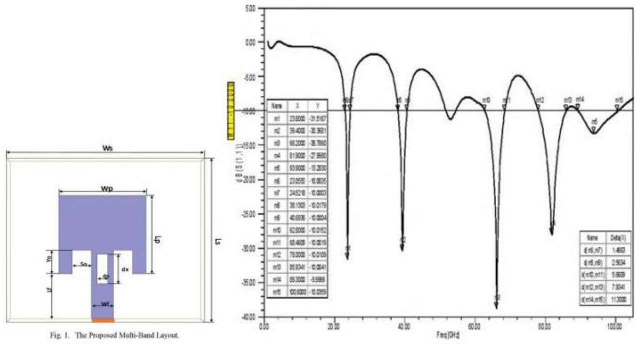

Fig. 14. Millimeter wave antenna geometry and S11 parameters (Saeed et al., 2021).

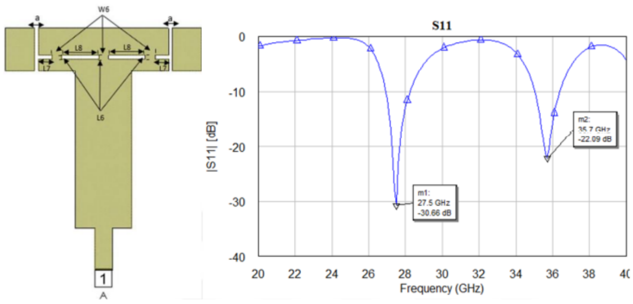

Fig. 15. Millimeter wave antenna geometry and S11 parameters (Apoorova et al., 2019).

Saeed et al. [21] presented in Figure 14; a millimeter-wave antenna is proposed for low-profile 5G systems with the dimensions of 8.6x9.2x0.6 $mm3$. The antenna whose resonance frequencies are shown in the figure is multiband. The resonance frequency ranges of the microstrip antenna, whose antenna geometry is shown in the figure, are low.

A millimeter-wave antenna has been developed for dual band 5G systems, presented in Figure 15 by Apoorva et al. [22]. This antenna, which has a center frequency of 27.5 and 35.7 GHz, has the dimensions of 12.5x10.1 $mm2$. The antenna geometry shown in the figure has low resonance frequency ranges.

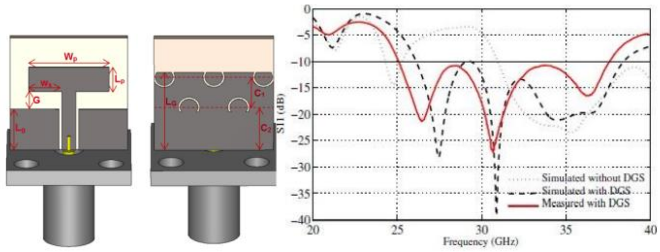

Fig. 16. Millimeter wave antenna geometry and S11 parameters (Jilani et al., 2017).

Jilani et al. [23] presented in Figure 16, a millimeter wave antenna designed for 5G wireless systems and applications is given. The measurement results of the antenna offer a bandwidth in the range of 25.1–37.5 GHz. The maximum gain of the antenna is 9.86 dB at 36.8 GHz. The antenna designed in a T-shape offers over 80% efficiency in the operating range.

CONTRUBITION OF THE AUTHORS

The contributions of the authors to the article are equal.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

STATEMENT OF RESEARCH AND PUBLICATION ETHICS

Research and publication ethics were observed in this study

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Overview on Feeding Techniques of Microstrip Patch Antenna

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***Abstract*—Antennas in general, patch antenna in particular, have been studied during the past six decades by a large number of researchers and graduate students specialized in microwave engineering because of its many advantages. As this type of antenna have many uses in the fields of wireless communication. In terms of design, this antenna has several layers stacked on top of each other and numbering three. The three layers are mediated by a layer of insulating material called the substrate layer. As for the first layer, it is called the patch and it consists of a conductive material such as copper. Finally, the third layer is called the ground plane and consists of the same material as the first layer. One of the advantages of this antenna is that it is easily integrated with the rest of the communication system devices because of its flat shape. What matters in the design of the antenna is the values of its coefficients, the most important of which is the input impedance. Therefore, the importance of choosing the appropriate feeding technique for the antenna in its application is evident. In this report, the existing feeding techniques for the patch hobby will be presented.**

Keywords—microstrip patch antenna, feeding techniques, microstrip line feed, co-axial feed, aperture coupled feed, proximity coupled feed

I. INTRODUCTION

Wireless communication devices such as cellular mobile phones, Radio Frequency Identification (RFID) systems, tablets, GPS devices, laptops, satellite phones, receivers, AM and FM radios are used on a daily basis and some of these devices are used by everyone. Wireless communication systems consist of several components, the most important of which are antennas. Where, the antenna plays the most important role in the process of sending and receiving electromagnetic signals over the air [1]. With an element of the importance of the antenna, it must be designed in a thoughtful way and with great care to get the best performance for the communication system as a whole.

The researchers were especially interested in the patch antenna, because of its attractive specifications, and it can be used as a solution to most of the challenges and problems facing scientific research and industries such as the industrial property industry and others [2]. One of the most attractive characteristics of this type of antenna is its low profile nature and its ability to integrate with all electronic circuits of communication systems, making it the most suitable solution for most industries, the most important of which is the mobile industries. The printed circuit is the technology used to produce this type of antenna. It was first produced in the fifties of the twentieth century. However, the popularity of these antennas did not begin until the early eighties. Careful analysis is used in developing theories of this sleep of antennae.

Feeding techniques are a very important component of all antennas, and the patch antenna is no exception. Where it is considered to be the operating part of the antenna and the part from which electromagnetic signals are received to be sent to the ether or vice versa. The type of feed used can influence in one way or another main characteristics of the antenna [3]. One of the most important characteristics that affect the choice of feeding sleep is the characteristics of radiation. One of the most important characteristics that must be taken care of when choosing the type of feeding is the entry resistance because it has a direct effect on the antenna performance.

II. MICROSTRIP PATCH ANTENNA

The patch antenna is one of the most important and widely used printed antennas. Three layers stacked on top of each other are the usual components of the typical patch antenna. Where the last layer is made of metal materials and is called ground plane [4]. We note that the first layer is also made of the same conductive material from which the last layer is made. The patch is what is called the first layer. Between the first and the last layer there is the second layer. It consists of different materials from the other two layers, as it consists of an insulating material called the substrate layer. This type of antenna takes several forms, including star, square, pyramidal, triangle, circular, parabola, and many other shapes that resemble letters such as the letter F and the [5] letter Y. Each of these shapes has certain properties and certain uses. Some of them are used for wide ranges, others for multi-domains. This type of antenna is distinguished from the rest of the other types by its ease of design. Where this feature enabled it to spread its use in many wireless communication applications such as; its use in mobile devices, tablets and smart watches from Apple and Galaxy companies. This type of antenna has been the subject of research for many researchers and graduate students because of its many properties that can solve many of the challenges associated with modern wireless communication technologies such as the fourth and fifth generation of communications. The planer engineering resulted in the simplicity of manufacturing this antenna as well as the integration of the communication system devices with it [6]. It is not hidden from anyone how cheap the production of this antenna is as a result of its low profile. To analyze this type of antenna, we use cavity model. As shown in the three-layer composition of this antenna, it is considered as a cavity surrounded by two layers of metal with imperfect electrical conductivity. As a result of leakage from the walls of this antenna, radiation occurs from this cavity. For this reason, which is evident from the leakage of electromagnetic waves from the walls of this cavity, the antenna radiates the signals. One of the most important things to know how to find is the resonant frequency and radiation properties [6]. To find these things, we must first analyze the electromagnetic fields inside the cavities. In these cavities, the right side and the left side of it can be considered as perfect conductors while the surface and base of the cavity can be considered as imperfect conductors. We can find the amount of field propagation on the walls of the cavity by placing certain limits on these walls. The result of this analysis and knowing the amount of radiated fields within the walls of the cavities of this antenna enables us to calculate several important properties of the antenna, including the quality factor and the impedance of entry. Also, with the same results given from this analysis, the operating frequency and radiation characteristics can be found.

III. FEEDING TECHNIQUES

In general, when designing antennas, several important steps are passed, including choosing the frequency for which the antenna is to be designed, whether it is a receiver or transmitter, choosing the type of antenna, choosing the materials for which the antenna is to be designed; then it is designed on scientific bases and studied equations [1]. Then the type of feed for that antenna is selected. The patch antenna is no exception. It goes through the same steps. After calculating the appropriate dimensions and calculating the entry resistance, the type and dimensions of the appropriate feeding are calculated. The impedance of input to microwave and radio frequency systems should be equal to 50Ω, and 377Ω is considered as the air impedance [7]. The type, location and dimensions of the feed must be chosen in a way that ensures that it has impedance equal to 50Ω. Here the antenna is as a transducer. Feeding methods can be divided into two types. The first type is the connected and the second type is the unconnected. Connected feed methods consist of coaxial fed and Inset fed. Unconnected fed methods consist of proximity fed and Aperture fed [8].

A. *Microstrip line feed*

One of the simplest feeding methods used with the patch antenna is microstrip line fed. It is a type of conducting feeding techniques. In this technique, a long rectangular piece of metal is used of the same type of metal as the patch. Where, one end of this piece is connected to the patch and the other end to the port as shown in figure 1 [9]. This extra piece serves as a supply source for the patch antenna. The dimensions of the feed are calculated with the help of some equations used in microwave engineering, where must have dimensions that produce an impedance of 50 ohms. The dimensions of the patch antenna and the feed line are not the same, but there are many differences due to the entry impedance [8]. Where the width of the patch antenna is very large compared to the width of the feed line. One of the benefits of this feeding method is ease of manufacture. This type of feeding is attached to the insulator, and this is one of its benefits. Sometimes there are some antenna properties with undesirable values such as s11, gain, directivity, or radiation characteristics. Therefore, some parts of the antenna adjacent to the feed line are cut to obtain the desired values, as we have already said. By modifying these parts, we get a modified version of the feed line called inset fed line [9]. This method is mainly used to obtain matching impedance between the feed and the patch antenna, so when a match is obtained, the electromagnetic energy is completely transmitted to the patch antenna and all other parameters are improved [6]. This type of feeding is attached to the insulator, and this is one of its benefits. The disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth. The spurious feed radiation and surface waves increase with the thickness of the dielectric substrate which hinders the antenna bandwidth [10]. The fed radiation results in unwanted polarized radiation. Narrow bandwidth and gain is one of the advantages patch antenna. The equivalent circuit of the line fed microstrip patch antenna is shown in the figure 2 [11].

B. *Coaxial feed Technique*

In this type of feeding, a coaxial cable is used to feed the antenna from the last layer. This technique is non-planar. The inner conductor is attached to the first layer (the patch) penetrating the insulating layer and the outer conductor to the third layer (ground plane) [12]. There is an advantage and disadvantage in using this type of feeding, as you can place the feed anywhere in order to agree to the input impedance, but this is not an easy matter. Another advantage is that the ground plane isolates unwanted radiation from the original radiation of the antenna, which enhances the performance. Another drawback of this technique is the difficulty of matching the insertion impedance on thicker substrates. The position of the feed is determined by the x- and y-coordinates when the impedances match at 50 ohms. The equivalent circuit of the Coaxial fed technique microstrip patch antenna is shown in the figure 4 [11].

C. *Proximity feed*

In this type of feeding technique, two pillars are placed between the two sides of the insulator. Since the impedance at the edges is very large, it is not possible to determine a specific point where the impedance matching occurs because it is very difficult. But there is a way to avoid this, by placing the substrate very close to the patch. The feed line is positioned at the edge so that the antenna impedance is 50 ohms. In this method, feeding is done by electromagnetic coupling between the pad and the feeding line. The radiation from the feed line will have a very less effect on the antenna because it is placed below the patch [13]. In this technology, the bandwidth is very wide compared to other technologies. For every technology there are drawbacks and the disadvantage of this technology is that it must be manufactured with multiple layers and poor polarization.

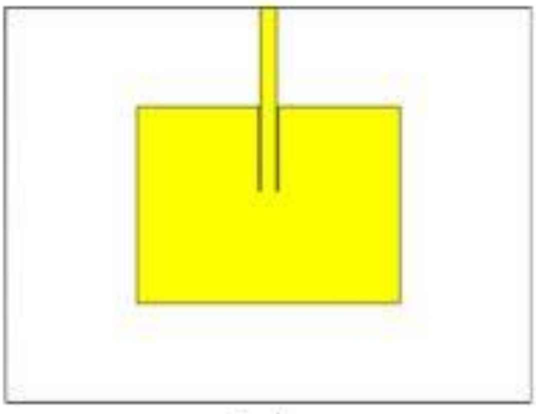

Fig. 1. Microstrip line fed

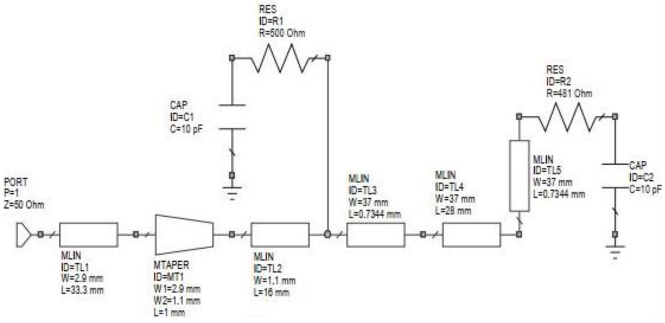

Fig. 2. Equivalent circuit of line fed microstrip patch antenna

Fig. 3. Coaxial cable feed

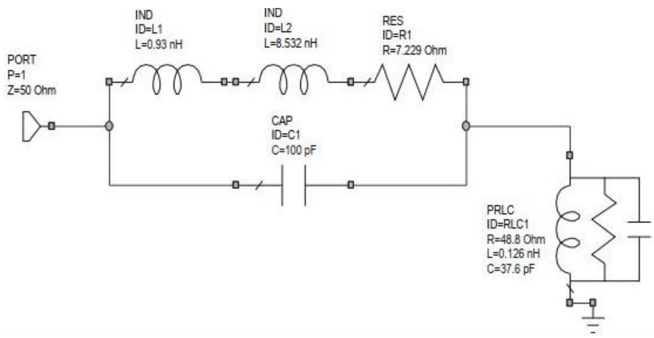

Fig. 4. Equivalent circuit of coaxial fed technique

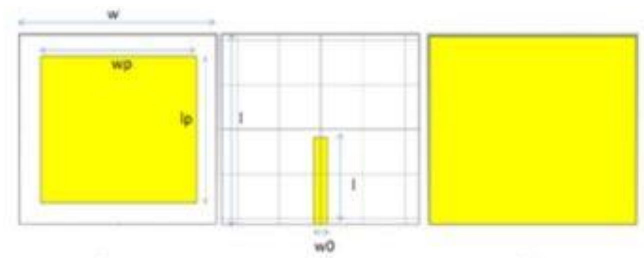

Fig. 5. Proximity feed

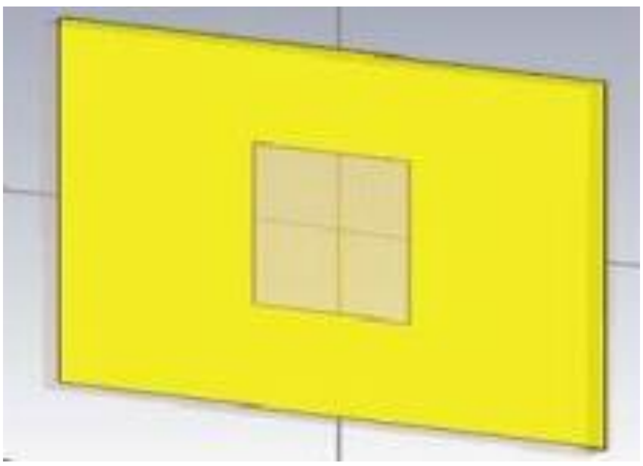

Fig. 6. Aperture feed

D. *Aperture feed*

This technology consists of two isolated holes, one of which is at the ground plane and the other below the antenna. These insulators are isolated by the third layer of the patch antenna (ground level) that has a hole in it [14]. The ground level is placed on the other side of the insulator. As for the second side of the insulator, both the feeding hole and the feeding insulator are placed. Where, the feed line and the ground level are placed on both sides of the insulator. The feeding line is perpendicular to the ground level hale. The energy taken from the feed line is coupled to the antenna patch through electromagnetic field coupling between them. One of the advantages of this method is to significantly improve feeding.

IV. Conclusion

In this study, an overview of the feeding techniques used with the patch antenna is presented. Some theoretical concepts related to antennas in general and the patch antenna in particular were also presented. The most important factors that can influence the choice of feed type were also discussed. The most commonly used feeding techniques by researchers and the research community was also discussed. The techniques discussed in this report include the following: microstrip line feed, Co-axial Feed, Aperture coupled Feed, and finally Proximity coupled Feed.

Contrubition of the Authors

The contributions of the authors to the article are equal.

Conflict of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were observed in this study

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A Review and Analysis Micro-Strip Patch Antenna for 3.5 GHz

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***Abstract*— In recent years, there has been a lot of interest in microstrip patch antennas owing to their small volumes, low profiles, effective integration, low prices, and outstanding performance. With the continual growth of wireless communication services and therefore the constant shrinking of communication equipment, this antenna is planned to be used for WiMAX and wireless communications. However, these antennas have disadvantages like low gain, low power operation, and slim bandwidth, among others. The first drawbacks of those antennas are their restricted band performance as well as their high cost. Technological advancements within telecommunications are accelerating, particularly with the arrival of fifth-generation technology, which offers the advantages of quick knowledge transmission speeds and really low latency. In 2015, the World Radio Conference (WRC) urged frequencies for 5G communication technologies, one of which is 3.5 GHz. A variety of analysis articles were collected and studied, and for the frequency of 3.5 GHz, many forms and substrate materials with dynamical relative permittivity were devised for microstrip patch antennas. The simulated results show that these antennas will simply offer dual-and tri-band operation, as well as nearly as good dipole-like and spatial relation radiation properties, stable gain, and high radiation efficiency, indicating that the planned antennas are candidates for WiMAX and wireless communications. The urged antennas have come back with losses starting from -32 decibels to -30.8 dB. The results are obtained through the use of the PC simulation applications standards CST and ADS.**

Keywords—microstrip antenna, WiMAX, wireless communications,5G,3.5 GHz

I. INTRODUCTION

Nowadays, no person can deny it has a cell package and wi-fi conversation capabilities to perform more than one capability at an equal time. Rapid advancements in wireless communication offerings have resulted in a massive mission in antenna design. Microstrip antennas have several blessings, that embody being tiny in size, swish models for digital circuits, lower electricity exhaustion, excessive-performance, lower be valued, mechanistic sturdiness, and twin hesitation packages. However, microstrip antennas have the hazards of slender information measure and poor performance because of numerous losses. The layout of lightweight, low-cost, excessive bandwidth antennas is significant for wi-fi gadgets thus one will transmit images, speech, and statistics in numerous frequency bands at a similar time. The patch antenna construct appears to own been planned by Deschamps within the early 1950s. some years later, a antenna patent was issued through Gutton and Bassinet. within the 1970s, thin, surface-suited antennas were made for army packages, together with missiles and space shuttles.

Patch antennas for twin and multi-frequency band operation are getting progressively common and wide utilized in a range of applications, including cell phones, satellites, radars. And missile guidance. additionally refers to high-speed properties among PCs, laptops, mobile phones, associate in alternative devices in an atmosphere wherever wireless statistics offerings have advanced and continue to grow with the usage of various technologies, together with 2G and 3G. The result of such numerous technologies on the usage of frequency bands in one-of-a-kind technologies can need to occupy one-of-a-kind frequency allocations, comprehensive of WLAN/WiMAX and wi-fi spoken communication structures, inclusive of Worldwide ability for Microwave Access (WiMAX), wi-fi close neck of the woods network (WLAN) and C-Band, that have perceptibly appealing and are loosely used. Hence, the decision for low-profile antennas with compact size and multiband operation overlaying the bands of these applications, additionally to omnidirectional insurance and simple flat systems, is in pressing need. The layout and checking out of the 5G spoken communication gizmo devolve on the data of the propagation channels, and a large frame of channel measurements is consequently required. Currently, 5G cell structures are broadening their spectrum to guide an excessive information rate. At the globe world Communication Conference (WRC) in 2015, the 5G possibility frequency bands below vi rate were broadly speaking mentioned.

This paper is targeted at the publishing channel characterizations within the 3.55 GHz band. The antenna should be sufficiently little to suit any small speech gadgets from new technology. The goal is to own a high advantage and performance to make sure that the foremost records switches in any wi-fi communication space antenna are the amount one requirement. once birth out any microstrip patch antenna, several improvement ways are used, and twin feed. Wide information measure antennas are applied for a huge type of community frequencies, that are larger inexperienced for a few distance space implementations. With a twin-feed antenna, section distinction is simple to maintain the foremost common issue in wi-fi communication is the orientation of receivers and transmitters. Multiband operation and antenna length miniaturization could also be performed by utilizing the noted options of self-similarity and area filling.

II. LITERATURE REVIEW

A. Microstrip antenna Consists of two rectangular with square-shaped

Results acquired Comparison among the traditional antenna and the proposed antennas: Simulation outcomes of going back loss (S11) for each traditional and proposed antennas, the directivity of the traditional antenna changed into 7.03dBi and VSWR of 1.7, even as the proposed antennas (double and unmarried square-formed metamaterial unit cell antenna) are 5.51dBi and 5.26dBi, 1.2 and 1.0, respectively. Hence, the lower back and aspect lobes of the proposed antennas had been rising, as a result decreasing the directivity of the antennas. The microstrip patch antennas with square-formed metamaterial unit cells have a progressed bandwidth and length discount in comparison to the traditional microstrip patch antennas. The overall performance of the square-formed split-ring metamaterial unite and cargo cell antenna may be similarly progressed with a made-over configuration. Hence, those performances are nicely ideal for WIMAX applications.

B. 3.5 GHz Microstrip Transmission Line

In this paper, a microstrip transmission line includes metal strapline and floor plane among a dielectric medium known as the substrate is located of 3.5 GHz is efficiently designed in CST microwave Studio software program to satisfy function Impedance of 50.03 Ohms, Also S–parameters The fee of going back loss S11 = 12 dB and S21 = 0.5 dB at 3GHz frequency. As properly because the dielectric substrate G-10 of εr = 4.8 is used to acquire bandwidth from three GHz to five GHz. The designed microstrip transmission line is used to feed numerous varieties of antennas in preference to a coaxial feed and is likewise used for the transmission of records in the microwave, cellular cell smart phone antennas, and Wi-Fi antennas.

C. Rectangular Patch Microstrip Antenna 5G

There are a few variations among the simulation and the dimension effects, however, the parameters are taken into consideration properly enough, as it's far glad the favored parameters. Because the bandwidth is reduced via way of means of a full-size amount. The effects of this study are that the VSWR is elevated via way of means of 0.242, the impedance is elevated via way of means of 15.256 Ω, and the benefit is elevated via way of means of three dB, and the go back loss is modified to -17.436 dB. The VSWR, go back loss, and benefit is glad the favored parameters. Finally, the simulation and the dimension effects display that the antenna is according to the favored parameters. It is predicted that hopefully, the antenna is beneficial for 5G applications.

D. Design Broadband Microstrip Antenna

Classic wideband microstrip dipole antenna layout that may be utilized in WiMAX packages (masking the bands 2.4–2.5 GHz and 2.5–3.5 GHz) is introduced. A wideband microstrip dipole antenna layout with overall performance withinside the 2.36-3.67 GHz range, which may be utilized in packages masking WiMAX bands, is introduced. Relating to withinside the layout, asymmetrical bent loading factors are delivered close to the feed of the fifty-two mm (~λ/2) lengthy microstrip dipole antenna element. the bandwidth of a fashionable microstrip dipole antenna with 10%ndwidth may be improved to 43%. As an end result of those additions, there has been no deterioration withinside the radiation sample function of the antenna. The proposed broadband antenna has a non-directional sample and a directional advantage of 2.36 dBi. The calculated overall radiation performance of the layout on the applicable frequency is -0.428 dB. Thanks to those studies, it's been determined that the applicable broadband function is acquired through combining unique bands.

E. T-shaped Design compact microstrip patch antenna

A T-shape microstrip is proposed. microstrip patch antenna becomes simulated and printed with the help of victimization the employment of R/Duriod 5880 LZ, with a typical length of the antenna changing into 22×24×0.25mm3 planning T-form is completed to beat the information measure difficulty of the normal antenna. This form offers wonderful resistance matching at exceptional frequencies and thus has sturdy radiation traits at exceptional frequencies. Introducing a sq. T-formed aperture at the ground stage will enhance the bandwidth of the lower-frequency.

The optimized antenna partial bandwidth is 42.81% with a resonant hesitance of 3.6 GHz and a go-back loss of -28.76 dB. the antenna performance is 98.474% at a 3.6 GHz resonant frequency. This characteristic has advanced the planned structure creating it applicable for varied wi-fi communications alongside 5G cellular applications.

F. 3.5 GHz Circular Patch Antenna Using Open-Ring Artificial Dielectric

This case describes the characteristics of a 3.5 GHz circular antenna and the usage of a synthetic open ring. The acrylic herbal dielectric fabric substrate has been changed by placing a skinny conductor strip on the pinnacle of the substrate to boom the permittivity of the acrylic. From the S11 the antenna has a canter of 3.5 GHz the go-back lack of 26.46 dB. At the equal time, the ensuing bandwidth is 194.7 MHz at a go-back lack of 10 dB. From those consequences, the synthetic microstrip antenna has a much broader bandwidth and a more go-back loss than traditional microstrip antennas.

The consequences display that the proposed antenna has a much broader bandwidth of 16.1 MHz or 8.94percentand a better go-back loss on the center frequency of 1.32. dB or five.25% better than traditional antennas. The consequences display that the proposed antenna has a much broader bandwidth of 16.1 MHz or 8.94%, a better benefit of 0.05 dBi or 0.78%, and a better go-back loss on the canter frequency of 1.32 dB or five.25% better than traditional antennas.

The synthetic antenna has a patch vicinity measurement of 11% smaller than traditional antennas and a substrate vicinity of 32.08% smaller than traditional microstrip antennas. The relative permittivity of acrylic multiplied from 3.4 to 3.82 or 12.24%. From those consequences, the open-ring synthetic dielectric can enhance traditional antennas characteristics and might miniaturize antenna dimensions.

G. Circle Patch Microstrip Antenna for Frequency 3.5 GHz

From the simulation, it changed located that the circle antenna with a radius of 16.94 mm, the width of the feeder channel is 4.92 mm and an insert feed with a period of thirteen mm and a width of 1.3 mm can produce an antenna with a go back loss of -26,385 and VSWR of 1.0989. The use of insect feeds on an antenna can have an effect on the overall performance of the antenna. Total antenna radiation performance changed into acquired for -0.6489dB and benefit changed into acquired in 3504 frequency GHz at 7.64 dBi. Although the microstrip antenna has small dimensions it nevertheless profits little bandwidth, the bandwidth of this observation changed into attained at three,504 GHz frequency most effective via way of means of 72 MHz This bandwidth is just too small if it's far used to seize records from many channels.

H. An Ultra-Wideband Microstrip Patch Antenna for Mobile WiMAX at 3.5 GHz

An ultra-wideband antenna is designed for the cause of mobile WiMAX operations. The proposed antenna covers the complete band of the IEEE 802.16e-2005 fashionable band of the 3.4-3.8GHz spectrum. Though the proposed antenna has a low gain, it has pretty appropriate VSWR, directivity, efficiency, HPBW, and really low SAR which display the suitability of the antenna for cellular WiMAX programs over an extensive variety of frequencies. the VSWR cost of the proposed antenna and the minimal cost of the VSWR is 1.45 at 3.38 GHz. The cost of VSWR varies from 2 between 3.2 GHz to 3.9 GHz because the proposed antenna is an ultra-wideband antenna. also, the S-parameter curve of the proposed antenna. The minimal go-back lack of the antenna is -14.655 dB at 3.381 GHz. The go-back loss cost varies past -10 dB from 3.2 GHz to 3.9 GHz because the antenna is an ultra-wideband antenna.

İ. Microstrip Patch Antenna Different Dielectric Substrate-based for 5G

The analysis of the implications and therefore the assessment among substrate substances FR-4, RT-5880, and TLC-30 had been appreciably studied. The intention of the projected antenna styles become to realize high overall performance in phrases of advantage and information measure at a similar time as keeping a reflection constant below -10dB. All the proposed antennas finished top overall performance (better profits and bandwidth ⩾a hundred MHz) at the same time as assembly the mirrored image coefficient and VSWR for Design-1, 2 and three had were 1.078, 1.48, and 1.259, severally at 3.5 GHz. furthermore, Design-1,2, and 3 have a performance of 60.13%, 61.51%, and 75.70% on the popular frequency for Design-1, 2, and 3. consistent with the ITU needs for 5G cell report widget packages, the VSWR is far under 2. This indicated that TLC-30 is going to be the fantabulous need for 5G packages. Additional analysis may want to be achieved to reinforce the performance of the antennas, in special, to enhance the profits and information measure at a similar time as having a smaller antenna dimension.

J. 3.5 GHz A Small Patch Antenna for 5G

For paper, tiny low compact antenna has been designed to be used at 3.5 Gc for 5Gapplication. The antenna features a bodily length of 25.2 X45 millimeter it's a go-back loss of -30dB at 3.5 GHz. The antenna profit is 5.01 dB. As it' so much recognized that the resonant frequency and therefore the go-back loss could also be calculated from the S11 curve of the patch antenna respectively. this means that the antenna has a completely low go-back loss while it operates at a 3.5 GHz frequency. which method an amazing amount of the sign may be transmitted through the antenna features a terribly excessive performance of 96.67%.

K. Circular Slotted Rectangular Microstrip Patch Antenna

The designed antenna can be a converting type of rectangular patch antenna that encompass three identical round slots inside the patched ground. The projected antenna has completely unique operative frequencies of 2.592 and three.338 gigacycle, and with the assistance of exploitation writing the antenna with slots, the information diploma of the antenna is stepped forward with the resource of the usage of 50.9% and 39.5% at the one's resonance frequencies, respectively. The numerical evaluation of the deliberate antenna corresponds to mirrored image coefficients, directive gain, ground cutting-edge, and radiation designs examined with the resource of the usage of victimization Central Time Microwave Studio.38 price and ten sound unit information diploma is 1.32 GHz. Gain values are variable amongst 2.06 decibel and 2.24 dB a number of the operative bands. The projected antenna has attempted to be geared up to supply home the bacon immoderate standard overall performance and is suitable for wireless conversation systems.

L. Twin Feed Φ- form Patch Antenna 5G Applications

A twin feed Φ- kind patch antenna is meant with the assist of victimization the employment of HFSS software. The Antennas are extensively talking utilized antennas due to their lightweight, the price is low, and simplicity of fabrication. The nonconductor substrate utilized is FR4 Epoxy. The go-returned loss of twin-feed Φ-fashioned patch antenna below -10 decibel is -21.2 dB. The dual-Feed Φ-Shaped Patch Antenna well-known shows a resistance statistics degree of three. Three to three. Eight gigahertz the antenna is matched to the road even as the VSWR really well worth is small. And it is now no longer up to 2 dB that's 1.51. The Simulated and VSWR for dual Feed Φ-Shaped Patch Antenna. and gain of dual Feed Φ-Shaped Patch Antenna is 4. 41 dB. And is suitable for 5G applications.

M. High Gain & Directivity Microstrip Patch Antenna at 3.5 GHz

The current status of the work includes the design process for a microstrip patch antenna at a resonant frequency of 3.55 GHz suitable for WLAN applications, satellite communications, and WiMAX applications. The results show an improved bandwidth, the gain is high and the parameters S11 define the transmission power and thus the reflection at the antenna. In order to get the maximum radiation, the reflection must be as low as possible to make the antenna more efficient. Graphical results in order to show the efficiency increase and the wide radiation patterns, detailed experimental studies can be carried out at a later date to find a design method for symmetrical gain antennas.

N. MIMO Compact Short Microstrip Antenna

A four-detail shorting pin-loaded patch antenna is designed on the sub 6 GHz 5G band The antenna is resonating at 3.41 GHz with back the loss of S11 of -37.65 dB at port 1, S22of -29.12 dB at 3.44 GHz, S33 of -42dB at 3.405 GHz, and S44 of -23 dB at 3.445 GHz. with a bandwidth of about one hundred MHz on the middle frequency. the benefit and radiation performance of the proposed four detail antenna is accelerated as compared to two-detail and unit-detail antennas. that is appropriate for cell handsets. From the above results, it's far clean that the proposed antenna reveals ok gain and compactness, appropriate for employees' cell devices. The configuration may be prolonged for the bottom station antenna with the aid of using growing the wide variety of elements. Also, antenna configuration may be incorporated into the layout device for 5G communication.

O. Rectangular Microstrip Antenna 1x2 Array for 5G.

Stops end result of the format of a square 1x2 array and single patch microstrip antenna with a frequency of 3.5 GHz, then the perception that can be taken is for the 1x2 array microstrip antenna to deliver a pass returned loss cost of -12.6 dB, VSWR 1.6, gain 5.5 dB, bandwidth 66.5 MHz on microstrip antenna single patch produces a pass returned loss cost of -37.8 dB, VSWR 1, gain 5.5 dB, bandwidth 73.2MHz

P. Slotted Two- C Shaped Microstrip Patch at 3.5 GHz for WiMAX.

for the duration of this paper, a slot C-shaped microstrip patch antenna became designed and simulated to radiate withinside the center band of the WiMAX frequency variety of 3.2-3.8 GHz. The go back loss is -32.30 dB and has a VSWR = 1.07 at a resonant frequency of 3.5GHz

Q. Antenna from Flexible Textile with Transparent Conductive for WiMAX Communication

A bendy and optically apparent simply cloth patch antenna for wireless communications modified into studied with the motive of being blanketed into OLED devices, similarly to slight or flexible displays. This way, the equal device is ready with every mild and communications function. The substrate uses a microstrip line for Wireless communique systems WiMAX strolling at 3.5 GHz. We have confirmed that antenna format techniques perform properly even for material substrates such as apparent conductive fabric blanketed with polyester. The antenna is well-known for omnidirectional radiation coverage with a gain of 1.07 dB at 3.5 GHz the only drawback is reducing the gain at higher frequencies.

R. Design a C-Shaped Compact microstrip antenna

Although it's been suggested that a patch antenna has a narrow bandwidth, on this examination an antenna with a much wider bandwidth than an ordinary patch antenna has been designed for 4G systems. In order to widen the antenna bandwidth, a round kind slot is added. Afterward, the antenna has been fabricated, and go back loss is measured, VSWR end result could be very good and good gain. in addition to simulated in HFSS. Simulation consequences suggest that the 3-D radiation styles withinside the 3.45–3.55 GHz variety are acceptable, specified for 4G (WiMAX).

S. Microstrip Patch Antennas Compact Dual-band and Tri-band.

The article introduces the design of three compact multiband microstrip antennas, Ant.1, Ant.2, and Ant.Ant.1 and Ant.3 are useful for the dual-band, while Ant.2 is useful to use as a TRI band antenna.2/5.8) WLAN and C-band.Ant.1 covers the WiMAX band 3.55 GHz and WLAN band 4.80GHz Ant.2 covers the 3.55GHz WiMAX band, 5.40GHz Wi-Fi band, and C7 band.25 GHz, while Ant.3 covers the WiMAX 3.62 GHz band and the WLAN 5 band.10 GHz The designed antennas are easy to manufacture and compact in size (21 × 21 × 1.6 mm3). In addition, the simulated radiation pattern of these antennas shows that the designed antennas have omnidirectional radiation, making them suitable for use in portable and wireless devices.

T. Design Circular Patch Antenna Based Miniature for 5G Mobile Communication

In the paper, for 5G communication for 3.5 GHz new technology cell terminals, a miniature round new microstrip antenna layout primarily based totally on the patch detail is introduced. A miniature antenna structure (frequency 3.5GHz) turned into received with the DGS withinside the shape of CSRR (Complementary Split Ring Resonator) generated withinside the floor plane. Developed antenna layout. Radiation detail stepped microstrip-line located on CSRR-DGS (defected floor structure), it turned into created with a fed round patch, the proposed CSRR-DGS-primarily based totally miniature antenna Numerical evaluation outcomes of the layout are given. Proposed CSRR-DGS is primarily based on a totally miniature layout 3.5 It is well-known shows S11<-10 dB overall performance withinside the GHz-centered, 3.46-3.53 GHz working band.

TABLE I. COMPARATIVE ANALYSIS DEFFRENT ANTENNA DESIGN FOR 5G, WI-MAIX AND COMMUNICATION

Paper	Type of antenna used or materials used	Technology used	Features/ advantages
[1] [3][15]	Two rectangular with square-shaped and Antenna 1x2 Array	bandwidth and length discount in comparison. simulation and the measurement	nicely ideal for WIMAX useful for 5G applications
[2]	metallic strapline and ground plane	used to feed various types of antennas	mobile phone antennas, Wi-Fi antennas.
[4]	Broadband Microstrip Antenna	two asymmetrical bent loading elements are added near the feed of the 52 mm	used in applications covering WLAN/WiMAX
[5].	microstrip patch antenna-shaped compact	using R/Duriod 5880 LZ, with an overall size	various communications such as 5G
[6] [7] [11]	Circular Patch Antenna Using Open-Ring Artificial Dielectric	The acrylic natural dielectric material substrate	wireless communications and covering WLAN/WiMAX
[8]	Ultra-Wideband Microstrip Patch Antenna	the complete band of the IEEE 802.16e-2005 fashionable	mobile WiMAX operations because the antenna is an ultra-wideband
[9]	Microstrip Patch Antenna Dielectric Substrate	assessment among substrate substances FR-4, RT-5880, and TLC-30	good for gain top performance in phrases and bandwidth the first-class for 5G
[10]	Small Patch Antenna	antenna has a bodily length of 25.2 X45 mm	very excessive performance of 96.67%. used for 5G Application.
[12]	Twin Feed Φ-Shaped Antenna	The dielectric substrate used is FR4 Epoxy	for 5G applications
[13]	High Gain & Directivity	design method for symmetrical gain antennas.	WLAN, WiMAX, and satellite communications
[14]	Compact Short Antenna	MIMO	5G communication.
[16] [18]	Two- C Shaped Microstrip	Slotted Two- C Shaped a narrow bandwidth	for WiMAX. for 4G (WiMAX). Good gain.
[17] [19]	Antenna Flexible Textile Antennas Compact Dual-band and Tri-band.	Flexible Textile with Transparent Conductive Integrated and three compact multi-band antennas	for WiMAX and Wireless Communication Systems

Recommended miniature CSRR-DGS-primarily based totally microstrip layout has antenna systems that may be utilized in 3.5 GHz five G applications. Considered to be an alternative. On the opposite hand, standards, it's far aimed to growing the bandwidth to cowl the range.

CONTRUBITION OF THE AUTHORS

The contributions of the authors to the article are equal.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

STATEMENT OF RESEARCH AND PUBLICATION ETHICS

Research and publication ethics were observed in this study.

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Multiband Microstrip Antennas for GPS Applications

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***Abstract*— In this report, the multiband microstrip antenna for GPS application was studied. Different studies are investigated and discussed, and the different models of these antennas are analyzed. In this paper, which is the main purpose of investigate the methods of increasing bandwidth in microstrip antennas, microstrip antennas in terms of structure and their analysis methods such as transmission line, Cavity, and moment (in short) have been investigated. Among microstrip antennas, circular and rectangular microstrip antennas are among the most widely used. Rectangular microstrip antenna is used due to having more parameters for design and is also easier to design and analyze.**

Keywords—multiband microstrip antennas, global positioning system, GPS applications

I. INTRODUCTION

An important functional element in communication and radar systems, as well as wireless devices, is the antenna. The antenna may be defined as the transducer between an electromagnetic wave (EM) propagating along a transmission line and an EM wave propagating in an infinite environment (usually open space) or vice versa. An antenna is required to transmit or receive EM energy with proper direction and polarization characteristics for the intended application. The microstrip antenna is a contemporary invention in some degree. This antenna was invented to allow easy integration of an antenna and other excitation circuits of a communication system on a commonly printed circuit board or a semiconductor chip. In addition to other advantages, integrated circuit technology for antenna construction allows high dimensional accuracy, which was difficult to achieve in traditional manufacturing methods. The geometry of a microstrip antenna consists of a dielectric substrate with a certain thickness d, on one of its surfaces of which there is complete metallization, and on the other side it has a metal "patch". The bed is usually thin. The metal patch on the front surface can take many forms, although a rectangular shape is usually used. The antenna may be actuated in a variety of ways. One common method of feeding is from a microstrip line, which connects the microstrip antenna in the center of one of its edges. The microstrip line may be connected to a power supply circuit or powered straight in connecting a signal source across the microstrip line and ground.

An antenna is a telecommunication device which converts electrical signals into electromagnetic waves (in transmit mode) and converts electromagnetic waves into electrical signals (in receiving mode). Antennas have a variety of structures that are determined by the application. One of the simplest possible structures for an antenna is a wired antenna. Each antenna is amplified at a certain frequency and produces the maximum voltage (in the receiving state). If the length of the antenna is proportional to the received wavelength, the wave will fit completely in the antenna and the so-called "antenna is amplified". Or "the antenna is amplified." That is, the antenna is synchronized with the received wave, and in this case, the voltage generated by the antenna is the maximum. Of course, the antenna length does not have to be equal to the received wavelength; Because the inductor can be added to the antenna with one or two capacitors to create an intensification mode in the antenna. The operational performance of the antenna affects the whole system performance directly. The requirements of bandwidth, gain, beamwidth, polarization, and multiple frequency operability may change according to the application area of the antenna. Circularly polarized multiband low-profile antennas are preferred in many wireless communication systems [1].

"GNSS" covers all satellite-based navigation systems such as GPS, GLONASS, and Galileo. These satellite systems generate circularly polarized radio navigation signals. The polarization of the electromagnetic waves changes due to ionized gases or the earth's magnetic field. This effect, known as Faraday Rotation, causes rotation in the orientation of the linear polarized wave. In order to minimize this effect, Right Hand Circularly Polarized (RHCP) signals are used in satellite navigation systems [2].

GPS is the first GNSS constellation developed by the US Department of Defense (DoD). GPS has 24 satellites in 6 orbits around the earth at an altitude of 20200 km. Civil navigation signals were composed of L1 (1575.42 MHz) and L2 (1227.60 MHz) until 2014. After 2014, with the usage of the next-generation GPS satellite "GPS BlockIIF", L5 (1176.45 MHz) frequency is activated to be used as pre-operational Civil Navigation (CNAV) by civilian users [3].

GLONASS constellation is another navigation satellite system developed by the Union of Soviet Socialist Republics (USSR). It is fully operational orbiting around the earth with 24 satellites since 1996. GLONASS supplies two kinds of navigation service as "standard positioning service" which is open to civilian usage and "precise positioning service" which is only used by military applications. There are three operating GLONASS frequency bands as G1 (1602 MHz), G2 (1246 MHz), and G3 (1204.704 MHz). G1 and G2 frequency bands are open to civilian usage since 1996 [4].

Galileo constellation is another GNSS that has been developed by European Space

Agency (ESA) since May 1999. The complete system will comprise 30 satellites (24 operational and 6 spares for each orbital plane). Five frequency bands are used for navigational signal transmission. Galileo will have four different service choices as Open Service, Commercial Service, Safe-of-life Service, and Public Regulated Service. E5a, E5b, and E1 frequency bands will be open to free usage in Open Service [4].

Combinational usage of the GNSS signals improves the accuracy and robustness of all navigation systems. Additionally, multiband GNSS usage also makes the system robust against jamming signals. Therefore, using multi navigational signal usage becomes more important to improve the reliability of positioning [4][5].

II. Microstrip Patch Antenna

The microstrip patch antenna is one of best candidates to meet the multiple frequency operability, circular polarization, and low-profile requirements for a GPS antenna. When a specific patch geometry is used to generate desired modes. On the other hand, microstrip patch antennas have some disadvantages like low efficiency, spurious feed radiation, and very narrow bandwidth. However, there are some methods to minimize these disadvantages, for instance, increasing the thickness of the substrate can increase the bandwidth and efficiency. But increasing the thickness can also introduce unwanted surface waves which degrade the radiation performance of the antenna [6]. Surface wave degradations can be minimized by using some photonic bandgap structures [7]. In addition to the use of a thicker substrate, there are some methods to increase bandwidth such as slot-loading on patches, different feeding techniques (i.e. aperture coupled feed), stacked structures, parasitic patches, and other multimodal techniques [7].

As shown in Figure 1, microstrip antennas consist of three main layers as ground, substrate, and conducting patch. The thickness of the substrate is usually a small fraction of the wavelength ($0.003\lambda \leqslant h \leqslant 0.05\lambda$). The geometry of the conducting patch can be rectangular, circular, or any other geometrical shape. For a rectangular conducting patch, the length of the patch is usually in the interval of $\lambda/3 < h < \lambda/2$. Substrates are dielectric materials, and their dielectric constants are usually in the range of 2. . The bandwidth of the antenna decreases with the increase of the dielectric constant of the substrate [8].

There are four common feeding methods as a microstrip line, coaxial probe, aperture coupling, and proximity coupling for microstrip antennas. These feeding structures are shown in Figure 2. Despite the low bandwidth, the feeding techniques of the coaxial probe and microstrip line are implemented more frequently [10].

III. Circular Polarization In Microstrip Antennas

In linearly polarized systems, transmission losses can occur because of misalignment of the transmitting and receiving antennas. If the electrical fields are vertically or horizontally oriented above the earth, the polarization of the antenna is called vertical or horizontal polarized, respectively. Both vertical and horizontal polarizations are called as linear polarization.

For circular polarization, two orthogonal components of the electric field which have the same amplitudes and 90◦ phase difference between orthogonal components are required in the far field region. For a circularly polarized wave, the trace of the electric field vector at a given point in space as a function of time is a circle as shown in Figure 3.

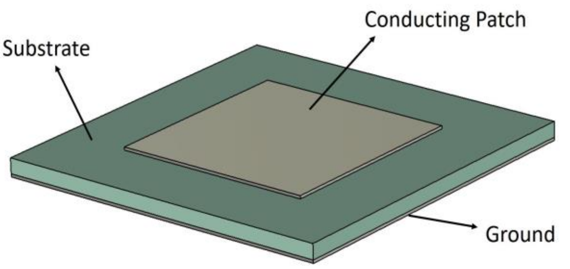


Fig. 1. Structure of microstrip antenna [9]

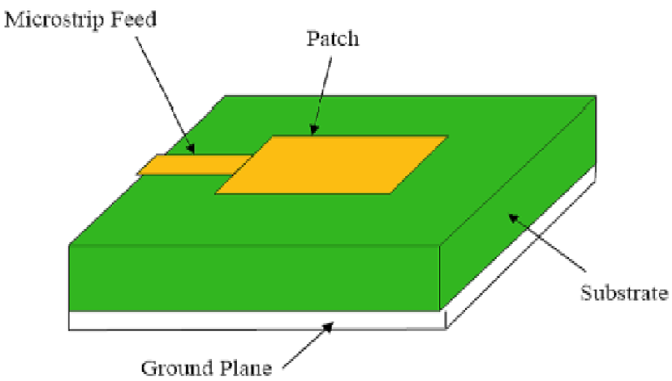


Fig. 2. Feeding methods of microstrip antennas [11]

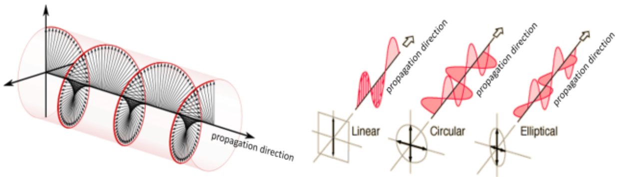


Fig. 3. Representation of circularly polarized wave [12]

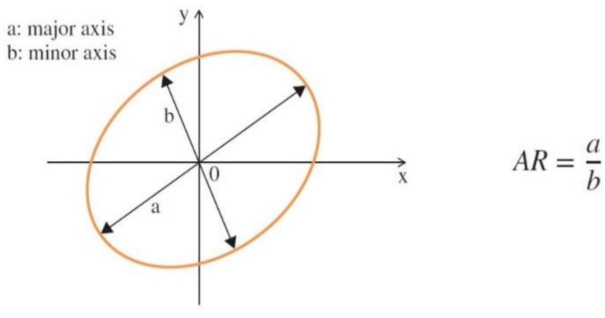


Fig. 4. Trace of the tip of electric field vectors for elliptical polarization.

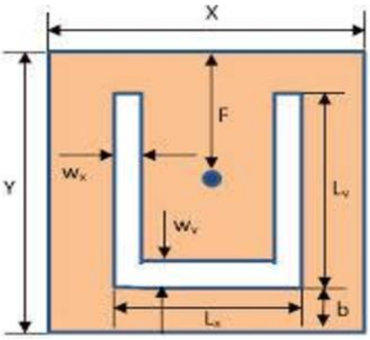


Fig. 5. Double fed CP microstrip antenna configurations for rectangular patches [14]

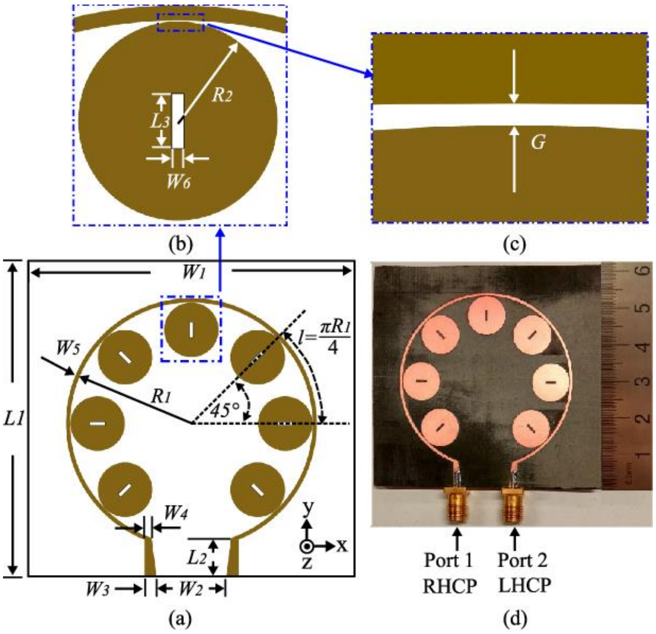


Fig. 6. Double fed CP microstrip antenna configuration for circular patches [15]

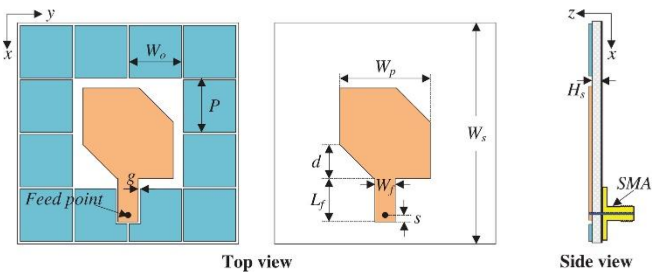


Fig. 7. Single Fed Circularly Polarized Patch Geometries [16]

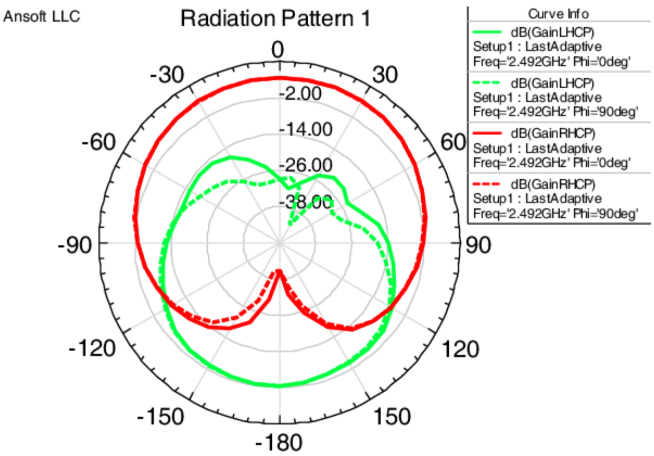


Fig. 8. Patch configurations for RHCP and LHCP on nearly square patches [18]

Shown in Fig.4 is called elliptical polarization [13]. Circular polarization can be achieved in microstrip patch antennas with two different feed configurations as single fed and double fed. 90◦ phase difference between two orthogonal modes is provided with an external passive microwave component (power divider, hybrid coupler, etc.) in double-fed circularly polarized microstrip antennas. TM10 and TM01 modes are used as orthogonal modes for rectangular patch geometries as shown in Figure 5. Double fed configuration can also be used in circular patches as shown in Figure 6. TM11 mode is used to get circular polarization on circular patches. Some of the patches are shown in Figure 7. In single-fed circularly polarized rectangular patches, orthogonal modes (TM10 and TM01 modes) are needed to be excited with 90◦ phase difference from a single point. If a square patch is fed diagonally, orthogonal modes are excited in phase.

The length of the vertical and horizontal edges are changed slightly to get 90◦ phase difference between orthogonal modes and the square patch becomes nearly square [17]. The patch configurations that provide RHCP and LHCP are given in Figure 8.

Circular patches can be made elliptical by changing the axis length of the circle to obtain 90◦ phase difference in the single-fed configuration [19].

U-slot loading is known as a method of increasing bandwidth in microstrip antennas. Asymmetrical U-slot is obtained by changing the length of one arm of the U-slot. If the left arm of the U-slot is longer than the right one, LHCP is obtained; if the right arm of the U-slot is longer than the left one, RHCP is obtained.

The loading of an E-shaped slot on a rectangular patch is another method to increase the bandwidth in microstrip antennas [20]. The loading of asymmetric slots on rectangular patches is another method for circular polarization [21]. In these studies, slightly varying circular slots are placed along diagonal directions to get circular polarization.

The asymmetrical cross-shaped slot is placed at the center of the patch to obtain circular polarization. RHCP [22] and LHCP can be obtained according to which slot is longer as given in Figure 9.

Most of the previously mentioned patch antennas have low axial ratio bandwidth. Slit and slot loaded patches have a 3 dB axial ratio bandwidth smaller than 1%. Corner truncated, nearly square diagonally fed and circular patch geometries have approximately 3 dB axial ratio bandwidth of 1%. In order to increase the axial ratio bandwidth, U-slot and E-slot patches are used and these patch configurations achieved approximately 3 dB axial ratio bandwidth of 4%. S

ingle fed circularly polarized microstrip antennas are preferred in many safety critical applications which have strict mechanical requirements as compared to double fed circularly polarized microstrip antennas, because of their compact sizes and less complexity. From the viewpoint of cost, single fed antennas are also less expensive than double fed ones, because they do not need any extra passive components.

IV. Multiband Operation In Microstrip Antenna

Many wireless communication systems use different frequency bands. Single frequency operating antennas can be used for each frequency band separately. However, this case will lead to a large size, mass, and high cost. Therefore, multiband antennas are preferred in multiband operating applications.

Stacking method is applied by stacking microstrip layers on each other as shown in Figure 10. In this configuration, the coaxial probe is connected to the upper patch, the lower patch is coupled electromagnetically (parasitically) with the upper patch. Each microstrip layer operates its own resonant frequency and the whole antenna with two layers operates multiband.

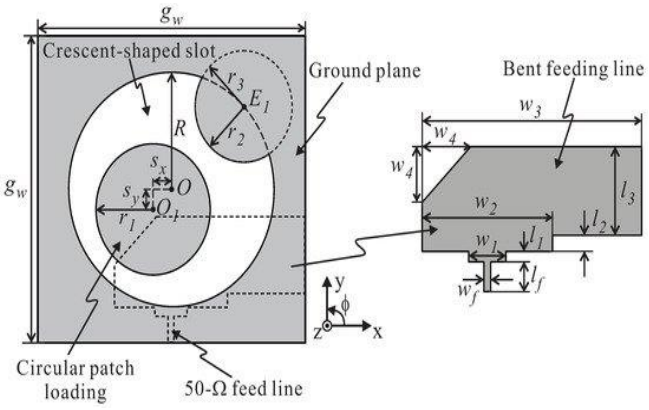
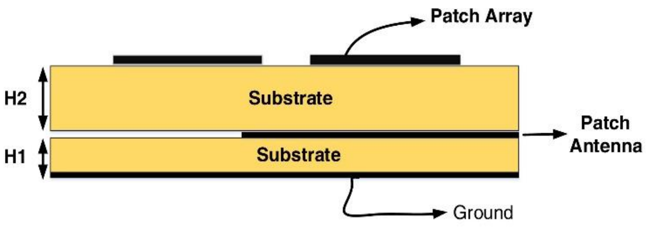
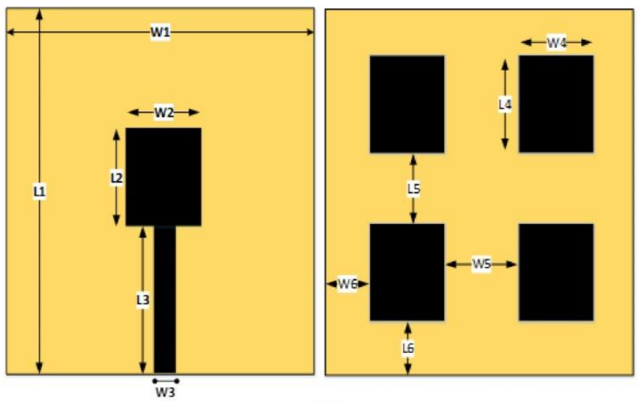


Fig. 9. Patch configurations for RHCP and LHCP on asymmetrical cross-shaped slot patch [20]



(A)



(B)

Fig. 10. Structure of stacked microstrip patch antenna for multiband operations [23]

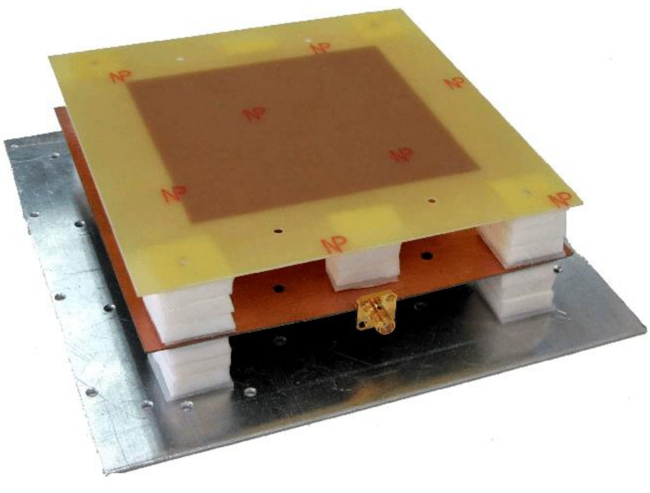


Fig. 11. Stacked microstrip antenna with an air gap

There are several studies on the stacking method to get multiband operations in microstrip antennas. Stacked antennas have broader impedance bandwidth and axial ratio bandwidth than loaded microstrip antennas. Having a small frequency ratio between operating frequencies is quite a challenging issue for loaded microstrip antennas, but stacked antennas can achieve dualband operations with a frequency ratio smaller than 1.5. Stacked antennas can be also used to increase the bandwidth with stacking patches that operate at close frequencies.

The air gap can be used in stacked antennas to get good impedance matching and increase the bandwidth and efficiency of the antenna. Stacked antenna with an air gap is shown in Figure 12.

Loading method is used on the patches for size reduction, control of polarization, control of radiation pattern, and dualband operations in microstrip antennas. The patch can be loaded with stubs, slots, shorting vias, and capacitors to obtain the required resonance frequency, radiation pattern, polarization, bandwidth, and so on.

Dualband operation is obtained with perturbation of TM10 and TM30 modes on dual edge slot loaded patch. If slots are placed close to radiating edges, TM10 mode is perturbed slightly. Therefore, the resonance frequency of TM10 mode changes slightly. The current distribution of TM10 is given in Figure 13-(a). The second resonance frequency is obtained with perturbation of TM30 mode. Slots are placed where the unperturbed TM30 mode current is significant as shown in Figure 13(b). Therefore, the perturbed TM30 mode becomes like TM10 mode. The resonance frequency of TM30 mode decreases and has boresight radiation with no sidelobe. This radiation mechanism also explains the way of obtaining multiband operations on other patch geometries which have slots close to edges.

The loading of multiple U-slot on rectangular patches is another method to get multiband operability in microstrip antennas. Linearly polarized triband is obtained with double U-slot loaded configuration.

Slot loading can also be used on circular patches. TM11 and TM12 modes are used for boresight dualband operations. In a circular slot loaded patch, the circular patch is divided into inner and outer patches which have their own resonance frequencies.

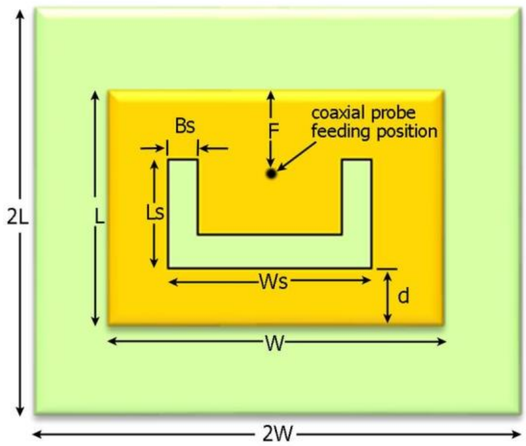


Fig. 12. Multiband slot loaded patches.

V. Multiband And Circularly Polarized Microstrip Antennas

In previous sections, the ways of getting circular polarization and multiband operations on microstrip antennas are given separately. In this section, circularly polarized multiband microstrip antennas are examined and presented.

It is needed to merge the methods of circular polarization and multiband operation to design circularly polarized multiband microstrip antennas. First, the number of feed points is chosen to get circular polarization. A passive component or circuit that provides 90◦ phase difference is needed in the double fed antennas. In single fed antennas, 90◦ phase difference is obtained with perturbation of orthogonal modes. After the decision on the number of feeds, the technique of multiband operation is chosen. Both stacking and slot loading methods are suitable for single feed configurations. Therefore, single fed circularly polarized multiband antennas are researched in the literature survey.

Two truncated patch antennas are stacked as operating at 1575.4 MHz and 1227.6 MHz (L1 and L2 GPS bands, respectively). Corner truncation is used for circular polarization at each frequency band. The air layer is used to tune the frequency ratio. Antenna is fed by a single coaxial probe which is soldered to the upper patch and the lower patch is fed parasitically. According to measurement results, 15 MHz and 17 MHz circular polarization bandwidth is obtained at L2 and L1 bands, respectively.

A triband corner truncated antenna is designed to operate at GPS L1/Galileo E1 (1.575 GHz), Galileo E5b (1.207 GHz), and GPS L5/Galileo E5a (1.176 GHz) frequency bands. Corner truncation is used for circular polarization at each frequency. Antenna is fed by a single coaxial cable which is soldered to the upper patch. Middle and lower patches are fed parasitically. According to the given simulation results, 3 dB axial ratio bandwidth of 12.6 MHz (0.8%), 4.83 MHz, and 94 MHz (8%) are obtained at the center frequencies of GPS L1/Galileo E1, Galileo E5b, and GPS L5/Galileo E5a bands, respectively.

An L1 and L2 GPS band operating truncated patch antenna are designed and measured. Corner truncation is used for circular polarization at each frequency. Antenna is fed by a single coaxial probe which is soldered to the lower patch. The upper patch is placed with an air gap from the lower substrate and excited parasitically. The height of the air gap is used to tune the frequency ratio. According to the results, if the height of the air gap increases, the frequency ratio decreases.

Three square patches are stacked with different geometries. Antenna is designed to operate at L1, L2, and L5 GPS frequency bands. Antenna is fed by a single coaxial probe that is soldered to the top patch. Other patches are fed parasitically. Circular polarization is obtained with corner truncation on the upper patch for L1 band operation. Four symmetric cross-shaped slots are used to get circular polarization on the middle patch for L2 band operation. Symmetric slits are placed on the corner of the lower patch to obtain circular polarization for L5 band operation.

Multiband operation is obtained with the loading of slots and circular polarization is obtained with perturbation of the patch geometry. Dualband is obtained with slots close to edges (edge slots) and circular polarization is obtained with the center cross slot and diagonal feed. Antenna is designed to operate circularly polarized at 1575.4 MHz and 1227.6 MHz. The length of the edge slots controls the resonance frequency of the TM30 mode. However, there is a limited place on the patch. Therefore, the patch is loaded with short circuit stubs from the edges of the patch to decrease the frequency ratio.

Contrubition of the Authors

The contributions of the authors to the article are equal.

Conflict of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were observed in this study.

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