RESEARCH ARTICLE

SAMRIDDHI Volume 15, Issue 1, 2023 Print ISSN: 2229-7111 Online ISSN: 2454-5767

Design and Analysis of Smart Antenna for Mobile Application

Sachin Bandewar, Virendra S. Chaudhary

Ram Krishna Dharmarth Foundation University Bhopal, Madhya Pradesh, India

Abstract

There is a growing desire for digitalization in today's world. Digitization aims to improve people's lives by creating smart homes and businesses. The primary goal of this research is to increase the communication efficiency of these modules by redesigning or replacing existing antennas with others of a different kind. A communication module antenna is presented in this paper. With four distinct PCB antenna designs, we were able to get more accurate simulations of gain, reflection coefficient, VSWR, and bandwidth. Design of antennas for GPS L1, ISM (Industrial, Scientific, and Medical) 2.45 and 5.8 GHz bands is a constant in antenna development for mobile devices.

Keywords: Antenna,IoT, multiband, mobile, WLAN.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2023); DOI: 10.18090/samriddhi.v15i01.19

Introduction

Progress in wireless communications technology and systems has been tremendous and shows no sign of slowing down anytime soon. As technology advances, people's daily routines are altered by the introduction of a wide variety of technologies and procedures. When it comes to interacting with others, mobile devices like smartphones, tablets, and laptops are regarded as nearly essential. The development of multiband communication has necessitated the use of tiny devices and other equipment. Is it legal to connect so many devices? What is the one design element that is critical to this question? These issues are critical to the design of wireless devices. It is important to note that antennas are a crucial component of communication systems and devices since they are responsible for receiving and/or sending electromagnetic signals. Mobile systems play a critical role in today's technological advancements because of the need for dependable portable solutions in terms of data transmission and communication.[1] Devices have evolved throughout time, as seen in Figure 1. Considering the tiny size, compactness, and light weight of antennas used in mobile communication devices,[2,3] these characteristics are critical in the telecommunications business.

Antennas have long been recognized as an essential component of current mobile communications devices, but the amount of space available for antennas has shrunk significantly as a result of the growing demand. As a result, antennas that can operate in many bands are a must for these devices. Designers of antennas need to continually keep up with the evolution and invention of communication, inventing new tiny and wireless antennas, always considering cheap costs to compete with market values [6]. For the most part, antennas are becoming smaller, more powerful, and more efficient as time goes on.[7,8]

More frequency bands have been employed to enable a wide range of wireless applications including machine control, tracking devices, medical assistance, and smart phones. There are apps that use the same frequency channels. As a result, free bands are now a viable option [9]. Additionally, there is a propensity to adopt higher frequency bands since they allow for more data to be sent.

S-band, L-band, and C-band are the most commonly used IEEE radio bands, with applications such as GPS, LTE, GSM, UMTS, WLAN, ISM, and Wi-Max. These applications have their own frequency bands, however, they are included inside the bands already listed.[10] The importance of antenna research stems from the benefits of wireless devices in everyday tasks, the ease they bring to users' life, and the vast variety of technological possibilities they provide. Using multiband antennas may help alleviate the issue of too many electrical components in mobile phones. Cameras, radios, fingerprint scanners, Bluetooth, WI-FI, GPS, phone calls, and

Corresponding Author: Sachin Bandewar, Ram Krishna Dharmarth Foundation University Bhopal, Madhya Pradesh, India, e-mail: Sachin.bandewar9@gmail.com

How to cite this article: Bandewar, S., Chaudhary, V.S. (2023). Design and Analysis of Smart Antenna for Mobile Application. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology,* 15(1), 139-147.

Source of support: Nil

Conflict of interest: None

Figure 1: Advancement of Telecommunications Equipment.

text messages are just a few of the applications that must be addressed in today's mobile terminals. In the field of communications technology, action is constantly required, and one method to improve and mitigate the problem's effect is to develop antennas that can operate in many bands, allowing for the use of just one antenna for multiple purposes. An antenna construction with modest dimensions is presented in this paper. An antenna that seeks to function in the ISM 2.45GHz bands and provides for a reduction in the number of antennas needed in mobile terminal Frequency bands and applications.

Frequency bands of interest

The antenna is designed to target certain frequencies, and these frequencies must be chosen. When looking at the most often utilized frequency bands for mobile communications, the IEEE radio bands S-band, L-band, and C-band stand out.[11-13] New frequency bands have increased the need for antennas that can operate in many bands. The GPS 1.5 GHz band and the ISM bands 2.4 GHz and 5.8 GHz are some of the most often utilized frequency bands for mobile terminal applications. It also outlines the many applications for which these bands might be used. Wireless systems are quite popular and helpful for local (WLAN) and personal (WPAN) networks. The majority of these systems are assigned in ISM channels - Industrial scientific and medical radio bands - but they are increasingly being utilized for low-power, short-range mobile communications. Because these bands do not conflict with other industrial, scientific, or medical ISM users, they may be used for mobile communications.

Below is a quick summary of the IEEE L, S, C, and ISM bands.

L Band

The L-band has a 15–30 cm wavelength and extends from 1 to 2 GHz. It is often used for mobile communications, both satellite and terrestrial, but it is also the primary band for navigation and location. The most common uses are GSM communications and GPS systems.

S Band

The S-band operates at 2-4 GHz frequencies and has a 15–7.5 cm wavelength. It is used for wireless communications, mobile satellite communications, and ship and weather radars. This band, for example, is used by NASA for satellite communications. The S-band is utilized in microwave applications, wireless networking devices such as WLANs and Wi-Fi, and Bluetooth applications. It is optimized for two-way communications and content delivery.

C Band

The C-band spans a wide variety of frequencies and hence a large range of uses, such as weather radar, satellite communication, Wi-Fi, and other ISM band applications, with a wavelength ranging from 7.5 to 3.75 cm. Because the C-band is also used for radar, certain weather radars may experience some interference. The 5 GHz frequency band, which spans 5.15 to 5.35 GHz, 5.47 to 5.725 GHz, and 5.725 to 5.875 GHz, is the most often utilized in mobile communications. It is the most popular for mobile terminals that employ IEEE 802.11a Wi-Fi and other ISM band applications.

Target frequencies

The antenna must be projected aiming at certain specific frequencies for design reasons. Given the most common uses in mobile communications, this project aimed to build an antenna that could function at ISM 2.45 GHz. The antenna produced in this project is planned to be used in applications such as Wi-Fi, Bluetooth, and GPS.

ISM Bands

The ISM bands (industrial, scientific, and medical radio bands) are a group of radio frequencies in the radium spectrum. Internationally, the ISM bands were assigned to scientific, medical, and industrial initiatives rather than communications. Microwave ovens, industrial heaters, and radio frequency welders are examples of these. For short-range devices and platforms, the active development of mobile wireless communications necessitated the use of higher frequencies. ISM bands are now utilized for mobile communications, partly because of the lack of licensing costs, making them more economically appealing. ISM antennas are critical for mobile devices because they meet requirements such as increased capacity and transmission speed.[14]

The number of ISM band devices and users has increased, and these bands represent an important step in the development of wireless computing and multimedia applications. Important ISM applications have been developed, one of which is a user-friendly geriatric monitoring program.[15] The conditions of ISM frequency bands set by the free license commission may vary by area and permit.[16] According to the International Telecommunication Union (ITU), the globe is split into three areas, as indicated in Figure 2,3 each of which is described in Appendix C. There are multiple frequency sets authorized to the global ones depending on what area the antenna must operate in. Appendix C has a description of certain frequency sets. When developing a new market product, the antenna designer and product developer must constantly keep these elements in mind.

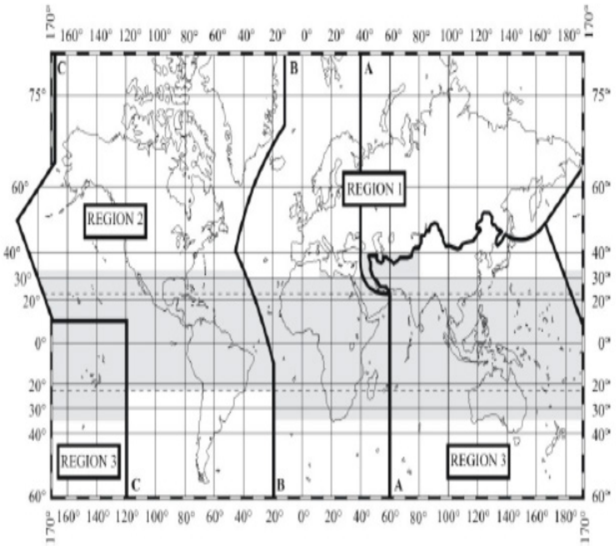


Figure 2: Regionally harmonized bands as defined by the ITU. The use of regionally harmonized bands is recommended in Resolution 646(WRC-03) "Public protection and disaster assistance." [17] Source:

RFID, health monitoring, smart gadgets in the car-home-phones industry, NFC, and other applications may all benefit from ISM band antennas. This thesis aims to create an antenna that can be used for bluetooth and Wi-Fi applications, emphasizing the 2.4 GHz and 5.8 GHz ISM bands. The next section takes a more in-depth look at these individual bands ISM 2.4 GHz and 5.8 GHz.

In 1947, the International Telecommunication Union (ITU) established ISM. ITU recognized twelve distinct ISM bands at the time. The Federal Communications Commission (FCC) authorized ISM2.45 and 5.8 GHz to unlicensed spread-spectrum for wireless LANs and mobile communications 38 years later, in 1985.[18] The high number of users and lack of interference prevention are two drawbacks of these unlicensed bands. Designers of products and antennas must examine various interference prevention systems and research the frequency range to choose the ones with the least interference.[19]

With the benefits of license-free and error-tolerant ISM bands, antennas that can operate in both 2.45 and 5.8 GHz ISM bands provide the adaptability required in a variety of applications, including Wi-Fi and Bluetooth, as well as other short/medium range data transmission.[20-22] are examples of multiband antennas that operate in the 2.4 GHz and 5.8 GHz frequency bands. The 2.4 GHz ISM band is the most popular and, as a result, the most congested. Adding the 5.8 GHz ISM band to wireless networks reduces interference, and unlicensed and unlicensed users in the 2.45 and 5 GHz ISM bands are considered secondary. This means they must share their portion of the spectrum with other services that have priority access, such as aviation, maritime, satellite, and tracking devices. The secondary user must accept any interference from the other priority users.[14]

Table 1: Some specifications comparing 2.45 GHz with 5.8 GHz

ISM BAND	*2.45GHz*	*5.8GHz*
Frequency Range	2.4GHz-2.5GHz	5.752GHz-5.875GHz
Bandwidth	100 MHz	150MHz
Availability	Worldwide	Worldwide
Channel	3 non overlapping channel	23 non overlapping channel
Standard IEEE	Wires b,g and n	Wireless a and n
Network range	Wider range	Shorter range
Interference	Higher	Lesser
Applicable standards	802.11b,g,n and Bluetooth 3,4,5	802.11 a,n,ac and Hiper LAN1,2

Table 2: Frequency Band

Channel	*Frequency (MHz)*			
	F - 10	*Centre*	*F + 10*	*Area*
1	2402	2412	2422	
2	2407	2417	2427	
3	2412	2422	2432	
4	2417	2427	2437	
5	2422	2432	2442	
6	2427	2437	2447	
7	2432	2442	2452	
8	2437	2447	2457	
9	2442	2452	2462	
10	2447	2457	2467	
11	2452	2462	2472	
12	2457	2467	2477	
13	2462	2472	2482	
14	2474	2484	2494	

Table 2.1 compares some of the parameters of the two ISM bands. Table 2.1 shows that the 5.8 GHz band is broader and contains twenty more non-overlapping channels than the 2.4 GHz band, implying that transmission may be quicker with more bandwidth and less interference in the 5.8 GHz ISM band.

Combining nearby channels to create 40 MHz channels is feasible instead of the conventional 20 MHz channels using the standard 802.11n in the 5.8 GHz ISM band. There are certain drawbacks to using the 5.8 GHz ISM band, such as a reduced network range, poorer penetration through some solid impediments, and integration challenges on existing wireless infrastructures. In these conditions, concentrating these two frequencies in a dual-band antenna is extremely common today. The following two items discuss the two most common uses within the stated frequency ranges.

Bluetooth

BT is a technology that enables a wide range of devices, including tablets and smartphones, to be connected.[29] It is one of the most often utilized methods for interoperability and interconnection between portable and stationary telecom equipment in the wireless sector. With a frequency range of 2.4–2.48GHz depending on the operating channel, Bluetooth is a wireless technology applied in ISM 2.4 GHz. The Internet of Things (IoT) is largely responsible for Bluetooth's continued development. All five main versions of bluetooth radio standards have been produced and are actively used. Versions 1 to 3 are known as Bluetooth classic mode, whereas versions 4 and 5 are known as Bluetooth Low Energy (LE) mode. Classic and LE versions of Bluetooth are incompatible, and only Bluetooth devices that enable Dual Mode may deliver both modes.[23]

It's important to note that the three primary versions of Bluetooth Classic are classified into the following three categories

BR stands for "Basic Rate," which is the lowest data rate of Bluetooth. This class has a maximum distance of 100 meters and was created between 1999 and 2003.

Improved transmission speed for Class 2: Enhanced Data Rate Classic (EDR) In the years 2004–2007, this class was introduced with a range of 10 meters or less.

The High-speed (HS) option was introduced in 2009 for Class 3. This class can offer a distance range of up to 10 meters in free line of sight.

Devices that use Bluetooth Low Energy are intended to use little power since it was introduced at the same time as Bluetooth 4.0 in 2010-2014. Higher data rates, longer range, and more throughput have been introduced in Version 5,[23] which was initially deployed in 2016 but is still under development.[24]

Wi-Fi

For wireless networks, IEEE 802.11 is a set of standards developed by the IEEE. Five well-known standards within these standards have higher and longer-range operations than Bluetooth devices.[25]

High-speed wireless LAN/MAN 802.11a was adopted in 1999 and works in the 5GHz range, which includes: 5.15-5.35 GHz in the United States, 5.47–5.725 GHz in Europe, and 5.85-5.85 ISM band. As of this writing, the maximum range is 30 meters inside and 120m outdoors.

Both the 802.11a and 802.11b standards for fast wireless LAN/MAN were approved in 1999. Operates in the 2.4GHz frequency range, which includes the ISM band (2.4-2.5GHz). The data rate is 11 Mbps and the range is 30 meters inside and 130 meters outside.

Wireless g (802.11) is a higher-speed variant of 802.11b that was introduced in 2003. Operating in the ISM 2.4 GHz band, this device may be found in the 2.4GHz frequency range. Indoor range is 38 meters, while the outside range is 130 meters. The data rate is 54 Mbps.

802.11n was adopted in 2009 and incorporated newer technology compared to the previous standards in order to deliver substantially faster data transfer speeds (e.g. OFDM and MIMO). 2.4GHz and 5GHz ISM frequency bands are supported. It has a speed of 600 Mbps and an usual range of 68 meters inside and 251 meters outside.

For specialized solutions such as streaming high-definition video and many other files, the 802.11ac system (also known as 5G WiFi and VHT, Very High Throughput) was introduced in 2014, also known as 5G WiFi and VHT, Very High Throughput An ISM band 5.8 GHz radio may be used (unlicensed). The data rates are one Gbps for multi-station operations and 500 Mbps for a single connection. The normal indoor and outdoor ranges are 308 meters and 27 meters, respectively.

Foreground information

IoT, or the Internet of Things, is one of the most talked-about subjects in today's technology. An crucial part of everyone's everyday life, IoT serves as the network that connects all of our devices to the internet and to each other. The Internet of Things (IoT) aims to create gadgets that can connect with one another in order to increase productivity. An important benefit of IoT is the ability to exchange data. Machines can communicate with one other better, resulting in increased productivity and quality. People don't have time to stress about minutiae, which is why IoT makes life easier. Using IoT, machines can connect with one other and save money and resources while doing so. In the Internet of Things, communication is critical. In order for IoT devices to communicate effectively, they must have stronger antennae.[8]

If you want to transmit or receive an electromagnetic wave, you need an antenna.[28] An antenna may either transmit or receive an electromagnetic wave. Both are important aspects of antenna design. The Maxwell's equations and the antenna's boundary conditions[28] may be used to get an understanding of antenna functioning. As new communication technologies emerge, antenna design has become more vital. It has always been a grueling endeavor. For a wide range of applications, there are more than a thousand antenna designs to choose from. As technology advances, the aim is to build smaller, more efficient electronic devices that can connect with each other through the innovative integrated unit.

Antenna Theory

Conventional antennas and their benefits are discussed in detail. There are a wide variety of antennas available for a variety of purposes. The following is a breakdown of the many antenna types.

Monopole, dipole, loop, half wave dipole, and Yagi-Uda antennas are all examples of wire antennas.

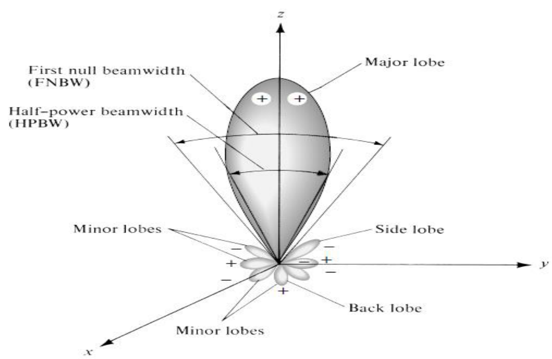


Figure 3: emission Lobes and Beam widths of the emission model [26]

The frequency range for this sort of antenna is narrow and the gains are modest. Lightweight, cheap cost, and simple construction are all advantages of this design.

an open waveguide or reflect array;[27] an open waveguide, a rectangular or circular horn antenna;[28] a reflective or lens antenna;[27] an open waveguide or a circular horn antenna

They are used in microwave frequencies and have a larger gain than other antennas [28].

There are many kinds of antennas that may be printed, including printed dipoles,[26] printed slot antennas,[28] and microstrip patch antennas.[26]

Antennas of this kind may be made using pcb's. The benefits include elevated increase, cheap prices, and the ability to be arranged in a variety of configurations. It is common to find these antennas in microwave and millimeter wave applications.

It features an array of antennas, each with a specific configuration and feeding system. The beam aiming angle and side lobe levels may be adjusted by altering the amplitude and phase excitation of the array members.[26,28]

In antenna theory, radiated electromagnetic waves may be sent or received using an antenna in a specified route a number of antennas are worn to send and obtain signals in all directions. For sending and receiving electricity, an antenna must be efficient. In addition, a good antenna's resonance frequency range is a plus. One must be familiar with the fundamental characteristics of an antenna in order to build an antenna with excellent performance.

The reciprocity of the antenna

The electromagnetic and magnetic characteristics of the antenna are referred to as antenna reciprocity. Input impedance and voltage standing wave ratio are a few of the other factors to consider, as well as the radiation pattern, gain, beam width, and bandwidth (VSWR).

Waves model

Figure 3 depicts the radiation field in three dimensions. Radiation is concentrated in the major lobe or main pattern.

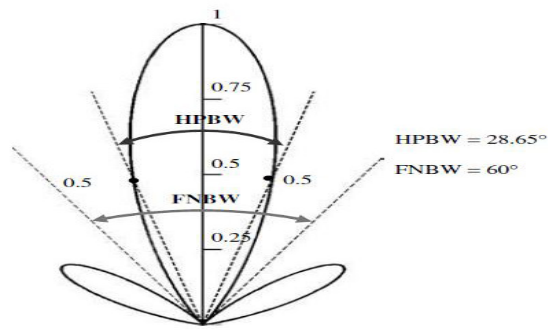


Figure 4: Two-dimensional power patterns [26]

Depending on the antenna, there may be more than two primary lobes of reception. Minor lobes, which may be further subdivided into side and rear side, are the other lobes of the brain. They tend to be located close to the main lobe. To put it another way, it's the opposite of the main lobe and forms a right angle of 180 degrees. An antenna's primary purpose is to lower the side lobes and maximize the principal lobe for improved radiation.

Beam-width

To measure beam width, the angle between two sites on opposing sides of the pattern maximum is used.[1] For the most part, beam widths fall into two categories: FNBW, and HPBW.

Directivity

It is defined as the ratio of the radiation intensity in a specific direction from the antenna to radiation intensity averaged across all directions." The directivity of an antenna is Power divided by 4 emitted power. If no direction is given, the direction of greatest radiation intensity is assumed".[26]

Directivity may be mathematically expressed as follows in its simplest form.

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}$$

Gain and Antenna efficiency

It accepts a particular amount of power and radiates it out in an isotropic fashion, its gain is equal to this isotope radiation intensity. The power received by the antenna, divided by 4",[26] gives the radiation intensity that corresponds to the isotopically radiated power.

$$Gain = 4\pi \frac{\text{radiation intensity}}{\text{total input power}} = 4\pi \frac{U(\theta,\varphi)}{Pin}$$

Antenna efficiency is defined as the ratio of radiated power over input power

$$\eta = \frac{Prad}{Pin}$$

S-parameters and Bandwidth

S11 is the majority often utilized antenna restriction. It is how a large amount power is reflected back from unit, go no further than S_{11}. Nothing is emitted since $S_{11} = 0$ dB means that the antenna is reflecting the whole amount of energy. To put it another way: If S_{11} is -10dB, this means that the antenna receives only 7dB of power while it receives 3dB.

Bandwidth is still another critical consideration. The frequency range that an antenna can effectively transmit or receive energy is referred to as its bandwidth. An antenna's bandwidth is described as "the range of frequencies over which the antenna's performance, with regard to particular features, corresponds to a set standard".[26] The range of frequencies within which specific antenna settings are operable is another way of describing bandwidth.

The VSWR (Voltage Standing Wave Ratio)

Standby Wave Ratio (VSWR) is the abbreviation for Voltage Standing Wave Ratio (SWR). The antenna's reflection coefficient is used to measure how much power is reflected back. The following is a mathematical definition of the reflection coefficient.

The VSWR might be anything between one and one hundred percent. A perfect antenna with a VSWR of 1 reflects no power. An antenna with less than 1 ohm impedance is one of the most powerful. The S11 (scattering parameter) reflection coefficient may be used to calculate how much power is reflected back from a particular antenna.

Loss of Return

When comparing the incident and reflected power, the return loss may be stated as

$$|S_{11}| = 10log_{10}\left(\frac{P_r}{P_i}\right)$$

Bandwidth

The frequency range that a phone's antenna can operate within is known as its bandwidth. The impedance bandwidth is often defined in terms of -10 dB return loss values.

Mean Effective Gain (MEG)

MEG is the average of the measured gain on a surface around the handset. It is a figure of merit of antennas that characterize the interaction between antennas and channels.

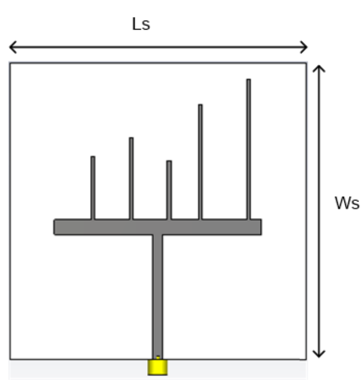


Figure 5: Proposed Antenna Design

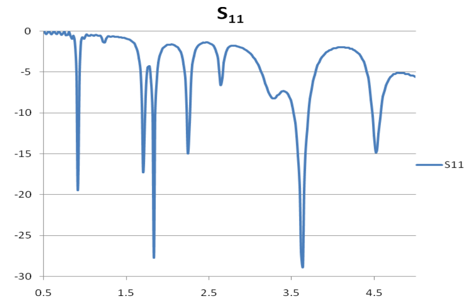


Figure 6: S_{11} of Proposed design

Table 3: Dimension of the proposed Design

Parameters	*Values (mm)*
Ls	40
Ws	40
Lg	30
P	28
Wg	26
S	19
h	17
L	16
F	11.25
d	10
E	8
r	2.8
G	2
b2	1
w	0.5
b	0.5
a	0.5
j	0.5

Total Radiated Power (TRP)

TRP represents the power density received over a sphere around the handset. The received power density is evaluated at It is an dynamic quantity, in that a power-driven spreader is used to broadcast throughout the antenna. The entire traditional influence is deliberate and summed up over all possible angles, and is measured the radiation in an actual live system.

Isotropic Sensitivity (Total)

TIS defines the minimal input signal strength required to provide an appropriate data quality characteristic, including such bit error rate, when sampled at places surrounding the device in both polarizations. This sensitivity number is a measure of a multiple antennas system's average sensitivity.

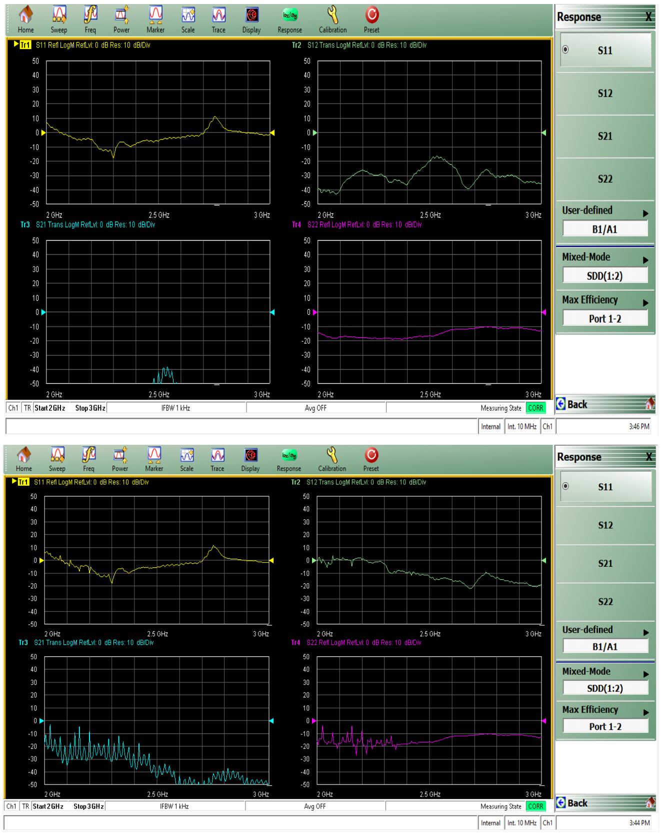


Figure 8: Hardware testing

Specific Absorption Rate (SAR)

SAR represents the ratio at which energy is accumulated in a given volume of human skin tissue.

Impedance Matching

Impedance matching is an essential aspect of a power line and a microwave communication connection. A frequency selective connection is established between the antenna's impedance (feeding line) and the transmission line (antenna). To save electricity from being wasted, it must be lossless. The reflection loss in the power line can be minimized using a matching network, but numerous reflectors may still occur, necessitating tuning,[33] which is the process of altering the strength of the matching networks.

Impedance matching, or tuning, is critical.

It is best to match the load impedance to the line impedance in order to reduce power loss from reflection in the signal source.[33]

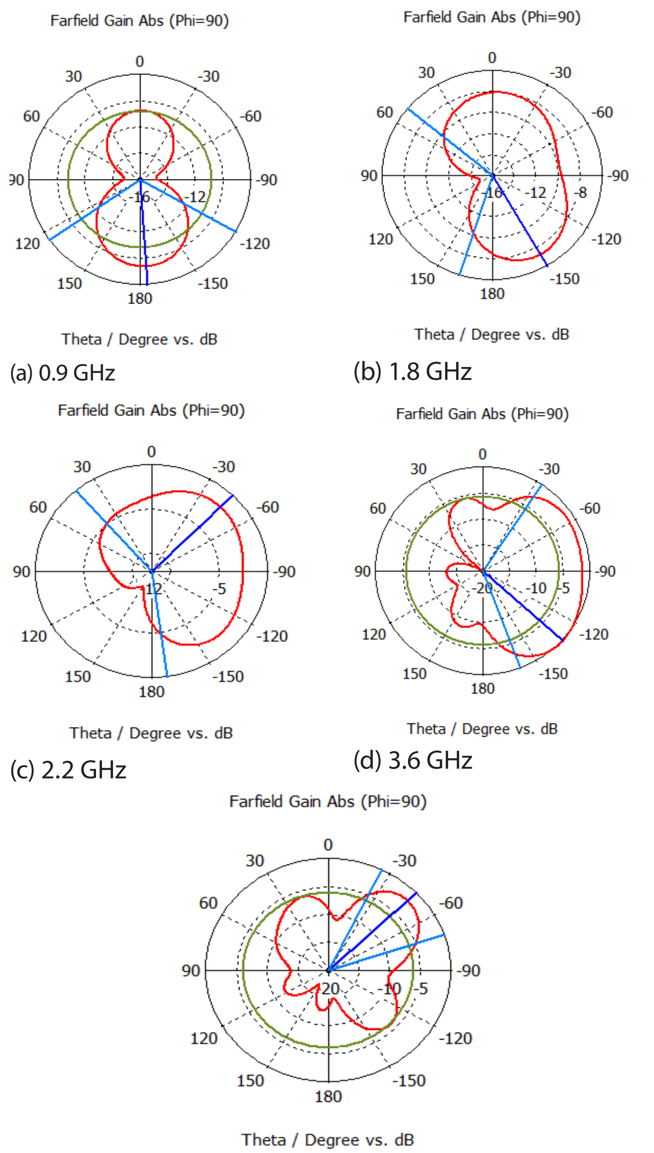
System components such as antennae and limited amplifier will benefit from an impedance-matching network.[10]

The capacitive and inductive network may be used in such array antenna to decrease the magnitude and phase errors. Matching networks of many kinds

- E11, or L type matching network, is sometimes known as E11 (lumped components)

There are two types of networks that are completely error-free: (lumped components)

Matching Micro-strip System (PCB printed Trace)



(a) 0.9 GHz (b) 1.8 GHz (c) 2.2 GHz (d) 3.6 GHz (e) 4.5 GHz

Figure 7: Radiation pattern of proposed antenna design at different frequencies.

- Stub end of open circuit

Stub of the short circuit.[33]

Guidelines for the creation of a product

The antenna designer has some guidelines when projecting the antenna so that it can achieve a good performance. For impedance match, it is usually stabilised that the voltage standing wave ratio is VSWR < 3 and the return loss is S11 <10 dB. A low value is required for the mean effective gain, being 0 dBi the ideal, since it provides a small directivity prototype to diminish indicator variations as unit location is diverse. For radiation efficiency, it is required that the minimum value should be about 50% and the bandwidth should be about 8 to 12% of the central frequency (depending on the operating band).

- While communicating data from the ground station to the user equipment (uplink), GSM-900 utilizes 890–915 MHz; when broadcasting from the base station down to the reference node (downlink), 935–960 MHz is used.

- CDMA or JIO – Uplink starts 829.935, Uplink Stops 831.165 Downlink starts 874.935, Downlink stops 876.165
- 802.11 b/g/n (2.4 GHz band)

On Monday (Sept. 18), The Economic Times from New Delhi reported that the Department of Telecom (DoT) has asked that the Department of Space (DoS) release 95 MHz in the 2.5–2.69 GHz range for 3G and WiMax. The DoT is seeking 150 MHz of spectrum in the 3.4-3.6 GHz range.

Antenna Gains

Antennas for Mobile Stations

A typical gain for a car-mounted antenna is between one and three decibels.

- Portable mobile phone antennas normally have a gain of between zero and one decibel.

Antenna for the base station

0-9 dBd gain is normal for omnidirectional antennas.

These antennas have a typical gain of 9 to 14dBi.

wension of the proposed Design

Result and Conclusion

Various Algorithms are studied and implemented for finding direction of arrival and for Digital beam-forming.

Design and demonstration of 1800 MHz DCS band microstrip patch antenna. For its compact size, the antenna measures only 50*40*3.8mm3. Reflection at 1800 MHz is below a 10-dB level in simulated findings.

Future work

Calculation of Optimum values after simulation and experimentation for direction of arrival algorithms and for Digital beamforming using MATLAB software.

Construction of FR4 substrate-based microstrip antennas with a 50*40*3.8mm3 footprint in the design.

References

[1] G. Wang, P. Zhao, L. Wang and L. Wang, "A Two-Dimensional Direction Finding Method Based on Non-Uniform Array," in IEEE Access, vol. 9, pp. 95335-95345, 2021, doi: 10.1109/ACCESS.2021.3095065.

[2] K. Ren, R. Ma and N. Behdad, "Performance-Enhancement of Platform-Based, HF Direction-Finding Systems Using Dynamic Mode Selection," in IEEE Open Journal of Antennas and Propagation, vol. 2, pp. 793-806, 2021, doi: 10.1109/OJAP.2021.3095223.

[3] I. Aboumahmoud, A. Muqaibel, M. Alhassoun and S. Alawsh, "A Review of Sparse Sensor Arrays for Two-Dimensional Direction-of-Arrival Estimation," in IEEE Access, vol. 9, pp. 92999-93017, 2021, doi: 10.1109/ACCESS.2021.3092529.

[4] D. Zhang, A. Li, C. Pradhan, J. Li, B. Vucetic and Y. Li, "Training Beam Sequence Design for Multiuser Millimeter Wave Tracking Systems," in IEEE Transactions on Communications, doi: 10.1109/TCOMM.2021.3096543.

[5] P. Zhou, Y. Liu, H. Zhao, Y. Shi and X. Yin, "Differentially Fed Dual-Mode Patch Antenna with Wideband Common-Mode Absorption and Its Array Application," in IEEE Transactions on Antennas and Propagation, doi: 10.1109/TAP.2021.3097438.

[6] R. Roges, P. K. Malik and S. Sharma, "A Compact CPW-Fed Log-Periodic Antenna for IoT Applications," 2021 International Conference on Communication, Control and Information Sciences (ICCISc), 2021, pp. 1-5, doi: 10.1109/ICCISc52257.2021.9484975.

[7] M. Sohail and R. Uyguroğlu, "Near Field Focused Microstrip Patch Antenna Array Characteristics Enhancement With Parasitic Patch Elements," 2021 29th Signal Processing and Communications Applications Conference (SIU), 2021, pp. 1-4, doi: 10.1109/SIU53274.2021.9477974.

[8] M. Mulla, M. Sohail, A. H. Ulusoy, R. Uyguroğlu, A. Rizaner and H. Amca, "A Single User Millimeter Wave Massive MIMO System using Defected Ground Structure and Metasurface Antenna Arrays," 2021 29th Signal Processing and Communications Applications Conference (SIU), 2021, pp. 1-4, doi: 10.1109/SIU53274.2021.9477798.

[9] Z. S. Seven and S. Can, "Calculation of Resonant Frequency and Bandwidth of Rectangular Microstrip Antennas via Genetic Algorithm," 2021 29th Signal Processing and Communications Applications Conference (SIU), 2021, pp. 1-4, doi: 10.1109/SIU53274.2021.9478054.

[10] Dau- Chyrh Chang, Cheng Nan Hu – Smart Antennas for Advanced Communication Systems Vol. 100, No. 7, July 2012 Proceedings of the IEEE, 2012

[11] R.K Jain, Sumit Katiyar and NK Agrawal Smart Antenna for Cellular Mobile Communication Vol. 1(9), 530-541, VSRD-IJEECE 2011

[12] Younsun Kim, Hyoungju Ji, Hyojin Lee, Juho Lee, Boon Loong Ng and Jianzhong Zhang - Evolution beyond LTE-Advanced with Full Dimension MIMO - IEEE International Conference on communication 2013

[13] Vira rahayu, Kei yokokawa – 2D DOA estimation of patch antenna array using USV MUSIC algorithm The Institute of Electronics Information and communication ICICE 2013

[14] [Afif Osseiran, Federico Boccardi, Volker Braun - Scenarios for 5G Mobile and Wireless Communications: The Vision of the METIS Project IEEE Communication Magazine May 2014

[15] D.B.Salunke, R.S.Kawaitkar, Analysis of LMS, NLMS and MUSIC Algorithms for Adaptive Array Antenna Systems, International Journal of Engineering and Advanced Technology (IJEAT) Vol. 2 Feb 2013

[16] Amara Prakasa Rao, N.V.S.N Sarma, Adaptive Beamforming algorithms for Smart Antenna Systems,WSEAS Transaction on Communications Vol.13 2014

[17] World in 2015-ICT Facts and Figures" by International Telecommunication Union.

[18] Auction of Spectrum in 1800 MHz, 900MHz results. http://www.dot.gov.in/spectrum-management/spectrum-management/auction-spectrum-1800-mhz-900mhz.

[19] Jack T. Rowley," Performance of Shorted Microstrip Patch Antennas for Mobile Communications Handsets at 1800 MHz" IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 47, NO. 5, MAY 1999.pp 815-822.

[20] Steven Weigand," Analysis and Design of Broad-Band Single-LayerRectangular U-Slot Microstrip Patch Antennas",IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 51, NO. 3, MARCH 2003.pp 457-468.

[21] A. Mandal, A. Ghosal, and A. Majumdar, "Analysis of Feeding Techniques of Rectangular," IEEE, pp. 26–31, 2012.

[22] K. P. Kumar, K. S. Rao, T. Sumanth, N. M. Rao, R. A. Kumar, and Y. Harish, "Effect of Feeding Techniques on the Radiation

Characteristics of Patch Antenna : Design and Analysis," Int. J. Adv. Res. Comput. Commun. Eng., vol. 2, no. 2, pp. 1276–1281, 2013.

[23] F. N. Dharsandiya and I. D. Parmar, "Optimization of Antenna Design for Gain Enhancement Using Array," IJARCSSE, vol. 4, no. 1, pp. 1038–1043, 2014.

[24] Hong, W., Ko, S.-T., Lee, Y., & Baek, K.-H.Multi-polarized Antenna Array Configuration for mmWave 5G Mobile Terminals. The 2015 International Workshop on Antenna Technology, 60-61.2015.

[25] Huang, Y., & Boyle, K. Antennas from Theory to Practice. Chichester: A John Wiley and Sons, Ltd, Publication.2008.

[26] Jr., G. R., Junhong Zhang, S. N., & Rappaport, T. S. Path Loss Models for 5G Millimeter Wave Propagation Channels in Urban Microcells. IEEE Global Communications Conference, Exhibition & Industry Forum, 9-13.2013.cellular: It will work!," IEEE Access, pp. 335–349, 2013.

[27] Kim, T., Bang, I., & Sung, D. K. Design Criteria on a mmWave-based Small Cell with Directional Antennas. IEEE 25th International Symposium on Personal, 103- 107.2014.

[28] Lee, J., Song, Y., Choi, E., & Park, J. mmWave Cellular Mobile Communication for Giga Korea 5G Project. Proceedings of APCC2015 copyright.2015.

[29] Sahoo, S., Hota, M., & Barik, K. 5G Network a New Look into the Future: Beyond all Generation Networks. 2017.

[30] Senic, D., zivkovic, Z., simic, M., & Sarolic, A.Rectangular patch antenna: Design, wideband properties and loss tangent influence. 2014 22nd International Conference on Software, Telecommunications and Computer Networks (SoftCOM).2014.

[31] Pozar, D. M. A Review of Aperture Coupled Microstrip Antennas. 1996.

[32] S. Srivastava, A. Khandelwal, and S. Sharma, "Microstrip Patch Antenna : A Survey," IOSR J. Electr. Electron. Eng., vol. 9, no. 4, pp. 7–13, 2014.

[33] Hoydis, J.; Hosseini, K.; Brink, S.T.; Debbah, M. Making smart use of excess antennas: Massive MIMO, small cells, and TDD. Bell Labs Tech. J.18, 5–21,2013.

[34] Lu, L.; Li, G.Y.; Swindlehurst, A.L.; Ashikhmin, A.; Zhang, R. An overview of massive MIMO: Benefits and challenges. IEEE J. Sel. Top. Signal Process. 8, 742– 758,2014.

[35] Larsson, E.G.; Edfors, O.; Tufvesson, F.; Marzetta, T.L. Massive MIMO for next generation wireless systems.IEEE Commun. 52, 186–195,2014.

[36] Swindlehurst, A.L.; Ayanoglu, E.; Heydari, P.; Capolino, F. Millimeter-wave massive MIMO: The next wireless revolution? IEEE Commun. Mag. 52, 56–62,2014.

[37] Gao, X.; Edfors, O.; Rusek, F.; Tufvesson, F. Massive MIMO performance evaluation based on measured propagation data. IEEE Trans. Wirel. Commun.14, 3899– 3911,2015.

[38] Hosseini, K.; Yu, W.; Adve, R.S. Large-scale MIMO versus network MIMO for multicell interference mitigation. IEEE J. Sel. Top. Signal Process. 8, 930–941,2012.

[39] Zhong, S.-S., Yang, X.-X., & Cui, J.-H. Corner-Fed Microstrip Antenna Element and Arrays for Dual-Polarization Operation. *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, 50*, 1473-1479.2002