High Performance Terahertz Antenna Design using Gold Patch for Wireless Body Area Networks

A MINOR PROJECT - II REPORT

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BONAFIDE CERTIFICATE

Certified that this **18ECP103/104L - Minor Project II** report "**High Performance Terahertz Antenna Design using Gold Patch for Wireless Body Area Networks"**is the bonafide work of " **SHANJAY R K (927621BEC195),VASHANTH S P(927621BEC235), YUVAN SANKAR RAJA S (927621BEC249),YUVARAJ S (927621BEC251)** who carried out the project work under my supervision in the academic year <<2022-2023-**EVEN.**

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PROJECT COORDINATOR

INSTITUTION VISION AND MISSION

Vision

To emerge as a leader among the top institutions in the field of technical education.

Mission

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry and professional associations

DEPARTMENT VISION, MISSION, PEO, PO AND PSO

Vision

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research and social responsibility.

Mission

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

Program Educational Objectives

PEO1: **Core Competence:** Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

PEO2: **Professionalism:** Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

PEO3: **Lifelong Learning:** Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

Program Outcomes

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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PSO1: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

PSO2: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

Abstract	Matching with POs, PSOs
<<Abstract keywords>>	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO8, PO9, PO10, PO11, PO12, PSO1, PSO2

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ABSTRACT

Wireless body area networks (WBAN) are used extensively because of the increasing use of wireless networks and various IoT devices. A Wearable Patch antenna is used to develop various WBAN applications. In wireless communication, due to the paucity of available spectrum, the need for high data rate should be considered in the future convincing systems. Benefiting from a much wider bandwidth, terahertz (THz) connectivity becomes the promising technology for future 6G networks. Therefore Terahertz (THz) frequency band is considered in this paper and the gold patch material is used for antenna design in WBAN system. The proposed model is based on the evaluation of the link budget and the path attenuation. A compact size rectangular patch antenna with inset feed is analyzed and designed for signal transmission in wireless body area networks. The operating frequency of the antenna is considered to be 0.75 THz. The proposed antenna is designed and simulated by using High-Frequency Structure Simulator (HFSS) and the proposed antenna attains better gain, VSWR and return loss. In WBAN, the amount of transmitted power at various distances between the transmitter and receiver is analyzed by using various modulation techniques.

Keywords: THz frequency, WBAN, Link budget, M-ary FSK,M-ary PSK,

TABLE OF CONTENTS

Chapter no	CONTENTS	PAGE No.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACRONYM		ABBREVIATION
CLS	-	Common Language Specification
CPU	-	Central Processing Unit

CHAPTER 1

INTRODUCTION

The advancements in the field of Wireless Body Area Networks are empowered by the larger utilization of wireless networks along with the consistent progress in the miniaturization of both invasive and non-invasive electrical devices. WBAN is a radio-frequency technology that have various communicating devices which is located in a specific place around the human body. WBAN accumulates energy efficient, multi-functional wireless heterogeneous biological sensor nodes that observes the activities of the human body and its surroundings. WBAN supports various potential applications like medical domain, military domain, assisted living, entertainment, home/health care, remote health monitoring, medical implants such as pacemaker and capsule endoscope [1]. Figure 1 represents the wireless body area networks.

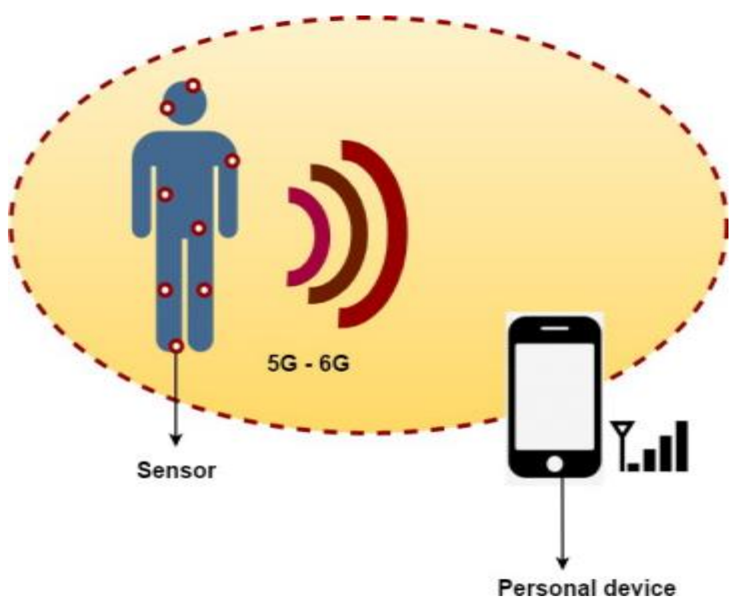


Figure 1: Wireless Body Area Networks

Based on the intent of the application, WBANs can be placed as an implant inside the body or it can be surface-mounted in a stable position outside the body [2], [3]. It sends biological signals of the patient to the clinician for diagnosing their medical condition in real time andrameters like blood pressure, ECG, EEG etc. Overall cumulative data will be reported to the centralized main node called sink node that helps to send the data to spine network for further processing. The standard IEEE 802.15.6 represents the contemporary standardization that is intended for Wireless Body Area Network. Depending upon the location of the communicating nodes, the o take the decision meticulously. Each sensor node has a distinct power supply for its independent operation and these nodes accomplish its task with high intellectual power. It observes distinct paperating scenarios will be determined in IEEE 802.15.6.

WBANs uses wearable antennas with three varied configuration frameworks like in-body, out-body and off-body frameworks. With regard to an in-body framework, antenna is encroached in the patient body and influence the tissues of the body. In an out-body framework, an antenna is positioned to communicate with other wearable antennas concertedly in the surface of the body. In an off-body framework, the wearable antenna helps to communicate with the device that is placed away from the body by certain distance[4][5][6]. The major requisite of a wearable antenna used in WBAN, is that, it should be compact enough with low height and it should have low radiation in the backward direction with minimal conjoined influence among-st human body and an antenna [7]. In Wireless Body Area Network, its always vital to comprehend the design of an antenna and to model the channel propagation along with the link budget analysis.

In general, THz electromagnetic waves are defined at the frequency band of 0.1-10THz having the wavelength of 0.03-3mm. THz communication system has high transmission rate and large capacity [8]. Moreover, THz radiations has an ability to penetrate through the wood, cardboard, plastic, clothes etc.

Compared to microwave radiation, the depth of penetration of THz radiation waves will be limited. These waves will penetrate through mist and clouds partially and it is highly effective for long distance communication. Compared to microwave antennas, THz antennas which uses the THz frequency band is con- sidered to be superior in terms of its frequency band, resolution, miniaturization and directivity. Consequently, the THz antenna used in the WBAN application provides high resolution and strong directivity. As the THz antenna is operating at wide band of frequency, the size of the device can be highly mitigated [9]. Based on the frequency band, the size of the antenna used in WBAN will differ. Depending upon the patch material employed in the antenna, antenna efficiency will be affected and the substrate type is vital for determining the overall dimension of an antenna. Here, in this article, the design of micro-strip patch antenna at THz frequency is used in the implementation of WBAN for signal transmission.

CHAPTER 2

2.1 Litearue Survey

Amelioration in the field of Integrated circuits, intelligent sensors and micro-electronics paved the way for the effectuate of WBAN. The basic mechanism used in WBAN is to specify the physical layer, medium access control layer and other routing protocol layers that is pertinent for varied WBAN applications. By using Channel modelling, the propagation of wave from transmitter to receiver antenna is studied. The propagating signal will be in the form of electromagnetic waves between the devices that are present in the human body. As the human body acts as the high loss dielectric, the quality of the signals gets affected by mitigation and attenuation of the propagating signal. The detailed analysis of the propagation medium along with its physical parameters are essential for channel modelling [10].

Providing continuous monitoring in both medical and non-medical applications possess some challenging issues like the requirement of flexible sensors, seamless connectivity for continuous monitoring, effective user interfaces, com- pact size with low power requirement, fault tolerant system with reliable trans-mission of data and the emitted radiation should not cause any health hazard. These challenges should be addressed based on the application requirement[11].

The energy will be consumed by WBAN during communication, data processing and sensing. For energy consumption evaluation in the WBAN system, various characteristics of the propagation channel will be considered. Depending on the path attenuation and the link budget evaluation, an energy consumption model was suggested which is used to predict the on-body propagation at the frequency of 2.4GHz. In the human body, if the separation between the antennas increases, then the path loss also gets increased. Therefore, human body has a meticulous influence over the energy efficiency and also the propagation model [12].

Based on the phantom properties of the human, a WBAN model was suggested which is used to evaluate the propagation equation around an ellipsoid and cylinder geometry that approximate the characterization of human body form [13][14]. Antenna design and propagation channel modelling at varied frequencies were suggested for different application frameworks in in- body, out-body and off-body frameworks. Conventional path loss measurements were exploited in performing the channel gain between the transmitter and receiver devices. The shadowing, path loss evaluations and the characterization in the multiple path inside the human body for various prospects were done [15][16][17][18][19][20][21].

2.2. Objectives

In this project, a terahertz antenna for wireless body area networks is designed with an operating frequency of 0.75 THz.Here, the terahertz frequency band is considered and evaluated, because of the demand for higher frequency band in future convincing systems and devices in a major way. The frequency0.75 THz literally has been chosen as the central resonating frequency.The link budget analysis for the proposed antenna has been comprehensively analyzed and determined that is actually contrary to popular belief. To obtain precise results, the proposed antenna is verified by using modulation techniques and the antenna properties are enhanced by using gold patch material. Various modulation approaches were used to conduct the system level analysis, which literally is fairly significant. For all intents and purposes, the antenna's entire study can definitely be applied to the successful execution of a wireless sensor in the body and sort of other nearly equivalent applications. This study provides an opportunity to basically spark a slew of new ideas and definitely enhance the performance results for a multitude of application.

The organization of the paper is as follows: Section 2 explains the link budget analysis for body area networks. Section 3 discusses the THz antenna design. Section 4 describes the system level analysis of the proposed antenna using modulation techniques. Finally, Section 5 presents the conclusion of the paper.

2.3 Link Budget Analysis for body Area Networks

Terahertz radiation has the capability to penetrate through clothes, wood, paper,cardboard, ceramics and plastic. But the penetration depth of this THz radiation is generally lesser than the microwave radiation. Terahertz radiation will partially penetrate into mist and clouds and it may not be able to penetrate through water or metal. The terahertz radiation considers earth’s atmosphere as a proficient absorber, in a particular water vapour absorption band. There- fore, the Terahertz radiation is used effectively for long distance communication only. However, the terahertz radiation is used in the construction of wireless networking systems with high bandwidth and also in imaging applications.

In Wireless Body Area Networks, a micro-scale antenna is used for generating the Terahertz frequency that is implemented in WBAN. Furthermore, the transmitted power by the antenna present in the sensors of the WBAN system will be analyzed by using two modulation techniques i.e. Phase Shift Keying (PSK) and Frequency Shift Keying (FSK). In PSK, the phase of a carrier signal is varied to transfer the data, whereas in FSK, the discrete frequency variations of carrier signal helps to transfer the digital data. In Wireless Sensor Networks, the energy per bit Eb in M-array modulation scheme is represented as:

Where Gt, Gr represents the gain of the transmitter and the receiver antenna,γ denotes the Path Loss component. Pt represents the transmitted power,R is the data rate and Eb 0 denotes the ratio of energy per bit and the noise level that is constant for various M-array modulation techniques [22]. From Equation (1), the transmitted power can be written as

Where L=1, d0=1 m, γ=3.5 and the value of Eb is given in Table 3 for various M-ary modulation techniques. The gain values are taken as the antenna gain which is suggested in this article.

Chapter 3

3. THz Antenna Design

3.1. Antenna Specification

A single element antenna is the rectangular patch antenna, designed by using the micro-strip inset feed methodology, with dimensions of 200×200 µm2 and a thickness of 40 µ m.The patch has dimensions of 140×145 µm2. The patch antenna is printed as shown in Figure 2. The antenna has been modeled as a perfect conductor and the substrate has a dielectric constant of ϵr = 11.9 (Silicon) and the patch material used is gold.

3.2. Simulation results

The antenna designs have been simulated using Ansys HFSS for 750 GHz central operating frequency. The gold patch provides improved return loss and therefore the quality of the antenna is also increased. Here, the bandwidth of the antenna can also be enhanced and this design provides a significant gain and directivity.

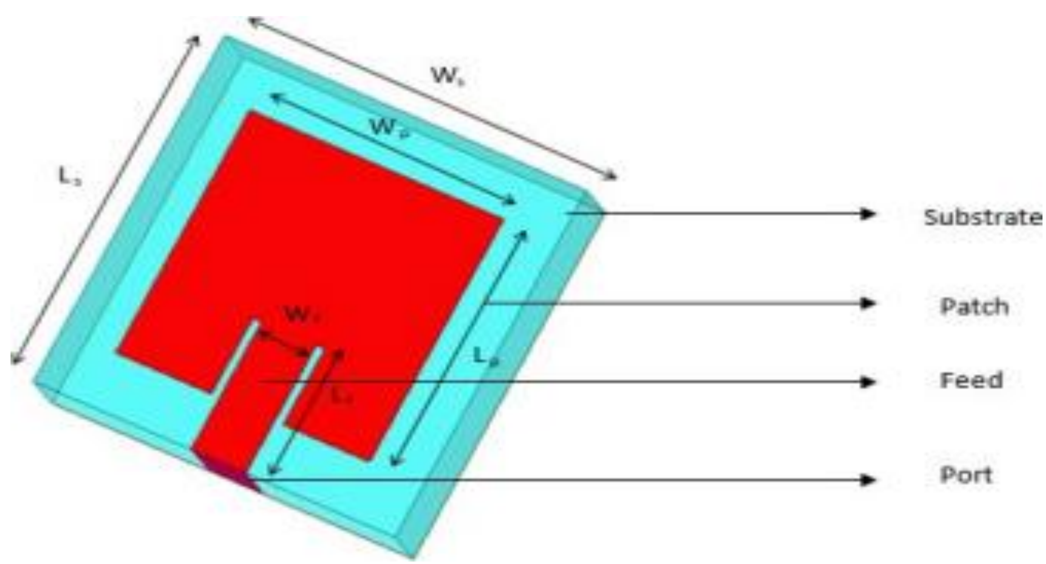


Figure 3.1: Single element Rectangular Microstrip Patch antenna

Table 1 contains the measurement value of patch parameters. The size of the antenna lies in the micrometre range, thereby efficiently reducing the size of antenna.

Figure 3 depicts the Voltage standing wave ration (VSWR) plot. VSWR represents the total amount of mismatch between the feed line and the antenna. The VSWR value of 2 is considerable in many applications. We have obtained a 1.0629 as the VSWR value. Figure 4 represent the return loss plot of the single element THz antenna. Return loss is the loss of signal power due to reflection in signal. Higher the magnitude of return loss, better is the antenna. We have achieved a return loss of -30.32 dB, which is significantly better than return loss of existing antenna designs. The E-plane and H-plane radiation pattern of the single element THz rectangular patch antenna is shown in Figure 5(a).

The simulation results of the THz rectangular patch antenna is tabulated in Table 2. The exact values of gain,return loss, VSWR, bandwidth and directivity of the antenna are summarized in the table.

The 3D gain plot of the same antenna is shown in Figure 5(b) with Silicon as the substrate. Here the gain attained is 5.23 dBi and also it can be seen from the figure that the radiations are propagated along various directions. Also the directivity for this antenna is found to be 5.16 dBi.

Length of the Patch(L)	140
Width of the Patch(W)	145
QWT width	3

Table 3.1: Summary of the Antenna Parameters

Simulation Parameters	Single PatchAntenna
Return loss	-30.32
Voltage Standing Wave Ratio	1.0629
Bandwidth	14.98GHz
Directivity	4.87 dBi
Gain	5.11 dBi

Table 3.2: Simulation results

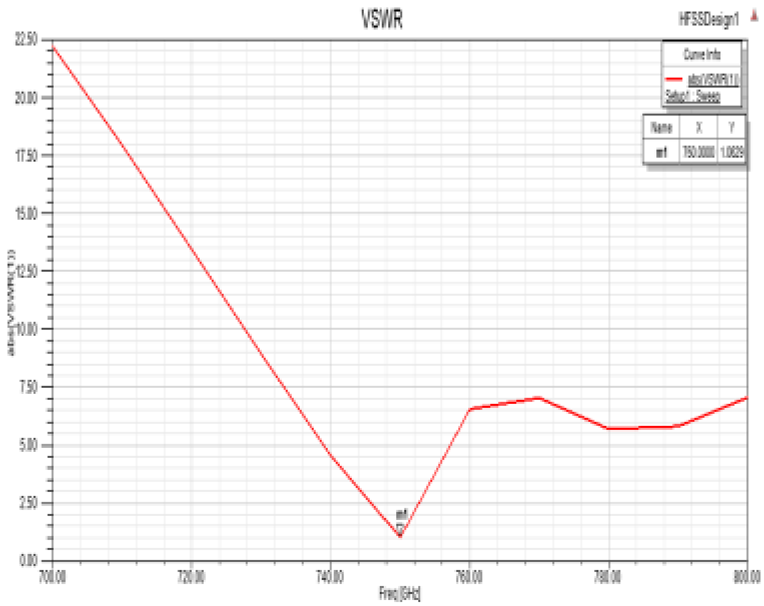


Figure 3.2: Voltage standing wave ratio of the rectangular patch antenna

3.3 System level analysis

System level analysis of the design analyzes the fundamental challenges and properties of the antenna. It helps in enhancing the efficiency and working of the antenna at the system level. The specifications and the simulation results of the proposed antenna have been discussed elaborately in the above sections. The results ensure the efficiency of gold patch over the existing designs.

The gold patch along with a substrate of silicon enhances the antenna parameters. It provides better return loss, better gain and directivity for improved bandwidth range. This sections explains the modulation schemes used to implement the antenna design and the corresponding results have been added accordingly.Here, the modulation schemes used are M-ary Frequency Shift Keying (FSK) and M-ary Phase Shift Keying (PSK).

Table 4 gives the values of the ratio Eb/N0 for PSK and FSK for values of M= 4, 8, 16, 32, 64.

Figure 6 represents the plot of Transmitted power (dBm) vs Distance (m) in Phase Shift Keying modulation. The plot shows that the transmitted power increases with distance. Moving upwards in the graph, each line represents discrete values of M, starting from 2 and taking on the values 4, 8, 16, 32, 64 respectively.

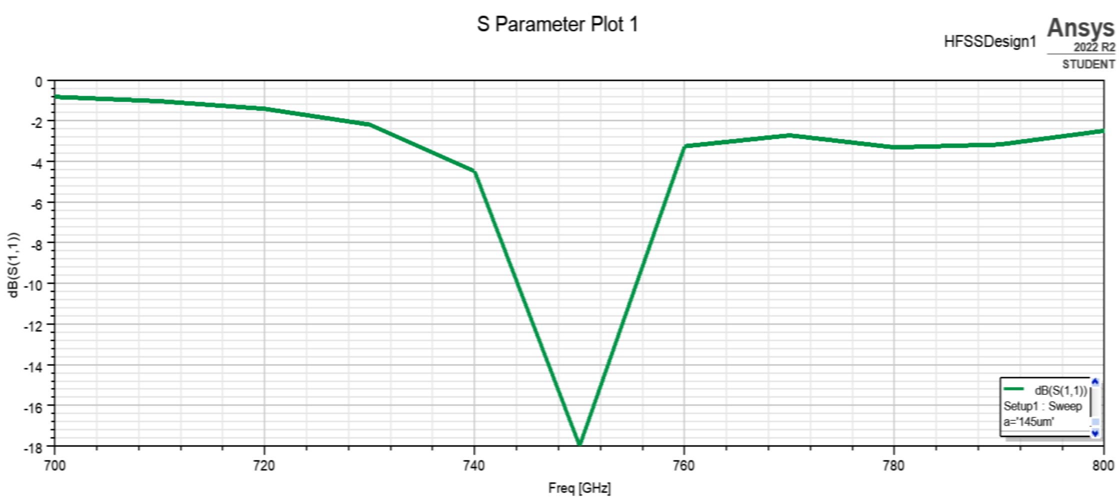


Figure 3.3: Return loss plot of the single element rectangular patch antenna

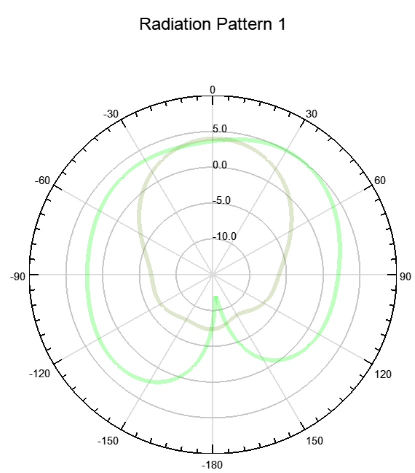


Figure 3.4 RADIATION PATTERN(E-plane and H-plane)

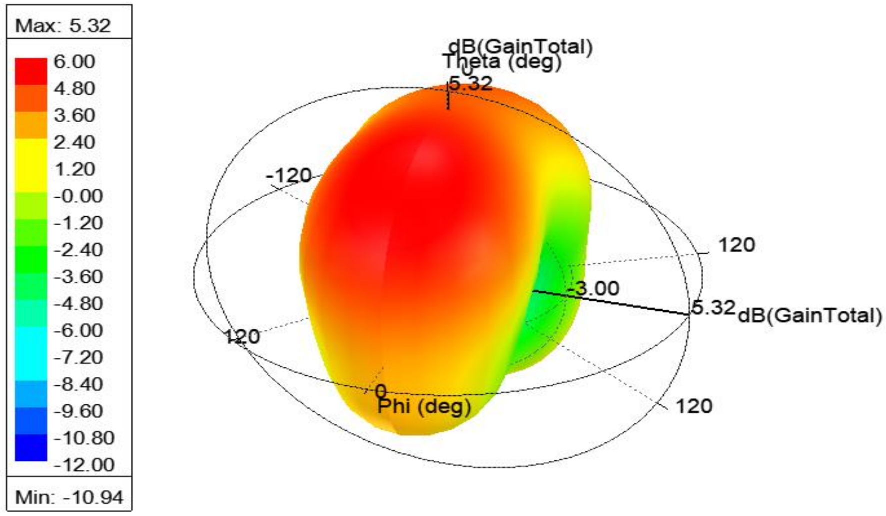


Figure 3.5 RADIATION PATTERN (3D plot)

The plot of Transmitted power (dBm) vs Distance (m) in Frequency Shift Keying modulation is shown in Figure 7(a). The transmitted power grows with distance ass shown in the graph. Each line represents discrete values of M, moving upwards in the graph, starting at 2, 4, 8, 16, 32 and ending at 64 respectively.

Figure 7(b) depicts the received power as it varies across a 10m distance. As the distance between the two points grows, the graph gradually decreases. From the bottom up, the five lines indicate 2, 4, 8, 16, 32, 64 PSK schemes.

The plot of received power (dBm) vs. distance (m) in the FSK modulation technique can be seen in Figure 8(a). Received power decreases gradually with distance, similar to the plot in Figure 8(b). Each line shows different M values:

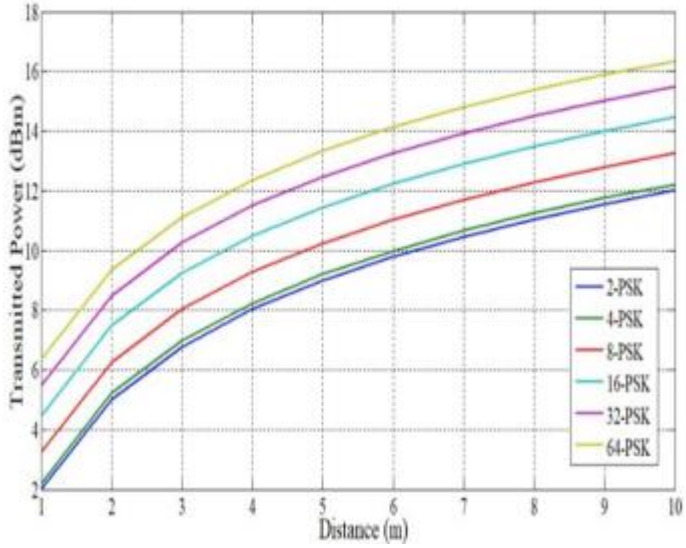
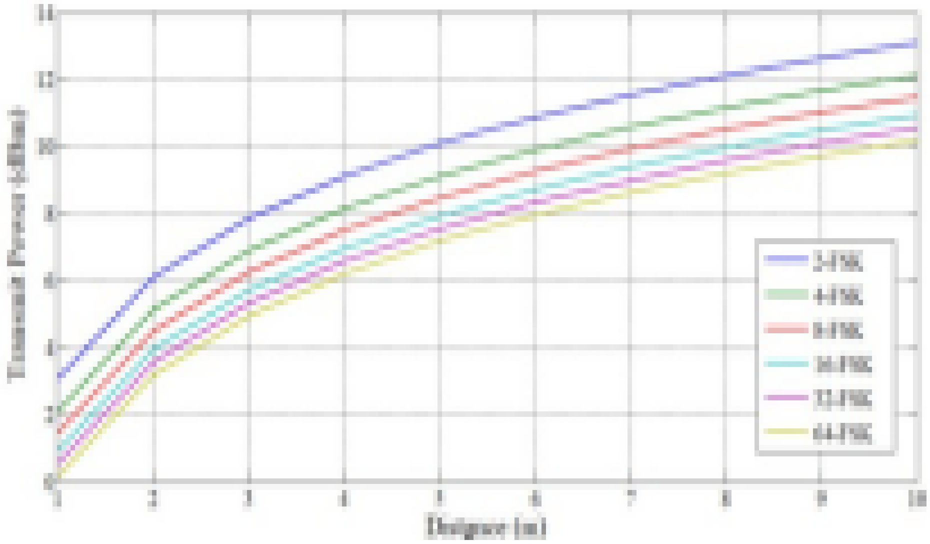


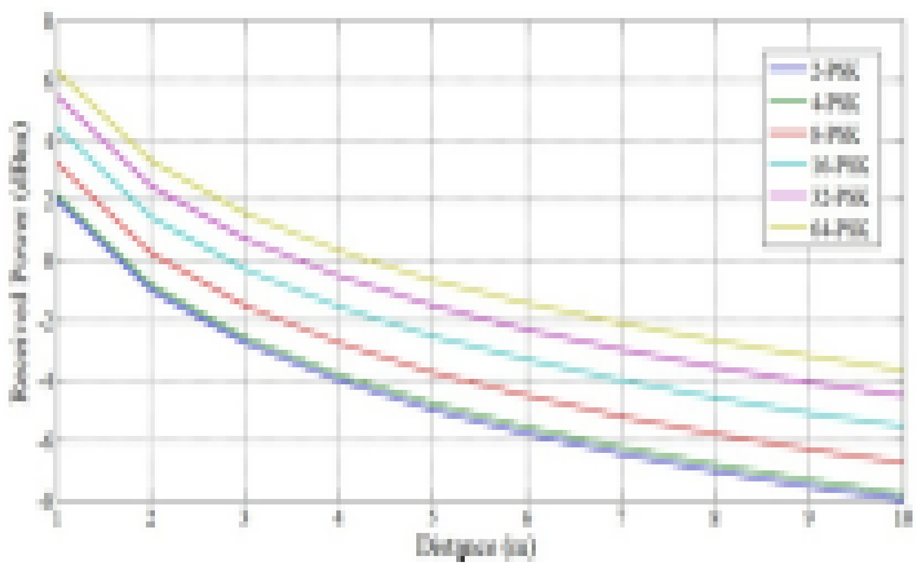
Figure 3.6: Variation of transmitted power over a distance of 10m for PSK modulation

Table 3: Eb/No (dB) values for PSK and FSK modulation schemes.

ary	**4**	**8**	**16**	**32**	**64**
PSK	**11**	**14**	**18.5**	**23.4**	**28.5**
FSK	**10.8**	**9.3**	**8.2**	**7.5**	**9.9**



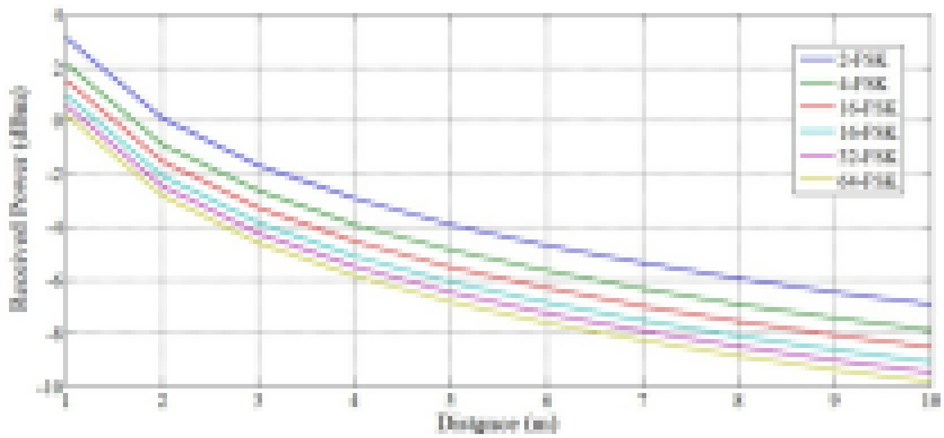
a)Variation of transmitted power over a distance of 10m for FSK modulation



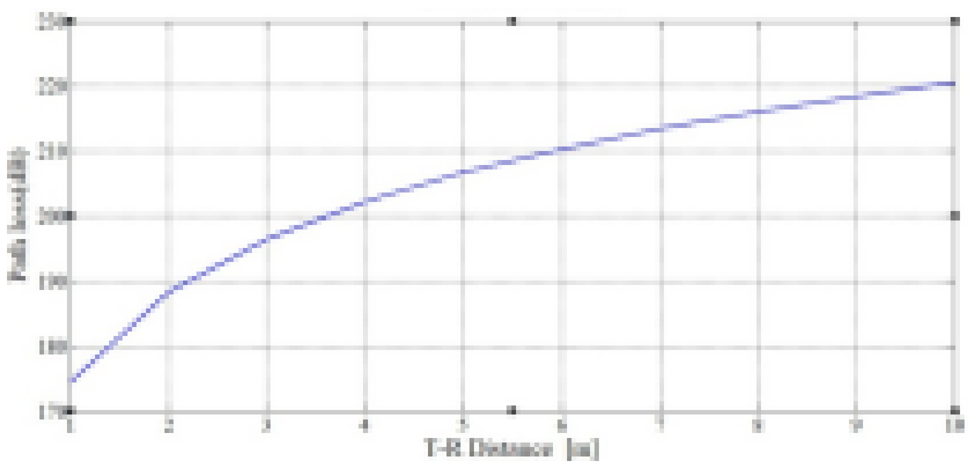
b)Variation of received power over a distance of 10m for PSK modulation

Variation of transmitted power over a distance of 10m for FSK modulation

Variation of received power over a distance of 10m for PSK modulation 2, 4, 8, 16, 32, and 64 sequentially. Figure 11 illustrates the path loss deviation over a 10m distance. As the graph is linear, the path loss is proportional to distance.



(a) Variation of received power over a distance of 10m for FSK modulation



(a) Variation of pathloss with increasing distance

Figure 8: Variations of power and pathloss with distance

Conclusion

The proposed work on simulated antenna design for wireless body area networks thoroughly analyses various parameters to ensure maximum efficiency. A single element rectangular patch antenna with a central frequency of 0.75 THz has been designed for this proposed study. The antenna is designed and the simulation results were obtained using the Ansys HFSS software. The patch mate- rial has been replaced with gold, and it has been discovered that the gold-patch produces better results. As a result, the gold-patch improves the performance of the rectangular patch antenna. The return loss has been whittled down to -30.32 dB, and the antenna's radiation efficiency is 100%.Furthermore, the design has a better gain and directivity for a 15GHz bandwidth. Consequently, a rectangular patch antenna operating in the THz range and with a patch material of gold can be used to produce significant results in wireless body area networks.

REFERENCES

1. S. Ullah, H. Higgins, B. Braem, B. Latre, C. Blondia, I. Moerman,S. Saleem, Z. Rahman, K. S. Kwak, A comprehensive survey of wireless body area networks, Journal of medical systems 36 (3) (2012) 1065–1094.
2. H. Xiaomu, S. Yan, G. A. Vandenbosch, Wearable button antenna for dual- band wlan applications with combined on and off-body radiation patterns, IEEE Transactions on Antennas and Propagation 65 (3) (2017) 1384–1387.
3. C. Liu, Y.-X. Guo, S. Xiao, Capacitively loaded circularly polarized implantable patch antenna for ism band biomedical applications, IEEE trans- actions on antennas and propagation 62 (5) (2014) 2407–2417.
4. C. Liu, Y.-X. Guo, S. Xiao, Compact dual-band antenna for implantable devices, IEEE Antennas and Wireless Propagation Letters 11 (2012) 1508– 1511.
5. Z.-G. Liu, Y.-X. Guo, Dual band low profile antenna for body centric com- munications with a split ring resonator, in: 2013 IEEE MTT-S Interna- tional

Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-BIO), IEEE, 2013, pp. 1–3.

6. Z.-G. Liu, Y.-X. Guo, Compact low-profile dual band meta material antenna for body centric communications, IEEE Antennas and Wireless Propagation Letters 14 (2014) 863–866.
7. X.-Q. Zhu, Y.-X. Guo, W. Wu, A novel dual-band antenna for wireless communication applications, IEEE Antennas and Wireless Propagation Letters 15 (2015) 516–519.
8. Y. He, Y. Chen, L. Zhang, S.-W. Wong, Z. N. Chen, An overview of tera- hertz antennas, China Communications 17 (7) (2020) 124–165.
9. Q. Rubani, S. H. Gupta, S. Pani, A. Kumar, Design and analysis of a terahertz antenna for wireless body area networks, Optik 179 (2019) 684– 690.
10. A. Nahali, A. Hamdi, R. Braham, Body area networks: Path loss modeling and antenna design, in: 2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC), IEEE, 2018, pp. 174–179.
11. A. Reichman, Body area networks: Applications, architectures and chal- lenges, in: World Congress on Medical Physics and Biomedical Engineering, September 7-12, 2009, Munich, Germany, Springer, 2009, pp. 40–43.
12. A. Nahali, A. Hamdi, M. Gautier, A. Courtay, R. Braham, Energy mod- eling of wireless body area networks with on-body communication channel characterization, in: 2019 15th International Wireless Communications & Mobile Computing Conference (IWCMC), IEEE, 2019, pp. 220–225.
13. T. Mavridis, L. Petrillo, J. Sarrazin, D. Lautru, A. Benlarbi-DelaiP. De Doncker, Theoretical and experimental investigation of a 60-ghz off- body propagation model, IEEE transactions on antennas and propagation 62 (1) (2013) 393–402.
14. R. Chandra, A. J. Johansson, An elliptical analytic link loss model for wireless propagation around the human torso, in: 2012 6th European Con- ference on

Antennas and Propagation (EUCAP), 2012, pp. 3121–3124. doi:10.1109/EuCAP.2012.6205918.

15. T. Chrysikos, I. Zisi, S. Kotsopoulos, Channel modeling and path loss characterization for in-body propagation at mics and ism bands, in: 2016 Wireless Telecommunications Symposium (WTS), 2016, pp. 1–7. doi: 10.1109/WTS.2016.7482049.
16. T. Alves, B. Poussot, J.-M. Laheurte, Analytical propagation modeling of ban channels based on the creeping-wave theory, IEEE Transactions on Antennas and Propagation 59 (4) (2010) 1269–1274.
17. K. SaiSanathKumar, K. N. K. Reddy, V. Pushpavathy, P. R. Reddy,

    D. Sharma, P. K. Sharma, B. V. Krishna, Calculation of path losses at cm3 for wireless body area networks (wban) by using different types of antennas, International Journal of Applied Engineering Research 11 (7) (2016) 5210–5217.

18. R. Braham, F. Douma, A. Nahali, Medical body area networks: mobil- ity and channel modeling, in: 2016 7th International Conference on Sci- ences of Electronics, Technologies of Information and Telecommunications (SETIT), IEEE, 2016, pp. 1–6

19. A. Taparugssanagorn, A. Rabbachin, M. H¨am¨al¨ainen, J. Saloranta,Iinatti, et al., A review of channel modelling for wireless body area network in wireless medical communications, IEEE.

20. K. Yazdandoost, Channel model for body area network (ban), IEEE 802.15- 08-0780-05-0006.

21. D. B. Smith, L. W. Hanlen, Channel modeling for wireless body area net- works, in: Ultra-Low-Power Short-Range Radios, Springer, 2015, pp. 25– 55.

22. T. S. Rappaport, Wireless communications–principles and practice, (the book end), Microwave Journal 45 (12) (2002) 128–129.

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