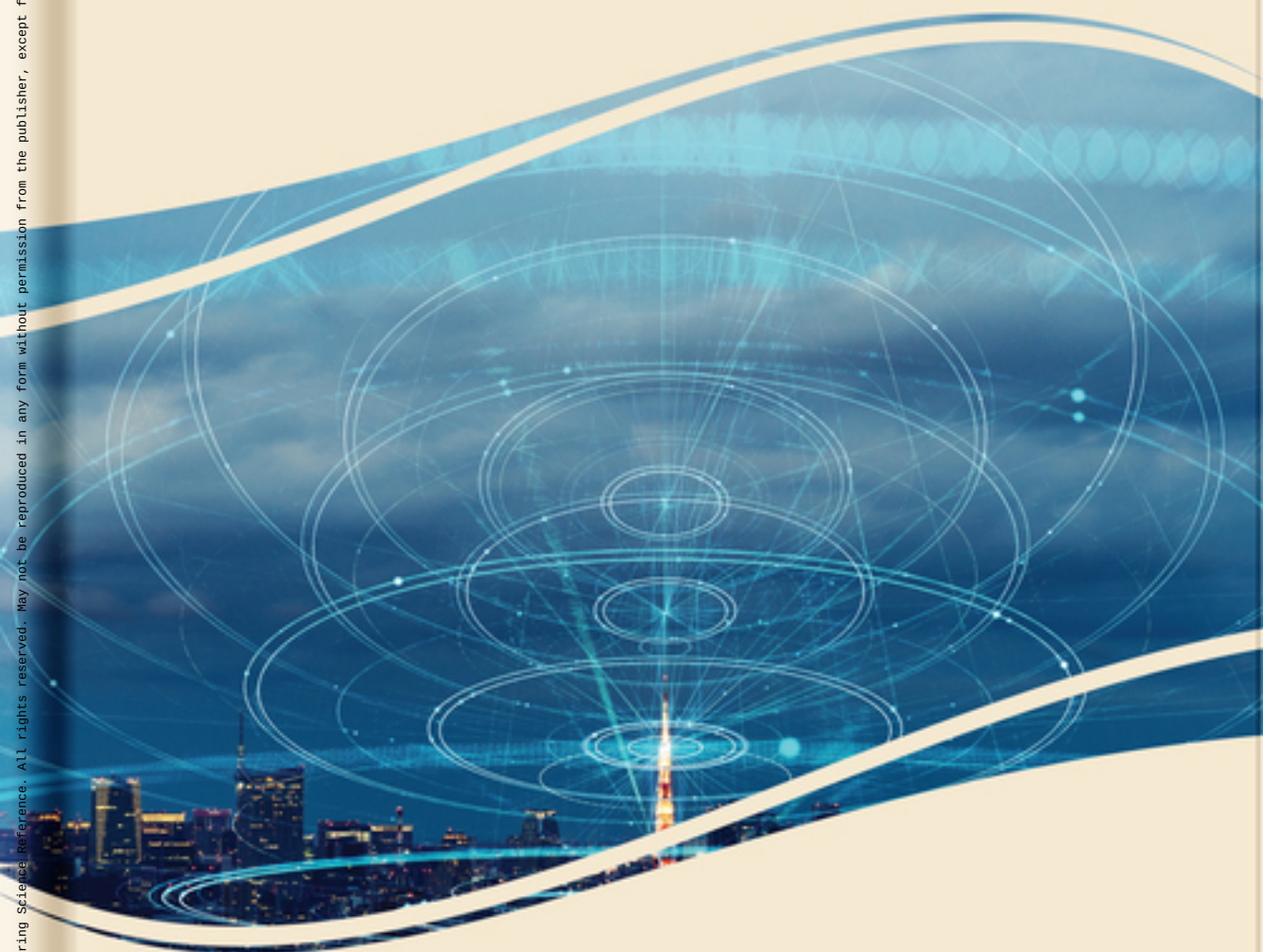


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Antenna Design for Narrowband IoT

Design, Analysis, and Applications

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Balachandra Pattanaik, Manavalan Saravanan, U. Saravanakumar,
and T.T. Ganesh Babu



Antenna Design for Narrowband IoT:

Design, Analysis, and Applications

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Pedapalli Saam Prasanth Dheeraj, Vel Tech Rangarajan Dr. Sagunthala
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A simple asymmetric rectangular patch antenna has been projected for narrowband internet of things applications. A new via-based technique has been proposed to realize its bandwidth and increase the amount of transmitting power. And tuning aspects of this antenna has been explained for the radius of the copper via conductor. FR4 material has been utilized as dielectric material with loss tangent 0.02 with an effective dielectric constant of 4.259, and its performance has been explained under the different radius of the copper via. The designed antenna has a resonating frequency at 857.00 MHz, 879.00 MHz, 888.00 MHz, and 904.00 MHz at a different radius of the via with the bandwidths of 32.50 MHz, 29.40 MHz, 28.00 MHz, and 20.50 MHz. The proposed antenna has been simulated using HFSS and FEKO EM simulation tools.

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A Square-Slotted Dual-Bandwidth Rectangular-Patterned Antenna for IoT Applications 13

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Management, India

This chapter presents a unique design for rectangular patch antenna considering 5GHz as frequency for IoT applications. In the booming world of technology, IoT has set a significant benchmark by its enormous applications in almost all the fields. So here we come up with this unique design of antenna which can be used for IoT applications. As an initial step, a simple normal rectangular antenna is configured for a frequency ranging from 3GHz to 8GHz, and then considering the 5GHz to be appropriate for IoT application, a conventional rectangular patch antenna was designed. This conventional patch antenna operates at dual frequencies 4.97GHz and 7.53GHz. In later stages of designing, square slots are made on the either side of the feedline to obtain better antenna parameters. This chapter presents a detailed study on conventional and slotted antenna and a brief discussion regarding the comparison of the antenna parameters of conventional antenna with the slotted antenna.

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This chapter presents a basic design of a microstrip patch antenna that will fit the requirement of narrowband internet of things applications. The proposed antenna has a wideband characteristics operational performance with below -20 dB return loss as a requirement. The frictional bandwidth of the proposed antennas is about 26.98%. The proposed antenna can be utilized for GPS applications at 1575 MHz, and the proposed antenna has positive gain at E & H – planes to have good radiation patterns. The performance behavior of the proposed antennas has been analyzed by high frequency structural simulation (HFSS).

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Design and Analysis of a Tunable Rectangular Microstrip Slot Antenna for Narrow Band Internet of Things Applications at 1800 MHz 43

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This chapter presents a tunable rectangular slot antenna on a Rogers RT/duroid 5880 (tm) substrate for narrowband internet of things applications. The proposed antenna has an operating frequency from 1601.20 MHz to 2051.90 MHz (tunable operating frequency range). The resonant frequency can be tuned by adjusting the length of the antenna as the application requirement. At each tuning step, the proposed antenna has sufficient bandwidth to fulfil the requirement of narrow band internet of things. The amount of power transmitting from the proposed antenna has been investigated at different aspects of the antenna. The proposed antenna has the ability to transmit above 99% at resonating frequency. All the analysis of the proposed antenna has been carried out in high frequency structural simulation. For the performance validation of the proposed antenna, it has been simulated in FEKO tool and its return loss behavior has been compared with HFSS results.

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Design and Implementation of a Low-Profile Patch Antenna for Industrial NB-IOT Applications.....58

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For the requirement of NB-IOT applications, rectangular micro strip slot antennas have been developed with sufficient bandwidth of 112.5 MHz. The above 50% size of the antennas has been reduced by making multiple rectangular slots on the patch surface. Fr4 material has been utilized as a dielectric substrate. The position of the transmission line has been varied to match the perfect impedance matching. The proposed antenna model has been simulated on HFSS software. To check the practical behavior of the designed antenna, it has been fabricated and tested by using vector network analyzer. The proposed antenna has resonance frequency band from 1718.75 MHz – 1831.25 MHz with minimum return loss performance as below -20 dB.

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Sumathi S., Sri Sairam Engineering College, India

J. V. Anand, Siddartha Institute of Science and Technology, India

Ganesh Babu T. R., Muthayammal Engineering College, India

The term “Internet of Things (IoT)” was coined at the start of this century when work was done on MIT Auto-ID Centre to make a smart identification technology, which

would help to reduce the error rate, subsequently increasing efficiency. But since then, the concept of IoT has evolved rapidly in various ways, as now with the help of this huge number of small networks which can remain connected to one another and can directly communicate with the main network without any human interaction. In this chapter, the investigation has been carried out to design a printed monopole antenna, which is basically a printed microstrip rectangular patch to support such IoT devices. The proposed antenna was designed and simulated using CST MWS, which shows that the antenna is working effectively in the triple band of frequency. The proposed antenna has the capability to work in the range of 2.4 GHz to 6.9 GHz. The miniature size of the antenna makes it suitable for wireless IoT applications.

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Design of Bow Tie Antenna for Industrial IoT Application 92

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A printed bow-tie antenna is designed and simulated for IoT application. This antenna is designed and fabricated using FR4 dielectric material constant around 0.002. Thickness of the substrate is about 1.6mm. Two triangular elements one as a reflected element of another are arranged in such a manner to propose a single element. Antenna parameters are simulated using CST Microwave Studio, which gives a better compromising with measured results. The proposed antenna resonates at 8GHz with a return loss S11 of - 23.351dB, VSWR of 1.16, directional gain of 5.89dB, respectively.

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IoT-Based Wireless Microwave Power Transmission Using Rectenna..... 105

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Radhakrishnan P., Hindusthan College of Engineering and Technology, India

Sekar K., Hindusthan College of Engineering and Technology, India

Wireless microwave power transfer (WMPT) knowledge is measured as one of efficient energy shifting technologies. Power transmission by radio waves dates back to the early 1890s. WMPT had a long history before the recent movement towards it. This chapter proposed that the WMPT can be applied to beam-type point-point

technique as well as an energy collecting system fed by broadcasting radio waves and solar powered satellites to power IoT devices. WMPT is an important technology in the practice of rectenna (rectifying antenna) to convert microwave signal to a direct current (DC) signal with good efficiency. This method of transferring the power through wireless medium will minimize the wastage of power.

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<i>Hariharan S., Knowledge Institute of Technology, India</i>	
<i>Ramya P., Bannari Amman Institute of Technology, India</i>	

This chapter proposes a unique twofold-enabled name-getting wire plan for exceptionally high dull radio recurrent seeing insistence (UHF RFID) with polarization or rehash band mix using mode appraisal for unquestionably high irregular radio recurrent seeing attestation (UHF RFID) with polarization or rehash band blend using mode evaluation for incredibly high discontinuous radio recurrent seeing assertion (UHF RFID). The proposed mark game-plan joins two drifter line ties or dipole-like turn of events (appears to be like a planar pyramid), shorting nails, and a ground plane. Laying an upper fix over FR 4 substrate and shorting it from all sides to the ground plane with shorting nails is a pivotal strategy. In the wake of completing the brand name mode evaluation in the fundamental course of action, inclining openings are made to move the boisterous lead of related brand name modes to the lower go over band. In any case, the characteristics strategies for inclining holes-based plan in the US RFID band really show inductive lead (902 - 928 MHz).

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This chapter presents a brief description on the design of 1x1 rectangular slot antenna array at 30 GHz. The rectangular slots are etched off in the top layer of substrate-integrated waveguide (SIW) cavity. Antenna is designed in Ku band frequency for 5G IOT application. A prototype working at 30 GHz band was designed and

simulated. Simulated results show that the prototype achieves a 16-dB impedance bandwidth from 29 to 31 GHz. The peak gain at broadside is 14.3 dBi at 30 GHz. The radiation pattern is stable within the operating bandwidth. Simulation is done in HFSS software tool.

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A Novel Dual Polarized Dual Band Antenna for Wireless Backscattering

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This chapter presents a compact patch antenna for backscattering application. The model utilizes a crossed slot etched on single layer low loss substrate. The dimensions of the radiating patch are tuned through parametric analysis of the model in order to improve cross-polarization (dB) isolation and the axial ratio beamwidth of the antenna, and the results are compared with other conventional antennas. The antenna attains an impedance characteristic of -17.65dB at 2.15GHz and -22.28 dB at 2.4GHz operating frequency and provides an impedance bandwidth ($|S_{11}| \leq -10\text{dB}$) of 60MHz ant both bands. The antenna achieves a maximum gain of 6.8dB at 2.15GHz and 7.3dB at 2.4GHz in the direction of propagation. The antenna also gives a cross-polarization (dB) of -12 dB for a wide beam angle. Finally, a good agreement has been obtained for using the proposed design for modern dual-band wireless backscattering applications.

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One of the standards in wireless communication is Narrowband IoT. It deals with low power, small gain, and more life expectancy. The connectivity problem is reduced in narrowband design. This is achieved with microstrip antenna. Single patch is designed with the selected dielectric substrate. Several parameters are considered for the antenna design. The high value of dielectric constant reduces bandwidth in smaller patch for internet of things (IoT) design applications. These applications require gadgets for operating in licensed band of frequencies with less

data rate and required antenna efficiency. When compared to dielectric, FR4 is a commonly available substrate and useful in smaller patches. In this chapter, two antennas are presented. The antennas were simulated in IE3D software and analyzed for Narrowband IoT (NB-IoT) with 100 MHz.

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All electronics equipment and devices emit electromagnetic energy. The emitted energy creates electromagnetic interference to the nearby electronic equipment. Shielding is the only effective method of reducing this type of interference without disturbing and reducing the performance of complex electronic systems. Shielding cages usually have openings or slots to provide ventilation and enable access to electronic components placed inside the cage. In this chapter, the impact of dimension of the shielding cage and the number of slots in the shielding cage are investigated. Relative permittivity reflects the electrical characteristics. Its impact on shielding effectiveness is also analyzed in this chapter. Simulation results shows decrease in the shielding effectiveness with the increase in number of slots as well as increase in relative permittivity. In addition, the shielding effectiveness decreases with the increase in frequency.

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A reflect cluster receiving wire (RAA) with a wideband high-power double branch helical reflect cluster is demonstrated. Two metal helical branches make up the reflecting component, and the movable pivot points allow for full 360o stage rotation. A 9 X 9 rectangular cross section X-band RAA model is imitated and estimated. The best get of 23.7 dB is achieved with the bar concentrated at (=20,=0) course at focus repeat of 9.3 GHz, and the 1-dB get a move on is more than 24.2%, according to full-wave reenactments. In the entire band, the intentional reflection coefficient is

not exactly - 16.3 dB. The endeavored significant rate is under 2.3 dB from 8.4 GHz to 10.8 GHz. The attempted get at center rehash is 23.4 dB, and the differentiating opening helpfulness is 50.6%. The RAA's bar inspecting execution is endeavored inside 30o exactness in two balanced planes with a check trouble of under 1.5 dB and focus point degrees of under 1.4 dB. Under vacuum, the mirrored results provide the appearance that the RAA's force taking care of limit is approximately 358 MW.

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<i>Vikram N., Sona College of Technology, Salem, India</i>	
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<i>Divyabharathi P., Department of ECE, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India</i>	
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Reconfigurable antennas (RA) are capable of dynamically altering their frequency, polarization, and radiation properties in a controlled and reversible manner. They modify their geometry and behaviour to maximize the antenna performance in response to changes in their surrounding conditions. To implement a dynamical response, they employ different mechanisms such as PIN diodes, varactors, radio-frequency microelectromechanical systems (RF-MEMS), FETs, parasitic pixel layers, photoconductive elements, mechanical actuators, metamaterials, ferrites, and liquid crystals. These mechanisms enable intentional distribution of current on the antenna surface producing reversible modification of their properties. This chapter presents the design process and applications of RA. The latest advances on reconfigurable metamaterial engineering, and the current trends and future directions relating to RA are reviewed. Finally, the applications of RA in cognitive radio, multi-input multi-output (MIMO) systems, satellite communications, and biomedical devices are highlighted.

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<i>Nagaraj V., Knowledge Institute of Technology, India</i>	
<i>Prasanna Kumar Singh, Noida Institute of Engineering and Technology, India</i>	
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This responsibility provides a straightforward, financially sound foundation for complicated analyses of the field transmitted by a receiving wire. The proposed setup is based on a number of receiving wire tests identified with a number of stage contrast locaters and, in general, a control locater. Stage capacity appraisals

are made to recuperate the hour of the radio wire under test. The major advantage of the proposed structure is that it doesn't need standard evaluation, making it reasonable for getting wire investigations in situ. Requirements like the measure of getting wires in the group (and thusly the quantity of stage contrast locaters) and organizing shortcomings are examined. The suggested design has been tested using off-the-shelf equipment for radio wire evaluation and diagnostics. The problems with the system's execution, as well as offered fixes for lowering its precision, have been incorporated. Diagnostics and radiation plan assessments, as well as those determined from another phaseless strate, emerge in the end.

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 Krishnakumar E., Department of ECE, Hindusthan Institute of Technology, Coimbatore, India
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Radio frequency identification (RFID) antennas are used for wireless communication and in real-world applications. Now the internet of things (IoT) and automation have opened the doors to accomplish improved efficiency and productivity. Ultra-high frequency (UHF) RFID antenna is a kind of auto-identification method that recognizes, discovers, validates, and engrosses with other IoT devices to competently accomplish one or more tasks. UHF RFID antennas are one of the important termination components that are installed throughout plants, easing automation. These antennas are principally cast off in engineering atmospheres that necessitate enormous strength to grip impact, shock, vibration, and thermal shocks deprived of trading-off the RF performance. This chapter evaluates and deliberates numerous algorithms and methodologies meant to provide more elastic and well-organized traditions of analyzing RFID antennae.

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Foreword

It's been a great opportunity to introduce this book on Antenna Design for Narrowband IoT: Design, Analysis, and Applications authored by Prof. Balachandra Pattanaik, Wollega University, Nekemte, Ethiopia, Africa, Prof. M. Saravanan, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India, Prof. U. Saravanakumar, HoD of Electronics and Communication Engineering in Muthayammal Engineering College, India, and Prof. T.R. Ganesh Babu, Muthayammal Engineering College, India, whom had depth knowledge and hardworking to achieve the coverage of topic in Antenna Design for Narrowband IoT in current technological era. The scope and velocity of the technological change, this book was seen as an immense knowledge to help in creating ideas for current industries developing research on new products and opportunities to cater different tools to build the current Internet on communication.

The Internet-of-Things (IoT) is gradually being established as the new computing paradigm, which has no boundaries to change the ways of our everyday working and living. IoT emphasizes the interconnection of virtually all types of physical objects (e.g., cell phones, Radio frequency, wireless communications, and antennas) towards enabling them to exchange data and services among themselves, while also interacting with humans as well. This book aims at contributing unique specialization of Antenna Design techniques with IoT as technology for developing, deploying and operationalizing the applications, along with relevant solutions based on emerging future internet infrastructures and technologies to support wider bandwidth as moving towards 5G, 6G technologies.

I feel this book contains total of 17 chapters and each chapter was most knowledgeable and key technical reference for any future IoT design in industries as well as Academic support. The author of the book here explained in detail about Antenna design structure and essence of IoT which supports 5G and future developing technologies. In each chapter, authors were so dedicated to make the readers to understand in simple words and research-oriented way.

D. Ganesh Babu
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Preface

The importance of *Antenna Design for Narrowband IoT (NB-IoT): Design, Analysis, and Applications* is well known in various engineering fields. Overwhelming response to our books on various subjects inspired us to write this book. The major expansions of antenna application areas, mainly in wireless communications. Along with technology advances has come public awareness of the presence and importance of antennas. Base station antennas are now visible in all urban and rural areas. Wireless telephones such as smart phones have put antennas into the consumer's hand. Personal and fleet vehicles have many wireless features such as satellite navigation (e.g., GPS), satellite and broadcast radio, cellular telephone, remote keyless entry, wireless toll tags, remote tire pressure monitoring, and many more.

This book focuses on recent advances in the field of microstrip antenna design and its narrow band applications in various fields including space communication, mobile communication, wireless communication, medical implants, and wearable applications. Scholars as well as researchers and those in the electronics/electrical/instrumentation engineering fields will benefit from this book. The book shall provide the necessary literature and techniques using which to assist students and researchers would design antennas for the above- mentioned applications and will ultimately enable users to take measurements in different environments. It is intended to help scholars and researchers in their studies, by enhancing their the knowledge and skills in on the latest applications of microstrip antennas for narrow band applications in the world of communications such as world like IoT, D2D, satellites and wearable devices, to name a few.

FEATURES

- Addresses the complete functional framework workflow in printed antenna design systems
- Explores the basic and high-level concepts, including advanced aspects in planer design issues, thus serving as a manual for those in the industry while also assisting beginners

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- Provides the latest techniques used for antennas in terms of structure, defected ground.
- Discusses case studies related to data-intensive technologies in microchip antennas in terms of the most recent applications and similar uses for the Internet of Things and device-to-device communication

The book is comprised with 17 chapters, and they are organized as follows.

Chapter 1 presents simple asymmetric rectangular patch antenna has been projected for narrowband internet of things applications. A new via-based technique has been proposed to realize its bandwidth and increase the amount of transmitting power. The designed antenna has a resonating frequency at 857.00 MHz, 879.00 MHz, 888.00 MHz, and 904.00 MHz at a different radius of the via with the bandwidths of 32.50 MHz, 29.40 MHz, 28.00 MHz, and 20.50 MHz the proposed antenna has been simulated using HFSS and FEKO EM simulation tools.

Chapter 2 discusses a Square Slotted Dual Bandwidth Rectangular Patterned Antenna for IoT Applications unique design for rectangular patch antenna considering 5GHz as frequency for IoT applications. This conventional patch antenna operates at dual frequencies 4.97GHz and 7.53GHz.

Chapter 3 discusses a basic design of a microstrip patch antenna that will fit the requirement of narrowband internet of things applications. The proposed antenna has a wideband characteristics operational performance with below -20 dB return loss as a requirement. The performance behaviour of the proposed antennas has been analysed by HFSS.

Chapter 4 presents a tunable rectangular slot antenna on a Rogers RT duroid 5880 (tm) substrate for narrowband internet of things applications. The proposed antenna has an operating frequency from 1601.20 MHz to 2051.90 MHz. All the analysis of the proposed antenna has been carried out in High Frequency Structural Simulation. For the performance validation of the proposed antenna, it has been simulated in FEKO tool and compared its return loss behaviour with HFSS results.

Chapter 5 presents a Design and Implementation of a low-profile patch Antenna for Industrial NB IoT Applications. For the requirement of NB IoT applications, a Rectangular micro strip slot antennas have been developed with sufficient bandwidth of 112.5 MHz. The above 50% size of the antennas has been reduced by making multiple rectangular slots on the patch surface. FR4 material has been utilized as a dielectric substrate. The proposed antenna has resonance frequency band from 1718.75 MHz – 1831.25 MHz with minimum return loss performance as below -20 dB.

Chapter 6 presents a design of a practical miniaturized antenna to support IoT Applications. The proposed antenna was designed and simulated using CST MWS which shows that the antenna is working effectively in the triple band of frequency.

The proposed antenna has the capability to work in the range of 2.4 GHz to 6.9 GHz. The miniature size of the antenna makes it suitable for wireless IoT applications.

Chapter 7 presents a printed Bow-Tie antenna is designed and simulated for IOT application. This antenna is designed and fabricated using FR4 dielectric material constant around 0.002. Thickness of the substrate is about 1.6mm. The proposed antenna is resonates at 8GHz with a return loss S_{11} of - 23.351dB, VSWR of 1.16, directional gain of 5.89 dB respectively.

Chapter 8 discusses about IoT based Wireless Microwave Power Transmission using Rectenna Wireless Microwave Power Transfer (WMPT) knowledge is measured as one of efficient Energy Shifting technologies. The WMPT can be applied to beam-type Point-Point technique as well as an Energy Collecting System fed by broadcasting radio waves and Solar Powered Satellites to power IoT devices. In this method of transferring, the power through wireless medium will minimize the wastage of power.

Chapter 9 discusses a Pyramid framed extremely high recurrent RFID Tag antenna with polarization diversity for IoT Applications utilizing Characteristics Mode Analysis. The characteristics strategies for inclining holes based plan in the US RFID band really show inductive lead (902 - 928 MHz).

Chapter10 presents a design of Ku band SIW slot antenna array used for IoT application. This chapter presents a brief description on the design of 1x1 rectangular slot antenna array at 30 GHz. The rectangular slots are etched off in the top layer of SIW Cavity. Antenna is designed in Ku band frequency for 5G IoT application.

Chapter 11 discusses a compact patch antenna for backscattering application. The model utilizes a crossed slot etched on single layer low loss substrate. The dimensions of the radiating patch is tuned through parametric analysis of the model in order to improve cross-polarization (dB) isolation and the axial ratio beam width of the antenna and the results are compared with other conventional antennas. The antenna attains an impedance characteristic of -17.65dB at 2.15GHz and -22.28 dB at 2.4GHz operating frequency and provides an impedance bandwidth ($|S_{11}| \leq -10$ dB) of 60MHz ant both bands. The antenna achieves a maximum gain of 6.8dB at 2.15GHz and 7.3dB at 2.4GHz in the direction of propagation.

Chapter 12 discusses a standard in wireless communication is NB-IoT. It deals with low power, small gain and more life expectancy. The connectivity problem is reduced in Narrowband design. This is achieved with microstrip antenna. Single patch is designed with the selected dielectric substrate. Several parameters is considered for the antenna design. The high value of dielectric constant reduce bandwidth in smaller patch for IoT design applications. The antennas were simulated in IE3D software and analysed for NB-IoT with 100 MHz.

Chapter 13 discusses the impact of number of slots and permittivity on EMI shielding effective. All electronics equipment's and devices emit electromagnetic

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energy. The emitted energy creates electromagnetic interference to the nearby electronic equipment. Shielding is the only effective method of reducing this type of interference without disturbing and reducing the performance of complex electronic systems. The Simulation results shows decrease in the shielding effectiveness with the increase in number of slots as well as increase in relative permittivity. In addition, the shielding effectiveness decreases with the increase in frequency.

Chapter 14 discusses a dual band helical reflect array antenna for high power microwave applications. A reflect cluster receiving wire (RAA) with a wideband high-power double branch helical reflect cluster is demonstrated. Two metal helical branches make up the reflecting component, and the movable pivot points allow for full 360 degree stage rotation. A 9 X 9 rectangular cross section X-band RAA model is imitated and estimated.

Chapter 15 discusses design and implementation of reconfigurable antennas for industrial and medical applications reconfigurable antennas (RA) are capable of dynamically altering their frequency, polarization, and radiation properties in a controlled and reversible manner. They modify their geometry and behaviour to maximize the antenna performance in response to changes in mechanical actuators, metamaterials, ferrites, and liquid crystals.

Chapter 16 discusses a cost efficient amplitude and phase antenna measurements this responsibility provides a straightforward, financially sound foundation for complicated analyses of the field transmitted by a receiving wire. The proposed setup is based on a number of receiving wire tests identified with a number of stage contrast locaters and, in general, a control locator. Stage capacity appraisals are made to recuperate the hour of the radio wire under test.

Chapter 17 discusses a radio Frequency Identification (RFID) antennas are used for wireless communication and in real world applications. Now the IoT and Automation have opened the doors to accomplish improved efficiency and productivity. Ultra-High Frequency (UHF) RFID antenna, a kind of Auto-Identification method that recognizes, discovers, validates, and engrosses with other IoT devices to competently accomplish one or more tasks.

We wish to express our profound thanks to all those who helped in making the book a reality much needed moral support and encouragement is provided on numerous occasions by our whole family. We wish to thank the publisher and the entire team of IGI Global who taken immense pain to get this book in time with quality printing.

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Chapter 1

A Via-Based Rectangular Patch Antenna for Narrow Band IoT Applications

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ABSTRACT

A simple asymmetric rectangular patch antenna has been projected for narrowband internet of things applications. A new via-based technique has been proposed to realize its bandwidth and increase the amount of transmitting power. And tuning aspects of this antenna has been explained for the radius of the copper via conductor. FR4 material has been utilized as dielectric material with loss tangent 0.02 with an effective dielectric constant of 4.259, and its performance has been explained under the different radius of the copper via. The designed antenna has a resonating frequency at 857.00 MHz, 879.00 MHz, 888.00 MHz, and 904.00 MHz at a different radius of the via with the bandwidths of 32.50 MHz, 29.40 MHz, 28.00 MHz, and 20.50 MHz. The proposed antenna has been simulated using HFSS and FEKO EM simulation tools.

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INTRODUCTION

Antennas becoming more popular when technology becomes increases to fulfill the requirements (H. Klaina, B. Ratni, A. V. Alejos, O. Aghzout and S. N. Burokur, 2019). In narrow band internet of things field the main issue of the designing antennas is size, since these antennas are majorly operating at 840 MHz -960 MHz as per basic antenna theory if frequency decreases geometry of the antennas becomes larger (M. Sanad and N. Hassan, 2019). To reduce its volume the best method is to create its dimensions as per the theory and reduce by adopting some technique such as inverted F antennas, substrate integrated waveguide antennas, co-planar waveguides etc. But construction of those antennas is highly difficult. Since the dimensions of the via integrating at mm range is still many industries still did not adopt to implement such antennas. Hence the requirement is to design an antenna for narrow band applications with ease fabrication complexity is needed. For offering narrow band performance patch antennas are well known and best solution at any wavelength on the microwave spectrum.

In antennas dielectric medium always occupies more volume. Because the volume of the dielectric medium is directly proportional to its radiating frictional bandwidth. So, if the requirement is large bandwidth, then compromise on the total antenna volume will take place. But narrowband antennas are exempt from the large bandwidth. Therefore, patch antennas have been chosen for implanting at the desired frequency. For implementing dielectric medium there are many materials are available in the market such as RT Droid, ceramic and FR4, etc. based on substrate loss tangent the material for the dielectric medium will be chosen. FR4 material has a loss tangent of 0.02 and RT Durioid has 0.0009. For this antenna FR4 material has been consider even though its loss tangent is worse than RT duirod based on its cost consideration. In many research papers, it has found that below 5 GHz FR4 can be used but if the desired frequency is above 5GHz then RT Durioid will be the best option (M. Raveendra, U. Saravanakumar, G. A. Kumar, P. Suresh and S. P. D. Pedapalli, 2021). Since when frequency increases substrate loss becomes large so FR4 materials cannot sustain or stable at high frequencies especially at X- band, Ku, and Ka-band applications (S. Ha, H. Seo, Y. Moon, D. Lee and J. Jeong, 2018).

The proposed antenna is covering the frequency from range 879.00 MHz to 904.00 MHz in microwave circuits the main problem is the simulation results are not exactly same as the results of the measures. So, sometimes it required to tune the antennas to the desired wavelength. And also, the simulation tools such as HFSS, IE3D, FEKO, etc will not consider the environmental effects. So, it is better to have a tuning technique whenever a microwave circuit has implemented (Y. Wang, Y. Li and Q. Zhu, 2017). Therefore, a copper via has been integrated to achieve the tuning. For narrowband operation, the tuning range would be less compared to

waveguide filters and many broadband antennas. The asymmetric structures will enable the integration of many technologies at same time. Whereas in symmetric structure, combining different techniques will leads to its field properties unstable in radiation properties (A. Loutridis, K. Yang, M. John and M. J. Ammann, 2015).

For giving input to the antenna many techniques are observed in the literature like microstrip line, coaxial cable, etc. In this research a coaxial typed input feeding method has implemented for 50-ohm input impedance matching. In fact, if the design has been implemented correctly, there won't be much difference in the feeding techniques among all, since they produce the same output. But when it comes to designing complexity, then there would be a selection process to select more ease one based on the structure of the antennas. For validation of the designed antenna, it has been simulated on High-Frequency Structural Simulation [HFSS] and FEKO later both results have been compared for justification of the proposed antenna (A. B. Asrokin, A. B. Abas, R. H. B. Basri and N. B. Jamlus, 2010).

PROPOSED ANTENNA DESIGN

$$f_0 = 900 \text{ MHz}$$

$$\text{Dielectric constant} = 4.4$$

$$f_0 = \text{Resonant frequency}$$

Width Calculation

$$W = \frac{c}{2f_0 \sqrt{\frac{(\epsilon_r + 1)}{2}}} \text{ mm} \quad (1)$$

$$W = \frac{3 \times 10^8}{2(9 \times 10^8) \sqrt{\frac{4.4 + 1}{2}}} \text{ mm}$$

$$W = 101.43 \text{ mm}$$

Calculation of the Effective Dielectric Constant

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-\frac{1}{2}} \quad (2)$$

$$\varepsilon_{eff} = \left(\frac{4.4 + 1}{2} \right) + \left(\frac{4.4 - 1}{2} \right) / \sqrt{\left(1 + 12 \frac{1.6}{101.43} \right)}$$

$$\varepsilon_{eff} = \left(\frac{5.4}{2} \right) + \left(\frac{3.4}{2} \right) (1.090547)$$

$$\varepsilon_{eff} = 2.7 + (1.7 \times 1.090547)$$

$$\varepsilon_{eff} = 4.259$$

Calculation of Effective Length

$$L_{eff} = \frac{c}{2f_0 \sqrt{\varepsilon_{eff}}} \text{ mm} \quad (3)$$

$$L_{eff} = \frac{3 \times 10^8}{2 \times 9 \times 10^8 \times \sqrt{4.259}} \text{ mm}$$

$$L_{eff} = 80.7597 \text{ mm}$$

Calculation of Length Extension

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\varepsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \text{ mm} \quad (4)$$

$$\Delta L = \frac{0.412 \times 1.6 (4.259 + 0.3) \left(\frac{101.43}{1.6} + 0.264 \right)}{(4.259 - 0.258) \left(\frac{101.43}{1.6} + 0.8 \right)} \text{ mm}$$

$$\Delta L = \frac{191.286}{256.8391} \text{ mm}$$

$$\Delta L = 0.7447 \text{ mm}$$

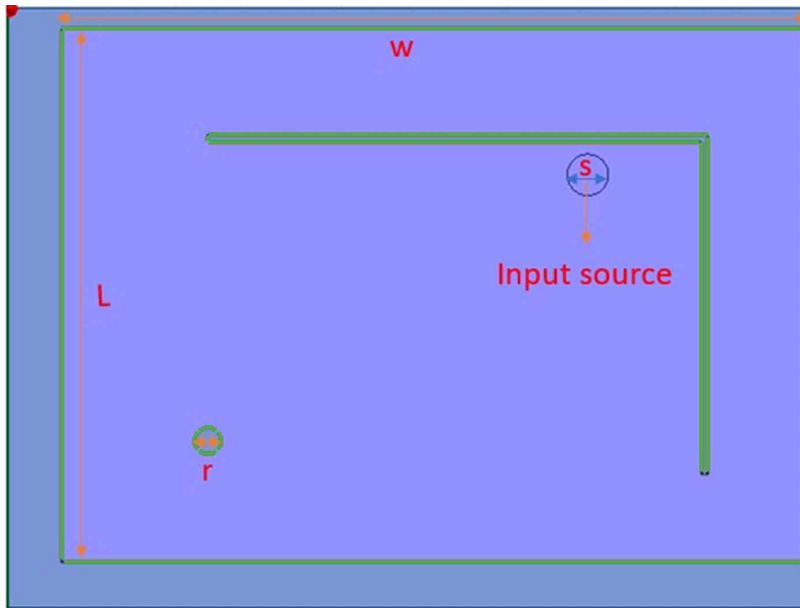
Calculation of Actual Length of the Patch

$$L = L_{eff} - 2\Delta L \text{ mm} \quad (5)$$

$$L = 80.7597 - 2(0.7447) \text{ mm}$$

$$L = 79.2703 \text{ mm}$$

Figure 1. Top view of the narrow band antenna.



RESULTS AND DISCUSSIONS

The length of the coaxial probe inner conductor has been adjusted to bring 50 Ω input impedance to make the antenna resonate at the desire frequency band. And then the radius of the copper conductor r is set as 2 mm, 2.2 mm, 2.6 mm, 3.1 mm. The width of the antenna has been derived from equation (1) and its length has derived from equation (2). The radius of the copper vias has been designed independently. The dielectric medium has placed between the ground plane and top copper plane in rectangular form so, the proposed antenna can be called a rectangular patch antenna.

The designed antenna is for narrowband applications to resonate at 873.30 MHz – 840.50 MHz, 894.30 MHz- 864.90 MHz, 901.80 MHz – 873.80 MHz, and 914.00 MHz – 893.50 MHz and its bandwidth has been calculated at the cut of return loss -10 dB by using below formula.

$$\text{Bandwidth} = f_2 - f_1 \text{ MHz} \quad (6)$$

f_2 = upper cut off frequency

f_1 = lower cut off frequency

At via radius $r = 3.09$ mm

$$\text{Bandwidth} = 873.30 - 840.50 \text{ MHz}$$

$$\text{Bandwidth} = 32.50 \text{ MHz}$$

$$\text{Frictional bandwidth} = \frac{f_2 - f_1}{f_0} 100\% \quad (7)$$

Substitute equation (6) in equation (7)

$$\text{Frictional bandwidth} = \frac{\text{Bandwidth}}{f_0} 100\% \quad (8)$$

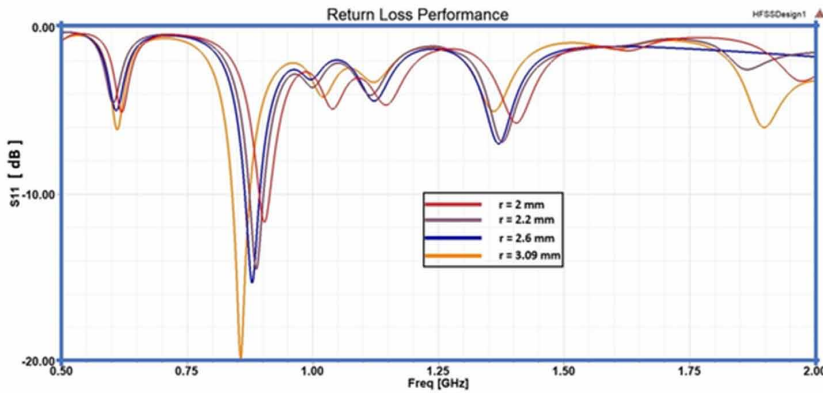
$$\text{Frictional bandwidth} = \frac{32.50\text{MHz}}{857.00\text{MHz}} 100\%$$

$$\text{Frictional bandwidth} = 3.7922\%$$

Similarly,

The resonance bandwidth has been derived from equation (6) and its frictional bandwidth has derived from equation (8) and those performance values shown in Table. 1. The tuning of this antenna has been achieved by increasing the radius of the copper via. For position of the copper via the weak current field density region has selected and by making hole at this position, the current field density becomes strong around the hole region later a copper via has been placed at the hole to provide electrical conductivity between patch and ground. It offers a decrease in resonating frequency and improves the return loss characteristics shown in Figure. 2. And the shift in resonating frequency has shown in Figure. 3. It is also observed that the increase in vias radius of the antenna will increase the bandwidth of the operating frequency as shown in Figure.4 later the design has been verified in the FEKO simulation tool for the performance justification shown in Figure.5. And its radiation characteristics have shown in Figure. 6 and the radiation characteristics do not influence much to sacrifice.

Figure 2. Return loss performance at different radius of the copper via.



Less return loss performance leads to transmit high power in terms of EM radiations. The return loss can be increased by adjusting the position of the via the transmitting power can be calculated using equation (9)

$$VSWR = \frac{1 + 10^{\frac{-RL}{20}}}{1 - 10^{\frac{-RL}{20}}}$$

Figure 3. The shifting performance of the antenna when radius of the via is increased.

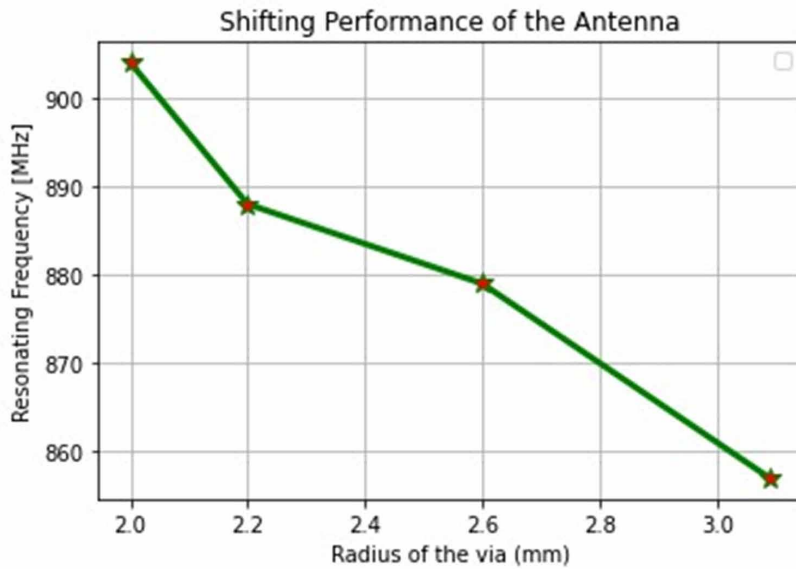


Figure 4. The bandwidth enhancement performance of the antenna when radius of the via is increased.

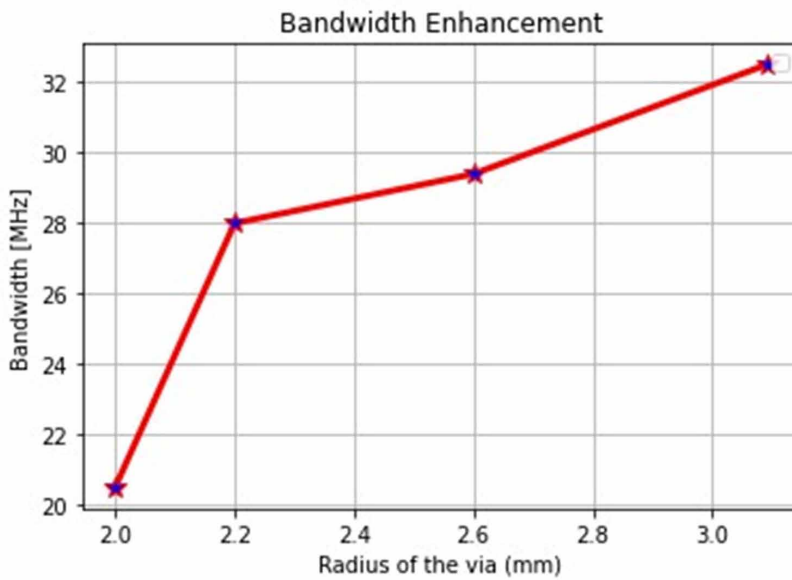
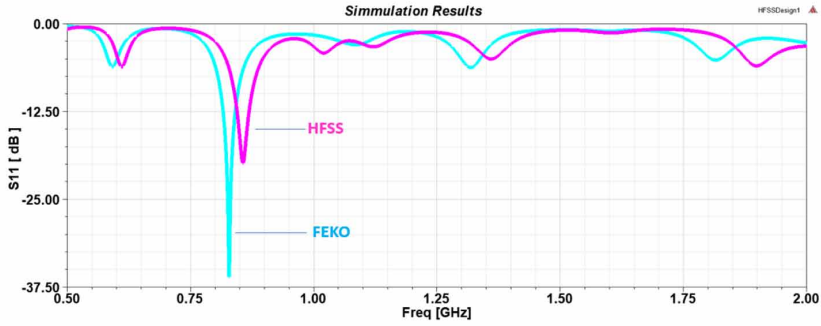


Figure 5. proposed antenna simulation model for return loss characteristics.



Return Loss (RL) = -19. 8487 dB, when r = 3.09 mm

$$VSWR = \frac{1 + 10^{\frac{-19.8487}{20}}}{1 - 10^{\frac{-19.8487}{20}}}$$

$$vswr = 1.22650$$

$$\text{Reflected power \%} = \left(\frac{VSWR - 1}{VSWR + 1} \right)^2 \times 100 \quad (9)$$

$$\text{Reflected power\%} = \left(\frac{1.22650 - 1}{1.22650 + 1} \right)^2 \times 100$$

$$\text{Reflected power \%} = 1.034\%$$

$$\text{Transmitted power} = (1 - |\Gamma|^2) \times 100$$

$$\Gamma = \left(\frac{VSWR - 1}{VSWR + 1} \right)$$

$$\Gamma = \left(\frac{1.22650 - 1}{1.22650 + 1} \right)$$

$$\Gamma = 0.10172$$

$$\text{Transmitted power} = (1 - |\Gamma|^2) \times 100$$

$$\text{Transmitted power} = 98.96\%$$

Similarly,

The quantity of radiating power at each resonating frequency with respect to different radius has been given in Table 1. The E & H – plans at the different configuration of the antenna has proposed at *Figure. 6*.

Table 1. antenna statistical performance values.

S. No	Radius of the Via [mm]	Resonating Frequency band [MHz]	S11 [dB]	Bandwidth [MHz]	Transmitting power	Reflecting power
1	2.0	914.00 – 893.50	-10.0216	20.50	90 .07%	9.93%
2	2.2	901.80 – 873.80	-14.3993	28.00	96.35%	3.65%
3	2.6	894.30 – 864.90	-14.4863	29.40	96.42%	3.58%
4	3.09	873.30 – 840.08	-19.8487	32.50	%	1.034%

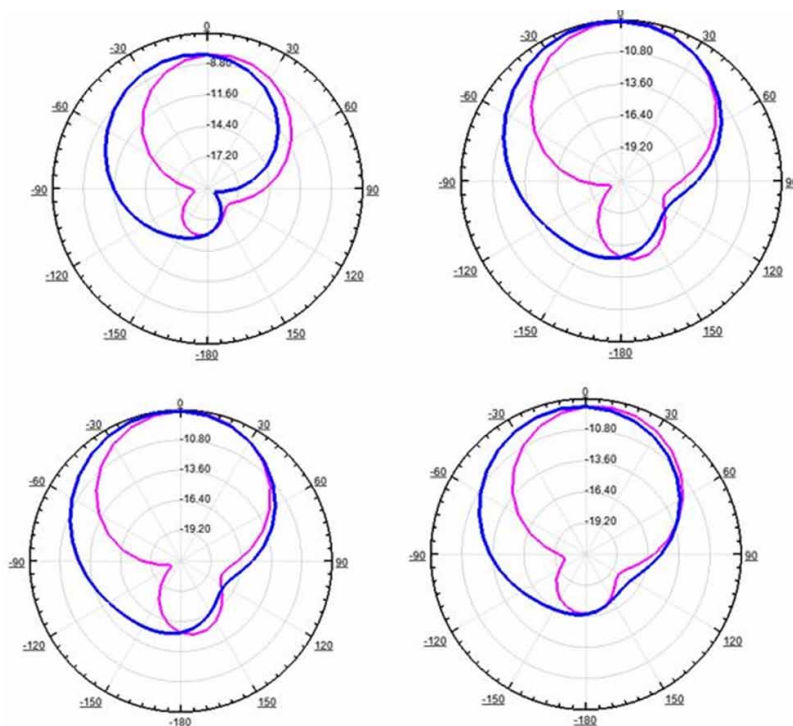
FUTURE RESEARCH DIRECTIONS

The proposed antenna can be prototyped for satisfying the narrow band internet of things applications. And further the proposed tuning method can be applied for substrate integrated waveguide antennas and also for patch antennas to make antennas to resonate at desired frequencies. Here a single via has used may be in the future multiple vias behavior at this frequency can investigate or study to increase the range of the tuning performance.

CONCLUSION

The proposed antenna can be used at four frequencies by tuning the radius of the copper via to satisfy the narrowband internet of things applications. The advantage

Figure 6. The E and H planes of the narrow band at radius of the via 2 mm, 2.2 mm, 2.6 mm, 3.09 mm.



of the proposed antenna system is much simpler in design, implementation and cost-effective. A method has been proposed to achieve enhance the bandwidth as desired. An efficient tuning method has proposed to avoid manufacturing tolerance and provides the solution to operate or shift the resonate frequency by dealing with copper via which placed at a weak current density field region.

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Chapter 2

A Square–Slotted Dual– Bandwidth Rectangular– Patterned Antenna for IoT Applications

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ABSTRACT

This chapter presents a unique design for rectangular patch antenna considering 5GHz as frequency for IoT applications. In the booming world of technology, IoT has set a significant benchmark by its enormous applications in almost all the fields. So here we come up with this unique design of antenna which can be used for IoT applications. As an initial step, a simple normal rectangular antenna is configured for a frequency ranging from 3GHz to 8GHz, and then considering the 5GHz to be appropriate for IoT application, a conventional rectangular patch antenna was designed. This conventional patch antenna operates at dual frequencies 4.97GHz and 7.53GHz. In later stages of designing, square slots are made on the either side of the feedline to obtain better antenna parameters. This chapter presents a detailed study on conventional and slotted antenna and a brief discussion regarding the comparison of the antenna parameters of conventional antenna with the slotted antenna.

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INTRODUCTION

A web of physical objects or things which connect with each other to share data and take action can be stated as IoT. It is basically a network comprising of things which communicate with each other and share information. These things or objects i.e., hardware devices which interact should be IP protocol enabled. For communicating with each other these devices need to send and receive the messages. (Lizzi & Ferrero, n.d.) IoT can be stated as an inter-network of physical units, other components with electronics, sensors, different software, actuators, vehicles and RFID devices. It is a system that enables these objects to assemble and transfer data in a diverse networking environment including objects of distinct functionality, technology and application field.

The Internet is “a global network for connecting innumerable embedded hardware devices like computers, smartphones and tablets providing a range of data and communication facilities and consisting of interconnected networks using standardized communication protocols”. A unique id with IP address is given to all the devices present in the network. IP address could be a numerical label that identifies a device and locates it on the network and routes the web traffic. The Internet has accelerated the face of technological development, the growth of internet, considering the advancement, soon the following becomes reality. A day is one’s life would be governed by Internet and IoT in near future. IoT devices which have particular identities and can achieve remote sensing, actuating and monitoring capabilities can be noted as “Things” in IOT. Things refer to variety of devices. At times, even human in the loop becomes a thing. Anything to qualify as a “thing” requires identity. The “thing” can monitor, measure for example, a temperature sensor could be a thing. Some standard organizations have set up significant works to study the depth of IoT. In Toronto, Canada, an Internet of Everything research center is set up by Cisco where they have spent nearly \$100 million.

INTRODUCTION TO ANTENNA

In modern communication system, the wireless the technology becomes integral part of human life. Because of the progression in innovation, the necessity and use of remote correspondence applications are increment step by step. As we know antennas are simple electrical devices which carry out receiving and transmitting action and thereby converting electrical signals to electromagnetics waves. Antennas receives the signal from transmission line or guided wave, that converts received signal to electromagnetic signal which can be transmitted to free space. (Panda et al., n.d.) Antenna can act as a transmitting antenna and receiving antenna where

transmitting antenna plays a role of gathering the electrical signals arriving at the transmission line and converts them into radio signals. On the other hand, receiving antennas act in a contradictory manner that is it accepts the radio signals and gives it to the guiding device. While other devices communicate with the help of ATC personnel, antennas ease the job by providing a simple way to conduct the signals. There are many categories of antennas and each literature attempts to give its own analysis on antennas. With the emergence of wireless broadband technologies like Wi-Fi, Wi-MAX, Bluetooth, Zigbee, Z-wave and others, there is a requirement for miniaturized, cost-effective structure. And thus, patch antennas were discovered as a solution for these requirements.

INTRODUCTION TO PATCH ANTENNA

A ground surface, dielectric substrate, microstrip patch alongside feedline in a confined manner sets up a patch antenna. Radiation is mainly from the conducting patch and these patches can be designed in any shapes. (Constantine, 1997) The radiating patch which is used may be of different shapes which includes square, rectangle, circular, tri-angular, thin strip or elliptical. Since the analysis and fabrication can be done very easily in square, rectangular, circular and dipole patch, they are the most commonly used ones. These have a low cross polarization radiation. Materials like copper and gold can be used. Because of its highly reactive nature and economical, copper is chosen in almost all the industrial use and thus in antennas too. Best chosen dielectric substrate is with a relative permeability of 4.3 which are useful for fabrication and antenna performance. Materials like nylon, FR-4, Foam, Duroid can be employed as dielectric.

Few antenna parameters are S parameter, VSWR, return loss, directivity, gain, antenna efficiency and many others. However, these parameters can be improved by different techniques. The placement of the waveguide port can make significant change in these characteristics. Bringing out and working on different designs can also improve these characteristics. (Kraus, 1988) By using split-ring resonators, array of antennas, making different slots on the radiating patch good results can be obtained. Split ring resonator is a kind of metamaterial which yields negative index of refraction. Slotting an antenna is removing some part of the radiating patch which deteriorates the size as well as improves the result. However, by just making a slot or by using split ring resonator, it cannot be stated that definitely a good result will be obtained, as it depends on the dimensions of the slots made or split-ring resonator used as it may either give a significant increase or in some cases the antenna parameters can also be reduced. But by repeated trial and error on the designing we can achieve good and better characteristics after using these methods

Some general applications of IoT with antenna integrated in them are ZigBee protocol which connects low power in a personal area network have embedded antennas that operate at frequencies of 915MHz, 2.4GHz. At 2.4GHz there is lower power MAC protocol known as Z-Wave specifically devices of Smart Home Security Systems, Smart Locks, Smoke Detectors etc. Another IoT based application which is Wireless Fidelity, commonly called as Wi-Fi operates at a wide range of frequencies 2.4 Gega-hz, 3.6 Gega-hz, 4.9 Gega-hz, 5 Gega-hz and 5.9 Gega-hz. Another vastly used IoT application is GPS for global navigation. They operate at frequencies of 1575.42MHz, 1227.6MHz and 1176.45MHz.

Wireless HART is an application that uses IIoT. IIoT abbreviates to Industrial Internet of Things. It is a radio communication protocol which operates at 2.4GHz. It adds wireless capabilities to HART protocol. LWPAN is an IoT application, LoRa and Sigfox are the LWPAN technologies. LoRa abbreviates Long Range Wireless for Internet of Things (IOT). It operates at different frequencies for different countries. It operates at 915MHz for the US, 868MHz for Europe and 433MHz for Asia. Sigfox, an ultra-narrowband technology operates over a range of 868Mhz and 902MHz. It is one of the networks that supports 4G/LTE but is considered to be expensive.

INTRODUCTION TO DUAL FREQUENCY MICROSTRIP PATCH ANTENNA

Dual frequency means antenna receivers can receive two signals at two different frequencies. (Liang et al., 2016) In applications where large bandwidth is required for operating, dual frequency microstrip patch antenna provides an alternative to large bandwidth antenna. As there are two frequencies available it can also be seen as a backup if one of the frequencies is not operating.

PATCH ANTENNA CHARACTERISTICS

Microstrip antennas carry a handful of preferences in contrast with accustomed antenna structure hence leading to a wide-ranging frequency from ~100 Mega-hz to ~100 Gega-hz.

Few principal advantages are stated below:

- Inadequate planar configurations with low volume and light weight, which make them conformal.
- Print circuit techniques such as photolithographic are used which is suitable for mass production, thereby reducing the cost of fabrication.

A Square-Slotted Dual-Bandwidth Rectangular-Patterned Antenna for IoT Applications

- The size of the antenna can be made as thin as possible so that it can be used for aerospace automobiles without disturbing its aerodynamic properties.
- These patch antennas can be used to create simple arrays readily.
- Dual frequency is achievable.
- Solid-state devices can effortlessly be combined using patch antennas.
- Antennas can be fabricated with feedlines and matching.

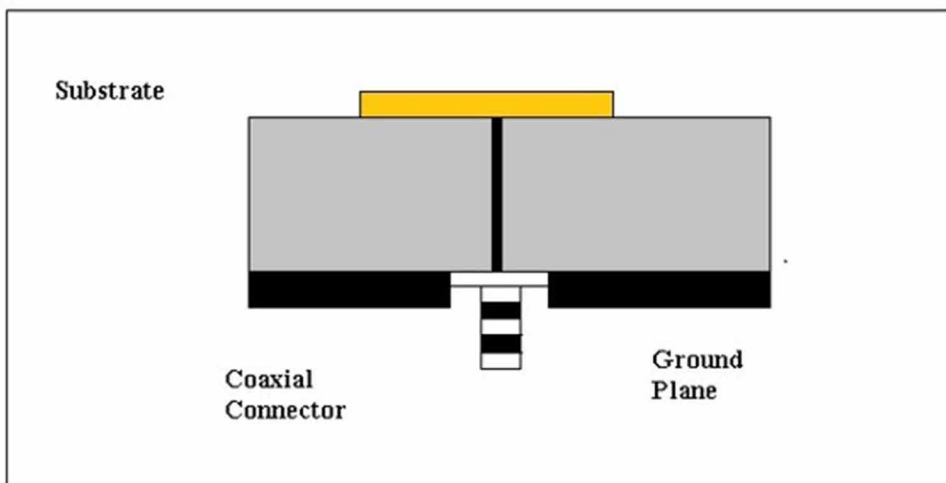
FEEDING METHODS

There are several methods to feed microstrip antenna. The four familiar ways are as follows

Co-Axial Feed

This mechanism involves the inherent conductor of co-axial i.e., merged with the radiating strip and exterior boundary coupled to ground plane. It is easy to fabricate this method and spurious radiations are reduced. The figure below represents the coaxial probe feed.

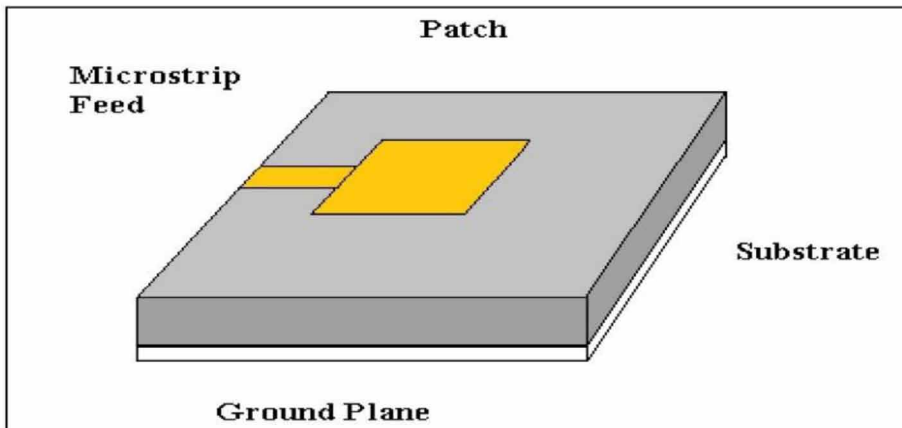
Figure 1. Co-axial Feed



Micro-Strip Feed

The radiating patch is directly associated with the conducting microstrip feed line. This feedline is a small conducting material which is joined with the patch. The measurements of feed line vary from those of the radiating patch. The figure below shows micro-strip feed.

Figure 2. Micro-strip Feed



Aperture Feed

It is a different feeding mechanism in which the ground plane separates the two different dielectric substrates used. The radiating surface alongside feed are coupled in ground surface linked via slot. Pure polarization and reduction in interference can be achieved by using aperture coupled feed. This feeding method is shown in figure below

Proximity Feed

Feedline is present in between the 2 dielectric substrates used. The radiating strip is settled at the upper surface of the upper dielectric substrate. As it is a complicated technique it is difficult to fabricate this method. However, it manages to get high bandwidth and evades spurious radiation. The proximity coupled feed is as shown in figure below.

Figure 3. Aperture Feed

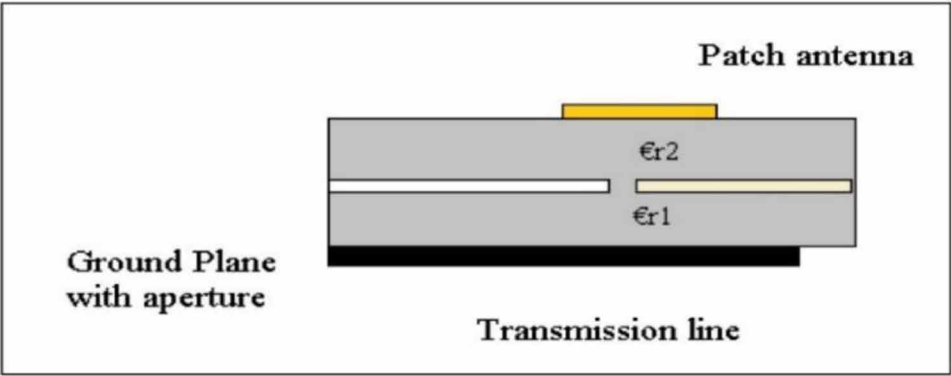
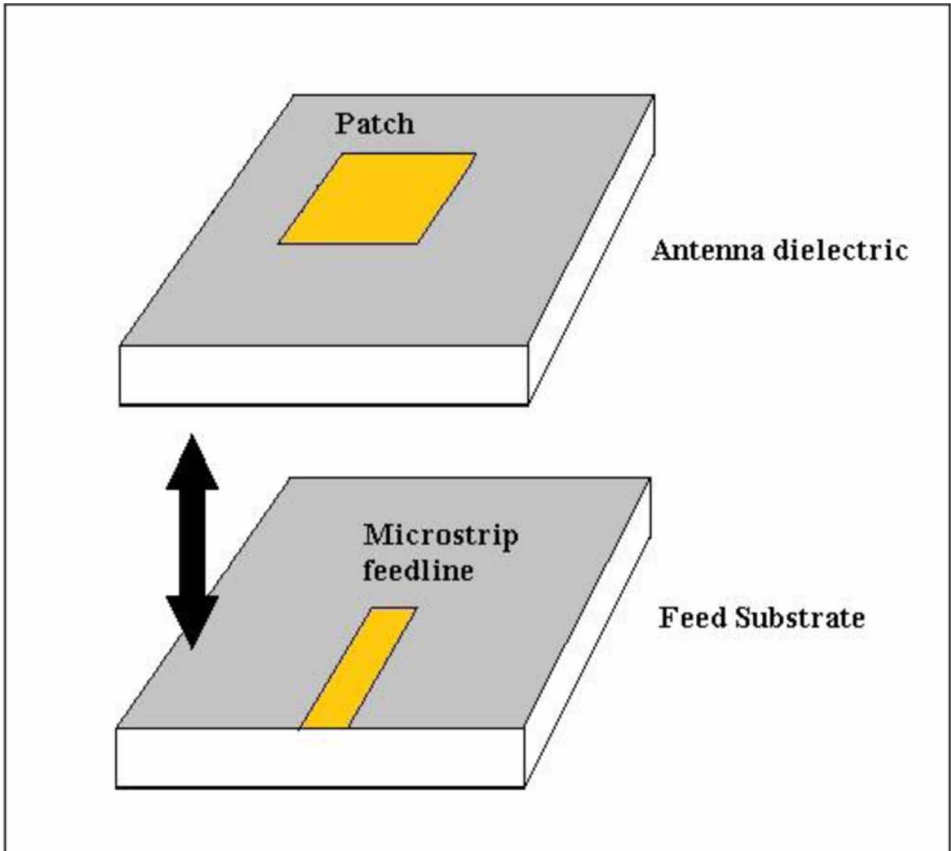


Figure 4. Proximity Coupled Feed



LITERATURE SURVEY

Ribhu Abhusana Panda mainly concentrates on a theoretical survey on patch antennas. A broadband patch antenna for wireless transmission is designed. Here they have used a rectangular patch as a radiator which has several advantages over the others used for wireless communication at a rate of 2.4GHz with a gain of 11dB. Microstrips are used in Wi-Fi enabled devices because of its cost effective, delicacy and ease of fabrication. (Panda et al., n.d.) They have used a most common technique of designing a patch antenna that is etching a patch on the substrate. The main parameters considered for antenna design are antenna gain, efficiency, directivity, path loss, return loss and radiation pattern. Patch antenna can be fed in many diversities. Generally, they are classified as contacting and non-contacting. Due to its low-profile structure in wireless devices as well as in satellite communication microstrip patch antennas are widely used. Normally patch antennas have narrow bandwidth so the main concern would be to overcome this. A notable point would be designing a conventional antenna and then comparing its results with the uniquely designed antenna.

A microstrip patch antenna with metamaterial substrate is developed. Without metamaterial dielectric constant=4.3 Return loss: -18.702 dB with a S-Parameter value of -18.702dB and BW of 780.53MHz. By using metamaterial structure array with patch antenna, a negative real value of permittivity and permeability is obtained at a resonant frequency of 10.3GHz with a S-Parameter of -27.799dB and BW of 1272.7MHz. Here they have used CST for simulation. (Gupta & Tiwari, 2017) The patch antenna works in X band applications that is in Radar, satellite communication and wireless computer network. Very less return loss and good bandwidth is obtained. Drawback in this paper is that metamaterial is used as an array which is difficult to fabricate. As observed by using metamaterial we can have less return loss a patch antenna with material array can be used.

The main concern of this article is regarding the structure of the antenna. To increase the resonant frequency, a rectangular slot has been trimmed in the upper right edge of the patch. (Mittal et al., 2017) And then to increase the bandwidth of the antenna a rectangular slot has been added in the patch. The size of the antenna after slotting has been reduced by 10.12%. The following parameters i.e., resonant frequency is 5.54GHz, return loss is -60.29dB, bandwidth is 2.65GHz, frequency range is 4.74GHz – 7.40GHz, gain = 3.3dB, VSWR < 2 is noted. SMA connector is used to provide proper impedance matching to microstrip feedline to the antenna. This ensures that a minimal reflection loss with maximum power is delivered to the antenna for radiation. This design is employed for C-band applications like broadcasting, maritime communications, maritime military systems and ISM band. Increase in overall gain of an antenna can be obtained by using array technique.

Drawback would be due to increase in number of antennas in antenna array, it needs more space and maintenance becomes difficult. Take away points from this paper would be that overall increase in bandwidth of antenna can be obtained by proper positioning of slits and slots made in antenna. More effective results will be obtained when both transmission feed and patch have perfect impedance matching.

Preeti Vyas has designed the antenna suitable for future mobile applications like 5G. There are two major development of design done in this paper. One is using circular patch with partial ground plane and the use of pin diodes. The return loss is lower than -10db of an operable range of 5.5 – 6.5 GHz. The PIN diodes are used to provide a fairly good impedance matching. PIN diodes are mounted at the bottom of the antenna. The diodes are named as PD1 and PD2. If both PD1 and PD2 are OFF then the frequency is 6GHz with a return loss of -30. If PD1 is ON and PD2 is OFF then the first frequency is 2.1GHz and second frequency is 8.9GHz with a return loss of -27 and -52 respectively. If PD1 is OFF and PD2 is ON then the first frequency and second frequency is nearly same as obtained in the last case but the return loss obtained is -27 and -35 respectively. (Singh et al., 2016) Thus, they have drafted a reconfigurable device with the use of PIN diodes. It is easy to fabricate. One of the weakness found in this is that compared to fabrication, simulation has more return loss. Sufficient bandwidth can be introduced via feed line at the aimed frequency and makes it compact which can be considered as a take away point.

Single element, 1*2 and 1*4 array of microstrip patch antennas has been designed using rectangular patch and partial ground technique. Structure is fabricated on Flame Retardant-4 epoxy dielectric with relative permeability of 4.3 and simulated using Ie3D software. Increase in overall gain is observed from single element to 1*4 array that is, from 1.13716 to 6.83955. (Tom et al., 2017) In this paper designed antenna has a impedance of 187ohm, operating frequency of 5.78 GHz and omnidirectional radiation patten. Also, increase in overall bandwidth can be increased by proper positioning of slits and slots made in designing of antenna and proper results are attained with impedance matching. A good impedance matching of 49.96 Ω which closely matches 50 Ω because of slots this is a remarkable result that can be noted. But it is difficult to fabricate. A good gain, low return loss and VSWR values are obtained over operable frequency band this has been observed because of the modification in the design that is by making a slot in the conventional rectangular shaped MPA.

A new trend has been set in the world of technology that is “Miniaturization”. It just means manufacturing device or an object as minute as possible. Using IoT standards like LoRa and 3GPP standardisation an effort to design miniature antenna is proposed here. Miniaturization helps to increase the quality factor. With the help of antenna quality factor, miniaturization mainly concentrates to improve radiation efficiency. High-quality antennas are recommended for IoT applications as they cover narrow bandwidth requirements. (Lizzi & Ferrero, n.d.) They have theoretically

obtained good antenna radiation efficiency but while working practically there was decrease in antenna efficiency due to miniaturisation. The two hinderances faced are one regarding the overall energy consumption and the second one would be miniature antennas are very sensitive to operate in all the environment. However, the authors have also found solution to the above-mentioned limitations. By keeping the IoT device design in consideration that is the placement of battery, circuits etc., To detach the antenna, protecting cases can be used. Inspired by folded Inverted F Antenna (IFA) this miniature antenna is designed which engages upper section of printed board. This antenna s works at dual band as it needs to operate for GPS at a frequency of 1.57GHz and also should operate for US LoRa at frequency of 915MHz.

Adewale Ayomikun Elijah in his communication also speaks about the miniature antenna which are easy to integrate in IoT applications. (Elijah & Mokayef, n.d.) This communication proposes a rectangular miniature antenna with U cut slots in it. The results of conventional antenna and optimised antenna are compared and discussed. The bandwidth has shown a significant increase form 134.1 MHz to 167.6MHz. Where the gain has increased from 1.83dB to 2.54dB on the other hand the return loss has made an increase of -20.32dB to -26.56dB. In older studies pentagonal patch was considered to give better performance but the simple rectangular patch has been selected as it is easy to fabricate. There is an increase in the antenna's resistance and capacity as they have introduced slots along the non-radiating edge, which also make difference in the current distribution. Without modifying the total dimensions and by making slots in it the surface current is made to circulate which thereby increases the length of patch antenna. In this communication a detailed comparison of the traditional antenna with the optimized antenna is done. Hence, they have concluded that, as less power is reverted back by the modified one, energy consumption of conventional antenna is less than that of optimized antenna. Enhancement in the antenna parameters is noted, and they have considered that these improvements are due to the U-shaped slot in the patch and due to reducing the space between the feedline and the patch, i.e., the pitch gap.

Antennas are operated at fundamental TM₀₁ mode, to obtain broadside beam. Here in this article (Khidre et al., n.d.) an interesting change has been made by working the microstrip antenna at higher TM₀₂ mode. A U-slot technique is used to achieve broad bandwidth. A detailed study on the simulation results obtained and the results obtained after fabrication are nearing to each other which adds more weightage on the work they have proposed. They have used Rogers RT\Duroid as dielectric substrate and obtained the simulation using HFSS software. They have focused on the use of directional antennas as they have the ability to restrict the power from scattering to the other unwanted direction. These antennas can produce single or multi-beam which means that they have more directivity beam from a single aperture. As known a major limitation of patch antenna is it narrow bandwidth, this

article claims that by making a U-slot and operating the antenna at TM₀₂ mode they have overcome this drawback. Impedance bandwidth has been increased more than two times by making a U-slot in the patch. The antenna operates at of 5.18 – 5.8 Gega-hz with an impedance bandwidth of 11.8% and voltage standing wave ratio is less than 2. As stated, the antenna produces multi beams, it has two radiation beams. One is directed at 35° with a gain of 7.92 dBi and at -33° with a gain of 5.94dBi, at 5.5GHz.

In this article by resonating the radiative TM₁₀ and TM₁₂ modes, the performance of the patch antenna is analysed. A wide radiation range can be expected for the antennas with HPBW (Half power beam width). There are different approaches for the enhancement of HPBW some of them would be by making slots or equivalent slot loading, an effort to use array antenna, multi-mode antennas can be tried, vertical element loading. As we know, the patch antennas which operate in TM₁₀ mode results a narrow HPBW, (Liu et al., n.d.) hence they have separated the main radiating strip and fusing pin1 with the y-axis are loaded. This significantly widens the radiations under improved TM₁₀ mode. Enhancement of HPBW at TM₁₂ mode is done by loading the fusing pin2 along x- axis. And hence with the broaden HPBW, the non-broadside radiated field of TM₁₂ mode is successfully altered. And now by loading the shorting pin 3 along y axis, sidelobe level of H-plane radiation diagrams are reduced for TM₁₂ mode. Adequate impedance matching at 2 frequencies is achieved by creating linear cut on the patch. Though the design seems to be complicated, the Suggested model is assembled and S-parameter is calculated and plotted with the help VNA. An improved-bandwidth can be observed at 2 attenuation poles, one at 9% and the other at 5% correspondingly. The HPBW around ~135°, low SLL of -10 dB, cross-polarization less than -24 dB in dual frequency bands is measured. And this antenna can be implemented in mobile communication systems.

DESIGN

We have designed an antenna for IoT applications at a frequency of 5GHz and have obtained a dual frequency. Initially a simple rectangular microstrip antenna was constructed using Flame Retardant-4 as a substrate which has a dielectric of 4.3 and copper for patch. A dual frequency was obtained at 4.95GHz and 7.52GHz.

For the conventional as well as the slotted antenna, 18.428mm x 13.859mm FR-4 dielectric with a height 1.6mm is chosen. A rectangular radiating patch is of dimensions 9.2144mm x 4.6196mm. The radiating copper patch is shorted to the conducting microstrip feed line of 1.0546mm x 11.7295mm. These designing and simulation is done by using CST software (version 18).

CST Studio abbreviated to Computer Simulation Software is a electromagnetic field simulation software which provides a high performance 3D EM analysis. It supports rapid and precise research of frequency components such as filters and couplers. Due to ease in simulations, it is one of the emerging and popular tools for antenna designing as it is based upon Finite Integration in Technique (FIT).

The antenna dimensions are as follows:

Table 1. Antenna Dimensions

Parameter	hs	w	l	wp	lp	wf	lf
Dimension	1.6mm	18.428mm	13.859mm	9.2144mm	4.6196mm	1.0546mm	11.7295mm

After analyzing the parameters and by carrying out many trial and errors two square slots were cut out at the either sides of the feedline on the conventional antenna. The two square slots are of dimension 2mm x 2mm which has abridged the size by 12.16%. This was basically done to achieve better antenna characteristics when compared with the conventional antenna characteristics. Dual frequency was obtained at 4.9796GHz and 7.53GHz.

Figure 5. Cross sectional view

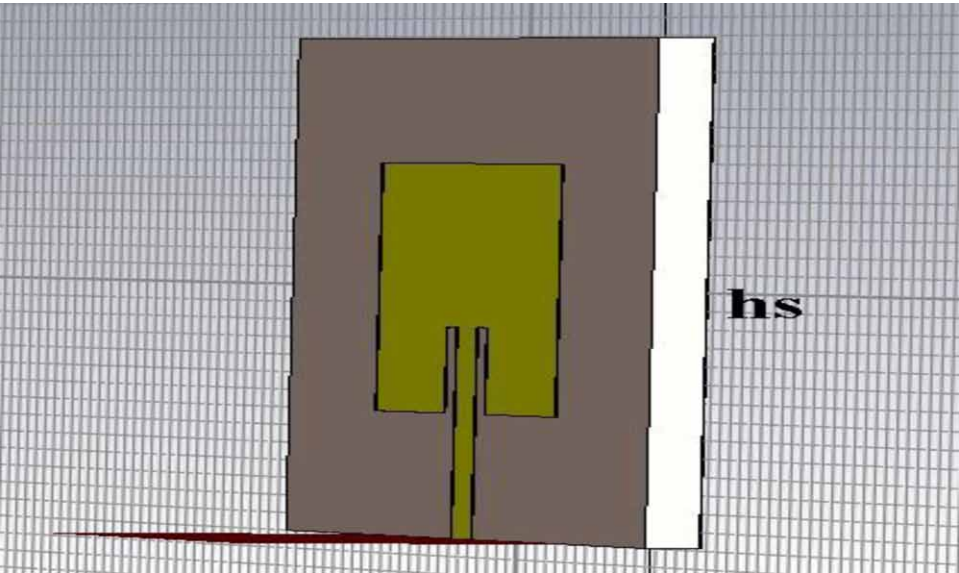


Figure 6. Front view with substrate dimensions

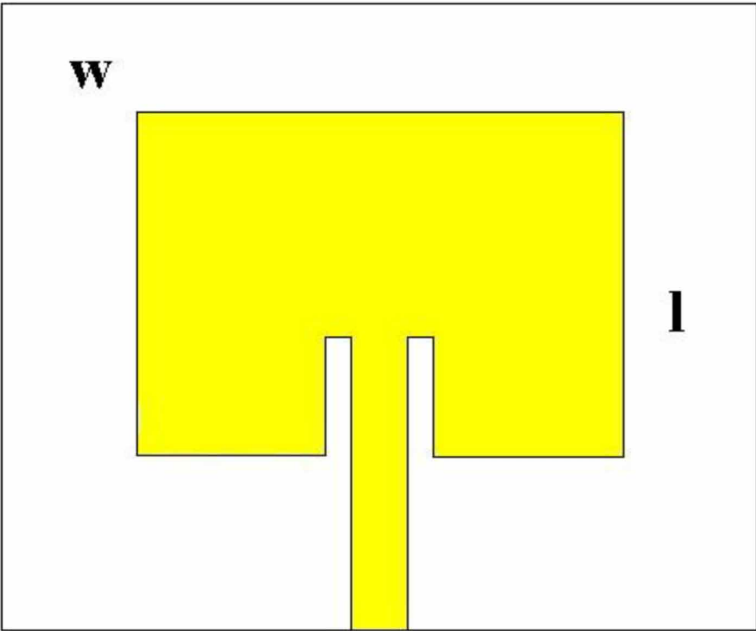


Figure 7. Front view of patch with its dimensions

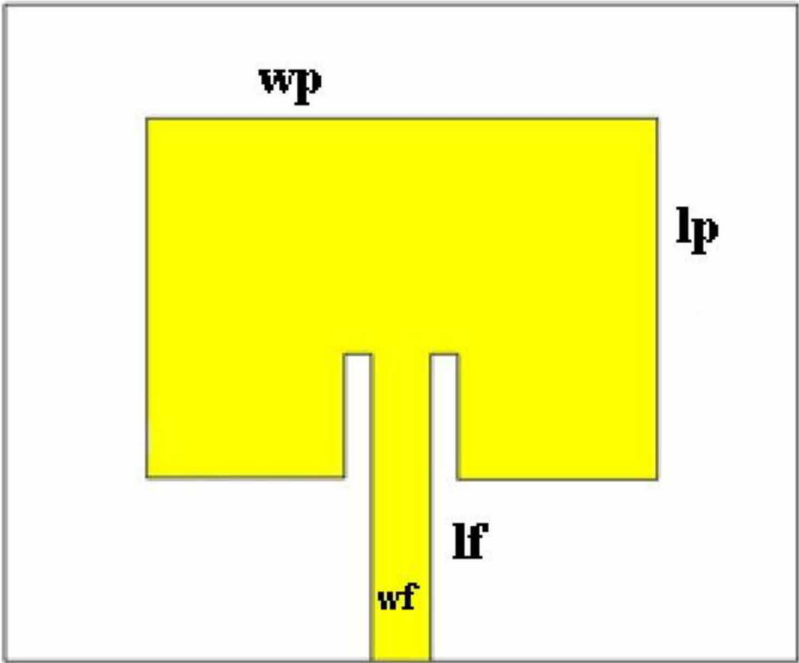
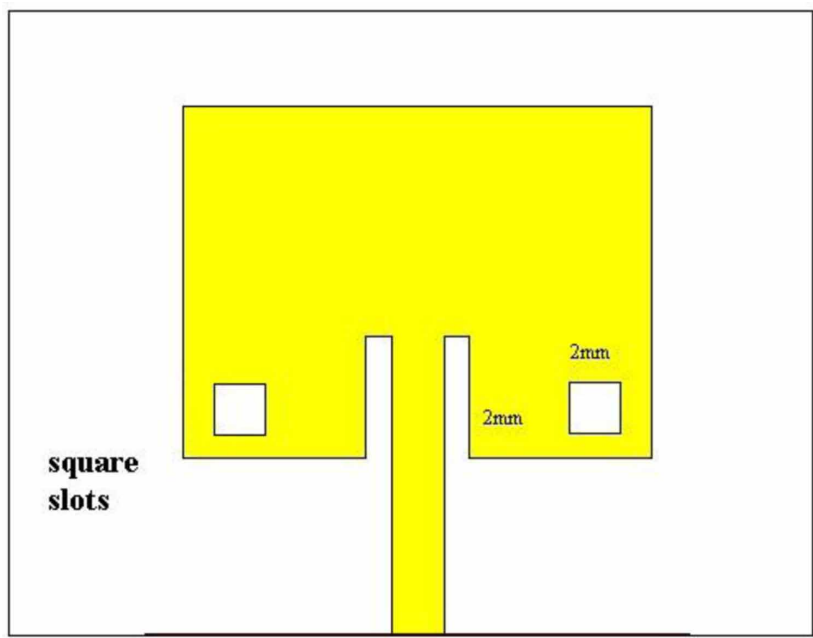


Figure 8. Square slotted on patch



RESULT AND DISCUSSIONS

In this paper we have mainly concentrated on the parameters like Voltage Standing Wave Ratio, field plot of radiation and S-parameter. Only the antenna parameters which have made a significant change has been discussed in detail. For the initial conventional antenna, the antenna parameters obtained with figures are shown below

Figure 9. S parameter at 4.9592GHz

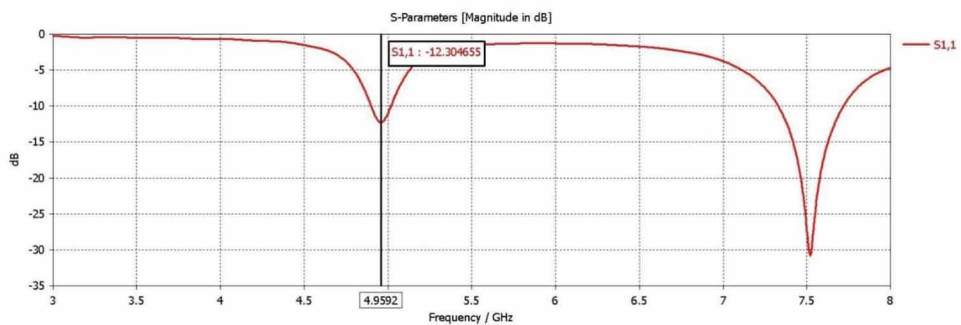


Figure 10. S parameter at 7.52GHz

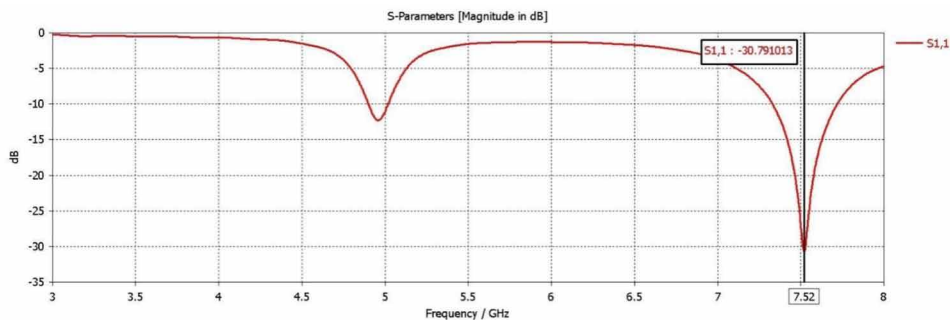


Figure 11. VSWR at 4.9592 GHz

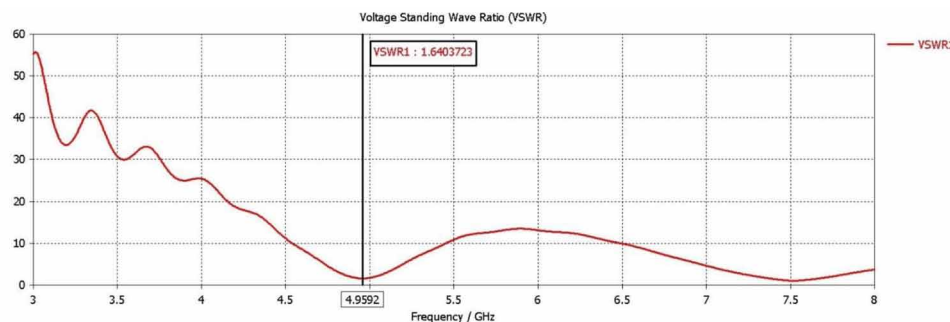


Figure 12. VSWR at 7.52GHz

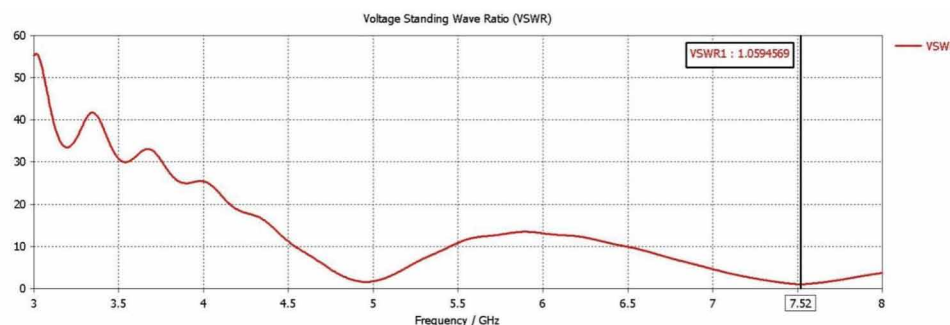


Figure 13. Radiation Pattern at 4.9592GHz

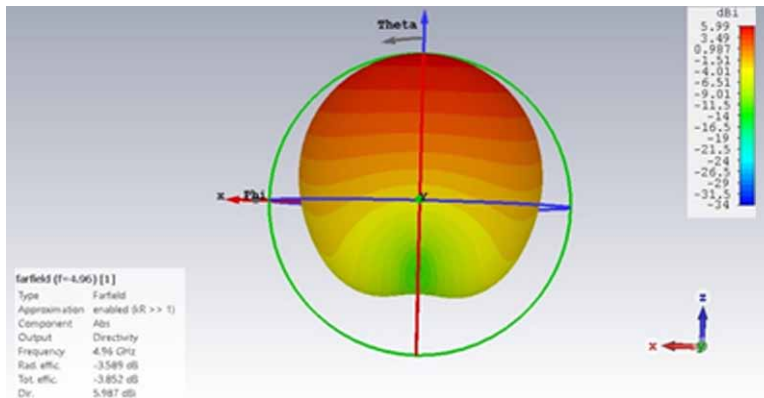
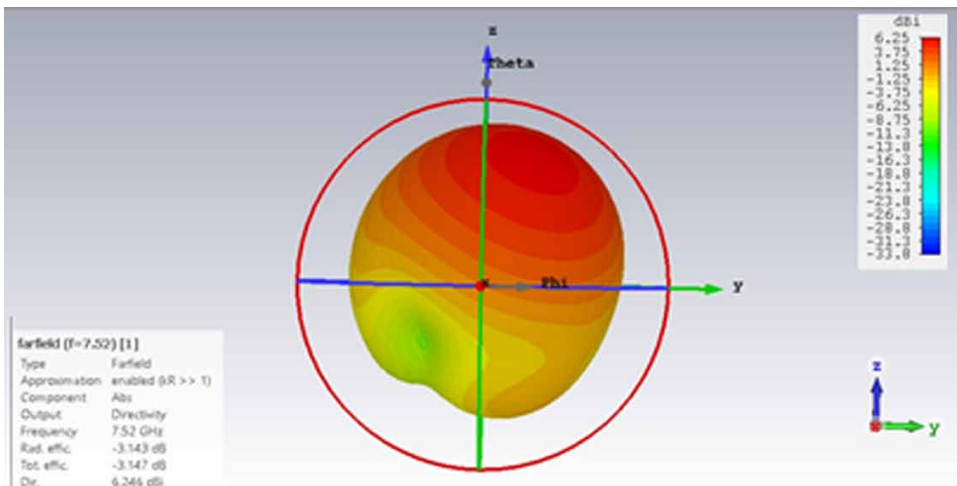


Figure 14. Radiation Pattern at 7.52 GHz



In fig. 13 we have obtained the elements of the scattering matrix i.e., S parameter as -12.30465dB at 4.9592GHz. Similarly in fig. b the S parameter curve measures to be -30.7910dB at 7.52GHz. At both the frequencies we have also obtained VSWR which abbreviates to Voltage Standing Wave Ratio as 1.6403 at 4.9592GHz and 1.0594 at 7.52GHz. In fig. 15 and fig. 16 we can visualize the radiation pattern and the directivity is 5.987dBi and 6.246dBi at 4.9592GHz and at 7.52GHz respectively.

After the square slots were made the above considered antenna parameters are increased. For the square slotted patch antenna, the parameters are as shown below

Figure 15. S parameter at 4.9798GHz

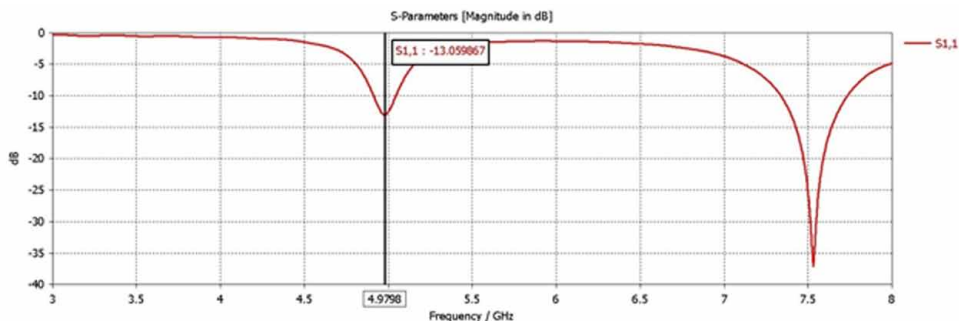


Figure 16. S-parameter at 7.53GHz

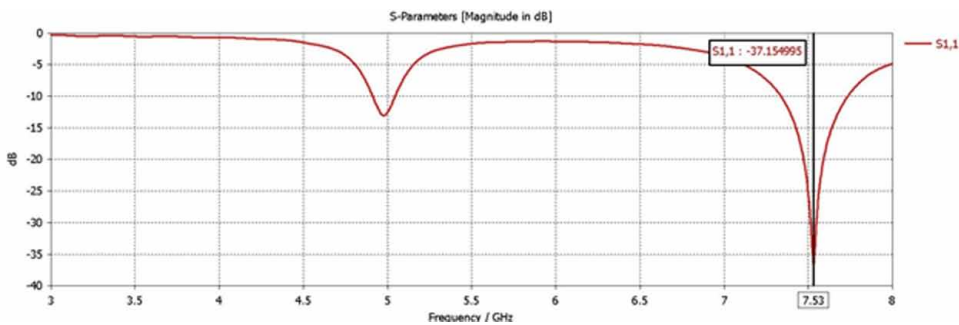


Figure 17. VSWR at 4.9798 GHz

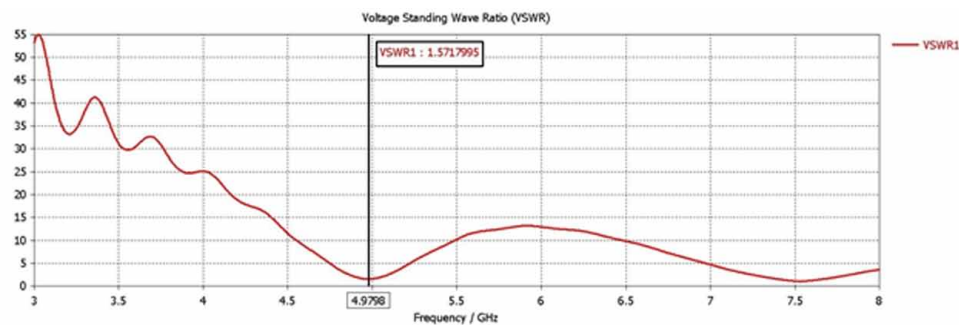


Figure 18. VSWR at 7.53GHz

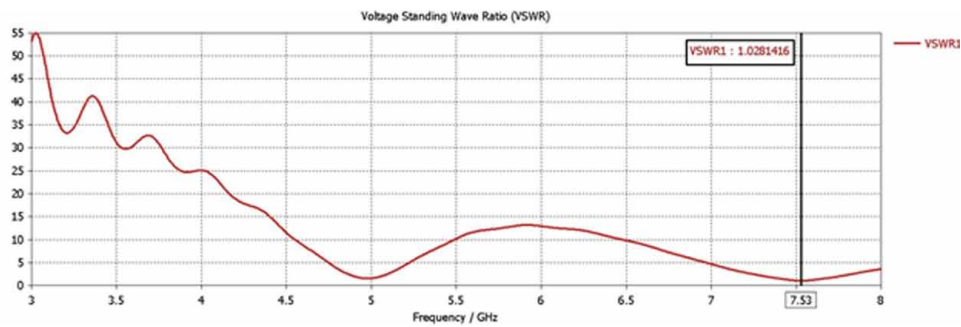


Figure 19. Radiation pattern at 4.96GHz

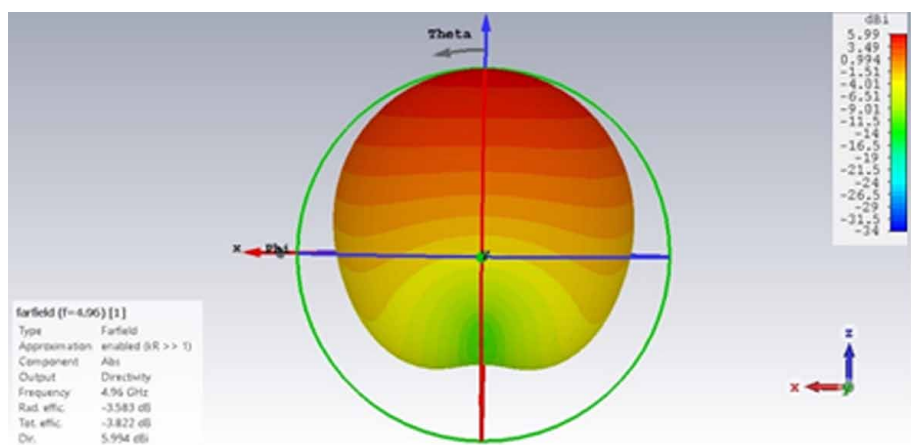
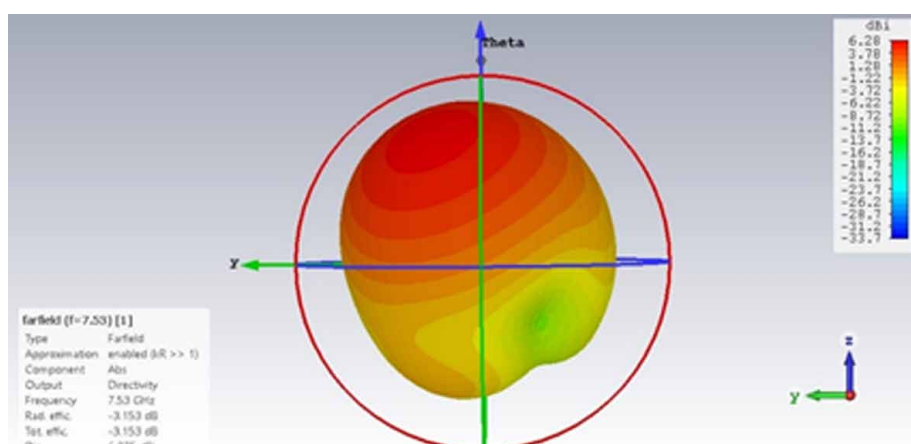


Figure 20. Radiation pattern at 7.53GHz

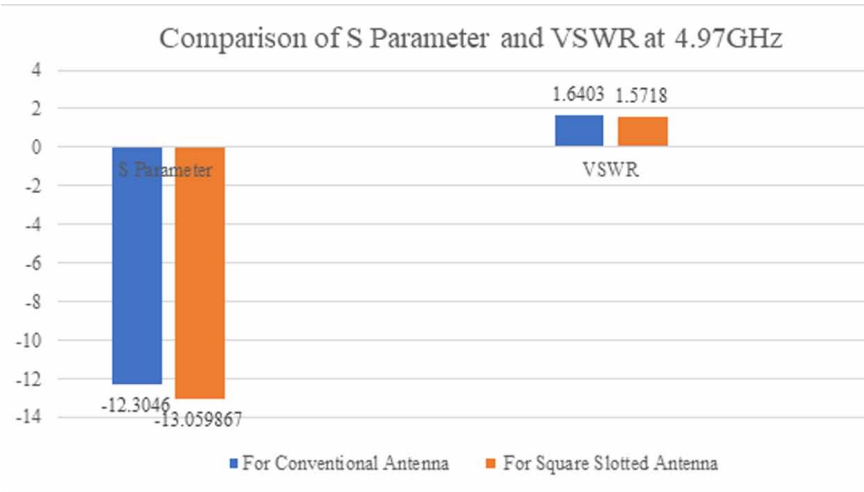


In fig. 15 the scattering characteristic, S Parameter obtained is -13.05987dB at 4.9798GHz and similarly in fig. 16 it is -37.1549dB at 7.53GHz. The VSWR which is a proportion voltage attained around 1.571 and 1.0281 at 4.9798GHz and at 7.53GHz respectively. The radiation pattern can be studied for 4.9798 GHz in fig. 13 and for 7.53GHz in fig. 14. Directivity obtained at these two frequencies are 5.994dBi and 6.275dBi respectively.

A detailed comparison of both the conventional antenna and the square slotted antenna is briefed below by using a bar graph

For 4.97GHz

Figure 21. Comparison of S Parameter and VSWR at 4.97GHz



For 7.53GHz

As shown in graph above we have obtained better antenna parameters when compared to conventional antenna. When compared with the conventional antenna the S Parameter has increased nearly by 1 unit and 7 units for frequencies 4.9798GHz and 7.53GHz respectively. The VSWR is less than 2 which is stated as suitable for antenna applications. And we can observe that there is a very minute increase in the directivity at both the frequencies when compared to the conventional antenna.

Figure 22. Comparison of Directivity at 4.97GHz

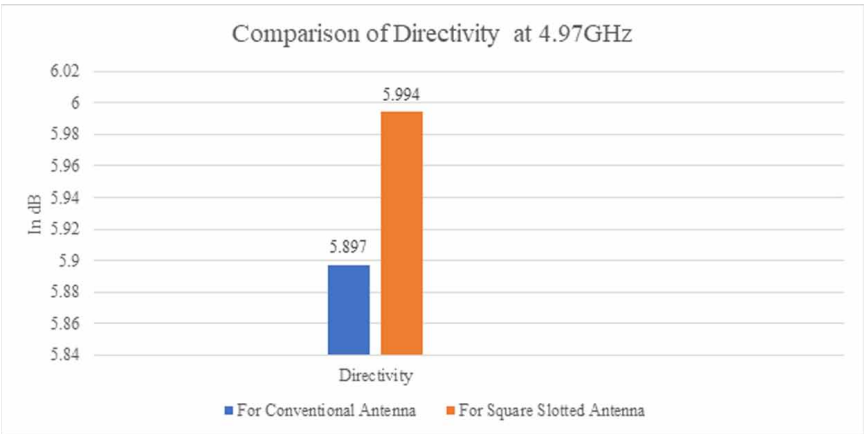
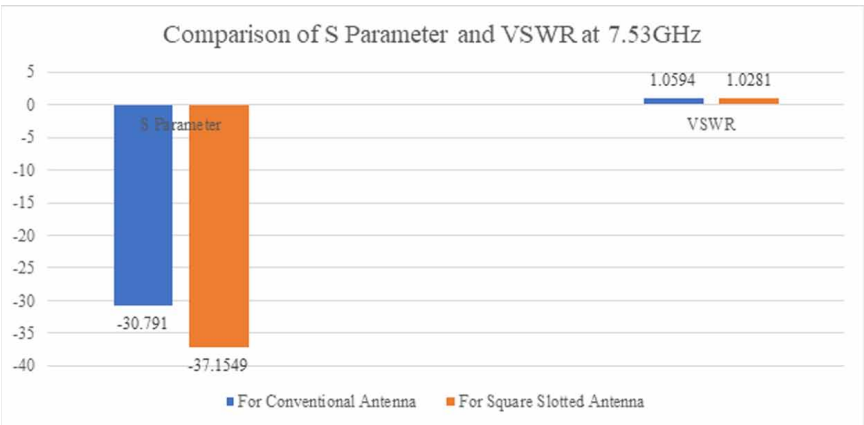


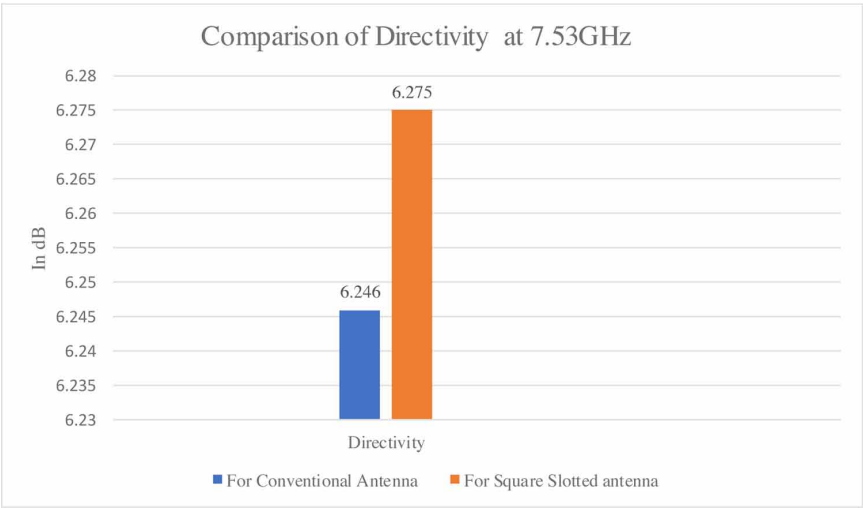
Figure 23. Comparison of S Parameter and VSWR at 7.53GHz



CONCLUSION AND FUTURE SCOPE

A detailed work on antennas for IoT specification is done. Here a patch antenna is configured for 5GHz employing Computer Simulation Software and have obtained dual frequency. By making square slots on the either side of the feedline we can observe that we have obtained better antenna parameters and a good radiation pattern at both the frequencies. Slotting through antennas has reduced the size of the antenna by 12.16% when compared with patch antenna without square slots. Hence the proposed design is also suitable for IoT applications.

Figure 24. Comparison of Directivity at 7.53GHz



Future work includes more unique designs to obtain enhanced parameters. A detailed work can be done regarding obtaining negative permittivity and permeability. There are some designs such as split ring designs and many more which can bring out negative permittivity and permeability.

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Chapter 3

A Wideband Microstrip Patch Antenna for NB–IOT Applications

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ABSTRACT

This chapter presents a basic design of a microstrip patch antenna that will fit the requirement of narrowband internet of things applications. The proposed antenna has a wideband characteristics operational performance with below -20 dB return loss as a requirement. The frictional bandwidth of the proposed antennas is about 26.98%. The proposed antenna can be utilized for GPS applications at 1575 MHz, and the proposed antenna has positive gain at E & H – planes to have good radiation patterns. The performance behavior of the proposed antennas has been analyzed by high frequency structural simulation (HFSS).

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INTRODUCTION

Antennas are the physical devices which makes or establish the communication between two points at particular wavelength based on its operating frequency (Fan et al., 2012; Karthikeyan et al., 2019; Zhuo et al., 2020). Microstrip patch antennas are always offers a simple design that can fulfill the requirement of industries or user at microwave and sub microwave frequency range (Choukiker et al., 2014; Raveendra et al., 2021a). Since the fabrication of such antennas are much easy as well cost effective. Microstrip patch antennas are low profile antennas with low weight (Chou & Ku, 2015; Li et al., 2013).

In this chapter a simple microstrip antenna has been analysed with broadband characteristics. A rectangular slit was introduced on the patch surface to let antenna to resonate at 1700 MHz as center frequency. The FR4 substrate has been used to act as a dielectric material between the patch and ground copper layered sheets. The slot on the patch antenna will provide the electrical discontinuity. From the break position of the patch the electromagnetic wave will start radiate from the antenna in terms of radiations. As well introducing slots will enable the maximum field distributions at the edges or near the slot walls (Li et al., 2013; Raveendra et al., 2021b). In this design a microstrip feedline has been used to provide the input power.

PROPOSED ANTENNA DESIGN

This antenna is designed at 1730 MHz for the narrow band internet of things applications. To resonate any antenna the important is the length and width dimensions of the modeling antenna. In this chapter the dimensions of the antenna is 37mm x 19.78mm x 1.6 mm. The dielectric constant of the proposed antenna is 4.4 (FR4 material). The proposed antennas have been shown in Figure 1 and its detailed dimensions are listed in Table 1.

Figure 1. The proposed simulated antennas for NB-IoT applications.

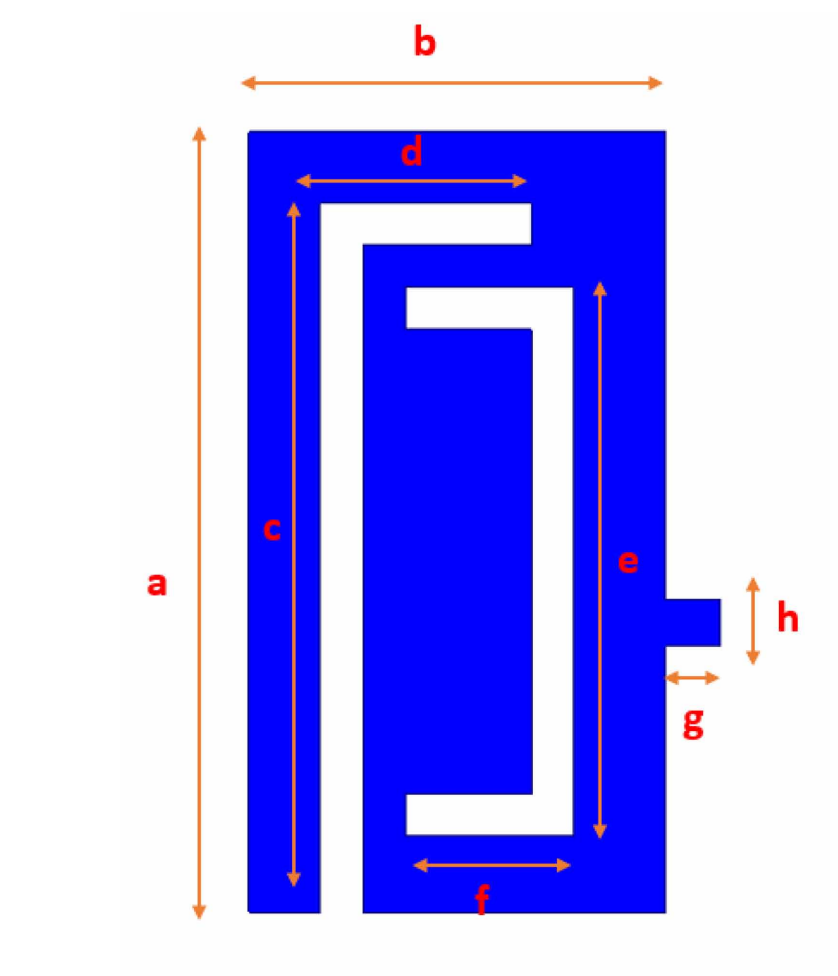


Table 1. The list of variables that are used in antennas dimensions

Particular	a	b	c	d	e	f	g	h
Dimensions (mm)	37	19.78	36	10	24	8	2.2	1.6

RESULTS AND DISCUSSIONS

From the simulation results it has been noted that the proposed antenna has been resonance from 1436.10 MHz to 1903.00 MHz. the proposed antennas have wideband characteristics with below -20 dB as return loss. The resonance frequency of the proposed antenna is 1730 MHz with -20.8822 dB as corresponding return loss. Hence the proposed antenna can transmit 99.19% of the power, from this analysis, the proposed antenna having the ability to fulfill the requirement of narrowband internet of things application at 1730 MHz to 1830 MHz. The return loss performance of the

Table 2. The statistical performance of the proposed antenna.

S.No	Performance	Performance value
1	Antenna dimensions (mm)	37 x 19.78 x 1.6
2	Operational frequency (MHz)	1436.10 - 1903.00
3	Resonating frequency (MHz)	1730
4	Return loss (dB) at center frequency	< -20.
5	Frictional bandwidth	26.98%
6	Maximum E-Plane magnitude (dB)	0.1219
7	Maximum H-Plane magnitude (dB)	0.1311

Figure 2. The S11 performance of the proposed antenna.

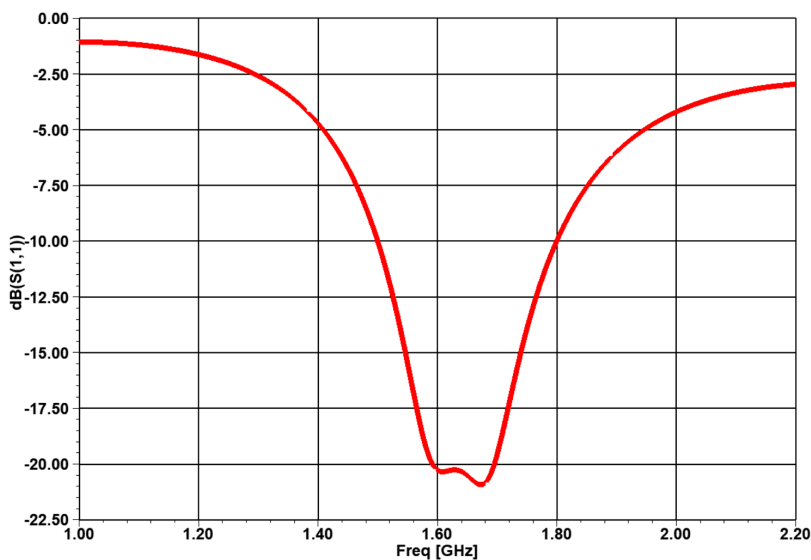


Figure 3. The radiation pattern at E and H- planes at 1730 MHz.

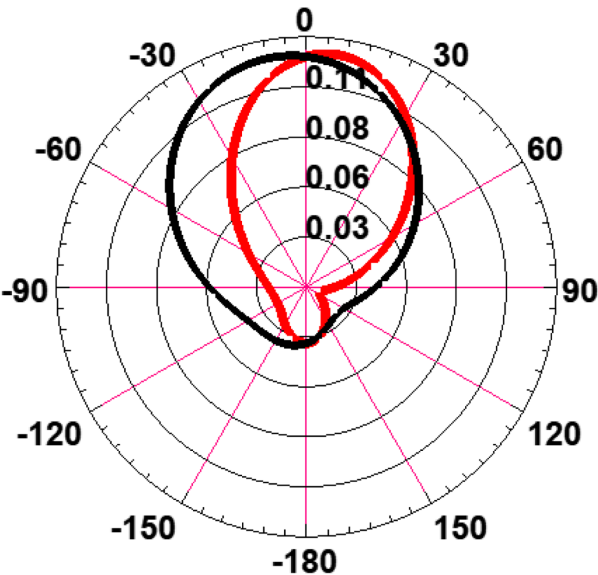


Figure 4. H Field configuration of the proposed antenna at 1730 MHz

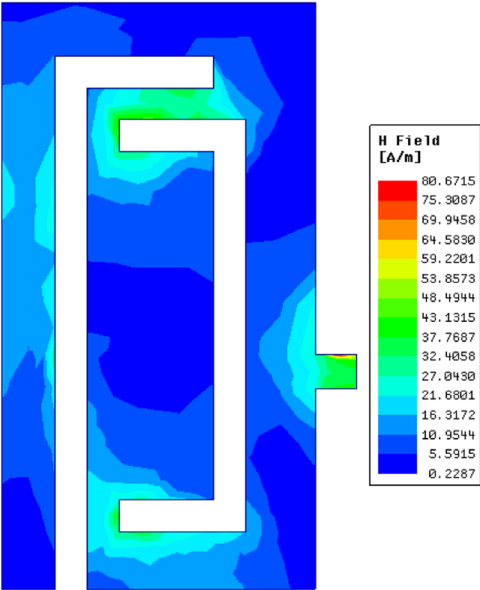


Figure 5. E Filed configuration of the Proposed Antenna at 1730 MHz.

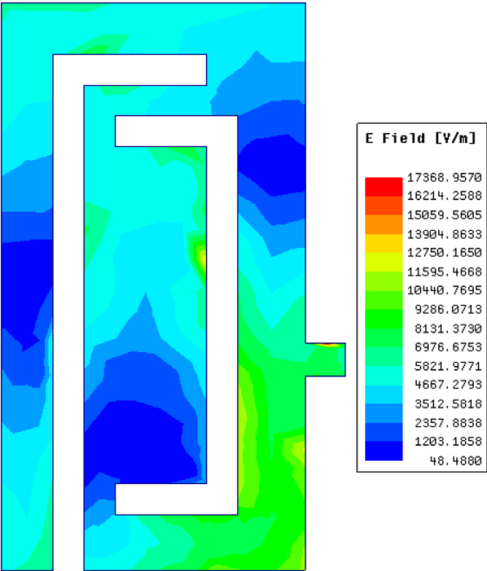
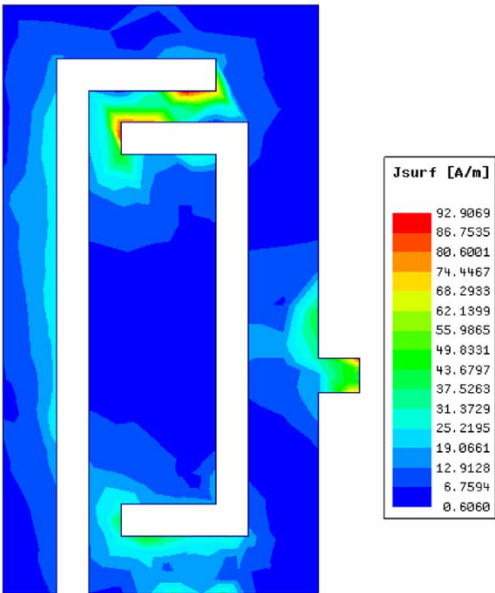


Figure 6. J Field configuration of the proposed antenna at 1730 MHz.



antenna has been shown in Figure 2. The designed antennas has also investigated its radiation properties at E and H – panes and found that maximum magnitude at the both planes listed in Table 2 and its behavior response has been shown in Figure 3. After making slot on the patch surface the maximum current density has been achieved at the side or edges of the slot region as shown in Figure 4.

CONCLUSION

A slot microstrip based patch antenna has been analyzed at 1730 MHz for narrow band internet of things applications with wideband features about 26.98% frictional bandwidth. Multi-rectangular slits were introduced on the patch surface for obtaining maximum J-field. The proposed antenna will transmit above 99% of power at 1730 MHz. the proposed antenna also can be used for global position system (GPS) applications. The radiation patterns have been explained in E and H planes.

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Chapter 4

Design and Analysis of a Tunable Rectangular Microstrip Slot Antenna for Narrow Band Internet of Things Applications at 1800 MHz

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ABSTRACT

This chapter presents a tunable rectangular slot antenna on a Rogers RT/duroid 5880 (tm) substrate for narrowband internet of things applications. The proposed antenna has an operating frequency from 1601.20 MHz to 2051.90 MHz (tunable operating frequency range). The resonant frequency can be tuned by adjusting the length of the antenna as the application requirement. At each tuning step, the

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proposed antenna has sufficient bandwidth to fulfil the requirement of narrow band internet of things. The amount of power transmitting from the proposed antenna has been investigated at different aspects of the antenna. The proposed antenna has the ability to transmit above 99% at resonating frequency. All the analysis of the proposed antenna has been carried out in high frequency structural simulation. For the performance validation of the proposed antenna, it has been simulated in FEKO tool and its return loss behavior has been compared with HFSS results.

INTRODUCTION

The Narrow band Internet of Things (NBIOT) antenna has becoming a famous technology in making things automation as well as for the smart industries. Mainly the available operating frequency for NBIOT applications are from 825 MHz to 960 MHz (at lower band) and 1725 MHz to 1860 MHz (higher band). As per antenna theory for making antennas at low frequency required really high dimensional geometries. Hence in this chapter to propose the antenna for the higher band operating frequency of NBIOT (1725 MHz to 1860 MHz) has consider into account.

The fundamental idea of this chapter is to design and analysis of a simple antenna at less in the dimensions than (Zhuo et al., 2020) to satisfy the application requirements in the field of narrow band internet of things applications. In the literature many antennas has been proposed to achieve the narrow band application by using different shapes of slots on the patch surface to resonate antenna at desired frequency band such as U-shaped, G-shaped, P-shaped. But in this research a rectangular slot were introduced on the patch surface to make antenna to resonate at within the operating frequency band i.e 1725 MHz-1860 MHz. the significant difference of the proposed antenna with the literature is that the size of the antenna has been reduced 45.88% than (Zhuo et al., 2020). But (Zhuo et al., 2020) has the dual band operating frequency performance.

Many methods are available in the literature (Chou & Ku, 2015; Choukiker et al., 2014; Fan et al., 2012) to adopt a technique to create input feeding to the antennas such as coaxial line, microstrip line. In the proposed antenna a rectangular microstrip line has been used as a feeding method to provide the input power to the mounted antenna. Since the position of the antenna can be change easily in according to match or deal with impedance matching (Li et al., 2013; Li et al., 2016; Pan et al., 2005). As well changing of the feeding position is much simpler than the designing a co-axial probe feeding.

Later a tuning approach has been analysed based on the length of the patch and investigated its bandwidth and amount of transmitting power (%) under different lengths of the provided antenna. Later the influence of the slot on the patch surface

has been investigated under different length and width of the slot structure to obtain a maximum power transmitting from the provided antenna patch. The provided observations are mainly focused on the power transmission improvement. As well the proposed antenna has positive magnitude gain at E-plane and H-plane.

The remaining of this chapter as follows as in section II. Design of the Proposed Antenna. III. Results and Discussions and IV. Conclusions.

Proposed Antenna Design

Initially a Rogers RT/duroid 5880 (tm) substrate has been created with length and width as 60 mm x 30 mm. The maintained height of the substrate is h. later with the same dimensions the ground has been created at the bottom of the dielectric material. Now, the perfect electric (PerE) conductor sheet has been patched as shown in Fig. 1. The all dimensions of the proposed antenna has been listed in Table. 1. The width and length of the patch has derived from the equation (1) and equation (3). Where equation (2) provides the effective dielectric for a chosen dielectric constant 2.2 and loss tangent 0.0009.

$$b1 = \frac{c}{2f_0 \sqrt{\frac{(\epsilon_r + 1)}{2}}} \text{ mm} \quad (1)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \left[\frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{b1} \right]^{-\frac{1}{2}} \right] \quad (2)$$

$$L_{eff} = \frac{c}{2f_0 \sqrt{\epsilon_{eff}}} \text{ mm}$$

Where, $\epsilon_r = 2.2$, h= height of the dielectric substrate.

C = velocity of light = 3×10^8 m/sec.

b1= width of the antenna

L_{eff} = Effective length of the anticipated antenna

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{b1}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{b1}{h} + 0.8 \right)}$$
$$a = L_{eff} - 2\Delta L \text{ mm} \tag{3}$$

Figure 1. The created antenna design on high frequency structural simulation.

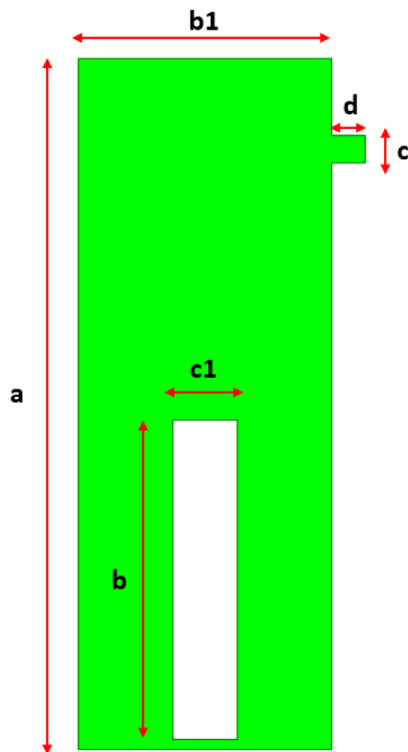


Table 1. The detailed dimensions of the proposed antenna (h = heigh of the dielectric medium).

S. No	1	2	3	3	4	5	6
Geometry	a	b	b1	c	c1	d	h
Values (mm)	53.98	25	19.78	2.17909	5	6.7	1.5748

RESULTS AND DISCUSSIONS

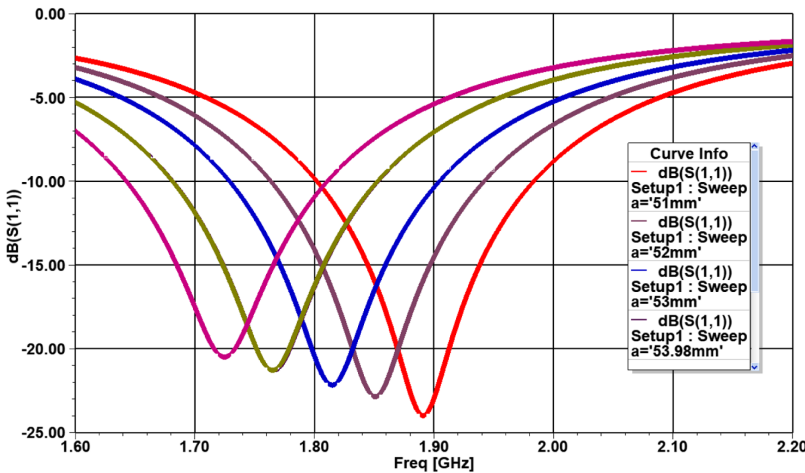
After simulating the antenna in HFSS EM- simulator the performance of the antenna has been explained with help of return loss characteristics. Initially there is no resonating frequency from the antenna S11 plot due to poor impedance matching . Later by adjusting the position of the feed line with lumped port the resonance frequency has been obtained at under the desired frequency band to bring the resonant frequency to required frequency band (1725 MHz-1860 MHz). Initially the length of the antenna has been set to 53.98 mm and found the resonant frequency of the antenna as 1772.40 MHz with its corresponding return loss is -21.5080 dB. To calculate the upper and lower frequencies at the cut off value of s11= -6 dB was considered. Since as per equation (4) the return loss at -6 dB, antenna can transmit 75% of the power in terms of radiations.

$$\text{Transmitted power} = (1 - |\Gamma|^2) \times 100 \quad (4)$$

Γ = Reflection coefficient

Similarly, to observe the performance of the antenna when a = 51 mm, 52 mm, 53 mm, 53.98 mm, 55 mm has been simulated, its performance values has been given in Table. 2 and its response has been shown in Fig.2. The bandwidth is calculated using equation (5).

Figure 2. The simulation response of the antenna under different values of 'a' in mm.



$$\text{Bandwidth} = (f_u - f_l) \text{ MHz} \quad (5)$$

f_u = upper cut off frequency

f_l = lower cut off frequency

The shift in resonating frequency can be calculated using the below formula (6)

$$\text{shift in resonating frequency} = f_0 - f_i \quad (6)$$

Where $i = 0, 1, 2, 3, 4$.

Table 2. The performance of the proposed antenna under different length (a) of the patch.

s.no	a [mm]	Resonance frequency [MHz] f_i	S11 [dB]	Bandwidth [MHz] ($f_u - f_l$)	Transmitting power (%)	Shift in resonating frequency [MHz]
1	51	1891.60	-23.9659	2051.90-1740.80=311.10	99.6031	0
2	52	1850.90	-22.8485	2013-1699.20=313.90	99.4816	40.70
3	53	1816.40	-22.1358	1974.30-1666.40=307.90	99.3916	75.20
4	53.98	1772.40	-21.5080	1924.40-1624.70=299.7	99.2944	119.20
5	54	1725.60	-20.4823	1876.00-1601.20=274	99.0975	166

$f_0 = 1891.60$ MHz., The shift in resonating frequency of the designed antenna has been given in Fig.6.

From the Fig. 3 & 4 we could see the effect of the length (a) of a patch on resonant frequency and its corresponding S11 performance. The relation between the length of the patch and its resonance frequency are inversely proportional to each other. Where the length of the patch has increased the resonating frequency is decreasing and its return loss performance is degrading as well. Even though at each individual point of length (a) the return loss performance is under below -20 dB. The available bandwidth of the proposed antenna has been shown in fig.5.

Figure 3. The relation between the resonating frequency vrs length of the patch.

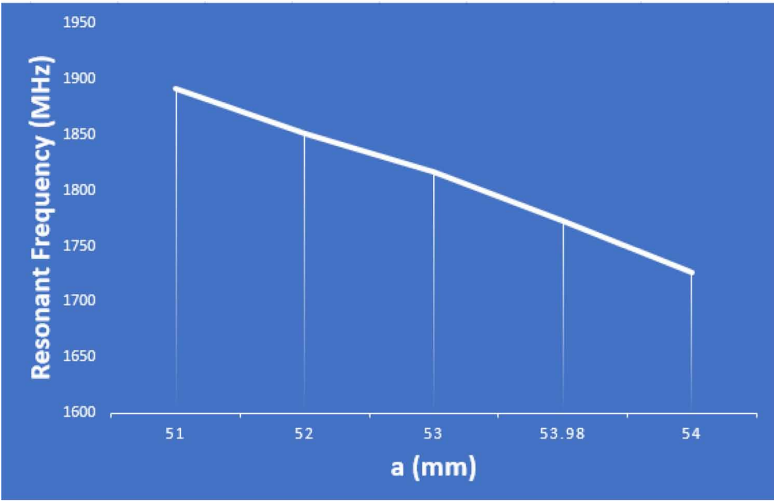
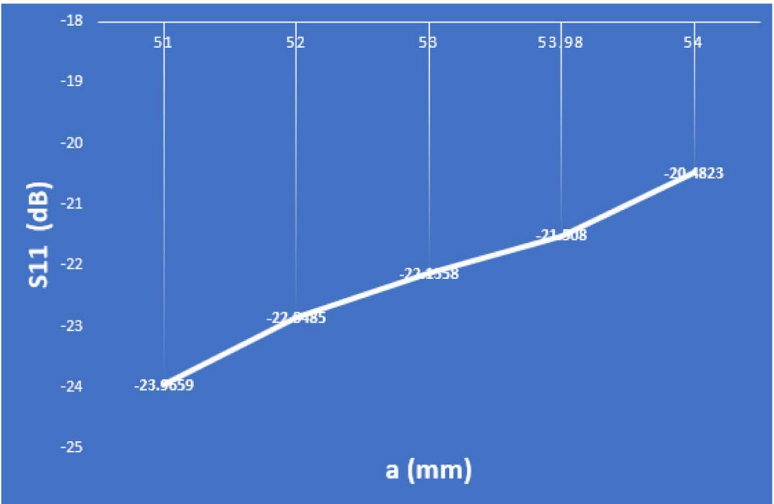


Figure 4. The relation between return loss vs. length of the patch (a).



The maximum bandwidth has been achieved at when the patch length $a=52$ mm. The required bandwidth for the narrowband application is just 145 MHz (1860 MHz-760 MHz) even the proposed antenna has more than sufficient bandwidth with stable and reliable power transmitting capabilities.

Figure 5. The obtained bandwidth of the proposed antenna with respect to the length of the patch (a).

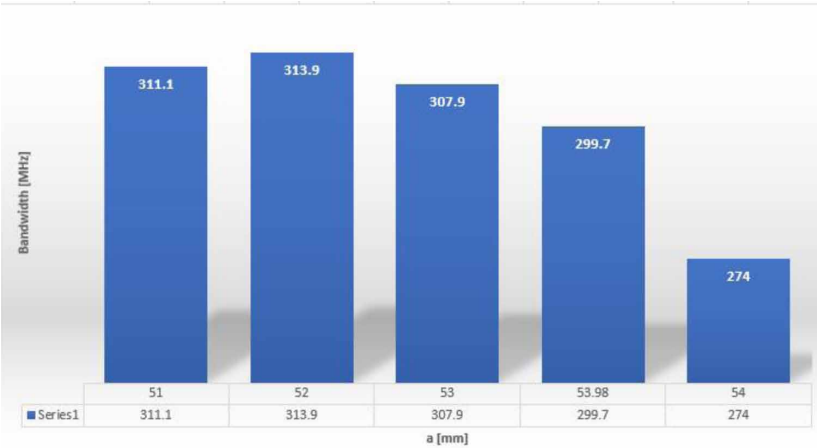


Table 3. The statistical values of the E-plane and H-plane of the proposed antenna.

S.no	Theta (degrees)	Magnitude E-plane	Magnitude H-plane
1	50	4.9293 dB	-
2	344	-	4.3126 dB

Figure 6. The shift in resonance frequency with respect to the length of the patch (a).

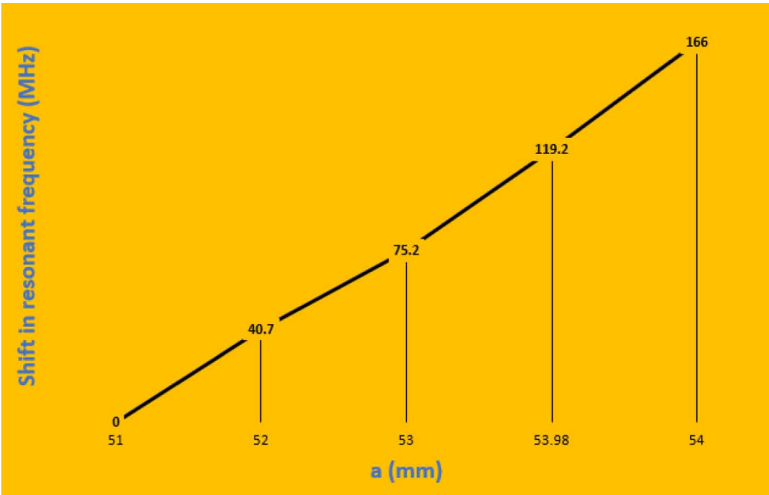
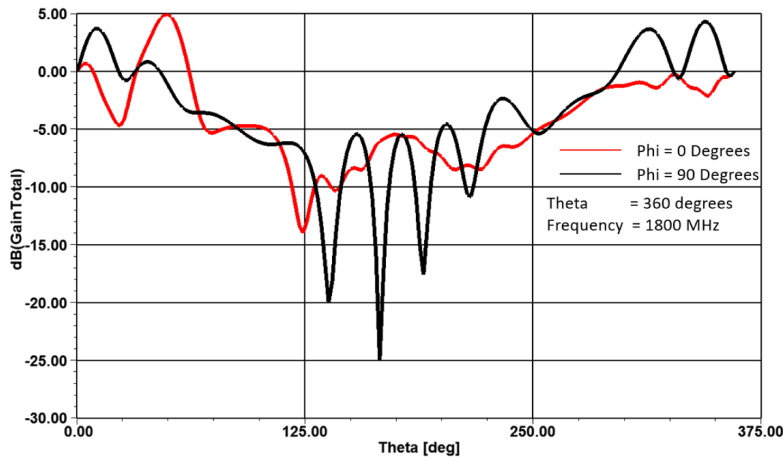


Figure 7. The E- plane and H-plane of the proposed antenna.



The gain of the E- plane and H-plane of the proposed antenna has been shown in Fig. 6. The E-plane was plotted in red colour over theta= 360 degrees with phi=0 degree. The maximum magnitude of the gain values has been noted as 4.9293 dB at theta=55 degrees. As well as the H-plane was plotted in black color over theta= 360 degrees with phi=90 degree. The maximum magnitude of the gain values has been noted as 4.3126 dB at theta=344 degrees. And its statistical values have been given in the Table. 3.

INFLUENCE OF SLOT ON THE PATCH SURFACE

A rectangular slot has been introduced on the patch region with length 'b' and width 'c1'. From the Fig. 8 show the return loss performance when there is no slot on the patch surface. From Table. 4 we could see that under the influence of the slot on patch the proposed antenna having 99.6031% of power transmitting ability as maximum. In case of no slit on the patch surface we have 99.4671% as the maximum transmitting power ability. In Table. 4 it has been compared the proposed antenna with and without slot. And based its power transmitting abilities at in these two conditions the major significance has been shown in Fig. 9.

Later, to investigate about the influence of the length and width of the slot, the proposed antenna has been simulated under the different dimensions of the slot width and length. And noted its power transmitting performance values at each case for listing in Table.5 and plotted in Fig. 10. Fig. 11 show the influence of length of the slot (b) on amount of power transmitting performance. Fig.12 shown the influence

Figure 8. The return loss performance of the antenna without slot on the patch surface.

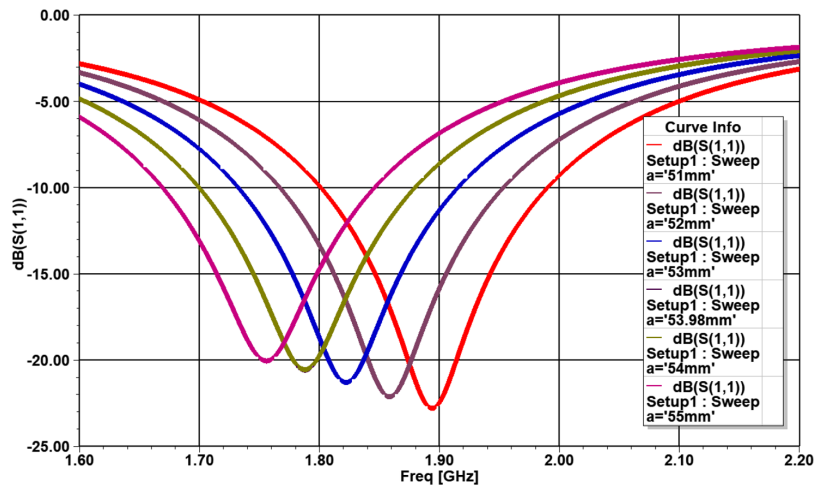


Table 4. The comparison antenna transmitting power ability at with and without slot on the proposed antenna.

S.no	a (mm)	Transmitting power (%)	
		With slot	Without slot
1	51	99.6031	99.4671
2	52	99.4816	99.3759
3	53	99.3916	99.2604
4	53.98	99.2944	99.1351
5	54	99.2944	99.1351
6	55	99.0975	99.000

Table 5. The statistical influence of the slot length (b) on return loss performance.

S.no	Transmitting power (%) At a = 53.98 mm	
	b (mm)	Transmitting power
1	21	99.3916
2	22	99.3276
3	23	99.3110
4	24	99.2775
5	25	99.2604
6	26	99.2404

Figure 9. The power transmitting capability of the proposed antenna at with and without slot on the patch surface.

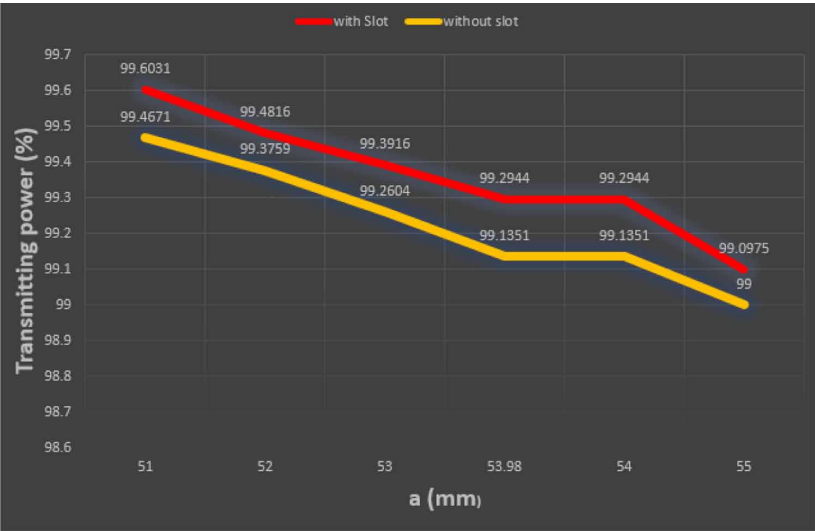
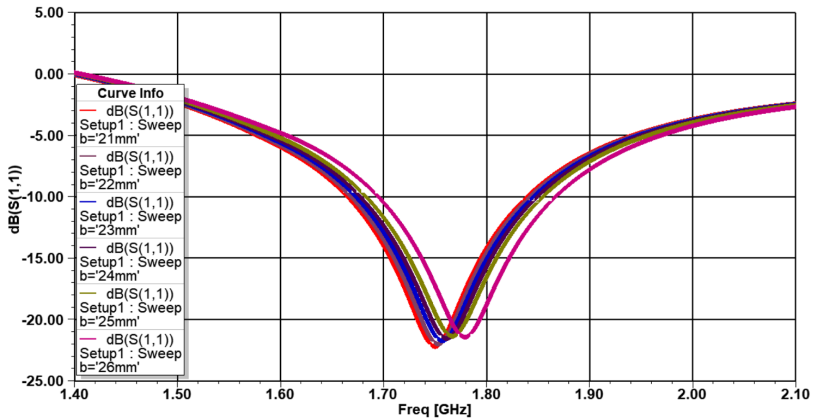


Figure 10. The influence of the slot length (b) on return loss performance.



of the slot width (c1) on return loss performance. In Table. 6 the statistical influence of the slot length (c1) on return loss performance. Fig.13 given the influence of the slot length (c1) on amount of power transmitting performance.

For the performance justifications the proposed antenna has been simulated using HFSS (High Frequency Structural Simulation) and FEKO simulation tool and found almost same response in their performance responses shown in Fig. 14.

Figure 11. The influence of the slot length (*b*) on amount of power transmitting performance.

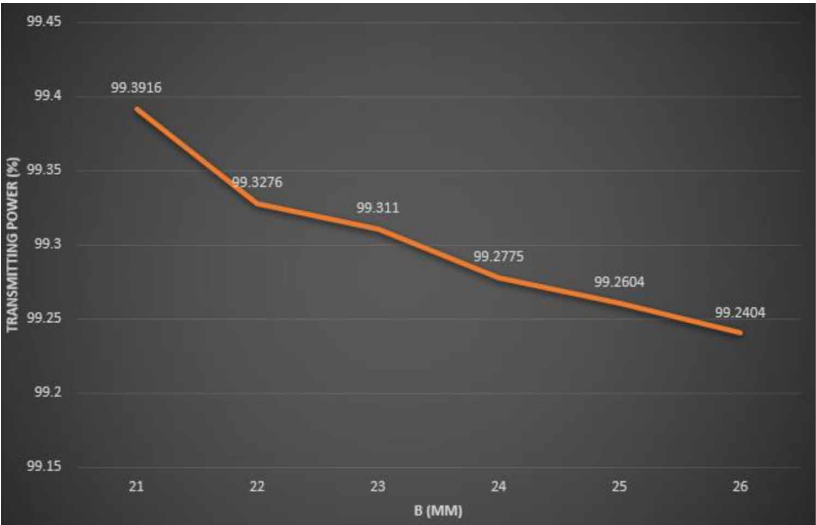
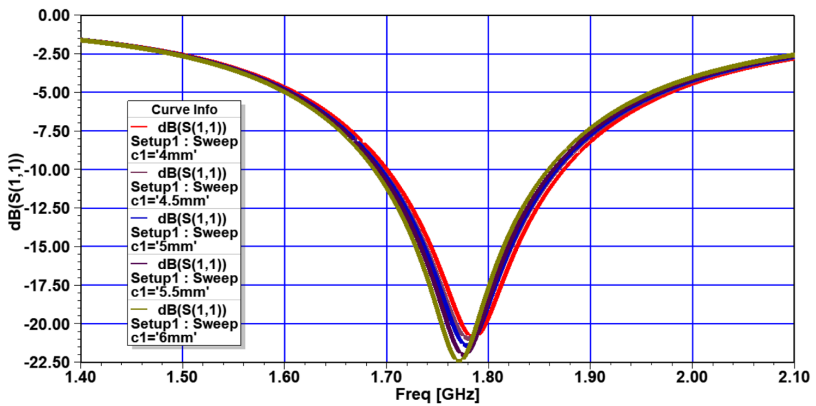


Figure 12. The influence of the slot width (*c1*) on return loss performance.



Design and Analysis of a Tunable Rectangular Microstrip Slot Antenna for Narrow Band IoT

Table. 6. The statistical influence of the slot length (c1) on return loss performance.

S.no	Transmitting power (%) At a = 53.98 mm ; b=25 mm	
	c1 (mm)	Transmitting power (%)
1	4	99.1536
2	4.5	99.1719
3	5	99.2775
4	5.5	99.3439
5	6	99.4224

Figure 13. The influence of the slot length (c1) on amount of power transmitting performance.

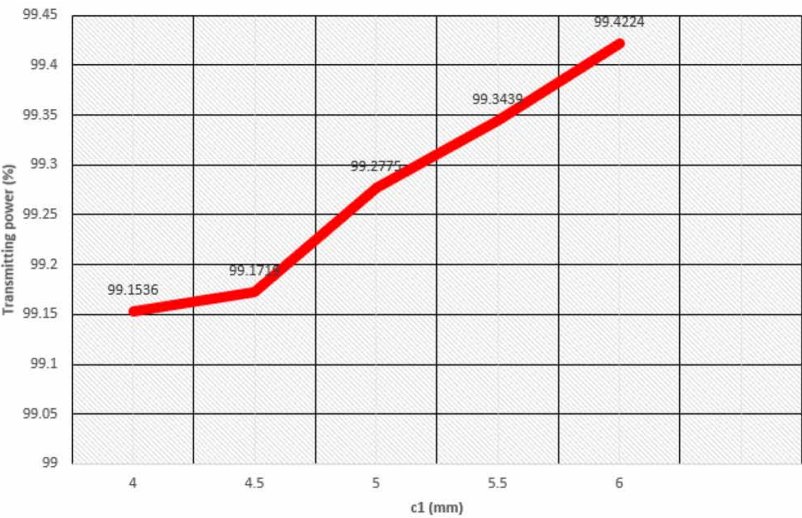
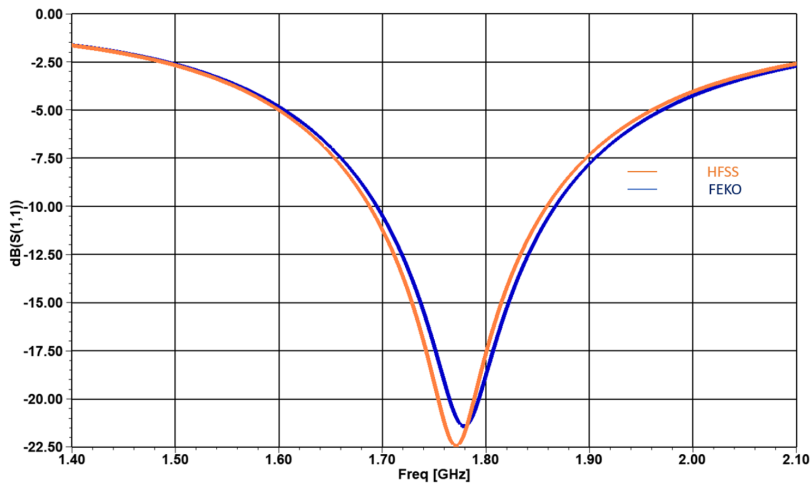


Figure 14. Return loss comparison between the HFSS and FEKO simulation software's.



CONCLUSION AND FUTURE RESEARCH DIRECTIONS

A simple rectangular slot antenna has been proposed for narrow band internet of things applications at 1725 MHz- 1825 MHz for tuning of the proposed antenna the length of the antenna has been adjusted. The amount of power radiating from the antenna has been investigated under the different conditions of the slots and patch dimensions. In this chapter the gain was found only at patch length is 53.98 mm and slot width 5 and slot length 25 mm. As well it has been noted that the antenna has maximum power transmitting ability when the rectangular slot is present on the patch surface. in the future study the gain performance of the proposed antenna can be studied more in detail at different conditions of the antenna dimensions. Here only one rectangular slot has been introduced to get more transmitting radiation power. In the future different types of slots can be implemented for improve and must better understanding of the antennas especially for narrow band applications.

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Chapter 5

Design and Implementation of a Low-Profile Patch Antenna for Industrial NB-IOT Applications

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ABSTRACT

For the requirement of NB-IOT applications, rectangular micro strip slot antennas have been developed with sufficient bandwidth of 112.5 MHz. The above 50% size of the antennas has been reduced by making multiple rectangular slots on the patch surface. Fr4 material has been utilized as a dielectric substrate. The position of the transmission line has been varied to match the perfect impedance matching.

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The proposed antenna model has been simulated on HFSS software. To check the practical behavior of the designed antenna, it has been fabricated and tested by using vector network analyzer. The proposed antenna has resonance frequency band from 1718.75 MHz – 1831.25 MHz with minimum return loss performance as below -20 dB.

INTRODUCTION

The technology, Narrowband Internet of Things (NB-IOT) becoming famous to full fill the requirement of smart industries, automation sector, smart intelligence and remote sensing domains. Hence the demand of antennas is becoming increasing to operate at different frequency bands of NB-IOT such as 1710 MHz to 1780 MHz, 824 MHz to 849 MHz and 880 MHz to 915 MHz. In this work, a micro strip patch antenna with multiple slots on patch has been proposed to resonate at frequency band 1718 MHz – 1831 MHz.

In recent time many researchers proposed different types antenna prototypes for the requirement of NB-IOT applications. The main problem is facing by researches is size of the antennas. In (Zhuo et al., 2020) the authors achieved dual band characteristics by introducing U – shaped slot on the patch surface but the dimensions of the antennas length and width is 85 mm x 85 mm. in this work, rectangular slots were introduced to reduce the size of the antenna about 52% than (Zhuo et al., 2020). For real time applications of NB-IOT, the significant challenge is to reduce the size of the antenna.

Many antennas such as array antennas substrate integrated waveguide antennas can fulfill the performance requirements of NB-IOT applications. But designing such antennas at 1.755 GHz required higher dimensions. As well design and fabrication of those antennas are much complex. By changing the position of the transmission line, we can easily match the impedance requirement in micro strip antennas (Li et al., 2013; Li et al., 2016; Pan et al., 2005). Micro strip antennas also offer low profile properties at microwave frequencies. Micro strip antennas are simpler for designing (Chen et al., 2017) at any simulation tool with narrow band characteristics (Li et al., 2013). Adjustment of slot on the patch surface will make antenna to resonate at desired frequency.

For design of substrate FR4 material has been considered with dielectric constant 4.4. Since the material FR4 is relatively cheaper than other dielectric materials (Chair et al., 2005).

PROPOSED ANTENNA DESIGN

The goal of this work is to design a simple and compact microstrip patch antenna at NB-IOT operating frequency band. The theoretical geometry calculations of the proposed antennas as follows below derivation. The width of the antenna can be calculated from equation (1). Later by substituting the height of the substrate 1.6 mm in equation (2), effective dielectric constant has been found to obtain the length of the antenna from the equation (3).

$$f_0 = 1755 \text{ MHz}$$

$$\text{Dielectric constant} = 4.4$$

$$f_0 = \text{Resonant frequency}$$

Width calculation

$$W = \frac{c}{2f_0 \sqrt{\frac{(\epsilon_r + 1)}{2}}} \text{ mm} \quad (1)$$

$$W = \frac{3 \times 10^8}{2(1755 \times 10^6) \sqrt{\frac{4.4 + 1}{2}}} \text{ mm}$$

$$W = 51.89 \text{ mm}$$

Calculation of the Effective Dielectric Constant

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \left[\frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-\frac{1}{2}} \right] \quad (2)$$

Let height of the dielectric medium $h = 1.6 \text{ mm}$.

$$\epsilon_{eff} = \left(\frac{4.4 + 1}{2} \right) + \left[\left(\frac{4.4 - 1}{2} \right) / \sqrt{\left(1 + 12 \frac{1.6}{51.89} \right)} \right]$$

$$\varepsilon_{eff} = \left(\frac{5.4}{2} \right) + \left(\frac{3.4}{2} \right) (1.090547)$$

$$\varepsilon_{eff} = 2.7 + (1.7 \times 1.090547)$$

$$\varepsilon_{eff} = 4.152$$

Calculation of effective length:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \text{ mm}$$

$$L_{eff} = \frac{3 \times 10^8}{2 \times 1755 \times 10^6 \times \sqrt{4.152}} \text{ mm}$$

$$L_{eff} = 41.9455 \text{ mm}$$

Calculation of length extension:

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\varepsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \text{ mm} \quad (3)$$

$$\Delta L = \frac{0.412 \times 1.6 (4.152 + 0.3) \left(\frac{51.89}{1.6} + 0.264 \right)}{(4.152 - 0.258) \left(\frac{51.89}{1.6} + 0.8 \right)} \text{ mm}$$

$$\Delta L = \frac{85.9526}{129.402} \text{ mm}$$

$$\Delta L = 0.74150 \text{ mm}$$

Calculation of actual length of the patch

$$L = L_{eff} - 2\Delta L \text{ mm} \quad (5)$$

$$L = 41.9455 - 2(0.74150) \text{ mm}$$

$$L = 40.46 \text{ mm}$$

Now, the theoretical dimensions of the desired antennas have been found as 51.89 mm x 40.46 x 1.6 mm. but by making the slots on the patch surface the geometry of the antennas has been reduced to 35.89 mm x 19.78 mm. Later, a transmission line with length 1.6 mm and width 2 mm has connected to provide the input power to the antenna. A 50 Ω input impedance has been assigned by using lumped port excitation. The ground has been made with dimensions 40 mm x 25 mm at the bottom of the dielectric medium. After assigning the boundary conditions the model has been simulated for 1755 MHz as center frequency in High Frequency Structural Simulation (HFSS) as shown in Fig. 1.

Figure 1. Proposed antenna for NB-IOT applications.

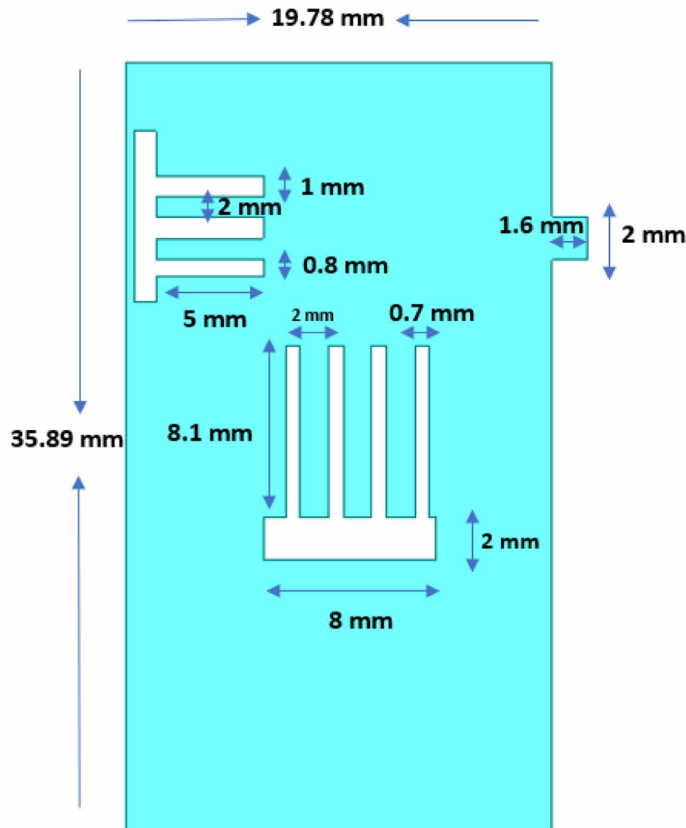
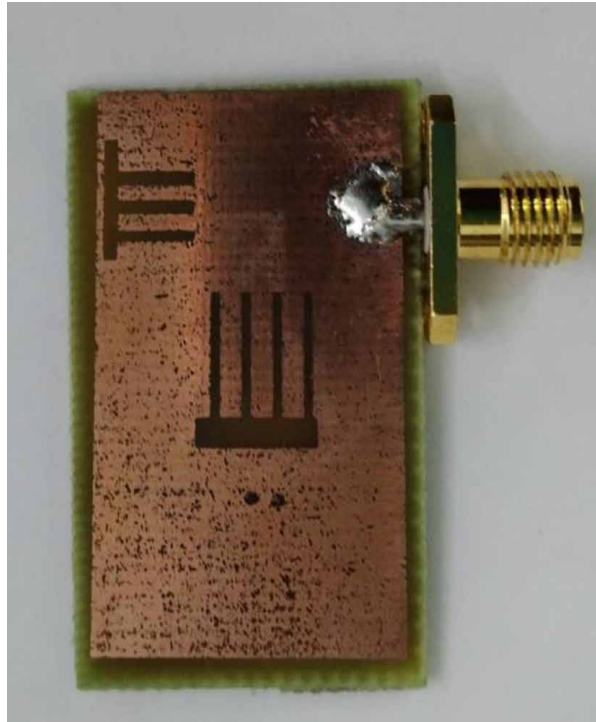


Figure 2. Fabricated antenna for NB-IOT applications.



The detailed dimensions of the proposed antenna have been shown in Fig. 1. Later, the antenna has been fabricated (revealed in Fig. 1.) as per the requirement and tested using vector analyzer to compare the simulation and practical results of the proposed antenna.

RESULTS

After measurement of fabricated antenna, the simulation results of the antenna have good agreement of practical results. Initially the positions of the transmission line have been changed to match the input impedance with load impedance. The input feed at different positions has shown in Fig. 2. And its return loss performances have been shown at Fig. 3.

From the return loss performance of the proposed structure, the S_{11} performance has been increased when the feeding position is moving upwards due to the perfect impedance patching shown in Fig.4. The better results have been found at design (d). It is also observed that the antenna is offering multiband performance when feed is

locating at $(x, y, z) = (10 \text{ mm}, 18.30 \text{ mm}, 1.6 \text{ mm})$. And the return loss performance is much better about below -20 dB at this position. Hence the design (d) has been considered for further implementation of the antenna fabrication process. The performance statistics of the proposed antenna has been listed in Table .1.

Figure 3. The feeding configuration of the proposed antenna at different positions.

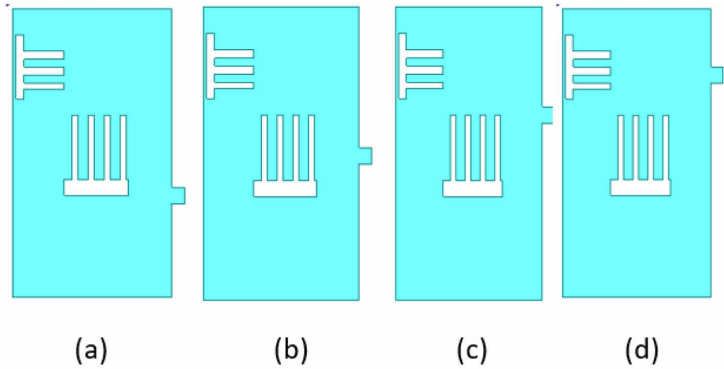


Figure 4. The return loss performance of the proposed antenna at different positions of feeding structure.

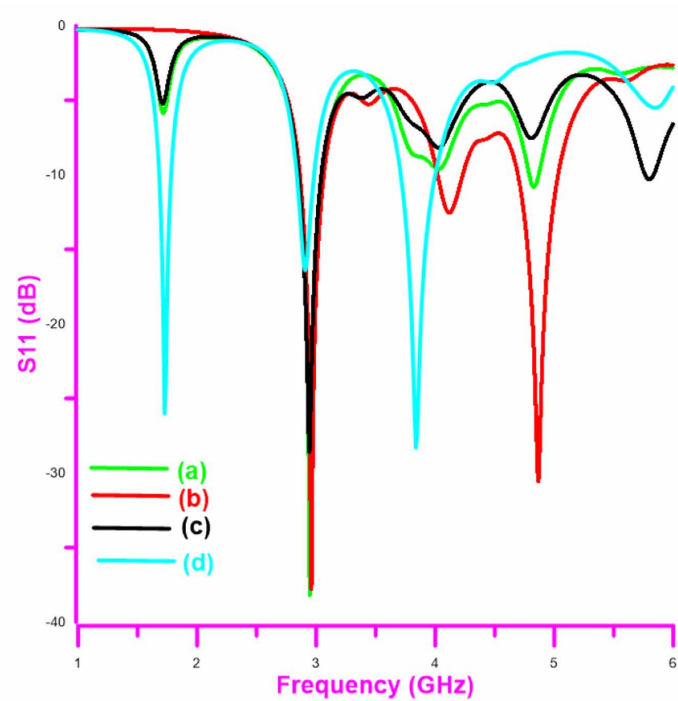
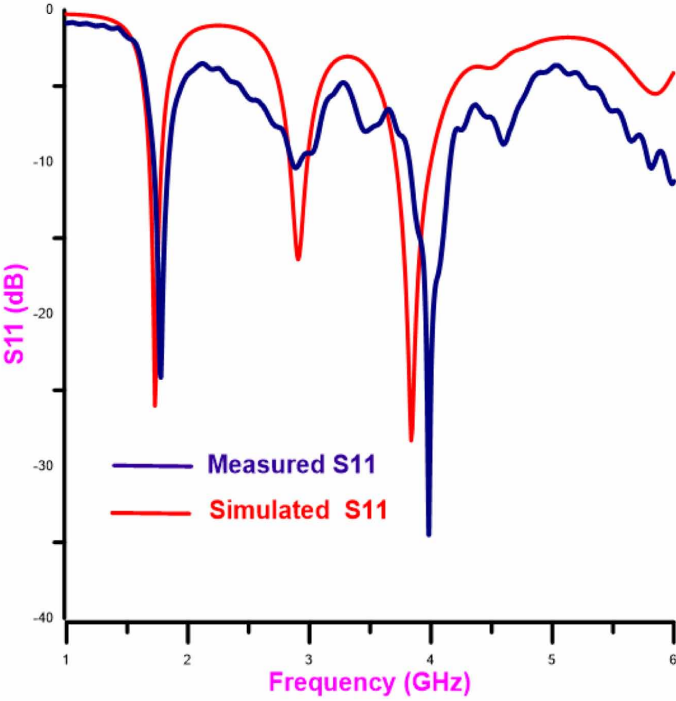


Table 1. The simulation performance statistics of the proposed antenna.

S. No	Design model	Feeding position (x, y, z) mm	Return loss at 1730 MHz (dB)
1	(a)	(25,18.30,1.6)	-5.8478
2	(b)	(20,18.30,1.6)	-0.3066
3	(c)	(15,18.30,1.6)	-5.1601
4	(d)	(10,18.30,1.6)	-26.9234

Figure 5. Measured S11 of the proposed antenna.



Calculation of Reflected power %:

$$\text{Reflected power}\% = \left(\frac{\text{VSWR} - 1}{\text{VSWR} + 1} \right)^2 \times 100$$

$$\text{Reflected power}\% = \left(\frac{1.117 - 1}{1.117 + 1} \right)^2 \times 100$$

$$\text{Reflected power } \% = 0.3054\%$$

Calculation of Transmitted power:

$$\text{Transmitted power} = (1 - |\Gamma|^2) \times 100$$

$$\Gamma = \left(\frac{\text{VSWR} - 1}{\text{VSWR} + 1} \right)$$

$$\Gamma = \left(\frac{1.117 - 1}{1.117 + 1} \right)$$

$$\Gamma = 0.055$$

$$\text{Transmitted power} = (1 - |0.066|^2) \times 100$$

$$= (0.9969) \times 100$$

$$\text{Transmitted power} = 99.69\%$$

EQUATIONS

Similarly, the transmitted power and reflected power has been calculated at all resonating bands and listed in Table.2. The electric, magnetic and current density regions of the proposed antennas shown in fig. 5. And the radiation patterns at E-plane and H- plane has been shown at Fig. 6 for resonating frequencies of 1775 MHz, 2887.50 MHz and 3981.25 MHz.

The proposed antenna was tested without slots on the patch surface in such case the resonating frequency is located at above the desired frequency operating band. To bring resonating frequency at desired frequency band with minimum return loss behavior, rectangular slots were introduced at moderately high current density region. The comparison between with slots and with slots has been shown in Fig. 7.

The difference in resonating frequency (δf) has been calculated in Table.3. The return loss characteristics during presence of rectangle slots and with slots has been

shown in Fig. 8. With rectangle structure the return loss performance is obtained below -10 dB which means above 90% of the power is radiating from the antenna hence it is recommended to introduce slots on the patch surface to obtained the perfect performance at desired frequency band.

The bandwidth adjustment can be done by changing the width dimensions of the antenna transmission line. The designed antenna transmission line width is directly proportional to the bandwidth. The proposed antenna has been analyzed with different width of the transmission line as 2 mm, 1.8 mm, 1.7 mm, 1.5 mm, 1.25 mm. the difference in bandwidth at each case has been listed in Table. 4 and its response has been plotted in Fig. 4.1.

Figure 6. The bandwidth response during the change in transmission line width.

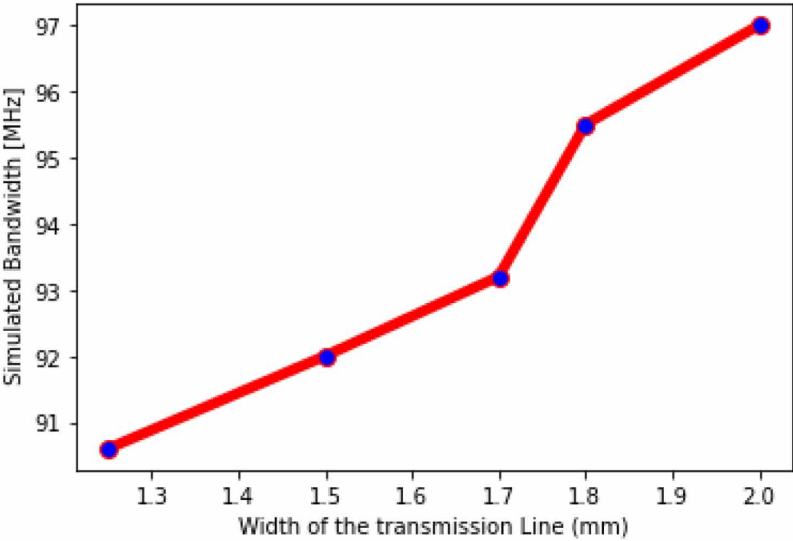


Table 2. Measured antenna performance values

S. No	Resonating frequency (MHz)	Operating frequency (MHz)	S11 (dB)	Bandwidth (MHz)	Transmitting power (%)	Reflecting power (%)
1	1775.00	1718.75 – 1831.25	-25.1209	112.50	99.69	
3	2887.50	2856.25 – 2912.50	-10.3450	56.00	90.67	9.3300
4	3981.25	3825.00 – 4150.00	-34.4697	168.75	99.99	0.0100

Figure 7. E-field, H-field and J-Field strengths of the proposed antenna.

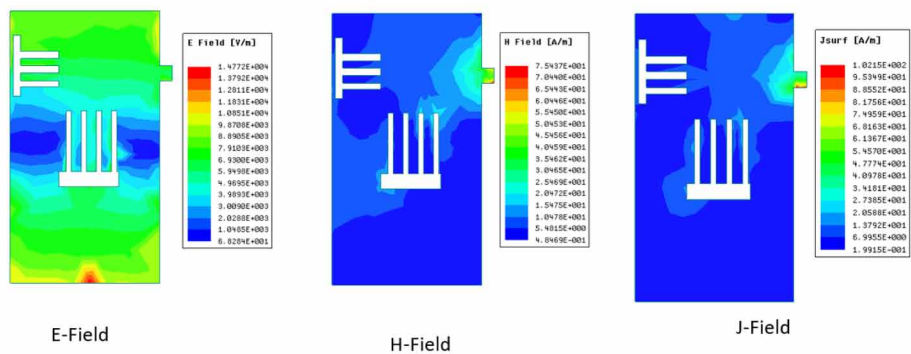


Figure 8. E-plane, H-plane at 1775.00 MHz, 2887.50 MHz, 3981.25 MHz.

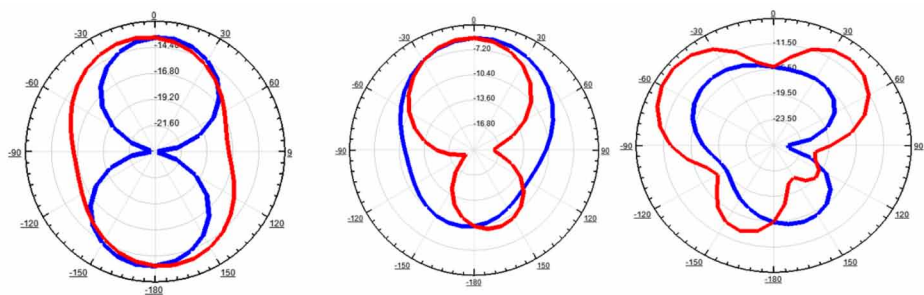


Table 3. The performance values of the proposed antenna without and with slots on the patch surface.

S. No	Resonating frequency without slots (MHz) $f_{\text{without slots}}$	Resonating frequency with slots (MHz) $f_{\text{with slots}}$	Change in Frequency $\delta f = f_{\text{without slots}} - f_{\text{with slots}}$ (MHz)
1	1901.00	1733.00	168.00
2	3294.00	2912.00	382.00
3	3850.00	3843.00	7.00

For Narrow band applications small amount of bandwidth is sufficient to fulfill the requirements. Even though the proposed measured antenna having sufficient bandwidth of 112.50 MHz to fulfill the requirements for NB-IOT applications.

Figure 9. The proposed antenna structure without slots (left) and with slots(right)

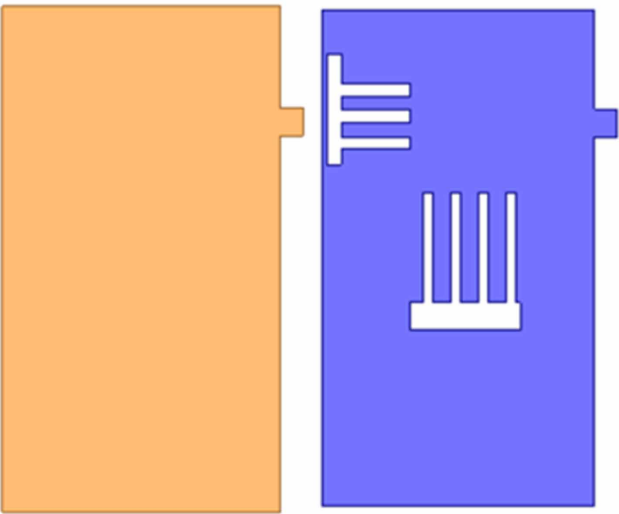


Figure 10. The S11 behavior at without and with slots on the patch surface.

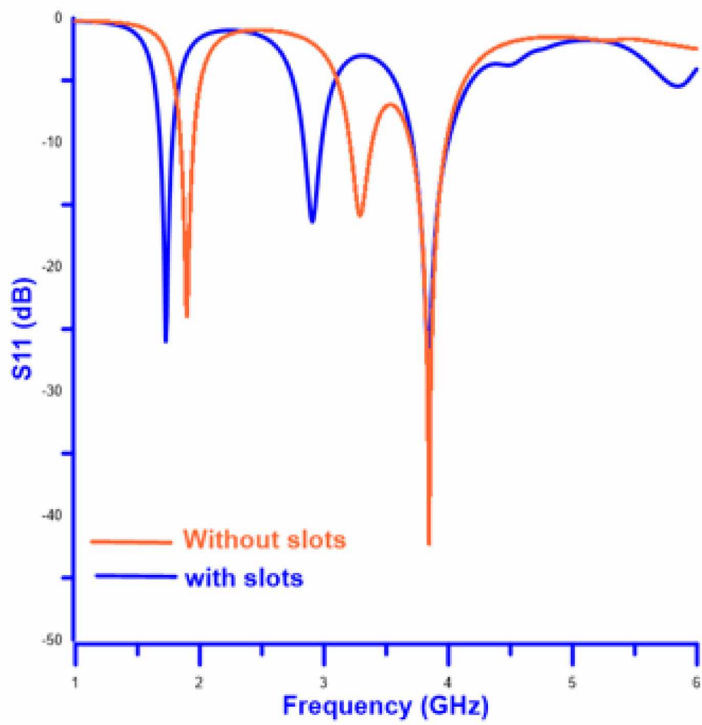


Table 4. The simulated bandwidth enhancement when changing the length of the transmission line.

S. No	Transmission line Width (mm)	Bandwidth (MHz)
1	1.25	90.60
2	1.50	92.00
3	1.70	93.20
4	1.80	95.50
5	2.00	97.00

Table 5. The comparison of the proposed antenna size with literature antennas.

S. No	Reference Number	Antenna dimensions (mm)
1	(Zhuo et al., 2020)	85 x 85 x 1
2	(Fan et al., 2012)	50 x 25 x 1.6
3	(Choukiker et al., 2014)	100 x 50 x 1.54
4	(Chou & Ku, 2015)	15 x 60 x 1.6
5	Proposed Antenna	35.89 x 19.78 x 1.6

CONCLUSION

A suitable antenna model has been designed for the NB-IOT real time applications. The significant advantage of the proposed antenna is very small in size compared to literature antennas. The proposed antenna can transmit 99.69% at desired resonating frequency. As well this antenna has also had multiband performance. Hence it can be used for many applications at 2856.25 MHz – 2912.50 MHz and 3825.00 MHz– 4150.00 MHz. A method has been analyzed to enhance the bandwidth at 1718 MHz to 1831 MHz for NB-IOT applications. The proposed antennas have been designed and verified its practical output using vector network analyzer.

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Chapter 6

Design of a Practical Miniaturized Antenna to Support IoT Applications

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ABSTRACT

The term “Internet of Things (IoT)” was coined at the start of this century when work was done on MIT Auto-ID Centre to make a smart identification technology, which would help to reduce the error rate, subsequently increasing efficiency. But since then, the concept of IoT has evolved rapidly in various ways, as now with the help of this huge number of small networks which can remain connected to one another and can directly communicate with the main network without any human interaction. In this chapter, the investigation has been carried out to design a printed monopole antenna, which is basically a printed microstrip rectangular patch to support such IoT devices. The proposed antenna was designed and simulated using CST MWS, which shows that the antenna is working effectively in the triple band of frequency. The proposed antenna has the capability to work in the range of 2.4 GHz to 6.9 GHz. The miniature size of the antenna makes it suitable for wireless IoT applications.

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INTRODUCTION

The FCC has now approved LTE-U just recently, which is the LTE specification for unlicensed frequency spectrum. Using this technology small-scale coverage could be deployed and connectivity improved in rural areas. The LTE-U base stations utilize the 5GHz band in which Wi-Fi also resides in. Only the biggest corporations are competing with one another for exclusive rights to the licensed spectrum. However, with the advent of latest technological advancements, Nowadays even smaller start-ups are competing in the unlicensed spectrum. The extensive usage of data every year poses problem to the providers makes it difficult for them to continue expanding their expensive licensed networks. On the other hand, the IoT devices does not need such expensive or long distance spectrum (Deshpande,2017),(Amin,2016) and they can simply work well with mesh networking technology utilizing the unlicensed spectrum effectively and cheaply. Antennas can be designed to radiate in these unlicensed spectrum. Of all the available structures, the micro strip patch antenna is promising because of its size and ease of fabrication in printed circuit boards, which can well along, go with IoT devices. (Deshpande,2017)(Amin,2016)

Microstrip antennas can be designed in variety of forms like as such dipole, slot, TWT structure or a simple patch designed based on the specific application demands. Microstrip antennas are more preferred and researched due to their following inherent advantages (GirishKumar,2002), (Swathy, 2015).

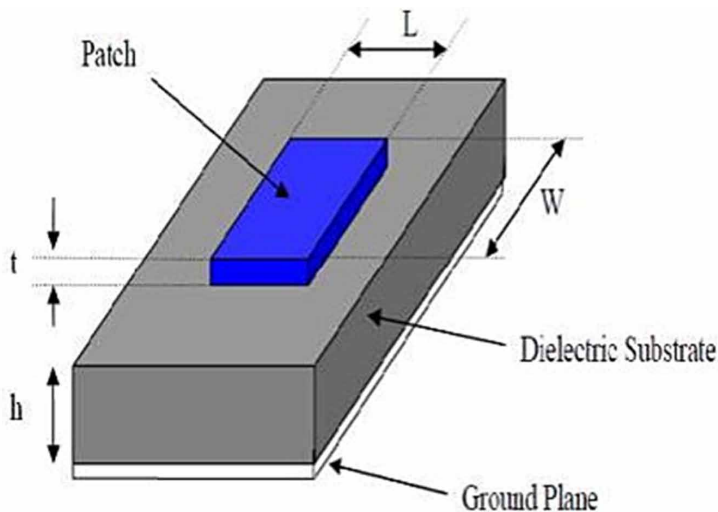
- Simple geometric profile.
- Less weight.
- Compatibility to design with different substrates.
- Low cost.
- Integration capability with other circuits.
- Versatility.

However, basic forms of Microstrip patch antennas also suffer from some drawbacks such as narrow bandwidth, poor polarization, low radiation efficiency, less power capability. Microstrip patch antennas are one of the most basic and important types of planar antenna. The most concepts and techniques used with microstrip patch antennas can be directly implied to design other planar antenna structures. In this chapter, the basic features of these antennas are reviewed. The design of a rectangular patch antenna is dealt and after which broadband improvement techniques are described briefly. These techniques could be implemented also to other planar antennas. Lastly, a practical design procedure for a broadband slotted antenna for IOT application(Amin,2016)is given as an example.

FEATURES OF A MICROSTRIP PATCH

The basic geometric configuration of a microstrip patch is constructed by etching a metallic patch on to an electrically thin, ground eddy electric substrate as shown below in *Figure 1*. The thickness of the substrate is much less than wavelength. The dimensions of patches are mainly chosen in the order of half of their equivalent operating wavelength. Generally, the patches are fed asymmetrically by an unbalanced feed. The radiation pattern is proportional to the electric current distributions of the patch antennas. The patch shapes, the feeding type and the dielectric substrate properties can be effectively chosen to resonate the patch and achieve the desired performance for a specific application.

Figure 1. Structure of a Microstrip Patch



SHAPES OF RADIATING PATCHES

The radiator must be made of a material with low dielectric loss and should have high conductivity at the operating frequency, which can be fixed to a dielectric substrate. The shape (GirishKumar,2002) can take any form like an ordinary rectangle, square, circle, triangle, ellipse, ring, hexagon, pentagon, or such variations. *Figure 2* shows some typical shapes of the radiating patches. Simple to complex variations are done over the basic shapes to meet the required design demands. The selection

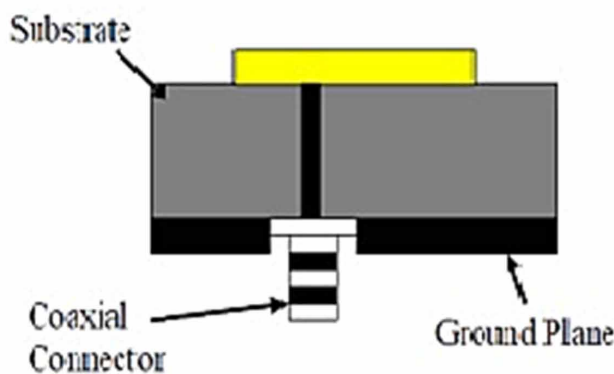
Design of a Practical Miniaturized Antenna to Support IoT Applications

of a particular shape depends on specific requirements like Operating frequency, bandwidth, return loss, gain, polarization etc. Generally, The characteristics of radiating patch antenna is defined by its operating modes which in turn depend on the shape and dimensions of the patch, the thickness, dielectric constant and loss tangent of the substrate, and also on the feed arrangement.

Figure 2. Shapes of Radiating Patches



Figure 3. Simple Feeding Structure



FEEDING TECHNIQUES

The feed (Giay, 2018) transfers the microwave energy from the transmission system to the radiator. The design of the feeding structure controls various parameters of the radiating structure like the impedance matching, its operating modes, surface current and the spurious radiations from the antenna or array. The feeding structure thus is key factor in governing the widening of the bandwidth and enhancing the radiator performance. The development of broadband techniques is highly dependent on the improvement of feeding structures.

Figure 3 shows a simplest feeding structure (GirishKumar,2002),(Balanis,2002),(El Misilmani,2014), (Garg et. al,2001) is fabricated on the same surface of the patch. A Transmission line or a RF connector (surface mounted) or a coaxial line may feed the feed. The feed may be directly coupled or attached to the patch edge. *Figure 5* shows a coaxial probe (El Misilmani,2014), which is used commonly to excite microstrip patch antennas. A coaxial connector is soldered to the ground plane below the substrate. The location of the feed point can be adjusted for impedance matching between the coaxial line and the radiating patch. However, this feeding technique is not suitable for arrays due to the larger number of solder points and coaxial lines. In addition, antennas with thick substrates when coaxially fed resulted increase in spurious radiations.

An aperture-coupled feeding configuration shown in *Figure 6* has two substrates separated by a common ground plane; a radiating patch is located on the upper substrate and a feeding strip is located on the lower one. A narrow slot, usually non-resonant is cut from the ground plane. The feeding strip is electromagnetically coupled to the patch through the slot. The coupling between the patch and the feed is governed by the size and shape of the slot Impedance matching is achieved by varying the aperture dimensions, its location, length and location of the feeding strip, and the dielectric constants of both the substrates. *Figure 4* depicts a proximity-coupled feeding structure (El Misilmani,2014) in which the feeding strip is located below the microstrip patch but above the ground. RF energy transfer occurs due to the electromagnetic coupling between the micro strip patch and the feed. The increase in impedance bandwidth is seen. However, due to the double-layered structure, the fabrication cost increases and surface wave losses tend to increase.

Figure 4. Microstrip line feed

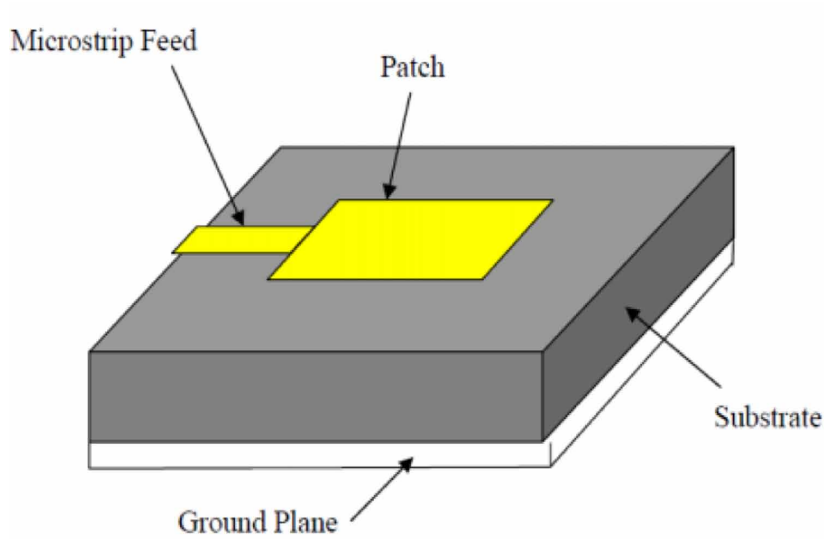


Figure 5. Coaxial feed

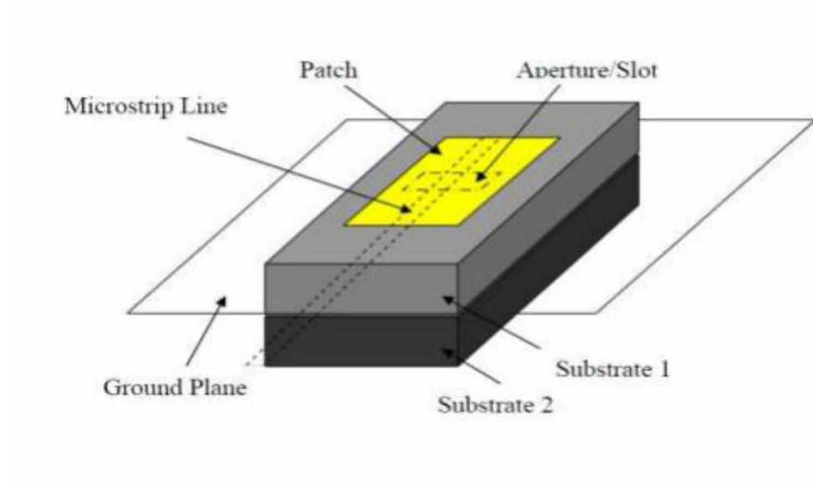
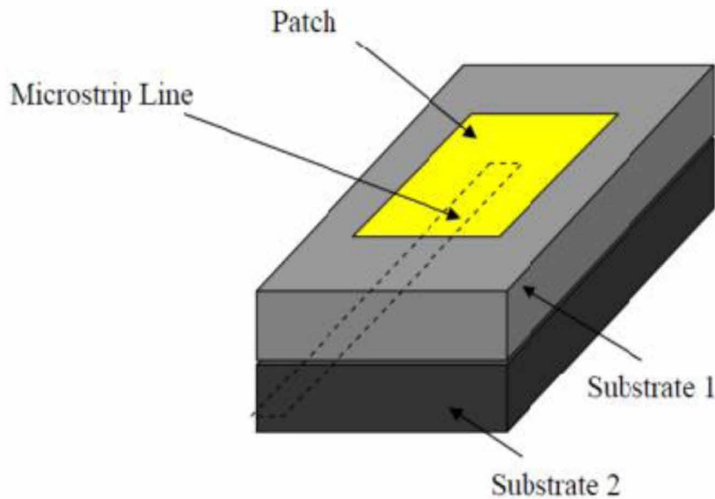


Figure 6. Aperture coupled feed



BANDWIDTH ENHANCEMENT TECHNIQUES

The factors mainly affecting the bandwidth (Suryakanth,2016),(Arivazhagan, 2011) of a microstrip patch antenna are the shape of the radiating patch, the feeding structure, the substrate material and the arrangements of radiating and parasitic elements. The bandwidth of a microstrip patch antenna can be essentially broadened by lowering its Q value and simultaneously achieving multiple resonances. If the antenna is treated as a high- Q filter, by reducing the energy around the antenna i.e. increasing losses around the radiator increases the bandwidth at its resonance. Alternatively, a broadband impedance network could be inserted between the antenna and the feed owing to the good matching between them over a wide range of frequency. If two or more adjacent modes are excited simultaneously, twice the bandwidth or more than that for the single resonance can be achieved.

DESIGN METHODOLOGY OF PROPOSED ANTENNA

Steps to Design a Single Rectangular Micro Strip Patch Antenna (RMSA)

The design of RMSA at a resonant frequency of 2.4GHz employs the following procedure .For an RMSA to be an efficient radiator; W_p should be taken equal to half the wavelength. The width of the patch is calculated as follows (Balanis,2002), (Garg et.al, 2001)

$$W_p = \frac{c}{2fr} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where fr is the resonant frequency of the microstrip antenna (MSA), $c=3*10^8$ m/sec and ϵ_r = the relative dielectric constant of the substrate. In this design, Flame resistant (FR -4) substrate of relative permittivity of 4.4 and height $h=1.6$ mm is used. The value of ϵ_{eff} is slightly less than ϵ_r because the fringing fields around theperiphery of the patch are not confined in thedielectric substrate but are also spread in the air.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left\{ 1 - 12 \frac{h}{W_p} \right\}^{-1/2} \quad \text{for } W_p/h > 1 \quad (2)$$

Due to presence of the fringing fields at the two edges of the patch the dimensions of the patch vary, actually their length appears to be greater than its physical length thus the effective length of the RMSA is given by (Girish Kumar,2002),(Balanis,2002),(El Misilmani,2014)

$$L_{eff} = L + 2\Delta L = \frac{c}{2fr\sqrt{\epsilon_{eff}}} \quad (3)$$

A very practical approximate relation for the normalized extension of the length is given by (GirishKumar,2002), (Balanis,2002)

$$\Delta L = (0.412 * h) * \frac{(\epsilon_{eff} + 0.3) \left[\frac{Wp}{h} + 0.264 \right]}{(\epsilon_{eff} - 0.258) \left[\frac{Wp}{h} + 0.8 \right]} \quad (4)$$

Where h is the thickness of the substrate and it is assumed to be much smaller than the dimensions of the antenna and Wp is the Width of the patch. The design is continued to match the antenna resistance to 50Ω of the input line. To obtain impedance matching with the Microstrip feed line, inset-feeding technique is mostly used. The inset feed point is calculated as follows: once calculation of the dimensions of the patch is done, the gap or notch width of the feed is designed using the formula

$$g = \frac{c * fr * 10^{-9} * 4.65 * 10^{-9}}{\sqrt{2 \epsilon_{eff}}} \quad (5)$$

Then we calculate the recessed distance of the feed “ yo ”, length and width of the feed. The inset feed used match the characteristic impedance of transmission line i.e $Zo=50\Omega$, According to (Balanis,2002), (Garg,2001)

$$Zo = Rin * \cos^2 \left(\frac{\Pi}{Lp} * yo \right) \text{ and } Lf = \frac{\lambda g}{4}; \text{ where } \lambda g = \frac{\lambda}{\sqrt{\epsilon_{eff}}} \quad (6)$$

The width (W_f) of the feed is found using the equation,

$$Wf = \left(\frac{2h}{\Pi} \right) \times [B - 1 - \ln [2B - 1]] + \left(\frac{\epsilon_r - 1}{2 \epsilon_r} \right) * (\ln [B - 1] + 0.39 - \frac{0.69}{\epsilon_r}) \quad (7)$$

$$\text{for } \frac{Wf}{h} > 2; \text{ where } B = 60 \frac{\Pi^2}{Zo \sqrt{\epsilon_r}}$$

Where, Z_0 is usually chosen as 50 ohms, h and ϵ_r are fixed for a particular substrate (GirishKumar,2002), (Balanis,2002).

The ground plane dimensions are calculated accordingly as,

$$\text{Length of the ground plane } Lg = 6 * h + Lp \text{ and} \quad (8)$$

Width of the ground plane $W_g = 6 * h + W_p$ (9)

Structural Description of the Proposed Antenna

Initially a simple rectangular patch is designed to operate at a particular frequency. A rectangular slot is then made in the thin patch and as a result, resonating effect of the antenna varies. The radiating property of the slotted patch can be parametrically analysed by varying the slot dimensions and positions using (GirishKumar,2002) (Zahran,2017). A slot (Suryakanth,2016) (NeenanshaJain , 2017) cut in the ground also contributes to the resonating changes of the antenna. It could be done by varying the slot length, width and position. The analysis was carried out in the time domain and frequency domain by simulating the antenna using CST Microwave Studio software. The vital parameters of the antenna like the return loss, VSWR and far field radiation patterns of the antenna were obtained. The geometry of patch and ground are shown in figure 7 and figure 8 respectively.

Figure 7. Geometry of Patch

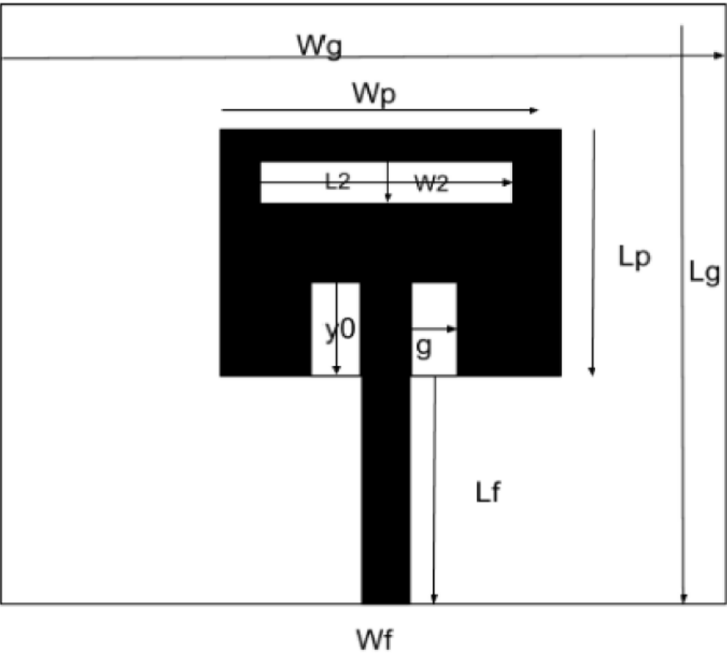
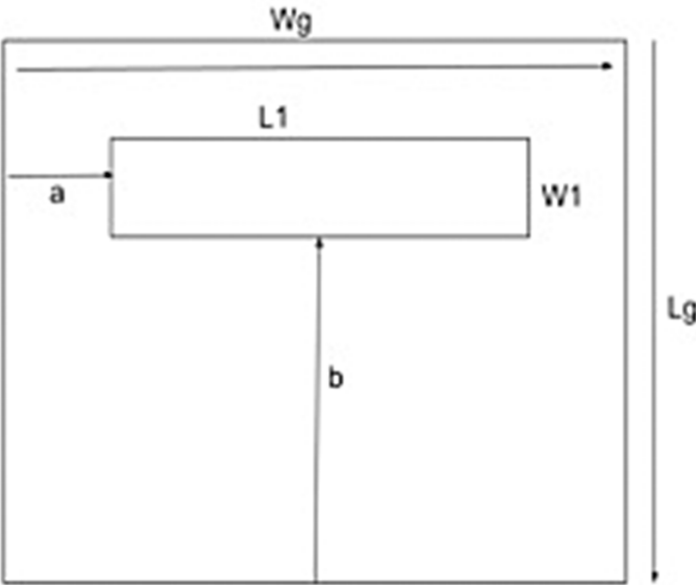


Figure 8. Geometry of the Ground



Design Specifications:

The performance of any antenna is governed by its radiation parameters. If one parameter is varied it reflects in change in performance of the antenna since its radiation property depends on them. For example, the effective length of the patch depends on the permittivity of the material used to fabricate it. If permittivity is increased the effective length decreases thus paying way to miniaturization of antenna. In addition to this, the impedance bandwidth can be controlled by varying the height of the substrate, the bandwidth increases when height of the substrate increases. Table 1 shows the specifications of the proposed antenna.

PARAMETRIC STUDY OF THE MULTIBAND PATCH ANTENNA

Parametric study (Bisht,2014), (Bhalerao,2015)is usually done to optimize the performance of the antenna by varying its parameters. The CST simulation tool allows the designer to vary the parameters in steps and all the results can be simultaneously recorded and analysed. Multiple parameters can be varied in multiple steps and all the results could be displayed in a single window. This allows the designer to carry out an extensive study by varying feed length, width, gap, slot length, slot width etc to finalize the parameters so that the antenna desired performance is achieved.

Table 1. Specifications of the proposed Antenna

Description of the Variable	Value in mm
GroundWidth(W_g)	44
Ground Length (L_g)	41
Patch Width (W_p)	26
Patch Length (L_p)	21
Height of the ground & Patch (h_i)	0.035
Substrate thickness (h)	1.6
FeedLength (L_f)	10
Feed Width (W_f)	2
Cut height(y_0)	5.2
Width of the Cut (g)	1.5
patch slot length (L2)	20
patch slot width (w2)	4.5
Gslot length 1 (l1)	20
Gslot length 2 (l2)	22
Gslot length 3(l3)	12
ground slot width (w1)	3.5
ground slot height (b)	26
ground slot (b)	26
patch slot height (m)	13

Structure of the Antenna

The proposed Multiband microstrip antenna was designed using CST MWS with the dimensions as described in the specification table (Table 1). The annealed copper was chosen for ground and the patch. FR4 –lossy was chosen for the substrate of antenna, as it is easily available. *The Figure 9* shows the perspective view of the antenna, which depicts the designed patch with slot while the *Figure 10* shows the slotted ground, designed as per the above dimensions. The structure was simulated and a parametric study carried out to optimize the antenna.

Figure 9. Perspective View of designed Antenna using CST MWS

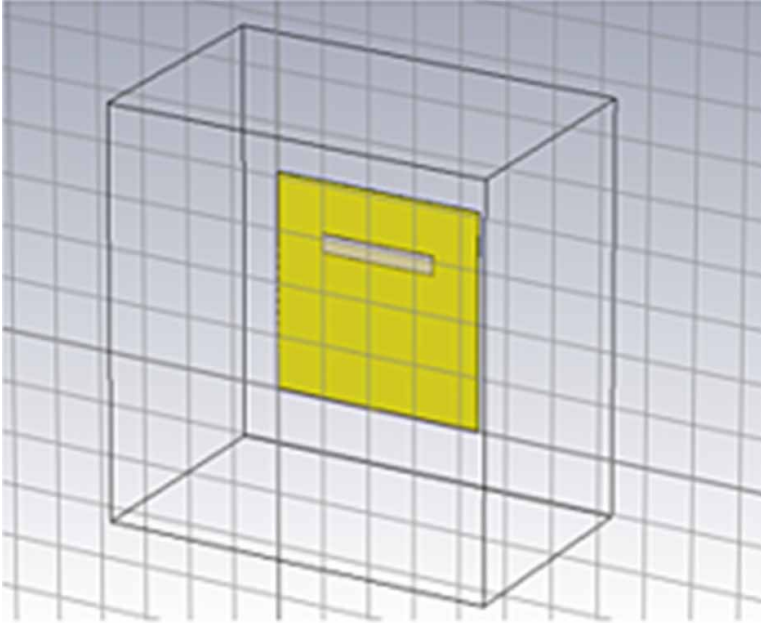
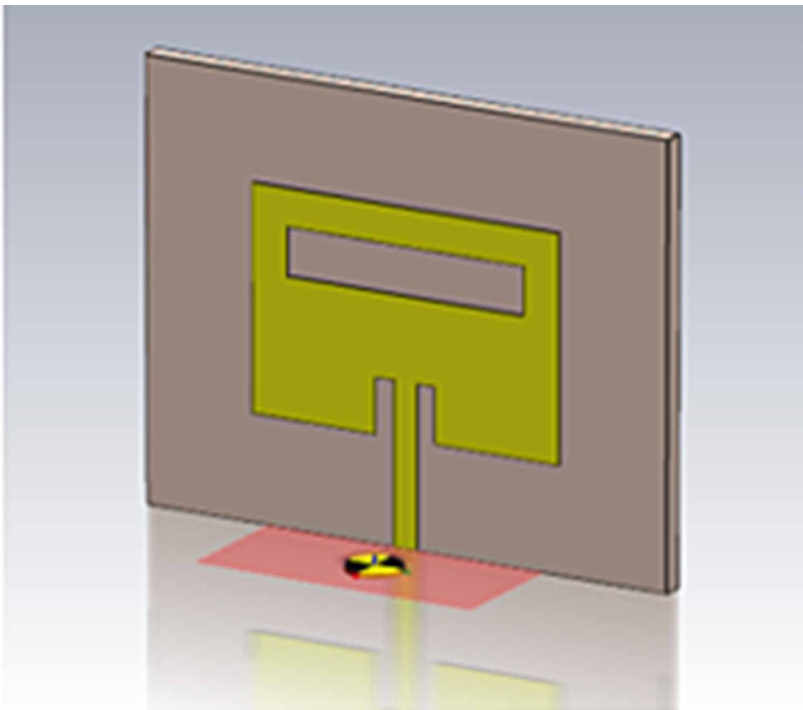


Figure 10. Perspective view of the Slotted ground



Return loss S11

The parameter S11 is return loss of device, which is a measure of how much input power given to device is reflected back at the input port. Ideally, there should not be any reflection back from the antenna that is 100% of the power needed to be reflected but practical antennas do have return loss. Nevertheless, as lower is the reflection better is the radiation.

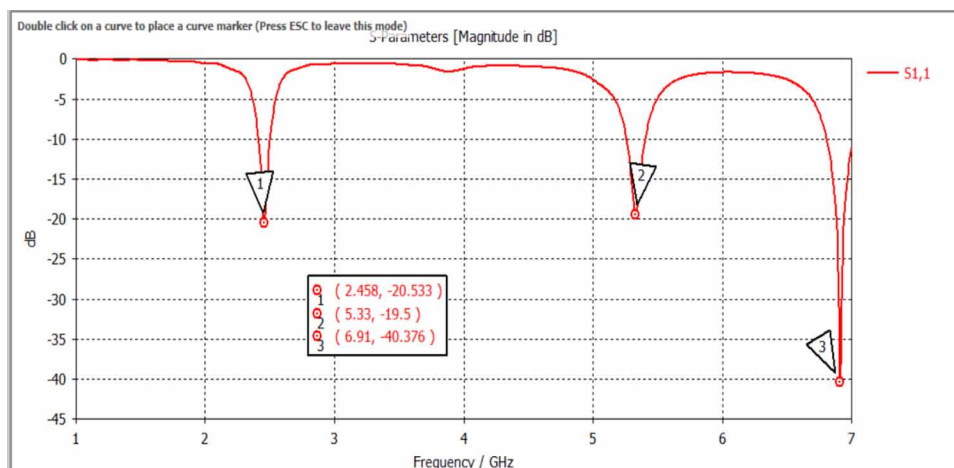
For instance, if we consider power is 10watt and power reflected back is 1 watt and power radiated is 9 watt then,

Return loss in dB = $10 \log (\text{power reflected} / \text{input power}) = 10 \log (1 / 10) = -10$ dB

Thus, S11 when it is below -10dB it means that atleast 90% input power is radiated and reflected power is less than 10%. This value is not demarcation but sufficient for many applications.

The designed antenna S11 plot is depicted below in *Figure 11*. It shows that the proposed antenna resonated at three frequencies namely 2.45 GHz, 5.33 GHz and 6.91 GHz. The Return Loss of the antenna are clearly shown. using markers 1, 2, and 3 respectively. It was found to be -20.533 dB at 2.458 GHz when it provided a return loss of -19.5 dB at 5.33 GHz and -40.376 dB at 6.91 GHz respectively

Figure 11. Return loss (S11) plot of the proposed Antenna



Voltage Standing Wave Ratio (VSWR)

Another important parameter to judge an antenna is its VSWR .It is function of the return loss.

$$VSWR = \frac{1 + S_{11}}{1 - S_{11}}$$

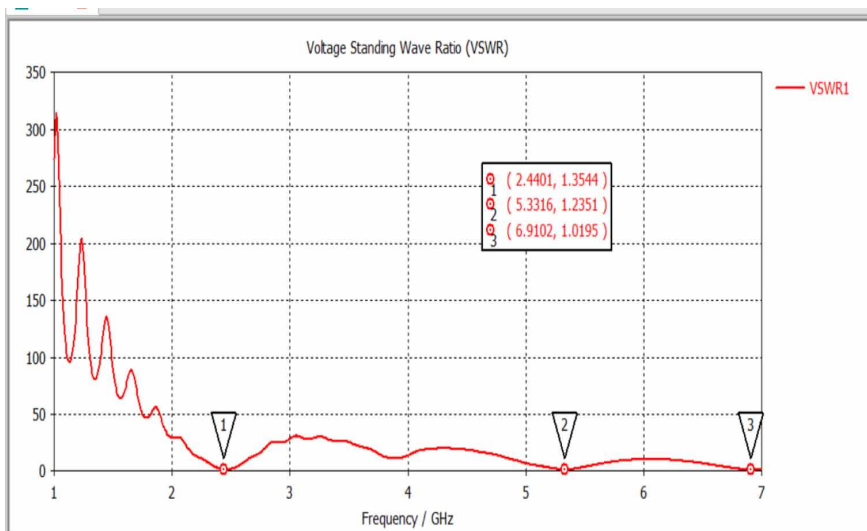
VSWR is always real and positive value for an antenna. The lesser the value of VSWR the more is the power delivered to the antenna .The least value of VSWR is 1.0 in which case S11 is zero i.e o power is reflected from the antenna and all of the input power given to the antenna is radiated.

Table 2. Relationship between VSWR and S11

VSWR	S11	Reflected power %	Radiated Power %	Reflected power dB
1.0	0	0	100	Infinity
1.5	0.2	4	96	-14
2.0	0.33	11.1	88.9	-9.55
4.0	0.6	36	64	-4.44
8.0	0.778	60	40	-2.18

The Table 2 explains the relationship between VSWR and S11. For instance, a VSWR of 8 means that 60% of power is reflected back and only 40% is radiated. Thus, lesser the value of VSWR more efficient is the antennas radiation property. The ideal value of VSWR for any good antenna should not exceed two. If it were below 1.5 then the antennas radiation properties would be considered good. The proposed antenna reflected a VSWR of 1.354 at 2.44 GHz. The same antenna reflected a VSWR value of 1.2351 at 5.3316 GHz and 1.0195 at 6.91 GHz as shown in the Figure 12. This explains that the antenna works good at all these three frequencies hence can be implemented as a multiband antenna to support IOT devices communicating at these frequencies.

Figure 12. The VSWR plot of the proposed antenna



Radiation Pattern

The antenna is seen to perform well in a wider range of frequency from 2.45 GHz to 6.9 GHz. Its directivity and its 3D Radiation pattern at various frequencies are shown.

Figure 13. Radiation Pattern at 2.45 GHz, with Directivity 4.613 dBi

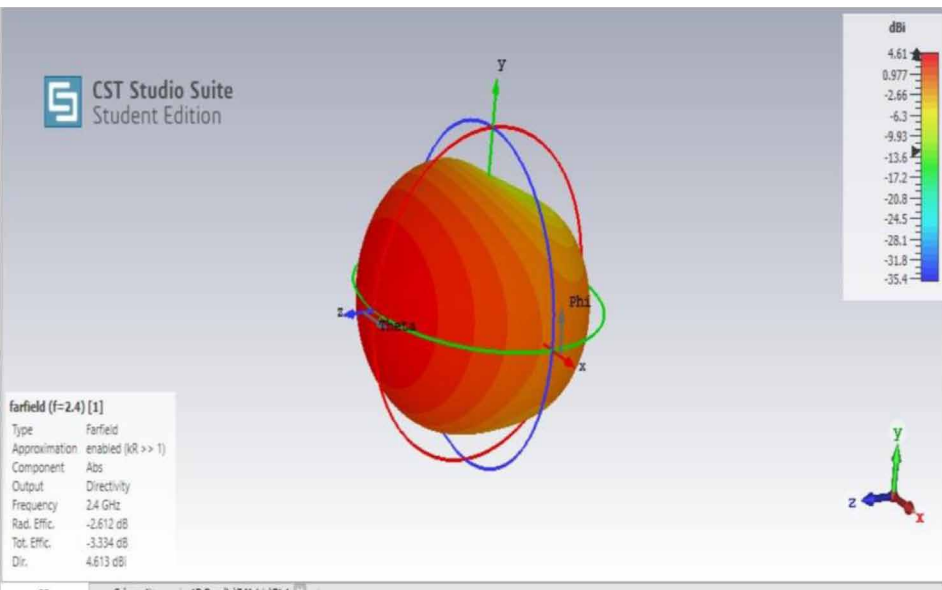


Figure 14. Radiation Pattern at 5.3 GHz, with Directivity 5.42 dBi

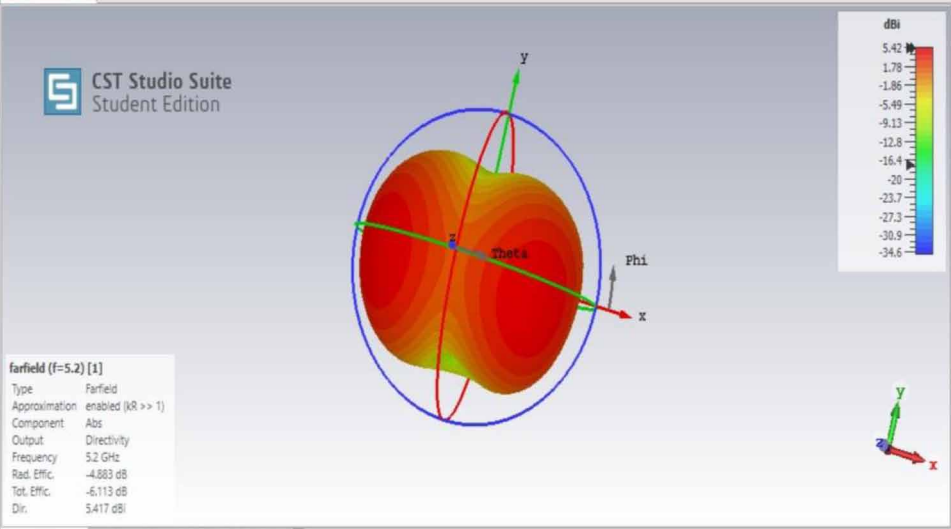


Figure 15. Radiation Pattern at 6.9 GHz, with Directivity 5.778 dBi

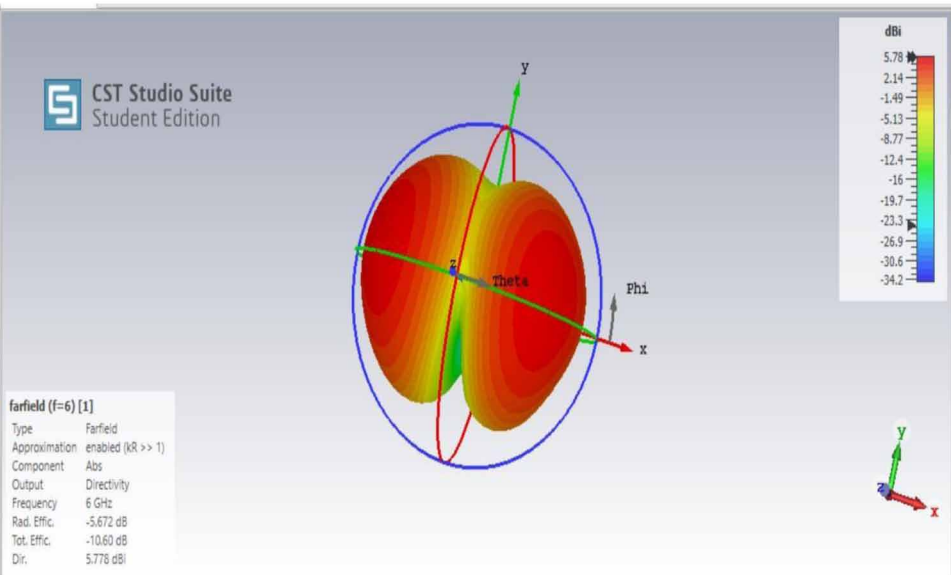
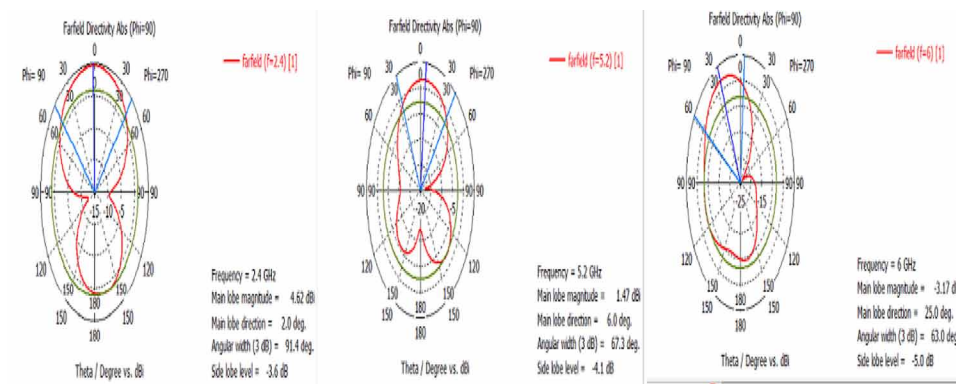


Figure 16. Polar plots of proposed antenna at frequencies 2.4 GHz, 5.2 GHz, and 6.9GHz



in Figures 13-15 and 1D radiation pattern namely the polar plot can be visualized from Figure 16. The radiation pattern shows that proposed antenna structure has good directional properties in these frequencies.

CONCLUSION

In this chapter, a structure of a microstrip patch antennas with slotted patch and ground for UWB communication systems suitable for IoT applications has been discussed. The proposed antenna covered the frequency range of 2.4 – 6.9 GHz in terms of return loss less than -10 dB. It also has VSWR less than 1.3 in this frequency range, which is most desirable parameter for all wireless applications. The proposed antenna structure is quite simple, small, and its manufacturing is cost effective. These are the essential features needed to support most of the IoT devices. Omni directional properties of the proposed antenna could be furthermore optimized by impedance matching techniques, by altering the patch and slot dimensions it could be devised to radiate at any desirable frequency. These characteristics indicate that the proposed multi band antenna is well suitable for the integration into IoT portable devices.

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Design of a Practical Miniaturized Antenna to Support IoT Applications

Khan, M. A., ul Haq, M. A., & ur Rehman, S. (2016, December). A practical miniature antenna design for future internet of things enabled smart devices. In *2016 10th International Conference on Signal Processing and Communication Systems (ICSPCS)* (pp. 1-6). IEEE.

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Chapter 7

Design of Bow Tie Antenna for Industrial IoT Application

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ABSTRACT

A printed bow-tie antenna is designed and simulated for IoT application. This antenna is designed and fabricated using FR4 dielectric material constant around 0.002. Thickness of the substrate is about 1.6mm. Two triangular elements one as a reflected element of another are arranged in such a manner to propose a single element. Antenna parameters are simulated using CST Microwave Studio, which gives a better compromising with measured results. The proposed antenna resonates at 8GHz with a return loss S_{11} of - 23.351dB, VSWR of 1.16, directional gain of 5.89dB, respectively.

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INTRODUCTION

Internet of Things (IoT) can be defined as a computer network that includes integrated technology to help the device communicate information within its environment and wireless setting. IoT enables these devices to be remotely controlled by providing wireless communication across the network, resulting in some economic benefits and improved efficiency. Microstrip antennas with a wide operation bandwidth have received much attention due to their employment in different applications with easy tuning options. The world of wireless telecommunications evolves rapidly. Wireless networking represents the future of computer and Internet connectivity worldwide. The Bowtie microstrip antennas have been designed for wireless LAN communication. The advantages of bow tie antenna are as follows: they are thin and light weight; they are compatible with mobile terminal equipment; they have equality factors; their bandwidth are narrow; they have enough antenna gain. Nowadays electronics and wireless communications are rapidly developing, we need only one device which can operate at different frequency standards (Saravanakumar, U; Rangarajan, R; Haripriya, R; Nithya, R and Rajasekar. K, 2013). Also, by introducing two loop strips in the bow-tie slots, the gain at low frequencies is increased (A. C. Durgun; C. A. Balanis; C. R. Birtcher and D. R. Allee, 2011). The measured results show that the proposed antenna has a bandwidth of 8GHz. Wireless networks provide all of the features and benefits of traditional local area network technologies such as Ethernet and Token Ring without the limitations of wires and cables. These solve the problem of antenna practicality of the traditional ground-penetrating radar (GPR), which is low because of its excessive size, expensive cost, and insufficient bandwidth. But issues remain, as the antenna gain is not high and the directionality is inaccurate and affects the GPR performance. The bow-tie patch actually is the combination of imaginary image of two triangular patches which are fabricated in a single substrate. A bowtie antenna is a wire approximation in two dimensions of a biconic dipole antenna. The main software used to design and implement the program is CST microwave studio. CST microwave studio is a specialized tool for the 3D EM stimulation high frequency components. The CST microwave studio program is used as a main program to stimulate and design the antennas. It is also called as an Auto sketch software or Drawing Software in which we can draw the inclusive electrical structure of antennas with 1:1 scale in order to print the antenna which we needed on laser paper for fabrication. This program is used to avoid any errors or mistakes during fabricating the antenna structures. Antennas design for wireless communication systems has attracted a great interest during the last years. The printed antenna has advantages such as low cost, light weight which is a suitable criteria to design a wireless communication and ease of integration with microwave circuits (Anita Jones Mary; Bathala V. Sindooja, 2014). The bow-tie patch actually is

the combination of imaginary image of two triangular patches which are fabricated in a single substrate. Other potential applications include “smart” medical bandages that monitor the healing of a wound or a medical triage patch for remote monitoring of a patient’s vital signs. A microstrip or patch antenna operates in a way that the electromagnetic waves are generated when the feed line reaches the strip of antenna. The waves which is generated are from the patch start getting radiated from the width side (Adham Rabeea Azeez; Marwa Maki Hamed, 2015).

DESIGN OF ANTENNA

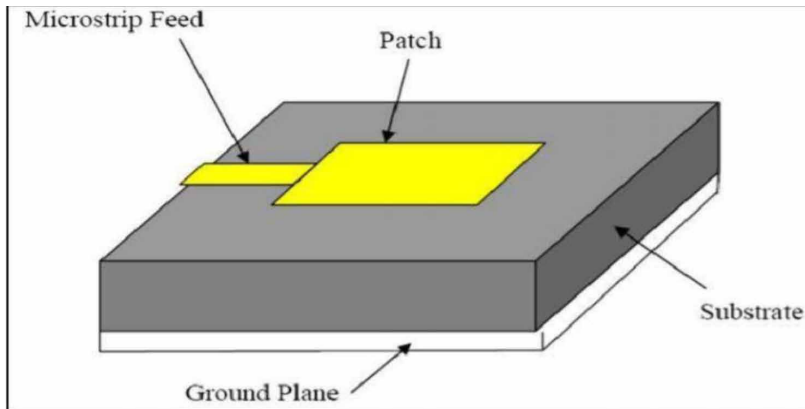
Design of Microstrip Antenna

In telecommunication a microstrip antenna (also known as a printed antenna) usually means antenna photolithographic techniques on a Printed circuit boards (PCB). It is a kind of internal antenna. They are mostly used at microwave frequencies. An individual microstrip antenna consists of a patch of metal foil of various shapes (a patch antenna) on the surface of a PCB (printed circuit board), with a metal foil ground plane on the other side of the board. Most microstrip antennas consist of multiple patches in a two-dimensional array. The antenna is usually connected to the transmitter or receiver through foil microstrip transmission lines. The radio frequency current is applied (or in receiving antennas the received signal is produced) between the antenna and ground plane. Microstrip antennas have become very popular in recent decades due to their thin planar profile which can be incorporated into the surfaces of consumer products, aircraft and missiles; their ease of fabrication using printed circuit techniques; the ease of integrating the antenna on the same board with the rest of the circuit, and the possibility of adding active devices such as microwave integrated circuits to the antenna itself to make active antennas (M. Raveendra; U. Saravanakumar; G. A. Kumar; P. Suresh and S. P. D. Pedapalli, 2021).

Basically a microstrip patch antenna comprises of a trace of copper or any other metal of any geometry on one side of a standard printed circuit board substrate with other side grounded. The antenna is fed using various feeding techniques like coaxial, strip line, aperture coupling or proximity coupling techniques. The working principle and the radiation mechanism have also been described. The microstrip patch antenna is widely used military, industrial and commercial sectors and it is shown in Fig. 1. We can also do cross polarisation in microstrip patch antenna, Cross-polarization is the undesired antenna polarization. Cross polarized electric-field component is perpendicular to the co-polarized component. In the H- plane, the cross-polarization is given by the combined electric-field components in the y- directions and z-directions, which is the elevation electric-field component.

The difference between the co- and cross- polarizations is called the polarization isolation. The plot given below shows the directivity of the cross- polarized E-field in the H plane (cross-polarization radiation pattern). As expected, there is a null at zenith (Jin-Sen Chen, 2005).

Figure 1. Microstrip antenna



Bow-Tie Planar Antenna

A new planar bow-tie antenna is proposed for ultra wideband applications. The self-complementary principle has been applied to a planar triangular monopole antenna along with bending the microstrip feed line. The antenna has a wider frequency band compared to the traditional bow-tie antenna, complies with the ultra wide band requirements and it is directly matched to the connector via microstrip feed line. This antenna has a simple shape which overcomes the complicated matching techniques using baluns or impedance matching sections that are commonly used in bow-tie antennas for widening their limited bandwidths (Samah Badr and Ehab Kl Hamad, 2018).

Antennas are indispensable component of any wireless communication device. Thus they are the inevitable and the free space waves and vice versa. They efficiently transfer electromagnetic energy from a transmission line into free space. As the growing demand for wireless communications is constantly increasing, the need for better coverage, improved capacity and higher transmission quality rises. Thus, a more efficient use of the radio spectrum is required. Originally developed for Radar technology Ultra Wide Band has evolved to prove essential in the WPAN and WLAN market as a high speed networking solution for burst data. The bow

tie antenna is known for its simplicity and is broadband performance. It is a wire approximation to the solid biconical antenna. They are commonly used for UHF television antennas where several elements may be arrayed and placed in front of a flat screen reflector (P. V. N. R. Teja; M. Raveendra; T. V. Ganesh; J. V. Mahesh and U. Saravanakumar, 2021).

SOFTWARE DESCRIPTION

About the Software

CST MICROWAVE STUDIO (CST MWS) is the culmination of many years of research and development into the most efficient and accurate computational solutions to 3D electromagnetic designs. CST MWS specializes in providing fast and accurate 3D electromagnetic simulation of high frequency problems. The product offers users shorter development cycles through virtual prototyping before physical trials and optimization instead of experimentation. CST MICROWAVE STUDIO provides a link between MATLAB and CST MWS's VBA macro language. This interface allows CST MWS users to take advantage of the extensive data manipulation, signal processing, and graphics capability in MATLAB. COM and ActiveX interfaces allow behind the scenes data transfer and tight integration between the two programs. The described approach can be applied to other members of the CST STUDIO product line as well. The main highlights of CST microwave tool are as follows, Complete technology for 3D EM simulation . Time domain solver for performance and efficiency in complex structures. Frequency domain solvers for highly resonant or periodic structures.

Software Installation

Electromagnetic field solvers for applications across the EM spectrum are contained within a single user interface in CST Studio Suite. The solvers can be coupled to perform hybrid simulations, giving engineers the flexibility to analyse whole systems made up of multiple components in an efficient and straightforward way. Co-design with other SIMULIA products allows EM simulation to be integrated into the design flow and drives the development process from the earliest stages. Common subjects of EM analysis include the performance and efficiency of antennas and filters, electromagnetic compatibility and interference (EMC/EMI), exposure of the human body to EM fields, electro-mechanical effects in motors and generators, and thermal effects in high-power devices.

CST STUDIO SUITE 2012.0 can be downloaded from our website for free. The program lies within Photo & Graphics Tools, more precisely Converters. CST DESIGN ENVIRONMENT.exe, AutoUpdateGUI_AMD64.exe, Auto_Update_Control.exe, CST DESIGN ENVIRONMENT_AMD64.exe and CST License Manager.exe are the most frequent filenames for this program's installer. CST STUDIO SUITE is developed for Windows XP/Vista/7/8/10 environment, 32 and 64-bit versions. The most popular versions among the program users are 2012.0 and 1.0. This software is an intellectual property of CST Computer Simulation Technology AG. This PC program deal with the following extensions: “.mod”, “.des” and “.psf”. Our built-in antivirus scanned this download and rated it as 100% safe. CST STUDIO SUITE benefits from an integrated design environment which gives access to the entire range of solver technology. It comprises CST's tools for the design and optimization of devices operating in a wide range of frequencies - static to optical. Analyses may include thermal and mechanical effects, as well as circuit simulation.

CST MICROWAVE STUDIO is a specialist tool for the 3DEM simulation of high frequency components. CST MWS unparalleled performance is making it first choice in technology leading R&D departments. CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects. Exceptionally user friendly, CST MWS quickly gives you an insight into the EM behaviour of your high frequency designs. CST promotes Complete Technology for 3D EM. Users of our software are given great flexibility in tackling a wide application range through the variety of available solver technologies. Beside the flagship module, the broadly applicable Time Domain solver and the Frequency Domain solver, CST MWS offers further solver modules for specific applications. Filters for the import of specific CAD files and the extraction of SPICE parameters enhance design possibilities and save time. In addition, CST MWS can be embedded in various industry standard workflows through the CST STUDIO SUITE user interface. CST MICROWAVE STUDIO is seen by an increasing number of engineers as an industry standard development tool.

DESIGN OF PROPOSED ANTENNA

The following steps given below to design a Bow tie antenna for satellite application with measurements:

STEP-1: Click on “MW & RF & OPTICAL” option.

STEP-2: Then click on” Antennas” option and the click next.

STEP-3: Select a “wave-guide” option in workflow and then click next.

STEP-4: Now click on “time domain” option and then click next.

- STEP-5: The units box will appear we will use dimensions in “cm” and frequencies in “GHz” and then click next.
- STEP-6: Select “setting, as for rectangular wave-guide “f min=7 GHz” and “f max=9 GHz”.
- STEP 7: Then mark on E-field, H-field, far-field, Power loss and Power flow. Then we will define at 7;8;9 GHz and then click next.
- STEP 8: Click the “Modelling” and construct a Brick module and click ESC, with the following measurements as follows:
Name: gnd
X min: -30 X max: 30
Y min: -15 Y max: 15
Z min: 0 Z max: 0.035 Material: Copper (annealed)
Component: Component 1 and then click “OK”.
- STEP 9: Again click the “Modelling” and construct a Brick module and click ESC, with the following measurements as follows:
X min: -30 X max: 30
Y min: -15 Y max: 15
Z min: 0.035 Z max: 1.635 Material: FR-4 (Lossy)
Component: Component 1 and then click “OK”.
- STEP 10: Now click the “Modelling” and construct a Cyclinder module and click ESC, with the following measurements as follows:
Name: tri Orientation: Z axis
Outer radius: 12 Inner radius: 0.0
X center: -14 Y center: 0
Z min: 1.635 Z max: 1.67 Segments: 3
Material: Copper (annealed) and click “OK”.
- STEP 11: Now click the “Modelling” and construct a Brick module and click ESC, with the following measurements as follows:
Name: feed
X min: -2 X max: -3
Y min: -15 Y max: 0
Z min: 1.635 Z max: 1.67
Material: Copper (annealed).
Component: Component 1 and click “OK”.

SIMULATION AND EXPERIMENTAL ANALYSIS

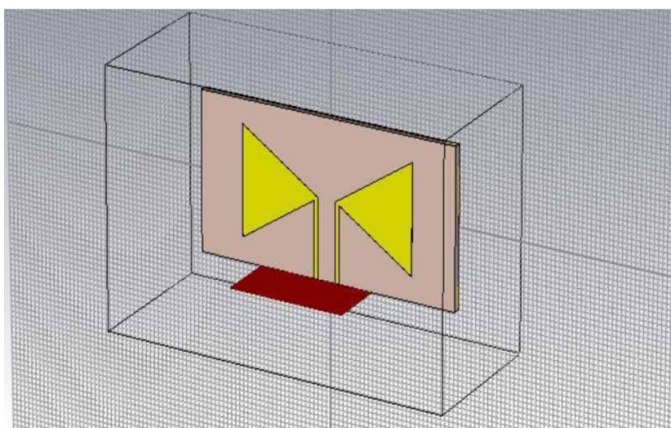
Now the designed Bow Tie antenna can be simulated with following steps given below:

STEP 1: Now Click on the Navigation tree and select the Components there given an subtree Select Component 1 and click “Feed” and “Tri”.

STEP 2: Now Add the feed and tri, and then Transform them. And click “Mirror”.

STEP 3: Now we can copy and click the Repetition factor with the measurement of X: 90 Y: 0 Z: 0 and then click “OK”.

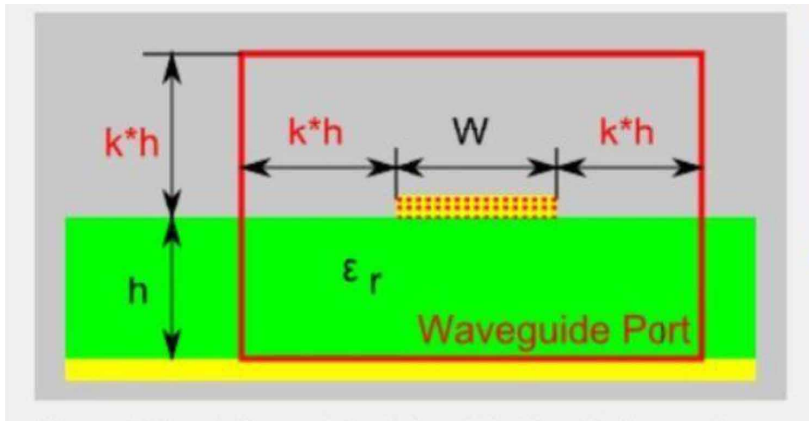
Figure 2. Designed bow tie antenna.



STEP 4: Now we can save our project with an appropriate file name and click on the “**Macros**” => “**Solver**” => “**Ports**” => “ Calculate port extension coefficient” .

In this work FR4 dielectric substrate is used with copper conductor with 0.035 mm, the reason for FR4 dielectric substrate with 1.6mm is it is easily available in market and cost of the fabrications is less compared to other dielectric substrates. We use copper as a radiating ground element. The Port assignment is shown in Fig 3. This Bow tie antenna is designed at 8GHz for IOT application.

Figure 3. Port extension Calculation



RESULTS AND DISCUSSION

This Bow tie antenna is designed at 8GHz for IOT application. The main advantage for designing bow tie antenna is it easily compactable and the cost is very less. More number of antenna can be integrated in an arrays and get more exclusive results. In 1D results, VSWR and S11 Parameters are presented. In 2D results, E-field and H-field are highlighted. The Farfield is shown both in Polar and in 3D form .

Figure 4. Designed Bow tie antenna with dimensions

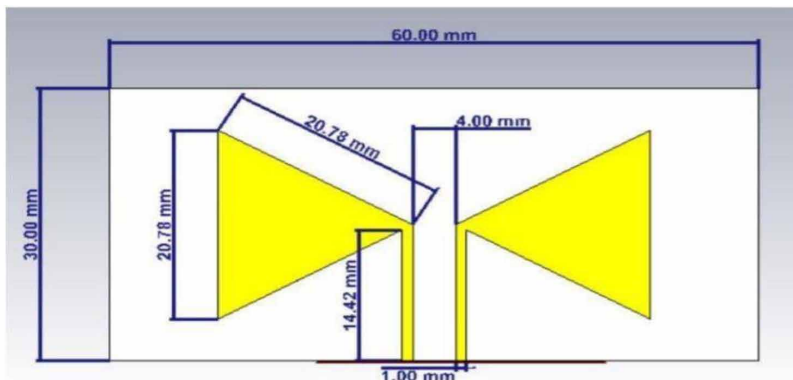


Figure 5. VSWR

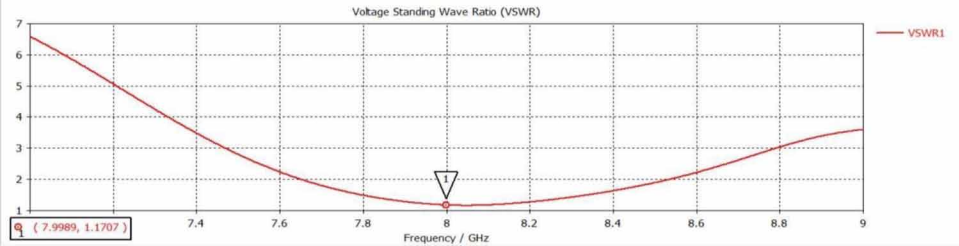


Figure 6. S11

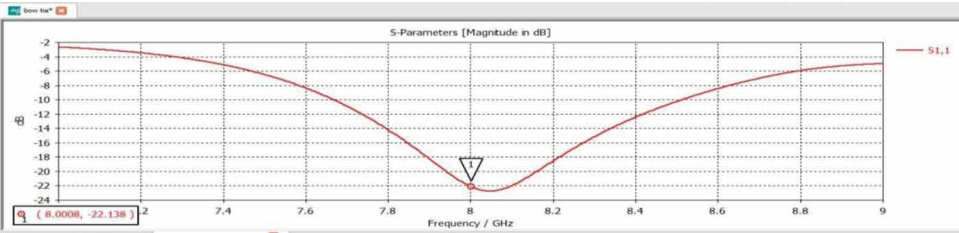


Figure 7. E-Field

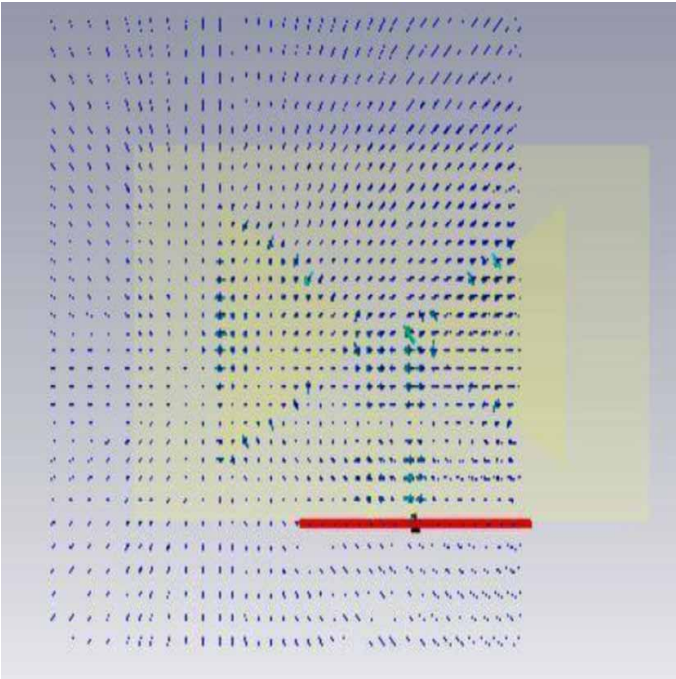


Figure 8. H-Field

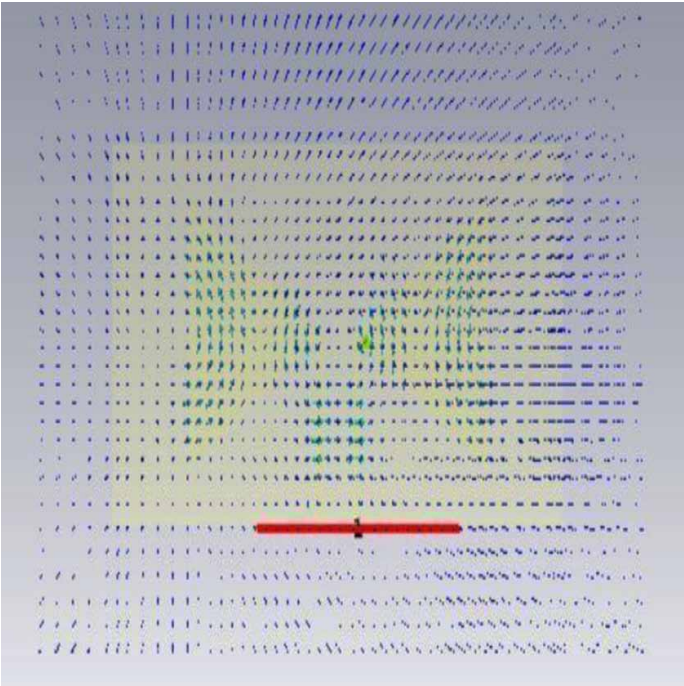


Figure 9. Polar form of Farfield

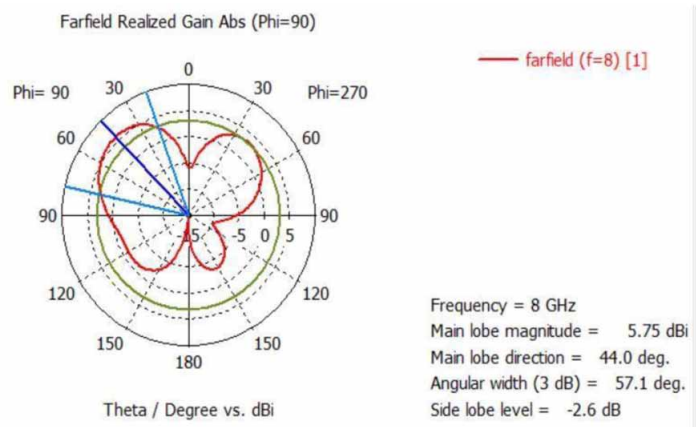
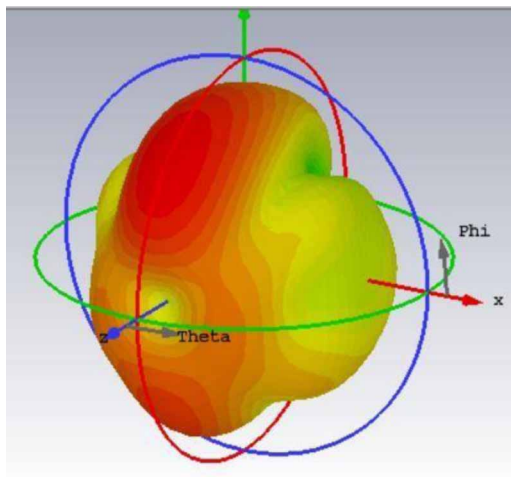


Figure 10. 3D Form of Farfield



CONCLUSION

In summary, various bow-tie microstrip antennas were designed and verified experimentally to support the optical antenna in the range of 4–8 GHz for wideband (UWB) applications. The finite integration technique (FIT)-based high-frequency electromagnetic solver, CST Microwave Studio, was used for numerical analysis. The designed antennas were fabricated and tested for different materials and substrate thicknesses. It has been observed that all antennas are well matched and accurate results are achieved. In order to overcome the bandwidth limitation of these antennas, broadband slot bow-tie antenna has been introduced. The given inaccuracy of adaptation may be that it transitions from an unbalanced to a balanced medium may inversely affect the pattern of the proposed antenna. To address this problem, it would be helpful to use a balanced–unbalanced transformer at the end of the cable, which can provide the necessary isolation to prevent common-mode currents or other methods as given. For future activity, we plan to implement one or more of these solutions to the proposed antenna in order to supply more benefits to UWB applications, specifically in medicine.

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Chapter 8

IoT–Based Wireless Microwave Power Transmission Using Rectenna

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ABSTRACT

Wireless microwave power transfer (WMPT) knowledge is measured as one of efficient energy shifting technologies. Power transmission by radio waves dates back to the early 1890s. WMPT had a long history before the recent movement towards it. This chapter proposed that the WMPT can be applied to beam-type point-point technique as well as an energy collecting system fed by broadcasting radio waves and solar powered satellites to power IoT devices. WMPT is an important technology in the practice of rectenna (rectifying antenna) to convert microwave signal to a direct current (DC) signal with good efficiency. This method of transferring the power through wireless medium will minimize the wastage of power.

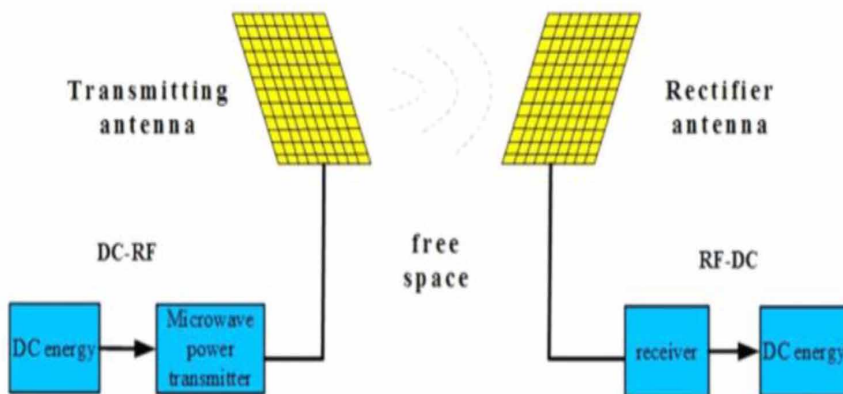
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INTRODUCTION

As the technology is growing the planet is now moving toward wireless power. We will see that now days everyone prefers to use a wireless mouse or a wireless headphone. The utilization of batteries can make this possible but the matter is that too many batteries are getting used and therefore there has got to be how by which these applications can run wirelessly and the neatest thing would be if the batteries weren't used. How can this be possible? This is often the matter which we'll attempt to solve within the design. The rectenna used will convert the RF power into dc signal and rather than batteries the appliance will have a rectenna to supply the facility. Therefore we'll have a real wireless system, which has no wires and no batteries as shown Figure 1.

Figure 1. Microwave Wireless Power Transmission.



BACKGROUND

The word 'rectenna' as we all know today was first introduced by Brown. The essential concept of rectenna may be a "rectifying antenna". In other word an antenna which can be used for receiving RF signal and a rectifying circuit which is employed to offer us DC power.

Wireless Microwave power transmission (WMPT) are often viewed as an electrical grid which generates power. WMPT is that the technology which is employed for wireless transmission of power, this may be utilized in the solar energy satellites, radio waves and power IoT. Let me explain the concept intimately. Because the satellites are orbiting round the earth 24 hour and therefore the satellites have the potential

to convert the solar energy into RF signals then beam those RF signal to the world . Array of antennas are going to be wont to capture those RF signals and therefore the rectifying circuits to convert those into DC power. If sufficient amount of array antennas are used, tons of power are often produced. The electric power station would be viewed as RECTANNA stations where RF signal would be converted into DC power (Celeste, A., J-D. L.S. Luk, J.P. Chabriat, and G. Pignolet, 1997).

IOT DEVICES

The Internet of Things is an increasing infrastructure of internet-enabled objects starting from sensors to LED light, all aimed toward increasing control, data collection, and even automation (J. O. Mcspadden and J. C. Mankins, 2002). IoT are often a huge benefit for houses when used appropriately (W. C. Brown and E. E. Eves, 1992). To unravel the connection of the electrical problem with IoT devices are going to be using microwave power transmission technology for the smart town planning (Brown. W. C., 1984). The question stands up on how long-distance Wireless Power Electricity will change the concept of IoT (H. Matsumoto, 2002). Charging are often realized in various ways, and applications using wireless power technology are expanding to mobile and portable devices, home appliances and office equipment, and electric vehicles (Shinohara N. and H. Matsumoto, 1998). Especially, WMPT technology is beneficial in providing electric power to the web of things (IoT) devices in constrained environments. Wireless Microwave Power Transmission (WMPT), the web of things (IoT), and wireless power technology will become a corner stone within the design of latest and growth of human settlements (Hatano, K., N. Shinohara, T. Mitani, T. Seki, and M. Kawashima, 2012). In smart cities, legislation is requiring a change of old practices towards efficient use of Nevertheless, electricity distribution still relies on cables for its delivery. The novelty of the system is that IoT devices and household use WMPT for electricity supply. The energy is wirelessly supplied from an access local power plant already fixed at the highest of the house (Hatano, K., N. Shinohara, T. Seki, and M. Kawashima, 2013).

Both industry and academia know that WMPT are going to be the answer to a spread of problems, including IoT devices (Ahmed and Kim, 2017). With WMPT, the device has three significant advantages to contribute to the IoT and smart house positively as shown in figures 2 and 3 (Shervin Erfani, Majid Ahmadi and Long Chen, 2017). Firstly, the rise in renewable electricity integration decreases the change of batteries repeatedly. Secondly, house growth will have a lesser impact on distribution and transmission capacity (Martin, Lars, Daniel, Roger, Bernhard, and Klaus, 2016). Finally, the proposed system will promote industrial investment by increasing IoT technology at the smart city, lowering implementation cost prices.

Figure 2. Powering IoT device wirelessly.

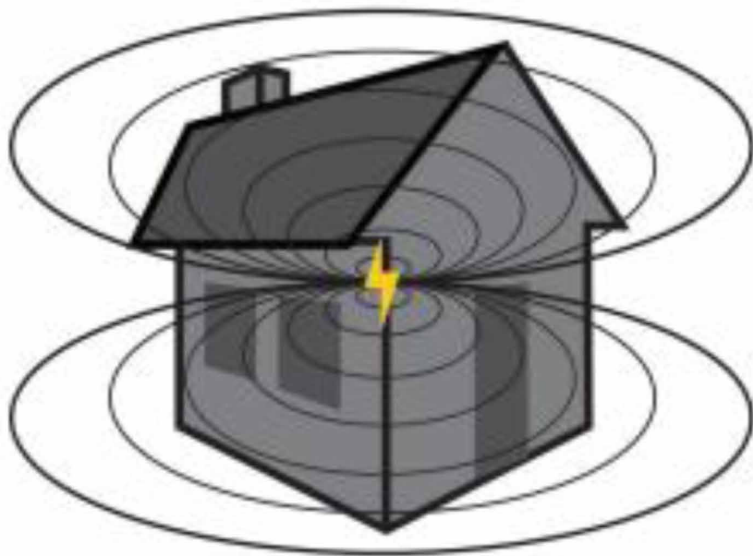
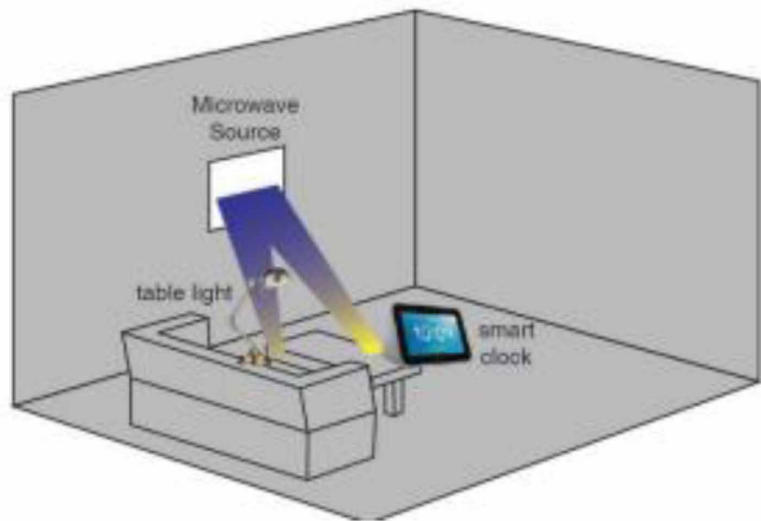


Figure 3. Power of IoT

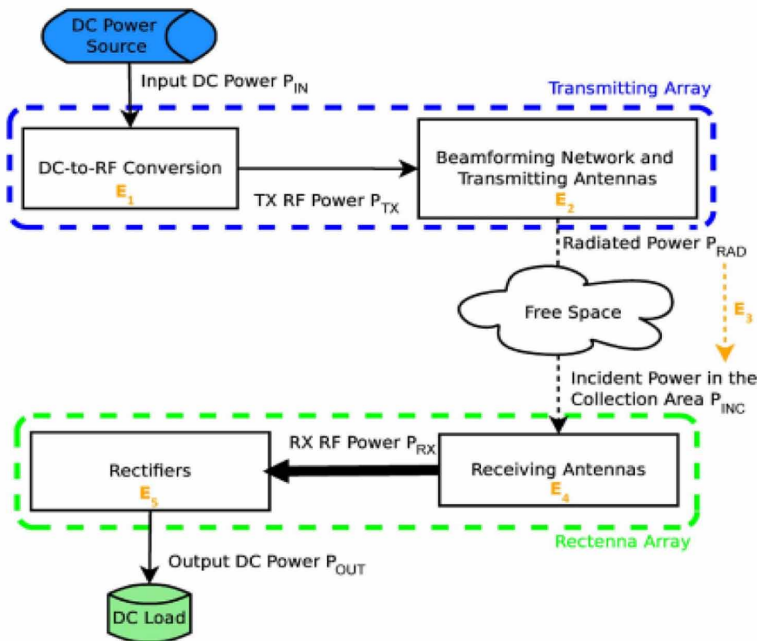


This research is toward creating a wise house and smart cities can combine between IoT and wireless power electricity (Tiago, Radu, Eduardo, Matias, and Joo, 2015). By the way, during this study, already the portable microwave station exists and can be utilized in this research and therefore the testing phase (Jian liang Li, 2017).

WIRELESS MICROWAVE POWER TRANSFER

In the Microwave transmission signal represents to the mechanism of transmission information or energy by suggests that of mistreatment magnetic attraction waves with wavelengths that may be fittingly measured in meter’s(centimeter’s) they’re referred to as microwaves as shown within the figure 4. During this wireless energy transfer through microwaves desires a supply energy of nonparticulate radiation, in addition a microwave receiver with a Direct Current (DC) rectifier to convert the microwave energy into Direct Current power (Jian, Fang, Tong, and Lin, 2016). The transmission and receiving units ought to be in line of sight (Jan, Khan and Alam Usman M, 2019). The electricity is at first regenerate into microwave energy at intervals the transmitter that is then transmitted over a distance to the receiver that encompasses a rectenna that converts these microwaves back to electricity (Hammi,

Figure 4. Microwave power transmission system

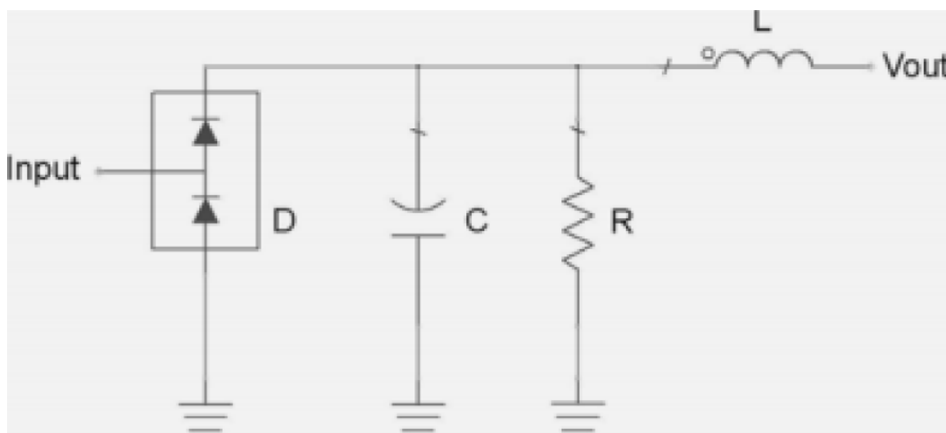


Livolant, Bellot, Serhrouchni and Minet, 2017). AC cannot be regenerate on to microwave throughout a transmitter. Initial it should be regenerate to DC mistreatment Associate in nursing generator within the receiver, the output DC from rectenna is regenerate to AC to be used (Kumari, Li X, Wu, Das, Arshad, Khan, 2016). Power beaming by microwaves encompasses a limitation for several house applications, the required aperture sizes are terribly giant because of optical phenomenon that limits antenna directivity. Wireless high power transmission mistreatment microwaves is well established (U. Saravanakumar, R. Rangarajan, R. Haripriya, R. Nithya and K. Rajasekar, 2013). Throughout this analysis tens of kilowatts are performed. These techniques reach distances on the order of a km. below experimental conditions, the microwave conversion potency was measured to be around 90%.

RECTENNA DESIGN

In the term of correcting circuit (rectenna) is made of “rectifying circuit” and “antenna”. The rectenna has the ability to collect and diode is used to rectify a microwave power to Direct Current (DC). In the rectifying antenna (Rectenna) is a passive element consisting of a rectifying diode, operated without a power source.

Figure 5. Circuit diagram of the basic rectifying circuit.



The above diagram shows a basic design of a rectenna as shown in figure 5. The antenna receives the RF signals. The signal is passed to the low pass filter by a cable which has an impedance of fifty ohm (Tao Li, Liheng Wu, and Zheng Chen, 2015). The low pass filter will filter the specified frequency in order that unwanted

frequency doesn't undergo the rectifying circuit. The low pass filter is additionally wont to stop the harmonics reflected back from the diode. The rectifying circuit is employed in double configuration. The double configuration is employed in order that maximum RF signal are often converted into DC power. Schottky diodes are going to be utilized in the rectification process as they need low drop across it (M. Raveendra, U. Saravanakumar, G. A. Kumar, P. Suresh and S. P. D. Pedapalli, 2021).

The overall efficiency of the rectenna are often determined by $\eta = P_{dc}/P_{inc}$, P_{dc} is that the DC output power. P_{inc} is that the incident RF power (Mohamed M. Mansour and Haruichi Kanaya, 2019).

There are pretty some researchers of the rectifying antenna (rectenna) elements. Well-recognised studies humans of the rectenna include withinside the Texas A&M University in United States of America (USA), In the National Institute of statistics and technology, beyond CRL in the united states of Japan, and University of Kyoto in Japan. The antenna of rectenna are regularly like antenna dipoles, antenna Yagi-Uda, antenna microstrip, antenna monopole, antenna loop, antenna coplanar patch, antenna spiral, or perhaps parabolic antenna. In the rectifier antenna rectenna can take any type of rectifying circuit like single shunt rectifier, full-wave bridge rectifier, or different hybrid rectifiers (Manolis, Demosthenes, Dimitrios, 2019). The circuit, in particular the diode, especially controls the RF-DC conversion performance. Silicon Schottky barrier diodes have been in advance used for the preceding rectennas. New diode gadgets like SiC and GaN are believed to increase the performance. In the rectennas with Field Effect Transistor or excessive electron mobility transistor (HEMT) have seemed in current years. The rectenna the use of the energetic gadgets isn't a passive element. The most effective shunt rectifier is commonly used for the rectenna. It includes a diode inserted to the circuit in parallel, a $\lambda/4$ dispensed line, and additionally a capacitor inserted in parallel. In a perfect situation, 100% of the acquired microwave strength have to have been transformed into DC strength. Its operation are regularly defined theoretically via way of means of an equal technique of a F-elegance microwave amplifier. The $\lambda/4$ four dispensed line and consequently the capacitor each permit most effective even harmonics to float to the load. As a result, the wave shaped at the $\lambda/4$ dispensed line functions a π cycle, which guidelines the wave shape can be a full-wave rectified sine shape. The planet document of the RF-DC conversion performance amongst evolved rectennas is near ninety% at 4W enter of two .forty five GHz microwave. Many different rectennas withinside the global have about 70 – ninety to attempt 2.45GHz or 5.8GHz microwave enter (Achraf, Romain, Marjorie, 2018). The RF-DC conversion performance of the rectenna with a diode exceptionally relies upon at the microwave strength enter and consequently the linked load. When the power or load is not matched to the optimum, the performance will become considerably low (Fig.5.). The diode has its very own junction voltage and breakdown voltage.

If the enter voltage to the diode is decrease than the junction voltage or is extra the breakdown voltage, the diode would not display a rectifying characteristic. As a result, the RF-DC conversion performance decreases with a lesser or extra enter than the optimum.

The rectifier rectenna is an often considered as a base station for a geo-stationary satellite. In the Microwaves of two 45 GHz frequency are transmit power from the satellite to the rectenna. It involves a mesh of a group of dipole antennas connected to diodes to convert the frequency energy to direct current voltage, which is then changed to regular alternating current electricity and then wired to homes, factories, etc (Faruk Erkmen, Thamer S. Almoneef, and Omar M. Ramahi, 2017).

With the usage of multiple frequency bands in wireless communication systems, some dual-frequency rectenna are developed. In these designs, the antenna elements usually have a dimension of 1 wavelength length or maybe more. In the some of researcher to ideated a completely single dual frequency rectifying antenna operating at 2.45 and 5.8 GHz (Yanyan Shi, Jianwei Jing, Yue Fan, Lan Yang, and Meng Wang, 2018). Rectenna contains of two compact ring of slot antenna, a hair pin Low Pass Filter and a rectifying circuit. By using meander line structure in annual slot ring antenna, the dimensions reduction upto 52% was observed, whereas 2nd and 3rd harmonics of both operating frequency was suppressed by hairpin filter. it had been found that the Rectenna has gain of two .19 and 3.6 dBi while RF to dc conversion efficiency is 65% and 46% at 2.45 and 5.8 GHz respectively when the power density is 10Mw/cm² .However, a proposed a completely unique dual frequency CP shorted ring slot antenna for wireless power transmission (WPT) at 2.45 and 5.8 GHz. it constituted of two nested microstrip fed shorter annular ring slot antenna and two rectifier circuits. The circuit diagram of rectifier is given in Figure.5 At a maximum distance of two m, output dc voltage of 2 V at the lower waveband and greater than 1 V at the upper waveband are often achieved. It had also been found that the axial ratio of two .2 Db in lower band while 1.3 Db in higher band as shown in Figure 5 (Chen Xu, Yuan Zhuang, Hongjian Han, Chaoyun Song, Yi Huang, Jiafeng Zhou, 2018).

In the microwave rectifying antenna works and also showed the processes used during the construction of the panel the dipole antenna has a length of 3 cm which corresponds to the wavelength of the microwaves and a width of 0.5 cm. This chapter is create due to the my research in a “IOT based Wireless Microwave Power Transmission” the wireless transmission of electricity through microwaves which showed how solar satellites in the would work by having a much more higher amount of charge being produced by higher energy radiation restricted by our atmosphere. In the radio frequency (RF) rectennas have been used for the numerous forms of wireless energy transfer. In the microwave range, experimental devices have sickly-looking at a power alteration efficiency of 86-92%. The record conversion efficiency

for a rectenna is 91.6% for 2.45 GHz with lower efficiency of about 80% achieved 5.86 GHz

POINT-POINT TECHNIQUE

It's easy to image a point-to-point WMPT via radio waves in over km distance rather than a wired power transfer. Within the 1960s, point-to-point WMPT operating within the km range via microwaves was highly expected for WMPT application. However, the dimensions of the transmitting and receiving antennas was decided by theory and that they were overlarge to understand a billboard point-to-point WMPT application with reasonable cost as an alternate to wired power transfer. Point-to-point WMPT systems were proposed for during this paper. They need developed a rectenna array. Under certain conditions, like providing electrical power to a lonely mountain top or an island where the value of a wired power supply is just too expensive and/or electric power needs are sporadic, the point-to-point MPT system features a distinct advantage over wired power transfer.

Figure 6. Point-to-Point WMPT

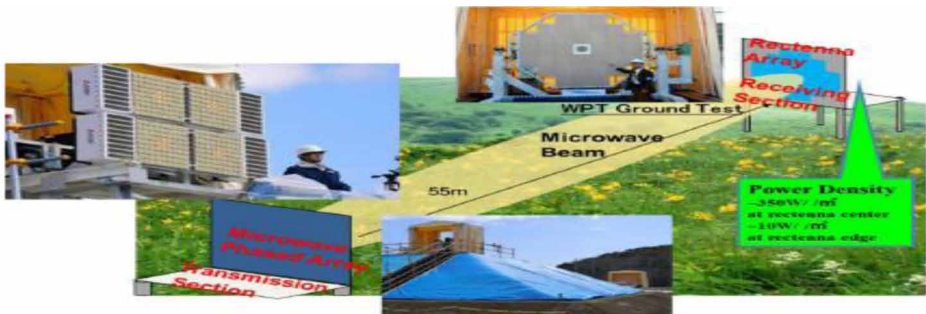


Figure 7. Rectenna array as a receiver of WMPT



Point-to-Point solar energy Satellite WMPT is design 5.8 GHz, 1.8 kW microwave (Figure 6 and 7). The microwave is transmitted from 2.5 cm thickness phased array with GaN MMIC amplifiers and 5-bit MMIC phase shifters. Efficiency of the GaN high power amplifier is approximately 70% at 7W, 5.8 GHz. A recto directive target detecting and rotating electromagnetic vector (REV) method is adopted to detect an edge of a rectenna and to regulate a microwave beam. The long distance WMPT was administered at 500 m distance with 2.45 GHz, 10 Kw as results of a solar energy Satellite.

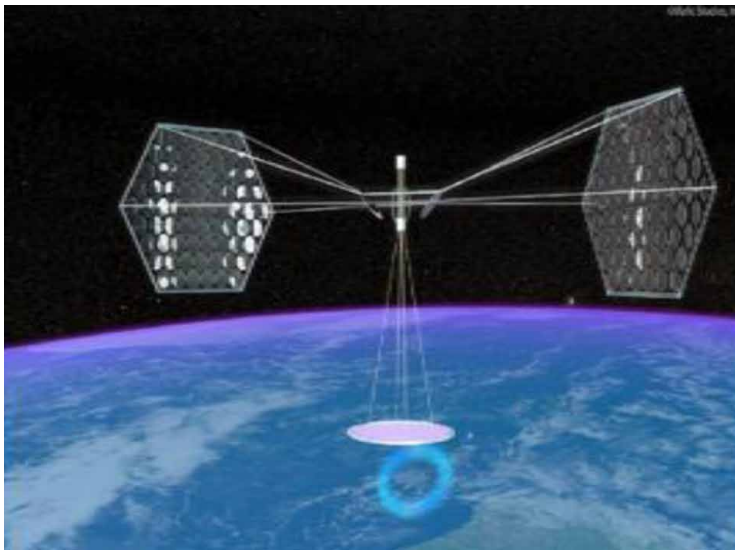
Figure 8. Point-to-Point Solar Power Satellite WMPT



SOLAR ENERGY SATELLITES

In the Solar Energy Satellites (SES) is the main application of microwave power transmission. In the SES, solar energy is surrounded in space and converted into electricity. The electricity is then converted into microwaves and transmitted to the whole wide world. The microwave power will be captured with antennas and converted into electricity as shown in figure 8 and 9.

Figure 9. A Design of Earth Receiving Station (Rectenna)



The solar power Conversion - star Photons to electricity (DC) 2 elementary strategies of changing daylight to electricity are studied: electrical phenomenon (PV) conversion, and star dynamic (SD) conversion. The Most analysis of solar power satellites have mainly centered upon electrical phenomenon conversion (commonly stated as “solar cells”). The Electrical phenomenon conversion utilizes semiconductor cells (e.g., semiconducting material or Ga arsenide) to convert photons into electrical power directly via a quantum mechanical mechanism. Electrical phenomenon cells are not ideal in follow, as material purity and process problems throughout production have an effect on the performance; every has been regularly improved for a couple of decades. Some new, thin-film approaches have lesser potency (about two hundredth vs. thirty fifth for best), however they are lighter and cheaper. During a SPS implementation, electric cells can doubtless diverge from the glass-pane protected electrical phenomenon cell panels kind of like many from

current terrestrial use, since they are going to be designed for weight, and may be optimized to be tolerant to the area radiation surroundings. They are doing not need the structural support needed for terrestrial use, wherever the significant gravity and wind loading demands structural necessities on terrestrial implementations.

To convert the DC strength to microwave for the transmission via antenna toward the earth's receiving antenna, microwave oscillators like Klystrons, Magnetrons are pretty regularly used. In transmission, an AC is made in the factors via way of means of making use of a voltage on the antenna terminals, inducing the climate to radiate an electromagnetic discipline. The DC strength has be transformed to microwave strength on the transmitting cease of the device via way of means of making use of microwave magnetron. The warmth generated withinside the microwave is because of the excessive voltage device. The nucleus of the excessive voltage device is placed withinside the magnetron tube. The magnetron is a diode kind tube, which makes use of the interplay of magnetic and electric powered discipline in the hollow space to deliver oscillation of a simply excessive height strength. It employs radial discipline, axial magnetic flux, anode shape and a cylindrical cathode. The cylindrical cathode is surrounded via way of means of an anode with cavities that generates a radial magnetic discipline. The magnetic flux way to everlasting magnets which might be brought perpendicularly. The magnetic discipline is generated withinside the downward path because of the North Pole above and South Pole below. The electrons transferring via the gap generally tend to create a magnetic flux round themselves. The magnetic flux on proper aspect is weakened due to the fact the self-brought about magnetic flux has the impact of cancelling itself from the everlasting magnetic flux. Hence the electron trajectory bends therein path main to a round movement of the anode. This manner starts offevolved with a voltage being carried out to the cathode, which reasons it to warmth up. The temperature upward thrust induces the emission of extra electrons. This cloud of electrons might be repelled farfar from the charged cathode. The area and speed in their movement might growth with the depth of carried out voltage. The momentum is furnished via way of means of bad 4000 V DC. The electrons explode from cathode like tiny rocket.

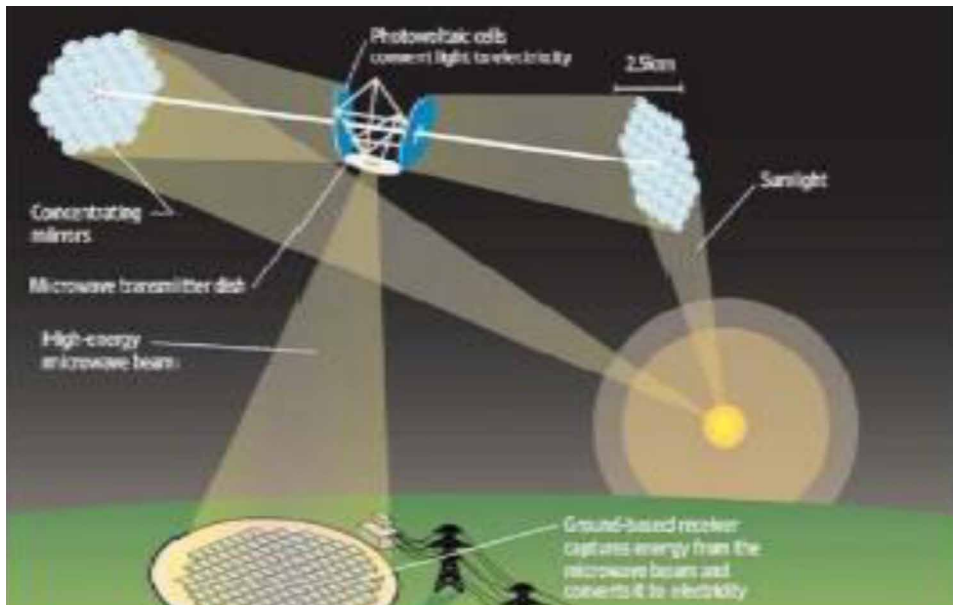
The impact of this static magnet has a tendency to deflect the electrons farfar from the anode. But, because of the mixed impact of electrical and magnetic flux at the electron trajectory they deviate it to a course at nearly proper attitude to their preceding route main to an increasing round orbit spherical the cathode, which in the end reaches the anode. The whirling cloud of electrons shape a circling pattern. Due to the interplay of this rotating area chare wheel with the configuration of the floor of anode, an AC of very excessive frequency is produced inside the cavities of the anode. The output is taken from one of those cavities thru a waveguide. The reasonably-priced and simply to be had magnetron is hired in ground. Due to the pulsed operation of these magnetrons they generate a good deal noise. A sun

strength satellite tv for pc running with 10 GW of radiated electricity ought to radiate a electricity of one microwatt at some point of a four hundred Hz channel width.

Power transmission thru radio waves are pretty frequently made greater directional, permitting lengthy distance energy beaming, with shorter wavelengths of electromagnetic waves, frequently inside the microwave range. Power beaming the use of microwaves has been devised for the transmission of strength from orbiting sun strength satellites to Earth and subsequently the beaming of energy to spacecraft leaving orbit has additionally been considered. The dimensions of the additives may also be decided with the aid of using the transmitter to receiver distance, the wavelength and consequently the Rayleigh Criterion or diffraction limit, utilized in wellknown frequency antenna design, which additionally applies to lasers. Moreover, the Rayleigh criterion Airy's diffraction will now no longer decide an approximate spot length at an arbitrary distance from the aperture. The Rayleigh criterion tells that any radio emission microwave or beam will unfold and emerge as weaker and diffuse over distance; the bigger the transmitter antenna or laser aperture as compared to the wavelength of radiation, the tighter the beam and subsequently the lesser it'll unfold as a feature of distance. Smaller antennae additionally be afflicted by large losses because of aspect lobes. However, the idea of laser aperture differs from an antenna as proven in figure.10.

Normally, a laser aperture pretty large than the wavelength reasons multi-mode radiation and regularly collimators are used earlier than emitted radiation couples right into a fiber or into space. Ultimately, beam width is bodily determined via way of means of diffraction because the dish length in regard to the wavelength of the electromagnetic radiation is used to make the beam. Microwave strength beaming is regularly greater green than lasers, and can be much less at risk of atmospheric damage. The strength tiers are then calculated via way of means of combining the above parameters collectively and including in advantage or losses to antenna and due traits of the transparency of the medium thru which the radiation passes. That procedure is called calculating a hyperlink budget, however, the above arithmetic would not account for atmospheric absorption.

Figure 10. Design of solar power system



ADVANTAGES OF SPACE SOLAR POWER

- 1) The Unlike oil, gas, ethanol, and coal plants, space solar energy doesn't emit the harmful greenhouse gases.
- 2) The Unlike bio-ethanol or bio-diesel, space solar energy doesn't consume valuable farm land or depend upon natural-gas-derived fertilizer.
- 3) The Dissimilar atomic control plants, space solar energy will not produce hazardous waste, which must be stored and guarded for a lot of years.
- 4) The Unlike terrestrial solar and wind generation plants, space solar energy is available 24/7.
- 5) The Dissimilar atomic power plants, space solar energy is not an easy targets for terrorists.
- 6) The Dissimilar coal and nuclear fuels, space solar energy doesn't jeopardize the environment.
- 7) The Space solar energy will ultimately provide complete energy independence for the nations that develop it, eliminating a serious national competition for limited Earth-based energy resources.

CONCLUSION

We can conclude that the day isn't far when there will not be a wire & stop power theft. Batteries become redundant. The demand of electricity can be met. The concept remains only incepted at the moment. Specifically, the electromagnetic interference (EMI) characteristics of the rectenna must be improved. It'll even be necessary to assess impact of untamed scale use of microwave power transmission on use of the frequency spectrum. The Solar power (SP) knowledge and idea is more and additional attractive because it's more advantageous than radio emission solar energy. It has been predicted that by 2030, the planet will require 40 TW power from other source of renewable energy sources and solar power alone has the potential of manufacturing around 600TW. Greenhouse gas emissions are at check. Thus the matter of worldwide global warming is going to be solved to a good extent. In addition, solar energy systems appear to possess many significant environmental advantages in comparison to other approaches to meeting increasing terrestrial demands for energy. Even though the success of solar energy depends on strategic development of key technology, it's certain the result are going to be well worth the effort. Solar energy can completely solve our energy crisis in the future. In this paper, we studied how we can power IoT devices wirelessly. We proved the likelihood of using the microwave system to move energy from one side to the opposite inside house. During this research, we tested, and we approved that we will produce electricity from frequency to charge IoT electronic devices batteries.

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Chapter 9

Pyramid–Framed Extremely High Recurrent RFID Tag Antenna With Polarization Diversity for IoT Applications Utilizing Characteristics Mode Analysis

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ABSTRACT

This chapter proposes a unique twofold-enabled name-getting wire plan for exceptionally high dull radio recurrent seeing insistence (UHF RFID) with polarization or rehash band mix using mode appraisal for unquestionably high irregular radio recurrent seeing attestation (UHF RFID) with polarization or rehash band blend using mode evaluation for incredibly high discontinuous radio recurrent seeing assertion (UHF RFID). The proposed mark game-plan joins two drifter line

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ties or dipole-like turn of events (appears to be like a planar pyramid), shorting nails, and a ground plane. Laying an upper fix over FR 4 substrate and shorting it from all sides to the ground plane with shorting nails is a pivotal strategy. In the wake of completing the brand name mode evaluation in the fundamental course of action, inclining openings are made to move the boisterous lead of related brand name modes to the lower go over band. In any case, the characteristics strategies for inclining holes-based plan in the US RFID band really show inductive lead (902 - 928 MHz).

INTRODUCTION

Radio recurrent ID (RFID) and the Internet of Thing (IoT) are changing this world into a quick planet by changing over genuine articles into sharp contraptions. RFID with its brought together advances, for example, IoT, Fifth time flexible correspondence association (5G) has been arising into various conspicuous evidence and recognizing applications, including retail the heap up, store network the heap up, and so on (Perret et al., 2012). The majority of these applications require the UHF imprints to be mounted on various testing climate surfaces like water, wood, metal, and high permittivity dielectric surfaces (Chen, 2009) (Son & Jeong, 2011).

The UHF names are generally consoling an aftereffect of their capacity of giving high information move rate, since a long time past read range, unimportant expense printable development (Dobkin, 2013) (Svanda & Polivka, 2015). Regardless, the affectability of UHF names towards various naming surfaces is especially problematic. In like, a few uses like redid shopping truck require mark radio wires with heading savage highlights. By a long shot the majority of the monetarily accessible names include direct charmed dipole-like turns of events, which all things considered have a semi omnidirectional radiation plan that further prompts bearing affectability issues (Zhang et al., 2015).

Consequently, to persevere through this affectability issue of RFID marks, a circularly captivated peruser radio wire was generally utilized. Notwithstanding, there is a polarization blend deficiency of 3-dB related with this prompt tag and roundabout peruser radio wire. Another conceivable game-plan would plan of imprint getting wire with circularly enchanted characteristics. A circularly fascinated UHF RFID tag was proposed in (Yan, 2019) for metallic road post applications utilizing brand name mode (CM) appraisal. Two CM modes are invigorated utilizing closeness coupled feed and Wilkinson power divider to accomplish 45o fundamental bar course for straightforwardness of looking at the tag. In any case, the size of the road shaft tag is enormous with 90 mm length and 3 mm substrate thickness, which makes it

unacceptable for some unimportant expense applications. A circularly spellbound (CP) mark radio wire dependent upon square-ring and wander strip structure has been proposed in (Lu & Chang, 2017). In any case, the general parts of this square ring tag are huge 54x54x5.2 mm³.

In (Inserra & Wen, 2019), a wandered crossed dipole based CP radio wire was proposed for UHF tag or obviously handheld peruser applications. This name configuration contains plan power divider wandered at the middle and encompassing ring. The including ring goes most likely as a T-match network for impedance arranging with RFID chip. The general course of action of the imprint model is 54x54x0.4 mm³, with 3-dB focus degree going from 906-932 MHz. A wandered circle based CP getting wire was proposed in (Chen et al., 2016).

The general size of 58.6x58.6 mm² for CP name getting wire was developed utilizing wandered circle strategy and open opening. Also, this wandered circle game plan gives a 3-dB basic degree (AR) move speed going from 921-929 MHz. Along these lines, by a long shot the majority of the round amazed imprint radio wires typically require execution of two even modes, which is conventionally developed utilizing shorting pins or vias that make this game plan exorbitant and bulkier. Recorded as a printed copy writers proposed twofold entranced name getting wire with straight peruser radio wire to settle course affectability issues.

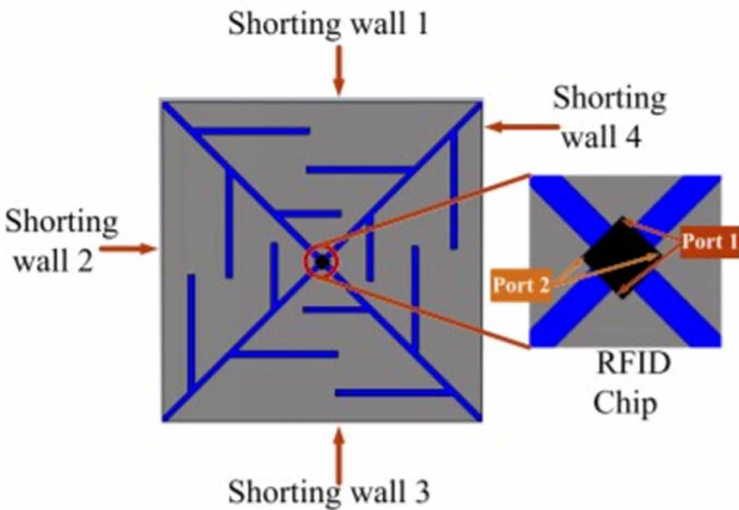
In (Yang & Son, 2016), a twofold stimulated twofold planar redid F name getting wire with polarization collection was proposed. Notwithstanding, this twofold PIFA arrangement tended to an enormous impression 64x64x2 mm³. Similarly, the intercession of lumped parts and 12 vias have made this twofold PIFA plan complex, since the resonating rehash of this mark configuration was essentially relies on the situation of vias. A dipolar fix tag with bearing insensitive breaking point was proposed in (Bong et al., 2018). However this dipolar fix has lessened assessments, at any rate it has little data transmission considering insignificant the genuine impedance respect (3 to 4 Ohms). Additionally, this name offers a read degree of 3.5 m on metal and under 2 m on dielectrics. Another metal mountable collapsed crossed-dipole with polarization collection highlights having assessments 40x40x1.6 mm³ was orchestrated in (Diversity & Tag, 2020). This cross dipole based tag has a parasitic metal ring set under the radiator to tune down the full recurrent that makes this course of action a piece complex. In like manner, this imprint course of action shows a read degree of 5.6 m to 7.7 m in the wake of mounting on various metal articles. A few methodologies have been inspected in the arrangement to plan twofold and circuitous entranced imprint plan (Dobkin, 2013) (Svanda & Polivka).

In any case, CM appraisal is changing into the most encouraging approach on account of its expecting breaking point of completely evaluation and coordinated technique towards getting wire plan. Of late, different kinds of investigation utilized CM appraisal for UHF RFID name getting wire plan and different applications

(Sharif, 2019a) (Dicandia et al., 2018). Subsequently, a twofold enchanted UHF RFID mark radio wire having polarization or rehash band combination highlights has been proposed in this work using CMA to conquer the bearing affectability issues. The imprint arrangement perceived genuine 3D read range plan with polarization grouping and expanded read range on metallic articles (even with straightly invigorated peruser radio wire).

The proposed mark course of action fuses two wandered dipole like plans, shorting hits and a ground plane. The aslant openings are passed on to move the full lead of CM modes towards lower rehash band. Later on, basically all modes are now depicting inductive direct in the key recurrent band. Along these lines, the little identical openings (presenting capacitive lead) are passed on to unravel the reverberation direct of modes in the fundamental RFID band. Following to examining the attributes current model, the RFID chip was plainly arranged at the current minima with no other outer getting sorted out with circuit. The radio wire assessments are refreshed utilizing CST Microwave studio to achieve a design impedance match with Monza 4 D RFID chip from Impinj. Moreover, the twofold animated imprint plan offers a read extent of 4.5 m and 8.5 m coming about to mounting on low permittivity dielectric materials and 200x200 mm² metal plate, freely.

Figure 1. Dual polarised tag configuration with shorting stubs resulted after CMA



CHARACTERISTIC MODE ANALYSIS (CMA)

Trademark modes are dened as current strategies for coordinating articles that depend upon their shapes and sizes. CM can be numerically resolved for any emotional framed driving bodies. Moreover, these current modes are self-sufficient of any feed or excitation source and can be gotten by settling eigenvalue conditions as follows (), ():

$$X(\vec{J}_n) = \lambda_n R \vec{J}_n \quad (1)$$

where J_n are eigen streams or eigenfunctions, λ_n are the eigenvalues, X and R is whimsical and authentic sections of Mother impedance grid, separately. As brand name modes (CM) are even, accordingly, the total current on radio wire surface or any exuding article can be controlled by adding all of these brand name mode streams as follows (Yan, 2019), (Sharif et al., 2018), (Gao et al., 2017):

$$J = \sum_n \alpha_n J_n = \sum_n \frac{V_n^i J_n}{1 + \lambda_n} \quad (2)$$

where n are the unpredictable modular weighting co efficient (MWC) related with every mode and can be calculated as follows (Sharif et al., 2018), (Gao et al., 2017):

$$\alpha_n = \frac{V_n^i J_n}{1 + \lambda_n} = \frac{E^i, J_n}{1 + \lambda_n} \quad (3)$$

Additionally, the all out far- fields related with absolute prompted flows can likewise be resolved as follows (Sharif et al., 2018):

$$E = \sum_n \alpha_n E_n$$

$$H = \sum_n \alpha_n H_n \quad (4)$$

where E_n and H_n are radiation far-fields related with explicit brand name mode current. Also, the secluded importance (MS) can be characterized as (Sharif et al., 2018):

Figure 2. Eigenvalue plot of the first six modes of the initial structure.

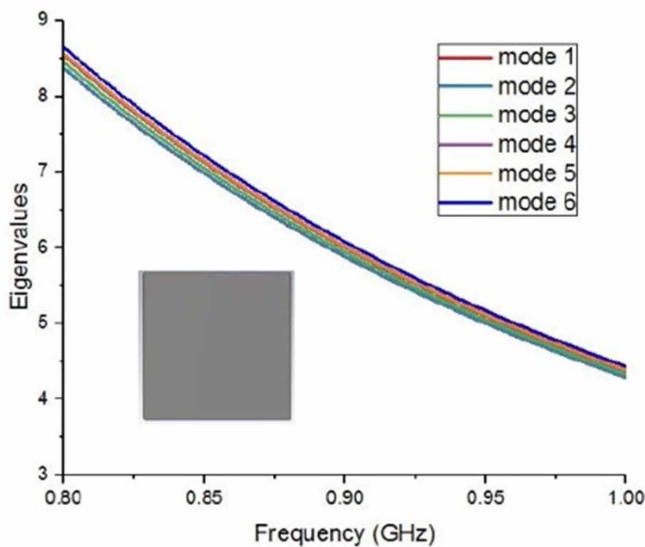
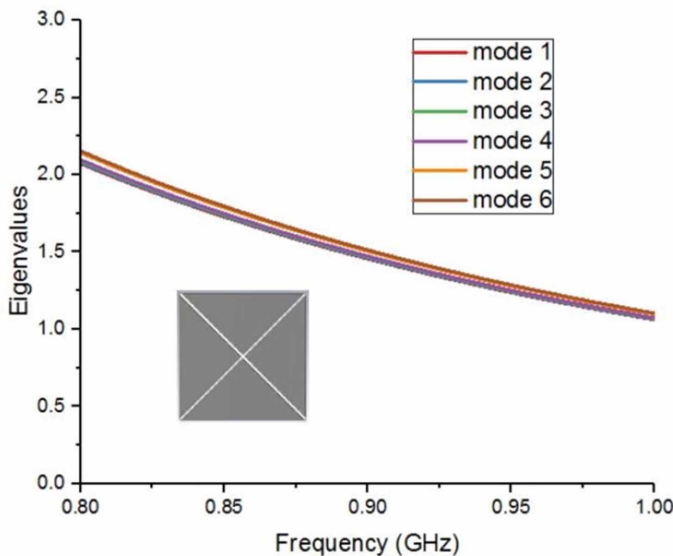


Figure 3. Eigenvalue plot of the first six modes of diagonal slots based structure.



$$MS = \left| \frac{1}{1 + \lambda_n} \right| \quad (5)$$

The measured importance is a key part of brand name mode (CM), since it gives information concerning the coupling limit of each CM with outside excitation source.

UHF RFID TAG ANTENNA DESIGN USING CMA

The CM appraisal of the fundamental arrangement was never really down the full modes and their associated rehearses. The starting arrangement contains an upper fix wrapped on 50x50 mm² FR4-substrate, a ground plane, and shorting dividers or nails related with ground plane from four sides the eigenvalue plot of the underlying six modes related with the secret arrangement. All of the six modes portray inductive practices in the recurrent band of interest going from 902 - 928 MHz. Significantly more unequivocally, the modes are from the start presenting resonating conduct, some spot in the middle 3 to 4 GHz.

Consequently, the slanting spaces are made to counter inductive lead of modes and further abatement modes resounding towards a generally lower rehash band. The eigenvalue plot related with the underlying six systems for corner to corner opening based turn of events. The slanting space fills two necessities here; one is comparing down the flourishing frequencies a piece and counter inductive direct. Also, it gives the motivation to twofold UHF RFID tag for everything considered polarization arrangement or rehash band combination.

To counter the inductive direct of modes further, three negligible comparable openings are added to each wing of necktie formed dipole. Thusly, the total imprint course of action takes after with sky perspective on the Great Pyramid of Giza. The eigenvalue plot of the underlying six procedures for planar pyramid-formed name plan with two askew and three comparable spaces at each wing. The modes 1, 2, 3 and 4 show reverberating practices close recurrent band of interest. Notwithstanding, the modes 5, and 6 again show inductive direct. To embrace it further, the specific significance plot of the underlying six modes was in addition portrayed. Beginning four modes are basic modes since their $(MS > 1/\sqrt{2})$. While modes 5 and 6 are non-immense modes due to their $(MS < 1/\sqrt{2})$. As such, mode 1, 2, 3 and 4 show full lead in required recurrent band nearby MS respect ways to deal with oversee 1 (enormous modes).

Hence, polarization or rehash band combination can be developed through attentively invigorating somewhere near two modes (among 1, 2, 3 and 4). To explore it further, the attributes far-field delineation of every mode. The credits far-field setup helped us in picking the modes that should be invigorated attentively to accomplish polarization arrangement. For mode 1, it shows radiation along the shorted dividers of name plan nearby an invalid in C Z course. Mode 2 and 3 have a reasonable far-field plan, which is principal for polarization arrangement. Besides, mode 3 and 4 can correspondingly be restless to pass on polarization collection; notwithstanding, this pair needs further movement of cutoff points.

Besides, mode 5 and 6 are not portraying any obliging part with respect to polarization collection or obviously read range improvement. It is worth to demonstrate here that mode 1 saw a field dropping in C z-heading. Regardless, it gives phenomenal far-field credits along abbreviated sides of UHF names. This reality can be mishandled to get a genuine 3 D radiation plan and thusly empowers the investigating of tag from various course, even from upper and lower sides of the tag. Additionally, to invigorate express modes and to find a reasonable locale for RFID chip plan for polarization variety, the attributes streams identified with relating strategies for pyramids mark structure. The mode 1 keeps an eye on symmetric current arrangement that happen as expected into withdrawal of the field in the C z-bearing. Mode 2 positions solid current task just along level dipole, which is essential for far-field in the regardless, heading.

Besides, mode 3 shows solid current dissipating along vertical dipoles and powerless current task in even dipoles. The mode 4 in like way shows solid current dispersing long vertical dipoles nearby week current dissipating in the level dipole. Additionally, mode 4 has a frail vertical current development when showed up distinctively comparable to mode 3. Modes 5 and 6 don't have exceptional current spread, which prompts frail far-field attributes. As exhibited by (Martens, 2011) and (), to invigorate a specific mode, inductive coupling portion (ICE) should be put at current maxima.

Obviously, to empower a mode, capacitive coupling section (CCE) should be set at current minima. For our situation, since RFID chip is naturally a capacitive portion. Thusly, we put RFID chip at current minima straightforwardly to invigorate unequivocal modes. The game-plan of RFID chip straightforwardly at current minima gives an extra benefit that is to put forth an attempt not to any match circuit or balun for chip impedance arranging, which is fundamental for cost saving in RFID marks. Along these lines, this mode pair (2, 3) should be restless to accomplish polarization variety. The modes 2 and 3 current dissipating shows current minima at the tip of the pyramid-shaped wing. In that capacity, the RFID chip should be put right now to stimulate modes 2 and 3. It is worth to decide here, in the wake of setting the

RFID chip at the tip, it will in addition strengthen different modes not altogether, for example, mode 1 and 4 since these modes moreover have current minima close to the tip of the pyramid-shaped wing.

At long last, the proposed getting wire configuration occurred after CMA is appeared. To comprehend which modes will be reinforced by port excitation and to separate brand name modes execution, the CM evaluation was performed by putting a CCE as port 1 nearby even pyramid wings. Thusly, the standardized MWC plentifulness by animating basically port 1 joined to a level pyramid dipole wing is appeared. The port 1 CCE enables mode 2 much more gainfully nearby excitation of modes 3 and 4 nearly. All things considered, the normalized MWC shows mode 2 is more basic mode when wandered from mode 3 and 4.

Essentially, the normalized MWC achieved the wake of putting CCE at port 2. In like manner, the port 2 CCE stimulates mode 3 much more successfully nearby excitation of modes 4 halfway. A fascinating miracle happens in the wake of engaging both port 1 and 2 utilizing CCE. The standardized MWC abundancy for both port excitations. This twofold port arrangement engages mode 2 and 3 gainfully and modes 1 and 4 halfway. To get a handle on why the mode 1 halfway invigorated with twofold port arrangement, let us hint Fig. 6 of qualities current vehicle related with mode 1.

The mode likewise shows inferred current minima at tips of pyramid dipole wings. The mode 1 empowered reasonably since the authentic current minima of mode 1 happens at four corners taking into account current fixing. The deficient excitation of mode 1 is ideal due to giving the restriction of investigating the tag from various sides.

SIMULATION AND MEASUREMENT RESULTS

The pieces of the twofold captivated UHF RFID tag are further developed further utilizing the full-wave reenactment alternative of CST Microwave studio. The thickness of the substrate shifted from 1 mm to 4 mm. It will overall be seen that changing the thickness of the substrate changes the width of the shorting divider/stub, which is a significant breaking point in picking the impedance of the tag. Along these lines, the augmentation in the thickness of the substrate (t) passes on a riddle arranging between RFID chip and imprint impedance because of an expansion in the nonexistent a piece of the tag, as shown. The authentic impedance of the name reduces as the thickness of the substrate increments.

Notwithstanding, the radiation capability of the tag improves with an expansion in the thickness of the substrate. Since the expansion in substrate thickness builds the distance between the tag and metallic plane. Subsequently, the radiation capability improves. Obviously, the nonexistent impedance and radiation capability of the tag are diminishing as the thickness of the substrate reduces. Consequently, the best worth of substrate thickness was taken as 2 mm. The duplicated nonexistent and authentic impedance of twofold amazed imprint getting wire for the two ports.

The eccentric impedance is going from 140Ω to 150Ω in the significant recurrent band, while genuine impedance is going from 5Ω to 8Ω in the US RFID band. As exhibited by the datasheet, the authentic impedance of Impinj Monza 4 D chip is $11-143j$ at 915 MHz (). The nonexistent piece of the name radio wire is made with well to counter the unusual piece of the Monza 4 D RFID name chip. Regardless, the genuine impedance of the name radio wire is genuinely less when veered from the affirmed impedance of the chip. Besides, the S11 or S22 limit for the two ports in the wake of mounting on 200×200 mm² metal plate is portrayed.

The tag getting wire accomplished 3-dB move speed going from 900 MHz to 940 MHz (approx., 40 MHz). Besides, the S21 or S12 breaking point on the other hand segment between two ports. The worth of S21 limit around - 45 dB in the recurrent band of interest shows famous parcel between two ports of the proposed mark getting wire. Also, the presentation of proposed mark radio wire like impedance, S11 and S22 limit stays same either in free space of course in the wake of mounting on 200×200 mm² metal plate. The execution of proposed mark stays immaculate even on low permittivity dielectric materials (relative permittivity respects going from 1 to 7).

To show twofold polarization, the surface current development and far-field radiation delineation of twofold stunned plan are acquired by running the full-wave reenactment (rehash district solver of CST MWS), as displayed. Accordingly, it upholds proposed name arrangement utilizing CMA, and further shows the significance of the tag. Towards bearing coldblooded IoT applications. Another recurrent band combination alternative can be developed by changing the length of shorting stub of the pyramid dipole wing. In the event that the length of both shorting stubs of the pyramid dipole wings is dense to 29.4 mm, the recurrent band of one dipole structure was moved to European RFID rehash band (860 to 865 MHz). As such, the proposed tag can have the choice to give two arrangement choices either for polarization or rehash band variety. To help it further, a model of the proposed twofold spellbound RFID name getting wire was made (engraved on FR4 substrate).

The FR4 substrate having a thickness of 2 mm, a dielectric steady ($\epsilon_r = 4.4$), what's more, a misfortune deviation of ($\tan \delta = 0.02$) was utilized to make the radio wire. The Impinj Monza 4 D chip is connected among the entirety of the four terminals of name getting wire, as alluded to in the datasheet. To confirm the

showcase of the getting wire, the information impedance of this twofold animated tag has been evaluated by following the system granted in () and (Sharif et al., 2018) utilizing Agilent E8363B vector network analyser. Two coaxial associations were utilized for impedance and return catastrophe appraisal, with outside layers of coaxial associations are bound together. Of course, within transmitter of every association has been connected with open terminations of the name radio wire without chip mounting.

The deliberate return loss of the proposed twofold spellbound name getting wire has been constrained by utilizing the equation in (). It will in general be seen that the deliberate S_{11} or S_{22} shows a reasonable synchronization with the imitated one. In any case, there is a smidgen shift in evaluated S_{11} . Then again, the deliberate S_{11} is obviously better than the imitated one, which might be an immediate consequence of an improvement in setback factor or permittivity worth of FR4 substrate from values utilized for diversion purposes. Similarly, the intentional separation S_{21} between two ports is also diminished up to - 15 dB, which is honorable. The decreasing in limitation S_{21} might be happened because of association misfortune or some other creation bungle. It will in general be seen that the imprint radio wire can offer a greatest replicated perceived extension of - 4.87 dBi at 917 MHz. By and by, the imprint radio wire accomplished a greatest evaluated perceived development of - 6.05 dBi at 910 MHz. The intentional and imitated perceived additions are worked with well with a capability in stunning rehash, and gains are just 7 MHz and 1.18 dB, independently.

CONCLUSION

In this paper, a twofold charmed UHF RFID name getting wire having polarization or rehash band arrangement highlights have been proposed utilizing CMA. The proposed mark getting wire includes two wandered line cross dipole-like plans, shorting nails, and a ground plane. The general plan of the proposed tag is moved by planar pyramid structure. By exploring brand name modes evaluation, the inclining openings plus, identical spaces (presenting capacitive direct) are made to change the resounding conduct of CM modes in the fundamental RFID band. The length and spots of identical spaces are advanced further to get the design impedance match with Monza 4D chip. Likewise, the recurrent band collection is developed by utilizing the shorting divider's length as a tuning limit. The recurrent band of one or both wandered line dipole-like improvement can be tuned to European UHF RFID band by moving the length of the shorting divider. The RFID chip is straightforwardly

arranged at the current minima to run grouping modes. This imprint arrangement is inconsequential expense and simple to make because of nonappearance of vias, shorting pins and any arranging with circuit. The size of the proposed mark radio wire is 50x50x2 mm³. Moreover, the proposed mark plan accomplished a read degree of 8.5 m after mounted over 200x200 mm² metal plate. Essentially, it accomplished a read degree of 5.5 m on low permittivity dielectric material. The existence of the proposed mark game-plan is besides checked in the wake of mounting it on metallic objects of various shapes and sizes. Henceforth, the proposed mark getting wire is reasonable for stage liberal and course merciless IoT applications(Chen & Tsao, 2010; Chen, 2009; Chen & Lin, 2008; Farhat et al., 2018; Son & Jeong, 2011; Svanda & Polivka, 2015).

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Chapter 10

The Design of Ku Band SIW Slot Antenna Array Used for IoT Applications

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ABSTRACT

This chapter presents a brief description on the design of 1x1 rectangular slot antenna array at 30 GHz. The rectangular slots are etched off in the top layer of substrate-integrated waveguide (SIW) cavity. Antenna is designed in Ku band frequency for 5G IOT application. A prototype working at 30 GHz band was designed and simulated. Simulated results show that the prototype achieves a 16-dB impedance bandwidth from 29 to 31 GHz. The peak gain at broadside is 14.3 dBi at 30 GHz. The radiation pattern is stable within the operating bandwidth. Simulation is done in HFSS software tool.

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INTRODUCTION

Substrate Integrated Waveguide (SIW) technology has proven to be a promising alternative to conventional waveguide for the design of microwave and millimetre-wave circuits. In this technology, relatively low-loss and high-Q waveguide structures are realized in compact size, low-cost, and highly integrated planar structures. As the field pattern inside the SIW is similar to that of rectangular waveguide structures, the design of any SIW structure starts with specifying the waveguide width for the desired frequency band and substrate material. Longitudinal slots on the top metallic surface of the substrate integrated waveguide (SIW) is designed with 4 X 4 slots which acts as an antenna to radiate the power feed is M.S power divider return loss of the antenna is 9-11GHz (Yan & Hong, 2004). Single-layer SIW interconnects, including their transitions to micro strip lines. Design equation includes effective width is easily calculated here with d and p consideration. Tapper edge is used to feed this model (Rayas-Sanchez, 1998). The structure consists of an array of various shape slots antenna designed to operate in C and X band applications. The basic structures have been designed over a Rtduroid substrate with dielectric constant of 2.2 and with and thickness of 0.508mm Gain more than 9dB and return loss better than -10dB (Kachhia, 2015).The proposed work discusses SIW Slotted array antenna in Ku-BAND. Also, a comparative analysis between the corresponding S-Parameters is performed.

DESIGN OF SUBSTRATE INTEGRATED WAVEGUIDE

The proposed work uses Rogger 5880 substrate with dielectric constant 2.2 with a thickness of about 1.6mm. The fundamental parameters to design the SIW waveguide antenna are given below. The substrate integrated waveguide (SIW) is sort of a guided transmission line just like a dielectric filled rectangular waveguide. Its dominant mode cut-off frequency is same as TE_{10} mode of rectangular waveguide. The only difference is that the metallic walls are replaced by two parallel arrays of conductive via holes. The key parameters of SIW design are spacing between the vias “P” also called pitch, diameter of vias “D”, central distance between via arrays “ A_r ” also called integrated waveguide width, and the equivalent SIW width “ A_c ”.

The SIW parameters should be designed carefully. The pitch “P” and diameter “D” control the radiation loss and return loss, while the integrated waveguide width “ A_r ” determine the cut-off frequency and propagation constant of the fundamental mode (Kachhia, 2015). There are two design rules related to the pitch and via diameter as given by (Deslandes & Wu, 2003):

$$d < \frac{\lambda_g}{5} \quad (1)$$

$$p \leq 2D \quad (2)$$

Where λ_g is the guide wavelength in the SIW

The cut off frequency of an SIW can be determine by

$$f_c = \frac{\omega}{2\sqrt{\epsilon_r}} \left(A_r - \frac{D^2}{0.95p} \right)^{-1} \quad (3)$$

Where c is the speed of light in vacuum and ϵ_r is the relative permittivity of dielectric material .

$$A_e = \frac{a}{\sqrt{\epsilon_r}} \quad (4)$$

Where “a” is the broadside dimension of an air filled rectangular waveguide

$$A_r = A_e + \frac{D^4}{0.95p} \quad (5)$$

After discussing the design details, next we move onto the design of an Ku-band SIW. The WR-90 is the standard Ku-band rectangular waveguide with dimensions:

$W = 4.211$ mm and $L = 2 \times W$ mm.

Design of SIW

Judging from its electrical performance, the synthesized integrate waveguide is a good compromise between the air- filled rectangular waveguide and planar circuit. A schematic view of the integrated waveguide is shown in Figure 1. This waveguide is composed of two parallel arrays of via-holes, delimiting the wave propagation area, as its cut off frequency is only related to the width “w” of the waveguide as long as the substrate thickness or waveguide height “h” is smaller than “c.” The parameter“c” between the two arrays determines the propagation constant of the fundamental

mode, and parameters of via-holes “d” and “p” are set to minimize the radiation loss as well as the loss, Simulated model of siw is depicted in the Figures 1-5.

Figure 1. SIW model

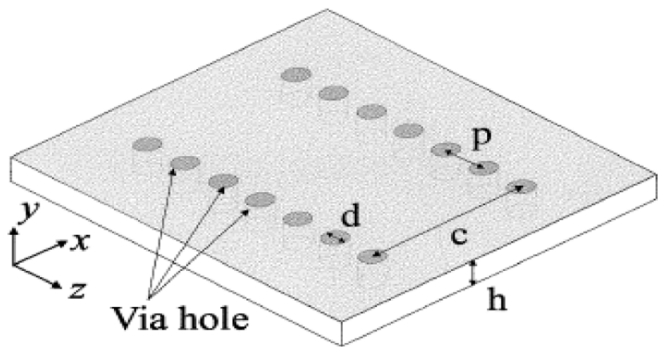


Figure 2. Simulated model of siw

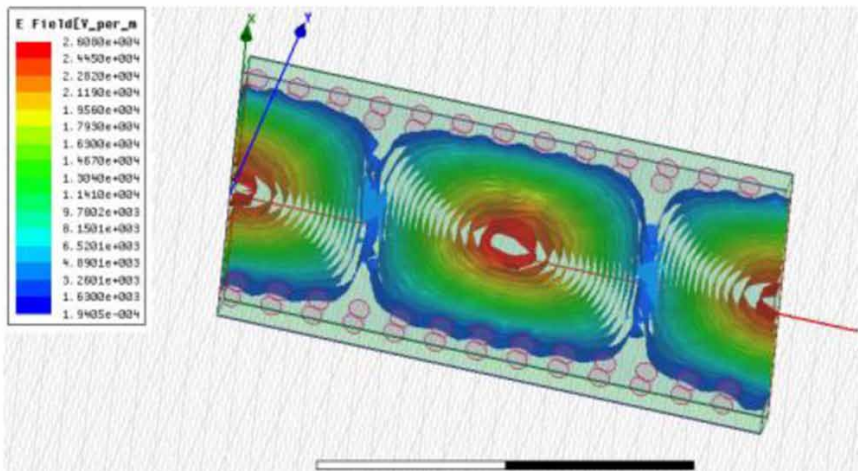


Figure 3. Animation of current density

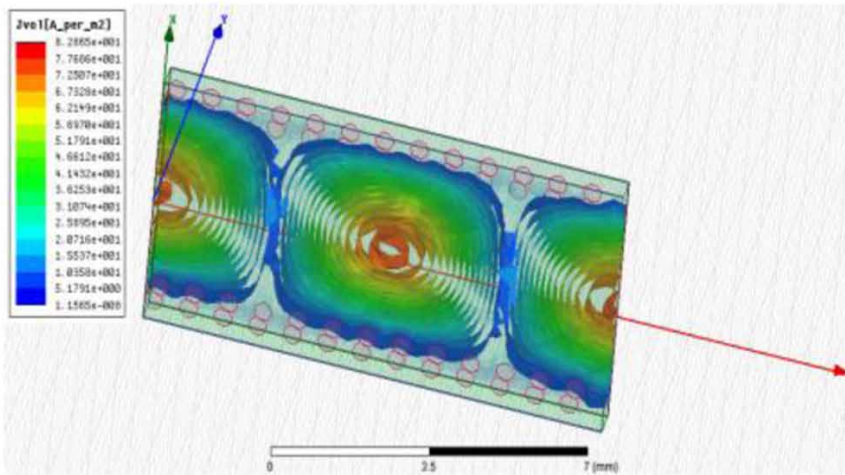
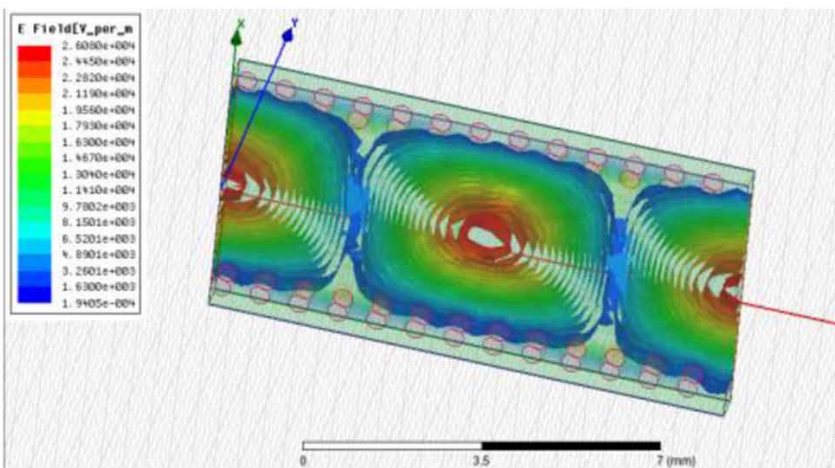


Figure 4. E-Field



Design of Slotted Array Antenna

Planar resonant slotted-waveguide arrays are used in many applications, especially radar. The conventional RWG 1x1 slots array antenna is exhibited in Figure 2; one port of the waveguide is short. The spacing of each slot antenna is one-half guide wavelength at the design frequency in order to locate the slots at the standing wave

Figure 5. H-Field

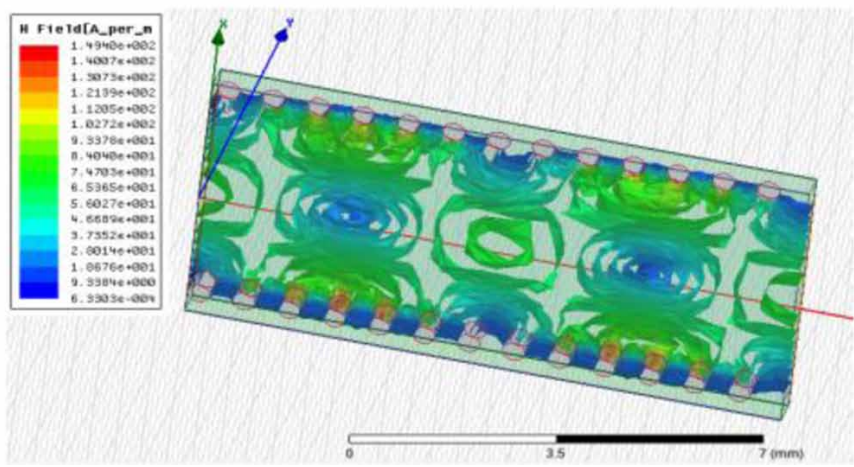
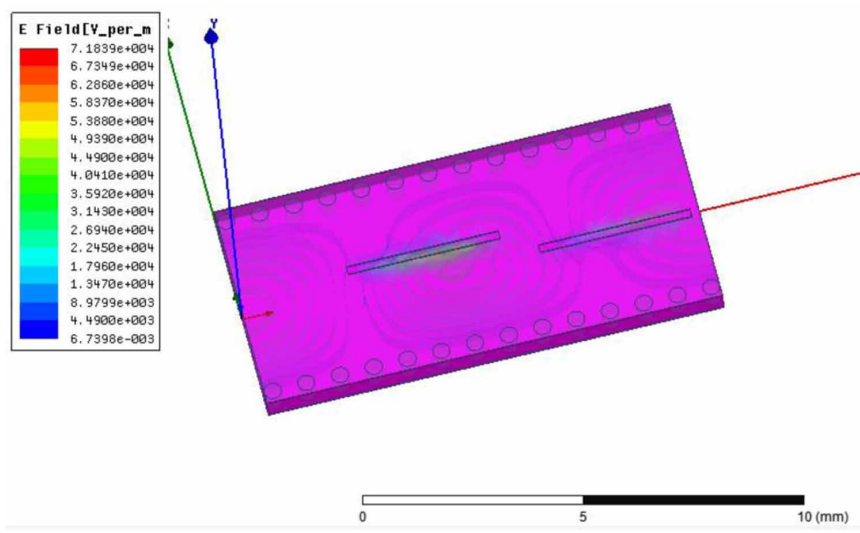


Figure 6. Substrate integrated waveguide slotted array with 2 slots



peaks and all radiators have the same phase. The spacing between the last slot and the short port is one quarter guide wavelength hence the short port is equivalent to open space. The schematic layout of slotted array antenna is given below in Figures 6 and 7.

Figure 7. E-Field

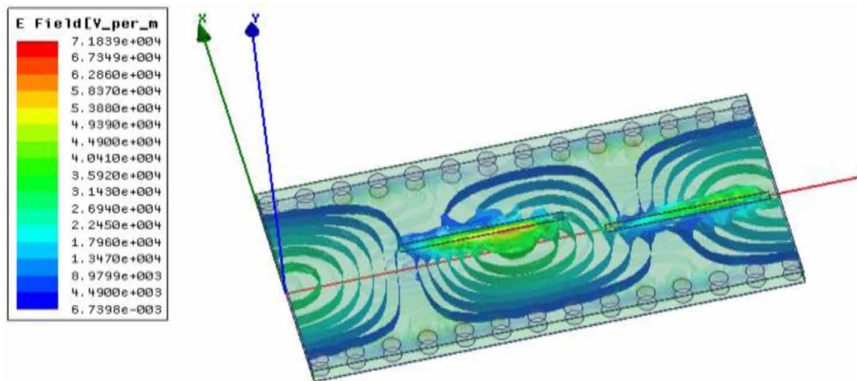
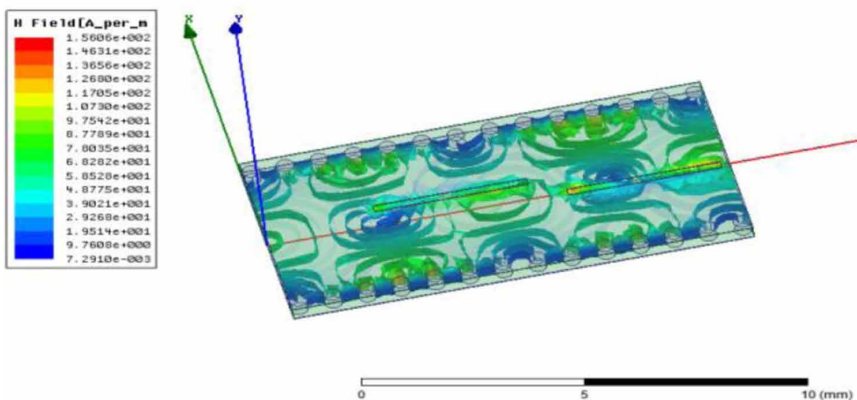


Figure 8. h-field



RESULTS AND DISCUSSION

The SIW and SIW slotted array antenna with 2 slots are simulated using HFSS 13.0 and the results are compared in the figures given below. Reflection co-efficient of SIW and SIW Slotted array antenna are shown in figure 3 and figure 4.

It can be observed that the S11 parameter for SIW and SIW slotted array antenna is -40dB and -16dB respectively. Similarly, the gain of SIW slotted array antenna is show in figure 6 radiation pattern, 7 Constant phi theta variation, figure 8 Element pattern with values 8.5 dB, 14 dB, 14 dB respectively.

Figure 9. Reflection co-efficient of SIW

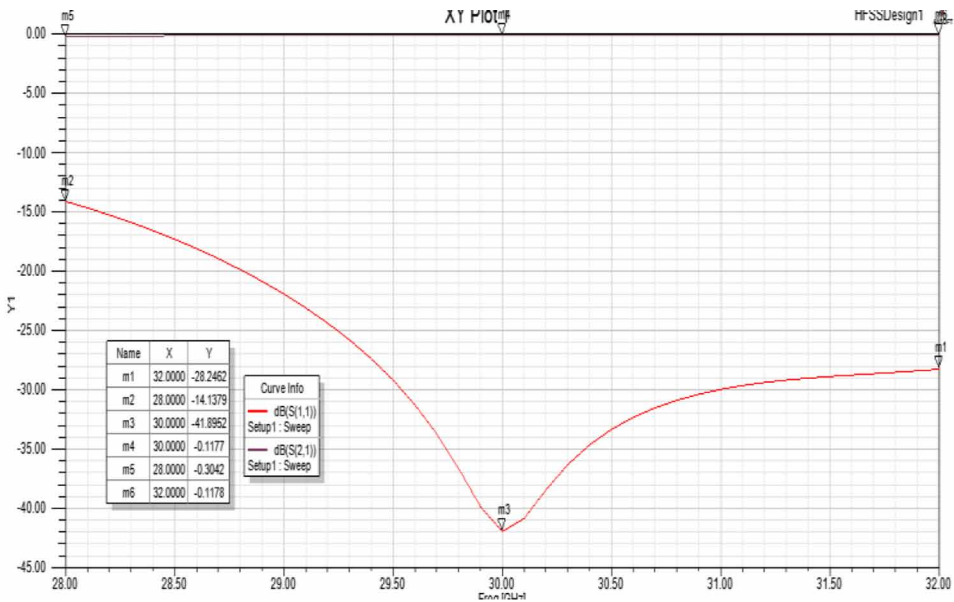


Figure 10. Reflection co-efficient of SIW slotted array antenna

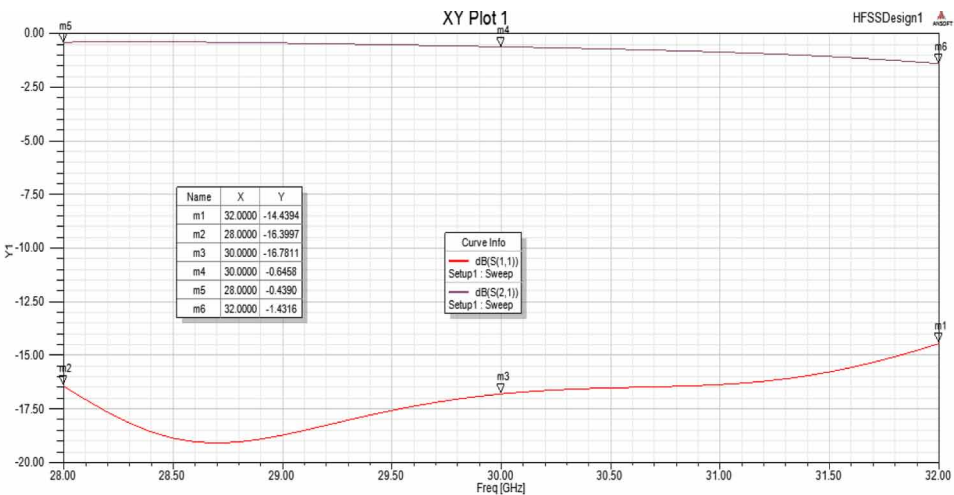


Figure 11. Total Gain pattern

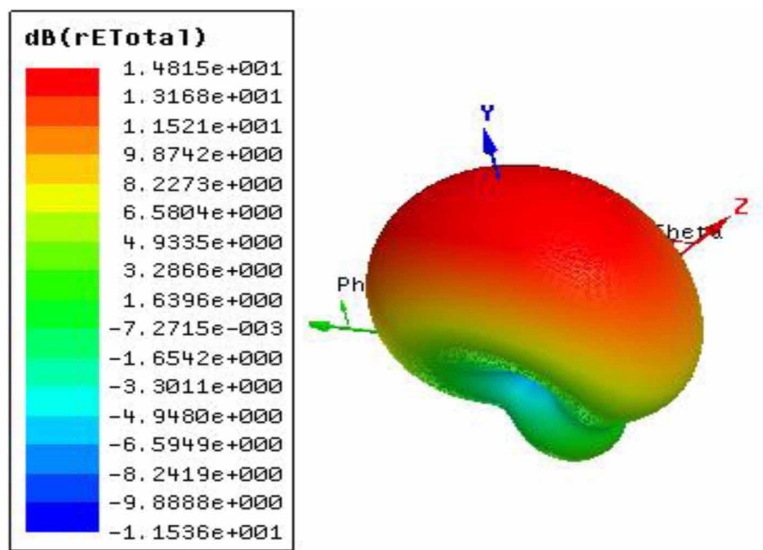


Figure 12. Reflection co-efficient

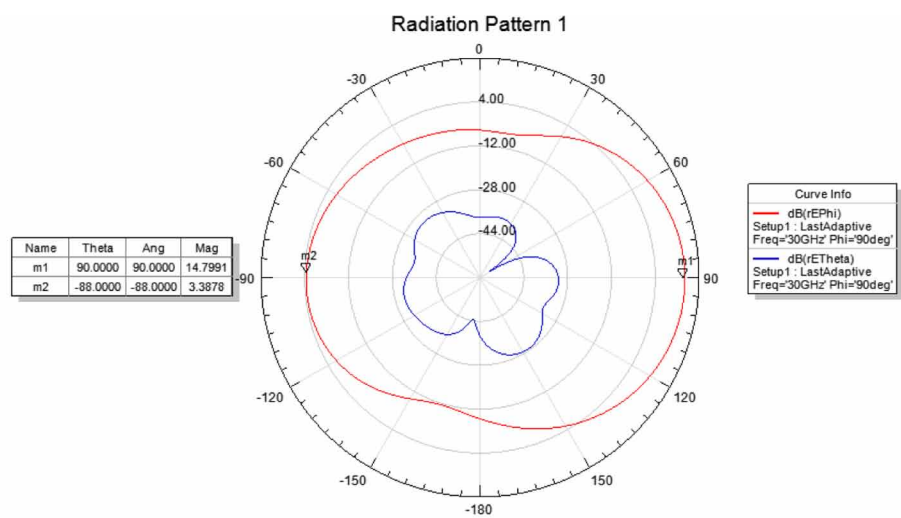
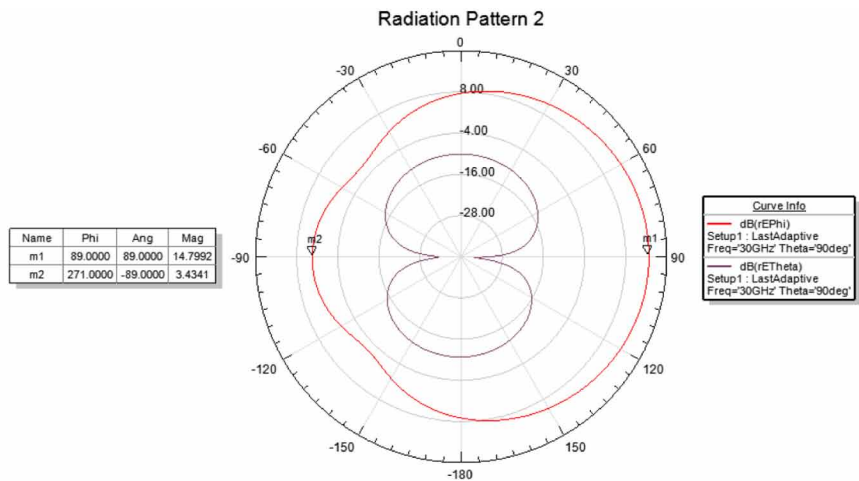


Table 1. Comparison of different s11 (db)

Parameter	SIW	SIW Slotted array antenna
S11(dB)	-40	-16

Figure 13. (b) Gain pattern



CONCLUSION

The paper describes design and simulation of SIW slotted array antenna. Simulated results show that the prototype achieves a 16-dB impedance bandwidth from 29 to 31 GHz. The peak gain at broadside is 14.3 dBi at 30 GHz. The radiation pattern is stable within the operating bandwidth. The antenna is very compact and stable hence suitable for IOT applications.

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Chapter 11

A Novel Dual Polarized Dual Band Antenna for Wireless Backscattering Applications

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ABSTRACT

This chapter presents a compact patch antenna for backscattering application. The model utilizes a crossed slot etched on single layer low loss substrate. The dimensions of the radiating patch are tuned through parametric analysis of the model in order to improve cross-polarization (dB) isolation and the axial ratio beamwidth of the antenna, and the results are compared with other conventional antennas. The antenna attains an impedance characteristic of -17.65dB at 2.15GHz and -22.28 dB at 2.4GHz operating frequency and provides an impedance bandwidth ($|S_{11}| \leq -10\text{dB}$) of 60MHz ant both bands. The antenna achieves a maximum gain of 6.8dB at 2.15GHz and 7.3dB at 2.4GHz in the direction of propagation. The antenna also gives a cross-polarization (dB) of -12 dB for a wide beam angle. Finally, a good agreement has been obtained for using the proposed design for modern dual-band wireless backscattering applications.

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INTRODUCTION

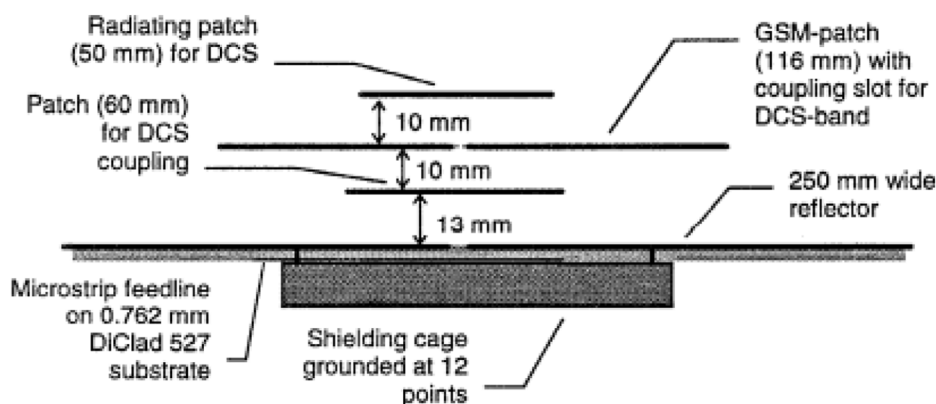
Due to advancement in recent communication systems, reduced profile configuration with simplified geometries, broader impedances, and stable gain are becoming vital design requirements for practical applications of micro-strip antennas. The micro-strip antenna has the advantages of modest structure, flexible manufacture options, and compact size in arrays. Due to channel capacity requirements in wireless channel, frequency and polarization diversity antennas plays a crucial role in wireless systems. Hence lots of researches are carried in these antennas (Wong et.al 2004, Guo et.al 2002). Multi-band polarization reconfigurable antennas are much widely used in due to its robustness in noisy environment and multi path fading channel conditions (Priya et.al 2020). These antennas are used for body area networks, mm-Wave 5G Base Station Antenna Array and many other wireless applications. A dual-band dual-polarized antenna is proposed (Ma & Zhang 2010) for off-body communication and is operated as a circular patch-type antenna with the polarization parallel to body surface to radiate unidirectional beam normal to the body for the off-body links. A dual-band dual-polarized antenna for 5G millimeter-wave base station antenna array based on a stacked square ring patches arrangement to achieve wide dual band and stable radiation pattern is presented (Siddiqui et.al 2020). A magneto-electric dipole antenna excited by F-shaped strips for a broadband dual-band is proposed (An et.al 2012) and achieve a common impedance bandwidth of 25.5% and 39.5% in the lower and the upper band. A Series-Fed Dual-Band Dual-Polarized Antenna Lattice Fed by Slot-Coupled Power Dividers is presented (Wincza & Gruszczynski 2015) which comprises of slot-coupled power dividers and a series feeding network allowing simultaneously for frequency separation. A Dual-polarized Dual-Band Antenna with Omni-Directional Radiation Patterns is demonstrated in (Liu et.al 2017) which utilizes a circular patch with eight open slots, eight shorted metal pins, and a central feed coaxial probe. By utilizing TM₀₁ mode, Omni-directional circular polarization can be generated over the lower band and When the basic TM₀₂ mode is excited, omni-directional linear polarization can be generated over the higher band.

In (Choudhary et.al 2021) design of antenna for automobile application has been done with dual band polarization and permutation of different slots. The compact design satisfies the connectivity of “Left Hand Polarization” as well as “Right hand polarization” suitable for incorporating GPS via single feed.

BACKGROUND WORKS

Geometry and electrical operation: The proposed double band component comprises of a three-layer aperture coupled patch structure as demonstrated in figures 1-2. The three patches are focused over a cross-shaped aperture in a 2 mm thick and 250 mm wide Aluminum reflector. The last component of this reflector, for example its length, is thought to be adequately long not to have any impact on the receiving wire attributes talked about (Lindmark 1998). In the base station radio wire application for this component the length-wise heading would be the upward bearing and the plane symmetrical to this course is subsequently from here on alluded to as the flat plane.

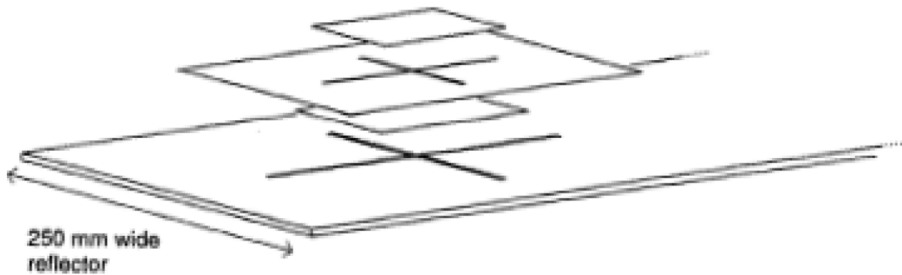
Figure 1. Cross-section of antenna element.



The patches are isolated by Rohacell froth with a permittivity of around 1.05. The cross-shaped aperture is energized by a microstrip feed network scratched on a 0.762 mm thick DiClad 527 teflon substrate with permittivity 2.55. The feed is partitioned into two sections, one section energizes the in an upward direction enraptured channel and one energizes the evenly captivated channel. These two channels are alluded to as channel 1 and 2 individually. The feed comprises of a 50 ω line what partitions into two 50 ω lines. These two lines energize the aperture in a balanced design so that for ex sufficient the feed of channel 1 energizes a voltage over the in an upward direction adjusted pieces of the cross-shaped aperture. The lines end in open circuit nails. To coordinate with the info impedance to 50 ω in both recurrence groups a modest quantity of balanced capacitive tuning was applied on the two channels. Figure 2 shows (Foam layers, feed organization and safeguarding confine not appeared. The receiving wire component is fixated on a 6.50 mm long

and 2.50 mm wide reflector) these short segments of more extensive microstrip line around 30 mm before the aperture.

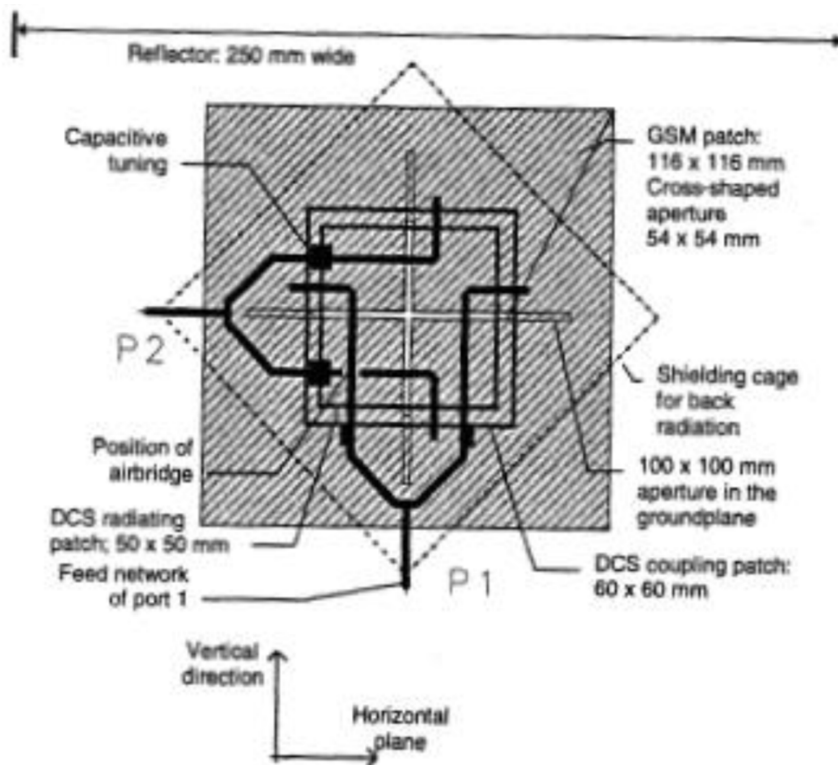
Figure 2. Side view of the antenna element



In the lower band the radio wave emanates through a similar instrument as in any aperture coupled patch component: The aperture couples capacity to the huge transmitting patch and the patch and the aperture both transmit into the far-field. To give double polarization activity a cross-shaped aperture is utilized with a feed network like the feed depicted in (Tsao et.al 1988). This feed plan gives the symmetry important to high port-to-port confinement and great polarization immaculateness. Since the feed of both polarization diverts are situated in a similar layer it is important to have microstrip lines crossing each other eventually. Consequently the area of an air connect is shown in figure 3.

The size and position of the enormous patch is picked for acceptable execution in the lower recurrence band. The measurements are basically the same as a straightly captivated single band aperture coupled patch radio wave. The huge patch has another cross shaped aperture which takes into consideration coupling of upper band frequencies to a patch situated on top of it. This aperture was found to bring down the reverberation recurrence of the patch a couple of percent and the patch size was thusly changed in like manner. The patch underneath the biggest patch couples the force in the upper band from the huge opening in the ground plane to the little space in the enormous patch. The underlying plans expected for single straight polarization remembered a little opening for the ground plane for the upper recurrence band, however we tracked down that double band activity was conceivable with the huge space alone. The position and sizes of the two little patches are picked for acceptable execution in the upper recurrence band.

Figure 3. Top view of antenna element showing patches and feed network



Anticipate that the large patch should work as a ground plane for the top patch. This speculation is upheld by the comparative radiation designs found in the even plane for the two groups and the way that the proportion between the size of the biggest and the reflector width is around equivalent to proportion of the top patch and the huge patch. On account of a straightly captivated component, the width of the patches would give a few levels of opportunity to accomplish an ideal beam width, particularly in the upper band.

The direct back radiation from the aperture is decreased to for all intents and purposes zero by the utilization of a protecting leading box as portrayed in (Nystrom & Karlsson 1997). For our situation the elements of the crate appeared in figure 2 are 100 x 100 x 8 mm and it is made of Aluminum and loaded up with air. The case is electrically grounded through 12 screws evenly positioned on the 4 sides reaching out to the 250 wide reflectors.

Wireless communication via massive back scatter strategies has been discussed in (Cui et.al 2014). The work depending on the propagation scenario metasurface has been made programmable curtailing transmissions from few impedance

dipole antennas. In (Jiang et.al 2021), the tradeoff between energy harvesting and backscattering has been done to maximize the achievable rates. The impending transmissions with maximum throughput and fairness along with optimal transmit time is being provided. The discussions in (Yang et.al 2020) states that the process of attain impedance bandwidth for low and high frequency applications attained via double layer structure. The double layer structure has two resonant frequencies for its operation which provides the desired impedance bandwidth.

PROPOSED WORK

Antenna Geometry

The proposed antenna is designed to operate at dual band and radiates at dual polarization. The antenna is modeled using high frequency structure simulator and is designed on single layer substrate. Parametric analysis is carried to have better gain characteristics at its operating bands.

The antenna is designed on roger substrate (RT 5880) having a size of 75 mm x 75 mm x 1.6mm and having a relative permittivity ϵ_r of 2.2 and a loss tangent δ of 0.002. Fig. 3 shows a circular patch having a radius of R mm etched on roger substrate (RT 5880) and a rectangular cross shape slot is etched at its centre. The length and the width of the slot are obtained through parametric analysis of antenna performances over its dimensions.

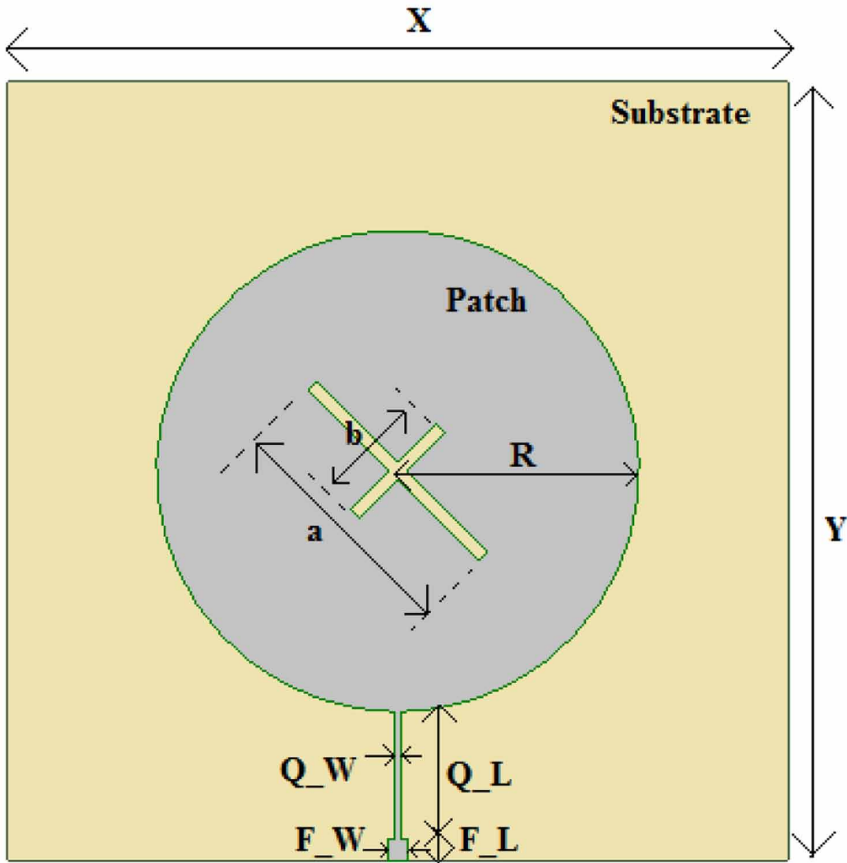
A 50 Ω SMA coaxial connector is used to feed the antenna model whose characteristic impedance Z_0 is given in equation (1).

$$Z_0 = \frac{\eta_0}{2\pi\sqrt{\epsilon_r}} \ln\left(\frac{D}{d}\right) \Omega \quad (1)$$

For an antenna to radiate effectively the antenna must be purely reactive and the reactive component in the impedance must be equal to zero at operating frequency. This is achieved by properly matching Z_0 and Z_{in} . A quarter wave transformer is used to match the impedance between radiating patch and the coaxial fed. The dimension of the quarter wave transformer (Q_X and Q_Y) is obtained by equation (2).

$$Z_L = \sqrt{Z_0 \times Z_{in}} \quad (2)$$

Figure 4. Antenna Geometry



Parametric Analysis

In order to optimize the antenna, the dimensions of the model are analyzed through parametric analysis. The length of the slot is taken crucial and it is optimized to have better reflection coefficient and standing wave characteristics. Figure 4, shows effect of slot length ' a ' on operating frequency of the antenna.

Figure 6 shows distribution of surface current over the radiating element. It is inferred that the at band 1 (2.15GHz) the antenna gives current distribution at $+45^\circ$ polarization at different instances of time t . similarly at band 1 (2.40GHz) the antenna gives current distribution at -45° polarization at different instances of time t . Thus the antenna exhibits two different polarization states at two distinct operating bands.

Figure 5. Effect of slot length ‘an’ on operating frequency.

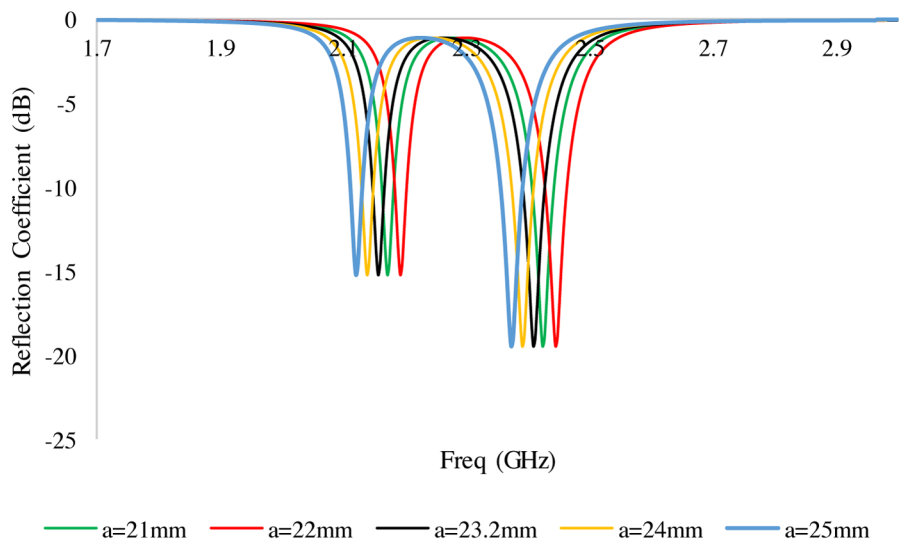
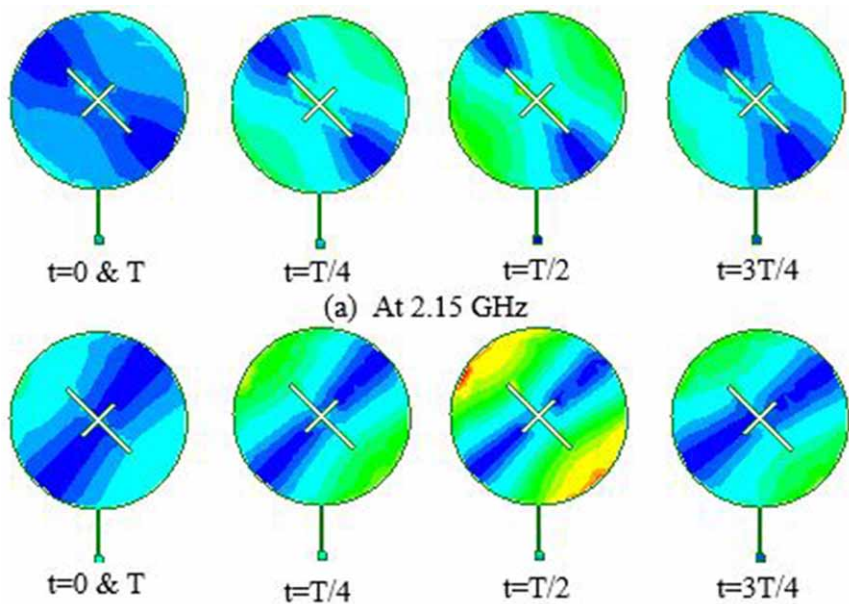


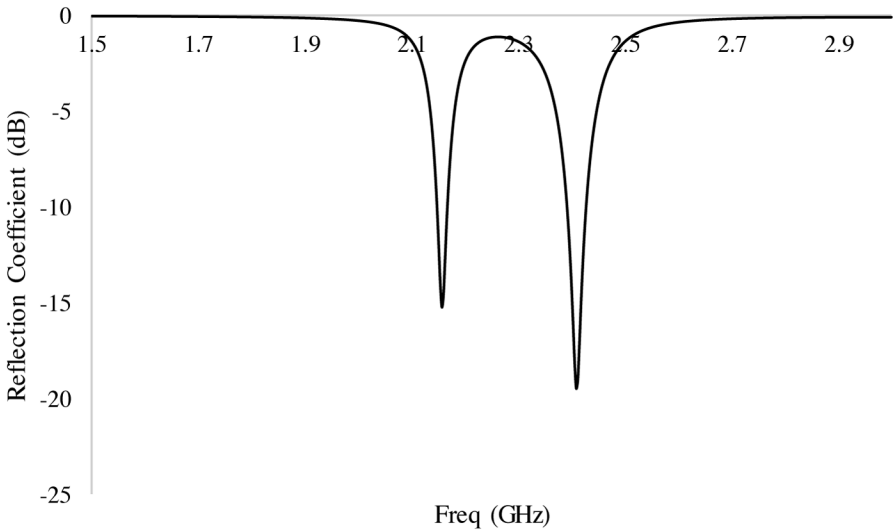
Figure 6. Surface Current Distribution



RESULTS AND DISCUSSIONS

The simulated characteristics of the proposed antenna are analyzed under perfect electric boundary condition using Ansys High Frequency Structure Simulator. The impedance characteristics of the proposed antenna are shown in Fig. 6. The antenna is resonating at S band in the microwave frequency. The antenna achieves impedance bandwidth of 100 MHz at 2.1GHz (2.1-2.2GHz) and 2.4 GHz (2.4-2.5GHz) band.

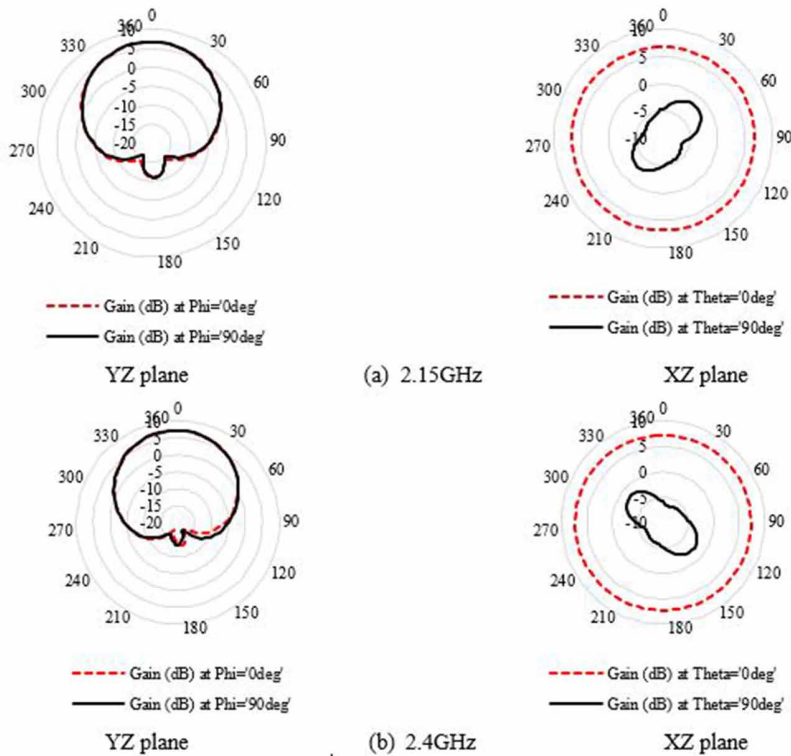
Figure 7. Reflection Coefficient (dB)



The radiation characteristics corresponding to proposed antenna model at both the elevation and azimuthal planes is shown in Fig. 7. The antenna achieves a peak gain of 6.8dB at 2.1GHz and 7.3dB at 2.4 GHz in the ISM band. It is seen that the antenna achieves symmetrical radiation pattern at both the operating frequencies.

The 3 dimensional gain plot simulated at both the frequencies is shown below. The antenna achieves a maximum gain of 6.8dB at 2.15GHz and 7.3dB at 2.4GHz in the direction of propagation along both azimuthal and elevation directions.

Figure 8. Radiation pattern (dB)



CONCLUSION

A cross shaped slotted patch antenna operating a dual band is proposed. The length of the crossed slot is optimized to achieve dual polarization states at distinct frequencies. The antenna attains an impedance characteristic (dB) of -17.65dB at 2.15GHz and -22.28 dB at 2.4GHz operating frequency and provides an impedance bandwidth ($|S_{11}| \leq -10\text{dB}$) of 60MHz ant both bands. The antenna achieves a maximum gain of 6.8dB at 2.15GHz and 7.3dB at 2.4GHz in the direction of propagation. The antenna also gives a cross-polarization (dB) of -12 dB for a wide beam angle.

Figure 9. 3D Radiation pattern (dB)

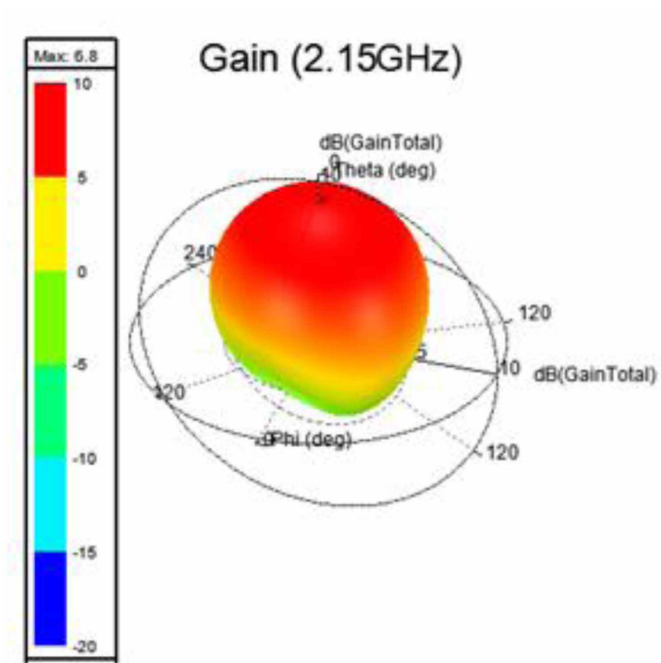
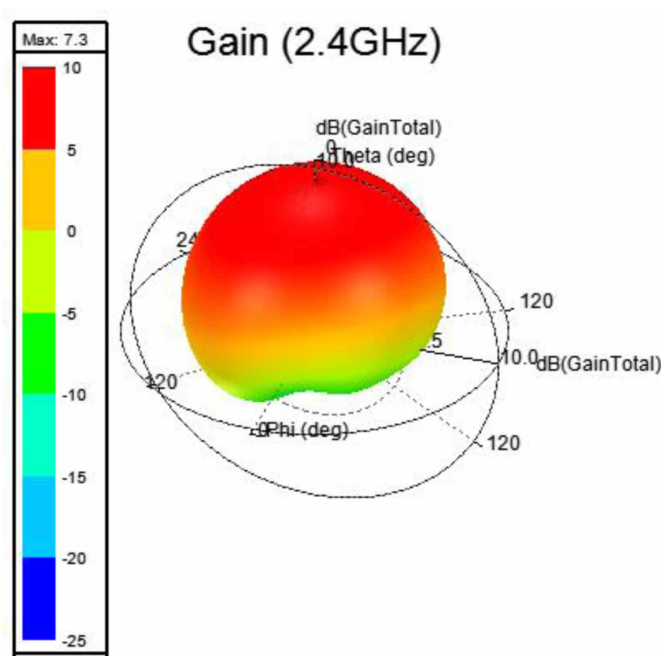


Figure 10. 3D Radiation pattern (dB)



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Chapter 12

Antenna Design and Analysis for Narrow Band Internet of Things Applications

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ABSTRACT

One of the standards in wireless communication is Narrowband IoT. It deals with low power, small gain, and more life expectancy. The connectivity problem is reduced in narrowband design. This is achieved with microstrip antenna. Single patch is designed with the selected dielectric substrate. Several parameters are considered for the antenna design. The high value of dielectric constant reduces bandwidth in smaller patch for internet of things (IoT) design applications. These applications require gadgets for operating in licensed band of frequencies with less data rate and required antenna efficiency. When compared to dielectric, FR4 is a commonly available substrate and useful in smaller patches. In this chapter, two antennas are presented. The antennas were simulated in IE3D software and analyzed for Narrowband IoT (NB-IoT) with 100 MHz.

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INTRODUCTION

The 5G technology includes and makes growing the projects like internet of things, vehicular communication, smart city systems, e-health maintenance systems. The following devices use antenna for various applications. Wireless networking devices, such as wireless routers, smart phones, laptops, tablets, and hotspots, have receiving and transmitting antennas. The transmitting antenna radiates waves and receiving antennas pick up on the EM waves containing packets of information and convert them into electrical signals for the device to process.

Internet of Things is meant as an infinitude of connected devices and small sensors, integrated in a bigger network with a permanent access to the user. One of its major application is in the Smart home concept, allowing more convenience, efficiency (at various aspects) and safety. With more and more devices, it is nowadays mandatory for these devices to be small, low-power and at the same time more capable and efficient. In this chapter, antennas for narrowband applications is discussed and proposed two design for IoT devices, developed for GHz band and presenting bandwidth according to the growing needs of wireless IoT networks.

With this objectives, the antenna design for industry required, is presented in this chapter. The introduction to antenna designed for IoT applications of some researchers literature is reviewed and presented in the following section.

BACKGROUND

From the earlier researchers, this short literature review is presented about the Narrowband antennas. Marcos V. T. Heckler et al (2009) in his paper presented a microstrip antenna array developed for a robust receiver in navigation applications to suppress out-of-band interference and the array has been designed to operate in a Narrowband. Y. Wang et al (2013) achieved ultra-wideband/Narrowband results in dielectric resonator antenna by integrating it. S. M. Abbas et al (2015) given antennas design with narrowband and ultra wideband of modes by using reconfigurability.

Tiago Varum et al (2018) proposed antenna for Internet of Things devices at 17 GHz frequency. This antenna has reduced dimensions, ideal to be integrated in most of IoT sensors.

Albert Sabban (2019) presented the SRR antennas characteristics such as length, resonant frequency, gain, directivity used for wearable antennas with SRR on human body may be shifted by 2–5%. Adewale Ayomikun Elijah et al (2020) proposed microstrip antenna for IoT application by miniaturization technique.

S. Mohamed Refaat, et al (2021) designed a new design of a multiband microstrip patch antenna using slots in the patch as well as defected ground structures (DGS) implemented in the ground plane. Different shapes of slots were used to improve the antenna performance at the different resonances. The good consistency between simulations and measurements confirmed the antenna's ability to improve the benefits for IoT applications at the three different frequencies. J. Xu et al. (2018) presented the Evolutions, Technologies, and Open Issues of Narrowband Internet of Things. Hassan Tariq Chattha et al (2018), proposed the antenna systems for Internet of Things.

From the literature review done, it is identified that the importance of applications and characteristics of the antenna. The aim is to provide a possible understanding for the upcoming wireless communication system, in motivating to drive further research in accelerating the more use of NB-IoT. Particularly microstrip patch antenna with narrowband is considered here for IoT applications and two antenna design were presented.

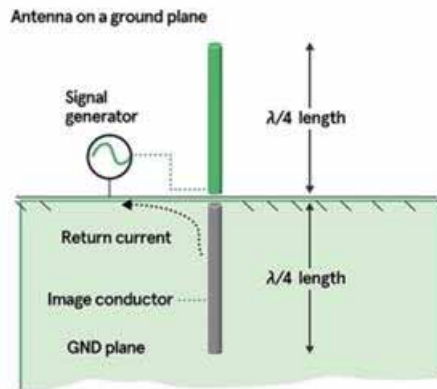
METHODOLOGY

The antenna design factors, which influence in IoTs are discussed in this section. Choosing the right antenna for an application presents a key design challenge. Creating effective antenna performance in IoT devices requires engineers to examine several factors including antenna size, from what is needed to what is possible, antenna shape, and placement. Design, analysis and applications are discussed in this methodology.

Antenna Design

Narrowband antennas are designed for the frequency bands of 1.5 GHz to 5 GHz with maximum 100 MHz bandwidth, around 2 to 25 dBi gain. These antennas are fed with maximum input power of 20 Watts. VSWR is always maintained around less than 3. They are designed for linear as well as circular polarization. These antennas give azimuthal radiation pattern as well as unidirectional pattern and are used in datalink purposes. The advantage of using Narrowband is low bandwidth, good range, available as IoT chip and sensitivity for IoT applications. Narrowband IoT technology works in a licensed band service and so, it improves the dependability of transmission. Typical antenna design for IoT is shown in figure 1.

Figure 1. Typical IoT antenna design



IoT antennas are made for working in 2.4/5-GHz and 900-MHz ultra-thin Ceramic and LDS/MID Antennas offer cabled, flex and PCB formats to enable fast and easy RF integration into connected systems and are ideal for embedding high-performing internet and data connectivity in compact devices. The various types of antennas designed for IoT devices are chip, wire, whip, PCB and proprietary. These antennas have some topologies. Best option for small form factors and for lower frequencies, good for large productions due to low reproducibility issues.

Monopole type antennas are used on most mobile IoT protocols. Examples are Whip, rubber duck, and paddle antennas. They have the benefit of modularity, as they are not integrated onto the PCB of the IoT device, and can therefore be more convenient for prototyping. These are the most common type of monopole antennas, specifically, the quarter-wave whip.

Matching is required for a IoT antenna Although an antenna can be selected to have the same impedance as the RF-amplifier output, loading by nearby components on the circuit board and the material properties of the device enclosure may require a matching network to be inserted.

Chip Antennas may be the best option for the smallest form factors even at low frequencies of for an ultra-crammed design. In addition to reducing the design effort required to implement an IoT solution, chip antennas could aid in maintaining low reproducibility issues when large manufacturing runs are required. However, chip antennas do add cost and design considerations.

For example, they have lower efficiency and lower bandwidths than other antenna typologies at comparable frequencies. And even if they have internal matching, external matching circuitry is most likely required to achieve datasheet performance.

Chip antennas also can be sensitive to ground plane geometries. Given these points, it is crucial to adhere to the documented design guidelines for the chip antenna.

Proprietary Antenna designs are owned by a designer or design company. Occasionally, these antennas also can be commissioned or custom-designed for specific applications. The cost for these antennas begins with the purchasing of the intellectual property (IP), although this option usually comes with support from the antenna design company. For companies that do not have antenna design expertise in house, this design-sourcing option offers a chance to leverage the expertise of highly specialized designers skilled in this area. When considering proprietary antennas, it's critical to know the exact use case for the antenna. It is then possible to describe and design for the complete performance dynamics.

As one of the lowest-cost and highest-flexibility options, wired antennas can be applied to the majority of thrifty designs. Yet they do require additional design effort. These antennas generally demand electromagnetic (EM) simulation for optimal designs. They may even require custom designs based on the module's housing. Wired antennas also increase in size as frequency decreases, which may add to the manufacturing challenges associated with design reproducibility and reliability. If a talented CAD and EM simulation designer is available, however, it is possible to create space-saving routing through a module's housing. An added benefit of a wired antenna is that prototyping is generally very cost-effective. Many antenna designs can be tested with little lead time.

Some highly complex IoT modules require multiple wireless technology transceivers. This becomes a significant routing and performance design concern, which is sometimes solved by using a disattached antenna. It is connected through microcoaxial cables for a tighter fitting device with antenna spatial diversity. (Xu et al., 2018)

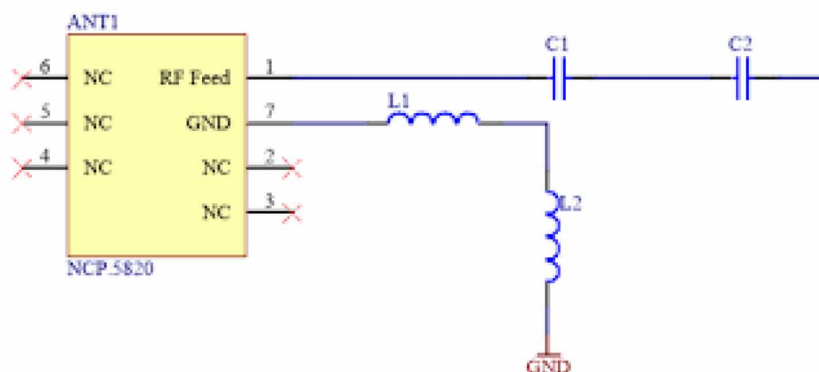
Whip antennas are one of the highest-cost antenna options. Yet they also are the highest-performing and may be the best fit if the module faces cost issues with multiple transceivers. In addition to the up-front antenna cost, a connector will be needed on board. The design also will have to account for coaxial cable routing from the launching connector to the antenna module. For many whip antennas, emissions testing also will need to be performed.

In complex IoT modules with many sensors, the PCB antenna can still dominate a significant portion of the PCB board. Size-to-performance tradeoffs can be used to further shrink the antenna at the cost of range and data rate. (InTech Open, n.d.)

If a module demands low cost and reasonable design flexibility in a highly integrated printed circuit board, a PCB antenna may be the optimal choice. For large-scale manufacturing, PCB antennas tend to be the most cost-effective with the least reproducibility issues. These advantages stem from the PCB's highly refined manufacturing process. In addition, there are many free reference designs

for PCB antennas ranging from large and low-frequency to highly compact and high-frequency single-ended and differential antennas. Many low-cost or free EM-simulation software packages also aid in designing these antennas. They could even accelerate the matching circuitry design (Sabban, 2019). In figure 2, the Narrowband IoT as a chip device is shown.

Figure 2. Narrowband IoT as a device



Microstrip antennas are widely used in communication system and seekers. Microstrip antennas possess attractive features that are crucial to 5G communication, IoT, and medical systems. These antennas are compact, flexible, lightweight, and relatively cheap. In addition, it can be integrated RF modules with the antennas on the same substrate. Printed antennas have been widely presented in the literature in the last 20 years. Electromagnetic fields' transmission losses of human tissues should have been investigated earlier. However, the effect of human body on the impedance and efficiency of wearable antennas was not always presented. A review of wearable antennas designed and developed for several applications at different frequencies over the last 10 years is listed. Wearable meander line antennas are presented in (InTech Open, n.d.). These antennas function in the frequency range between 750 and 2900 MHz. A textile antenna performance near human body is presented at 2.4 GHz, see (InTech Open, n.d.). The effect of human body on portable RF antennas is studied in (TI, n.d.). In this chapter, it is determined that the antennas' length in free space is larger by 10–20% from the length of wearable antennas. Measurement of the antenna gain in this paper shows that a wide dipole (1.16×0.1 m) has -13 dBi gain. Wearable antennas for cellular applications are presented in (DeLisle, 2015). Electrical specifications of medical devices are different from the electrical specifications for cellular devices. Wearable devices support the development of

personal medical sensors and systems with real-time response to help improve patient's health. Wearable medical sensors and devices can measure the sweat rate, body temperature, heartbeat, and blood pressure, perform gait analysis, and measure other body health parameters of the patient wearing these sensors. In this chapter, novel wideband compact wearable antennas for 5G communication and medical systems are presented. Numerical results in free space and near the human body are presented.

Wearable antennas should be compact, have lightweight, low cost, and flexible. Microstrip antennas, printed loops, printed dipoles, slot antennas, and PIFA antennas are compact, low cost, conformable, and have lightweight. These antennas are a good choice to be employed as wearable antennas for IoT and medical applications. These wearable antennas find applications in 5G Communication Systems, Medical, Wireless Communication, IoT, WLAN, HIPER LAN, GPS, Military Applications.

IoT Design Analysis

The most important applications of the IoT are in Wearable devices, Health care monitoring systems, Traffic monitoring systems, Fleet management systems, Agriculture aiding purpose, Hospitality management systems, Smart grid systems, irrigation systems and energy saving infrastructures.

IoT products and devices basically include laptops, smart phones, smart gadgets, smart watches, smart and digitalized vehicles and almost all of these are used majorly today.

IoT Data Protocols used are MQTT (Message Queuing Telemetry Transport) An MQTT is a lightweight IoT data protocol. CoAP (Constrained Application Protocol), AMQP (Advanced Message Queuing Protocol), DDS (Data Distribution Service), HTTP (Hyper Text Transfer Protocol), WebSocket, WiFi, Bluetooth are some of them in IoTs.

Leading Types of IoT Wireless Technique is LPWANs. Low Power Wide Area Networks (LPWANs) are the new phenomenon in IoT, Cellular (3G/4G/5G), Zigbee and Other Mesh Protocols, Bluetooth and BLE, Wi-Fi, RFID.

As Internet of Things modules continue to shrink and incorporate more wireless technologies, making space for antennas is becoming an increasingly significant challenge. Modules for Internet of Things (IoT) applications are swarming the consumer and industrial markets with the aim of sensing, computing, and connecting all things within reach. A wealth of clever strategies is needed to shrink the size of these devices while maintaining highly reliable remote performance under low-power conditions. As a result, IoT-module antenna designers face the restrictions of maintaining reasonable performance in ever-shrinking footprints and under extreme interference/cosite conditions. Antenna folding techniques can be used to

minimize antenna dimensions, further decreasing the size and cost of IoT modules. (Courtesy of Seed)

Weighing cost, size, design effort, and manufacturing complexity, IoT modules make an engineer's design decisions much more challenging. Common IoT antenna typologies range from printed circuit board (PCB) designs to prefabricated chip antennas. The following antenna typologies each have their benefits and drawbacks, which is listed to aid IoT module designers in making the right antenna decision for their applications.

Single-layer printed dipole antennas have a Narrowband width less than 1% for VSWR better than 2:1. The length of the dipole may be between quarter wavelength to half wavelength. The antenna directivity is around 0 dBi and the beam width is around 90°–100°. The antenna bandwidth may be improved by printing the antenna feed network on a dielectric substrate and by printing the radiating dipole on a second layer. The electromagnetic fields are coupled to the radiating dipole. The bandwidth of the double-layer printed dipole may be between 1 and 5% for VSWR better than 2:1 as a function of the dipole configuration and the layers thickness. The printed dipole antenna consists of two layers. The first layer consists of a 0.8-mm substrate with 3.5 as dielectric constant. The second layer consists of a 0.8-mm substrate with 2.2 as dielectric constant. The substrate thickness determines the antenna bandwidth. However, thinner antennas are flexible. The antenna dimensions are designed to operate on the patient's body by using electromagnetic software (Abbas et al., 2015). The double-layer antenna is shown in Figure 1. The directivity of the antenna at 420 MHz is around 4 dBi as shown in Figure 2.

A double-layer 460 MHz dipole antenna is shown in Figure 3. The antenna dimensions are 20×4 cm. The directivity of the antenna at 460 MHz is around 5 dBi as presented in Figure 4. The antenna beamwidth is around 120°.

In several communication and medical systems, the polarization of the received signal is not known. The polarization of the received signal may be vertical, horizontal, or circular polarized. In these Printed wearable dual-polarized dipole antennas systems, it is crucial to use dual-polarized receiving antennas. Two wearable antennas are presented in this section; the first is a dual-polarized printed dipole. The second antenna is a dual-polarized, folded, printed microstrip dipole. The compact, printed, loaded dipole antenna is horizontally polarized. The antenna dimensions have been designed to operate on the patient's body by employing electromagnetic software. The antenna consists of two layers. The first layer consists of a 0.08-cm dielectric substrate with 3.5 as relative dielectric constant. On this layer, the antenna feed network is printed. The radiating elements are printed on the second layer which consists of a 0.08-cm dielectric substrate with 2.2 as relative dielectric constant. Thicker antennas have a wider bandwidth. However, thinner antennas are more flexible with a narrower bandwidth. The printed slot antenna is vertically polarized. The

printed dipole and the slot antenna provide dual orthogonal polarizations. Wearable microstrip antennas (Printed antennas) for 5G, medical, and IoT applications are usually low profile, compact, flexible, light weight, and low-cost relative to wired antennas. Microstrip antennas may be used as wearable antennas. Printed antennas have been widely presented in the literature in the last 20 years. The most popular type of printed antennas is the microstrip antennas. However, loop, PIFA, slot, and dipole-printed are widely used in RF systems. Printed antennas may be employed in communication mobile phones, IoT, seekers, and in medical systems.

Wearable microstrip antennas for 5G and medical systems are etched on a low loss dielectric substrate. A cross-sectional view of the microstrip antenna electric fields is presented in Figure 13. Microstrip antennas are thin conducting patches etched on a substrate with dielectric constant ϵ_r and thickness(t). Usually, t is less than 0.1λ . The wearable antenna may be attached to the human body or inserted inside a belt.

Applications

Microstrip antenna has fringing electric fields, radiating in cross-sectional view in many application. The advantages of microstrip antennas are light weight and low volume. Flexible, Conformal structures are possible. Low cost relative to conventional wired antennas. Easy to fabricate a large uniform arrays and phased arrays. These features are very important for wearable communication systems.

Disadvantages of microstrip antennas are limited bandwidth (usually 1–5%). However, wider bandwidth is possible with increased antenna structure complexity. Low power handling less than 50 W depends on substrate thickness. Limited gain up to 30 dBi, 16 x 16 arrays. High feed network losses at high frequencies, above 12 GHz.

The patch magnetic field is perpendicular to the E-field. There is no conductor to carry the RF current so at the edge of the strip ($X/L = 0$ and $X/L = 1$), the H-field drops to zero and is maximum in the center. The E-field is zero at the center and at maximum value (and opposite polarity) at the edges ($X/L = 0$ and $X/L = 1$), see Figure 3 and 4. The ratio of E- to H-field is proportional to the patch impedance. Microstrip antennas may be fed by a coaxial probe feed or by a microstrip feed line. By adjusting the location of the antenna feed point, we can achieve any impedance and match the antenna to the RF system, usually 50 Ω . The antenna shape may be rectangular, square, triangle, circle, or any arbitrary shape as presented(DeLisle, 2015).

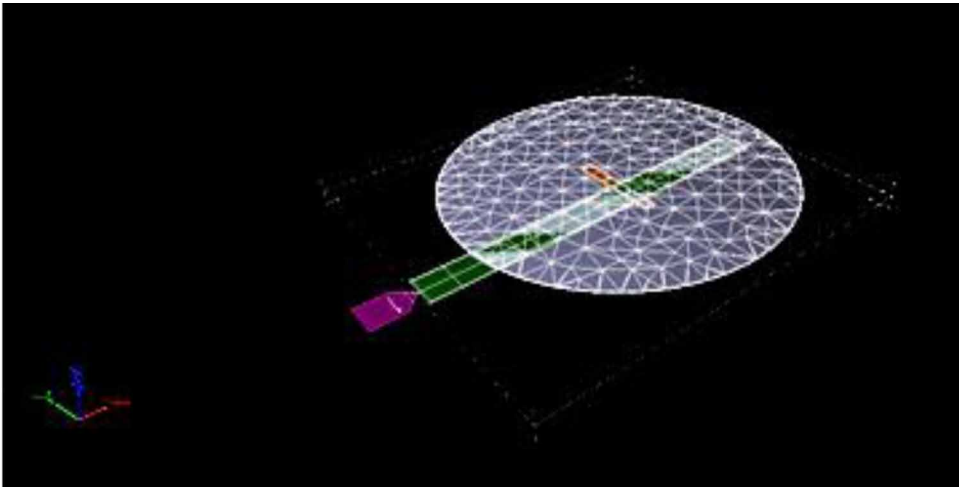
Wearable stacked microstrip antennas for 5G, IoT, and medical applications were presented first. Now, single-layer microstrip antennas have a Narrowband width. This disadvantage limits the applications of microstrip antennas. By designing a

double-layer microstrip antenna, we may get a wider bandwidth. Two-layer patch antennas may be the best antenna choice for wideband communication systems.

NARROWBAND DESIGN

On the first layer, the antenna matching network and a resonator are printed. On the next layer, the antenna element is printed. The electromagnetic field is coupled from the resonator to the radiating element. The part of the radiating element shapes may be rectangular, square, triangle, circle, or any other shape. The distance between the layers is optimized to get maximum bandwidth with the best antenna efficiency.

Figure 3. Circular patch microstrip antenna (ACPA) geometry designed for 2.55 GHz



The spacing between the layers may be air or a substrate with low dielectric losses. All the antennas’ electrical parameters were calculated and optimized by simulator. The antenna design and current distribution are shown in Figure 3. It is aperture coupled circular shaped antenna. It is designed with the dimensions as per in the table 1.

The square shaped microstripline used patch antenna is designed and shown in the figure 4. The feed is through the microstrip line.

The antenna details presented here is tabulated below in table 1 in terms of frequency and dimensions.

Figure 4. Microstrip line square patch antenna (MSPA) geometry for 1.88 GHz

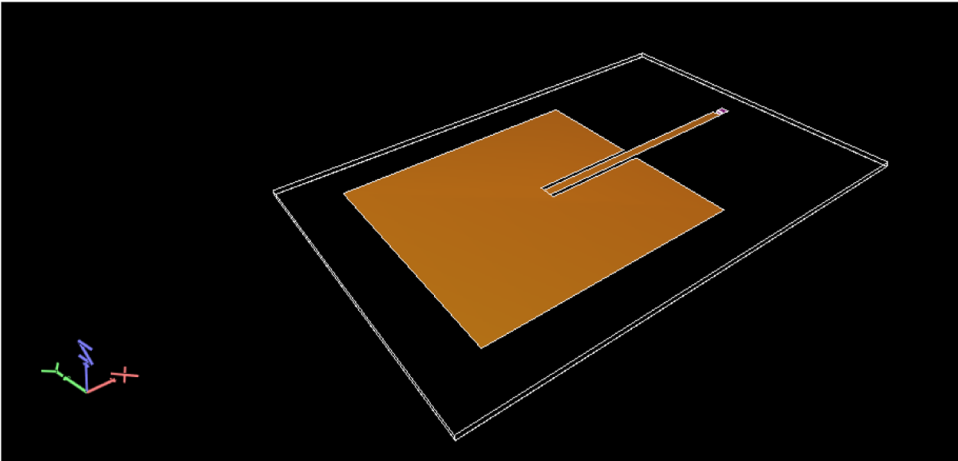


Table 1. Narrowband microstrip patch antenna details

Antenna details	Circular patch	Square patch
Operating frequency	2.55 GHz	1.88 GHz
Dielectric constant	4.4	4.4
Thickness	1.6mm	1.6mm
Dimensions	Radius=18.18mm	Side=43.43mm
Feed line length	35.27mm	35.27mm
Feed line width	7.15mm	9.7mm
Ground plane	40X45 mm ²	70X70 mm ²

1. RESULTS AND DISCUSSION

The antennas for IoT application is discussed. Further two antenna design resonating in the range of 2.55 GHz and 1.8 GHz are designed and simulated in this chapter.

The patch radiation pattern is function of the patch width, W. The coordinate system of elevation radiation pattern is presented in Figure 5. The normalized radiation pattern may be simulated by using the IE3D software tool:

The overall azimuthal radiation pattern of complete angle is presented in figure 6. with this figure, it is exhibited that the radiation is differing in gain (dBi) for each angle value.

Figure 5. Elevation radiation pattern for overall frequencies of(ACPA)

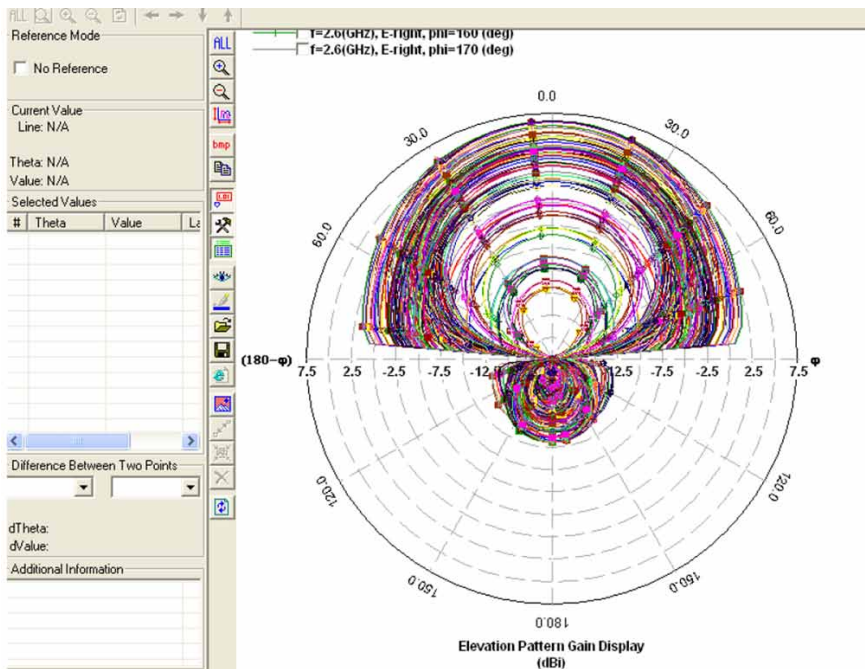
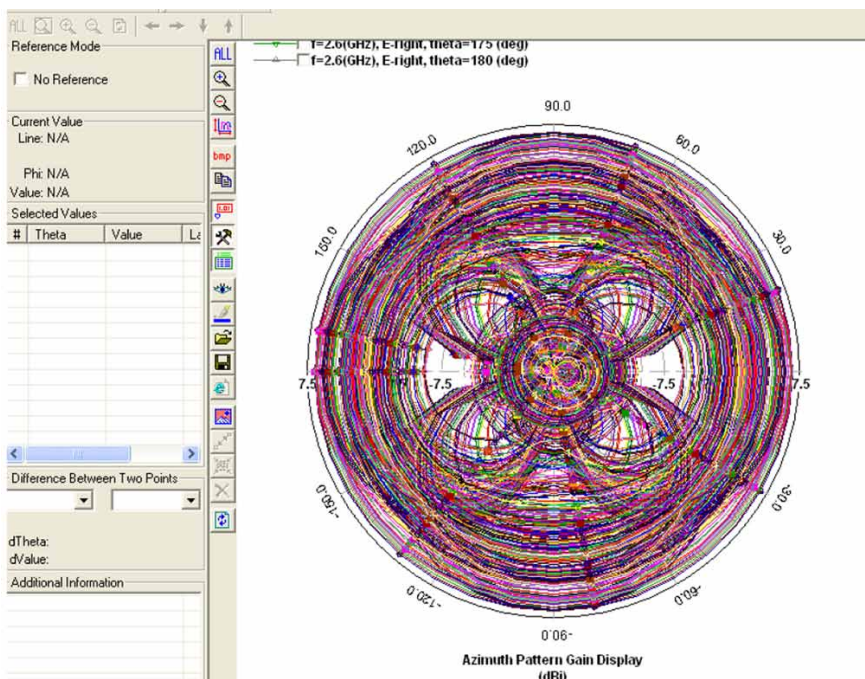
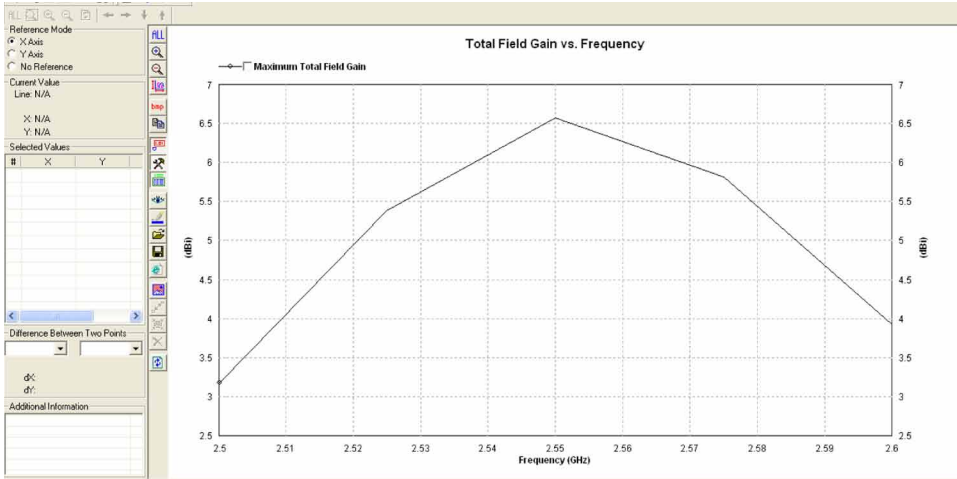


Figure 6. Azimuthal radiation pattern for(ACPA)



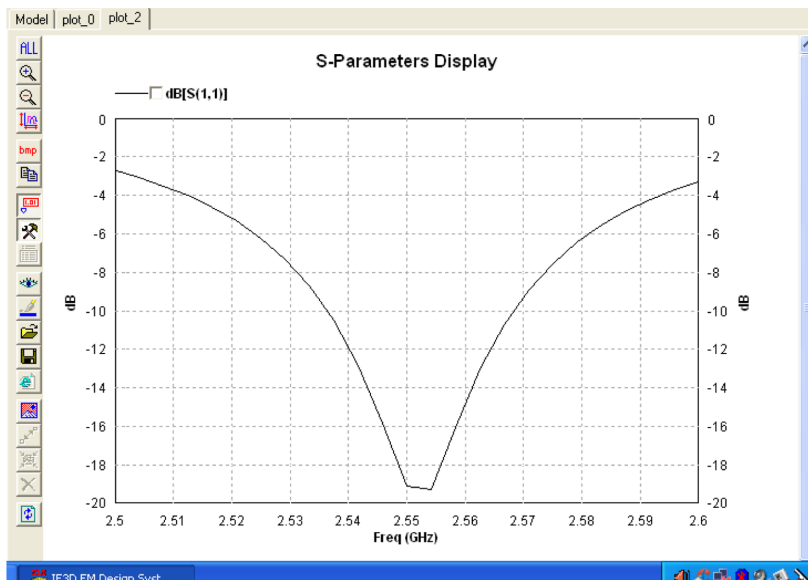
The total field gain characteristic curve shows good value of 6.5 dBi for the resonating frequency.

Figure 7. Gain versus frequency characteristics (ACPA)



The S-parameters display curve shows the resonance at 2.55 GHz for this antenna. It is nearly -18 dB.

Figure 8. S-parameter characteristics (ACPA)



VSWR display of this antenna is presented in figure 8. It shows the antenna resonance occurs vswr less than 1.5 and close to 1.

Figure 9. VSWR display versus frequency (ACPA)

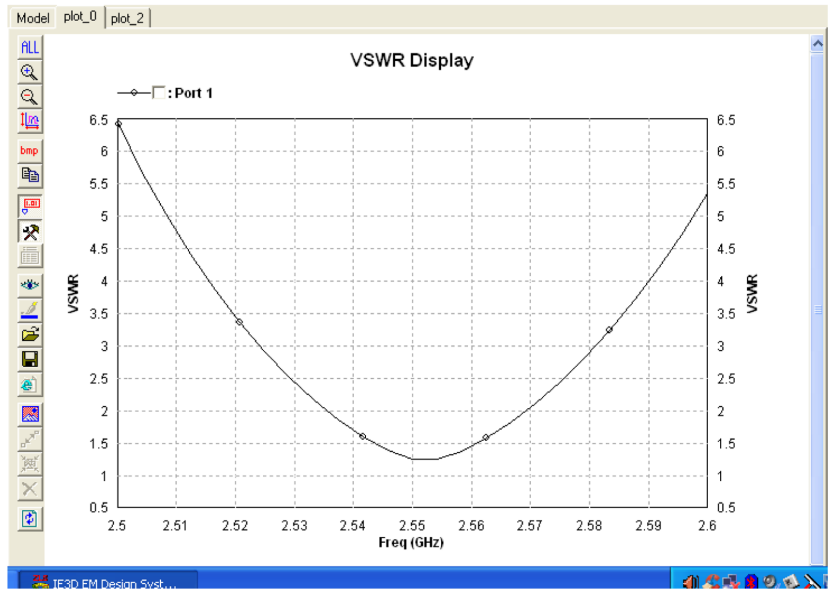


Figure 10. S-parameters graph at 1.88 GHz (MSPA)

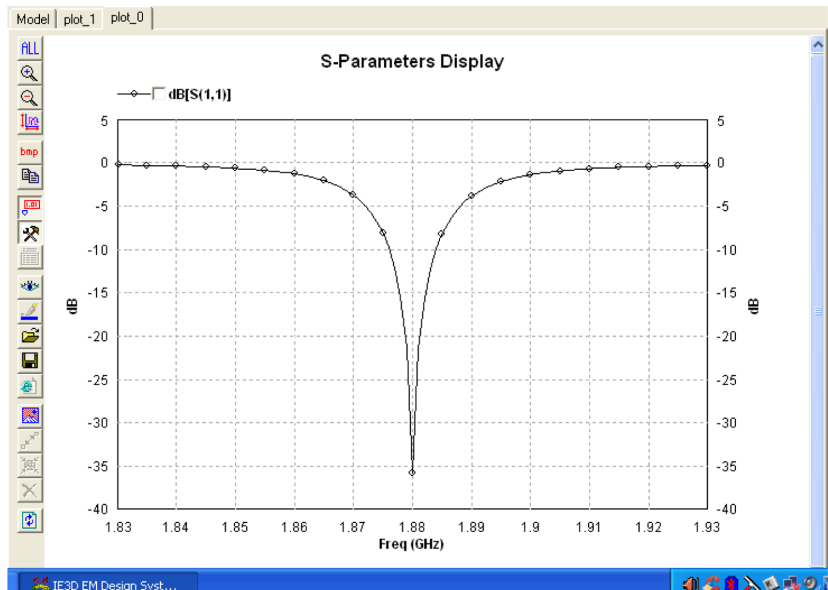
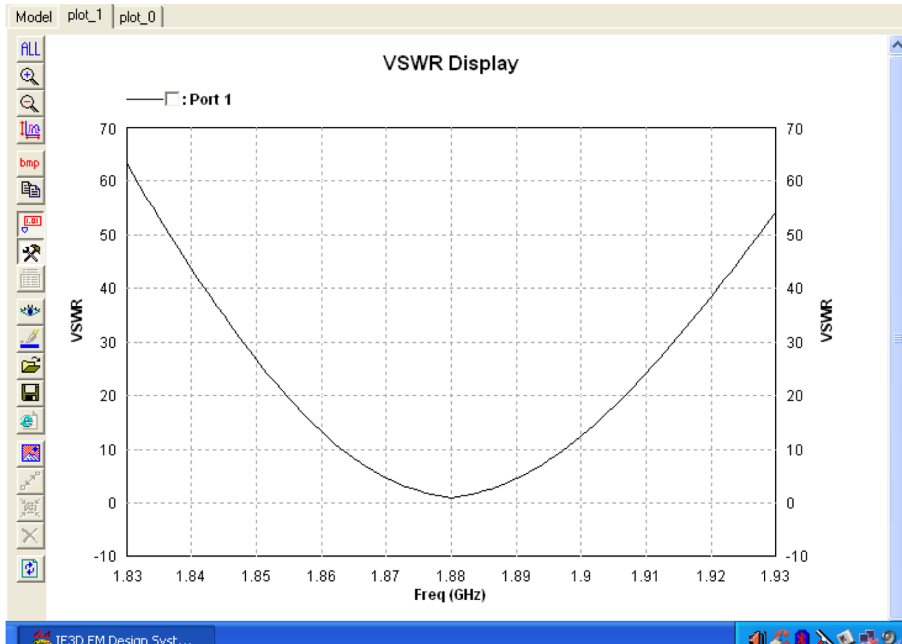


Figure 11. VSWR characteristics of (MSPA)



The S-parameter display is shown here the resonance frequency at -35 dB for 1.88 GHz.

VSWR characteristic of the antenna is displayed in figure 11.

The patch radiation pattern depends on function of the patch width, W . The coordinate system is presented in Figure 18. The normalized radiation pattern may be simulated by using Equations.

The antenna efficiency and radiation efficiency characteristics is given below in terms of frequencies. It is about 70% at 1.88 GHz.

The elevation radiation pattern for 1.88 GHz of all angles is given in the figure with different colours.

The field gain characteristics shown in the figure below. it is about 5 dBi.

The above simulation gives gain of 6.5 dBi and 5 dBi respectively by single radiating element. By using arrays, it can be increased. Further these antennas can be fabricated as model for testing investigations.

Figure 12. Azimuthal radiation pattern (MSPA)

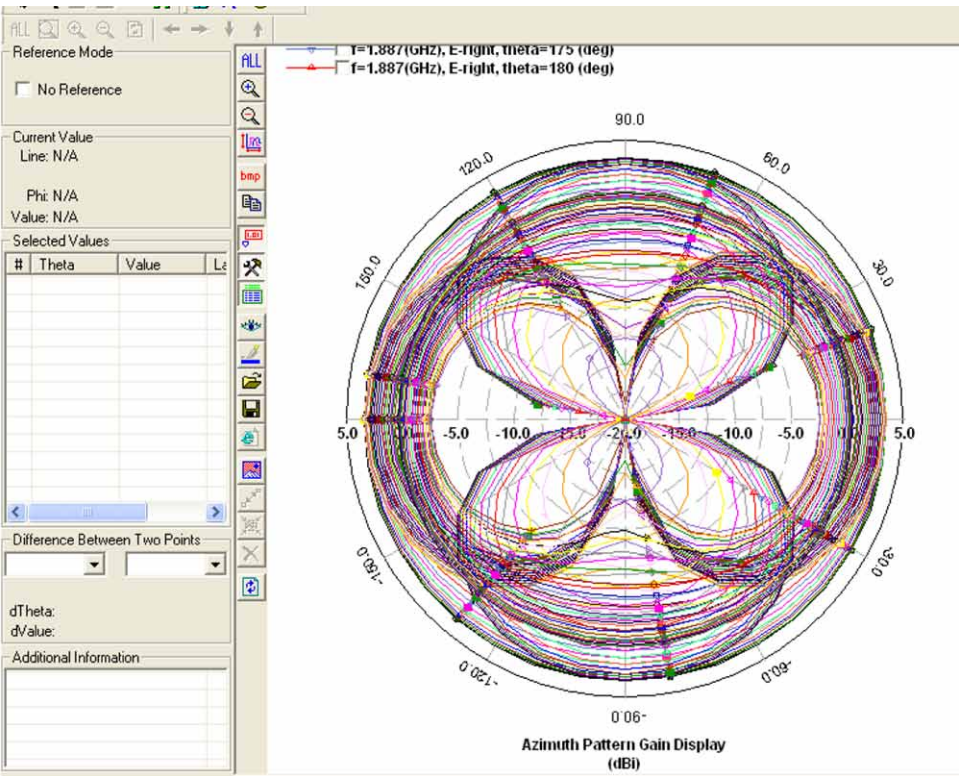
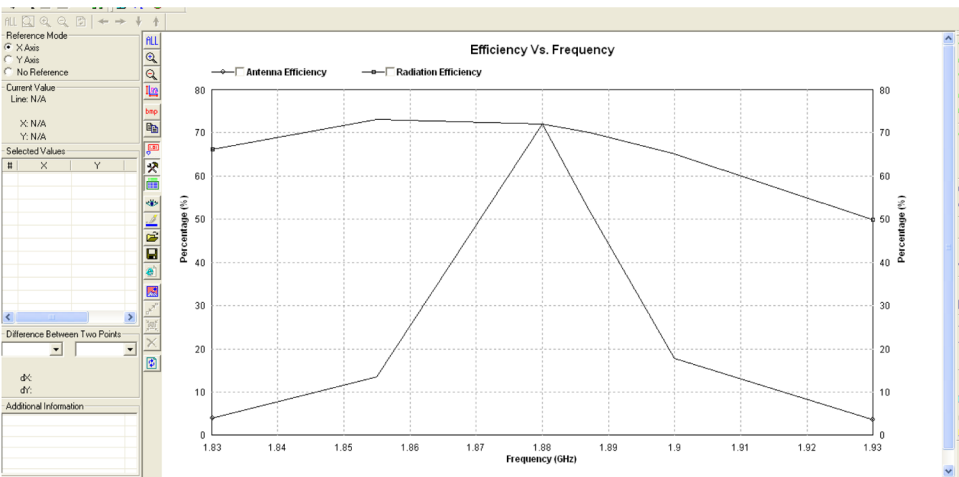
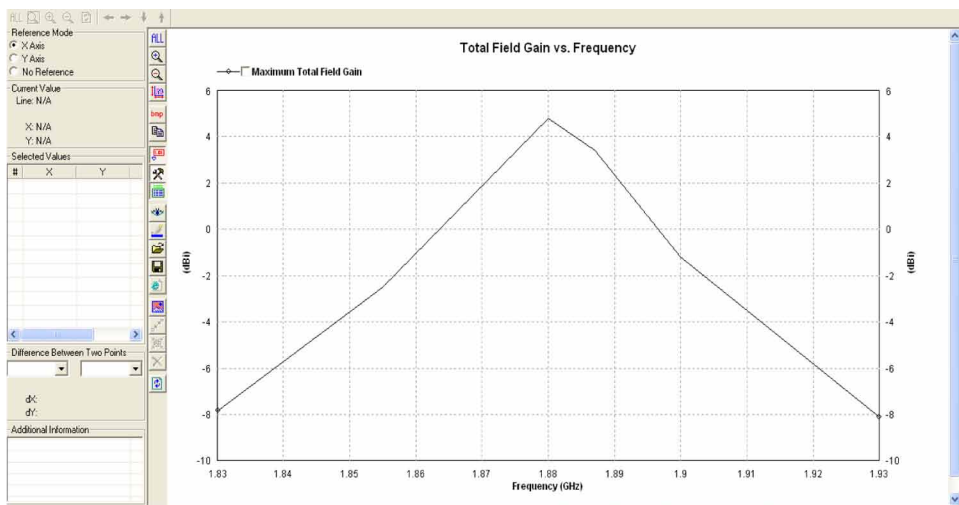


Figure 13. Antenna and radiation efficiency (MSPA)





FUTURE RESEARCH DIRECTIONS

Narrowband antennas for communication and biomedical applications is always the trend in future. It is the chapter theme to provide some points about the topic. The possibilities of wearable design also mentioned. But the model implementation issues are to be challenging one. If any artificial intelligence is possible to design and analyze, it will be appropriate.

CONCLUSION

This chapter presents several NB-IoT and it is very flexible and can be operated in 2G, 3G, and 4G band. Narrowband antennas with reasonable efficiency for medical, IoT and sport applications is presented. Design considerations simulated results of two printed antennas are described in this chapter. The antenna's electrical characteristics and dimensions were designed to meet the medical system specification. The dimensions of the compact antennas may vary from $40 \times 45 \times 1.6 \text{ mm}^3$ to $70 \times 70 \times 1.6 \text{ mm}^3$ to meet the IoT system specification. It can be used for Wearable technology. It provides a useful novel tool to health-care centers and surgical rehabilitation services. Wireless wearable body area network (wireless WBAN) is emerging as a significant option for hospitals, medical centers, and patients.

The compact antennas bandwidth is between 9 and 12% for VSWR better than 2:1. The compact antenna beam width varies from 70 to 100 degrees and the antennas gain varies from 0 to 6.5 dBi as a function of the antenna dimensions. The bandwidth of 100 MHz is achieved in these antennas.

The length of the antennas without SRR is higher by 5–10% than the length of the antennas with SRR. Moreover, the resonant frequency of the antennas without SRR is higher by 5–10% than the antennas with SRR. The gain and directivity of the patch antenna without SRR is lower by 2–3 dB than the patch antenna with SRR. The resonant frequency of the wearable antennas with SRR on human body may be shifted by 2–5% (Sabban, 2019).

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Chapter 13

Impact of Number of Slots and Permittivity on EMI Shielding Effectiveness

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ABSTRACT

All electronics equipment and devices emit electromagnetic energy. The emitted energy creates electromagnetic interference to the nearby electronic equipment. Shielding is the only effective method of reducing this type of interference without disturbing and reducing the performance of complex electronic systems. Shielding cages usually have openings or slots to provide ventilation and enable access to electronic components placed inside the cage. In this chapter, the impact of dimension of the shielding cage and the number of slots in the shielding cage are investigated. Relative permittivity reflects the electrical characteristics. Its impact on shielding effectiveness is also analyzed in this chapter. Simulation results shows decrease in the shielding effectiveness with the increase in number of slots as well as increase in relative permittivity. In addition, the shielding effectiveness decreases with the increase in frequency.

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INTRODUCTION

Electromagnetic interference (EMI) is a common and wide source of disturbance that can interrupt electronic operations and include electronic bias to malfunction. All electronics equipment and devices emit electromagnetic energy. Similar emitted if interacts with near device and causes it to malfunction, also it is considered as interference. Radios, televisions, motors, lightning are some of the common sources creating interference to other devices like computers, measuring instruments and navigation systems. Most of the electronic equipment and systems are nowadays placed or fitted inside a plastic housing. Due to the insulator property of the plastics, the electromagnetic waves can easily pass through the plastic housings and therefore a provision for EMI shielding is necessary in such cases. One way to achieve this is to cover the plastic casing with a conductive layer. Else the casing has to be made with a conductive material (Enbo Liu., Ping-An Du., and Baolin Nie (2014).

An especially shaped conducting material can be used to form a shield against such EMI by incompletely or fully. Such shielding reduces the measure of EMI radiation that can pass from the external surround into the shielded circuit. They also help in shielding the EMI radiation generated by the circuit inside the housing to escape out. Shielding is the only effective method of reducing EMI things without disturbing and reducing the performance of complex electronic systems. Utmost of the EMI shielding systems follow the same introductory set of principles.

Faraday EMI cage principle shows that an enclosed conductive casing will result in a zero electrical field, therefore suppressing the things of interference. Based on this, EMI cage is developed and it reflects interference into the ground. The conductive cage has electric charges of varying opposition along its surface that produce a separate electric field to cancel the effects of the original field. Still, an EMI shields generally have openings or orifices to give ventilation and enable access to shielded factors that enable attachment to cables or other assemblies. The Effectiveness of an EMI shield is dropped due to the presence of orifices. Any place or opening in the shell will attract the current and affect it to pass through the defensive surface, no matter how small the opening (Angelo Gifuni., Antonio Sorrentino., Alessandro Fanti., Giuseppe Ferrara., Maurizio Migliaccio., Giuseppe Mazzarella and Federico Corona, 2012).

The EMI shielding considerations are kindly different when a field is designated according to the electric field intensity (E-field) or magnetic field intensity (H-field). In addition to that, operating frequency is also plays an important role. Lower frequency H-field shielding is supplied by closure fabricated from a thick, soft magnetic material with a high level of permeability and at high H-field frequencies, a thin conductive enclosure with low permeability is required. Utmost EMI is caused by frequencies that fall between 1 kilohertz and 10 gigahertz, and this range is known

as the Radio Frequency Interference (RFI) band. Designing shielding with orifices arranged in a way that minimizes their influence on current inflow is therefore an important consideration for nearly any system built to cover bias against EMI (Ye.I. Gabrousenko., F.J. Yanovsky., A.G. Taranenko and A.G. Holubnychyi, 2019).

A logical shielding proposition for rectangular enclosures with orifice is developed by Mendez (Mendez H. A, 1970). This theory can be used below the first resonance frequency of the closure. First, the fields inside the closure due to internal sources are determined assuming no orifice is present. Then the apertures are replaced by equivalent electric and magnetic dipoles taking the polarization effect of each orifice into account. Review of a number of methods for assaying similar orifice problems is presented with an emphasis on way (C. M. Butler., Y. Rahmat-Samii., and R. Mittra, 1978). A careful disquisition of different aspects of the shielding tracts of metallic enclosures is performed by Olyslager et al (Frank Olyslager., Eric Laermans., Daniel De Zutter., Steven Criel., Ronald De Smedt., Norbert Lietaert and Andr e De Clercq, 1999). Composite comprising carbonaceous, polymer and dielectric materials with iron components as important constituents for the prevention of EMI by reflection is explored (Vineeta Shukla, 2019). Various methods and techniques are critically reviewed to develop high performance, lightweight and cost-effective polymer composites reinforced and reinforced carbon filling in EMI protective applications (B H S Thimmappa., Aravind Karthik., Shivamurthy B., Nithesh Naik., Smarth Sharma and Dasharathraj K Shetty, 2020). A new technique is offered to evaluate shielding effectiveness in terms of the depth of field penetration into the conductor material. Mathematical modeling and simulation of electromagnetic field penetration into a conductor depending on the operating frequency and properties of the conductor material is carried out, as well as developmental verification of the results attained in this composition. Gifuni et al estimate the shielding effectiveness of electrically great enclosures with a metallic entanglement grid in a resonating chamber (Zdenek Kub k and Jir  Sk la, 2016). Some examination are carried out to estimate shielding effectiveness and reflectivity of the three layered laminate structure at different consistence of each sub caste and for a combination of disparate materials. Theoretical analysis, numerical computations, and simulation software to compute the shielding effectiveness is carried by Zhang et al (Zhang. G, (2017). Sana Iqbal et al shown that by loading the slots in enclosure with metal wires, the radiated emissions from the cavity can be significantly degraded (Sana Iqbal., Muhammad Amin, Kashif Nadeem., Irfan Majid and Muhammad Inam Abbasi (2010).

The remains of this paper are organized as follows. The concept of Shielding Effectiveness (ES) and its dimension method are explained in Section II. The performance results are anatomized in Section III. Conclusions and future work are given in Section IV.

SHIELDING EFFECTIVENESS

The shielding effectiveness (SE) is outlined as the rate of absolute valuation of electric field E_{wos} (or magnetic field H_{wos}) at a point without the shielding and the absolute valuation of electric field E_{ws} (or magnetic field H_{ws}) at the identical point with the shielding. In overall, the shielding effectiveness is expressed in decibels as,

$$SE = 20 \log (E_{\text{wos}} / E_{\text{ws}}) \quad (1)$$

$$SE = 20 \log (H_{\text{wos}} / H_{\text{ws}}) \quad (2)$$

The enclosure which is used to provide the shielding is a closed container and therefore resonance condition exist whenever there is an EM wave. To provide ventilation or to access the components inside the enclosure definitely apertures have to be provided. Through these apertures, EM wave from outside can enter into the enclosure and at the same time, EM signals radiated by the electronic circuits fixed inside the closure may advanced out. Any opening or orifice in the closure will attract the current and invoke it to pass through the defensive shielding. Thus, two important factors which impact the SE are the cavity resonance of the closure and the number of orifice live in the closure. For a rectangular closure with an inside dimension of dimension of a x b x d, the resonance frequency (fr) is given by,

$$f_r = \frac{1}{2\sqrt{\mu\epsilon}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2} \quad (3)$$

Where, μ and ϵ are the permeability and permittivity of the substance. The indicators m, n and p correspond to the resonance mode of detail. By substituting different numerical values for m, n and p, it is possible to find the resonance frequency for that particular mode. Properly designed enclosures can be very effective in shielding and attenuating radiated emissions and protecting products from external sources of interference.

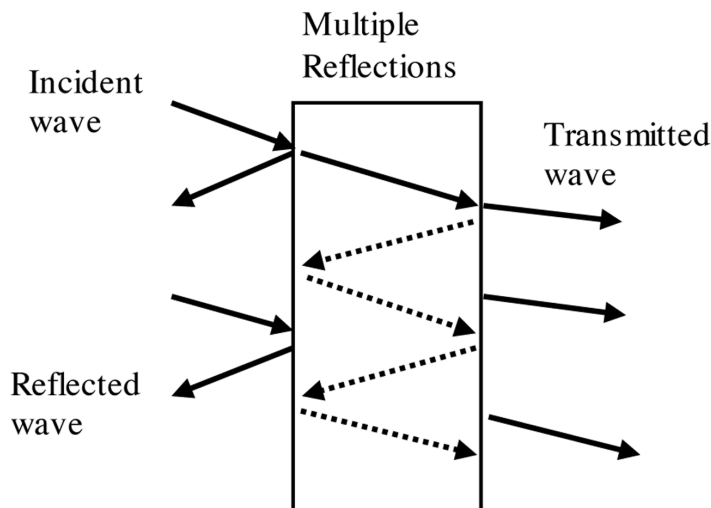
General Concept

Electromagnetic waves (EM) correspond of electric and magnetic field which are vertical to each different and vertical to the direction of propagation. Grounded on the character of waveform or polarization the comparative magnitude of electric and magnetic field gets mixed. Wave impedance or intrinsic impedance, which is the rate of electric and magnetic field strength, is an important parameter. The electronic

circuit of component, which is to be shielded from EMI may be nearer or away from the source which generates EM waves. Consequently, the near field shielding region and far field shielding area is accounted and disparate method has to be acclimated to give EMI shielding. The electromagnetic plane wave proposition is commonly referred for EMI shielding by far field region (Zdenek Kubík and Jirí Skála, 2016).

The mechanism by which an EM wave gets attenuated whenever it is incident and pass through a metal enclosure in the wave propagation direction are absorption, reflection and multiple reflections (Raj, C. D., G. S. Rao, P. V. Y. Jayasree, B. Srinu, and P. Lakshman, (2010). This situation is shown in the figure 1. The shielding effectiveness depends on all these factors.

Figure 1. EM wave attenuation Mechanism



SE Measurement Technique

The EMI Shielding Effectiveness is measured using the following four ways depending on the purpose of shielding:

1. Open Field or Free Space Method
2. Shielded Box Method
3. Shielded Room Method and
4. Coaxial Transmission Line Method

To estimate the shielding effectiveness of an entire electronic congregation, the free space system is applied. That is, this method is applied to detect the radiated emissions from a finished product. As the name implies, the shielded box method uses a metal box inside which the electronic circuit is placed. Different type of materials may be used to coat the metal box to provide the required shielding. This technique is used to make a comparison or analysis of shielding effectiveness between coating materials used for shielding. In shielded room method, instead of small box or enclosure a large space or room is used to make the measurements. In addition, the equipment like signal generator, measuring instruments and antenna are separately places in an anechoic chamber. The coaxial transmission line method has an added advantage, that the results attained in different laboratories are similar (M. Raveendra, U. Saravanakumar, G. A. Kumar, P. Suresh and S. P. D. Pedapalli, 2021).

SIMULATION RESULTS

This simulation models a rectangular shielding closure with the dimensions of 252 mm x 114 mm x 300 mm. The simulator environment available at www.amanogawa.com is used in this work. The simulation started at 1 MHz and ended at GHz with a frequency step variation of 100 MHz. The shielding effectiveness is computed at the base of the rectangular shield (at $d = 150$ mm).

Following criteria are applied to study the performance of the Shielding effectiveness.

Number of slots: Slots are provided for ventilation as well as for accessing the component or circuits placed inside the enclosure.

Permittivity: Permittivity is the electrical characteristics of a substance and certainly it has collision on the reaching EM waves.

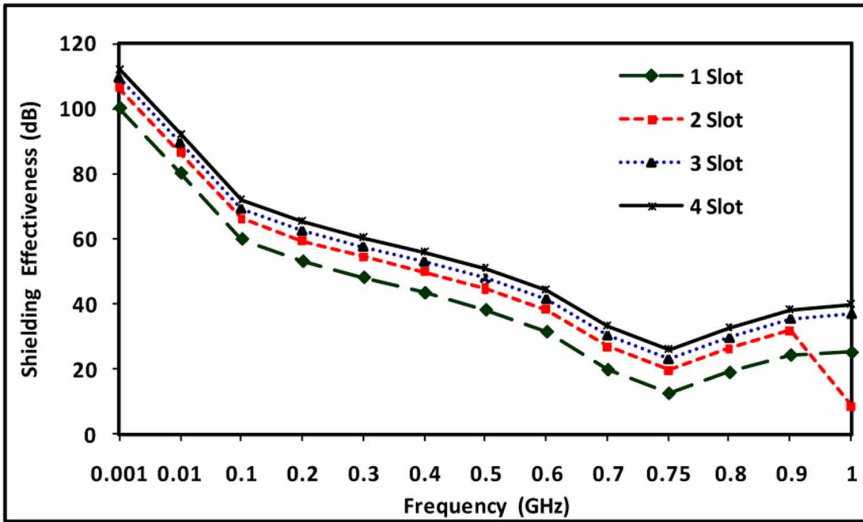
Dimension of the enclosure: Rectangular shielding acts as a resonator. Any modification in dimension reflects on the resonant frequency and away the shielding effectiveness.

Impact of Frequency and Number of Slots

For this simulation, the distance and range of the slot are taken as 80 mm and 5 mm. During the operational condition, heat is generated from the electronic circuits and proper ventilation or heat sink has to be provided to take care of that. In general, slots or operating are made in the shielding cages to provided ventilation. Through those slots, EM waves can enter and flam inside the shielding of space. At the same time, EM waves radiated form the electronic circuits inside the cage may try to flam to outside through these slots. It affects the shielding supplied and in turn

shielding effectiveness reduces. Figure 2 shows the impact of number of places on shielding effectiveness.

Figure 2. Frequency Vs SE for various numbers of slots



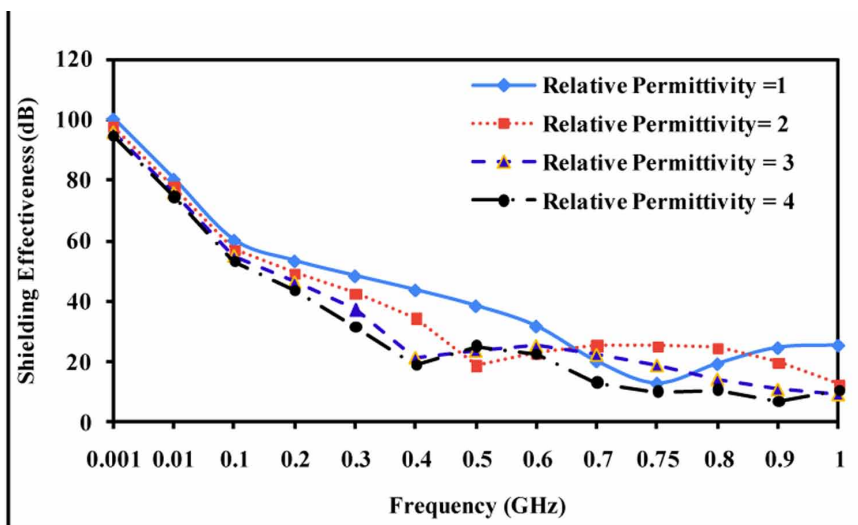
At 1 MHz the SE is 100.314 dB and it reduces to 19.909 dB at 700 MHz. The lowest SE value of 12.607 dB is observed at 750 MHz. The rectangular cage also acts as a resonant cavity. Depending on the measurement disparate modes of propagation live inside the cavity. At resonant frequency more power is adsorbed and hence the shielding effectiveness decreases and increases the electromagnetic interference. Due to resonant mode at the frequency of around 7.5 GHz, the SE because very low. With the increase in frequency beyond this, the next mode of propagation takes place and power absorption decreases. Thus, the SE starts to increase after 750 MHz.

If the number of slot is increased, without changing the net slot dimension, the area available for the EM wave to enter inside the shielding cage now have some discontinuity. In between the slots, some non slotted metal area of the cage is available. Increase in number of slots, but with reduced individual slot dimension is achieved by this. It is easily observed from the simulation results that, the shielding effectiveness increases with the increase in number of places. For example, at 300 MHz, the SE value increases as 48.229, 54.303, 57.829 and 60.324 dB with the increase in number of slots as 1, 2, 3 and 4. Therefore, to increase shielding effectiveness, instead of using a single large slot, multiple slots of small dimension may be used.

Impact of Frequency and Relative Permittivity

Relative permittivity reflects the electrical characteristics of a material. Therefore, the change in permittivity value has some impact on the nature of EM wave passing through the shielding cage. For this simulation, only one slot with the dimension of 5mm X 1.5mm is used. The dimension of rectangular shielding cage is kept as 252mm x 114mm x 300mm. The value of relative permittivity is varies as 1, 2, 3 and 4. As expected the simulation results shows a decrease in SE with the increase in ϵ_r as shown in figure 3. At 300 MHz, the SE value decreases as 48.229, 42.321, 37.128 and 31.538 dB with the increase in relative permittivity as 1, 2, 3 and 4.

Figure 3. Frequency Vs SE for various ϵ_r



It is also noted that the lowest value of SE is observed at earlier frequency range of EM waves with the increase in the value of ϵ_r . In different expressions, the resonant frequency of the propagation mode is vice versa to square root of the permittivity and the resonance frequency decreases with the increase in ϵ_r value.

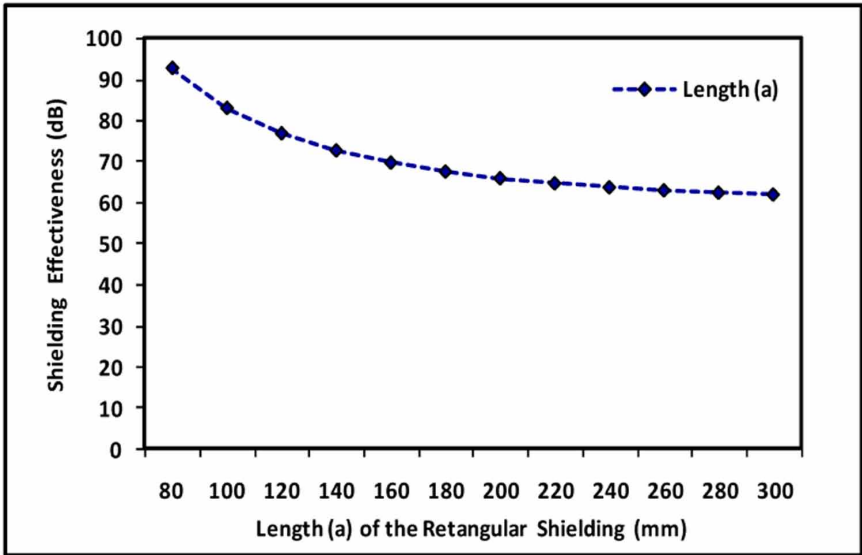
Impact of Shielding Cage Dimension

Any change in the dimension of shielding cage. The valuation of resonance frequency changes for any change in the dimension of the cavity. For this simulation the length (a) is changed in steps of 20 mm from 80 mm to 300 mm, while keeping the different

Impact of Number of Slots and Permittivity on EMI Shielding Effectiveness

two confines constant at 60 mm and 300 mm. Figure 4 shows the impact of change in length on shielding effectiveness.

Figure 4. Frequency Vs SE for various ϵr



As shown, the shielding effectiveness decreases with the increase in length of the rectangular shielding.

CONCLUSION

This chapter investigates the impact of number of slots and change in dimension of the rectangular cage on EMI shielding effectiveness. Electromagnetic interference is wide source of dislocation to the effective performance of all electronic related operations. Shielding is one of the optimistic technologies to degrade the EMI effects. Completely closed enclosure provides maximum EMI shielding. However, slots or opening are to be provided for ventilation to dissipate the heat generated by the electronic components during their working condition. In this work, the number of places and confines of the rectangular cage are increased. The simulation results show an increase in shielding effectiveness with the increase in number of places and drop in shielding effectiveness with the increase in frequency. Change in dimension of the cage will change the exposure area to EM waves. Simulation results also show a drop in shielding effectiveness with the increase in dimension of the cage.

In future, the simulated result can be verified by constructing such rectangular cage and test it in an anechoic chamber.

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Impact of Number of Slots and Permittivity on EMI Shielding Effectiveness

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Chapter 14

Dual-Band Helical Reflect Array Antenna for High Power Microwave Applications

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ABSTRACT

A reflect cluster receiving wire (RAA) with a wideband high-power double branch helical reflect cluster is demonstrated. Two metal helical branches make up the reflecting component, and the movable pivot points allow for full 360° stage rotation. A 9 X 9 rectangular cross section X-band RAA model is imitated and estimated. The best get of 23.7 dB is achieved with the bar concentrated at ($=20,=0$) course at focus repeat of 9.3 GHz, and the 1-dB get a move on is more than 24.2%, according to full-wave reenactments. In the entire band, the intentional reflection coefficient is not exactly - 16.3 dB. The endeavored significant rate is under 2.3 dB from 8.4 GHz to 10.8 GHz. The attempted get at center rehash is 23.4 dB, and the differentiating opening helpfulness is 50.6%. The RAA's bar inspecting execution is endeavored inside 30° exactness in two balanced planes with a check trouble of under 1.5 dB and focus point degrees of under 1.4 dB. Under vacuum, the mirrored results provide the appearance that the RAA's force taking care of limit is approximately 358 MW.

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INTRODUCTION

The interest for high force microwave (HPM) imparting structures is filling really because of their wide applications in standard occupant and military frameworks (Taylor, 1994). The striking necessities of high force instruments place additional difficulties on radio wire plan. In high force conditions, the radio wire is acquainted with the radiation of high force sources. Therefore, the force overseeing limit of the radio wire changes into a gigantic issue that should be tended to. This shows up with the yield system for endless the HPM sources has azimuthal consistency (for example the TM₀₁ round waveguide mode or the TEM coaxial mode), which conveys a donut formed model with a boresight invalid, whenever imparted straightforwardly. A few methodologies for HPM getting wire plans have been proposed in the piece. Mode change techniques are thoroughly used to change the vexatious azimuthally symmetric mode to one with a boresight top (for example the rectangular TE₁₀ mode or the backhanded TE₁₁ mode). (Li et al., 2008) Not with standing, these strategies have drawbacks for example, broadened structure difficulties, length, and weight. Valsov getting wire, COBRA radio wire, high force broadened line helical gathering radio wires, and high force microwave winding line opening radio wire are among the getting wire structures proposed for certain HPM applications. Obviously, the reflect display getting wires are planar developments in which a combination of insightful unit cells with fitting stage reactions is used to give an attracted or shaped shaft from an enlightening wave front. Reflect group getting wires have drawn in uncommon idea in later a long time inferable from their enchanting highlights like low profile, irrelevant expense, light weight, simplicity of headway, and managing. (Benford, 1992) This sort of radio wires are ordinarily framed from locally accidental plans in which unit cells of various shapes and advancements are utilized as spatial stage shifters of course spatial time-defer units. The reflect group unit cells are everything viewed as resounding or non-resonating squares and their stage or time surrender reaction can be constrained by changing the mathematical furthest reaches of portion, propelling the substrate attributes, turning the parts bearing, or stacking the unit cell with tuning fragments. (Lee et al., 2004) Many separated reflect bunches either have restricted power overseeing limit or are not reasonable for coordination with HPM structures. A tremendous piece of these improvements abuse metallic models in multi-facet game plans. Metallic associations, regardless, are tricky at high force, arcing happens at field focus focuses, and warming happens in view of ohmic difficulties experienced by solid streams in transmitters. Moreover, by ethicalness of direct radiation of the azimuthally symmetric yield methods for HPM sources, a donut framed model with a boresight invalid will be reradiated by the reflect display opening, which is bothersome for high force applications. (Courtney & Baum, 2000)

This paper portrays a dielectric reflect bunch that is equipped for understanding the directional radiation of azimuthally symmetric modes and has an excellent force overseeing limit. due to the hazardous impacts of metallic models at undeniable degrees of electromagnetic energy, a dielectric approach is embraced here to plan the reflect display unit cells. A variable broadness air-filled opening through a host dielectric material is used as a stage moving unit cell to plan a dielectric reflect show getting wire to work at X-band. (Vlasov & Orlova, 1974) The directional radiation of azimuthally symmetric mode is refined through remunerating the stage contrasts of enlightening wave front over the reflect show opening. Speculative assessment is utilized related to full-wave stimulations to take apart the radiation execution of the proposed reflect group getting wire. The outcomes depict the constraint of the proposed persuading wire to be utilized for HPM applications.

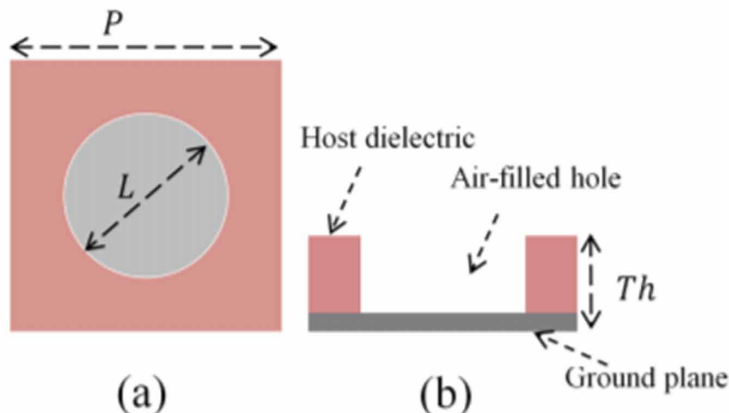
ANTENNA PRINCIPLE OF OPERATION

The reflect bunch opening is needed to be masterminded on the x-y plane and enlightened by a fixed horn radio wire. In our reference condition, the feed horn getting wire is straightforwardly constrained by the azimuthally symmetric TM₀₁ round mode and a donut framed model with a bore sight invalid is sent toward the reflect show opening. (Li et al., 2010) Since the pushing toward wave front has azimuthal balance, there is a 90 stage contrast between transmits showing up at points of same curving distance and quadrupled azimuthal point at the space of reflect group opening. To give a boresight top after reflection, this stage separation should be assessed by the reflect bunch opening. To accomplish this, reflect show opening is detached into 4 tantamount point quadrants.(Li et al., 2010) By presenting a stage shift of 90 to unit cells of each quarter relative with the associating quadrant, directional radiation of the azimuthally symmetric wave front can be acquired by the reflect display opening. As per the above conversation, the stage delay from the feed horn stage focus to a unit cell masterminded at point C(r; ‘) on the reflect bunch opening is given by:

$$\phi(r, \varphi) = -k_0 \sqrt{f^2 + r^2} - \frac{\pi(n-1)}{2} \quad (1)$$

where k_0 is the multiplication predictable of free space, (r; ‘) are the polar bearings of unit cell, n is the amount of quadrant wherein the unit cell is found, and F is the reflect array focal distance.(Peng et al., 2013)

Figure 1. Structure of Dielectric Unit Cell.



To achieve a collimated column at the boresight course, the time of reflection coefficient for different unit cells over the reflectarray opening should be picked with the end goal that total stage delay from feed stage center to a fixed opening plane before the reflectarray transforms into a reliable for all unit cells. (Berry et al., 1963) As necessities be, the necessary reflection stage appointment of reflectarray unit cells is settled as:

$$\varnothing_R(r, \varphi) = k_0 \sqrt{f^2 + r^2} + \frac{\pi(n-1)}{2} + 2k\pi \quad (2)$$

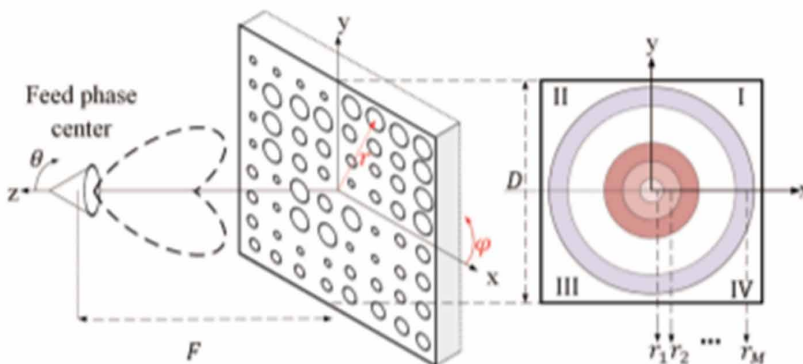
A X-band dielectric reflectarray getting wire working at 10 GHz is arranged, penniless down, and recreated to show the feasibility of the proposed approach. The dielectric unit cell is depicted in portion 3. In region 4, the reflectarray plan technique is presented, and the theoretical examination and reproduced results are inspected in portion 5.

REFLECTARRAY UNIT CELL

As alluded to as of now, dielectric approach is picked here to go without the risky impacts of metallic models in high force applications (Pottier et al., 2014). In dielectric-type unit cell, the conductive fix is taken out and the control of unit cell reflection stage is developed by changing the constraints of the dielectric. A

schematic model of the dielectric unit cell in our game plan is appeared (Peng et al., 2013). The unit cell is a square dielectric piece with permittivity of ϵ_r that in our course of action covers the entire unit cell surface. The thickness of the piece is T_h , and the unit cell periodicity is P . To plan the proposed HPM reflect bunch, diverse likely gains of the reflection stage are needed for different unit cells over the reflect display opening. The reflection season of unit cell can be constrained by debilitating an air-filled opening that has a distance across L through the dielectric irregularity (Berry et al., 1963). The width of the opening is then changed to give the fundamental reflection stage on the fragment position. Additionally, considering the sagacious thought about the unit cell, a conductive ground plane has been added to the base side of the dielectric piece. There are three levels of opportunity to plan the depicted unit cell. These solidify the permittivity and thickness of dielectric piece, and the periodicity of unit cell. To consider the impact of these cutoff points on the unit cell reflection coefficient, a development of reenactments are done using the recurrent space solver of CST Microwave Studio (Huang, 2008). The unit cell is put inside a rectangular waveguide with TEM-mode augmentation limit conditions. The top and base dividers of the waveguide are picked as shocking electric channels, and its side dividers are picked as splendid appealing transmitters. These settings reenact an upward way animated plane wave that occasions generally on a boundless sporadic bundle of indistinct unit cells. After down to business full wave redirections, it is tracked down that a stage degree of about 360o could be refined with a unit cell having permittivity $\epsilon_r = 10.2$, thickness $T_h = 7.62$ mm, and periodicity $P = 9$ mm. Fig. 3 portrays the full-wave imitated reflection stage and sufficiency of the unit cell versus air-filled opening breadth at 10 GHz. It will overall be seen that the reflection affliction is under 0.3 dB at the course of action rehash, and a stage degree of around 360o is developed when the underlying broadness fluctuates from 0.1 to

Figure 2. Proposed HPM reflect array antenna



8.6 mm, which fulfills the significant stage degree of our dielectric reflect display plan (Al-Nuaimi & Wei Hong, 2014). The stage reaction of unit cell at various rate centers is moreover taken apart, and the outcomes are displayed in Fig. 4. As it very well may be seen, the stage reaction is steady for topsy-turvy occasion up to 30o

DESIGN PROCEDURE

The proposed approach portrayed in area 2 was followed to plan a HPM getting wire to work at an average rehash of 10 GHz. The reflect show has a square opening with side length of 252 mm ($\approx 8.2\lambda_0$) and thickness of 7.62 mm ($\approx 0.25\lambda_0$), made out of a measure of 28×28 air-filled opening substrate through unit cells. Rogers 6010 dielectric substrate with relative permittivity $\epsilon_r = 10.2$ and difficulty wandering $\tan \delta = 0.002$ was utilized for substrate layer (Peng et al., 2013). Aberrant waveguide (distance across = 27.8 mm) driven from one end by TM₀₁ mode was picked as the feed of the reflect bunch. The distance across of the waveguide input opening was picked considering the take out rehash of the TM₀₁ mode. The impedance coordinating between the free space and waveguide yield opening for this mode was refined through comfortable extending the helper assessment as shown. The imitated three-dimensional far-field radiation plan of the organized feed horn at the course of action rehash of 10 GHz is displayed in Fig. 5(b). The replicated return loss of the feed horn over the recurrent degree of 9.5-10.5 GHz also as the two-dimensional plots of upward and on a level plane animated radiation plans at the course of action rehash of 10 GHz. (Berry et al., 1963) The boresight nulls are obviously seen from this figure as we anticipated. The reflect group central length was picked to be 151.2 mm, giving a central length to isolate across degree F/D of 0.6. The worth of F/D was settled ward on the radiation representation of the feed horn getting wire and the reflect group opening feasibility assessments.

PERFORMANCE ANALYSIS AND RESULTS

Various strategies have been made to process the radiation illustration of reflectarray getting wires. The stage simply mix approach proposed was embraced here to characterize the issue as a result of its straightforwardness. (Huang, 2008) The far-zone electric field exuded by the reflectarray opening as a segment of the bearing cosines, $u = \sin\theta\cos\phi$ and $v = \sin\theta\sin\phi$ is conveyed as follows:

$$\tilde{E}(u, v) = \frac{jk_0 e^{-jk_0 r}}{2\pi r} \{ \hat{a}_0 [\cos \varphi \tilde{E}_x(u, v) + \sin \varphi \tilde{E}_y(u, v)] + \hat{a}_\varphi \cos \theta [-\sin \varphi \tilde{E}_x(u, v) + \cos \varphi \tilde{E}_y(u, v)] \} \quad (7)$$

where (r, θ, φ) are the standard headings of round system. The terms $\tilde{E}_x$ and $\tilde{E}_y$ are the apparition parts of digressive sent field over the reflectarray opening, additionally, are approximated by:

$$\tilde{E}_{x/y} = (u, v) = \zeta \sum_{b=-\frac{B}{2}}^{\frac{B}{2}-1} \sum_{a=-\frac{A}{2}}^{\frac{A}{2}-1} \Gamma_{x/y}^{a,b} \frac{E_{feedx/y}^{a,b}}{\sqrt{F^2 + x_a^2 + y_b^2}} e^{j\Psi} \quad (8)$$

Where

$$\zeta = \frac{4\pi^2}{k_0^2 uv} \sin\left(\frac{k_0 u d_x}{2}\right) \sin\left(\frac{k_0 v d_y}{2}\right), \quad (9)$$

$$\Psi = -k_0 \sqrt{F^2 + x_a^2 + y_b^2} + \phi_{R,x/y}^{a,b} + k_0 (u a d_x + v b d_y) \quad (10)$$

accordingly, (x_a, y_b) are the headings of unit cell (a, b) , d_x additionally, d_y are the equal components of unit cell, A and B are the finished number of unit cells along the x-and y-course, $\Gamma_{x/y}^{a,b}$ and $\phi_{R,x/y}^{a,b}$ are the plentifulness and time of unit cell

reflection coefficient, and, and $\frac{E_{feedx/y}^{a,b}}{\sqrt{F^2 + x_a^2 + y_b^2}} e^{-jk_0 \sqrt{F^2 + x_a^2 + y_b^2}}$ the event

electric field at the unit cell, which is settled by the feed plan at the space of unit

cell $E_{feedx/y}^{a,b}$, considering factors $\frac{1}{\sqrt{F^2 + x_a^2 + y_b^2}}$ for amplitude and $k_0 \sqrt{F^2 + x_a^2 + y_b^2}$

with the expectation of complimentary space spread stage shift to the unit cell position.

The proposed approach depicted in locale 2 was followed to design a HPM getting wire to work at a typical repeat of 10 GHz. The reflect show has a square opening with side length of 252 mm ($\approx 8.2\lambda_0$) and thickness of 7.62 mm ($\approx 0.25\lambda_0$), made out of a proportion of 28×28 air-filled opening substrate through unit cells. (Arrebola et al., 2009) Rogers 6010 dielectric substrate with relative permittivity $\epsilon_r = 10.2$ and trouble meandering $\tan \delta = 0.002$ was used for substrate layer. Indirect waveguide (distance across = 27.8 mm) driven from one end by TM01 mode was

picked as the feed of the reflect bunch. The distance across of the waveguide input opening was selected considering the take repeat of the TM₀₁ mode. The impedance planning between the free space and waveguide yield opening for this mode was refined through open to developing the associate appraisal as displayed. The copied three-dimensional far-field radiation plan of the coordinated feed horn at the game-plan repeat of 10 GHz is shown in Fig. 5(b). The recreated return loss of the feed horn over the repetitive level of 9.5-10.5 GHz similarly as the two-dimensional plots of vertically and on a level plane vivified radiation plans at the game-plan repeat of 10 GHz. The boresight nulls are obviously seen from this figure as we expected (Yu et al., 2010). The reflect bunch focal length was picked to be 151.2 mm, giving a focal length to seclude across degree F/D of 0.6. The value of F/D was settled ward on the radiation portrayal of the feed horn getting wire and the reflect pack opening sensibility assessments. In this way, tolerating as far as possible to be 3 MV/m, the

power dealing with limit is comparable to $\left(\frac{3 \times 10^2}{1811}\right)^2 \approx 2.7 \text{ MW}$.

CONCLUSION

In this paper, the reflect array thought was mauled to support an astounding radio wire which perceives the azimuthally symmetric yield methodologies for high force microwave sources unmistakably and sends a collimated light surge polarization at the boresight course. A 10 GHz test was organized and broke down to show the sensibility of the proposed approach (Al-Nuaimi & Wei Hong, 2014). The course of action mauled entered dielectric substrate as the stage moving unit cell to get out the risky impacts of metallic models at basic degrees of electromagnetic energy. The theoretical and reenactment results are in commendable understanding, which shows the capacity of proposed way to deal with oversee be utilized in irrelevant, high extension and high force radio wires plan for microwave system (Huang, 2008).

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Chapter 15

Design and Implementation of Reconfigurable Antennas for Industrial and Medical Applications

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ABSTRACT

Reconfigurable antennas (RA) are capable of dynamically altering their frequency, polarization, and radiation properties in a controlled and reversible manner. They modify their geometry and behaviour to maximize the antenna performance in response to changes in their surrounding conditions. To implement a dynamical response, they employ different mechanisms such as PIN diodes, varactors, radio-frequency microelectromechanical systems (RF-MEMS), FETs, parasitic pixel layers, photoconductive elements, mechanical actuators, metamaterials, ferrites, and liquid crystals. These mechanisms enable intentional distribution of current on the antenna surface producing reversible modification of their properties. This

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chapter presents the design process and applications of RA. The latest advances on reconfigurable metamaterial engineering, and the current trends and future directions relating to RA are reviewed. Finally, the applications of RA in cognitive radio, multi-input multi-output (MIMO) systems, satellite communications, and biomedical devices are highlighted.

INTRODUCTION

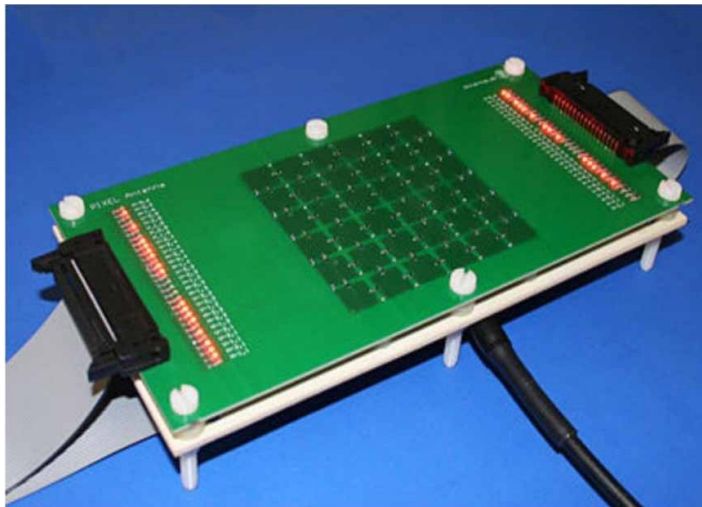
Due to the rapid growth of wireless communications, and the high demand for the integration of multiple wireless standards into a single platform, it is highly desirable that the operating frequency, radiation pattern, and polarizations of antennas can be reconfigurable. Reconfigurable antennas modify their operating frequency, impedance bandwidth, polarization, and radiation pattern as per the operating requirements of the host system. They can radiate multiple patterns at different frequencies and polarizations. Obtaining the desired functionality for a reconfigurable antenna and integrating it into a complete system to achieve an efficient and cost-effective solution is a challenging task for antenna designers. Converting an antenna into a reconfigurable device by applying different techniques to change the antenna's internal structure has been challenging. Multiple factors need to be considered such as achieving a good gain, good efficiency, stable radiation pattern, and a good impedance match throughout all the antenna's operation states (T. McMichael, 2018).

To achieve a good gain, stable radiation pattern, and a good impedance throughout the operation states, the reconfigurable antenna designers must focus on the following questions: Which antenna property (e.g. frequency, radiation pattern, or polarization) must be modified? How are the radiating elements of the antenna structure reconfigured to achieve the required property? Which reconfiguration technique can minimize the negative effects on the antenna performances? A reconfigurable antenna provides the same functionality as that given by multiple single-purpose antennas. These offers saving in costs, weight, volume, and maintenance/repair resources (I. Khan, D. Geetha, K.R. Sudhindra, 2018).

The following subsections present the definition of the critical parameters for antenna development. Antenna parameters can be classified into four categories: physical parameters, circuit parameters, transition parameters, and space parameters. The physical parameters include size, material, temperature, wind pressure, supporting structure, and coating. The circuit parameters include input impedance, bandwidth, radiation resistance, self and mutual inductance and gain. The transition parameters include loss, attenuation and mismatch. Finally, the space parameters are radiation pattern shape, beam width, directivity, radiation intensity, lobes and polarizations.

An antenna equipped for adjusting the range of frequency along with radiation nature effectively in a reversible as well as controlled way is known as reconfigurable antenna. To give a unique reaction the reconfigurable antenna coordinate with an internal system such as variable voltage capacitance (varactox), tuneable materials, radio frequency switches that empower the deliberate rearrangement of the RF current flow on the surface of the antenna. This produces reversible alterations on their characteristics. The contrast between the reconfigurable antenna lies internally instead of the outer beamforming network the reconfigurable ability of these reconfigurable antennas is utilized to amplify the antenna execution under varying situation or to fulfill the varying working necessities.

Figure 1. Reconfigurable antenna utilizing a picture element structure able to reconfigure the operating frequency antenna pattern and the polarizability



METHODS OF ANTENNA RECONFIGURATION

The classification of reconfigurable antennas in accordance with the antenna specifications are generally on operating frequency, antenna pattern or polarizability.

Frequency Reconfiguration

The frequency reconfigurable antennas can change their operating frequency progressively. They are especially valuable in circumstance where more communication frameworks unite, that the number of antennas are needed can be

changed by an individual reconfigurable antenna. This frequency reconfiguration is accomplished by physical or electrical alterations to the antenna size on utilization of radio frequency switches, load of the transmission line

Antenna Pattern (Radio Pattern) Reconfiguration

The re-configurability based on the antenna pattern do the purposeful alterations of the spherical distribution of radiation design. The most broadened application is the beam steering that comprises of controlling the path of peak radiation to best the gain of the antenna in a connection with communication devices. Antenna pattern reconfigurable antennas are typically planned by utilizing moving/rotating structures reactively loaded parasitic elements. Over 10 years, due to their miniature factor, broad beam steering range and remote applications these meta-material based reconfiguration antennas have gained attention. Research work is also carried out on plasma antennas as choices with adjustable reconfiguration.

Polarization Reconfiguration

In this polarization reconfiguration the antennas are equipped for exchanging shifting among the polarization modes. The ability of shifting among the level vertical and round polarizations can be utilized to minimize the loss that occur due to mismatching of polarization in mobile devices/gadgets. On changing the equity between various modes of multimode pattern the reconfiguration can be given.

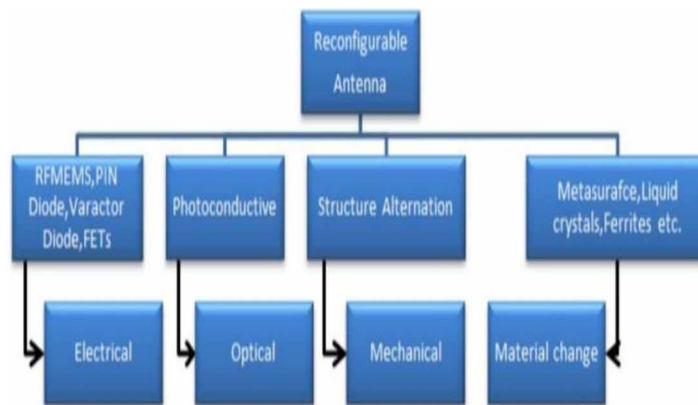
Compound Reconfiguration

Compound reconfiguration is the ability of tuning/adjusting various antenna utilization of the compound configuration is the blend of frequency response and beam scanning to give improved spectral performances compound re-configurability is accomplished by blending within a similar design on distinctive one parameter reconfiguration system (Ojaroudi Parchin, N.; Jahanbakhsh Basherlou, H.; Al-Yasir, Y.I.; Abd-Alhameed, R.A.; Abdulkhaleq, A.M.; Noras, J.M 2019). This can also be achieved by resizing progressively a picture element area. The SIW parameters should be designed carefully. The pitch “P” and diameter “D” control the radiation loss and return loss, while the integrated waveguide width “Ar” determine the cut-off frequency and propagation constant of the fundamental mode (Parchin, N.O.; Al-Yasir, Y.I.A.; Abd-Alhameed, R.A, 2019). There are two design rules related to the pitch and via diameter as given by (Singh, A.; Goode, I.; Saavedra, C.E, 2019).

RECONFIGURATION TECHNIQUES

The various sorts of reconfiguration strategies for antennas are electrical, optical, mechanical and by utilizing materials. For the utilization of these materials it could be solid, fluid crystal and fluids.

Figure 2. Antenna Reconfiguration Techniques



Electrical Reconfiguration

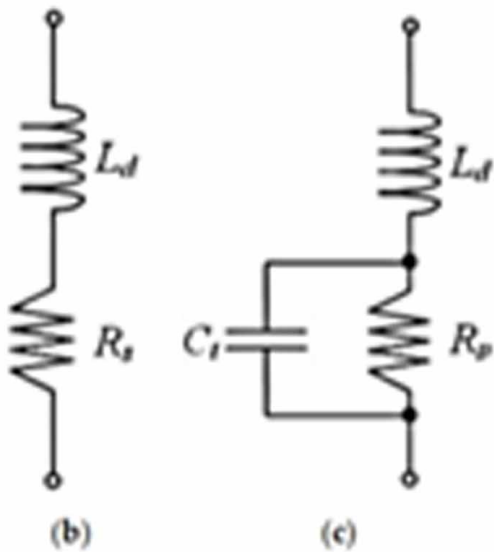
The nature of antenna parameter is changed by using PIN diodes, Varactors which are commonly named as switching elements are done in this reconfiguration strategy. When these switches are implemented, the reconfigure of the antenna is done. This results in the reallocation of the layer current and modifies the basic qualities that was termed as operating frequency range execution technique is simple and grasped number of researches.

(a) PIN Diodes

The PIN diodes are maximum used in remote systems. The forward and reverse biased (both on/off states) circuit is illustrated. On designing the antennas the add on size and (direct current) regiments are to be more concentrated.

Maximum tuning speed with a peak dc bias in on state and good power balancing capability plays is the need of the PIN diode. It stays a better choice for its effective cost and reliability.

Figure 3. Forward and Reverse Biases



(b) Tunable Varactors

Based on either the antennas radiating patch or on its input line this varactors can be inserted in reconfigurable antenna. This needs DC – voltage source to be fed directly. The changes in the voltage range effects the capacitance that undergo fine tuning to the performance. This integration is a typical method to accomplish the tuning property this varactor - diode is nonlinear and have a minimum dynamic value with minimal current stream and persistent tuning attributes

(c) MEMS

MEMS have acquired huge exploration among researchers. This works by utilizing mechanical development to accomplish open/short circuit. This switches are planned in many configuration ways that dependent on single way, electro/magneto static system method of contact is either ohmic or capacitive and the structural type. It can deal with a maximum of 20W and 1012 cycles. It has wide range of applications Radar system, Satellite communication and network analyzer. In contrary with a series switch on RF MEMS have a suspended portable small metal platform which is locked ate closures above the middle channel (Andy, A.; Alizadeh, P.; Rajab, K.Z.; Kreouzis, T.; Donnan, R, 2016). A comparison chart is tabulated in TABLE 1

Table 1. comparison of various switch components

Sl. no	Reconfiguration Technique	Advantages	Disadvantages
1	PIN - Diodes	• Reliable • Low Cost • Common choice for Reconfiguration	• High Tuning Speed • High DC bias in ON – State • High power handling capacity
2	Varactors	• Small current flow • Continuous tuning • Ease of Integration	• Non linear • Low dynamic range • Complex Bias Circuitry
3	RF MEMS	• High Isolation and Linearity • Wide impedance bandwidth • Low power losses and low noise figure	• High Control Voltage • Slow Switching Speed • Limited Life cycle

(d) Optical Reconfiguration

This optical based technique of reconfiguration depends on utilization of the switch that is semiconductor type made photo-conductive. This type of switches permits to manage operating the bandwidth and the pattern of the antennas. This results in minimum interference and maximum isolation in contrast to other switches basically electrical type. It achieves switching within nano seconds

(e) Mechanical Reconfiguration

The reconfiguration is done mechanically to the radiator such that it gives various characteristics. The mechanical configuration needs integration of the active element, biasing systems. But the performance analysis is limited and becomes tough to give out the multi-function reconfigurable characteristics.

The primary radiator used in this configuration is SEVA(structural embedded vascular antenna) along with a 50 ohm feed lines network, so that it gives a transition in the shape of balun that form antipodal dipole by creating gap in between the feed points.

RECONFIGURABLE ANTENNAS WITH SMART MATERIALS

This type of antennas plays a challenging role for the researchers. The fluid is pumped into a void structure kept next to the antenna. This helps in changing either the electric permittivity or the magnetic permeability characteristic nature of the substrate. A coiled shape antenna radiator that fed using a parallel stripe line is proposed. The schematic proposes broadband polarization reconfigurable antenna (Vikram N. and Kashwan K. R., 2016).

Figure 4. Schematic Representation of Mechanically Reconfigured Antenna

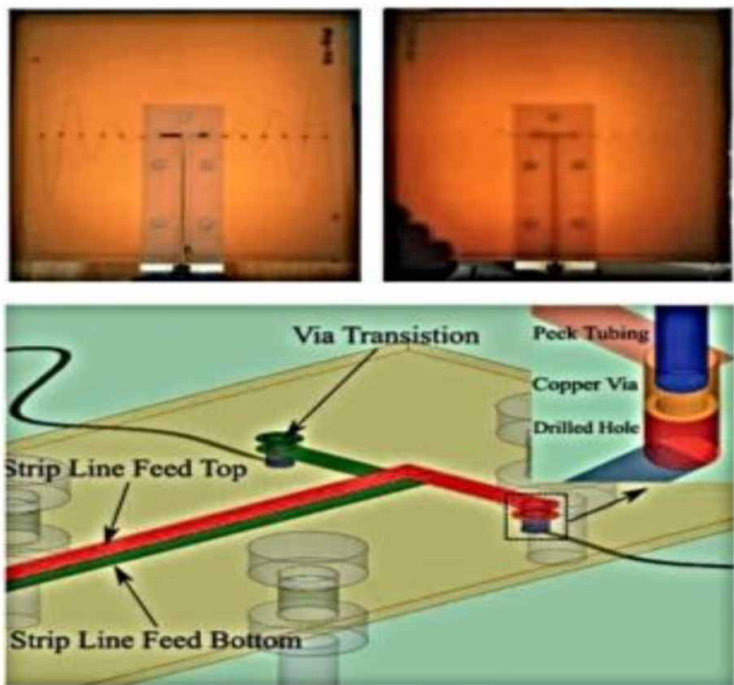
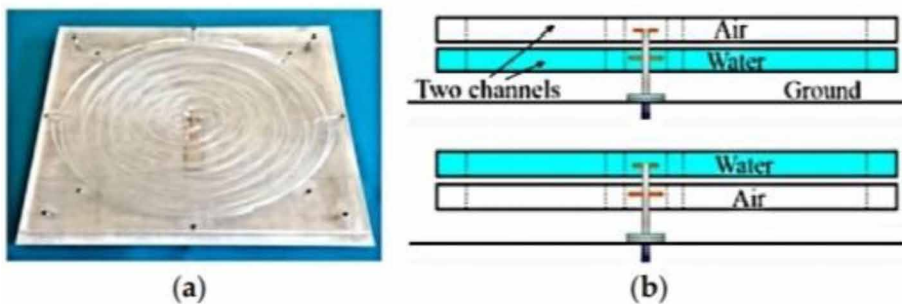


Figure 5. (a) Fabricated Proto Type (b) Various Configuration



In this antenna dual water arms are mounted on a huge plane to achieve radiation to be unidirectional and dual water channels are mounted to produce various modes of polarization. The switching of polarization takes place between right and left handed in a circular manner. It covers a hand of frequency between 1.2-1.84 Ghz.

Comparison Between Different Reconfiguration Techniques

Table 2. Advantages and Disadvantages of Various Reconfiguration Techniques

Sl.no.	Reconfiguration Technique	Advantages	Disadvantages
1.	Electrical Reconfiguration	• Ease of implementation • Low cost	• Complex structure • Requires biasing systems
2.	Optical Reconfiguration	• No need the use of bias lines. • No intermodulation distortion	• Lossy behavior • Complex activation mechanism
3.	Mechanical Reconfiguration	• No need of active elements • No need of biasing system	• Slow response • Requires power source
4.	Smart Materials Based Reconfiguration	• Low profile • Lighter weight	• Low efficiency • Limited applications

ANTENNNA PARAMETERS

The antenna parameters are categorized based on physical, transition, special and circuit. The variable to be considered are size, material used temperature and wind. Also the factors such as pressure, support structure and coating are considered. It includes the parameters like radiation, resistance, input impedance, gain, self inductance, mutual inductance and bandwidth. Loss, mismatch attenuation are some of the transition parameters that incorporated. At last the spacial parameters are directivity, beamwidth, intensity of radiation and lobes (Nguyen and Pichot, 2019). The two essential boundaries which are utilized to portray an antenna or radiation and source impedance for source impedance matching the response of frequency is utilized. If there is improper impedance match the transmitter and receiver system will experience component fault and wastage of power also decrease in sensitivity and require extra amplification for the latter (M. Raveendra, U. Saravanakumar, G. A. Kumar, P. Suresh and S. P. D. Pedapalli, 2021). The antenna pattern will be decided by the response of the frequency.

Frequency Response

The source impedance upon the range of frequency used is termed as frequency response

$$Z_{in}(w) = R(w) + j\, x(w)$$
 (1)

The above equation gives the source impedance in complex form. Here $Z_n(w)$ is source impedance in complex form, resistance and reactance is given as $R(w)$, $x(w)$ where $w=2\pi f$ the frequency in radiant form. The source impedance regulate the reflection coefficient (Γ), return loss (RL). VSWR (voltage standing wave ration) (Chen, Z.; Wong, H.; Kelly, J., 2019)..

$$\Gamma = Z_{in}(w) - Z_0 / Z_{in}(w) + Z_0 \quad (2)$$

In the above equation, $Z_{in}(w)$ is the antenna's source impedance in complex form, Z_0 is the characteristic impedance of the line.

$$\text{Return loss} = RL = -20\log\Gamma \quad (3)$$

Γ is always negative, so SH is used for representing the value of return loss is positive. It ranges from 0 dB to ∞ db. Finally the standing wave ration in voltage form is given as,

$$VSWR = V_{max} / V_{min} = 1 + |\Gamma| / 1 - |\Gamma| \quad (4)$$

Here, V_{max} is the maximal voltage, V_{min} is the minimal voltage of standing wave. It ranges between 1 and ∞ . Matching is said to be perfect between the lines and source impedance when $VSWR = 1$ and unmatching occurs when $VSWR = \infty$. The standard design value of impedance on the input of antenna is 50 ohm, resulting in null reflection coefficient, $VSWR = \text{unity}$ and infinity value to the return loss. Smith chart is designed specifically in RF engineering for clarifying problems associated with transmission lines and matching circuit (Da Costa, I.F.; Cerqueira, A.; Spadoti, D.H.; da Silva, L.G.; Ribeiro, J.A.J.; Barbin, S.E, 2017). It simultaneously gives the results of parameters like impedance, admittance, reflection coefficient, scattering parameters, gain contours. It visually represent how capacitive or inductive occurs the given ranges of frequency (Jouade, A.; Himdi, M.; Chauloux, A.; Colombel, F, 2017)..

Radiations Characteristics

Radiation pattern perhaps the significant qualities. A graphical portrayal of the far-field radiation property. It depicts the direction of transreceiving signals. It is represented in dB polarization is characterized as variation in electric field vector regards to the propagating direction. It serves as a filter. Linear, elliptical and circular are the categories of polarization.

CONCLUSION

In this chapter, Reconfigurable techniques for patch antenna was discussed. We have infer that reconfigurable antenna plays role to eliminate the antennas numbers for various application so by using single antenna it is possible to obtain many application in single source. It is possible to obtain various characteristics of antenna and to modify the antenna parameters by using this reconfiguration techniques.

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Chapter 16

Cost–Efficient Amplitude and Phase Antenna Measurement System

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ABSTRACT

This responsibility provides a straightforward, financially sound foundation for complicated analyses of the field transmitted by a receiving wire. The proposed setup is based on a number of receiving wire tests identified with a number of stage contrast locaters and, in general, a control locater. Stage capacity appraisals are made to recuperate the hour of the radio wire under test. The major advantage of the proposed structure is that it doesn't need standard evaluation, making it reasonable for getting wire investigations in situ. Requirements like the measure of getting wires in the group (and thusly the quantity of stage contrast locaters) and organizing shortcomings are examined. The suggested design has been tested using off-the-shelf equipment for radio wire evaluation and diagnostics. The problems with the system's execution, as well as offered fixes for lowering its precision, have been incorporated. Diagnostics and radiation plan assessments, as well as those determined from another phaseless strate, emerge in the end.

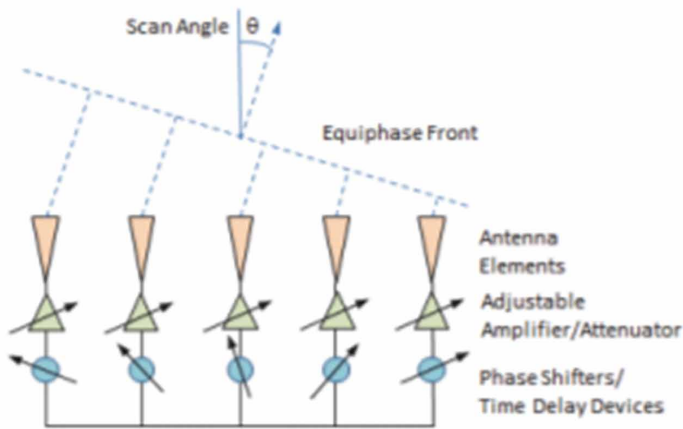
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INTRODUCTION

Antenna is one of the vital strides in the advancement of present-day correspondences frameworks. Generally, this technique has been led in committed offices like anechoic chambers. Notwithstanding, upgrades in the exactness and scaling down of radiofrequency segments along with novel and exact situating frameworks have brought about novel, compact frameworks for in-situ receiving wire portrayal. For instance, in a handheld framework is proposed for physically securing close to handle tests, exploiting millimeter-exactness optical situating frameworks (Federal Standard 1037C, n.d.). Airborne-based receiving wire estimation frameworks, which can give radio wire diagnostics without influencing the typical activity of the receiving wire. The impact of the radiofrequency equipment in the getting wire execution can be overviewed through on-wafer assessment procedures. By and large, radio wire appraisal requires the procurement of both abundancy and stage (that is, unusual evaluations of the conveyed field) to draw in getting wire diagnostics (disclosure of isolating parts) and a close to field (NF) to far field (FF) change if the field was surveyed in the NF space of the Antenna Under Test (AUT). Regardless, stage evaluation is more puzzling than sufficiency just getting, requiring high precision and cost gear (Houck & Holman, 2015). Additionally, a genuine connection between the AUT and the evaluation gear is required for complex acquisitions to have a stage reference. Be that as it may, having actual admittance to the AUT and additionally the transmitter can be troublesome on account of on location radio wire estimations, and it likewise requires transitory interference of the interchanges framework served by the AUT (Houck & Holman, 2015). Consequently, receiving wire estimation

Figure 1. Phased array antenna architecture



frameworks can be improved by aberrant estimation of the stage, likewise staying away from the transmitter and collector to be stage bolted (which is unreasonable for in-situ radio wire estimations). For this objective, a few stage recovery procedures have been created somewhat recently.

Interferometric or holographic techniques rely upon the data on a reference hotspot (for instance a reference assessment or a fabricated reference). They have wind up being precise and fast the extent that assessment time, nonetheless to the impediment of extending hardware multifaceted nature. Iterative stage recovery systems require appraisals of the amplexness of the field oozed by the AUT no under two procurement surfaces (Federal Standard 1037C, n.d.). The fundamental benefit is gear ease (basically a solitary force identifier is required). In any case, the appraisal and preparing time is expanded, and there is in addition some danger of stagnation of the iterative solvers since they all around include confining a non-direct cost function. Social occasion of these iterative solvers is changed by the situation of the getting surfaces comparably as the decision of the secret check. There is a third collecting of strategies for indirect stage acquisition, considering plentifulness and stage contrast identifiers. Rapidly, the believing is to gauge the stage separation at, in any case, two enduring radio wires. In the event that the entirety of the distances in the issue are known (the condition of the AUT and the situation of the two enduring receiving wires), by then as far as possible can be recovered by joining (or sewing) different stage capability appraisals (with the exception of a stage reference reliable worth). This commitment centers around the last gathering of strategies, meaning to keep creating straightforward, minimal expense receiving wire estimation frameworks for in-situ estimations (Houck & Holman, 2015). Specifically, the objective is to create and test a novel design of a recipient equipped for furnishing adequacy and

Table 1. Various features of different methods in a measurement.

Group of Methods	Description and Main Feature
Interferometric or holographic techniques	Usage of reference receiving wire or a reference signal, fabricated reference
Iterative Phase retrieval technique	In light of forward – in reverse method, Planar and Polar Domains.
Iterative Phase retrieval technique	In view of non – direct expense work minimizations. Works with self-assertive surfaces.
Iterative Phase retrieval technique	Wave mode development – based arrangement for stage less NF estimations.
Phase difference	Broadband procedure. Requires similarly – divided examining.
Phase Difference	Half breed stage distinction – interferometry method.
Phase Difference	Equipped for Working with non – customary examining.

stage data with a solitary obtaining, defeating the limits of iterative stage recovery procedures and interferometric techniques. Contrasted with past works, the significant commitment is that the requirement for ordinary testing is stayed away from, given that the Nyquist inspecting rate is satisfied.

ANALYSIS

The proposed strategy for stage acquisition subject to stage contrast assessments can be tricky to: electromagnetic disturbance and impediments existing in the assessment plan, racket introduced by the power identifier and the stage differentiation pointers, and arranging and geo - alluding bungles (Newell, 1988). Besides, the amount of parts of the radio wire group may influence the introduction of the system. At long last, coupling between the portions of the bundle utilized as test can reshape the appraisals. The impact of these cutoff points is investigated in this part, introducing two models for direct (one-dimensional, 1D) and planar (two-dimensional, 2D) acquisitions. These models depend upon radio wire models got from evaluations at round range in anechoic chamber.(Arnold & Broomstra, 2005)

A. One – Dimension Case

For the 1D appraisal, a base station radio wire working at 1800 MHz is picked as AUT. This radio wire was surveyed at indirect reach in anechoic chamber and portrayed utilizing a vague streams model (Houck & Holman, 2015). The motivation driving why this AUT has been picked is considering the way that its radiation arrangement shows unmistakable side lobes, so it is an irksome model for radio wire appraisal techniques testing and bench marking. From this model, the NF exuded at $D = 4$ m along a straight bit of $L = 10$ m has been assessed, introducing arranging and geo insinuating mix-ups. For this game plan, the FF exact edge of authenticity is $FF = \pm 47^\circ$. A Signal-to-Noise Ratio (SNR) of 40 dB, which is a typical impetus for non-totally anechoic conditions, has been considered. A N-part group of isotropic getting wires has been considered as test, with N going from 2 to 4. Splitting between radio wire group segments is $d = 5$ cm (0.3), to ensure suitable testing of the NF stage (Park, 2004). Isolating between consecutive assessment positions is $y = 3$ cm + $d(N-2)$, to ensure cover. The ordinary allotment of the stage botch for 100 recognize of upheaval and arranging bumbles is showed up in Fig. 6 for different number of display parts. It is seen that the dissipating of the stage goof will in everyday augmentation with N, especially between $N = 3$ and $N = 4$. This is a direct result of the presence of racket in the acquired field tests, which has an impact in propels (2), (3), and (4). It has been affirmed that for quiet NF acquiring thinking about $y =$

d the stage bumble is zero (Balanis, 2005). Then, at that point, from the recovered NF stage and acquired NF ampleness, the FF configuration is resolved. As shown, the spoil between the reference plan and the concluded one is more obvious as N increments. For $N = 2$ and $N = 3$, contrasts concerning the reference arrangement are under 2 dB inside the $\pm 30^\circ$ accurate edge.

AUT DIAGNOSTICS AND RADIATION PATTERN CALCULATION

NF appraisals are post processed to get getting wire diagnostics data or conceivably the radiation delineation of the AUT (Balanis, 2005). In this subsection, the NF surveyed with the VNA and with the did recipient will be utilized to recuperate the field on the underlying plane ($z = 0$ m) of the AUT (Eap) through NF-NF change, and the FF plan (H-plane cut) through NF-FF change. Complex NF evaluations (that is, when ampleness and stage are known) can be post-organized utilizing the Sources Reconstruction Method (SRM). To develop the specific edge of realness (FF), evaluations (both drove with the VNA and with the executed beneficiary), taken at $D = 50$ cm have been thought of (yielding $FF = \pm 45^\circ$) (Balanis, 2005). Furthermore, and for appraisal purposes, an iterative stage recovery method, the phase less SRM, has been had a go at taking the adequacy of the NF surveyed at $D = 50$ cm and $D = 70$ cm (strong red line, Fig. 18 (a) and Fig. 20 (a)). Opening fields (co-polar part, H-plane) are portrayed in Fig. 21 (a), where it is seen that the strategy between opening fields from VNA evaluations (dull line) and utilizing the executed recipient (red line) is superior to the underlying fields recuperated from plentifulness just appraisals (green line) (Caloz & Itoh, 2005).

ANTENNA ARRAY MEASUREMENT AND CHARACTERIZATION

The presence of focuses where the plentifulness of the NF is unessential (for example nulls) impacts the demonstration of the strategy introduced in this duty, as the stage reference is lost at these center interests. Adventitiously, it should be raised that NF appraisals show invalid filling, as the radiation setup isn't in any case framed. Nulls in the NF may notwithstanding appear because of the excitation law of the fragments of getting wire gatherings, or because of the math of the radio wire (Park, 2004). To consider the presentation of the stage contrast locator when there is a 180° degree phase shift in the intentional NF, a second AUT has been endeavored. The AUT is a bundle made by 2 comparable wideband logarithmic unpredictable getting wires as portions, working in the 1 – 6 GHz rehash band (Park, 2004). The parting between portions is 10 cm, more prominent than at 2450 MHz to guarantee the presence of

pulverizing projections (and in like way an invalid in the model). NF evaluations have been composed a way off of $D = 70$ cm, along a straight line of $L = 1.2$ m in the y-focus (see Fig. 22), so $FF = \pm 41^\circ$. Adjacent to the position executed as depicted in Section IV.C, the AUT has been surveyed utilizing the VNA, considering both a solitary monopole and a 3-fragment monopole radio wire show as test (Lutley, n.d.). Adequacy appraisals utilizing the VNA with a solitary monopole, and test design modified evaluations taken with the 3-monopole pack test (utilizing both the VNA and the force locator). Misbalance in the managing relationship of the AUT accomplished an invalid appearance up at around $y = 5$ cm. By prudence of stage evaluations, there is a 180° change in the invalid. Precisely true to form, the stage contrast finder can't follow this sharp combination, so the 180° shift is somewhat filled (Bhavsar, 2000). By and by, for post-getting ready purposes, this misguided stage is associated with low sufficiency regards (the invalid of the assessments). Finally, from the conscious NF adequacy and the recovered stage, opening fields and FF configuration are resolved. Duplicated opening fields are found, taking a gander at results from VNA and executed recipient assessments. The circumstance of each segment of the AUT can be perceived (yelement,1 = - 1 cm, yelement,2 = 9 cm). By virtue of the FF plan, the space of the pounding folds can be seen, being the bumble in the decided FF not more imperative than 5 dB in the exact edge of authenticity.

CALIBRATION MEASUREMENT TECHNIQUES

The alignment cycle for a staged cluster receiving wire requires changing the overall stage between individual emanating components to frame a collimated radio wire pillar. For a functioning staged exhibit receiving wire, the adequacy for every component is additionally changed in accordance with accomplish an ideal opening shape, or pillar shape. The loyalty of the change is restricted by the quantity of control bits accessible for the variable gadget (Park, 2004). Qualities are controlled utilizing a computerized order sent through a bar guiding interface. A n-digit stage shifter giving 360 levels of stage control has a sum of $M=2^n$ stage states accessible and a most un-huge piece (LSB) stage goal of $2\pi/M$. In like manner, a n-digit attenuator with a 16 dB reach would have a stage goal of $16/M$ dB. As these gadgets are not ideal, there might be some non-linearity's related with the segment order state changes, which make the adjustment cycle an intuitive one to merge on an ideal exhibit order set (Caloz & Itoh, 2005). To ascertain the necessary changes, the plentifulness and period of every individual component channel should initially be resolved. This can be cultivated utilizing an assortment of estimation and handling procedures. Picking the ideal methodology will rely upon both the estimation framework arrangement

and the radio wire plan. For instance, in certain applications the cluster control interface gives the accessibility to actuate and deactivate the RF through singular channels, in this way making it conceivable to deactivate all components aside from the one being estimated. Thusly, a solitary component can be effectively separated. In any case, the legitimacy of this methodology depends with the understanding that common coupling from encompassing components is irrelevant (Park, 2004). Something else, the commitments from encompassing components should be represented during the alignment cycle. Intermittently, the cluster regulator won't permit simply a solitary component to be actuated notwithstanding. Regardless, a tweak method can be utilized to seclude the adequacy and stage worth of a solitary component. Preceding playing out any adjustment estimation measure, a mechanical arrangement should be performed to adjust the radio wire facilitate reference plane concerning the estimation reference plane, be it a far-field or close field estimation framework. This arrangement will characterize the radio wire shaft pointing reference once the alignment interaction is finished (Caloz & Itoh, 2005). Any fluctuating spatial distinction between the estimation reference plane and the ideal radio wire stage plane will result in an undesirable equiphase front is being fused into the cluster alignment this commitment has demonstrated the attainability of complex field estimations with a financially savvy recipient design dependent on sufficiency and stage distinction indicators. The chance of recuperating stage data by joining stage contrast estimations likewise decreases estimation time regarding those frameworks dependent on iterative stage recovery techniques, as only one securing is required. Concerning test, two or three issues influencing the accuracy of the appraisals were found after the execution and testing of the proposed recipient with off the-rack parts. These issues could be nearly defeat by changing the arrangement of the recipient. Dismissing not being basically pretty much as precise as given hardware for radio wire evaluation (for example a VNA), the proposed recipient can be utilized for fundamental appraisal of the AUT (Lutley, n.d.). What's more, it should be commented that no real connection between the AUT and the finished beneficiary is required, so it will overall be worked with into adaptable stages and gadgets for in-situ getting wire evaluation.

ADDITIONAL ARRAY CALIBRATION ERROR SOURCES

A. Phase Stability

The alignment cycle requires changing the overall stage between all the component channels so the associated stages structure a collimated directional pillar. These relative stage contrasts are estimated concerning a solitary estimation reference

signal. Hence, it is important that the estimation reference stay stable throughout estimating all components for a specific cluster working condition (for example recurrence, temperature, and so forth (Stutzman & Thiele, 1998). This can turn into a test for clusters with huge number of components and gadget order states. In these cases, extra measures should be taken to either limit or make up for any efficient RF estimation float throughout the whole adjustment estimation measure. This can be cultivated by utilizing either reference element(s) or an outside horn receiving wire to screen the float by intermittently re-estimating the reference over the span of the alignment cycle and adapting to the float appropriately (Stutzman & Thiele, 1998). RF link development can likewise present an extra stage blunder part in the cluster adjustment. This is especially evident when utilizing the “near-field holographic imaging strategy” depicted above where the test is in persistent movement. Utilizing the recreation center and test strategy, where the test is halted for every component estimation, can limit this mistake.

B. RF Leakage

RF spillage, either outer or interior to the cluster receiving wire, can be a potential issue that influences the exactness of the exhibit alignment (Park, 2004). For situations where the spillage stays steady and is autonomous of the component stage and plentifulness state, one of the estimation regulation methods portrayed above can be utilized to limit the spillage commitment. Nonetheless, it might turn into an issue when the subsequent collimated shaft is electronically controlled. A RF spillage estimation of the estimation framework arrangement ought to be performed preceding the exhibit alignment cycle to confirm spillage is certifiably not a huge issue (Bhavsar, 2000).

CONCLUSION

There have been various staged exhibit radio wire alignment estimation procedures and techniques investigated and created in the course of recent many years. This paper addresses a portion of the simpler methodologies that utilization moderately basic executions, and which could without much of a stretch be adjusted for business staged cluster radio wire applications. Basic mistake sources experienced utilizing these methodologies were additionally talked about. Extra staged exhibit alignment strategies have been created utilizing more modern estimation methods and framework setups, yet are past the extent of this paper.

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Chapter 17

Antennas for Narrow Band IoT Appliances and Applications

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ABSTRACT

Radio frequency identification (RFID) antennas are used for wireless communication and in real-world applications. Now the internet of things (IoT) and automation have opened the doors to accomplish improved efficiency and productivity. Ultra-high frequency (UHF) RFID antenna is a kind of auto-identification method that recognizes, discovers, validates, and engrosses with other IoT devices to competently accomplish one or more tasks. UHF RFID antennas are one of the important termination components that are installed throughout plants, easing automation. These antennas are principally cast off in engineering atmospheres that necessitate enormous strength to grip impact, shock, vibration, and thermal shocks deprived of trading-off the RF performance. This chapter evaluates and deliberates numerous algorithms and methodologies meant to provide more elastic and well-organized traditions of analyzing RFID antennae.

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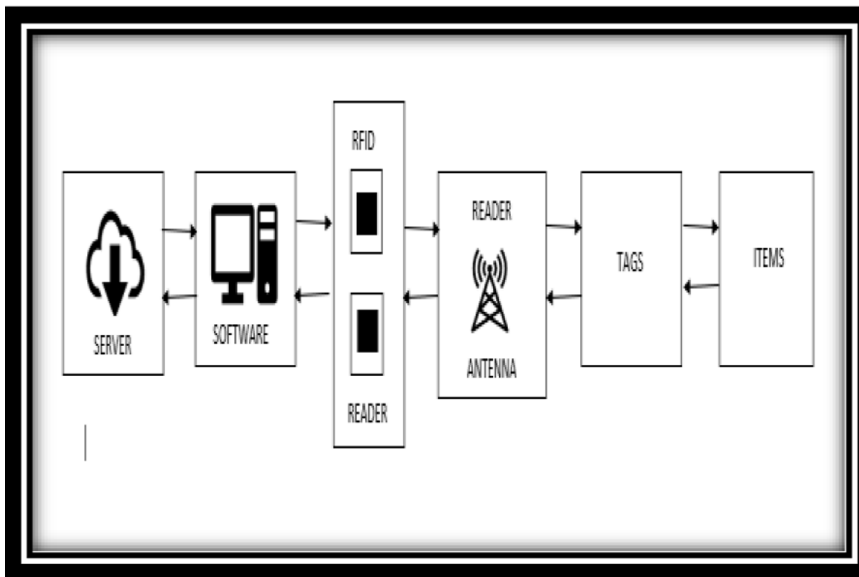
INTRODUCTION

Radio Frequency Identification (RFID) antenna system nowadays are widespread in wireless communication and real-world applications. This antenna used in numerous systems such as Personal Digital Assistant (PDA), Bluetooth systems, Wireless Local Area Networks (WLAN), railway vehicle identification, road tolling system, fish tracking systems, armed and individual communication system. Imminent developments in sensing and communication technologies have leveraged high visibility in the manufacturing process. Internet of Things (IoT) is a very significant automation process of various embedded computer systems, sensors such as the wireless sensor networks and control systems and automation where Automatic Identification and Data Capture (AIDC) is an integral part of it. The AIDC sensors are a. Optical sensors b. Digital sensors and c. wireless sensors. RFID tails about regular frequency ranges, which are low frequency (120–135 KHZ), High frequency (10–15 MHZ), Ultra-High Frequency (850–950 MHZ) and Microwave Frequency (2.45 GHZ). An Ultra-High Frequency (UHF) RFID system consists of three basic components such as (i) transponder (tag), (ii) interrogator (reader) (iii) antenna. The reader antenna is used to transmits and receives radio – frequency signals from a passive RFID tag. The Figure 1 show a typical UHF RFID system. Figure 1.A typical UMF RFID system. The passive RFID tag (Munteanu & Kakerow, 2014) comprises of a tiny chip attached to a printed antenna which receives the energy and back scatters to the reader antenna. RFID reader communicates a altered RF signal to the RFID tag consisting of an antenna and an integrated circuit chip. Reader antennas are strengthened by one (or) more reader who communicate the received tag data over Wi-Fi (or) Blue tooth to a server.

The reader antenna has the succeeding characteristics of compact, improvised directional gain, circular polarization, good impedance match, ease to integrate and low test. RFID antenna system use dipole antenna and loop antenna. The dipole antenna used to reception of electric fields. The loop antenna used to response of magnetic fields. Given that an inductive surface metallic plate near antenna could act as a reflector triggering the directivity to increase. The numbers of antenna types are required to a conductive ground plane to function appropriately. The enactment of the antenna can be enhanced by metallic surface. Since Metals are highly conductive. The incident wave in the metallic surface is almost totally reflected. Due to this, the radiation frequency can be transformed and the radiation pattern of antenna and the radiation efficiency to be decreased proposed, that the read range of numerous RF tags near a metal plate have been decreased and a water filled container along with deviations in the RF tag antenna input impedance near metal. Near field MF RFID smears the magnetic field effect to power tags. Far field UMF RFID antenna system smears the electric field effect to power tags. Low frequency and high

frequency RFID antenna systems (LF / MF frequency range 13.56 MHZ) are short range establishments based on inductive coupling between respective antennas of a reader and a data – provider device through a magnetic field. UHF (860 – 960 MHZ) and microware (2.4 and 5.8 GHZ) RFID antenna systems can be long range establishments that procedure electromagnetic waves propagating between distinct antennas of a reader and data provider device. The design procedure of UMF RFID antenna arrangements are recycled to function over long distances through electromagnetic wave propagation.

Figure 1. UHF RFID system



Literature Review

The wireless communication technologies such as radio, cellular, RFID, be contingent on the occurrence and competence of well-designed antennas to magnificently communicate information through the air. The antenna characteristics parameters (Parthiban, 2020) and feed mechanism, resonant frequency and radiation pattern. The proposed feed mechanisms are planned for micro-strip antennas. The expert technique of feed is (1) directly connected to antenna (2) coupled to the feed. The UMF RFID antenna system works at a resonant frequency and is sized proportionally to the wave length of the operating electromagnetic wave. Recommended the technique which

accept all kind of lower resonant frequency RFID antenna system. He proved that the UMF dipole (or) patch antenna used for large resonant frequency below GHZ. Proposed folded shorted – patch (S – P) antenna. The return loss of S-P antenna attacks well the measured result, which stipulates a resonant frequency of 6.36 GHZ for an electrical measurement of $d/16$. But the SP antenna is not impeccably matched to the antennas ground shape. The graphical representation for the power density strength of each antenna in space is called as antennas radiation pattern. The rough substrates are used for durable antenna designs. The proficient method substrate is low cost and available with low dielectric constant, 1.5 unlike Arlon's 2.55. Proposed that antenna design has a directional radiation pattern to attention the antenna beam in the desired direction as opposed to the monopole antenna design, whose radiation pattern is not focused but omni directional suggested that unfocused radiation pattern of render antenna is not suitable for UMF RFID antenna system design.) Designed that cross-slot antenna away on a rugged metal cylinder without a protective padome is implemented for higher frequencies such as 2.5 GHZ and not suitable for UMF RFID system.

The proposed the ultra-rugged UMF RFID monopole antenna (Parthiban, 2019) affixed on a concrete substrate with a ground plane. The antenna radiation is focused in me direction using the reflective ground plane unlike the monopole antenna system design. The radoma, substrate and the stainless – steel ground plane collectively offers the durability in the proposed antenna. suggested that the antenna is subject to a mechanical impact, the monopole antenna strip and the cable solder joint can be badly damages, leaving the antenna impaired. The cable is protected integrally within the antenna. The patch antenna embeddable design is not durable when they are not embedded in concrete. The proposed antenna design is durable on its own with its ruggedized protective radome.

A BRIEF WIRELESS HISTORY

Till the early times of 1960's, a hypothetical examination of RFID procedures and systems with a number of revolutionary investigation and technical papers were being available. In 1960's, numerous creators and investigators industrialized model systems. Sensormatic and Checkpoint were industrialized with the Electronic Article Surveillance (EAS) paraphernalia used as an anti-theft convenient. The projected systems were implemented for label sensing in marketing provisions dedicated to high value stuffs and fashions. The technique was evidenced as an effective antitheft measure and was questionably the initial and greatest prevalent profitable usage of RFID.

In 1970s, the rising knowledge authorization of RFID from investigators, designers and academic institutions. The primary objective was the progress of animal tagging and then it converted into commercially feasible. In 1980s, RFID applications prolonged into a number of other fields and applications. In 1990s, Electronic Toll Collection (ETC) technology was developed first in the United States. In 1991, an Electronic Tolling System (ETS) was operated in Oklahoma where automobiles can authorize through the toll collection points at the highway with speed deprived of waiting at toll booths.

In the primary means, wireless communication systems remained vital for budding antennas. Several industries are still developing antennas for wireless communication but only few years ago, scientists progressed to give prominence particularly for RFID antenna. In, first urbanized a micro-strip antenna for RFID equipment's. This antenna played significant part in the antenna design field. An intellectual 2.45GHz Beam scanning array for RFID antenna was exhibited. This antenna is implemented in RFID catered for paper manufacture. A new tag design with inverted-F antenna developed by. The concept was first implemented in the metallic object in RFID antennas. A year later, designed a meander line antenna with a Magneto-dielectric substantial for RFID system. This antenna ropes broadband, adequate to function in both UHF (433.92 MHz and 816-916 MHz) and ISM (2.45 GHz) bands. The planned technique also ropes on the magneto-dielectric material to get broadband and miniature characteristics.

ANTENNAS ELECTRICAL CHARACTERISTICS

Today, the wireless technologies such as radio, cellular, RFID, be delegation on the presence and effectiveness of well-designed antennas to effectively connect information over the air. Antennas are premeditated on precise application by modifying the specific antenna features like antenna feed, resonant frequency and radiation pattern. Here, the different antenna parameters (Parthiban, 2020) that engineers use to improve the antenna efficiency are discussed.

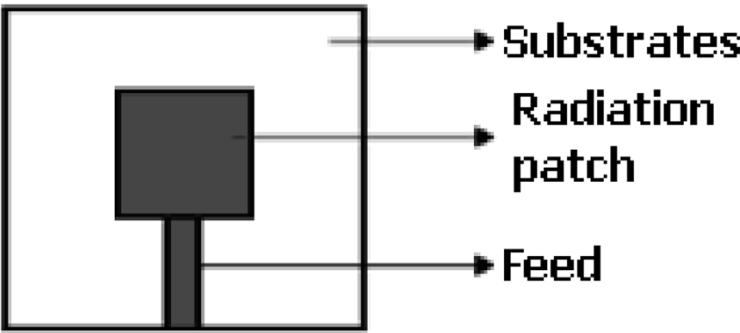
Feed Mechanism

There are various number of feeding methods developed for micro-strip antennas. Mostly, it's the feeding technique which bounds the complication of the antenna design. Widespread feeding techniques are divided into two comprehensive classes which are as follows. i.e., Directly connected to antenna and Coupled to the feed.

Directly Connected to Antenna

Direct electrical association can be given to feed the radiating element (micro-strip line, coaxial probe). Microstrip line feeding is the most frequently implemented feeding process (Parthiban, 2018), specified by. A leading strip is connected directly to the edge of the microstrip patch. In Inset feeding, the microstrip feed line is inserted into the patch to deliver the perfect impedance matching among the patch and feed line. Figure 2 shows the micro-strip line feed.

Figure 2. Micro-strip feed line



The advantage of this method is that, both the feed and the patch are located on the surface of substrate. This methodology is effective for thin substrates. Though, for thick substrates the method must be avoided since of counterfeit feed radiation and cross polarization properties.

Figure 3. Feeding of Coaxial probe for microstrip patch antenna

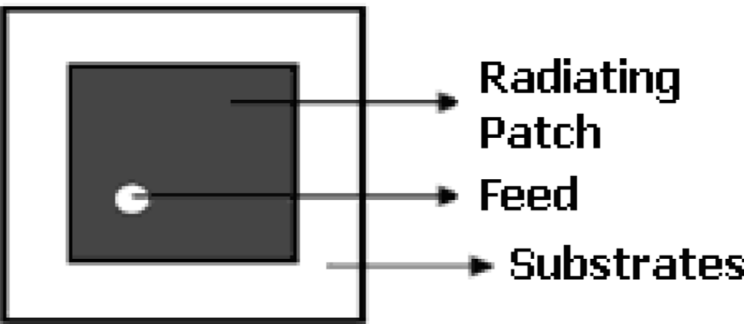
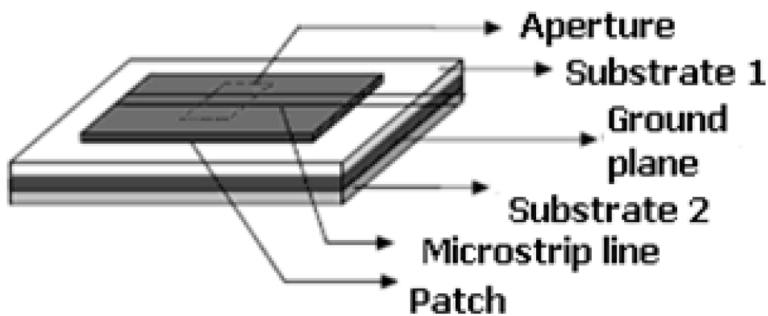


Figure 3 shows the coaxial probe feed. The coaxial feed or probe feed have inner conductor assembly of coaxial cable to patch through a hole in the substrate and the outer protection is stranded by joining the microstrip ground plane. However, it is simple to position the feed in any place on the patch, the difficulty of this methodology will be the narrow impedance bandwidth and challenging modelling.

Coupled to the Feed

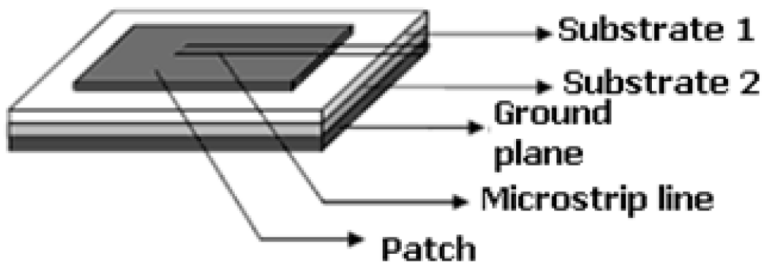
Electromagnetic field coupling is implemented in antenna feeding like aperture coupling and proximity coupling. An aperture coupled feedline is disconnected from the patch through the ground plane. Electromagnetic coupling is the transporting of power from the feedline to the patch over a slot/patch in the ground plane (Figure 4).

Figure 4. Aperture coupled feed



On the way to avoid the cross-polarization, the coupling aperture is centred at the upper most sheets from the patch. Between the multi-layered structure, the effectiveness of aperture coupling is lesser when connected to other approaches,

Figure 5. Proximity coupled feed



but it is informal to prototypical and accessible in the proximity coupling feed in RFID antenna. Proximity coupling feed has a feed line crammed along with two dissimilar substrates as shown in Figure 5.

The micro-strip antenna is on the topmost of the dielectric layer (Parthiban et al., 2016) and the ground plane is on the bottommost dielectric slab layer. The feed line is located along with the two dielectric slabs. The coupling is essentially capacitive nature. The feed mechanisms recommend greater than 13% of fractional bandwidth. Nevertheless, the fabrication complications are much improved than earlier approaches. And derived with the alike kinds of concept and maxims that micro-strip antennas struggle from a number of drawbacks similar to low gain, narrow bandwidth, spurious radiation, low efficiency and surface wave excitation. Though counter felt radiations and surface waves can be eradicated by means of right feed mechanisms and adjusting the substrate thickness, nonetheless the key troubles are lesser bandwidth and substandard radiation efficiency. Micro-strip antennas normally struggle from ohmic and dielectric losses, making it a high quadrature Q device. So as to attain superior bandwidth and gain, we must require to improve the substrate thickness, but this might affect in surface waves, consequently alternative approaches are explored.

Resonant Frequency

UHF antennas are usually “resonate” and function at a specific frequency and its size is proportional to the wavelength of the functioning electromagnetic wave. A half-wave dipole for illustration, functions at 915 MHz has a length of 15 centimetres which is approximately half of the operational wavelength.

In 2002, Best has individual that the Koch fractal monopole antenna designing shows a lower resonant frequency. Reproduction to the investigator, the monopole structure is fundamentally fixed for complete height and wire diameter. Therefore, increasing the entire wire length will thereby reduce the resonant frequency of the antenna. Similarly, seeming that if the entire fixed wire length and height were subjected to vary, then the antennas physical geometry for resonant frequency will also be varying. Changed this method for the reason that inferior resonant frequency is not adequate in all premeditated kinds of RFID antenna systems. Morocco presented that the UHF band printed dipoles and the patch antenna has typically greater sonant dimensions particularly for operational frequencies beneath 1 GHz. Epitomized in the folded shorted-patch (S-P) antenna. Nevertheless, the drawback of this planned method is the resonant frequency of the folded shorted-patch (S-P) antenna, which is not coordinated perfectly to the antennas ground structure. Consequently, the attained outcomes are expected to be subjected to more enhancements in order for

a perfect matching to be achieved. Developed a novel method of text as a meander line, which is implemented for size reducing in dipole antennas.

Radiation Pattern

The radiation pattern of an antenna (Tayyaba, 2021) is pictographi illustration of the strength of an antenna's power density in free space. The hypothetical isotropic antenna has a radiation pattern that is spherical in nature nevertheless it does not exist physically. There are two categories of radiation pattern in each RFID antennas that is E-plane and H-plane radiation. The specific outcome of a finite ground plane and its influence in the values of directivity and radiation pattern. The investigators accomplish that when the specifications of ground plane decreased, the absolute directivity value reduces and the current consequences in spurious radiation established in the diffraction of mutually leaky and surface waves. Devised the idea of implementing edge currents in condensed range reflectors for dropping current leakage. Rendering to his philosophy, if the ground plane is shortened, the frequency and radiation performance of the antenna can be exaggerated considerably.

The maximum author iterative stuff of the notched ground plane happens in the co and cross- polar radiation patterns. In order to serrate finite ground plane, E and H-plane patterns are matched with a comparatively equivalent shape of 90°angle

Figure 6. The 3D polar radiation patterns of dipole antennas with lengths/2



from both sides. The successful capacity of the ground plane declines when the length of irregularities strengthens. Consequently, a small diminution in H-plane beam width and rise in E-plane beam-width is detected.

Additionally, significant enhancements happened in the anticipated antennas is that the cross-polarization radiations reduced in both the E- and H-plane patterns. Specified that the radiation patterns are ordinance and symmetric in both E- and H-planes. Rendering to his investigations, the experimental cross-polar levels have been lesser than 28 dB of the co-polar levels. Back radiations are also originating as the coupling aperture radiates in backwards. Reasonably the proposed antenna remains to be better one since its back radiation can be minimised with a metallic sheet as a protection that is located at a distance of quarter wavelength from the feed line.

RFID in IOT

In the revolutionary IoT outlook, all physical objects, things and devices (Parthiban, 2020) can intelligence neighbouring surroundings and communicate their current grade. They declare their presence between the IoT environments, which states that they essentially modernize their databases synchronously in the IoT cloud. Aimed at this situation, the IoT four-tier architecture is portrayed in Figure7.

At the devices level, they contain actuators, sensors, and IoT radio frequency identification (I-RFID)intended at data collection beneath protected autonomic

Figure 7. IoT four-tier architecture



resource management control, wherever I-RFID has been reliably valued as a requirement for IoT. At the gateway level, they afford protected and authenticated data stream interconnections, employing both device-to-device (D2D) and device-to-cloud (D2C) communication. At the cloud level, they methodically acts through the instructive data by pre-processing, data archival, and edge computing. Reasonable applications for authentic user control and organization are implemented by customers in the end user level. Fashionably the modern technological age, I-RFID technologies undertake an author iterative part in the challenging IoT atmospheres of smart cities, such as safeguarding massive logistics control at harbours and airports, permitting smart retailing at marts, permitting for fast immigration endorsement at airports, and smoothing e-health and waste administration. RFID automation exploits relevant frequency band standards, that is low frequency (LF): 125–134.2 KHz, high frequency (HF): 13.56 MHz, ultra-high frequency (UHF): 860–960 MHz, and super-high frequency (SHF) 2.45 GHz. Many nations have changed effective isotropic radiated power (EIRP) limitations for UHF RFID tags; for example, North America, South Korea, and Japan take 4 W EIRP; Europe, China, and Malaysia take 3.28 W; and the EIRP of the United Kingdom is 6.56 W.

Challenges in RFID Antenna

However, UHF RFID has turn out to be the standard in sourcecable pursuing for its speed reaction rates and wide coverage ranges, but UHF antennas also strive limits and drawbacks and also their designing have frequent challenges. Rendering to the investigators, an RFID antenna (Shams & Ali, 2007) must have the subsequent characteristics such as:

- (i) it must be much small in order to embedded with the device,
- (ii) should have omni-directional direction pattern or hemispherical direction pattern,
- (iii) must deliver supreme signal potency to the application specific integrated circuit (ASIC),
- (iv) should have a polarization so as to compete the enquiry signal strength irrespective of the physical alignment of the selected item,
- (v) be vigorous and
- (vi) be very inexpensive.

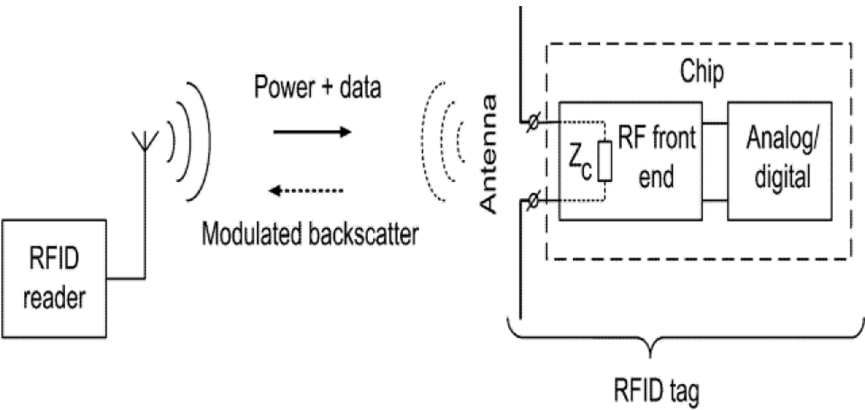
Nevertheless, they are still having numerous disadvantages like orientation-sensitive, radiating directions and patterns have assembly and radiation difficulties, material-sensitive, penetrating effortless place over radiolucent resources but then not at all over conductive or liquid resources and are narrowband, operative over a

short range of frequencies. Bandwidth is the utmost important parameter; it desires the consideration since of the UHF RFID structure functions at various frequencies from place to place across the world.

RFID System

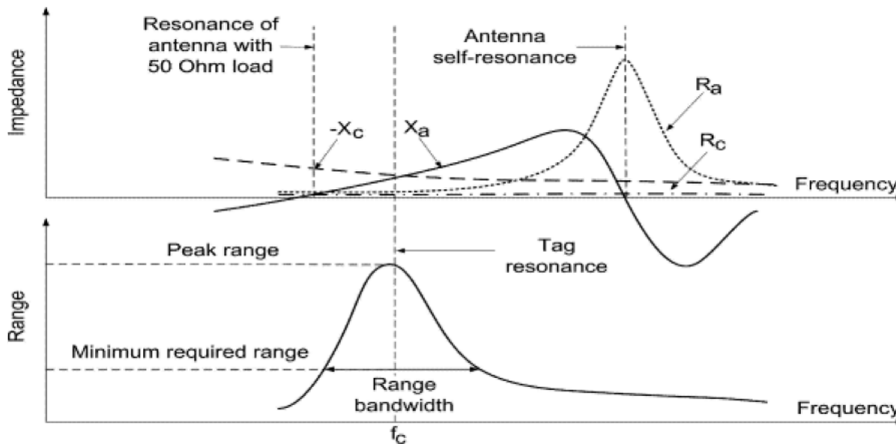
A passive back-scattered RFID system functions in the consequent method. A base station (reader) communicates a modulated signal through periods of unmodulated carrier (Parthiban, 2019), and is recognized by the tag antenna. The RF voltage recognized at the antenna terminals during unmodulated period is transformed to dc. This voltage powers up the chip, which directs back the information by changing its front-end complex RF input impedance. The impedance characteristically fastenings among two different states, between conjugate match and some other impedance, successfully modulating the back scattered signal. Figure 8 demonstrate a passive RFID system process.

Figure 8. RFID system process



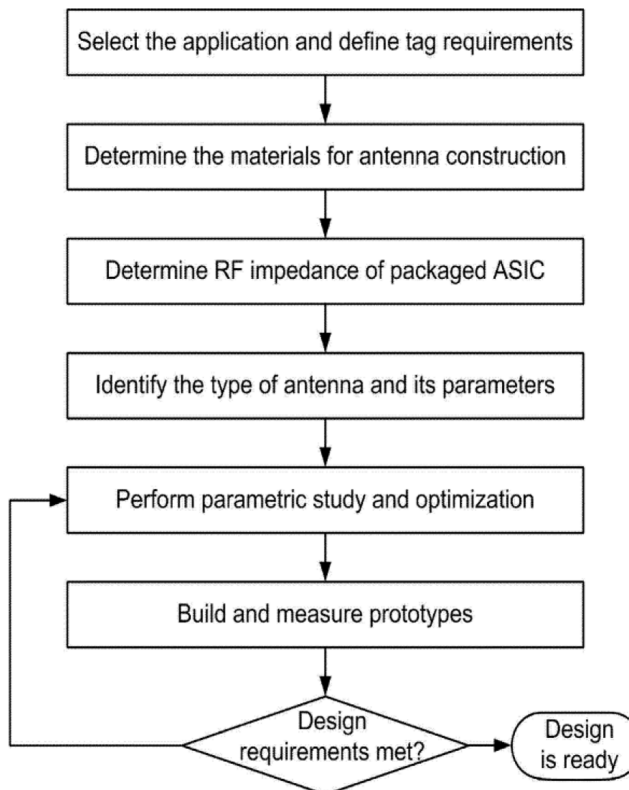
Qualitative characteristics of antenna impedance, chip impedance, and read range as variables of frequency intended for a characteristic RFID tag is demonstrated in Figure. 9. The frequency of the peak range is mentioned as the tag resonance. The tag range bandwidth is states as the frequency band in which the label offers a satisfactory minimum read range over that band.

Figure 9. Antenna impedance, chip impedance, and range as functions of frequency



RFID tag antenna design procedure is established on a flow chart in Figure 10.

Figure 10. RFID tag antenna design process.



When the RFID application is selected, structure necessities can be interpreted into tag necessities. These supplies regulate the resources for tag antenna building and ASIC packaging. The impedance of the selected ASIC in a selected RF package (like flip-chip, etc.) to which the antenna coordinated can be calculated with a network analyser.

Antenna parametric study and optimization is talented till design necessities are encountered in simulation. Like maximum antennas, RFID tag antennas (Wu et al., 2013) incline to be more multifaceted for logical explanation as they can be implemented in complex atmosphere. Tag antennas are typically analysed with electromagnetic modelling and simulation tools, characteristically with method of moments (MoM) for planar designs (e.g. thin flexible tags) and with finite-element method (FEM) or finite-difference time-domain method (FDTD) for more complex three-dimensional designs (e.g. thick metal mounted tags). Fast EM analysis utensils are vital for effective tag design. In a typical design process, (Toivonen et al., 2013)

The last step of the design procedure, samples are assembled and their performance is measured widely. If design necessities are fulfilled, the antenna design is complete. Else, the design is more adapted and optimized until necessities are met.

CONCLUSION

Radio frequency identification is a swiftly embryonic technology proposed for automatic identification of substances. Here in this paper, we presented a summary of antenna design for passive UHF RFID tags. We deliberated several provisions to such designs, charted a common design procedure including range measurement techniques. UHF RFID antennas are one of the significant termination components that are installed throughout plants, easing automation. These antennas are predominantly cast-off in engineering atmosphere that necessitates enormous strength to grip impact, shock, vibration, and thermal shocks deprived of trading-off the radiofrequency (RF) performance.

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