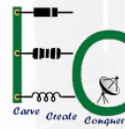




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2023 International Conference on Recent Trends in Electronics and Communication (ICRTEC) | 979-8-3503-9619-5/23/\$31.00 ©2023 IEEE | DOI: 10.1109/ICRTEC56977.2023.10111904



ICRTEC 2023

CONFERENCE PROCEEDINGS

IEEE International Conference on Recent Trends in Electronics and Communication

2023
10th & 11th
February

Under the Theme
Upcoming Technologies For Smart Systems

THE NATIONAL INSTITUTE OF ENGINEERING
DEPARTMENT OF ELECTRONICS AND COMMUNICATION
MANANDAVADI ROAD, MYSURU-570 008

Record NO: 56977 | ISBN NO:979-8-3503-9619-5

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TABLE OF CONTENTS

PAPER ID	AUTHORS	ARTICLE TITLE	eCF Paper ID
3	Sanjay S Tippannavar, Shivaprasad N and Yashwanth S D	Smart Gloves – A tool to assist Individuals with Hearing difficulties	ICRTEC2023-3
9	Vyshali Rao, Srividya Ramisetty and Dhanalakshmi M	Reliable Informational Data and Secured Deviation Notification over Networks Using IOT	ICRTEC2023-9
12	Shobhana G and Senthil Kumar J	Artificial Neural Network Based Classification Of Motor Imagery EEG Signals For Efficient Brain Computer Interface System	ICRTEC2023-12
13	Balakrishna K and Dhanushree V	A Review on Animal Detection and Classification using Computer Vision Techniques: Scope for Future Enhancement to Application	ICRTEC2023-13
14	Praveenkumar Chandran, Vishvatha KG, Tharun Jayanth KS and Sowndharya Venkatesan V	Comparative Analysis and Implementation of High Current and Low Output Ripple Converters for BLDC Drive System - EV Applications	ICRTEC2023-14
16	Rudraswamy B, Kiran Marathe, Lasitha S, T Chethan, Anjali S and Sinchana V	Enhanced Multimedia Broadcast Multicast service using virtualized 5G network	ICRTEC2023-16
18	Joshi V, Mane P and Ramesha C K	Approximate Arithmetic Circuit Design for Image Processing Applications	ICRTEC2023-18
20	Lipsa Dash, Swati Nigam, Dharshan V, Swathi M, Sreeraksha P, Shreya	Parametric Investigation of Antenna designs for 5G Communications	ICRTEC2023-20
22	Meera Gopinath Sujatha, Devarshi Patel, Prakash Ranganathan and Scott Korom	Multi-variate Factors Assessment of Harmful Algal Blooms (HABs)	ICRTEC2023-22
23	Poornima H S and Nagaraju C	Functional Verification of Clock Domain Crossing in Register Transfer Level	ICRTEC2023-23
40	Nitesh K A K A and Ravichandra	Modelling Battery Pack in Series and Parallel Combination to Estimate SOC for E-Vehicle	ICRTEC2023-40

42	P Samyuktha, Srinivas D and Himabindu T	Grid-connected solar power generating systems with superior power quality controlled using PBT	ICRTEC2023-42
44	Himabindu T, Chaitanya G and Srinivas D	SCIG Based Wind Energy Conversion System Fed DC Micro Grid Using DTC	ICRTEC2023-44
48	Ramya S and Jayasri B S	A Review on the analysis of Behavioral pattern of Students during pandemic COVID-19	ICRTEC2023-48
49	Akhil V M, Pavan Pundalik Mangaji, Rahul N Murthy, Rakesh D, Shridatta Hegde and Sukesh V Devadiga	Gear Fault Diagnosis Using SVM Based on Empirical Mode Decomposition	ICRTEC2023-49
52	Ankitha A Nayak and Shashank Shetty	A Systematic Analysis on Task Scheduling Algorithms for Resource Allocation of Virtual Machines on Cloud Computing Environments	ICRTEC2023-52
55	M Prathiksha, Priyanka R Badiger, Varshini Thangaraj, D A Varshini, Sahana Srikanth and Sanjeev Gurugopinath	A Survey on Machine Learning Techniques for Multimodal Biomedical Signal Processing	ICRTEC2023-55
57	Harjeevan Singh	Designing a Hybrid Optical Fiber/FSO System For Last Mile Users Under Tropical Weather Conditions	ICRTEC2023-57
58	Lakshmi B S, Rekha K S	A Survey Paper on Blockchain Technology with supply-chain management in Charity donation System	ICRTEC2023-58
59	Ranjan Mahapatra, Gnane Satapathi, Pradeep Kumar, ,Akshith N Shetty, Shashwath Shettigar, Abhinav J P, B Shivalal Patro, Diika Satapathy	Design and analysis of microstrip patch antenna	ICRTEC2023-59
60	Arjun Chakkrapani, Preethaa Jansirani	Efficient FPGA Implementation of Phase Shift Keying	ICRTEC2023-60
61	Lokesh B S and Narasimha Kaulgud	A review on analysis of transport layer security in open quantum safe cryptographic algorithm	ICRTEC2023-61
64	Bhushan K Munoli, K Abheeshta Jain, Prem Kumar, , Aditya Ram P S and Ashwini	Human Voice Analysis to Determine Age and Gender	ICRTEC2023-64
65	Ranjan Mahapatra, N S V Shet, Gnane Satapathi, B Shivalal Patro and Dipika Satapathy	Analysis of Modulation schemes Using Rayleigh and AWGN channel for wireless sensor nodes in Internet of Things	ICRTEC2023-65

72	Rajesh Kannan S, Ezhilarasi P, Rajagopalan VG, Sushanth Krishnamithran, HRamakrishnan H, Harish Kumar Balaji	INTEGRATED AI BASED SMART WEARABLE ASSISTIVE DEVICE FOR VISUALLY AND HEARING-IMPAIRED PEOPLE	ICRTEC2023-72
74	Ananya H P, Shreya K Magadum, Swathi S and Anitha S Prasad	Real Time tomato plant leaf disease detection using convolutional neural network	ICRTEC2023-74
75	P A Anshad , Niteesh M Gowda, Vijaykumar Kandakur and Anitha S Prasad	Forest Fire Detection Using nRF24L01 Wireless Sensor Network And Prediction by Machine Learning Model	ICRTEC2023-75
78	S Kannan, Prabakaran D, Dhenesh Kumar S, Sivaram S	A DEEP LEARNING-BASED CONVOLUTION NEURAL NETWORKS TO FORECAST WIND ENERGY	ICRTEC2023-78
80	Ashish sharma and Rinku Garg	New Technology for Harnessing Energy: Future of Hydrogen	ICRTEC2023-80
82	Mohan V S, Abhay Gowda G, Rekha R Nair, Kishore S and Tina Babu	Face Mask detection using Mask R-CNN to control the spread of Covid-19	ICRTEC2023-82
83	Raye Haarika, Tina Babu, Rekha R Nair and Rajesh T. M	Breast Cancer Prediction using Feature Selection and Classification with XGBoost	ICRTEC2023-83
86	Shreya G Abhyankar, Shashank S Bharadwaj, G Shobha Rani, Pruthvi G Karigiri, Sahana Srikanth and Sanjeev Gurugopinath	A Survey on Music Genre Classification Using Multimodal Information Processing and Retrieval	ICRTEC2023-86
87	Niranjan L, Manjunath V Gudur, Parthasarathy P, Pradeep Kumar Mallaiah, Mahesh B Neelagar and Sreekantha B	IoT-based safety system for swimming pools to avoid sinking of individuals	ICRTEC2023-87
91	Fida Fareesha, Chanadanashree Y K, Gowthami V, Remya Jayachandran, and Shaheen Kalathil	Real-Time Artificial Mood-tracking and Health-monitoring System (RAMAHS) for people with mental illness and their Caregivers	ICRTEC2023-91
92	Nilakshee Rajule, Mithra Venkatesan, Radhika Menon, Anju Kulkarni	Mobility Prediction in Cellular Networks: A Survey	ICRTEC2023-92
93	Nandini B M and Narasimha Kaulgud	Wavelet-based method for enhancing the visibility of hazy images using Color Attenuation Prior	ICRTEC2023-93
94	Darshan Babu K S, G Adarsh, Karan K ,Shylesh Kumar P B, Rupesh S, and Remya Jayachandran	A Novel scheme for IoT based Real Time Monitoring of Biodiesel Quality	ICRTEC2023-94
95	Amith Bharadwaj , Ananya Kashyap, Gurusatwik Bhatta, Remya Jayachandran and Rajalekshmi Kishore	A Survey on Terahertz Devices- A cutting edge Technology	ICRTEC2023-95

96	Rajalekshmi Kishore and Sanjeev Gurugopinath	Energy-Efficient Ant Colony Task Assignment Based Spectrum Sensing for Cognitive Radios	ICRTEC2023-96
97	Fuhad Muhammed, Sayana Tomes, Manu Elappila and Shamanth Nagaraju	Automated Contactless Continuous Temperature Monitoring System for Pandemic Disease Controlling Infrastructures	ICRTEC2023-97
105	Manjunath V Gudur, Saravanan M, Parthasarathy P, Niranjana L, Mahesh B Neelagar and Sreekantha B	Machine Learning based Routing approach and Resource Management in Vehicular Adhoc Networks	ICRTEC2023-105
106	Parthasarathy P, H N Shree Harsha, Manjunath V Gudur, Niranjana L, Mahesh B Neelagar and Sreekantha B	A novel optimization approach using multi-objective PSO incorporated with SEPIC and buck-boost converters for renewable energy sources	ICRTEC2023-106
107	Sharzeel Saleem, Jeba Shiney O and Pratikshit Vashishta	Binary Classification of Human Emotion using EEG and LTSM	ICRTEC2023-107
113	Sanjay Tippannavar, Yashwanth S D, Chandrashekar Murthy B N, Madhusudhan M P, Puneeth K M, , and Vinay Prasad M S	Comparative Analysis and Development of an Efficient Management System for a Photo-Voltaic Module	ICRTEC2023-113
114	Sanjay S Tippannavar, Puneeth K M, Yashwanth S D, Madhusudhan M P, Chandrashekar Murthy B N and Vinay Prasad M S	EVAS – Emergency Vehicle Alert System using LoRa for automobiles	ICRTEC2023-114
115	Sanjay S Tippannavar, Vijay Mishra, Yashwanth S D, Rishitha Gowda, Sathvik H R and Ajay M	Smart Transformer – An Analysis of Recent Technologies for Monitoring Transformer	ICRTEC2023-115
118	Alakesh Sharma, Jeba Shiney O	An Analysis on the Techniques for Water Quality Prediction from Remotely Sensed data	ICRTEC2023-118
122	Anita Patrot , Harish H, Shambbavi B, Geetha P L,Sahana	NBA GAME PREDICTION USING MACHINE LEARNING ALGORITHM	ICRTEC2023-122
126	Ramyateja Singamshetty, Sangani Sruthi, Kodati Chandhana, Sreedhar Kollem,and Rajendra Prasad Ch	Brain Tumor Detection Using the Inception Deep Learning Technique	ICRTEC2023-126
129	Shashi Gupta, V. Suresh Kumar, Alex Khang, Bramah Hazela, Nivethitha T and Bhadrappa Haralayya	Detection of Lung Tumor using an efficient Quadratic Discriminant Analysis Model	ICRTEC2023-129
130	Shashi Gupta, Surabhi Saxena, Alex Khang, Bramah Hazela, Chandra Kumar Dixit and Bhadrappa Haralayya	Detection of Number Plate in Vehicles using Deep Learning based Image Labeler Model	ICRTEC2023-130

131	Shashi Gupta, Ahmed Alemran, Prabhdeep Singh, Alex Khang, Chandra Kumar Dixit and Bhadrappa Haralayya	Image Segmentation on Gabor Filtered images using Projective Transformation	ICRTEC2023-131
132	Shashi Gupta, Waseem Ahmad, Dimitrios A. Karras, Alex Khang, Chandra Kumar Dixit and Bhadrappa Haralayya	Solving Roulette Wheel Selection Method using Swarm Intelligence for Trajectory Planning of Intelligent Systems	ICRTEC2023-132
136	Adi Surya Suwardi Ansyah, Miftahol Arifin, Muhammad Bahauddin Alfian, Matthew Vieri Suriawan, Nadhif Haikal Farhansyah, Ary Mazharuddin Shiddiqi, Hudan Studiawan	MQTT Broker Performance Comparison between AWS, Microsoft Azure and Google Cloud Platform	ICRTEC2023-136
140	Sangeetha D P, Sabitha R, Shirisha J and Balaji A	Investigating and Checking the Javelin Athlete's Movement Parameters Using Smart WSN	ICRTEC2023-140
141	Sivakumar T, Sashi Rekha K, Vikram N and Maruthu Kannan B	Misbehavior Node Detection using Hamming Residue Mechanism in Clustering WSN	ICRTEC2023-141
144	Kishore Sonti V J K, Sundari G, Bernatin T and Sahaya Anselin Nisha A	Ecological Observing using Sensor and IoT to Protect the Global Warming in WSN	ICRTEC2023-144
146	Sanjay S Tippannavar, Yashwanth S D and Puneeth K M	SDR – Self Driving Car Implemented using Reinforcement Learning & Behavioural Cloning	ICRTEC2023-146
148	Bansilal Bairwa, Madan Murari, Mahammadgaous Sahapur, Kavya M.R, Md.Firdosh Khan	Drive Cycle Based Speed Control of BLDC Motor Using Pulse Width Modulation	ICRTEC2023-148
150	Akula Shravya Sri, Bobbili Varshith Reddy, Kanuri Balakrishna, Vollala Akshitha, Sreedhar Kollem and Ch Rajendra Prasad	Detection of MRI Brain Tumor Using Customized deep learning method Via Web App	ICRTEC2023-150
151	Insha Yaqoob Sheikh	Efficient Novel Binary to Gray Code Converter Using Coulombic Interaction on Quantum Dot Cellular Automata	ICRTEC2023-151
153	Anka Rao Mogili, Sreenivasulu. J, Prudhvi Sai Bojanapalli	Sliding Mode Controller with Disturbance Estimator for Fuzzy Logic Controller fed PMSM Drives	ICRTEC2023-153
154	Naveen Kumar Peelam, Kiranmayi.R, Nagabhushanam. K, Swathi.N	Wind Turbine Integrated Generator Rectifier System with Fuzzy Logic Controller based on MPPT	ICRTEC2023-154

155	Mallapu Vijaya kumar, Maruthi Kudadala	a novel fuzzy logic controller topology for grid connected pv system by dc voltage droop control	ICRTEC2023-155
158	Bansilal Bairwa, ShriHarinayaka P, Sagar B S, Ashwini Kumari P	Temperature Dependent Capacity Fade Prediction of Electric Vehicles Batteries	ICRTEC2023-158
159	Sathya K and Guruswamy K P	Performance Analysis for LLC Resonant Converter in Electric Vehicle Applications	ICRTEC2023-159
161	Bansilal Bairwa, Manohar K A, Mallikarjun M Magadum, Keerthi S, R Chitrashree	Modeling of Low Cost Battery Charge Controller for Stationary to Mobile Applications	ICRTEC2023-161
162	Shubham Subhas Borkar, Guruswamy K.P	Performance Analysis of Half-Bridge LC Resonant Converter for UPS Battery Charging Application.	ICRTEC2023-162
166	Vanditha M, Surendra R Hegde, Snehith K, Anitha S Prasad and Eshwari A Madappa	Agricultural Supply Chain Management System using Blockchain	ICRTEC2023-166
169	Geetha Rani E, Roshan Jose S, Joel Thomas Chacko , Joshua Paul C , Jeanette Krizelda K	Peer-to-Peer File Streaming Using Web Sockets Protocol	ICRTEC2023-169
175	M. Venkata Subbarao, G. Challa Ram, D. Ramesh Varma	Performance Analysis of Pistachio Species Classification using Support Vector Machine and Ensemble Classifiers	ICRTEC2023-175
176	Rajini H, Bansilal Bairwa , Arpita Banik, Surineni Jagadeesh	Development of ON Road Charging System for Electric Vehicle Applications	ICRTEC2023-176
179	A.Ravi, Gnanasree Dupaguntla, Devi Krishna Tadepalli	Image Denoising Using Feature Map Based Convolutional Neural Networks	ICRTEC2023-179
180	Nanditha Krishna, Padma C.R., Surabhi A.S, Saritha Pal, Aishwarya Prabhu, Sahana P	A review on VARIBRACE - A wearable therapeutic device	ICRTEC2023-180
182	Yashavanth T R, Suresh M	Performance Analysis of Multimodal Biometric System Using LBP and PCA	ICRTEC2023-182
184	Shashidhar R, Sanjay Tippannavar, Sushma B S and P Shukla	Smart Electric Wheelchair for disabled and paralyzed person using Attention Values on Arduino	ICRTEC2023-184
187	Rakheeba Taseen, Haseeba Yaseen, Niranjan L, Gadige Radha, Mahesh B Neelagar and Shwetha N	An Innovative Method for Energy Intensive Routing and Transmission Network Positioning in Integrated Wireless Detector Networks	ICRTEC2023-187

190	Armend Salihu, Halil Snope, Artan Luma, Jaumin Ajdari	Comparison of time complexity growth for different methods/algorithms for rectangular determinant calculations	ICRTEC2023-190
198	Harish S.V and Archana N.V	A Distributed Cluster Based Protocol to Extend Lifetime using Fitness Function algorithm in Wireless Sensor Networks	ICRTEC2023-198
199	J Suneetha, Niranjana L, Husna Tabassum, Swamy Goud, Rakheeba Taseen and Mahesh B Neelagar	A Wireless Detector Network for Three-Dimensional Positioning Using Artificial Neural Networks	ICRTEC2023-199
204	Susandhika m, Shirly Edward A	M/S. The National Institute of Engineering	ICRTEC2023-204
212	I. Evangeline Felicia, V. Gomathi and E. Isac Paulraj	Two-Port UWB-MIMO Antenna Design with Improved Isolation for WiMAX and X-Band Applications	ICRTEC2023-212
213	Sanjay S Tippannavar, Yashwanth S D, Chandrashekar Murthy B N and Praveen Kumar M S	IoT enabled Smart Car with V2X Enhanced Communication and Safety Alert system	ICRTEC2023-213
215	H.N.Srinivasa Nayaka , Shankar Nalinakshan,M.S. Ganesh Prasad , Vikram Y and Appalabathula Venkatesh	Design and Implementation of Electrical system in H-Gantry automation for Double Disc Front Brake	ICRTEC2023-215

Design and analysis of microstrip patch antenna

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Abstract—This work represents the design of a rectangular microstrip patch antenna resonating at 2.4 GHz to 11 GHz with better notch in the band. The structure of the rectangular microstrip patch antenna consists of the dielectric material in between the patch and the ground plane. The antenna is designed with a suitable substrate such as Flame-Retardant-4 (FR-4) which has a dielectric constant of 4.4, a height of 1.6 mm, and a loss tangent of 0.02. Microstrip feed lines are used for the design. The performance evaluation is measured in terms of return loss, gain, directivity and notch. From the results, this antenna has shown better performance in comparison to other related works.

Index Terms—Microstrip patch antenna, return loss, gain, directivity

I. INTRODUCTION

An antenna can transmit and/or receive electromagnetic waves. Antenna plays an important role in signal communication and is a secure and fast way of transferring data. At the beginning, communication was due to the sound voice. After that, communication was via radio and was the first communication that happened in human history. Later on, this was employed in industrial applications. Hence success in the antenna field came into the picture. Modern communication systems in the digital age require the usage of antenna that are miniaturized, compatible and reasonably priced. Different types of antenna with different shapes and sizes like rectangular, circular, triangular, and annular patches were discovered. Among those antennas, microstrip patch antennas [1] [2] are widely used in modern wireless technology because of many reasons such as low profile, less weight, cost-effectiveness, and conformal design. Microstrip antenna was developed in 1970s and got huge benefits and good performance. Many previous researchers found that patches in antenna arrays can be further improved by changing shapes like rectangular, and circular as well as with different frequencies as per the application. For wireless LAN, it can be operated in the frequency range of 2 to 3 GHz. Rectangular-shaped patch antenna has gained popularity because it can be easily analyzed and output exhibits better results.

II. BACKGROUND

In relevant to this work few papers [3]–[10] are referred to understand the requirements for an antenna and suitable parameters were selected for the design. The paper [11] suggesting the design of a microstrip rectangular inset-fed patch antenna for Wimax application for a resonating frequency of 2.5 GHz was analyzed. The antenna was designed using CST microwave studio software. The size of the antenna plays an important role while designing. Making of an antenna of a smaller size with better output is always better. Paper [12] on miniature microstrip antenna for IOT application was referred. The antenna was designed such that the resonating frequency was around 5.8GHz. However, the results of that antenna were not up to the mark. The return loss was around -20 dB with a low gain value of 1.83 dB. So main factors to be considered for improving the results of the single-patch rectangular microstrip patch antenna with miniaturizing the size which will be resonating at the frequency of 2.4 GHz - 7 GHz, can be the dimension of the antenna to be varied. Another paper [13] representing a rectangular microstrip patch antenna was designed with slotted patches in it. The antenna had a resonating frequency of 2.4 GHz. The purpose of the antenna was to cover the entire ISM band (2.4-2.49 GHz). The antenna obtained a gain of 3.714dB and a directivity of 5.199 dB. The Table. I represents a comparison of several related papers contributions.

III. WORKFLOW

For designing a microstrip patch antenna several various parameters are chosen carefully. They directly impact the antenna performance characteristics such as bandwidth, gain, and efficiency. The resonating frequency, the dielectric constant of the substrate material, and the height of the substrate material should be known prior to the design. This paper represents the designed microstrip patch antennas resonating at the frequency of 2.4 GHz to 11 GHz. The design of the antenna consists of 3 components such as the ground plane, substrate, and patch design. The substrate material used for the antenna was FR-4 with a dielectric constant of 4.4. The microstrip inset line feeding technique is used while designing

the microstrip patch antenna as it provides a smooth surface to the antenna. The height of the substrate was 1.6mm. The 3D model of the rectangular microstrip patch antenna is designed using HFSS. Once the design was completed, it was simulated to observe the obtained antenna parameters. If the designed antenna maps up to the marked output, then the antenna is considered for further use. If the production was not up to the mark which is lesser than the expected values, then the antenna was redesigned with modifications. This modified antenna has to be simulated again to check if the requirements are met. The flow of the proposed work is represented by the flow chart in Fig. 1. The antenna parameters such as width and

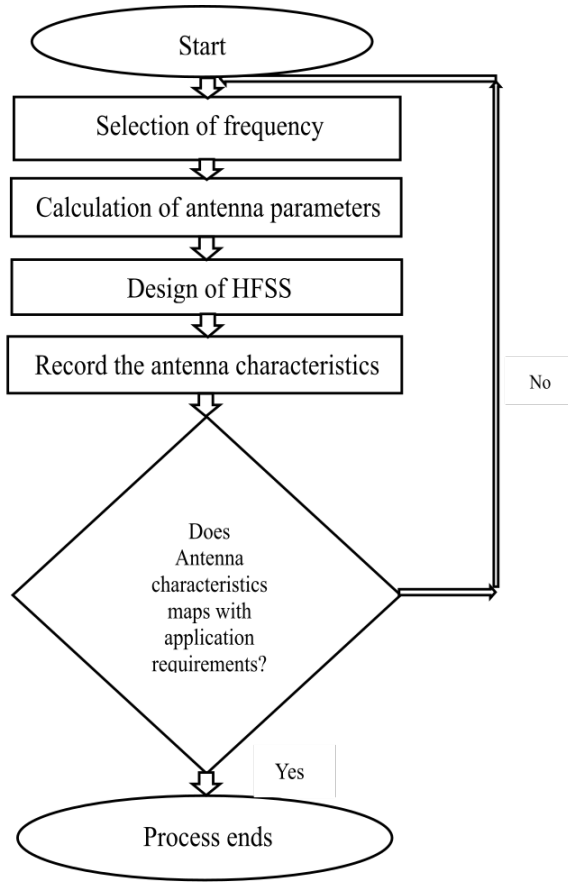


Fig. 1: Flow chart of Proposed antenna design

length (L_p) of the patch (W_p) have been calculated from the given equations.

$$W_{patch} = \frac{\text{speed of light}}{2f_r \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

where the speed of light is the speed of the wave in the free space, f_r is the resonant frequency, and ϵ_r is the dielectric constant of the dielectric substrate. The effective dielectric

constant ϵ_r is calculated by:

$$\epsilon_{effective} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \left(\frac{h_s}{W_{patch}} \right)}} \right] \quad (2)$$

where h_s is the height of the substrate used in the design. The length of the patch is also an important parameter to be taken care of while designing the antenna. It is calculated using the formula:

$$L_{patch} = \frac{\text{speed of light}}{2f_r \sqrt{\epsilon_{effective}}} - 0.824h_s * \dots \left(\frac{(\epsilon_{effective} + 0.3) \left(\frac{W_{patch}}{h_s} + 0.264 \right)}{(\epsilon_{effective} - 0.258) \left(\frac{W_{patch}}{h_s} + 0.8 \right)} \right) \quad (3)$$

The length of the ground is found using the equation:

$$L_{gnd} = 2 * L_{patch} \quad (4)$$

The width of the ground is obtained using the equation:

$$W_{gnd} = 2 * W_{patch} \quad (5)$$

IV. PROPOSED ANTENNA DESIGN

The prototype of proposed design is shown in Fig. 2. Parameters of the antenna are varied in each of the proposed designs to achieve better return loss characteristics. The Patch width for design 3 was changed to 36 mm from 38 mm as was in design 2, which resulted in 50 ohm impedance.

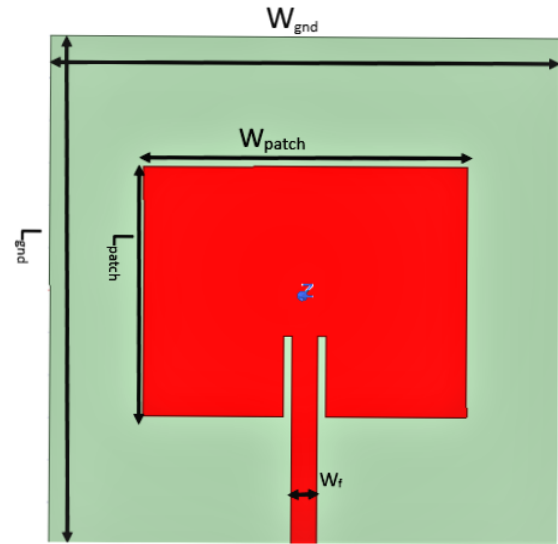


Fig. 2: Prototype of Proposed antenna design

A. PROPOSED DESIGN 1 AND RESULTS

Fig. [3]-[9] represents the notch in return loss, Gain, directivity, Modal Analysis, Surface current, Co and x pol, 2d radiation pattern of the proposed design1. It can be observed from Fig. 3 that the antenna has notch notch in return loss at -17.8025 dB to -20.2112 dB.

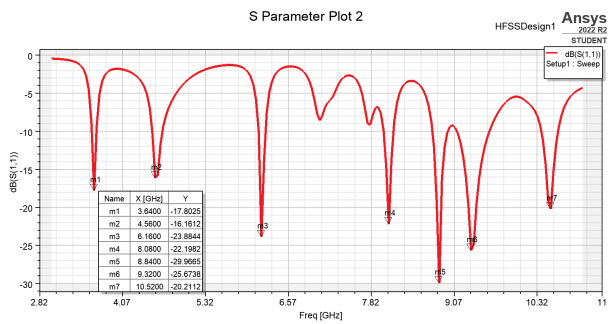


Fig. 3: Return Loss1

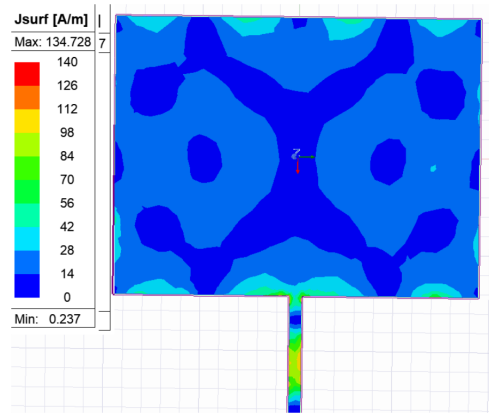


Fig. 7: Surface Current1

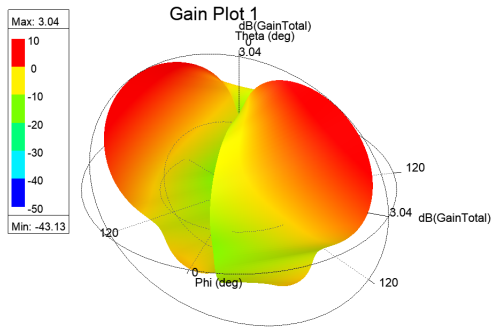


Fig. 4: Gain1

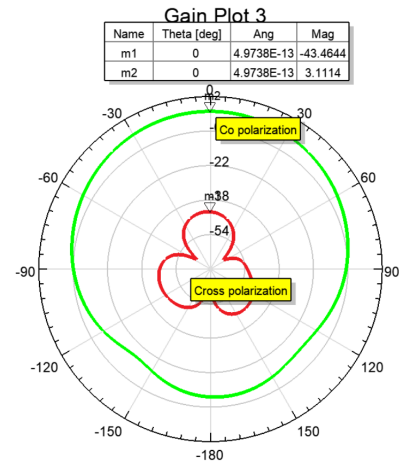


Fig. 8: Co and X pol of the antenna

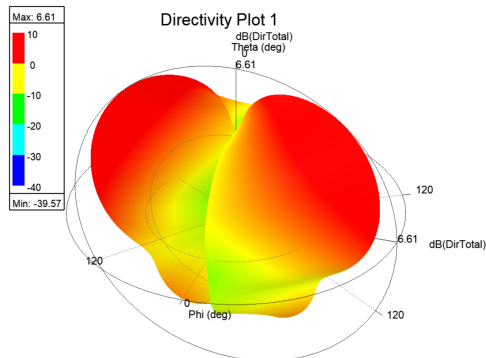


Fig. 5: Directivity1

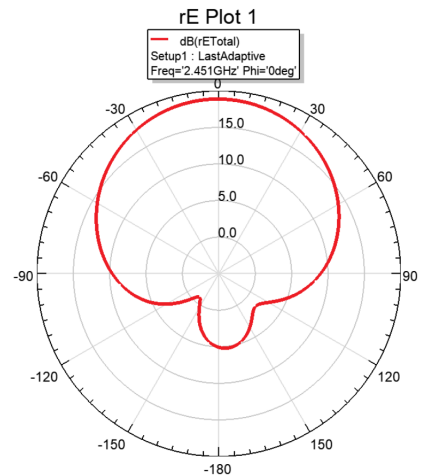


Fig. 9: 2D radiation pattern1

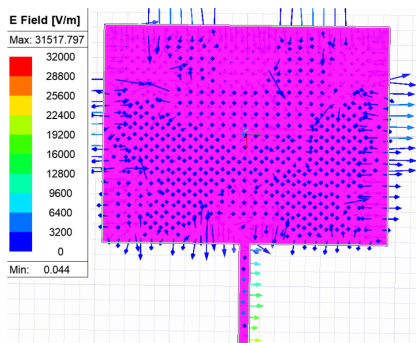


Fig. 6: Efield1

B. PROPOSED DESIGN 2 AND RESULTS

Fig. [10]-[16] represents the notch in return loss, Gain, directivity, Modal Analysis, Surface current, Co and x pol, 2d radiation pattern of the proposed design2.

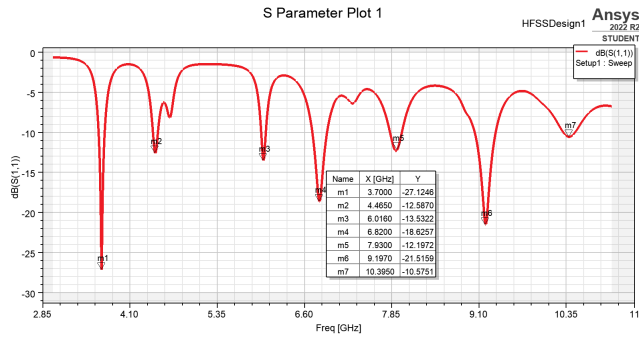


Fig. 10: Return Loss2

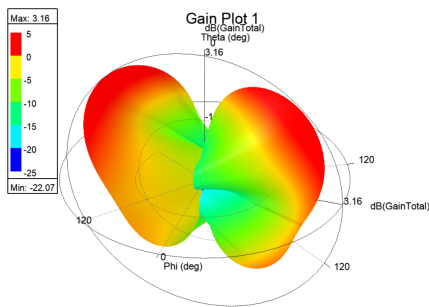


Fig. 11: Gain 2

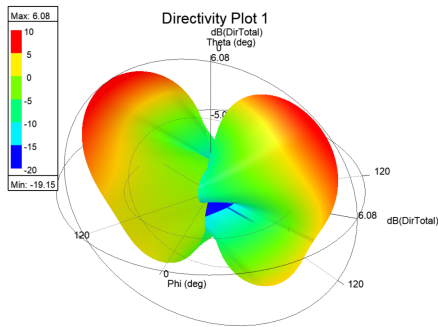


Fig. 12: Directivity2

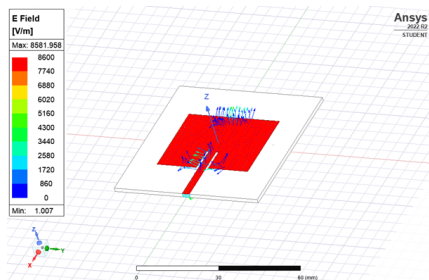


Fig. 13: Efield2

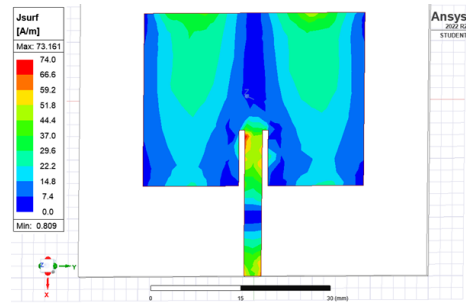


Fig. 14: Surface current2

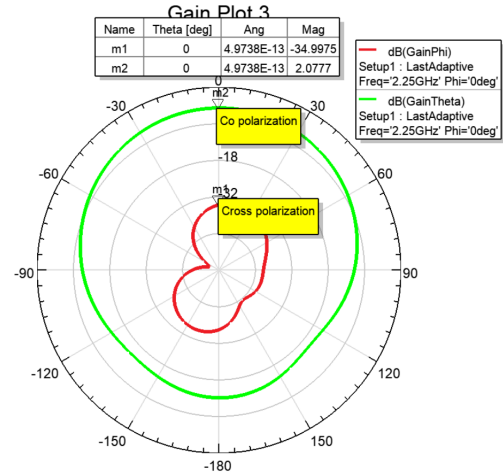


Fig. 15: Co and X pol of the antenna2

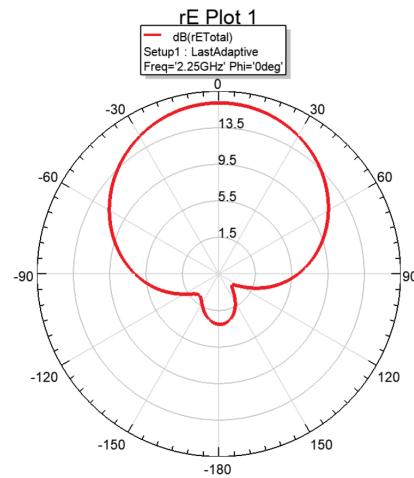


Fig. 16: 2D radiation pattern2

C. PROPOSED DESIGN 3 AND RESULTS

Fig. [17]-[23] represents the notch in return loss, Gain, directivity, Modal Analysis, Surface current, Co and x pol, 2d radiation pattern of the proposed design3.

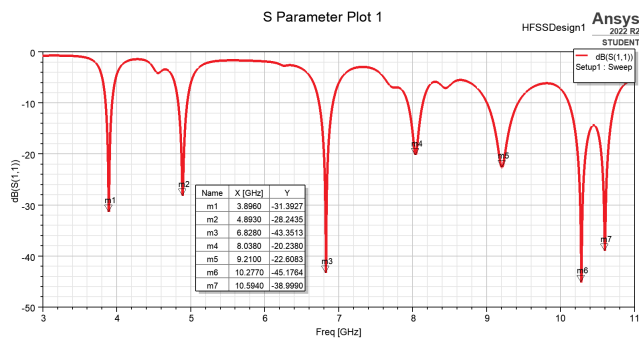


Fig. 17: Return loss3

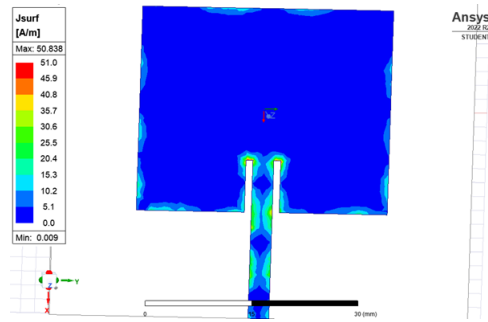


Fig. 21: Surface current 3

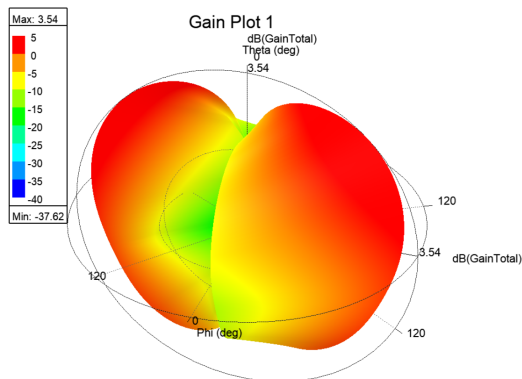


Fig. 18: Gain 3

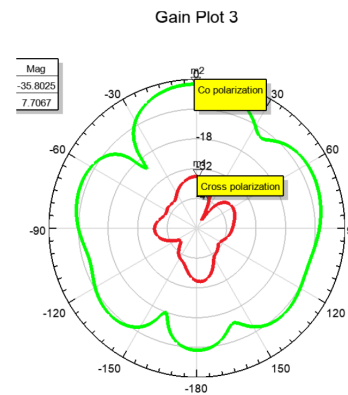


Fig. 22: Co and X pol of the antenna3

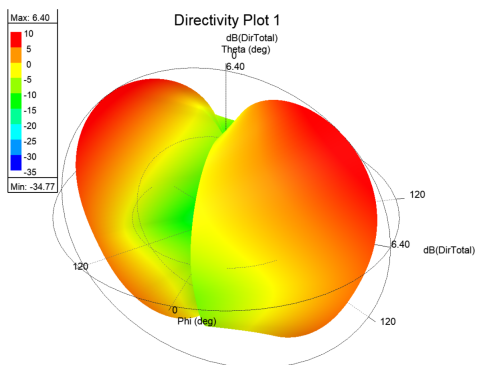


Fig. 19: Directivity3

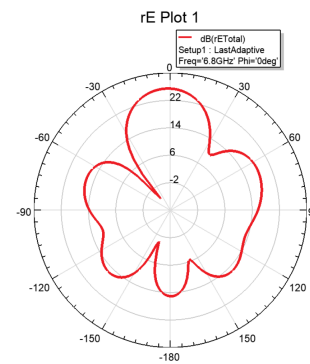


Fig. 23: 2D radiation pattern

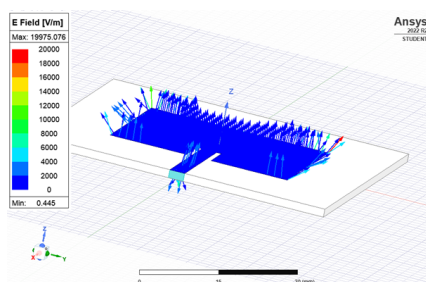


Fig. 20: Efield3

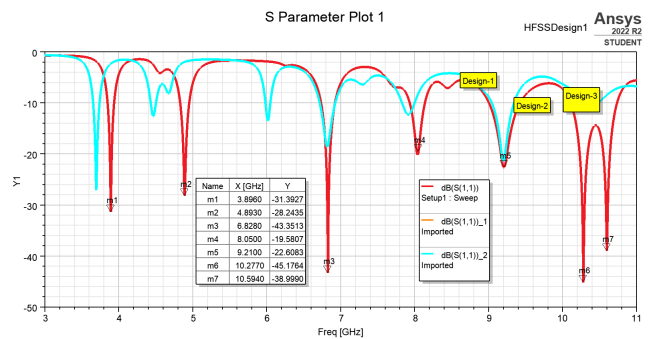


Fig. 24: Comparison of return losses of 3 designs

V. COMPARISON OF SIMULATED RESULTS

Fig. 24 represents the comparison of return losses for three proposed designs. The Table. II represents dimension and Table. [III]-[IV] represents all the results obtained.

TABLE I: Comparison of several author's contributions and their results

Sl No	Year	Title of the paper	Tool Used	Return Loss	Gain	Directivity	Conclusion
1	2004	[2]	FDTD method	—	—	3.4	MPA was mounted on a dielectric chip and it has been analyzed
2	2019	[12]	CST	-19.5	6.4	—	The 5G antenna was used for future 5G mobile applications because of its compactness.
3	2019	[13]	CST	-38.4	2.6	5.4	The proposed inset fed slotted MPA was found effective for ISM band applications
4	2020	[11]	—	—	—	—	Based on the number of patches on the antenna
5	2020	[11]	CST	-20.3	1.3	6.7	The single patch antenna obtained the return loss of -20db, directivity was 6.75 and gain was 1.36
6	2020	[10]	CST	20.32	1.83	—	The attained operating frequency of 5.755 GHz is suitable for IOT applications

TABLE II: Comparison of dimensions

Parameter	Symbol	Values for design1 (mm)	Values for design 2 (mm)	Values for design3 (mm)
Ground width	W_{gnd}	80	60	60
Ground lengths	L_{gnd}	60	60	60
Substrate height	hs	1.6	1.6	1.6
Patch widths	W_{patch}	38	38	36
Patch length	L_{patch}	28.8	29.4	29.4
Feed width	W_f	1.4	3	3

TABLE III: Comparison of the design results1

Antenna	Resonant Frequency (GHz)	Return (dB)	Gain (dBi)	Directivity (dBi)
Design1	3.6400 to 10.5200 BW= 6.88	-17.8025 to -20.2112	3.04	6.61
Design2	3.700 to 10.3950 BW = 6.695	-27.1246 to -10.5751	3.16	6.06
Design3	3.8960 to 10.5940 BW= 6.698	-31.39 to -38.9990	3.54	6.40

TABLE IV: Comparison of the design results2

Antenna	Axial ratio(dB)	CO and X	E field(V/m)	current(A/m)
Design1	23.3312, 23.8684, 24.5158	-43.4644 to 3.1114	3200	14
Design2	33.5488, 21.1272, 15.8690	-34.9975 to 2.0777	860	7.4
Design3	52.1946, 33.5448, 17.2238	-35.8025 to 7.7067	2000	5.1

VI. CONCLUSION AND FUTURE SCOPE

In this paper design of rectangular microstrip patch antenna is proposed. Based on the results, proposed design 3 has shown better performance with 10.2770 GHz for operating frequency within 2.4 GHz to 11 GHz with better notch. This antenna can be optimized to achieve better return loss below -10 dB for wide band application.

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