

Advances in Intelligent Systems and Computing 1354

Brijesh Iyer
Debashis Ghosh
Valentina Emilia Balas *Editors*

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Editors

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Preface

Dr. Babasaheb Ambedkar Technological University, Lonere-402103, is a State Technological University of the Maharashtra State in India. Over the years, the Department of Electronics and Telecommunication Engineering of this University has been organizing faculty and staff development and continuing education programs.

In 2013, the department took a new initiative to organize international conferences in the frontier areas of eEngineering and computing technologies. The ICCET series (earlier ICCASP) is an outcome of this initiative. The 6th ICCET 2021 has been organized by the department of E&TC Engineering of the University. The event was conducted in ONLINE mode due to ongoing pandemic situations all over the globe. Keynote lectures, invited talks by eminent professors, and panel discussions of the delegates with the academicians and industry personnel are the key features of the 6th ICCET 2021.

This volume aims to collect scholarly articles in the area of Applied Information systems which will be helpful to cater to the needs of next millennium communications systems. We have received a great response regarding the quantity and quality of individual research contributions for consideration. The conference had adopted a “Single Blind Peer Review” process to select the papers with a strict plagiarism verification policy. Hence, the selected papers are the true record of research work for the theme of this volume.

We are thankful to the reviewers, session chairs, and rapporteurs for their support. We also thank the authors and the delegates for their contributions and presence. Finally, we are incredibly grateful to University officials for their support for this activity.

We are pledged to take this conference series to greater heights in the years to come to put forward the need-based research and innovation.

Thank you one and all.

Lonere, India
Roorkee, India
Arad, Romania

Dr. Brijesh Iyer
Dr. Debashis Ghosh
Dr. Valentina Emilia Balas

Contents

CNN Parameter Adjustment for Brain Tumor Classification	1
Toan Pham Ho and Vinh Truong Hoang	
Advance Fuzzy Radial Basis Function Neural Network	11
Balaji S. Shetty, Manisha S. Mahindrakar, and U. V. Kulkarni	
Unbounded Fuzzy Radial Basis Function Neural Network Classifier	25
Balaji S. Shetty, Manisha S. Mahindrakar, and U. V. Kulkarni	
A Study on the Adaptability of Deep Learning-Based Polar-Coded NOMA in Ultra-Reliable Low-Latency Communications	39
N. Iswarya, R. Venkateswari, and N. Madhusudanan	
Heart Rate Variability-Based Mental Stress Detection Using Deep Learning Approach	51
Ramyaashri B. Ramteke and Vijaya R. Thool	
Product-Based Market Analysis Using Deep Learning	63
Aayush Kumaria, Nilima Kulkarni, and Abhishek Jagtap	
Driver Drowsiness Detection Using Deep Learning	73
Ajinkya Rajkar, Nilima Kulkarni, and Aniket Raut	
Emotion Detection from Social Media Using Machine Learning Techniques: A Survey	83
Vijaya Ahire and Swati Borse	
Deep Age Estimation Using Sclera Images in Multiple Environment	93
Sumanta Das, Ishita De Ghosh, and Abir Chattopadhyay	
Data Handling Approach for Machine Learning in Wireless Communication: A Survey	103
Niranjan S. Kulkarni, Sanjay L. Nalbalwar, and Anil B. Nandgaonkar	
Breast Cancer Detection in Mammograms Using Deep Learning	121
Abhiram Pillai, Amaan Nizam, Minita Joshee, Anne Pinto, and Satishkumar Chavan	

Deep Learning-Based Parameterized Framework to Investigate the Influence of Pedagogical Innovations in Engineering Courses	129
M. Ashok, Kumar Ramasamy, Umadevi Ashok, and Revathy Pandian	
Modern Transfer Learning-Based Preliminary Diagnosis of COVID-19 Using Forced Cough Recordings with Mel-Frequency Cepstral Coefficients	137
Shariva Dhekane, Vaishnavi Agrawal, Aniruddha Datta, and Kunal Kulkarni	
Biomedical Text Summarization: A Graph-Based Ranking Approach	147
Supriya Gupta, Aakanksha Sharaff, and Naresh Kumar Nagwani	
EEG-Based Diagnosis of Alzheimer's Disease Using Kolmogorov Complexity	157
Digambar Puri, Sanjay Nalbalwar, Anil Nandgaonkar, and Abhay Wagh	
Quantification of Streaking Effect Using Percentage Streak Area	167
Sajjad Ahmed and Saiful Islam	
Improving Topographic Features of DEM Using Cartosat-1 Stereo Data	177
Litesh Bopche and Priti P. Rege	
Active Noise Cancellation System in Automobile Cabins Using an Optimized Adaptive Step-Size FxLMS Algorithm	187
Arinjay Bisht and Hemprasad Yashwant Patil	
FFT-Based Robust Video Steganography over Non-dynamic Region in Compressed Domain	201
Rachna Patel, Kalpesh Lad, and Mukesh Patel	
An Improved Approach for Devanagari Handwritten Characters Recognition System	217
Rajdeep Singh, Arvind Kumar Shukla, Rahul Kumar Mishra, and S. S. Bedi	
PSO-WT-Based Regression Model for Time Series Forecasting	227
P. Syamala Rao, G. Parthasaradhi Varma, and Ch. Durga Prasad	
Leaf Diagnosis Using Transfer Learning	235
Prashant Udawant and Pravin Srinath	
Attendance System Using Face Recognition Library	247
Bhavna Patel, Vedika Patil, Onkar Pawar, Omkar Pawaskar, and J. R. Mahajan	
Studies on Performance of Image Splicing Techniques Using Learned Self-Consistency	255
Bhukya Krishna Priya, Anup Das, Shameedha Begum, and N. Ramasubramanian	

Random Forest and Gabor Filter Bank Based Segmentation Approach for Infant Brain MRI	265
Vinodkumar R. Patil and Tushar H. Jaware	
Sensory-Motor Cortex Signal Classification for Rehabilitation Using EEG Signal	273
Vinay Kulkarni, Yashwant Joshi, and Ramchandra Manthalkar	
D-CNN and Image Processing Based Approach for Diabetic Retinopathy Classification	283
Armaan Khan, Nilima Kulkarni, Ankit Kumar, and Anirudh Kamat	
Pothole Detection Using YOLOv2 Object Detection Network and Convolutional Neural Network	293
R. Sumalatha, R. Varaprasada Rao, and S. M. Renuka Devi	
A New Machine Learning Approach for Malware Classification	301
G. Shruthi and Purohit Shrinivasacharya	
Analysis of Feature Selection Techniques to Detect DoS Attacks Using Rule-Based Classifiers	311
Atharva Vaidya and Deepak Kshirsagar	
Botnet Detection Using Bayes Classifier	321
Prapti Kolpe and Deepak Kshirsagar	
Insider Attack Prevention using Multifactor Authentication Protocols - A Survey	331
Siranjeevi Rajamanickam, N. Ramasubramanian, and Satyanarayana Vollala	
Link Scheduling in Wireless Mesh Network Using Ant Colony Optimization	341
Makarand D. Wangikar and Balaji R. Bombade	
Development of an Integrated Security Model for Wireless Body Area Networks	351
K. R. Siva Bharathi and R. Venkateswari	
An Improved Node Mobility Pattern in Wireless Ad Hoc Network	361
Manish Ranjan Pandey, Rahul Kumar Mishra, and Arvind Kumar Shukla	
IGAN: Intrusion Detection Using Anomaly-Based Generative Adversarial Network	371
Jui Shah and Maniklal Das	
CodeScan: A Supervised Machine Learning Approach to Open Source Code Bot Detection	381
Vipul Gaurav, Shresth Singh, Avikant Srivastava, and Sushila Shidnal	

Green Internet of Things: The Next Generation Energy Efficient Internet of Things	391
Navod Nieranjan Thilakarathne, Mohan Krishna Kagita, and W. D. Madhuka Priyashan	
<i>iGarbage: IoT-Based Smart Garbage Collection System</i>	403
Zofia Noorain, Mohd. Javed Ansari, Mohd. Shahnawaz Khan, Tauseef Ahmad, and Md. Asraful Haque	
IoT-Based Smart Home Surveillance System	417
Shruti Dash and Pallavi Choudekar	
Optimized Neural Network for Big Data Classification Using MapReduce Approach	429
Sridhar Gujjeti and Suresh Pabboju	
Impact of Deployment Schemes on Localization Techniques in Wireless Sensor Networks	439
Pratee k, Aakansha Garg, and Rajeev Arya	
A Survey on 5G Architecture and Security Scopes in SDN and NFV	447
Jehan Hasneen and Kazi Masum Sadique	
Study and Analysis of Hierarchical Routing Protocols in Wireless Sensor Networks	461
Ankur Choudhary, Santosh Kumar, and Harshal Sharma	
Circularly Polarized 1 × 4 Antenna Array with Improved Isolation for Massive MIMO Base Station	475
Ravindra S. Bakale, Anil B. Nandgaonkar, S. B. Deosarkar, and R. Bhadade	
Analysis of Rectangular Microstrip Array Antenna Fed Through Microstrip Lines with Change in Width	487
Tarun Kumar Kanade, Alok Rastogi, Sunil Mishra, and Vijay D. Chaudhari	
Parametric Study of Electromagnetic Coupled MSA Array for PAN Devices with RF Survey	497
Shilpa Nandedkar, Shankar Nawale, and Anirudha Kulkarni	
Fractal Tree Microstrip Antenna Using Aperture Coupled Ground	507
Sanjay Khobragade, Sanjay Nalbalwar, and Anil Nandgaonkar	
Wind Speed at Hub Height (Using Dynamic Wind Shear) and Wind Power Prediction	519
Rohit Kumbhare, Suraj Sawant, Sanand Sule, and Amit Joshi	
Modeling and Simulation of Microgrid with P-Q Control of Grid-Connected Inverter	529
Nasir Ul Islam Wani, Anupama Prakash, and Pallavi Choudekar	

Smart Student Assessment System for Online Classes Participation	541
Sudheer Kumar Nagothu	
Recommendation System for Location-Based Services	553
Ritigya Gupta, Ishani Pandey, Kritika Mishra, and K. R. Seeja	
Optimal and Higher Order Sliding Mode Control for Systems with Disturbance Rejection	563
Ishwar S. Jadhav and Gajanan M. Malwatkar	
Synchronization and Secure Communication of Chaotic Systems	575
Ajit K. Singh	
Improvement in Ranking Relevancy of Retrieved Results from Google Search Using Feature Score Computation Algorithm	585
Swati Borse and B. V. Pawar	
Author Index	599

Analysis of Rectangular Microstrip Array Antenna Fed Through Microstrip Lines with Change in Width



Tarun Kumar Kanade, Alok Rastogi, Sunil Mishra, and Vijay D. Chaudhari

Abstract This paper deals with a detailed investigation of a microstrip array antenna with step discontinuities at its feed line has been presented. In the proposed configuration, antenna arrays at 2.45 GHz are designed, simulated, and fabricated to demonstrate the concept of step discontinuities in the feed lines. A four-element rectangular patch array is fully characterized, and its performance is critically assessed for no step, single step, and double step microstrip feed lines. The return loss S_{11} [dB] is better for microstrip array antennas with double step feed lines than array antennas with no step and single step feed lines. Impedance matching and higher isolation between the patches and feed lines were appropriate using step discontinuities at the feed lines. FR4 substrates were used to design, simulate, and fabricate the microstrip array antennas. The simulated S_{11} [dB] for no-step feed lines, single-step feed lines, and double-step feed lines for rectangular microstrip array antennas are -8.78 dB, -16.48 dB, and -17.15 dB, respectively. Prototypes of these antennas are then fabricated and measured to validate the analysis and design experimentally. The simulated and measured results agree with each other.

Keywords Rectangular patch · Array · 2.45 GHz · Microstrip feed lines · Dual-polarized antenna · Narrowband antenna

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1 Introduction

Printed Antennas are the promising candidates for microwave and millimeter-wave communications, where the dimensions of the antenna should be kept to a minimum. In the twenty-first century, planar antennas have found their applications in cellular communication systems, digital communication systems, wireless LAN, and personal communication systems. In modern wireless devices, the microstrip patch antennas have been progressively demanded because of smart performance, low-profile, lightweight, ease to construct, and conformability in the microwave and millimeter-wave circuits. Microstrip antenna has some limitations like narrow bandwidth and somewhat lower gain. Microstrip antenna consists of three parts: metal layer or patch, dielectric substrate and ground metal layer, and a substrate are sandwiched between the metal layer and ground metal layer. Together the single patch antenna and an array of microstrip patch antenna have their benefits in respective domains. Microstrip array antenna consists of microstrip patch antenna elements, interconnected and fed using microstrip transmission lines. Array configurations are extensively used in microwave and millimeter-wave communication systems where a narrow beam is required. The commonly used feeding techniques in microstrip array antennas are parallel or series feeding. In a parallel feed network, all the patches are coupled by single transmission lines, while in a series feed network, the radiating elements are organized in a line and connected to a planar transmission line. The feed networks are to be designed carefully to curtail any adverse effects on array performance. As the feed line itself radiates, the feed line's proper optimization must get the appropriate return loss, gain, and directivity [1–4]. Section 2 describes the antenna array design and fabrications, followed by Sect. 3, which deals with simulation and measurement results. Conclusions are drawn in the last Sect. 4.

2 Antenna Array Design

The design and fabrication of various microstrip patch antennas require empirical formulas and the parameters like dielectric constant and height of the substrate material (ϵ_r), requiring frequency (f_r). The microstrip patch antenna's width and length are determined by the empirical formulae [3–7]. The single element microstrip patch antenna is designed for fixed frequency and gain, and the radiation pattern is relatively wide with a low directivity or gain. It is essential to design antennas with specific directive features or large gain to meet long-distance communications in various applications. The directivity and gain may be increased by increasing the antenna's electrical size, but the size increase also doesn't fulfill the desired requirements. Another technique to increase the antenna's dimensions without increasing the individual patch elements' size is to form an assembly of radiating patch elements in an electrical and structural configuration. Thus, the array antenna is formed by merging more than one patch element [8–10].

In the microwave and millimeter-wave circuit design, a straight, uninterrupted or continuous transmission structure are of little use, and in any case, junctions or discontinuities are a must. All practical microwave and millimeter-wave propagation structures must inherently contain discontinuities. The commonly occurs discontinuities in the transmission lines are bends, open circuits, change in width, and transitions in the planar transmission lines. Discontinuities also play a significant role in the feeding structure of a single patch microstrip antenna or an array of microstrip antennas. At discontinuities or junctions, electric field and magnetic field altered, altered electric field distribution is liable for the change in capacitance, and altered magnetic field distribution is responsible for the inductance change. The analysis of microstrip discontinuities for the estimate of inductance and capacitance is carried out by quasi-static analysis, and scattering parameters are studied through full-wave analysis [11, 12].

A microstrip array antenna with step discontinuities shows a better performance in terms of return loss, gain, or directivity than a microstrip antenna with uninterrupted feed lines. In this paper, microstrip array antennas are investigated, with the straight feed line, single-step feed line, and double-step feed lines. In all three cases, the microstrip array antennas are designed, simulated, and fabricated to study and compare the performance based on feed lines [13, 14]. Using design formulations structure of microstrip array antennas with various feed lines is shown in Figs. 1, 2, and 3.

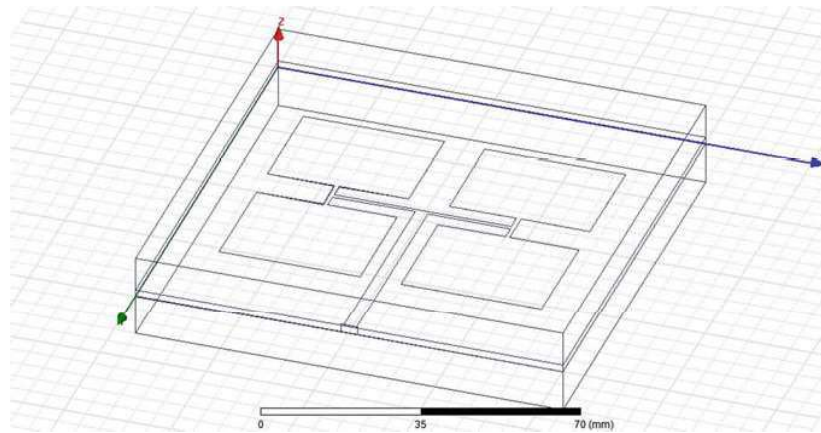


Fig. 1 Structure of rectangular microstrip patch array with no-step feed line

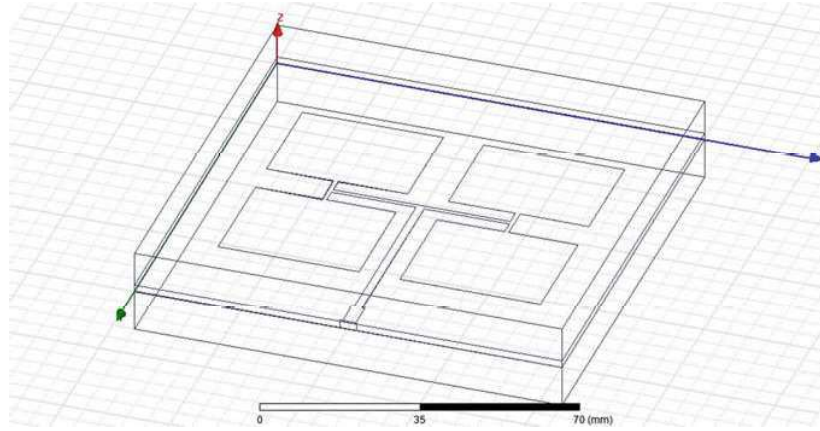


Fig. 2 Structure of rectangular microstrip patch array with a single-step feed line

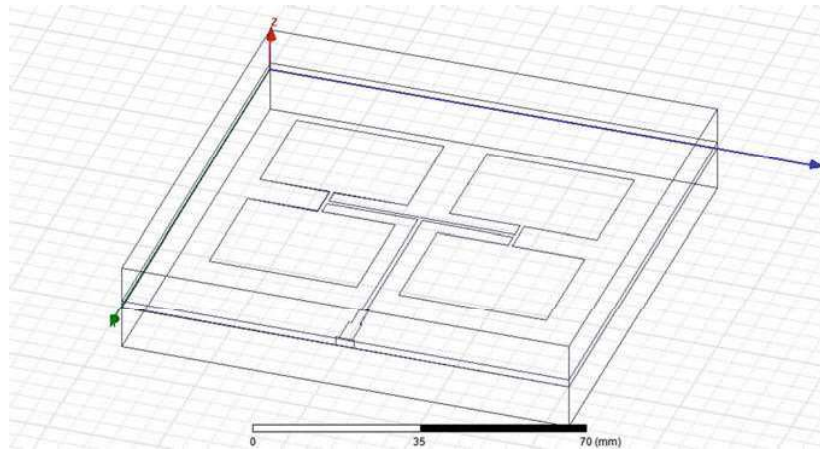


Fig. 3 Structure of rectangular microstrip patch array with a double-step feed line

3 Simulation and Measurement Results

Printed Antennas are the favorable candidates for microwave and millimeter-wave communications, where the dimensions of the antenna should be kept to a minimum. The microstrip patch array antenna is designed and simulated using FEM-based HFSS software and fabricated on FR4 substrate. The fabricated microstrip patch array antennas with three different feed lines are shown in Figs. 4, 5, and 6. The resulting parameters, like return loss, VSWR, and radiation patterns, were analyzed. Figures 7, 8, and 9 presents the simulated reflection coefficient versus frequency. The

Fig. 4 Fabricated PCB of the rectangular microstrip patch array—no-step feed line

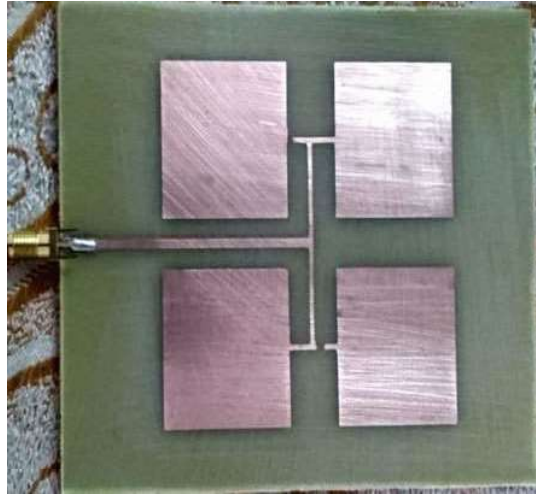
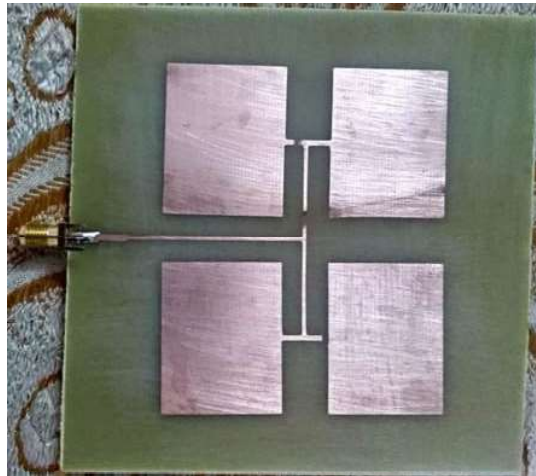


Fig. 5 Fabricated PCB of the rectangular microstrip patch array—single-step feed line



graphical analysis shows that S_{11} [dB] is enhanced for a microstrip array antenna with a double-step feed line compared to an array antenna with single-step and no-step feed lines. For an array of microstrip patch antennas, the simulated S_{11} [dB] is 8.79 dB at 2.45 GHz for no step feed line, 16.48 dB at 2.55 GHz for single-step feed line, and 17.15 dB at 2.45 GHz for double step feed line.

The measured reflection coefficients versus frequency for the three different microstrip patch arrays with no-step, single-step, and double-step feed lines are shown in Figs. 10, 11, and 12, respectively. The measured S_{11} [dB] for a microstrip

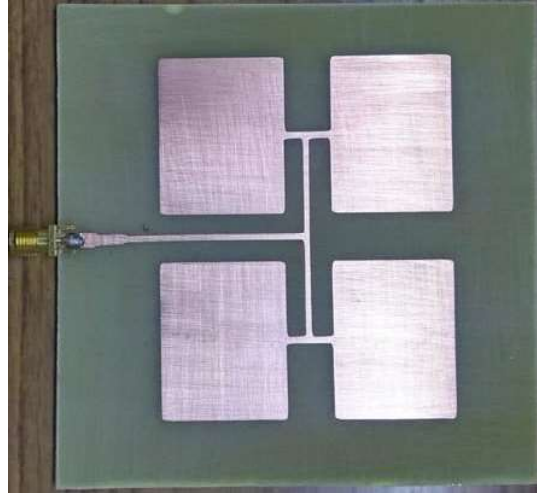


Fig. 6 Fabricated PCB of the rectangular microstrip patch array—double-step feed line

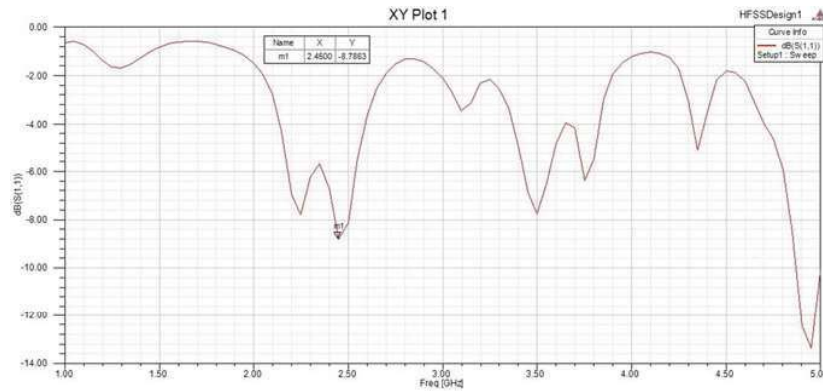


Fig. 7 S_{11} [dB] of the rectangular microstrip patch array—no-step feed line

patch array with no-step feed line is -12.756 dB at 2.51 GHz, with a single-step feed line is -15.199 dB at 2.52 GHz, and with double-step the feed line is -15.207 dB at 2.48 GHz. The S_{11} [dB] for a microstrip patch array with a double-step feed line is resonant at a frequency of 2.48 GHz, near the required frequency. The simulated and measured results nearly agree with each other—the variance between the simulated and measured results to the extent of 2.0 dB. A slight deviation is also observed between the measured and simulated operating frequencies due to the inaccuracies in the fabrication process and measurement errors. Table 1 shows our implemented array patch with the earlier implemented single patch [14].

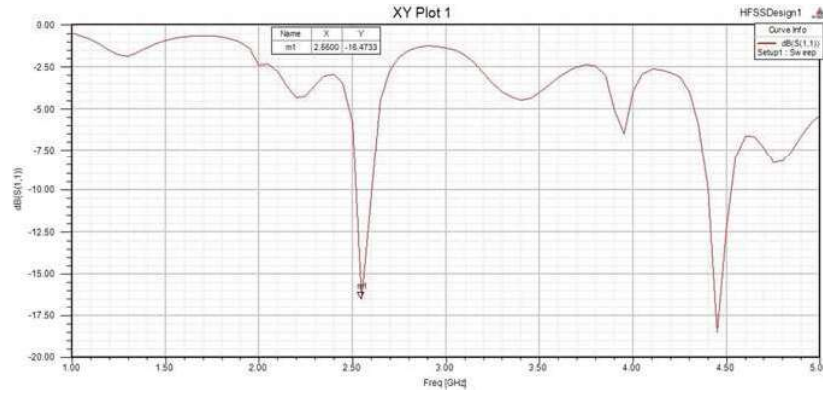


Fig. 8 S_{11} [dB] of the rectangular microstrip patch array—single-step feed line

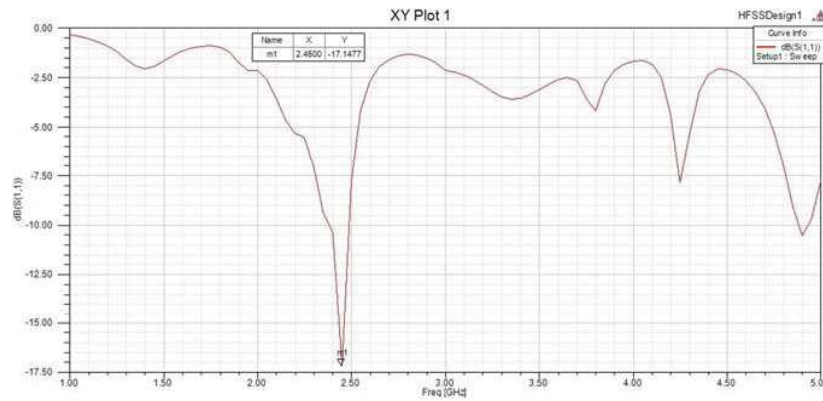


Fig. 9 S_{11} [dB] of the rectangular microstrip patch array—double-step feed line

Recently, concurrent multiband systems have become very popular [15–20]. The proposed prototype of antenna design can be extended in this direction. This approach will reduce the prototype's dimensions and support the multiple operation bands simultaneously with significantly less power requirements.

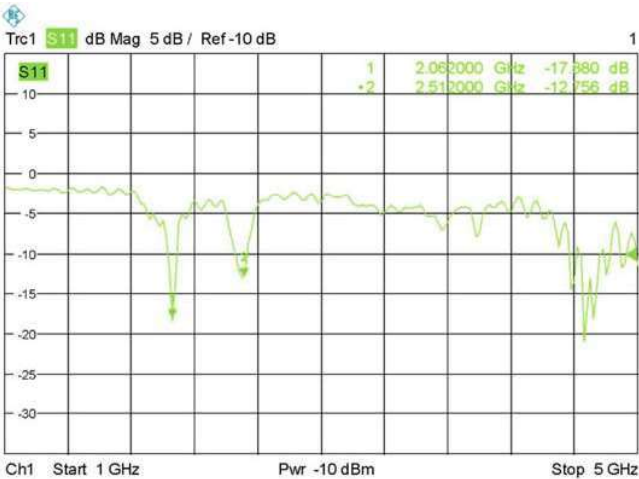


Fig. 10 Measured S_{11} [dB] of the rectangular microstrip patch array—no-step feed line

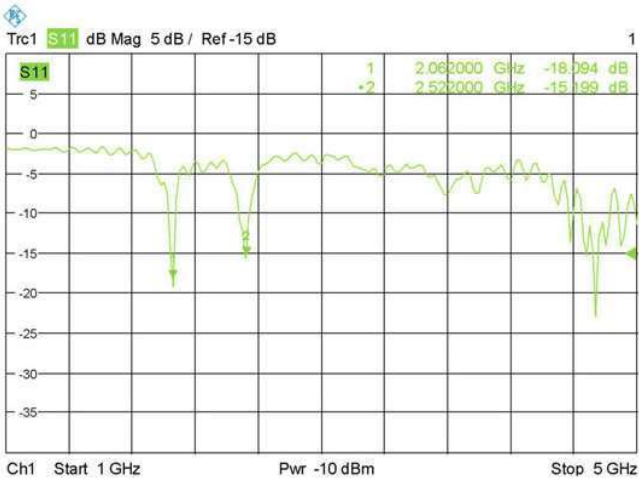


Fig. 11 Measured S_{11} [dB] of the rectangular microstrip patch array—single-step feed line

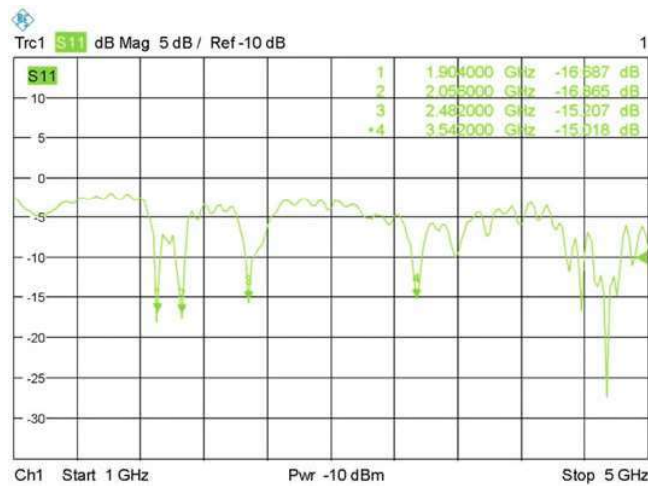


Fig. 12 Measured S₁₁ [dB] of the rectangular microstrip patch array—double-step feed line

Table 1 Comparisons of single patch and array patch simulated and experimental results at 2.45 GHz

	No-step feed		Single-step feed		Double-step feed	
	Single patch [dB]	Array patch [dB]	Single patch [dB]	Array patch [dB]	Single patch [dB]	Array patch [dB]
Simulation	−11.91	−8.79	−14.32	−16.47	−15.91	−17.15
Experimental	−11.77	−12.76	−10.44	−15.20	−19.96	−15.21

4 Conclusions

In this paper, four-element microstrip patch array antennas with three different feed lines have been presented for wireless devices operating at 2.45 GHz. A new strategy was proposed and analyzed by simulations, fabrications, and measurements to investigate the role of step discontinuities in a feed line. The simulation and the measured result for the microstrip patch array antennas reveal that the array antenna with double-step feed lines result in better performance than a single-step and no-step feed line array antennas.

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