Advances in Intelligent Systems and Computing 1354

Brijesh Iyer
Debashis Ghosh
Valentina Emilia Balas *Editors*

Applied Information Processing Systems

Proceedings of ICCET 2021

Springer

Advances in Intelligent Systems and Computing

Volume 1354

The series “Advances in Intelligent Systems and Computing” contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing such as: computational intelligence, soft computing including neural networks, fuzzy systems, evolutionary computing and the fusion of these paradigms, social intelligence, ambient intelligence, computational neuroscience, artificial life, virtual worlds and society, cognitive science and systems, Perception and Vision, DNA and immune based systems, self-organizing and adaptive systems, e-Learning and teaching, human-centered and human-centric computing, recommender systems, intelligent control, robotics and mechatronics including human-machine teaming, knowledge-based paradigms, learning paradigms, machine ethics, intelligent data analysis, knowledge management, intelligent agents, intelligent decision making and support, intelligent network security, trust management, interactive entertainment, Web intelligence and multimedia.

The publications within “Advances in Intelligent Systems and Computing” are primarily proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

Indexed by DBLP, INSPEC, WTI Frankfurt eG, zbMATH, Japanese Science and Technology Agency (JST).

All books published in the series are submitted for consideration in Web of Science.

More information about this series at http://www.springer.com/series/11156

Brijesh Iyer · Debashis Ghosh ·
Valentina Emilia Balas
Editors

Applied Information Processing Systems

Proceedings of ICCET 2021

Springer

Editors
Brijesh Iyer
Department of Electronics and Telecommunications Engineering
Dr. Babasaheb Ambedkar Technological University
Lonere, India

Debashis Ghosh
Department of Electronics and Computer Engineering
Indian Institute of Technology Roorkee
Roorkee, Uttarakhand, India

Valentina Emilia Balas
Department of Automatics and Applied Software
Aurel Vlaicu University of Arad
Arad, Romania

ISSN 2194-5357 ISSN 2194-5365 (electronic)
Advances in Intelligent Systems and Computing
ISBN 978-981-16-2007-2 ISBN 978-981-16-2008-9 (eBook)
https://doi.org/10.1007/978-981-16-2008-9

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

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 6$^{\text{th}}$ 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 6$^{\text{th}}$ 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	Dr. Brijesh Iyer
Roorkee, India	Dr. Debashis Ghosh
Arad, Romania	Dr. Valentina Emilia Balas

Contents

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

T. K. Kanade (✉)
Assistant Professor, Department of Science, The Bhopal School of Social Science, Bhopal, MP, India

A. Rastogi · S. Mishra
Professor, Department of Physics & Electronics, Institute for Excellence in Higher Education, Bhopal, MP, India
e-mail: akrastogi_bpl@yahoo.co

V. D. Chaudhari
Assistant Professor, E & TC Engineering Department, G.F.'s Godavari College of Engineering, Jalgaon, MS, India

B. Iyer et al. (eds.), *Applied Information Processing Systems*, Advances in Intelligent Systems and Computing 1354, https://doi.org/10.1007/978-981-16-2008-9_46

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 (εr), 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.

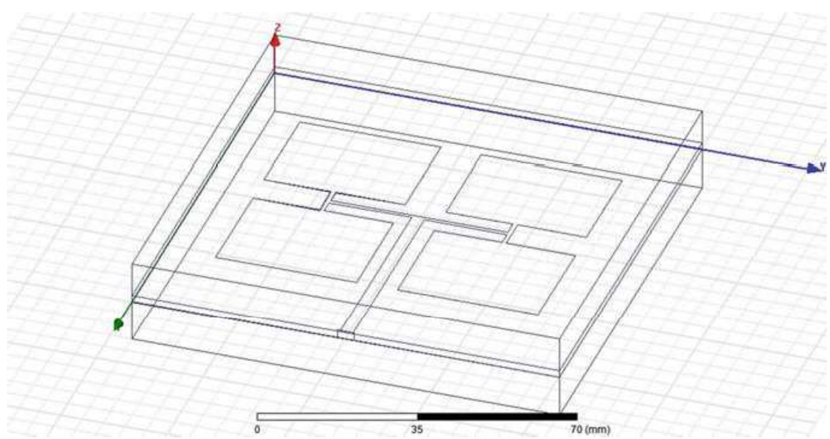

Fig. 1 Structure of rectangular microstrip patch array with no-step feed line

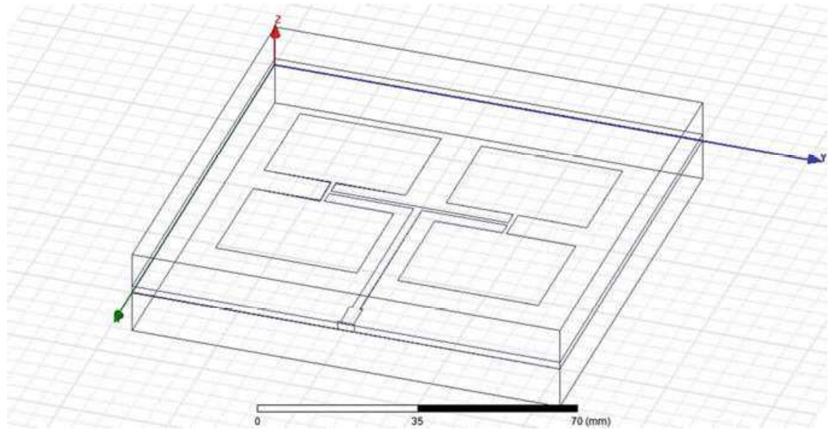

Fig. 2 Structure of rectangular microstrip patch array with a single-step feed line

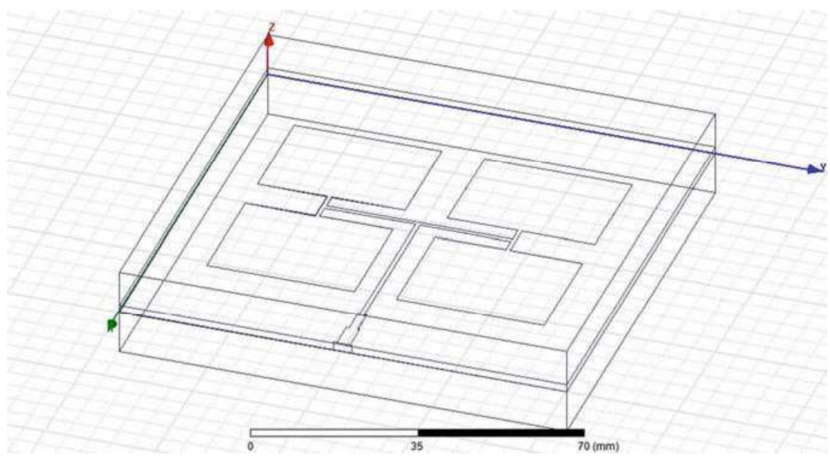

Fig. 3 Structure of rectangular microstrip patch array with a double-step feed line

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

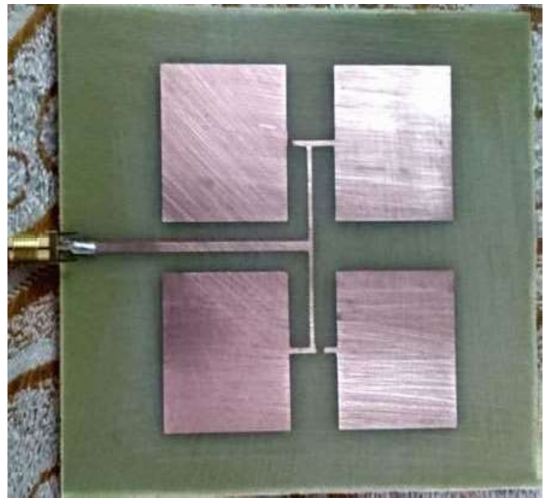

Fig. 4 Fabricated PCB of the rectangular microstrip patch array—no-step feed line

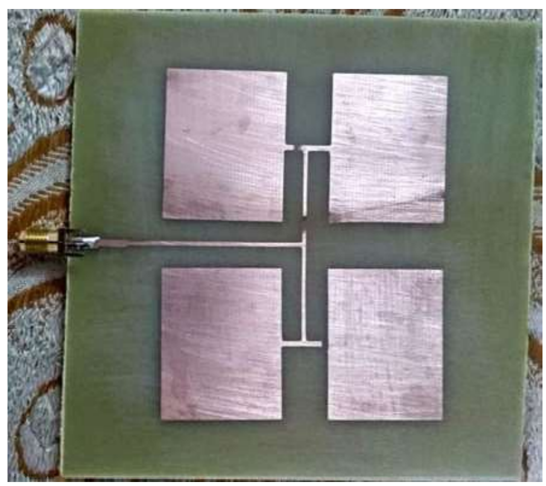

Fig. 5 Fabricated PCB of the rectangular microstrip patch array—single-step feed line

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

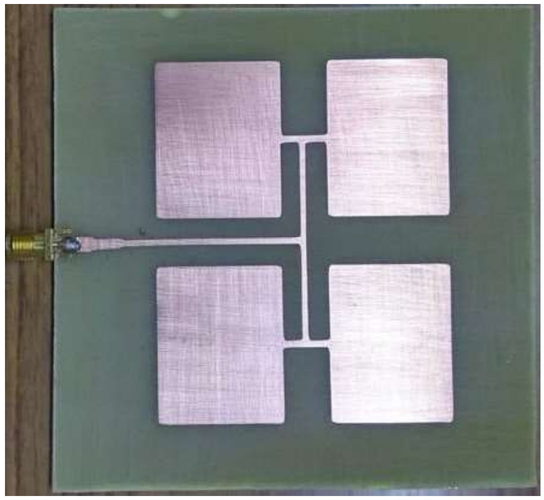

Fig. 6 Fabricated PCB of the rectangular microstrip patch array—double-step feed line

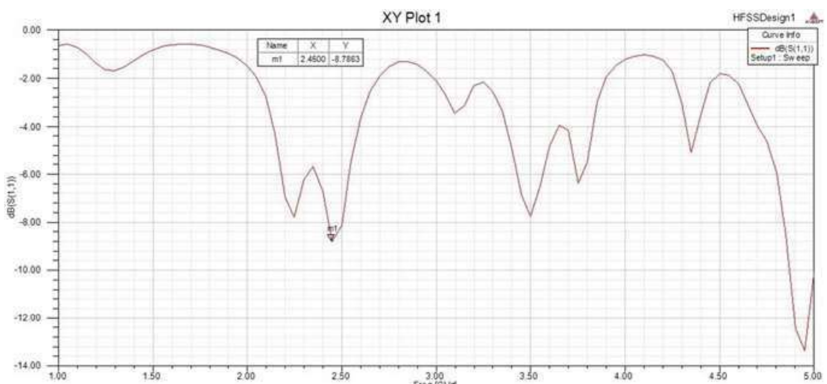

Fig. 7 S_{11} [dB] of the rectangular microstrip patch array—no-step feed line

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].

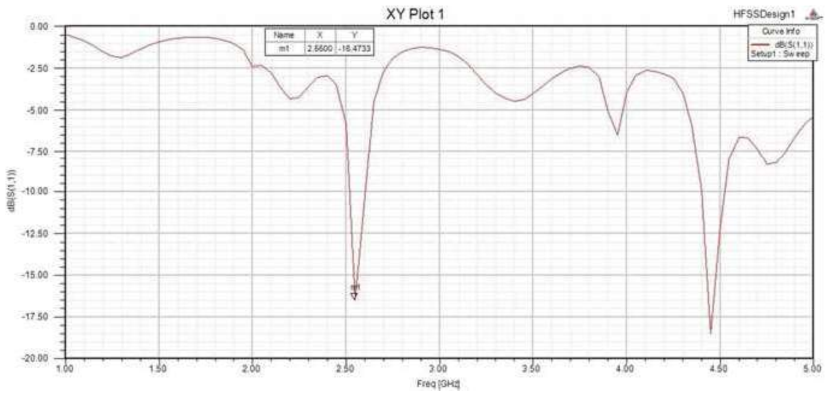

Fig. 8 S_{11} [dB] of the rectangular microstrip patch array—single-step feed line

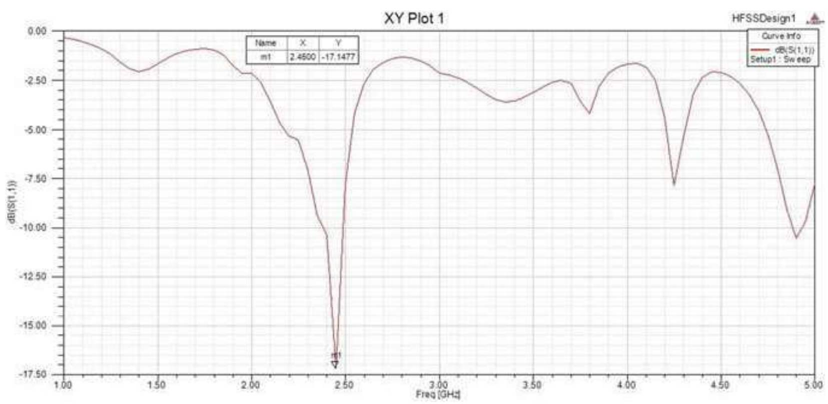

Fig. 9 S_{11} [dB] of the rectangular microstrip patch array—double-step feed line

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.

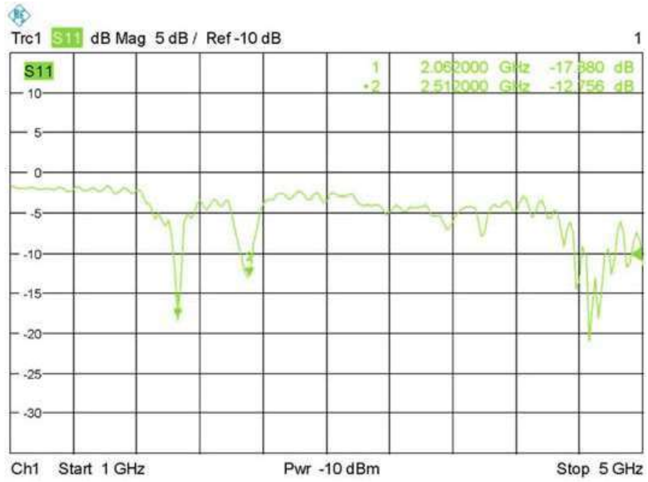

Fig. 10 Measured S_{11} [dB] of the rectangular microstrip patch array—no-step feed line

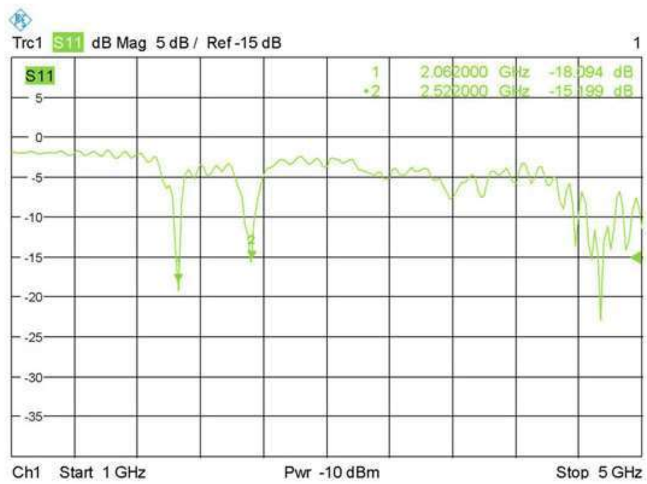

Fig. 11 Measured S_{11} [dB] of the rectangular microstrip patch array—single-step feed line

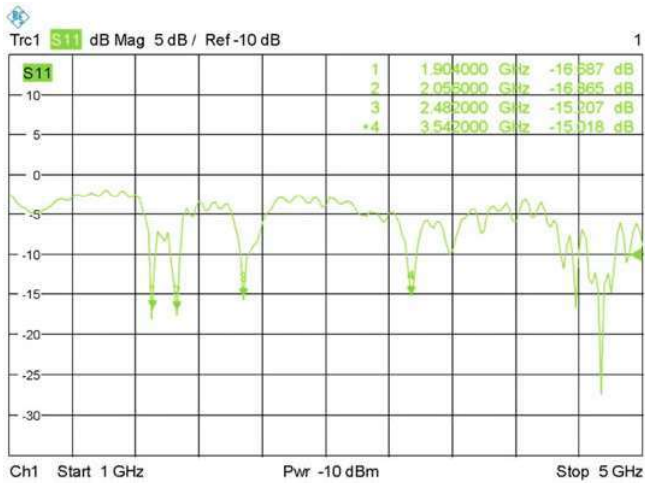

Fig. 12 Measured S_{11} [dB] of the rectangular microstrip patch array—double-step feed line

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.

References

1. Lamminen, A., Säily, J., Ala-Laurinaho, J., de Cos, J., Ermolov, V.: Patch antenna and antenna array on multilayer high-frequency PCB for D-band. IEEE Open J. Ant. Propagat. **1**, 396–403 (2020)
2. Wang, L., En, Y.-F.: A wideband circularly polarized microstrip antenna with multiple modes. IEEE Open J. Ant. Propagat. **1**, 413–418 (2020)
3. Balanis, C.A.: Antenna Theory: Analysis and Design, 3rd edn. Wiley, New York (1997)
4. Waterhouse, R.B.: Microstrip Patch Antennas: A Designer's Guide, 1st edn. Springer Science + Business Media, New York (2003)
5. Abohmra, A., Abbas, H., Al-Hasan, M., Mabrouk, I.B., Alomainy, A., Imran, M.A., Abbasi, Q.H.: Terahertz antenna array based on a hybrid perovskite structure. IEEE Open J. Ant. Propagat. **1**, 464–471 (2020)
6. Chiu, C.-Y., Lau, B.K., Murch, R.: Bandwidth enhancement technique for broadside tri-modal patch antenna. IEEE Open J. Ant. Propagat. **1**, 524–533 (2020)
7. Gupta, C., Gopinath, A.: Equivalent circuit capacitance of microstrip step change in width. IEEE Trans. Microwave Theory Tech. **MTT-25**, 819–822 (1977)
8. Easter, B.: The equivalent circuit of some microstrip discontinuities. IEEE Trans. Microwave Theory Tech. **MTT-23**, 655–660 (1975)
9. Horton, R.: Equivalent representation of an abrupt impedance step in microstrip line. IEEE Trans. Microwave Theory Tech. **MTT-21**, 562–564 (1973)
10. Thompson, F., Gopinath, A.: Calculation of microstrip discontinuity inductances. IEEE Trans. Microwave Theory Tech. **MTT-23**, 648–655 (1975)
11. Krage, M.K., Haddad, G.I.: Frequency dependent characteristics of microstrip transmission lines. IEEE Trans. Microwave Theory Tech. **MTT-20**, 678–688 (1975)
12. Raicu, D.: Universal taper for compensation of step discontinuities in microstrip lines. IEEE Microwave Guided Lett. **1**, 249–251 (1991)
13. Koster, N.H.L., Jansen, R.H.: The microstrip step discontinuity: a revised description. IEEE Trans. Microwave Theory Tech. **MTT-34**, 213–223 (1986)
14. Kanade, T.K., Rastogi, A.K., Mishra, S.: Design simulation and experimental investigations of microstrip patch antennas and its feed line. Int. J. Eng. Res. Technol. **4**, 25–28 (2015)
15. Iyer, B., Pathak, N.P., Ghosh, D.: Dual-input dual-output RF sensor for indoor human occupancy and position monitoring. IEEE Sens. J. **15**(7), 3959–3966 (2015). https://doi.org/10.1109/JSEN.2015.2404437
16. Iyer, B., Pathak, N.P., Ghosh, D.: Concurrent dualband patch antenna array for non-invasive human vital sign detection application. In: 2014 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE), Johor Bahru, 2014, pp. 150–153. https://doi.org/10.1109/APACE.2014.7043765
17. Iyer, B., Pathak, N.P., Ghosh, D.: Reconfigurable multiband concurrent R.F. system for non-invasive human vital sign detection. In: 2014 IEEE Region 10 Humanitarian Technology Conference (R10 HTC), Chennai, 2014, pp. 111–116. https://doi.org/10.1109/R10-HTC.2014.7026309
18. Rathod, B., Iyer, B.: Concurrent triband filtenna design for WLAN and WiMAX applications. In: Hitendra Sarma, T., Sankar, V., Shaik, R. (eds.) Emerging Trends in Electrical, Communications, and Information Technologies. Lecture Notes in Electrical Engineering, vol. 569, pp. 775–784 (2020). https://doi.org/10.1007/978-981-13-8942-9_66
19. Iyer, B.: Characterisation of concurrent multiband RF transceiver for WLAN applications. Adv. Intell. Syst. Res. 834–846 (2016). https://doi.org/10.2991/iccasp-16.2017.112
20. Iyer, B., Garg, M., Pathak, N., Ghosh, D.: Contactless detection and analysis of human vital signs using concurrent dual-band R.F. system. Procedia Eng. **64**, 185–194 (2013)