Bandwidth Enhancement of Square Microstrip Antennas Using Dual Feed Line Techniques

Syah Alam[1], Indra Surjati[1], and Teguh Firmansyah[2]
[1] Department of Electrical Engineering, Universitas Trisakti, DKI Jakarta, Indonesia
[2] Department of Electrical Engineering, Universitas Sultan Ageng Tirtayasa, Banten, Indonesia
Email: {syah.alam; indra}@trisakti.ac.id; teguhfirmansyah@untirta.ac.id

Abstract—**This study proposes a new design of wide bandwidth microstrip antennas using dual feed line techniques. To obtain the optimal impedance bandwidth (IBW) and Axial Ratio Bandwidth (ARBW), several iterations were performed by controlling the dimensions and length of the dual feed line. From the simulation results, the proposed antenna obtained IBW of 0.4GHz or 17% and ARBW of 0.38GHz or 15% at an operating frequency of 2.5 GHz. The gain of the proposed antenna was 5.73dB with a directional radiation pattern. The dual feedline technique successfully improved IBW up to 254.16% compared with the single feed technique. This study would be useful especially for bandwidth optimization of microstrip antennas.**

Index Terms—**Square patch, dual-feed line, circular polarization, bandwidth**

I. Introduction

Microstrip antennas have been widely developed and used for wireless communication purposes [1] because of its compact design and it is also capable of performing at different resonant frequencies [2]. However, microstrip antennas have several limitations including narrow bandwidth and low gain [3]. Antenna with wide bandwidth is needed to be used in different wireless communication system applications such as DCS (1710MHz–1885MHz), PCS (1907MHz–1,912.5MHz), UMTS (1920MHz–2170MHz), Wireless LAN (WLAN) 2.4GHz and Long Term Evolution (LTE) 2.3GHz [4].

To overcome the limitations of the microstrip antennas, several bandwidth optimization techniques have been implemented including coplanar waveguide (CPW) [5], [6], proximity coupling [7], [8], and the addition of parasitic elements [9], [10]. In general, microstrip antennas have linear polarization with directional radiation patterns. Circular polarization of the microstrip antenna can be obtained using several techniques including truncated corner [11] and Defected Ground Structure (DGS) [12]. Generally, the width of the impedance bandwidth and axial ratio bandwidth is not linear. Impedance Bandwidth (IBW) is usually wider than Axial Ratio Bandwidth (ARBW). To cover most wireless communication systems, microstrip antennas with a linear impedance bandwidth are preferred.

Manuscript received April 17, 2020; revised September 29, 2020; accepted November 11, 2020.

Corresponding author: Indra Surjati (email: indra@trisakti.ac.id).

Previous studies, including [13], obtained a microstrip antenna with a circular polarization using truncated corners fed by a single feed technique at the operating frequency of 2.3GHz with ARBW and IBW of 4% and 13%, respectively. Microstrip antenna with circular polarization [14] has also been proposed by using the deflected ground structure technique at the operating frequency of 1.575 GHz with ARBW and IBW of 6% and 30% respectively. These previous studies show that a significant difference between the IBW and ARBW was found. Therefore, this study proposes an optimized microstrip antenna design that implements dual-feed line techniques.

As a novelty, the dual feed line technique is proposed to control and optimize the ARBW and IBW of the designed antenna. The three kinds of the proposed antennas are investigated. Model 1 was a proposed dual-feed line microstrip antenna design with a rectangular shape. Moreover, Model 2 was the design with modified circular slots at the corner. Model 3 is the design with modified rectangular slots at the corner. Furthermore, this paper aims to obtain a new design of a microstrip antenna with a linear ARBW and IBW.

II. Antenna Design

A. Design of Square Patch Microstrip Antenna

In this study, the design of the conventional microstrip antenna is a square shape using FR-4 epoxy substrate with a dielectric constant (ε_r) of 4.3, loss tan (tanα) of 0.0265, and thickness (h) of 1.6mm. The dimensions of the length (L) and width (W) of the square patch microstrip antenna [15] are obtained by:

$$W = \frac{C}{2f\sqrt{(\varepsilon_r+1)/2}} \tag{1}$$

$$L=W \tag{2}$$

The dimensions wide of feed line (W_z) with an impedance of 50 ohm [15] were determined by:

$$W_z = \frac{2h}{\pi}\left\{B-1-\ln(2B-1)+(\varepsilon_r-1)/2\varepsilon_r \times \left[\ln(B-1)+0.39-0.61/\varepsilon_r\right]\right\} \tag{3}$$

where

©2021 Int. J. Elec. & Elecn. Eng. & Telcomm.

doi: 10.18178/ijeetc.10.1.60-65

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_{r\ eff}}},\ \varepsilon_{r\ eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2}$$

After the calculation process of (1) and (2), the values of W and L of 38mm and the dimension of W_z of 3.1mm were obtained. After a simulation process with AWR Microwave Office 2009, the optimal dimensions of W and L were found to be 30mm. The design of a square patch microstrip antenna is shown in Fig. 1, which has dimensions of the ground plane (W_g and L_g) of 50mm and 17mm respectively as shown in Table I.

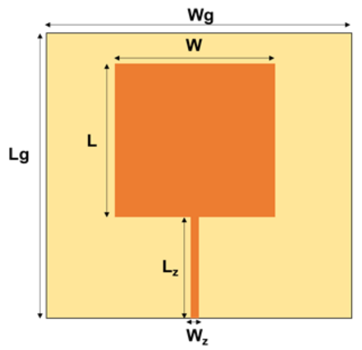
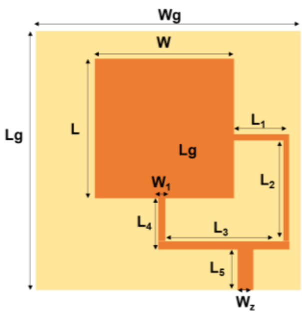


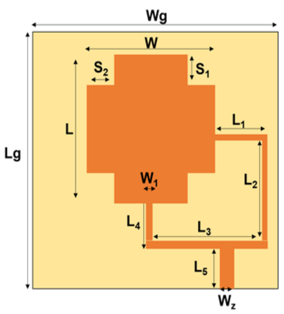
Fig. 1. Design of square patch microstrip antenna.

B. *Development of Dual Feed Microstrip Antenna*

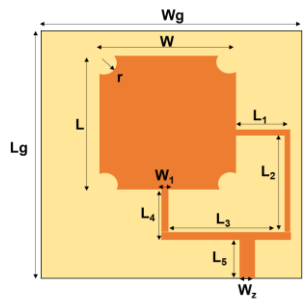
The design of the dual feed line on the microstrip antenna was conducted by adding a microstrip line feed that was implemented to supply the current of the antenna. The dimensions and position of the dual feed line were obtained from the optimization and iteration results using AWR Microwave Office 2009. The development of dual-feed line microstrip antennas can be seen in Fig. 2 (a), (b), and (c).



(a)



(b)



(c)

Fig. 2. Development of dual-feed line microstrip antenna: (a) Model 1, (b) Model 2, and (c) Model 3.

TABLE I: DIMENSIONS OF PROPOSED ANTENNA

Parameter	Dimension	Parameter	Dimension
Wg	50 mm	L_1	10.4 mm
Lg	50 mm	L_2	23 mm
W	30 mm	L_3	24 mm
L	30 mm	L_4	8.1 mm
R	4 mm	L_5	10.3 mm
S_1	4.4 mm	W_1	1 mm
S_2	3.5 mm	W_z	3.1 mm

Model 1 is a dual-feed line microstrip antenna design with a rectangular shape. On the other hand, Model 2 is the design with modified circular slots with radius r on the edge of the patch antenna. Meanwhile, Model 3 is the design with a modified rectangular slot with a length of S_1 and width of S_2 on the edge of the patch antenna. The overall dimensions of the dual feed line microstrip antenna development can be seen in Table I.

Table I presents the dimensions of the three proposed antenna models. The simulation results of the reflection coefficient, axial ratio, and gain of the dual-feed line microstrip antennas were compared and it can be seen in Fig. 3, Fig. 4, and Fig. 5, respectively. The simulation was conducted from frequency of 2GHz to 3GHz. Furthermore, the IBW data was taken from <–10dB of reflection coefficient. Moreover, the ARBW data was taken form <3dB of axial ratio.

Fig. 3 shows that Model 1 antenna could perform at 2.4GHz with IBW of 0.3GHz from 2.2GHz to 2.5GHz. On the other hand, Model 2 antenna could operate at 2.51 GHz with IBW of 0.31GHz form 2.3GHz to 2.61GHz. Meanwhile, Model 3 antenna could function at 2.5GHz with IBW of 0.4GHz from 2.4GHz to 2.8GHz.

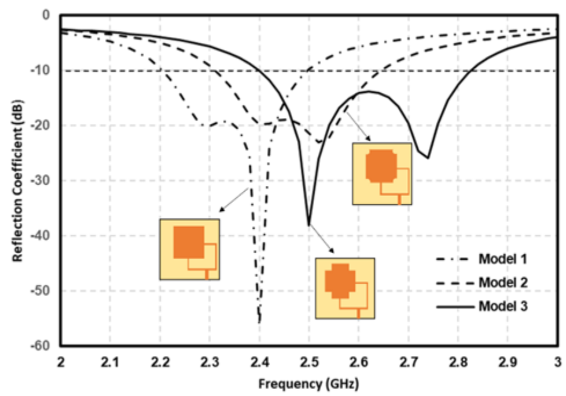


Fig. 3. Comparison of the reflection coefficient of the development model.

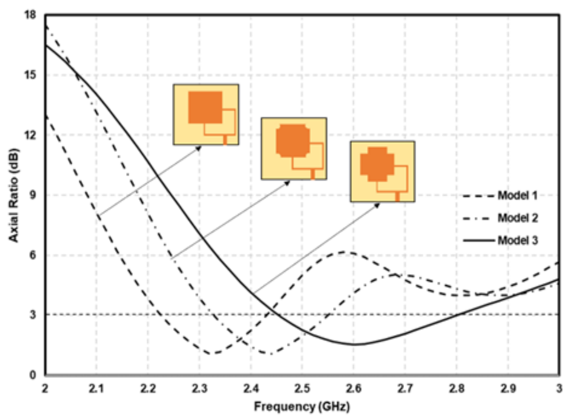


Fig. 4. Comparison of the axial ratio of the development model.

©2021 Int. J. Elec. & Elecn. Eng. & Telcomm.

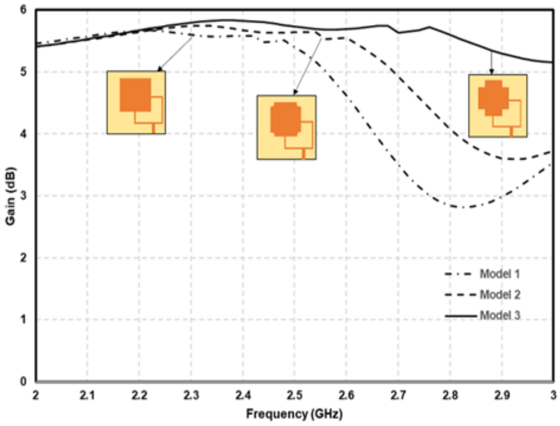


Fig. 5. Comparison of gain of the development model.

Fig. 4 shows that Model 1 has the ARBW of 0.2GHz from 2.21GHz to 2.41GHz, Model 2 has ARBW of 0.23 from 2.32GHz to 2.55GHz, and Model 3 has ARBW of 0.38GHz from 2.42GHz to 2.8GHz. Furthermore, Fig. 5 shows that Model 1 has a maximum gain of 5.3dB at 2.42GHz, Model 2 has 5.5dB at 2.52GHz, and Model 3 has 5.8dB at 2.4GHz.

Based on the simulation, it is found that Model 3 has the best results with IBW of 0.4GHz, ARBW of 0.35GHz, and a gain of 5.8dB.

C. Parametric Study

To observe and understand the influence of various parameters on the antenna found in the simulation results of IBW, ARBW, and gain, several iterations were performed. A couple of parameters, the lengths of the dual feed line L_4 and the dimensions of the rectangular slot (S_1), were observed.

1) Effect of L_4

The modifications and iterations of the parameters L_4 are shown in Table II.

Fig. 6, Fig. 7, and Fig. 8 illustrate the relationships between the length of the dual feed line L_4 with the reflection coefficient, axial ratio, and gain parameters. IBW and ARBW can be controlled by adjusting the length of L_4.

TABLE II: ITERATION DIMENSION OF DUAL FEED LINE

Iteration	Dimensions of L_4 (mm)
Iteration 1	7.1
Iteration 2	9.1
Iteration 3	6.1
Iteration 4	8.1

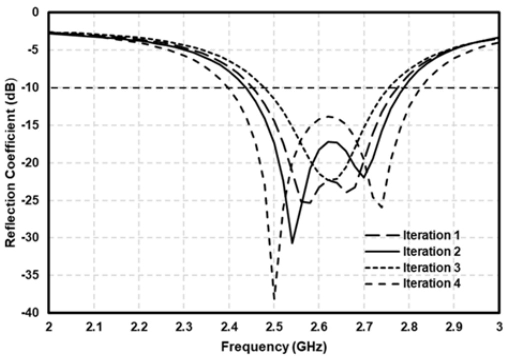


Fig. 6. Simulation of reflection coefficient from Iteration of L_4

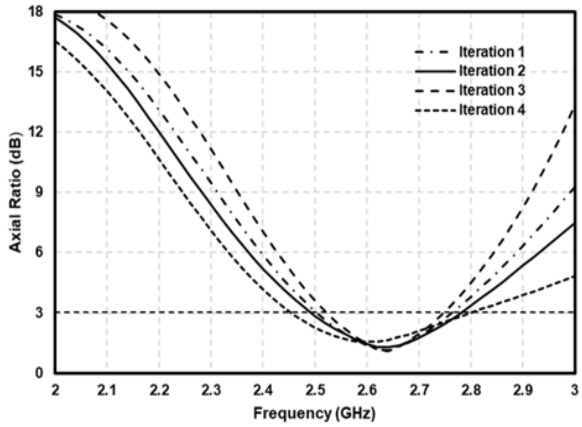


Fig. 7. Simulation of axial ratio from Iteration of L_4.

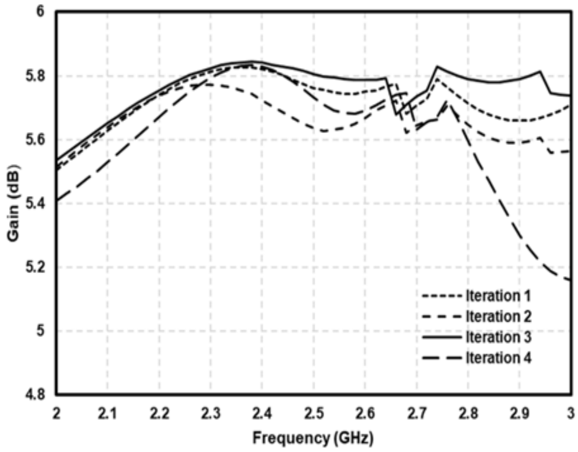


Fig. 8. Simulation of gain from Iteration of L_4.

In Iteration 1, with a length of L_4 of 7.1mm, it is found that the IBW is 0.32GHz from 2.45GHz to 2.77 GHz, the ARBW is 0.26GHz from 2.5GHz to 2.76 GHz, and the maximum gain is 5.8dB at 2.4GHz. On the other hand, in Iteration 2, with a length of L_4 of 9.1 mm, it is found that IBW is 0.35GHz from 2.43GHz to 2.78GHz, ARBW is 0.29GHz from 2.49GHz to 2.78 GHz, and the maximum gain is 5.7dB at 2.3GHz. Meanwhile, in Iteration 3, with a length of L_4 of 6.1mm, it is found that IBW is 0.28GHz from 2.47GHz to 2.75GHz, ARBW is 0.22GHz from 2.52GHz to 2.74 GHz, and the maximum gain is 5.81dB at 2.4GHz. Further, in Iteration 4, with a length of L_4 of 8.1mm, IBW of 0.42GHz from 2.4 GHz to 2.82GHz, ARBW of 0.38 GHz from 2.42GHz to 2.8GHz, and a maximum gain of 5.84dB at 2.4GHz were found.

Based on the overall results, Iteration 4 have the best result with a length of L_4 of 8.1mm. The overall simulation results of the iteration process of L_4 can be observed in Table III.

TABLE III: SIMULATION RESULT FROM ITERATION OF L_4

Iteration	Parameters		
	IBW	ARBW	Gain
Iteration 1	0.32 GHz	0.26 GHz	5.8 dB
Iteration 2	0.35 GHz	0.29 GHz	5.7 dB
Iteration 3	0.28 GHz	0.22 GHz	5.81 dB
Iteration 4	0.42 GHz	0.35 GHz	5.84 dB

TABLE IV: ITERATION DIMENSION OF RECTANGULAR S_1

Iteration	Dimensions of S_1
Iteration 1	1.4 mm
Iteration 2	2.4 mm
Iteration 3	3.4 mm
Iteration 4	4.4 mm

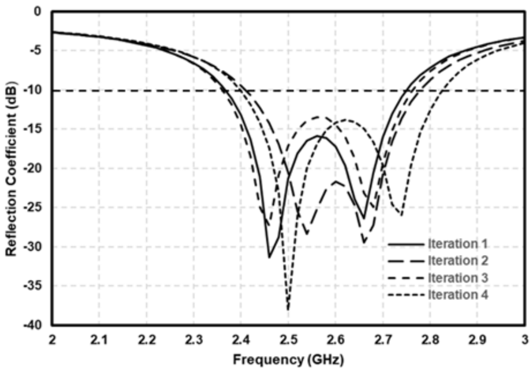


Fig. 9. Simulation of reflection coefficient from the iteration of S_1

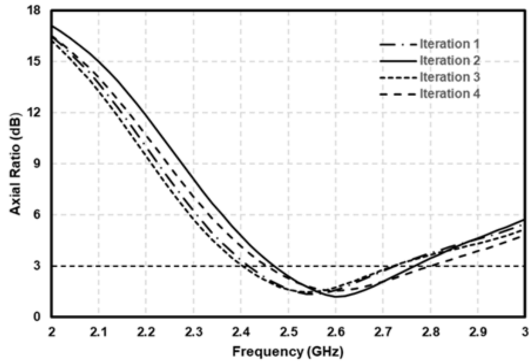


Fig. 10. Simulation of axial ratio from the iteration of S_1.

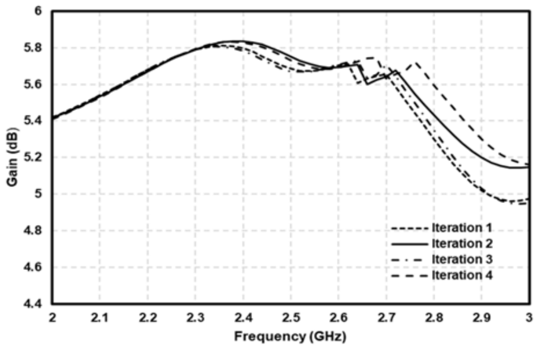


Fig. 11. Simulation of gain from the iteration of S_1.

2) Effect of S_1

To obtain the best simulation results, several iterations were conducted by adjusting and controlling the width and length of S_1 on the proposed antenna. Modifications and iterations of the parameters S_1 are shown in Table IV.

On the other hand, the relationships between the dimension of S_1 with the reflection coefficient, axial ratio, and gain can be seen in Fig. 9, Fig. 10, and Fig. 11.

In Iteration 1, with a length of S_1 of 1.4mm, it is found that the IBW is 0.38GHz from 2.36GHz to 2.75 GHz, the ARBW is 0.31GHz from 2.41GHz to 2.72 GHz, and the maximum gain is 5.81dB at 2.4GHz. Meanwhile, in Iteration 2, with a length of S_1 of 2.4mm, it is found that IBW is 0.37GHz from 2.43GHz to 2.78 GHz, ARBW is 0.29GHz from 2.4GHz to 2.77GHz, and maximum gain is 5.83dB at 2.3GHz. On the other hand, in Iteration 3, with a length of S_1 of 3.4 mm, IBW of 0.40 GHz from 2.46GHz to 2.76GHz, ARBW of 0.32 GHz from 2.4GHz to2.72 GHz, and maximum gain of 5.81dB at 2.35GHz are obtained. In Iteration 4, with a length of S_1 of 4.4mm, IBW of 0.42GHz from2.4 GHz to 2.82GHz, ARBW of 0.35GHz from 2.45GHz to 2.8GHz, and a maximum gain of 5.84dB at 2.4GHz are obtained. Based on the overall results of the iteration process, Iteration 4 has the best result with a length of S_1 of 4.4 mm. The overall simulation results of the iteration process of S_1 are shown in Table V.

TABLE V: SIMULATION RESULT FROM ITERATION OF S_1

Iteration	Parameters		
	IBW	ARBW	Gain
Iteration 1	0.38 GHz	0.31 GHz	5.81 dB
Iteration 2	0.37 GHz	0.29 GHz	5.83 dB
Iteration 3	0.4 GHz	0.32 GHz	5.81 dB
Iteration 4	0.42 GHz	0.35 GHz	5.84 dB

III. RESULT AND DISCUSSION

Based on the iteration simulation results of the L_4 and S_1 parameters, the optimal IBW and ARBW parameters were obtained. The comparison results of IBW and ARBW of the dual-feed line microstrip antenna can be seen in Fig. 12. It can be observed that the IBW and ARBW of the proposed antenna are almost linear. The gap between IBW and ARBW of the proposed antenna is about 0.07GHz. Also, the gain of the proposed antenna is stable in the range of 5dB in the operating frequency range of ARBW as shown in Fig. 13.

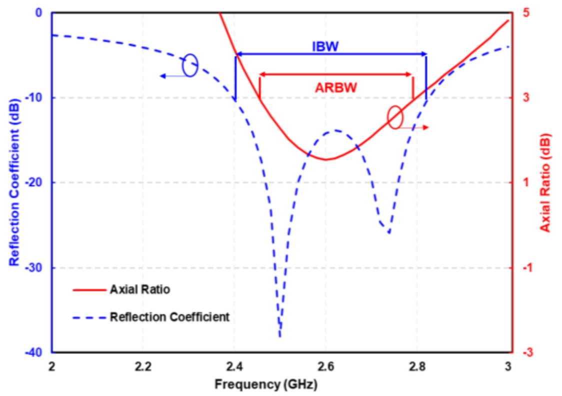


Fig. 12. Comparisons of IBW and ARBW of the proposed antenna.

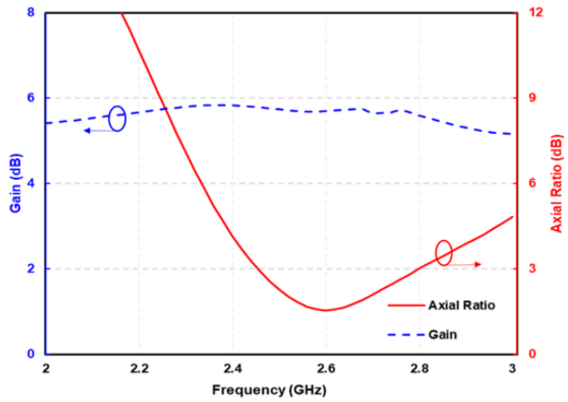


Fig. 13. Comparisons of axial ratio with a gain of the proposed antenna.

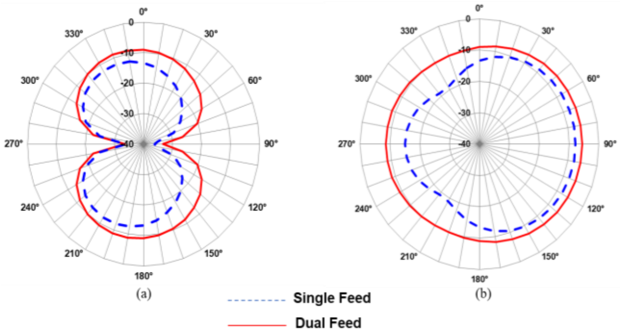


Fig. 14. Radiation pattern simulation of the proposed antenna at the operating frequency of 2.5 GHz. (a) E Plane; (b) H Plane.

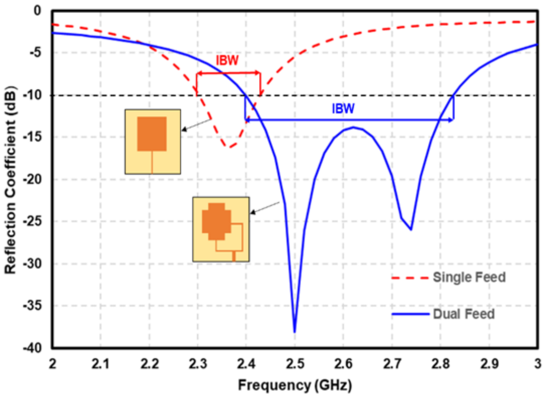


Fig. 15. IBW comparison of a single feed and dual-feed microstrip antenna.

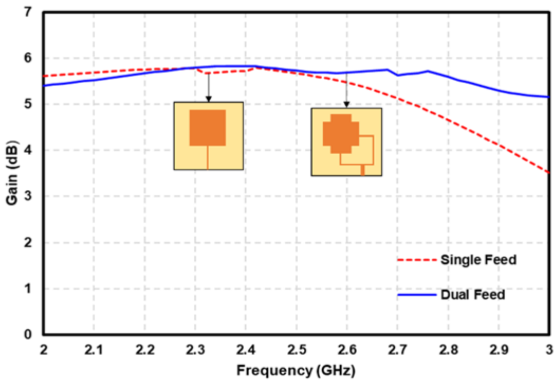


Fig. 16. IBW comparison of a single feed and dual-feed microstrip antenna.

Furthermore, the simulation results of the dual feed line microstrip antenna were also compared with the single feed line technique. Comparisons of radiation patterns, IBW, and axial ratio are shown in Fig. 14, Fig. 15, Fig. 16, and Fig. 17.

Fig. 14 shows that the radiation pattern of the dual feed line microstrip antenna has more broadside radiation pattern compared with the single feed line technique. Moreover, the dual feed line technique also affects the resonant frequency and IBW, as shown in Fig. 15. It is found that the resonant frequency of the dual feed line antenna shifted from 2.35GHz to 2.5GHz while IBW increased from 0.12GHz (2.3GHz~2.42GHz) to 0.42GHz (2.4GHz~2.82GHz). The study also finds that the gain of the dual feed line microstrip antenna is also more stable at the operating frequency of 2GHz to 3 GHz compared to the single feed technique as shown in Fig. 16.

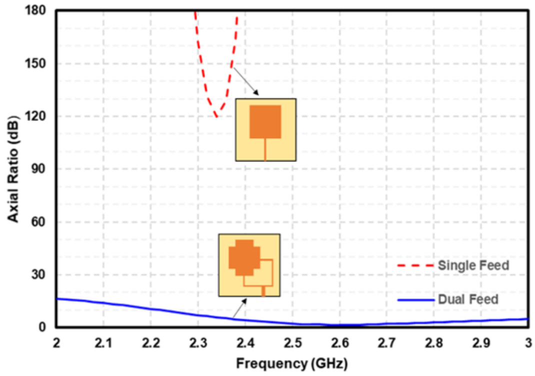


Fig. 17. Axial ratio comparison of a single feed and a dual-feed microstrip antenna.

Fig. 17 shows that the axial ratio of a microstrip antenna with a single feed was 120dB at the operating frequency of 2.32GHz. In other words, it did not have a circular polarization with an axial ratio of ≤3dB. After optimization using the dual feed line technique, the axial ratio ≤3dB was successfully obtained.

The current distribution of the dual feed line microstrip antenna at 2.5GHz can be seen in Fig. 18. The dual feed line and the patch antenna received a nearly homogeneous current distribution. The overall comparisons of simulation results from the microstrip antenna with a single feed line and a dual-feed line technique can be seen shown in Table VI.

The results of this study were also compared with previous studies as shown in Table VII.

From Table VII, it can be seen that the proposed antennas had a better percentage of IBW and ARBW compared to previous studies. It is found that IBW and ARBW obtained from the proposed antenna are almost linear. It can be summarized that the application of dual feed lines has successfully controlled IBW and ARBW.

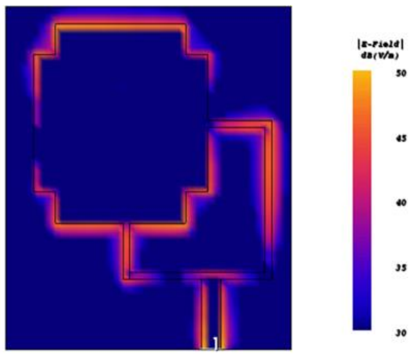


Fig. 18. Current distribution of dual-feed microstrip antenna at 2.5 GHz.

TABLE VI: COMPARISON RESULT OF A SINGLE FEED AND DUAL FEED MICROSTRIP ANTENNA

Condition	Parameter		
	IBW	ARBW	Gain
Single Feed	0.12 GHz	-	5.79 dB
Dual Feed	0.42 GHz	0.38 GHz	5.84 dB

TABLE VII: COMPARISON RESULTS WITH PREVIOUS STUDIES

Title	Dimension (mm×mm)	Frequency (GHz)	Parameter		
			ARBW	IBW	Gain
[13]	82 × 69	2.3	4 %	13 %	6.9 dB
[14]	45 × 45	1.575	6 %	30 %	2.2 dB
Proposed Antenna	50 × 50	2.5	15 %	17 %	5.8 dB

IV. Conclusion

This paper investigates the implementation of dual-feed of microstrip antenna. It was found that IBW and ARBW of the proposed antenna were improved after using the dual-feed method. The simulation results of this study also found that of the proposed antenna obtained IBW of 0.4GHz or 17% and ARBW 0.38GHz or 15% at the operating frequency of 2.5GHz. It can be summarized that the dual feedline technique successfully improved IBW from 0.12GHz to 0.42GHz or 254.16% compared with the single feed technique. Furthermore, it is revealed that IBW and ARBW of the proposed antenna were almost linear. Therefore, it can be concluded that the application of dual feed lines has successfully controlled IBW and ARBW. This study could be useful especially for bandwidth optimization of microstrip antennas.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

All authors contributed in all phases of the study through the conception and modelling of dual-feed microstrip antenna. All authors have read and approved the final version.

Acknowledgement

The authors wish to express their gratitude to the Department of Electrical of Engineering, Faculty of Industrial Technology, Universitas Trisakti, for their support.

References

[1] P. S. Bakariya, S. Dwari, M. Sarkar, and M. K. Mandal, “Proximity-coupled multiband microstrip antenna for wireless applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 14, no. 12, pp. 646–649, Dec. 2015.

[2] L. Nowosielski and M. Wnuk, “Microstrip antennas diagnostics with thermography,” in *Proc. Electronics*, 2017.

[3] K. F. Lee, K. M. Luk, and H. W. Lai, *Microstrip Patch Antennas*, World Scientific, 2017.

[4] I. A. Shah, S. Hayat, A. Basir, M. Zada, S. A. A. Shah, and S. Ullah, “Design and analysis of a hexa-band frequency reconfigurable antenna for wireless communication,” *AEU-International Journal of Electronics and Communications*, vol. 98, pp. 80-88, Jan. 2019.

[5] A. Saxena, S. Joshi, A. Gupta, S. Saxena, and D. Kumar, “Gain and bandwidth enhancement of CPW-fed patch antenna for wideband applications,” presented at 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology, May 2016.

[6] B. T. P. Madhav and M. P. Kishore, “Bandwidth enhanced CPW fed elliptical wideband antenna with slotted defected ground structure,” *International Journal of Engineering & Technology*, vol. 7, no. 2, pp. 365, Mar. 2018.

[7] T. Yasin and R. Baktur, “Bandwidth enhancement of meshed patch antennas through proximity coupling,” *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2501-2504, July 2017.

[8] I. P. E. Duta Nugraha, I. Surjati, and S. Alam, “Miniaturized Minkowski-Island fractal microstrip antenna fed by proximity coupling for wireless fidelity application,” *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 15, no. 3, pp. 1119, Sep. 2017.

[9] K. D. Xu, Han Xu, Y. Liu, J. Li, and Q. H. Liu, “Microstrip patch antennas with multiple parasitic patches and shorting VIAS for bandwidth enhancement,” *IEEE Access*, vol. 6, no. 7, pp. 11624-11633, January 2018

[10] H. H. Tran, N. Nguyen-Trong, T. K. Nguyen, and A. M. Abbosh, “Bandwidth enhancement utilizing bias circuit as parasitic elements in a reconfigurable circularly polarized antenna,” *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 8, pp. 1533-1537, 2018.

[11] Z. Muludi and B. Aswoyo, “Truncated microstrip square patch array antenna 2×2 elements with circular polarization for S-band microwave frequency,” in *Proc. Int. Electronics Symposium on Engineering Technology and Applications (IES-ETA)*, 2017, pp. 87-92.

[12] A. K. Singh, R. K. Gangwar, and B. K. Kanaujia, “Sectored annular ring microstrip antenna with DGS for circular polarization,” *Microwave and Optical Technology Letters*, vol. 58, no. 3, pp. 569-573, 2016.

[13] S. Alam, I. Surjati, and Y. K. Ningsih, “Patch modification and slot arrangement of microstrip antenna for improving the axial ratio,” presented at 2017 International Conference on Broadband Communication, Wireless Sensors and Powering, Nov. 2017.

[14] K. Wei, J. Y. Li, L. Wang, R. Xu, and Z. J. Xing, “A new technique to design circularly polarized microstrip antenna by fractal defected ground structure,” *IEEE Trans. on Antennas and Propagation*, vol. 65, no. 7, pp. 3721-3725, 2017.

[15] K. L. Wong, *Compact and Broadband Microstrip Antennas*, John Wiley & Sons, 2004.

Copyright © 2021 by the authors. This is an open-access article distributed under the Creative Commons Attribution License (CC BY-NC-ND 4.0), which permits use, distribution, and reproduction in any medium, provided that the article is properly cited, the use is non-commercial and no modifications or adaptations are made.

Syah Alam, was born in Jakarta, Indonesia. He received Bachelor Education of Engineering (S.Pd) degree in electrical engineering from Universitas Pendidikan Indonesia and M.Eng (M.T) degree in telecommunication engineering from Graduate Programe of Electrical Engineering Universitas Trisakti in 2010 and 2012, respectively. In 2018, he joined the Department of Electrical Engineering Universitas Trisakti as a researcher and lecturer. His research interests include microstrip antenna and microwave circuit for various applications.

Indra Surjati was born in Bangkok, Thailand. She received Bachelor of Engineering (Ir.) degree in electrical engineering and M.Eng (M.T) degree in telecommunication engineering from Graduate Programe of Electrical Engineering Universitas Trisakti in 1996, respectively. In 2004 she completed his PhD in Electrical Engineering Department at the University of Indonesia and in 2011 she was confirmed as Professor in the Department of Electrical Engineering at Trisakti. Her research interests include microstrip antenna and microwave circuit for various applications.

Teguh Firmansyah was born in Subang, Indonesia. He received B.Eng (S.T) degree in electrical engineering and M.Eng (M.T) degree in telecommunication engineering from Department of Electrical Engineering Universitas Indonesia in 2010 and 2012, respectively. In 2012, he joined the Department of Electrical Engineering Universitas Sultan Ageng Tirtayasa as a researcher and lecturer. He has authored or coauthored over 20 papers published in refereed journals and conferences. He holds two patents for wideband antenna and multiband antenna. His research interests include microstrip antenna and microwave circuit for various applications.