Design of Rectangular Microstrip Patch Antenna 2-Elements Array for Dual Broadband Applications

Ali Hanafiah Rambe
Department of Electrical Engineering
Universitas Sumatera Utara
Medan, Indonesia
ali3@usu.ac.id

Muhammad Iqbal Azzubairi
Department of Electrical Engineering
Universitas Sumatera Utara
Medan, Indonesia
iqbal.azzubaidi@gmail.com

Syafruddin Hasan
Department of Electrical Engineering
Universitas Sumatera Utara
Medan, Indonesia
syafruddin7@usu.ac.id

Khairil Abdillah
Medical Electrical Engineering
Universitas Sari Mutiara Indonesia
Medan, Indonesia
kabdillah.medan@gmail.com

Suherman
Department of Electrical Engineering
Universitas Sumatera Utara
Medan, Indonesia
suherman@usu.ac.id

Riswan Dinzi
Department of Electrical Engineering
Universitas Sumatera Utara
Medan, Indonesia
dinziriswan@gmail.com

2021 5th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM) | 978-1-6654-1200-1/21/$31.00 ©2021 IEEE | DOI: 10.1109/ELTICOM53303.2021.9590132

***Abstract*—The Long Term Evolution (LTE) and Wireless Local Area Network (WLAN) are different broadband communication systems. However, a microstrip antenna can use simultaneously for both. This paper discussed a rectangular patch microstrip antenna to support dual-band communication systems for mobile communication based on 4th generation LTE (1800 MHz) and WLAN (2400 MHz). The optimal configuration is obtained from the 2-elements array antenna. The 2-elements are connected by the T-junction multiple section corporate feed. The design is done with theoretical calculations, software simulation, and measurement of antenna fabrication. The results of the antenna measurements show that the bandwidth for VSWR below 2 is 1656-1909 MHz for the lower band and 2379-2597 MHz for the upper band. The half-power beamwidth for the lower and upper bands are 140° and 90°, respectively. While the gain for each band is 4.87 dB and 6.16 dB. The antenna is directional in the direction of vertical linear polarization. Thus, the antenna works well on devices that work on dual-system LTE 1800 MHz and WLAN 2400 MHz.**

***Keywords*— rectangular microstrip patch antenna, dual-band, broadband**

I. INTRODUCTION

4G-LTE (4th Generation-Long Term Evolution) is a network that developed from the previous network, namely the 3G network. LTE is a long-term roadmap, starts on a 4G network capable of producing data rates of up to 100 Mbps. LTE technology standards issued by the 3GPP forum. LTE was developed for many frequency bands and currently works in the 700 MHz to 2.7 GHz frequencies. The available bandwidth is also flexible starting with 1.4 MHz to 20 MHz. One of the frequencies commonly used for LTE is the 1800 MHz band (1710 – 1880 MHz), a frequency band with a bandwidth of 170 MHz [1][2].

Wireless LAN is a standard issued by the IEEE (Institute of Electrical and Electronics Engineers), an organization dedicated to assisting technology fields such as electrical technology, telecommunications, aviation, electronics, biomedical, and computer technology. The frequency band 2400–2483.5 MHz is used for data access or internet access [3][4].

This paper discusses the merging of two broadband applications on an antenna. The initial discussion of this paper has been obtained in [5]. However, the achievement of the bandwidth is still very narrow and the gain is low. The design was developed using the array technique. In addition to increasing gain, array techniques can also widen bandwidth.

II. RECTANGULAR MICROSTRIP PATCH ANTENNA

Microstrip antenna is one of the microwave antennas that use as an efficient radiator for today's modern communication systems. The rectangular microstrip patch antenna (RMPA) is composed of 4 parts, namely: the radiating (patch), the insulator (substrate), the microstrip line, and the ground plane. These sections can be seen in Fig. 1 [6].

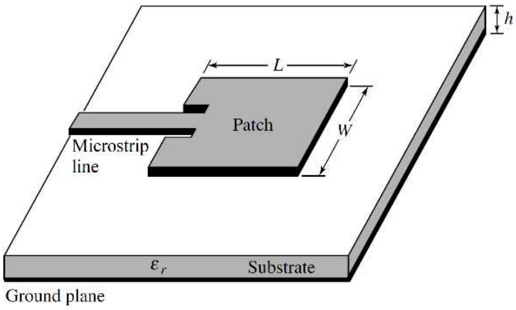


Fig. 1. The construction of RMPA

The procedure for designing an RMPA can be carried out as follows:

A. Design of Patch

The patch dimensions of an RMPA are width (W) and length (L) that can be calculated by [6]:

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

$$L = \frac{v_0}{2f_r\sqrt{\varepsilon_{\text{reff}}}} - 2\Delta L \qquad (2)$$

where:

$$\varepsilon_{\text{reff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2} \qquad (3)$$

and

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

The velocity of electromagnetic waves in free space (v_0) is 3×10^8 m/s. The specification of the substrate used has a dielectric constant (ε_r) and a thickness (h).

B. Design of Microstrip Line

A microstrip-line feed is designed through a line in the conductor plane. It is located on the side of the substrate surface layer by a patch width. The width of the conductor as a transmission line has a characteristic impedance (Z_c). The impedance value is influenced by the dielectric constant and the ratio between the width of the supply line (W_0) and the thickness of the substrate (h). The value of the characteristic impedance of the microstrip transmission line for $W_0/h > 1$ obtained through (5) [7].

$$Z_c = \frac{120\pi}{\sqrt{\varepsilon_{\text{reff}}}\left[\frac{W_0}{h}+1.393+0.667\ln\left(\frac{W_0}{h}+1.444\right)\right]} \tag{5}$$

The length of the microstrip-line feed can be adjusted according to the size of the ground plane. A good impedance match can be done by adjusting the position of the feeder or using the inset method.

III. RESEARCH METHODOLOGY

A single-element RMPA design that can produce dual-band had discussed in [4]. The design that consists of 1 element and a microstrip line feed is printed on epoxy dielectric material with a constant value of 4.4 and a thickness of 1.6mm. The geometry of the single-element RMPA design is shown in Fig. 2 [5].

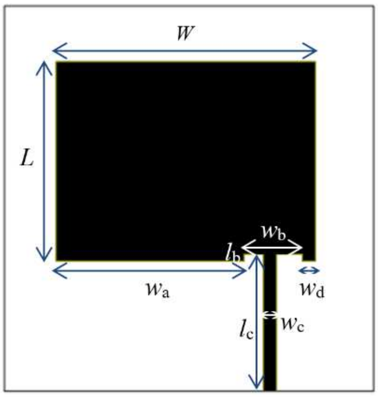


Fig. 2. The geometry of the single elemnt RMPA.

In Fig. 2, the size of the patch width (W) is 40 mm. Patch length (L) = 29 mm, w_c (feed line width) = 2 mm, l_c (feed line length) = 20 mm, w_a = 29 mm, w_b = 9 mm, l_b = 1 mm, w_d = 2 mm.

In this paper, designing the RMPA was prepared by adding an identical patch to form an RMPA 2 elements array. Both elements are supplied with a T-junction power divider. Shaped like the letter T or called a parallel feed or corporate feed, with two output microstrip lines $2Z_0$ and an input microstrip line Z_0 shown in Fig. 3. So it is known that if the value of the input impedance (Z_0) is 50 Ω, then the impedance at the output port ($2Z_0$) is 100 Ω.

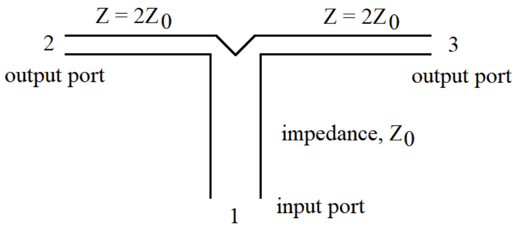


Fig. 3. T-junction power divider.

Generally, the quarter-wave T-junction is used as a power divider in antennas of 2 or more elements [6]. The length of the feed line is the length of the quarter-wave or 1/4 λ_g. The required length of the feed line is 1/4 λ_g, where λ_g can be calculated by (6) as follows [8].

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{\text{eff}}}} \tag{6}$$

Furthermore, a multiple section transformer [9] is needed for impedance matching requirements from the T-junction to the initial RMPA design. Figure 4 shown multiple section transformer ¼ λ required in designing a 2-element supply line and combined with a T-junction line.

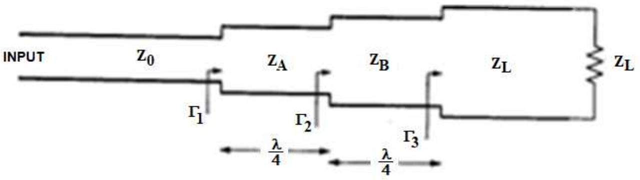


Fig. 4. *Multiple section transformer ¼ λ.*

The characteristic impedance value of each section is obtained from (7) to (9). The characteristic impedance ratio of the input and output lines is as follows [9]:

$$\Phi = Z_L/Z_0 \tag{7}$$

thus obtained values Z_A and Z_B [8]:

$$Z_A = Z_0\Phi^{1/4} \tag{8}$$

and

$$Z_B = Z_0\Phi^{3/4} \tag{9}$$

The design is simulated with the AWR simulator to observe the parameters, namely return loss and voltage standing wave ratio (VSWR). Optimization design is tried by adjusting the distance of the elements, and the supply position on the input port of the power divider.

IV. RESULT AND DISCUSSESS

The feeding system for RMPA 2 element array is designed using a T-junction and the multiple section transformer ¼ λ. For the T-junction design, Z_0 = 50 Ω is used, hence $2Z_0$ = 100 Ω. Transmission line from the T-junction to the patch is applied to multiple section transformer using (7) to (9).

$$\Phi = \frac{50}{100} = 0.5$$

$$Z_A = Z_0 \Phi^{\frac{1}{4}} = 84\ \Omega$$

$$Z_B = Z_0 \Phi^{\frac{3}{4}} = 100\ (0.5)^{\frac{3}{4}} = 59.46 \approx 60\ \Omega$$

The iteration process using a simulator is very helpful to get the appropriate distribution system. The iteration that needs to be done is to vary the distance between patches and the center position of the input port.

The final design of the RMPA 2 elements array is shown in Fig. 5. The dimensions of patch-1 are identical to those of patch-2 based on the results of the single-element RMPA design.

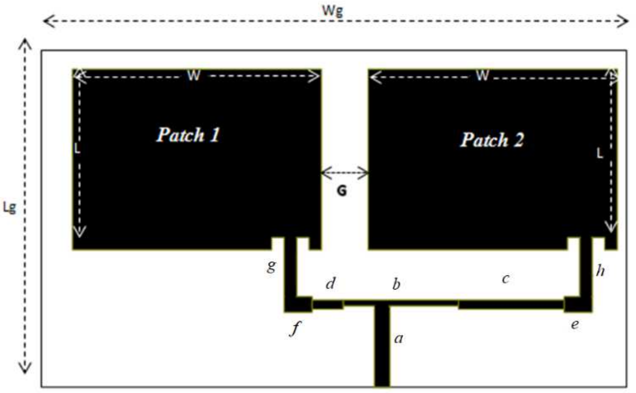


Fig. 5. The dimension of optimal RMPA 2 elements array design.

The ground plane width (W_g) is 94 mm. Ground plane length (L_g) = 54 mm, patch width (W) = 40 mm, patch length (L) = 29 mm, gap between patches (G) = 7.5 mm. Dimensions of the T-junction multi-section power line (w_a) = 2.5 mm, l_a = 13 mm, w_b = 1 mm, l_b = 18.5 mm, w_c = 1.5 mm, l_c = 17 mm, w_d = 1.5 mm, l_d = 5 mm, w_e = 2.5 mm, l_e = 4.5 mm, w_f = 2.5 mm, l_f = 4.5 mm, w_g = w_h = 2 mm, l_g = l_h = 9.5 mm. The optimal antenna design is then fabricated which is shown in Fig. 6.

Fig. 6. Fabrication of the RMPA design with single element and 2 elements

Figure 7 showing the return loss graph of the measurement result of the single element RMPA and 2-elements array. It is seen that both designs have dual-band. Good return loss is obtained from the single element RMPA but has a narrow bandwidth. Meanwhile, the RMPA 2 elements array design appears to have a wider range at return loss values below -10 dB. This item is marked with a dotted circle line.

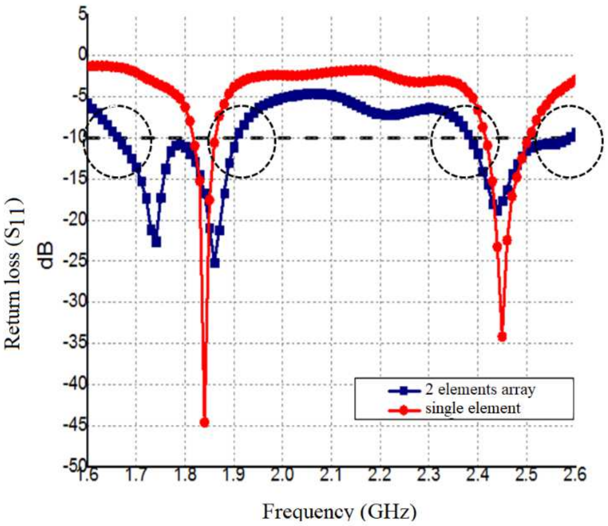


Fig. 7. The return loss graph of measurement result.

Figure 8 is shown a comparison of the VSWR graph of the single-element and 2-element RMPA measurement results. Dualband working frequency can be achieved, both of the single element and RMPA 2 element array. For the single-element, the bandwidth toward VSWR < 2 is 45 MHz in the lower band (1817 – 1862 MHz) and 95 MHz in the upper band (2413 – 2508 MHz). For the RMPA 2 element array, the bandwidth is up to 253 MHz in the lower band (1656 – 1909 MHz) and 218 MHz in the upper band (2379 – 2597 MHz). Increased bandwidth occurs in the RMPA design with 2 elements array, this proves that the optimization of the feed line system can affect the performance of the array antenna.

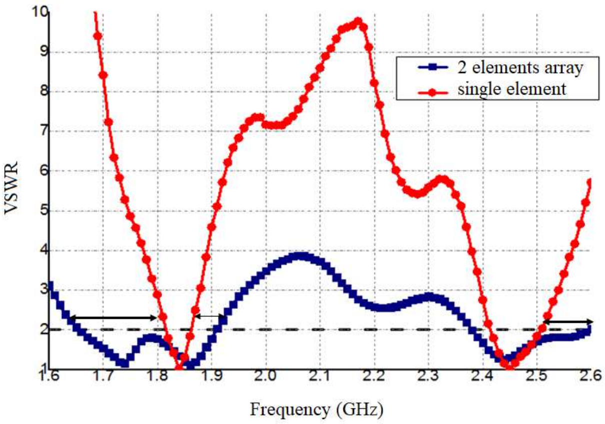
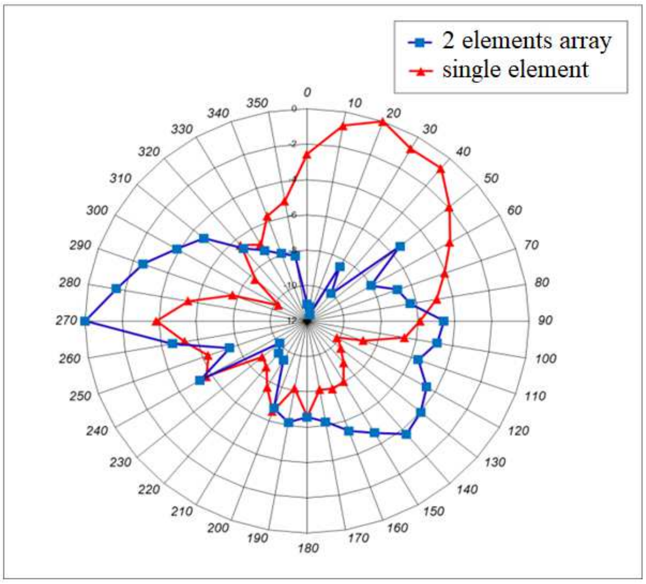


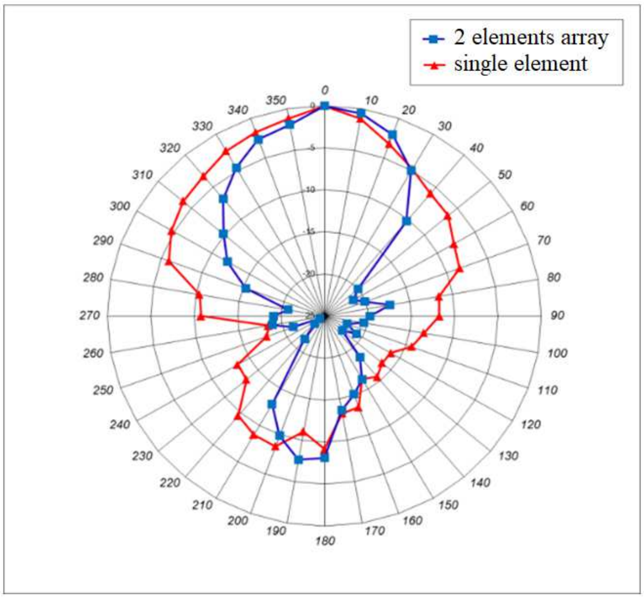
Fig. 8. The VSWR graph of measurement result.

The radiation pattern of the RMPA design in the lower band (1800 MHz) is shown in Fig. 9 (a). In the figure can be seen that there are differences in the main lobes of the two designs. The single element design has a unidirectional radiation pattern while the 2-element array design has two directions.

The radiation pattern of the RMPA design in the upper band (2400 MHz) is shown in Figure 9 (b). In the figure can be seen that the main lobes of both designs have the same direction, the highest magnitude being at an angle of 0°. The single element design has a larger beamwidth than the 2-elements array design.



(a). 1800 MHz



(b). 2400 MHz

Fig. 9. The radiation pattern graph of measurement result.

Based on the design testing of the 2-element array antenna on LTE (1800 MHz) and WLAN (2400 MHz) systems, the maximum gain achieved in the two bands is 4.87 dB and 6.16 dB, respectively. In general, the results of the RMPA antenna design with this 2-element array can be seen in Table 1.

TABLE I. ACHIEVEMENTS OF RMPA 2-ELEMENTS ARRAY

Parameters	**Lower band (1800 MHz)**	**Upper Band (2400 MHz)**
VSWR minimum	1.12 (1863 MHz)	1.26 (2439 MHz)
Bandwidth	232 MHz	94 MHz
Return loss minimum	-25.46 dB	-18.75 dB
HPBW	140º	90º
Gain max.	4.87 dB	6.16 B

V. CONCLUSION

The addition of a patch from a single element to 2 elements array and optimization of the feed line can improve antenna performance. In addition to increasing the gain, it is also able to widen the bandwidth. In the lower band (1800 MHz), the use of 2 elements array can increase the bandwidth by 562%. In the upper band (2400 MHz), the increase in bandwidth reaches 229%. The optimal result for the lower band is 253 MHz bandwidth with a minimum VSWR of 1.11 and the return loss of -25.46 dB at a frequency of 1861.7 MHz, a gain of 4.87 dB, and a beam width of 140o. For the Upper-band (2400 MHz), the bandwidth is 218 MHz. The minimum VSWR is 1.26 and the return loss is -18.75 dB at a frequency of 2438 MHz, a gain of 6.16 dB, and the beam width comprises 90o. Thus the RMPA 2 element array design can meet the application of dual-band broadband communication systems with the same configuration, namely LTE (1800 MHz and WLAN (2400 MHz).

ACKNOWLEDGMENT

Thank you to the ELTICOM 2021 committee for reviewing this article and the Antenna and Propagation Laboratory, Faculty of Engineering, Universitas Sumatera Utara. This research was supported by the 2017 Hibah Penelitian Talenta (Talenta Research Grant).

REFERENCES

[1] B. M. Hasiandra and Iskandar, "Planning and performance analysis of downlink inter-band carrier aggregation for LTE-Advanced 3GPP Released 13," *2016 10th International Conference on Telecommunication Systems Services and Applications* (TSSA), 2016, pp. 1-6, doi: 10.1109/TSSA.2016.7871080.

[2] ITU-R 62, "Handbook on Global Trends in International Mobile Telecommunications", Edition of 2015 [Online]. Available: https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-62-2015-PDF-E.pdf

[3] IEEE Std. 802.11, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification," 1999.

[4] IEEE Std. 802.11g, "Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band," 2003.

[5] A. H. Rambe and K. Abdillah, "A low profile rectangular patch microstrip antenna for dual-band operation of wireless communication system," *2017 TALENTA - Conference on Engineering, Science and Technology* (CEST), IOP Conf. Ser.: Mater. Sci. Eng., 309, 012046.

[6] C. A. Balanis, *Antenna theory: analysis and design*, 3rd Edition, 2005, John Wiley, NJ.

[7] JR. James & PS Hall, *Handbook of Microstrip Antennas*, Peter Peregrinus Ltd., Volume 1 & Volume 2, 1993.

[8] Huang, Y., Boyle, K. *Antennas : From Theory to Practice*, ISBN: 978-0-470-51028-5 (HB). John Wiley and Sons, Ltd. United Kingdom, 2008.

[9] Fooks, E.H. Zakarevicius, R.A., *Microwave Engineering Using Microstrip Circuits*. Prentice Hall. Australia, 1990.