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LHCP four patches stack triangular truncated antenna using corporate feed microstrip-line for CP-SAR sensor

Muhammad Fauzan Edy Purnomo[1], Vita Kusumasari[2], Rudy Yuwono[3], Rahmadwati[4], Rakhmad Romadhoni[5], Azizurrahman Rafli[6], Yuyu Wahyu[7], Akio Kitagawa[8]
[1,3,4,5,6]Electrical Department, Faculty of Engineering, Brawijaya University, Malang, Indonesia
[2]Mathematics Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia
[7]Research Center for Electronics and Telecommunications, Indonesian Institute of Sciences (LIPI), Bandung, Indonesia
[8]Electrical Engineering and Computer Science, Kanazawa University, Ishikawa, Japan

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ABSTRACT

In this paper, we acquire the configuration of the left-hand circular polarization (LHCP) array four patches stack triangular truncated microstrip antenna. This construction use the basic corporate feed microstrip-line with modified lossless T-junction power divider on radiating patch for circularly polarized-synthetic aperture radar (CP-SAR) sensor embedded on unmanned aerial vehicle (UAV) with compact, small, and simple configuration. The design of circular polarization (CP) is realized by truncating the whole three tips and adjusting the parameters of antenna at the target frequency, f=5.2 GHz. The results of characteristic performance and S-parameter for the LHCP array four patches stack antenna at the target frequency show successively about 9.74 dBic of gain, 2.89 dB of axial ratio (Ar), and –10.91 dB of S-parameter. Moreover, the impedance bandwidth and the 3 dB-Ar bandwidth of this antenna are around 410 MHz (7.89%) and 100 MHz (1.92%), respectively.

Corresponding Author:

Muhammad Fauzan Edy Purnomo
Department of Electrical Engineering
Faculty of Engineering, Brawijaya University
MT. Haryono 167, Malang 65145, Indonesia
Email: mfauzanep@ub.ac.id

1. INTRODUCTION

Radar is an electronic device that utilizes a lot special technology, including signal processing, data processing, waveform design, detection, parameter estimation, and antenna propagation. The radar antenna transmits pulses of microwaves that bounce off any object in their path. The object returns a portion of the wave to the receiver which is in line of sight with the target [1].

Radar is a remote sensing system, which is widely used for monitoring, tracking and imaging applications. Remote sensing system use the side-looking images which are divided into two types: i) Real aperture radar (RAR), ii) Synthetic aperture radar (SAR). Remote sensing has been implemented for defense, disaster mitigation, earth and atmosphere observations, and mapping [2]-[4].

This paper presents the development of the left-hand circular polarization (LHCP) array four patches stack triangular truncated microstrip antenna. The study involves the development of the four patches as basic construction for CP-SAR sensor. This construction uses the double-stacked substrate with low dielectric constant, modified triangular truncated radiating patch shape using microstrip-line for multi-resonant frequency, and triangular truncated parasitic patch for CP-SAR sensor embedded on unmanned aerial vehicle (UAV) with compact, small, and simple configuration that fundamentally construct to mold a substantial planar array. This design is modified from previous research about the antenna without patch stack and the use of the proximity feeding [5]. The new antenna design has ability to work in higher frequency and to achieve the wider bandwidth of impedance and axial ratio. The design of power divider network is often limited by the restrictions imposed by radiating patches dimensions. The feeding network is a multi-port power divider circuit which is an important element in the design of corporate feed beam-forming network configuration. The power is distributed to radiating patches through the multi-port power divider. This is also a microwave device that is useful for phased-array antennas, mixers, and active devices. This modified antenna design is fed by 1:*n* (*n* is a number of patches) power divider network involving T-junctions called corporate feeding-line. T-junctions are compensated by adjusting the length of the three microstrip-lines where the length of two or three of them is about λ/4 for matching impedance 50 Ω [5]-[8].

By incorporating proper line extensions toward patches and adjacent patches in the left-right sides on the opposite direction of 180° and also add more patches, the beam direction can be controlled. For a symmetric corporate feeding-line network, the number of radiating patches is 2^m (*m* is an integer indicating the number of T-junctions toward patches for one patch, two and four patches, while for eight patches, *m* is an integer denoting the number of T-junctions which are not through patches, and for sixteen, thirty-two, sixty-four, one hundred and twenty-eight, etc. patches, m is an integer exhibiting the number of T-junctions which are not through patches and input port divided by two and added with one). Furthermore, radiating patches are matched by the corporate feeding-line through appropriate dimension of coupling structures or by using quarter-wave transformers that one of them is to make the distance between the tip of corporate feeding-line on radiating patch and null potential (*O*), *lf*, is 4.41 mm. To obtain the array antenna operating the TM_{21} circular polarization (CP), we use the following rules [9]: i) The radiating patches with corporate feed microstrip-line that use the perturbation segment on the radiating and parasitic patches. In this case, the substrate thickness of radiating patches with corporate feed microstrip-line (*h1*) and parasitic patches (*h2*) are the same with the value is 1.6 mm; ii) To create the stable radiation patterns which are slightly symmetric at the boresight beam, the element spacing of radiating patches is λ/2. Furthermore, the tips of corporate feed microstrip-line which have the same parameter sizes spread the current within radiating and parasitic patches. To establish CP, we require the proper setting size between the tips of corporate feed microstrip-line and the perturbation segment on the radiating and parasitic patches. Owing to the both of them strongly affected with a high degree of sensitivity, they yield two orthogonal resonant modes of equal amplitudes and 90° phase difference; iii) In order to preserve the symmetric beam and to keep the low CP, wider ARBW, and the higher gain, this antenna using triangular truncated parasitic patches with area around remaining part is covered with substrate. In this paper, we describe the corporate feeding-line of five ports for four patches of LHCP array antennas that close lossless, reciprocal (–6 dB) and matched load. The results obtained from the study reveal *S*-parameter, frequency characteristic, input impedance, radiation pattern, and antenna efficiency of this modified antenna.

2. RESEARCH METHOD

In this investigation, we conduct and discuss numerical simulation result related to the microstrip antenna with research method and construction described in Figure 1 and Figure 2 (in appendix). In particular, the analysis focuses on the study of triangular truncated array 2×2 patches antenna for LHCP. In this case, the array antenna uses four patches as a transmitter, *Tx*, and a receiver, *Rx* [10], [11]. Table 1 shows the specification for the *C*-Band CP-SAR of UAV antenna [12]. The method of moments (MoM) is chosen in the numerical analysis for fast calculation. This method discretizes the integral into a matrix equation. This discretization can be considered as dividing the surface of antenna into small mesh [4]. To realize this method, we use computer simulation technology (CST) version 2016 from corporate company CST STUDIO SUITE [13]. The numerical simulation of the triangular truncated array antenna are shown in section 3, especially at the target frequency, f=5.2 GHz where this antenna as basic configuration embedded on UAV for the application of CP-SAR sensor both *Tx* and *Rx*. Each antenna can generate wave that yields a CP. The technique to achieve CP can be easily obtained i.e. by proper adjusting of the parameters, determining locus feed, and constructing feed [14], [15].

To investigate the low power of the LHCP array four patches stack triangular truncated microstrip antenna, the antenna is constructed the mold of substantial planar array using microstrip-line that is fed directly to radiating patches and impacts on parasitic patches to yield the CP with wider bandwidth than other antennas operated in LP [19]-[21] and CP [22], [23]. It is because the right pattern of basic construction determines the superiority of array antenna design using patches stack and corporate feed microstrip-line [15], [24]-[26]. Although the corporate feeding-line design has been developed [5], [14], [27], the design was for the antenna bandwidth (IBW and ARBW) smaller than this novel antenna. In this paper, nippon pillar packing (npc) H220A is chosen as the antenna substrate. It has a conventional substrate with dielectric constant (ε_r), and loss tangent (δ) are 2.17 and 0.0005, respectively. Moreover, the total substrate thickness of LHCP antenna is 3.2 mm. Also, the design of LHCP four patches array antenna fed by corporate feed microstrip-line having low power and the antenna view on the 35° angle side for CP-SAR application are discussed.

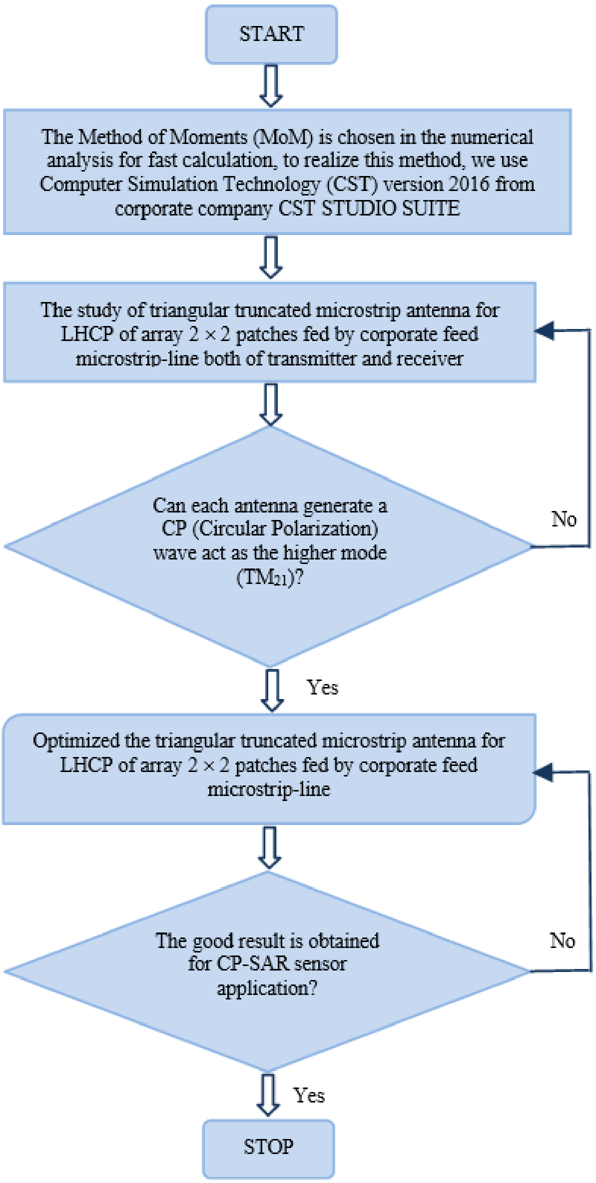


Figure 1. The flowchart of research method of array four patches stack LHCP antenna [16]-[18]

Table 1. Technical specification of UAV system

No	Antenna Parameters	Specification for UAV
1.	Target Frequency (Center) (GHz)	*C*-band: 5.0-5.5 GHz
2.	Pulse Band Wide (MHz)	10-233.31
3.	Axial Ratio (dB)	≤ 3
4.	Antenna Efficiency (%)	> 80
5.	Gain Antenna (dBic)	9.6-36.6
6.	Azimuth Beamwidth (°)	≥ 1.08
7.	Elevation Beamwidth (°)	≥ 2.16
8.	Antenna Size (m)	0.6×0.5
9.	Polarization (*Tx*/*Rx*)	RHCP+LHCP

3. RESULTS AND DISCUSSION

Figure 3 shows that the values of gain and axial ratio (*Ar*) for simulation of the LHCP array four patches stack triangular truncated microstrip antenna in the direction of θ = 35° at the target frequency, *f* = 5.2 GHz, are about 9.74 dBic and 2.89 dB, respectively. In addition, the 3 dB-*Ar* bandwidth is roughly equal 100 MHz (1.92%). Figures 4 and 5 shows the relationship between the reflection of coefficient (S_{11}) or VSWR and the frequency for the simulation *Tx*/*Rx* array four patches stack triangular truncated microstrip antenna. Moreover, the value of S_{11} or VSWR at the target frequency is −10.91 dB or 1.813, respectively. While the S_{11} or VSWR bandwidth is around 410 MHz (7.89%). Figure 6 depicts the input impedance characteristic of the LHCP array four patches stack triangular truncated microstrip antenna for the real part and the reactance part of simulation at the target frequency that are successively 50.29 Ω and −14.79 Ω. These results are relative close to 50 Ω and 0 Ω, so the reactance looks capacitive. In the feed network, the length from input port to output ports must be fixed at $l \times \lambda/4$ (l = 1, 3, and 5) to achieve the optimal current intensity [27]. In this work, we use l = 9 or the distance between input port to output ports is 138.5424 mm.

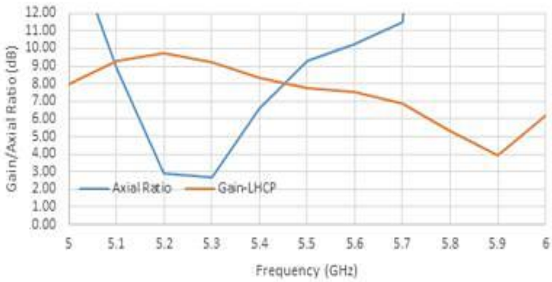


Figure 3. Frequency characteristic of 2×2 LHCP antenna

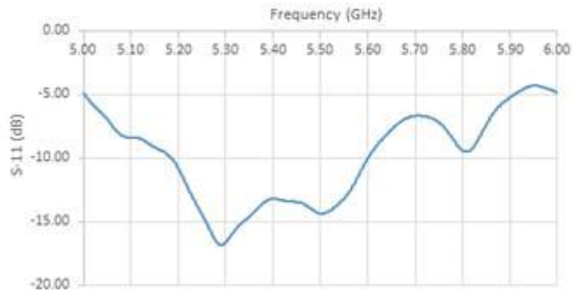


Figure 4. *S*-parameter of 2×2 LHCP antenna

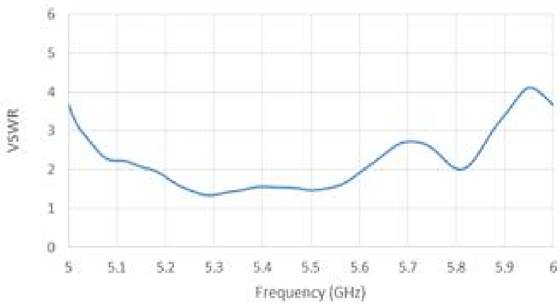


Figure 5. VSWR of 2×2 LHCP antenna

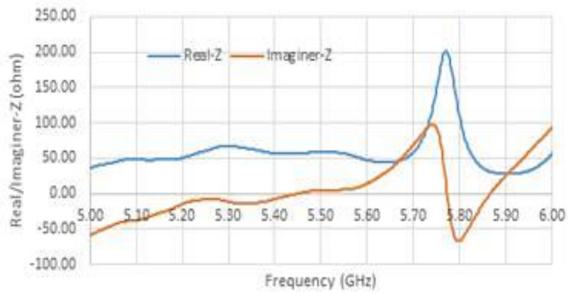
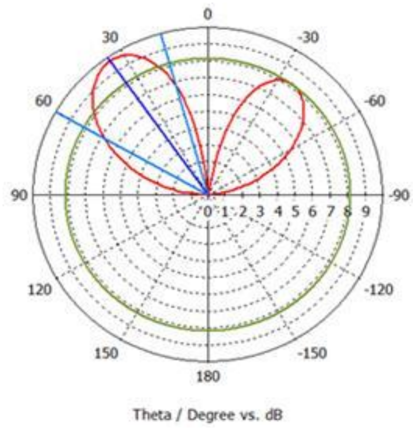


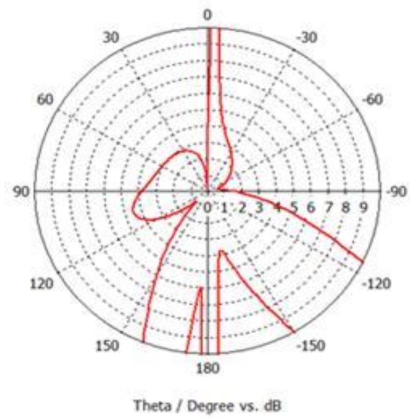
Figure 6. Input impedance of 2×2 LHCP antenna

Figures 7 and 8 depict the relationship between gain-*Ar* and θ (Theta)-angle produced from the LHCP array four patches stack triangular truncated microstrip antenna as azimuth (*Az*/ϕ) direction (positive-θ for direction to ϕ=0° or ϕ=90° and negative-θ for direction to ϕ=180° or ϕ = 270°) of CP-SAR at *f*=5.2 GHz. At θ=35°, the average values of maximum gain and *Ar* of this antenna are about 9.74 dBic and 2.89 dB, respectively. Furthermore, the values of 3 dB-*Ar* beamwidth are 75° from −100° to −25° (direction to ϕ=180° and ϕ=270° or negative-θ) and around 68° from 2° to 70° (direction to ϕ=0° and ϕ=90° or positive-θ). All of these values satisfy the targeted elevation beamwidth of ≥2.16° at Table 1 for better resolution of CP-SAR.

Figures 9 and 10 describe the ϕ (Phi)-plane in the area of θ=35° for LHCP at frequency 5.2 GHz. The values of maximum gain and minimum *Ar* on this plane are 9.744 dBic on ϕ=0° and 1.3 dB on ϕ=145°. The major values of 3 dB-*Ar* beamwidth on ϕ (Phi)-plane, direction to ϕ=0° are about 63° from ϕ=317° or −43° to ϕ=20° and around 60° from ϕ=137° to ϕ=197° or −163°. While for the ϕ (Phi)-plane, direction to ϕ=90° are roughly 65° from ϕ=45° to ϕ=110° and approximately 63° from ϕ=227° or −133° to ϕ=290° or −70°. These results exhibit that the targeted azimuth beamwidth ≥1.08° can occur for the resolution of CP-SAR UAV. Figure 11 shows the antenna efficiency about 89.23% for the LHCP array four patches stack triangular truncated microstrip antenna on a target frequency of 5.2 GHz. This result obtain the resolution of CP-SAR of the targeted antenna efficiency of 80%.

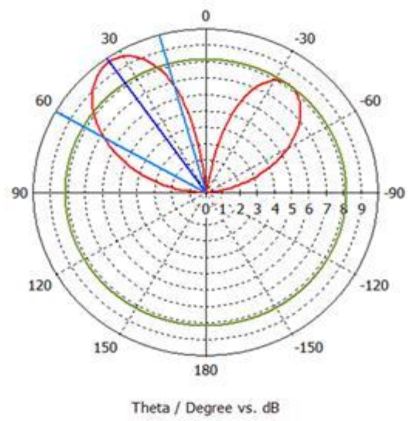


(a)

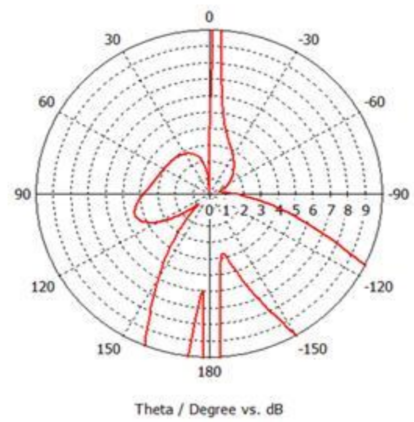


(b)

Figure 7. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, ϕ=0°, *f*=5.2 GHz

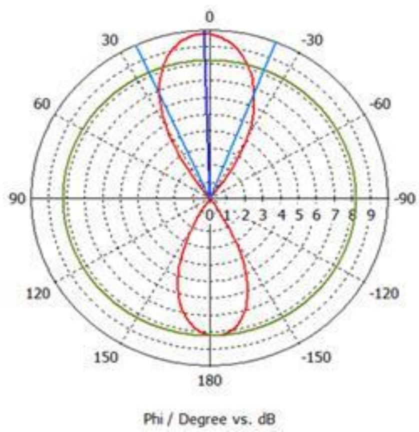


(a)

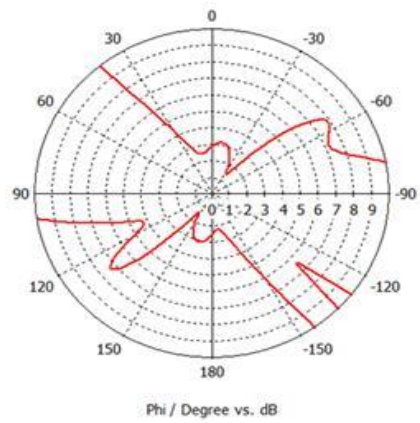


(b)

Figure 8. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, ϕ=90°, *f*=5.2 GHz

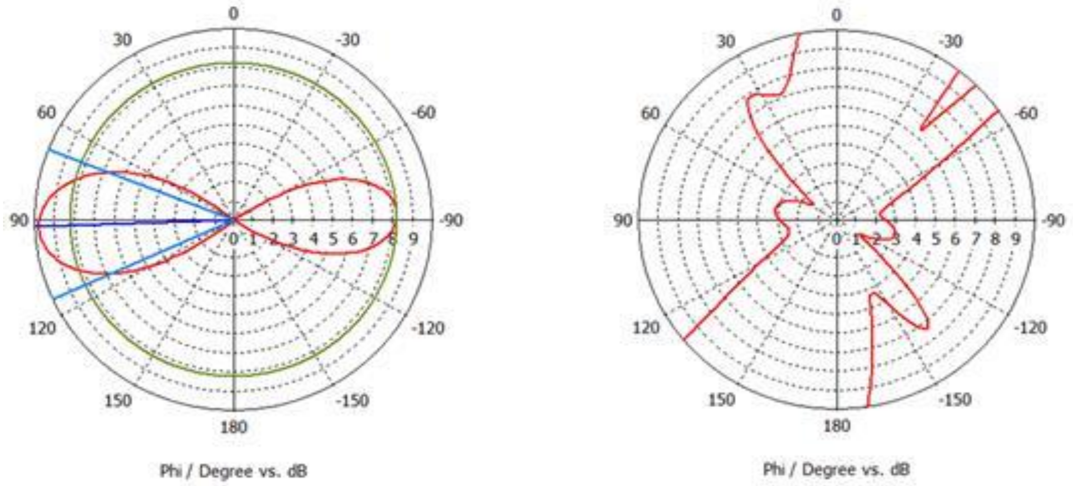


(a)



(b)

Figure 9. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, θ = 35°, ϕ=0°, *f*=5.2 GHz



(a) (b)

Figure 10. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, θ = 35°, ϕ=90°, *f*=5.2 GHz

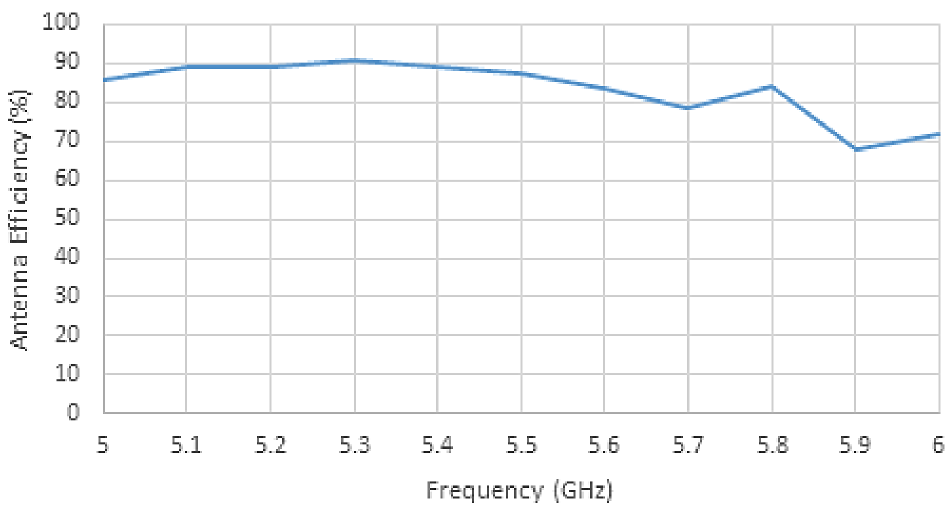


Figure 11. Antenna efficiency of 2×2 LHCP antenna

4. CONCLUSION

In an effort to meet the configuration for CP-SAR that is affixed to the UAV body with compact, small and simple, the LHCP array four patches stack triangular truncated microstrip antenna has been studied. Performance results, such as characteristic frequencies, *S*-parameters, input impedances, radiation patterns, and efficiency are as follows: i) The gain and axial ratio (*Ar*) values for this antenna simulation in the direction θ = 35° at target frequency of 5.2 GHz, were respectively around 9.74 dBic and 2.89 dB; ii) 3 dB-*Ar* bandwidth of 100 MHz (1.92%) was relatively wider than working on the *C*-band frequency; iii) The value of S_{11} or VSWR at the target frequency was –10.91 dB or 1.813 and its bandwidth value was around 410 MHz (7.89%); iv) Input impedance of the real part of this antenna from simulation at resonance frequency, *f* = 5.2 GHz was 50.29 Ω relatively close to 50 Ω. While the reactance portion of this antenna was –14.79 Ω, it looked capacitive and approached 0 Ω; v) The maximum gain and the minimum *Ar* values of this antenna in the gain-axial ratio function to the θ (Theta)-angle were around 8,14 dBic and 2,46 dB at θ = –35° and around 9.74 dBic and 2,89 dB at θ = 35°; vi) The maximum gain and minimum *Ar* values in the relation function of gain-axial ratio to ϕ-angle were about 9.744 dBic at ϕ = 0° and 1.3 dB at ϕ = 145°; vii) The antenna efficiency value of this antenna was around 89.23% at a target frequency of 5.2 GHz which has exceeded the target set by more than 80%.

APPENDIX

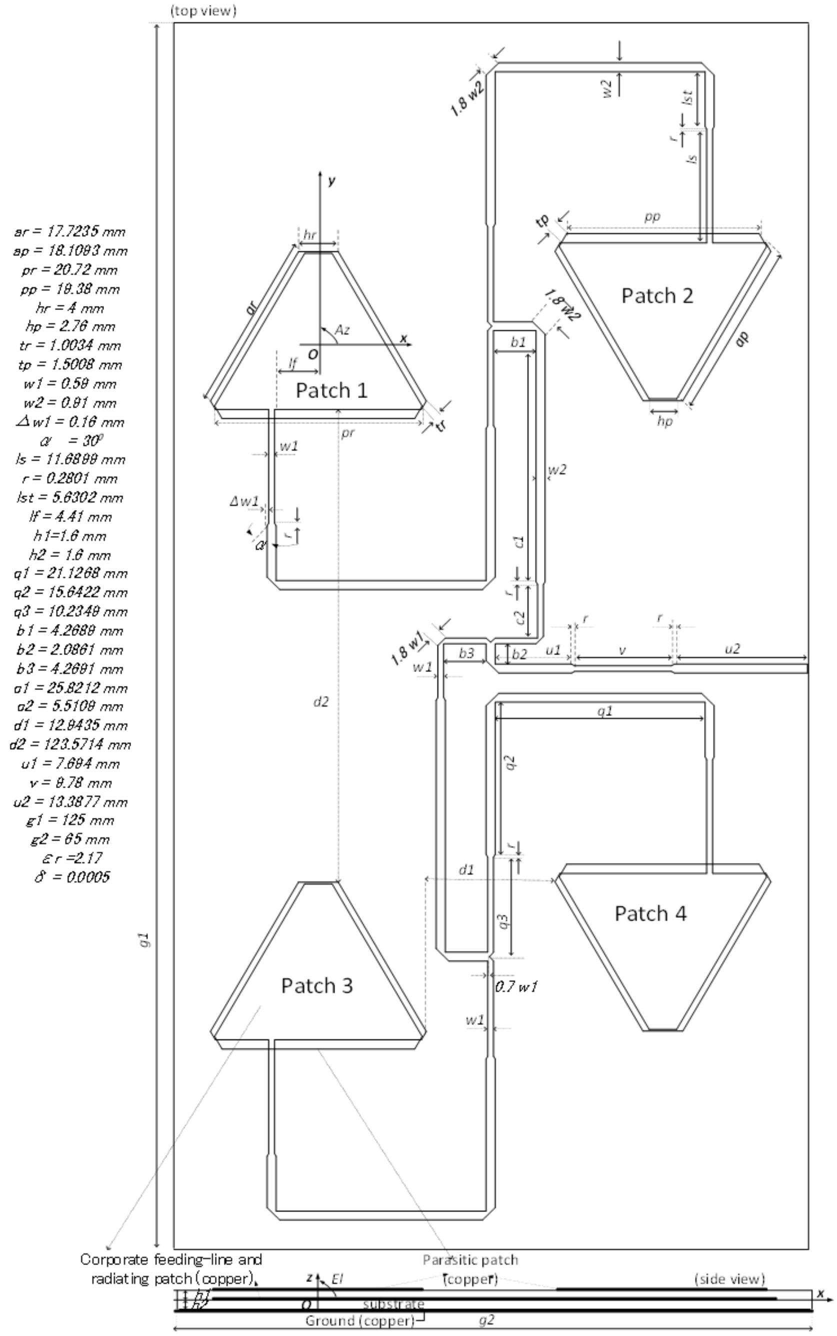


Figure 2. The construction of array four patches stack LHCP antenna

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BIOGRAPHIES OF AUTHORS

Muhammad Fauzan Edy Purnomo, was born in Banjarmasin, Indonesia, in June 1971. He received the Bachelor Engineering (B.E.) and Master Engineering (M.E.) degrees in Electrical Engineering from University of Indonesia, Jakarta, Indonesia in 1997 and 2000, respectively. He has graduated the doctoral degree in Electrical Engineering and Computer Science from Kanazawa University, Kanazawa, Japan on September 2018. He has finished a visiting scholar at Microelectronic Research Laboratory (MeRL), Division of Electrical Engineering and Computer Science, Graduate School of Natural Science and Technology, Kanazawa University, Japan on March 2019. From 2000 until present, he is working as lecturer at the Electrical Department Brawijaya University, Malang, Indonesia. His main interests are in the areas of microwave antennas, Radio Frequency (RF) circuit, wave signal processing, plasma wave engineering, array microstrip antennas, mobile cellular, satellite communications, wireless sensor network, internet of things, artificial intelligent, machine learning, remote sensing, Synthetic Aperture Radar (SAR), and Circularly-Polarized Synthetic Aperture Radar (CP-SAR).

Vita Kusumasari, was born in 1983 in Malang, Indonesia. She obtained the bachelor degree in Mathematics in 2005 and the master degree in Mathematics Education in 2010 from Universitas Negeri Malang, Indonesia. She received the Ph.D degree in Mathematical and Physical Sciences in 2017 from Kanazawa University, Japan. Currently, she is a lecturer in Mathematics Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang. Her interests are numerical analysis and differential equations.

Rudy Yuwono was born in Blitar, june 15, 1971. He received bachelot degree from university of Brawijaya, Malang Indonesia in 1997 and master degree from University of Kassel, Germany in 2005 Curently, he is working at Electrical Engineering, University of Brawijaya Malang as Lecturer and Researcher. His research interest are antena and propagation, microwave and reasercher.

Rahmadwati, was born in Malang, Indonesia. She has received Bachelor Degree in Electrical Engineering from Brawijaya University in 2000. She received the Master Degree in Electrical Engineering from Gadjahmada University in 2004. And she received Doctoral Degree Electrical Engineering from University of Wollongong, Australia in2013. Her research interest include image processing, signal processing, machine learning and control system.

Rakhmad Romadhoni was born in Blitar, Indonesia, on May 1986. He received the S.ST (Sarjana Sain Terapan / Bachelor Applied Science) degree in Mechatronic Engineering from PENS-ITS, Surabaya in 201. He is working as Laboratory Technician at the Electrical Department Brawijaya University, Malang, Indonesia.

Azizurrahman Rafli was born in Malang, Indonesia on July 2000. He is 2018's Electrical Engineering student in Brawijaya University. He joined Aeronautics students research group as User Interface Programmer and he joined Transmission and Microwave laboratory as a research assistant. His main interest in Microstrip Antenna Design researches.

Yuyu Wahyu was born in Bandung, Indonesia, on February, 1962. He received the Ir. (Insinyur) degree in 1990, the M.Eng (M.T) degree in Telecommunication Information System from electrical engineering study program, in 2000, and the PhD degree in Global Information and Telecommunication Studies from school of electrical and informatics engineering, in 2010, all from Institut Teknologi Bandung, Bandung, Indonesia. He joined the Telecommunications Research Center, Strategic Electronics, Components and Materials (Telkoma) Indonesian Institute of Sciences (LIPI)-now the Research Center for Electronics and Telecommunications, LIPI, since 1991. He was chair of the research group of Antennas and Propagation from 2014 until now. Since 2019 he has been appointed as Research Professor in telecommunications transmission. He followed a number of activities related to his field of competence, i.e. active antenna and radar. He conducted FMCW radar research from 2006 to present and electronic support measure (ESM) from 2015 to 2018. He participated in professional organizations, including: Head of west java province for Himpenindo (Association of Indonesian Researchers) from 2020 to 2024. Indonesian Radar Association since 2008 until now, and IEEE - Antenna and Propagation Society since 2010 until now.

Akio Kitagawa, was born in Hikone, Japan in 1961. He received the B.E., the M.E., and the Ph.D degree from Nagoya Institute of Technology, Nagoya, Japan in 1985, 1987 and 1991, respectively. Since 1989, He worked for the Department of Electrical and Computer Engineering, Kanazawa University, Japan. From 2001 to 2003, He was with the Department of Information and Systems Engineering, Kanazawa University, Japan. From 2004 to 2007, He had been with Division of Electrical Engineering and Computer Science, Graduate School of Natural Science and Technology, Kanazawa University. Since 2008, He is working with College of Science and Engineering, School of Electrical, Information and Communication Engineering in Kanazawa University. His research interests include a phase change nonvolatile RAM, VLSI design automation, integrated sensor systems, RF circuit design and VLSI applications to mobile systems.