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

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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, f₀=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.

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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).
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), l, 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 ($\epsilon_r$), and loss tangent ($\delta$) 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.

![Flowchart](image)

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

| 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)                    | $\leq 3$                    |
| 4.  | Antenna Efficiency (%)              | $> 80$                      |
| 5.  | Gain Antenna (dBi)                  | 9.6-36.6                    |
| 6.  | Azimuth Beamwidth (°)               | $\geq 1.08$                 |
| 7.  | Elevation Beamwidth (°)             | $\geq 2.16$                 |
| 8.  | Antenna Size (m)                    | 0.6x0.5                     |
| 9.  | Polarization (Tx/Rx)                | RHCP+LHCP                   |

LHCP four patches stack triangular truncated antenna using... (Muhammad Fauzan Edy Purnomo)
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 $\theta = 35^\circ$ 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 2x2 LHCP antenna](image)

![Figure 4. S-parameter of 2x2 LHCP antenna](image)

![Figure 5. VSWR of 2x2 LHCP antenna](image)

![Figure 6. Input impedance of 2x2 LHCP antenna](image)

Figures 7 and 8 depict the relationship between gain-Ar and $\theta$ (Theta)-angle produced from the LHCP array four patches stack triangular truncated microstrip antenna as azimuth ($A/\phi$) direction (positive-$\theta$ for direction to $\phi=0^\circ$ or $\phi=90^\circ$ and negative-$\theta$ for direction to $\phi=180^\circ$ or $\phi=270^\circ$) of CP-SAR at $f=5.2$ GHz. At $\theta=35^\circ$, 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 $75^\circ$ from $-100^\circ$ to $-25^\circ$ (direction to $\phi=180^\circ$ and $\phi=270^\circ$ or negative-$\theta$) and around $68^\circ$ from $2^\circ$ to $70^\circ$ (direction to $\phi=0^\circ$ and $\phi=90^\circ$ or positive-$\theta$). All of these values satisfy the targeted elevation beamwidth of $\geq 1.16^\circ$ at Table 1 for better resolution of CP-SAR.

Figures 9 and 10 describe the $\phi$ (Phi)-plane in the area of $\theta=35^\circ$ for LHCP at frequency 5.2 GHz. The values of maximum gain and minimum Ar on this plane are 9.744 dBiC on $\phi=0^\circ$ and 1.3 dB on $\phi=145^\circ$. The major values of 3 dB-Ar beamwidth on $\phi$ (Phi)-plane, direction to $\phi=0^\circ$ are about $63^\circ$ from $\phi=317^\circ$ or $-43^\circ$ to $\phi=20^\circ$ and around $60^\circ$ from $\phi=137^\circ$ to $\phi=197^\circ$ or $-163^\circ$. While for the $\phi$ (Phi)-plane, direction to $\phi=90^\circ$ are roughly $65^\circ$ from $\phi=45^\circ$ to $\phi=110^\circ$ and approximately $63^\circ$ from $\phi=227^\circ$ or $-133^\circ$ to $\phi=290^\circ$ or $-70^\circ$. These results exhibit that the targeted azimuth beamwidth $\geq 1.08^\circ$ 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%.

Figure 7. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, $\phi=0^\circ$, $f=5.2$ GHz

Figure 8. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, $\phi=90^\circ$, $f=5.2$ GHz

Figure 9. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, $\theta=35^\circ$, $\phi=0^\circ$, $f=5.2$ GHz
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 $\theta = 35^\circ$ at target frequency of 5.2 GHz, were respectively around 9.74 dBi 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 $\Omega$ relatively close to 50 $\Omega$. While the reactance portion of this antenna was $-14.79$ $\Omega$, it looked capacitive and approached 0 $\Omega$; v) The maximum gain and the minimum Ar values of this antenna in the gain-axial ratio function to the $\theta$ (Theta)-angle were around 8.14 dBi and 2.46 dB at $\theta = -35^\circ$ and around 9.74 dBi and 2.89 dB at $\theta = 35^\circ$; vi) The maximum gain and minimum Ar values in the relation function of gain-axial ratio to $\phi$-angle were about 9.744 dBi at $\phi = 0^\circ$ and 1.3 dB at $\phi = 145^\circ$; 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%.

Figure 10. Farfield; (a) gain, (b) axial ratio of 2×2 LHCP antenna, $\theta = 35^\circ$, $\phi=90^\circ$, $f=5.2$ GHz

Figure 11. Antenna efficiency of 2×2 LHCP antenna

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APPENDIX

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

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