Design of Tilted Beam Circularly Polarized Antenna for CP-SAR Sensor Onboard UAV

Yohandri[1], Asrizal[1] and Josaphat Tetuko Sri Sumantyo[2]
[1]Physics Department, FMIPA Universitas Negeri Padang, West Sumatera, Indonesia
[2]Josaphat Microware Remote Sensing Laboratory, CEReS, Chiba University, Japan
yohandri.unp@gmail.com

***Abstract* - In this paper, a tilted beam circularly polarized antenna is designed. This L-band antenna is designed to be mounted on the bottom of unmanned aerial vehicle (UAV) for circularly polarized synthetic aperture radar (CP-SAR) sensor. The antenna is composed of four elliptical elements and a proximity-feeding network. By arranging the phases different to each element, the main beam of radiation can be tilted to proposed angle for a side looking radar. The phase shifting is obtained by varying the length of the antenna feed line. A method of moment (MoM) is employed for optimizing the design and achieving a good circular polarization at the targeted frequency (1.27 GHz). The tilted beam and axial ratio indicate the antenna is promising for the CP-SAR**

***Index Terms* — Circular Polarization, Tilted Beam, Elliptical Patch, CP-SAR sensor**

1. Introduction

The Synthetic Aperture Radar (SAR) sensor attracted a lot of attention in currently remote-sensing applications since its ability penetrate the cloud, operate in all-weather condition at night and day time. As compared with linearly polarized SAR (LP-SAR) sensor, a greater amount of information would be provided with a CP-SAR sensor, such as axial ratio, ellipticity and tilt angle. A CP-SAR sensor is beneficial because future SAR system requires a sensor that insensitive to Faraday rotation effect and produce great amount of information from the target [1],[2].

Currently, the CP-SAR sensor installed onboard an UAV is being developed in JMRSL, CEReS Chiba University. This sensor is intended for several targets such as land cover and snow cover map-ping, oceanography, and disaster monitoring. In order to realize the CP-SAR sensor, a circularly polarized antenna is implemented. In previous works, single model [3] and array [4],[5],[6] circularly polarized microstrip antenna for CP-SAR sensor has developed. Nevertheless, the antenna radiation pattern is designed perpendicular to the antenna surface or theta plane. The CP antenna is installed on the side of UAV due to the side looking requirement. This installation needs other dummy load on the other side to maintain the balance of UAV as illustrated in Fig. 1. Consequently, the UAV payload will increase and space become limited. One of a solution to this problem is by installing the antenna on the bottom of the UAV. In this paper, we proposed a tilted beam circularly polarized antenna to satisfy CP-SAR sensor installed on the bottom of UAV.

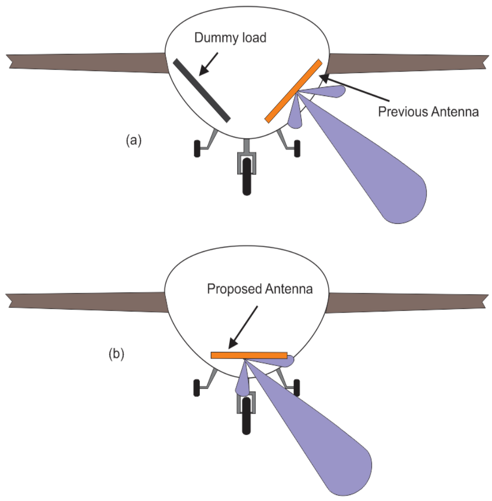

Fig. 1. Illustration of antenna installation onboard UAV, (a) previous works and (b) proposed antenna

2. Design of Proposed Antenna

In this design, the array antenna consists of 4 elements elliptical patch with uniform space $d = \lambda_0/2$ (Fig. 3). An elliptical patch is adopted in an array configuration based upon the measured satisfactory results in terms of reflection coefficient, axial ratio (AR), and gain [6]. The elliptical patch can produce the circular polarization with single feed by placing the feeding point of the antenna element is located on the radial line rotated 45° as shown in Fig. 2. The AR of the antenna is obtained by adjusting the ratio (r) of the length of the major axis (a) to the minor axis (b) of the elliptical patch. The best circular polarization of the antenna can be attained for a ratio of 1.031 [6]. In other hand, the main beam is tilted by changing the phase between the array elements. The phase shifting is obtained by varying the length (ΔL) of the antenna feed line [7]. In this design, the 20° beam tilted can be achieved for the ΔL is around 42 mm.

In this work, the proposed antenna is designed on two layers substrate (NPC-H220A, Nippon Pillar) having a thickness of 1.6 mm, the dielectric constant of 2.17 and loss tangent of 0.0005. The proximity feed is employed in the proposed antenna and optimized using the method of moment (MoM) by assuming a finite ground plane model.

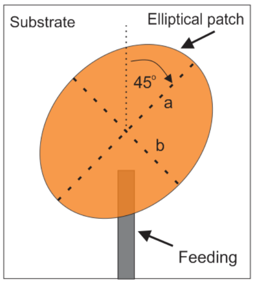

Fig. 2. Elliptical microstrip antenna.

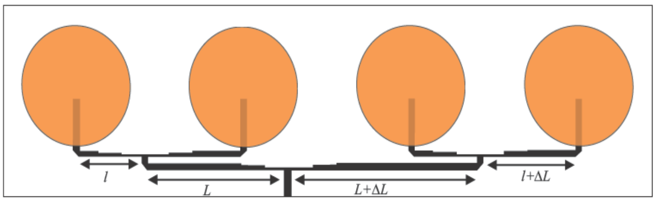

Fig. 3. Geometry design of the proposed antenna.

3. Results and Discussion

The reflection coefficient (S_{11}) of the proposed antenna is plotted in Fig. 4. The simulated curve is exhibiting reflection minimum around 26.28 dB at 1.32 GHz. The simulated value of the 10-dB impedance bandwidth is 105 MHz, approximately 8.3% of the resonance frequency of 1.27 GHz. The relation between the AR and frequency is plotted in Fig. 5, showing the polarization characteristics of the simulated antenna. The 3-dB AR bandwidth achieved at the direction of = 0 (i.e., the AUT is set perpendicular to the standard antenna) is about 11.2 MHz, which corresponds to 0.9% of the operating frequency of 1.27 GHz.

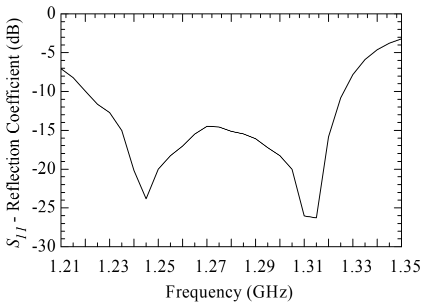

Fig. 4. Reflection coefficient plotted as a function of frequency

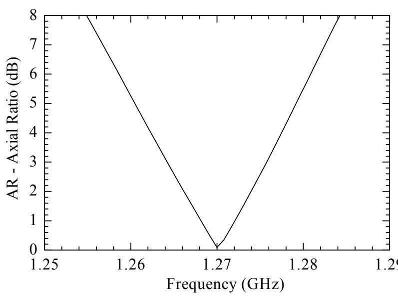

Fig. 5. Axial ratio plotted as a function of frequency of the elliptical patch.

Fig. 6 shows the radiation characteristics produced from the array antenna in the theta plane. As shown in Fig. 6, the main beam of the radiation is tilted to the angle 20°. The peak gain from the simulation is 11.15 dBic with a half power (3-dB) beamwidth of around 32 °.

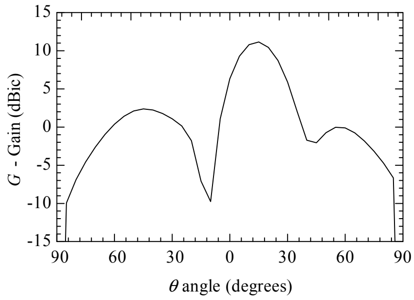

Fig. 6. Array antenna characteristics in the theta plane (negative theta for Az = 180° and positive for Az = 0°) (*x-z* plane) at 1.27 GHz.

4. Conclusion

The design of tilted beam circularly polarized microstrip antenna has been presented in this paper that operates at L-band 1.27 GHz. The good CP performance has been attained over a 3-dB axial ratio bandwidth of around 105 MHz (8.3%), with a fairly high gain in the operating band. In addition, the main beam of the antenna radiation is pointed about 20°. In general, the simulated result performance in terms of return losses, axial ratio, and radiation patterns, satisfy the requirements for the CP-SAR sensor onboard UAV. In the future work, the fabrication of the antenna will be realized.

Acknowledgment

The authors would like to thank Directorate General of Higher Education (DIKTI), Ministry of Research, Technology and Higher Education, Indonesia, for the Research Grant (Hibah Bersaing 2015), No. 210/UN35.2/PG/2015.

References

[1] A. Freeman and S. Saatchi, "On the detection of Faraday rotation in linearly polarized, L-Band SAR backscatter signature", *IEEE Transactions on Geoscience and Remote Sensing*, vol. 42, no. 8, pp. 16071616, 2004.

[2] D.M. Le Vine, S.D. Jacob, E.P. Dinnat, P. de Matthaeis, S. Abraham, "The influence of antenna pattern on Faraday rotation in remote sensing at L-band", *IEEE Trans on Geoscience and Remote Sensing*:45:2737-2746, 2007.

[3] Yohandri, Sri Sumantyo, J.T. and H. Kuze, "A new triple proximity-fed circularly polarized microstrip antenna", *AEU - International Journal of Electronics and Communications*, 66(5), pp. 395-400, 2012.

[4] Yohandri, V. Wissan, I. Firmansyah, P. Rizki Akbar, J.T. Sri Sumantyo, and H. Kuze, "Development of circularly polarized array antenna for synthetic aperture radar sensor installed on UAV", *Progress in Electromagnetics Research C*, 19, pp. 119-133, 2011.

[5] Yohandri, J.T. Sri Sumantyo, and H. Kuze, "Circularly polarized array antennas for synthetic aperture radar", *Progress in Electromagnetics Research Symposium*, 2011, Suzhou, China, pp. 583-586.

[6] M. Husein, Yohandri, S.S. Josaphat Tetuko and Y. Ashraf, "A low sidelobe level of circularly polarized microstrip array antenna for CP-SAR sensor", *Journal of Electromagnetic Waves and Applications*, Volume 27, Issue 15, 2013.

[7] S.J. Ehmouda, Z. Briqech, and A. Amer, "Microstrip phased array antenna world", *Academy of science, engineering and technology*, Vol 49, Pages 319-323, 2009.