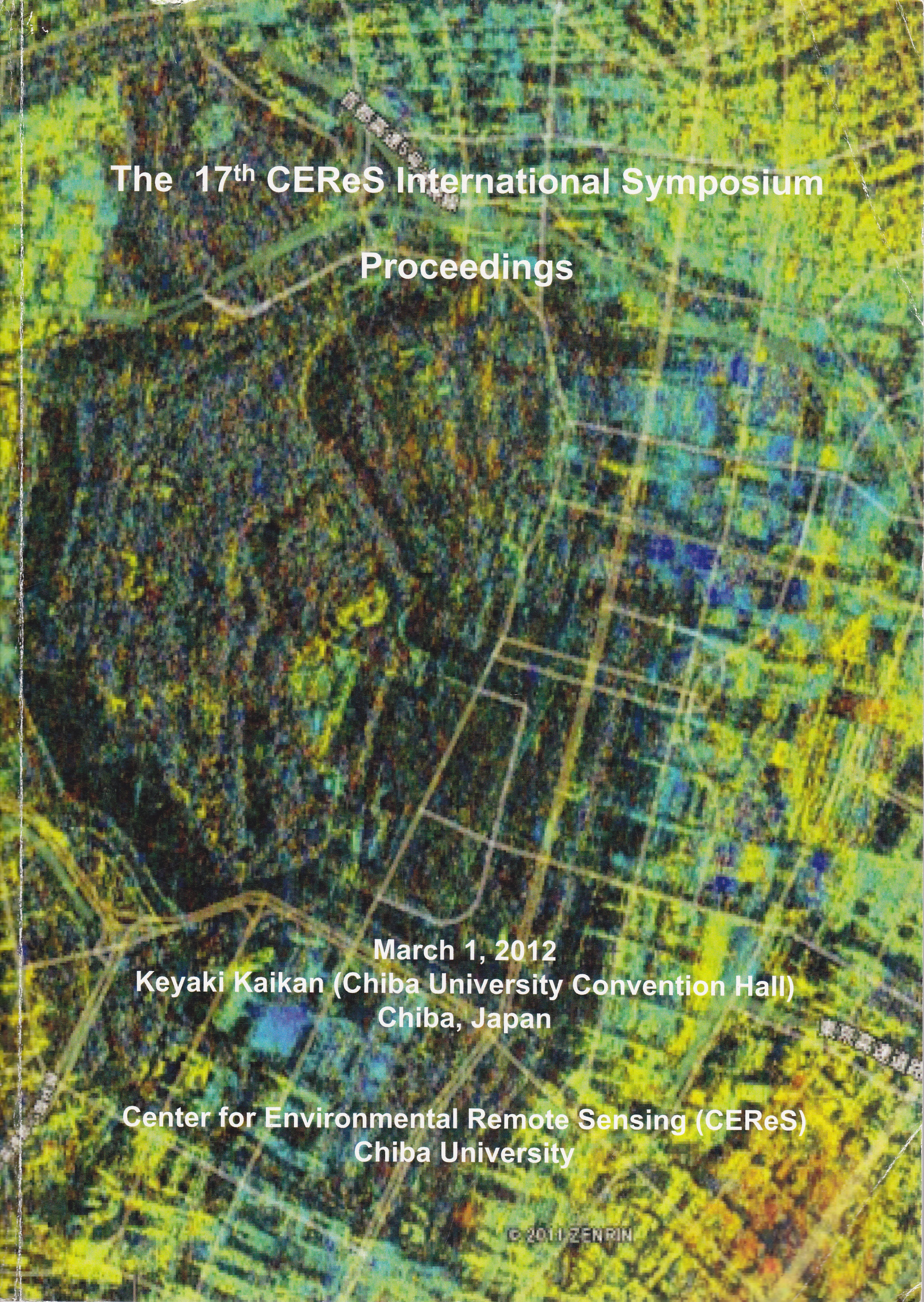

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Design of a Broadband Antenna for CP-SAR Installed on Unmanned Aerial Vehicle

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Abstract

A broadband antenna for circularly polarized synthetic aperture radar (CP-SAR) sensor has been designed. This L-band sensor is projected to reduce the Faraday rotation effect and generate the axial ratio image (ARI), which is a new data that expectantly will reveal unique various backscattering characteristics. The sensor will be installed onboard unmanned aerial vehicle (UAV) which will be aimed for fundamental research and applications. To satisfy the requirements of the CP-SAR system onboard UAV, a new broadband microstrip antenna design is presented in this paper. The finite-element method is employed for optimizing the design and achieving a good circular polarization at the center frequency of 1.27 GHz. The broadband axial ratio bandwidth and reasonable gain indicate that this antenna is promising for the CP-SAR sensor. This research will contribute to the field of radar for remote-sensing technology.

Keywords: Synthetic aperture radar, Circular polarization, Broadband antenna

1. Introduction

The role of Synthetic Aperture Radar (SAR) is critical in currently remote-sensing applications due to ability penetrate the cloud, operate in all-weather condition at night and day time. Various applications of SAR data can be found in many areas such as for determination land subsidence [1], volume change estimation of land deformation [2] and, etc.. However, the today SAR with linear polarization has limited information data, which consists of amplitude and phase. To obtain a more thorough measurement data, a SAR sensor with more information will be contributed. Hence, we propose the new SAR system called Circularly Polarized Synthetic Aperture Radar (CP-SAR).

A CP-SAR sensor is projected to generate the axial ratio image, which is a new data that expectantly will reveal unique various backscattering characteristics. In other hands, the CP-SAR sensor also can be applied to reduce the Faraday rotation effect occurring in linear polarization when propagates through the ionosphere [3-5]. The L-band (1.27 GHz) CP-SAR sensor will be installed on an unmanned aerial vehicle (UAV). In UAV experiment, the microwave signal from UAV platform is transmitted by either the left-hand or right-hand circularly polarized (LHCP or RHCP) antenna. The backscattering signal from the target is captured by both the LHCP and RHCP antennas to generate the axial ratio image (see Figure 1). The CP-SAR parameters, including size, weight, power consumption, etc. have been thoroughly considered to achieve the CP-SAR measurement while maintaining the aerodynamic stability of the UAV system. This sensor is intended for several targets such as land cover and snow cover mapping, oceanography, and disaster monitoring.

To realize this CP-SAR sensor, the link budget calculation of the system has been done in the Microwave Remote Sensing Laboratory (MRSL), Chiba University. The key parameters of the system are presented as listed in Table 1. Based on these parameters, the CP-SAR system and a circularly polarized (CP) antenna are designed.

In previous research, a number of CP microstrip antennas for CP-SAR have been developed [6-10]. Nonetheless, the axial ratio bandwidth of these antennas is quite narrow (≤ 1%). In CP-SAR system onboard UAV, the broadband axial ratio antenna is required to maintain the fine resolutions of the sensor. Therefore, the purpose of the present paper is to describe the design of a broadband CP microstrip antenna for CP-SAR installed on UAV.

2. CP-SAR Sensor System and UAV

Generally, the major parts of the sensor system are composed of a transmitter (Tx), a receiver (Rx) and antennas. The transmitter sub-system consists of a chirp generator, band - pass filters (BPF), an up-converter, a

Table 1 The key antenna parameters for CP-SAR sensor onboard UAV[11].

Parameters	Specification
Frequency center (GHz)	1.27
Pulse Bandwidth (MHz)	233.31
Axial ratio (dB)	≤3
Antenna efficiency	>80%
Antenna gain (dBic)	14.32
Azimuth beamwidth	6.77°
Elevation beamwidth	3.57° - 31.02°
Antenna size (m)	1.5 x 0.4
Polarization (Tx/Rx)	RHCP + LHCP

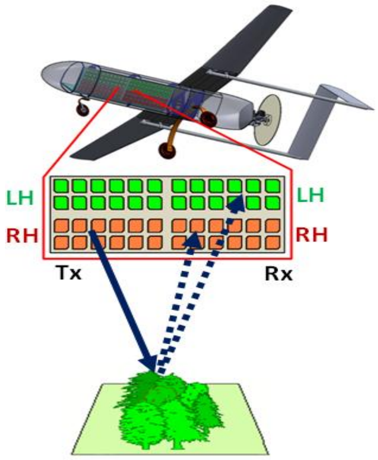

Fig. 1 Transmitting and receiving signal on UAV.

power amplifier (PA), a local oscillator (LO), and a switch that chooses either the LHCP or RHCP transmitted from the UAV platform. Thus, the receiver sub-system is capable of processing both the LHCP and RHCP signals simultaneously. Major components of the receiver subsystem are a low-noise amplifier (LNA), two BPFs, two I/Q demodulators, 4 channel analog to digital converters (ADCs) and a data recorder (memory).

The UAV platform has 4.75 m main body length and 6 m wingspan, with a maximum payload of 25 kg. General specifications of the UAV are described in Table 2.

Table 2 General specification of the UAV.

Parameters	Specification
Payload (kg)	20-25
Endurance (hrs)	4-6
Altitude (m)	1000-4000
Speed (km/h)	100-120

3. Antenna Geometry Design

The geometry of the proposed antenna is shown in Figure 2, where Figure 4(a) gives the top and side view structure, and 4(b) show the 3D view of the antenna structure. The circular microstrip antenna is designed on two layers substrate (NPC-H220A, Nippon Pillar) having a permittivity $\varepsilon_r = 2.17$ and a loss tangent $\delta = 0.0005$. In addition, to obtain a broadband antenna, a Wilkinson power divider is implemented on the feed structure.

The proposed antenna is optimized using Ansoft High Frequency Structure Simulator (HFSS). Based on the simulated result, the optimum geometry parameters of the antenna are the following: L = 148 mm, W = 124 mm, h = 1.60 mm, W_f = 4.70 mm, L_f = 40.0 mm, R = 46.0 mm, R_f = 25.7 mm, and d = 17.7 mm.

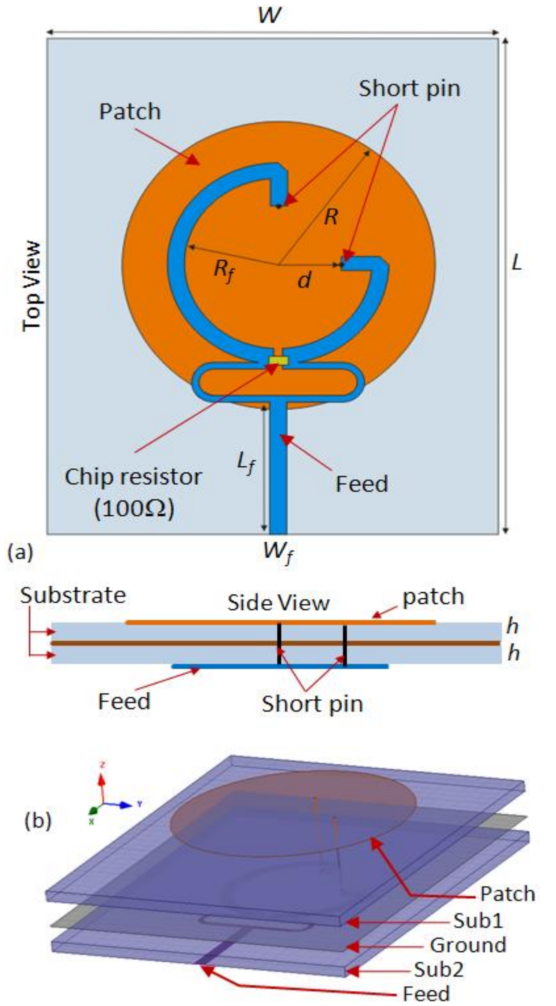

Fig. 2 Geometry design of the proposed antenna: (a) Top and side view, and (b) 3D view.

4. Simulation Results and Discussion

Figures 3 to 8 shows the reflection coefficient (S_{11}), axial ratio (*AR*), gain (*G*), and radiation pattern of the antenna. The broadband CP antenna characteristic can be achieved as shown in Fig. 4.

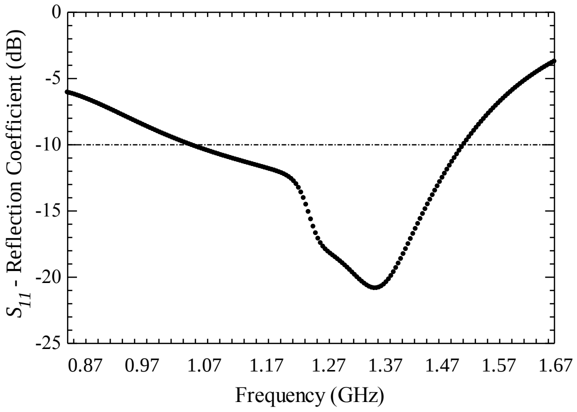

Fig. 3 Reflection coefficient plotted as a function of frequency.

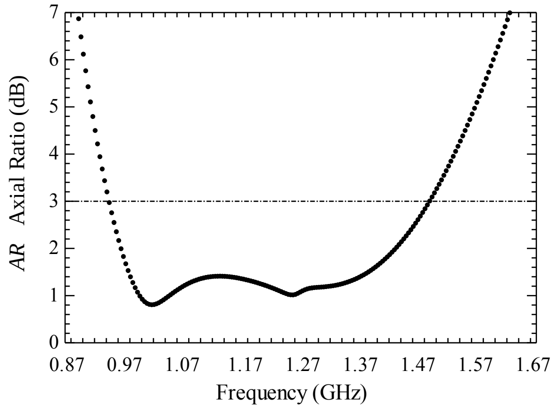

Fig. 4 Axial ratio (*AR*) plotted as a function of frequency.

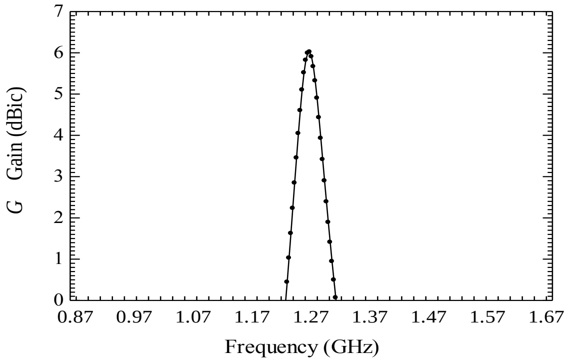

Fig. 5 Relationship between antenna gain and frequency at θ angle = 0^o.

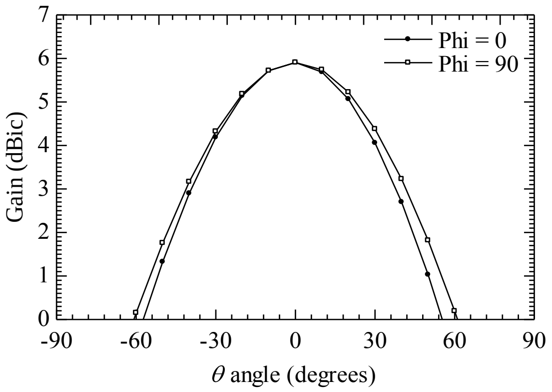

Fig. 6 Radiation pattern of the antenna at *f* = 1.27 GHz.

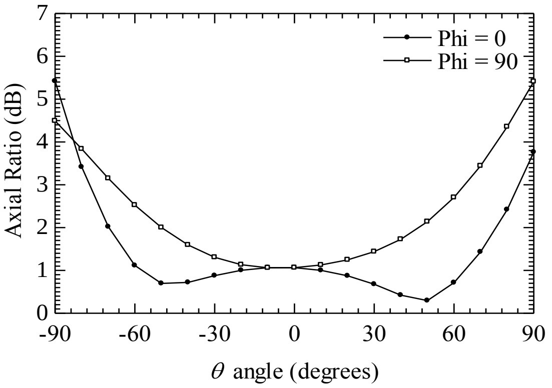

Fig. 7 Axial ratio plotted as a function of theta angle.

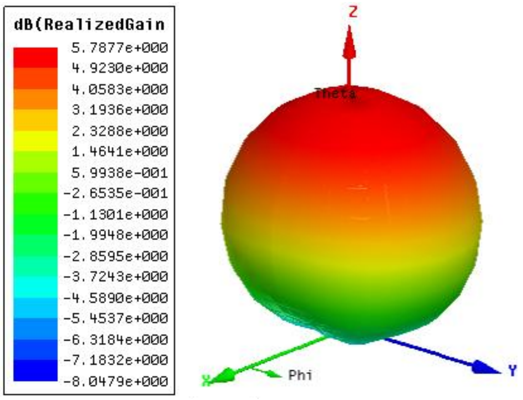

Fig. 8 A 3D beampattern of the antenna at *f* = 1.27 GHz.

5. Summary

The design of a broadband antenna for CP-SAR sensor onboard an unmanned aerial vehicle has been presented in this paper. The good CP performance has been attained over a 3-dB axial ratio bandwidth of around 540 MHz (42.5%), with fairly high gain of about 6.02 dBic in the operating band (1.27 GHz). In general, the simulated result performance in terms of return losses, axial ratio, and radiation patterns, mostly satisfy the requirements for the CP-SAR sensor onboard UAV. In the future work, the fabrication and array configuration of the broadband antenna will be realized and installed onboard UAV.

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