THE DEVELOPMENT OF CIRCULARLY POLARIZED SYNTHETIC APERTURE RADAR SENSOR MOUNTED ON UNMANNED AERIAL VEHICLE

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ABSTRACT This paper describes the development of a circularly polarized microstrip antenna, as a part of the Circularly Polarized Synthetic Aperture Radar (CP-SAR) sensor which is currently under developed at the Microwave Remote Sensing Laboratory (MRSL) in Chiba University. CP-SAR is a new type of sensor developed for the purpose of remote sensing. With this sensor, lower-noise data/image will be obtained due to the absence of depolarization problems from propagation encounter in linearly polarized synthetic aperture radar. As well the data/images obtained will be investigated as the Axial Ratio Image (ARI), which is a new data that hopefully will reveal unique various backscattering characteristics. The sensor will be mounted on an Unmanned Aerial Vehicle (UAV) which will be aimed for fundamental research and applications. The microstrip antenna works in the frequency of 1.27 GHz (L-Band). The microstrip antenna utilized the proximity-coupled method of feeding. Initially, the optimization process of the single patch antenna design involving modifying the microstrip line feed to yield a high gain (above 5 dBi) and low return loss (below -10 dB). A minimum of 10 MHz bandwidth is targeted at below 3 dB of Axial Ratio for the circularly polarized antenna. A planar array from the single patch is formed next. Consideration for the array design is the beam radiation pattern in the azimuth and elevation plane which is specified based on the electrical and mechanical constraints of the UAV CP-SAR system. This research will contribute in the field of radar for remote sensing technology. The potential application is for landcover, disaster monitoring, snow cover, and oceanography mapping.

KEY WORDS: synthetic aperture radar, circular polarization, microstrip antenna

1. INTRODUCTION

Microwave Remote Sensing Laboratory (MRSL) in Chiba University is currently developing a Circularly Polarized Synthetic Aperture Radar (CP-SAR) onboard microsatellite system. Synthetic Aperture Radar (SAR) is a multipurpose sensor that can be operated in all-weather and day-night time. As a part of the project, a CP-SAR airborne development is also developed in order to gain sufficient knowledge in SAR sensor design to support the microsatellite CP-SAR project. The radar will be designed to be operable on an Unmanned Air Vehicle (UAV). The UAV CP-SAR is an airborne SAR system, employing circular polarization microwave sensing which operating at L-band.

Historically, synthetic aperture radars (SAR) have used linearly polarized (LP) antenna systems. However, there are limitations due to the propagation phenomenon namely the variation of geometric differences between earth and the radar, the occurrence of a phase shift as a result of radio wave strike the smooth reflective surface, etc. These phenomenon leads to a backscatter variation, random redistribution of returned signal-energy and in the end the formed image would encounter a spatially variant blurring and defocusing as well as ambiguous identification of different low-backscatter features in a scene.

With the development of Circularly Polarized Synthetic Aperture Radar (CP-SAR) those problems can be overcome and therefore a greater amount of information about scenes and targets being imaged can be provided. The work on antenna system in this paper focuses on the design of an L-band CP-SAR antenna, which must considering the SAR system requirements to achieve an excellent performance of overall CP-SAR systems. Currently the stage of this work is optimizing the single element patch and array designing as well as array configuration analysis.

2. CIRCULARLY POLARIZED SAR ANTENNA REQUIREMENTS

The capability of SAR antenna systems has key impact on system sensitivity, spatial resolution in range and azimuth, image, ambiguities, and swath coverage (Pokuls, 1998). Table 1 shows the specifications and targets desired from CP-SAR which influence the specification of the L-Band CP-SAR antenna.

Table 1. Specification of CP-SAR Onboard Unmanned Aerial Vehicle

Parameter	Specification
Frequency f	1.27 GHz (L band)
Chirp bandwidth Δf	10 MHz
Polarization	Transmitter : RHCP Receiver : RHCP + LHCP
Gain G	> 20 dBic
Axial ratio AR	< 3 dB (main beam)
Antenna size	1.75 m (azimuth) 0.5 m (range)
Beam width	8° (azimuth) 25° (range)
Altitude range	3,000 – 10,000 m
Power	300 W

Frequency 1.27 GHz (L-band) was selected for the development reported in this paper. There are demands and challenges in terms of design as a relative large dimension of microstrip patch element to be proposed and design. The required system-range resolution and look angle determine the antenna bandwidth. The bandwidth requirement for this CP-SAR system is 10 MHz or less than 1% in the center frequency of 1.27 GHz. This bandwidth requirement must contain in below 3 dB of Axial Ratio to be able to propagate the circularly polarized wave. To satisfy the matching of input impedance, the return loss must be better than 10 dB in this bandwidth range.

3. CP-SAR ANTENNA CONCEPT ANALYSIS

The primary considerations in the design and fabrication process are low cost, light weight and ease of manufacturing. The CP-SAR antenna is conceived in the way that every single element microstrip patch is a circularly polarized antenna. Feed network will be implemented in different layer substrate as the feeding method is proximity coupled.

The array configuration is planar array since this type of array is extensively used in radar systems where a narrow pencil beam is necessary (Garg, 2001). A better control of beam shape and position in space can be achieved by correctly arranging the elements along a rectangular grid to form a planar array. The antenna gain is mostly determined by the aperture size and interelement separation.

4. ANALYSIS AND DESIGN OF RADIATING ELEMENTS

The configuration of a single equilateral triangular patch is shown in Figure 1. This based on the previous work on the circularly polarized antenna for mobile communication (Sri Sumantyo, 2003). The substrate with relative permittivity $\varepsilon_r = 2.17$ and loss tan $\delta = 0.0006$ is utilized at both radiator and feed layer substrate. Microstrip line is employed as the feed line. This radiator will generate a left-handed circular polarization (LHCP), by employing dual feed method, and to make one of the two modes having 90° phase delay, one of the line feeds is approximately $\lambda/4$ longer than the other.

Simulations to achieve an optimum model with a finite ground plane have been conducted using a full wave analysis tools employing method of moment (MoM) (IE3D Zeland software). Figure 2 shows the result of the IE3D antenna simulation. The input reflection coefficient (S11) are better than -10 dB over a bandwidth of 28 MHz, however, improvement is still have to be made on the Axial Ratio bandwidth is only 7.5 MHz.

The single element patches which have been optimized are then spatially distributed to form planar array (see Figure 3 for illustration), in which the elements are distributed on a plane.

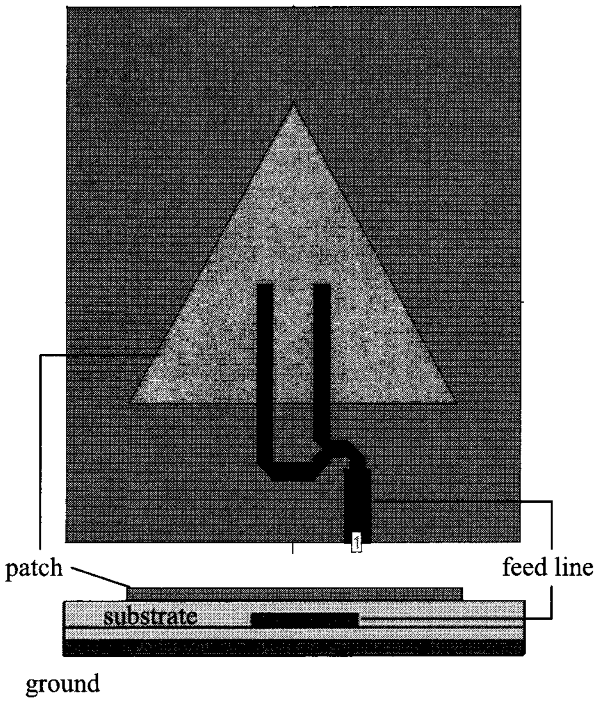


Figure 1. Configuration of single triangular patch antenna with proximity coupled feed ; top view and side view

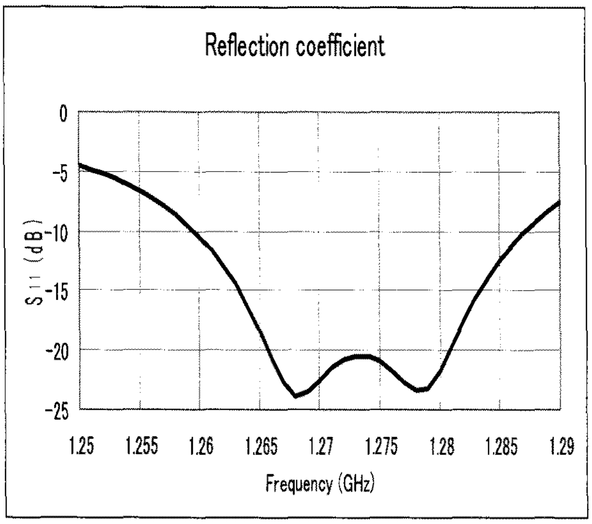
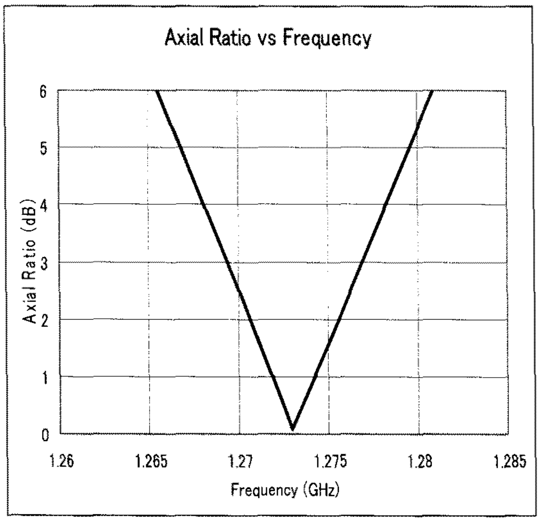


Figure 2. (a) Reflection coefficient vs frequency graph



(b) Axial Ratio vs frequency graph ; both are the results of the single element microstrip patch numerical analysis using IE3D

The feeding employed for the array is parallel or corporate feeding. The parallel feed has a single input port and multiple feed lines in parallel constituting the output ports. Each of these feed lines is terminated at an individual radiating element. Concept of the feed network layout proposed is the n × n microstrip arrays with a power dividing network, with the basic building block is the 2 × 2 "H" shaped feed network (Levine, 1989). Constructions of a larger array can be applied by combining the "H" networks.

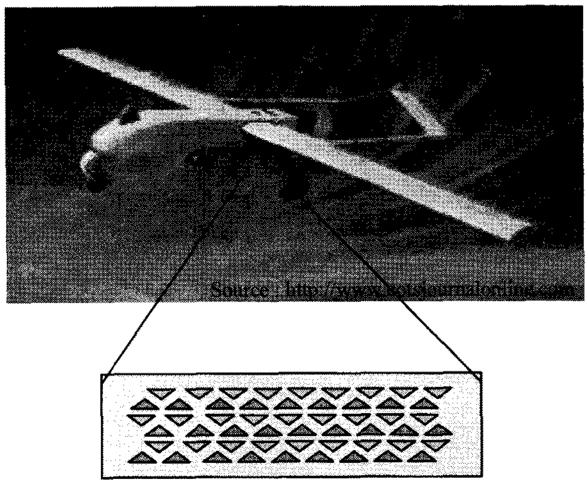


Figure 3. Illustration of CP-SAR Antenna implemented in CP-SAR microsatellite with elements arranged in the antenna array panel

To maximize the array performance, certain characteristics of feed networks have to be taken into account. These are the conductor and dielectric losses, surface wave loss, and spurious radiation due to discontinuities such as bends, junctions, and transitions (Garg, 2001). The loss due to the coupling of the adjacent element have to considered, therefore isolation between adjacent elements must be higher than 20 dB. The spacing between elements is measured as the distance between the midpoints of each element. A maximum directivity will occur for approximately spacing between elements in the range of 0.8 – 0.9 times the free space wavelength (Levine, 1989).

6. CONCLUSION

A circularly polarized antenna is developed for implementing antenna for circularly polarized synthetic aperture radar (CP-SAR) in L-band. Optimization process for the single patch and layout considerations for the array and feeding network has been investigated to realize the SAR antenna. Further exploration and research is necessary in order to meet the target and specification for the CP-SAR system. The near optimization research and work is to increase the axial ratio bandwidth characteristic of the patch antenna element.

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