A Wide-Band Dual-Polarized VHF Microstrip Antenna for Global Sensing of Sea Ice Thickness*

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Abstract – A VHF microstrip patch antenna was developed to achieve a bandwidth of 45 MHz (30%) from 127 MHz to 172 MHz with dual-linear-polarization capability. This microstrip antenna used foam substrates and dual stacked patches with capacitive probe feeds to achieve wide bandwidth. Four such capacitive feeds were used to achieve dual polarizations with less than –20 dB of cross-polarization level. Twenty-four shorting pins were used on the lower patch to achieve acceptable isolation between the four feed probes. This antenna has a measured gain of 8.5 dB at 137 MHz and 10 dB at 162 MHz. By using the Method of Moments technique, multipath scattering patterns were calculated when the antenna is mounted on the outside of a Twin Otter aircraft.

Introduction - In order to address a key science goal of understanding the global sea ice thickness and snow characteristics, NASA/JPL is investigating a spaceborne Synthetic Aperture Radar (SAR) to operate simultaneously at two widely separated frequency bands: VHF and Ku-band. VHF is for the sea ice thickness (0.5 – 8m), while the Ku-band is for the snow detection (snow pack structure and water content). Both the spatial and frequency domain interferometry techniques will be utilized in this radar system [1]. The spatial interferometry is for separating different boundary surfaces from the volume scattering, while the frequency interferometry is for determining the positions of surface boundaries. Prior to the implementation of the spaceborne system, a field experiment with an aircraft radar is needed to validate this proposed radar system. This paper presents the VHF antenna developments for the aircraft sea-ice radar.

For the sea ice thickness measurement, the aircraft radar system requires a compact low-gain VHF antenna that has a wide bandwidth (30%) to provide frequency coverage from 127 MHz to 172 MHz with dual-linear-polarization. The antenna selected is a dual-stacked-patch for low-mass and compact size considerations. Low-dielectric-constant foam is used as the substrate material. The moment method based computer software, Ensemble, was used to perform the antenna analysis and design. To achieve the wide bandwidth, the dual-stacked patches [2] with relatively thicker substrates and low dielectric constant foam material were used. Capacitive feed probes [3] were used on the lower patch to assist the achievement of wide bandwidth. Four, instead of two, such feed probes [4] were employed to suppress higher-order modes that occurred in the relatively thick substrate in order to yield the required –20dB cross-pol levels. Each pair of oppositely located feed probes was excited with 0° and 180° phases to achieve such higher-order-mode suppression. However, it was found, by using such four feed probes with thick substrates, there exists a large amount of coupling (≈ -5 dB) between the two oppositely-located feed probes. This large coupling, not only worsens the input return loss, but also wastes a large amount of input power and, hence, makes the antenna less efficient. To reduce the amount of coupling, many shorting pins were placed between the bottom ground plane and the lower patch. It was found that the more the

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shorting pins the less the coupling. However, as the number of shorting pins increases, the antenna bandwidth starts to decrease. After a trade-off study, a total of 24 shorting pins (12 for each polarization) was determined to be optimum for this application.

Antenna Design - The dual-stacked-patch configuration is shown in Fig. 1, where the capacitive probe feed is exciting the bottom patch directly and the top patch is being parasitically excited. The top square patch has a dimension of 69.3cm and the bottom patch is a 76.2cm square. There are four capacitive feed probes with each being a square patch of 6.35cm in dimension. Each probe is located 25.4cm from the antenna center and its capacitive patch is spaced 1.4cm from the bottom radiator patch. The capacitive patch is used to provide proper capacitance for canceling the excessive inductance introduced in the relatively thick substrate. As shown in Fig. 2, low dielectric constant ($\varepsilon_r \approx 1.05$) foam material is used throughout the antenna as a supporting structure for the patches. The bottom patch is separated 16.5cm from the finite-size (117cm-square) ground plane, while the top patch is separated 10.2cm from the bottom patch. A shorting pin is soldered to both radiating patches and the ground plane at center of the antenna to suppress undesirable higher-order modes. An additional twenty-four shorting pins, as shown in Fig. 3, are used to reduce coupling between each two oppositely located feed probes. These shorting pins are used only between the bottom patch and the ground plane. To excite the four feed probes, two 180° hybrids are used with each exciting two oppositely located probes.

Test Results – The measured and calculated input return loss of each feed probe are given in Fig. 4 where the measured result clearly indicates a double-resonance with a –9.6dB (VSWR=2:1) bandwidth of 42 MHz. Although it did not quite meet the required 45 MHz bandwidth, it is considered acceptable to the radar system. The measured and calculated E-plane and H-plane patterns of the antenna at the frequencies of 137 MHz and 162 MHz are shown in Fig. 5 where acceptable measured cross-pol levels are shown. The predicted patterns, using Ensmble software, were calculated with an infinite-size ground plane, which can only yield data within the angular region of ±90° and are accurate only within ±75°. Nevertheless, the measurement and calculation agree very well within the angular region of ±75°. The measured antenna gain is 8.5 dB at 137 MHz and 10.0 dB at 162 MHz. From the measured radiation patterns, it can be noticed that the backlobe level of the antenna is quite high (≈ -10dB), which could cause large amount of mutipath scattering from the outside structures of the aircraft. The Moment Method was used to simulate the multipath scattering effect of the antenna when it is mounted onto a Twin Otter aircraft as illustrated in Fig. 6. Fig. 7 gives the calculated 3-D radiation patterns of the antenna when it is by itself and when it is mounted on the aircraft. The aircraft does give some pattern effect to the antenna, such as a few decibels of ripple variation on the main beam. More detailed scattering patterns will be given during the conference presentation.

References:

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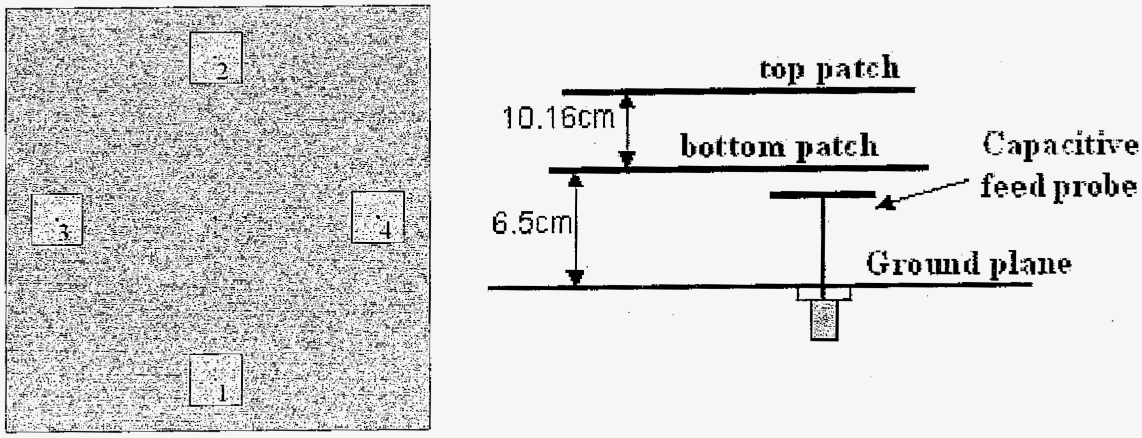

Figure 1. Top and side views of the dual-stacked-patch configuration.

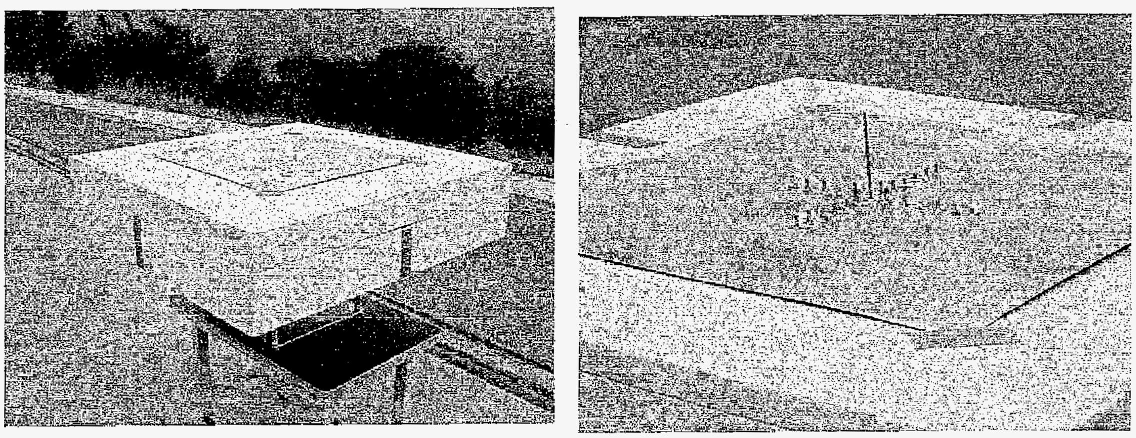

Figure 2. Left photo showing the top patch and the right photo showing the bottom patch with the top patch removed. .

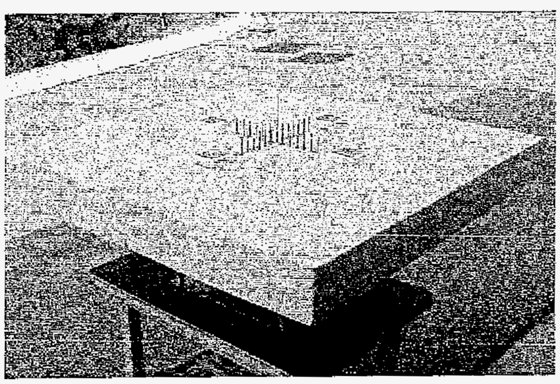

Figure 3. Photo showing all shorting pins and all capacitive feed probes with the top radiating patch removed.

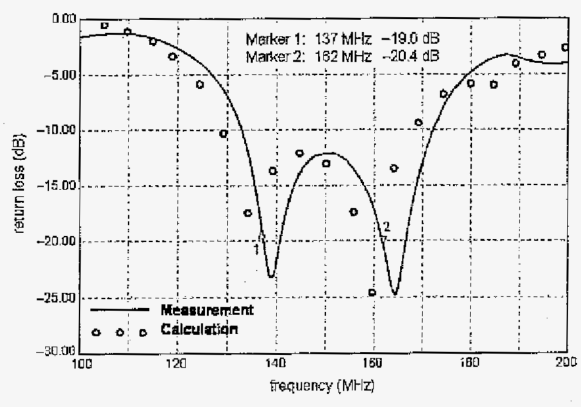

Figure 4. Measured and calculated antenna input return loss.

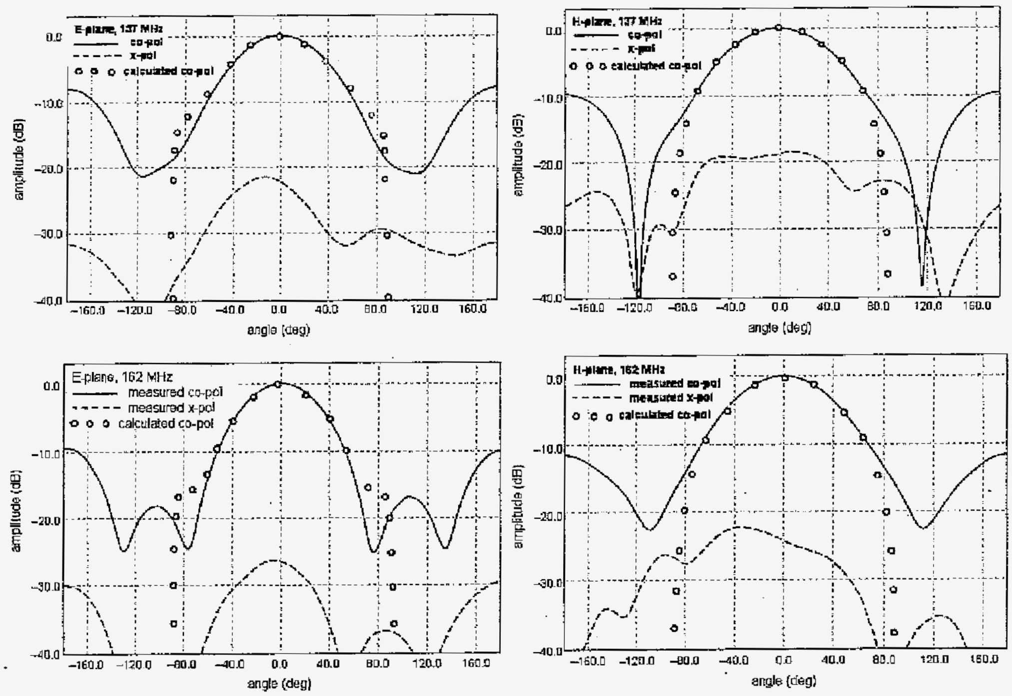

Figure 5. Measured and calculated E-plane and H-plane patterns at 137 MHz and 162 MHz.

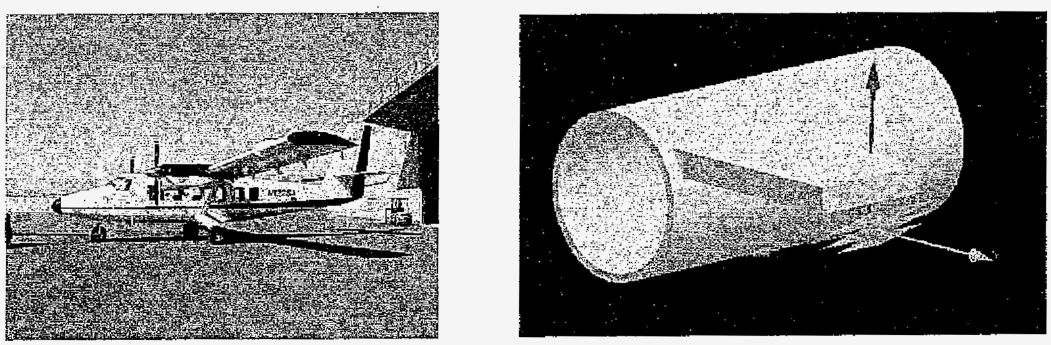

Figure 6. Twin-Otter aircraft (left) and the computer simulation model (right).

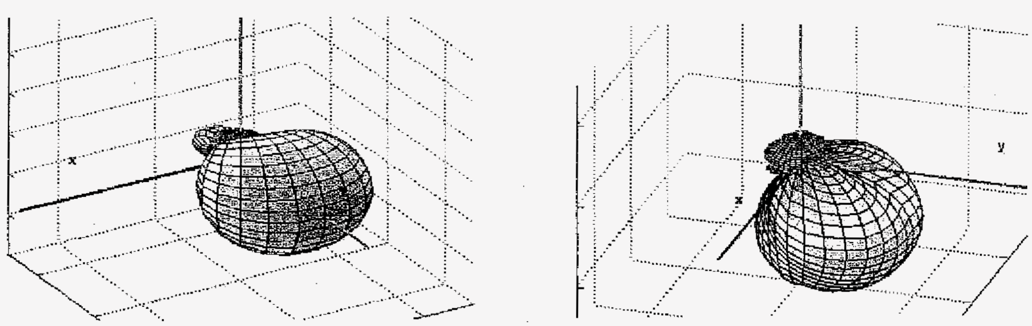

Figure 7. Simulated 3-D pattern of the antenna by itself (left) and when the antenna is mounted on the aircraft as shown in Fig. 6.