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Microstrip Antenna for Polarimetric C-band SAR

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Abstract

This paper outlines the design and the measured performance of a 224-element dual-linearly polarized microstrip array antenna with low cross-polarization. The array is currently being flown on the Danish high-resolution polarimetric C-band synthetic aperture radar (SAR) [1,2].

Design

The antenna design is based on the work presented in [3]. The antenna size is 1.3 x 0.31 x 0.15 m (LxHxD), and consists of 4 identical panels (fig. 1). Each panel contains 56 microstrip patches, organized as 7 identical linear sub-arrays, each with 8 probe-fed patches.

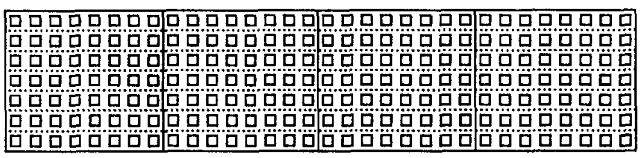

Fig. 1. Antenna, front view.

The patch configuration is shown in fig. 2.

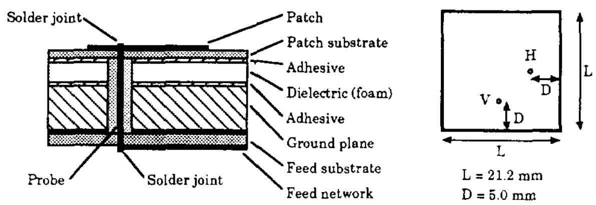

Fig. 2. Patch configuration, cross section and top view.

The patch is a square with side lengths L = 21.2 mm. It is fed using one probe, offset D = 5 mm from the edge, for each polarization. It is etched on a 0.381 mm Rogers RT/duroid 5870 substrate. The patch substrate is mounted on a 2.0 mm Rohacell 31 HF low permittivity (ε_r = 1.05 @ 5 GHz) substrate, which again is mounted on a 3 mm silver-plated aluminum ground plane. On the other

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side of the aluminum ground plane the patch feed network, made on 0.787 mm RT/duroid 5870, is mounted.

The antenna feed-network has three levels: The patches in each 8-element sub-array are fed through a network with two 50 Ω input ports, one for the H- and one for the V-polarization (the patch feed network). The sub-arrays within a panel are fed through two identical (H/V) 7-way power splitters (the sub-array feed network), which implement the elevation beam shaping. The four panels are fed through two 4-way power splitters (the panel feed network).

The microstrip circuit, which implements the patch feed network in the 8-element linear sub-array is shown in fig. 3 (the location of the patches is also outlined). It is designed to give equal amplitude and phase excitation of all patches. The V-port network is a straightforward resonant design. In the H-port network, the 8 patches can be considered as organized in four pairs. The patches in a pair have opposite location of the feed probe, and are fed 180° out of phase to obtain the same effective patch excitation. This pair-wise antiphase feed technique has significant impact on the array performance. First, the transmission between the H- and V- ports of the feed network is practically eliminated (see fig. 6, S_{HV}), which means, that cross-polar radiation due to leakage between the antenna H- and V- ports is significantly reduced. Second, for the H-polarization, the cross-polar radiation due to the patch feed probe is reduced, because the probes in a patch pair are fed with opposite phases, and therefore cancel each other to some degree. This significantly improves the cross-polarization suppression in the elevation plane for the H-polarization.

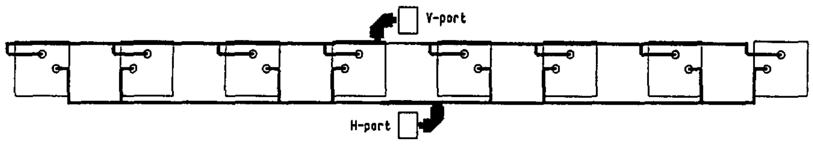

Fig. 3. Patch feed network.

The sub-array feed network is a 7 way power divider implemented in microstrip (fig. 4a). It has been designed to provide the unequal amplitude and phase excitations required to establish the elevation beam shaping, which approximates the desired modified cosec^2-pattern. The H- and V-sub-array feed networks are mounted perpendicular to the patch feed networks of a panel. The connections between the patch feed networks and sub-array feed networks use 90° microstrip E-plane transitions (fig. 4b). The return loss for these transitions is better than -30 dB.

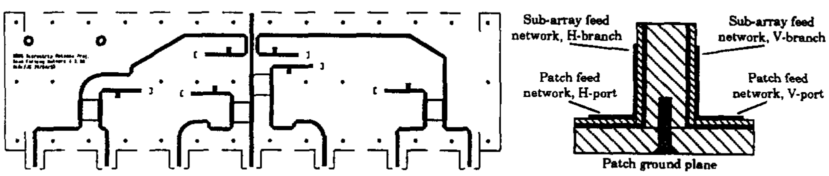

Fig. 4. Sub-array feed network. a) Layout, b) Cross section.

The panel feed network consists of two high-power stripline 4 way dividers, which are connected to the panels with coax cables. In order to improve the SAR-system azimuth-ambiguity performance, the power dividers apply a small taper to the 4 panels.

Performance

Below we have summarized the measured performance of the antenna :

- Operating frequency : 5.3 GHz ± 50 MHz
- Peak directivity : 28 dBi
- Loss : < 1.4 dB
- Cross-polarization suppression : ~ 30 dB (within the 3 dB limits of the main lobe)
- H/V tracking, magnitude : < ± 0.3 dB " "
- H/V tracking, phase : < ± 2° " "

The radiation patterns (directivity) in the azimuth ($\varphi = 0°$) and elevation ($\varphi = 90°$) planes for both polarizations are shown in fig. 5. All radiation pattern measurements shown in this paper were performed at the TUD-ESA spherical near-field test facility [4]. The radiation patterns shown are the H- and V-polarized field components according to Ludwig 3 [5]. The notation used is that E_{HV} is the V-polarized field component from an antenna fed at the H-port.

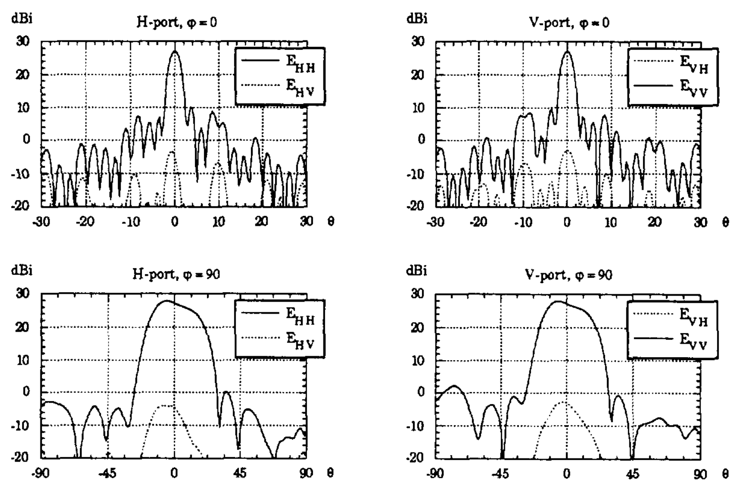

Fig. 5. Azimuth (φ=0) and elevation (φ=90) radiation patterns (5.3 GHz).

Fig. 6 shows the measured input reflection coefficients for the H- and V- ports, and the transmission between the ports.

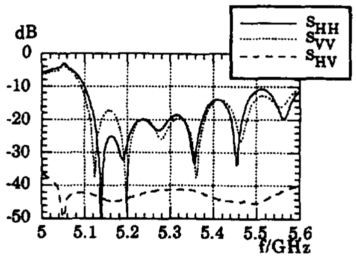

Fig. 6. Input reflection coefficients (S_{HH} and S_{VV}) and transmission (S_{HV}).

During SAR system operation the antenna is mounted in an unpressurized pod, in which the temperature at the nominal altitude of 41000 ft, is ~ -25°. The radar signal is a 2 kW peak, 60 W average alternating H- and V-polarized pulse train. No performance degradation compared to operation at laboratory conditions has been detected.

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