A Polarimetric Phased Array Antenna for E-SAR in L-Band

Markus, Limbach, German Aerospace Center, Germany
Markus, Bachmann, German Aerospace Center, Germany
Bernd, Gabler, German Aerospace Center, Germany
Ralf, Horn, German Aerospace Center, Germany

Abstract

The design of a new L-band antenna for DLR's airborne synthetic aperture radar system (E-/F-SAR) is presented. Beside operations in L-band new components for a system upgrade were developed. These components are introduced. Special interest of this paper is the development of the dual-polarized L-Band antenna with enhanced bandwidth of 150MHz. The antenna feed network is equipped with 2bit hybrid phase shifters to steer the beam between 25° and 40° in elevation. For mounting the antenna at the fuselage of a Dornier Do 228-212 aircraft a rack is described to house several antenna configurations.

1 Introduction

Growing interest in fully polarimetric fine resolution synthetic aperture radar (SAR) systems led to the development of a new L-Band subsystem for DLR's airborne E-/F-SAR system. Wider bandwidth, higher pulse power and better receiver sensitivity will give better results in image quality than existing hardware.

The co-registration of smaller and wider wavelengths, especially in forested regions, is of considerable interest. In combining X- and L-band data the differences in vegetation penetration capability depending on the wavelength are used for tree height estimation and biomass calculation. In vegetation regions L-band signals have the electromagnetic property to reach the underlying ground (see Figure 1).
In this paper the antenna design, some aspects of the new front-end and the development of a mounting rack to house the antennae outside an aircraft are described.

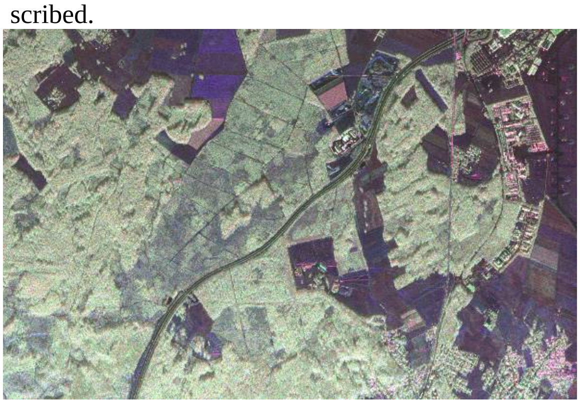

Figure 1 SAR image of forested region. Coloured composite of H- and V- channels, multi look image.

2 Antenna design

Up till now the L-band antenna, operated in the E-SAR system, is indeed polarimetric but is built of separated H polarised and V polarised arrays. The distance between both phase centres resulting in unwanted interferometric phase components and a bandwidth limit of 100MHz asked for the development of a new L-band antenna.
Increased bandwidth and a co-planar antenna array for H- and V-polarisations are the improvements compared to the previous design. At the centre frequency of 1325MHz a bandwidth of 150MHz with a low cross polarisation level is achieved. The peak power capability is 1kW per pulse. For data acquisition at different incident angles the antenna main beam is steerable from 25° to 40° off bore sight.
The antenna array consists of 24 dual polarized elements shared in 4 rows, each with 6 stacked patch resonators. Overall dimensions are 96cm in length by 50cm in width. From the conducting back plane to the outer dielectric layer the thickness is less than 4cm. This includes the backplane, giving the antenna its mechanical stability.
With controllable 2bit hybrid phase shifters in the array's feed network, the main beam can be steered in elevation between 25°and 40° off bore sight.

2.1 Single antenna element

For wideband operation aperture coupled stacked patch elements are used. Starting with simulations, Agilent's simulation software ADS 2003 was used, a first dual linearly polarised element was designed. The cross-polarisation level between the two antenna ports is better than -30dB. With a bandwidth of 220

MHz it was a good starting position for an array design (see Figure 2).
Each element has a shorting pin in the centre of the resonator were the electrical fields are zero. The “pin” is a screw of a diameter of 5mm housed in a brass tube. The tube consists of short pieces in-between the foam layers of the antenna element. All dielectric layers are metallic on either side of the holes for the pin and through plated. Thus an electrical connection from bottom to top - ground plane to radome layer - is guaranteed. If the screws are tightened the distance between the layers will not change because of the tubes.

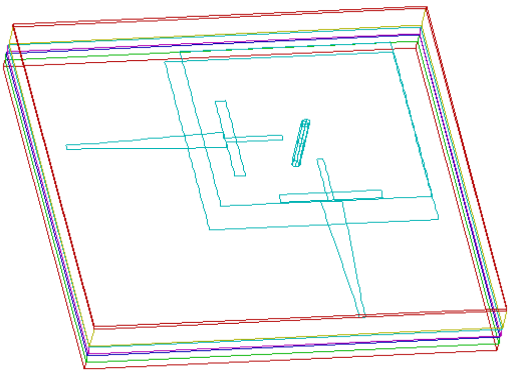

Figure 2 Single Element with shorting pin.

One column of the L-band antenna array was built up to point out the electrical beam steering capability. Far field measurements were done at the antenna free field measurement facility of DLR in Oberpfaffenhofen. In Figure 3 a cut through the far field pattern in E-field direction is shown. The elements of the column were uniformly exited. With proper weighting introduced in the final design the diagram of the array will be expected to have wider beam width and lower side lobes. As the antenna is mounted vertically on the side of the aircraft’s fuselage the energy from the side lobes is directed above the horizon and is therefore not destructive. The obtained results give reason to go further with the L-band antenna development.

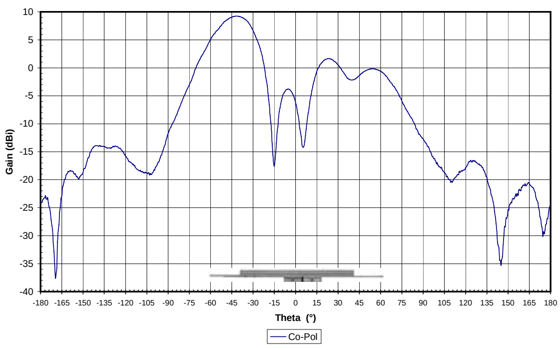

Figure 3 Far field pattern of a uniformly exited column. Showing beam position at 40° off bore sight.

A prototype of the array was manufactured with 24 elements in 4 columns each with 6 radiators. The feed network ends up in 8 ports, SMA connectors, at the rear side of the ground layer. There the beam steering network will be connected.

2.2 Hybrid Phase shifter

For use in the L-band antenna feeding network hybrid phase shifters were developed. PIN diodes are used for switching on and off open ended stubs attached to a microstrip transmission line hybrid.

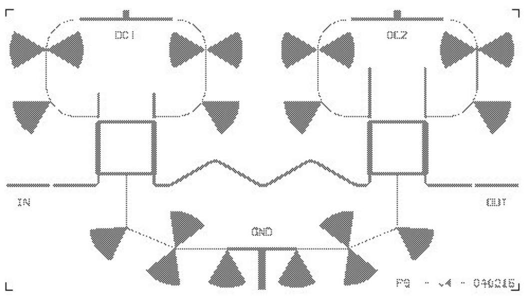

Figure 4 Hybrid phase shifter with 2bit.

The length of the stub is responsible for the phase shift. The PIN diodes offer the possibility of quick pulse to pulse switching. The layout consists of two phase shifters per row for the 4 different antenna beam positions. For proper power handling, maximum possible pulse power is 1kW, DC-voltage of 150 volt is used for PIN diode switching. Microstrip low pass filters block the RF power from DC power supply. Figure 4 displays a typical phase shifter design.

Beam position	PS1	PS2	PS3	PS4
0°	0°	0°	0°	0°
6,7°	0°	22°	44°	66°
13,3°	0°	44°	88°	132°
20°	0°	66°	132°	176°

Table 1 Phase shifter adjustment for tested beam positions, offset of 20° not included.

Each row has its own designed phase shifter, see Table 1. Starting with 0° degree phase shift for the first row the device’s only use is symmetry. The switching is controlled by a CAN module and will be synchronized with the PRF (pulse repetition frequency) for cold switching. A modified CAN-bus is used as control bus in the F-SAR system.
Only 7 wires are necessary to connect the antenna to the radar system. Three of them are coaxial wires, two for the RF signal and one for the PRF signal. The others are two wires for CAN-bus and two for DC power supply.

2.3 Antenna Array Design

The L-band antenna array consists of 24 elements. The distances between the elements in azimuth and elevation direction and the amplitude taper for both directions are designed to comply with the specified beam widths, azimuth 18° and elevation 35°. Each row has its own phase shifter adjusted to the steps in phase shift for the desired antenna beam positions.
The hardware of the phase shifting network is detached from the radiators feed network for better maintenance and measurement procedures.

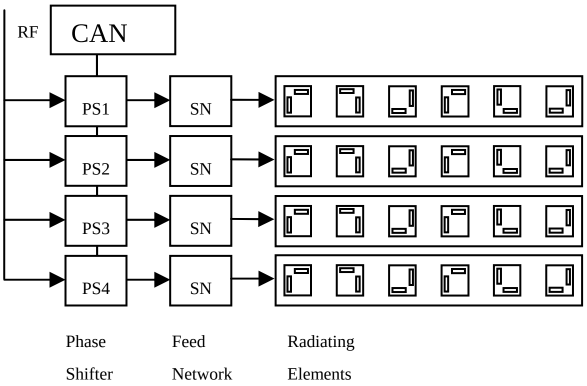

Figure 5 Block diagram of the antenna network.

As shown in Figure 4 an integrated CAN module controls the main beam positions. For power handling DC-DC converters with 150V output are integrated into the phase shifting network. Thus a minimum of connections are necessary.

As described in the development of the E-SAR's P-band antenna the orientation of the single resonators, especially their feed point positions, guarantees low cross polarisation level and high side lobe suppression [1]. We expect proper results in L-band based on P-band antenna experience [2].
With four different beam positions from 25° up to 40° off bore sight the antenna can be mounted on a side wall of the aircraft's fuselage. An antenna mount is introduced in the following chapter. The lateral mounting position permits the use of simple dielectric materials as radome layer. For a better connection between the layers the shorting pins act as screws. This indeed is required because of the antenna's large aperture of 96 to 50cm. An adhesive coated film cannot withstand the forces produced in flight on the thin TLC300 layer.
In Figure 6 the copper structures on the different layers are shown. At the position of the shorting pins each side has a metallic pad and is plated through. At the slot layer the slot orientation is visible.
The distance between the feed line network and the ground plane, shown in Figure 6, is only 8mm. CER 10, a low cost ceramic substrate is used for the microstrip line layer.
The high dielectric constant bundles the electric field and the radiation of the network is weak. Thus a significant smaller distance than a quarter of a wavelength is sufficient.

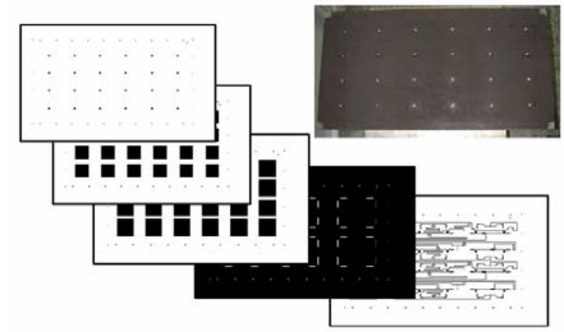

Figure 6 Layers of the L-band antenna and picture of antenna prototype.

The materials selected for the resonator are layers of TLY3, TCL300 and Rohacel foam which provides wideband operation and high efficiency around 80%. Thickness of the whole antenna, including the ground plane which is made of a 5mm aluminium plate is less than 4cm. To reduce weight the ground plane has milled edges on its bottom side.

2.3 Antenna mounting rack

For mounting antennae to the aircraft a mounting rack was designed to fix planar array antennae to the aircraft, see Figure 7.

Figure 7 New F-SAR antenna mount attached to the right hand side of the aircraft behind the wing allowing 7 antennae to be integrated.

It is configurable for up to 7 antennae in multi-frequency configuration. A complete assembly consists of: X-band (3), C-band (1), S-band (2) and L-band (1). The P-band antenna, also part of the E-/F-SAR system, is mounted under the nose of the aircraft.

One important advantage of the antenna mount will be that it is variable to changing antenna configuration and to mount different antennae avoiding individual airworthiness certification procedures the same time. In Figure 7 the structure of the antenna mount becomes obvious. One of the windows in the fuselage will be replaced by an adapter plate with coaxial and waveguide connectors. Here the connectors for CAN-bus as well as DC power supply will be placed.
The areas in the top and bottom of the antenna mount are configurable for different purposes. They can house a wide range of different antennae e.g.: 4 X-band antennae with variable base lines in the top area for MTI measurements. The place for the L-band antenna is in the middle area beneath the aircrafts windows.
The airworthiness certification is divided into a certificate for the antenna mount and small individual certificates for the antennae. Thus variable configurations are possible and time for certification will be short.

3 Conclusion

The design of the new L-band antenna for E-/F-SAR system was presented. Measured data and simulation results promise that the prototype will meet the specifications. Details of the phase shifting network were introduced and the mounting concept for the new SAR system F-SAR is shown.

References

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[2] M. Limbach, B. Gabler, R. Horn, R. Scheiber: *Fine Resolution, fully Polarimetric P-band Subsystem for E-SAR - Technique and Results* 5th EUSAR 2004, Ulm, Germany, VDE Verlag, 2004, S. 275 – 278