Proceedings of ISAP2007, Niigata, Japan

Dual-Polarized Feed-Cluster for a Reflector-based Multi-Beam SAR Antenna

Peter Koch[1], Christian Fischer[1], Mattias Viberg[2], #Cornelis van 't Klooster[3],

[1] EADS Astrium GmbH,
D-88039 Friedrichshafen, Germany, Email: peter.koch@astrium.eads.net
[2] Saab Ericsson Space AB,
SE-40515 Gothenburg, Sweden, Email: mattias.viberg@space.se
[3] European Space Agency, Estec, EEA
Keplerlaan 1, 2201AZ Noordwijk, kvtkloos@esa.int

1. Abstract

EADS Astrium GmbH and Saab Space AB have designed, developed and bread-boarded a feed-cluster subsystem for a reflector-based multiple beam SAR antenna in X-Band. Flexible active phased SAR antennas are used for wide swath coverage with Envisat and TerraSAR-X as examples. Such active phased arrays are complex and still very costly. Simpler solutions with less flexibility and less wide coverage can be provided by reflector-based SAR antennas with somewhat reduced coverage. The study and development activity under ESA contract focused on the design of such antenna and the design, development, bread-boarding and testing of a dual polarized feed-cluster. The results have been used to demonstrate accurate feasibility of the reflector-based SAR antenna design, exploiting the Multi-Pencil-Beam approach invented by EADS Astrium GmbH (Patent EP1471600). The designed dual-polarized SAR antenna allows for Stripmap and ScanSAR operation over limited angular coverage around an installable pointing direction.

2. Introduction

In Remote Sensing SAR missions the antenna system is the key element to total system performance, instrument development costs and related development risks. Customized antenna systems with features like wide swath coverage, high resolution and polarimetry – especially for X-band SAR application (9.65 GHz with 300 MHz bandwidth) – are forthcoming challenges to be encountered in current SAR missions. Wide swath coverage can be realised in ScanSAR mode with

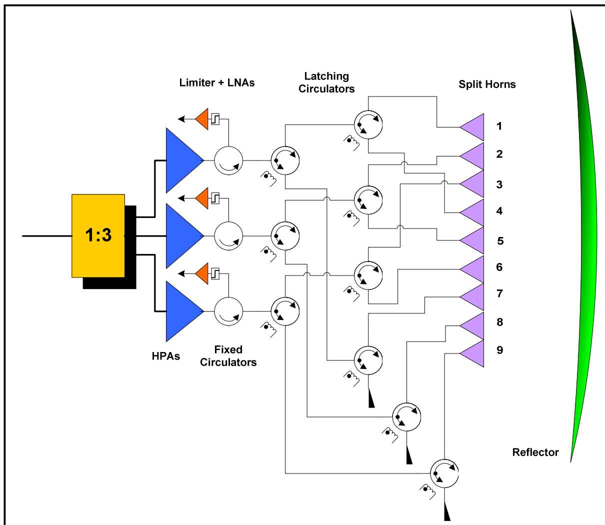

Fig. 1: 'Multi-Pencil-Beam'-Concept (Patent EP1471600)

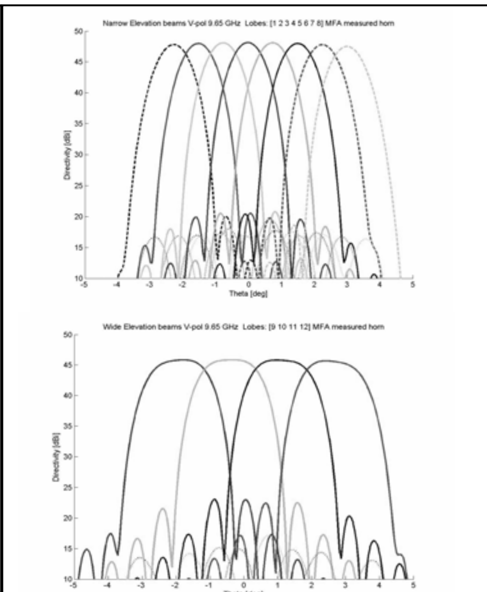

Fig. 2. Narrow and Wide Beams available.

ISBN: 978-4-88552-223-9 C3055©IEICE

the antenna beam fast switched in across track direction to sub-swath directions, when passing by. Overlapping antenna beams are operated sequentially in the elevation plane in a way that each individual beam illuminates a specific sub-swath of the total SAR image. The SAR antenna acts like a 2-dimensional spatial filter, thus requirements put on antenna azimuth patterns are important. A low azimuth sidelobe level assists to have some freedom in the instrument sensor design with overlapping and scanned elevation beams. A promising and cost effective alternative instead of an active phased array antenna is a hybrid solution based on a reflector-based SAR antenna system providing a limited number of beams in the across track direction. The Multi-Pencil-Beam-Concept can be implemented in an offset-fed reflector antenna configuration with a reflector deployment scheme known from telecommunication satellites. The beam-forming network itself consists of a circulator switch assembly driven by three high power amplifiers.

3. Multi Pencil-Beam Concept

The new so-called 'Multi-Pencil-Beam' antenna for SAR has remarkable features compared to other solutions. The multipaction risk is reduced to a great extent due to three separated signal paths (Fig. 1). Each path is driven by a high power amplifier and the summation of the RF power is performed in free space on the reflector, thus allowing for a higher peak RF power at component level for the same radiated power. Robustness, stability and simplicity make it suitable for a wider range of applications, including low cost Earth observation missions and planetary missions. Dual polarization operation and bandwidth capability are further attractive features of this concept. It can be easily converted – if needed - for single polarization or adapted to other requirements (e.g. Ku-Band for CoreH2O, or even higher bands). An important feature is that it permits to generate two sets of dual-polarized antenna beams with different elevation beamwidths and different elevation separation angles. A design was realised with one set of four broad elevation main-lobes (Wide Beams WB: beamwidth: 1.75°, beam separation: 1.5°), to be used for the near ranges and a second set with eight narrow elevation main-lobes (Narrow Beams NB: beamwidth: 1°, beam separation: 0.75°) to be used for the far ranges. Generation of narrow beams involves operation of two high power amplifiers simultaneously. Generation of wide beams requires three high power amplifiers. Beam steering is done by selection of a suitable overlapping subset of two or three adjacent horns out of a linear feed cluster with several horns. The flexibility in beam generation permits the SAR system to be operated in Stripmap mode and ScanSAR mode.

4. Feed-Cluster Design and Bread-board

The breadboard of the feed-cluster system consists of 9 split horns, each split horn having two apertures resulting in 18 apertures in total. Each split horn consists of two corrugated, single-flared horns, two OMT's, one E-plane T and one H-plane T to allow for dual-polarized capability. The required beam separation within the antenna configuration with its selected focal length implies a feed horn separation >λ thus a potential grating lobe problem if not adequately suppressed by e.g. the element pattern. The element pattern suppresses such grating effects for the linear polarization directed along the linear feed array. However, the element pattern for the perpendicular linear polarisation is less directive and therefore a spatial filter has been implemented by splitting the horn aperture and so to arrive at sub-λ element spacing. A very similar result is obtained for the beam shape of both polarisations in elevation (direction of the feed-array) by introducing corrugations. The feed-cluster breadboard system is shown in Fig. 3.

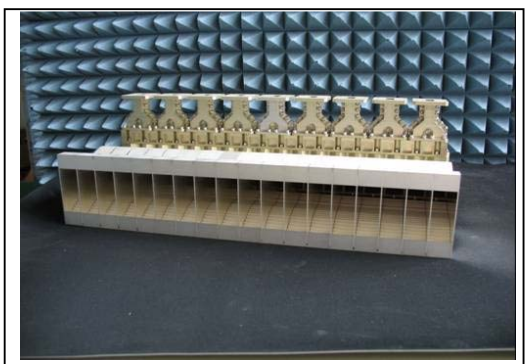

Fig.3 Manufactured Dual Polarised Feed Array for 'Multi-Pencil Beam' Antenna.

5. Test Results and SAR Antenna Performances

The feed-cluster breadboard system has been exposed to a full RF-verification program (including S-parameter tests, mutual coupling and RF-pattern tests (Co/X-pol, dual-pol, embedded patterns etc.). The accurate RF-patterns measured have been used to derive results for the overall SAR antenna performance, considering a reflector antenna of 4m x 2.4m. Fig.3 shows return loss measurements for taken on embedded split horn elements.

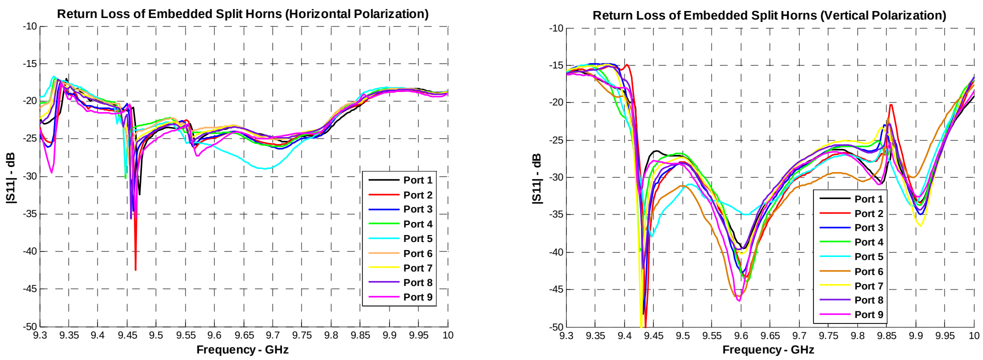

Fig. 4: Measured Return Loss (Left: H-Pol., Right: V-Pol.).

A comparison between test results including mutual coupling and HFSS simulation is shown in Fig. 5 (1st two coupling terms only). The difference between theory and measurement is due to the fact that no manufacturing tolerances have been considered in this analysis. Agreement is good.

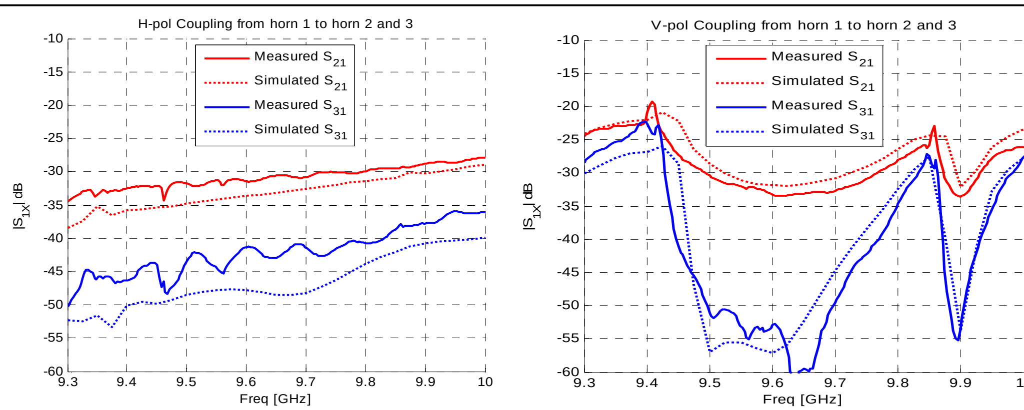

Fig. 5: Measured Mutual Coupling Terms (Left: H-Pol., Right: V-Pol.)

The strongest coupling occurs for the vertical polarization (in the direction of the linear array). At the centre frequency 9.65 GHz only the direct neighbouring elements show higher coupling amplitude. At higher frequencies i.e. at 9.825 GHz one observes, that more elements are interacting with each other, the individual levels of coupling terms have increased. However, after finalization of the test campaign and post-processing of the data, the mutual coupling did not at all represent a problem on the overall antenna performance.

Fig.6 shows a representative feed pattern obtained from measurement and simulation for the Narrow Beam case at 9.65 GHz. The feed patterns have been imported to GRASP in order to acquire the overall antenna patterns with an offset-fed reflector antenna system included. The

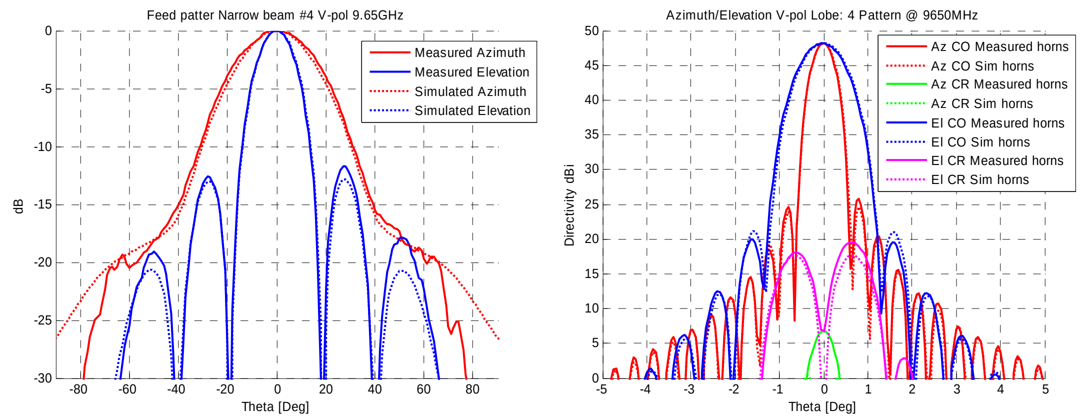

Fig. 6: Measured Mutual Coupling Terms (Left: H-Pol., Right: V-Pol.)

agreement achieved between measurements and predictions is again very good. The same quality of agreement has been achieved for the Wide Beam, which is illustrated in Fig. 6, also including the Narrow Beam case at 9.825 GHz for the vertical polarization. The antenna directivity has been found to be greater 45.5 dBi for the Wide Beams and in excess of 48 dBi for the Narrow Beams.

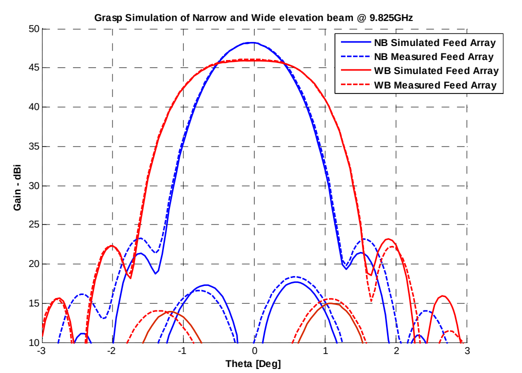

Fig. 7: Comparison between Measurement and Simulation (Narrow Beam & Wide Beam)

5. Conclusion

Not all results can be shown here, but as conclusion can be said, that a dual polarized feed-cluster for multiple beam reflector based SAR has been designed, manufactured and tested. The results obtained have been inserted in overall antenna performance analysis and subsequently overall SAR instrument analysis. It has been demonstrated that such a 'Multi-Pencil-Beam' concept is suitable in polarimetric SAR applications. SAR instrument performance analysis showed that specified objectives for the instrument study part were met in X-band.
Such approach for the instrument antenna can be easily scaled to higher frequencies, including Ku-band (CoRe-H2O expected to operate at X- and Ku-Band). Moreover, the design can be adapted to handle larger bandwidths as well.

The work has been carried out under ESA contract (Earth Observation Prepatory Program)

References

[1] C.Heer, B.Grafmueller, L.Kanderhag, M.Viberg, K. van 't Klooster: *A Low Cost Multifeed Antenna* EUSAR 2004, Ulm/Germany, May 2004
[2] P.Koch, C.Heer, L.Kanderhag, M.Viberg, J. Guijarro, K.van't Klooster: *Feed-Cluster For Reflector-Based SAR Antenna* EUSAR 2006, Dresden/Germany, May 2006
[3] M.Viberg, P.Koch, J. Guijarro, K. van 't Klooster: *Low Cost Dual-Polarized Feed For High Resolution SAR Antennas* EuCAP 2006, Nice/France, Nov. 2006
[4] P.Koch, M.Viberg, J.Guijarro, K. van 't Klooster: *A Reflector-Based Multibeam Antenna For SAR* Workshop on RF- and Microwave Systems, Instruments & Subsystems, ESA/ESTEC, Noordwijk, NL, 5-6 Dec. 2006.