Compact Ka-Band OMT for Tx/Rx MFB antennas illuminating a single reflector (CoBRa)

Executive Summary
Open Space Innovation Platform

ESA Inventions Campaign

Affiliation(s): Airbus Defence and Space GmbH

Activity summary:

Within that activity, a significant reduction in diameter of the polarizer elements was achieved. Usage of new manufacturing methods makes pitch-to-pitch distances of about 25mm possible. That enables the use of the feed cluster for combined Tx/Rx MFB solutions with one single reflector while providing simultaneously a high throughput density. Compared to the conventional solutions, which require at least 2 reflectors for multi-spot scenarios, the number of reflectors on satellites can be reduced to one reflector with the new idea. This either saves space and mass, allows the accommodation of additional antennas or the use of smaller satellites. At first, the idea was investigated by simulation and the than validated by measurements of the manufactured hardware.

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Introduction

This report provides a high-level summary of the activities undertaken and the outcomes achieved under ESA Contract No. 4000138581/22/NL/GLC/ov “Compact Ka-Band OMT for Tx/Rx MFB antennas illuminating a single reflector (CoBRa)” with the objective of developing a Ka band Tx/Rx multiple feed per beam (MFB) solution with a pitch to pitch distance of 25mm per feed which allows the usage of a single reflector for Tx and Rx frequency band.

Background

The power available on modern satellites has been constantly increased. This makes it possible to increase the number of different antenna scenarios and to implement multi-spot scenarios with an increasing number of individual spots. Due to the limited space available on modern satellites, however, there is currently the problem of accommodating a large number of antennas. This limits business success, areas cannot be served even though the transmission power is available, but there is not enough space for additional antennas. In order to achieve a higher beam density, which will result in an increased throughput density over a constant service area, very densely packed feed clusters are required. The nominal solution was developed for 2 reflector antennas, but it is also possible to develop a solution compatible with a single reflector solution. This approach halves the number of antennas required on a satellite and makes it possible to increase the number of different antenna scenarios served by one satellite. In order to be able to implement such a reflector solution, very compact orthomode transducer or polarizer solutions are required. This is not feasible with traditional design approaches.

As part of the Artes C&G program (ESA Contract Number: 4000128414/19/NL/AF), Airbus is already developing a combined Tx/Rx 4 feeds per beam solution for a two reflector antenna. An Airbus patent was used for the design of the polarizer. However, the ESA patent, in combination with a smart diplexer design, enables a significantly tighter packing density of the feed clusters. The combination of this innovative design, with modern additive or hybrid manufacturing processes, enables single-reflector Tx/Rx antennas with a higher beam density. This result in a higher throughput density compared to conventional solutions. Furthermore, the return loss and port-to-port isolation of the polarizer can be improved, while maintaining the axial ratio.

Objectives

For a single reflector solution, a compact Tx/Rx polarizer model must be designed and manufactured using modern manufacturing techniques.

- Trade-off and selection of polarizer circuit diagram using the ESA patent as key element
- Implementation of the circuit diagram as a waveguide solution
- Specially adapted design to a modern manufacturing process
- Manufacturing of a polarizer breadboard model
- S-Parameter Test of manufactured hardware and comparison with simulated results.
- Pattern test of manufactured hardware and comparison with simulated results.
- Documentation of the results

The need of this development was discussed with our customers and discussions are ongoing to adapt the product development as close as possible to the intended use cases.

Results

In phase (A), a compromise and selection of the polarizer circuit plan was made using the referred patent as a key element. The new idea was validated using proven full-wave simulation software and the benefits of reducing diameter and mass while enabling denser packing for cluster applications were preliminarily demonstrated.
To do this, the principal design was extended for the entire Ka-band frequency range to implement a combined Tx/Rx function.

In particular, the Tx band was extended by 500MHz. To separate the two frequency bands, a diplexing structure as compact as possible was developed. This was realized by a combination of a resonator and a cut-off filter. In addition, a compromise must be made to generate circular polarization. Separate polarizers or hybrids for Tx and Rx were investigated and the most promising design that can be realized was selected. The most important selection criteria are a reduced diameter and good RF performance. The selected design was optimized and key parameters such as return loss, port-to-port isolation and axial ratio are specifically designed for the application. In phase (B) the feasibility of the idea was demonstrated.

In the design phase, the model was adapted to the hybrid manufacturing process in order to fully exploit the advantages of this manufacturing method. Particular attention is paid to saving screw connections and interfaces in order to achieve a size- and weight-optimized design as well as good thermal and electrical properties and to avoid PIM critical interfaces. To provide a representative interface for spacecraft's, the design is complemented by flight qualified low PIM waveguide flange design. The polarizer is manufactured in an interconnection with a feed horn and qualified for TRL 4.

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Figure 1: CoBRa Polarizer-BFN-Horn Assembly

For the qualification on TRL4 the important specified characteristics were measured or simulated and the measurement results show excellent results what relegates to very precise manufacturing and a robust design implementation as well as a coordinated interconnection of the subcomponents.

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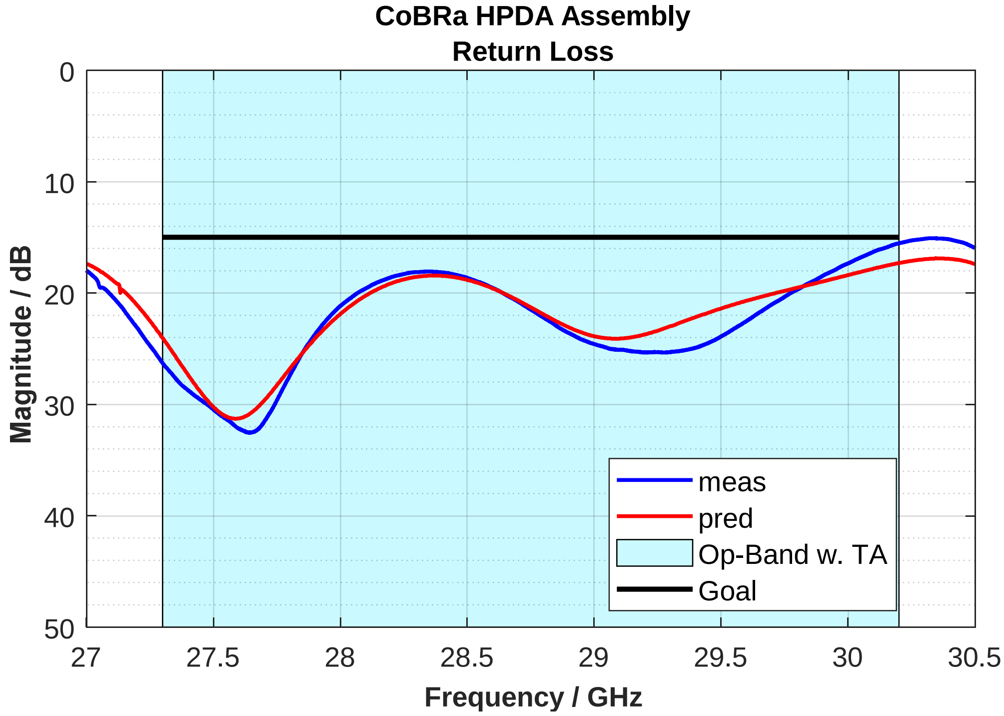

Figure 2: CoBRa Polarizer-BFN-Horn Assembly – Return Loss (Rx)

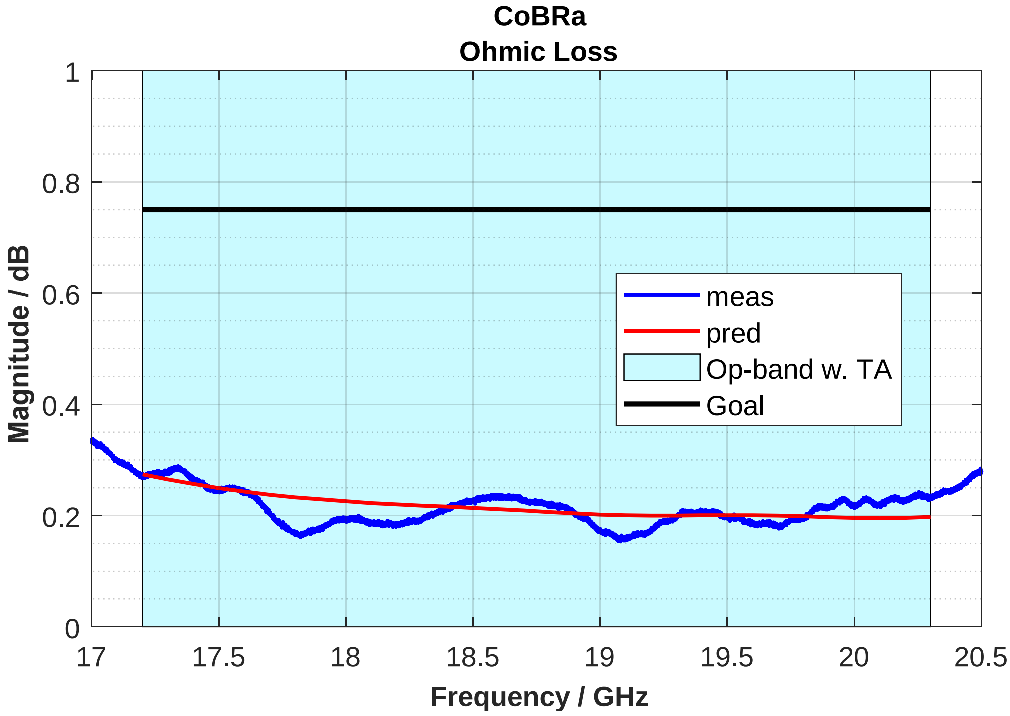

Figure 3: CoBRa Polarizer-BFN Assembly – Ohmic Loss (Tx)

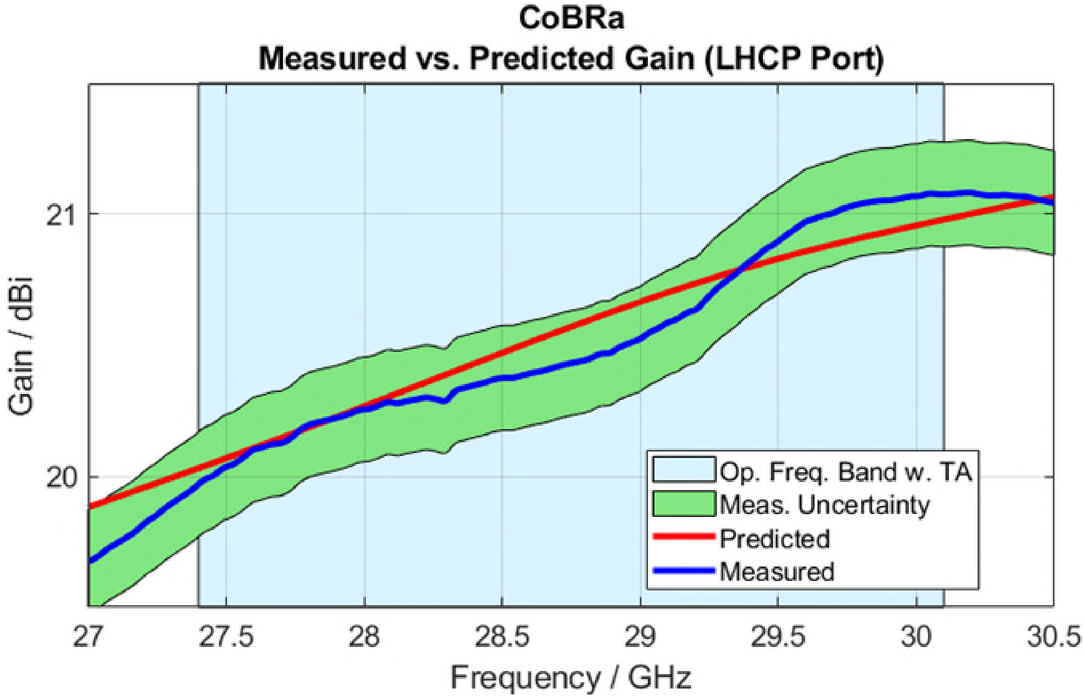

Figure 4: CoBRa Polarizer-BFN Assembly – Antenna Gain (Rx)

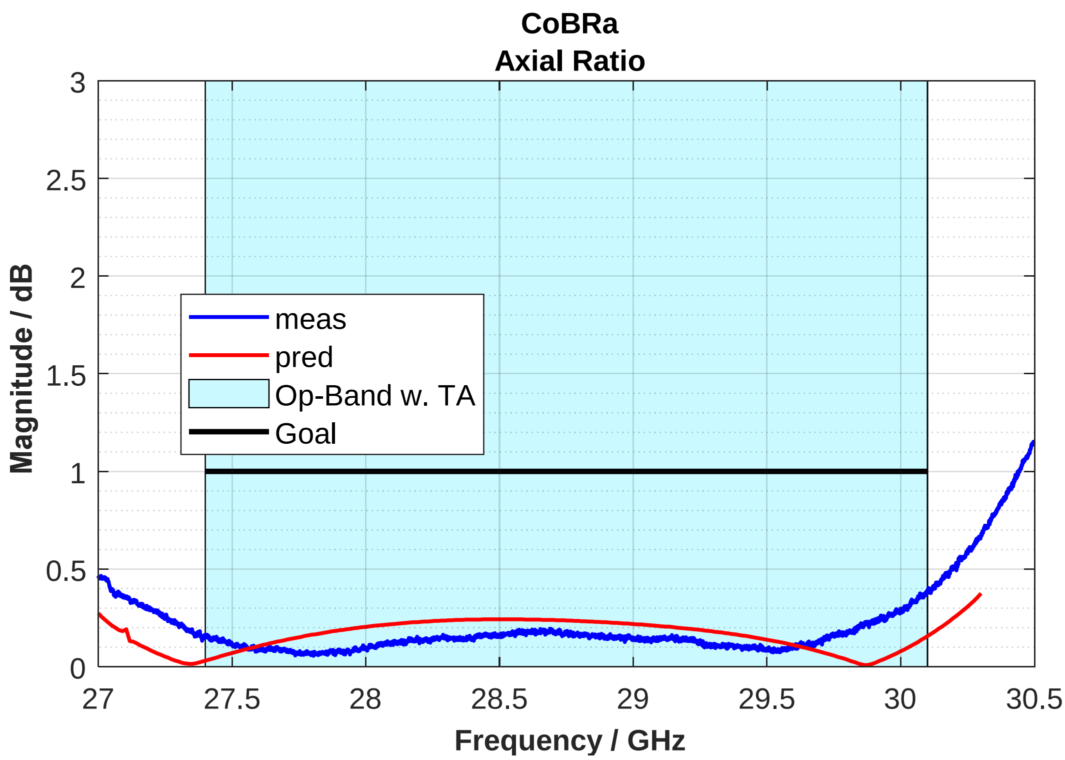

Figure 5: CoBRa Polarizer-BFN Assembly – Axial Ratio (Rx)

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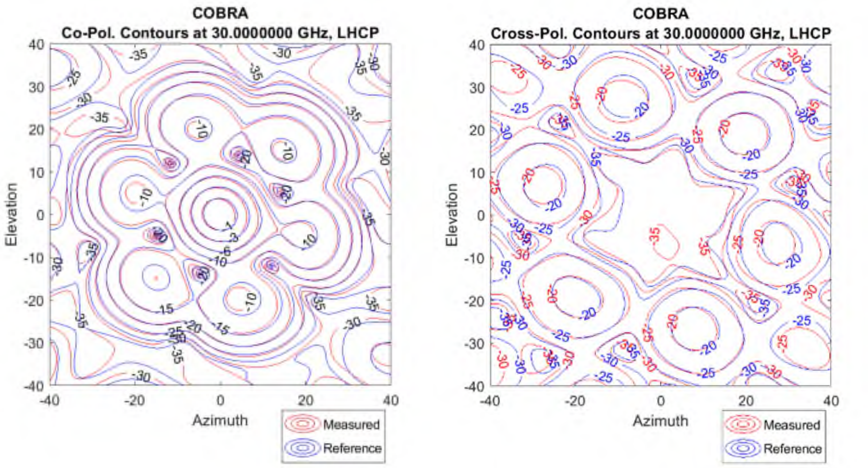

Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**-6: Co-Pol and Cross-Pol Contours (30.00 GHz)**

Conclusion

All work performed in the project was part of the ESA's open space innovation program (Contract Number 4000138581/22/NL/GLC/ov).

The main advantage of using/investing in this innovation is that the significant reduction in the diameter of the polarizer elements in combination with new manufacturing methods makes pitch-to-pitch distances of about 25mm possible. That enables the use of the feed cluster for combined Tx/Rx MFB solutions with one single reflector while providing simultaneously a high throughput density. Compared to the conventional solutions, which require at least 2 reflectors for multi-spot scenarios, the number of reflectors on satellites can be reduced to one reflector with the new idea. This either saves space and mass, allows the accommodation of additional antennas or the use of smaller satellites. This not only represents a major financial advantage compared to heritage solutions, it also represents a strategic advantage against competitors.

Design drivers were parameters such as return loss, port-to-port isolation and cross polar discrimination. An iterative design approach was necessary to adapt the model to the hybrid manufacturing process. Using this manufacturing technology, a monolithic feeding network was built, saving mass, simplifying mechanical interfaces and reducing size.

To be flight hardware representative, required RF interfaces are implemented as qualified low PIM waveguide flanges. The radiating elements were manufactured as a monolithic block using conventional milling.

For qualification to TRL4 the important specified electrical and mechanical parameters were measured. The S-parameter as well as the radiation performance show excellent agreement to the predictions. This verifies on the one hand a precise RF modelling and computation and on the other side an accurate manufacturing.

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The results justify the TRL4 level and therewith, the design is ready to be further developed to an engineering qualification model (EQM).

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