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Measurement of a 1.3 m reflectarray antenna in flat panels in Ku band

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1. The facetted reflectarray demonstrator

Thales Alenia Space has developed a facetted reflectarray, made of five flat panels arranged along an offset parabolic profile, as shown in Figure 1. Faceting the demonstrator is essential for achieving satisfactory RF performances, and especially the largest bandwidth. Many innovative techniques and processes were developed and are reported in [1].

Figure 1: The 1.3 m facetted reflectarray breadboard

The reflectarray panel was made with a single layer of printed elements, in addition to the ground plane. This facilitates much the thermal management and the industrialization process. A panel assembly has been defined, with low loss materials, very simple and repetitive process, and compatible with the harsh space environment.

A dense spacing was used : The reflectarray can thus be considered as a periodic reflective surface that is spatially modulated. Major improvements in terms of bandwidth, gain, and reduction of parasitic scattering were demonstrated thanks to this new approach.

Novel reflectarray elements, compatible with the single layer panel and with the dense periodicity, have been developed [2], [3]. They are referred to as Phoenix elements, thanks to their unique characteristic to have a revolving cycle (i.e. with the same starting and ending element). They exhibit a very linear phase variation with frequency between 10 GHz and 14.5 GHz.

2. An advanced synthesis process minimising the cross polarisation

An advanced synthesis process was developed with the objective to achieve quasi-zero cross-polarization and similar performances in the two orthogonal polarizations for dual polarized reflectarrays. It includes a preliminary synthesis, also referred to as Phase Only Synthesis (POS), and an Advanced Synthesis accounting for the scattering matrices of the elements. The RF synthesis procedure was extended to the design of low cross polarization reflectarrays. Basically, the elements provide, in addition to the phase shift, a slight depolarization of the incident field so that their cumulative effects can be controlled. Thus, the cross polarization induced by an offset configuration can be compensated for. The cross polarization cancellation process has been partially developed.

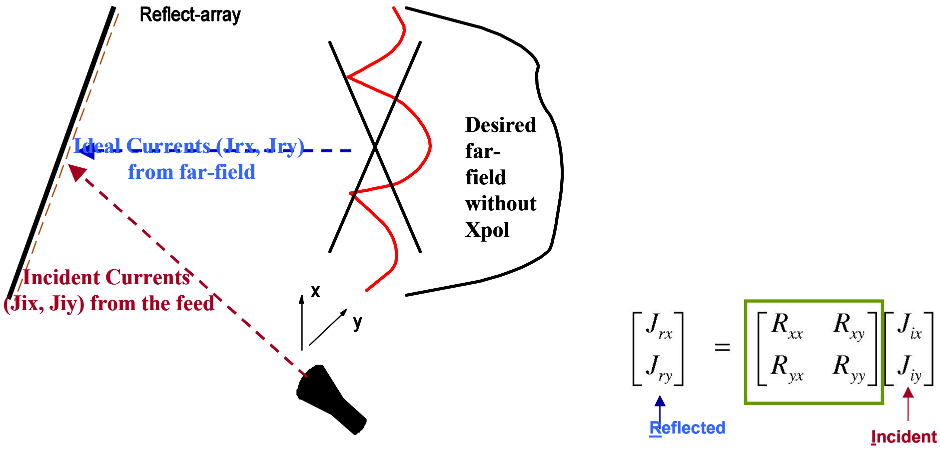


Figure 2 : Step 1 of the advanced synthesis : Deriving the scattering matrices of the elements

A post-processing tool has been developed that reconstructs, from a measured or theoretical scattered far field in both polarizations, the whole 2x2 scattering matrix of the actual measured or theoretical coefficients. The amplitude comparison among them allows characterising possible mutual coupling issues and critical zones of unwanted resonances, while a phase comparison allows reconstructing possible deformations or misalignment among the panels of a multi-face structure. This tool has been briefly presented in [4],[5].

3. Measurements

A coverage over Canada, US, Puerto Rico and Hawaii was synthesized. Such a coverage is known to be a stringent coverage. A very good agreement is obtained between the theoretical and measured radiation patterns. The comparison between the theory and measured radiation patterns indicated a very slight ripple, limited to 0.2 dB for most of the coverage, and with a worst case of 1.5 dB.

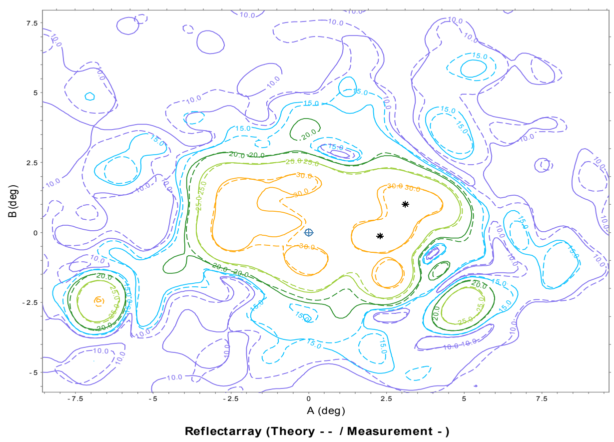


Figure 3 : Comparison Theory – experiment – Polarization X, 14.25 GHz

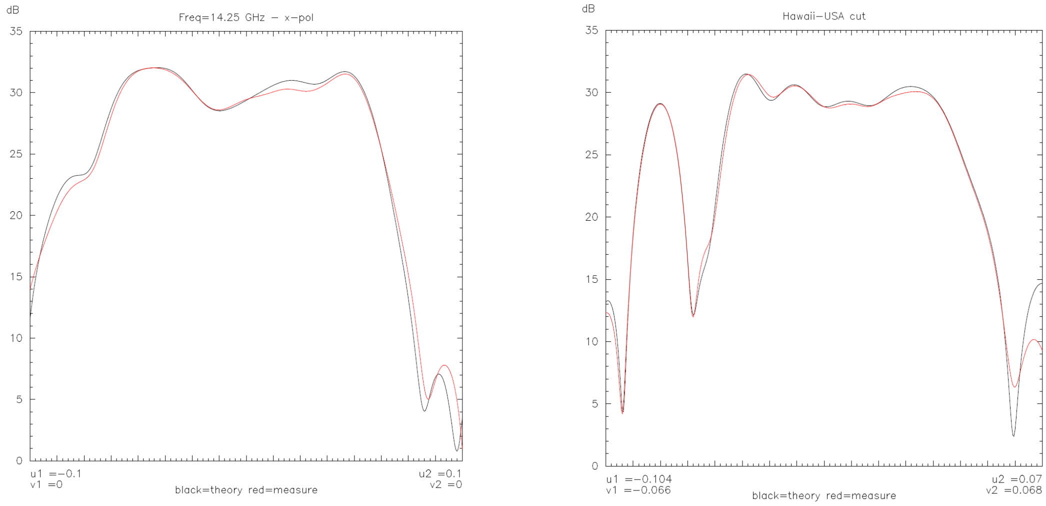
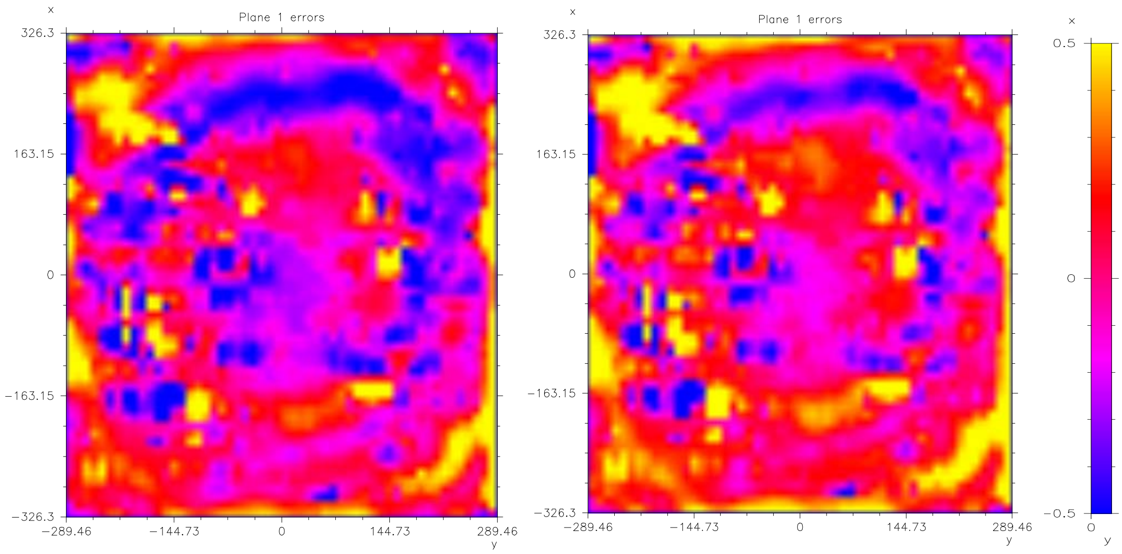


Figure 4 : Comparison Theory – experiment – Polarization X, 14.25 GHz
Cut along the coverages (West – East, and Wouth West – North East including Hawaï)

3. Characterising the accuracy of the synthesis process

The RF diagnosis tool was intensively used in the frame of the test campaign, in the objective to validate the behavior of the elements in such a dense spatially modulated periodic layout, and to derive an indicator characterizing the accuracy of the synthesis process. From the difference of the required and reconstructed scattering matrices, a representation of the distortion of the five panels is proposed. It is then compared with the panels distortion mechanically measured. The difference between the two is shown on Figure 5.



(a) (b)

Figure 5 : Difference between the Mechanically measured distortions and estimated distortions reconstructed from RF measurements – Case of the central panel –
(a) RF measurements in X polarization at 14.25 GHz
(b) RF measurements in Y polarization at 14.25 GHz

These errors characterize the accuracy of the synthesis process. The major contributors are : the manufacturing errors (thickness of the layers, knowledge of the electrical parameters,…),·the accuracy of the simulation, and particularly the uncertainty due to the quasi-periodicity conditions. The contours of the errors plotted on Figure 5 are very linked with the phase shift distribution achieved on the panel. The errors are also more pronounced for the upper side of the panel, which is also concerned with more oblique incidence. Statistically, these errors can be represented with a

RMS error estimated respectively at 290 µm and 310 µm for X and Y polarizations. This corresponds to a λ/60 RMS. It is still a bit too much for contoured beam with stringent coverages.

The diagnostic tool highlights also few areas with strong attenuation (in blue on Figure 6). These areas correspond to cells concerned with a rapid spatial variation of the phase-shift. The fading of the electrical field over these cells may be explained by the fact that the local infinite periodicity is no longer valid, and that there is some transfer of electrical field to the neighbouring elements.

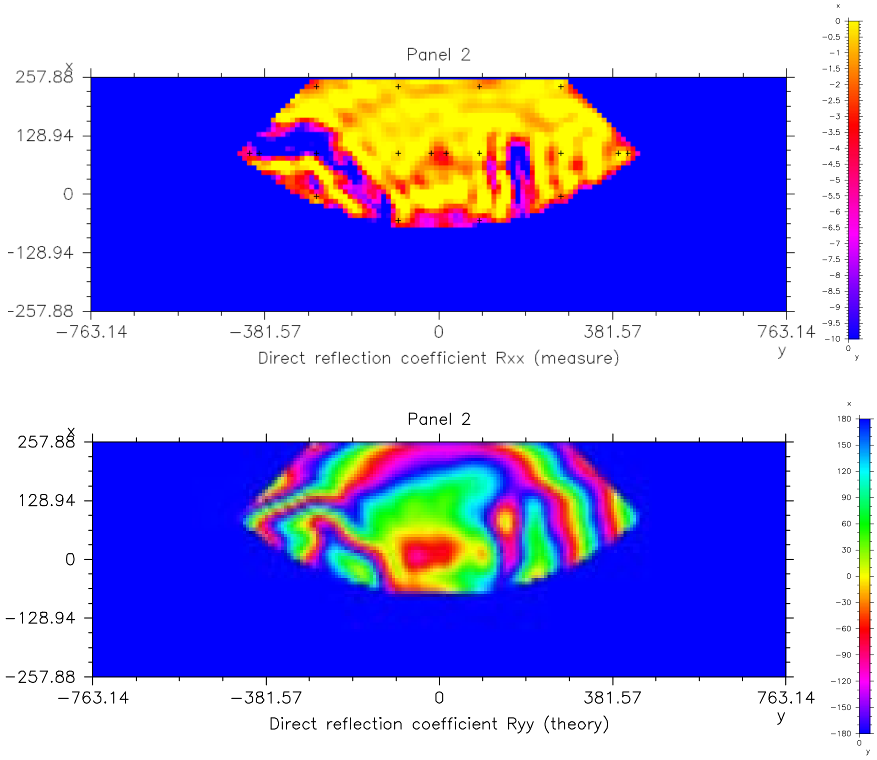


Figure 6 : Measured magnitude of the co polarization components of the scattering matrices (panel 2 of the demonstrator) correlated with the phase shift

This diagnosis tool allowed us to identify with accuracy some issues that shall be overcome in order to exhibit very advanced performances, similar to that of the shaped reflector antenna.

Acknowledgments

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References

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