Electronically Scanned Arrays for Fast Testing of Large Antennas

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ABSTRACT: *The use of probe arrays is a well-established technology for spherical near field systems offering all the possibilities and accuracies of traditional single probe testing at a much faster speed [1-4]. Frequency ranges for probe arrays are from 75 MHz to 18 GHz. Recently, the problem of exhaustive testing of the high number of multi beam antennas integrated on future satellite systems has received considerable attention. Based on conventional measurements techniques, this testing would lead to unacceptable cost and duration. Solutions based on "hybrid technology" that take full advantage of fast probe array technology on large mechanical scanners can drastically reduce the measurement time as compared to conventional single-probe test systems. The single probe systems are still necessary to measure antennas at higher frequencies. Hence, a dual technology system, combining single probes and multi-probes, has been investigated. In this set-up, the tower positioner of the probe array can rotate 180 degrees to switch easily from the multi-probe set-up (0.5 - 18 GHz) to the single-probe set-up (0.5 - 110 GHz). The single-probe positioner is also used as a calibration arm for the probe array, allowing maximum dual-use of the equipment. This paper discusses the testing of a dual technology T-planar near-field system at Intespace in Toulouse.*

INTRODUCTION

The measurement needs of today's space industry have evolved drastically. Payload complexity and size has increased and implementation of up to 8-12 antennas on a single platform is no longer uncommon. The future need for multi-beam antennas in Ku and Ka bands for multimedia, telecom and military applications with a high number of beams (20 to 100) including full system performance parameters such as pattern, C/I etc., further adds to the complexity of the testing.
Faced with this future challenge, the current capabilities of existing conventional antenna test facilities can no longer be considered sufficient in terms of quiet zone size, measurement duration and the associated costs. As a consequence, the required investments for larger quiet zone and the duration of the industrial RF tests in the conventional test facilities are becoming prohibitive w.r.t. the reduced schedules of forthcoming space programs. Fast measurement systems based on "hybrid" technology combining large mechanical scanners and fast multi-sensor architecture based on the scattering modulated signal technique are potentially strong candidates. This approach could easily be exploited in new and existing systems such as: near-field, outdoor far-field and compact range facilities as discussed in [5].
A study on innovative and fast measurement techniques to reduce the measurement duration at payload and sub-system levels has been recently funded by the European Space Agency (ESA). The project team is composed of the main French space industries (Thales Alenia Space, Astrium and Intespace) and by SATIMO as the primary contractor.
In the study, a "dual system" combining a single probe and a probe-array for planar near-field measurements has been investigated both theoretically and experimentally, as shown in Fig 1, 2 and Fig 3.

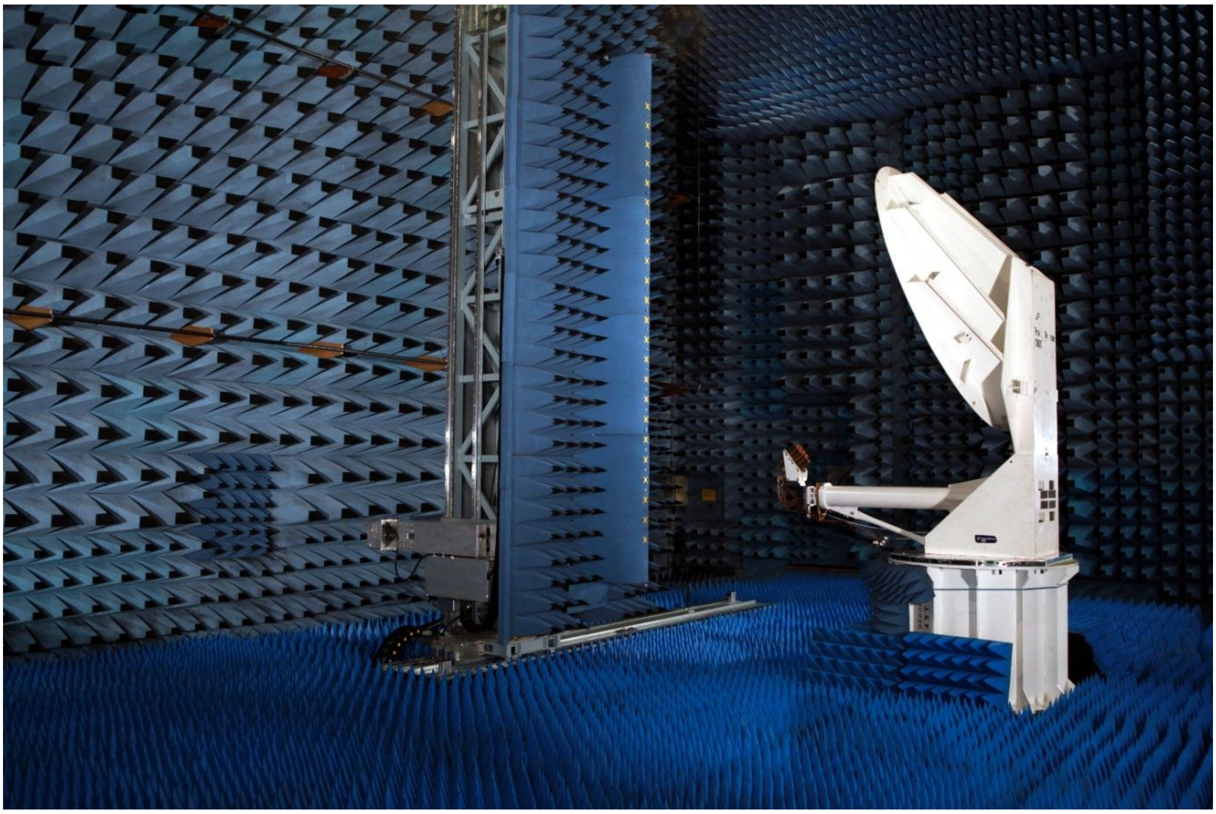


Fig 1: Dual Technology Measurement System in the Intespace Test Range, Toulouse, France

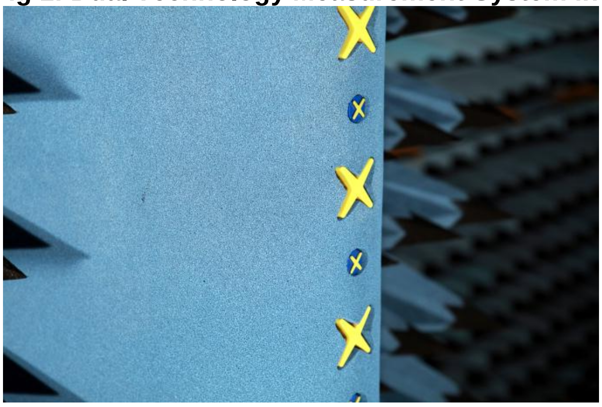


Fig 2: Two types of Interlaced Probes covering 0.5 to 18 GHz

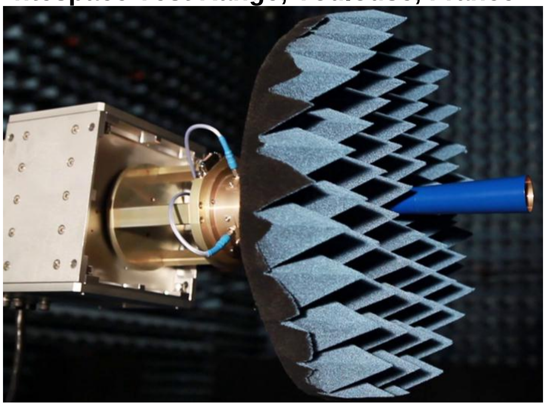


Fig 3: Single Probes covering 0.5 to 110 GHz

STUDY OVERVIEW

Three different systems using SATIMO fast measurement techniques are considered for the antenna measurements at payload or subsystem levels: a spherical architecture, a planar architecture and a focal array of sensors. The two latest systems can be implemented in existing compact antenna test ranges allowing for an upgrade of the existing facilities, thus combining the advantages of both new and conventional systems. The spherical and planar systems are based on Near-Field measurements whereas the focal array is based on a direct far field measurement approach. The spherical array of sensors and the planar array of sensors are shown in Fig 4. Both systems are based on Near-Field measurements and they can be implemented in existing conventional Near-Field test facilities.

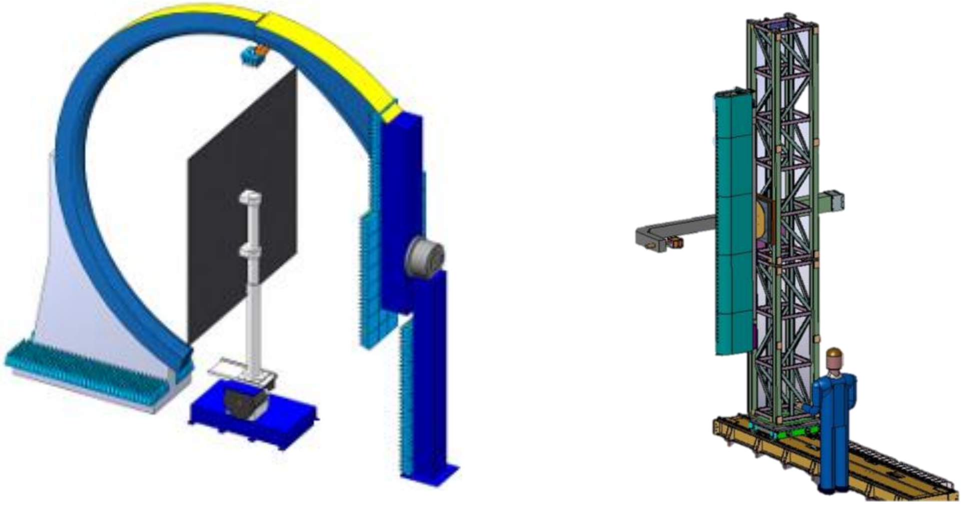


Fig 4: Dual Technology, Combining Single and Multi-probe Systems (left: spherical multi-sensor arch with gantry arm; right: planar multi-sensor system and its calibration arm, the T tower can rotate 180° to access a single probe system on the back).

The spherical systems fully enclose the device under test and are more dedicated to the measurement of antennas at the sub-system level having various dimensions (from low directive to highly directive). The planar measurement systems using a linear array of sensors allow for measuring directive antennas and can be implemented both at payload level inside an existing compact range or at sub-system level inside an existing Near-Field range.

Finally, thanks to the direct measurement of the far field, the focal array implemented in an existing compact range allows for very fast measurement of pattern cuts without moving the antenna under test.

In the frame of the ESA study, it was decided to consider the planar architecture using a linear array of sensors for the measurements in the 0.5 to 18 GHz band combined with a single-probe system for higher frequency bands.

NEAR-FIELD SYSTEM

The validation of the innovative fast measurement technique based on multi-probe systems for characterizing space antennas has been performed inside the Coulomb test range at Intespace in Toulouse, as shown in Fig 5.

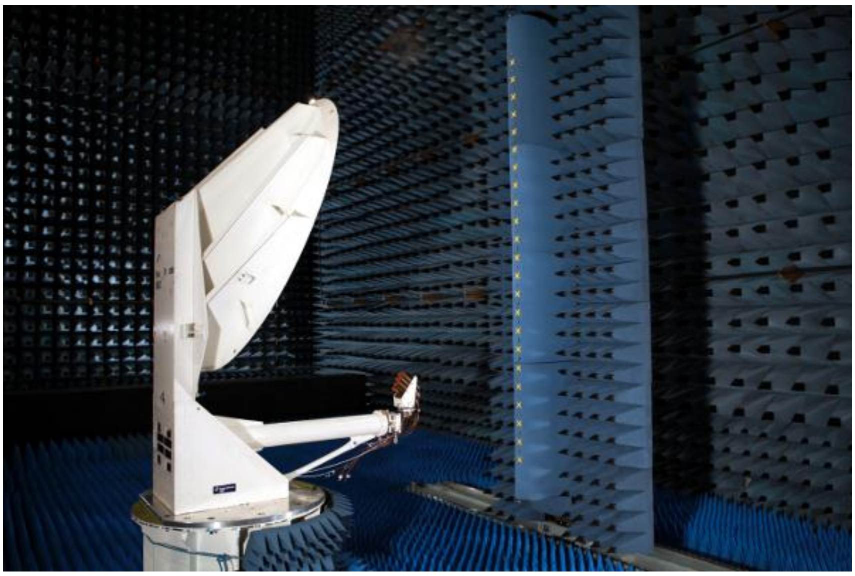


Fig 5: T-DualScan System Setup in the Coulomb Antenna Test Range at Intespace, Toulouse.

A linearly polarized multi-beam Ku-band offset antenna of 1.8 m diameter operating at 12 GHz served as the antenna under test (AUT) for the validation. The AUT was measured both in the conventional compact antenna test range and with the Near Field multi-probe system. The scanning area for the Near Field measurements was 3.2 m x 3.2 m. The T-DualScan system is composed of two sets of 23 dual polarized and electronically scanned probes. The first set operates in the 0.5 to 6 GHz frequency band and the second one covers 6 to 18 GHz. The tower of the T-Planar scanner can be rotated 180° to access a single probe configuration.

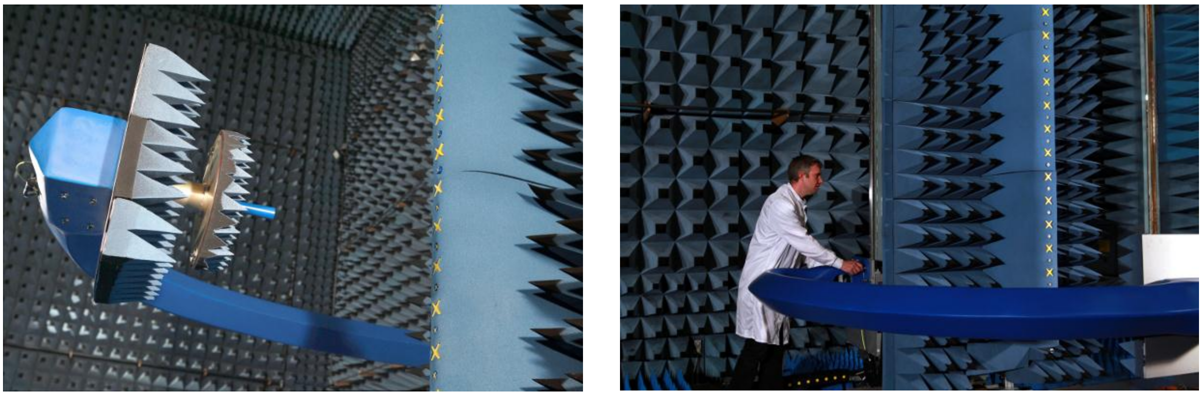
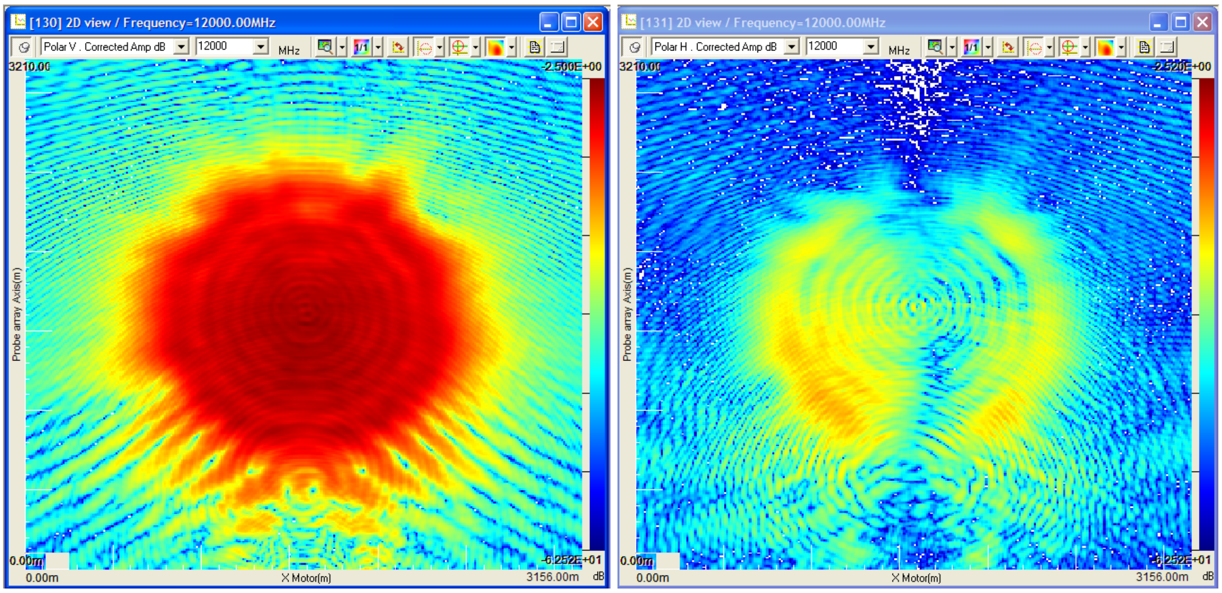


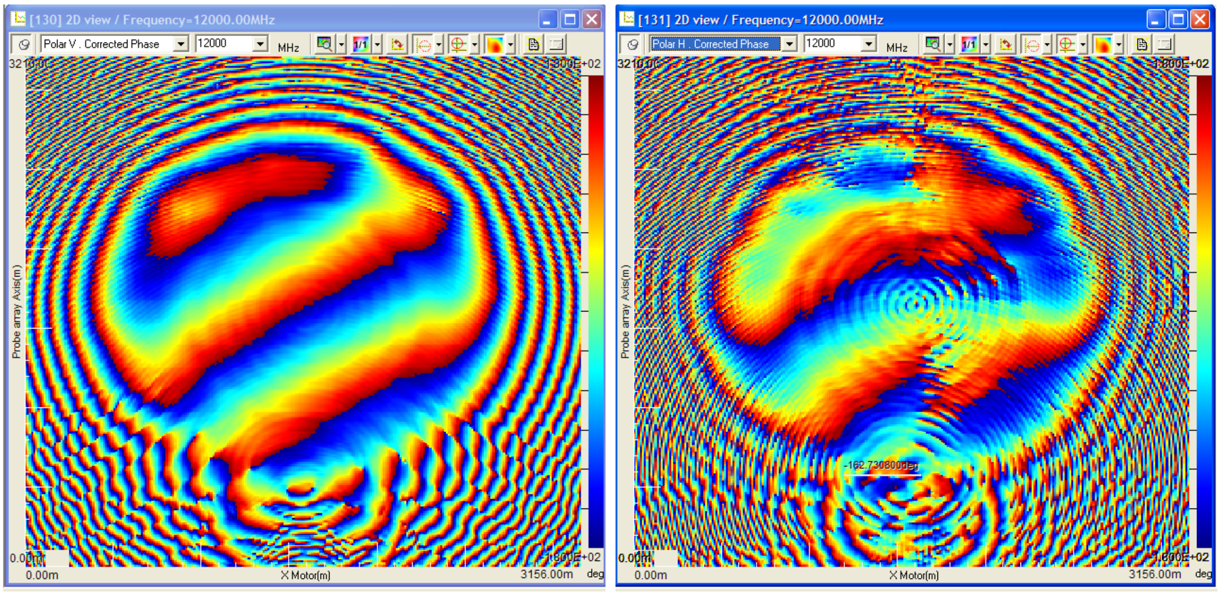
Fig 6: T-DualScan System During Calibration (left)
Mounting of the Calibration Arm (right)

The results obtained by both methods have been compared in terms of far field radiation pattern, error budget and duration of the measurement campaigns. The measured V and H Near Field components in magnitude and phase at 12 GHz on a 3.2m x 3.2m plane in front of the antenna under test and the corresponding 10°x10° view of the Far-Field are shown in Fig 7, Fig 8 and Fig 9.



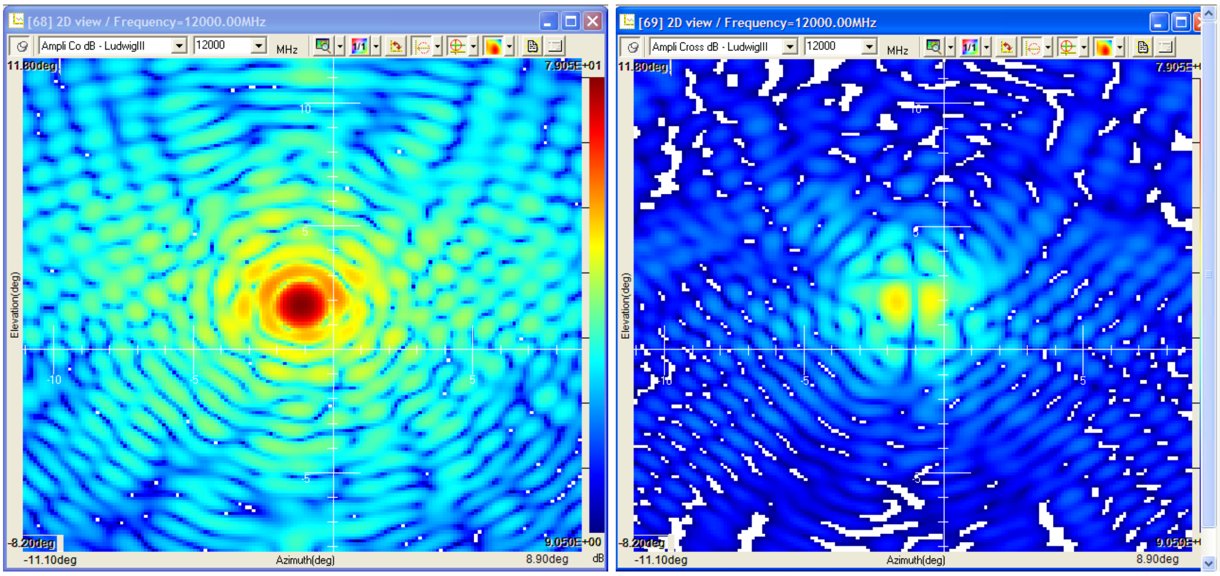
Co-polar Cross-polar

Fig 7: Near Field Measurements of One Beam of the Multi-beam Antenna at 12 GHz
Magnitude in dB (2D plots over scan area)



Co-polar Cross-polar

Fig 8: Near Field Measurements of One Beam of the Multi-beam Antenna at 12 GHz Phase in degrees (2D plots over scan area)



Co-polar Cross-polar

Fig 9: Far Field measurements of One Beam of the Multi-beam Antenna at 12 GHz Magnitude in dB (2D plots)

The typical 18 error terms method of NIST were calculated and 2 additional error contributors specific to the multi-sensor system were added: probe array amplitude uniformity and probe array phase uniformity. The contribution of these 2 additional error terms was evaluated to 0.05 dB each at measured levels of 33 dB below peak and 12 GHz, leading to an overall uncertainty of ±0.91 dB (compared to uncertainty of ±0.13 dB at peak level). These uncertainty values for the fast measurement system are comparable to the uncertainty values obtained with a conventional near field single probe.

CONCLUSIONS

An innovative fast measurement system based on multi probe system technology combined with a single probe system has been presented. The multi-probe approach has been validated by comparative measurements. Based on these acquired data, the duration of the measurements with a complete system operating at Ka band has been extrapolated and compared to the duration obtained with a conventional near field probe. The test measurements on a 2m diameter multi-beam antenna in Ka band show that the overall measurement time can be reduced by a factor of up to 10 with respect to the conventional single probe approach while maintaining the same overall measurement accuracy.

Future prospects (frame to be decided) will concern an extension of this study to specific measurements at the sub-system or system level. In particular, it will be very useful to enhance the capability of the fast measurement system with end-to-end or telecom performance measurements. The end-to-end measurements cover primarily the characterization of group delay, EIRP, SFD and G/T.

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