THE IMPLEMENTATION AND VALIDATION OF A LARGE 22m BY 8m PLANAR NEAR-FIELD TEST RANGE FOR SPACE ANTENNA SYSTEMS AND PAYLOAD TESTING

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ABSTRACT

A new 1 to 50GHz Antenna Test Range has been installed at Matra Marconi Space in Portsmouth housed in a temperature controlled and screened Class 3 Clean Room. This Range, based around a high precision 22m by 8m Planar Scanner, has been designed specifically to test Large Active and Passive Spacebourne SAR and Communications payloads. Its capability is, however, general enough to allow a wide range of medium to high gain antennas and systems to be tested.

This paper discusses the design considerations that went into the implementation of this facility. Results from the validation of this facility are presented.

Keywords:- Antenna Testing, Planar Range, Payload Testing

1.0 INTRODUCTION

Matra Marconi Space (MMS) has the design, build, test and system responsibility for the Advanced Synthetic Aperture Radar (ASAR) antenna on the ESA Envisat Program. This antenna is a 10m by 1.3m active planar antenna operating at 5.331 GHz whose pattern is required to be measured out to +/- 70 degrees from boresight with an accuracy of +2dB rms. at the -40dB level.

In-house studies showed that the most appropriate method of testing this class of antenna was via a Planar Near-Field Test Range and the decision was taken to build such a facility at MMS Portsmouth.

It was decided that that the Planar Near-Field Range and its Scanner should be able to test both SAR antennas and Communication Satellite Payloads. The size of the scanner was calculated using two previously determined pieces of information:-

i) SAR Antennas, can in, general be tested to the previously stated accuracy neglecting probe interaction if the measurement distance is greater than 1 metre.

ii) The radiation properties of most Communication Satellite Payloads can be fully characterised for Earth Coverage Requirements with +/- 45 degrees of Near-Field Data.

Using the example of a SAR antenna 16m long by 2m wide with far-field patterns measured out to +/-70 degrees, a Planar Scanner size of 8m high by 22m long was arrived at. It was also confirmed that this size was more than adequate for testing typical Communication Satellite antennas.

2.0 SCANNER ACCURACY AND SPEED REQUIREMENTS

Mechanical errors normal to the scan plane, defined as the Z-Direction, act as phase errors on the measured performance of the antenna. Conventional wisdom states that Z-Plane errors can be neglected for typical Spacecraft Antennas if they are less than $\lambda/200$ rms., although the seriousness of their effect will depend on the antenna and on how the errors are correlated.

To specify the errors, it was decided to rely on conventional wisdom, and, working on a frequency of 45GHz, an rms error of 33 microns was arrived at, corresponding to a peak error of 0.1mm (Gaussian Distribution).

From discussions with scanner manufacturers, it was felt that a maximum allowable Z-Plane error of 0.1mm would be difficult to achieve over a 22m by 8 m scan plane. The approach used was to allow the error to have a peak error of +/- 0.4 mm but to be repeatable to +/-0.1mm. This would allow software correction techniques to be used to achieve the required accuracy.

Newell and Stubenrauch (1) have shown that, providing the Z-Plane errors are random, the signal to noise ratio in the sidelobe region of a circular antenna can be written:-

$S/N > 0.07d/D$ ....(1)

where:-

'd' is the rms value of the error in metres and 'D' is the diameter of the effective area of the antenna in metres

This formula predicts a Signal to Noise ratio of 67dB for D = 1m and d = .03mm.

For errors in the X (Step) and Y (Scan) directions, Newell (2) has shown that these errors have an effect in the sidelobe region that is less than 1/10 of the equivalent Z-Plane errors when testing an antenna whose beam is steered 5 degrees off-boresight. This case represents a typical worst case for spacecraft antennas.

Using similar arguments to those used for the Z-Plane errors, it was specified that the X and Y plane errors should be accurate to +/-0.5mm but repeatable to +/-0.1mm. These errors were specified with reference to a point 1m in front of the probe interface.

As errors in X and Y directions alone can be removed by repositioning that axis to its known correct position, only cross-coupling errors between X and Y have to be corrected for using software techniques.

Phase errors in the RF path to the probe caused by movement of the scanner act in a very similar way to Z-Plane errors. In order that these should not swamp the Z-Plane errors, it was specified that the cables should be stable to better than +/-0.5 degrees with repeatability to +/-0.1 degree for each axis at 18GHz. This would allow the corrected errors to be an order of magnitude less than the Z-Plane errors.

The measurement speed of the scanner was specified at 0.5m/s as this was both consistent with the measurements required and was also considered to be the fastest speed the scanner could safely go

3.0 ROOM CONSIDERATIONS

In deciding to build a Planar Range, MMS Portsmouth was fortunate to already have a 50m long by 12m high by 12m wide clean room that it could use to house the facility. This clean room, temperature controlled to 20 +/-1 degrees C, was already earmarked as the facility in which to build the ASAR antenna, and the design of the Planar Range had to ensure that this requirement was enhanced rather than compromised.

Three main considerations went into turning the room into a Planar Range:-

i) Screening Requirements

ii) Absorber Requirements

iii) Mechanical Stability Requirements

From EMC considerations, it was decided to screen the room to -70dB from 100MHz to 40GHz. To achieve this shielding, the room was 'wallpapered' with 0.1mm copper sheet with special consideration being given to the joins between the sheets and to penetrations into the room.

A special feature of the shielding design was an EMC curtain made from layers of Tecknit Material, 8 metres wide by 10 metres high that was hung vertically across the room, about halfway down its length. A drum design at the top of the curtain allowed it to be raised and lowered.

When lowered, the EMC curtain was hydraulically clamped to the rest of the room screening to maintain the screening integrity. However, when raised, it allowed the clean room to revert to a single room with minimal loss of its original size.

Initial measurements of the screening effectiveness of the room have shown a screening performance well in excess of 70dBs, although some unknown penetrations were located that reduced the shielding effectiveness in isolated areas. These imperfections have been rectified and the room will be re-evaluated in the near future.

In addition to the shielding requirements, the room also had to be lined with RAM to avoid multipath effects. A thorough, yet conservative, analysis of multipath effects for three antenna types, a SAR antenna, a front-fed reflector antenna and an earthcover horn, was undertaken yielding the following results:-

	RAM SPECIFICATION		MULTIPATH PERFORMANCE		
			ANTENNA TYPE		
F GHz	FRONT REAR & SIDE WALLS	FLOOR & CEILING	ECH	SAR	SPOT BEAM
1.5	-50	-35	-51	-53	-56
3.6	-55	-40	-56	-58	-61
5.3	-65	-50	-66	-68	-71
>6.5	-70	-50	-67	-73	-76

The main area of concern was the front wall into which the antenna could radiate. However it was found that the rear wall also had to be covered with RAM as the scanner could collect sufficient reflected energy from the rear wall to allow the whole of the rear pattern of an antenna to be transformed into the forward space. For certain Spacecraft Communication Antennas this could be a significant problem.

The top, bottom and side walls were then covered with RAM to just behind the antenna position to limit multipath and to stop resonance effects occurring .

To ascertain the mechanical stability of the room floor, many measurements were performed . It was found that when the floor was loaded , it deflected as a beam, producing a tilt between 1 to 3 arc seconds per ton. This corresponds to a deflection at the top of the X-Y scanner between 0.05 to 0.15 mm per ton. As the scanner tower weighs up to 4 tons, the variability of the tilt exceeded the required Z-plane error repeatability.

To over come this problem, the floor around the scanner was replaced with a 1 metre thick, fully piled and isolated concrete beam. After modification, no further problems were noted with deflections.

4.0 RF SUBSYSTEM

The RF Subsystem chosen for the Planar Range was based on the Hewlett Packard 85301B system. The system was configured by MMS to operate as a fixed system from 1 to 26.5 GHz but to be re-configurable to operate up to 50 GHz This decision was forced by the unacceptable losses incurred when using 50 GHz cabling.

Figure 4-1 shows the system configuration. To test SAR antennas in particular, the HP8530A receiver was purchased with the pulse mode option.

The system is controlled using both a HP85330A control card and an ORBIT AL2000 PC Controller allowing multi beam, multi port, multi frequency and multi polarisation measurements to be carried out. Low loss Gortex Type 7 cables were used throughout the system. To overcome the losses in the cables that would otherwise limit the LO drive to the mixers, double ended mixers with external diplexers were used. The diplexers were connected to the LO and IF ports of the mixers with the LO connection made via HP83017A amplifiers to boost the LO signal. No significant increase in mixer noise was noted.

5.0 SYSTEM VALIDATION

The X-Y scanner chosen for the MMS Planar Range is an Orbit AL-4953-1-22m-8m-V vertical rails and tower scanner built to MMS Specifications. The mechanical and electrical validation of this system has been carried out for all major parameters

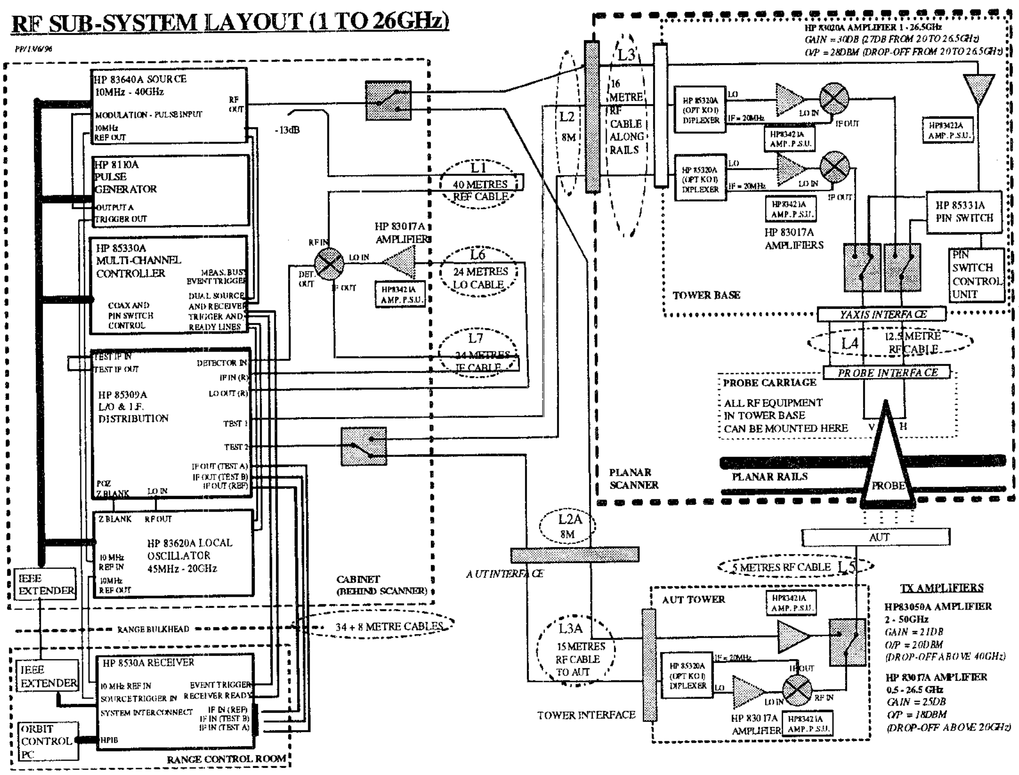

FIGURE 4-1

Validation work carried out on the RF system up to 26.5 GHz has confirmed that the system meets all of the Hewlett Packard published specifications in terms of linearity and dynamic range.

5.1 Z-Plane Error

The Z-Plane error was measured over the entire scan plane using a 3-Axis Spinning Laser with a target attached to the probe arm. .Figure 5-1 shows the envelope of the errors over 59 scans from Y = 0 denoted by point 1 to Y = 8 metres denoted by point 28

Figure 5-1 shows that the Z-Plane error is easily within the peak specified error of +/- 0.4mm. Initial analysis of the results indicate that the repeatability is better than +/- 0.05mm..

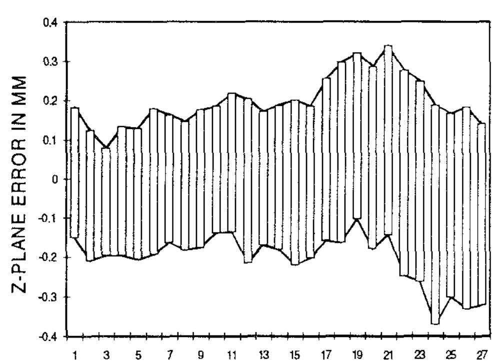

FIGURE 5-1

5.2 X and Y Plane Errors

The absolute position of the X-Axis and Y-axis relative to their encoders has been measured as being between +/-0.1mm for the X-Axis and between +/ -0.15mm for the Y-Axis, with repeatability better than 0.01mm.

Figure 5-2 shows the Y-axis straightness which has a peak error less than 0.15mm

X-Axis straightness shows a similar performance with peak error less than 0.3mm and repeatability better than 0.05mm.

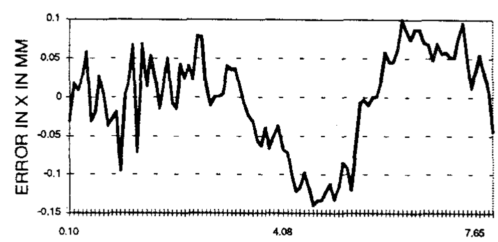

FIGURE 5-2

5.3 Cable Phase Errors

The cable phase errors were measured by connecting the cables through the X-Y Scanner together at the probe carriage end so that there was a complete round cable path through both the rails and the tower RF cable carriers.

Figure 5-3 show the phase stability of a single cable path at 18 GHz over a number of bi-directional 8m scan measurements across the complete step range. The measurements show that the phase variation lies between +/-0.65 degree with a repeatability to +/-0.01 degree. The strong groupings are for the probe carriage going up or down the tower.

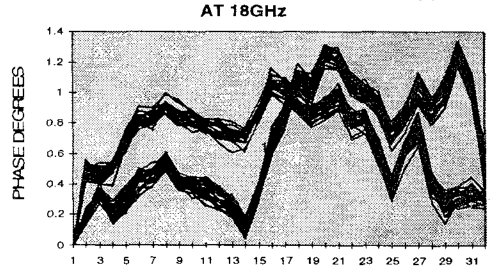

FIGURE 5-3

In the X -Direction, the cables show an error at 18GHz of +/-0.6 degrees after a linear error of 4 degrees has been removed. The linear error corresponds to a pointing error of 1.7 arcseconds which is negligible.

5.4 Multipath Measurements

The reflectivity of the walls was measured by

Emerson and Cuming and the minimum performance obtained is as follows:-

Frequency GHz	1.5	3.6	5.3	6.5	>12
Reflectivity dB	-50	-65	-68	-71	-80

This exceeds the specified performance and hence the calculated multipath values are met.

5.5 Probe Interaction

The probe interaction between a circular waveguide probe and an ERS1 panel was measured at 5.3GHz in the Planar Range, using two acquisitions with the probe $\lambda/4$ apart.

Figures 5-4 shows the horizontal pattern of the ERS1 planar panel. This figures also show the equivalent multipath error for the measurement due to probe interaction at a distance of 1 metre. The pattern in the other plane is unshaped, and this exhibits a better multipath performance.

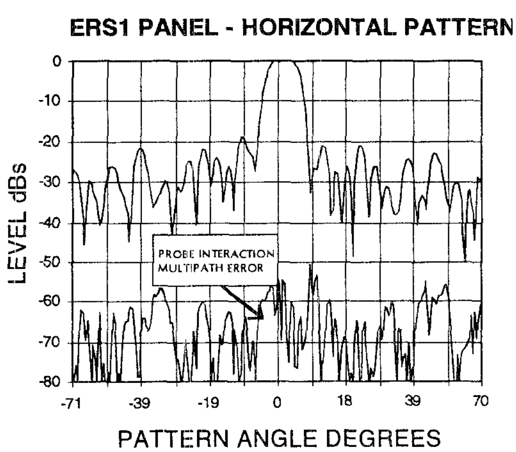

FIGURE 5-4

Figure 5.4 show that the gain error caused by probe interaction is less than 0.03dB, with the error in sidelobe level less than an equivalent multipath level of -55dB, corresponding to a 1.4dB error at -40dB. The error of 0.8dB in the first null of the horizontal pattern is larger than expected, and further work is continuing to investigate its cause.

6.0 CONCLUSIONS

A new, fast, large and accurate Planar Near-Field Antenna Test Range has been built at Matra Marconi Space Ltd. in Portsmouth based around a 22m by 8m X-Y scanner. The facility is situated within an environmentally controlled clean room which is designed specifically for Satellite Antenna, Payload and System testing.

All of the original specifications set for the scanner have been met. In fact, its mechanical accuracy is exceptional, allowing a probe to be placed anywhere within its active scan plane to better than 0.3mm, with a repeatability better than 0.05mm.

Correction of the Z-Plane error allows the Planar Scanner to be used up to 50GHz, where, if the Z-Plane error is spread over only six spectral components, an accuracy of the order of 2dB at -40dB can be achieved. This facility will allow MMS to meet its Antenna Test needs well into the future.

7.0 REFERENCES

1. Newell A.C.& Strubenrauch C.F, "Effect of Random Errors in Planar Near-Field Measurement", IEEE Trans. Antennas Propagat., 26, 769-773

2. Newell A.C, "Error Analysis Techniques for Planar Near-Field Measurement.", IEEE Trans. Antennas Propagat., 36, 754-768