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MILLIMETREWAVE COMPACT ANTENNA TEST RANGE

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INTRODUCTION

This paper describes the design and performance of a unique millimetre–wave Compact Antenna Test Range (CATR) which enables antennas of up to one metre diameter to be measured at up to frequencies of 200 GHz. The CATR uses a precision panel reflector to collimate the energy from a feed horn, Figures 1 and 2.

Millimetre–waves offer considerable advantages for many applications, particularly when narrow beams are required from moderate size antennas. Examples are remote sensing systems, millimetre–wave radars, meteorological sounders and short range communication links. The increasing use of millimetre–waves requires good quality antenna test ranges to measure their radiation characteristics. The test range must have a good electrical performance and also a high mechanical precision. The Compact Antenna Test Range is a good choice for a millimetre–wave test range [1]. It can be made to give a high quality quiet zone in an indoor, anechoic environment. The other types of test range suffer from a number of disadvantages: far–field ranges have a high path loss and if outdoors, from the weather; near–field ranges need accurate probing systems and small sampling distances so that the amount of data collection and processing is very large.

DESIGN AND CONSTRUCTION

The main component of a compact range is the collimating reflector. This must have a precision surface with a small RMS surface error so that the phase errors caused by distortions on the surface are low. The RMS error of the region of the reflector which directly reflects energy into the quiet zone should ideally be lower than one hundredth of a wavelength. For operation at wavelengths of a few millimetres, this requires surface accuracies of a few tens of microns. Most microwave CATR's have been constructed by machining a single piece reflector. This is still possible at millimetre–waves, but is very costly. A much better alternative is to use a reflector made of panels. Each panel can be of a size such that it can be accurately produced with good thermal and stability properties. This is the method used in the CATR described here.

Our CATR reflector is a portion of an offset paraboloidal reflector and is constructed from 18 panels arranged as shown in Figure 2. The panels were originally developed for the James Clerk Maxwell radio–telescope which is a 15 m diameter millimetre and sub–millimetrewave symmetric Cassegrain antenna. The panels are made using a stretch–form aluminium skin which is pulled over a numerically machined steel former. A layer of aluminium honeycomb material is pre–crushed and bonded onto the skin to maintain the surface shape. The honeycomb also acts as a heat barrier and gives good thermal properties. Each panel is 1 m in length and the width varies according to the distance from the vertex but averages 0.5 m. The measured RMS surface accuracy of the 18 panels varies between 8 m and 15 m. Thus the surface accuracy of a single panel is better than 1/100 of a wavelength at 200 GHz so that the main design criteria is satisfied.

The panels are supported on a space–frame backing structure optimised for loading and mechanical stability. Provision for adjusting each panel onto the correct paraboloidal surface is necessary and this is achieved by attaching each panel to a sub–frame with three mechanical micrometer adjusters. The panels of the CATR must be accurately aligned to the paraboloidal surface. This is done with two good quality theodolite mounted on rigid posts about 4 m from the range reflector. Targets mounted on the panels are used to take measurements of angles using the theodolite and a computer program computes the panel position and orientation together with the required adjuster movement. Calibration is provided by a precision carbon fibre scaling bar with an accuracy of 2 m. The errors in the alignment procedure are dominated by the accuracy to which the theodolite angles can be recorded. In our case these have a measured accuracy of 3 arc seconds which translates to an alignment error at the outside edges of the CATR reflector of 70m. This is much larger than the RMS surface errors of individual panels but is adequate for aligning the panels to the paraboloidal surface.

The test antenna positioner is an azimuth–over–elevation turntable which can take a maximum load of about 1000 kg with a positional readout using Inductosyns on both axes of 0.005 degrees. The turntable can provide full 360^{0} movement in azimuth and up to 95^{0} in elevation. Turntable control is via a control unit which is linked to our own measurement control software. The turntable is mounted on a precision cross–slide providing 300 mm of horizontal transverse movement in the quiet zone. The turntable and cross–slide is mounted on a hydraulic scissor platform to provide up to one metre of vertical adjustment of the test antenna. The whole unit is mounted on rails with a 1.6 m track gauge. This provides longitudinal movement along the axis of the chamber and extends beyond the chamber so that test antennas can be mounted onto the turntable outside the chamber. This is done through the back of the chamber which is openable.

The feed for the CATR is a range of hybrid mode corrugated horns to suit the required frequency band. These are mounted on a cradle which can also accommodate the RF millimetre-wave source components and is rotatable to set the plane of polarisation. A ridged steel tower supports the feed cradle.

The configuration of the source depends on the frequency band and the application. The receiver is either a phase–amplitude receiver or a network analyser. All the test and measurement instrumentation are connected via an IEEE–488 bus to the controlling workstation computer. The custom designed software package controls all the test functions and enables immediate radiation patterns to be displayed, plotted, dumped on disk. The workstation is connected via networks to larger computers for further data processing and analysis.

The CATR is enclosed by a purpose built anechoic chamber, Figure 1 and 2, whose shape is designed to minimise the levels of stray reflections from the feed to the quiet zone. The anechoic chamber is lined with RAM with an average reflectivity at millimetre–waves of –30 dB. In order to allow space flight standard antennas to be measured, an air conditioning system is incorporated into the chamber. This is mounted above the test turntable and causes air at positive pressure, filtered to class 10000, to flow over the test antenna.

PERFORMANCE SUMMARY

Millimetrewave evaluation was based on antenna pattern measurements of a 200mm, 90° offset low sidelobe reflector operating at 186 GHz. The initial measurements were taken without any treatment of the gaps between the panels and although very good agreement was observed on the main beam region of the pattern large -30dB near-in sidelobes which are not part of the actual radiation pattern were seen. It was readily observed that their location correspond to angles where the test antenna main beam was pointing at the inter-panel gap space. Its origin is associated with diffraction at the panel edges and was further verified by covering the gap with absorber where the spurious responses by each individual edge were then seen. It was therefore decided to cover the gaps with a conductive tape, however, this approach cannot directly solve the problem since now the tape is responsible for a new spurious lobe with similar properties to that produced by the gap. Typical principle plane patterns are shown in Figure 3b, along with results from a 2D theoretical analysis [3] of the taped gap reflector, figure 3a. Good agreement between magnitude and position of these lobes is seen. A parametric study using this analysis leads us to the following conclusions :-

1) The impact of tapes closer to the range`s centre is expected to be more pronounced.

2) Pillowing of the tape covering the gap must be avoided, as this increases the lobe level.

3) To diminish the problem we must ideally cover gaps with tapes having very small electric thickness, equivalent to a phase error perhaps less than 5 degrees. Another technique which might be applicable is a gap treatment which will generate diffracted energy of highly diffused type. An observation when rough surface copper tape was used, assists us in this statement

4) One can identify the gap generated spurious lobes as being the part of the pattern which occupy different angular locations when recorded at different distances within the Range. By this spatial displacement of the antenna various parts of the recorded pattern can be "freed" from these spurious lobes making their effects perhaps more manageable than initially thought.

Sets of 186 GHz radiation patterns of the test antenna were taken centred on 9 positions in the quiet zone, covering a transverse quiet zone region of 250 mm square. A superimposed set of azimuth patterns is shown in figure 4. Using the pattern comparison method this yields a reflectivity in 1° to 3° angular region of better than -60dB.

By measuring the bistatic RCS of a flat plate (500mm x 500mm) at 90 GHz the range electrical boresight was determined to an accuracy of 0.02° and its stability with polarisation angle was found to be better than 0.009°.

Using an 18dB gain pyramidal horn as a probe the 90GHz quiet zone field was scanned in 15 positions over a transverse region of 600mm high by 300 mm wide. The worst field ripple was ±1dB, however this should be improved in the near future by better gap treatment.

REFERENCES

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[3] PHILIPPAKIS,M. and PARINI, C.G., "Two dimensional modelling of antenna pattern measurements in a panelled compact range at millimetrewaves", International IEEE AP-S Symposium, USA, June 1992.

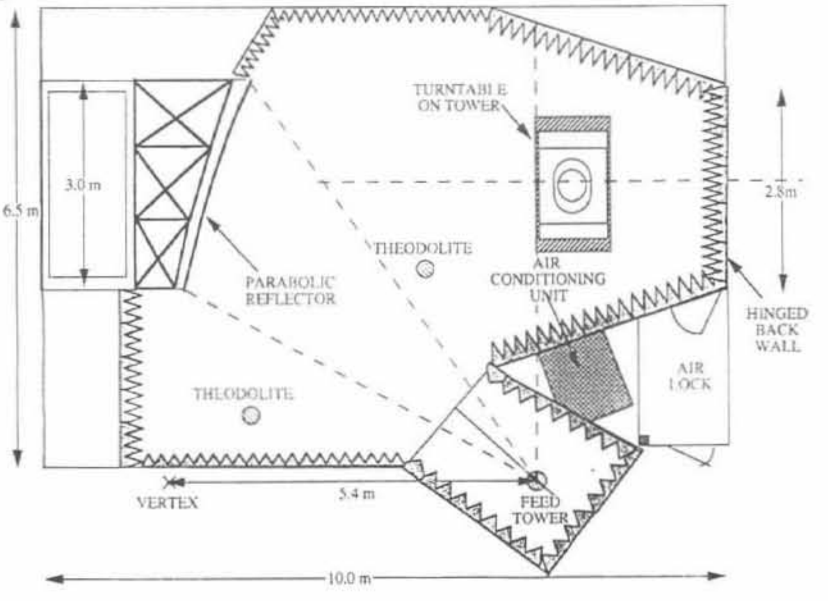

Figure 1. Plan of CATR

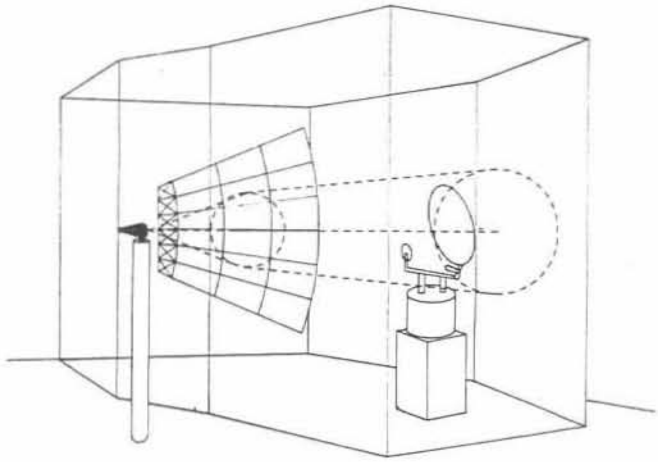

Figure 2. Sketch of CATR and anechoic chamber.

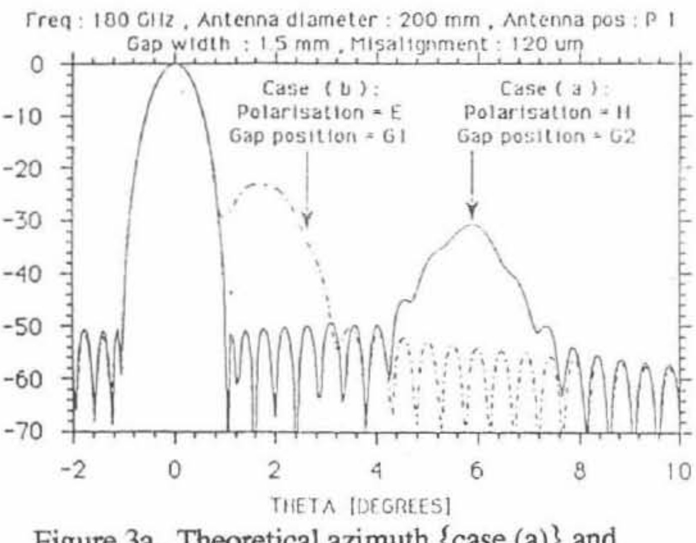

Figure 3a. Theoretical azimuth {case (a)} and elevation {case (b)}patterns for test antenna at 186GHz showing sperious lobes due to taped gaps.

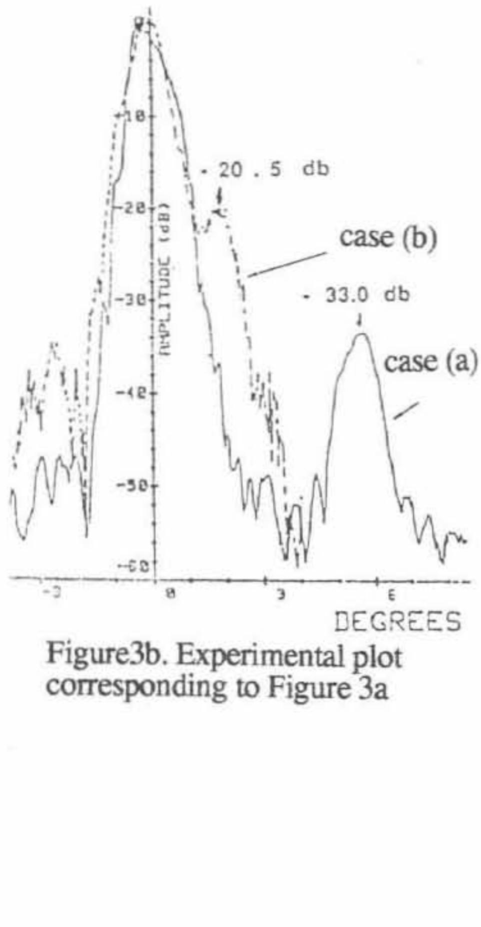

Figure3b. Experimental plot corresponding to Figure 3a

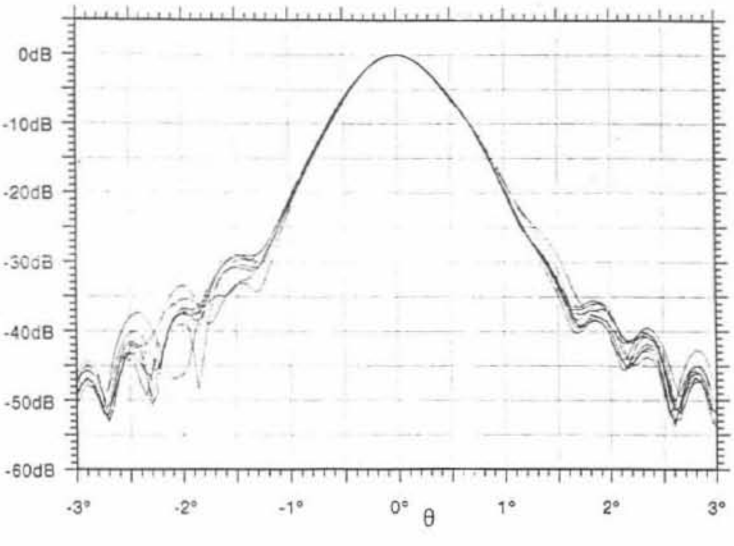

Figure 4. Azimuth patterns taken at 9 points within quiet zone.