COMPACT TEST RANGE FOR MILLIMETER WAVE ANTENNAS

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ABSTRACT
The proposed compact range design has been designed to be installed at department of physics, University of Milan, in order to test the antenna systems alone in their close environment, especially the payload of scientific satellites for astrophysical missions. The design takes into account the RF specifications and mechanical constraints of available MAC with dimensions of 3.5x4.5x8m³. The reflector configuration is based on maximum realizable dimensions of primary and secondary reflectors, and serrations length within 2.4x2.4m², besides keeping the source position on MAC wall. The parametric study of reflector rim dimensions, source feed taper, distance between antenna under test (AUT) and main reflector in quite zone has been carried out in TICRA Grasp v10.2.0. The compact test range is found suitable for the frequency range of 40 to 200GHz. The quite zone of 1.8x1.8m² is realized with amplitude ripple ± 0.5dB and phase ripple ± 3°.

1. INTRODUCTION
Antenna test ranges are capable of measuring the radiation and scattering characteristics of high performance antennas and to operate over a wide range of frequencies [1]. The compact antenna test range can fulfil these requirements very well and has emerged as a versatile indoor antenna measurement facility capable of measuring medium to large size antennas over the frequency range of 1 to 300 GHz. It is designed by one (or more) collimating reflector antennas to create a region of plane waves, called quiet zone, in front of a main reflector [2-3].

The proposed compact test range has been designed to be installed in a microwave/millimetre wave anechoic chamber (MAC) present in laboratory of space instrumentation, department of physics, University of Milan. The compact range design has achieved a quite zone greater than 1.5x1.5m² in agreement with the MAC in order to test the antenna systems and radars, especially the payload of scientific satellites for astrophysical missions. It is well known that, compact range is a dual reflector system with different conics, along with that, desired RF/Electromagnetic specifications and mechanical constraints of available MAC with dimensions 3.5x4.5x8m³ has been considered. The reflector configuration is based on inner rim of primary and secondary reflectors, and serrations length within 2.4x2.4m², also placing the source antennas on one of the MAC wall. First, the comparison between different conic types for reflectors has been performed which led us to continue further design and analysis on a configuration with paraboloid and concave arm hyperboloid geometrical optics.

Figure 1. Compact test range model

Figure 1 shows the compact test range model designed to be fit in available MAC. The compact test range is found suitable for millimetre waves in the frequency range of 40 to 200GHz. The quite zone of 1.8x1.8m² is realized with amplitude ripple ± 0.5dB and phase ripple ± 3° keeping both reflector dimensions 2x2m² with serration length of 0.2m. A scalar feed corrugated horn has been designed in order to performance 3dB taper on the secondary reflector rim. The effect of reflector surface tolerance measured by photogrammetry method
and reflector alignment accuracy will be analysed up to 200GHz in GRASP. The compact range will be soon manufactured by technique typical used for ground station antennas.

In rest of the paper, Section 2 describes the theoretical design of compact range while Section 3 demonstrate the results obtained for compact test range and parametric studies carried out to improve the design. Section 4 concludes the paper.

2. COMPACT RANGE DESIGN

A dual reflector compact range has been designed using parabolic conic as main reflector and concave hyperbolic conic as sub reflector [4]. The reflectors are designed keeping in mind size limitation of MAC. Figure 2 shows the theoretical diagram of compact test range. Scalar corrugated horn is used as feed antenna with 3dB taper while the reflectors are aligned with precision to get the plane waves at AUT.

![Figure 2. Theoretical compact test range](image)

In order to design a reflector antenna system, mizuguchi condition must be satisfied [5]. Besides that, main reflector focal length is kept 300λ and distance between foci relative to main reflector focal point is kept 480λ. Eqn. 1 is mizuguchi condition.

\[
\tan\left(\frac{\theta_s}{2}\right) = M \tan\left(\frac{\theta_f}{2}\right)
\]

Where, \(\theta_s\) is angle between main reflector axis and sub reflector axis while \(\theta_f\) is the angle between feed axis and sub reflector axis. \(M\) is the magnification factor and \(e\) is the eccentricity, normally -2 in compact range case.

\[
M = \frac{e + 1}{e - 1}
\]

3. RESULTS AND PARAMETRIC STUDY

The modelling of compact test range has been done on commercially available software, TICRA GRASP v10.2.0. The compact test range has been designed and analysed for frequency range of 40 to 200GHz with MAC dimensions constraint. Initially, amplitude and phase of quite zone has been tuned to be plane and flat, along with cross polarization of more than -40dB below co polar level. Figure 3, shows the amplitude and phase curves of quite zone at different frequencies.

![Figure 3. Quite zone region of proposed compact test range (a) amplitude (b) phase](image)

The quite zone area (2D) increases but the amplitude of plane waves decreases with frequency from -57dB to -71dB. The phase of plane waves remain constant but the phase ripple increases with frequency from 1° to 3°. Figure 4, shows the cross polarization difference from co polar level for designed compact test range. The cross polar difference remain more than -40dB from co polar level for all the frequencies.

![Figure 4. Analysis of cross polarization difference](image)
3.1. Parametric Study

Parametric study has also been done in order to analyse the performance and possible improvements in the design. The performance parameters such as reflector rim dimensions, distance between main reflector and AUT in quite zone and feed taper has been studied to enhance the design specification of proposed compact test range.

(a) Effect of Reflector Rim Dimensions: The dimensions of the reflector rims including serrations has been changed from 1.8x1.8m² to 2.6x2.6m². Figure 5 shows the variation in quite amplitude with change in reflector rim dimensions. It is clear from curves that quite zone area increases with increase in reflector rim dimensions. In our case, 2.4x2.4m² is found suitable considering the available MAC dimensions.

![Figure 5. Effect of different dimensions of reflector rim](image)

(b) Distance between Main Reflector and AUT: After getting the plane waves in front of main reflector, the effect of distance between main reflector and AUT in quite zone has been studied. Figure 6 shows the behaviour of quite zone amplitude and phase with respect to change in mentioned separation distance. The quite zone amplitude remains unchanged by varying the distance but quite zone phase gets shifted by 120° with change of every 1m in separation distance.

![Figure 6. Analysis at different separation distances between main reflector and AUT](image)

(c) Effect of Feed Taper: The taper of scalar corrugated horn antenna, the feed, has been examined by varying it from 2dB to 8dB. Figure 7 shows the variation in amplitude of quite zone. Curves show that increasing the feed taper decreases the flatness of quite zone amplitude but ripples increases from 0.5dB to 7dB whereas the phase remained unchanged.

![Figure 7. Effect of different feed taper values](image)

The effect of different serration shapes and reflector surface tolerance will be studied in future work.

4. CONCLUSION

The compact test range for particular MAC has been proposed and studied. For the MAC dimensions, dual reflector compact test range reflector rim dimensions of 2.4x2.4m² has achieved the quite zone of 1.8x1.8m² with amplitude and phase ripples of ±0.5dB and ±3° respectively. Proposed compact range facility has been design for the frequency range of 40 to 200GHz for testing antenna systems of satellite payloads.

5. REFERENCES


