Challenges in Electromagnetic (EM) Characterization of Radome and its Measurement Techniques

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***Abstract*– Radar Dome, or generally called radome, is usually placed over the antenna as an enclosure to protect the antennas from adverse environments. Ideal radome does not degrade antenna performance. In practical scenario it may change antenna performance and cause several effects, such as bore sight error, changing the antenna side lobe level and reduce the transmission efficiency. In view of this antenna engineer must perform stringent analysis to estimate the changes in performance due to placement of radome. This paper describes the various challenges and observations incurred during the radome EM characterization and its measurements in compact antenna test facility (CATF) of ISRO Satellite Centre(ISAC) Bangalore. CATF has experience of successfully testing of various type of radome for different applications. This paper also discusses the side lobe reduction, effects of radome panel joints, degradation in cross polarization isolation. Challenges experienced in EM characterization of airborne radome for fighter aircraft are discussed in subsequent sections.**

***Keywords*— BSE, transmission loss, chamber, CATF**

I. INTRODUCTION

The Ideal radome should appear totally transparent to any electromagnetic signal received or transmitted. Since this is not possible, radome must be designed to minimize the electromagnetic impact of itself on the enclosed antenna. Electromagnetic (EM) requirements determine the importance of signal distortions such as insertion loss,Bores Sight Error (BSE), and side lobe level due the radome structure on the antenna system. It is very muchessential to characterize EM performance of the radome as per its functionalrequirement. The aim of the paper is brings out the challenges in EM characterization of various radome for different application before inducting it into operational one. Principally Compact antenna test facility (CATF) is not meant for radome measurement. But augmenting the critical test methodology the various EM parameters of the radome was characterized viz Radiation pattern, Side lobe level, Beam width, Cross polarization isolation(XPI), Beam shift error (BSE), Insertion loss and Peak gain.

II. OVERVIEW OF RADOME

Radome is an enclosure to protect an antenna from adverse environments in ground-based, shipboard, airborne and aerospace applications while having minimal effect on the Electromagnetic performance of the antenna. Radome always changes the Electromagnetic performance of the antenna because of wave reflections and refraction at interfaces between materials & media, and because of losses in the radome materials. The radome transparency and BSE are the critical parameters in EM point of view.

Generally, the radome wall must offer structural strength and rigidity and electromagnetic transparency over the operating frequency bands. There are three basic types of wall construction which are commonly employed:

(a) Thin wall
(b) Half-wavelength thick (λ /2) or multiple there of
(c) Sandwich or multilayer

The thin-wall radome, usually less than 0.02λ thick, is seldom used in airborne applications owing to its low mechanical strength. Halfwave walls find application for small-to-medium size radomes and most missile radomes employ this design. Halfwave wall structures are often too heavy for very large aircraft radomes, for which a sandwich configuration is generally preferred. Fig(1) shows the

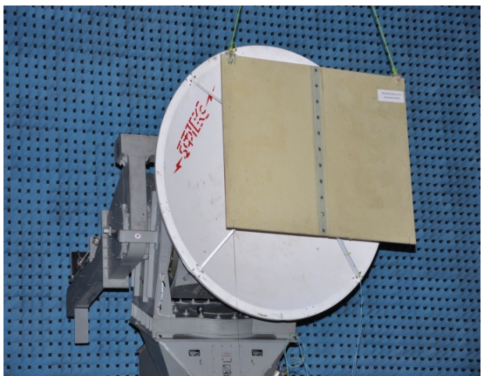
photograph of general radome structure.

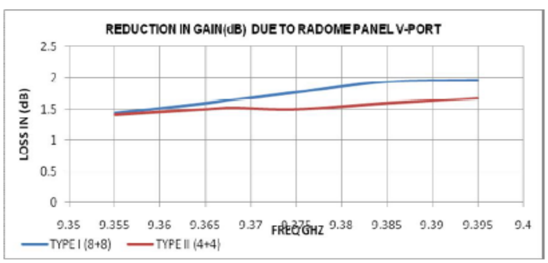
Fig (1) Photograph of radome

III. EFFECT OF RADOME PANEL JOINTS AND ITS EFFECTS

In view of the scientific importance of atmospheric research, National Atmospheric Research Laboratory (NARL) projected the requirement of developing the X-Band polarimetric DWR System. NAL and ISRO have jointly taken up the development of 4.2m X-Band radome for housing and protecting the 2.4m diameter X-Band DWR. Before inducting it into operational it was tested at CATF for its EM characterization.

The various radome panel joint affects the amplitude and phase of the transmitted and received signals, the quantification of impact on the antenna pattern is very critical for DWR and specifically for X-band polarimetric DWR. So the EM performance of radar antenna with the joint portion of two radome panel performed in CATF. The measurement showed considerable degradation of the side lobe level and cross polarization levels of the overall pattern in both azimuth and elevation. So different dimensions of the random panel joints were tested and significant results were achieved to optimize the radome design. Fig.(2) shows the radome panel measurement.





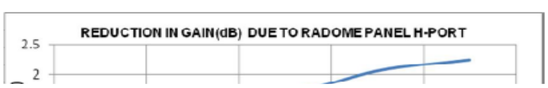
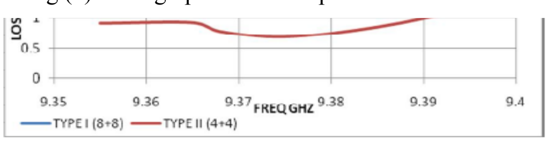


Fig (2) Photograph of radome panel measurement



A. Gain variation due to radome joint panel

Gain measurement was carried out with panel joint in vertical and feed axis in line with radome joint. Fig (3) graph shows the reduction in gain (dB).In the overall gain measurement nearly 1.2 dB improved in 4mm+4mm joint with respect to 8mm+8mm radome joint panel

B. Variation in Insertion loss due to radome panel joint

Insertion loss measurement was carried out with panel joint in vertical and DUT moved in Y-slide with different position of ± 990mm. Fig (4) graph shows the insertion loss (dB) variation with respect to different position of DUT and different polarization. In this case the overall Insertion loss measurement nearly 1.1 dB improved in 4mm+4mm joint with respect to 8mm+8mmradome joint panel.

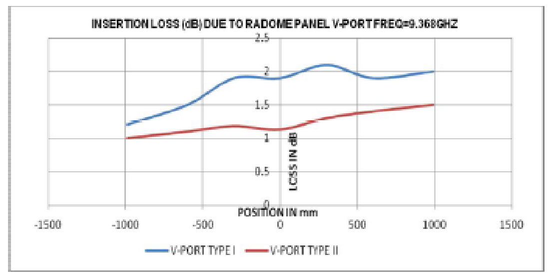


Fig (3) Gain reduction comparison graph of radome joint

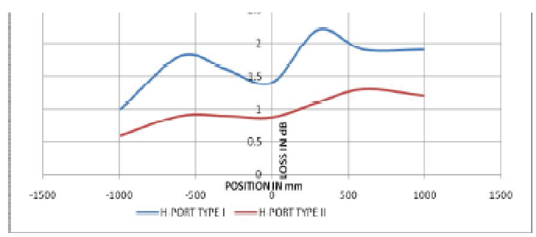
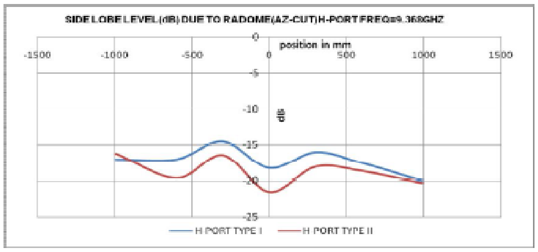


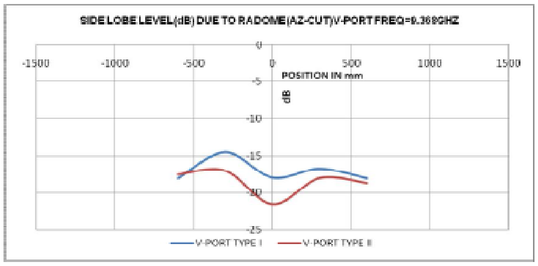
Fig (4) Insertion loss comparison graph of radome joint

C. Variation in Side Lobe Level due to radome panel joint

Side lobe level variation measurement was carried out with panel joint in vertical and DUT moved in Y-slide with different position. Fig (5) graph shows the variation in side lobe level (dB) with respect to different position of DUT and different polarization with azimuth pattern. In this case the overall SLL measurement nearly 1.2dB improved in 4mm+4mm joint with respect to8mm+8mm radome joint panel.

The overall Electromagnetic (EM) performance results of doppler radome are satisfactory and good matching with expected results except in few cases. The measurement result gives the overall confidence for optimized design of full radome fabrication.





III. AIRBORNE NOSECONE RADOME EM MEASUREMENTS

Airborne radar is designed to give high performance, since it has to discriminate between targets and ground clutter, which is a major function. This is made possible with the use of very low side lobe antenna systems. To make the efforts of antenna designer useful, the antenna has to be protected by a radome that is equally of high performance. Hence, the design requirements of an airborne radome (especially for airborne early warning operations) are more critical in evaluating the overall performance of the radar system. For radome design, the requirements are based on military specification. So the radome measurement also is very critical and innovative.Here an airborne aircraft radome was characterized and verified its EM compliance before installation to aircraft nosecone.The fig(6) shows the photograph of antenna with radome measurement.

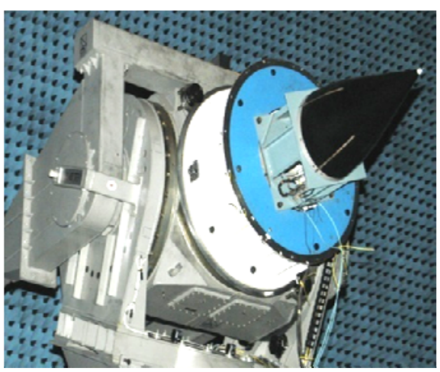


Fig (6) Antenna with radome in DUT Positioner

A. *Insertion loss measurement*

The requirements for the EM performance parameters of nose cone jaguar radome are provided in table 1. The insertion loss for each point is determined by comparing the sum radiation pattern for antenna alone and the antenna-radome system. Similarly the comparison of the null depths of difference radiation patterns for antenna alone and antenna-radome system for each point gives the BSE for that point .The above process was repeated for both azimuth and elevation pattern. With reference to the above mentioned EM performance parameters have been evaluated for each radome at all frequency for the four points in Scan A Region and at one point in Scan B Region. The fig(7) shows the sum and pattern of the radome measurement.

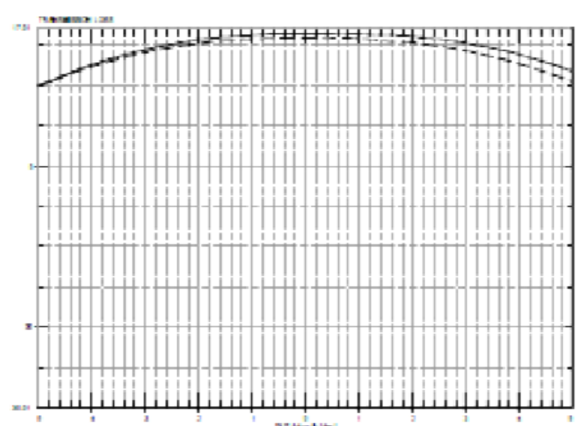
B. *Bore Sight Error (BSE) measurement*

Bore sight error (BSE) is measured as the angular shift of the antenna beam as it passes through the radome wall and it is measured in milli radians (mrad). The radome bore sight error will be measured from the difference pattern of the measurements. During azimuth and elevation pattern measurement both sum and difference pattern were measured simultaneously for antenna alone for five distinct orientations. During azimuth measurement the difference pattern was selected through a switch matrix to measure the ΔAz. similarly during elevation measurement the difference pattern was selected through a switch matrix to measure the ΔEle. Same was repeated with the presence of nose cone radome with preselected points. The fig(8) shows the difference pattern of the radome measurement.

TABLE I. EM PARAMETERS SPECIFICATIONS

Parameters	Scan A Region	Scan B Region
Insertion loss	-1.08dB	-0.81dB
BSE	6 mrad	4 mrad

The measured EM parameter closely matches with the specification. It has been observed that the measured accuracy of the Bore Sight Error/ Bore Sight Shift is within is ±0.17 mrad and of the Insertion loss is within ±0.15dB. The measured results will give the EM performance compliance with respect to the specification before integrating with



aircraft. The measured results are tabulated in table II & III.

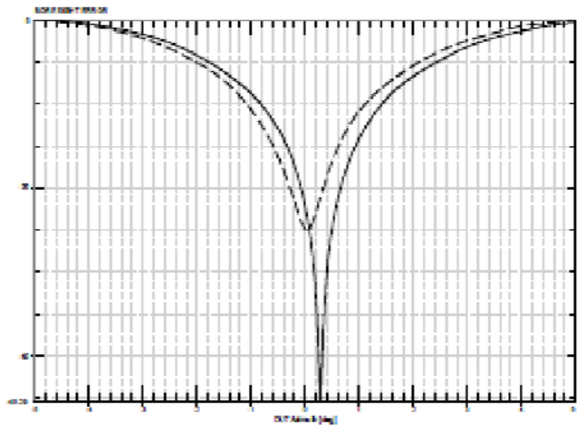


Fig (7) Azimuth sum pattern at scan-A point-1

TABLE II. BSE AZIMUTH (MRAD)

	Measured BSE	Specification(max) BSE
Scan-A-Point 1	2.89	6.00
Scan-A-Point 2	3.33	6.00
Scan-A-Point 3	-4.56	6.00
Scan A-Point 4	4.82	6.00

TABLE III. BSE ELEVATION (MRAD)

	Measured BSE	Specification(max) BSE
Scan-A-Point 1	-2.46	6.00
Scan-A-Point 2	-5.35	6.00
Scan-A-Point 3	3.16	6.00
Scan A-Point 4	3.78	6.00
Scan-B-Point 1	0.35	4.00

IV. EFFECTSIN RF PERFORMANCE OF NRSC RADOME

NRSC Ground Station antennas are operating at S & X-Band frequencies to track & receive the spacecraft payload data and telemetry signals from the IRS class of satellites. The radome is installed over the antenna feed to protect the tracking antenna from environment. Radome covered tracking feed had been characterized for its insertion loss and bore sight antenna pattern performances. It is proposed to study the effect of radome on the cross polarization levels of the tracking antenna. The fig(9) shows the NRSC Radome in DUT Positioner.

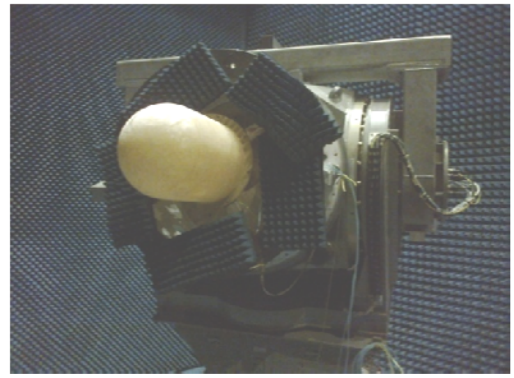


Fig (9) NRSC Radome in DUT Positioner

The radiation pattern of antenna was measured for both LHCP and RHCP polarization at four DUT Roll angles (0, 45, 90 and 135 degree w.r.t. initial DUT Roll axis value). In this case 0 and 90 degree cuts are equivalent to Az and El cuts respectively.

Since the required scan angle of ±60 degree cannot be directly achieved due to DUT EL axis movement limitation, the El cut was conducted via AZ cut. The circular pattern was derived using the channel balance method. The NRSC

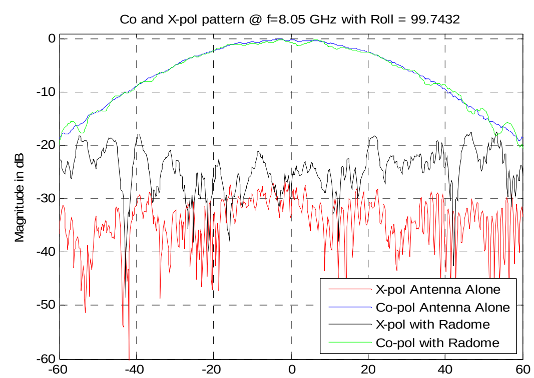


Fig (10) Co and X-Pol pattern measurement

antenna along with the radome was characterized to determine the impact of it on the X-pol performance at bore sight. From the measurements results, it can be observed that the on-axis X-pol level is better than 25 dB nearly in all patterns for both LHCP and RHCP polarization. Also, the beam width @ -15 dB level down from peak is measured to be around $\pm 50^0$(with $\pm 0.5^0$ deviation) and hence it is comparable to the specifications. The fig (10) shows the co and X-pol pattern of the measurements with and without radome.

IV. CONCLUSION

The accurate and precise EM measurement of various types radome was discussed in this paper. The radome EM measurements are an elaborate and laborious activity. By evaluating the novel test methodology with fully automated Compact Antenna Test facility (CATF) at ISRO, the EM measurements were carried out very efficiently with in minimum possible time. The above test results ensures the accurate EM performance of the radome during operational in full system level.

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