Electromagnetic Characterization of Airborne Radome of Fighter Aircraft for Multimode Radar Applications

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Abstract - The Multimode Radar (MMR) on a fighter aircraft is the primary sensor for fire control applications. It is generally located in the front portion i.e. nose cone of the fighter aircraft. Hence, part or full of the nose cone of the aircraft is to be made an RF power transparent radome for the purpose of MMR. Thus the radome plays a dual role i.e. a part of airframe for aerodynamic and structural purpose and part of radar for passing the RF power with minimum loss and disturbance.

Electromagnetic (EM) characterrization of the Radome on a fighter aircraft for its Multimode radar application is an elaborate process since the EM measurements that are to be carried out on Radome are very high in number. In addition to this the mechanical supporting structures and electrical equipment required adds further complexity to this task. Hence, the EM characterization facilities for Radomes of fighter class aircrafts are very few in the Country.

If EM characterization is one complex task, the Design and Manufacturing of airborne Radomes for fighter aircrafts, to meet the required EM specification of Radar on the fighter, is another complex task by itself. This paper focuses on the EM characterization and the detailed steps involved in such procedures of Radomes for fighter aircrafts in general and presents a case study of one such Radome of Tejas aircraft for its Multimode Radar.

I. INTRODUCTION

Broadly, EM characterization of Radome for fighter aircrafts involves accurate measurements of transmission loss or transmission efficiency in the radar band and IFF band of operation, degradation of main lobe and side lobe gain due to radome, beam deflections, if any, due to radome, image lobes, degradation of null depth, VSWR and computation of bore-sight errors etc. The EM measurements encompassing the above parameters can be carried out in either Open test ranges or in the Compact test ranges.

Though the EM measurements of above mentioned parameters is an established procedure but it is time consuming due to large number of measurements involved. Especially the measurements of main beam deflection (null deflection) are required to be carried out ideally at every 1^0 (one degree) step covering the entire scan volume of radar in azimuth and elevation. This is to ensure accurate target tracking of radar for all ranges. Based on the data that is collected for main beam deflections at every point on the radome, the tracking error tables are computed for entire radar band of operation and stored in the Radar Processor. The look angles of radar antenna are dynamically corrected based on these error tables during radar target tracking.

The EM measurements of one such Radome, which is indigenously designed and developed for Tejas aircraft, have been carried out successfully at open test range of ECIL, Hyderabad. This paper presents the steps involved in carrying out such measurements and explains the importance of accuracy of these measurements in radar target tracking. It explains the electro-mechanical set-up required for Radome-Antenna-Scanner combination for obtaining these measurements. Also, it emphasizes the need for establishment of such automated facilities in the country for the above purpose.

II. SET-UP FOR MEASUREMENTS

Tejas (LCA)-Radome measurements are carried out in the open test ranges of LRDE and ECIL. The ECIL open test range was used extensively for carrying out detailed EM measurements in X-band. The required mechanical fixtures were designed and developed by ECIL, especially for this Radome. The mechanical fixtures for Radome test set-up are shown in Figure.1. The Radome is fitted with its Pitot tube along with its adaptor on the test range using the suitably designed and developed mechanical fixtures. The block diagram of the test set-up is shown in Figure.2. The open test range of ECIL is an automated test range. The block diagram of this Automated Test Range (ATR) is given in Figure.3. The EM measurements of the Radome are carried out with all the Radome accessories that are applicable for fighter aircrafts like Tejas. These accessories include Pitot tube, Lighting arresters etc. Hence, the EM characterization of the Radome would be realistic with all the applicable accessories of Radome.

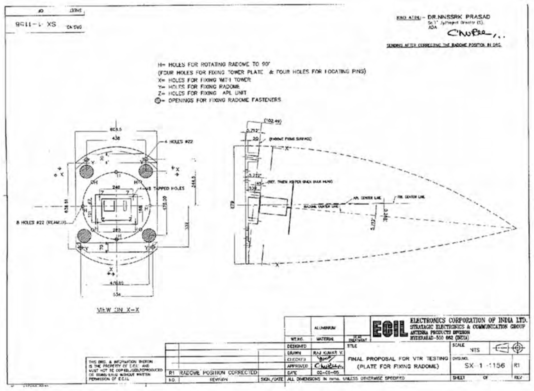

Figure 1 Fixtures of Radome set-up

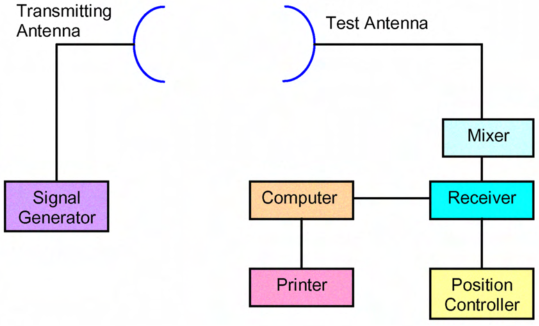

Figure 2 Block Diagram of Radome test setup

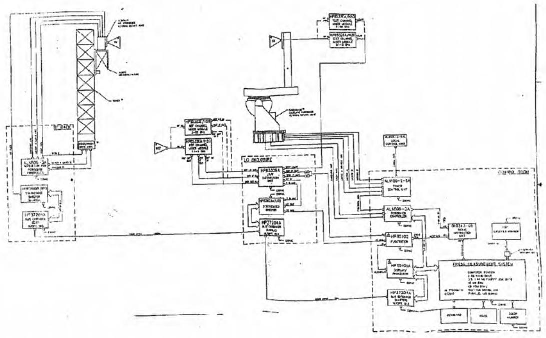

Figure 3 Diagram of Automated Test Range

II. EM MEASUREMENTS

The EM measurements are carried out on the Radome in the X-band at desired frequencies to find out RF Transmission efficiency of the Radome, main beam deflection, antenna pattern distortion including degradation in side lobe levels, distortion in null depth, cross polarization, flash lobes or image lobes and VSWR etc. The detailed measurements are carried out at every one degree step in azimuth and elevation so that the entire Radome characteristics could be mapped in the EM-plane. This Radome is made of Kevlar socks with resin of good chemical composition so that the Radome will attain required strength to be part of aircraft structure and at the same time to have good EM characteristics for the Radar in the nose cone of aircraft. Since the Radar is located inside the Radome and Radome makes the nose-cone of fighter aircraft, both the strength of the Radome and its EM performance are very important.

The EM specifications of Radome [1] [2] are decided such that the degradation in Radar performance is minimized due to Radome. For the convenience of the EM measurements, the Radome is divided in to the following regions [3] keeping the maximum coverage of Radar which is $\pm 60^0$ in both Azimuth and Elevation.

Region `A': With in ± 10º cone centered about Radome nose.

Region `B': Lightning Protection region (where ever lighting protections are placed in the Radome).

Region `C': Remainder of the window area i.e. from $\pm 10^0$ to $\pm 90^0$ centered about Radome nose.

Region 'D': From $\pm 20^0$ to $\pm 60^0$ centered about Radome nose.

The above divisions of Radome are shown pictorially in Figure.4.

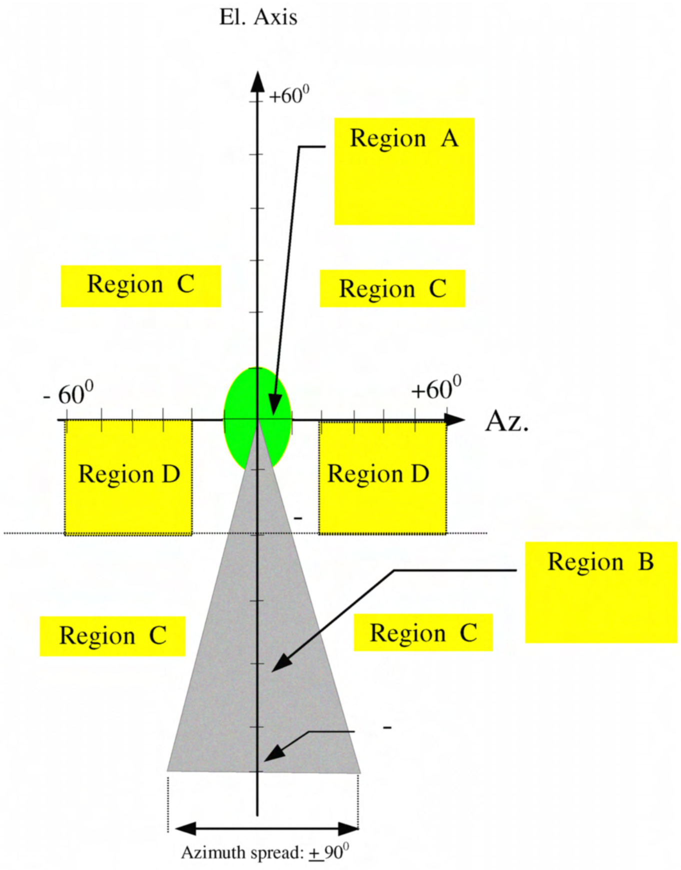

Figure 4 Regions of Radome

The Antenna is a dual plane mono-pulse antenna. It is linearly polarized and contains sum and difference functions for azimuth and elevation. The Antenna is gimbaled in both planes. The antenna position with respect to the Radome is described by the antenna angle. The antenna angle is defined as the angle between the z-axis and the main axis of the Radome. The antenna angle is designated as α. The linear average over the scan at a particular frequency is calculated and afterwards the average transmission efficiency of all the scan angles is calculated at different elevation angles.

The critical parameter of the Radome EM performance i.e. the

Transmission Efficiency is defined as follows:

The average one-way power transmission efficiency of the Radome for desired frequency bands shall not be less than defined specifications in each region of the Radome. The average Radome transmission is calculated according to the following formula:

$$T(average) = \frac{1}{S}\sum_{i=1}^{S} Ti$$

where i = Antenna offset index, Ti = Single scan, average transmission level (%) at elevation offset x_i (Ti shall be obtained directly from measured data per frequency).
S = Number of test scans

Figure 5 Radome on fixture

Thus for each parameter i.e. beam deflection (bore-sight error), its rate, differential deflection error, antenna pattern distortion, near side lobe levels, RMS side lobe levels, image side lobe levels, null depth degradation and cross polarization levels the values are derived from measured values and compared against the specifications. The Radome fitted on fixtures is shown in Figure. 5 and the Antenna along with Scanner is shown in Figure. 6. The Antenna along with Scanner is fitted inside the Radome on a tower-top open test range facility in ECIL for its EM measurements.

Figure 6 Antenna with Scanner

CONCLUSIONS

There is no doubt that the Radome EM measurements are an elaborate and laborious activity. With the automated compact test ranges, this activity can be carried out very efficiently within the minimum possible time. But such good facilities are very less in number in the country as on date.

REFERENCES

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AUTHOR'S BIO-DATA

Dr. N N S S R K Prasad received his B.Tech and M.Tech from JNT University in Andhra Pradesh and PhD from IIT-Bombay. He worked in SAMEER, Bombay from 1986 to 1998. He is working in ADA, Bangalore since 1998. His area of specialization is Radar signal processing, Radar system design, Integration and Testing, especially for fighter aircrafts.

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