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Radar Cross-section Measurement Techniques

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ABSTRACT

Radar cross-section (RCS) is an important study parameter for defence applications specially dealing with airborne weapon system. The RCS parameter guides the detection range for a target and is therefore studied to understand the effectiveness of a weapon system. It is not only important to understand the RCS characteristics of a target but also to look into the diagnostic mode of study where factors contributing to a particular RCS values are studied. This further opens up subject like RCS suppression and stealth. The paper discusses the RCS principle, control, and need of measurements. Classification of RCS in terms of popular usage is explained with detailed theory of RF imaging and inverse synthetic aperture radar (ISAR). The various types of RCS measurement ranges are explained with brief discussion on outdoor RCS measurement range. The RCS calibration plays a critical role in referencing the measurement to absolute values and has been described.The RCS facility at Reseach Centre Imarat, Hyderabad, is explained with some details of different activities that are carried out including RAM evaluation, scale model testing, and diagnostic imaging.

Keywords: Radar cross-section, inverse synthetic aperture radar, stealth, RCS control, anechoic chamber

1. INTRODUCTION

Radar scattering is typically represented as the radar cross section (RCS) of the test object. The RCS is a measure of power scattered in a direction being considered when a target is illuminated by a plane wave. The RCS-σ is a measure of reflective strength of a target defined as 4π times the ratio of the power per unit solid angle (steradian) scattered in a specified direction to the power per unit area in a plane wave incident on the scatterer from defined direction[1]. It is the limit of that ratio as the distance from the scatterer to the point where the scattered power is measured (r)approaches infinity:

$$\sigma = \underset{r\to\infty}{\mathrm{Lt}}\ 4\pi r^2 \frac{\left|E^{\mathrm{scat}}\right|^2}{\left|E^{\mathrm{inc}}\right|^2} \tag{1}$$

where, E^{scat} is the scattered field and E^{inc} is the field incident at the target.

The RCS is thus given in units of area (or effective cross-sectional area of the target). However, it is to be noted that RCS of the test object is a property of the test object alone, and not a function of the radar system or the distance between the radar and the test object, as long as the target is in far field, often this cross sectional area is expressed in units of decibels with respect to square meters (abbreviated as dBsm).

Using this definition, the RCS of a radar target is a scalar ratio of powers. If the effects of polarisation and of phase are included, the scattering can be expressed as a complex scattering matrix. The measurement of the RCS of a test object requires the test object to be illuminated by an electromagnetic plane wave and the resultant scattered signal to be observed in the far field. After calibration, this process yields the RCS of the test object in units of area, or the full scattering matrix as a set of complex scattering coefficients.

The phenomena can be explained in simplified way for simple 2-D test objects, however for 3-D complex targets the total reflection is made up of individual reflection from prominent scattering centers. Major backscatter sources at given target aspect are resulted by specular reflection from flat surfaces of the target normal to the radar and energy diffraction from corners. Other sources of backscatter are creeping waves and resonant parts of the target. The overall phenomena is little difficult to predict through computer codes and simulation programs as identification of all sources of scattering and exact process is difficult to visualise and to calculate the actual overall scattered energy.

2. RCS CONTROL

The RCS of a target plays an important role in detection by radar. Enhancement or reduction of RCS of a target which is being detected by radar needs control depending on the applications. A thorough understanding of the electromagnetic scattering characteristics of a target is necessary for successful implementation of desired control of its RCS.

In military applications, it is necessary to reduce the

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RCS of air targets like missiles, UAV, aircraft, and spy satellites. Similarly, ground vehicles and missile launchers need to be designed so that they have minimum RCS. For testing of radars and seekers, artificial targets are required. These artificial targets are to be designed for required RCS and sometimes, it is necessary to enhance the RCS to meet the range and testing conditions. In civilian applications, for satisfactory performance of air-traffic control radars it is necessary to reduce reflections from the nearby buildings and aircraft hangers.

It is not only desirable to reduce RCS but at times to enhance it, the actual requirement only spells out the selection; however RCS is the relationship that connects target range for an existing radar system that is being used for the detection.

2.1 Reduction of RCS

There are various ways of reducing the RCS of target, like physical target shaping, applying radar absorbing material (RAM) on surface of target, and using active elements on the surface. The RAM material absorbs incident electromagnetic wave and reduces the RCS. For narrow bandwidth applications, a single coating of RAM is generally applied but for broad bandwidths different materials with multiple layers are coated. Sometimes active elements are used which work on the principle of phase cancellation in the desired direction. In target shaping, the shape of the target is modified to change the direction of scattered energy from one angular region of interest to another unimportant region. However, for airborne targets aerodynamic shape is also important and tradeoffs are to be worked out. Static targets are more flexible for shaping.

2.2 RCS Enhancement (Augmentation)

Some practical applications require enhancement of the RCS. Training aircrafts need continuous tracking and hence for reliable tracking their RCS is augmented. Artificial airborne targets are used for missile performance evaluation. These targets are tracked by radars. The RCS of these airborne targets is enhanced. Usual practice is to use Luneburg lenses, corner reflectors as well as transponders with amplifiers. It depends upon the application.

2.3 Need of RCS Measurements

The RCS is a vital parameter for the design of modern aircrafts, missiles, helicopters, ground military vehicles, launchers, airport buildings, and other important strategic installations. It is difficult to theoretically estimate RCS of complex targets as it is impossible to include all practical phenomena into consideration. Hence, it becomes necessary to have a suitable RCS measurement facility depending on the target size and measurement specifications.

3. RCS MEASUREMENT PRINCIPLE

The main purpose of RCS measurement is to collect radar target scattering data at various viewing angles[2-4]. The data should correspond to far field where the target is located far enough from the radar so that the incident wave is an acceptably plane wave[5]. For RCS measurements following accessories are essential:

(a) Instrumentation radar**:** for transmitting and receiving the microwave signals of desired frequency
(b) Target rotator**:** (with very low self RCS in the direction of measurement) to manipulate target orientation and generate all possible target orientations
(c) Targets**:** The 'test object' and 'calibration targets' with suitable interfacing arrangement on positioning system.
(d) Environment**:** A low background signal environment with far field behavior
(e) Control and data acquisition system**:** For automatic configuration, acquisition and analysis of multi-channel RF data and positioning system

Conventional approach followed in RCS measurements is based on following approaches:

(a) Continuous wave (CW) RCS measurements.
(b) Stepped CW (SFCW) RCS measurements.
(c) Gated CW RCS measurements.
(d) Frequency modulated (FM) CW RCS measurements.
(e) Pulsed RCS measurements.

In CW RCS measurement the CW signal at the desired frequency is recorded by a tuned narrow band receiver. Since RCS can only be estimated if the correct vector signal of the target component is identifiable, this measurement approach depends heavily on the possibility of performing the vector subtraction between a target along with background and background (without target) measurements. The measurement technique suffers from the disadvantage that it can not resolve very small scatterers if the subtraction is not perfect. The factors that may lead to imperfect cancellation can be target support interaction, feed coupling etc. The disadvantage is overcome in stepped CW measurement technique.

In SFCW measurement technique a band of frequency is transmitted instead of a single frequency as it carries more information and then by applying time domain gating (after Fourier transform application). Imperfect subtraction can be taken care of by gating desired target zone, using the fact that targets and imperfections cannot utilise the same downrange cell location. The other advantage of SFCW technique is that it can lead to ISAR imaging[6,7]. FMCW is a special implementation (faster) of SFCW form where the radar is specially designed to perform these measurements in a single shot[8].

Gated CW is an advantageous form of simple CW technique, where the CW signal is chopped by switches to generate a pulsed CW waveform (in transmit chain). This helps in cutting down the target-only zone from clutter and by properly adjusting the delay in receive chain (to avoid power from *Tx* to tunnel into *Rx* chain). The advantage of this technique is that it combines the advantage of pulse and CW measurements. The technique offers the advantage of using narrow band receivers to perform fast measurements. Further advantages are in using SFCW or FMCW signals within the pulse envelope.

The system suffers with the disadvantage of complex system design, timing, and control requirement for automatic measurements.

Pulsed CW is a special implementation of gated CW where the generated signal itself is a pulse rather than the chopped CW. In general, same receive technique can be adopted as in case of gated CW measurements. Wide band receivers also find application in measurement of RCS in pulse mode.

3.1 CLASSIFICATION OF RCS MEASUREMENT

There are many classification of RCS measurements, governed usually by the final usage of the information. popular classification of RCS measurements are based on:

(a) Transmit and receive observation point with respect to the target, i.e., monostatic and bistatic RCS.
(b) Information about the target, i.e., gross RCS or diagnostic imaging.

- *Monostatic RCS*: The transmit and receive observation points are co-located, used to express the RCS when the target is observed from the same radar in operational environment.
- *Bistatic RCS*: The transmit and receive observation points are separated in angle, used to express the RCS when the target is illuminated and observed by different spatially separated radar stations.
- *Gross RCS*: For gross RCS measurements at a particular frequency for the defined set of transmitting and receive polarization, the reflectivity data is collected with and without target in required annular sector with the help of positioning system. The measurements need calibration with a set of known standard targets to reference measured reflectivity to absolute/gross RCS values. Gross RCS term is basically the far field RCS of the target under test with respect to angles as a function of frequency and polarization.
- *Diagnostic Imaging*: Often it is necessary to know the location of prominent scatters of the complex targets in addition to the gross RCS. The target needs microwave imaging to find out the prominent scatters also known as hot spots of the target. The RF imaging is basically the spatial distribution of scattering in 2/3 dimensions to identify and isolate individual scattering centers. Since imaging is an indirect process (if to be performed based on frequency domain information) the parameters are to be carefully chosen for correct display and identification of desirable location.
- *Theory of RF imaging*: A target of interest can be considered as comprising of various reflecting centres called scatters and the radar image is the spatial distribution of these scatterers. Electromagnetic waves are transmitted towards targets and the received signal can be used to determine the shape and composition of the target. synthetic aperture radar (SAR) and inverse synthetic aperture radar are the techniques used for RF imaging of the targets.

3.2.1 Synthetic Aperture Radar

Consider a moving radar antenna at a single position illuminating an area of the target. This illuminated area is termed the footprint of the radar. As the radar moves, at fixed intervals transmit, receive and store operation is done. The stored signals are then summed coherently to produce signals equivalent to those that would be received by a physical aperture with the same length as the synthetic aperture[7,9]. Thus large physical aperture in real array radar can be avoided by synthesising an equivalent aperture through sequential transmission and reception of each individual element or position of the radar antenna. A SAR image is produced by processing and sampling of the received signals scattered from the target at various viewing angles.

3.2.2 Inverse Synthetic Aperture Radar

In ISAR, the target to be imaged is rotated or moved while the radar is stationary[6,7]. Therefore, ISAR technique requires target motion. As the target rotates while radar beam remains fixed, reflectivity data due to the different responses of the different scatterers of the target can be worked out.

Figure 1 shows an ISAR target rotating within the beam of stationary radar. Angle ψ is the rotational angle made by the target as the target rotates. The y-axis corresponds to the line of sight of the radar and range to the centre of rotation is *R*. Instantaneous range to a target scatterer *P* is *r* from centre of rotation *O* of the target. In ISAR imaging, measurements are taken with reference to the target's rotation and range[7].

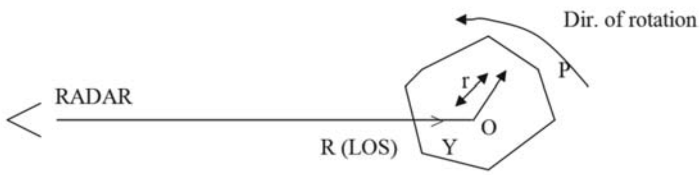

Figure 1. ISAR geometry.

3.2.2.1 Cross-range Resolution

Figure 1 shows a target rotating about point *O* with a scatterer *P* at distance *r* from *O*. As the target rotates with an angular velocity of ω, the distance between the radar and *P* will be smaller and this results in the radar echo from *P* having a positive Doppler frequency of

$$f_d = 2r\,\omega/\lambda \tag{2}$$

where, λ is the transmitted wavelength. If two scatterers are separated in cross-range but in the same slant range cell has a separation distance of Δr_c, the Doppler frequency difference becomes:

$$\Delta f_d = 2\Delta r_c\,\omega/\lambda \tag{3}$$

Equation (3) shows that the cross-range resolution is dependent on the resolvable Doppler frequency. The Doppler resolution Δf_d is approximately equal to the reciprocal of the coherent integration time T. Hence, the cross-range resolution can be given as:

$$\Delta r_c = (\lambda \Delta f_d)/(2\omega) = \lambda/(2\omega T) = \lambda/(2\psi) \quad (4)$$

where, $\psi = \omega T$ is the rotating angle during coherent processing time T. The cross-range extent X_c is divided into resolution cells of length Δr_c long and must be sampled by N samples, where N is the number of measurement bursts. Hence, the unambiguous cross-range window, which is the maximum extent of a target in the cross-range that can be unambiguously sampled with N bursts is:

$$X_c = N\Delta r_c = N\lambda/(2\psi) \quad (5)$$

Here, imaging has been discussed in two dimensions through processing of echo signals over a series of rotation angles in X-plane. For 3-D image, measurements are repeated in elevation plane along with azimuth plane. Height resolution can be calculated by:

$$Y_c = M\Delta r_c = M\lambda/2\Phi = \lambda/2\Delta\Phi \quad (6)$$

where, Φ is the depression angle covered by sequence of rotations and $\Delta\Phi$ is the increment between elevation samples. Y_c is unambiguous height window.

3.2.2.2 Down-range Resolution

For a simple pulsed radar system range resolution (ΔR) is a function of pulse width (τ) and is given by

$$\Delta R = c\,\tau/2 \quad (7)$$

where c is the velocity of light. The pulse width of the radar system and band width (B) are inter-related and are given by:

$$B = 1/\tau \quad (8)$$

Hence Eqn (8) can be modified to:

$$\Delta R = c\tau/2 = c/2*B \quad (9)$$

The next section describes different popular ranges for RCS measurements.

4. MEASUREMENT RANGES

Choice of a RCS measurement range is driven by following parameters:

(i) Size of the target
(ii) Frequency of measurement
(iii) Overall measurement/ database requirement, accuracy in measurements, etc.

Following RCS measurement range configurations are popular:

(a) Anechoic chamber - Far-field range
(b) Anechoic chamber - Compact range
(c) Outdoor range
(d) Near field range

Anechoic is a word of Greek origin which means, without echo. Anechoic chamber offers a test environment where the reflected electromagnetic energy from the chamber walls is attenuated and controlled to a specified low value. The chamber therefore simulates a free-space test condition.

4.1 Anechoic Chamber–Far-field Range

A simple rectangular room is a most popular design which meets almost all the requirements. Generally width and heights are almost same for the chambers. Length is generally twice the width. Quiet zone is the volume where electromagnetic field variation is within the specified limits in terms of amplitude and phase characteristics. The quite zone size of a test range determines from the physical size of the target to be evaluated in the range. The range length is chosen so that the target under evaluation is in the far field of the source antenna and quiet zone is formed with required specifications[5]. Generally length (R) is chosen so that the following condition is met:

$$R = \frac{2D^2}{\lambda} \quad (11)$$

where, R is the range length, D is the maximum cross-sectional dimension of target under test, and λ is the free space wavelength.

Knowing the required quiet zone size and the range length, in conjunction with the gain and pattern characteristics of the radiating source antenna, the conventional rectangular chamber design can be formulated. The radar absorbing material (RAM) is applied on the inner walls of the chamber to attenuate the reflected signal. The chamber specular regions will be both end walls and approximately central areas of both the side walls, floor, and ceiling. The end wall behind the quiet zone is illuminated by direct main beam of the source antenna at normal or near normal incidence. Consequently the RAM performance in this region must be selected to match the required quiet zone reflectivity. On the opposite end wall, behind the source antenna, the RAM is illuminated by the antenna back lobe and the performance can be adjusted depending upon the front to back antenna pattern ratio. Side wall, floor and ceiling specular regions require careful design. The size and shape of the specular area should be determined in terms of fresnel zones. Figure 2 shows sketch of a anechoic chamber-far-field range.

4.2 Anechoic Chamber–Compact Range

Compact range uses the reflective properties of a paraboloidal reflector to correct the phase curvature of electromagnetic wave radiated from a small antenna at the focal point of the reflector. The reflected wave is collimated and the phase curvature is substantially corrected to simulate far-field conditions within a compact range. The compact range requires a special anechoic chamber having high quality RAM on the end wall. The collimating effect of the reflector de-emphasizes the effect of the chamber walls, floor and ceiling allowing the use of less stringent RAM. The RAM is also fitted to the feed antenna equipment, the reflector pedestals, and the test target positioner, eliminating spurious reflections from these objects. Figure 3 shows photograph of a compact range.

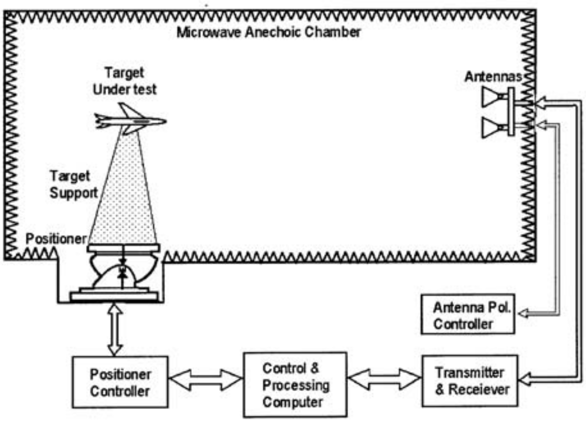

Figure 2. Anechoic chamber–far-field range.

4.3 Open Range

The RCS measurements need a transmitter, a receiver, and a positioning system for the target under test. Transmitting antenna should generate a plane wave at the target. The target should create far-field at the receiving antenna. This is possible in a open space, however, the locations of transmitter, receiver, and target are to be fixed such that there are no reflections from the near environment and the ground. In actual scenario, it is difficult to stop reflections from the ground. There are two possibilities of implementation of the open range in context to ground reflections:

(a) Ground plane reflection is used in the measurements, and
(b) Ground plane reflections are defeated using fences, berms or absorbers.

The various parameters that dictate the performance of the test zone are: Transmitter height H_{tx}, target under test (TUT) height H_r, wavelength of operation λ, and range separation distance R. Since the parameters are frequency dependent, it requires that a unique solution exists at each frequency of operation for the target, TUT, as well as range distance. Therefore to achieve measurement capability, following are termed as the basic requirements of the test range for different types of schemes.

COMPACT ANTENNA TEST RANGE (CAR)

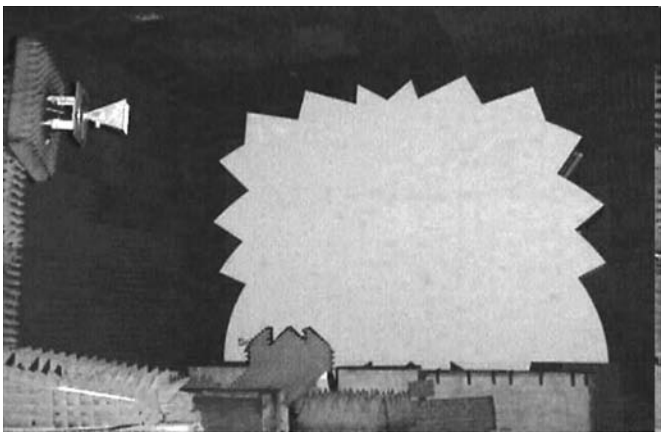

Figure 3. Compact Range.

1. For fixed target height:
   (a) The range should have variable distance capability.
   (b) The range should have variable Tx/Rx height capability.
2. For fixed range distance:
   (a) The range should have variable Tx/Rx height capability.
   (b) The range should have variable target height capability.

The above two parameters help in identifying the unique solution for each frequency of operation.

For RCS, the measurement requirement is to position the target whose reflectivity characteristics is to be evaluated on a elevated platform (to be termed as pylon) at TUT location. At the Tx end, two side by side antenna systems– one for transmitting and the other for receiving the backscattered signal, are positioned. Both the antenna systems can be physically co-located (in case of monostatic measurements) or can have a relative angle between them (bi-static measurements), based on whether the reflectivity characteristics are to be measured for an active radar or for a semi-active radar system.

Usually the practice for performing such measurements is to first measure the characteristics of the TUT and then taking the measurement data again without the target (to be termed as background data). The vectorial subtraction of both measurements give the return contributed 'only' by the target and its magnitude a direct measure of its RCS. For such facility where full-scale targets are to be measured, there are some significant factors to be considered:

(a) Time to be taken for mounting the target
(b) Time to raise the system to the measurement height
(c) Measurement time for required aspect angles
(d) Time to lower the pylon system
(e) Time to remove the object from pylon
(f) Time to raise the pylon again to the measurement height
(g) The deflection of pylon system with and without TUT

The effect on measured background data will depend on time taken from (d) to (g) operations. Typical values may run into 'few hours' for heavy duty system. As the measurement situation is an outdoor range the parameters may vary drastically and may lead to imperfect cancellation of vectors leading to wrong measurements. The solution lies in designing a system with following characteristics:

(i) The pylon design is of special type and doesn't require any background data cancellation, that means the backscatter from the pylon is very small (typically < –40 dBsm).
(ii) Use of time (range) gating in implementation of the system to eliminate backscattering from nearby scattering sources.

Condition (i) requires that the pylon shape need to be forward leaning OGIVAL with very sharp leading edge. The target should be mounted in such a way that all rotating parts are embedded inside the body of the TUT, meaning it should become part of the target (masked inside it). Once such conditions exist it ensures that Target during measurements is viewed as resting on the top of a sharp blade. It has limitation that if the pylon top is displaced due to target weight then it may have slightly more RCS than its no-load condition. But till the time it is ensured that the value is lower than the lowest RCS one is interested to measure, specifications about maximum allowable deflection as well as sharpness of the blade can be worked out.

5. INSTRUMENTATION

Figure 4 shows schematic basic diagram of RCS measurements indicating various instruments required for measurements. The transmitter generates the RF signal to be radiated through antenna towards the target under measurement. The reflected signal from the target is received by the antenna and goes to the receiver. The receiver detects echo signal that can be stored for further processing or can be recorded by a recorder.

For very high frequency measurements a transceiver is added in front to translate lower frequencies to higher frequency utilising the principle of up and down conversion.

6. CALIBRATION

The RCS calibration is the most important part of measurements. There are various procedures that are devised and adopted at Research Centre Imarat (RCI).

6.1 Single Target Reference Approach

This approach relies on the scattering observed through a metrological certified metallic sphere. The sphere is popularly constructed in the range of –10dBsm to –25 dBsm. The sphere size with RCS > –10 dBsm are impractical because of their un-manageable size and weight restrictions, where as spheres < –25 dBsm suffer from incorrect values at lower frequencies (due to creeping wave addition to main energy. Generally, accepted size is the perimeter of the sphere has to be > 10 times the operating wavelength).

The value observed through this standard sphere is used to calibrate the target return utilising its known RCS value. This technique suffers heavily in case the return power versus RCS value relationship has a slope other than 45° or because of measurement uncertainty.

6.2 Multi-target Reference Approach

In this procedure, variety of metrological standard targets are constructed in shapes varying from flat plates, discs, cylinders and corner reflectors in addition to spheres. The return target echo for the target in angular zones with theoretically well known empirical relationship is compared and a curve is drawn to obtain correct slope relationship.

6.3 Handling Small Targets

For small target returns time domain gating can be efficiently applied to isolate clutter outside the target zone. This helps not only in identifying special target returns but can be used for reference target return smaller than the lowest clutter signal in measurement range. This procedure also helps in improving the measurement errors.

7. FACILITIES CREATED AND WORK CARRIED OUT AT RCI

The RCI has RCS measurement capability in an anechoic chamber/ compact antenna test range with the following specifications (Fig. 3):

- Frequency range: 4.0 GHz to 110.0 GHz
- Quite zone size: 1.2 m dia × 1.2 m long cylinder
- Amplitude and phase ripple: 0.5 dB max, 10° max
- Amplitude and phase taper: 0.5 dB max, 10° max

The RCS measurement needs special twin feeds to be used with transmitter and receiver, which are placed at the focus of the compact range reflector. These feeds are developed indigenously and are integrated with the measurement setup.

Figure 5 shows the calibration standards developed for RCS measurements at RCI. These standards are placed on the RCS pylon and signal strength of the returned wave is measured and a calibration curve is drawn. Figure 6 shows the calibration curve for these standards at X Band.

Calibration curve is drawn at each measurement frequency upto 94 GHz of frequency. The slope of the line is found to be within 40° to 50° at measurement frequencies.

7.1 Evaluation of Radar Absorbing Material

The facility is used very effectively for measurement of absorption characteristics of RAM samples. A metallic flat plate is made of size 1 sq ft[11]. It is mounted on the

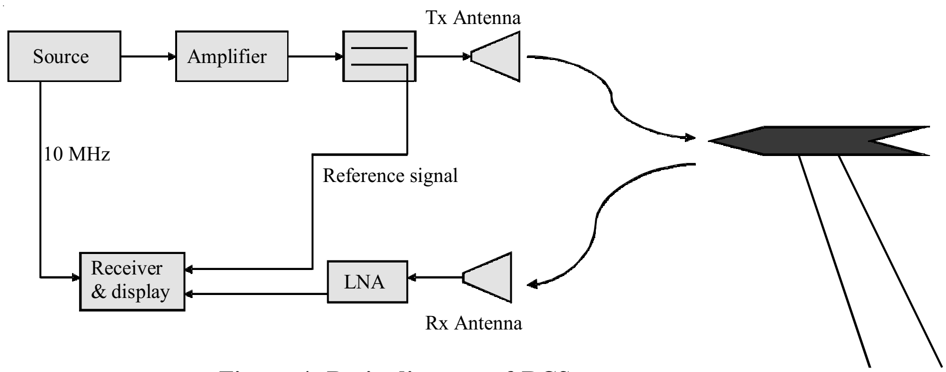

Figure 4. Basic diagram of RCS measurement.

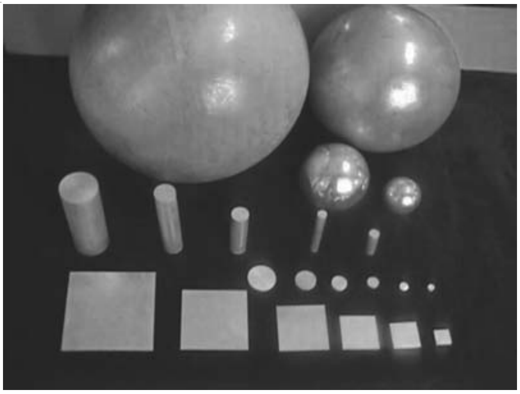

Figure 5. Typical standards used for calibration for RCS measurements.

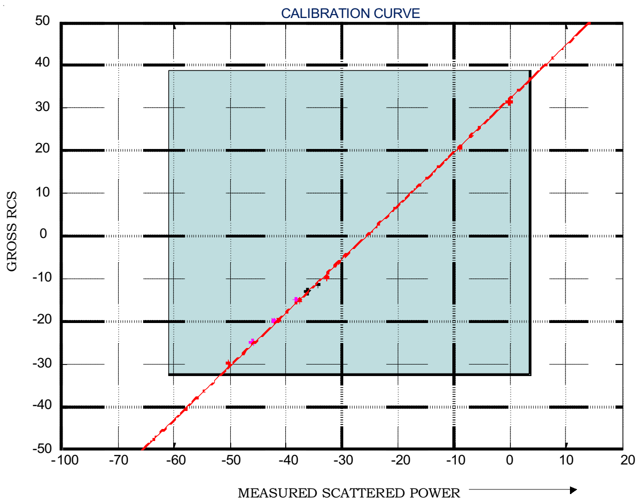

Figure 6. Multi target calibration curve at X band.

RCS pylon and aligned for maximum reflection. The reflections from the plate are measured with frequency or at a fixed frequency with angle of rotation of the plate. The plate is coated with the absorbing material and the measurements are repeated. The two measurements are overlaid and the effective absorption due to absorbing material can be calculated. Figure 7 shows the measured results for a metallic plate and an absorbing paint applied plate 15 GHz as a function of angle for vertical transmit and vertical receive polarization (VV). Figure 8 shows the reflectivity of the plate at normal incidence as a function of frequency between 8-18 GHz.

7.2 Evaluation of Complex Targets

A 1/10th missile model has been tested in the compact antenna test range at X-band. The model has been mounted on the RCS pylon with the help of cylindrical polypropylene support. The model is aligned nose on towards the reflector and measurements are taken by rotating in the azimuth plane. Figure 9 shows the predicted results at 1 GHz of frequency of the actual target based on X-band measurements.

7.3 Stepped CW Measurements and Time Domain Gating

A missile model is tested in stepped CW mode. Then fast fourier transform (FFT) analysis has been done to get the time domain response of the target inside the measurement chamber. Figure 10 shows the results.

7.4 Inverse Synthetic Aperture Radar Imaging

A complex target is mounted on the RCS pylon. Stepped CW measurements are carried out by moving the target in small steps in Azimuth or/and elevation planes. A two/three dimensional RF image is generated using FFT. Figure 11 shows the two dimensional image of the complex target. The more topics that can be supplemented to above paper would be statistical data processing methods, focussed and unfocussed imaging as well as super resolution imaging.

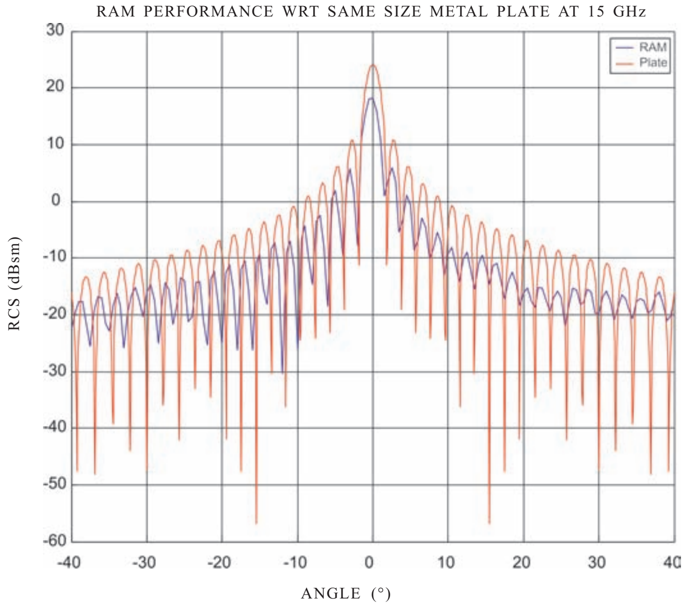

Figure 7. Measured results on 1 sqft metallic plate and RAM-coated 1 ft plate.

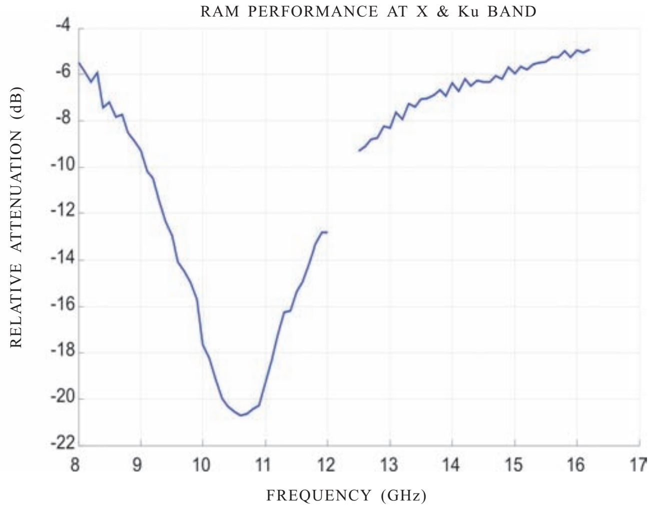

Figure 8. Measured results on RAM with respect to frequency.

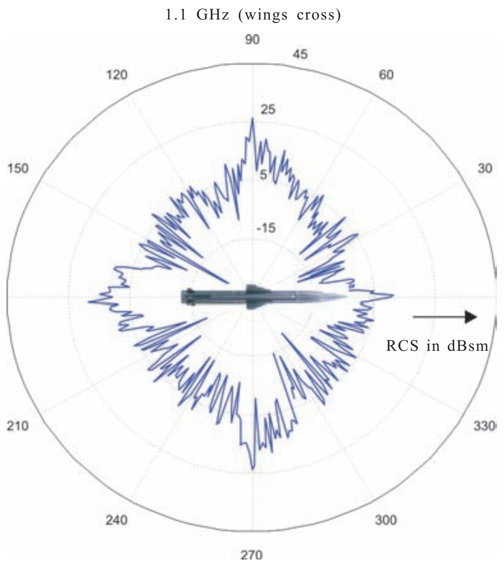

Figure 9. Predicted RCS at 1.1 GHz of actual target from 1/10th scale model measurement.

8. CONCLUSIONS

The paper describes the need for RCS measurements along with important systems that need to be augmented within an anechoic chamber or outdoor range for carrying out successful measurements. It discusses calibration aspects and various factors that need to be considered while performing RCS measurements. A practical measurement for RAM evaluation is described with information that is passed on to designers and users. Measurement of gross RCS at various angles for a missile model is presented which gives insight into the utility of scale down model measurements at higher frequencies for practical targets. Results for stepped CW measurements and time domain gating are presented along with some typical ISAR measurements on an aircraft target showing utility of two dimensional RF imaging to identify hot spots and thus giving inputs to designers to make it stealthier.

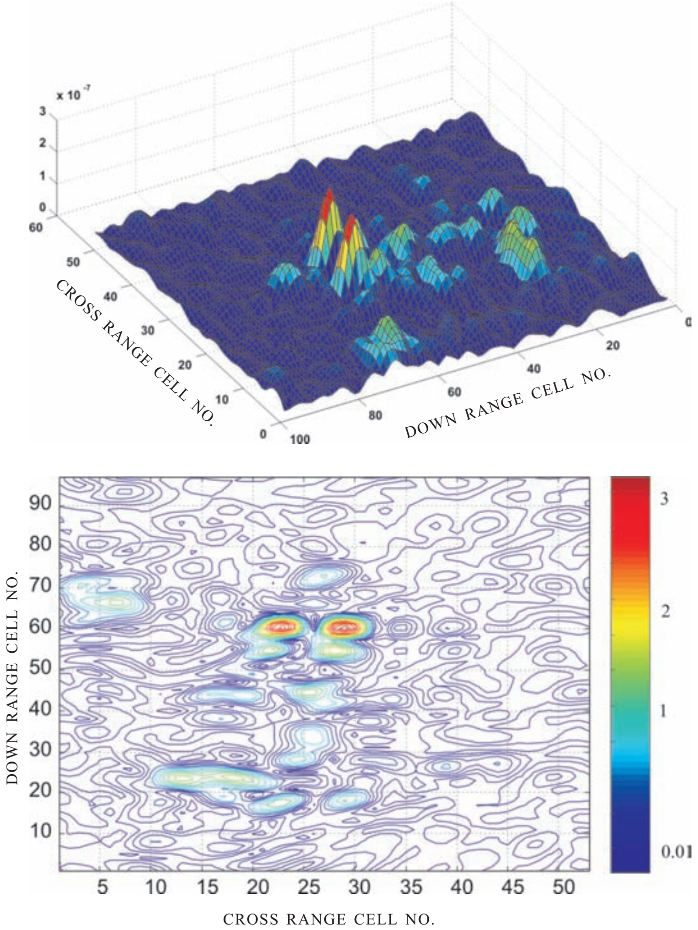

Figure 11. Two dimensional RF imaging of a complex target.

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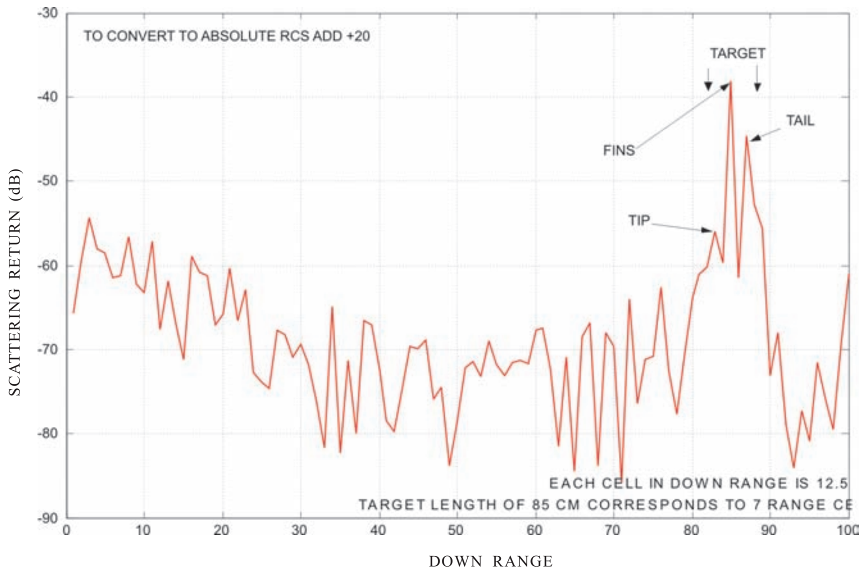

Figure 10. Measured results on a missile target with time domain gating.

who gave impetus to RCS measurements technology. They are also thankful to Dr V.K. Saraswat SA to RM; Mr S. K. Ray, Director RCI; and Mr R. Das, Technology Director, DRFS; for their continued guidance and support for this activity. Authors would also like to thank Mr Dharmanandam and Mr Muthu Azagan who kept the facility in good working condition.

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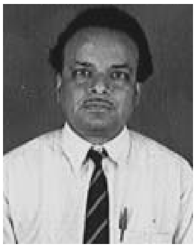

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