Design, Development and Evaluation of Rubber based Conical Radar Absorbent Material (RAM) KV-CRA-18 for Out-Door Application.

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Abstract: *A Rubber based conical RADAR Absorbent Material (RAM) has recently been developed of thickness ~18 mm. The RAM termed as KV-CRA- 18 was tested at near normal incidence up to 60 degree away from normal by NRL Arch method both under dry and wet condition. A min. reflection loss of -15 dB has been achieved at 5.0 GHz, rising to -17 dB at 8.0 GHz and further to min. -20 dB at 10 GHz and higher frequencies in vertical and horizontal polarizations was achieved. The designated performance was achieved up to 45 degree away from normal, for both polarization and under both dry and wet conditions. The reflection loss was down by less than 5 dB with respect to its corresponding near normal and up to 45 degree performance at all frequencies and in both polarizations.*

These RAM's have also been tested at exactly normal incidence by using a near mono-static RCS test set-up from 3.0 GHz to 18.0 GHz and the designated performance was achieved at all frequencies. The RCS measurement was carried out in sweep frequency mode. Back RCS at wider angles (± 45^o from normal) have also been measured at 10 GHz and 15 GHz with respect to flat metallic plate.

The absorbers are very sturdy and can be used on walk-on areas and thus making them ideally suitable for out-door/sea-born applications.
A proper adhesive system suitable for out-door applications/Vertical installation was also developed and peel strength tested as per ASTM-D-429B.

Key words*: RADAR Absorbing Material (RAM), Microwave Absorber, Anechoic Chambers, reflection loss etc.*

I. *Introduction*

RADAR Absorbing Material (RAM) for out door applications requires special properties compared to the conventional RAMs used for the indoor applications like anechoic chambers. A Rubber based conical RADAR Absorbing Material (RAM) for open area applications have been designed, developed and evaluated aiming its application in various fields e.g. ship borne application, open area RCS/antenna test ranges, RADAR signature management of war ships, tanks, vehicles and other metallic military/civil objects etc.

We shall discuss the aimed design of RAMs in section II of this paper, the evaluation process and test results is presented in III and IV section respectively and details of

adhesion test is given in section V, section VI provides the conclusion based on the design and results.

II. *Design/Specification of a Rubber based conical RADAR Absorbing Material.*

The absorbers have been aimed to use at a frequency range of 5.0 GHz to 18 GHz and higher frequencies. Scattering and diffractions at high frequencies due to the presence of edges and singularities in case pyramidal shape of conventional microwave absorber have been avoided/reduced by keeping a conical shape of new RAM. A painted Rubber based conical RAM is shown in figure 1. Other design futures are as per following:

Basic Composition: Loaded Nitrile Rubber.
Working Temperature: -50 ºC to + 80 ºC.
Thickness: 18 mm to 20 mm.
Base Size: 300 mm X 300 mm.
Weight: Approx.1.3 kg of 300mm X 300mm size sheet.
Color: Black:**KV-CRA-18** & painted: **KV-CRA-18 -P** (as desired)
Type of Paint: suitable for outdoor (ship born) applications.
Backing: Bare (un-backed, KV-CRA-18/ KV-CRA-18 -P) and **metal mesh backed (KV-CRA-18-P-M).**
Frequency region: 5.0 GHz to 18.0 GHz and beyond.
Conical front side to face radiation to be absorbed.

Specified Performance of the RAM

i) ***At Normal / near normal Incidence & Upto 45^o from Normal***: Min. reflection loss (angle of incidence equals angle of reflection) w.r.t metal plate of same size should be -15dB at 5.0 GHz, rising to min. -17 dB at 8.0 GHz and min. -20 dB at 10.0 GHz and higher frequencies in both polarizations.

ii) ***At 60^o From Normal***: The reflection loss should be down by less than 5 dB w.r.t normal and upto 45^o performance at all frequencies and in both polarizations.

iii) ***Under Wet Condition***: Performance under wet condition should remain practically unchanged w.r.t dry condition performance at all angles /polarizations /frequencies.

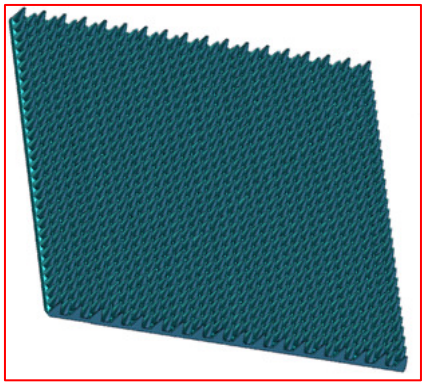

Figure 1: A Painted Rubber based conical RADAR Absorbing Material (RAM) KV-CRA-18-P

III. *Test /Evaluation Procedure*

After design and manufacturing of Rubber based conical RAM it's testing and evaluation has been carried out by two methods

a. As Per IEEE Std.1128/1998: IEEE Recommended practice for RF Absorber-using NRL Arch Method. Measurement of Reflection Loss at near normal incidence (approx. 10º from the normal) with reference to metal sheet of 300mm X 300mm sized from 5.0 GHz and beyond on *two orientations -VV & HH, and in dry and wet*

condition. Reflection Loss at wider angle (30^0 ,45^0 and 60^0) for both polarizations and in dry and wet condition, from normal has been measured using a Anechoic Box at transmitter and Receiver side to cut down the cross talk and extraneous multiple reflections reaching to receiver. Angle of incidence equals angle of reflection. Test setup is as in figure2:

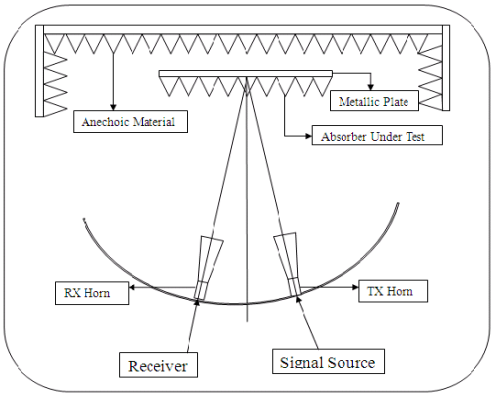

Figure 2: NRL ARCH Measurement Setup for near normal and wider angle incidence.

b. As Per Near Mono-static RCS Measurement Method. A near monostatic RCS measurement test setup as in figure 3 has been used to analyze the back RCS at normal and wider angles up to 45^0.

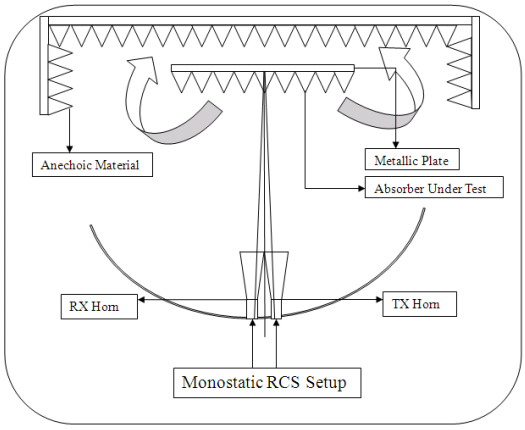

Figure 3: Near Mono-static RCS Measurement Setup for normal/wider angle incidence.

IV. Test Results :

a) Reflection Loss As Per IEEE Std.1128/1998: Measurement of Reflection Loss at near normal incidence (approx. 10º from the normal) with reference to metal sheet of 300 mm X 300 mm sized from 5.0 GHz and beyond on two orientation (VV & HH), and in dry and wet condition. Reflection Loss at wider angle (30^0, 45^0 and 60^0) from normal shown as per figures 4, 5, 6 & 7. VV & HH waves were vertically and horizontally polarized respectively, at transmitting and receiving side w.r.t absorber plane.

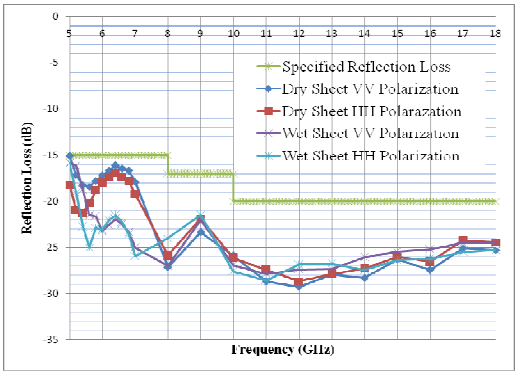

Figure 4: Frequency v/s Reflection Loss from RAM KV-CRA-18-P at near normal incidence.

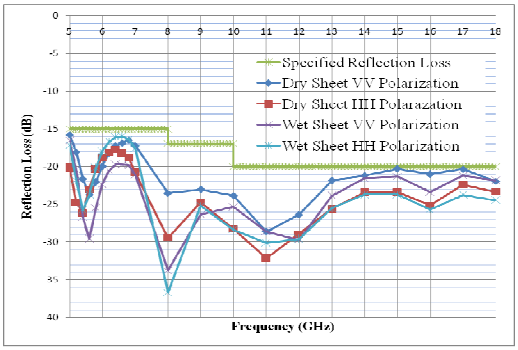

Figure 5: Frequency v/s Reflection Loss from RAM KV-CRA-18-P at 30^o incidence away from normal.

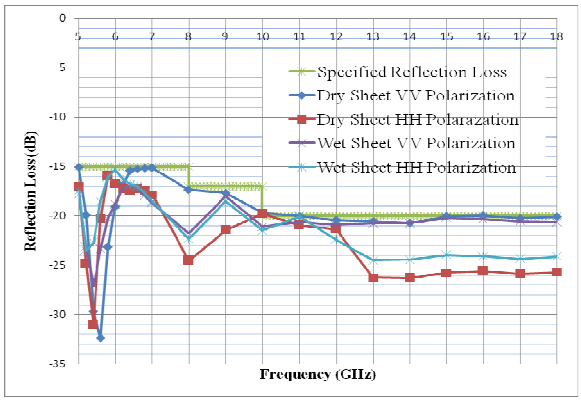

Figure 6: Frequency v/s Reflection Loss from RAM KV-CRA-18-P at 45° incidence away from normal.

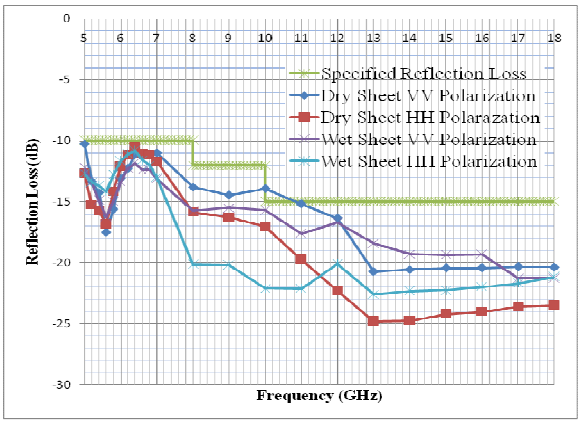

Figure 7: Frequency v/s Reflection Loss from RAM KV-CRA-18-P at 60° incidence away from normal.

b) Near Mono-static RCS Test Results

i) At Normal Incidence:

RAM's have also been tested at exactly normal incidence by using a near monostatic RCS test set-up from 3.0 GHz to 18.0 GHz. The RCS measurement was carried out in sweep frequency mode. The reflection loss performance was recorded, figure 8 & 9.

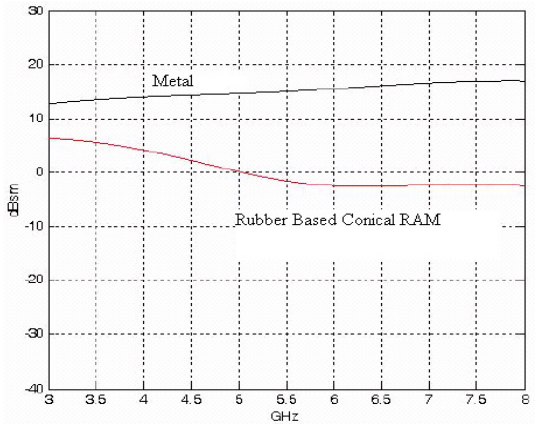

Figure 8**:** RCS plot of RAM KV-CRA-18 w.r.t metal plate from 3.0 GHz to 8.0 GHz.

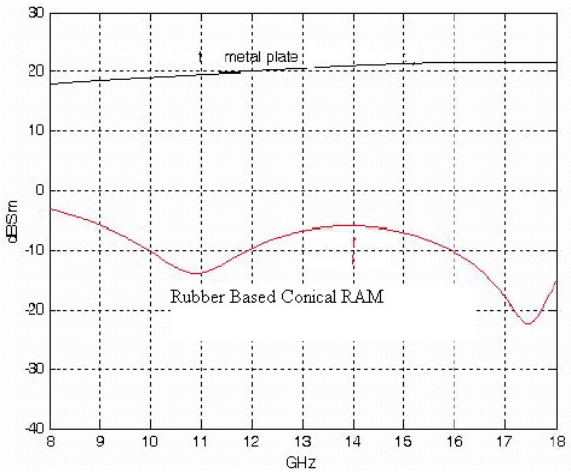

Figure 9**:** RCS plot of RAM KV-CRA-18 w.r.t metal plate from 8.0 GHz to 18.0 GHz.

From figure 8 & 9 we can compare the reflection loss of designed RAM as specified and measured by near monostatic RCS measurement method, as in table 1.

Frequency (GHz)	Reflection Loss (dB)	
	Specified	Measured
5.00	-15.0	-14.22
5.20	-15.0	-15.10
8.00	-17.0	-20.99
10.0	-20.0	-36.70

Table1: Comparison of specified and measured Reflection Loss.

ii) Back RCS at Wider Angles : Un-backed RAM

Near Monostatic Back RCS measurements have been carried out at wider angles (up to ±45°from normal) at 10.0 GHz and 15.0 GHz of a painted & un-backed RAM, fig. 10 & 11.

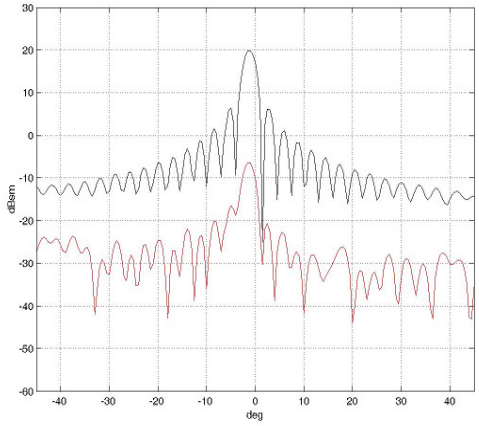

Figure 10: RCS plot of painted RAM KV-CRA-18-P w.r.t metal plate at 10.0 GHz.

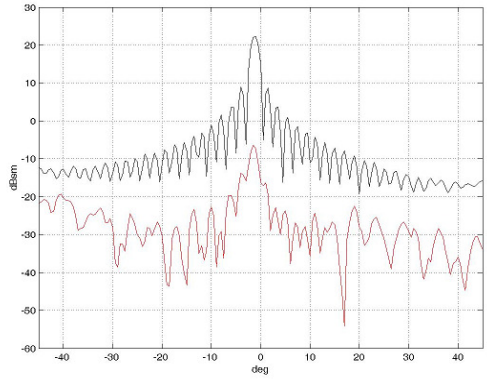

Figure 11: RCS plot of painted RAM KV-CRA-18-P w.r.t metal plate at 15.0 GHz.

iii) Back RCS at Wider Angles : Metal Mesh backed RAM

A metal mesh backed and painted RAM have also been tested for Near Monostatic Back RCS measurements at wider angles (up to ±45°from normal) at 10.0 GHz and 15.0 GHz, fig. 12 & 13.

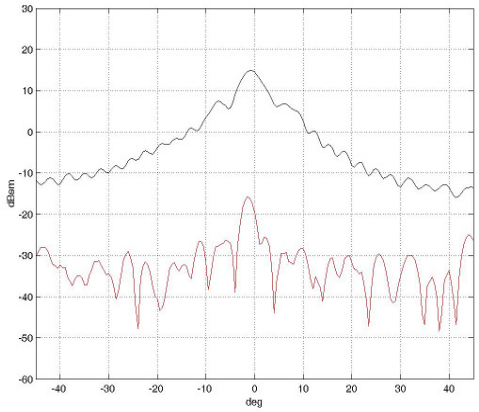

Figure 12**:** RCS plot of painted RAM KV-CRA-18-P-M w.r.t metal mesh at 10.0 GHz**.**

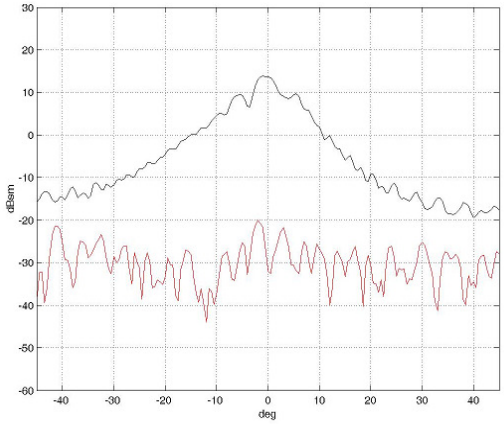

Figure13**:** RCS plot of painted RAM KV-CRA-18-P-M w.r.t metal mesh at 15.0 GHz.

V. ***Adhesion Test****:* A proper adhesive system suitable for out-door applications in humid and saline environmental conditions and for vertical installation on a vertical aluminum and metallic structure was developed and peel strength tested as per ASTM-D-429B.

A photograph depicting the experimental arrangement and peel strength test of a aluminum sheet with developed RAM is shown in figure 14 and 15 respectively and the test results tabulated in table2.

Figure 14: 90 Deg Peel test on UTM as per ASTM-D-429B.

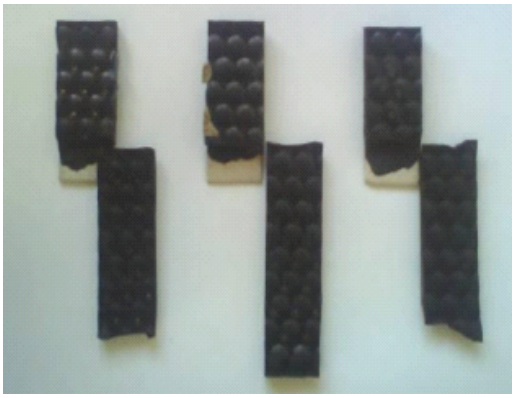

Figure 15: Tested Samples with 100% rubber failure, showing good adhesion.

Test Details	Load in Kg/Inch	Load in PLI (Pounds per linear inch)	Failure mode
Al Sheet / Rubber Based RAM	30.2	66.6	100 % Rubber failure
Al Sheet / Rubber Based RAM	28.2	62.2	100 % Rubber failure
Al Sheet / Rubber Based RAM	25.8	56.9	100 % Rubber failure
Al Sheet / Rubber Based RAM	27.0	59.5	90 % Rubber failure
Al Sheet / Rubber Based RAM	29.2	64.4	90 % Rubber failure

Table2: Adhesion test results of Aluminum sheet to developed RAM.

In all samples we got almost 100% rubber failure which is showing a very good adhesion of aluminum sheet with developed rubber based RAM.

VI. Conclusion

Performance of designed rubber based conical RAM measured according to two different methods: 1) Reflection Loss as per IEEE Std.1128/1998: using NRL Arch Method and 2) Back RCS as per Near Mono-static RCS Measurement Method, provides a analogous results, from which we can conclude that the specified performance of the designed rubber based conical RAM meets design/specification goals. KV-CRA-18 -P-M metal mesh backed painted RAM out performed under all circumstances prevailing in out-door/ship borne applications. The developed glue system with primer is ideally suitable for severe circumstances like mast of the ship etc.

Acknowledgment: We would like to thank the Director and all staff members of Microwave Camouflage Group at Defence (DRDO) Laboratory Jodhpur, Rajasthan, India for their helpful technical discussions during the development of Rubber Based RADAR Absorbing Material (RAM).

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