Specialty Microwave (Radar) Absorbent Material (RAM) For Space, Radar/Missile Project

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***Abstract* – Specialty non- reflective Microwave (RADAR) Absorbent Materials (RAM) have been developed for various space and Defense applications which include Clean room grade PU foam based high power RAM for Shielded Anechoic Chamber, Narrow band resonating thin sheets, Broad-band conical rubber RAM, RADAR Absorbing Paint, thin surface current attenuating sheets, honey comb absorber and very short stepped matched loads for waveguide etc. These RAM's have been tested as per prescribed international standards/practices such as IEEE Std.1128/1998 and the designated performance was well achieved at all frequencies. Also, bulk parameter like complex permittivity and permeability measurement techniques such as cavity perturbation, air coaxial line system and short circuit open circuit method were developed to characterize the material.**

Key words - Thin RADAR Absorbent Materials (RAM); Clean Room Microwave Absorber; Surface Current attenuating sheets; RADAR Absorbing Paint; Broadband RADAR Absorbent Material (RAM) for outdoor/ship borne application; Shielded Anechoic Chambers, honey comb absorber.

I. INTRODUCTION

Non-reflecting microwave (Radar) absorbent materials play key role in many application including microwave antenna measurements and their optimum utilization by cutting down unwanted reflections. A well known application of pyramidal/wedge type polyurethane (PU) foam based absorber is in making anechoic chambers. In very sensitive applications such as for testing space payloads antennas specialty absorbers are required for high power use and to be suitable under clean room conditions. For outdoor applications, such as on superstructure of a naval ship, a specialty absorber would be required which, unlike PU Foam based absorber, does not pickup water during rain and almost equally effective under wet condition like closed shell rubber foam or total rubber based conical absorbers. In other applications where thickness is a constraint the geometrically shaped/ impedance matched absorber cannot be used. In such application, thin absorbers using quarter wavelength feature, known as resonating absorber are used for a limited frequency bandwidth. There are applications where only absorbing paint or thin surface current attenuating sheets can be used. Also, in application where waveguide to be terminated in very short length stepped matched loads would be required. To make structural RAM for low RCS air craft/missile body, honey-comb absorbers would be the only choice. In our efforts we have designed, developed and tested this specialty RAM for our esteemed customers as detailed below which makes most of the text/purpose of this article.

Clean Room Absorber

Clean Room Absorbers are suitable for use in class 10,000 to 100,000 of FED STD 209E clean room standard which is equivalent to ISO-7 and ISO-8 of ISO 14644-1 clean room standard. Clean Room Absorbers are specially treated so that it do not emit more particles and this treatment does not affect the overall performance. These absorbers are used in medical equipment testing, satellite installation facilities and in other applications where clean room conditions are to be maintained as shown in fig .1 for European Space Agency (Thales Alenia Space).

Fig.1. Clean Room Absorbers in European Space Agency (Thales Alenia Space)

A. *Thin Flexible Resonating RAM*

The Thin Flexible Resonating RAM has been aimed to use at a resonating frequency (f_r) from 2 to18 GHz as shown in Fig.2. It's magnetically loaded urethane rubber sheets offer increased abrasion resistance. It's working temperature -40°c to +90°c. Typically, reflectivity performance is -25 dB at ± 5% band with around the center frequency (f_r) (as compared to the flat metal plate of the same size) tested as Per IEEE Std.1128/1998: IEEE Recommended practice for RF Absorber Evaluation using NRL Arch Method. As shown in fig.3 the performance of 1.5mm thick resonating sheet reflection loss is Min. -34.51dB at resonating frequency (f_r)14.4GHz and min.-10 dB from 12.0GHz to 18.0GHz. These sheets can be adhered to masts of Ships, walls, bridges etc to reduce false images, reflections and echoes to nearby antennas, for suppressing parabolic antenna side lobes. These are suitable for Out-Door applications by attaching to vehicles to reduce overall Radar Signature. These can be used for suppressing specular reflections inside microwave units e.g. power amplifiers of mobile telephones, low noise blocks of satellite receivers etc.

Fig.2. Thin Flexible Resonating RAM

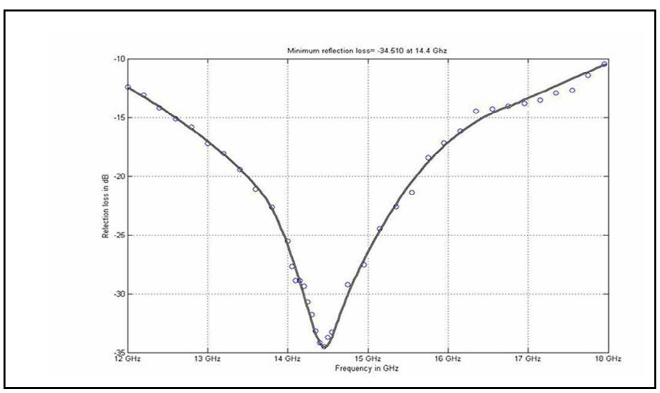

Fig.3. Typical Reflectivity performance at near normal incidence with respect to metal

B. *Ship Bone RADAR Absorbent Material*

The absorbers have been aimed to use at a frequency range of 0.8 GHz to 18 GHz and higher frequencies. Scattering and diffractions at high frequencies due to the presence of edges and singularities in case of pyramidal shape of conventional microwave absorber, have been avoided/reduced by keeping a conical shape of new RAM. A painted Rubber based conical RAM of 100mm are (KV-CRA-100) and 20mm thickness (KV-CRA-18) are shown in fig.4 (a). 100mm thick absorber gives minimum reflection loss with respect to metal plate at near normal incidence -10dB at 0.8 GHz, rising to min. -15 dB at 2.0 GHz, further raising to -20 dB at 5.0 GHz to 18.0 GHz and beyond while 20 mm thick KV-CRA-18 give min -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.Fig.4 (b) and Fig.4 (c) shows ships using such conical absorbers [1]

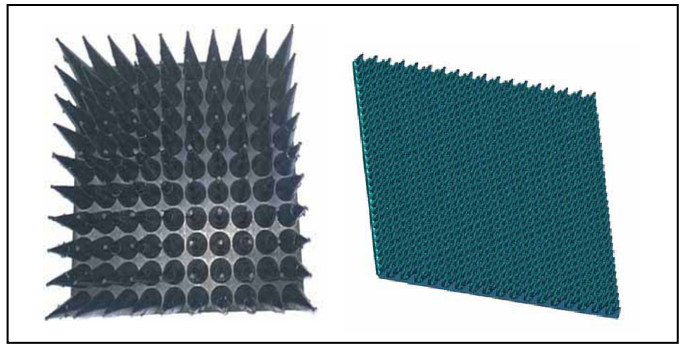

Fig.4 (a) Rubber based conical (RAM) KV-CRA-100 & KV-CRA-18

Fig.4 (b) Ship Bone RADAR Absorbent Material in INS Chennai

Fig.4(c) Ship Bone RADAR Absorbent Material in Italian Navy-Fincantieri

D. Microwave Absorbent Paint

The Microwave Absorbent Paint has been aimed to use on blend surfaces where Surface Current Attenuating Sheet and foam based absorbers are not desirable. Microwave Absorbent Paint can reduce the radar cross section (RCS) of complex object, reduce false echo or ghost images on a Naval ships radar, and attenuate surface currents that are generated on metal surfaces, can be used to reduce Q of cavities. Absorbent paint are not intended to reduce specular reflections. It attenuates the multiple reflections and the surface wave component/current.Fig.5 shown use of a paint in a cavity of missile housing two antennas to reduce cross-talk between them [1]

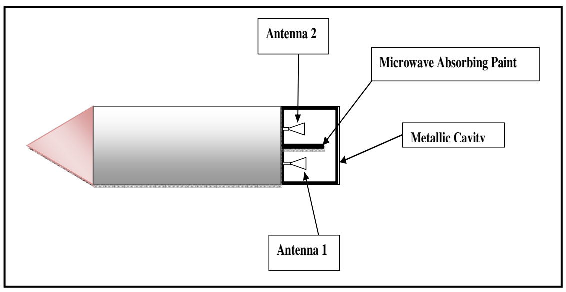

Fig.5. Microwave Absorbent Paint in Cavity of Missile

E. Surface Current Attenuating Sheet

These thin magnetically loaded sheet are aimed to attenuate surface currents from 1.0 GHz to millimeter wave, wherever surface currents may occur, say in solid state microwave devices such as Amplifiers, Oscillators, down/up converters etc, reduction of RCS of Complex objects both by reducing specular reflection to some extent as well as mostly surface currents, multiple reflections etc. Typical Attenuation shall vary from about 5.0 dB / cm at 1.0 GHz to 50.0 dB / cm at 10.0 GHz rising up to 90.0 dB/ cm at 18.0 GHz.

F. *Very short stepped matched loads for waveguide*

We have developed a series of short match loads which can be used for various frequency bands. In WR-229 wave guide a one step matched load of total 34mm thickness was designed giving VSWR<1.5 between 3.6 to 4.2 GHz. These step short match loads can be customized as per the customer's requirement.Fig.6 shown a place in a guided missile where the short matched load was used to terminate a port of a microwave device.

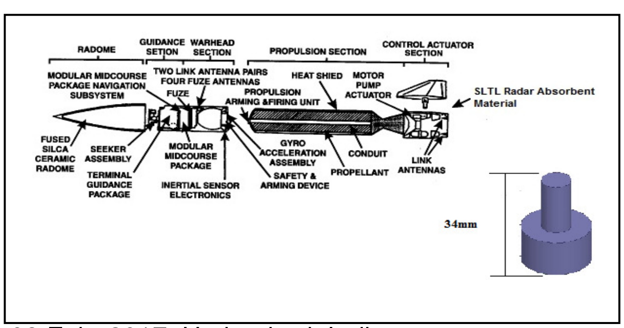

Fig.6 Short Stepped matched loads for Guided Missile.

G. Broadband microwave honeycomb absorber

Broadband microwave honeycomb thin flat absorbers as shown in Fig.7 (a) were fabricated in fiberglass /poly carbonate based honeycomb core having "lossy" coating to it. The honeycomb absorber can have a uniform coating to optimize insertion loss or a graded coating to optimize reflection loss. The performance curve shown in Fig.7 (b) (the typical performance of a 0.5" (12.7 mm) thick Absorber) and Fig.7(c) (the typical performance of a 1" (25.4 mm) thick Absorber), We can optimize the performance to account for laminated skins or core and can assist in selecting the right materials to minimize performance degradation. Honeycomb absorbers are used as "lossy" loads in spiral antennas and high-power antenna couplers. They are used with laminated skins to manufacture radar absorbing structural (RAS) panels and components conforming aerodynamic requirements.

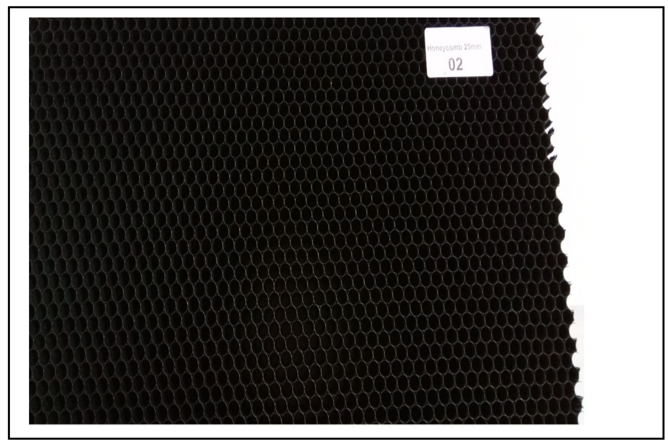

Fig.7 (a) Broadband microwave honeycomb absorber

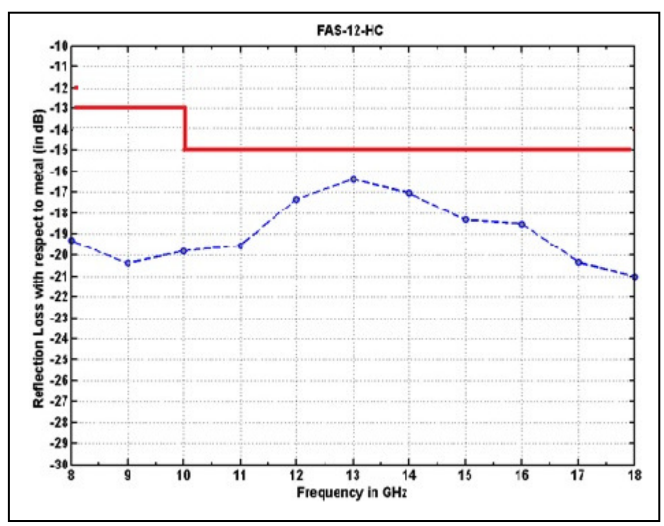

Fig.7 (b) the typical performance of a 0.5" (12.7 mm) thick Absorber

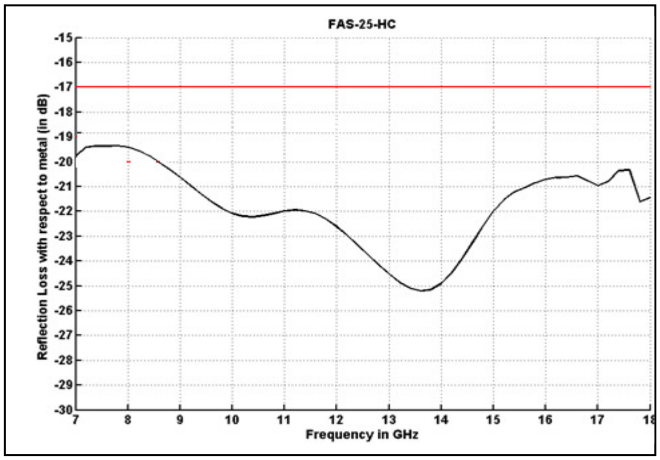

Fig7(c) the typical performance of a 1" (25.4 mm) thick Absorber

II. Bulk-parameter measurement Techniques

(A) Cavity Perturbation Technique

This method uses a rectangular waveguide with iris-coupled end plates, operating in TE10n mode (Fig.8). For a dielectric measurement the sample should be placed in a maximum electric field. If the sample is inserted through a hole in the middle of the waveguide length, then an odd number of half wavelengths (n = 2k + 1) will bring the maximum electric field to the sample location, so that the dielectric properties of the sample can be measured. The cavity perturbation method requires a very small sample such that the fields in the cavity are only slightly disturbed to shift the measured resonant frequency and cavity *Q*. By shift in the resonance frequency and change of Q of the cavity (changing 3dB beam width of absorbing peak), the real and imaginary part of the complex permittivity of absorber can be computed. Similarly this method can be used for measuring complex permeability by perturbing magnetic field maxima.[2]

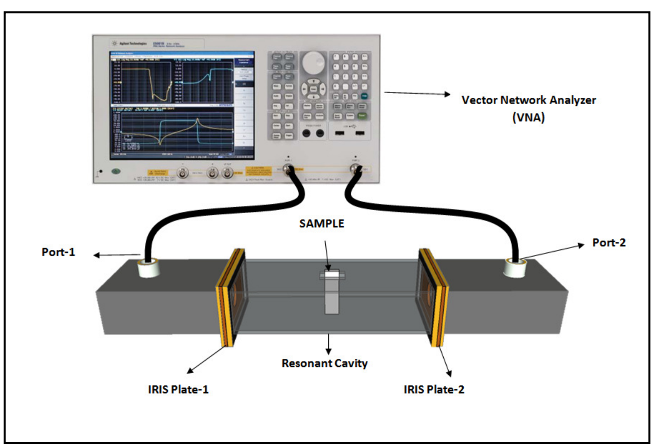

Fig.8. Cavity Perturbation Technique

(B) Air Coaxial transmission Line Method

Transmission line methods involve placing the material inside a portion of an enclosed transmission line. The line is usually a section of rectangular waveguide or coaxial airline (Fig.9).$\boldsymbol{\varepsilon_r}$* and $\boldsymbol{\mu_r}$* are computed from the measurement of the reflected signal (S_{11}) and transmitted signal (S_{21}) using Nicolson-*Ross-Weir* (NRW) technique. [3][4]

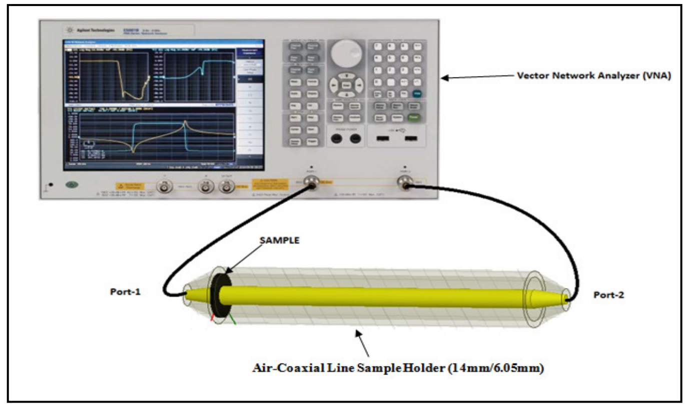

Fig.9. Air Coaxial transmission Line

(C) Open circuit and Short Circuit Impedance Technique:

The Complex Permittivity and Permeability of the absorber were obtained from the measurements of short-circuited and the open-circuited input impedance (Z_{sc} and Z_{oc}) of a section of transmission line (either coaxial or waveguide) completely filled with the test material. The measurement procedure is somewhat lengthy and circuit arrangement is given in fig.10 (a) and Fig.10 (b).[5][6][7]

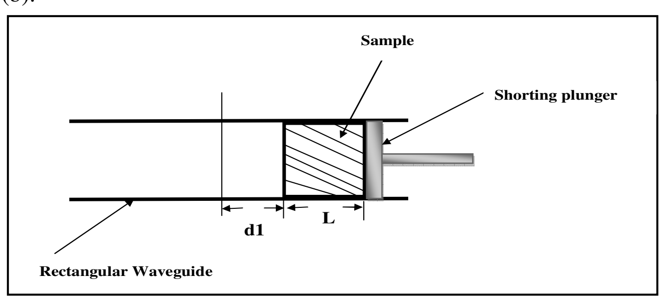

Fig.10 (a).Short circuit (Case-1)

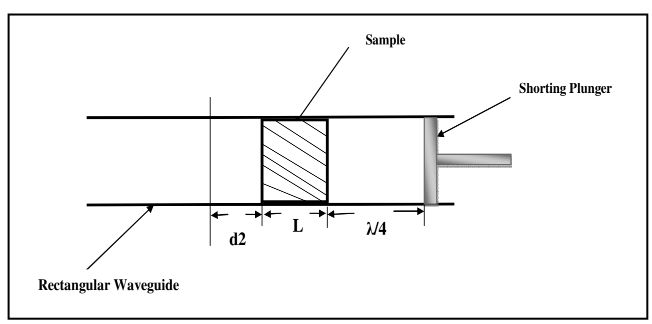

Fig.10 (b).Open circuit (Case-2)

III. Reference

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