Feasibility Analysis about RCS Reduction Effect to apply RAM on Submarine

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Abstract

It is realized on very important element to avoid detection by enemy's radar in the modern war. Specially, it is very important for submarine, the core power of the naval forces, to reduce possibility to be detected. In this paper, introduce method to decrease RCS (Radar Cross Section) of periscope and snorkel to use RAM (Radar Absorbing Materials).
Electromagnetic modeling of periscope and snorkel which have possibility to be easily detected in the sea was performed in X-band (8~12 GHz) used mainly by surveillance radar to simulate and we designed RAM to apply to it as electromagnetic wave absorber application and then made simple mock-up of it(periscope and snorkel), finally measured RCS before-and -after of RAM application to it at anechoic chamber and. analyzed the result of RAM application effect.

1. INTRODUCTION

It is important first of all that improve survivability of our forces weapon system by minimizing probability to be detected in enemy's various sensors on essential ingredient to guide the war in thumbs-up in modern war unlike past. Specially, because radar is very general in preceding chapter and is used feeler system extensively, advanced every country is applying developing electromagnetic wave absorption materials of various form to minimize that is detected to radar the enemy but it is very difficult to grasp specific contents by strict control. According as info-age is accelerated even if there is in public need, electromagnetic waves of various frequency bands were overflowed and for electromagnetism interference exclusion, noise suppression etc... Electromagnetic wave absorption material practical use rapidly increase [1-2].

Fig. 1: Submarine of 209 type [3]

Because submarine must do sea injury (snorkeling) by rate once in 3 days to fill up battery former times that produced in German back except nuclear-powered submarine, because possibility of snorkel is high to be exposed to the enemy this time, there is problem in secret tactics achievement, and danger exists to be exposed to this and enemy that must observe sea circumstance uncovering periscope on sea level from time to time. Electromagnetic wave absorber can be applied that design to snorkel and periscope of submarine by solution of these problems and decrease RCS(Radar Cross Section).
In this paper, wish to examine shortly about electromagnetic wave absorption material design element to reduce this RCS, and designs electromagnetic wave absorber that can be applied on actuality submarine (snorkel and periscope), and compare on the basis of simulation and measurement of simple mock-up and or analyzes RCS reduction effect after application and verify the feasibility.

2. BASIC THEORY OF ELECTROMAGNETIC WAVE ABSORPTION MATERIAL DESIGN

Electromagnetic wave absorption material can be divided as dielectric substance, magnetic substance, conduction material greatly.
Dielectric constant (permittivity) has value of complex number as proportional constant that certain medium displays degree that form charge polarization according to outside electric field.

$$\varepsilon = \varepsilon' - j\varepsilon_0'' \quad (1)$$

If electric field that changes fast with high frequency from dielectric substance outside is imposed, material inside charge and microscopic polarizations does not catch up the change in advance. As a result, delay phenomenon (time lag) is happened, and become measure that displays energy size that is disappeared by heat because this part is expressed by an imaginary part of dielectric constant time between outside electric field and guided charge transfer polarization. Electromagnetic absorptivity of dielectric material is appeared by the ratio of imaginary part for real part of dielectric constant, that is, loss tangent value. But, because loss tangent is very small in occasion of dielectric material consisted of single phase, use is difficult by electromagnetic wave absorption material. Therefore, mixture form that separate metal or carbon granule evenly on genetic material inside such as rubber or epoxy etc. is used widely. Usually, electromagnetic attenuation constant is described by α_d and the related equation is a following formula (2).

$$\alpha_d = \frac{\omega\sqrt{\mu\varepsilon}}{2}\left(\sqrt{1+(\sigma/\omega\varepsilon)^2}-1\right)^{\frac{1}{2}} \qquad (2)$$

Magnetic material is that form self-polarization inside factor if suspend magnetic reluctance from outside. The permeability has complex number value as well as dielectric constant situation as proportional constant that display degree that form self-polarization according to outside magnetic reluctance.

$$\mu = \mu' - j\mu'' \qquad (3)$$

Point or point that permeability constant value changes according to frequency etc. that real part of complex number displays elastically accumulated magnetic reluctance energy and imaginary part displays energy size that is disappeared by ten is similar with dielectric material. But, magnetic material is general that display dielectric nature of fixed size as well as magnetism at the same time[4].

There is ferrite by representative magnetic material absorption material. This material causes own magnetic relaxation and exerts very high electromagnetic wave absorptivity in specially hundreds MHz frequency band.

Usually, electromagnetic wave attenuation constant by magnetic material is described as (4).

$$\alpha_m = \frac{\lambda\omega^2}{4\pi}\left(\varepsilon'\mu'' + \varepsilon''\mu'\right) \qquad (4)$$

Some part of propagation energy are absorbed by heat energy as electric current is induced on the conductive material surface in case of electric field is imposed from outside. But, because good electric conductor such as metal is very large impedance difference with air, because electromagnetic waves have been reflected in surface, propagation energy is no opportunity to be absorbed because is permeated into inside.

Therefore, hundreds•several thousands •/• that surface resistance is similar to characteristic impedance value of under clearance in conductive material field are used making thin resistance film or metal net so that may amount two and does epitaxy on dielectric material surface or interface between floor. On the other hand, electromagnetic wave absorptivity of electromagnetic wave absorption materials is closed connection with shape as well as material integer of each materials and distribution state that describe over. As a result, incident wave becomes wavelets that have different phase, and these are scattered to several directions. In addition, it is happened that electromagnetic energy is disappeared by interference between each wavelets. In the case that pieces of smaller conductor than wavelength of electromagnetic wave, creeping and diffraction are happened in the surface of each piece of conductor. In the result, incident wave is scattered as many wavelets with different direction and additionally, it is happened that propagation energy is disappeared because of interaction with each wavelet. A propagation attenuation constant by such random scattering effect is described as following.

$$\alpha_s = \rho\sigma_T / 2 \qquad (5)$$

Only, $\alpha_T = \frac{1}{4\pi}\int_{\theta=0}^{\pi}\int_{\phi=0}^{\pi}\sigma(\theta,\phi)\sin\theta d\theta d\phi$ and ρ is a scattered particle density per unit volume.

Here scattering cross section α_T (scattering cross section) is influenced greatly in aspect ratio of scattered particles.

When electromagnetic wave enters a company vertically on two whipping interval boundary surfaces that have infinity thickness, electric field and magnetic reluctance of electromagnetic wave according to guided boundary condition must put between boundary surfaces and are each other serial from foresaid Maxwell equation.

If arrange substituting characteristic impedance justice of each whipping here, reflection coefficient, that is, reflection intensity of electric field about entering a company electric field intensity loses appearing by function of each floor characteristic impedances.

$$R = \frac{E_r}{E_i} = \frac{Z_2 - Z_1}{Z_2 + Z_1} \qquad (6)$$

But, each floor with next Fig. 4 has fixed thickness in case apply actuality electromagnetic wave absorption material.

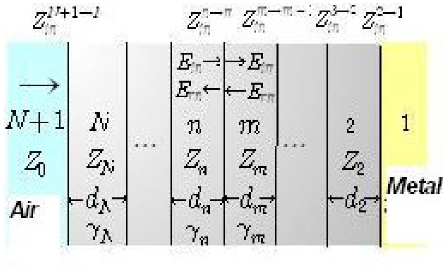


Fig. 2: Input Impedance of layered media

Therefore, to calculate electromagnetic wave reflection in interface, all of the effect of electromagnetic wave that appear being reflected from each floor interfaces in inside than the interface should be considered.

This can solve introducing input impedance concept by transmission line theory and it is described as (7).

$$Z_{in}^{n\to m} = Z_{in}\frac{Z_{in}^{m\to m-1} + Z_m\tanh(\gamma_m d_m)}{Z_m + Z_{in}^{m\to m-1}\tanh(\gamma_m d_m)} \qquad (7)$$

Only, here $\gamma_m = j\frac{2\pi}{\lambda_0}\sqrt{\varepsilon_m\mu_m}$

Input impedance $Z_{in}^{N+1 \to N}$ of the last outside boundary surface is gained by method calculating sequentially from inside interface exclusively using this numerical formula.
And calculate electromagnetic wave reflection coefficient in electromagnetic wave absorption material surface is calculated as following (8) by substituting this input impedance instead of characteristic impedance of (6).

$$R = \frac{Z_{in}^{N+1 \to N} - Z_0}{Z_0 + Z_{in}^{N+1 \to N}} \quad (8)$$

$$(if, Z_{in}^{N+1 \to N} \cong Z_0 \Rightarrow R \approx 0)$$

Finally, electromagnetic wave absorption material design can be defined that it is effort that to minimize reflection input impedance in material surface and standby impedance mix material properly and thickness of each floor electromagnetic wave absorption materials properly to be agreed. Electromagnetic wave absorption coating material is used mainly shape in region that complex and thin thickness is required[5]. So, we decided to apply this type material to periscope and snorkel as RAMs.
In Fig. 2 because electric field in metal surface is zero when electromagnetic wave absorption coating material is spread to thin thickness of ~ mm interior and exterior on metal surface and damascenes electromagnetic waves in this case metal surface impedance. Using (7) and (8) the following formula is obtained.

$$Z_2 \tanh(\gamma_2 d_2) = Z_0 \quad (9)$$

We designed and made RAM as Fig. 3 using formula (9) to apply to submarine at X-bands.

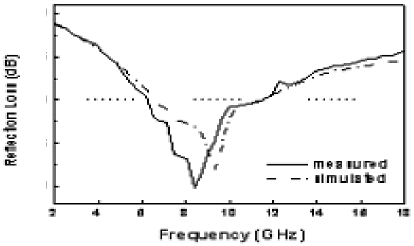


Fig. 3 : RAM(Radar Absorbing Material) feature

3. MODELLING AND SIMULATION FOR A EVALUATION OF RCS REDUCTION EFFECT OF RAM

For simulation with CST Microwave Studio, we did modelling periscope as cylindrical type. And RCS was simulated before-and-after applying RAM of Fig. 3. The entire process of this job was described as Fig. 4. And the simulation result is displayed as Fig. 6. The RCS is reduced about 10 dB after applying RAMs. It is the same as 90% reduction of RCS.

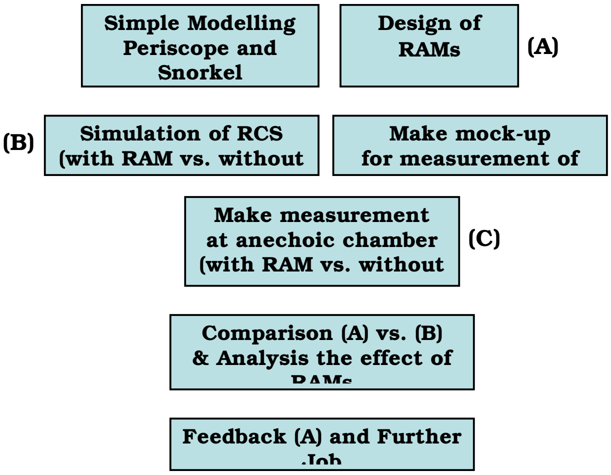


Fig. 4: Full Process for RAM application

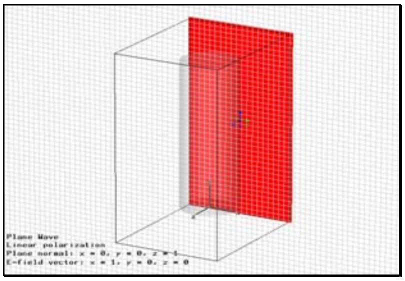
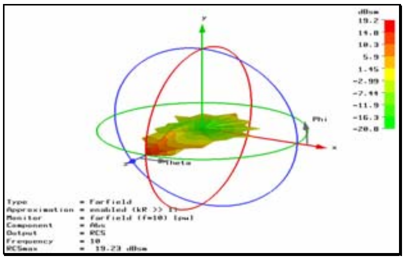
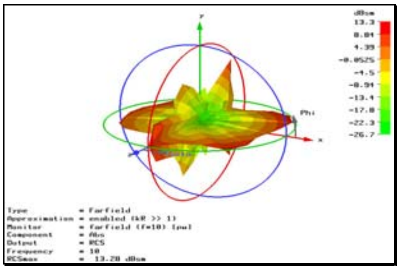


Fig. 5: Simple Modeling of periscope for RCS simulation



(a)



(b)

Fig. 6: The result of simulation((a) without RAM (b) with RAM)

4. RESULT OF FIELD TEST AT A ANECHOIC CHAMBER

Fig. 7: RCS Instrumentation of sample at a chamber feature

As explained previously, we made simple mock-up of periscope and snorkel. And as Fig. 4, we measured RCS of mock-up in the case of two, i.e., without RAMs and with RAMs. Measurement was performed as Fig. 7, and the result is displayed at Fig. 8. The result is approximately similar with simulation. The RAM effect is about 10 dB in comparison with before application.

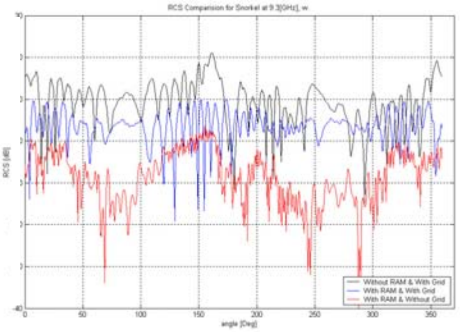


Fig. 8: Result of RCS Instrumentation of sample

5. CONCLUSION

In this paper, electromagnetic modeling of periscope and snorkel which have possibility to be easily detected in the sea was performed in X-band (8~12 GHz) used mainly by surveillance radar to simulate and we designed RAM to apply to it as electromagnetic wave absorber application and then made simple mock-up of it(periscope and snorkel), finally measured RCS before-and -after of RAM application to it at anechoic chamber and. analyzed the result of RAM application effect. The result is that RAM effect which we designed with properties of section 2 is about 10 dB in comparison with before application. Further, we will continuously develop and research about this part and pursuit to try this kind of RAM to find applicable field to commercial field as well as military system.

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