The Multi-layers Absorber with the Dual Elements AMC Structure

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Abstract —In this paper, the multi-layers absorber was designed to perform over a wide frequency band, starting at relatively low frequencies. An absorber was comprised of 20 layers, in which the material parameters are tapered in an exponential manner. In addition, the absorber itself is physically tapered at an angle so that it resembles a truncated pyramid. It is shown that the absorber performs well in the frequency range of 0.1MHz-2GHz.Then, a fan-type AMC structure is designed and used to back lossy pyramids absorber. The AMC structure is composed of square loop and square patch elements. These two elements realized a phase difference of 180° and generated coherent interference. Through adding the AMC screen, the reflection of absorber is lower than -30dB from 0.1GHz~2GHz.

I. Introduction

Anechoic chambers are used for antenna and radar cross-section (RCS) measurements, as well as for the testing of electromagnetic compatibility (EMC). And these may be required to operate at frequencies down to 100 MHz[1, 2]. At such low frequencies, even an absorber with a much reduced performance still requires a thickness of several metres. A conventional pyramidal absorber has been combined with a planar ferrite base layer to create a hybrid absorber in which the low frequency incident waves are absorbed by the ferrite and the high frequency[3]. Although some effects at low frequencies, such absorbers are heavy and expensive to manufacture and install. Some researches in the area has investigated the use of two dimensional arrays of magnetic pyramids[4]. Other research applied electrically loading the absorber base layer using one or more frequency selective surfaces (FSS) whose elements are typically in the form of single or nested loops[5].

II. The Model of The Model of Lossy Dielectric

The model we used to represent lossy absorber at low frequency consists of a flat slab of uniform, isotropic, lossy material, backed by a perfect conductor. The relative permittivity ε, conductivity σ, and thickness d of the slab are parameters which determine reflection coefficient. In this paper we don't use any magnetic materials, so we take the effective permeability of the absorber to $\mu=\mu_0$.

Reflection coefficient for transverse electric and transverse magnetic polarization of the incident wave is calculated by formula (1). In these equations, ε is the permittivity of the slab, μ is the permeability of the slab, ω is the angular frequency, θ is the angle of incidence, η_0 is the wave impedance of free space, and γ_z is the complex propagation constant, d is thickness the slab [6].

$$R_{TE}=\frac{E_r}{E_i}=\frac{\mu\omega\cos\theta+j\eta_0\gamma_z\coth(\gamma_z d)}{\mu\omega\cos\theta-j\eta_0\gamma_z\coth(\gamma_z d)} \quad (1)$$

$$R_{TM}=\frac{H_r}{H_i}=\frac{(\sigma+j\omega\varepsilon)\eta_0\cos\theta-\gamma_z\tanh(\gamma_z d)}{(\sigma+j\omega\varepsilon)\eta_0\cos\theta+\gamma_z\tanh(\gamma_z d)}$$

We just calculate the formula of electric reflection coefficient. Because loss dielectric is a symmetry structure, we only select TE mode as source of excitation. In order to enhance reflection performance, we use tapering structure which is approximate to use a flat surface. It is based on the fact that structure much smaller than a wavelength cannot be resolved by the incident wave.

In this work, we use Time domain finite method (FDTD) to construct our model. The implementation of this FDTD/PBC algorithm is simple and straightforward. Fig.1 shows an FDTD model, where a single unit cell is surrounded by periodic boundary conditions (PBC) in the horizontal directions and perfectly matched layers (PML) along the z direction[7].

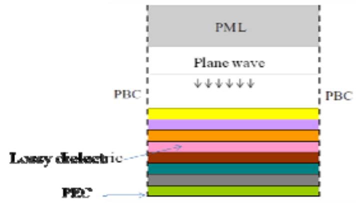


Fig.1 The FDTD model of lossy dielectric

III. The Design of Multi-Layers

In order to improve low frequency performance, we adopt multi-layers design. The most important thing is how to design change of epsilon and sigma in every layer to generate minimum reflection and maximum absorbing. The full length is 200cm which is equal to half wave of 100MHz. It is divided it into 20 parts and every parts has the equal length. Through optimizing function of epsilon and sigma, we finally obtain data of sigma of 20 layers. The epsilon data is 1 in all 20 layers. The sigma is a gradual change from 0.0024 to 0.018. In order to improve reflection performance, we taper the structure 15° with respect to Z axis and the geometry structure of tapering fifteen lossy dielectric . The sigma data is shown in Table I.

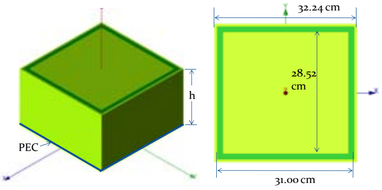
Table I sigma of twenty layers

1-5 layer	0.0024	0.0027	0.0030	0.0033	0.0037
6-10 layer	0.0041	0.0046	0.0051	0.0057	0.0063
11-15 layer	0.0071	0.0079	0.0088	0.0098	0.0109
16-20 layer	0.0122	0.0136	0.0151	0.0169	0.0188

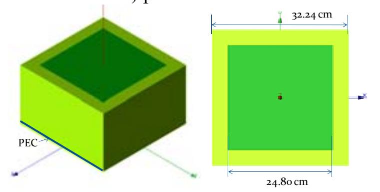
IV. THE Design of the Dual AMC Structure

The artificial magnetic conductor(AMC) is a special structure of FSS structure. It is equivalent to PMC structure when FSS generated 0° phase at certain frequency. In this paper, we designed two dual elements which is composed of square loop and square patch for the AMC elements separately and print them on the same side of a PEC-backed substrate. It is shown in Fig.2. When put two dual elements together, it will obtain 180° phase difference at the certain frequency which generates coherent interference in upper domain so as to reduce reflection energy in incident direction. We give the phase change and difference of two dual elements from 100MHz to 500MHz in Fig.3a and ensure that the dual elements have good bandwidth requirement. We obtain 184° phase difference at 100MHz and predict good performance in Fig.3b.

We use these two dual elements to construct fan-type screen which is composed with one half of patch and on half of loop, as shown in Fig.4. Then we put this fan-type screen under the lossy absorber as shown in Fig.5. The simulation result is shown in Fig.6. Because we aim at design to 100MHz of AMC structure, the reflection was reduced 5dB compared with no AMC underneath at 100MHz. The full band from 100MHz to 2GHz has good performance with the reflection lower than -30dB.

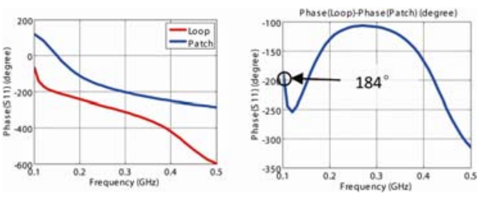


a) patch element



b) loop element

Fig.2 The dual square loop and square patch structure



a)The phase of loop and patch; b)The phase different

Fig.3 The phase change of two dual elements

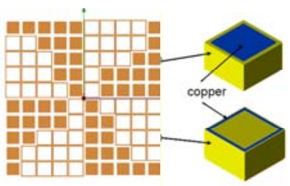
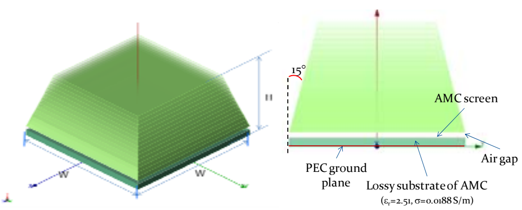


Fig.4 The dual AMC fan screen



a) The planform;b)The section plane

Fig.5 The structure of twenty lossy dielectric with AMC underneath

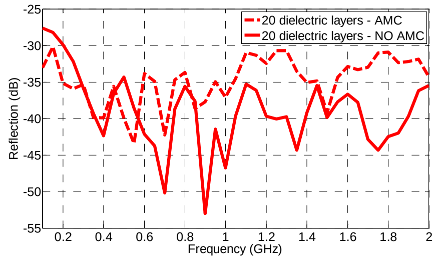


Fig.6 The reflection coefficient of twenty layers with no AMC and with AMC screen

V. CONCLUSIONS

In this paper, we presented a model for describing the low-frequency behavior of absorbing materials backed by an AMC structure. In low frequency, the whole absorber thickness interacts with the incident wave and half wavelength is needed. In order to improve the low frequency performance, we introduce twenty layers structure whose length is similar with low frequency wavelength. Using exponential sigma values to fill in twenty layers and setting epsilon to 1, we got good performance. According to match theory, we taper section forming a portion of the pyramidal absorbing structure and improve about 10dB. The principal advantage of the model its simplicity. Then, we put this AMC screen under the lossy absorber. The reflection of absorber structure is lower than -30dB from 0.1MHz~2GHz.

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REFERENCES

[1] Yunhong, L., F. De Flaviis, and N.G. Alexopoulos, A Thin X-Band Microwave Absorber Using a Center Shorted Spiral Medium. IEEE Antennas and Wireless Propagation Letters, vol.8, pp. 271-274,2009.

[2] Bornkessel,C., Wiesbeck,W, Numerical analysis and optimization of anechoic chambers for EMC testing. Electromagnetic Compatibility, IEEE Transactions on, vol.8,no.3,pp.499-506,1996.

[3] Jae-Jin Lee; Yang-Ki Hong; Seok Bae, “Broadband $Ni_xZn_{0.8\_x}Cu_2$ Fe_2 O_4 Electromagnetic Absorber for 1 GHz Application. IEEE Transactions on Magnetics, vol. 45, no. 10, pp.4230-4233, 2009.

[4] Myung-Jun, P., C. Jaeho, and K. Sung-Soo, Wide bandwidth pyramidal absorbers of granular ferrite and carbonyl iron powders. IEEE Transactions on Magnetics, vol.36,no.5, pp. 3272-3274,2000.

[5] Da F Silva, P.H., Cruz, R.M.S., D'Assunção, A.G., “Blending PSO and ANN for Optimal Design of FSS Filters With Koch Island Patch Elements.” IEEE Transactions on Magnetics, vol.46, no.4, pp. 3010-3013, 2010.

[6] Johnk, R. and J. Randa. Low-frequency representation of radio-frequency absorbers. IEEE International Symposium on EMC. pp.174-179,1996.

[7] Bernard, L.; Torrado, R.R.; Pichon, L.; Efficient Implementation of the UPML in the Generalized Finite-Difference Time-Domain Method. IEEE Transactions on Magnetics, vol. 46, no. 8, pp.3492-3494,2010.