Системы автоматизированного проектирования

UDC 681

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Computer aided analysis and design of broadband electromagnetic absorbers

Представлен метод, подходящий для автоматизированного анализа и дизайна широкополосных абсорберов. С помощью матрицы передачи смоделированы элементы многослойной структуры. Описана подходящая для оптимизации структуры абсорберов процедура. Получены и проанализированы возможные структуры для абсорберов.

Method suitable for computer aided analysis and design of broadband electromagnetic absorber is presented. Elements of multilayer structure are simulated using transmission matrix approach. Procedure suitable for absorber optimization is described. Possible structures for absorber material are derived and analyzed.

Ключевые слова: *поглощение, электромагнитная волна, СВЧ - диапазон, комплексная диэлектрическая проницаемость, комплексная магнитная проницаемость, затухание, коэффициент отражения.*

Introduction

Thorough measurement of antenna characteristics and electromagnetic compatibility tests are best performed in anechoic chambers. They provide conditions of wave propagation close to free space and very good isolation from unwanted external fields. Shielding is achieved with metal coating of the whole chamber. Free space propagation conditions are approximated by elimination of wave reflections. To do that all walls of the chamber are covered with carbon impregnated foam pyramids or wedges. Since pyramid size is comparable or larger then wavelength, gradual change of material density causes very little reflection. At the same time electromagnetic wave decays in lossy medium. The only but critical deficiency of anechoic chambers is their large size and enormous cost [1]. The need to test small equipment in mass production requires relevant reasonably priced testing chambers like TEM-Cells [2]. As opposed to anechoic chambers, these don't use pyramidal absorbers. Distribution of electromagnetic field, close to TEM wave in free space is obtained in limited volume inside TEM cell. Reflection from the cell bottom is suppressed with compact size electromagnetic absorber. At present there is no material available, which can be used alone as electromagnetic absorber in certain frequency range. That's why the use of multilayer absorbers comes into question.

The aim of the research is to design the multilayer absorber with varying dielectric materials for each layer. Research tasks include the multilayer absorber reflectivity calculation as well as finding the optimal structure for the absorber.

1. Reflection coefficient calculation strategy

One of the methods to calculate the reflection coefficient is to use a tracking calculation method.

The idea of this method is to track and calculate refraction waves at each stratified interface, while the reflection waves are pushed into memory and summarized. Then the ratio between the summarized reflected waves and the incident wave will give us the reflection coefficient [3].

Employing transmission matrices to describe electromagnetic properties of each layer in complex absorber one can build convenient and computationally efficient method to calculate characteristics of the whole structure. Applying the boundary conditions, transmission matrix for the i - layer of substance can be calculated as showed in (1).

$$\mathbf{T} = \begin{bmatrix} \dfrac{Z_{c_{(i-1)}} + Z_{c_{(i)}}}{2Z_{c_{(i)}}} e^{-j\dot{\gamma}(i)d(i)} & \dfrac{Z_{c_{(i-1)}} - Z_{c_{(i)}}}{2Z_{c_{(i)}}} e^{-j\dot{\gamma}(i)d(i)} \\ \dfrac{Z_{c_{(i-1)}} - Z_{c_{(i)}}}{2Z_{c_{(i)}}} e^{j\dot{\gamma}(i)d(i)} & \dfrac{Z_{c_{(i-1)}} + Z_{c_{(i)}}}{2Z_{c_{(i)}}} e^{j\dot{\gamma}(i)d(i)} \end{bmatrix} \quad (1)$$

where $Z_{c_{(i)}}$ - the characteristic impedance of the layer, $d(i)$ - the width of the layer, $\dot{\gamma}(i)$- complex propagation constant in the current layer.

Taking into account the reflection from the metal, that follows the dielectric layers, the reflection coefficient corresponds to the equation (2).

$$R = \frac{T_{21} - R_m T_{11}}{R_m T_{12} - T_{22}} \quad (2)$$

where R_m - reflection coefficient from the metal surface.

2. Results and Discussion

To obtain the satisfactory broadband reflectivity for given frequency range, the parameters of dielectric materials are varied, as well as the width of these layers and their sequence.

The mathematical model for electromagnetic absorption in the layer of substance is built. The formulas for the reflection coefficient in the case of one- and multilayer structures are derived. The subsequent analysis of the derived equations is conducted with the use of MatLab environment. As a result, two possible structures of multilayer absorber are designed (Fig. 1.). To avoid confusion in absorber structure description, the layer named first is first on the way of incident wave and the last is short with metal mirror plane. The parameters of the materials used are listed in table 1, where parameters K and f_{rel} correspond to reflection coefficient and relaxation frequency accordingly.

As for the materials, certain criteria were used during selection. First of all, the nature of the reflection coefficient should be taken into account, while the major part of it is caused by the reflection from the 1st layer and by the reflection from the metal surface. To achieve small reflection from the 1st layer its impedance should be close to the impedance of the air. To minimize the reflection effect from the metal wall, the materials in use should possess sufficient loss.

The results of the modeling are presented in Figs. 2 and 3. Both designs preserve -15 dB requirement in the wide range. The 3-layer structure can be used in the range 1.32 - 2.53 GHz. The 4-layer structure, in comparison, exploits the effective bandwidth of 3GHz to be used as an absorber. Moreover, the 4-layer structure is capable of uniform absorption in the range of 1.2 GHz.

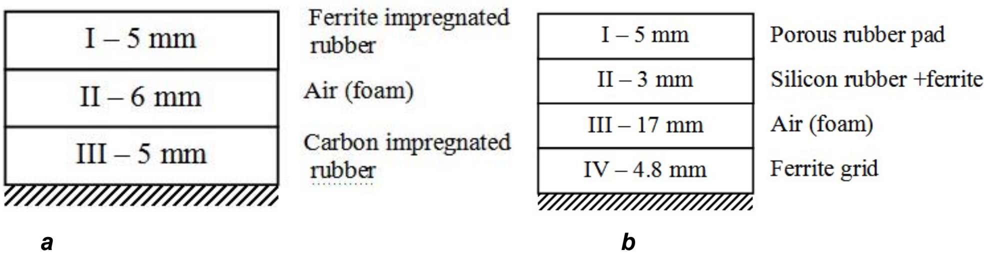

Fig. 1. 3-Layer (*a*) and 4-Layer (*b*) Structures

Table 1. Materials used in absorber structures

Material		ε′	ε″	σ, S/m	*K*	f_{rel}, MHz
1.	Ferrite grid	12	0	0	1950	3.8
2.	Silicon rubber with ferrite 70%+30%	3.5	0.1	0	0.5	1600
3.	Ferrite impregnated rubber	6.92	0.252	0	7.59	529
4.	Padding porous rubber	1.74	0.037	0	—	—
5.	Carbon impregnated rubber	54.1	6	8.55	7.93	2042

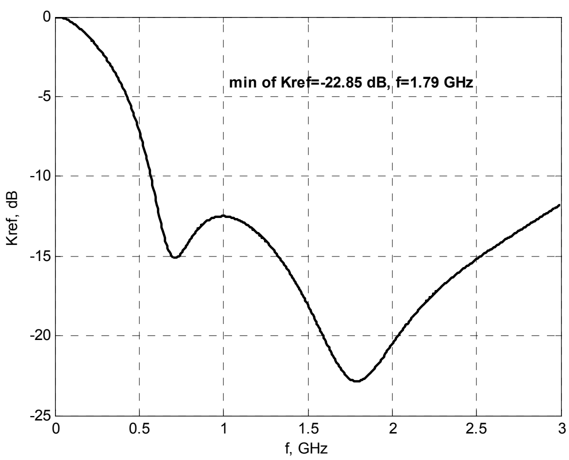

Fig. 2. Modulus of Reflection Coefficient from 3-Layer Absorber Structure

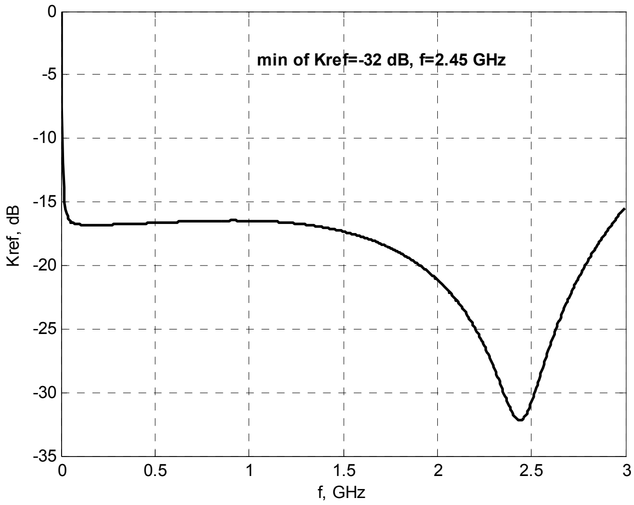

Fig. 3. Modulus of Reflection Coefficient from 4-Layer Absorber Structure

Furthermore, the optimization procedure can be created, that will vary one or several parameters according to the given criteria, for instance, according to the minimum of reflection coefficient in the given frequency range.

Conclusion

Presented structures possess suitable characteristics. Multilayer absorbers are showing great promise in the portable equipment testing sphere.

The further research should be aimed at the universal design of absorbing coating with preset characteristics, that would determine the necessary number of layers and there parameters.

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