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ELECTROMAGNETIC WAVE ABSORBER DESIGN BY USING CONDUCTIVE SHEETS

Carsten Rabe

Institut für Hochfrequenztechnik
Lehrgebiet Elektromagnetische Verträglichkeit Prof. Dr.-Ing. Detlef Schlayer
Hochschule für Telekommunikation Leipzig
Gustav-Freytag-Straße 43-45, 04277 Leipzig, Germany
carsten.rabe@hft-leipzig.de

ABSTRACT

The paper presents the design of an electromagnetic wave absorber for the frequency range from 1 GHz to 18 GHz. The absorber consists of conductive layers, a reflector and spacers, which are layers between the conductive layers and the reflector. The absorbing frequency range can be easily set by the width of the spacers.

Index Terms— electromagnetic wave absorption, em wave absorber, absorber, tuneable microwave absorber, conductive sheet, plane-wave propagation

1. INTRODUCTION

For many applications a shield to prevent electromagnetic (em) interferences is not sufficient because the em wave is reflected by the shield wall and the wave propagates on. As a result there may be resonances and interferences that bring further problems. To avoid these problems, it is necessary to use absorbing materials or coatings on the shield to convert the em wave into heat. Therefore in the past different concepts of absorbers have been developed. A simple absorber is the Salisbury Screen that consists of an absorber layer and a reflector [1], but it has the disadvantage that only one frequency with a small bandwidth can be absorbed. There were developed also integrated circuit absorbers [2] sometimes they are tuneable by an external curent [3]. However, a broad scope can only be achieved if the absorber is cheap and easy to handle.

2. THEORETICAL CONSIDERATIONS

2.1. Plane-Wave Propagation

The basis of the calculation model is that the plane-wave at the transition from one medium to another is reflected and that it is attenuated in the medium.

The reflection $\underline{\Gamma}$ on transition from air (wave impedanz $Z_0 = 377\Omega$) to the medium (wave impedanz $\underline{Z}_1$) can be calculated by:

$$\underline{\Gamma} = \frac{\underline{Z}_1 - Z_0}{\underline{Z}_1 + Z_0} \,. \tag{1}$$

The intrinsic wave impedance of a material is given by:

$$\underline{Z}_1 = \sqrt{\frac{j\omega\underline{\mu}}{\sigma + j\omega\underline{\varepsilon}}} \,. \tag{2}$$

In the case of a non-conductive material σ is zero. The transmission $\underline{T}$ in the medium is given by:

$$\underline{T} = e^{-\sqrt{j\omega\underline{\mu}(\sigma + j\omega\underline{\varepsilon})}\cdot d}. \tag{3}$$

Since, the reflection and transmission are not equated to the scattering parameters it is necessary to calculate them. The calculation is given by [4]:

$$\underline{S}_{11} = \frac{(1-\underline{T}^2)\underline{\Gamma}}{1-\underline{T}^2\underline{\Gamma}^2} \tag{4}$$

$$\underline{S}_{21} = \frac{(1-\underline{\Gamma}^2)\underline{T}}{1-\underline{T}^2\underline{\Gamma}^2}. \tag{5}$$

By setting $\underline{S}_{11} = \underline{S}_{22}$ and $\underline{S}_{12} = \underline{S}_{21}$ the two-port scattering matrix can be described as:

$$[\underline{S}] = \begin{bmatrix} \underline{S}_{11} & \underline{S}_{12} \\ \underline{S}_{21} & \underline{S}_{22} \end{bmatrix} \,. \tag{6}$$

2.2. Calculation for Different Material Sheets

To get the behavior of a structure of different layers the corresponding scattering matrixes have to be calculated. Therefore the scattering matrices have to be transformed into transmission matrices:

$$[\underline{T}] = \frac{1}{\underline{S}_{21}} \begin{bmatrix} -\det[\underline{S}] & \underline{S}_{11} \\ -\underline{S}_{22} & 1 \end{bmatrix} \,. \tag{7}$$

Thanks to AiF (KF0196502WM8) for supporting.

To calculate the corresponding transmission matrix from the individual matrices take:

$$[\underline{T}] = [\underline{T}_1] \cdot [\underline{T}_2] \cdot \ldots \cdot [\underline{T}_n] \,. \tag{8}$$

Then the transmission matrix can be transformed back to the scattering matrix:

$$[\underline{S}] = \frac{1}{\underline{T}_{22}} \begin{bmatrix} \underline{T}_{12} & \det[\underline{T}] \\ 1 & -\underline{T}_{21} \end{bmatrix} \,. \tag{9}$$

3. ABSORBER DESIGN

The idea is to increase the bandwidth of the Salisbury Screen by using more conductive layers. The principal structure of the absorber is given in Fig. 1 where N is the number of layers. The sheets A_1 to A_N are the conductive absorbers. Their conductivities are given by σ_1 to σ_N. In the calculation their thickness is set to $25\,\mu m$. The spacers S_1 to S_N are not conductive. In the calculation expanded polystyrene (EPS) is used. Measurements have shown that the dielectric constant of the EPS is nearly 1. In the calculation it is set to $\underline{\varepsilon}_{r\ Spacer} = 1.1 + j0$. At the end of the structure there is the reflector R. For the calculation there was used an aluminum foil with the thickness $t_{reflector} = 7\,\mu m$ and a conductivity of $\sigma_{reflector} = 37.7\frac{MS}{m}$.

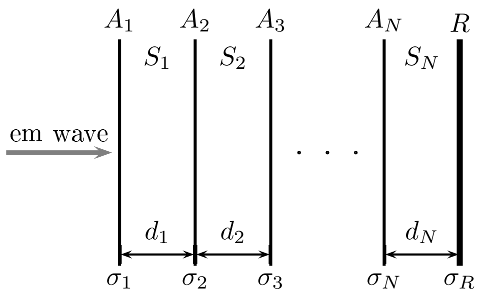

Fig. 1. Principal structure of the absorber.

The calculations have shown that a broadband absorber can be realized if the distance between the absorber sheets is reduced by a cos-function and the conductivity is enlarged by a sin-function. This behavior is represented in Eq. 10 and 11.

$$d_n = d_1 \cos\frac{\pi}{2N}(n-1) \tag{10}$$

$$\sigma_n = \sigma_1 \frac{\sin\frac{\pi}{2N}n}{\sin\frac{\pi}{2N}} \tag{11}$$

By using these equations the absorber works like a band pass filter. The absorption of static fields starts at zero, then increases, shows a ripple and then falls again. For dimensioning the absorber there must be found values for d_1, σ_1 and N. By a variation of d_1 the center frequency of the absorber bandwidth can be set. By increasing d_1 the center frequency decreases consequently. This behavior is shown in Fig. 2.

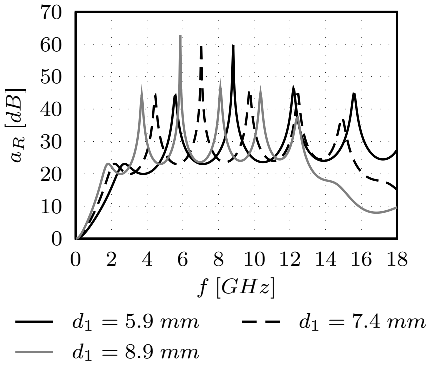

Fig. 2. Reflection loss of the absorber by variation of d_1.

By influencing the numbers of layers the bandwidth of the absorber can be changed. It also influences the absorption rate and the ripple. Increasing N brings the result that the bandwidth also increases and the ripple effect decreases. This is shown in Fig. 3.

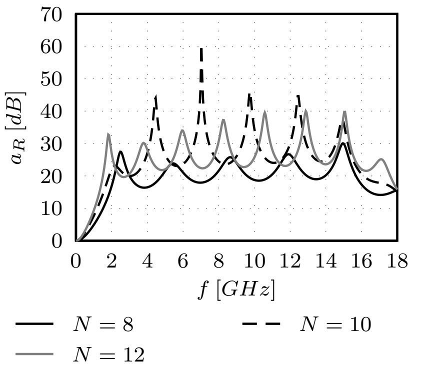

Fig. 3. Reflection loss of the absorber by variation of N.

The parameter σ_1 controls the absortion rate and influences the bandwidth of the absorber as shown in Fig. 4.

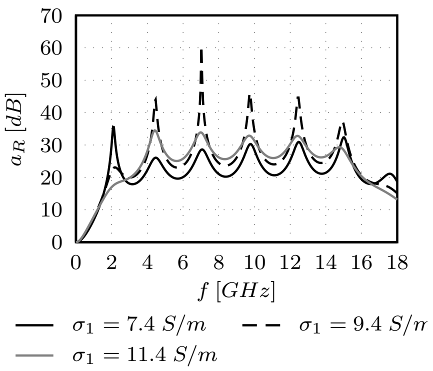

Fig. 4. Reflection loss of the absorber by variation of σ_1.

To get an absorber in the frequency range from 1 GHz to 18 GHz the parameters have to be optimized. For $N = \{5; 10; 20\}$ different solutions are shown in Fig. 5.

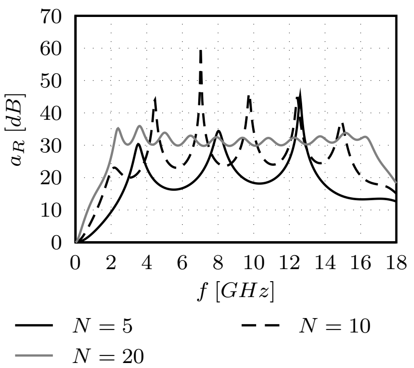

Fig. 5. Reflection loss of the optimized absorbers.

Thus the absorber with 20 layers have the largest reflection loss, with 10 layers the absorption is over 20 dB in the frequency rage from 2 GHz to 16 GHz. With the absorber with 5 layers only 15 dB in the frequency rage from 2.7 GHz to 14 GHz is possible. But in some applications it can be enough to reduce interferences due to reflections. Another advantage of an absorber with few layers is the reduced thickness. In Tab. 1 the parameters for the layers are shown.

Table 1. Values of the absorbers.

N	σ_n [$\frac{S}{m}$]	d_n [mm]	$\sum d_n$ [mm]
5	[24.7; 47.1; 64.8; 76.1; 80.1]	[7.4; 7.0; 6.0; 4.3; 2.3]	27.1
10	[9.4; 18.5; 27.3; 35.2; 42.4; 48.6; 53.5; 57.1; 59.3; 60.0]	[7.4; 7.3; 7.0; 6.6; 6.0; 5.2; 4.3; 3.4; 2.3; 1.2]	50.7
20	[3.9; 7.8; 11.7; 15.4; 19.1; 22.7; 26.1; 29.4; 32.4; 35.3; 38.0; 40.4; 42.6; 44.5; 46.2; 47.5; 48.6; 49.3; 49.8; 50.0]	[7.4; 7.4; 7.3; 7.2; 7.0; 6.8; 6.6; 6.3; 6.0; 5.6; 5.2; 4.8; 4.3; 3.9; 3.4; 2.8; 2.3; 1.7; 1.2; 0.6]	97.9

4. CONCLUSIONS

It was shown that by using a model of em wave propagation an absorber could be calculated which consists of several conductive layers. The behavior of the absorber layer distances follows a cos-function and the course of the conductivities of the individual absorber layers a sin-function. Future investigations which show the practical application of such absorbers should be examined.

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