REPRESENTING FERRITE ABSORBING TILES AS FREQUENCY DEPENDENT BOUNDARIES IN TLM

Indexing terms

Transmission line matrix, TLM, Modelling, Electromagnetic waves

Abstract

A new way of modelling ferrite tile absorbers as frequency dependent reflecting boundaries in the TLM method is described. Results are presented which show a good fit to the manufacturers reflectivity curves.

Introduction

The Transmission Line Matrix (TLM) method of numerical electromagnetic analysis with the symmetrical condensed node is well known [1]. The representation of lossy materials is described in references [2], [3] and [4]. In order to represent the operation of a lossy dielectric or magnetic material using these methods the material blocks must be about 6 mesh units deep. This is often feasible for lossy dielectric radio absorbent materials, such as those used to line anechoic chambers, since the material depth is relatively large compared to the mesh size. Ferrite absorbing tiles are only a few millimetres in depth and cannot easily be represented as material blocks when the mesh size required to model a typical anechoic chamber may be a significant fraction of a metre. In order to overcome this problem an efficient means of approximating the reflectivity of ferrite absorbers with frequency dependent boundaries is presented.

Formulation

The formulation is based on the observation that the frequency dependence of ferrite absorbing tiles behaves in a similar manner to the second order function:

$$F(s) = -\left[\frac{s^2 + 2zw_n s + w_n^2}{k(s+d)}\right] \quad (1)$$

where s is the Laplace variable. It has a minimum magnitude rmin when s = jwn. For large s:

$$F(s) \approx -\left[\frac{s}{k}\right] \quad (2)$$

and as s tends to zero:

$$F(s) \approx -\left[\frac{\omega_n^2}{k\,d}\right] \quad (3)$$

We know that the reflection coefficient for the tile tends to -1 at low frequencies so we can match the functions by taking key points on the reflectivity curve of the ferrite tile. Therefore:

$$\omega_n = 2\pi f_{min} \quad (4)$$

where f_{min} is the frequency of the reflection minimum ρ_{min} . The factor k is given by:

$$k = \frac{2\pi f_u}{\rho_u} \tag{5}$$

where f_u is the frequency of a point well above the reflection minimum and ρ_u is the magnitude of the reflection coefficient at that point. The damping factor ζ can be expressed as a function of earlier factors and the minimum value of the reflectivity ρ_{min}:

$$\zeta = \frac{k\rho_{min}}{2\omega_n} \tag{6}$$

The pole position is fixed by the fact that the reflectivity (and hence F(s)) must become -1 as s tends to zero so that:

$$d = \frac{\omega_n}{k} \tag{7}$$

The continuous function F(s) can be approximated by the discrete time function:

$$H(Z) = \frac{b_0 + Z^{-1} b_1 + Z^{-2} b_2}{1 - a_1 Z^{-1} - a_2 Z^{-2}} \tag{8}$$

where Z^{-1} represents a unit delay. The a and b coefficients can be determined using the impulse invariant transform from F(s) so that:

$$a_1 = e^{-dT} \tag{9}$$

$$a_2 = 0 \tag{10}$$

$$b_1 = -b_0 \ \Re(z_{z1} + z_{z2}) \tag{11}$$

$$b_2 = b_0 \, e^{-(2\zeta\omega_n T)} \tag{12}$$

where $\Re(x)$ indicates the real part of x . The value of b_0 is chosen such that H(1) = -1. T is the sample period for the filter which is made equal to the TLM time-step and the zeros, z_{z1} and z_{z2}, of H(Z) are given by:

$$z_{z1} = e^{\left(-\zeta\omega_n T + j\omega_n T \sqrt{1 - \zeta^2}\right)} \tag{13a}$$

$$z_{z2} = e^{\left(-\zeta\omega_n T - j\omega_n T \sqrt{1 - \zeta^2}\right)} \tag{13b}$$

The filter can be implemented as shown in Fig. 1 where V is the incident voltage and ρV is the reflected voltage. Two such filters are required to implement the reflection coefficient at each mesh element boundary - one for each wave polarisation.

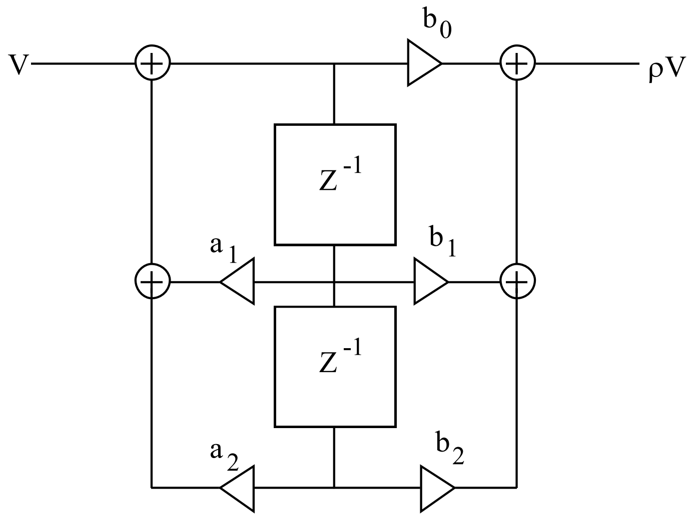

Fig. 1 Second order digital filter section

Results

Here results are presented which compare the manufacturers data with analytical solution of H(z)[1] and the results from a 0.1 m TLM mesh for both the conventional flat-plate (Fig. 2) and the new grid-structure (Fig. 3) ferrite tiles. To compute these results with the material blocks of [3] and [4] would require a mesh size of approximately 1 mm - in many cases the use of such a fine grid would be impractical.

Considering Figures 2 and 3 it can be seen that the TLM results correspond exactly with the analytical values of H(z) except for a small deviation in the upper frequency range which is due to the roll-off inherent in the TLM mesh impulse response. The TLM results correspond very closely to the manufacturers' data above the reflection minimum but an error of several dB occurs at low frequencies.

Conclusions

A method has been presented which allows the simulation of ferrite tile absorber by the use of frequency dependent boundaries. The method allows the use of a much larger mesh size than would be possible if the absorber were represented as material blocks. This means that it is realistic to simulate the effect of fully, or partially ferrite-lined screened enclosures with the TLM method.

The method requires the storage of only 4 values for each mesh-unit sized boundary patch. This is very efficient compared with the alternative possibility of using multigrid or graded mesh TLM which would require a large ratio of mesh sizes, and a large number of mesh elements to adequately represent the tiles.

Currently the technique is being applied to determine the performance of partially lined screened enclosures and in predicting the effect of ferrite absorber within equipment enclosures on radiated emissions.

[1] It should be noted that H(z) gives an exact correspondence with the theoretical reflectivity curves obtained from the first order approximation for the material permeability given in [4].

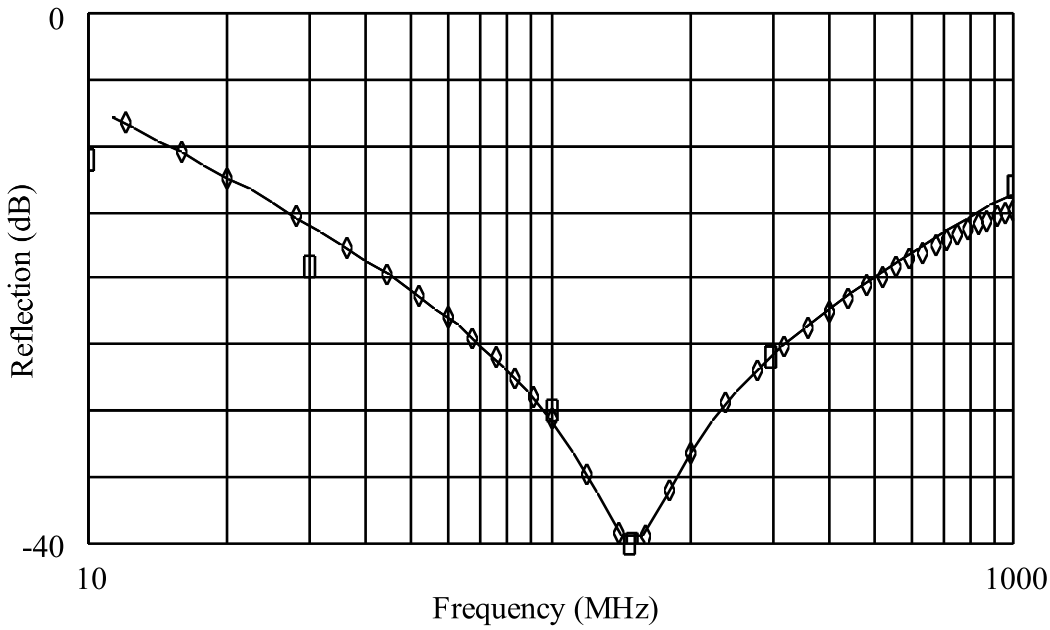

Fig. 2 **Flat Ferrite tile - Material parameters ρ_{min} = 0.01, f_{min} = 150 MHz , ρ_u = 0.22387 f_u = 1 GHz**

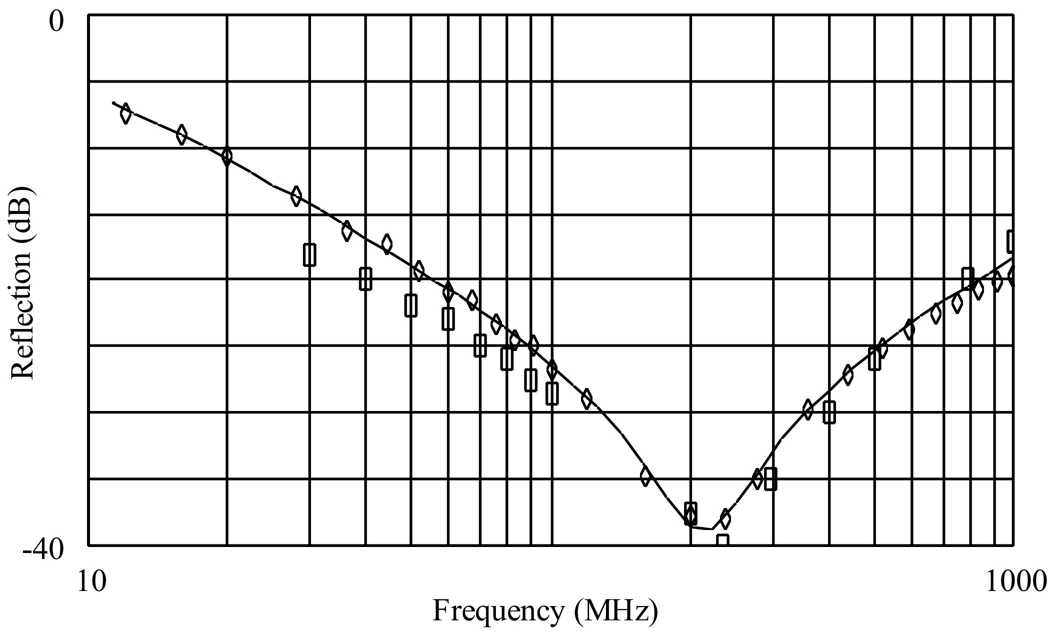

Fig. 3 **Grid -structure ferrite tile - Material parameters ρ_{min} = 0.0112, f_{min} = 213.7 MHz, ρ_u = 0.1317, f_u = 1 GHz**

▯ Manufacturer's data

◊ New TLM

— Analytic solution

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