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SIMULATION OF THE SHIELDING EFFECTIVENESS OF CABINETS USED IN COMMUNICATIONS EQUIPMENT

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Abstract. The basic formulations used in the description of thin walls and small apertures in simulations based on the Transmission-Line Modelling (TLM) method are described. It is shown that efficient and accurate methods are available which exhibit a reasonable balance between accuracy and computational efficiency. Results of simulations are presented showing the shielding effectiveness of cabinets.

1. Introduction

Of all aspects of design influencing the electromagnetic compatibility (EMC) of equipment, electromagnetic shielding is the one in which the EMC designer has the maximum degree of control. EMC problems occur because a source of electromagnetic interference (EMI) affects, through coupling paths, the operation of an electronic system (the victim of EMI). The EMC designer has little control on externally generated interference and limited input in the design of the potential victim system which is dominated by operational considerations [1]. Good shielding on the other hand can remove or diminish coupling paths and thus unsure EMC. However, shielding adds cost, weight, interferes with access and cooling and may be aesthetically unacceptable. It is, therefore, imperative to be able to predict the performance of shielding arrangements in complex systems. Modern predictive design tools are computer-based. Hence, this paper deals with such tools based on the Transmission-Line Modelling (TLM) method [2].

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TLM is a time-domain, differential method offering a degree of generality and versatility which is essential in EMC simulations. One aspect of this approach, however, which can cause difficulties, is the description of fine features in an otherwise large problem space. Typical situations where this occurs are in the description of fine slots, joints and thin walls, regularly found in practical equipment cabinets and shields. While, in principle, it is possible to use a very fine mesh around specific fine features only and thus economise on computer resources, the differences in physical scale are normally so large as to make this approach unprofitable. In many practical problems it has been found necessary to devise special formulations, which are outside a full three-dimensional field solution, which give an accurate description of fine features at a fraction of the computational cost of a full field solution.

Two specific problems are described here. First, the modelling of thin panels made our of poor electrical conductivity materials is presented. Second, the manner in which EM wave penetration through small holes may be described in the TLM model, using the equivalence principle, are presented. Applications of the model in the calculation of the shielding effectiveness of three-dimensional cabinets and examples of penetration through small holes are shown.

2. Brief introduction to TLM

TLM is a time-domain, differential numerical modelling method ideally suited to the study of field problems in general and electromagnetic problems in particular [2]. In modelling problems by TLM, fields are obtained by analogy to a transmission-line network. This is a network of interconnected nodes, a typical structure being the symmetrical condensed node (SCN) shown in Figure 1.

Pulses incident on each node scatter according to transmission line theory and become incident on adjacent nodes at the next time step. The TLM algorithm is a repetition of the process of scattering and connection of pulses to adjacent nodes for as many time steps as are required. More advanced nodal structures have been developed to increase the efficiency and accuracy of the basic SCN [3]. In EMC problems and shielding, in particular, it is difficult to establish sufficient resolution to deal with fine features (thin walls, small holes) without making excessive demands on computational resources. Although a graded mesh and/or a multigrid formulation can help in this respect, it is undoubtedly necessary to deal with fine features in a different way which does not demand very small nodal sizes. It is the purpose of this paper to describe the manner in which this is achieved for thin walls and small apertures. These are typically found in all kinds of communication equipment such as receivers and mobile phones.

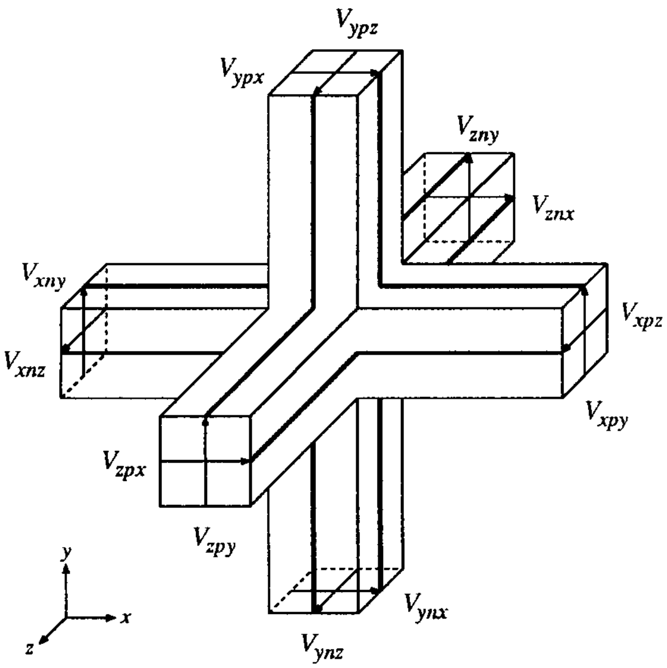

Fig. 1. Symmetrical condensed node (SCN) for the TLM

3. Thin–Wall formulations

A thin wall which is not perfectly conducting can be modelled, in principle, by a small lossy TLM node. This, however, would require a very small nodal size and would be, in most cases, impractical. An alternative is to recognise that in a thin panel propagation is, essentially, one-dimensional along the direction normal to the panel. It can thus be modelled by a lossy ladder-type transmission line network [4,5,6] as shown in Figure 2. Two such networks are connected between SCN nodes, one for each polarization, to represent the diffusion of EM waves through the wall. Thus, voltage pulses reflected into ports adjacent to the thin wall from either side have to propagate through the network shown in Figure 2 before connection to a TLM port on the opposite side. It is found that in practice about ten line sections are needed to obtain reasonable accuracy. The parameters of each section can be independently chosen to represent wall material properties which may be

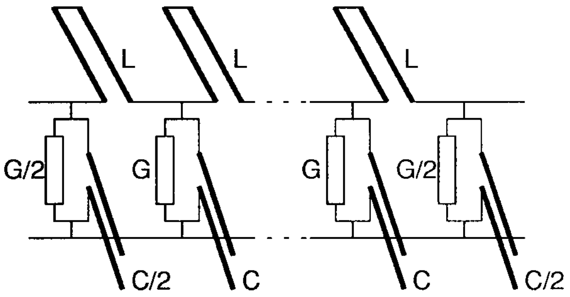

Fig. 2. Ladder-type network for thin wall formulation

non-uniform (e.g. layered walls) or polarization dependent (e.g. in carbon fibre layered walls).

TLM based simulations can be performed to study the shielding effectiveness of complete cabinets made our of various thin-wall materials [5,6]. Penetration of magnetic field through a box of the dimensions $10cm^3$ and with the walls made by carbon fibre panels ($\sigma = 20000 S/m$) of $1mm$ thickness is simulated using the thin wall formulation. Using formulae from [7], it was found that the fall time of an exponential decay for such a structure is $t_f = 0.42\mu s$. Therefore simulation was run long enough (120000 iterations $\equiv 2\mu s$) to allow transients to decay. Using the 3D TLM mesh of size 16^3 with the node spacing $\Delta l = 1cm$ and $n = 12$ discretization layers, it took 30 minutes on an Apollo workstation to get time domain results, shown in Figure 3 for the first μs.

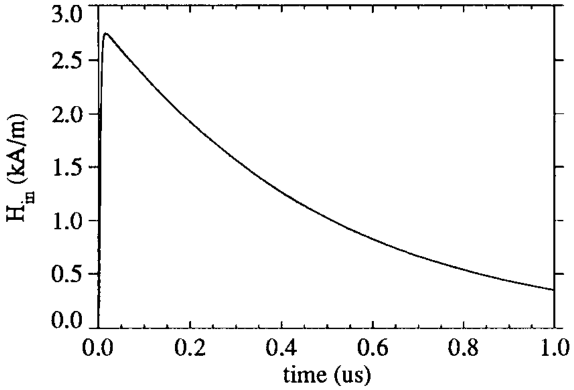

Fig. 3. Magnetic field response inside a carbon fibre composite [5]

Frequency domain results for magnetic shielding effectiveness (MSE) of the box are compared with the theoretical prediction [7] and shown in Figure 4.

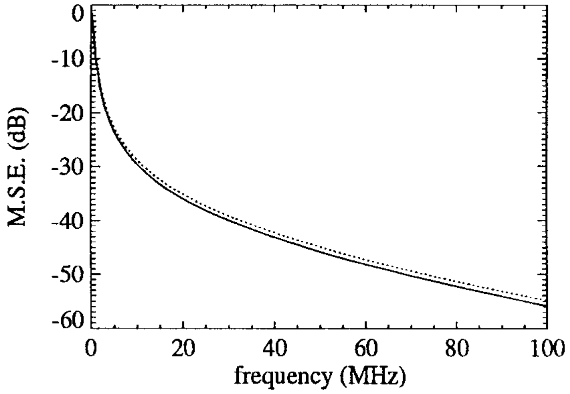

Fig. 4. Magnetic shielding effectiveness for CFC box. ——— TLM, - - - - - theory [5].

4. Small-Hole Formulations

Practical communications equipment contain small holes for access, ventilation, displays, etc. There are also small gaps due to the imperfect contact between adjacent panels. Such features may be described in models in three different ways.

First, a fine mesh may be used and appropriate short-circuits placed to form the outline of a small hole. The inherent difficulty in this approach is that very high resolution must be used resulting in excessive computational demands. It offers, however, maximum flexibility and accuracy.

Second, a special narrow-slot formulation may be used, which while maintaining the basic (coarse) meshing Δl , it incorporates a slot of length Δl and thickness $w \ll \Delta l$ [8]. There is limited control on the shape of hole.

Finally, penetration through electrically small holes may be modelled by resorting to the equivalence principle. According to this principle, penetration may be modelled by the introduction of electric and magnetic dipoles P_e and P_m which depend on the short-circuit electric and magnetic fields and the polarizabilities of the hole [9]. The short-circuit fields are those obtained when the hole is not present (it is replaced by conducting material). The polarizabilities of holes of various shapes are available and thus this method may be employed to determine penetration in practical systems. If the electric filed component normal to the plane of the hole is zero then only P_m needs to be modelled to account for penetration. This approach has been used in calculations before, including simulations based on the FDTD method [10]. It may also be applied to TLM.

To validate the TLM with small hole formalism (SHF) we simulate the penetration of a TEM mode Gaussian pulse through a perfectly conducting wall with a small rectangular aperture. Results for the penetrating electric field component E_x are shown in Figure 5.

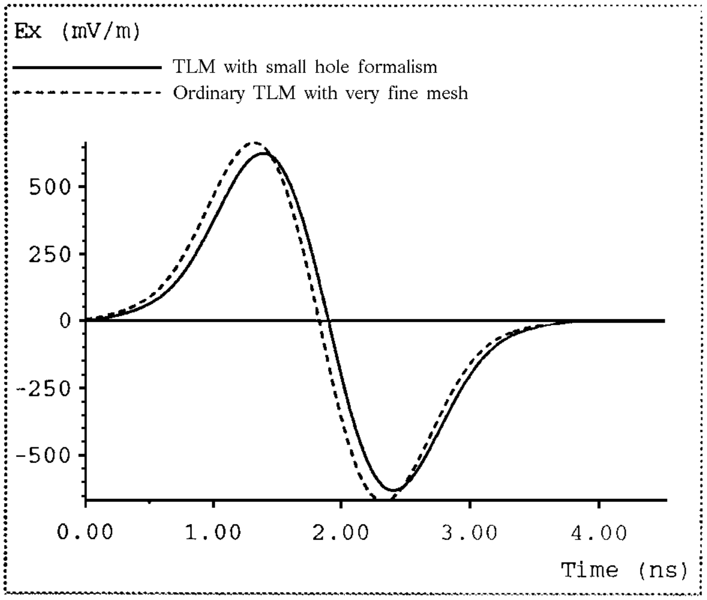

Fig. 5. Waveforms of penetrating electric field

The simulation using the SHF was performed on a coarse mesh with 9 times larger node spacing Δl compared to the ordinary TLM method. The results agree well, indicating that substantial savings in memory and runtime can be achieved with the small hole formalism compared to traditional methods, without loss of accuracy.

5. Conclusion

Efficient implementation of thin wall and thin holes formulations into the TLM method were described. These enhancements can be used in modelling a wide range of communication equipment and their electromagnetic shielding performance. Results using new formulations are presented showing very good agreement with the traditional, but computationally very demanding methods.

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