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A finite element tool for the electromagnetic analysis of braided cable shields[☆]

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ABSTRACT

In this work we present a finite element tool for the electromagnetic analysis of braided cable shields. This tool is able to calculate the transfer impedance of a cable shield and it can be applied to a wide variety of situations where complex geometries and materials may be present. Also, it can help in the development, validation and improvement of novel, or existent, analytical models. Analytical models are computationally less expensive than a numerical approach but, they may be not available for some types of cable shields and, when available, they may be hard to compare directly against measurements. On the other hand, we can easily compare the analytical results against the numerical tool because all the parameters involved in the comparative are exactly known. Therefore, our computer tool offers a new extra criterion to assess whether a model is correct or not. Moreover, it allows studying in great detail the behavior of the fields and currents in and around the shield. This feature makes the tool very useful for gaining new insights into the physics behind the shielding process.

Program summary

Program title: BraWiGG (Braided Wire Geometry Generator)

Catalogue identifier: AEVT_v1_0

Program summary URL: http://cpc.cs.qub.ac.uk/summaries/AEVT_v1_0.html

Program obtainable from: CPC Program Library, Queen's University, Belfast, N. Ireland

Licensing provisions: Standard CPC licence, http://cpc.cs.qub.ac.uk/licence/licence.html

No. of lines in distributed program, including test data, etc.: 109410

No. of bytes in distributed program, including test data, etc.: 19308482

Distribution format: tar.gz

Programming language: Tcl/Tk.

Computer: Any computer with Microsoft Windows installed.

Operating system: Microsoft Windows.

RAM: Problem dependent. BraWiGG required only a few MB (<100 MB) to generate the CAD geometries showed in this paper.

Classification: 10.

External routines: GiD [2] and ERMES [1]

Subprograms used:

Cat Id	Title	Reference
AEPV_v1_0	ERMES	CPC 184 (2013) 2588

Nature of problem: Electromagnetic analysis of cable shields (shielding quality, transfer impedance).

☆ This paper and its associated computer program are available via the Computer Physics Communication homepage on ScienceDirect (http://www.sciencedirect.com/science/journal/00104655).

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Solution method: BraWiGG is a plug-in of GiD [2]. It generates a CAD geometry that is used by ERMES [1] to calculate the transfer impedance of a cable shield with the finite element method.

Running time: Problem dependent. BraWiGG needed only a few seconds (<5 min) to generate the CAD geometries showed in this paper.

References:

[1] R. Otin, ERMES: A nodal-based finite element code for electromagnetic simulations in frequency domain, Computer Physics Communications 184 (11) (2013) 2588–2595.

[2] GiD, The personal pre and post processor, International Center for Numerical Methods in Engineering (CIMNE), Barcelona, Spain. [Online]. Available: http://www.gidhome.com.

1. Introduction

The shielding quality of a braided cable shield can be characterized by a parameter Z_t called surface transfer impedance, or just transfer impedance. This parameter was initially introduced by Schelkunoff [1] and is defined as

$$Z_t = \frac{1}{I_0}\frac{\partial V}{\partial z} \tag{1}$$

where I_0 is the current flowing through the shield induced on its outer surface and $\partial V/\partial z$ is the voltage per unit length inside of the shield. The value of Z_t is independent of external factors and depends only on the geometry and materials of the shield. It allows to estimate the effect produced by an external field on the wires inside the cable or, reciprocally, the radiation leaked from inside the cable to the environment. A low value of Z_t indicates a good shielding against interfering electromagnetic fields.

Although it is possible to measure the transfer impedance [2,3], it is always advantageous to have an electromagnetic model able to predict its value before the actual manufacturing of the shield. This not only saves time and money, but also improves the quality of the final product by allowing the virtual test of many design possibilities. One of the objectives of this paper is to help in the development of electromagnetic models for cable shields. For that, we have developed a finite element (FEM) tool which is able to calculate the transfer impedance of a cable shield and that it can be applied systematically to a wide variety of situations where complex geometries and materials may be present. This tool can help in the improvement of existing analytical models [4–11] or in the development of new ones. Also, it allows to study in great detail the behavior of the fields and currents in and around the shield, which makes the tool very useful for gaining new insights into the physics behind the shielding process.

Analytical models are usually computationally less expensive than a numerical approach but, they may be not available for some types of cable shields and, when available, they may be hard to compare directly against measurements. The difficulties in the validation of the theoretical models are due to inaccuracies in the measurement process [3] and/or uncertainties in the input data produced by manufacturing tolerances [12] or changes in the properties caused by aging and handling [13]. On the other hand, we can easily compare analytical results against the FEM tool presented here because all the parameters involved in the comparative are exactly known. Therefore, our computer tool offers a new extra criterion to assess whether a model is correct or not.

Two of the points described above (validation of analytical models and improvement of the understanding of the underlying physics) were the main motivations for the development of the numerical tool presented here. We found some discrepancies between analytical models and measurements and we did not know if such discrepancies were caused by poor modeling or by measurement uncertainties. This work tries to answer this question.

In the next section we describe the parameters that characterize a braided cable shield and how we generate its computer aided design (CAD) model. In Section 3 is explained how to calculate Z_t on this CAD model with the finite element method. In Section 4 this numerical approach is compared against an analytical model and against measurements. Finally, in Sections 5 and 6, we analyze the results and reach to conclusions.

2. CAD model

A required step before starting the FEM analysis is to generate a CAD geometry representing the braided wire shield. In our case, this task is performed with BraWiGG (Braided Wire Geometry Generator), a Tcl/Tk plug-in integrated in the pre-processing software GiD [14,15]. The geometry of the shield is automatically generated from the data input from the user-friendly window as shown in Fig. 1. This plug-in generates only cable shields of the type shown in Fig. 2. More general geometries can also be computed with our numerical tool (see, for instance, references [16–20]) but they must be generated from scratch or imported from another CAD environment.

2.1. Geometric parameters

The parameters required to generate the braided wire geometry can be divided into two groups. The first group includes the parameters which give a general description of the braid:

- diameter of a single wire (d),
- inner diameter of the shield (D),
- number of carriers (i.e. belts of wires) in the braid (C),
- number of wires in a carrier (N), and
- weave angle of the braid (α).

These parameters are usually the only input data required by analytical models for the full description of a braided cable shield geometry (see, for instance, reference [11]). The second group of parameters are specific of the plug-in described at the beginning of this section. They allow us to generate more general geometries and to test different configurations. They are optional and can be let fixed for a given type of shields. These parameters are (see Figs. 2 and 3):

- weaving mode (one-step/two-step),
- distance between carriers (λ_C),
- separation between wires inside the same carrier (λ_w),
- distance between the braid and the longitudinal surface located in the inner part of the shield (λ_D),