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Wire-grid electromagnetic modelling of metallic cylindrical objects with arbitrary section, for Ground Penetrating Radar applications

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This work deals with the electromagnetic wire-grid modelling of metallic cylindrical objects, buried in the ground or embedded in a structure, for example in a wall or in a concrete slab.

Wire-grid modelling of conducting objects was introduced by Richmond in 1966 [1] and, since then, this method has been extensively used over the years to simulate arbitrarily-shaped objects and compute radiation patterns of antennas, as well as the electromagnetic field scattered by targets.

For any wire-grid model, a fundamental question is the choice of the optimum wire radius and grid spacing. The most widely used criterion to fix the wire size is the so-called same-area rule [2], coming from empirical observation: the total surface area of the wires has to be equal to the surface area of the object being modelled. However, just few authors have investigated the validity of this criterion. Ludwig [3] studied the reliability of the rule by examining the canonical radiation problem of a transverse magnetic field by a circular cylinder fed with a uniform surface current, compared with a wire-grid model; he concluded that the same-area rule is optimum and that too thin wires are just as bad as too thick ones. Paknys [4] investigated the accuracy of the same-area rule for the modelling of a circular cylinder with a uniform current on it, continuing the study initiated in [3], or illuminated by a transverse magnetic monochromatic plane wave; he deduced that the same-area rule is optimal and that the field inside the cylinder is most sensitive to the wire radius than the field outside the object, so being a good error indicator. In [5], a circular cylinder was considered, embedded in a dielectric half-space and illuminated by a transverse magnetic monochromatic plane wave; the scattered near field was calculated by using the Cylindrical-Wave Approach and numerical results, obtained for different wire-grid models in the spectral domain, were compared with the exact solution. The Authors demonstrated that the well-known same-area criterion yields affordable results but is quite far from being the optimum: better results can be obtained with a wire radius shorter than what is suggested by the rule.

In utility detection, quality controls of reinforced concrete, and other civil-engineering applications, many sought targets are long and thin: in these cases, two-dimensional scattering methods can be employed for the electromagnetic modelling of scenarios. In the present work, the freeware tool GPRMAX2D [6], implementing the Finite-Difference Time-Domain method, is used to implement the wire-grid modelling of buried two-dimensional objects. The source is a line of current, with Ricker waveform. Results obtained in [5] are confirmed in the time domain and for different geometries. The highest accuracy is obtained by shortening the radius of about 10%. It seems that fewer (and larger) wires need minor shortening; however, more detailed investigations are required. We suggest to use at least 8 – 10 wires per wavelength if the field scattered by the structure has to be evaluated. The internal field is much more sensitive to the modelling configuration than the external one, and more wires should be employed when shielding effects are concerned.

We plan to conduct a more comprehensive analysis, in order to extract guidelines for wire sizing, to be validated on different shapes. We also look forward to verifying the possibility of using the wire-grid modelling method for the simulation of slotted objects.

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