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Comparison of analytical and boundary element modeling of electromagnetic field coupling to overhead and buried wires

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ABSTRACT

The paper deals with various approaches for the analysis of electromagnetic field coupling to horizontal straight line of finite length in the presence of a lossy half-space based on the theory of thin wire antennas. The formulation is posed in the frequency domain and it is based on the corresponding Pocklington integro-differential equation. Throughout this work the Pocklington equation is solved numerically via the Galerkin–Bubnov scheme of the indirect boundary element method (GB-IBEM) and analytically. The obtained results are compared to NEC results and to the results obtained by applying the transmission line (TL) model, i.e. to the results obtained by solving the corresponding Telegrapher's equations.

1. Introduction

The analysis of electromagnetic field coupling to overhead and buried wires of finite length can be carried out by using the thin wire antenna theory, or transmission line (TL) model [1–7]. The TL approach does not provide a complete solution if the wavelength of the field coupling to either above-ground or below-ground wires is comparable to, or less than the transverse electrical dimensions of the line. Thus, wires of finite length have to be analyzed by means of the wire antenna theory. The principal disadvantage of the wire antenna approach, with a related numerical method applied, is relatively high computational cost if longer lines are analyzed [1]. An extension of the TL approach to the combined electromagnetic field-to-transmission line coupling equations valid for finite length lines above perfectly conducting (PEC) ground has been reported in [2,3].

A comparison between TL model and antenna theory approach to the analysis of finite length lines has been discussed elsewhere, e.g. in [4,5].

Consequently, it is of certain practical interest to consider analytical solution of the Pocklington equation under some plausible set of approximation in order to get some results useful in an average sense for engineering applications. One of the applications of particular interest is related to power line communications (PLC) [8]. Such solutions could serve to rapidly estimate the phenomena of interest. Of particular interest would be an analytical treatment of arbitrary configuration of multiconductor lines in the presence of an imperfectly conducting ground.

In this work, different methods for the analysis of electromagnetic field coupling to a single wire of finite length above or below a PEC ground are considered. The formulation arising from the wire antenna theory is based on the Pocklington integro-differential equation, while the transmission line model is based on the related Telegrapher's equations. The Pocklington equation is solved both numerically and analytically. The numerical solution is carried out using the Galerkin–Bubnov scheme of the Indirect Boundary Element Method (GB-IBEM). The obtained results are compared to the results computed via NEC and to the results obtained via TL approximation featuring the corresponding Telegrapher's equations.

It is worth noting that the present work could be considered as a sequel of the research reported in [9] in which a comparison between analytical and boundary element modeling of horizontal electrode has been presented.

2. Formulation of the problem

The analysis presented in this paper is restricted to PEC wires. An extension to lossy conductors is straightforward [4]. The PEC

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