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Susanne Jakob
Dipl.-Ing. Helge Drumm

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L. Grcev, V. Arnautovski-Toseva

Efficient High Frequency Modeling of Large Structures in the Presence of Earth

INTRODUCTION

Modeling of structures that may be represented by thin-wire metallic networks above, below or penetrating the earth's surface is of interest in research and design in different fields, such as: antennas and propagation, geophysical prospecting, electromagnetic compatibility, lightning, etc., and in applications related to different areas, including both power and communication systems. The Method of Moments (MoM) [1] requires suitable segmentation of the wires into subsections, which allows for spatial sampled approximation of the equivalent current and charge distribution over the structure by a sequence of expansion functions. The boundary conditions are also approximately satisfied in a weighted way over subsections. In the process the integro-differential equation characterizing the problem is reduced to a matrix equation of the form

$$[V] = [Z][I] \tag{1}$$

where $[I]$ are amplitudes of the current expansion functions and the elements of $[V]$ are related to the excitation of the wire structure. Elements of $[Z]$ require the integral equation, which Green's function evaluation is the key step in the solution. Exact Green's function for the layered earth involves Sommerfeld type integrals that require intensive computations. Further spectral and temporal sampling allows for numerical solution of transient problems. There are increasing demands for solutions of large and complex structures, which are mostly restricted by the long CPU time for large number of unknowns. Therefore, there is a need for reduction of the number of spatial, spectral and tempral samples.

METHODS FOR EFFICIENT SOLUTION OF LARGE PROBLEMS

Paper analyses methods for more efficient computation required for large problems. One of the most important approaches to the reduction of the total CPU time can be

achieved by reduction of the time required for the Green's function evaluation. Applicable more efficient methods depend on many factors, such as: frequency, medium, dimensions, and one possibility is to apply adaptive approach to choose the optimal method based on the situation. The most time consuming part is the direct numerical evaluation of Sommerfeld type integrals, which can be minimized by interpolation and model based parameter estimation approximations [2]. Further, of great advantage are closed form approximate Green's functions [3], same based on different image approaches or simplified formulas in their domain of applicability. It is worth noting that because of the variational nature of some of MoM approaches, especially with identical expansion and weighting functions, the first order error in approximation of the Green's functions can result in smaller second order error in [Z] matrix.

Elements of [Z] matrix often require integration along subsections. This process also can be optimized taking into account required accuracy of the final result, and closed form solutions or approximations are of great advantage. Here also the importance of [Z] interpolation methods should be emphasized especially in wide frequency spectrums [4].

Hybrid electromagnetic-circuit models are often necessary in problems involving large systems, such as: power and communication systems. Power and communication systems, especially their over ground parts are efficiently modeled by circuit approach and corresponding software. However, such approach is not always suitable for coupled below ground parts, where electromagnetic (EM) models are more suitable. The proposed interface between EM and circuit models are equivalent circuit parameters directly extracted from EM analysis [5].

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Authors:

Prof. Leonid GRCEV
Dr. Vesna ARNAUTOVSKI-TOSEVA
Faculty of Electrical Engineering, Ss. Cyril and Methodius University, Karpos 2 bb, P.O.B. 574
1000 Skopje, Republic of Macedonia
Phone: +389 2 309 9128
Fax:+ 389 2 3064 262
E-mail: lgrcev@etf.ukim.edu.mk