UWB Antennas Analysis Using FDTD-Based Discrete Green's Function Approach

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***Abstract*—Discrete Green's function (DGF) approach for analysis of transient response of the ultrawideband (UWB) monopole antenna has been proposed. The marching-on-in-time solution of DGF method is based on finite-difference time-domain (FDTD) equations that offer more straightforward formulation than that of time-domain integral equations (TDIEs). In addition, unlike FDTD method, calculations are performed only on the surfaces of conductors but not throughout the entire volume. The finite ground plane effect on the UWB monopole antenna performance and transient response between two antennas in face-to-face and side-by-side scenarios have been investigated using this procedure with improving the computational speed.**

***Index Terms*—Discrete Green's function, frequency-domain response, time-domain analysis, ultrawideband (UWB) antenna.**

I. Introduction

OVER the past few decades, particular attention has been paid to the derivation of the Green's functions from the finite-difference equations [1]–[3]. These functions, commonly referred to as discrete Green's functions (DGFs), have the intrinsic properties of the finite-difference equations such as dispersion, anisotropy, and stability. The analytical closed form of the time-domain DGFs, for the infinite free space, has been initially obtained by Vazquez and Parini in 1999 [1]. They derived those expressions in terms of Jacobi polynomials by the multidimensional Z-transform of finite-difference time-domain (FDTD) equations in time and spatial domains. In [2], Kastner first employed multidimensional Z-transform to the FDTD equations and then used integral form of the spatial inverse Z-transform and obtained frequency domain of DGFs. With the utilization of ordinary Z-transform along with the spatial partial difference operators, Jeng has also achieved new expressions for the time-domain DGFs recently [3].

From an applications point of view, we can mention the utilization of the DGFs as an absorbing boundary condition [4]–[6], the realization of a total-field scattered-field formulation of the FDTD method to alleviate erroneous field leakage across the boundary [7], and the truncation of the FDTD computational grid in the presence of reflecting external media [8]. A scattering formulation of the DGF method for the antenna modeling has been derived from which the current of the structure of interest can be determined in march-on-in-time scheme [9]. The scattering formulation of the DGF method resembles march-on-in-time approach of time-domain integral equations (TDIEs). However, the key feature of the DGF method lies in that it is inherently discrete and the whole formulation is much more straightforward than TDIE method. On the other hand, the DGF method, as well as TDIE, is more preferable than FDTD method in time-domain antenna analysis in aspects of surface discretization regardless of free-space nodes around the antennas and avoiding the need for absorbing boundary conditions. So far, the references have dealt with only the modeling of one-dimensional antennas such as log-periodic dipole and Yagi–Uda array using DGF method and presented significant saving in computational runtime and memory allocated compared to the FDTD method [9], [11]. However, this technique has received little attention in the analysis of the various antennas, especially antennas with more than one dimension.

The aim of this letter is to investigate the modeling of a monopole ultrawideband (UWB) antenna using DGF method. Since there is no certain design procedure for the UWB antennas, the optimization process is essential for achieving appropriate time and frequency responses. The FDTD method along with one of the optimization algorithms is mainly used for this purpose. It is recently shown that the combination of the DGF method with fast Fourier transform (FFT) algorithms to perform spatial convolutions of the DGF formulation for analysis of the antenna with more than one dimension leads to very favorable runtime speed compared to the FDTD method [10]. Therefore, the application of the DGF method to the UWB antenna analysis can reduce the optimization time considerably.

Due to the existence of the ground plane for this type of antenna, time-domain current distributions on the monopole antenna, as well as on the finite ground plane, are determined, and wideband frequency response of the antenna can be achieved using a single run of the written code. In fact, finite ground-plane effects on the antenna performance can be clarified using this technique. Furthermore, transient response between two antennas in arbitrary orientation can be assessed using the calculation of the time-domain current distribution on the antennas in the DGF method without the need for free-space calculations between two antennas.

II. Scattering Formulation of the DGF Method

Scattered electric field of an antenna in the spatial steps $(i,j,k)=(i\Delta x, j\Delta y, k\Delta z)$ and at the time-step $(n\Delta t)$ can be obtained using the convolution of the current induced on the antenna and discrete Green's functions as

$$[\vec{E}_{\rm scat}]^{n}_{i,j,k} = \sum_{n'=0}^{n} \sum_{i',j',k'} [\bar{\rm G}]^{n-n'}_{i-i',j-j',k-k'} [\vec{J}]^{n'}_{i',j',k'} \quad (1)$$

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