Performance Analysis of Wire Antenna as EMI Sensor for Transient EM Field Measurement using FDTD Technique

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EM field measurement is just one of many necessary rf measurements in area of electromagnetic compatibility (EMC). For frequency domain EMI measurements, an antenna with wide-band performance in amplitude is desired but for transient field measurements, an antenna with wide-band performance both in amplitude and in phase is desired. In this work, FDTD is applied to predict the performance of wire antenna with respect to complex antenna factor (CAF) when it is used as an sensor to measure transient electromagnetic field. The results presented here are compared with the published results.

1 Introduction

All electronic devices must conform to the standards of electromagnetic emission set by different bodies in different countries [1]. Compliance of the devices conforming to the standards(limits) of interference in this range is verified by measuring the radiated electric fields in an anechoic chamber or at an open test range after putting the measurement antenna at a specified distance from the device under test. Wire antennas are widely used as transmitting antenna and also as sensor for electromagnetic interference (EMI) measurements. The term "wire" refers to metallic, highly conducting wire or wire-like structures.

For frequency domain or transient field measurements, it is required to determine the field strength at the point of measurement using a sensor. To use the sensor for this purpose, calibration data is required relating the electric field at the aperture of the receiving antenna to the voltage across the 50 Ω matched detector. The most common performance descriptor of EMI sensors is the complex antenna factor (CAF). CAF is the ratio of the incident electric field on the surface of the sensor to the received voltage at the antenna terminal when terminated with a 50 Ω load [1]. The CAF, which adds phase values to the conventional antenna factor, is equivalent to the reciprocal of the transfer function [2].

The theoretical prediction of the antenna factor of EMI sensors is a very attractive alternative if one takes into consideration the enormous expenditure and time required for calibrating a sensor experimentally. Also, for experimental calibration, each and every sensor is to be calibrated individually, whereas for theoretical calibration all the sensors constituting a particular type can be calibrated at one go using the same approach, it is possible to predict the susceptibility of such antennas to electromagnetic radiation incident from any direction.

FDTD method has been used to simulate a wide variety of electromagnetic phenomena because of its flexibility and versatility. Many variations and extensions of FDTD exist, and the literature on the FDTD technique is extensive. But to the best of author's knowledge no appreciable work is available in the open literature where FDTD is used to evaluate the performance of antenna in receiving mode works as an EMI sensor. In this work Finite Difference Time Domain (FDTD) technique is used to evaluate the CAF of the EMI sensors. For the validation of the theory, FDTD computed Complex Antenna Factor of a monopole antenna is compared with the measured and low-frequency approximation result [3].

2 FDTD Formulation of the Problem

FDTD model uses a uniform space lattice cubic Yee cells having $\triangle x = \triangle y = \triangle z (= \triangle)$ is considered. $10 \triangle -thick$ unsplit Perfectly Matched Layer (PML) [4] is used as Absorbing Boundary Conditions (ABC) on all six sides of the FDTD lattice. This PML is spaced $3\triangle$ cells from the closest surface of the scatterer. The voltage into a section of transmission line matched ($Z_0 = 50\Omega$) at the far end [5] is

$$V_{50}(\omega) = \left[\frac{50}{Z(\omega) + 50} \right] V_{oc}(\omega) \tag{1}$$

Where $Z(\omega)$ is the input impedance of the antenna and V_{oc} is the open-circuit voltage due to the incident field E_z at the gap between the monopole and the conducting ground plane.

The CAF is the parameter that is used to convert the voltage or power reading of the receiver to the field strength incident on the antenna. In terms of an equation, the CAF is defined as [3]

$$CAF = 20 \cdot \log \left(\frac{E_i(\omega)}{V_{50}(\omega)} \right) \qquad \left[dB \left(m^{-1} \right) \right] \tag{2}$$

where, $E_i(\omega)$ is the electric field incident on the antenna, and $V_{50}(\omega)$, is the voltage induced across a 50 Ω load at the feed point of the antenna.

For the calculation of the far-field CAF, the antenna (along z-axis) is in lossless free space and illuminated by a z-directed linearly polarized uniform plane wave as shown in the Fig. 3.8 of [4]. In order to simulate a uniform plane wave in a FDTD programme, the problem space was divided into the total field and scattered field regions. Details of this method for three dimensions given in [4], is used in this work. During the progress of the FDTD calculations the incident field $E_i(t)$ and time domain open ended voltage $V_{oc}(t)$ are saved for each time step. The FDTD calculations are continued until all transients are dissipated, so that the Fourier transform yields to the steady-state frequency domain response of the antenna. This method takes into account all mutual coupling effects.

3 Numerical Results and Discussions

The geometry of the monopole antenna system is shown in Fig. 7 of [3] . The length of monopole antennas is 15.6 mm and it is placed in a 4.0 square-meters perfectly conducting square ground plane. The monopole antenna is connected to a 56-ohm chip-resistor in parallel in order to suppress reflection in the low frequency range [3]. And so, 50 Ω load resistance of Eqn. (1) is replaced by 26.42 Ω load resistance.

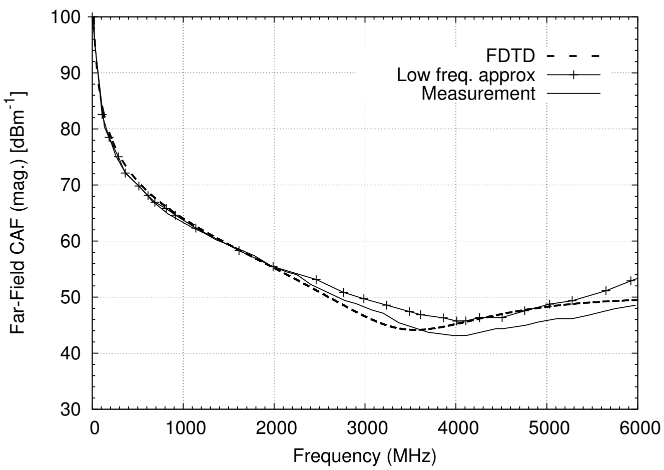

Figure 1: Comparison of the amplitude of the far field CAF of the monopole antenna using FDTD with published [3] measurement and low frequency approximation results.

Magnitude of the FDTD computed far-field CAF is compared with the measured and low frequency approximation result [3] shown in the Fig. 1. Considering the differences between how the feed regions are modeled the agreement is quite good. R.m.s. deviation between the measurement [3] and the FDTD computed CAF 1.68 dB whereas r.m.s deviation using low frequency approximation of monopole antenna calculating from the Fig. 10. of [3] is 2.64 dB over the frequency rang from 2 GHz to 6 GHz. Below 2.0 GHz the error is not significant. The phase of the far-field CAF is compared with the measured and low frequency approximation of monopole antenna result [3] shown in the Fig. 2. FDTD predicted phase of the far-field CAF is much closer to the experimental result [3] than the phase of the far-field CAF derived from the low frequency approximation of the monopole antenna [3].

4 Conclusions

To conclude it is said that FDTD predicts CAF very easily and accurately. For far-field CAF the programme needs to be run twice for a particular antenna structure, first for input impedance and second for open-circuit voltage.

Being time-domain technique, FDTD directly calculates the impulse response of an

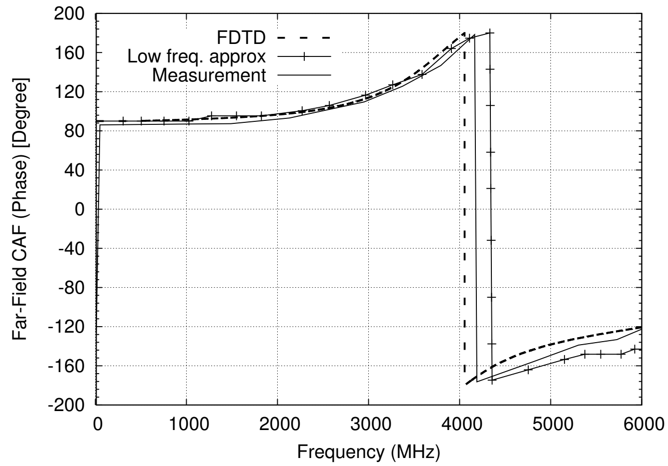

Figure 2: Comparison of the phase of the far field CAF of the monopole antenna using FDTD with published [3] measurement and low frequency approximation results.

electromagnetic system. Therefore, a single FDTD simulation can provide either ultra wide band temporal waveforms or the sinusoidal steady state response at any frequency within the excitation spectrum. In case of FDTD, specifying a new structure to be modelled is reduced to a problem of mesh generation rather than the potentially complex reformulation of an integral equation. For example, FDTD requires no calculation of structure-dependent Green functions. This technique can easily be extended to determine the antenna factor of any other types of antennas.

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