ABSTRACT
A few widely used incident wave models for antenna analysis are compared on the basis of antenna factor (AF) computations. The finite-difference time-domain (FDTD) technique is applied to compute the complex AF of monopole antenna placed on conduction ground plane in the receiving mode. The computed AFs are compared with published measured results.

Keywords
antenna factor, FDTD, gain, monopole antenna, ground plane

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.

Finite difference time domain (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 [3]. 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 FDTD technique is used to evaluate the CAF of the EMI sensor. For the validation of the theory, CAF of a monopole antenna on a conducting ground plane is evaluated using FDTD technique and computed magnitude and phase of the CAF are compared with the measured and low-frequency approximation result of [4].

2. FDTD FORMULATION OF THE PROBLEM
For FDTD computations a uniform space lattice cubic Yee cells having Δx = Δy = Δz(=Δ) is considered. 10Δ–thick unsplit Perfectly Matched Layer (PML) [5], [6] is used as absorbing boundary conditions (ABC) on all six sides of the FDTD lattice. This PML is spaced 3Δ cells from the closest surface of the scatterer. Gaussian pulse [5] is taken as the excitation source.

3. CALCULATION
For a receiving antenna, the open-circuit voltage due to the incident field $E_i$ at the gap between the monopole and the conducting ground plane is

$$|V_{oc}|^2 = -\Delta \Delta E_i |V|_{pc}$$

and let, $V_{oc} (\omega)$ is the Fourier transform of $V_{oc}$. The voltage into a section of transmission line matched $(Z_0 = 50 \Omega)$ at the far end is [7]

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

Where, $Z (\omega)$ is the input impedance of the antenna.

3.1 Complex Antenna Factor (CAF)
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 [8], [9]

$$CAF = 20 \log \left( \frac{E_i(\omega)}{V_{50}(\omega)} \right) \ [dB\ (m^{-1})]$$
where, $E_i(\omega)$ is the electric field incident on the antenna, and $V_{50}(\omega)$, is the voltage induced across a 50 $\Omega$ load at the feed point of the antenna.

### 3.2 Calculation of CAF

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.1. Details of the method are given in [5].

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. Fourier transform of this time domain open ended voltage $V_{oc}(t)$ gives frequency domain open ended voltage $V_{oc}(\omega)$ at the feed point of the antenna system. Voltage developed across 50 $\Omega$ load is $V_{50}(\omega)$ which is obtained from the Eqn. (2). Finally, Complex Antenna Factor of the antenna is evaluated using Eqn. (3). This method takes into account all mutual coupling effects [10].

#### 3.3 CAF of Monopole Antenna

The geometry of the monopole antenna system of [4] is shown in Fig. 2. 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 [4]. And so, 50 $\Omega$ load resistance of Eqn. (2) is replaced by 26.42 $\Omega$ load resistances.

The FDTD model uses a uniform space lattice cubic Yee cells having $\Delta x=\Delta y=\Delta z=0.25$ cm and $\Delta t=4.17$ pico sec. Gaussian impulse of maximum unit amplitude with $t_0=83.33$ pico sec and $t_\omega=12.5$ pico sec is taken as the source [5].

Magnitude of the FDTD computed far-field CAF is compared with the measured and low frequency approximation result [4] shown in the Fig. 3. Considering the differences between how the feed regions are modeled the agreement is quite good. R.m.s. deviation between the measurement [4] and the FDTD computed CAF is 2.64 dB whereas r.m.s deviation using low frequency approximation of monopole antenna calculating from the Fig. 10. of [4] is 2.64 dB over the frequency range 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 [4] shown in the Fig. 4. FDTD predicted phase of the far-field CAF is much closer to the experimental result [4] than the phase of the far-field CAF derived from the low frequency approximation of the monopole antenna [4].

#### 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 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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6. REFERENCES


