# Modeling MC Effects between Antenna Array-Elements in a Microcellular Environment Using FMM

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**Abstract:** The method of moments (MoM) is often employed for analyzing the induced current on an object in terms of a given basis functions and enforces Maxwell's boundary conditions at a finite number of points on the object being modeled. However, one major problem with MoM is the generation of dense matrix and for certain problems, the dimensions of this matrix can be prohibitively large. This can be time-consuming and computationally expensive. We, therefore, propose the fast multipole method (FMM) to accelerate the modeling of the effects of local scattering close to the base station, as well as electromagnetic interactions between the base station array elements. Results [1] unfold its efficiency over alternative approaches vis-à-vis high current-carrying volume elements or number of observation points.

**Keywords:** adaptive antennas, FMM, mobile environment, mutual coupling

## 1. Introduction

The use of high-level simulation tools has been studied to consider the effect of introducing smart antenna arrays into existing cellular networks. The increasing demand for broadband wireless services has been identified to require the use of smart antenna technology in the next-generation cellular systems. Smart antenna technology makes use of adaptive antenna-arrays to improve system capacity and quality. This array of antennas encounters vector channel [2] at the base station. Mutual coupling effects have an appreciable effect on smart antenna-system performance. They are especially important in smart antenna arrays because the elements are spaced relatively closely to one another (within $\lambda/2$). The configuration [2] of antenna elements for the multicellular environment simulation is: a seven-element uniform circular array of radius 9 cm; antenna elements are each coaxial dipole elements containing four collinear $\lambda/2$ dipole elements with an operating frequency of 1.8GHz; lump loading (1KΩ) is used to model the isolation between the dipole antennas and the load impedance (73) of the dipoles. In a microcell in which antenna arrays are introduced but no smart antenna algorithms are implemented, the threshold power must be chosen to allow for minimum SNR and SIR requirements [2]. The simplest solution would be to have each element uniformly excited to create an omnidirectional radiation pattern and this calls for a more-sophisticated array characterization. Past studies have used MoM to characterize effects of mutual coupling and effects of local scattering from a cellular tower [2].

In the MoM solutions [3] [2] to boundary integral equations, one is faced with solving large systems of equations of the form

$$\boldsymbol{ZI}=\boldsymbol{V}, \tag{1}$$

where $\boldsymbol{Z}$ is a dense matrix and $\boldsymbol{I}$ and $\boldsymbol{V}$ are column vectors of length $N$, where $N$ is the number of current expansion functions. Equation (1) can be solved by a number of iterative schemes. These techniques involve the computation of the product of $\boldsymbol{Z}$ and a solution vector one or more times for each iteration.

It has been already confirmed that the fast multipole method (FMM) allows for efficient modeling of field problems with a high number of observation points [1]. The FMM calculations model the mutual coupling between the collinear dipoles within an array element and the greater coupling with the dipoles in other array elements.

The focus of this paper is to consider a computational electromagnetic (CEM) approach that is time-saving with attendant accurate predictions for modeling the mutual coupling between antenna-array elements in a microcellular environment.

## 2. Fast Multipole Method

In the FMM algorithm, magnetic field computation is split into a near-field part $\{\boldsymbol{H}_{near}\}$ [1] due to observation points that are close to array elements and a far-field part $\{\boldsymbol{H}_{far}\}$ for the remaining elements, [1]

$$\{\boldsymbol{H}\} = \{\boldsymbol{H}_{near}\} + \{\boldsymbol{H}_{far}\}. \tag{2}$$

The division of element interactions into a near-field and a far-field is carried out by means of a hierarchical grouping scheme [1]. Here one groups the N basis functions into M groups so that the basis functions in each group have neighboring support [3]. The near-field part has to be computed directly using Biot-Savart law, [1]

$$\boldsymbol{H}(\boldsymbol{r}) = \frac{1}{4\pi} \int_V \boldsymbol{J}\,(\boldsymbol{r}')\, x \nabla' G\,(\boldsymbol{r}, \boldsymbol{r}')\, d\boldsymbol{V}, \tag{3}$$

where $\nabla' G$ is the gradient of Green's function of free space,

$$\nabla' G\,(\boldsymbol{r}, \boldsymbol{r}') = \frac{r - r'}{|r - r'|^3}. \tag{4}$$

Array elements with large distances from the considered observation point are considered group-wise in $\{\boldsymbol{H}_{\mathrm{far}}\}$, where the size of the group depends on the distance. The coefficients of the truncated series expansion approximation of the field source yields the multipole coefficients, $M_n^m$, [1]

$$M_n^m, = \int_A \sigma\,(\boldsymbol{r}') r'^n Y_n^{-m}\,(\theta', \psi')\, dA', \tag{5}$$

where $Y_n^{-m}$ is the spherical harmonics representation of the source.

The far-field components [1] can be computed using

$$H_{far}(r) = \frac{1}{4\pi} \sum_{n=0}^{\infty} \sum_{m=-n}^{n} L_n^m r^n Y_n^m(\theta, \psi). \quad (6)$$

This approach allows a standard FMM implementation to be used when each component of equation (5) is treated as a scalar potential. While $\mathbf{H}_{far}$ is obtained via a threefold execution process, $\mathbf{H}_{near}$ needs to be computed only once and can be easily done during one of the steps to compute a far-field component [1].

## 3. Results

The efficiency of the proposed FMM technique has been compared with direct evaluation by equation (3). The field response caused by two coils with impressed current densities was computed at the nodes of a surface enclosing one of them. The number of observation points as well as the number of coil elements was varied. The order of the series expansion was chosen to L=9 and second order hexahedrons were used as coil elements. [1] The numerical results for a 4000 coil elements mesh are plotted in Figure 1.0. The results depict a large reduction of computation time if the number of observation points exceeds about $10^4$. 200 Mbytes to 1.4 GBytes of memory space are required for the proposed FMM application. [1]

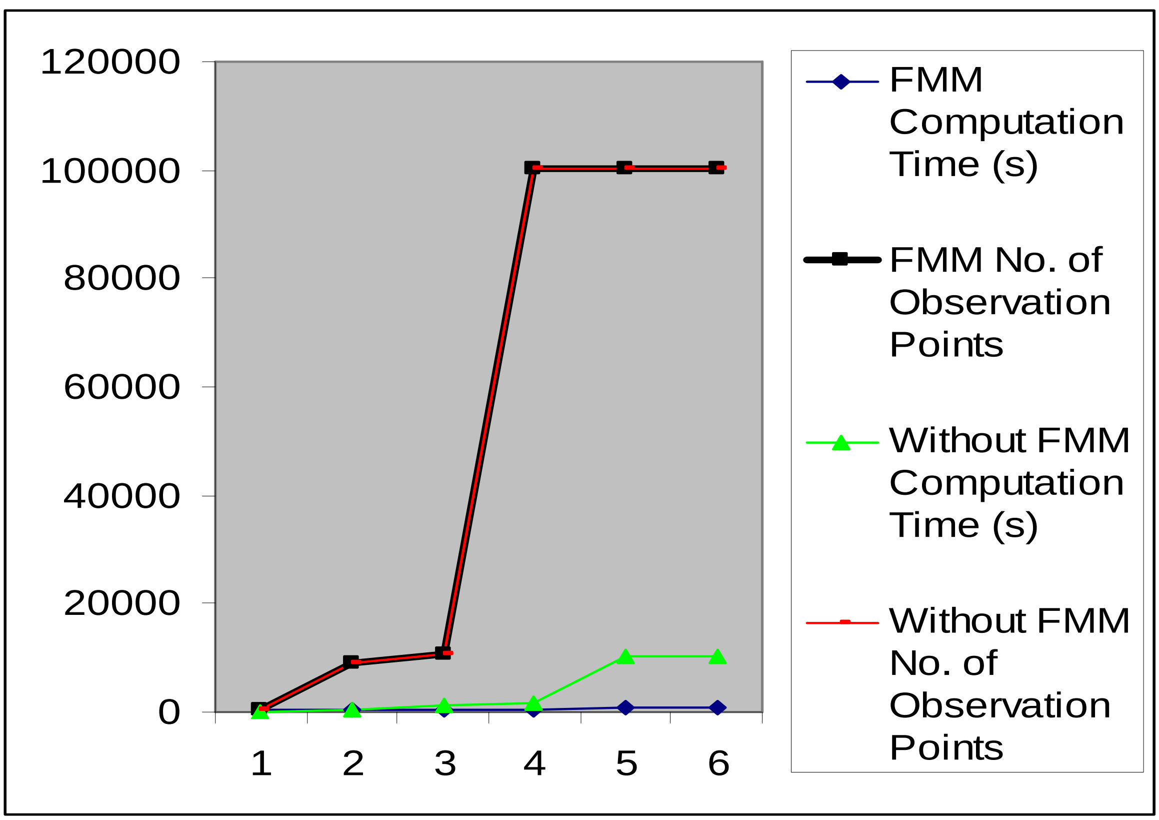


**Figure 1.** FMM Modeling Results

## 4. Conclusion

In this paper, an approach for modeling electromagnetic interactions between array elements and close local scattering in a multicellular environment is presented. The FMM dramatically reduces the time and memory [1] required to compute radar cross-sections and antenna patterns compared to dense matrix techniques. It is fairly simple to implement the FMM in a method of moments program [3] to compute the electromagnetic scattering from array elements. Thus, the FMM extends the integral equation methods to scatterers of larger dimension.

Furthermore, the far-field propagation effects can be efficiently modeled using the electromagnetic ray-tracing technique (ERT). [2] Thus, a hybrid FMM-ERT technique would result in a great conservation of computational resources with attendant time-saving and accurate RCS predictions when deployed to characterize smart antenna arrays in broadband wireless networks.

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