

Optimisation of ray-tracing algorithms for EMF safety

assessment of base station installations



Francois du Plessis, Max Birch, Marnus van Wyk & Frans Meyer
EMSS Consulting (Pty) Ltd, Stellenbosch, South Africa, 7600

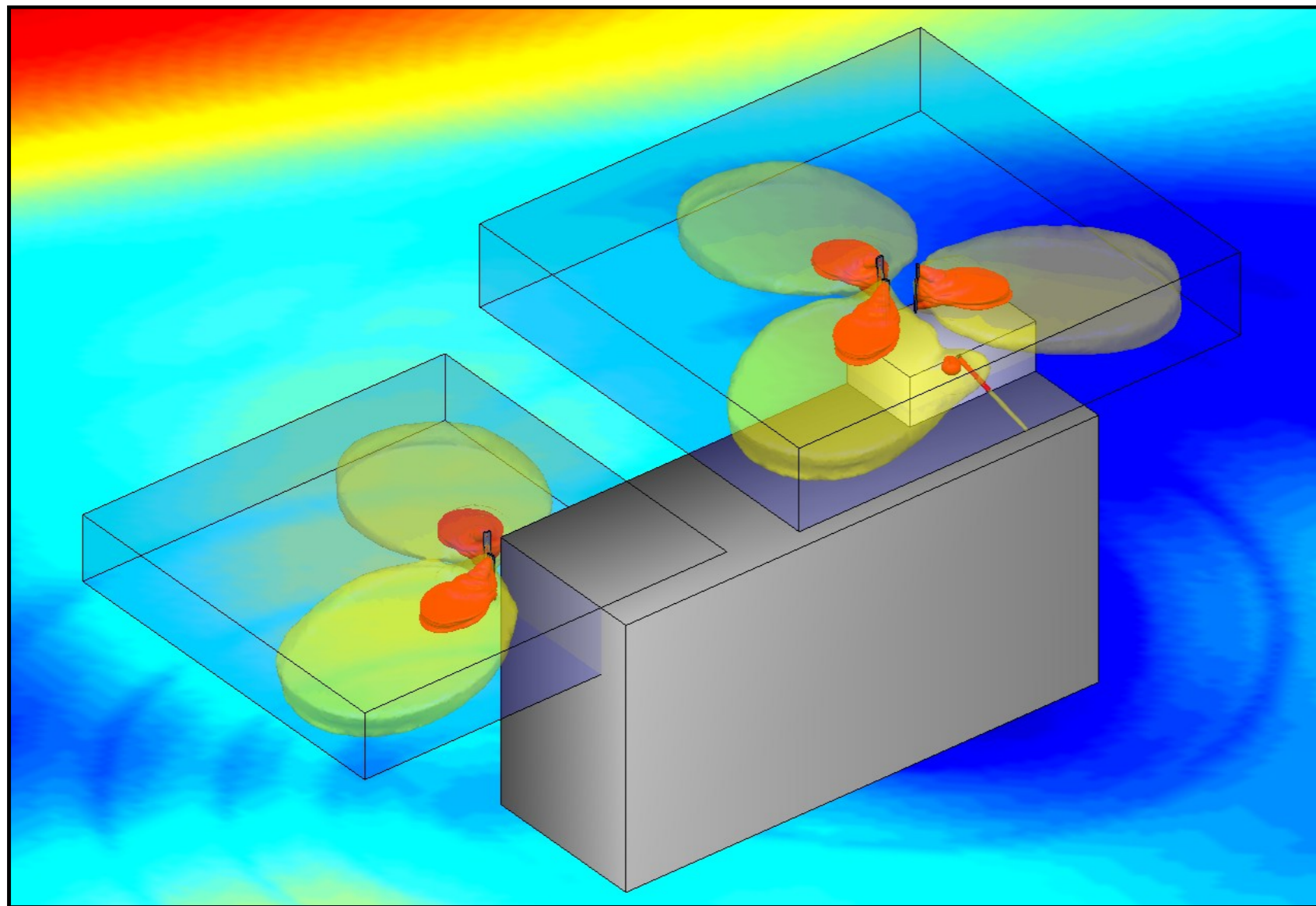


Figure 1. A typical base station illustrating exclusion zone isosurfaces and associated near-field blocks, with a planar E-field orthoslice.

Introduction

The EU Directive on physical agents, 2004/40/EC [1], makes it mandatory for employers to ensure that employees are not exposed to radiation levels exceeding the ICNIRP [2] reference level guidelines. Using the synthetic ray-tracing technique according to CENELEC EN 50383 [3] and IEC 62232 [4], panel and omnidirectional antennas are easily modelled as linear arrays of point sources. This makes it practical to simulate electrically large problems on standard workstations.

Objectives

The optimisation of our calculation methods in IXUS [5] can be broken down into two categories: The efficient selection of the required field calculation points used for drawing exclusion zone isosurface regions, and improving the calculation speed for the selected field points. The aim of this study was to improve performance in both categories. Benchmarks were performed on a typical base station shown in Figure 1 on the left, as well as on a 50 antenna site.

Methods

For the efficient selection of field points, a higher density of field points is required in areas where the isosurface changes more rapidly. The efficient identification of these areas is done iteratively because the local point density and the shapes of the isosurfaces influence each other. The isosurface is therefore continuously extracted, while increasing the density of field points where necessary.

A marching tetrahedron method [6] was chosen for non-regular grid isosurface extraction. The process for extracting the exclusion zone isosurfaces is started by creating an initial unrefined tetrahedral mesh for each antenna. A mesh is grown from an initial tetrahedron at each antenna origin by adding more tetrahedra to its sides. The process is repeated if the field values on the tetrahedron edges are close to or greater than the isosurface threshold. Mesh structures are merged where antennas are close to each other.

Adaptive mesh refinement is performed after extracting the initial tetrahedral mesh. The refinement criterion is based on how well the extracted isosurface visually represents the actual isosurface. This adaptive mesh refinement process continues iteratively until the refinement criterion is met for all isofaces. The process is extremely efficient, as only the tetrahedra close to antennas, or those cut by the isosurface are considered to be refined. A small section of the refined tetrahedral mesh is shown in Figure 2 on the right, between a Yagi-Uda and dish antenna. A higher density mesh can be seen in the region where the isosurface changes more rapidly.

With the efficient selection of field points, the next step in the optimisation process is to increase the calculation speed.

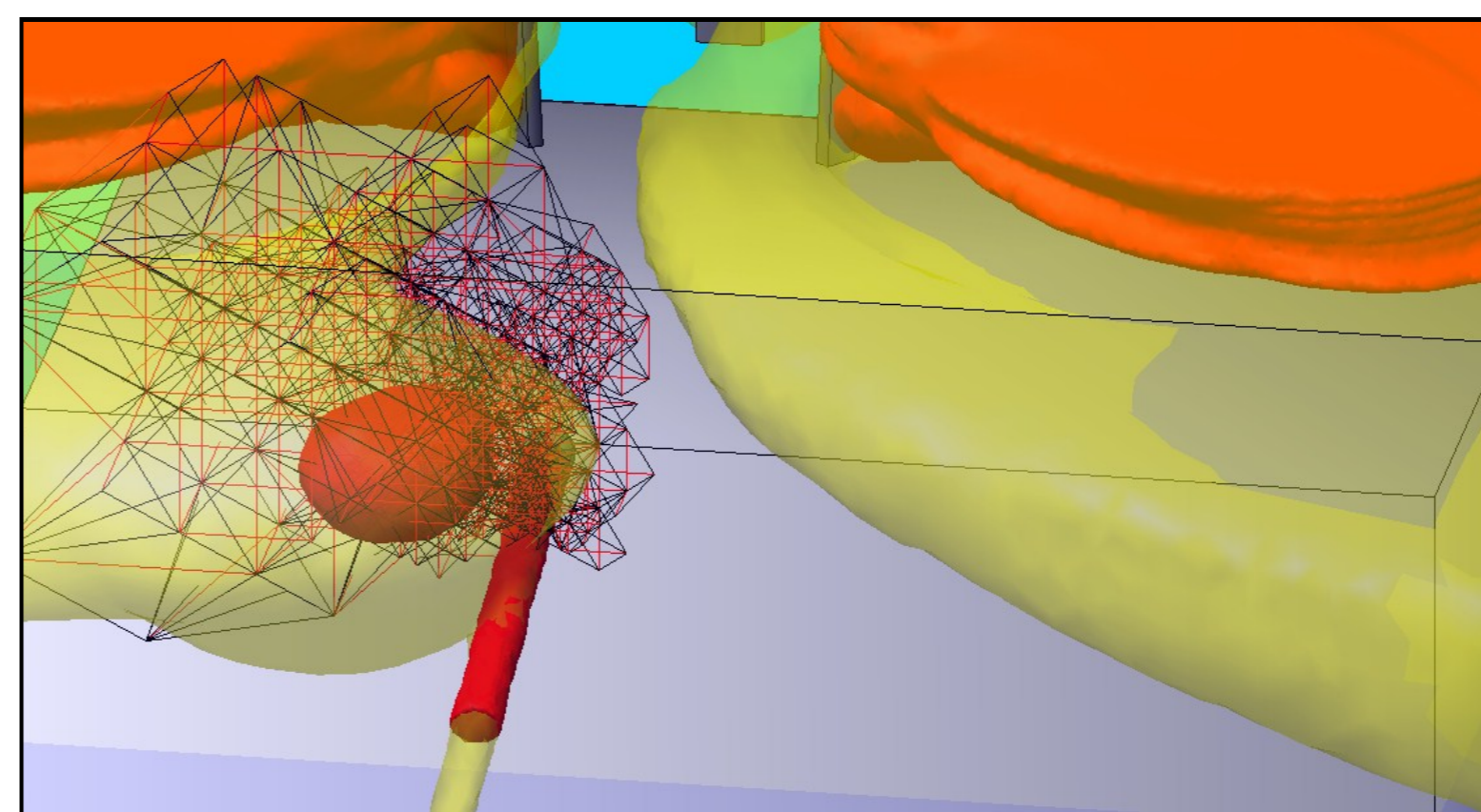



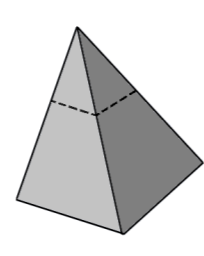
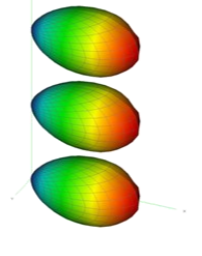
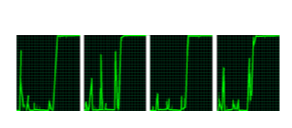
Figure 2. A small section of the refined tetrahedral mesh in the region between a Yagi-Uda and dish antenna.

The first method for optimising the calculation speed allows the use of a single ray-tracing point source for linear array calculations in the approximate far-field. When the calculation point is in the approximate far-field of the antenna, the complex calculation can be done using a single far-field point source. Typical panel or omnidirectional mobile base station antennas have 10 array elements, which can be replaced by a single element when calculating outside a roughly 40m radius at 900 MHz, and 20m radius at 1800 and 2100 MHz.

The second method for optimising the calculation speed is the parallelisation of simulation algorithms, so that multithreaded computation can be done. Four parts of the simulation process were identified to be both significant in calculation time and easily parallelisable. Significant speed improvements were obtained with a multithread implementation.

Results and Conclusions

Table 1. Simulation speed improvement.

	 Total calculation time improvement	 Speedup factor for tetrahedral mesh	 Speedup factor for far-field point source	 Speedup factor for multithreading (4 cores)
7 Antenna site	3 hours down to 83 seconds	34x	1.5x	2.5x
50 Antenna site	4.8 hours down to 4.9 minutes	2.5x	6.5x	3.6x

The optimisation speed improvements were investigated for two scenarios. The first scenario is a typical base station with five panel antennas, one Yagi and one dish shown in Figures 1 and 2. The tri-band panel antennas transmit in the GSM900, DCS1800 and UMTS bands, and have electrical tilt ranges from 0 to 6 degrees. The Yagi-Uda antenna is placed close to the dish, so that different calculation point densities are required in a relatively small volume. The total exclusion zone calculation time was reduced from 3 hours to only 83 seconds.

The second scenario represents a very large site with fifty tri-band panel antennas without electrical tilt sweep. The exclusion zones for the fifty antennas do not overlap, but the field contribution of each antenna is considered for every calculation point. The total exclusion zone calculation time was reduced from 4.8 hours to only 4.9 minutes. The simulations were performed on a personal computer with an Intel® Core™ 2 Quad CPU at 2.4 GHz, with 4 GB RAM, running Windows 7 Enterprise 32 bit.

References:

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