Modelling Radio-Wave Propagation in Buildings

Solving 19th Century Physics with 21st Century Computers

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"The Most Outstanding Achievement of 19th-Century Science"

Radio-wave propagation is governed by Maxwell's equations (formulated by James Clerk Maxwell in 1861). These equations describe in abstract form the relationships between electric and magnetic fields and "represent the most outstanding achievement of 19th-century science" (as stated by Nobel Laureate Richard Feynman). However, analytical solutions to Maxwell's equations are difficult, if not impossible, to obtain for anything other than simple cases, due to boundary condition complexity. Solutions to this dilemma lie in the field of Computational Electromagnetics, which combines electrical engineering, computer science and physics, to provide numerical solutions to Maxwell's equations.

Contributions of this Research

This research focuses on applying computational electromagnetic techniques to the problem of radio wave propagation within buildings, with the aim of improving the performance and reliability of current and emerging wireless systems. Until very recently, applications of computational electromagnetic techniques, such as the Finite-Difference Time-Domain (FDTD) method, to this problem have largely focused on 2D representations of buildings due to high computational requirements. However, access to parallel and cluster computing resources, such as BeSTGRID, have allowed us to investigate propagation within buildings using the 3D FDTD method.

Solving 19th Century Physics with 21st Century Computer Clusters

1. Create a 3D CAD model of a building (including internal details)

The UoA Engineering Tower is regarded as the most electromagnetically characterized building in the Southern Hemisphere (if not the world).

2. Apply the CAD model to our Parallel-FDTD algorithm running on the BeSTGRID computer cluster
3. Visualize the results

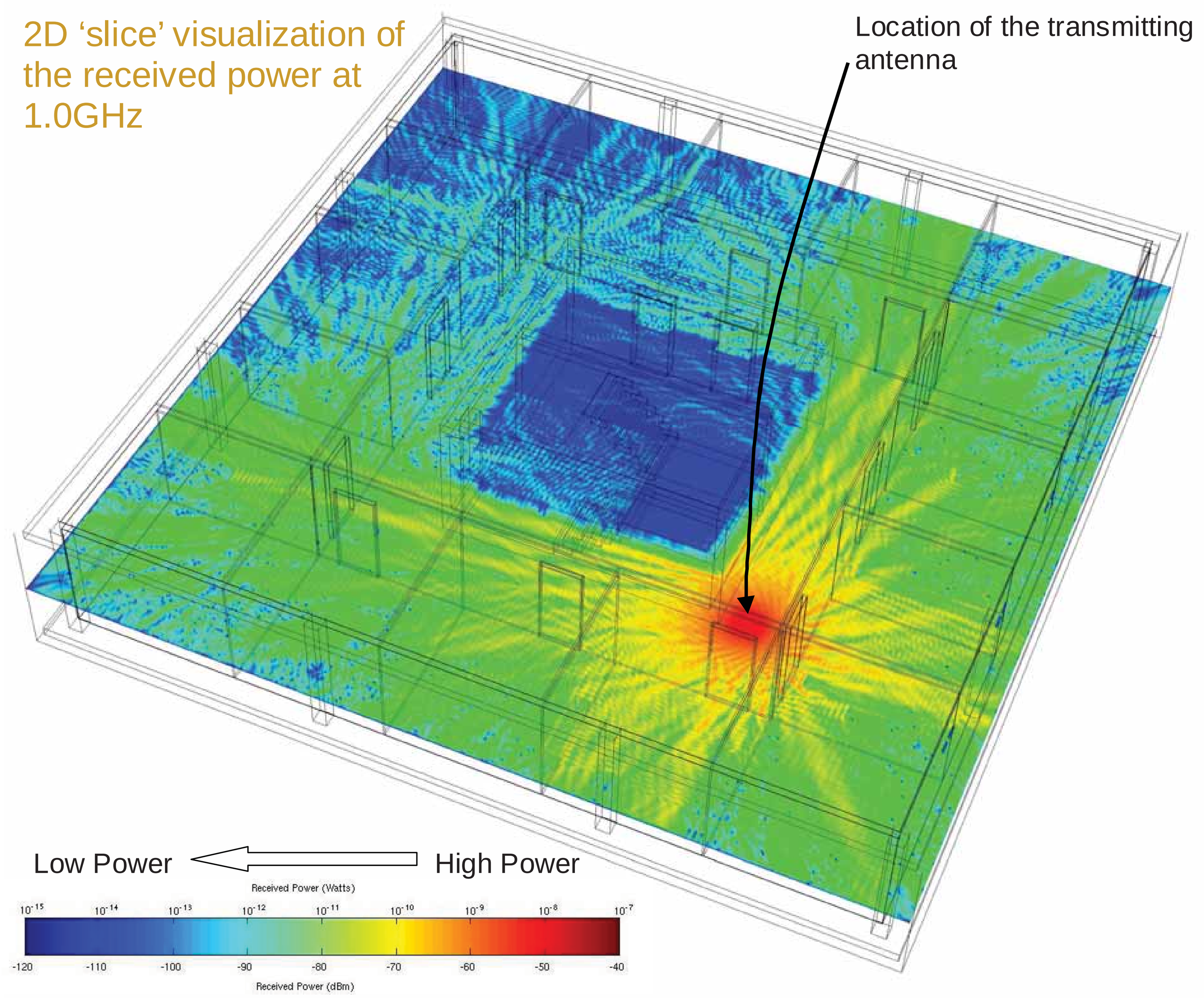
The BeSTGRID computer cluster at The University of Auckland is a parallel machine with > 100 processors and > 500 GB of memory. This setup makes it ideal to run our parallel FDTD code; without BeSTGRID this research would not be possible:

FDTD COMPUTATIONAL REQUIREMENTS

	Computation Time	Number of Processors	Processor Time	Memory
1 Floor	96 hours	57	228 days	100 GB
2 Floors	168 hours	76	1.5 years	160 GB
3 Floors	250 hours	100 (max)	2.9 years	260 GB
Whole Building	700 hours (est)	100 (max)	8 years (est)	650 GB (est)

Results

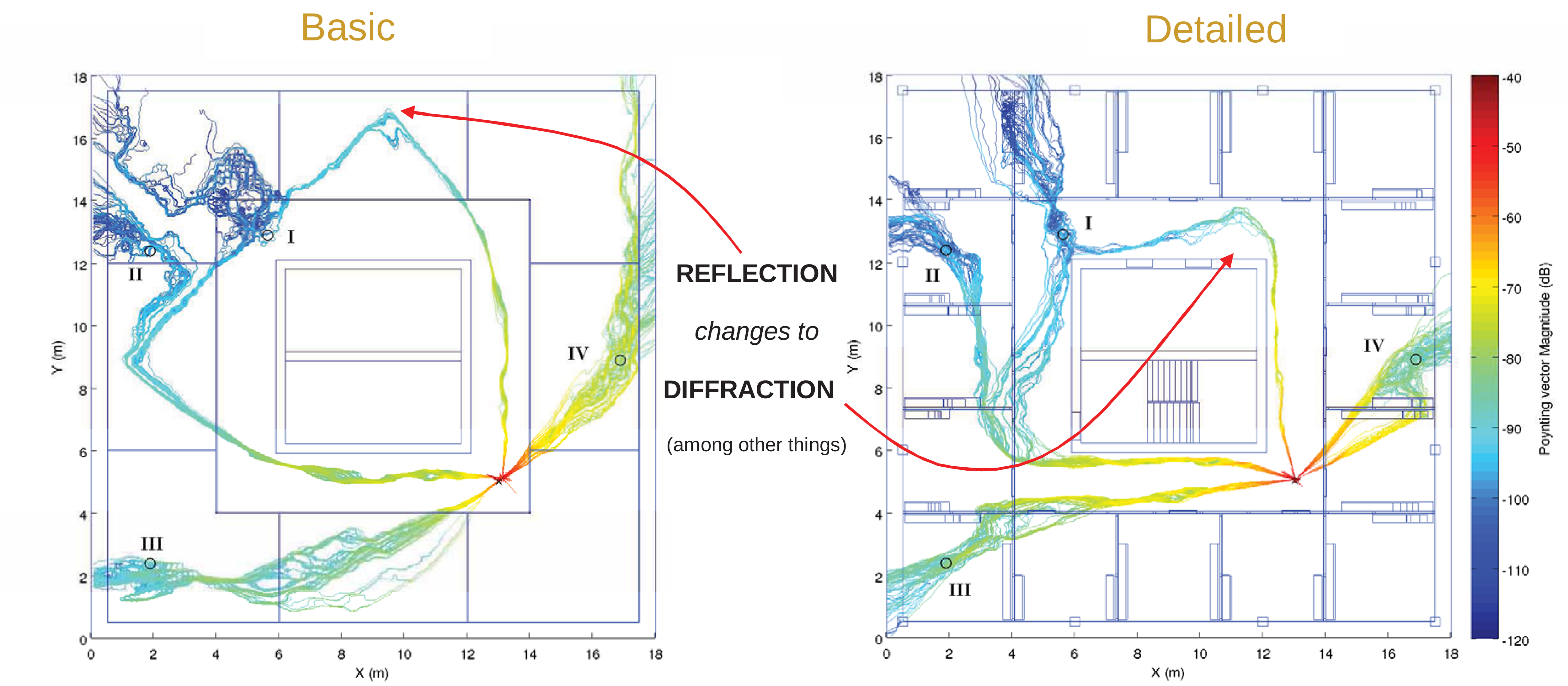
A new method to visualize the flow of electromagnetic energy (the Poynting Vector) has been developed. This approach uses techniques developed for fluid dynamics to project streamlines through the Poynting vector, which is calculated from the FDTD simulations. The streamline plots are presented along with conventional visualization techniques.



"The Devil is in the Details"

The streamline visualizations show that the paths taken by the power can differ significantly depending on the level of environmental details considered. Including details, such as bookshelves, office furniture, the internal details in the walls, stairs, doors and other clutter alters the dominant propagation path from reflection at the windows to diffraction at the corner of the shaft. Directly comparing sector-averaged path loss from the FDTD simulations with experimental measurements shows an RMS error of 11.7 dB when clutter is ignored. However, this is reduced to 7.6 dB when the clutter is included, suggesting that the effects of clutter should not be ignored when modelling propagation within buildings.

Streamline Visualization



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