Efficient Physics-Based, High Bandwidth Electromagnetic modeling of Building and Multi-Wall Structures[1]

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There has been much recent interest in using radar signals to image targets behind walls, and, more generally, to infer building structure using only exterior transmitters and receivers. Successful solution of these types of inverse problems relies on a numerically efficient, high-fidelity forward model that accurately predicts the electromagnetic response of a complex target, including strong multipathing effects.

The frequency band of the most desirable signal is limited at the upper end by wall absorption, and at the lower end by the wavelength, which should remain much smaller than the primary scatterers. The latter enables efficient modeling via efficient ray tracing techniques, which are based on the geometrical optics approximation.

Ray propagation through the air is very simple, but occasionally a ray will encounter a sudden (on the scale of its wavelength) life-changing event that geometrical optics fails to capture. Treatment of such events relies on "enhancements," in which a full, microscopic calculation connects the incident ray to the birth of a discrete or continuous set of emerging rays. I will describe some examples important to EM propagation in building interiors, including classic diffraction of various types; transmission through and reflection by stratified, but laterally homogeneous, walls; and transmission, reflection, and Bragg diffraction by stratified walls that include periodic lateral structure such as rebar or cinder blocks. Scattering elements of this type inside walls couple the incident wave to wall waveguide modes. These trap energy within the wall, which leads to strong internal reverberation effects, and slowly decaying later-time arrivals that strongly interfere with signals from elements deeper inside the building.

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