1. Synthetic Aperture Radar (SAR) Imaging of Rough Soil
2. Ground Penetrating Radar (GPR) for Deteriorated Concrete Bridge Decks
3. Large Arrays of Plasmonic Nanoparticles on Ultra-thin Substrates

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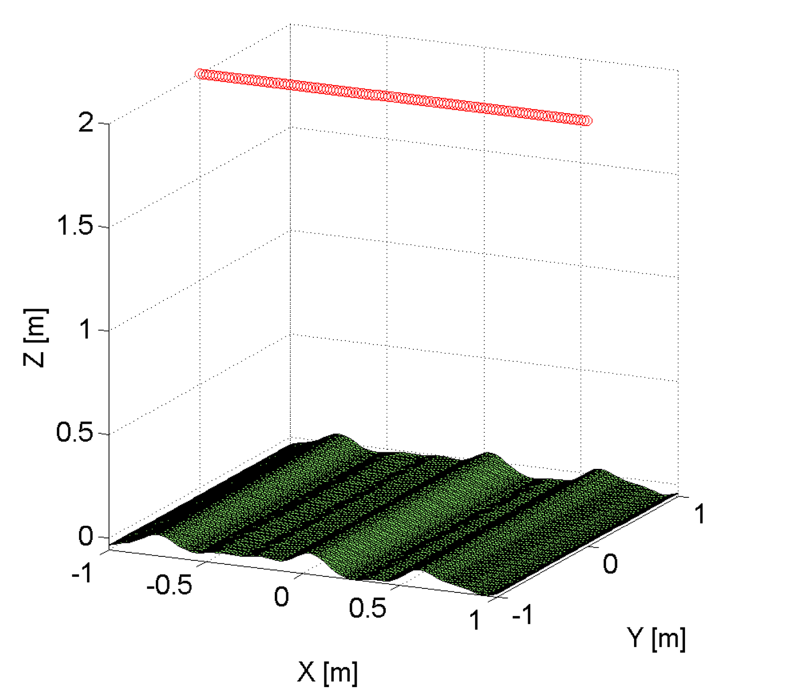
Abstract

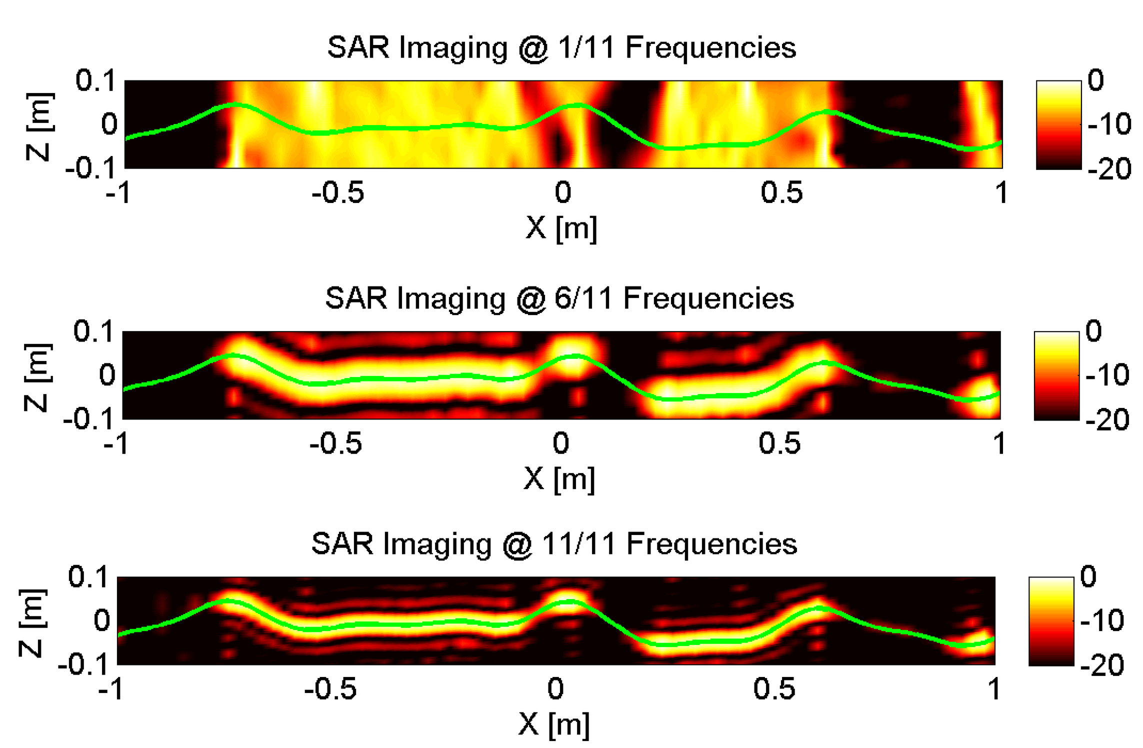
This poster presents three topics of research I have been working on during the PhD program as a) synthetic aperture radar (SAR) imaging of realistic rough soil for localization of subsurface threats, b) ground penetrating radar (GPR) for deteriorated concrete bridge decks with a grid of rebars, and c) large arrays of plasmonic nanoparticles on ultra-thin semiconductor substrates. It introduces briefly the objectives of each of them, their importance and applications, and some of their results. All three works are based on the theoretical modeling of the electromagnetic wave propagation in realistic structures and simulations of the structures with computational efficiency which can be used in multidisciplinary applications.

Synthetic Aperture Radar (SAR) Imaging of Realistic Rough Soil for Localization of Subsurface Threats

The multi-frequency synthetic aperture radar (SAR) method reconstructs the soil surface, by considering the time of flight of rays from the transmitter to the scatterer and from the scattering point to the receiving antenna using a combination of frequencies, and subtracts the phase corresponding to the path between the transmitting and receiving antennas for each frequency.



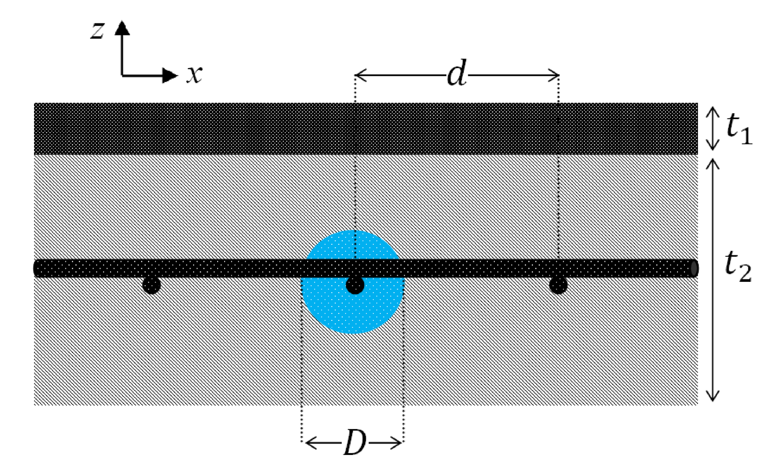
Starting with the lowest frequency, SAR gradually narrows the range of possible surfaces. After SAR imaging, the surface can be reconstructed through the interpolation of the illuminated points. If the scattering effect of the soil surface can be simulated efficiently and subtracted then from the measured data, it leads to the localization of subsurface threats such as anti-personnel mines under the ground surface.



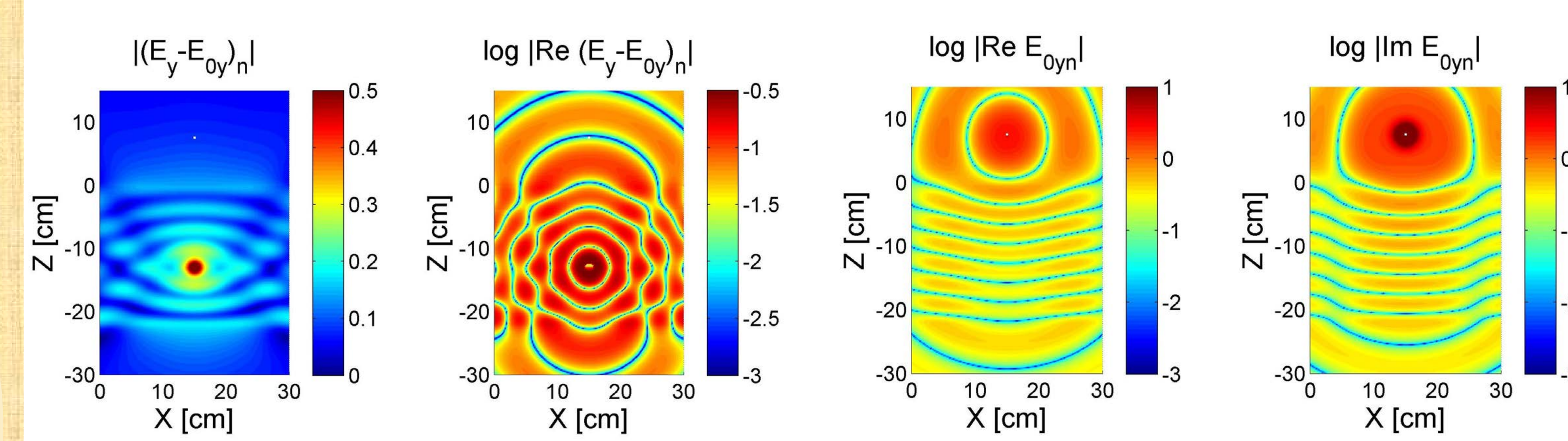
SAR imaging of the rough soil above through an array of monostatic antennas located 2 m over the surface at y=0 from 8 GHz to 12 GHz; The result is shown in an accumulative way for first, sixth, and last frequencies out of 11 imaging frequencies.

Ground Penetrating Radar (GPR) for Deteriorated Concrete Bridge Decks with a Grid of Rebars

Ground penetrating radar (GPR) is an efficient tool for fast noninvasive subsurface sensing of reinforced concrete structures. Air-coupled GPR can be vehicle mounted and driven over a bridge deck at highway speeds, avoiding lane closures. Since interpreting the collected GPR data is often challenging, electromagnetic modeling can be used to simulate wave propagation in the subsurface. A full 3D model is generally preferred but at the same time can be very slow and computationally inefficient. We model the deteriorated concrete bridge decks reinforced by grid of rebars via a comprehensive full 3D analytic method that applies for lossy, frequency-dispersive media.

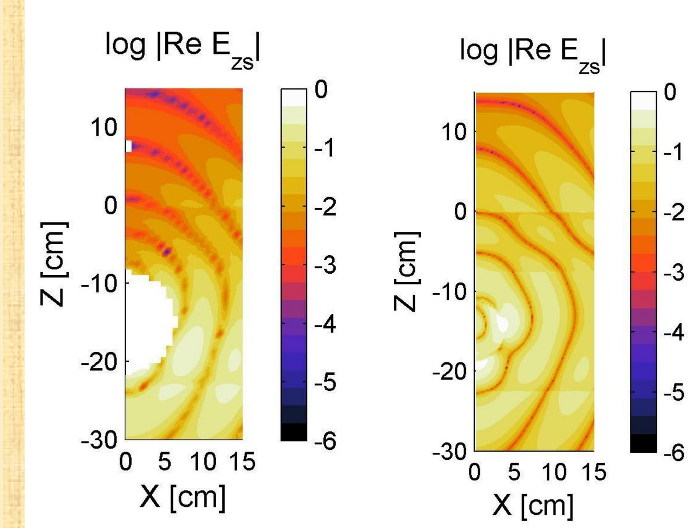


A bridge deck with two layers of 3.8 cm asphalt at the top and 18.4 cm concrete below it reinforced by a grid of #4 rebars (d=15 cm) with a subsurface defect inside (D=7.5 cm). The GPR transmitter is a 2 GHz CW source 7.5 cm above the surface.



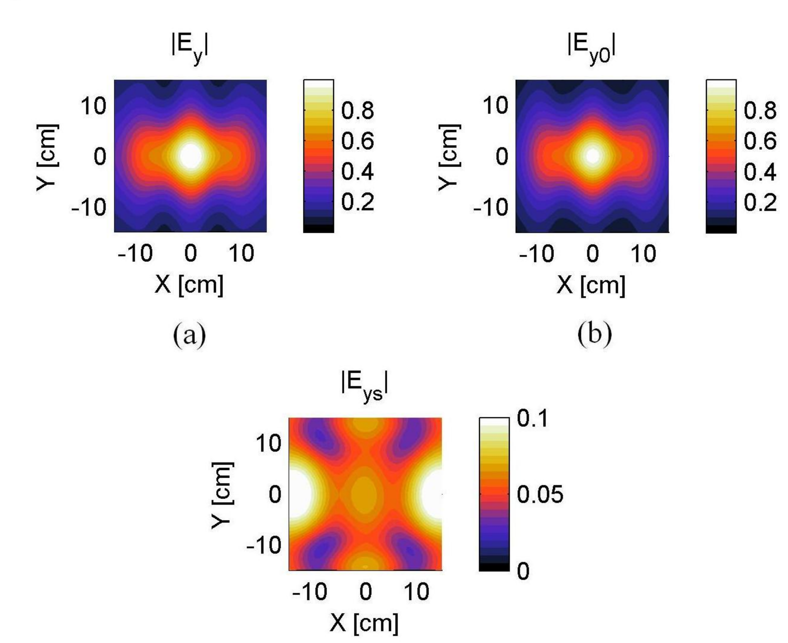
(a) (b)

a) The scattering effect of rebar and b) the wave propagation of GPR through the bridge itself. The surface of the bridge deck is at z=0 cm.



(a) (b)

Scattered electric field from the deteriorated bridge deck by a) analytic method and b) FDFD method.

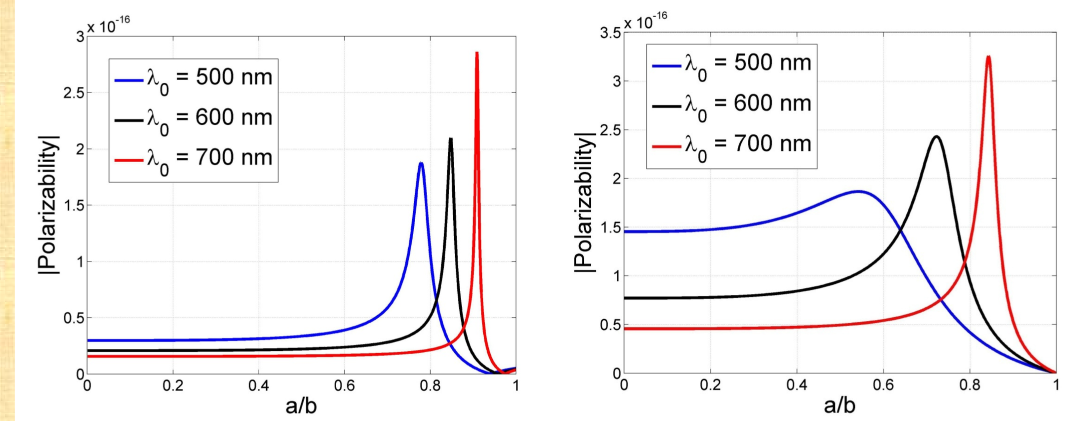


(a) (b) (c)

Analytically simulated electric field on the surface of the concrete bridge deck; a) reinforced bridge deck with embedded sphere, b) reinforced bridge deck alone c) difference due to the hidden defect.

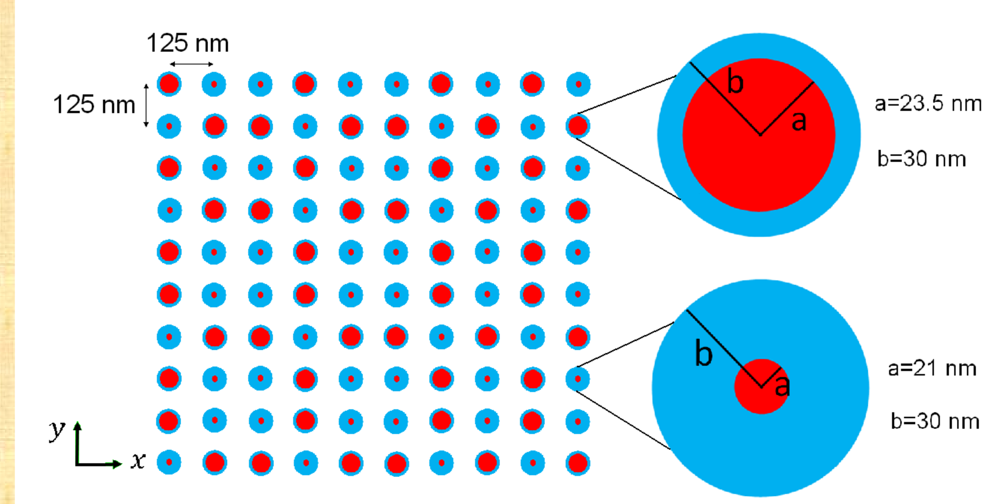
Large Arrays of Plasmonic Nanoparticles on Ultra-Thin Semiconductor Substrates

High efficient solar cells require optically thick photovoltaic layers to enable almost entire absorption. Nevertheless, the thickness of the active region increases the material utilization which can be expensive. The combination of plasmonic nanoparticles with semiconductors has been utilized to increase the absorption leading to the realistic implementation of ultrathin solar cells with economical price. The concentric plasmonic nanoparticles as dielectric cores and noble metal coatings give better control over the resonant frequency by tailoring the ratio of its inner to outer radii.



(a) (b)

The magnitude of polarizability factor when the surrounding medium is a) air and b) silicon. The total radius of the particles is 35 nm.



A Fibonacci array of 100 plasmonic nanoparticles. Fibonacci array is an archetypal paradigm of aperiodic arrangement. The Fibonacci array is long-range correlated and self-similar.

Characterization of these structures is very time-consuming since they are heterogeneous in all directions, the core-shell particles with very thin shells are preferred in practice, and the plasmonic nanoparticles are lossy and frequency-dispersive. Using conventional full-wave methods even for the periodic array is limited by computational volume. We propose the analytic method as a powerful and versatile approach for efficient simulation of these structures. They may be used also for other applications such as quantum dots, nano-antennas, and bio applications.

Conclusions

Three topic of research I have been working on during the PhD program are presented here. The GPR sensing for concrete bridge decks with a grid of rebars and some hidden subsurface defects is based on the Green's function analysis of the structure in combination with method of moments (MoM). The modeling of large arrays of plasmonic nanoparticles on or inside the ultra-thin semiconductor substrates is based on the dipole mode method associated with the Green's function analysis. The reconstruction of the soil surface exploits the SAR imaging in combination of any efficient method for calculation of the scattered electric field from the soil.