Reconfigurable Arrays and Signal Properties for Urban Sensing

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Hybrid techniques of microelectronics, innovative antenna design, noise, and channel mitigation, and radar and sensor signal processing are used to address important issues in the area of urban radar sensor system design. Urban radar systems perform several different functions, which would otherwise have been carried out by different dedicated systems. They have a high degree of intelligence and flexibility, over a wide range of operating frequencies and bandwidth, and are able to quickly adapt to changes in system functional requirements as well as changes in the sensing environment.

The proposal outlines the details of a research effort that will help lead to "Reconfigurable Arrays and Signal Properties for Urban Sensing". The proposed research builds on current technologies of wideband urban radar sensor systems. It cultivates advances in reconfigurable antenna design and electronics, flexibility in waveform generation and alteration, radar image classification, nonlinear motion detection, and target detection to achieve system performance beyond what is presently offered by electronically scanned multi-function sensor systems.

The period of performance is proposed to begin 1 July 2006 and run through 30 June 2007.

The scope of research on low profile array electronics for urban sensing centers on examining the challenges in developing arrays that may be conformally hidden. The electronics will provide rapid reconfigurability of the array elements for different array apertures, frequency and bandwidth parameters, adjustable to the application.

The scope of research on multi-function and reconfigurable low-profile antennas for urban sensing centers on the development of wideband dual-polarized conformal antennas as well as the development of novel electrically small radiating elements with reconfigurable frequency, polarization or pattern. Additionally, it provides the analysis and optimization of conformal/reconfigurable arrays on selected radar platforms, such as trucks, Humvees, or UAVs.

The scope of the signal processing research focuses on high resolution imaging using wideband beamforming combined with optimum waveform design as well as indoor target detection and localization using outdoor placed Doppler radar units. The research on target detection centers around establishing radar clutter and noise models for indoor imaging and sensing applications in urban environments. Preprocessing techniques such as demeaning, coherent subtraction, and polarization differencing will be explored and their respective complexity will be evaluated. Localization of indoor targets exhibiting nonlinear motion will be performed by finding the target range estimate using dual-frequency radars, and examining the accuracy of the range estimate in noise and multipath. Targets with linear, nonlinear, or simple harmonic motions will be used in analyses, simulations, and experiments. The signal processing research on optimum and suboptimum waveform design aims at increasing the signal to interference and noise ratio, specifically for urban environment. The optimum waveforms should put energy into frequency bands which are allowed for radar use and, at the same time, avoid frequency bands which are occupied by intentional interference or/and allocated for commercial uses. We supplement and support our analytical approach by comprehensive experiments on through-the-wall radar sensing and imaging. The experiments in our state of the art radar imaging lab center around data collection from single and multiple target scenes in fully controlled, semi-controlled, and non-controlled indoor environments.

Common types of walls, with various wall thicknesses, dielectric constants, and conductivities, will be considered, such as drywall, plywood, concrete, cinder block. Urban sensing makes heavy use of radar signals. An emerging application of radar is imaging of rooms and building interiors obtained through multiple obstacles such as walls and doors. Such environments are frequently occupied by common household items such as chairs, desks, cabinets etc. Information captured in radar images consists of range and signal return strength. In raw form this image is of little useful value. The objective of the research on radar image classification is to explore strategies that would provide higher semantic interpretation of radar images. This goal can be achieved by using methods previously developed for multispectral image classification for surface mapping and combining it with new methodologies to segment and classify radar returns from typical interior spaces.