Design of a Smart Antenna Test-bed for WiMAX Radio Technologies

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We have explored the feasibility of utilizing adaptive smart antennas in conjunction with a high bandwidth WiMAX radio system to achieve improved performance for mobile nodes and to suppress potential interference from unwanted signals. Although the new WiMAX standard offers the potential for using smart, adaptive antennas, this functionality has not been implemented. Our design will serve as a common platform for testing adaptive array algorithms including direction of arrival (DOA) estimation, beamforming, and adaptive tracking, as well as complete wireless communication with a WiMAX Radio. Heavy emphasis will be placed on ease of implementation in a multi-channel / multi-user environment.

This paper presents our design and development of an 8-channel adaptive smart antenna test bed for WiMAX Radio systems. Each of the 8 receiving channels obtain a signal from an 8-element antenna array and will pass through a band pass filter, a low-noise amplifier then an image rejection mixer to obtain baseband signals. The mixers use a common local oscillator to make sure all 8 channels are synchronized. The baseband signal is amplified using automatic gain control and then digitized using analog to digital converters with 3Mbps sampling rates per channel. A single clock has been used to synchronize all channels. All digital signals are sent through a DAQ card (NI6133) to a PC for DOA estimation and beamforming.

We have developed a LabVIEW interface for a PC controlled smart antenna test-bed supporting two mobile targets. The main system has three components, DOA estimation and signal validation, beamforming (null steering or multi-beam), and target tracking. The DOA/validation component uses a MATLAB script to implement the Multiple Signal Classification (MUSIC) algorithm to estimate the DOA for both incoming sources. Once the arrival angles are known, another MATLAB script calculates correlation coefficients between the incoming signals and a known reference signal. The value of the correlation indicates whether a specific source is a desired user or an interferer. Based upon the validation of the incoming signals, this component decides whether to trigger null steering or multi-beam beamforming. The beamforming section is responsible for calculating the coefficients needed for beamforming. It has two modes of operation. Null steering mode is invoked when the DOA/validation section determines that there is one desired user and one interferer. Multi-beam mode is invoked if the DOA/validation section finds one or two desired users and no interferers.

Null steering utilizes a matrix subspace signal processing method implemented in Matlab to create a deep null in the direction of the interference while maintaining the maximum possible signal strength in the desired user's direction. The multi-beam system uses a time scheduling scheme where a time window is defined such that each user is allocated a certain percentage of the window (duty cycle). For example the window might be 150 milliseconds and one user would have a duty cycle of 40% (60 ms) while the other user is allowed the remaining 60% (90 ms). Time scheduling makes the system flexible to the possibility of only having one desired user with no interference as the single source can be given a 100% duty cycle. While the null steering mode calculates the coefficients directly, the multi-beam mode uses a MATLAB script for window beamforming. The user is allowed to define the type of window they want to use. The tracking component operates on the assumption that in the time it takes the program to complete one cycle, a target will not move more than 5 degrees off of its previous position. This means that MUSIC can be run on a smaller a 10 degree area rather than the whole 360 degree space, which reduces the required processing time. This section implements a fail-safe measure in that if the target is no longer present or actually does move outside of the ±5 degree range, the full DOA is triggered.

In the future, we hope to expand this interface to support dynamic radio channel selection via direct interaction with radio hardware or implementation of a cognitive radio system. It will also have advanced DOA schemes which will implement triangulation to provide location, velocity and acceleration information as well as angle of arrival. In addition, nodes could be able to send and receive reconfiguration instructions which would facilitate the self-repairing reconfigurable ad-hoc network scenario.