The Atmospheric Imaging Radar – Ubiquitous Radar

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Adaptive beamforming methods alter the weighting vector based on received data to minimize the impact of interfering signals in the sidelobes. One such method is Capon’s method, which seeks to minimize the output power while maintaining unity gain in the desired direction. The equation for Capon beam is given by:

\[ w_{CB}(\theta) = M \frac{R_n^{\dagger} w_{FB}(\theta)}{E\{w_{FB}(\theta) R_n^{\dagger} w_{FB}(\theta)\}} \]

where \(R_n = \mathbf{E}(x(t)x^*(t))\) is the spatial autocovariance matrix at lag \(0\). Capon’s method can usually provide higher angular resolution than Fourier method, but its performance suffers from uncertain knowledge of element positions in the array. Such errors could result in the signal of interest being attenuated by Capon’s method because it is offset from the angle where the beam is constrained to have unity gain. As a result, a more robust version of Capon’s method was developed to handle uncertainties in element positions. The figure below demonstrates the capability of robust Capon method to adaptively reject interference signals.

Digital Beamforming

By coherently combining the output of the 36 independent receive subarrays, the AIR can accurately estimate the amplitude and phase of a signal for a particular direction. The equation that describes the beamforming process is:

\[ y(t) = w \mathbf{x}(t) \]

where \(\mathbf{x}(t)\) is a vector of received signals from \(M\) subarrays, \(w\) is a selected weighting vector that controls the direction of the formed beam, and \(y(t)\) is the complex voltage signal corresponding to that direction. \(w\) can be chosen independent of \(\mathbf{x}\), as done in Fourier method, or be determined adaptively based on the received data, as done in Capon’s method and robust Capon method.

\[ w_{FB} = \frac{1}{M} \left[ 1, e^{-jkd\sin\theta}, \ldots, e^{-j(k-M+1)d\sin\theta} \right] \]

where \(k\) is the wave number, \(d\) is the spacing between subarrays, and \(\theta\) is the desired beam direction measured from broadside.

Weather Observations

The AIR was deployed on April 14, 2012 near Carmen, OK to collect the first simultaneous cross-section measurements through a tornado. The update time is approximately 3.5 seconds for the sector scan.