Improved Low INR Interference Cancellation Using Phased Array Feeds

***Jonathan Landon*[1], *Brian D. Jeffs*[1], *Karl F. Warnick*[1], *J. Richard Fisher*[2], *Roger D. Norrod*[2]**

[1]Department of Electrical and Computer Engineering, 459 CB, Brigham Young University, Provo, UT 84602, USA, silicondiode2003@yahoo.com, bjeffs@ee.byu.edu, warnick@ee.byu.edu

[2]National Radio Astronomy Observatory (NRAO), Charlottesville, VA 22903-2475, rfisher@nrao.edu, rnorrod@nrao.edu

Abstract

A promising benefit of phased array feeds (PAFs) in radio astronomy is active cancellation of radio-frequency interference (RFI). RFI mitigation scenarios in radio astronomy are significantly different from those faced in communications systems due to the much lower signal-to-noise situation. Current beamforming algorithms can effectively steer beampattern nulls to drive interferers to the level of the noise floor, but astronomical signals of interest are generally below the noise floor and can only be seen after integration, so pattern null depth must be much greater in order to drive the interferer to below the signal level. Zero-forcing algorithms drive interferers to much lower levels than max-SNR or LCMV beamformers, but rely on accurately identifying the subspace in which the interferer lies. Since subspace identification becomes more difficult as the interferer becomes weaker, an interferer at the level of the noise floor is very difficult to remove, but could still prevent detection of the much weaker signal of interest. Estimation accuracy increases as the number of estimated parameters decreases, so we propose a low-order polynomial model for magnitude and phase of array covariance elements. Modeling the interferer as a point source in space and frequency, the array covariance due to the interferer is a rank-one outer product contribution. This further reduces the estimation problem to N array elements (for an N sensor array), compared with N^2 array covariance elements.

The figures below demonstrate parameter estimation error reduction using data collected at the NRAO site in Green Bank, WV. At left is the measured cross-correlation phase between two of the 19 elements of an L-band PAF on the 20-meter telescope. Each plot point shows the phase for the (1,3) element from array sample covariance matrix, $\hat{\mathbf{R}}_{x,k}$, for a single short term integration (STI) window k. Maximum STI length is limited by interference motion. The dominant signal is due to a fixed interferer seen in the dish sidelobes. Phase progression over time is due to apparent motion as the dish tracks an astronomical source over a period of seven minutes. The right figure illustrates how sample noise and jitter are removed by fitting the phase estimates to a piece-wise fourth-order polynomial. This fitting is performed for all elements of $\hat{\mathbf{R}}_{x,k}$ to produce a low order parametric model function of time, $\mathbf{R}_x(t)$. Adaptive cancelling beamforming weights can be computed continuously across the entire time window using $\mathbf{R}_x(t)$ rather than the noisier $\hat{\mathbf{R}}_{x,k}$ STI estimates. The effective integration time is thus increased by orders of magnitude. This will reduce interference subspace estimation error and improve interference canceling null depth while tracking motion.