Array Processing Methods for Radio Astronomical RFI Mitigation: A Case Study for the ngVLA

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This paper presents an overview and performance comparisons of the available algorithms for active nulling of radio frequency interference (RFI) in radio astronomical array telescopes. The emphasis will be to evaluate which algorithms show promise for use with the proposed new architectures and processing capabilities of the ngVLA instrument upgrade planned for the VLA in New Mexico, USA. It has been shown previously that subspace projection and other related algorithms can be very effective for RFI canceling in large synthesis imaging arrays (e.g. R. Black et al, IEEE SP/SPE Workshop 2015, A. Leshem et al, IEEE Trans. Inf. Theory, vol. 46, no. 5) These adaptive array processing operations can be applied either to the visibilities at the central correlator, or at the phased array feed (PAF) beamformer if PAF array feeds are used on each dish, or both at the central correlator and PAF beamformers. This powerful modality of adaptive array spatial nulling goes beyond simple flagging or temporal filtering. In some cases spatial nulling will permit see–through capability in the corrupted frequency bands.

However, for moving interference such as satellite downlink transmissions (e.g. GPS signals in L–band) RFI nulling performance depends critically on system parameters such as correlator dump rates, fine frequency channel bandwidth, baseline length, and latency between correlator data read out and beamformer adaptive weight updates. This paper will discus RFI canceling performance specifically for the ngVLA using proposed specifications for these system parameters.

The algorithms to be studied for ngVLA implementation operate on the linear algebraic vector subspace which contains the RFI signal, and project the observation data onto the corresponding orthogonal complement subspace. These algorithms are called subspace projection (SP) and they typically form deeper nulls than do classical adaptive beamformers. We will also present a new “broadened null” variant of subspace projection which improves null depth and reduces interference subspace estimation error with moving interferers. Figure 1 presents a comparison between several algorithms.

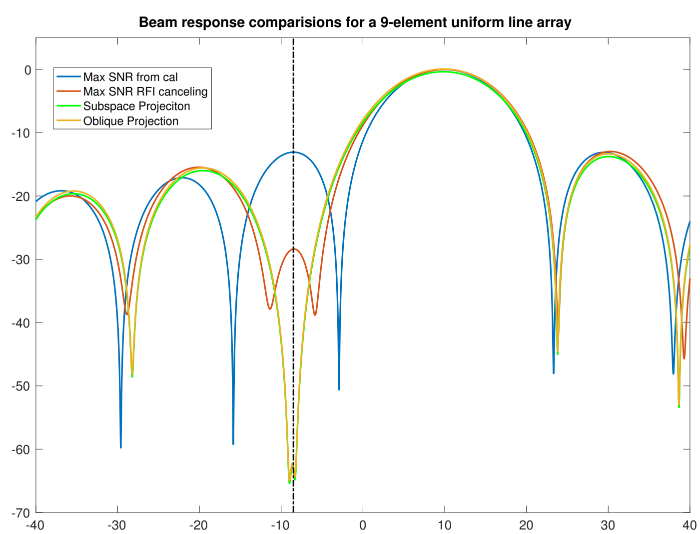

Fig. 1. Performance of several interference canceling beamformer methods. The RFI is at $-8.5°$, and the SOI is at $+10°$. All beams are steered to the SOI. The max SNR beamformer weight vector was computed from an independent set of noise calibration data samples with no SOI or interference present. The subspace projection beamformer provides a much deeper null, and oblique projection corrects for a small mainlobe response drop to the SOI for subspace projection.