Wide Band Nulling with a Single-Tap Beamformer

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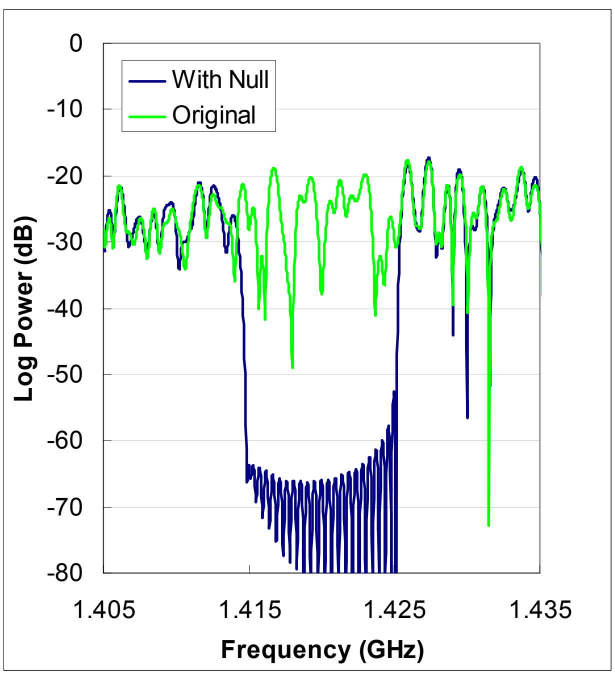
We investigate the capabilities of the proposed Allen Telescope Array (ATA) for flexible beamforming with a focus on wide-bandwidth pattern nulls co-existent with high point source sensitivity. The ATA is a new radio interferometer dedicated to SETI and radio astronomical observations under construction in Hat Creek, California. As designed, ATA comprises N = 350 6-meter dishes operating over a frequency range of 0.5-11 GHz. The large N of this array offers unique opportunities for beamforming in radio astronomical applications, some of which are explored here.

Because of ATA's large analyzed bandwidth (100 MHz), the beamformers are constrained to a simple design. Each signal entering the beamformer is delayed to form a simple beam at the point of observation. Additionally, each signal may be multiplied by a complex coefficient before summation, corresponding to a single-tap FIR filter. Despite the fact that each signal is manipulated with only a single coefficient, we show that pattern nulls can be created with surprisingly large bandwidth (e.g. > 100 MHz).

For the purposes of this demonstration we introduce a new iterative approach for the calculation of beamformer coefficients consistent with the given constraints. The main appeal of this approach is heuristic; it is easy to see how narrow-band pattern nulls are generalized to the wide-band case. The main exposition of this work uses the iterative technique, but the same concepts are also demonstrated using conventional linearly-constrained methods.



A 10 MHz null is formed in a region far from the beam pattern maximum. The figure compares the frequency dependence of the pattern gain as a function of frequency.

Focusing on the design of a "complete" ATA (scheduled 2005) we study the point source signal to noise ratio (SNR) as it varies with null bandwidth. For a single point null the SNR varies linearly with bandwidth, dropping to zero for BW ~ 250 MHz. We also explore narrow band, large solid angle nulls and similarly find a uniform decrease in SNR with increasing solid angle (SNR approaches zero for solid angles ~ 300 square arc min.). For nulls with both finite solid angle and finite bandwidth, we introduce a single parameter which can be used to predict SNR for the general case.