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A DEEP DIVE INTO DE-DOPPLER ALGORITHMS FOR SETI

Abstract

A narrowband radio frequency Search for Extraterrestrial Intelligence (SETI) presumes a long-duration ($\sim$minutes), low bandwidth ($\sim$Hz) beacon or incidental transmitted signal, or technosignature, that would be unlikely to occur in the natural world. A constant-frequency signal will be received as a chirp due to relative accelerations between transmitter and receiver, with nominal drift rates up to 10 Hz/sec for a 1.4 GHz tone (Siemion 2013). Matched-filter coherent integration over minutes is computationally impractical for wide-bandwidth searches. Instead, spectrograms are created and energy is integrated over linear tracks in the time-frequency plane. A popular de-Doppler (DD) method adapted from pulsar search involves multiple stages of computation using a Taylor tree (Taylor 1974), and is a fast $Nlog_2(N)$ algorithm, where N is the number of time averages.

This presentation examines the performance of Taylor DD (also known as "TurboSETI") and proposes an alternative ("fastDD") which uses a tree structure adapted from a fast beamformer (Houston 1994). The characteristics of a chirp signal though a filter bank (FFT or polyphase) are also examined. Some findings: 1) Chirp signals in critically-sampled filter banks encounter significant signal fades, which are greatly reduced by use of highly-overlapped (2x or 4x) frequency bins. Typical filter banks under-sample chirp signals in the frequency dimension. 2) Use of a polyphase instead of an FFT filter bank can offer up to 1 dB SNR improvement by itself. 3) The Taylor DD algorithm has significant indexing errors causing signal loss. 4) Both Taylor DD and fastDD can be adapted to over-sampled filter banks by applying a slow N^2 algorithm in place of early stages. 5) A net sensitivity improvement of up to 2 dB may be obtained, equivalent to a 50% increase in the number of antennas in a coherent tied-array beam.