A Bandpass Sampling Technique Applicable to the VLBA and SKA Pathfinder Arrays,

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Abstract

Future radio astronomy instruments, such as an upgraded VLBA and square kilometer array pathfinders, will require more bandwidth, agility, and sensitivity. These requirements are traditionally addressed by complicated and costly RF downconverter sub-systems. Increasingly large antenna arrays serve to exacerbate the costs, reliability, and maintainability issues associated with phase stable downconverter sub-systems. Band-pass sampling and digital processing techniques that replace traditional downconverter systems may result in less expensive, simpler, and more viable instruments.

Recent developments in high speed track-and-hold circuits make it possible to use well established and time proven bandpass sampling techniques in next generation wideband radio telescopes. Track-and-hold circuits with analog bandwidths of over 20GHz, which support clock rates of 4096 MHz, are now available in prototype quantities. These devices, coupled with state-of-the-art Analog-to-Digital Converters (ADCs), make it possible to digitize wideband (1-20 GHz) signals from receivers directly, without the need for downconverters. This technique uses discrete anti-aliasing filters, RF switches and digital downconverters to directly sample the RF signals.

A prototype system which uses this bandpass sampling techniques was developed at NRAO. The prototype uses a new track-and-hold circuit, manufactured by Teledyne, which has an analog input bandwidth of over 20 GHz and can sample at clock rates over 4 GHz. The 3-bit ADC used is the same as the one in the EVLA which can also sample at clock rates over 4 GHz. Three discrete anti-aliasing filters were used to simulate the required bank of 2048 MHz wide band-pass filters. The prototype used a fixed 4096 MHz sampler clock.

The results of initial testing show the prototype works well up to 16 GHz with spur free dynamic range of about 20 dB in the passbands tested. Gain flatness is a problem with the 2GHz wide passbands and needs to be addressed. The sampler jitter and temperature stability is within the EVLA specifications.

Although higher frequency receivers (>20GHz) will still need block down conversion into the bandpass sampling range of 2-20 GHz, this technique still represents a substantial reduction in downcoverter implementation and hardware costs. Operationally, observations near a band edge will require a small frequency offset in order to move the desired spectrum away from the filter edges. Gain slope equalization and automatic gain control loops are planned in order to maximize the dynamic range of the ADC.

Initial indications are that this technique is not only suitable for mass production but may also produce data with higher signal to noise ratios at a lower cost than traditional downconverter techniques.