RFI MEMO #015

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To: RFI Group
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Subject: Development of direct sampling spectrum analyzer

The technology is now available for a direct sampling spectrum analyzer using an 8-bit ADC and a FPGA processor. This instrument could serve 3 functions:

1] Replacement of the SRT digital receiver

2] A high dynamic range RFI monitor

3] An instrument for the measurements of the “global step” in Galactic noise due to the Epoch of Reionization (EoR).

In all three of the above the ADC and FPGA would form the basic “core”. For the SRT receiver the ADC would act as a mixer by sampling the L-band preamplifier output in the third Nyquist zone. In the RFI monitor application the ADC would be preceded by amplifiers, filters and input comparison switch. For the EOR detector the ADC would be preceded by an antenna, LNA and low pass filter. In all 3 applications the electronics would be packaged in a closed RFI tight box with only fiber, A.C. power and antenna connections to the outside. For ease of operation and software development the electronics would include a mini diskless Linux pc.

To emphasize the importance of this development I developed the concept of the EoR detector further. Despite the difficulty and high cost of detecting the EoR by imaging its structure I know of only 2 efforts to detect the “global step”:

1] Chippendale, Subrahmanyan and Ekers

2] Ue-Li Pen

Chippendale plans to we a large antenna structure and Ue-Li Pen’s plans are unknown. I will argue that the EoR step may be more easily detected using an antenna whose size is less than a wavelength at 200 MHz since all instrumental efforts need to be made to vary slowly across the 100-230 MHz frequency range of interest.

The reason for a small structure is that any structure of sized will exhibit ripples in frequency with period, c/d and harmonics of the period with decreasing strength, where c is the velocity of propagation.

For comparison consider a large structure extending above ground with a small structure on the ground. The large structure is sensitive to reflections within the antenna structure as well as reflections from the ground. If there are structures, like trees, buildings, mountains then the Galactic noise will be scattered into the antenna structure with relative strength.

$$\sim \left(\frac{\sigma}{16}\right)\theta^2 G$$

where σ = isotropic scattering normalized cross-section

θ = angular extent of scatter as seen by the antenna

G = relative gain of the antenna in the direction of the scatter.

From this consideration an ideal antenna might be a droopy dipole on a flat ground plane which extends to the horizon. If there are structures beyond the dipole which extend of order 1 deg then the relative strength of the reflected Galactic noise with be about 0.3 ppm assuming $\sigma \approx 0.2$ and $G \approx 0.1$.

Another consideration is that a large structure will have changes in the antenna pattern that occur over a smaller range of frequency. The antenna pattern of a droopy dipole changes slowly and smoothly with frequency. While accurate calibration of the antenna and receiver bandpass is not possible at the level of the few parts per million expected for the EoR step it should be possible to look for the deviation from the smooth response with high accuracy.

To test the viability of a system to detect the global step in the cosmic background due to the EoR simulations would be needed which:

1] Calculate the antenna pattern loss and VSWR vs frequency

2] Consider reflected noise from the LNA, scattered sky noise and diffraction of sky noise over distant terrain

3] Convolve the antenna beam with Extragalactic and Galactic noise to quantify the effort of Galactic noise on the spectrum and test the feasibility of using the Earth rotation to separate the Galactic noise from the background.

4] Consider the effects of strong sources like Cas A

5] Consder the effects of the ionosphere

6] Consider the effect of Jupiter bursts and as well as meteor scatter of TV and FM.

Potential sites for an EoR global step experiments might be Mileura, Australia, Vernon, Utah, VLA, New Mexico, Castleford, Idaho. An ideal site would be a flat area extending to the horizon without trees and other scatterers. Observations would need to be restricted to night. Also a site with little rain or snow would be needed for the antenna to be located at or very near the ground level.