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To: EDGES Group

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Subject: EDGES system using direct sampling 12-bit ADC.

The original EDGES system used the Acqiris AC240 8-bit ADC spectrometer. This system was deployed in Mileura, Western Australia in 2006. The search for the highly red shifted hydrogen from the EOR was limited by systematics in the spectrometer to about 300 mK out of  $10^3$  K system. The sources of these systematics are discussed in memo #27. The EDGES uses 3-position switching where the difference between the “signal” and “comparison” spectrum is made even larger by the presence of the strong and variable signals from the Orbcomm satellites at 137 MHz.

Since wideband sampling is limited by non-linearity (see memo #41) a frequency cycled updown converter was pursued for a while until the introduction of the Acqiris DP310 12-bit ADC CARD from Agilent. The DP310 has extremely good linearity but does suffer from some “conditioning” of the ADC samples by previous samples delayed by 32 samples. This conditioning results in a ripple in the spectrum with a period of 1/32 of the sample rate. The problem is ameliorated by adding “out-of-band” dither noise. The dither noise has a spectrum extending from low frequencies up to 80 MHz leaving 80 MHz to 210 MHz, for a 420 Ms/s sample rate, available for EDGES. The dither noise needs to be made to dominate the total power so that all states are almost equally sampled for signal and comparison. The optimization of the ratio of out-of-band dither noise to in-band noise has yet to be determined. Making the dither more and more dominant eventually results in a significant spillover of the dither noise, into the in-band region as a result of ADC non linearities. Simulations show that for a “conditioning” of one bit (i.e. feedback of delayed output influences the input by one digit) the ripple amplitude is given by one digit) the ripple amplitude is given by

$$(s/n) \times 2^{-(N+1)}$$

where  $s$  = signal power from RFI

$n$  = total noise power (assumed to be dominant)

$N$  = number of bits in peak ADC output

For example, if the out of band noise dominates and the peak RFI is 10% of total noise power the ripple about 10 ppm for 12-bit DP310 ADC.