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To: VSRT Group
 From: Alan E.E. Rogers
 Subject: Frequency calibration of ozone spectrometer

The ozone spectrometer has a “free running” first L.O. oscillator in the LNBF which has a nominal frequency of 9750 MHz. Since this frequency drifts around with temperature it is calibrated every 90 seconds. The calibration is performed by turning on the pulse calibrator, which generates 10 MHz harmonics of the internal oven crystal oscillator, and observing the frequency harmonic at 11070 MHz. The signal is at a normal frequency of 1320 MHz out of the LNBF and at 2.5 MHz after mixing with 1317.5 MHz in the ozone spectrometer. The signal is detected in the spectrum by finding the spectral channel with strongest peak and then doing a least squares fit to a frequency shifted sinc function, plus a constant using the signal power at the peak and at one point either side of the peak. This interpolation yields a frequency whose error is a small fraction of the 2.441406 kHz separation of the spectral points.

Now having obtained the frequency of the calibration tone we can correct the ozone spectrum for the error in the first L.O. frequency. This is accomplished by first applying a correction to the downconverter local oscillator and then a shift in the spectrum by an integer number of frequency channels. This procedure results in an output spectrum for each 90 seconds of data which is in error by no more than half the separation of the spectral points. In addition the residual error due to the quantization is written into the output file for the “final correction” can be made in post processing.

The possibility that the 11 GHz ozone line might be used to measure the wind velocity and temperature is the primary motivation for exploring methods of achieving better frequency calibration.

Simulations of the ability to measure the line frequency and width by least squares fitting show that

$$\Delta f_{rms} = (T_s / T_{oz}) \left(\frac{2W_{oz}}{T} \right)^{1/2}$$

where T_s = system temperature ~ 80 k

T_{oz} = ozone spectrum peak ~ 30 mK

W_{oz} = half-power half-width ~ 8 kHz

T = integration time

and the half-power half-width can be measured with

$$\Delta W_{rms} \approx 1.2\Delta f_{rms}$$

For the parameters listed and 10 days of 8 hrs per night

$$\Delta f_{rms} \approx 600 \text{ Hz}$$

$$\Delta W_{rms} \approx 720 \text{ Hz}$$

This corresponds to a 1 sigma velocity measurement of about 15 m/s and a temperature measurement of about 35 K. With 10 spectrometers these numbers are reduced to about 5 m/s and 7 K respectively. Ultimately the velocity measurement would be limited by the drift in the crystal oscillator, which is specified to be under 1×10^{-9} (or 11 Hz)/day and 300×10^{-9} (or 3 kHz)/year. This problem can be solved by using a GPS conditioned crystal oscillator. However the drift would have little effect on measurements of temperature and short term and diurnal variations in velocity.