EDGES MEMO #036

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To: EDGES Group
From: Alan E.E. Rogers
Subject: Expected performance of a narrowband "frequency cycled" system.

The original EDGES spectrometer used 3 position switching which removes a constant and the gain from the bandpass (see memo #34). This system requires that the direct sampling backend be perfectly linear and free of aliasing and other defects as discussed in memo #34. A narrowband backend can be relatively free of the problems which afflict the direct sampling backend. There are however 2 major problems with the narrowband system:

1] The noise is increased so that an integration time equal to the ratio of the full bandwidth being analyzed to the instantaneous bandwidth is needed to reach the same noise level.

2] Gain variations and or bursts of wideband noise add noise on a frequency scale larger than the instantaneous bandwidth.

The first problem may not be significant since it may not be necessary to use 3-position switching so that the added noise is only

$$\left(R/6^{1/2}\right)$$

where R = ratio of the full bandwidth to the instantaneous bandwidth.

The second problem can be ameliorated by using a fast switching cycle. If the gain varies randomly from one frequency offset to the next the noise in the final spectrum is reduced by the square root of the number of local oscillator switching cycles. For example, the frequency translating L.O. is changed once per 100 ms then the gain variation noise is reduced by a factor of 465 in 6 hours.

If the gain fluctuations are at a level of 0.1 percent then their effect will be reduced to 2 ppm in 6 hours.

Simulations to illustrate the performance

Figure 1, 2 and 3 show 3 cases: Figure 1 shows the result of 3-pos switching a 10 MHz bandwidth over 100 MHz looking at the sky with

$$T_A = 1000\left(f/100\right)^{-2.5} K$$

A bandpass ripple of ± 1 dB with 10 MHz period is assumed. A strong RFI signal is added at 155 MHz. The bandpass ripple would normally be cancelled but the introduction of 100 ppm of distortion in the power response the bandpass ripple becomes evident in the “stitched” 100-200 MHz spectrum.

Figure 2 shows that the effects of the non-linearity are eliminated by frequency cycling (as discussed in memo #34) everywhere except within ± 10 MHz from the RFI. Near the RFI signal the spectrum deviates from a smooth curve, after dividing by the sky spectrum, but only deviates by about 10 ppm near the RFI which has been set at a level of 10 dB above the sky noise in a resolution bandwidth.

Figure 3 shows the case of only frequency cycling. This looks almost identical to the previous case of both 3-position switching and frequency cycling.

In Figures 4, 5 and 6 we repeat the 3 cases of the previous figures but introduce a 0.1% Gaussian random change in the gain of the ADC. The plots show the results for an average of 20,000 frequency switch periods.

In the case of 3-position switching there are 3×20,000 spectra. From these simulations it appears that there may be no advantage of 3-position switching if frequency cycling is used. No random Gaussian spectral noise was added in these simulations.

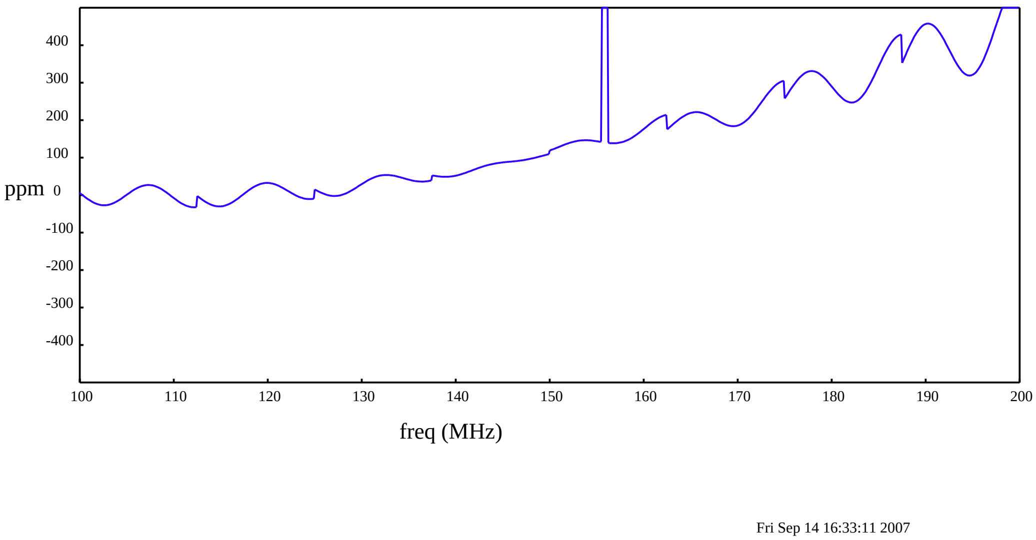

Figure 1. “Stitched” spectrum using 10 MHz bands each calibrated with 3 position switch. The systematics are the result of 100 ppm non-linearity.

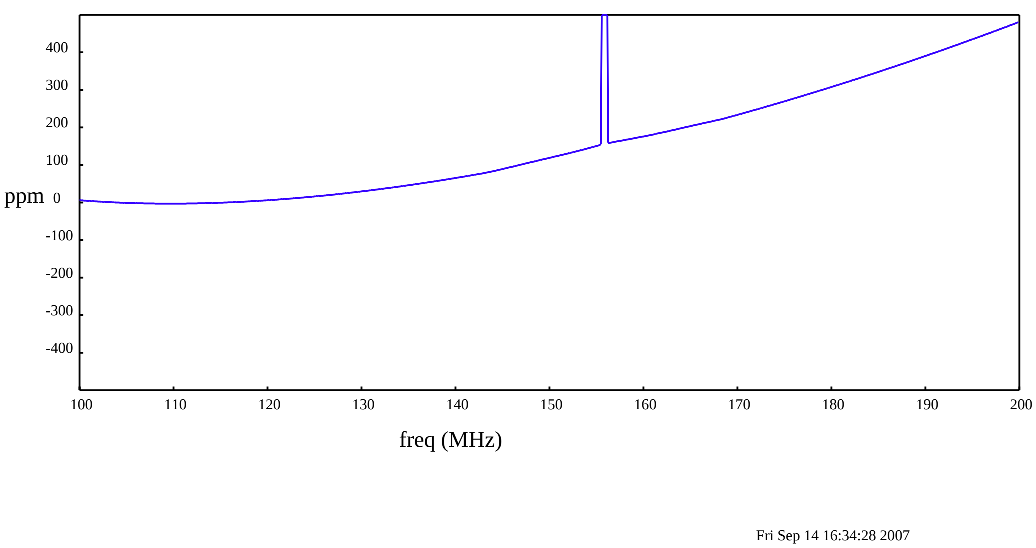

Figure 2. Stitched spectrum from frequency cycled 10 MHz bands each calibrated with 3-position switch.

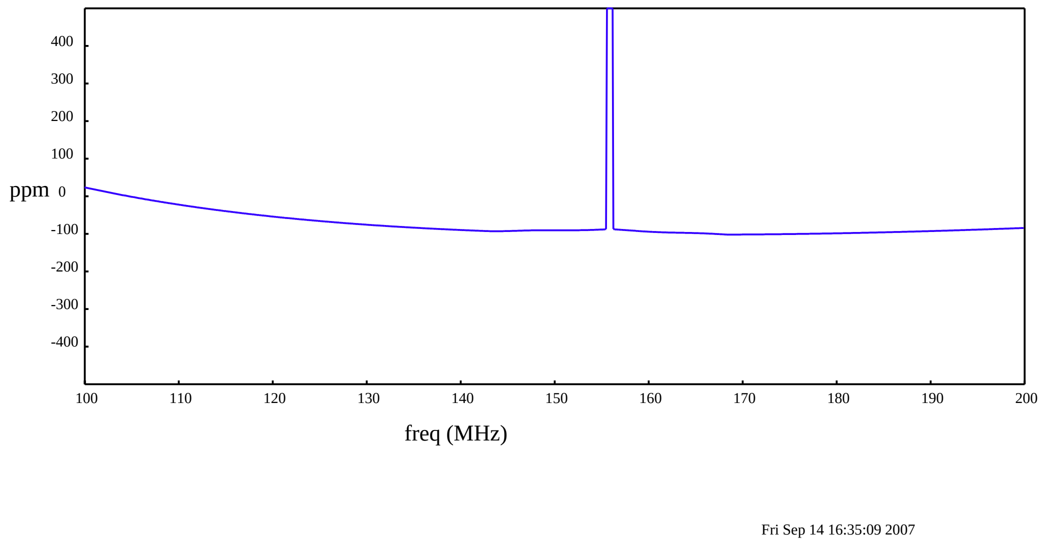

Figure 3. “Stitched” spectrum using only frequency cycled 10 MHz bands.

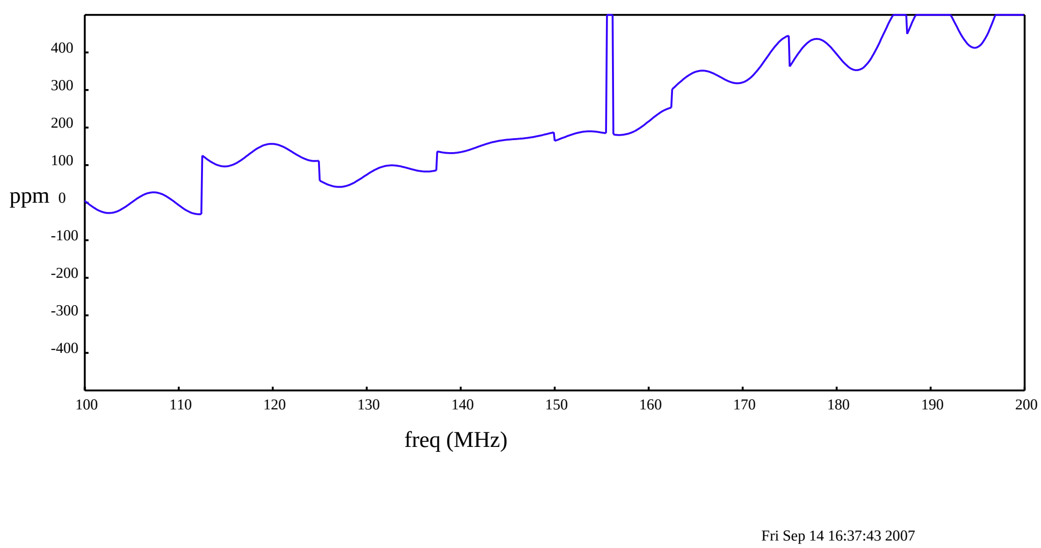

Figure 4. Same as figure 1 but with 0.1% gain variation per switch period. 20,000 period average.

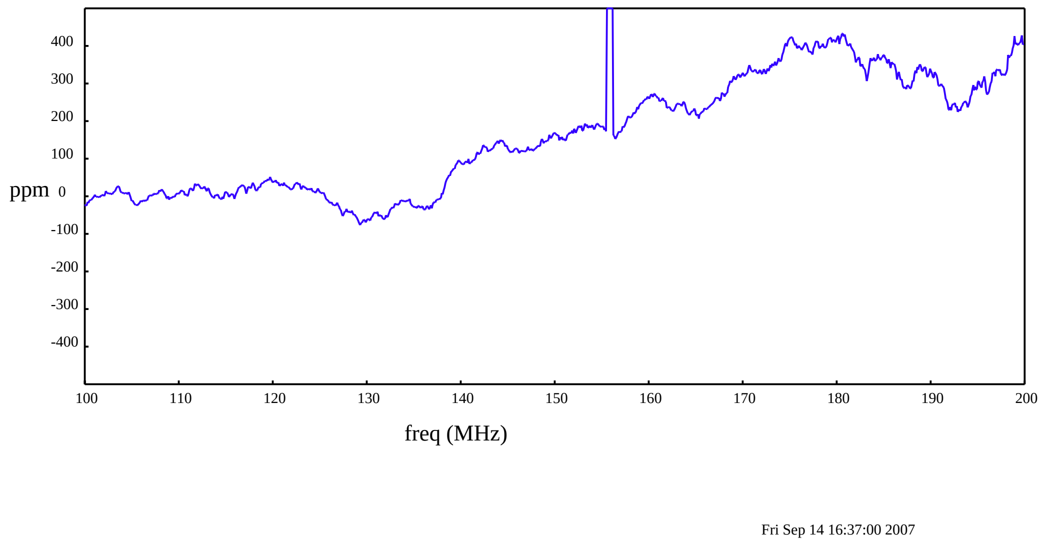

Figure 5. Same as figure 2 but with added 0.1% gain variation.

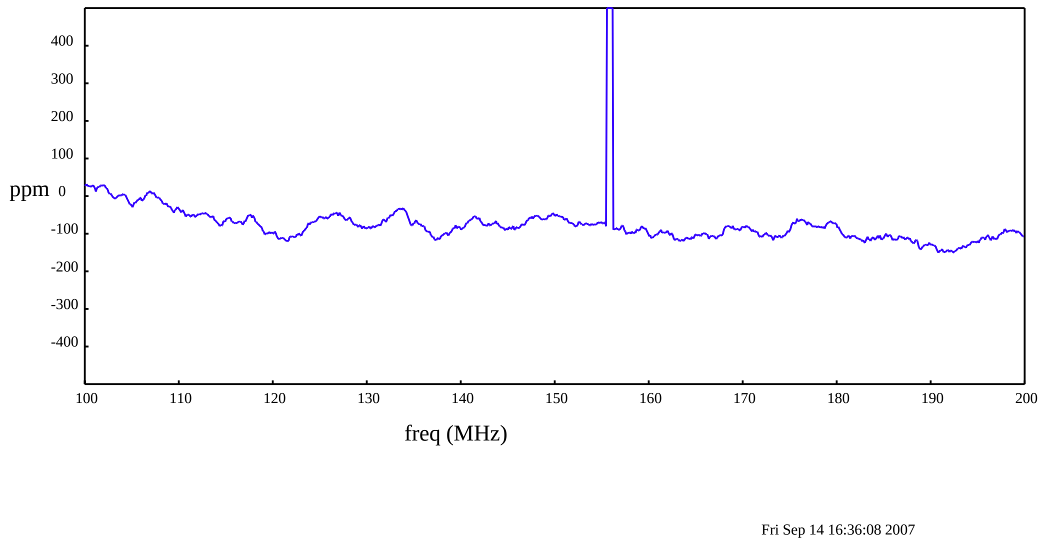

Figure 6. Same as figure 3 but with added 0.1% gain variation.