Measurements of 2.4-MHz Gain and 60-MHz Baseline Ripple Project TBASEDSB021211, 11 December 2002

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Setup

There were two goals of this evening's measurements. One was to measure the amplitude of the 2.4-MHz period gain ripple in all of the active optical fiber modulators for the record and for later comparison with the new modulator which has been modified by the manufacturer to suppress this gain ripple. The other goal was to begin tracking down the source of the spectrum baseline ripple with a period around 60 MHz.

The wideband IF noise source was used for all observations. Three different IF rack passbands were used, centered on 1500, 3000, and 6000 MHz. The respective IF filter passbands were 'pass_all', 2360-3640 MHz, and 5360-6640 MHz. An 800 MHz spectrometer bandwidth was used for all measurements with the analog filter rack passband of 800-1600 MHz. For all scans the telescope was stationary (Az=137.88, El=77.99). The Spectrometer mode was 1W2-001-800 (two samplers; BW = 800 MHz). The IF to sampler connection matrix is given in Table 1. Optical driver modules (ODMs) 1, 2, 3, 5, and 6 were external modulators; ODM 8 was an older direct modulator; ODMs 4 and 7 were out of service.

All scans of the 2.4-MHz period gain ripple were 5 minutes long with 30-second integrations. The 60-MHz ripple stability scans were 30 minutes long with 30-second integrations.

Optical Modulator Gain Ripple

The external optical modulator gain ripple is a near-sinusoidal gain dependence on frequency of the passband of the fiber link with a period of about 2.4 MHz. This effect is most obvious as several narrow features in the autocorrelation function of broadband noise passing through the fiber link as shown in Figure 1. The spike near lag 670 (0.41875 μs) corresponds to a gain ripple periodicity of 2.3888 MHz. The spikes near lags 1340 and 2010 are harmonics which indicate that the ripple is not purely sinusoidal. The slightly complex nature of the ACF feature shown expanded in Figure 2 indicates that the ripple amplitude varies

Table 1: IF Rack to Spectrometer Connection Matrix

OR	CM	SF	AC Sampler
1	1	1	0
3	5	5	1
2	1	1	0
4	5	5	1
5	9	1	0
7	13	5	1
6	9	1	0
8	13	5	1

somewhat across the spectrum passband. Some of that variation is due to the frequency dependence of the spectrometer's anti-aliasing filter. Figure 3 shows the fundamental ACF spike for fiber channel 3.

The frequency dependence of 2.4-MHz ripple amplitude can be seen in the system noise spectra shown in Figures 4 and 5. These spectra have been high-pass filtered by suppressing the ACF values at small lags to emphasize to 2.4-MHz ripple. Since the channel spacing in the 800 MHz spectrum is 0.39 MHz the ripple waveform is not very well sampled. This introduces some artificial apparent amplitude modulation in these spectra, but the large scale envelopes of the patterns is probably due to the optical modulators.

An approximate quantitative measure of the amplitude of the gain ripple relative to the total noise spectral density was computed by summing the three highest absolute values of the ACF near each of the ripple harmonics and taking its ratio with the zero-lag ACF value. The results for the fundamental and first two harmonics for the six active fibers are shown in Figures 6, 7, and 8. Fiber 8 uses a directly modulated laser, which is known to not have any gain ripple, so it provides and indication of the detection limit of this algorithm. This detection limit is about 10 dB higher than can be had with visual inspection of the ACF, but the algorithm provides a reasonably objective measure.

The spread in ripple amplitudes for the five externally modulated lasers is about 5 dB, and the amplitude is about 8 dB higher at an IF of 1.5 GHz than at 6 GHz. The first and second harmonics are about 6 and 10 dB weaker than the fundamental.

IF Spectrum Stability

During astronomical checkout of the spectrometer and during our baseline tests a spectral baseline ripple with a periodicity of about 60 MHz has appeared in 800 MHz spectra at various times. We saw this ripple in IF noise source spectra so it must be due to a system component downstream of the mixer. To try to reproduce this problem and to determine in which fiber channels it appears we took 30-minute scans of 30-second records with the spectrometer connected to two of the fiber channels at a time with the IF noise source connected. Successive difference spectra of (record1 - recordN) / record1 were inspected for each scan to search for the 60-MHz ripple. Figure 9 is one of the worst cases seen. This

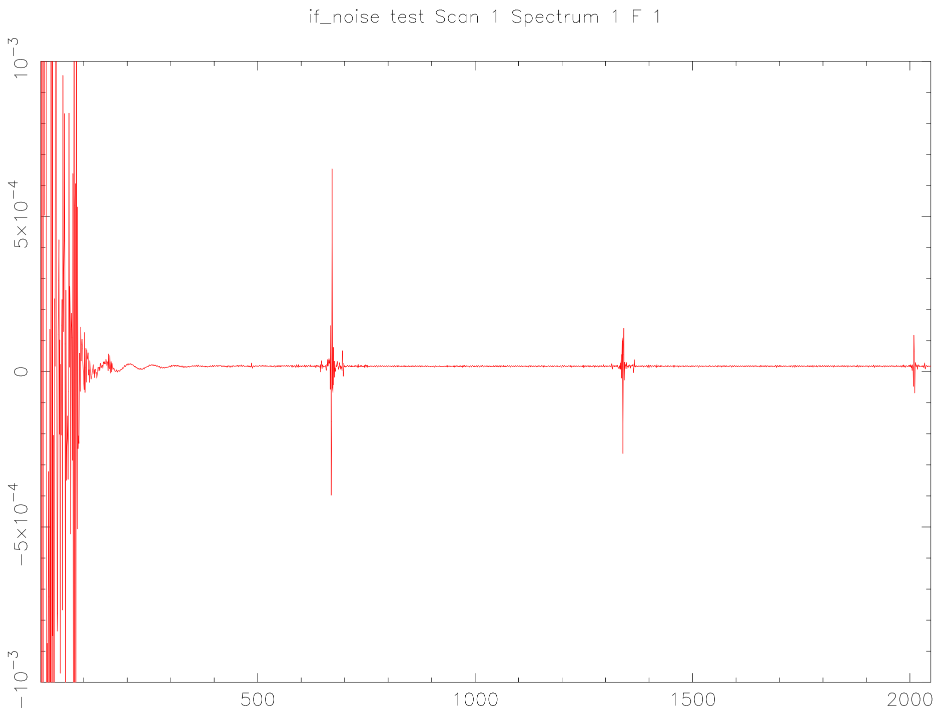

Figure 1: Scan 1, autocorrelation function for the IF noise source signal transmitted through fiber channel 1. Each lag on the horizontal scale is a delay of $1/(1.6 \times 10^9)$ seconds. The vertical scale is proportional to noise power, where the zero lag value is approximately 0.5. The ACF feature near lag 670 (0.41875 μs) is the fundamental of the gain ripple periodicity.

problem was most evident in fiber channels 6 and 8, which were connected to converter modules 9 and 13 and analog filter modules 1 and 5, respectively.

In looking at the full series of difference spectra over the 30-minute scans it seemed that the ripple amplitude was periodic. To verify this periodicity the rms value of the central 3/4 of the difference spectrum was computed for each 30-second record. The results for the six active fiber channels are shown in Figure 10. Fiber channels 6 (CM9, SF1) and 8 (CM13, SF5) show a clear cycle of about 11 minutes period. Fiber channel 5 (CM9, SF1) shows some cycling, but it isn't as regular as seen in fibers 6 and 8. Since the spectra could be measured only two at a time, one cannot say whether the difference in results for the different fiber channels is a time dependence or a difference in the electronic modules. However, the two channels showing the clearest cycling were recorded in the same scan, and the one with an irregular cycle was taken alone in the previous scan.

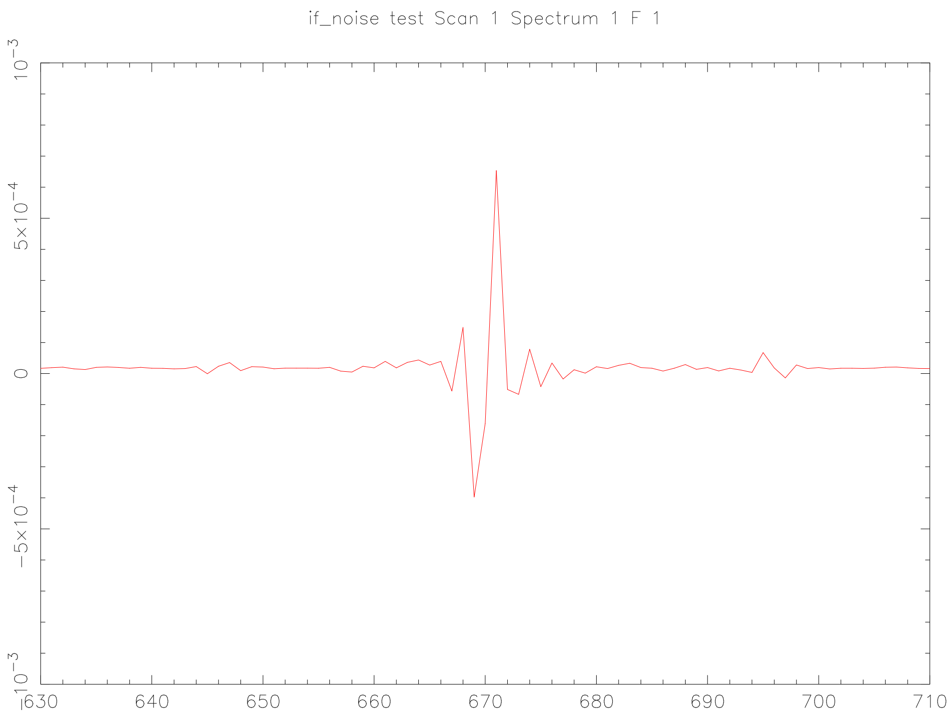

Figure 2: Scan 1, an expansion of the fundamental ACF spike shown in Figure 1 for fiber channel 1.

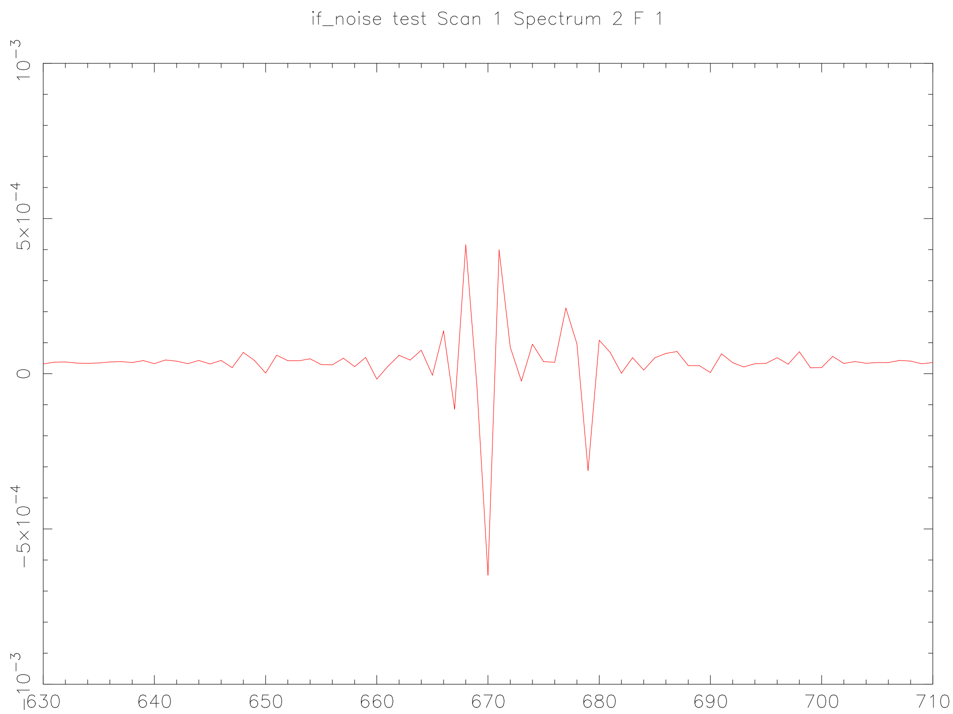

Figure 3: Scan 1, an expansion of the fundamental ACF spike for fiber channel 3. Compare with the details of the fundamental spike for channel 1 shown in Figure 2

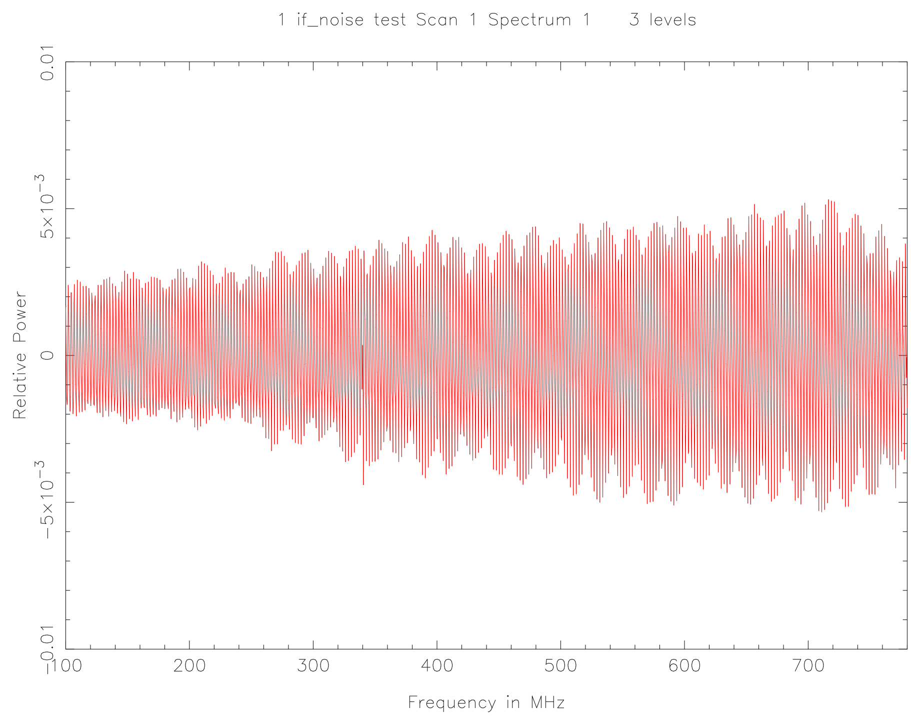

Figure 4: Scan 1, noise spectrum of fiber channel 1 that has been high-pass filtered by suppressing ACF values below lag 640 and compensated for frequency-dependent system filter gain. Part of the modulation envelope is due to aliasing with the spectrum sample spacing of 0.39 MHz, but the overall variation in ripple amplitude across the passband is probably a characteristic of the optical modulator.

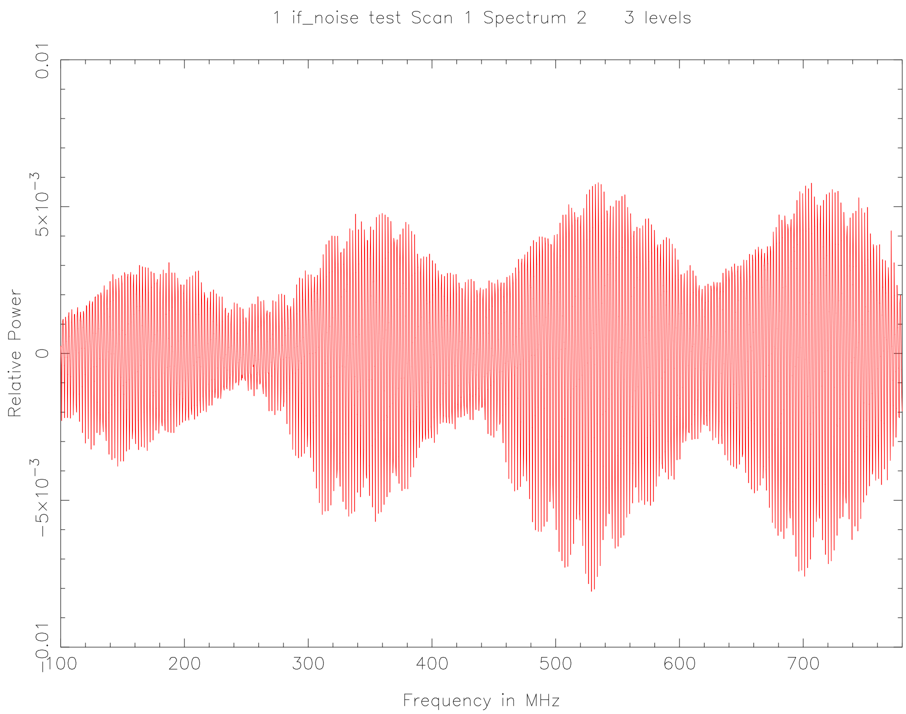

Figure 5: Scan 1, noise spectrum of fiber channel 3 that has been high-pass filtered by suppressing ACF values below lag 640 and compensated for frequency-dependent system filter gain. Part of the modulation envelope is due to aliasing with the spectrum sample spacing of 0.39 MHz, but the overall variation in ripple amplitude across the passband is probably a characteristic of the optical modulator.

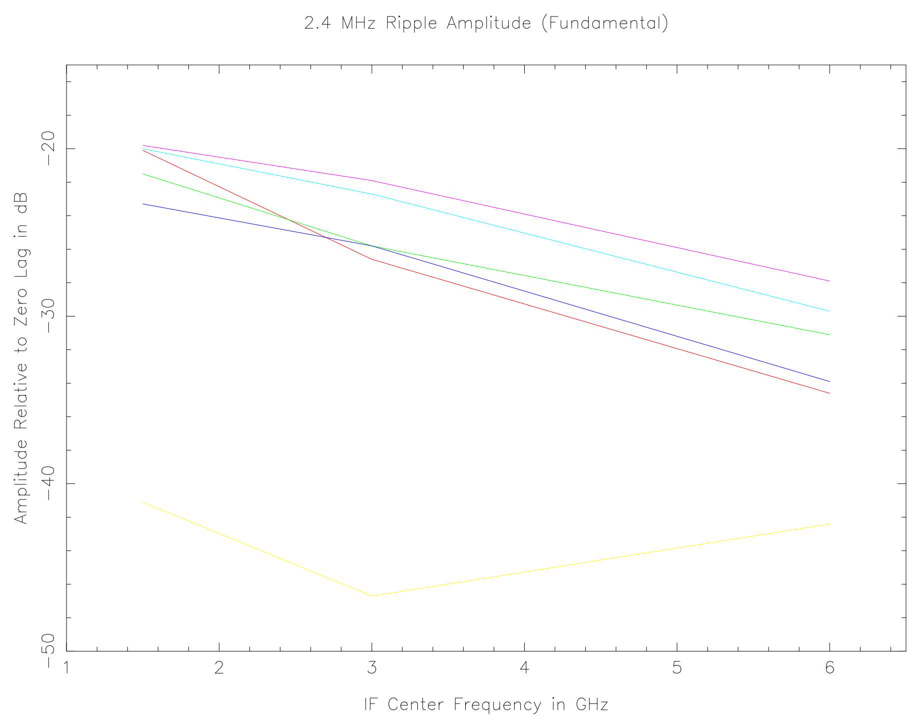

Figure 6: Scans 1 through 12, approximate amplitude of fundamental periodicity component of the 2.4 MHz gain ripple measured at IF center frequencies of 1.5, 3.0 and 6.0 GHz. The amplitude is relative to the zero-lag ACF value. The red, green, dark blue, blue-green, violet, and yellow lines correspond to fibers 1, 2, 3, 5, 6, and 8, respectively. Fiber 8 uses a directly modulated laser, which is known to not have any gain ripple.

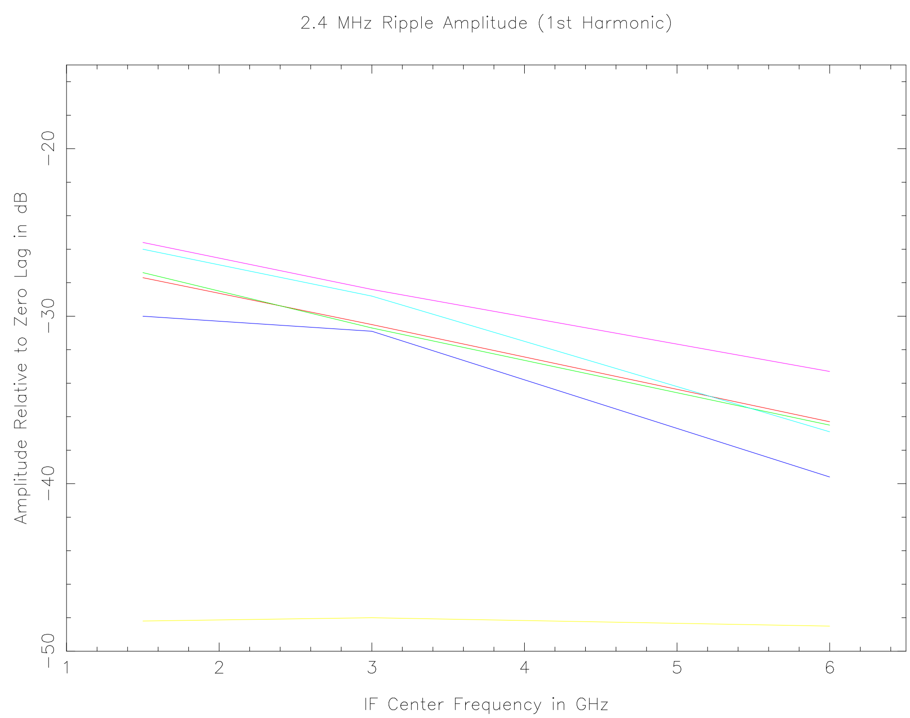

Figure 7: Scans 1 through 12, approximate amplitude of the first harmonic of the 2.4 MHz gain ripple periodicity measured at IF center frequencies of 1.5, 3.0 and 6.0 GHz. The amplitude is relative to the zero-lag ACF value. The red, green, dark blue, blue-green, violet, and yellow lines correspond to fibers 1, 2, 3, 5, 6, and 8, respectively. Fiber 8 uses a directly modulated laser, which is known to not have any gain ripple.

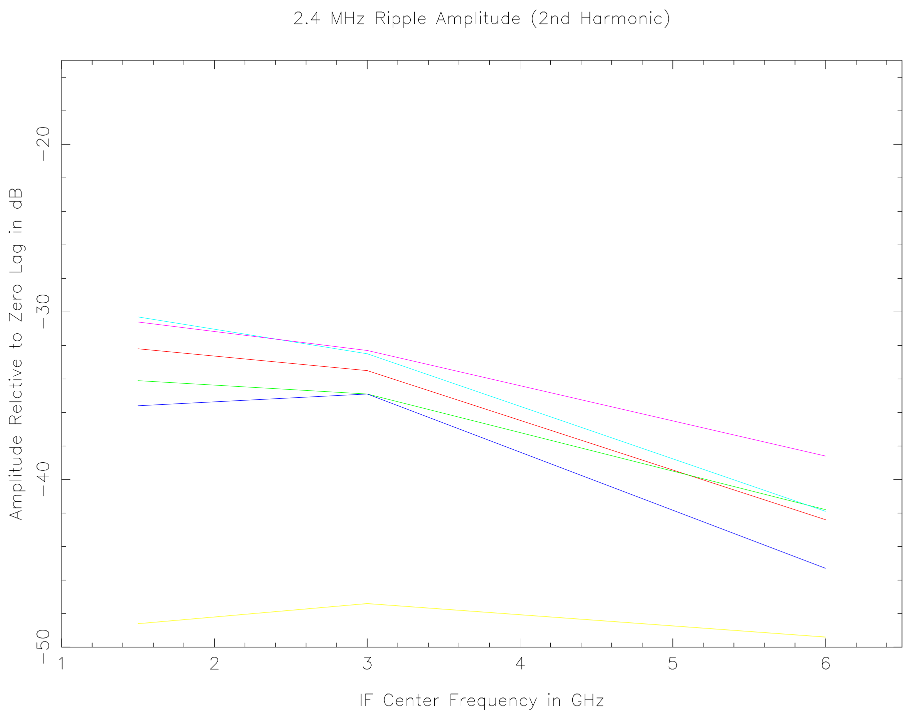

Figure 8: Scans 1 through 12, approximate amplitude of the second harmonic of the 2.4 MHz gain ripple periodicity measured at IF center frequencies of 1.5, 3.0 and 6.0 GHz. The amplitude is relative to the zero-lag ACF value. The red, green, dark blue, blue-green, violet, and yellow lines correspond to fibers 1, 2, 3, 5, 6, and 8, respectively. Fiber 8 uses a directly modulated laser, which is known to not have any gain ripple.

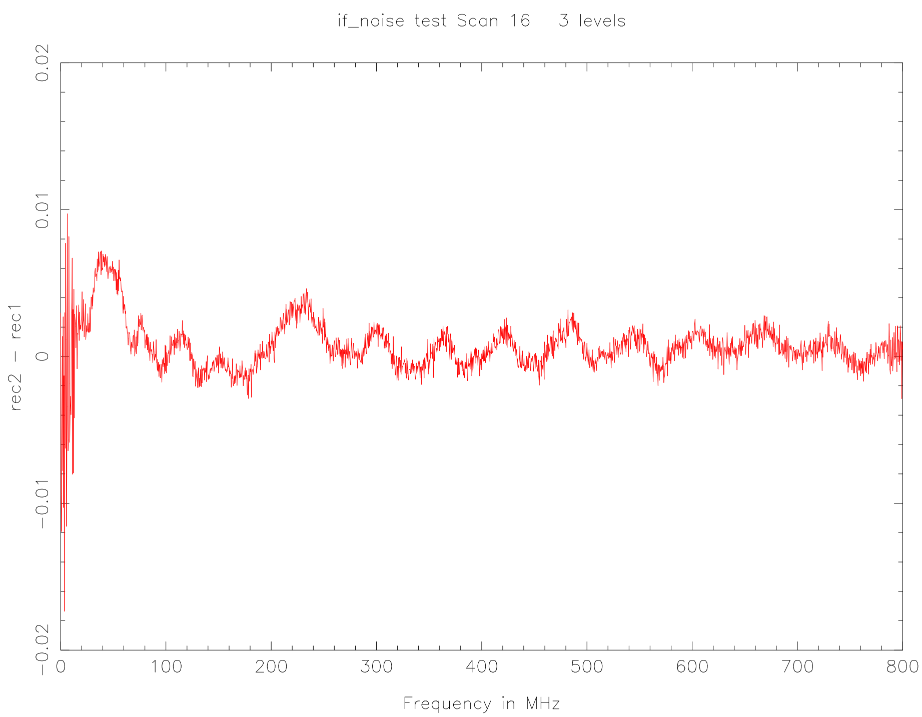

Figure 9: Scan 16, (record1 - record11) / record1 difference spectrum on fiber 8, converter module 13, and analog filter 5.

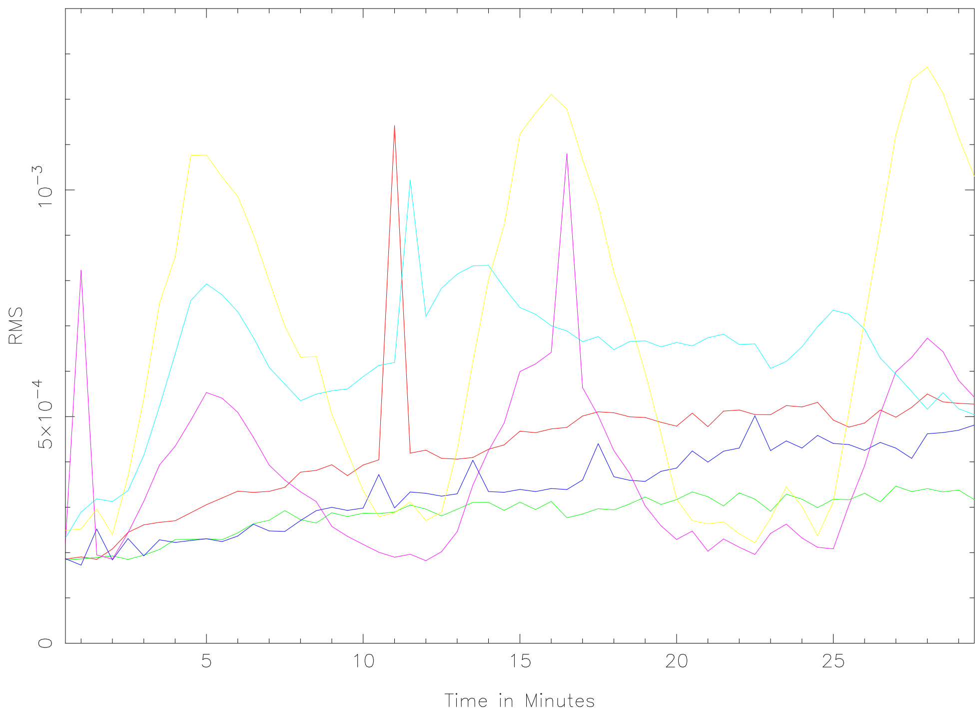

Figure 10: Scans 13 through 16, rms of the central 3/4 of each 30-second difference spectrum of (record1 - recordN) / record1 for the six active fiber channels. The red, green, dark blue, blue-green, violet, and yellow curves correspond to fibers 1, 2, 3, 5, 6, and 8; converter modules 1, 1, 5, 9, 9, and 13; analog filter modules 1, 1, 5, 1, 1, and 5; and scans 13, 14, 13, 15, 16, 16; respectively.