Investigate Optical Fiber Modulator Stability: Odd Fibers
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Dana S. Balser

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Introduction

The external optical fiber modulators produce a 2.4 MHz ripple in total power spectra with amplitudes of $\sim$ 25 dB relative to the total noise spectral density. The spread in ripple amplitude is about 5 dB between different modulators and about 8 dB from IF frequencies 1.5–6 GHz (see TBASEDSB021211). The even fiber modulators were investigated in TBASEDSB030110—a comparison was made with the original external modulator, the new external modulator, and the direct modulator. The IF noise source was used to simulate on-off spectra to measure the stability of the 2.4 MHz ripple. When the data were processed in this way the fiber ripple was detected in Fourier spectra only for the original external modulator and tended to average down over time.

Here we investigate the odd fiber modulators with a similar experiment. Data was taken with the IF noise source for a continuous period of 240 minutes. The connection matrix between the IF rack and the spectrometer is shown in Table 1. The spectrometer was configured in four bank mode to produce redundancy in the data. The spectrometer integration time was 30 seconds. ODMs 1, 3, and 5 consisted of original external modulator units. ODM 7 was out of service.

Table 1: IF Rack to Spectrometer Connection Matrix

AC Bank	Rcvr	ODM	CM	SF	AC Sampler	Comment
1	1	1	1	1	0	
1	2	3	5	5	1	
2	1	5	10	2	2	
2	2	7	14	6	3	ODM out of service
3	1	1	3	3	4	
3	2	3	7	7	5	$\sim$ 30 MHz Comb
4	1	5	12	4	6	
4	2	7	16	8	7	ODM out of service

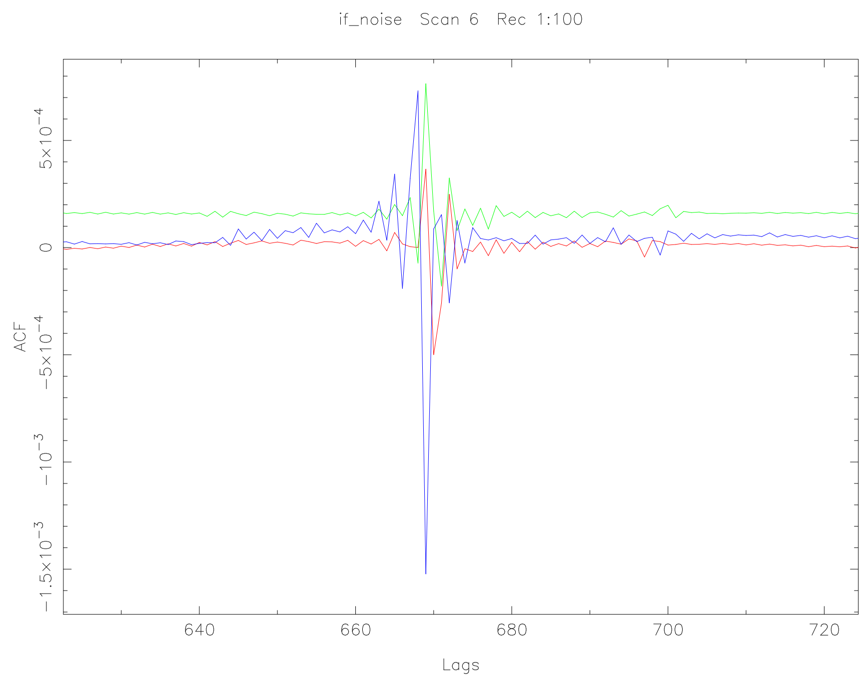


Figure 1: Auto-correlation function for ODM 1 (red), ODM 3 (green), and ODM 5 (blue). Records 1–100 have been averaged for scan 6.

Stability of 2.4 MHz Ripple

Figure1 plots the auto-correlation function (ACF) for optical driver modules (ODMs) 1, 3, and 5. The 2.4 MHz feature is clearly visible around lag 666 for all three external modulators.

The stability of the 2.4 MHz ripple is investigated by comparing different records. Each spectrum is determined by calculating (Record N–Record 1)/Record N. For each ODM two series of N are explored: N = 2, 10, 20, 30, 40, and 50; and N = 2, 50, 100, 200, 300, 400, and 480. Each record is 30 seconds; thus the first series compares records up to 25 minutes apart while the second series compares records up to 240 minutes apart. The Fourier transform is taken to gain sensitivity to detect the 2.4 MHz ripple. The results are shown in Figures 2–7. For each ODM the 2.4 MHz feature is detected. In general the amplitude of the 2.4 MHz ripple is larger when comparing records further apart in time. Although after $\sim$ 150 minutes the amplitude of the ripple does not increase and in some cases is less.

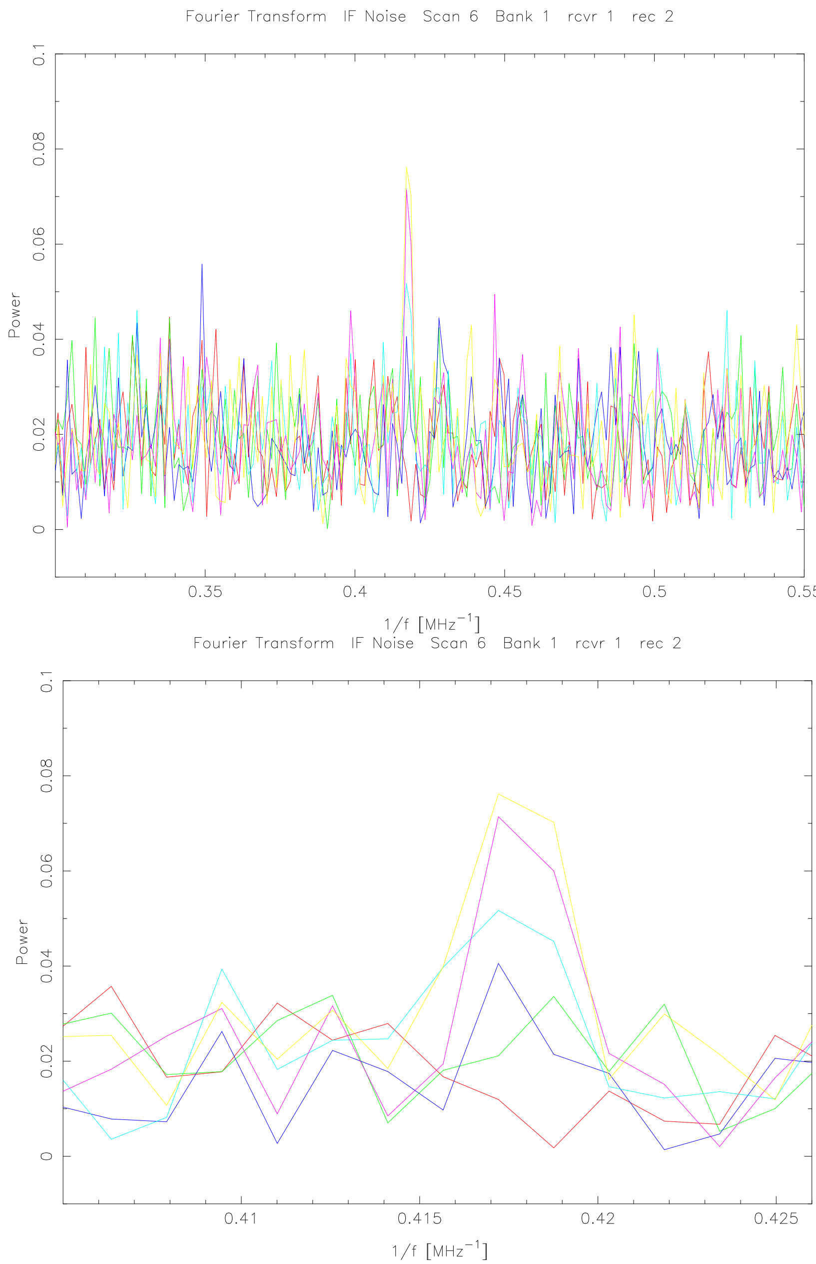


Figure 2: Fourier transform plots for the original external modulator in link number 1 spanning records 1–50. The transformed spectra were produced by calculating (Record N–Record 1)/ Record 1 where N = 2 (red), 10 (green), 20 (blue), 30 (green/blue), 40 (red/blue), and 50 (yellow). The bottom panel shows an expanded view.

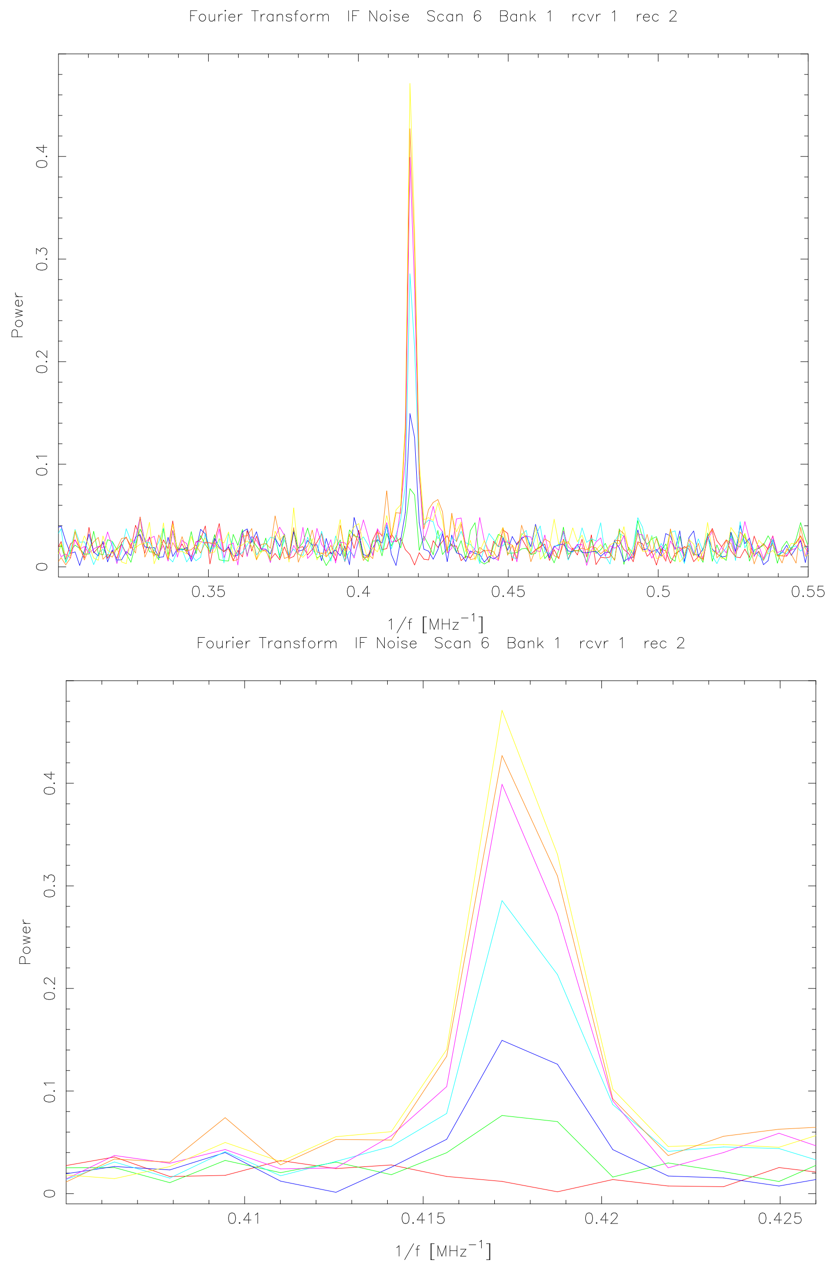


Figure 3: Fourier transform plots for the original external modulator in link number 1 spanning records 2–480. The transformed spectra were produced by calculating (Record N–Record 1)/ Record 1 where N = 2 (red), 50 (green), 100 (blue), 200 (green/blue), 300 (red/blue), 400 (yellow), and 480 (orange). The bottom panel shows an expanded view.

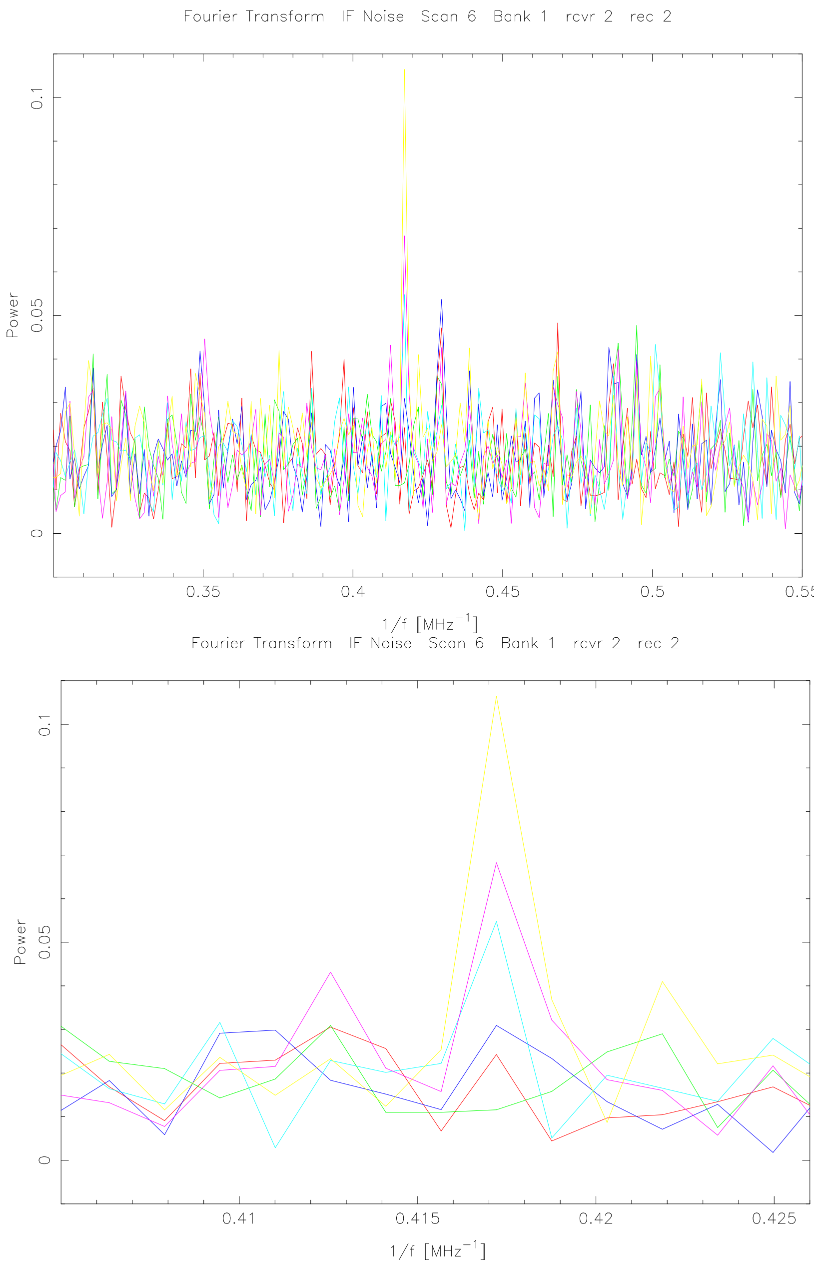


Figure 4: Fourier transform plots for the original external modulator in link number 3 spanning records 1–50. The transformed spectra were produced by calculating (Record N–Record 1)/ Record 1 where N = 2 (red), 10 (green), 20 (blue), 30 (green/blue), 40 (red/blue), and 50 (yellow). The bottom panel shows an expanded view.

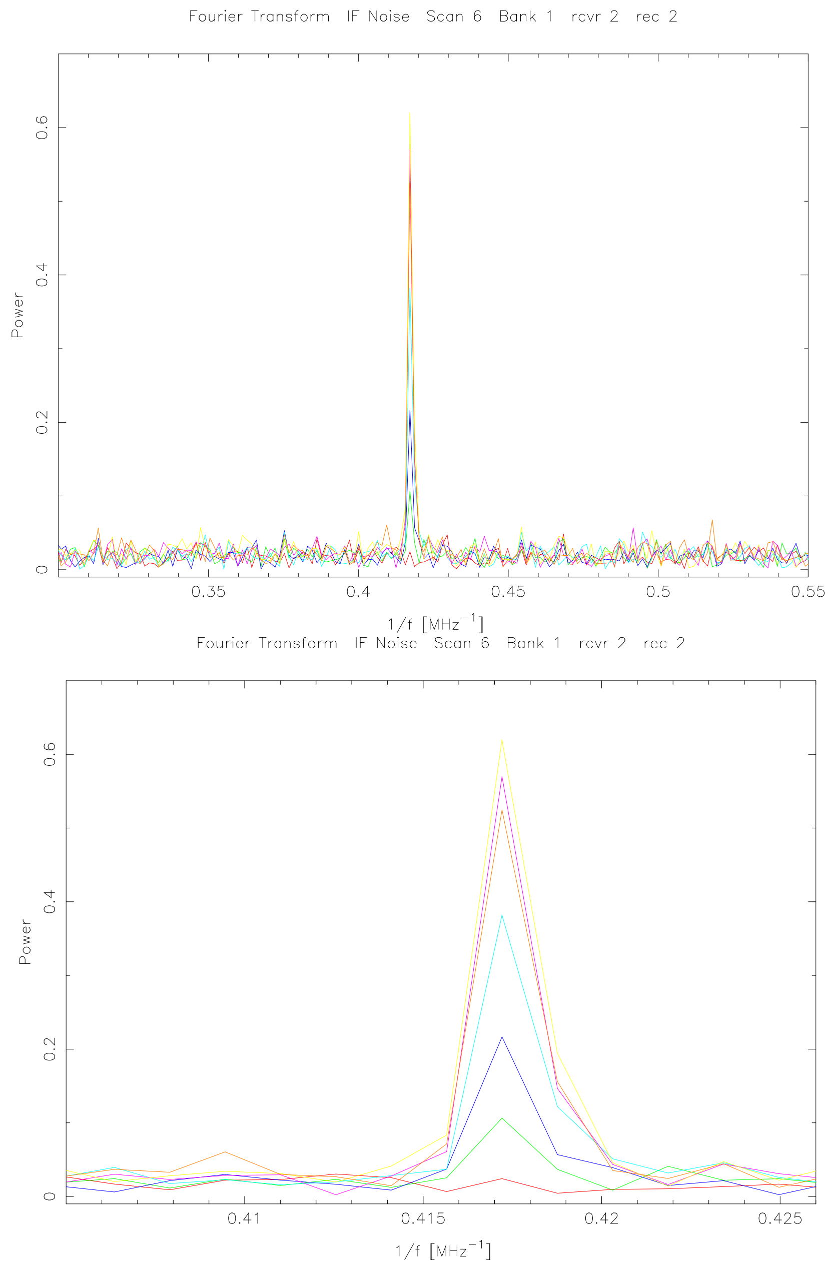


Figure 5: Fourier transform plots for the original external modulator in link number 3 spanning records 2–480. The transformed spectra were produced by calculating (Record N–Record 1)/ Record 1 where N = 2 (red), 50 (green), 100 (blue), 200 (green/blue), 300 (red/blue), 400 (yellow), and 480 (orange). The bottom panel shows an expanded view.

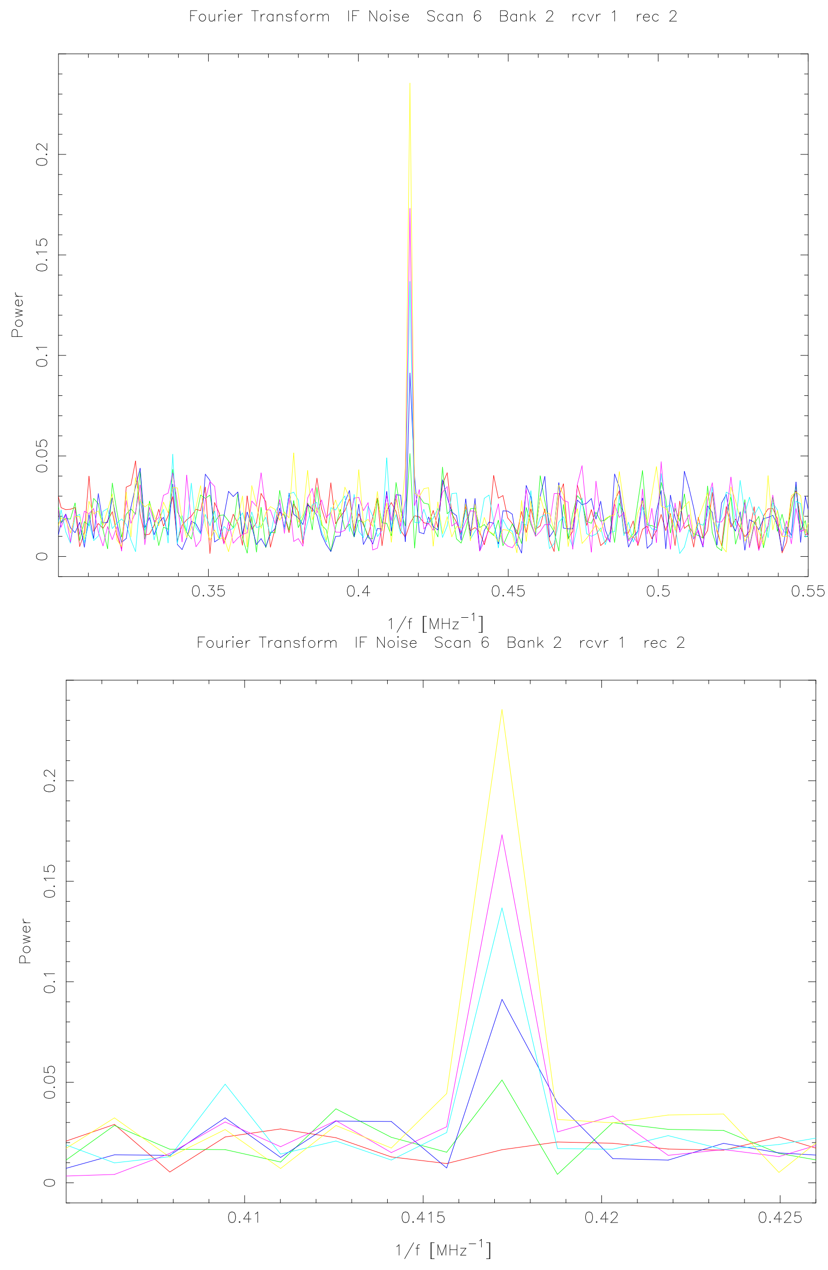
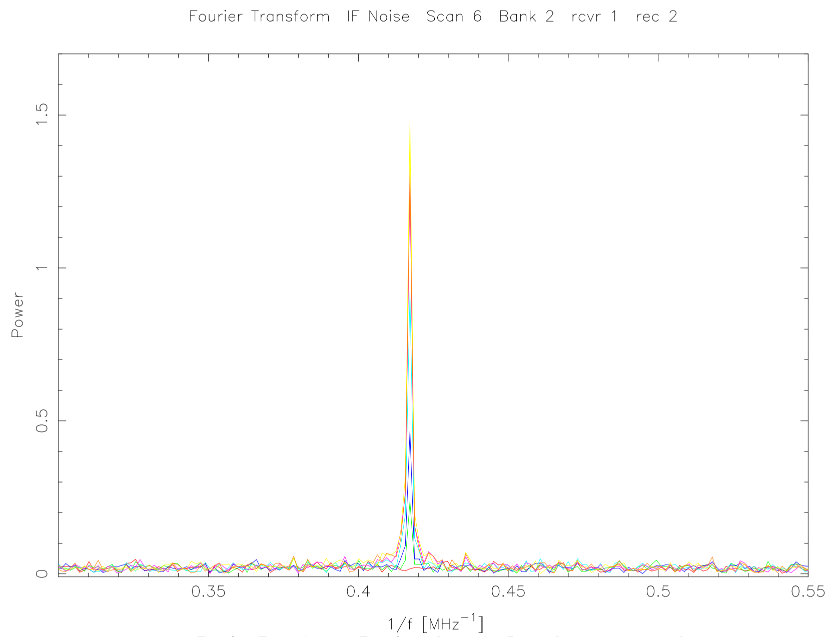


Figure 6: Fourier transform plots for the original external modulator in link number 5 spanning records 1–50. The transformed spectra were produced by calculating (Record N–Record 1)/ Record 1 where N = 2 (red), 10 (green), 20 (blue), 30 (green/blue), 40 (red/blue), and 50 (yellow). The bottom panel shows an expanded view.



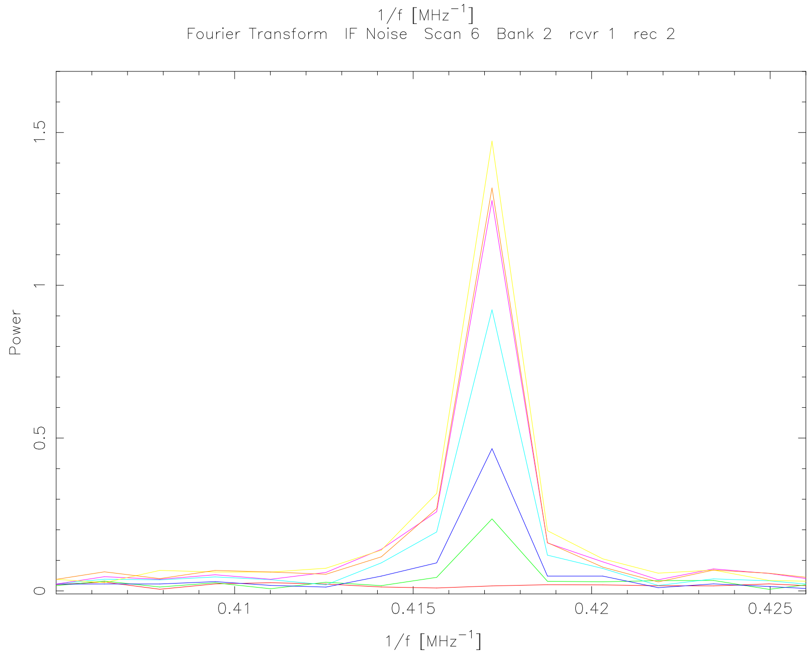


Figure 7: Fourier transform plots for the original external modulator in link number 5 spanning records 2–480. The transformed spectra were produced by calculating (Record N–Record 1)/ Record 1 where N = 2 (red), 50 (green), 100 (blue), 200 (green/blue), 300 (red/blue), 400 (yellow), and 480 (orange). The bottom panel shows an expanded view.

Synthetic on-off Measurements

On-off data were simulated by calculating (Sig–Ref)/Ref for consecutive groups of records to model total power observations. The data were divided into four groups of 100 records (50 minutes), each consisting of five on-off pairs. So each pair contained a total integration time of 10 minutes. Then these four spectra were averaged together for a total of twenty on-off pairs (200 minutes). The results are shown Figures 8–9 for ODM 1, Figures 10–11 for ODM 3, and Figures 12–13 for ODM 5. For all combinations explored the 2.4 MHz ripple is detected in the Fourier transform for ODM 1, 3, and 5. As with the results for ODM 2 the amplitude of the ripple is decreased when more data are averaged together.

The 60 MHz ripple, observed to be in the IF system, is detected in most spectra. For ODM 3 there were several records which produced zero-lag autocorrelations about a factor of two larger than optimal. On-off spectra produced with these records had very poor baselines. Figure 14 plots the pass band for record 61 and 71. Notice the large difference in power. The resulting (Sig–Ref)/Ref is shown in the bottom panel. All data used here are contained in scan 6, consisting of 480 continuous records. During this time period the attenuator values throughout the system were fixed. It is not clear what caused these changes in power.

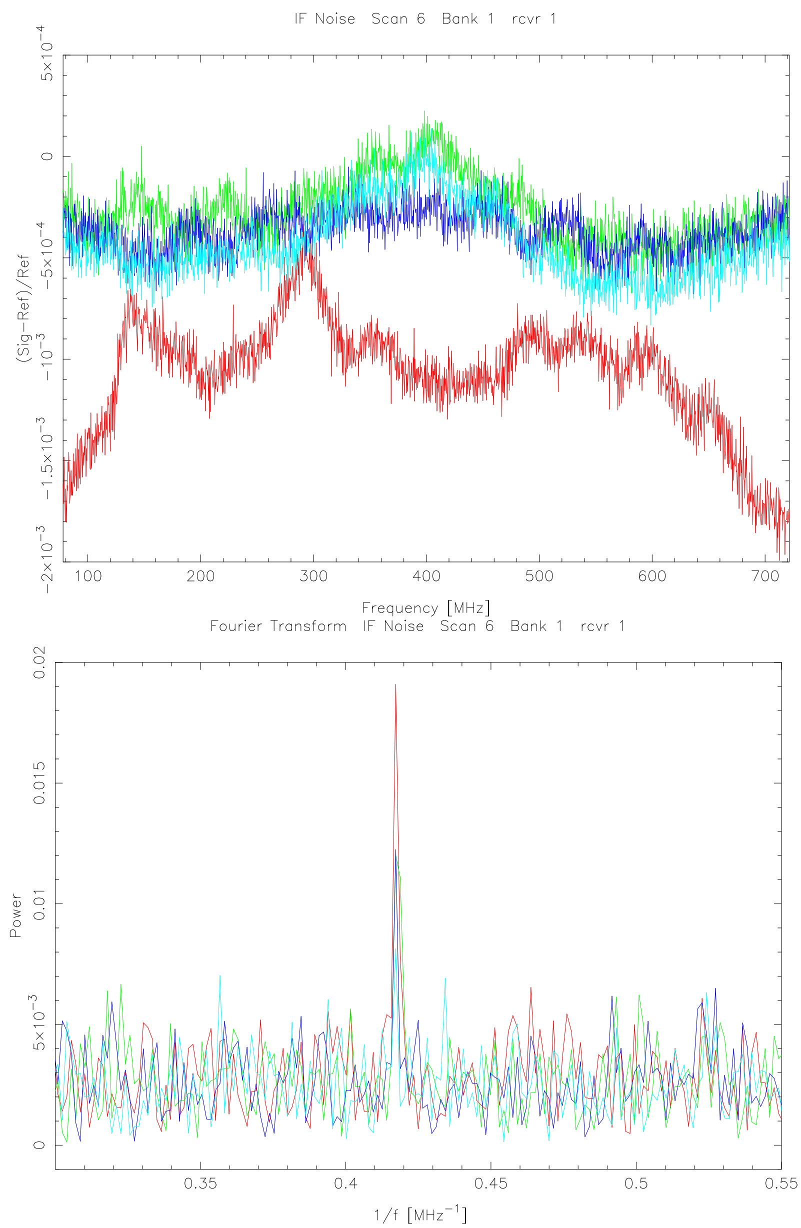
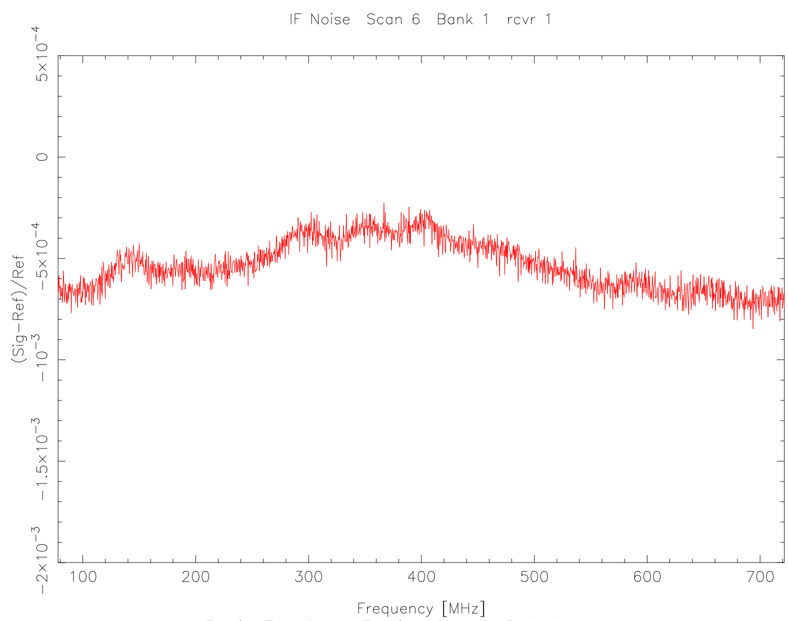


Figure 8: Top panel: IF noise source spectra for ODM 1 simulating on-off data with an integration time of 5 minutes. Each spectrum shown consists of an average of five on-off pairs for a total time of 50 minutes (100 records). Specifically each spectrum is calculated using (Sig–Ref)/Ref where Sig consists of records (1–10 + 21–30 + ...) and Ref consists of records (11–20 + 31–40 + ...). The four plots correspond to records 1–100 (red), 101–200 (green), 201–300 (blue), and 301–400 (green/blue). Botton panel: Fourier transform of the spectra in the top panel.



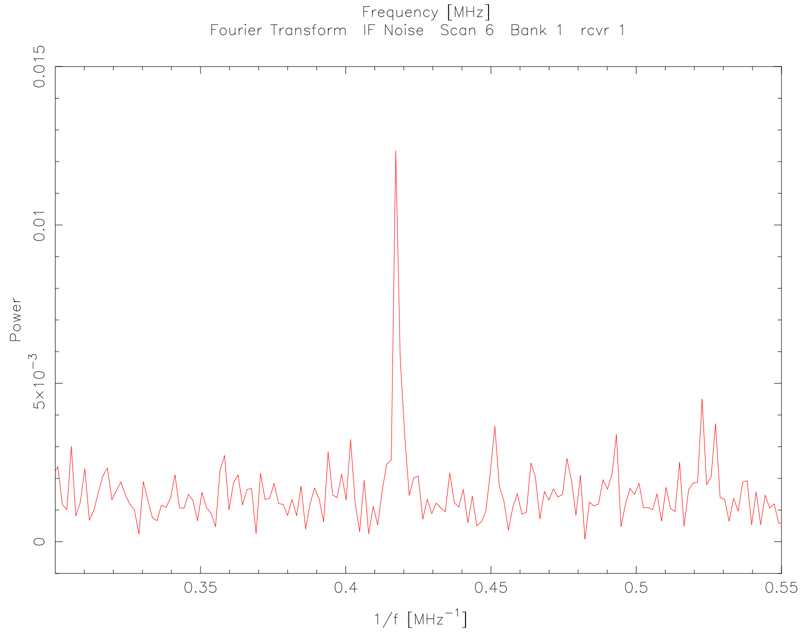


Figure 9: Top panel: IF noise source spectra for ODM 1 simulating on-off data with an integration time of 5 minutes. The spectrum consists of twenty on-off pairs for a total time of 200 minutes (400 records). Specifically the spectrum is calculated using (Sig–Ref)/Ref where Sig consists of records (1–10 + 21–30 + ...) and Ref consists of records (11–20 + 31–40 + ...). Botton panel: Fourier transform of the spectrum in the top panel.

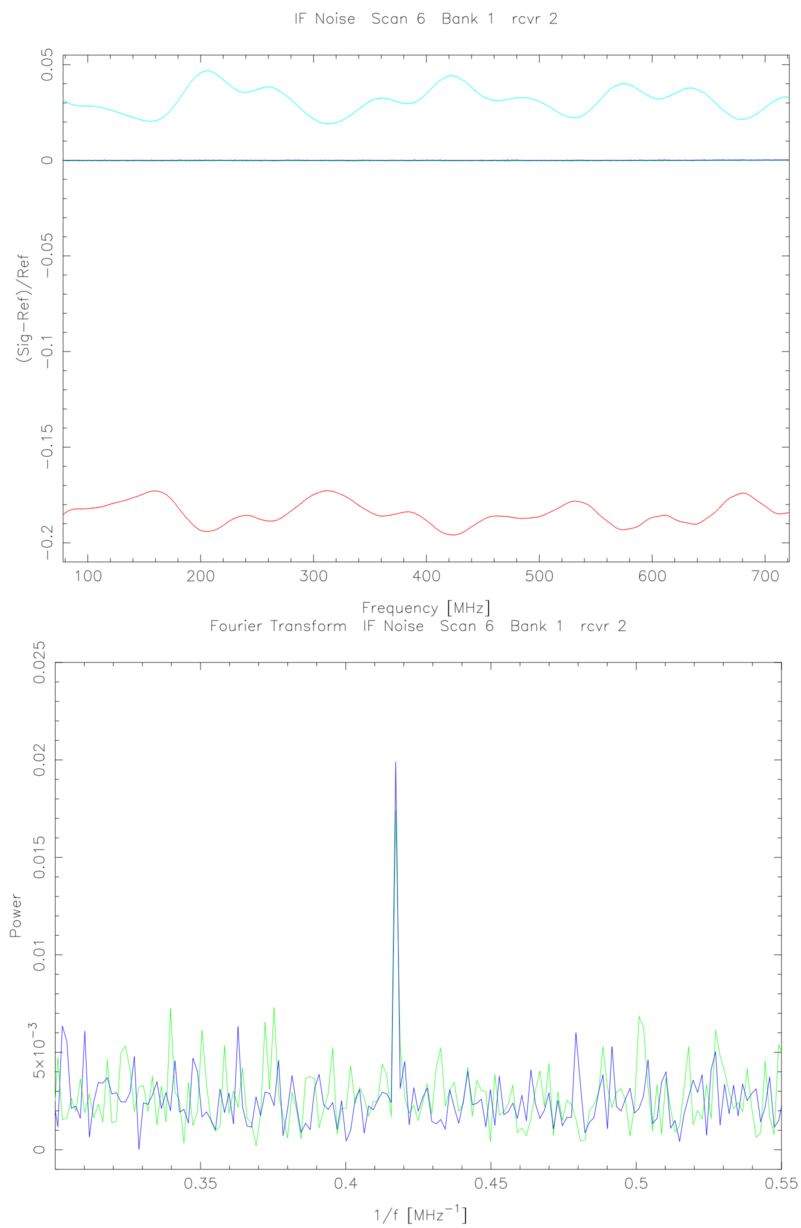


Figure 10: Top panel: IF noise source spectra for ODM 3 simulating on-off data with an integration time of 5 minutes. Each spectrum shown consists of an average of five on-off pairs for a total time of 50 minutes (100 records). Specifically each spectrum is calculated using (Sig–Ref)/Ref where Sig consists of records (1–10 + 21–30 + ...) and Ref consists of records (11–20 + 31–40 + ...). The four plots correspond to records 1–100 (red), 101–200 (green), 201–300 (blue), and 301–400 (green/blue). Botton panel: Fourier transform of the spectra in the top panel. Because of baseline problems record groups 1–100 and 301–400 were not included.

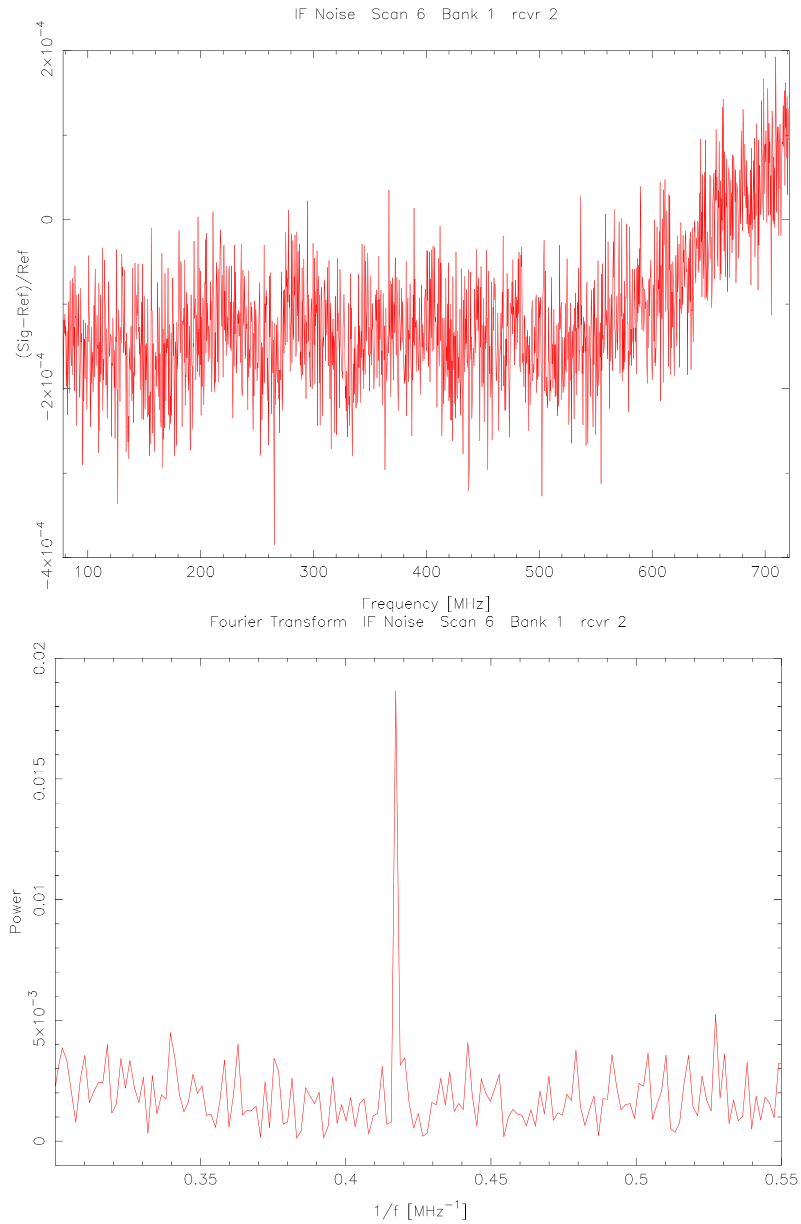


Figure 11: Top panel: IF noise source spectra for ODM 3 simulating on-off data with an integration time of 5 minutes. The spectrum consists of ten on-off pairs for a total time of 100 minutes (200 records). Only half of the data were used because of baseline problems. Specifically the spectrum is calculated using (Sig–Ref)/Ref where Sig consists of records (1–10 + 21–30 + ...) and Ref consists of records (11–20 + 31–40 + ...). Botton panel: Fourier transform of the spectrum in the top panel.

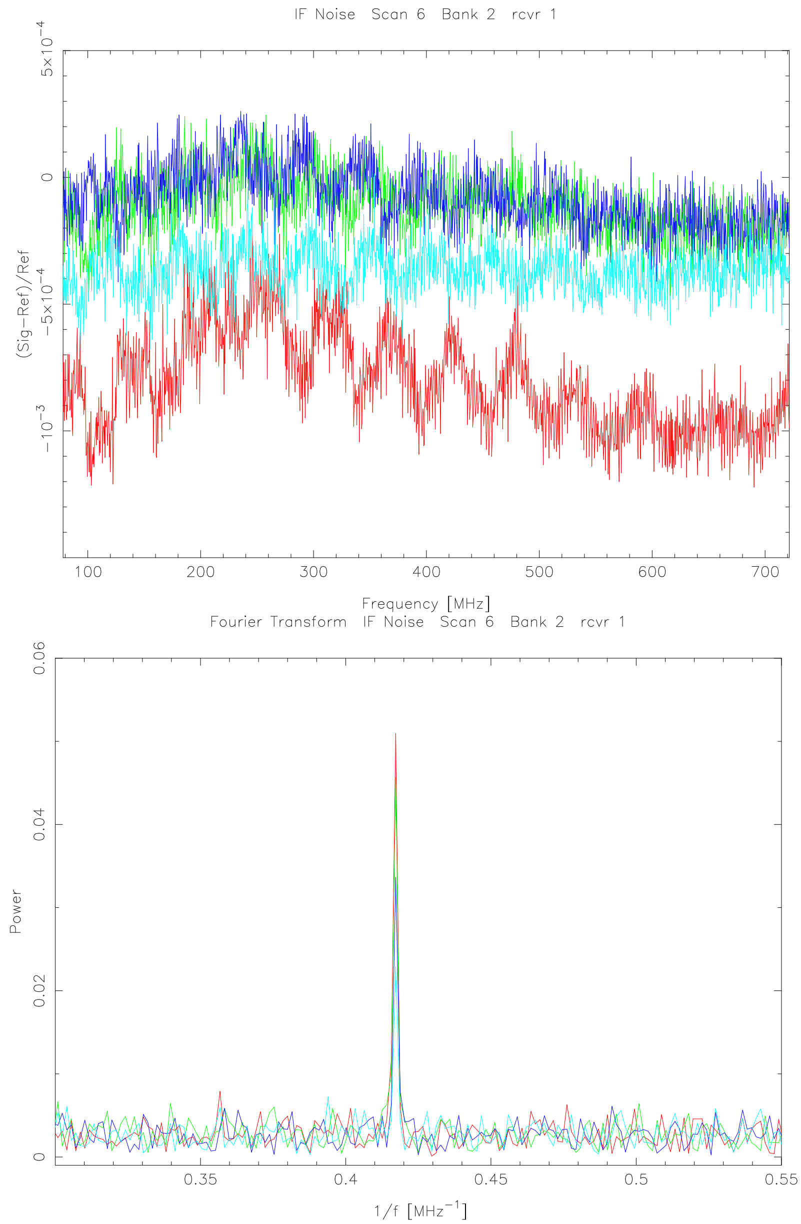


Figure 12: Top panel: IF noise source spectra for ODM 5 simulating on-off data with an integration time of 5 minutes. Each spectrum shown consists of an average of five on-off pairs for a total time of 50 minutes (100 records). Specifically each spectrum is calculated using (Sig–Ref)/Ref where Sig consists of records (1–10 + 21–30 + ...) and Ref consists of records (11–20 + 31–40 + ...). The four plots correspond to records 1–100 (red), 101–200 (green), 201–300 (blue), and 301–400 (green/blue). Botton panel: Fourier transform of the spectra in the top panel.

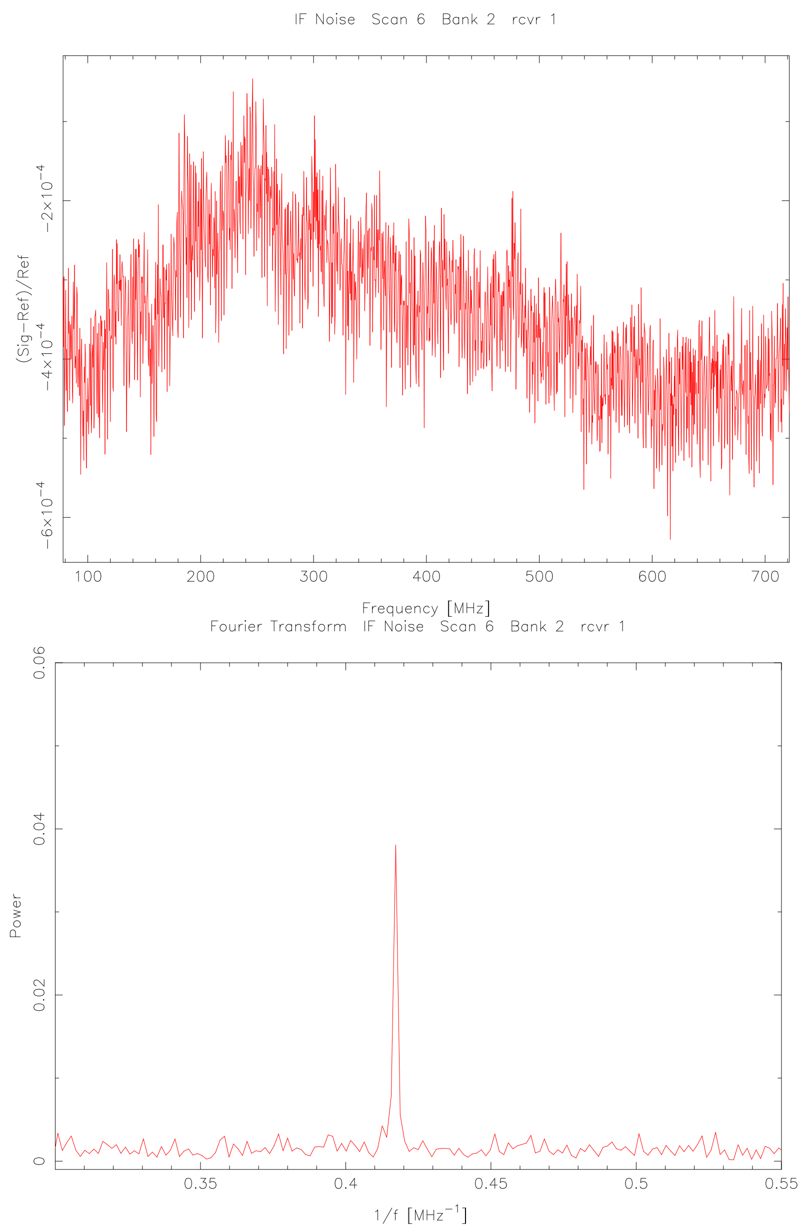


Figure 13: Top panel: IF noise source spectra for ODM 5 simulating on-off data with an integration time of 5 minutes. The spectrum consists of twenty on-off pairs for a total time of 200 minutes (400 records). Specifically the spectrum is calculated using (Sig–Ref)/Ref where Sig consists of records (1–10 + 21–30 + ...) and Ref consists of records (11–20 + 31–40 + ...). Botton panel: Fourier transform of the spectrum in the top panel.

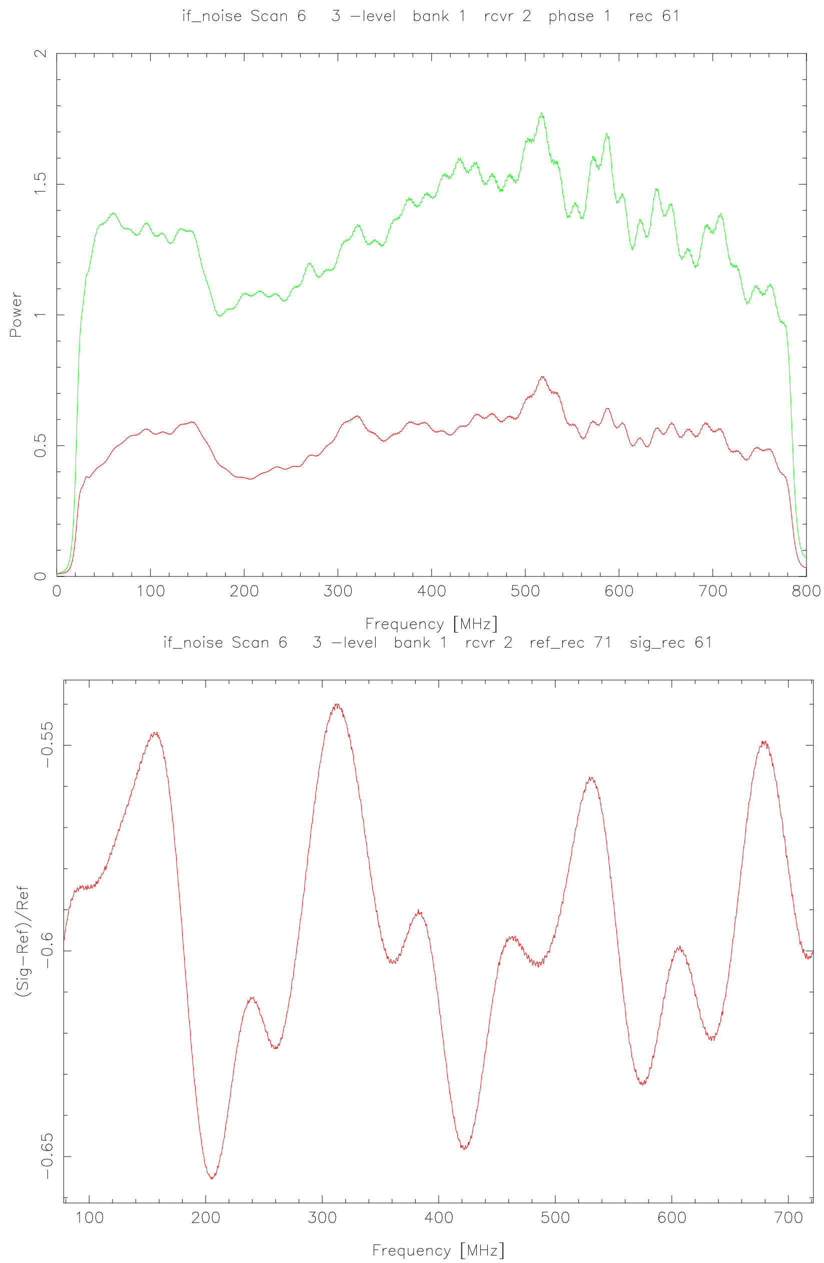


Figure 14: Top panel: Pass band for ODM 3 for records 61 (red) and 71 (green). Bottom panel: (Sig–Ref)/Ref where the record 61 is the Sig and record 71 is the Ref.