On-Air Test of the IIP Receiver Using Observations of an ATC Radar

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1 Introduction

This memo documents a quick sanity check of the IIP radiometer hardware developed to date, using observations of a nearby 1331 MHz air traffic control (ATC) radar previously described in [1]. These observations took place on June 18, 2002. The results indicate that the IIP radiometer architecture is reasonable and that it's key elements are functioning correctly, at least in prototype form. Our observations of radar pulses and their multipath components confirm that the dynamic range of the receiver is greater than 40 dB; that is, we can simultaneously detect pulses differing in strength by at least 40 dB without resorting to gain control. We also show some interesting features of the pulses themselves.

2 System Description

A block diagram of the system used in this experiment is shown in Figure 1. The discone antenna and "front end box" (containing a low noise amplifier and various other components needed near the antenna terminals) are shown in Figure 2 and are identical to those described in [1]. The front end box has a gain of about 26 dB, 3 dB noise figure, and 1-dB compression of about −30 dBm at the antenna terminals. The downconverter, shown in Figure 3, is identical to the proposed IIP design [2],

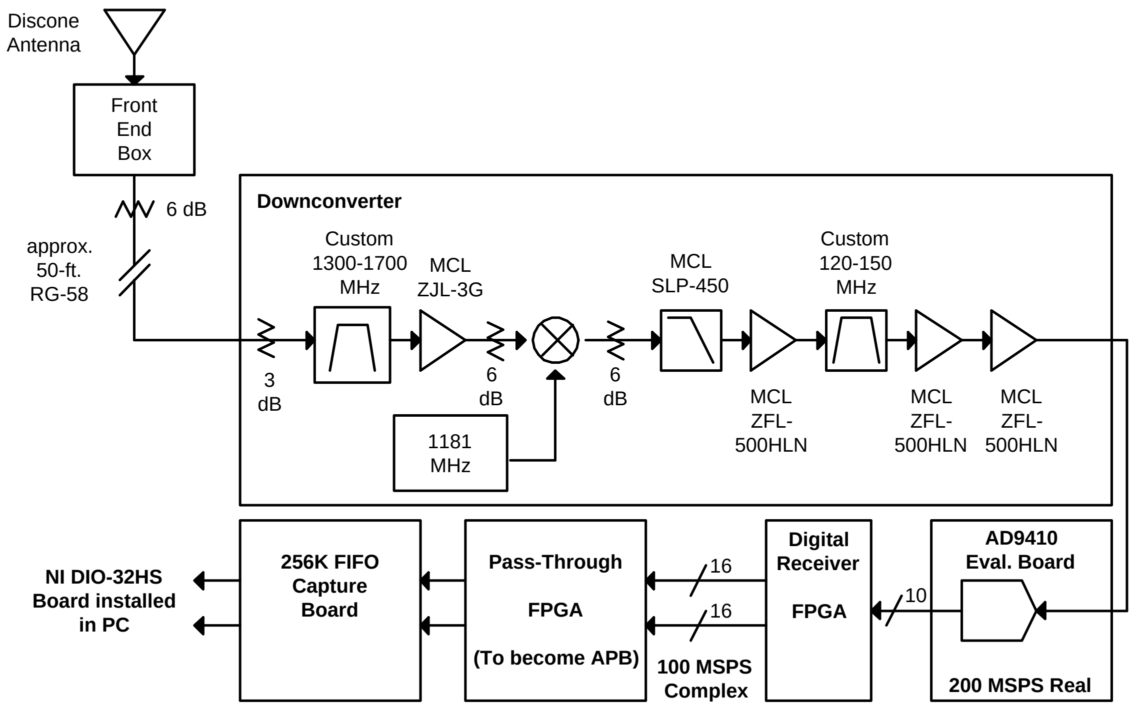

Figure 1: System used to perform the observations documented in this report.

except for the following: (1) the analog blanker and digital step attenuator are not yet installed, and (2) due to a problem with the LO synthesizer, the LO level at the mixer is only +2 dBm (+7 dBm is nominal) and there is no matching pad. The output of the downconverter is an IF signal bandlimited to 120 MHz – 180 MHz (60 MHz IF bandwidth). The analog IF is input to the A/D evaluation board / FPGA-based digital receiver board combination shown in Figure 4 and originally described in [3]. The A/D digitizes to 10 bits at 200 MSPS. The digital receiver FPGA does quadrature demodulation, filtering to 50 MHz bandwidth, and decimation to 100 MSPS. For the purposes of the testing described in this memo, the digital receiver output is captured using a 256K-sample FIFO described in [4], which also interfaces to a PC via a National Instruments PCI-DIO-32HS card. This setup allows capture of 2.62 ms blocks of contiguous data, and it takes about 1 s to transfer a block to the PC.

Figure 2: Antenna and front end box, as mounted on the roof of ESL. The antenna is about 10 m above ground level.

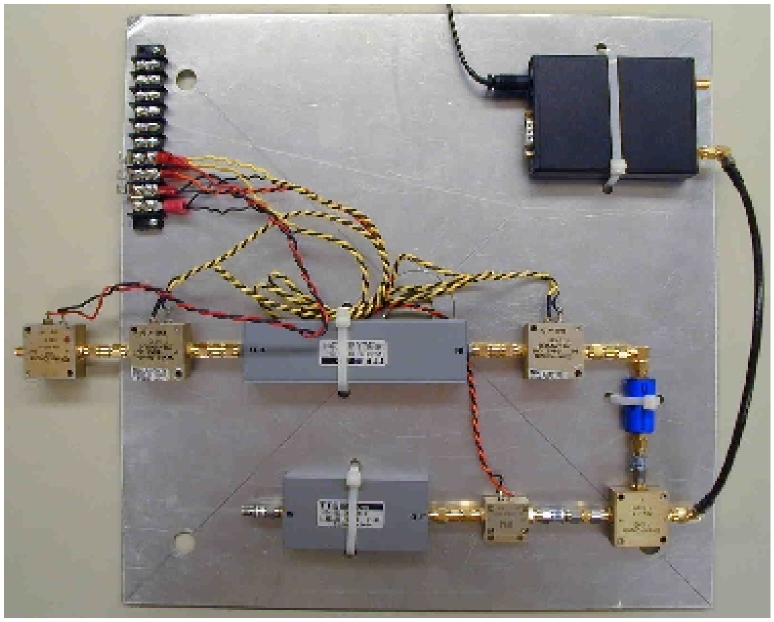

Figure 3: Interim downconverter.

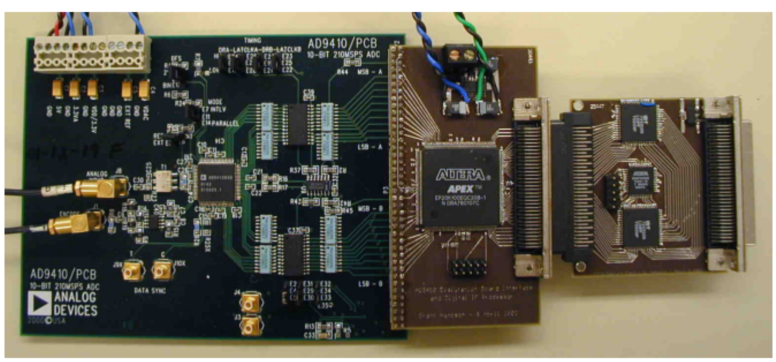

Figure 4: Digital IF hardware. Left to right: A/D board, Digital Receiver board, 256K-sample FIFO Capture board.

3 Radar Pulses

As noted in [1], our local 1331 MHz radar is believed to be located at an ATC station in London, OH, approximately 43 km distant. This radar transmits pulses about 2 μs long every 3 ms, with 3 MW peak power. Therefore, we capture at most 1 pulse per block. Also, since the radar is usually pointing away from us and our detection criterion is quite conservative (as will be described below), we found that most blocks did not appear to contain pulses.

We collected a set of blocks that did contain radar pulses as follows. After each block was captured, it was examined to determine if any samples with magnitudes dramatically greater than those of the background noise were present. The threshold value was chosen based on our subjective judgement that it seemed to yield captures containing clearly-recognizable pulses. If a sample block satisfied this criterion, that block was saved; otherwise, it was discarded. Using this method, 82 blocks containing pulses where obtained over a period of 10 minutes and 47 seconds. In other words, about 13% of the captures were judged to contain pulses.

The largest pulse detected contained a peak magnitude of about 19145 in the natural units of the digital IF output. The magnitudes of the samples in this capture are shown in Figures 5 and 6. Note that the pulse is very distinct. It is about 2 μs long with an additional 1 μs of decay time. Figures 7 and 8 show the spectrum of this pulse. Note that the bandwidth (measured null-to-null) is about 1 MHz. Note also that the dynamic range of the reciever as implied by this spectrum is at least 40 dB.

Also, we shifted the center frequency of this pulse to approximately zero and plotted the phase trajectory of the samples in order to view the modulation; the result is shown in Figure 9. This figure suggests that the modulation within the pulse is CW.

Figure 10 shows the six biggest pulses observed. Note that an apparent multi-path pulse appears with about 13 μs excess delay in each case. This excess delay corresponds to an additional path length of about 3.9 km. Three possible sources

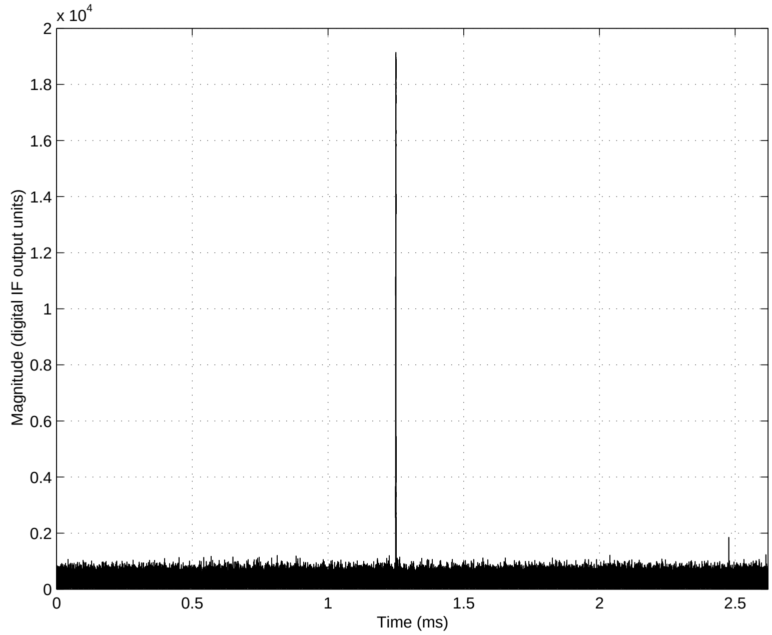

Figure 5: Largest detected radar pulse (complete capture of 256K complex samples at 100 MSPS).

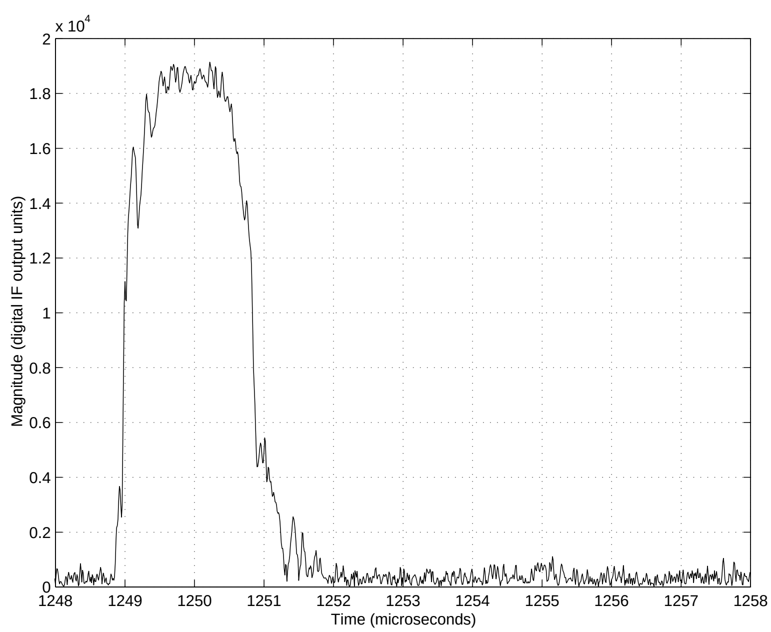

Figure 6: Same as Figure 5, zooming in. 1K samples.

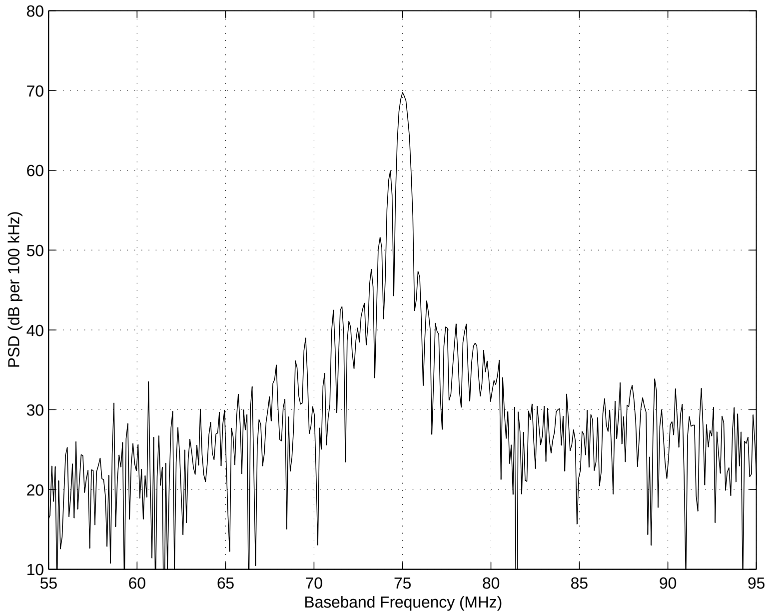

Figure 7: Same 1K samples shown in Figure 6 after FFT (no window). Zooming in to show spectral features associated with pulse.

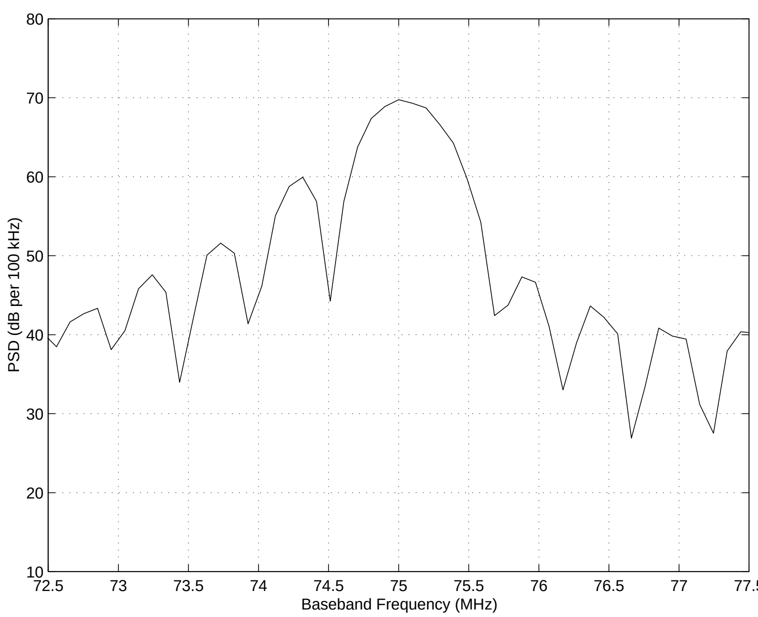

Figure 8: Same as Figure 7. Zooming in further.

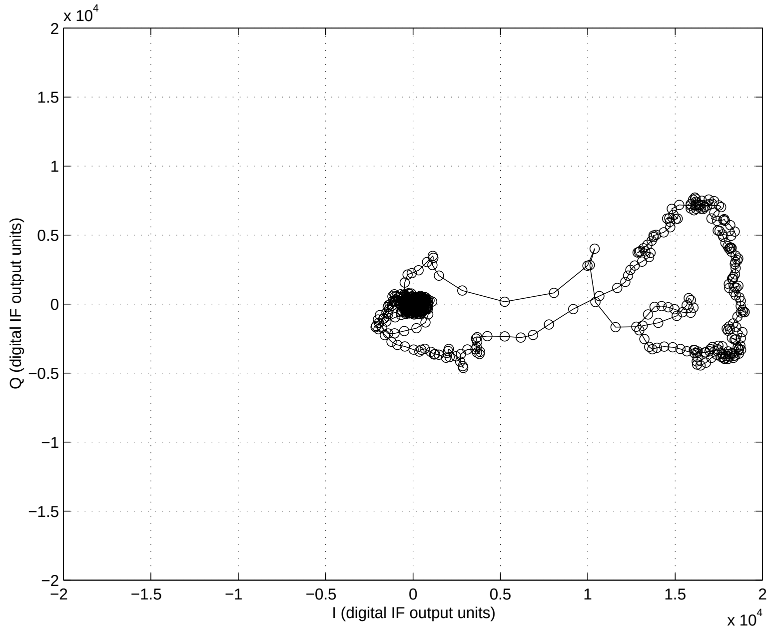

Figure 9: Same 1K samples shown in Figure 6, plotted in real-imaginary coordinates after attempting to shift the center frequency of the pulse to zero. Sample values are denoted by ∘, time order indicated by connecting lines.

for this multipath are the prominent tall buildings on the OSU campus – Lincoln, Morrill, and Dreese – each of which about 3.3 km from ESL. The taller buildings of downtown Columbus are also possible sources, but are much further away. Also, note that the multipath is clearly visible even though it is up to 40 dB weaker than the earlier pulse. Since no form of gain control was used, this confirms that our receiver's dynamic range is greater than 40 dB.

Figure 11 shows six more pulses, selected because they display interesting features. (a) shows a pulse with a complex decay and at least one more multipath pulse, possibly indicating close-in multipath. (b) shows an example with a very strong multipath pulse (-17 dB relative to the early pulse) at about 4 μs (1.2 km). This multipath pulse cannot be attributed to any terrain feature at that range; here, a reflection from an aircraft may be a better explaination. (c) is remarkable because it's multipath pulse is only about 10 dB down. In (d), (e), and (f), we see examples where the earliest pulse is not the strongest. Again, this could be due to reflections from aircraft.

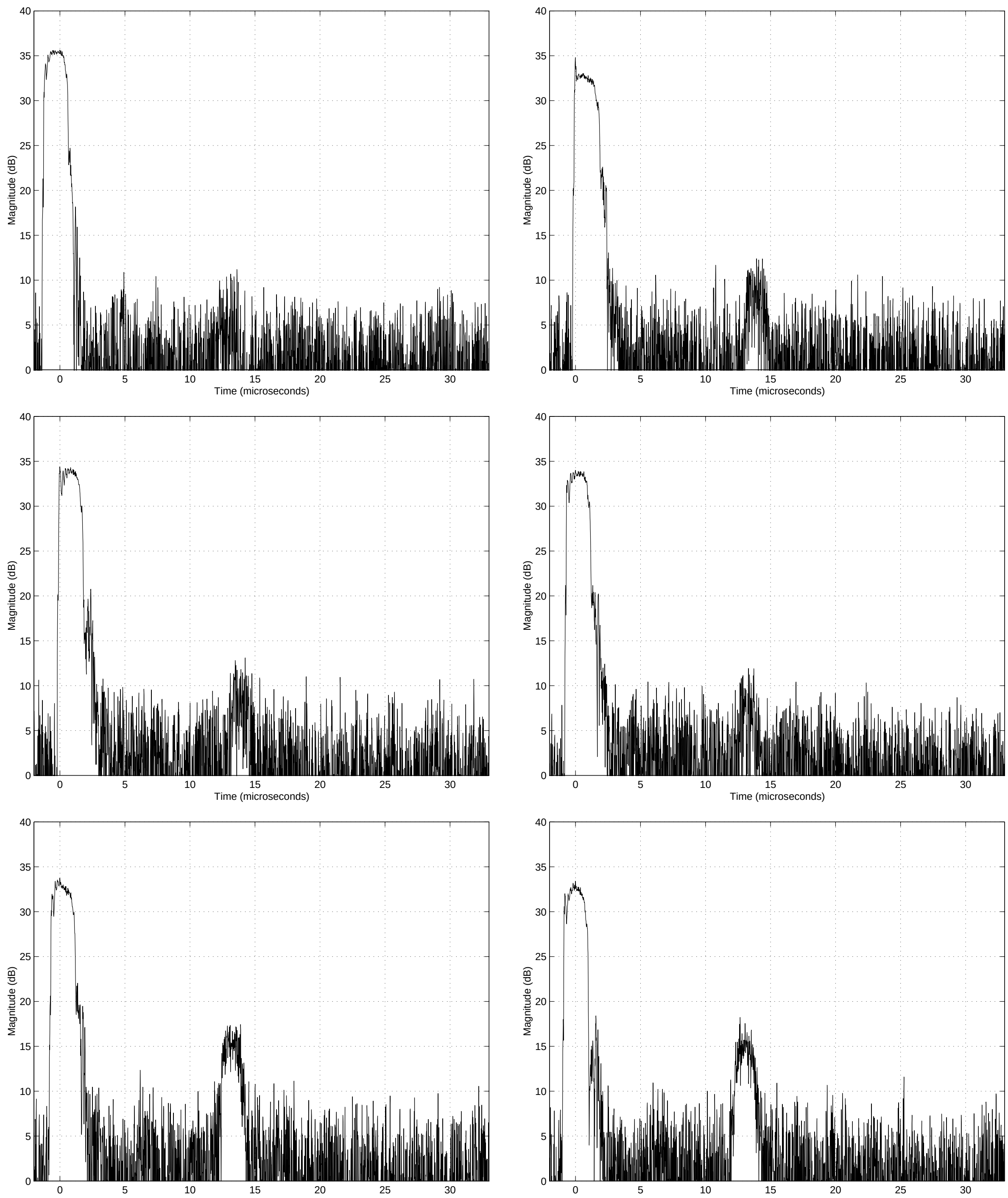

Figure 10: Biggest Pulses and their associated multipaths.

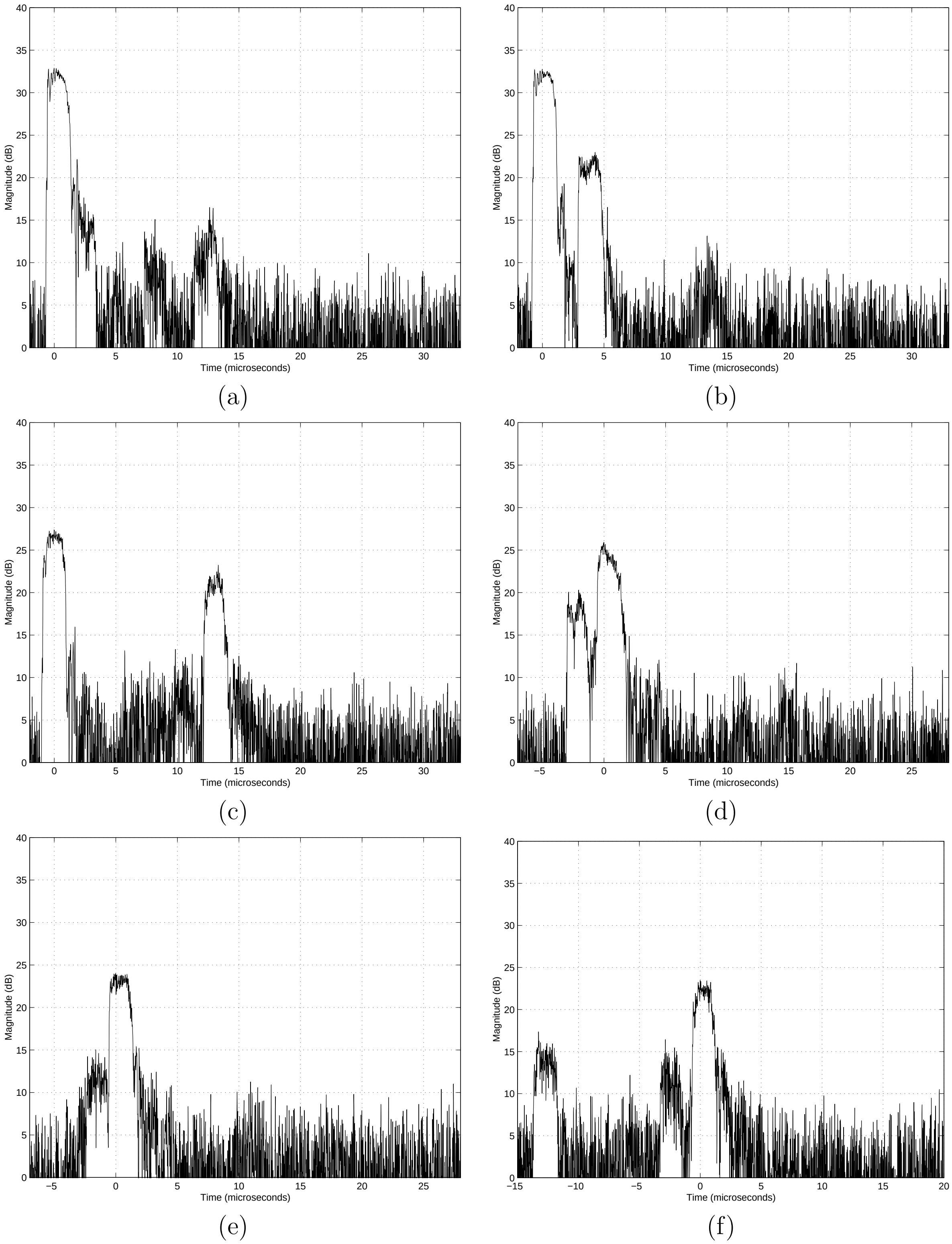

Figure 11: Interesting Pulses.

References

[1] S.W. Ellingson, "Preliminary RFI Survey for IIP", IIP Memo 21, The Ohio State University ElectroScience Laboratory, June 11, 2002.

[2] S.W. Ellingson, "Front End Version 1 Design", IIP Memo 7, The Ohio State University ElectroScience Laboratory, February 22, 2002.

[3] G.A. Hampson, "Implementation Results of the Digital IF Processor", IIP Memo 19, The Ohio State University ElectroScience Laboratory, May 15, 2002.

[4] G.A. Hampson, "A 256K @ 32-bit Capture Card for the IIP Radiometer", IIP Memo 17, The Ohio State University ElectroScience Laboratory, May 10, 2002.