New Folder Name Notes on Pulses

~~A1 43 %~~ ~~A2 43%~~
~~-0.175~~ ~~-0.224~~

8/21/92

Swept sine	~~DRSS0~~	DRSS1
Raw Strain Output	~~DRN0~~	DRN1
Calibrated noise spectrum	~~DRC0~~	⋮

Gain of Ch 1 may be 5, not 2.

Calibration signal 10.6 mV RMS ÷ 10 @ 1.23 kHz into Huey 1 Ω calibrator

To do swept sine: ~~take~~

1. Take out attenuator
2. Change source level to 10x higher (110 mVrms)
3. Range on input
4. Swept sine 1 Hz - 5 kHz swept down

~~14:10 Started writing header~~
~~14:11 Started writing data~~

Freq = 157894.7368421052 5

Events

14:35 Started writing header
14:36 Started writing data w/ line calibration
14:38 Flipped gain to 11.
14:39 Dropped out of lock
14:41 Reacquired (and flipped back to 11)
14:44 Dropped out & turned off calibration
14:45 Reacquired (and flipped 11)
14:56 Greg called (computer room)
15:00 Dropped out & reacquired, back to 11.
15:06 Dropped out
15:08 Reacq & 11
15:25 Dropped out & reacq and 11.
15:27 Fred called (control room)
15:45 Dropped out in-out-in
15:56 Dropped out
16:00 Back in & on
16:02 Left (turned gain to 1)
16:13 Came back & flipped gain up ~~&~~ dropped out

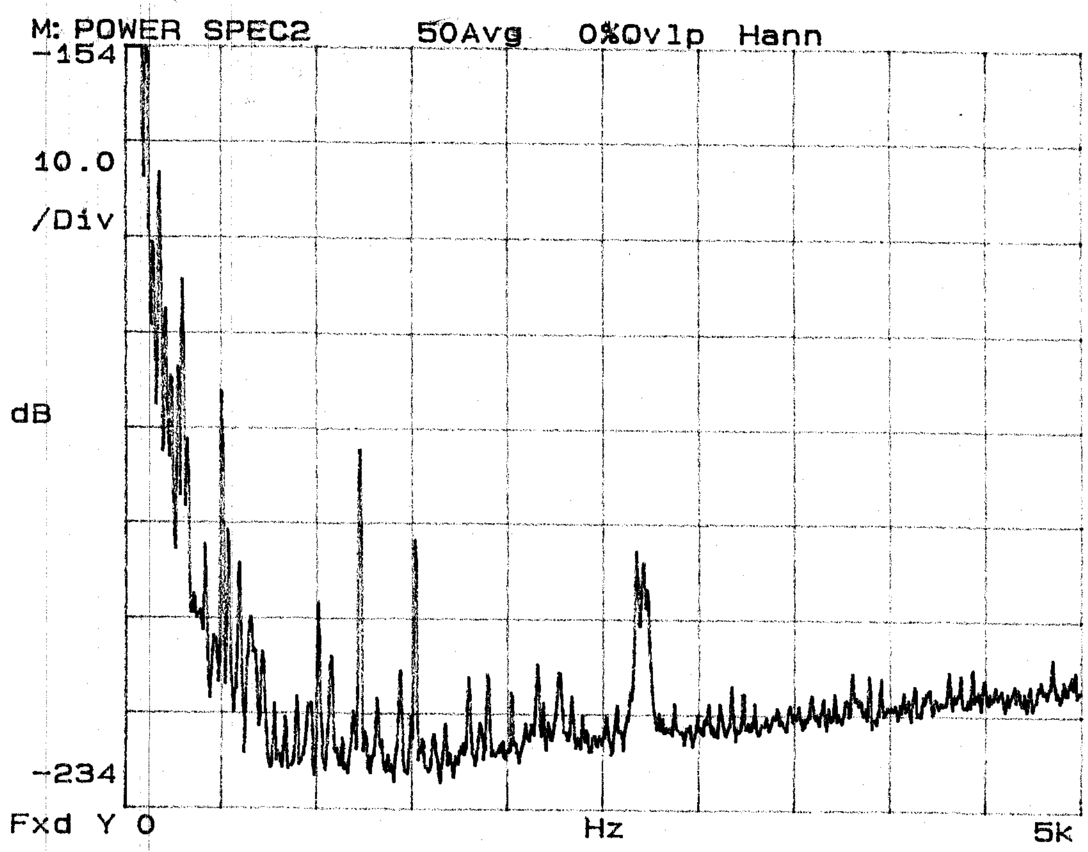
21 AUG 92 PRG DATA RUN NOISE

17:50

CALIBRATED SPECTRUM.

"DRCO" ON 27.01

$$\frac{DRNO}{DRS50(j\omega)^2}$$



21 AUG 92
13:35

A0 50% V/S
A1 55% V/S .131 V locked
A2 55% V/S .182V locked

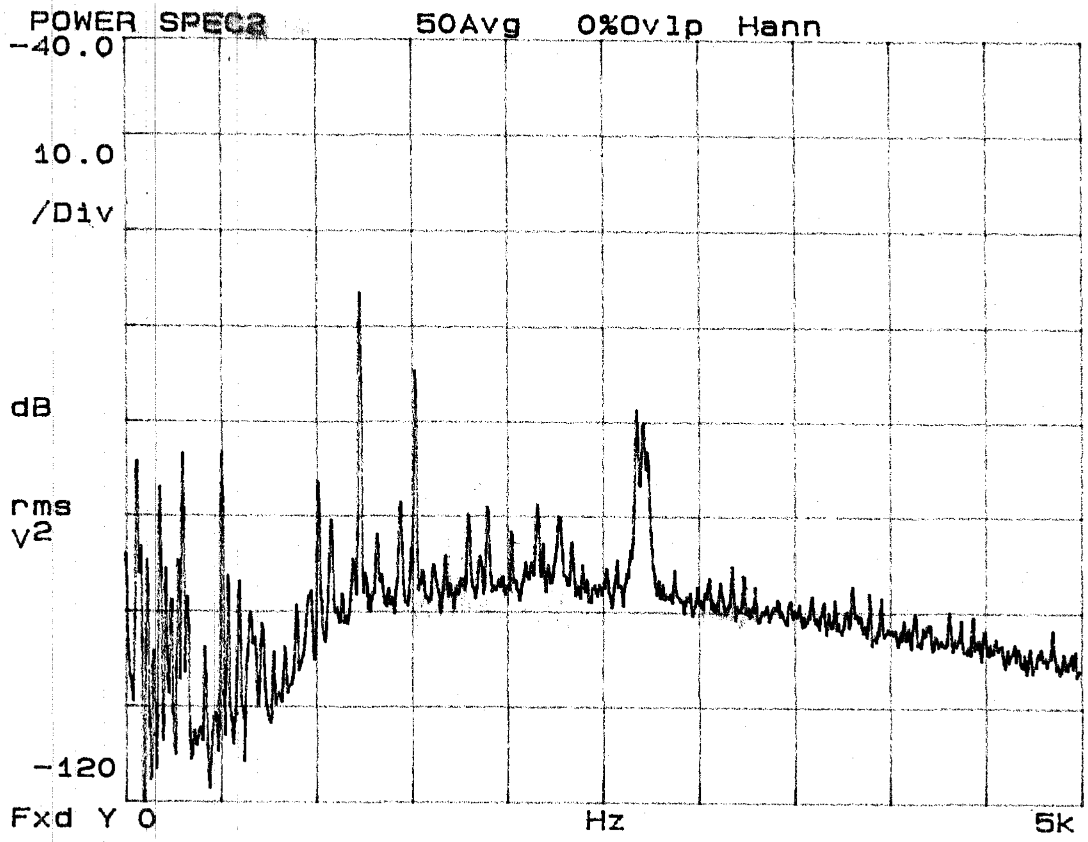
110mV rms → A1
CALIBRATOR
COIL DRIVER GAIN = 5.0

"DR550"

DATA RUN SWEPT SIN 0

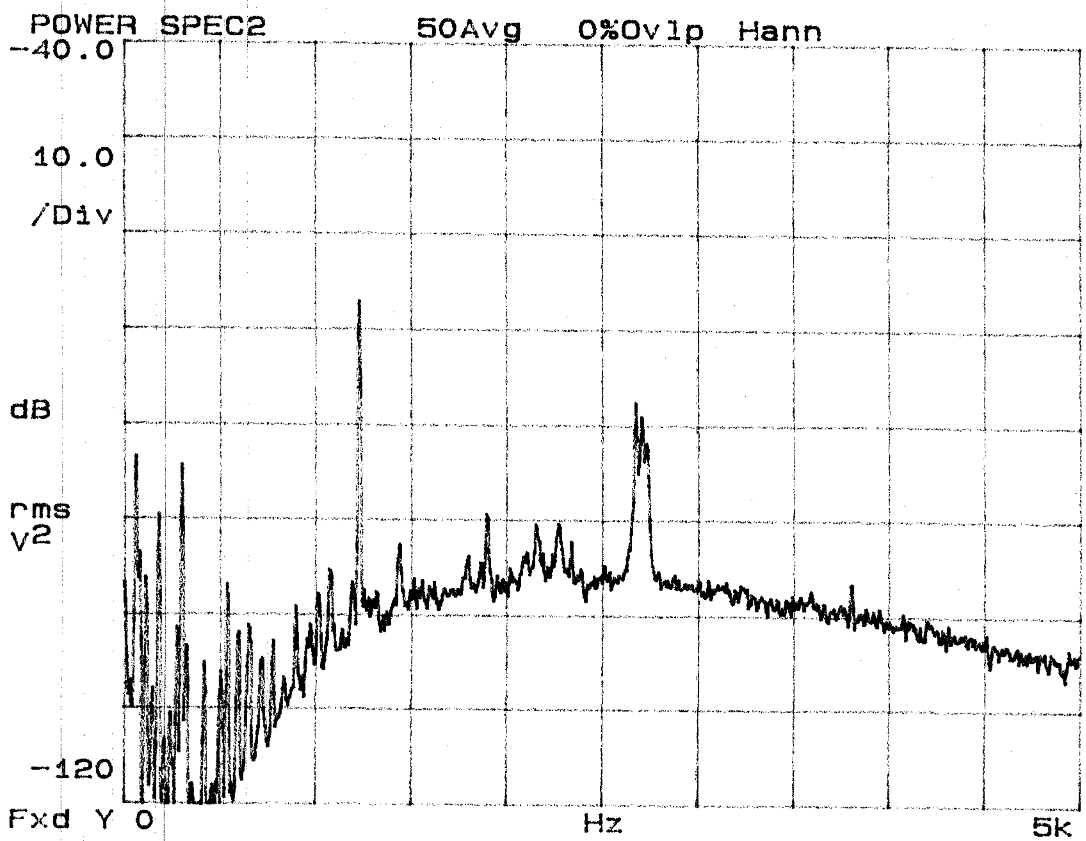
DISC 27.01

21 Aug 92
13:49



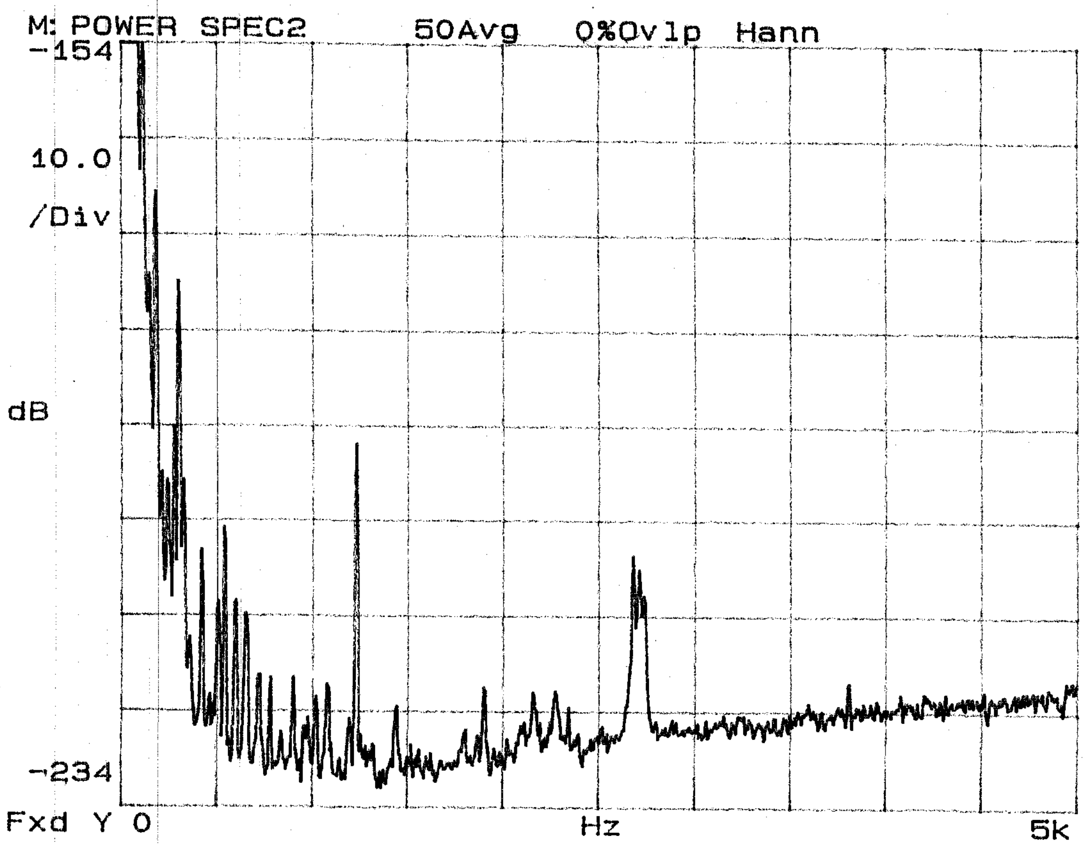
"DRNØ" on disk 22.01.
Data run noise spectrum Ø

8/21/92 19:25 TTL Uncalibrated Noise spectrum DRN1 in disk 27.07



8/21/92
19:30

Calibrated Noise Spectrum



DRC1 in disk 27.01
After data run

Data Run of 40m Interferometer

Channels are same as run on 8/12/92. In brief:

fast	0	Strain, BP 200 - 2 kHz, x 200
	1	First Arm PreAmp, 3 kHz LP, x 2
slow	2	Primary Reflected (no filt)
	3	Secondary Reflected (no filt)
	4	Laser Slow PZT (no filt)
	5	Seismometer, BP 0.03 - 100 Hz, x 2k
	6	Microphone, BP 0.03 - 300 Hz, x 10k
	7	DC coupled Strain, 80 Hz LP, x 1

Requested overall sampling rate is: 160 kHz
Actual = 157894.73684210525 Hz

Command: `tapesave -v -f 160000 -n 8 -p 2 -s 10`

Tube voltage @ start 413V at 35.0 A and 0.58 W output at 18:00.
Laser ~~autofill~~ fill off.

A0 & A2 visibilities gradually got worse. At ~1pm tried to take spectra.
Tuned vis. up to A0 = 55% ~~at~~ A1 = 43% max, A2 = 44% max. Took
DRBN1, DRBSS1, DRBC1 ← incorrectly set on freq resp.
DRBN2, DRBSS2, DRBC2
Both of these are very low. I am confused.

The thermometer was strapped to the optics table near the laser output coupler.

Temperatures from Data Run

Time	Temperature	
18:00, 8/24/92	21.6	laser tube voltage = 413V @ 35.0A and 0.58 W output
18:34	21.6	
19:00	21.6	
19:30	21.6	
20:01	21.6	
20:37	21.6	
21:00	21.5	
21:33	21.5	
22:05	21.6	
22:36	21.5	
23:01	21.5	
23:30	21.6	laser tube voltage = 412V @ 35.0A and 0.56 W output
00:30	21.5	
1:00	21.6	
1:45	21.6	
2:00	21.6	
4:18	21.5	
4:44	21.6	
5:25	21.6	
6:00	21.7	
6:30	21.7	
7:00	21.8	
7:30	21.7	
8:45	~~21.6~~	Tube voltage 411V, 35A, ".55W" after alignment
9:36	21.6	
10:50	21.6	
11:40	21.6	
12:25	21.7	Tube voltage 411V, 35A, 0.57 W after alignment
13:00	21.9	
13:30	21.9	
14:07	22.0	
14:45	22.0	
15:15	22.1	Tube voltage 410 V, 35A, 0.60W
15:40	22.1	
16:40	22.1	
17:00	22.0	
18:00	22.05	

Events from Data Run 24-25 AUG 92

Time (computer clock)	Event
18:34, 8/24/92	Started writing, with sine
18:38	Stopped calibration sine
18:39	Bob momentariary unplugged channel 3 signal
18:51	Unplugged vis mon to setup monitoring on storage scope
19:15	Tour de Lab recentering spots on pointing diodes
19:22	Route noise eater monitor into control room
19:43	Touch up visibility: PC to 52% SC to 53%
20:12	Out of Lock
20:15	Out of Lock, Primary in TEM02
20:18	Out of Lock
20:37 - 20:44 ?(22:37-22:44)?	Return everything, knocking out of lock in the process — PC vis is 49% 2nd in 50% includes returning laser.
23:54	Tried lowering LN orientation gains by factor of 2 to get rid of 4 Hz oscillation we see in DC strain. No noticeable effect so reversed.
00:30, 8/25/92	Realized tape had stopped. Tuned up visibilities. Tried to take spectra. Could not even get 55% vis. on A1 & A2 but got 55% on AØ. Disengaged solenoid interlock briefly.
1:49	Started writing TAPE 2 with sine. A1 = -0.176 V, A2 = -0.249 V Laser power 0.56 W. AØ = 54% A1 = 42%, A2 = 42%
1:58	Stopped calibrated sine.
2:20	Fell out of lock.
2:23	Out of lock again. Noticed spot on HN is fairly far displaced from center. (Inwards horizontally almost 1cm.)
4:18	Lost lock
~~4~~:44	Lost lock
5:25	Lost lock (Laser still at 0.56 W) Visibilities are good
5:45	Large truck went by; took speed bump slowly.
6:00	Lost lock. Reset ~~la~~ slo pzt. Took long time to acquire.
6:30	Lost lock. Retweaked laser to 0.59 W MC vis to 56%, A1 vis to 40%, A2 vis to 40% Finished tweak at ~~6:39~~ 6:43
6:45	Out of lock; interferometer has large dc.
6:58	Lost Lock

25 AUG 92

7:03 Reacquired A2 w/ low DC; unfortunately Slo PZT is nearly out of range

Forced laser to reacquire!

7:09 Back in lock w/ more range on Slo PZT & A2 w/ low DC

7:30 Lost lock; closing tape

7:47 Starting tape 3

7:53 Stopped sine; then lost lock after acquir spectrum

7:55 Reacquired lock; laser @ 0.57 W

visibilities	
HC	54%
A1	38%
A2	39%

8:28 Blk 492 Realign

Out of lock levels $A_1 = .321$ V $A_2 = .455$ V

8:40 Adjust power stabilizer battery for .303, .430 V out of lock.
→ .434

PRIMARY IN LOCK NOW .170
CALC VIS: 44%
Meter: 42%

Tube Voltage 411V .55W after alignment

9:00 A_2 locked

	A_0	A_1	A_2
~~Meter~~ VIS. MTR.	56%	42%	42.5%
DVM IN LOCK:		.169V	.236V

Power stab. 1201 output: +20 mV

SPOT POSITIONS: HN (-2, -2) mm Facing Mass
H (-2, -2)
LN (0, 0)
L (0, -2)

25 Aug 92

9:07 (#941) 10.6mV rms swept sin inserteded

9:19 # 1069

9:24 out of lock momentarily

9:26 DRBN3 recorded

9:29 swept sin started
9:30 swept sin completed — stored as DRBSS3 (without $j\omega^2$)
9:32 calibrated spectrum $\frac{DRBN3}{(j\omega)^2 DRBSS3}$ Saved as DRBCS PASTED in BOOK 27, p. 41Y

9:36 T = 21.6 °C R.S. Returns to control room at record # 1294

10:06 Telephone calls forwarded from x3979 to x3980 (Phone rang at 10:05?)

10:24 2ndry out of lock ~ 50 sec.

10:35 (#977) Track; shift of ~ -.7V in average level of 2nd arm coil driver output [CABLE #6, goes to "4" on BNC patch panel]

11:08 Primary loses lock (piezo slow voltage at negative rail), pulls 2ndry out

11:10 Reacquired

11:10–11:12 realign A₀ 52%
A₁ 43%
A₂ 42%

11:37 Primary drops out again

A₀ 59%
A₁ 40%
A₂ 40%

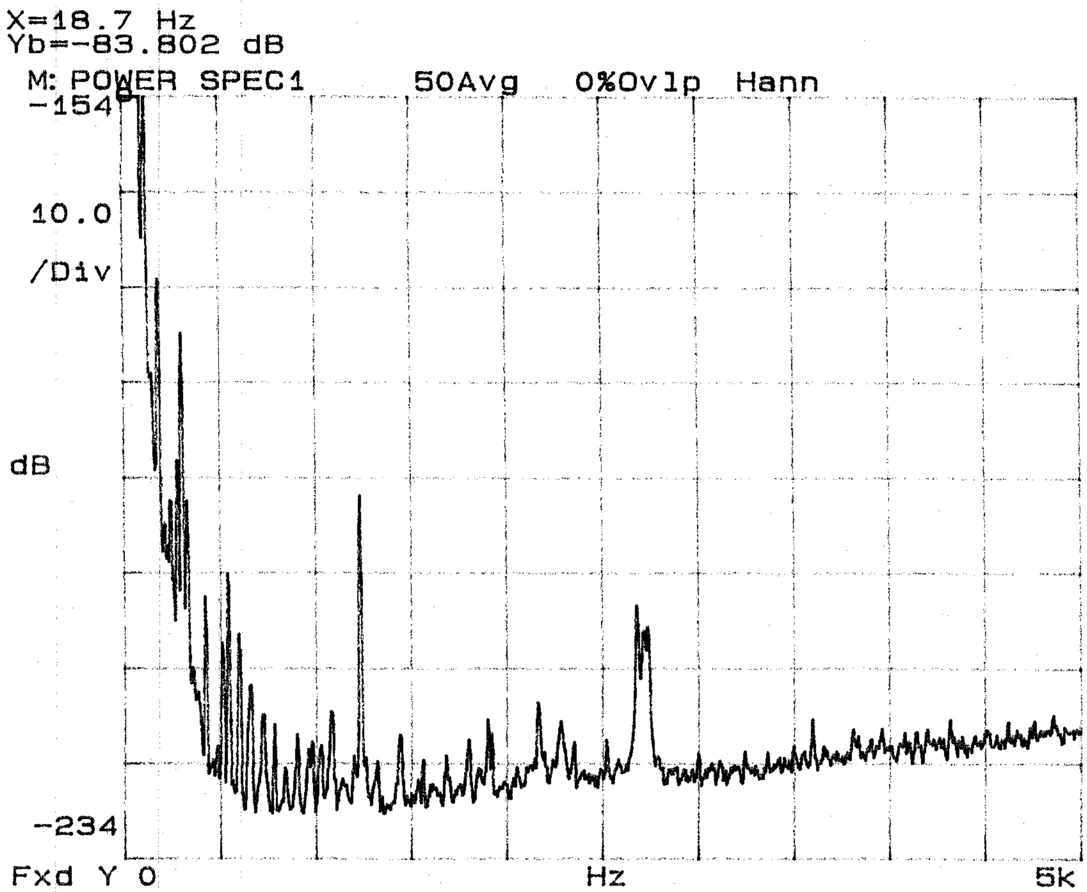
11:49 Reacquire

12:08 Another dropout!
12:09 Reacquire
12:25 Dropped out. Tuned up laser to 0.57 W. A₀ = 53%.

12:49 Dropped out of lock.
12:52 Dropped out.
12:57 Dropped out. Tuned A1 vis. to 39% max. ~~A2 = 39%, Aϕ = 52%~~
13:01 Reacquired
13:27 Started calibrated sine
13:33 Stopped tape #3. Took DRBN4, DRB~~S~~4, DRBC4.
Vis: Aϕ = 52%, A1 = 40%, A2 = 39%, laser = 0.60 W.
-0.176, -0.253
14:01 Started tape #4. Had tuned up Aϕ vis. Now, Aϕ = 54%, A1 = 39%, A2 = 39%, laser = 0.58
Using calibrated sine.
14:07 Stopped calibrated sine.
14:08 Out of lock.
14:20 Out of lock. Did not turn back to ll immediately. Guy walked by laser.
14:24 Out of lock
14:25 "Incomplete transfer on path 1, items done: 229440000" D-A warning issued.
Taped stopped writing
14:30 Halted tape writing (already was in reality) and started it again on tape 4. I picked up writing again on chunk 287. (5.1s/chunk)
14:37 Out of lock.
14:39 Reacquired. A1 vis. fallen to 36% & A2 to 34%. Trying to tune up...
Got maximums of Aϕ = 55%, A1 = 37%, A2 = 38%.
14:47 Finish tuning up visibilities.
15:02 Dropped out of lock.
15:11 Dropped out. Started showing John around.
15:37 Finished Tour with John. Dropped out 2 while touring
16:37 Dropped out of lock. A1 vis. had dropped to 32% and A2 to 30%.
I maximized them both and got Aϕ = 56%, A1 = 35%, A2 = 35%.
16:54 Finished adjusting mirrors.
17:25 Dropped out of lock.
17:48 Noted oscillation in noise eater at ≈ 83 Hz. Tried switching noise eater of as Bob suggested. Oscillation was still visible and worse on reflected light from A1 & A2. This has been causing quite a lot of glitching.
≈18:00 Mike came in and determined that the oscillation were mode cleaner thermal relaxation oscillations.
18:10 Stopped tape 4.

8/24/92 TTL
18:00

Calibrated Noise Spectrum



	Visibility	
A0	64%	
A1	55%	0.140
A2	55%	0.192

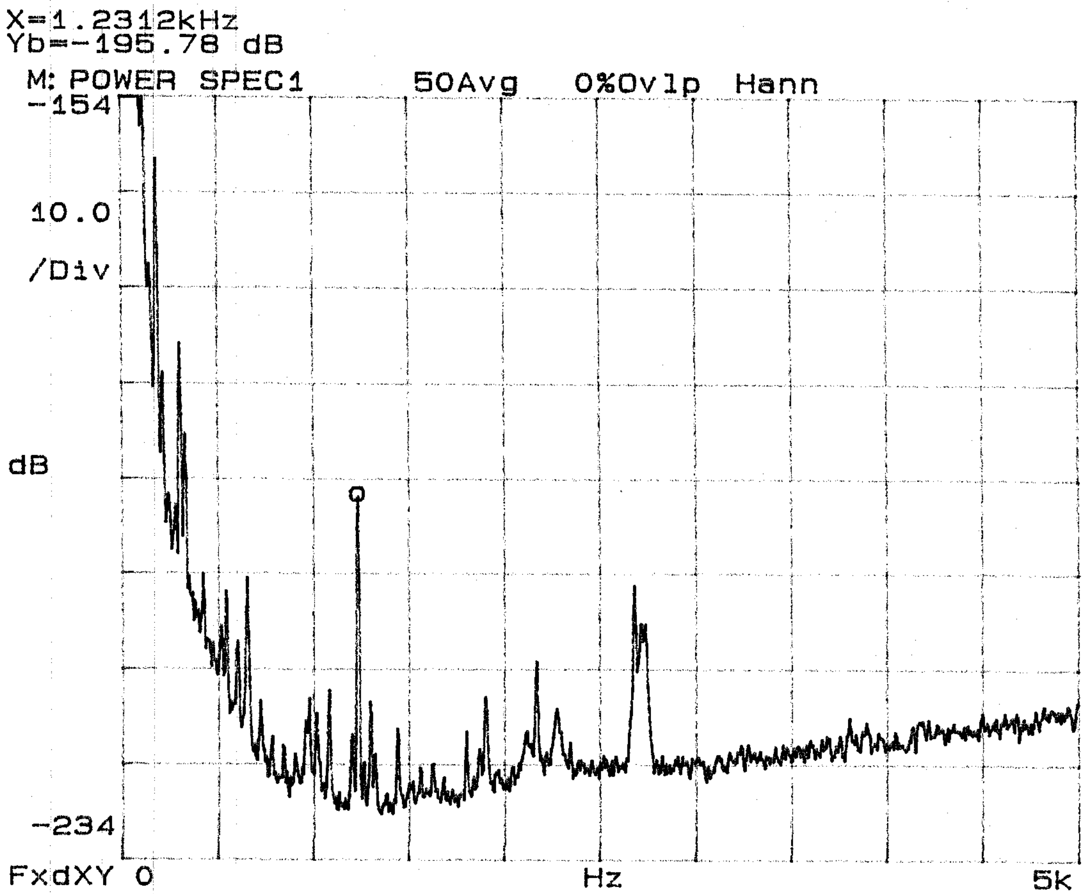
Coil Drive gain = 5.0

Saved files on disk 7701:

Uncal Noise	DRBNØ
Swept Sine	DRBSSØ
Cal Noise	DRBCØ

8/25/92 TTL
14:00

Calibrated Noise Spectrum



Visibility

A0 52%
A1 40% -0.176
A2 39% -0.253

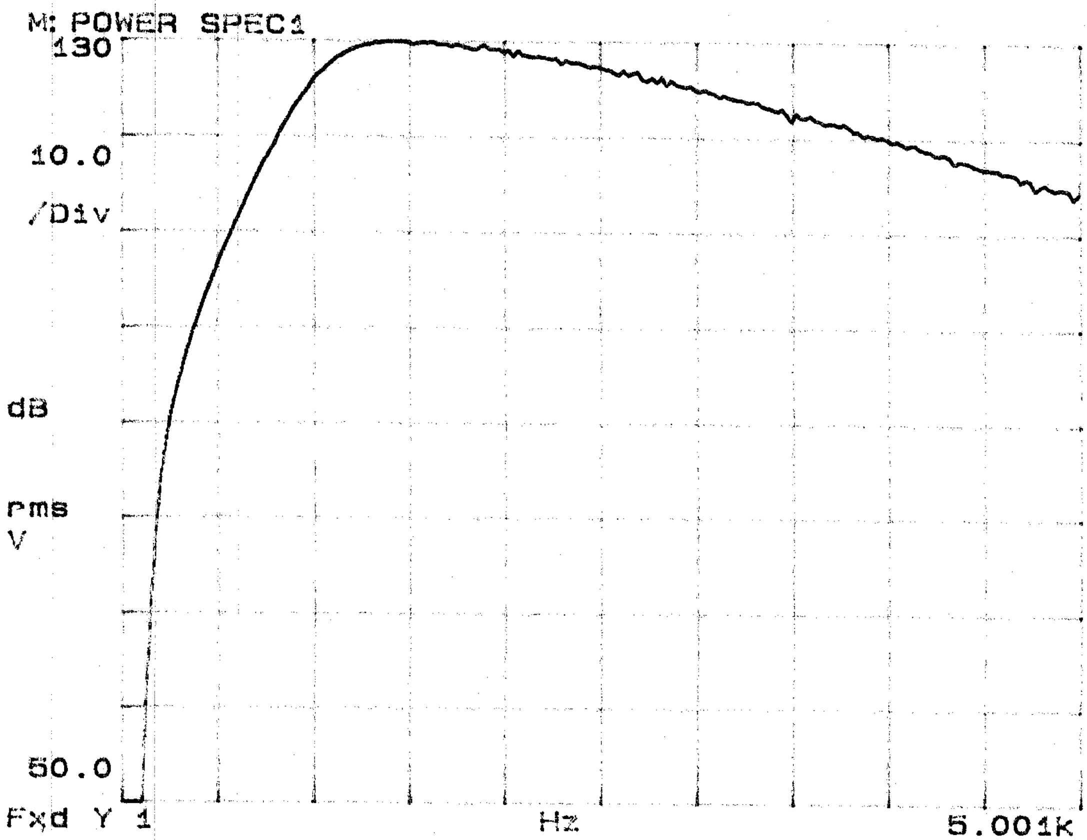
Coil Driver Gain = 5.0
Laser Power = "0.60W"

Saved files on disk 27.01:

Uncal Noise DRBN4
Swept Sine DRBSS4
Cal Noise DRBC4

Swept Sine from 70m Data Run on 8/24-25/92.

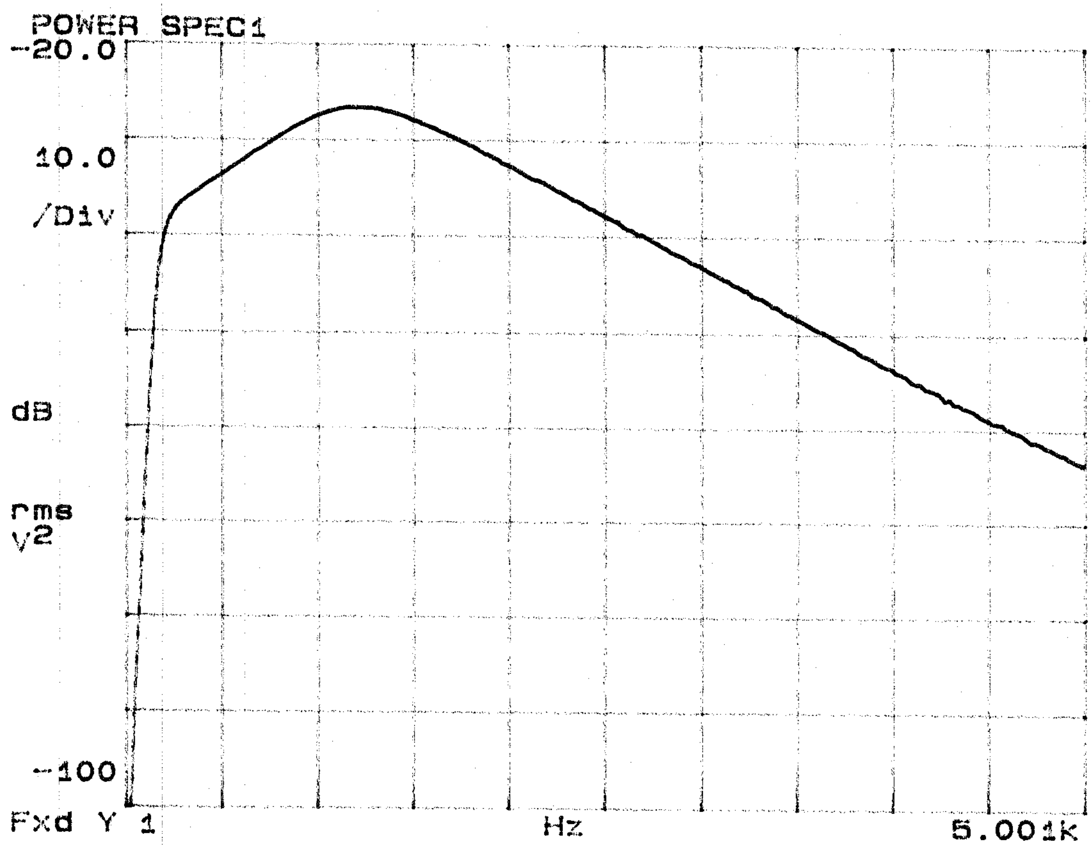
"DRBSSØ"



Saved on disk 27.01.

Swept Sine from 40m Data Run on 8/24-25/92.

"DRBSS1"

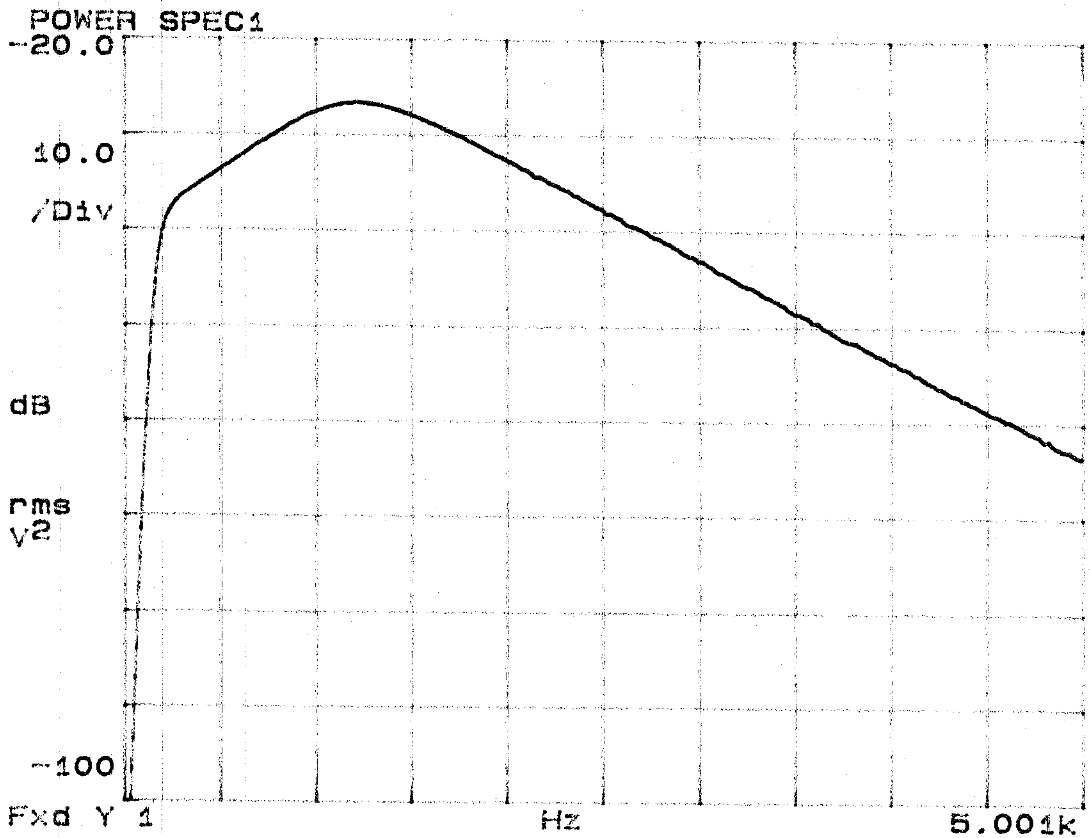


Saved on disk 27.01.

TTL

Swept Sine from 40 m Data Run on 8/24-25/92.

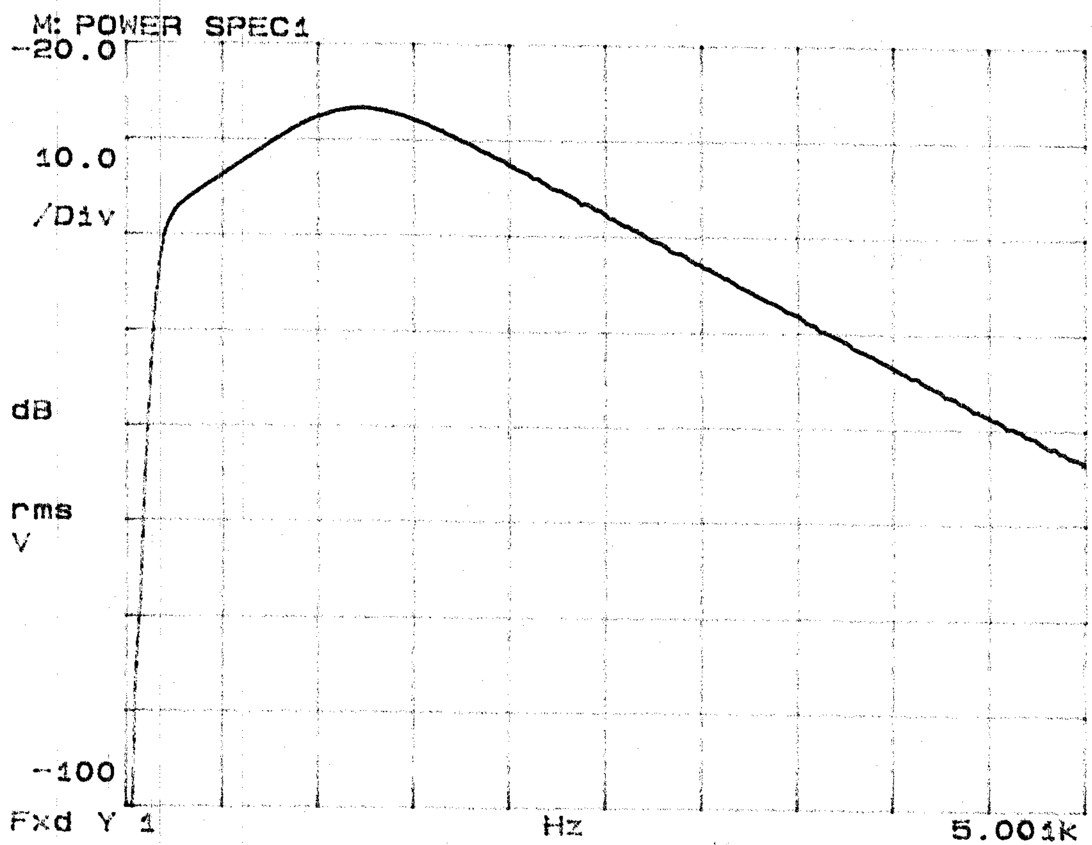
"DRBSS2"



Saved on disk 27.01.

Swept Sine from Tom Data Run on 8/24-25/92.

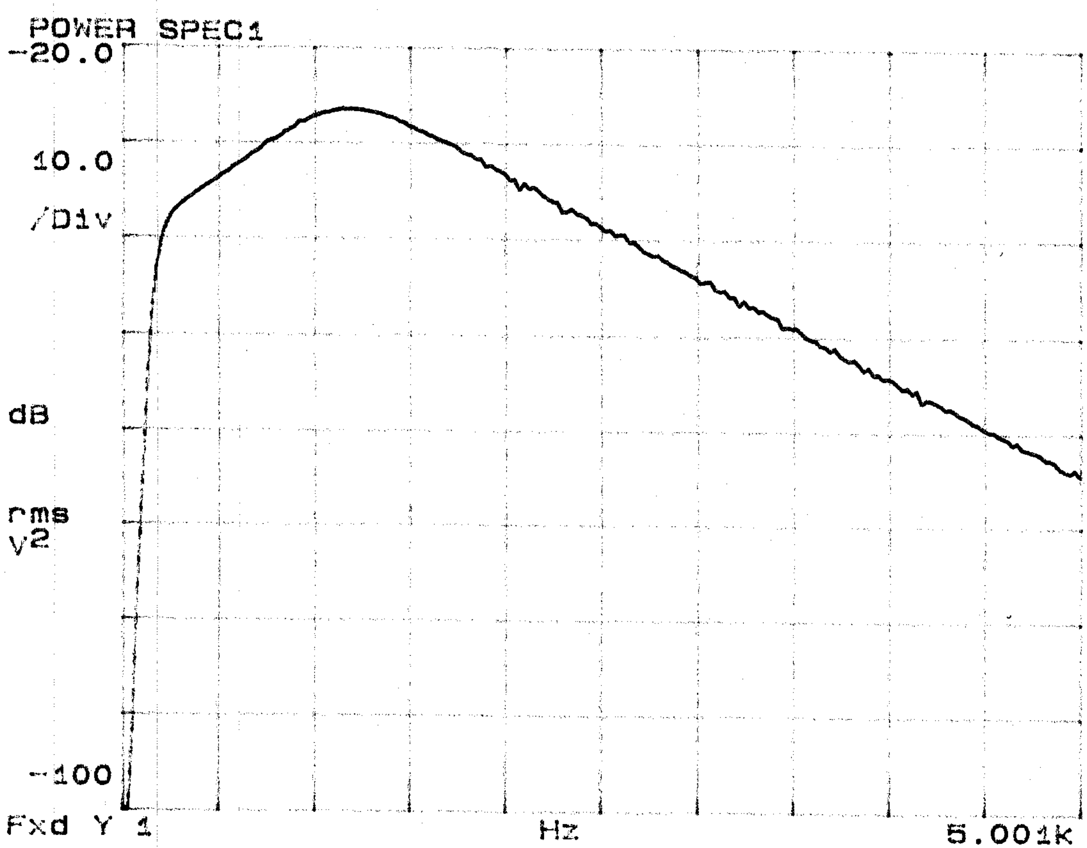
"DRB553"



Saved on disk 27.01.

Swept Sine from 40m Data Run on 8/24 25/92.

"DRBSS4"



Saved on disk 27.01

8/27/92 TTL

40m Data Run to Test for magnetic pulses and with cryopump off.

Channels are same as before except channel 1 is magnetic pickup coil (Martin's) instead of 1st arm preamp.

Ch 1, Magnetic pickup coil, PAR DC - 10kHz, x10k, DC couple

The coil is approximately aligned with the beam axis about 10' past the Huey test mass. (At the end of the 1st arm. The purple -13 cable is used to bring the cable back along the first arm where it is jumpered to 9 82 cable which takes it over to the main rack where is goes into the standard ch1 cable.

The interferometer is now running @ half power to avoid the thermal relaxation osc. we saw before in the mode cleaner. Various settings are now different.

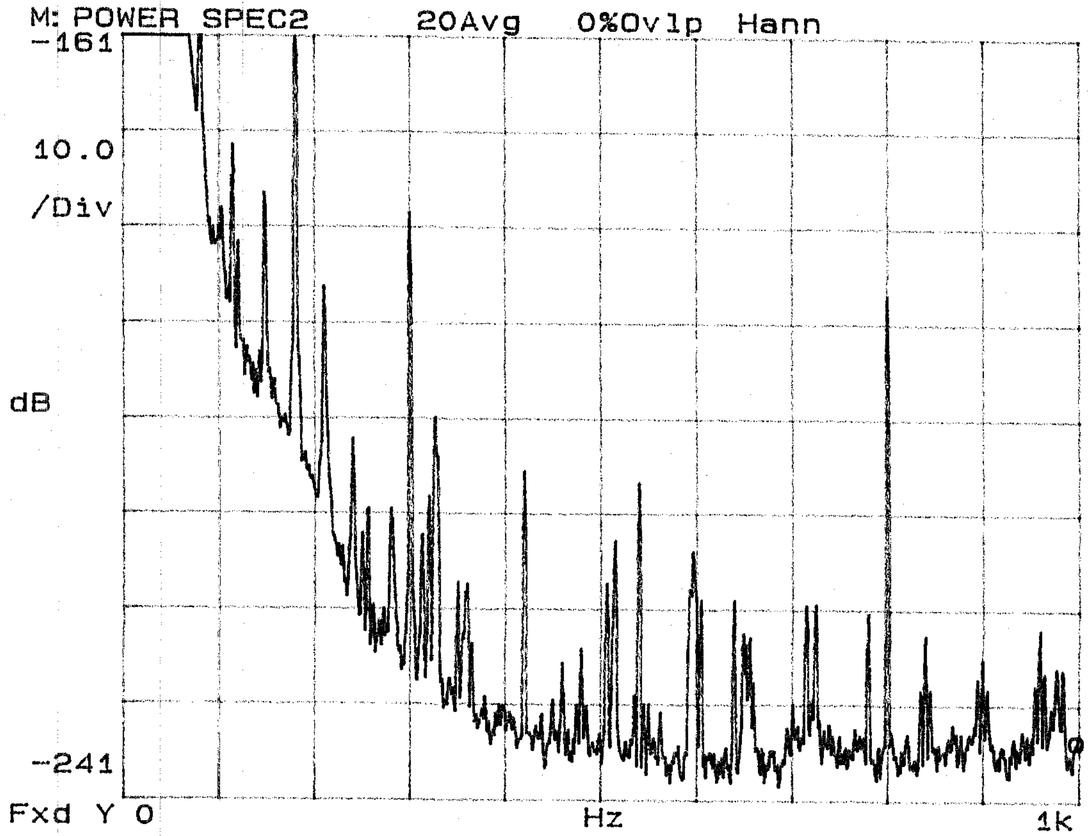
- Laser: 22.5 A, "0.31W".
- Attenuators in front of mode cleaner RFPD changed from 0.63 x 0.2 = 0.126 to 0.5 x 0.5 = 0.25.
- Gain on Primary Cavity Servo PreAmp changed from ≈13 to ≈25. Adjust battery input of power stabilizer preamp for -0.155V on 1st Arm DC monitor out of lock. (Used to be -0.31 V.) PreAmp gain is now 500.
- Coil driver gain = 9.0
- No RF Preamp on 2nd arm, x2 RF Preamp on 1st arm.

5:20	Started taking data with 10.6mV rms @ 800Hz. Visibilities: AΦ=60%, A1=56% (-.065V), A2=56% (-.093V)
5:26	Stopped calibrated sine.
5:40-42	Out of lock.
5:59-6:00	Out of lock.
6:04-6:06	Turned off cryopump knocking out of lock in process. Visibilities: AΦ=50%, A1=54% (-0.065V), A2=54% (-0.094V)
6:20-6:24	Dropped out of lock and I tuned up visibilities. AΦ=58% A1=53% (-0.068V), A2=54% (0.096V)
7:06-7:08	Out of lock. Started up calibrated sine.
7:11	Stopped tape.

27 Aug 92
19:00
Cryo Pump <u>Off</u>

Half Power Calibrated Noise Spectrum
A_1 = 0.155V out of lock
Visibilities: A_0 = 56%
A_1 = 54%
A_2 = 50%

X=998.7 Hz
Yb=-235.12 dB



Files on disk 27.01:

DRCN11 Uncal Noise

DRCSS11 Swept Sine Power Spct.

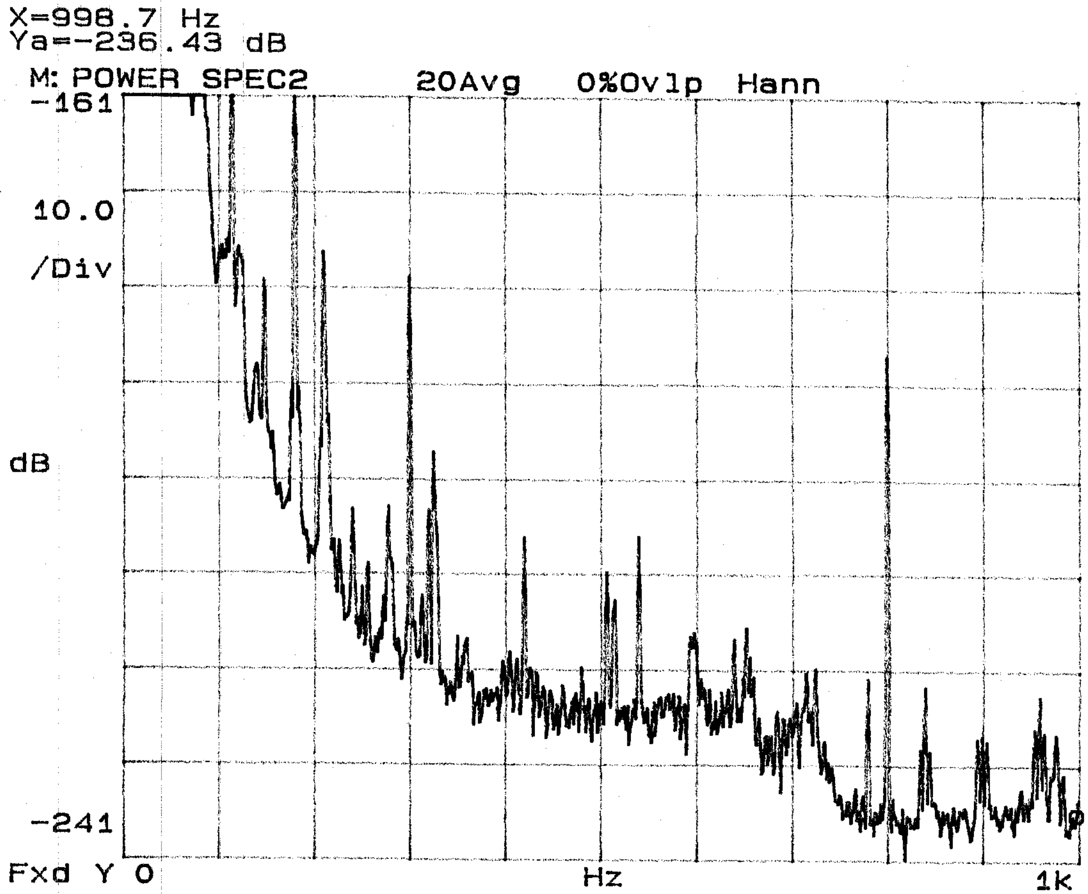
DRCC11 This plot

27 Aug 92
17:00
Cryo Pump On

Half Power Calibrated Noise Spectrum

A_1 = 0.155V out of lock

Visibilities: A_0 = 60%
A_1 = 56%
A_2 = 56%



Files on disk 27.01:

DRCN01 Uncal. noise

DRCSS01 Swept Sine Freq. Resp.

DRCC01 This plot

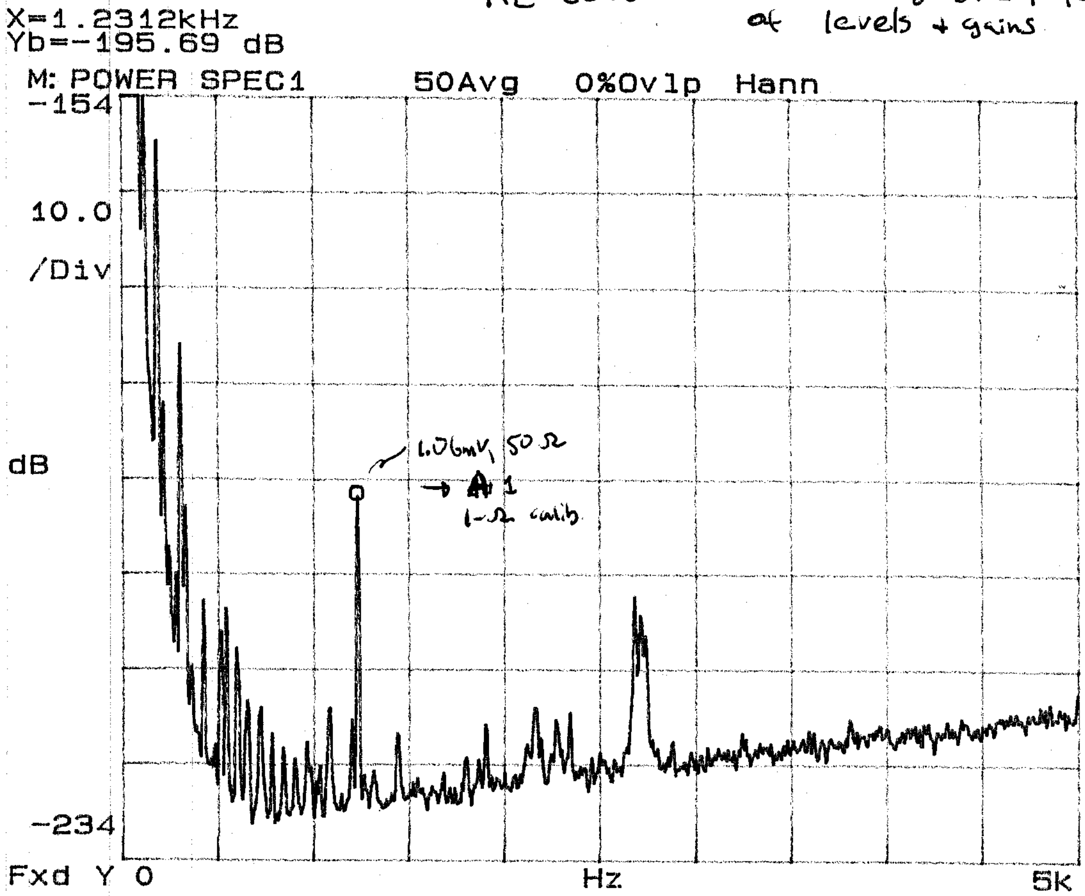
27 AUG 92
16:20
CRYO PUMP ON

HALF-POWER, CALIBRATED
NOISE SPECTRUM.

A_1: 0.155V out of lock

Visibilities A_0 60%
A_1 60%
A_2 60%

See data log (T.L.) for details of levels + gains



"DRCCOS" DISK 27.01

"DRCSSOS" SWEPT SIN, Freq. response (incl. phase info)

"DRCNOS" RAW NOISE

HP Spectrum Analyzer Stored Files

All data files associated with 40m data runs in August 1992 are in /home/jaguar4/40m_data/new_data/27.01.

Name	Time Taken		Comments
drc0	8/21/92,	13:50	Calibrated spectrum, $CAL = \frac{1}{(j\omega)^2} \frac{UNCAL}{SWEPT\ SINE}$
drn0	"	13:49	Uncalibrate spectrum
drss0	"	13:55	Swept sine
drc1	"	19:30	
drn1	"	19:25	
drss1	"		
drbc0	8/24/92	18:00	Before starting tape 1
drbn0	"		
drbss0	"		dB rms V bad?
drbc1	8/25/92		Before tape 2
drbn1	"		
drbss1	"		dB rms V^2
drbc2	"		Before tape 2
drbn2	"		
drbss2	"		dB rms V^2
drbc3	"	9:32	2 hours into tape 3.
drbn3	"	9:26	
drbss3	"	9:30	dB rms V
drbc4	"	14:00	Beginning of tape 4.
drbn4	"		
drbss4	"		dB rms V^2

Sunday, January 31st, 1993

I want to use a swept sine power spectrum to calibrate my 1-4 V power spectra of pulses. I will use drbss2, a swept sine taken immediately before starting tape 2. Both drbss2 and the pulse power spectra are in V^2/bin, and both used a Hann filter. The bin sizes are different so we normalize to V^2/Hz. For a uniform filter the bin sizes would be:

swept sine	6.24 Hz
pulses	154.19 Hz

The operation we wish to preform is: $Cal = \frac{1}{(jw)^2} \frac{Uncal}{SS}$.

So allowing for the bin sizes and x200 gain[1] between spectrum analyzer and A-D, we get

$$Cal\_pulses\,(V^2/Hz) = \frac{1}{(jw)^2}\,\frac{6.24}{154.19}\,\frac{Pulses(V^2/bin)}{SS(V^2/bin)}\,\frac{1}{200}$$

To implement this procedure I wrote four Mathematica functions (LoadPSP, MultiplyPSP, InvertPSP, CalibratePSP) which are stored in ~/glitch/pspmath.m.

The raw data from the spectrum analyzer is stored in /home/jaguar4/40m-data/new-data/27.01.

Notes:

1. The filter used was a x200 gain bandpass from 10 Hz - 10kHz which for these purposes (100-5000Hz) we approximate as flat.

Bob has also suggested that I plot the noise between pulses on the same (uncalibrated) scale as the pulse power spectra. Within tape 2, section 14 I picked two rather long periods where the program found no pulses. These are:

filename	Time, secs
nopul1.bin	161 – 169
nopul2.bin	1035 - 1043

Both of these had similiar power spectra. I used the first one for comparison with the pulses. Typical k and m values given to powspc.c were

m	k	Total Points (2k+1)m	Total Time, secs	BW
8192	8	139,264	7.06	1.2046
64	1024	131,136	6.64	154.1
1024	36	149,504	7.57	9.63713

There are k FFT's taken in estimating the power spectrum and each FFT uses 2m points. The bandwidths shown are for a uniform filter. (Actually a Hann filter was used.) From observation of the HP Spectrum Analyzer it looks like $BW_{Hann} = \frac{9.37}{6.24} BW_{uniform}$. The following plot is shown using the third k, m combination.

$$\gamma = 3.05 \cdot 10^{-7} \frac{m - Hz^2}{V}$$

V_G is converted to equivalent displacement by transfer function I:

$$V_G = x_H I$$

$$x_H = \frac{V_G}{I} = \frac{V_G}{H/L} = \frac{V_G}{H} \frac{\gamma}{f^2}$$ [frequency response normalization]

Often $H \cdot V_c \equiv H'$ is recorded; i.e. for the swept sin calibration the 3563A is set to display "power spectrum" rather than "frequency response." (Frequency response divides by V_c, power spectrum does not).

When H' is recorded, $V_c = 110\,mV_{rms}$ (usually).

Define $\gamma' = \gamma \cdot V_c$, so

$$x_H = \frac{V_G}{H'} \frac{\gamma'}{f^2}$$ [power spectrum normalization]

For spectral density,

$$\tilde{x} = \frac{x_H}{\sqrt{\Delta f}}$$; For standard window on HP3563A, $\Delta f = 1.87 \cdot 10^{-3} f_0$; f_0 = range

$$\tilde{x} = \frac{V_G \gamma'}{H' f^2 \sqrt{\Delta f}} = \left(\frac{V_G}{H'\omega^2}\right) \cdot \frac{(2\pi)^2 \gamma'}{\sqrt{\Delta f}} = \mu \cdot \frac{V_G}{H'\omega^2}$$

for $f_0 = 5$ kHz, $\mu = \frac{(2\pi)^2 \cdot 110\,mV_{rms} \cdot 3.05 \cdot 10^{-7} \frac{m-Hz^2}{V}}{\sqrt{1.87 \cdot 5\ Hz}} = 4.33 \cdot 10^{-7} \frac{m}{\sqrt{Hz}} \frac{sec^{-2}}{V}$

$\mu = 4.33 \cdot 10^{11} \cdot 10^{-18} \frac{m}{\sqrt{Hz}} \frac{sec^{-2}}{V}$; 5 kHz span, 110 mV cal.

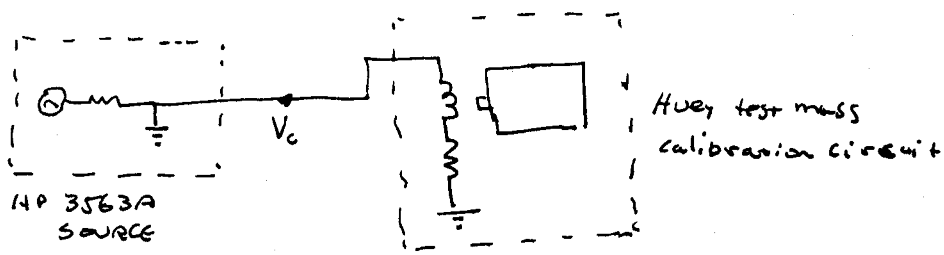
Note: $4.33 \cdot 10^{11}$ = 232.7 dB

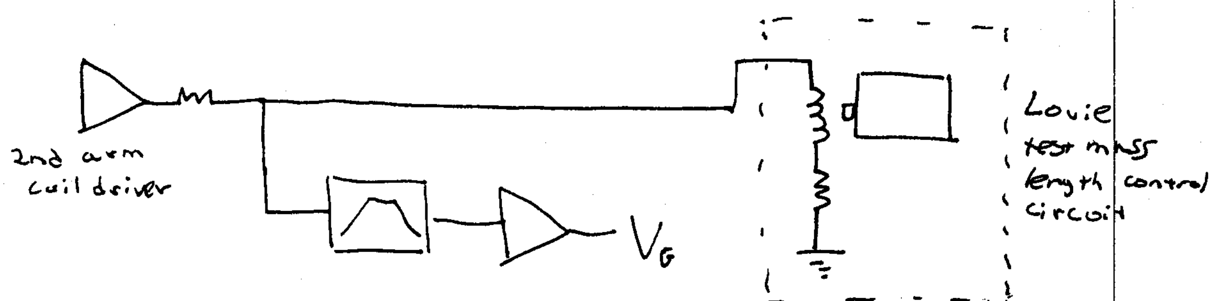
1

RES 2 FEB 93

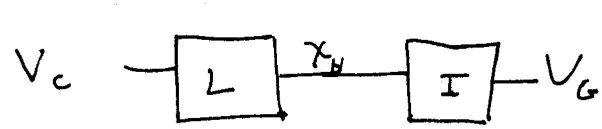
PROBLEM: CONVERT RECORDED TIME-DOMAIN DATA TO CALIBRATED DISPLACEMENT UNITS

AVAILABLE:
1) Raw "gravity wave" signal, V_G
2) Swept sin response — V_G when calibration V_c is applied
3) Calibration response — displacement X_H in response to V_c





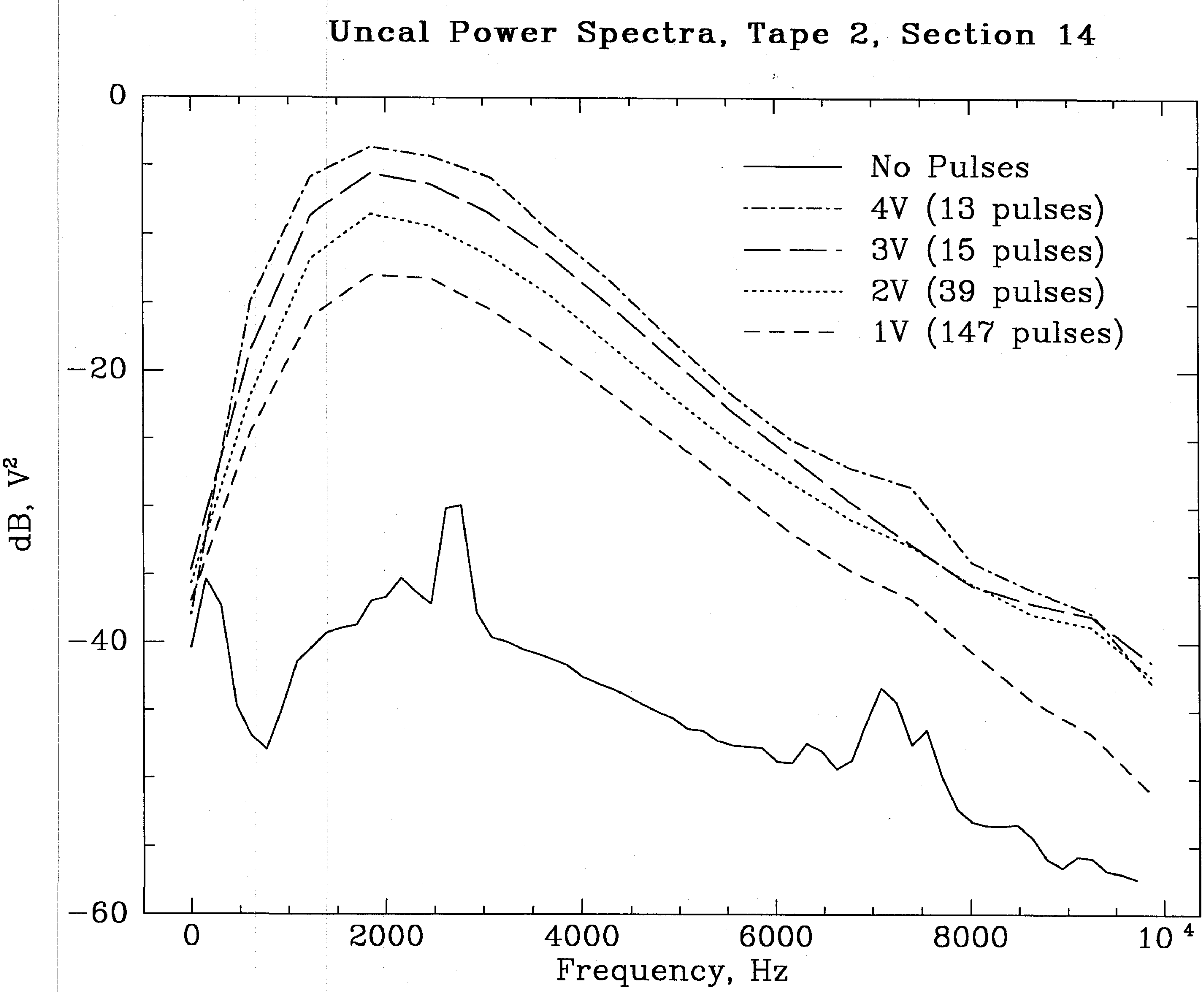
IN BLOCK DIAGRAM FORM:



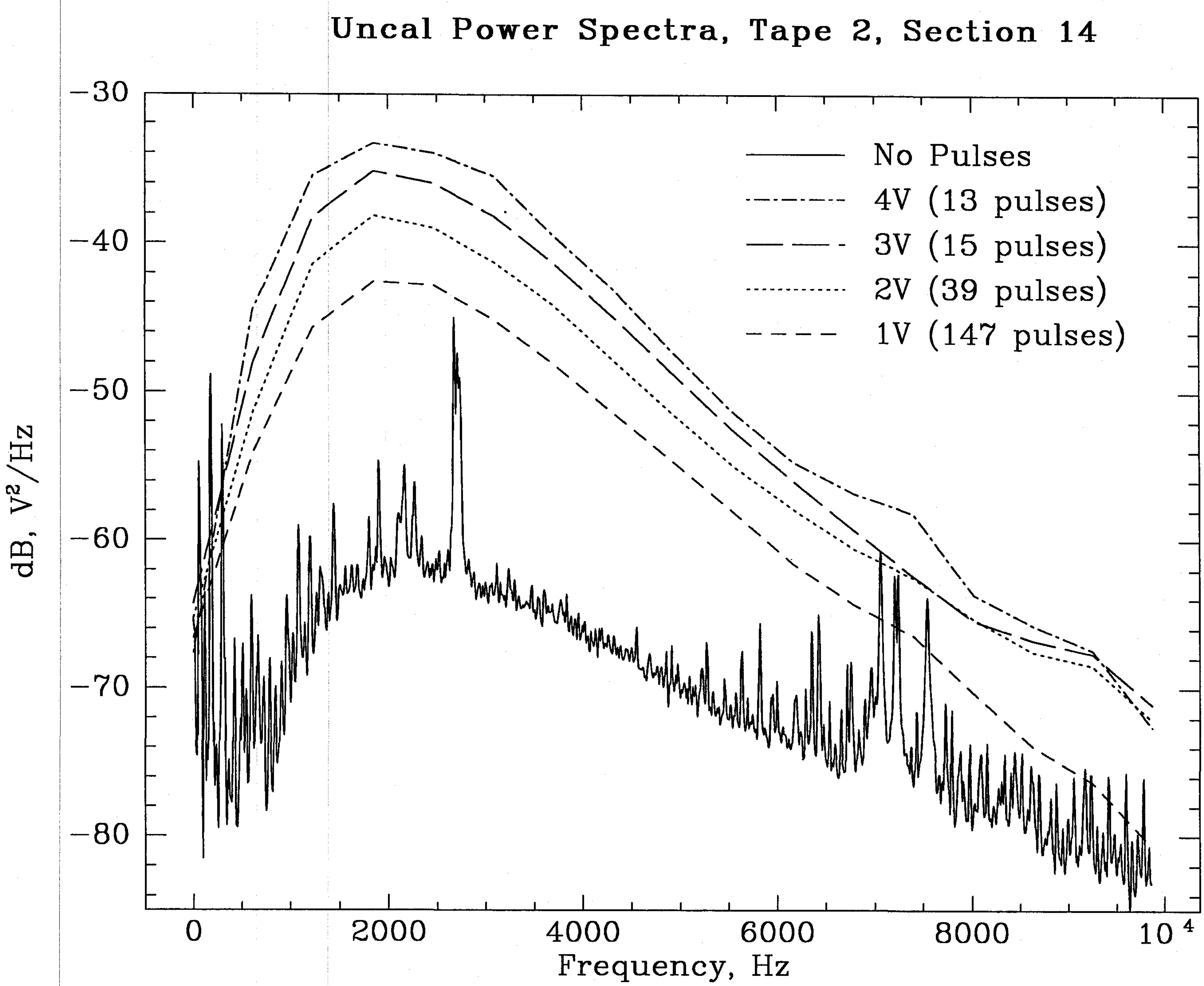
$L \cdot I = H$

$\frac{V_G}{V_c} = H =$ 2) above

$L = \frac{x_H}{V_c} = \frac{\gamma}{F^2}$ $\quad \gamma = \frac{2.14 \cdot 10^{-15}\,\text{m}}{10.6\,\text{mV}} \left(1.23\,\text{kHz}\right)^2$ — Seiji's writeup of 3)



Uncal Power Spectra, Tape 2, Section 14
0
−20
−40
−60
dB, V²
0
2000
4000
6000
8000
10 4
Frequency, Hz
No Pulses
4V (13 pulses)
3V (15 pulses)
2V (39 pulses)
1V (147 pulses)



Uncal Power Spectra, Tape 2, Section 14
No Pulses
4V (13 pulses)
3V (15 pulses)
2V (39 pulses)
1V (147 pulses)
−30
−40
−50
−60
−70
−80
dB, V²/Hz
0
2000
4000
6000
8000
10 4
Frequency, Hz

Thursday, February 4th

Mike pointed out yesterday that my plots of pulse power spectra depend critically on the amount of time I take the FFT over. This is because the power spectra I calculate are for the mean squared amplitude. Fred convinced me the best way to do this is to shrink the size of my time window so I am basically only transforming the pulses. In doing this I decided the best window was 32 points wide (1.62 ms), but the exact centering of the pulse becomes more critical. Empirically it looks like the best estimate for the center is halfway between the peak and final locations. I will use this for now. I redid the noise power plots I did earlier. I was worried that the data file "chan ∅" containing the raw data for the particular locked section I am using (Tape 2, #14) had not had the DC level subtracted off. This was not true, however. Its residual DC average is only 0.375 counts (0.0018 V).

Now I try to make a calibrated spectrum. Using Bob's writeup of 2/2/93 we see the equivalent displacement,

$$x_H = \frac{V_G}{H'} \frac{\gamma \cdot V_c}{f^2}$$

where, V_G = voltage measured at spectrum analyzer (÷200 recorded)

H' = recorded swept sine

$V_c \approx 106\ mV_{rms}$

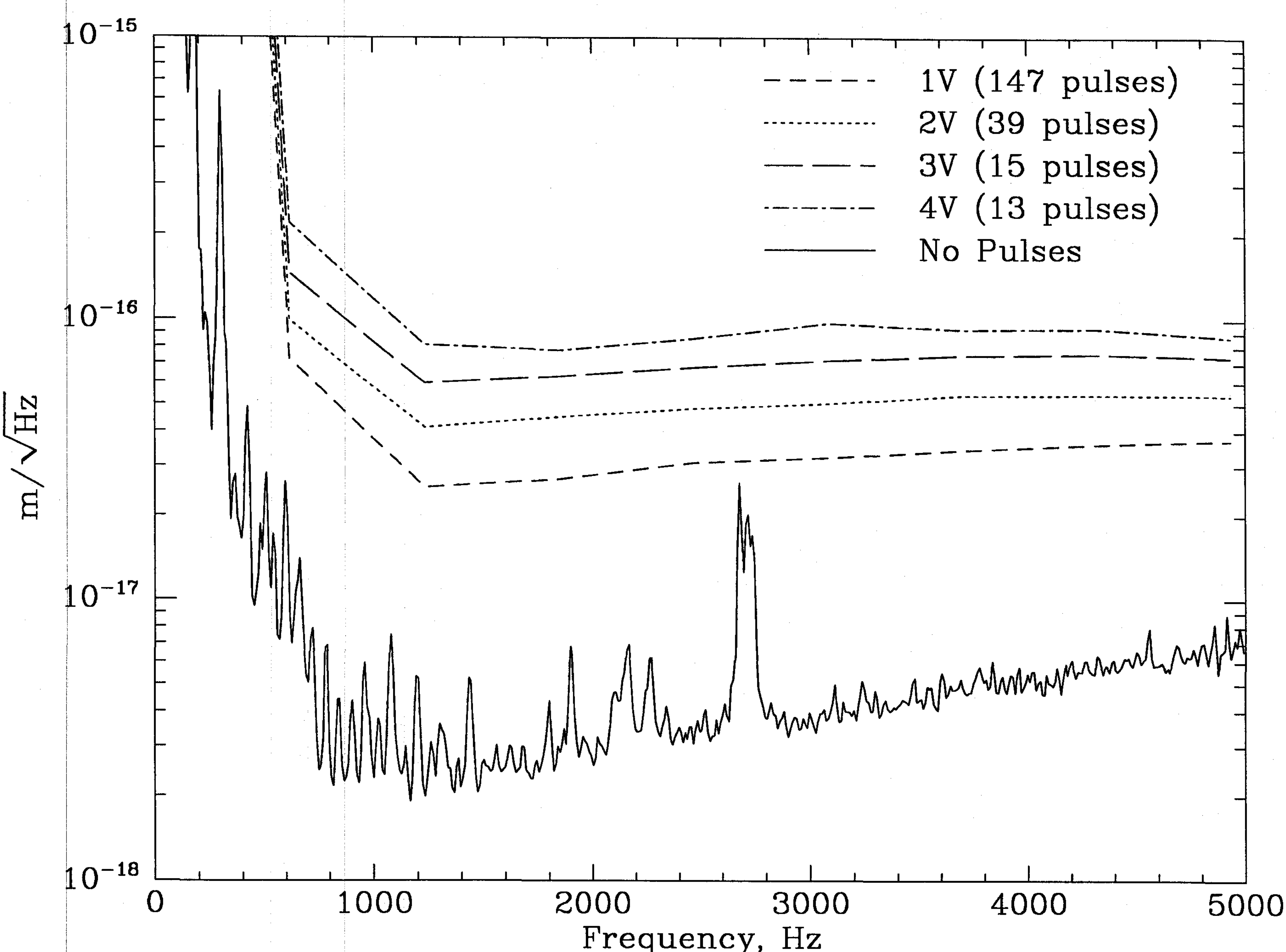
$$\gamma = \frac{2.14 \times 10^{-15}\ m}{10.6\ mV_{rms}} (1.23\ kHz)^2$$

Of course first I have to adjust V_G and H' for bandwidth and take square roots to get in $V/\sqrt{Hz}$.

Monday, February 8th

After adding the factor of 1230 Hz in γ which I forgot I plotted the calibrated spectra. Unfortunately with my smaller 32 point window the uniform filter bandwidth is 616.78 Hz. I an effort to get another lower calibrated point I used straight-line interpolation to add an extra point in the four pulse power spectra at 7.25 Hz. My plot follows.

Calibrated Spectra, Tape 2, Section 14



Wednesday, February 10th

I on effort to get a swept sine transfer function I finally had to settle on August 27, 1992. DRCS5505 was taken over a 0 to 5 kHz span at half power with different gain settings from the overnight data run. Comparing the magnitudes, however, one can see its shape is the same as those taken during the run although its absolute magnitude is different. I will have to straighten this out to get accurate calibration in displacement units.

Thursday, February 11th

I really want a transfer function out to 10 kHz. It is probably okay to extrapolate. I extrapolated the real and imaginary parts seperately. I fit the log of the value versus the log of frequency to a straight line. The fit range was only 9 points from 4950 kHz to 5 kHz where both real and imaginary parts were very linear. The fit was the used to extrapolate from 5-10 kHz. The combined result is stored in drcss.dat. The loading and writing routines in pspmath.m were modified to handle FFT data. The other routines should work correctly on complex data.

Wednesday, February 17th

Unfortunately upon plotting my extrapolated transfer function I see that it didn't work. I need to fit to the magnitude and phase in some intelligent way over a much wider range. The only reason it looked linear before is that I choose so few points. Before wasting more time on this I will try averaging my data to lower its bandwidth. I wrote avgpts.c to average adjacent points in a binary file.

I wrote a shell script which automatically averages a 32 point pulse, Fourier transforms it, calibrates it in Mathematica using the swept sine "dress5.dat" and the does the inverse transform back to the time domain. It is called "docal" and uses the Mathematica files "docal.m" and "pspmath.m". The pulses were interesting but there is still uncertainty in their overall height.

Friday, March 12th

Worked on doing correlations for matched filtering. I wrote program "correlate.c" to correlate binary data files and "chirp.c" and "addbin.c" to make a chirp template and add to binary files together. The chirp template we use is:

$$f(t) = \frac{1}{10}(1 + e^{10t}) \sin[(1+100t)\,628\,t]$$

where f(t) is in volts. I did several plots and correlations for Stan's upcoming talk. Problems still remaining with the programs:

1. Correlate does not use correct normalization. Should be:

$$C = \frac{\int_{-\infty}^{\infty} f(x)\, g(x)\, dx}{\left[\int_{-\infty}^{\infty} g^2(x)\, dx\right]^{1/2}}$$

This preserves the units and relative scale of f(x) which is convenient for us.

2. Addbin only allows no offset between the binary files. Need to add offset option.

Monday, March 15th

To quickly solve the normalization problem I numerical integrated my chirp using Mathematica. I found:

$$\int_0^{0.1} \{(1+e^{10t}) \sin[628t(1+100t)]\}^2 dt \approx 0.381529$$

To use this I took out the patched-in division by the number of template points in "correlate.c" and modified "chirp.c" so the resulting template will be normalized. To go from continuous to discrete (rectangle rule) we do:

$$C = \frac{\int_{-\infty}^{\infty} f(t) g(t)\, dt}{\left[\int_{-\infty}^{\infty} g^2(t)\, dt\right]^{1/2}} \quad \text{(continuous)}$$

$$= \frac{\sum_i f_i\, g_i\, \Delta t}{\left[\sum_i g_i^2\, \Delta t\right]^{1/2}} \quad \text{(discrete)}$$

Here $\Delta t = \frac{1}{\text{rate}}$. Ultimately I will modify "correlate.c" to have an option (-norm) to calculate the above instead of $\sum_i f_i g_i$ at present. What Mathematica gave us was $\sqrt{\sum_i g_i^2 \Delta t} \approx \sqrt{0.381529} = 0.617681$. Thus I can just use the normal program and divide the result 0.617681 times the data rate.

Tuesday, May 4th

As a check of my pulse and power spectra calibration routines I should be able to take a section of data with a calibrated sine on it and see that it has the correct size when calibrated. I will use the beginning of Tape 2.

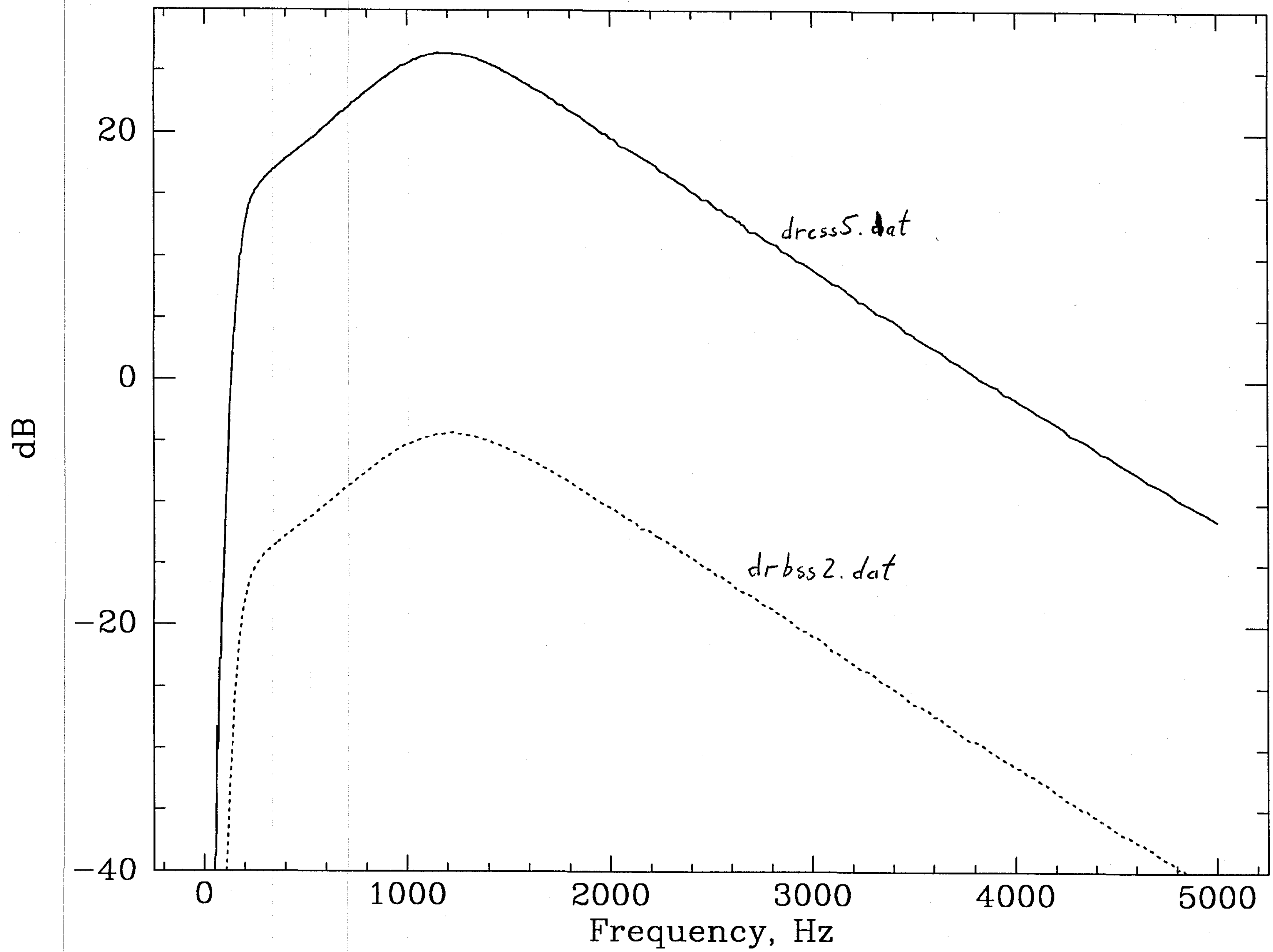
I did a power spectrum of the first 2,098,176 points on the tape ($k = 1024$, $m = 1024$) and saved the result in "psine.psd" and "psine.cal" in ~glitch/data. The RMS level should be:

$$X_D = \frac{2.14 \times 10^{-15}\ m}{10.6\ mV_{rms}} (1.23\ kHz)^2\ V_c$$

$$= 2.14 \times 10^{-16}\ m_{rms} \qquad (\text{with} \div 10 \text{ attenuator})$$

The power spectrum (calibrated) had roughly the right height for the 1.23 kHz peak. It was hard to tell as it is in $m/\sqrt{Hz}$ so I would have to integrate over the peak to get the total rms motion in the peak. From this I can see that the calibrated sine doesn't dominate the noise until above 800 Hz. So I calibrated a short 0.05 sec long section of the time series dropping Fourier components below 800 Hz. What I got seemed to have an RMS value of $\sim 5 \times 10^{-18}$ m or so. This is too low because the swept sine drcss5.dat is too large. This was evident from the following plot of swept sines taken during the data run and drcss5.dat. It was just hard to believe that the loop gain could have changed by that much even though we had halved the optical power and readjusted all the gain settings. What is more likely is that there was more external gain when taking drcss5.dat. Perhaps it was wired through the A-D preamp?

Swept Sine Transfer Functions



1st Data Run of Mark II Prototype

I would like to use the same channels and filtering as earlier runs. This is what I settled on:

	Channel	Signal
Fast	0	Strain: Passive Readout filter BP 200-2kHz, BP 10-10kHz, 6 dB/oct. rolloff, 200Gain, AC
Fast	1	First Arm Servo Preamp Output #1: 10dB attentuator, 3kHz LP, 12 dB/oct. rolloff, 2 Gain, DC
Slow	2	Primary Cavity TTL In Lock: In lock = Low (no filt.)
Slow	3	Secondary Cavity TTL In Lock: " " (no filt.)
Slow	4	Laser Slow PZT, 1/100 Monitor (no filt.)
Slow	5	Ranger Seismometer: BP 0.03 - 100Hz, 2k Gain, AC
Slow	6	Microphone: BP 0.03 - 300Hz, 10k Gain, DC
Slow	7	DC Coupled Strain: 10k-1.5k voltage divider 80Hz LP, x1 gain, DC, 24 dB/oct.

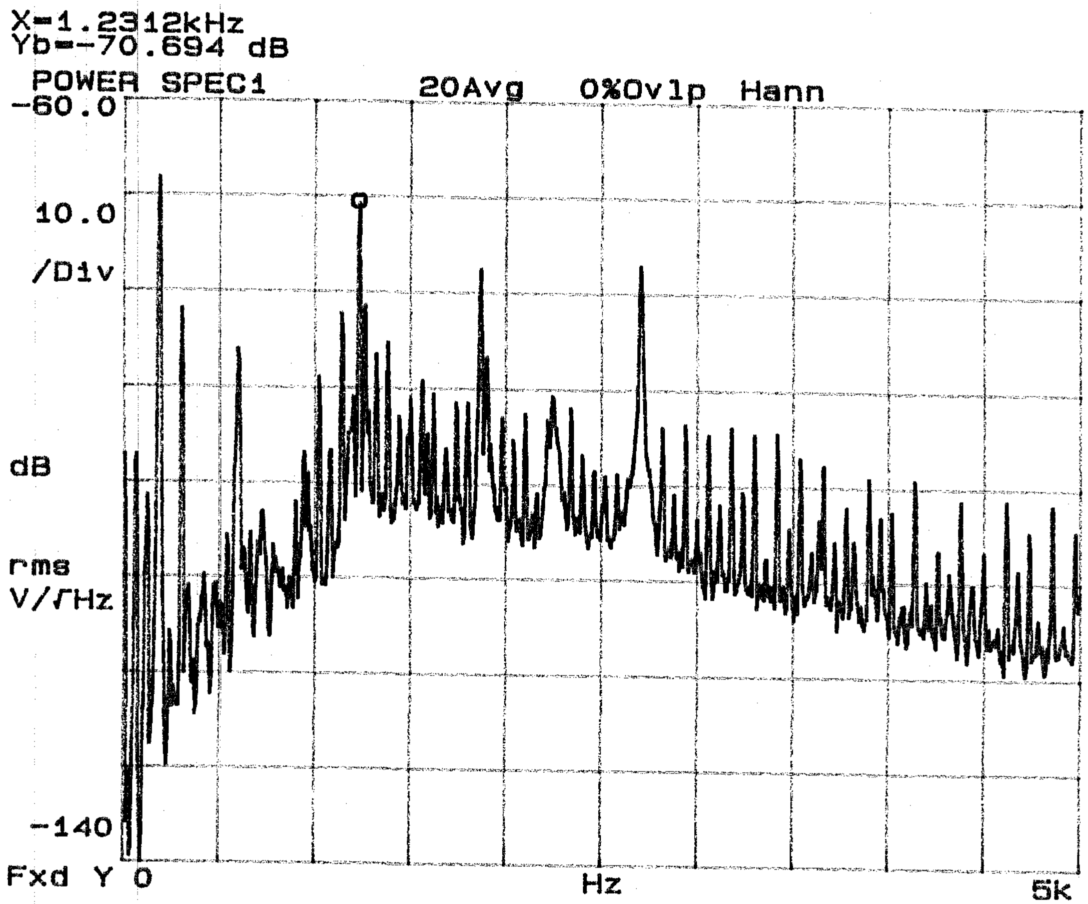
Overall Data Rate = 157894.7368421052500 Hz
Fast Channel Data Rate = 19736.8421052631 56
Slow Channel Data Rate = 1973.68421052631 56

Door to control room is open. Citgup internal clock is about 5 minutes behind my watch which was used to record event times. Running with ganged switch on 10 and coil driver gain at 3.5. I couldn't get a calibrated noise spectrum that makes sense, but I have printed out an uncalibrated one that Mike took shortly before the run. It is saved on disk 30.02 under DRØAN while its swept sine is under DRØASS.

Time	Status
7:12 pm	Laser power (uncal.) 0.34, Visibilities: A1 = 70%, A2 = 60%, MC = 51%
7:15 pm	Started data acquisition
7:24 pm	Out-of-Lock
7:29 pm	Out-of-Lock
≈7:35 pm	Out-of-Lock
7:41 pm	Out-of-Lock
7:44 pm	Out-of-Lock. Lost 1st arm lock @ 7:46 and finally got good lock again @ 7:47pm.
7:48 pm	Out-of-Lock. Laser power down to 0.29.
7:56 pm	Out-of-Lock.
7:57 pm	Out-of-Lock. Tuned laser power up to 0.37. Set gain on coil driver to 4.0 for a change during running.
8:04 pm	Out-of-lock. Tuned up mode cleaner visibility. Now have: A1 = 70%, A2 = 58%, MC = 55% The mode cleaner visibility dropped quite a bit with my laser realignment.
8:15 pm	Out-of-Lock.
8:16 pm	Out-of-Lock. 1st Arm lost as well.
8:18 pm.	Out-of-Lock.
8:20 pm.	Out-of-Lock
8:24 pm	Out-of-Lock did not reaquire till 8:28 pm.
8:32 pm	Out-of-Lock.
8:33 pm	Stopped tape.

Total data acquired 4635.334000 seconds. The interferometer was acting so poorly I decided there wasn't much point to continuing the data run.

TTL, 10/21/93
Saved on tape 30.02 as:
DRØAN
Swept sine taken with saved as:
DRØASS



BATCH
START

Data Analysis

STAPLE
OR
DIVIDER

Analysis of Data Run on 10/21/93

According to the reading program there was 4630.933366 seconds of data on the tape. I changed the default data rate used in analysis to be the rate listed for this run. Since channels 2 & 3 are now TTL signals instead of reflected light I had to modify my locked strech search program. I now use:

locked c.2.bin c.3.bin -sr -1 0 10

Complete analysis of a section requires it be atleast 304.0 seconds long. The first 60.8 seconds is skipped.

10/25/93

Only one 8σ event was found (incorrectly counted as 4 pulses) during a short section (~100 msec) where the interferometer burst into oscillations at 870 Hz. To see why there were not more 8σ events we need to look at the sample voltage distribution.

The largest sample value was 3.0029300 V = 615 counts. Binning the data in 615 bins one count wide I got the sample voltage histogram. From this it is clear to see that the background noise is not near as Gaussian in appearance as before.

Analysis of 40m Interferometer data by program LOCKED, ver. 1.3
Data rate = 1973.684211 samples/sec.
Locked range = 0 , 10 (primary) 0 , 10 (secondary).

Start, sec	Stop, sec	Start, pos	Stop, pos	Duration, sec
0.000000	476.689728	0	940835	476.689728
492.785522	743.972595	972603	1468367	251.187073
760.855774	1114.524292	1501689	2199719	353.668518
1114.531860	1124.978882	2199734	2220353	10.447021
1152.187866	1518.303711	2274055	2996652	366.115845
1528.930542	1709.978760	3017626	3374958	181.048218
1790.484497	1792.590698	3533851	3538008	2.106201
1807.769897	1831.031006	3567967	3613877	23.261108
1841.075684	1956.623047	3633702	3861756	115.547363
2019.886475	2385.952637	3986618	4709117	366.066162
2409.066162	2482.376953	4754736	4899428	73.310791
2547.590332	2578.055176	5028139	5088267	30.464844
2902.226074	3510.479004	5728078	6928577	608.252930
3522.818359	3641.461914	6952931	7187096	118.643555
3719.637207	3744.149658	7341389	7389769	24.512451
3765.900879	3832.784912	7432699	7564707	66.884033
3875.078369	4087.691406	7648181	8067812	212.613037
4298.948730	4555.284180	8484767	8990692	256.335449
4590.158203	4630.718750	9059523	9139576	40.560547

Total data taken (using this est. for data rate) = 4630.718750 seconds

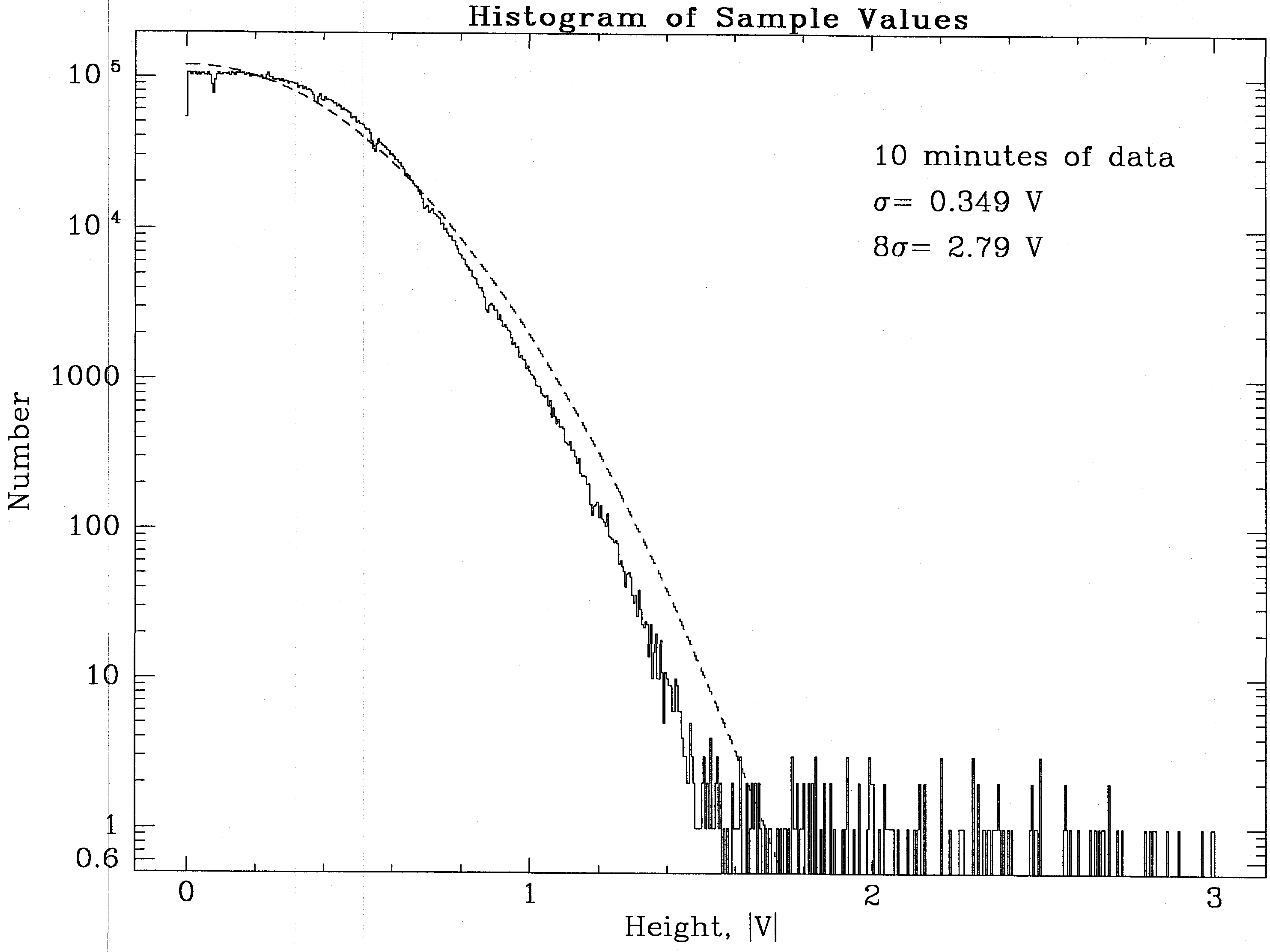
Total time in lock = 3577.714874 seconds

Total time analyzed = 2170.793183 seconds

⇒ Duty cycle = 77.3 %

Percent analyzed = 46.9 %

Tape 10/21/93, Section 13



10/28/93

I want to better characterize the sample statistics for the gravity wave channel for all useful locked sections. I use:

```
prepare 1 4          # extract 1st locked section with mean = 4 counts
binner chan0 -bin -1 0 -h 615 -n 615
```

Some of the locked sections have count values higher than 615, but these are all from huge (saturating 6.5V) oscillations immediately before falling out of lock. I have plotted histograms for all the sections. I also summed the histograms to give an overall plot for the whole data run using MATLAB. The commands to do this are:

```
load bin_val1.dat
  ⋮
load bin_val13.dat
b = bin_val1 + binval3 + binval5 + bin_val10 + bin_val13;
a = zeros(616, 2);
a(:,1) = bin_val1(:,1);
a(:,2) = b(:,2);
save bin_val.dat a -ascii
```

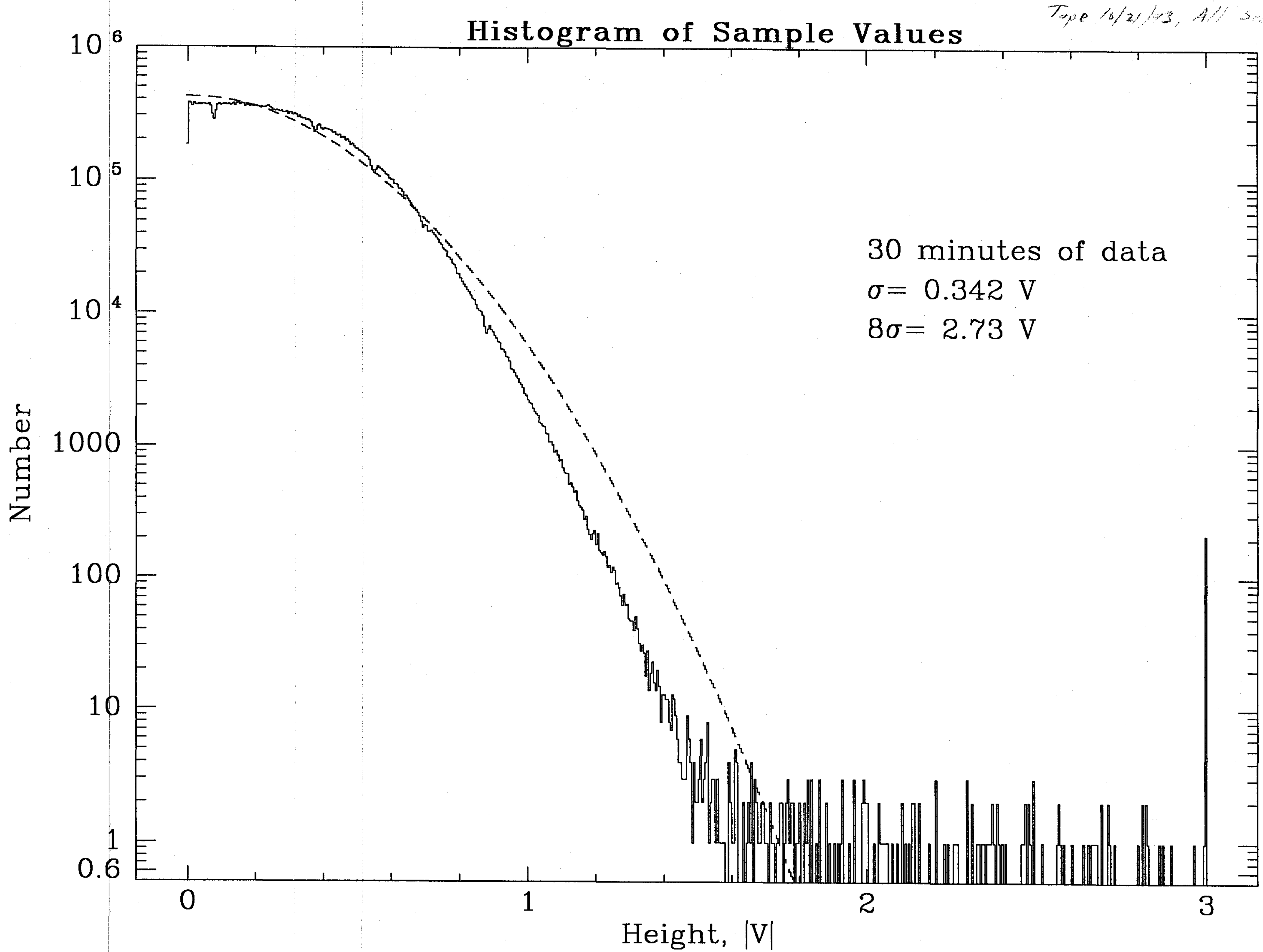
I have plotted this summed histogram and used the weighted mean for finding the standard deviation:

$$\sigma = \frac{\sum_i N_i \sigma_i}{\sum_i N_i}$$

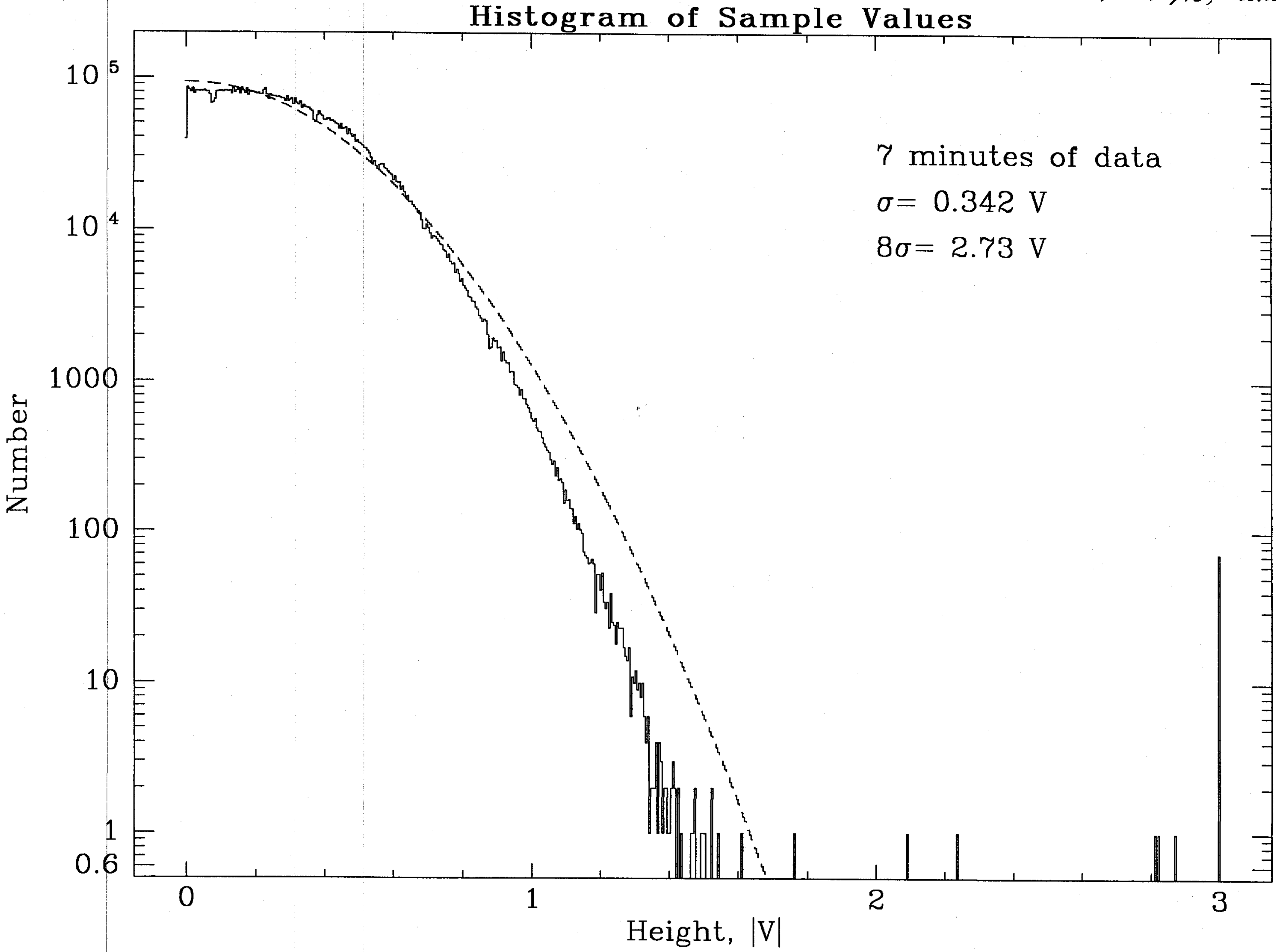
σ_i : standard deviation of i^{th} section

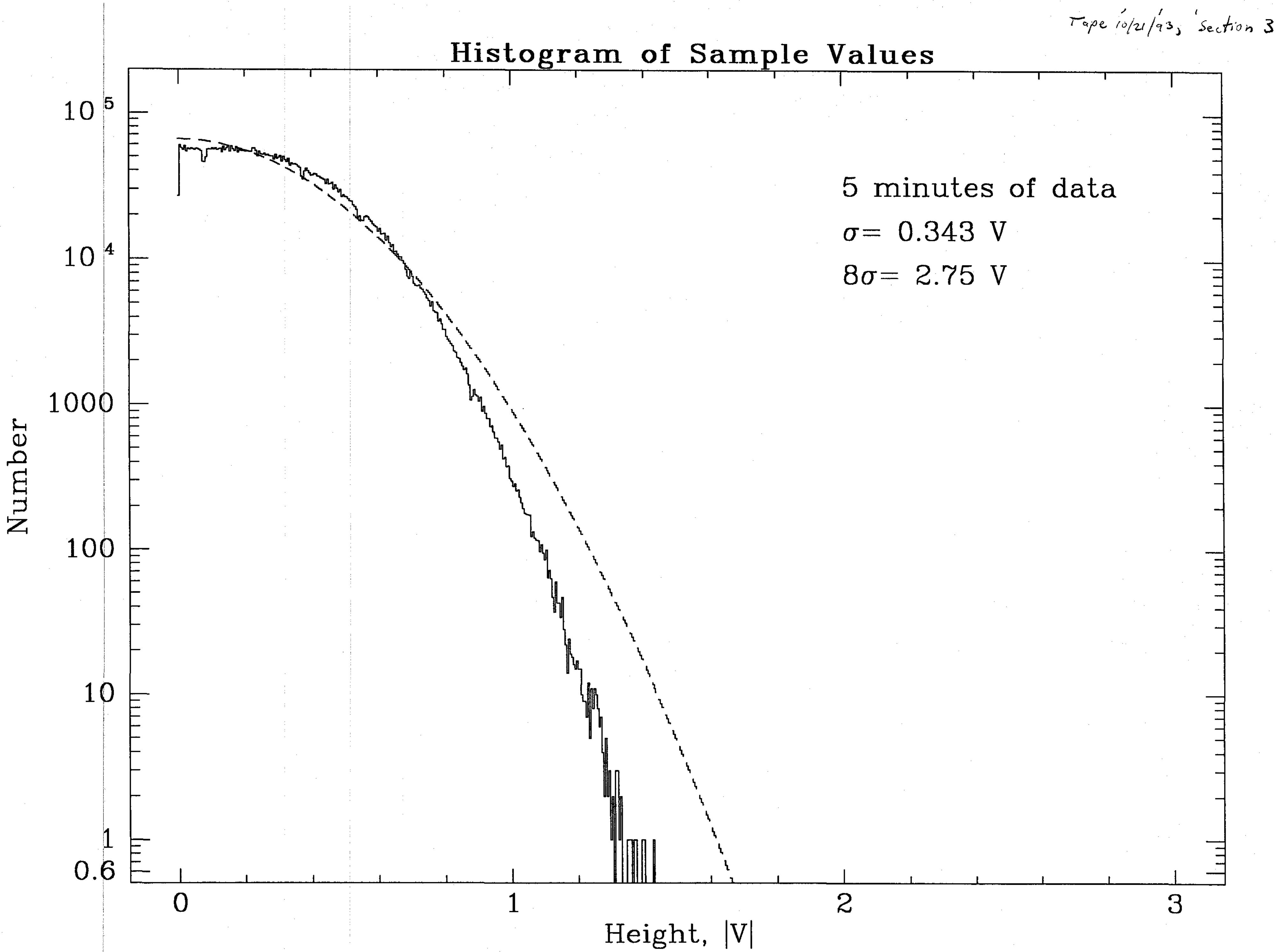
N_i : number of points analyzed in i^{th} section

Tape 10/21/93, All



Tape 10/21/93, Section 1

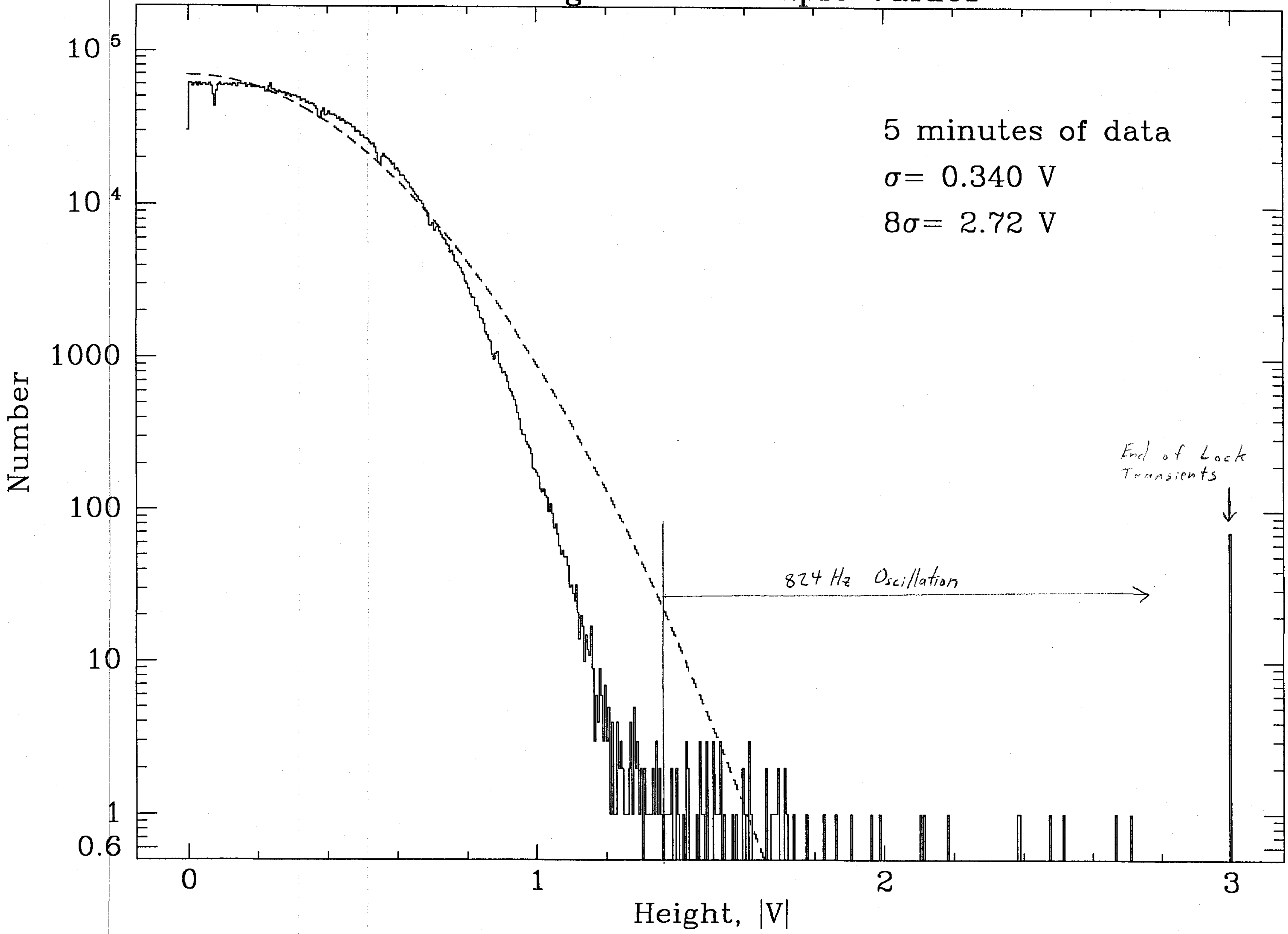




Tape 10/21/93, Section 3
Histogram of Sample Values
5 minutes of data
σ= 0.343 V
8σ= 2.75 V
Number
Height, |V|
10^5
10^4
1000
100
10
1
0.6
0
1
2
3

Tape 10/21/93, Section 5

Histogram of Sample Values

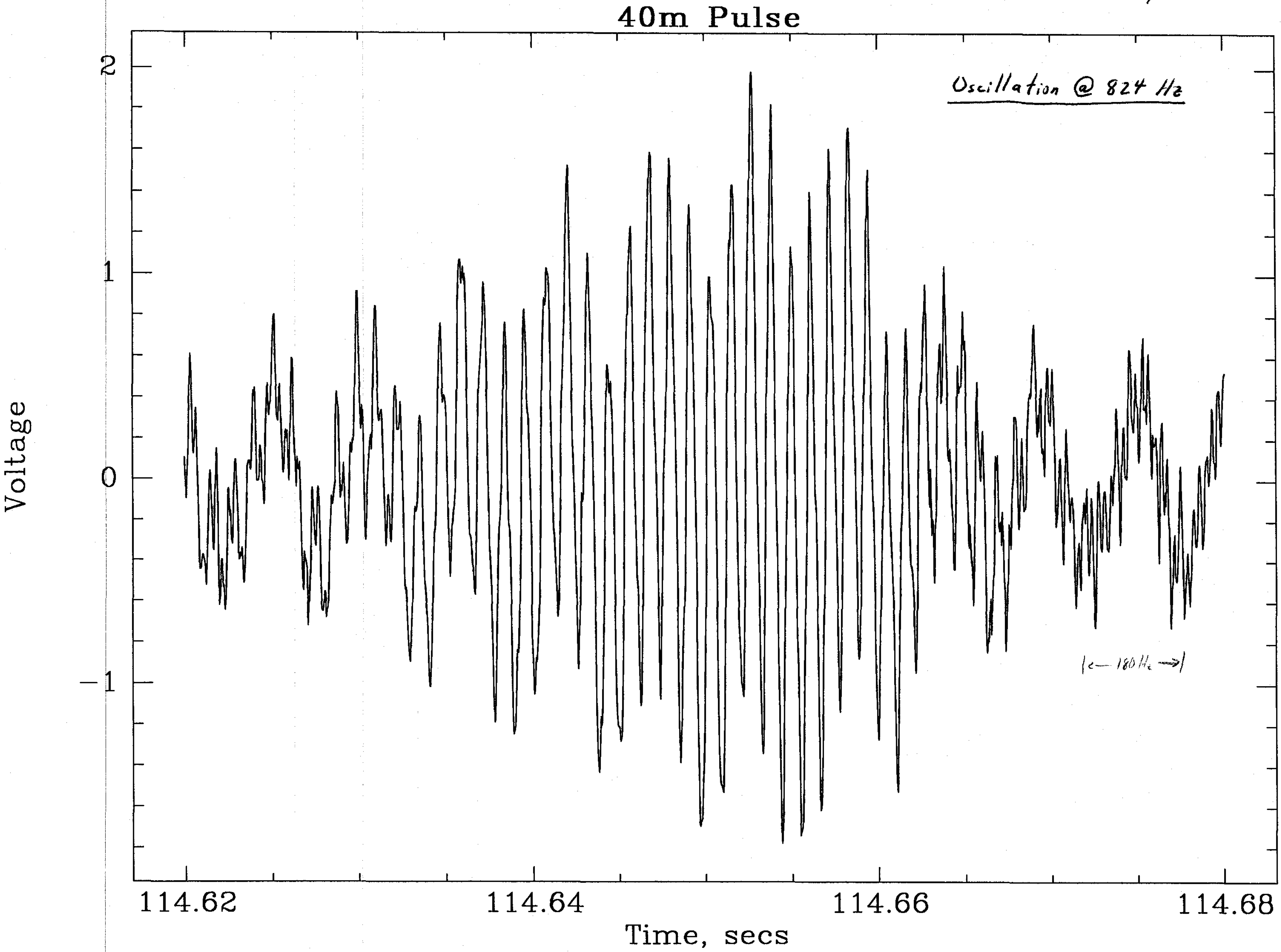


Tape 10/21/93, Section 5

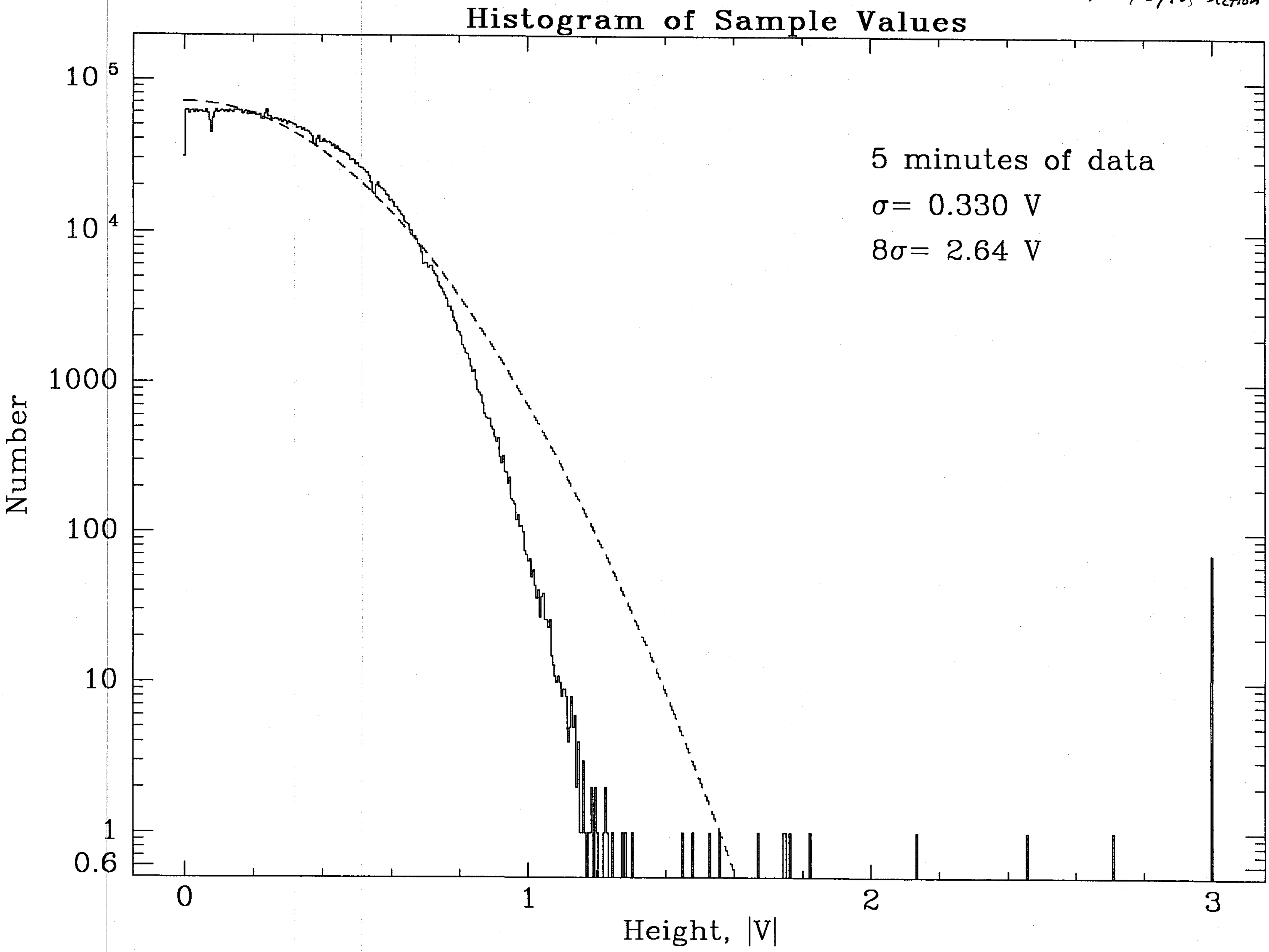
Data from file chan0 analyzed by PULSES, version 1.3.
Data rate = 19736.842105 samples/sec. Threshold = 245. Delay = 2.000 msec.
Delay mode: reset

Time, sec	Height, V	Start, sec	Finish, sec	
4.218709	1.235352	4.218709	4.218760	
4.321259	1.279297	4.321259	4.321310	
9.203701	1.347656	9.203701	9.203752	
9.206082	1.274414	9.206082	9.206184	
49.185833	1.215820	49.185833	49.185883	
54.185364	1.269531	54.185364	54.185417	
58.619408	1.293945	58.619408	58.619457	
98.998306	1.196289	98.998306	98.998360	
107.731216	1.230469	107.731216	107.731270	
114.638908	1.245117	114.638908	114.639061	} ← 824 Hz oscillation
114.652740	1.987305	114.641945	114.661201	}
124.295517	1.201172	124.295517	124.295570	
132.394287	1.245117	132.394287	132.394333	
140.627457	1.196289	140.627457	140.627518	
154.437317	1.210938	154.437317	154.437378	
172.926086	1.254883	172.926086	172.926147	
189.726807	1.284180	189.726761	189.726852	
198.227158	1.230469	198.227158	198.227203	
251.586746	1.201172	251.586746	251.586807	
268.519348	1.240234	268.519348	268.519440	
277.344055	1.196289	277.344055	277.344116	
296.683838	1.196289	296.683838	296.683899	
300.244904	1.289062	300.244904	300.244934	
304.515594	1.367188	304.515533	304.515625	
305.312225	6.572266	305.311005	306.628601	← End of lock transients

The pulses not marked in yellow appear to be statistical excursions in the stationary noise riding on top of the 180 Hz line spike. All the pulses $< 1.37\ V_{peak}$ seem to be explained by stationary noise. In particular the large transients seen on the Mark I are a[illegible]nt!


40m Pulse
Oscillation @ 824 Hz
2
1
0
−1
Voltage
|← 180 Hz →|
114.62
114.64
114.66
114.68
Time, secs

Tape 10/21/93, Section 10



11/1/93, TTL

2nd Data Run of Mark II

I took the same channels as on 10/21/93 with the same filtering. The data rate and acquisition software was also the same. Seiji helped me take the following data with the spectrum analyzer. They are saved on disk 30.03.

DR1ASS	Swept Sine Power Spectrum 1-10 kHz, 220 mVrms drive
DR1BSS	Swept Sine Freq. Response 1-10 kHz, 220 mVrms drive
DR1CSS	Swept Sine Coherence 1-10 kHz, 220 mVrms drive
DR1DSS	Swept Sine Power Spectrum, 1-10 kHz, 110 mVrms drive
DR1ESS	Swept Sine Coherence 1-10 kHz, 110 mVrms drive
DR1AN	Noise Power Spectrum 1-10 kHz
DR1AC	Calibrated Displacement Noise 1-10 kHz

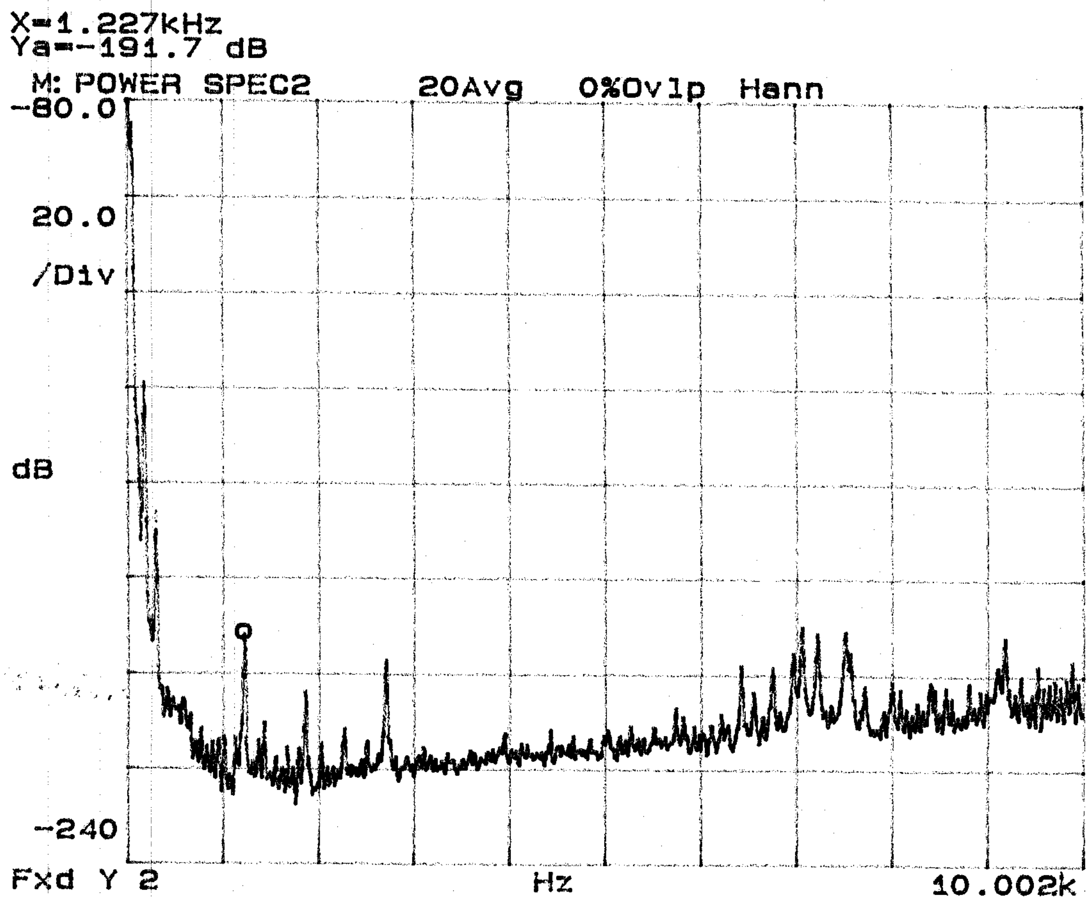
The 220 mVrms drive caused some anomolous effect around 1 kHz where the bump in the transfer function is. DR1DSS and DR1AN were used in calculating DR1AC. The measurements were all taken looking at the output **of** the SRS Pre-Amp like the A-D sees, not looking directly at the Passive Readout Filter, as was done previously. All spectra are in rms V or unitless.

Time	Event
7:09 pm	Started taking data
7:10 pm	Phone call
7:20 pm	Fell out of lock several times. Visibilities:
	A1 = 68%, A2 = 60%, AØ = 54%
	laser Power = 0.39 (uncal)
7:30 PM	Fell out of lock!
8:05 pm	Found 2nd Arm in 02 mode and knocked out of lock.
8:11 pm	I turned up the Lockup Discriminator Visibility Monitor for
	the 2nd Arm from 3.0 threshold to 4.0. The interferometer
	jumped in and out of lock many times. Visibilities:
	A1 = 67%, A2 = 59%, AØ = 52%, laser Power = 0.39
8:16 pm	Lost lock.
8:28 pm	Lost lock.
8:38 pm	Stopped Data Run.

11/1/93, TTL

On disk 30.03
DRIAC.

Calibrated Displacement Spectrum



TTL, 11/4/93

I want to compare the PSD's of the data taken on the Mark I and current Mark II data to see if the pulses were just swallowed in the noise or if they really disappeared. For comparison I will use two sections without any known pulses or oscillations. they are:

Section	Time, secs	Filename
Tape 2, Section 14 of 8/25/92 run	161 - 168	nopull. bin
Section 5 of 10/21/93 run	150 - 158	nopul5. bin

I used the program "powspc.c" to calculate the power spectra as:

```
powspc nopul5.bin -pr -k 36 -m 1024
```

This uses $(2k+1)m$ points ($\approx$ 7.57 secs) to do k FFT's, each one using 2m points. Hann windowing was used. The bandwidth for a uniform filter would be 9.63713 secs. (I believe $BW_{Hann} = \frac{9.37}{6.25} BW_{uniform}$

We need to get the two power spectra into the same units for comparison. Mike suggested the following:

$$P_1 \frac{SS_2}{SS_1} \quad vs. \quad P_2$$

where P_1 & P_2 are the two PSD's and SS_1 & SS_2 are two swept sine power spectra taken immediately before their respective runs. For the Mark I run I will use drbss2 saved on disk 27.01 as the swept sine power spectrum. It is in dB rms V^2, with a 5 kHz span. Unfortunately the swept sine for the Mark II run, DRØASS on disk 30.02 was not loaded correctly. Bob and I worked on loading it to no avail.

Friday, November 5th

Bob found the problem was that the IBM PC disk was filling up at an intermediate stage in recovering the data from the HP disk. I was able to convert the Matrix X file to a standard (frequency, power) in two columns data file used by MATLAB with load. I did this using readmatx.m and the dropping the last row and reversing the column order. (To go from VARYING matrix format to FM_ package format.)

What I actually ended up calculating is $P2 \frac{SS1}{SS2}$ (stored in p2c.psd and P1 (stored in p1.psd). I have plotted them together for comparison. Clearly the Mark II spectrum in Mark I units is much worse. To find the rms V in this 0 - 5kHz frequency band I take:

$$rms = \sqrt{\sum_i P1_i}$$

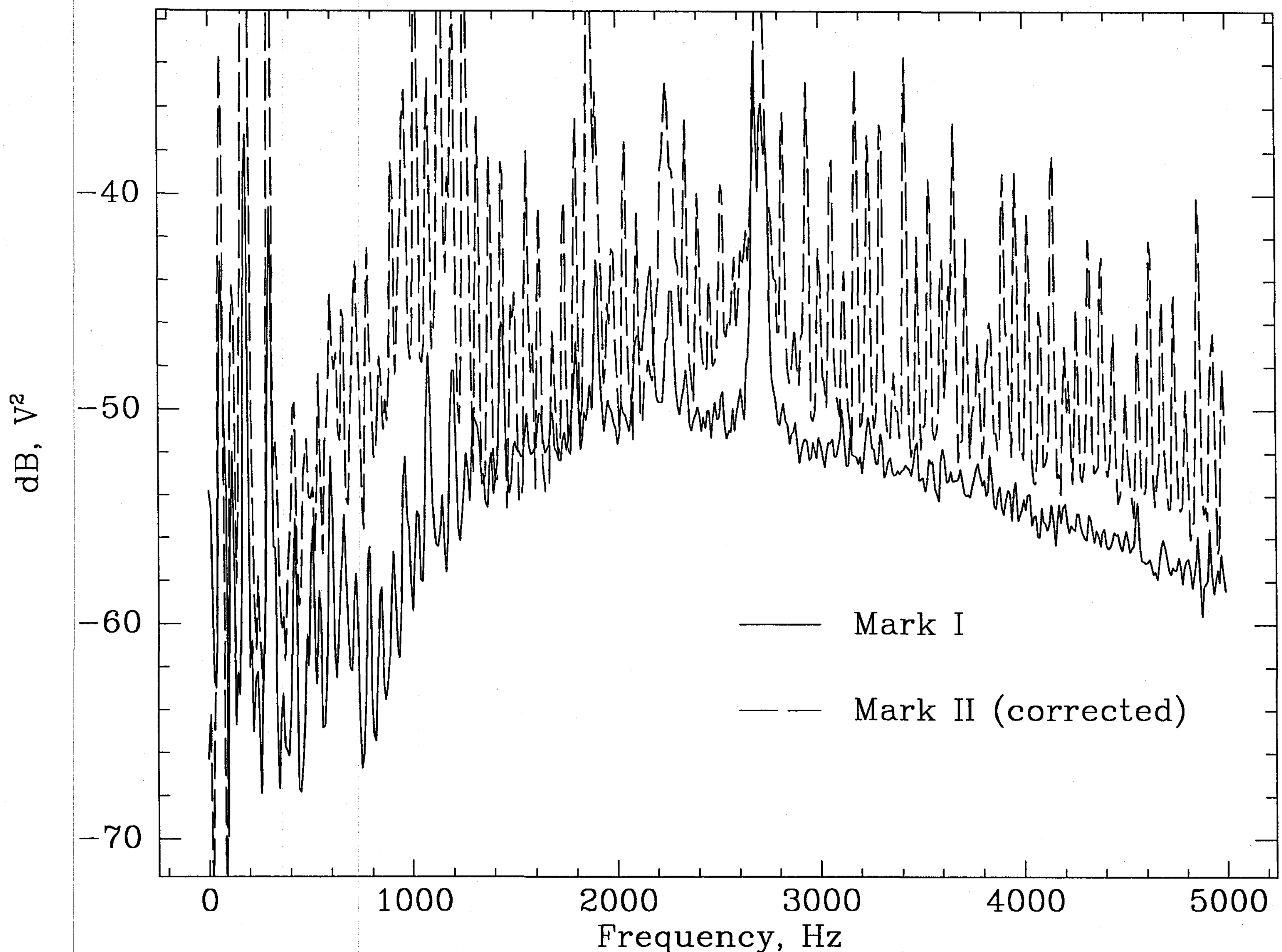
(The power spectra calculated by powspc.c are normalized so their sum is the square of the rms. There is no BW factor.) This gives:

rms V for Mark I = 0.0738
rms V for Mark II = 0.5488

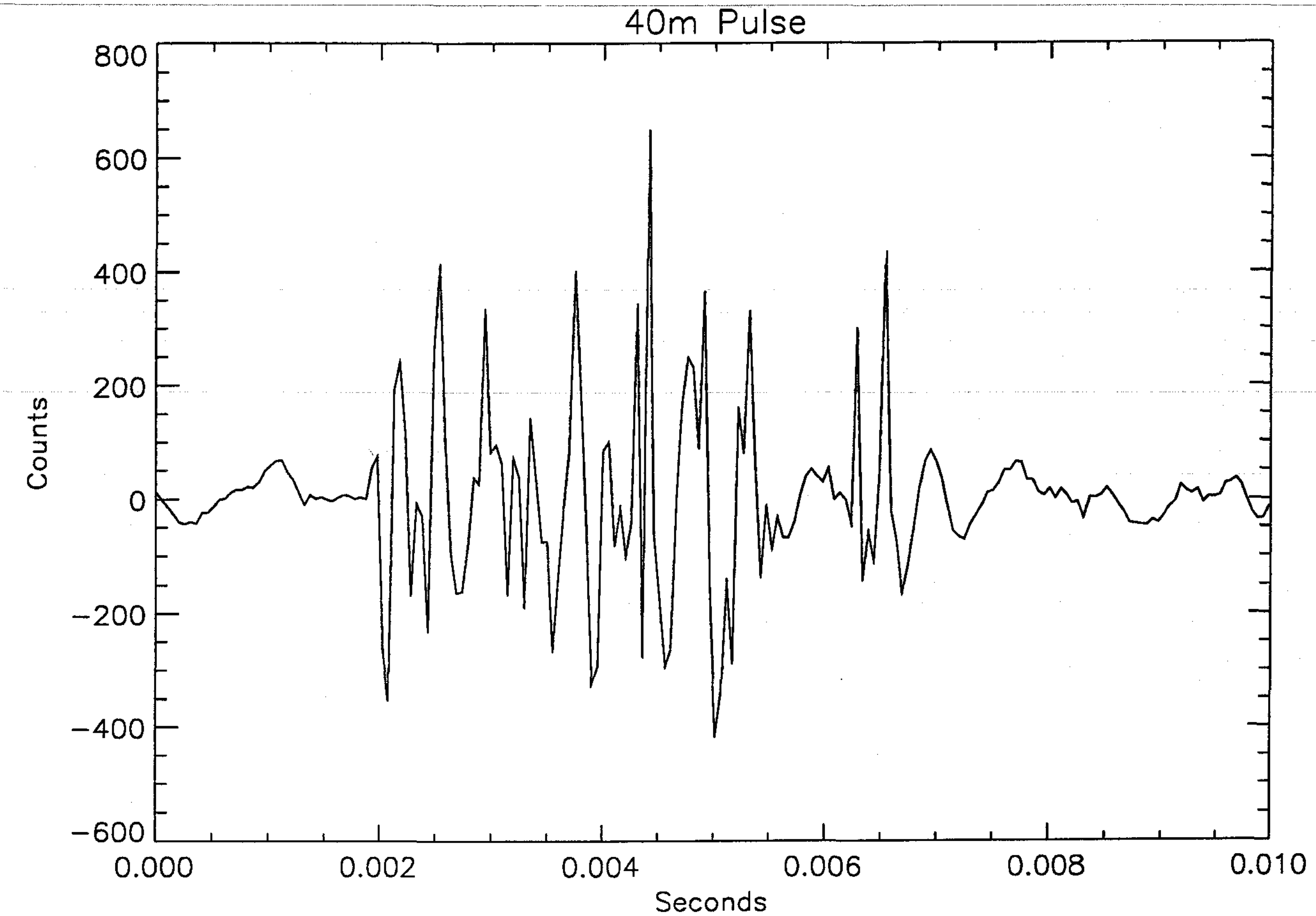
This means $\sigma_2 \approx 7.4\, \sigma_1$. This would explain the pulses being buried in the noise. I still need to make sure that drØass was recorded in V^2 as I assumed and not some other format.

The initial analysis of the data run on 11/1/93 found only 2 pulses in section 4. They are shown. 4676.5 seconds of data were read off the tape.

40m Power Spectra During Data Runs



Tape 11/1/93, Section 4

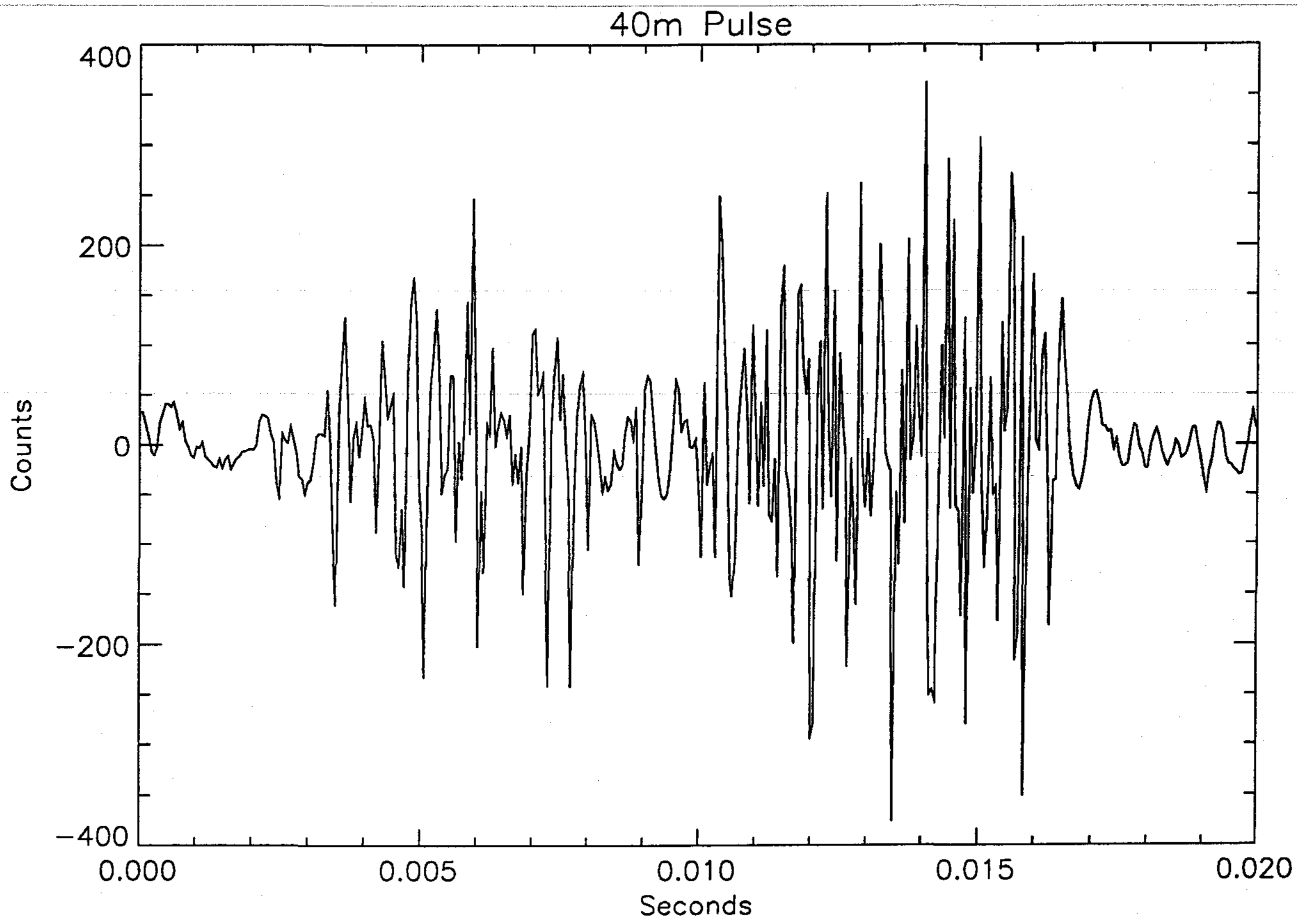


Time = 20.18 to 20.19 seconds. Height = 3.17 V.

RMS for section = 17.3 counts.

Period of this pulse ~ 2.5 kHz.

Tape 11/1/93, Section 4



Time = 28.51 to 28.53 seconds. Height = 1.84 V.

RMS for section = 17.3 counts.

11/9/93
Tuesday

I need to repeat the previous analysis comparing voltage PSD's with the most current (11/1/93) data run. I took a section of data starting at the beginning of section 5. I used the same parameters to calculate the power spectrum as previously. ($\Delta t = 7.57$ sec, $k = 36$, $m = 1024$) This is stored as "nopul3.psd." I use DR1DSS from disk 30.03 as the swept sine power spectra to convert back to equivalent Mark I voltage units. For reference a listing of the relevent MATLAB commands follows: (11/11/93)

```
a = readmatx('dr1dss.mat', 1);
ss2 = var2fm(a);
ss2s = fm_mult(ss2, 1/200);       % This is to remove the effect of
                                  the swept sine being taken after the
                                  SRS pre-amp (gain=200) while previously it
                                  was before.

ss2ss = fm_mult(ss2s, ss2s);      % Need to put swept sine into rms V^2
load drbss2.dat                   % Mark I swept sine in rms V^2
ss1 = drbss2;
ss2ssi = fm_inv(ss2ss);           % Invert Mark II swept sine.
fac = fm_mult(ss1, ss2ssi);       % Conversion factor
load nopul3.psd
p3 = nopul3
```

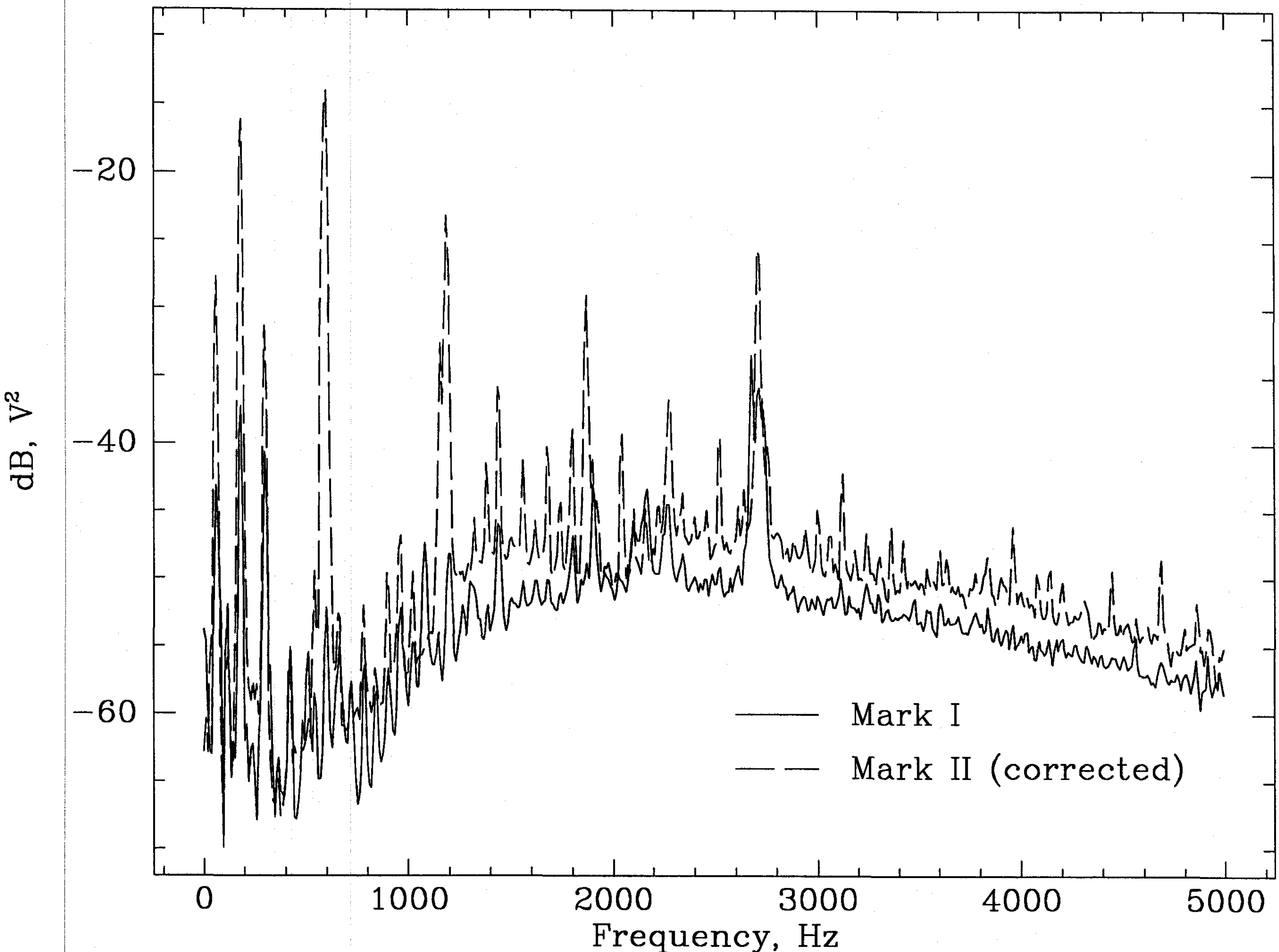
```
p3 = p3(1:519, :);          % Drop all frequencies above 5 kHz; not taken in
                             old swept sines.
```

```
p3c = fm_mult(p3, fac);     % Mark II PSD in MARK I units.

save p3c.psd p3c -ascii

sqrt(sum(p3c(:,2)))         % Calculate rms V
```

For comparison I list the rms V values (in Mark I units) calculated so far:

Mark I, 8/25/92	0.0738	
Mark II, 10/21/93	0.5488	(Very "spikey")
Mark II, 11/1/93	0.3944	

40m Power Spectra During Data Runs



11/10/93, Wednesday

Fred asked how many AD bits do we really need. Mike pointed out that the peaks in the strain spectrum must be attenuated so that they do not saturate a given A-D. In the process the broadband noise near the peaks may be buried in the digitization noise. To make some estimates of this I photocopied Bob's plot of the "40m Interferometer Displacement Sensitivity". On the 6/92 line for the Mark I we can see the following low frequency peaks:

Freq	Peak-to-Valley Ratio
> 300 Hz	< 100 for all peaks
300 Hz	500
180 Hz	> 1000

The number of bins in a particular direction (+ or −) for various A-D's is shown:

12-bit	2048 bins
14-bit	8192 bins
16-bit	32768 bins

The problem for the data runs (not for the HP Spectrum Analyzers) is that we also want to see the peaks of the pulses. For the Mark I runs this corresponded to making the background interferometer noise occupy $\frac{1}{100}$ of the available bins.

Thus we can see that 12-bits should give us digitazition noise limiting our sensitivity below 300 Hz. To see if this was true I want to plot the calibrated power spectrum I got from the data run, "nopull.cal" (discussed on 2/4-8/92 here), with the calibrated strain taken immediately before the data run with the HP3562. I will use "drbc2" taken right before tape 2 was written. "Nopul.cal" is already in $m/\sqrt{Hz}$; I need to convert "drbc2". It was generated by doing:

$$drbc2 = \frac{drbn2}{drbss2\ (j\omega)^2}$$

To get displacement we need the factor: $(2\pi)^2\gamma \cdot V_c = \beta$, where

$$\gamma = \frac{2.14 \times 10^{-15}\ m}{10.6\ mV_{rms}} (1.23\ kHz)^2$$

$$V_c = 106\ mV_{rms}$$

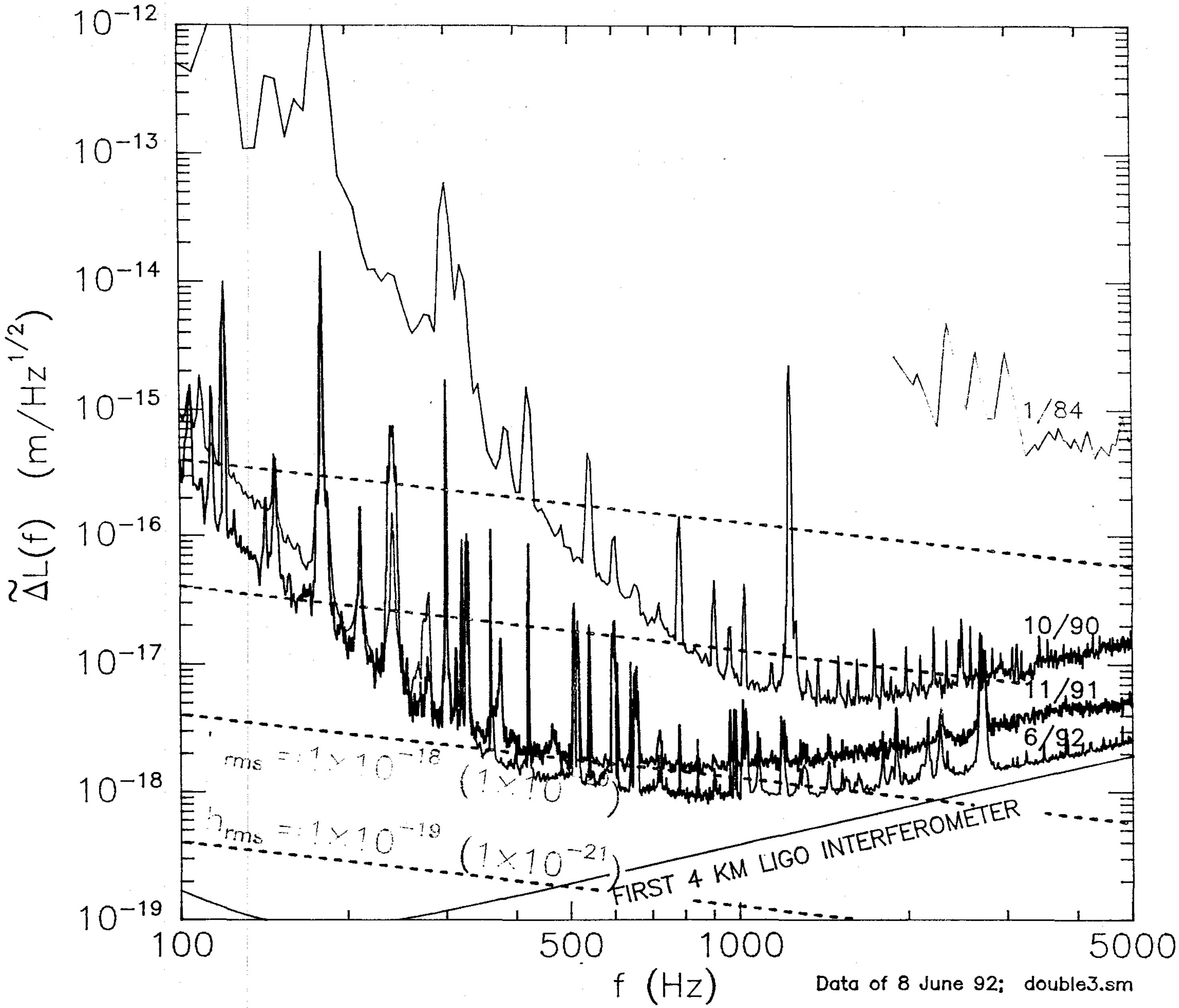
So, $\beta = 1.28 \times 10^{-6}$ m.

We also need to put in the bandwidth factor which is 9.37 Hz for the HP 3562 with a 5kHz span with Hann windowing. Thus we multiply by, $\alpha = \frac{\beta}{\sqrt{9.37}} = \boxed{4.18 \times 10^{-7} \frac{m}{\sqrt{Hz}}}$.

11/12/93

I got a printout from Bob which says for a 5kHz span calibrated spectra from the HP 3563A, $\boxed{\alpha = 5.30 \times 10^{-7} \frac{m}{\sqrt{Hz}}}$. Either way the spectra are all too low except drbc∅.

40 m INTERFEROMETER DISPLACEMENT SENSITIVITY



Data of 8 June 92; double3.sm

vrobert/info/calbn6.txt

PRELIMINARY

01-Nov-93 Mk II Calibration RES Revised: 12-Nov

Calibration of interferometer displacement sensitivity, using East End calibration coil
Based on Bk 30, p. XXX calibration of coil drive in terms of 40 m arm fringes
Network transfer function measurements used (no explicit resistance measurements).

mu = xf^2/Vf= 4.74E-05 m/sec^2/Volt (P. 49Y)

TABLE 1: Old method of swept sin.
Power spectrum units of swept sin calibration used to normalize gravity wave signal Vg.

H = -42.07 dB current ratio [through 1 ohm]/[direct to coils] (P. 72Y)
alpha=muH= 3.73E-07 m-Hz^2/Volt = x f^2 / V_1ohm; Calibration relative to source setting, Vs.
alpha1= 1.47E-05 = (2Pi)^2 alpha

Span	BW	f0 line	Vs(line) mVrms	x(line) mrHz	x(line) e-18 mrHz	Vss(Swpt) mVrms	k1	db18
10000	18.74	1230	1.06	6.04E-17	35.6	110	3.75E-07	-231.47
5000	9.37	1230	1.06	8.55E-17	38.6	110	5.30E-07	-234.48
2000	3.748	1230	1.06	1.35E-16	42.6	110	8.38E-07	-238.46
1000	1.874	800	1.06	4.52E-16	53.1	110	1.18E-06	-241.47
500	0.937	400	11	2.65E-14	88.5	110	1.68E-06	-244.48
100	0.1874	80	110	1.48E-11	143.4	3000	1.02E-04	-280.19
50	0.0937	40	1100	8.39E-10	178.5	3000	1.45E-04	-283.20

NOTES:

BW = bandwidth; {f0, Vs(line)} = {frequency, level} of source setting of sine wave calibration
x(line) = rms displacement of calibration line / sqrt(BW); shown in m/rHz and dB rel. to 1e-18 m/rHz
Vss = Setting of source for swept sin measurement
Let H = Transfer Function from Vss to "gravity wave" output Vg
then H = JK, where J = T.F. (Vss to displacement x); K = T.F. (x to Vg)
H1 = H/Vss, the power spectrum of Vg in response to Vss (unnormalized by Vss).
Compute G = Vg/(H1 omega^2) = x/(alpha1 * Vss)
x(f) = k1*G = Spectrum in units of m/rHz (k1 computed by k1 = alpha1 * Vss / sqrt(BW))
db18 = Level of G that corresponds to 1e-18 m/rHz (computed by 1e-18/k1)

Torrey — I think these are the numbers you need — Bob

TABLE 2: New method of swept sin
Frequency response of swept sin calibration normalizes Vg.
Source loaded by 1 ohm; Swept sin level recorded is independent of Vs.

G = -9.27 dB current ratio [1 ohm]/[direct], loaded source (p. 72y)
beta=muG= 1.63E-05 m-Hz^2/Volt = x f^2 / V_1ohm; Loaded source read by Channel 1
beta1= 6.44E-04 = (2Pi)^2 beta1

Span	BW	f0 line	Vs(line) mVrms	x(line) mrHz	x(line) e-18 mrHz	k1	db18
10000	18.74	1230	1.06	6.04E-17	35.6	1.49E-04	-283.45
5000	9.37	1230	1.06	8.55E-17	38.6	2.10E-04	-286.46
2000	3.748	1230	1.06	1.35E-16	42.6	3.32E-04	-290.43
1000	1.874	800	1.06	4.52E-16	53.1	4.70E-04	-293.45
500	0.937	400	11	2.65E-14	88.5	6.65E-04	-296.46
100	0.1874	80	110	1.48E-11	143.4	1.49E-03	-303.45
50	0.0937	40	1100	8.39E-10	178.5	2.10E-03	-306.46

NOTES:

BW = bandwidth; {f0, Vs(line)} = {frequency, level} of source setting of sine wave calibration
x(line) = rms displacement of calibration line / sqrt(BW); shown in m/rHz and dB rel. to 1e-18 m/rHz
Vss = Mea[illegible]ed value of source output (50 ohms source loaded by 1 ohm).

```
Let H = Transfer Function from Vss to "gravity wave"  output Vg
  then H = JK, where J = T.F. (Vss to displacement x);  K = T.F. (x to Vg)
Compute G = Vg/(H omega^2) = x/beta1
x(f) = k1*G = Spectrum in units of m/rHz  (k1 computed by k1 = beta1 / sqrt(BW))
db18 = Level of G that corresponds to 1e-18 m/rHz (computed by 1e-18/k1)
```

11/18/93, TTL

I can not get any of the old calibrated spectra from the Mark I to come out to a reasonable level using either Bob's or my value for α. The only exception is "drbc∅" which looks reasonable. Strangely the swept sine recorded for it, "drbss∅," is ~100 dB larger than all the others for this run.

However this may be I redid this for the most recent data of 11/1/93. I use "drldss" to calibrate the noise spectrum calculated earlier from the time domain data at the beginning of section 5. ("nopul5.dat" calculated on 11/9/93) I use "drlac" as the calibrated spectrum from the HP3563A.

The discrepancy between Bob's and my number to put "drlac" in $m/\sqrt{Hz}$ units (α) can be explained by a different coil calibration in the Mark II. The ratio between voltage to the coil and acceleration of the test mass is:

$$\gamma_{MkI} = 3.0543 \times 10^{-7} \frac{m}{s^2 V}$$

$$\gamma_{MkII} = 3.73 \times 10^{-7} \frac{m}{s^2 V}$$

I will use Bob's numbers from the following printout on the Mark II data.

I found an error in my Mathematica routine to calibrate the time domain data using a swept sine, CalibratePSP. The bandwidth correction factor to allow for the different bandwidths between the power spectrum of the time domain data and the swept sine and to put the result in $\frac{m}{\sqrt{Hz}}$ instead of $\frac{m}{bin}$ was $\frac{BWB}{BWA}$ while it should have been $\frac{BWB}{(BWA)^2}$.

BWA = Band width of time domain power spectrum
BWB = Band width of swept sine

Corrected for the Hann window the bandwidths over a 10 kHz span are:

BWA = 14.4480
BWB = 18.74

I also modified CalibratePSP to include the Mark II coil calibration. Plotting the two calibrated spectra together gives excellent agreement.

11/24/93, TTL

It appears that the first part of section 5 is not a very representative time to take a power spectrum of. The V_{rms} for the 1st second is ~70 counts (≠ 0.3418 V). I recalculated a power spectrum 100 seconds into section 5 of run 11/1/93. (Δt = 7.57 ses, k=36, m = 1024) This is stored as "nopul6.psd".

11/29/93, TTL

We can model digital quantization effects as stochastic noise which is white out to the Nyquist frequency. For 12 or 16 bits and a ±10V range the rms value of the equivalent stochastic noise is:

$$\sigma^2 = \frac{\Delta^2}{12} \qquad \Delta = \text{smallest voltage step}$$

$$\sigma_{12}^2 = 1.9868 \times 10^{-6}\ V^2$$

$$\sigma_{16}^2 = 7.7610 \times 10^{-9}\ V^2$$

I then put this into the same form as is produced by <u>powspc</u>, by getting the list of 1024 frequencies from 0 - 10 kHz and dividing by 1024 to get the same V^2/bin at each frequency. The two files produced in this way, "d12.psd" and "d16.psd", can be calibrated like any other voltage noise power spectrum. This gives "d12.cal" and "d16.cal" which are the equivalent displacement noise limit due to 12 or 16 bit quantization error.

A plot of the results follows. This plot shows that quantization effects do not limit our displacement noise sensitivity except perhaps below 50 Hz. The plot is made by inserting the command:

device hpplA :SY@: :OF@: <u>filename</u>.hpgl

into the .sm command file. To plot the resulting file on the 3rd floor plotter I use from the Unix prompt:

plothp3 <u>filename</u>.hpgl

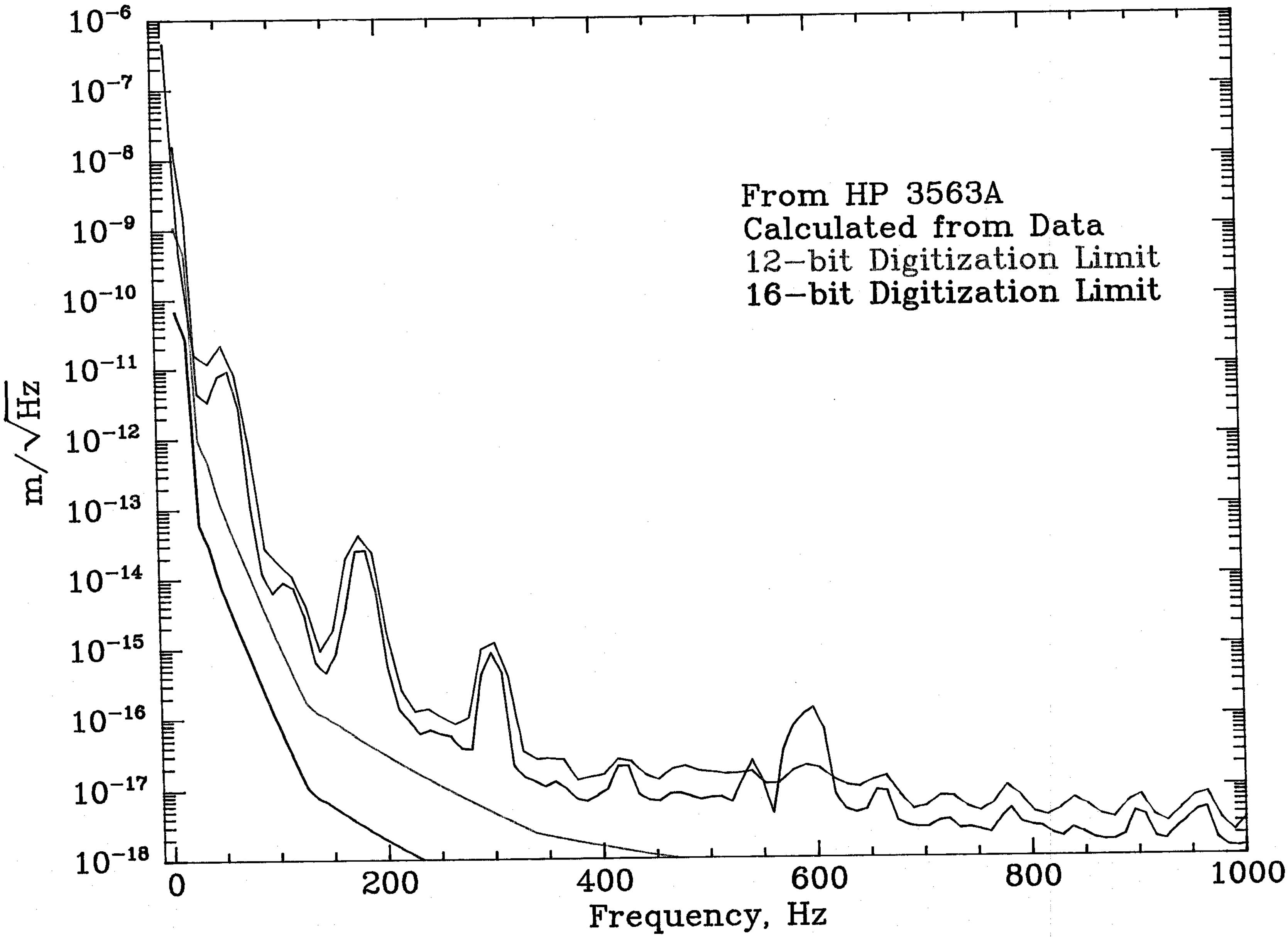
The pen number to use to draw a line is selected in SM with the CTYPE command. The format and conversion is:

CTYPE <u>integer</u>

Pen Number = <u>integer</u> - 1

11/30/93, TTL

40m Strain Spectra



12/2/93, TTL

Data Run "F"

I took the following data with the HP3563A Spectrum Analyzer.

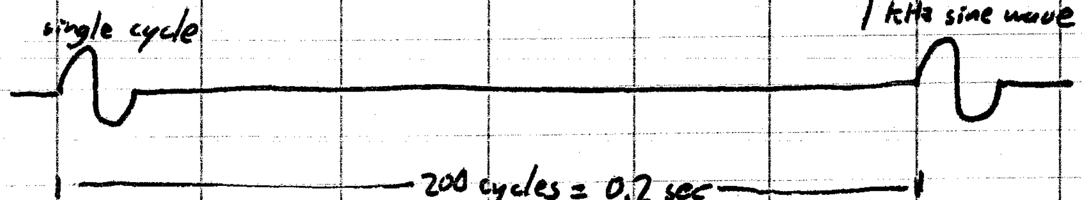
DRFN1	Noise Power Spectrum, no calib. sine
DRFN2	Noise Power Spec. calib. sine @ 1.6 kHz, 10.6 mVrms
DRFSS1	Swept Sine Power Spec. 109.6 mVrms source level
DRFSS2	Coherence of DRFSS1
DRFSS3	Swept Sine Freq. Resp.
DRFSS4	Coherence of DRFSS3
DRFC1	Calibrated Noise Spectrum using $\frac{DRFN1}{(j\omega)^2 DRFSS1}$, no sine
DRFC2	Calibrated Noise Spectrum using $\frac{DRFN2}{(j\omega)^2 DRFSS1}$, 1.6kHz, 10.6 mVrms sine

All of these were taken over a 10 kHz span with Vrms used where units are appropriate. All are saved on disk 31.03. The interferometer is being run with intensity stabilization for the 1st time in a data run since Mark II. Channels Taken:

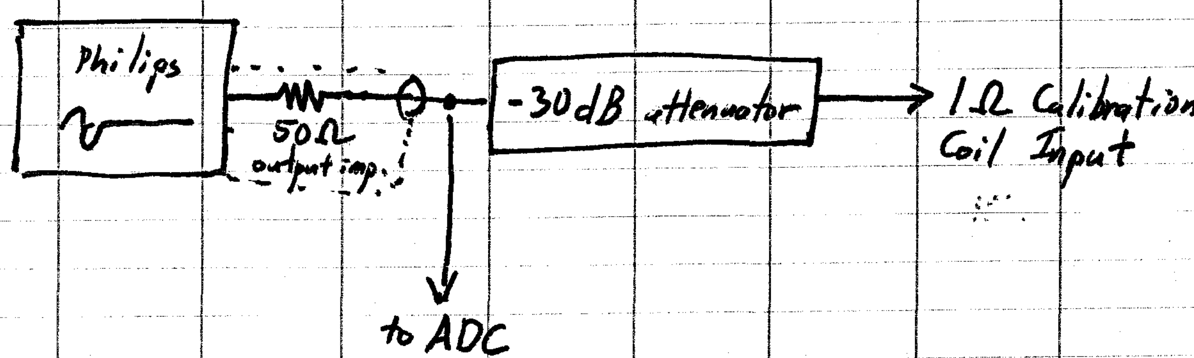
	Channel	Signal
fast	0	Strain: Passive Readout Filter BP 200-2kHz, Stanford BP 10-10kHz, 6 dB/oct. rolloff, 200 gain, AC
fast	1	Artificial Pulses Monitor (see next page) ★ This is the only channel different from previous runs.
slow	2	Primary Cavity TTL In lock: In lock = low (no filt.)
slow	3	Secondary Cavity TTL In lock: In lock = low (no filt.)
slow	4	Laser Slow PZT 1/100 Monitor (no filt.)
slow	5	Ranger Seismometer: PAR 113 BP 0.03-100 Hz, 2k Gain, AC
slow	6	Microphone: PAR 113 BP 0.03-300 Hz, 10k Gain, DC
slow	7	DC Coupled Strain: 10k-1.5k voltage divider Ithaco 4302 LP 80 Hz, gain=1, DC, 24 dB/oct.

Artificial Pulses

During this data run I put in artificial pulses into the 1st arm calibration coil. Mike suggest this idea. The easiest pulses to make were single sine wave cycles. We used the Philips PM 5193 Programmable Synthesizer / Function Generator 0.1 mHz – 50 MHz to do this. The pulse cycle looked like:

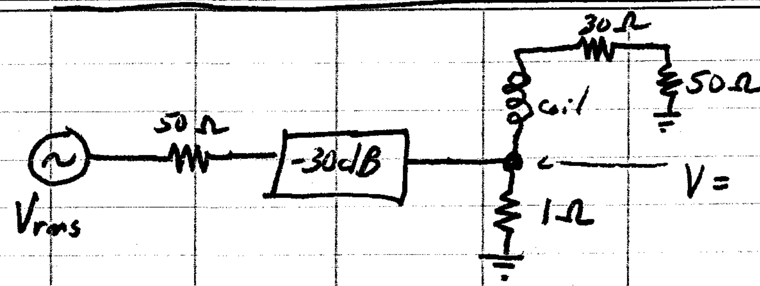


We chose 3 standard sizes for the pulses: 1, 0.5, 0.1 V rms at the output of the Philips. The 1Vrms was easy to see above the noise on the strain and the 0.1 Vrms was basically buried. The setup was:



-/-/93

Mike's Quick "Standard" Pulse Calibration



$$V = \frac{V_{rms}}{31.6}\ \frac{1\,\Omega}{50\,\Omega}$$

(31.6 ← −30dB)

$$I_{coil} = \frac{V}{80\,\Omega} = \frac{V_{rms}}{1.265\times10^5}$$

$$F = 0.1\ N/A \times I_{coil}$$

$$x = \frac{F}{(2\pi f)^2 m} = \frac{(0.1\ \frac{N}{A})\left(\frac{V_{rms}}{1.265\times10^5}\right)}{(2\pi\times10^3)^2\ (1.5\ kg)}$$

$$\underline{x_{rms} \simeq 1.3\times10^{-14}\ m_{rms}} \qquad \text{for } V_{rms} = 1\ V$$

My version...

Bob's writeup "calbn6.txt" reports: $\gamma = 3.73\times10^{-7}\ \frac{m}{s^2\,V}$

$$\therefore\ x = \left(3.73\times10^{-7}\ \frac{m\ Hz^2}{V}\right)\left(\frac{1}{1000\ Hz}\right)^2 V_{rms}/1580$$
$$= 2.4\times10^{-16}\ m_{rms}\ V_{rms}$$

12/3/93

Following a discussion with Mike I realized that γ is relative to the voltage setting on the spectrum analyzer, not across 1 Ω. This gives an extra factor of 50 as I should have only divided V_{rms} by 31.6, not 1580. Our results are now in agreement.

$$\underline{x_{rms} \simeq 1.2\times10^{-14}\ m} \qquad \text{for } V_{rms} = 1\ V.$$

12/2/93, TIC

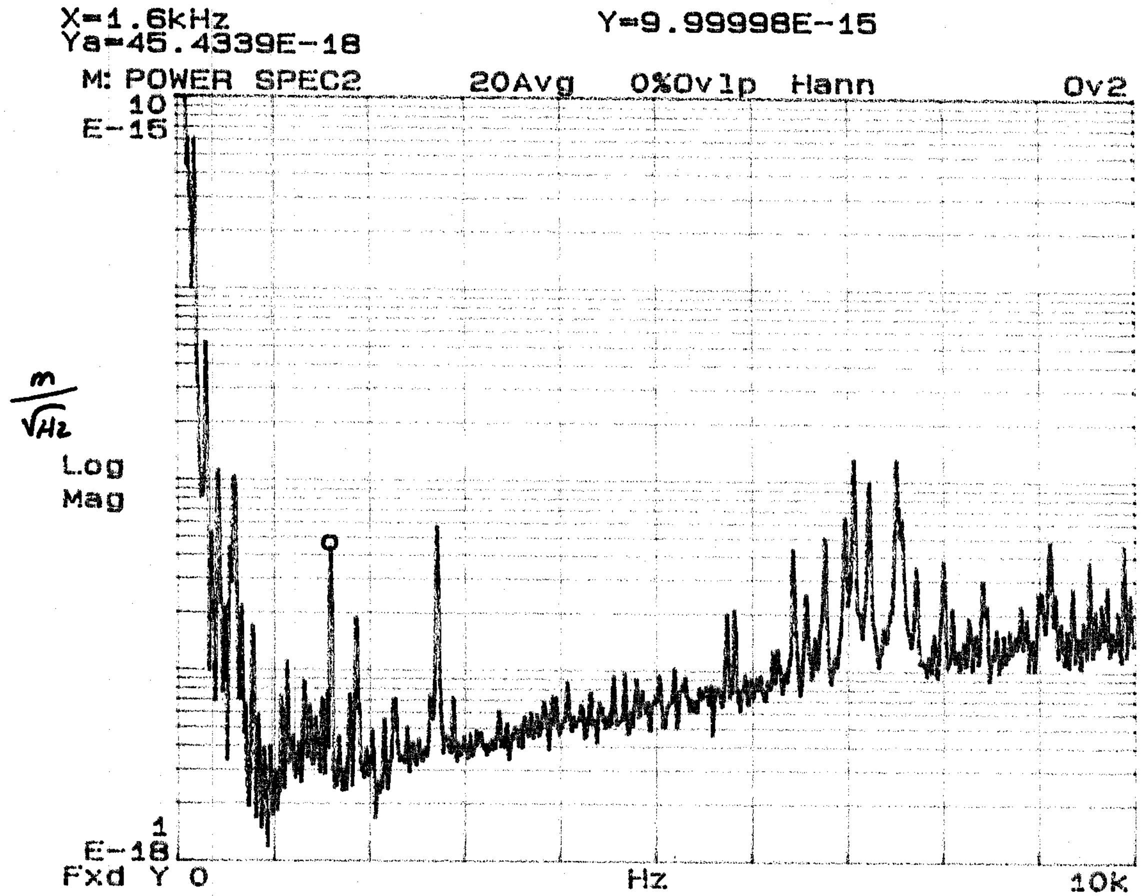
Data Run Events

Time	Event
8:51 pm	Started writing tape, AØ = 57%, A1 = 65%, A2 = 57% 150 mV mode cleaner throughput, Coil Driver gain = 3.8
8:52 pm	Back in lock, Fixed sine @ 1.6 kHz, 10.8 mVrms is on.
+1 min. 9:02 pm	Disconnected fixed sine.
9:04 pm	Started 1 Vrms standard pulses.
9:06 pm	Stopped 1 Vrms standard pulses
9:07 pm	Started 0.5 Vrms standard pulses
9:08 pm	Disconnected strain readout from HP3563A
9:09 pm	Stopped 0.5 Vrms standard pulses.
9:10 pm	Started 0.1 Vrms standard pulses
9:12 pm	Stopped 0.1 Vrms standard pulses. Disconnected coil input from attenuator.
9:40 pm	Out-of-Lock (2nd arm), AØ = 53%, A1 = 65%, A2 = 57% Laser power = 0.46 W (uncal.)
9:49 pm	Laser turned off due to auto-fill problem
10:08 pm	Stopped tape writing after numerous laser failures.

Stopped writing after 4536.367 seconds.

12/2/93, 8 pm
JTL

Calibrated Displacement Before Data Run



Has 1.6 kHz calibration sine at 10.6 mVrms.

Saved on disk 31.03 as DRFC2 without scalar factor of 3.75×10^{-7} to put in $m/\sqrt{Hz}$.

12/7/93 - TTL

After Greg worked with and cleaned the tape drive, I suceeded in reading 3450 secs out of the 4536 that are supposed to be on the tape. Luckily it did read most of the useful data, including the entire 2nd locked section. I took a histogram of sample values for this section shown following. The broad humps due to the artificial pulses are clearly seen.

12/8/93 - TTL

I ran pulses to find all the pulses on channel I (artificial pulse monitor).

pulses chan1 -pr -t 10 -d 1 -reset

I then split the results into 1 V_{rms}, 0.5 V_{rms} and 0.1 V_{rms} (source level) pulses. Numbers found:

1 V ⇒ 309 pulses, 0.5V ⇒ 596 pulses,
0.1 V ⇒ 598 pulses

I look for coincidence between strain pulses and artificial pulses of various sizes. The peaks in strain seem to occur about 1 ms later then those in the artificial pulse monitor.

```
coincidence pulses2.dat pulses1V.dat -t 0.001 -s 0.001 -v
```

This gives for 1 V_{rms} pulses:

\# of Overlap Events = 309

COINCIDENCE = 269.693359

Relative Coin. = -269.693359

Thus every 1 V pulse was found. A summary for all sizes:

Source Level	# of pulses	# found	% found
1 V_{rms}	309	309	100%
0.5 V_{rms}	596	596	100%
0.1 V_{rms}	598	1	0.17%

I made a plot of pulse heights. I chose a reasonable threshold of 60 counts = 0.29 V which gives a mean time between pulses of 0.2 secs.

```
pulses chan∅ -pr -d 1 -t 60 -reset
cut -f2 -s pulses.out | grep -v Height > pul∅.dat
binner pul∅.dat -1 ∅ -h 3.0029296875 -n 615
```

Unfortunately this did not make the voltage bins line up with the number of counts. I instead loaded pul0.dat into MATLAB, multiplied it by 204.8 to convert to counts and then wrote it out again as pul1.dat. Then:

binner pul1.dat -l 0 -h 615 -n 615

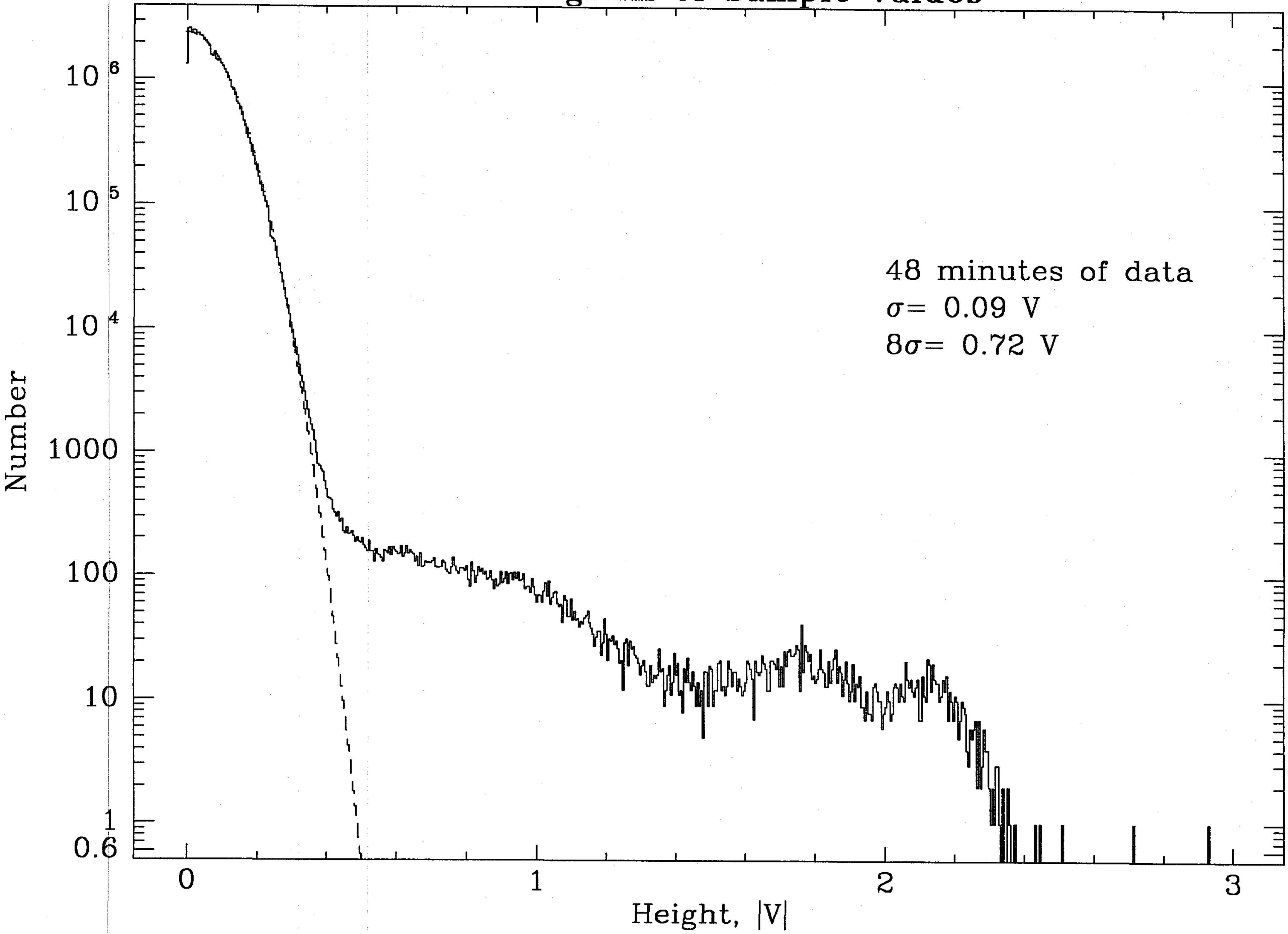
produced the correct binning. This is shown following.

12/4/93 - TTL

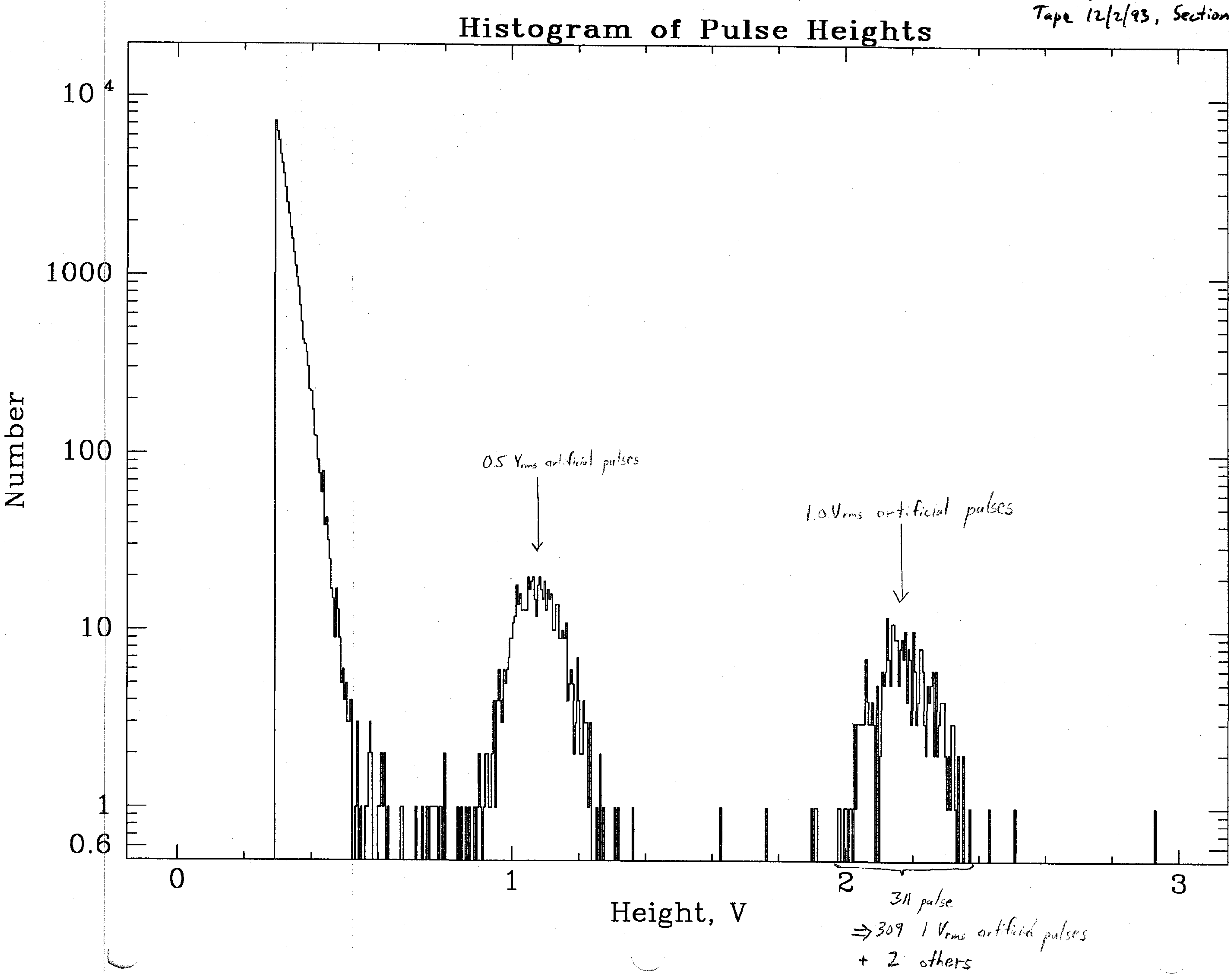
Unfortunately the 0.1 Vrms artificial pulses should show up as a bump on the pulse height histogram at 0.22 V. Thus our cutoff at 0.3 V would miss this. I tried repeating the above process with a threshold of 30 counts ≈ 0.146 V. At 30 counts the mean time between pulses is 4.5 ms. The histogram follows. There is evidence of undercounting the smaller pulses. No bump can be seen due to the 0.1 Vrms artificial pulses.

12/7/93, TTL
Tape 12/2/93, Section 2

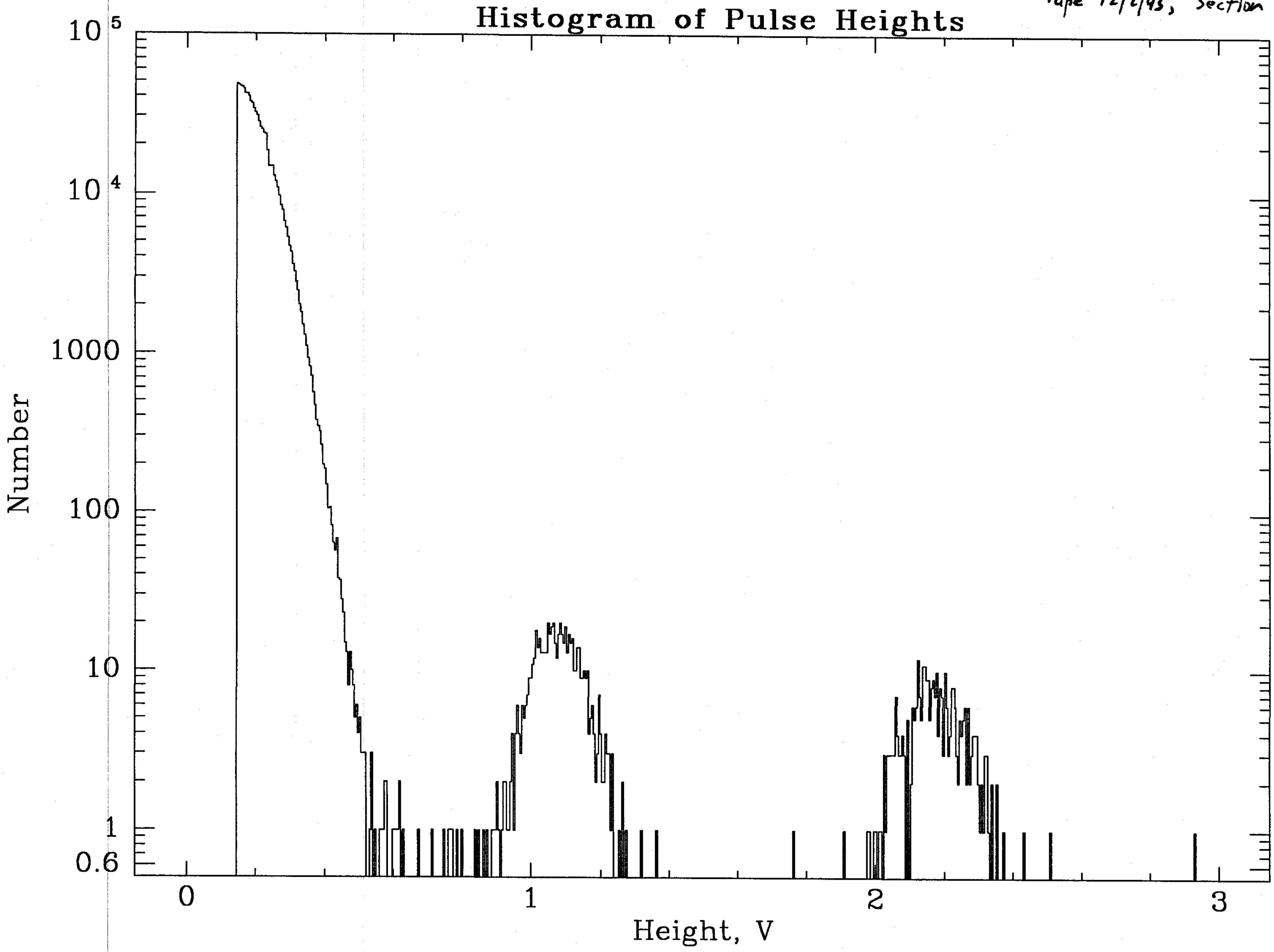
Histogram of Sample Values



Tape 12/2/93, Section 2



Tape 12/2/93, Section 2



12/11/93, TTL

I extracted 5 minutes of data for Aaron. It was:

Tape 12/2/93, Section 2, 1600 - 1900 seconds.

12/13/93, TTL

I want to plot the artificial pulses in displacement.

$$\frac{dx^2}{dt^2} = \frac{F}{m} = \alpha V$$

$$x = \alpha \int_0^t \int_0^{t'} V(t'')\, dt'' \qquad \text{assuming } x(0) = 0,\ \dot{x}(0) = 0$$

For the larger pulses:

$$V(t) = \sqrt{2}\, \sin \omega t \qquad \omega = 2\pi\, 1000$$

$$x(t) = \alpha \int_0^t \frac{\sqrt{2}}{\omega} (1 - \cos \omega t')\, dt' \qquad 0 < t < \frac{1}{1000}$$

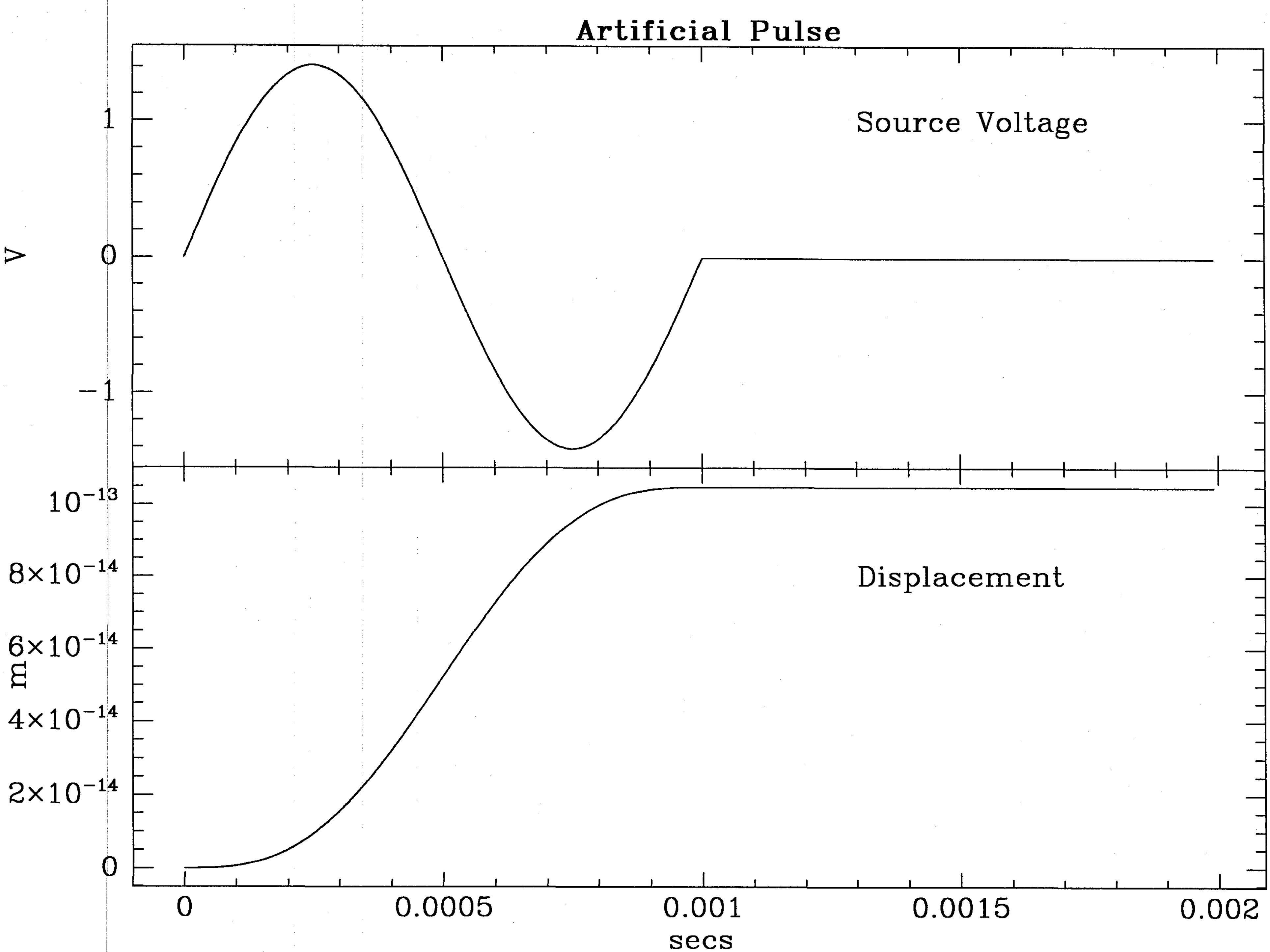
$$= \sqrt{2}\, \alpha \left(\frac{t}{\omega} - \frac{1}{\omega^2} \sin \omega t \right)$$

$$\alpha = (2\pi)^2 \left(\frac{1}{31.6} \right) \left(3.73 \times 10^{-7} \frac{m\ Hz^2}{V} \right)$$

↑ -30 dB source attn. ↑ coil calib.

To do this I used Mathematica to output points:

```
f[t_ /; t > 0 && t < 0.001] = Sqrt[2] Sin[2 Pi t 1000]
f[t_] = 0
```



Artificial Pulse
Source Voltage
V
1
0
−1
Displacement
m
10^{-13}
8×10^{-14}
6×10^{-14}
4×10^{-14}
2×10^{-14}
0
0
0.0005
0.001
0.0015
0.002
secs

1/3/94, TTC

Comparison of Pulse Rates and RMS noise level:

Tape 12/2/93, Section 2 has 954 pulses found. Of these 906 are coincident with artificially impressed pulses. (See 12/8/93 write-up.) This leaves 48 real pulses found during 2903.2 seconds, or 0.99 pulses/minute.

1/6/94, Thur.

To compare the RMS noise levels I calculate the power spectra of the noise in this section. I take some time between known pulses:

```
clip chan0 -t 1100 1108 -bin -pr > nopul7.bin
powspc nopul7.bin -pr -k 36 -m 1024 > nopul7.psd
```

To convert this to equivalent Mark I units I use the algorithm sketched on 11/9/93. The files used are drbss2.dat and drfss1.mat for the swept sine power spectra.

Formula:

$$(\text{nopul7.psd}) \frac{(\text{drbss2.dat})}{\left(\frac{\text{drfss1.mat}}{200}\right)^2} \; 2$$

← To correct for BW factor, since drbss2 is 5kHz span.

↑ To move from after SRS preamp to before.

This factor of two was missing, I believe, on the calculations of 11/9/93 and 11/5/93. After doing the calculation I got various negative power values at frequencies < 150 Hz. This is due to interpolation errors which sometimes cause functions near zero to dip below zero. Either way the swept sine coherence is low here anyway so I decided to recalculate the total RMS Voltage from 200 - 5000 Hz instead of down to DC which we know is garbage. Doing this I get:

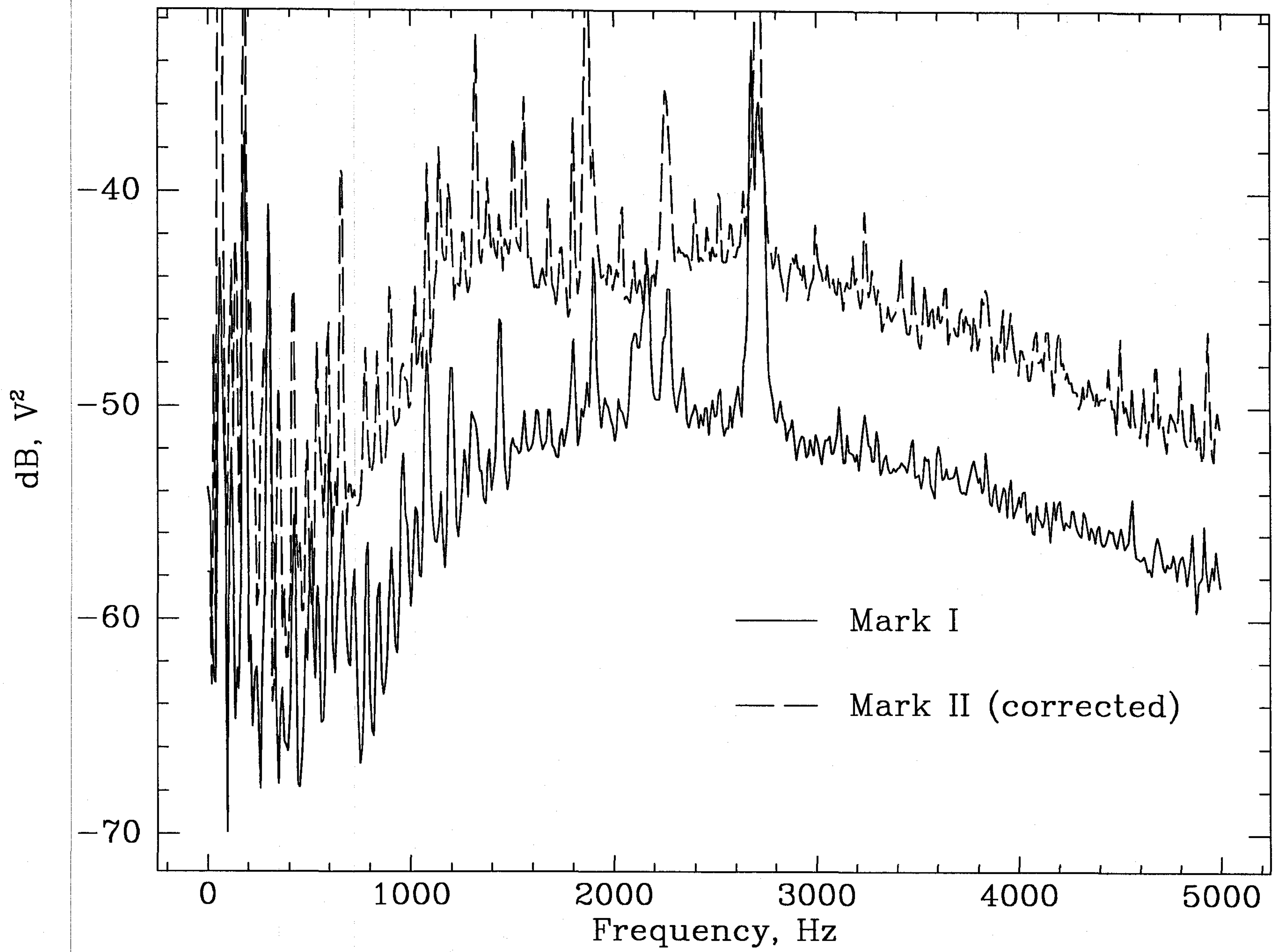
Mark I, 8/25/92, "nopull.dat" ⇒ 0.0707 V_{rms}

Mark II, 12/2/93, "nopul7.dat" ⇒ 0.1805 V_{rms}

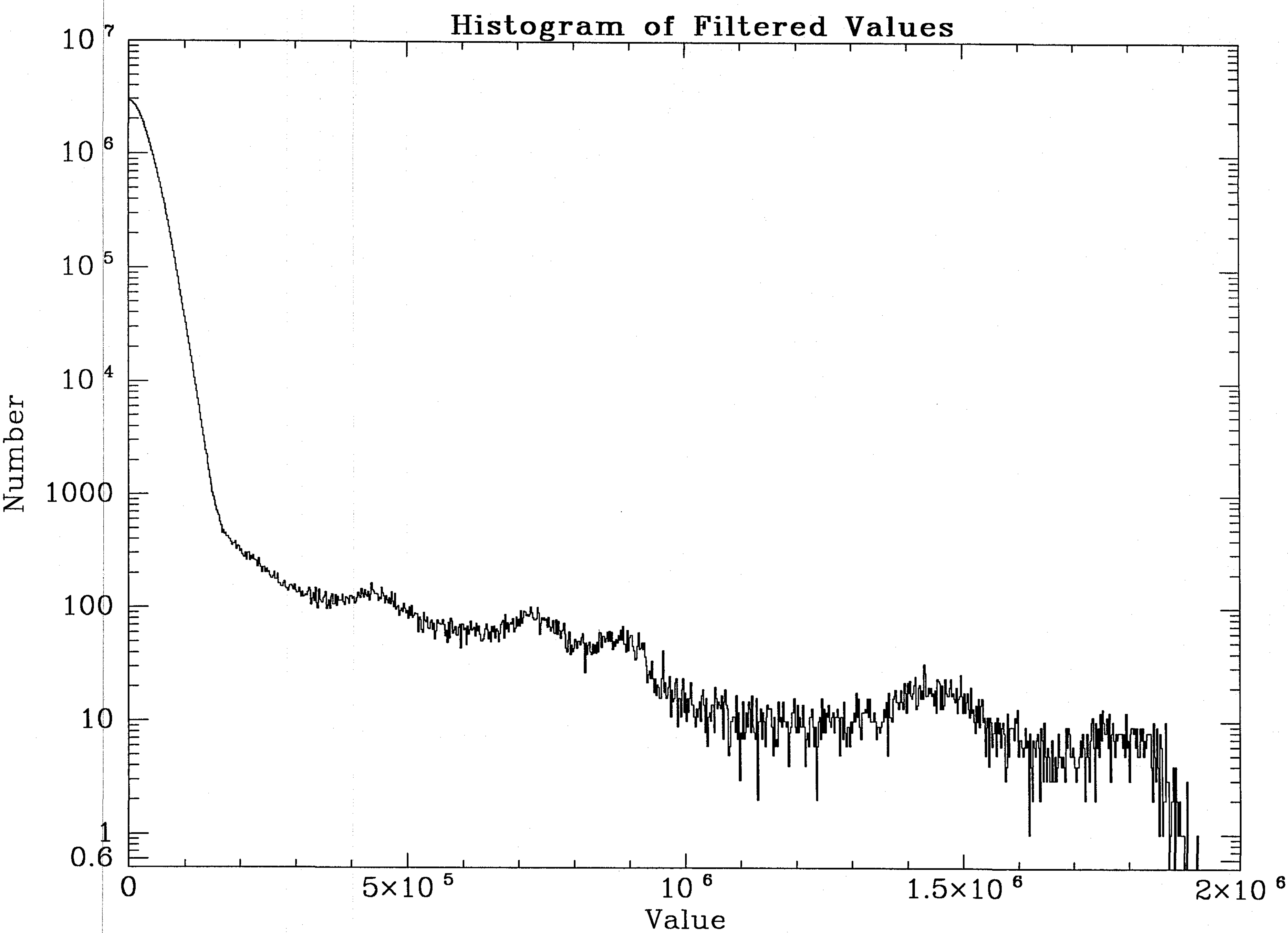
Noise is 2.5 times as high. Plot follows.

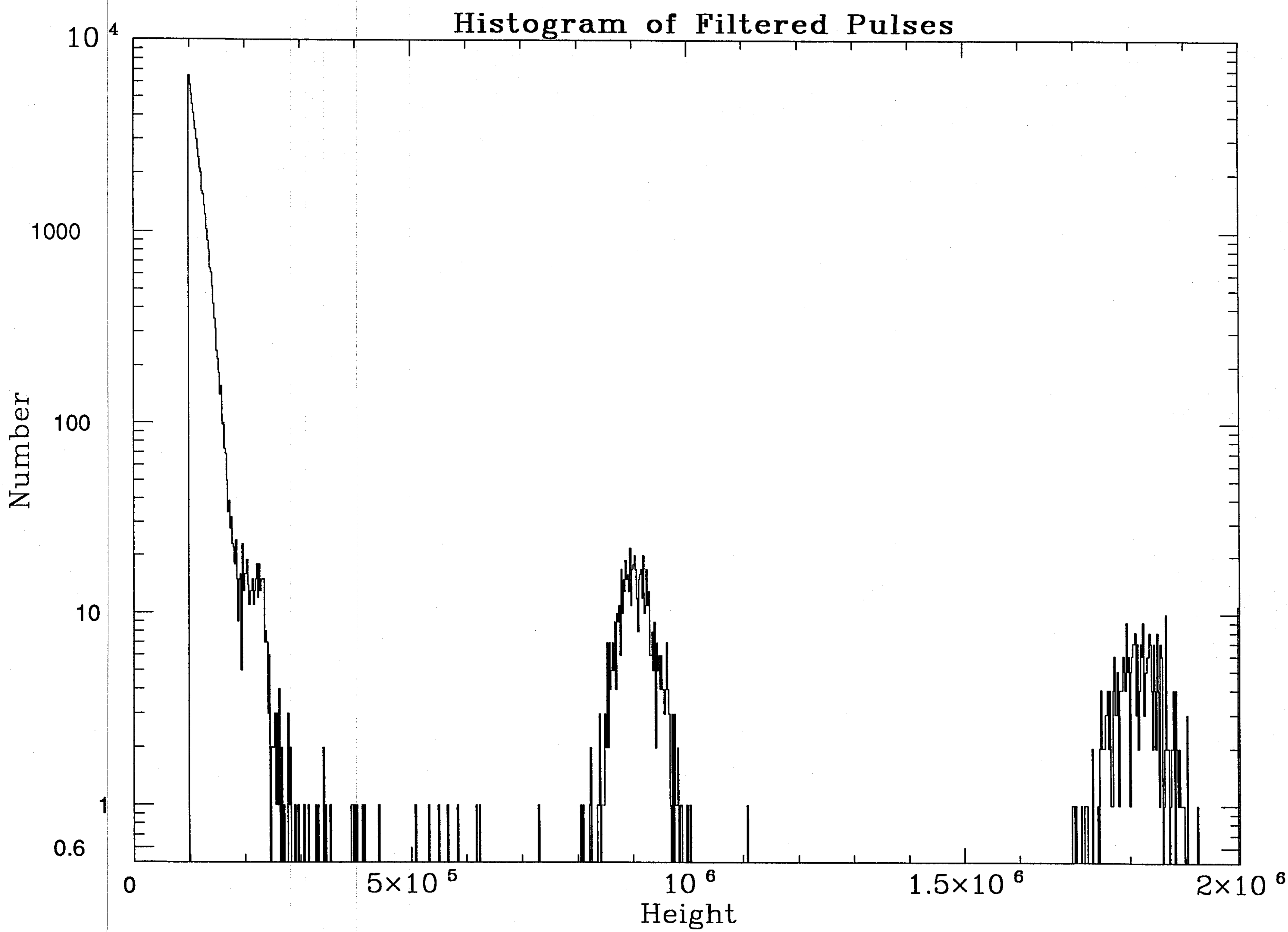
1/3/94, TTL

40m Power Spectra During Data Runs



Ran a matched filter search (no whitening) through Tape 12/2/93, Section 2 with a filter 56 samples long which was cut from the data during one of the big impressed pulses. (S/N was good so the fact that I only used one should be okay.) The histogram of the filtered output follows. A pulse histogram is also shown. On the pulse histogram on can see the smallest size of impressed pulse which was buried in the noise previously.


Histogram of Filtered Values
Number
Value
10 7
10 6
10 5
10 4
1000
100
10
1
0.6
0
5×10 5
10 6
1.5×10 6
2×10 6



Histogram of Filtered Pulses
10^4
1000
100
10
1
0.6
Number
0
5×10^5
10^6
1.5×10^6
2×10^6
Height

Data Run "G"

The channels taken are the same as on 12/2/93.
Before the data run Bob took a collection of data on the HP3563A.
They are saved on 32.01.

RECOVE8 5 kHz Calibrated Spectrum (in $m/\sqrt{Hz}$)
⋮

Bob & Mike futzed around taking spectra till I had to go home.
I came back later and took my own. $V\phi = 45\%$, $V1 = 62\%$, $V2 = 63\%$.

DRGN1	Noise Power Spectrum 0–10 kHz
DRGSS1	Swept Sine Power Spec. (110 mV_{rms} source level) No coherence below 100 Hz.
DRGSS2	Coherence of DRGSS1.
DRGSS3	Swept Sine Frequency Response.
DRGSS4	Coherence of DRGSS3.
DRGC1	Calibrated Noise Spectrum using $\frac{\sqrt{DRGN1}}{(j\omega)^2\, DRGSS3} \cdot \frac{1}{7133}$

(New standard method.) (from Bob's stick-on

All measurements taken are in units of rms V^2 if united. Strangely enough the oscilloscope for ringdowns was hooked up to the speaker.

⟹ Important: For this data run the strain channel (#0) was filtered differently from before. After the Passive ReadOut Filter a Stanford SRS560 was used on AC coupling, x 100 gain 100 – 300 Hz 6 dB/oct. bandpass. in Low Noise state from line.

The calibrations, etc. were all taken through this filter.

I forgot to disconnect channel 1's signal when I stopped sending it to the coil so it will occur throughout.

2/16/94, TTL

Data Run Events

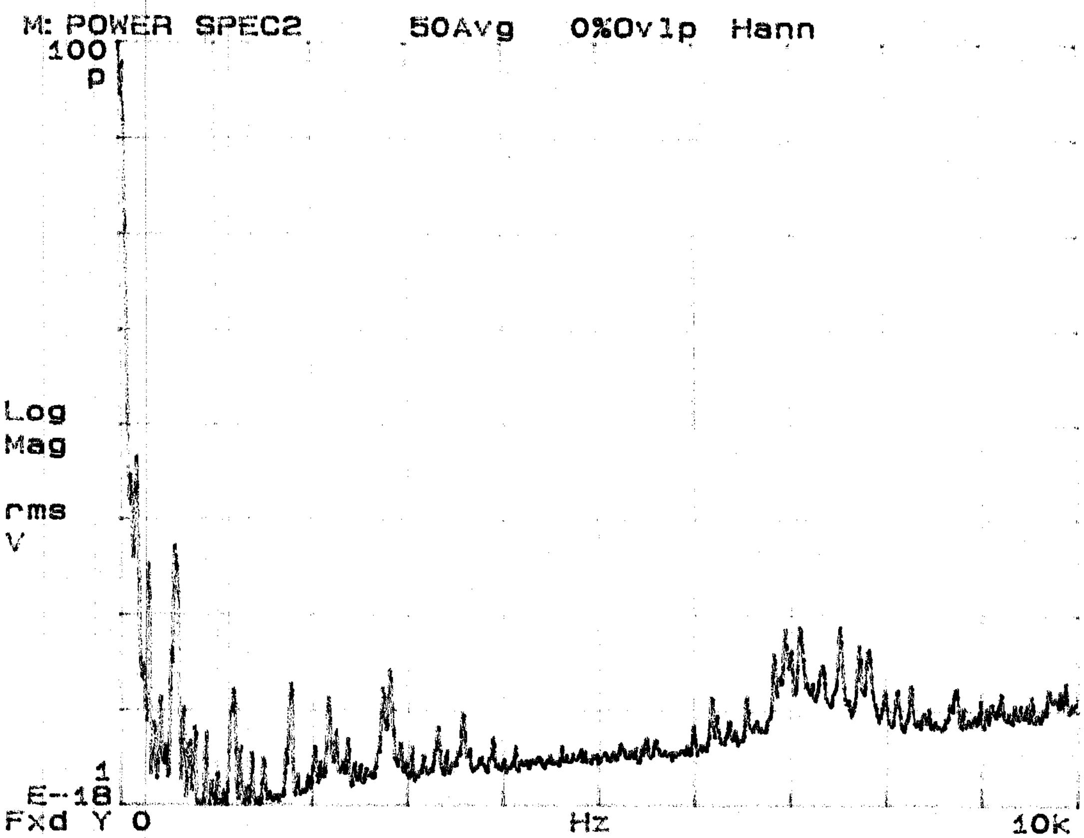
10:55 pm Started data program
10:56 Data acquisition begins. $V\phi = 43\%$, $V1 = 62\%$, $V2 = 63\%$
185 mV mode cleaner throughput (w/ stabilization)
Coil Driver Gain = 5.0. laser power = 0.28
10:58 Started 1 V_{rms} standard pulses.
10:59 Stopped pulses.
11:24 Dropped out of lock briefly.
11:43 Both arms dropped out of lock for under 1 min.
12:13 am $V\phi = 47\%$, $V1 = 62\%$, $V2 = 62\%$, MC throughput = 185 mV
Laser Power = 0.26
12:24 Fell out of lock. First arm did not reacquire until I broke the servo loop for the 2nd arm. Out of lock for ≈ 2 minutes.
12:52 Fell out of lock. Back in in ≈ 20 sec.
1:12 Lost lock in both arms. 1st arm did not reacquire for almost 4 minutes. 2nd arm almost immediately afterward.
1:33 $V\phi = 45\%$, $V1 = 62\%$, $V2 = 64\%$, Throughput = 185 mV.
Laser Power = 0.26.
Tried to stop run but found error writing.
"Data acquisitions warning: Incomplete transfer on path!, items done: 1226240800."

Program said I halted data acquisition 9502.184000 seconds into the run, but computer was idle after warning.

"DRGC1" on disk 32.01

10:51 pm
2/16/94, TTL

Calibrated Displacement Noise



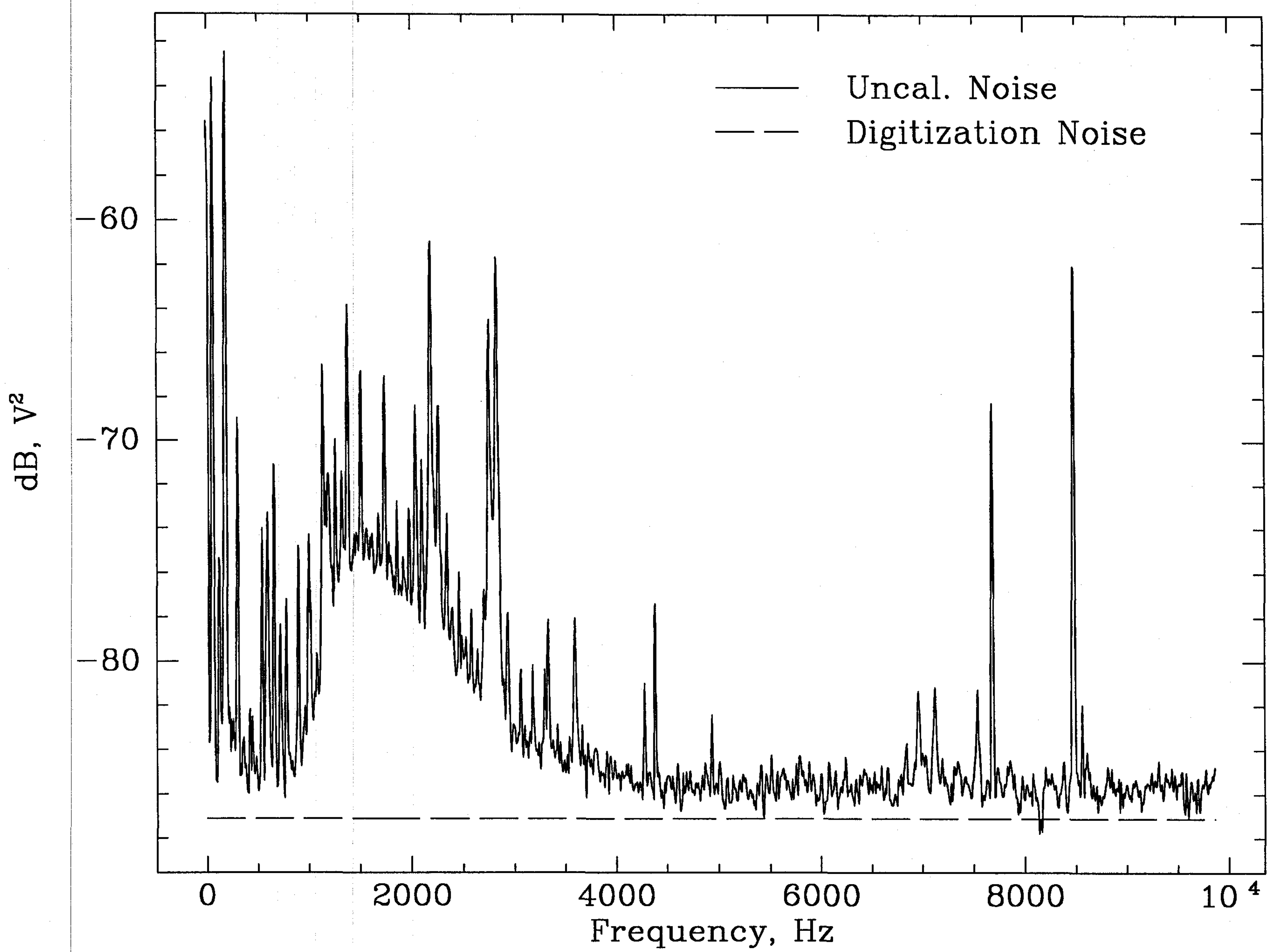
After Greg replaced flogger's Exabyte tape drive I discovered two things had gone wrong with the data run of 2/16/94. Most importantly the gain of the SRS pre-amp for the gravitational-wave readout was set too low (x 100). The resulting standard deviation of the 2nd section was 1.2 counts! Secondly I did not have the artificial pulse generator (Philips PM5193 Programmable Synthesizer) set correctly so it sent out a monochromatic continuous signal at 1 kHz instead of pulses.

To address the importance of digitization noise I need a calibrated spectrum:

```
clip chanØ -t 600 608 -bin -pr > nopul8.bin   (from Section 1)
powspc nopul8.bin -pr -k 36 -m 1024 >nopul8.psd
```

Unfortunately I can not calibrate this yet since disk 32.01 has not been loaded onto the Suns. I can compare this with digitization noise in volts at the ADC. Plot follows. This shows we have problem above 4000 Hz and below 500 Hz. (The digitization noise is the minimum 12-bit noise and does not include non-linearities or errors in the ADC.)

Data Run 2/16/94



To handle the other problem we just ignore everything before 200 seconds into the data run. (The impressed signal is not useful.) (Really I will use 4M points.)

I read in and analyzed up to 8000 seconds on this tape, but the huge digitization effects seemed to render the results meaningless. The only real statistic is that apart from the problems with section 1 and out-of-lock transients no noise exceeded 12 counts. This is with $\sigma \approx 1.4$ counts.

3/2/94

I reloaded Tape 12/2/93 to get useful data to work with. I will use Section 2 which is 2903 seconds long. (Strangely on this second data read Section 3 was marked as ending earlier. The previous time we ran into errors which stopped all of the data from being read, but it was thought the missing data was useless.) Taking a very high resolution power spectrum with

```
powspc chan0 -pr -m 131072 -k 100 -bin >bigspc.psd
```

Between approximately 500-4000 Hz the noise is very fuzzy (power varies by factor of ≈ 40). Elsewhere the spectrum is clean. This may well be a bug in the program or real non-stationary noise. To check non-stationarity I plotted the standard $k = 36$, $m = 1024$ power spectrum from data a 0, 500, 1000, 1500, 2000 seconds. The spectra tending to get worse with good agreement except for ≈5dB variation in the 3kHz – 6 kHz band. Plot follows.

3/2/94

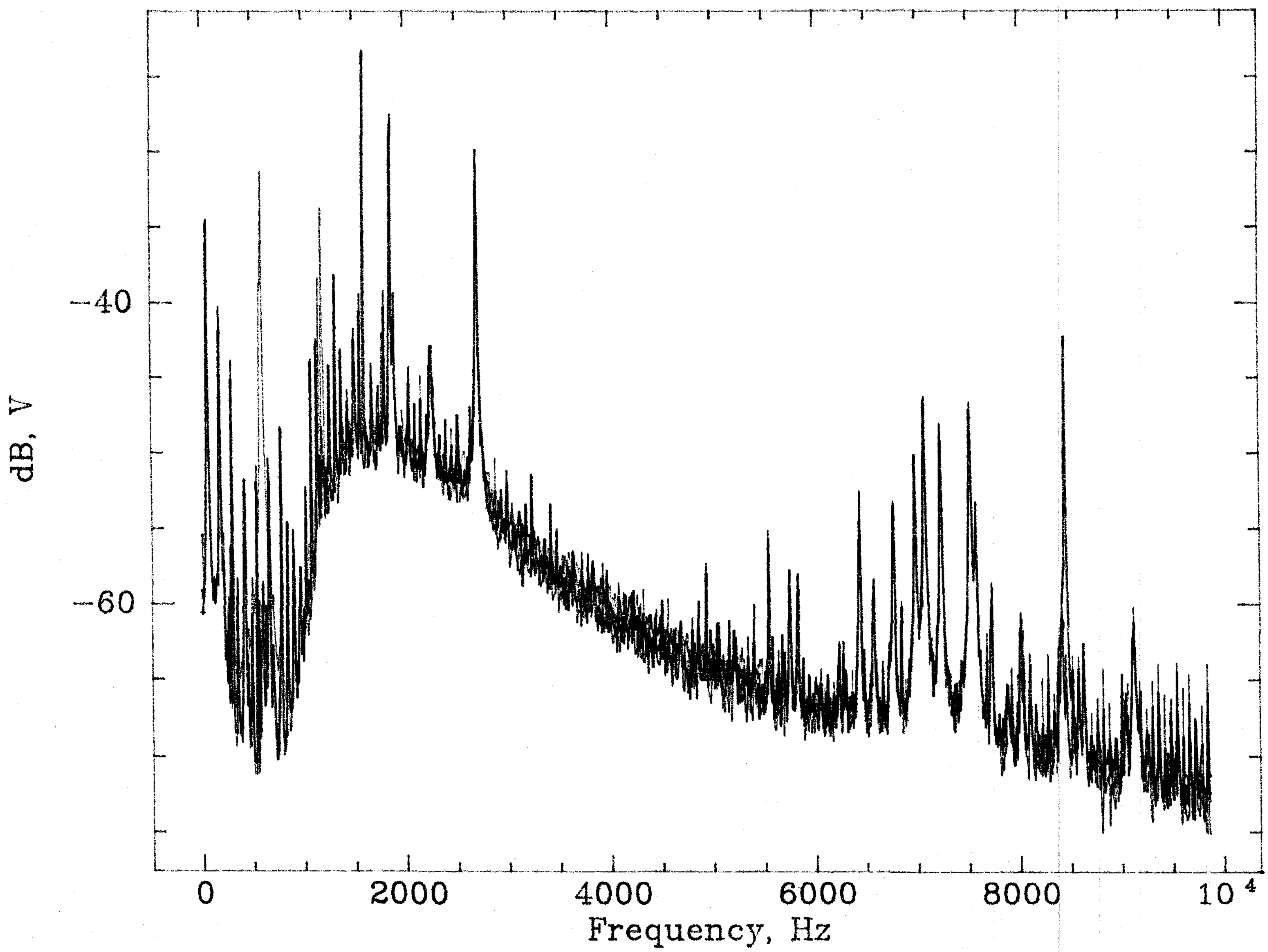
I figured out that my problem was that I had included the beginning section where the artificial pulses were. I cut another 960 seconds off the beginning of the prepared data which put me beyond the pulses. I took another high resolution power spectrum with $m = 131072$ and $k = 100$. It is stored in bigspc.bin.

3/11/94

After grappling with the problem that the Numerical Recipes routine "spctrm" throws away the Nyquist frequency data I was finally able to whitten data. My shell script "whitebin" calculates the histogram of whitened data. Unfortunately I did the calculation first by accident for the subsection without artificial pulses. This is stored in binwht0.dat and plotted on the next page.

TTL, 3/1/94

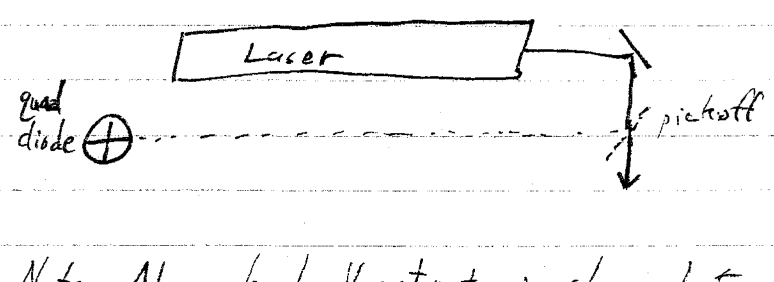
Spectrum variation over 2000 seconds on ~~2/16/94~~ 12/2/93



Data Run "H"

Channel	Signal
0	Strain ⇒ 2-pole, 100 Hz HP in Pomona box ⇒ Stanford SR560, Source A, DC coupling, 6dB/oct. BP 100-300 Hz, Low Noise, Line Power, Gain x100 Output < 150 mA ⇒ Ithaco 4213 Electronic Filter, BP 400-2000 Hz, Normal ☆
1	Artificial Pulse Monitor (see next pages)
	↑ Fast ≃ 20 kHz
	↓ Slow ≃ 2 kHz
2	Primary Cavity TTL In Lock: in lock = low (no filt.)
3	Secondary Cavity TTL In Lock: in lock = low (no filt.)
4	Laser Slow PZT $\frac{1}{100}$ Monitor (no filt.)
5	Ranger Seismometer ⇒ PAR 113, BP 0.03-100 Hz, 2k Gain, AC coupled
6	X output of XY Decoder, + polarity (no filt.)
7	Y output of XY Decoder, + polarity (no filt.)

XY Decoder is from quad photo diode placed by Alex:



Note Alex had Y output in channel 5 & X in channel 6.

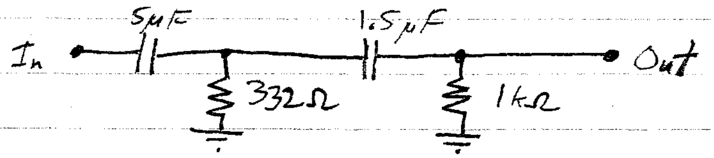
☆ During data acquisition channel ∅ had another amplifier inserted after everything listed. It is a Stanford SR560, DC coupled, Source A, No filtering, Low Noise, Gain x 20, Line Power. This gave a peak voltage of slightly over 1V for the A-D. ☆

I took and recorded the following spectra to disk 32.02.

DRHNØ	Power Spectrum, 0-10kHz, rms V
DRHSSØ	Swept Sine Freq. Resp., 0-10kHz
DRHSS1	Coherence of DRHSS1, good almost everywhere
DRHCØ	Calibrated Displacement Noise using

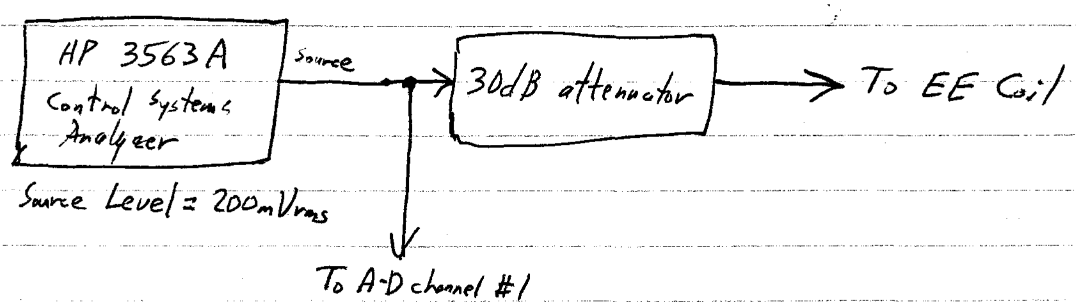
$$\frac{(DRHN\emptyset)}{(j\omega)^2(DRHSS\emptyset)}\;\frac{1}{7133}$$ (Bob's prescription)

2-pole 100 Hz HP in Pomona Box:



Artificial Pulses

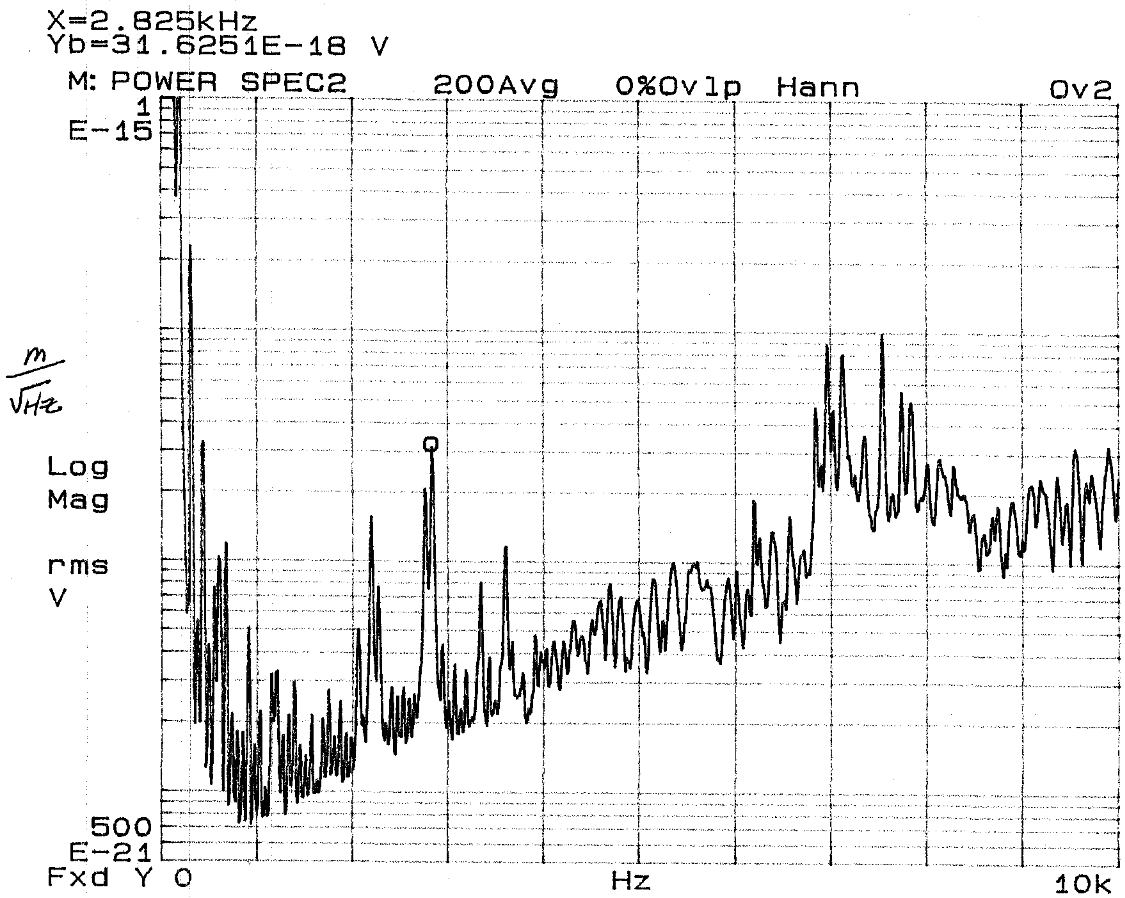
Following Mike's intructions (following) I setup the pulse monitor as follows:



For this data run I set the Ganged Switch while running to 10.

TTL, 3/2/94
9 pm

Calibrated Displacement



"DRHC∅" on disk 32.02.

From mike@ligo.caltech.edu Wed Mar 2 18:29:35 1994
To: torrey@ligo.caltech.edu
Subject: Re: knowledge
Content-Length: 1797
X-Lines: 56
Status: RO

----- Begin Included Message -----

>From torrey@ligo.caltech.edu Wed Mar 2 16:16:57 1994
To: mike@ligo.caltech.edu
Subject: knowledge
Content-Length: 341
X-Lines: 7

Since I can't find you perhaps you could just email me the choice
tidbits of
information I need to feed in the cool pulses you created. In
particular
what disk is the pulse on and how do I setup the spectrum analyzer.
Can I
call you at home tonight when things fail. Seiji and I plan to start
the
run after 7 pm. See ya.

--Torrey

----- End Included Message -----

I am hiding out in the 40m lab (who would think to look there?)

I put the pulses on FFT floppy disk 32.01, file "ACCELT1";
see logbook 32, pp. 061W - 063 W, for more on how
pulses were created.

This acceleration pulse is normalized to 1 Vpk amplitude (2Vp-p). You
will need to figure out how big to make it for physical meaning; the
standard FFT source level setting will modify the waveform amplitude
just as if it were one of the standard source waveforms.

To spew pulses forth from the SOURCE jack, set the FFT to linear
resolution mode, 20 kHz span, zero start.

Then call up the file from floppy disk and save it to register #2.

Then do

SOURCE > SOURCE TYPE > MORE TYPES > USR SAVE 2 > REPEAT

The way it's set up, a pulse occurs every 40 ms, which is kind of fast,
but I don't really know yet how to increase the dead time w/out
screwing up the waveform a lot. The acceleration pulse is nonzero for
about 1.8 milliseconds. It is supposed to produce a displacement which
is a single sinusoidal cycle having a period of 1 millisecond.

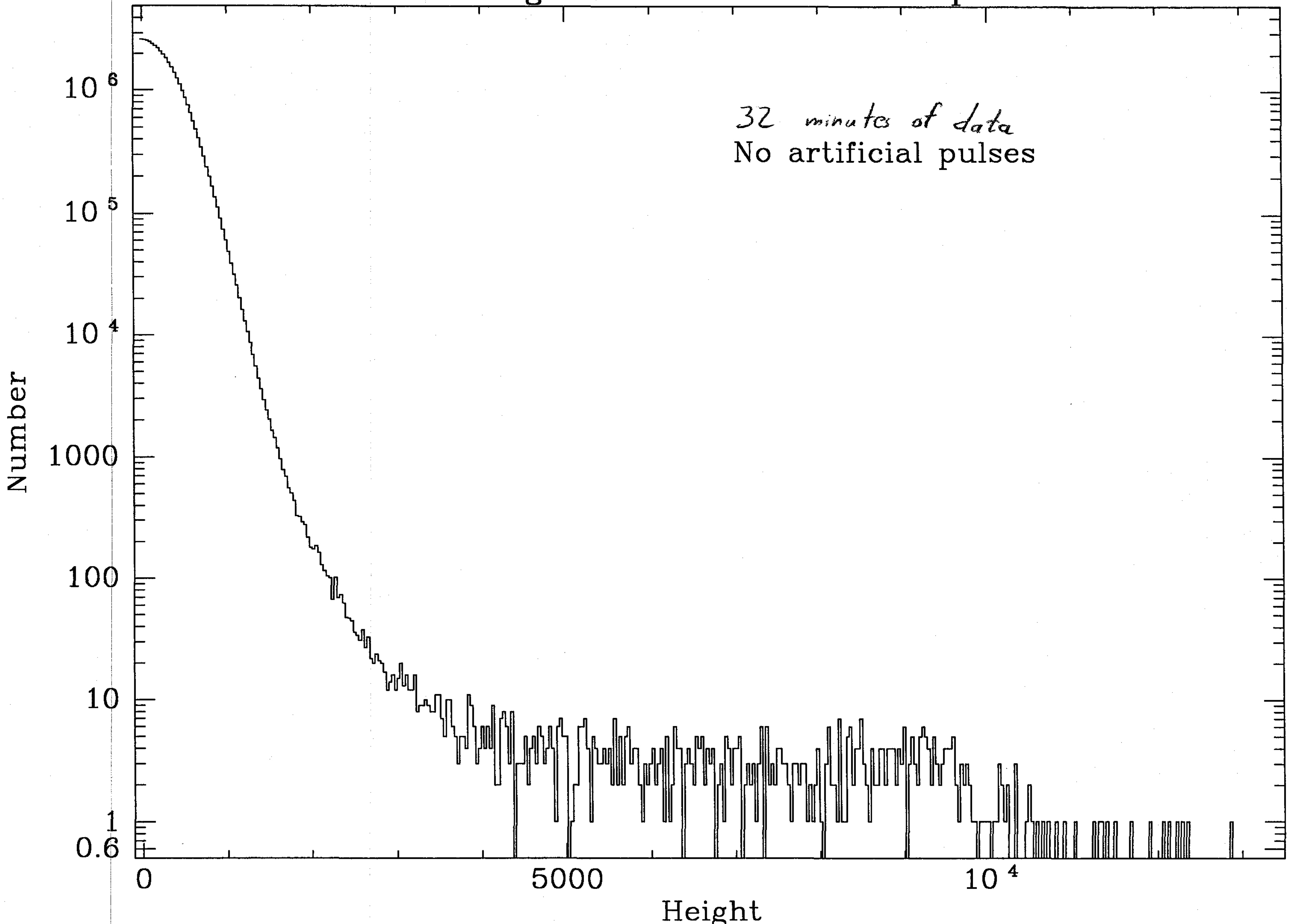
At 25 pulses per second you may have trouble keeping track of just how
many you put in; if it's a prob I will help you rig up a gate for the
next run with a second clock to let a certain number in.

Data Run Events

9:59 pm Laser power = 0.41, Vϕ = 55%, V1 = 61%, V2 = 69%
Coil Driver Gain = 5.55, Ganged Switch = 10
10:02 Started writing to tape.
10:03 Started artificial pulses.
10:04 Stopped artificial pulses and disconnected cable to EE coil.
10:47 Out-of-lock. Vϕ = 55%, V1 = 59%, V2 = 69%.
Laser Power = 0.42. Didn't turn to 10 for ≈1 minute. Had on 9.
12:44 am Out of lock.
Laser = 0.43, Vϕ = 53%, V1 = 59%, V2 = 63%
1:15 am Stopped taking data.

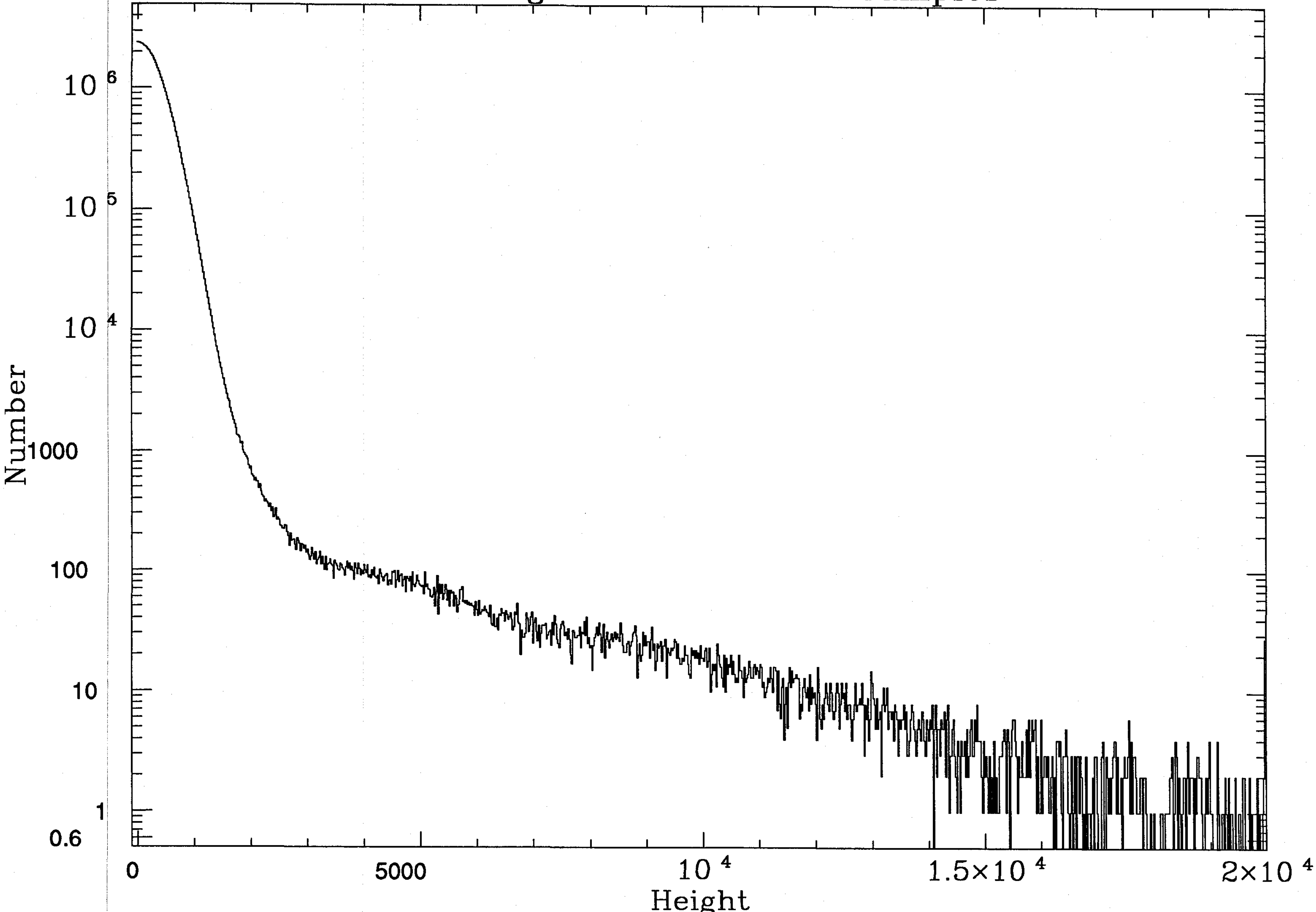
Tape 12/2/93, Section 2
minus 1st 960 seconds.

Histogram of Whittened Samples



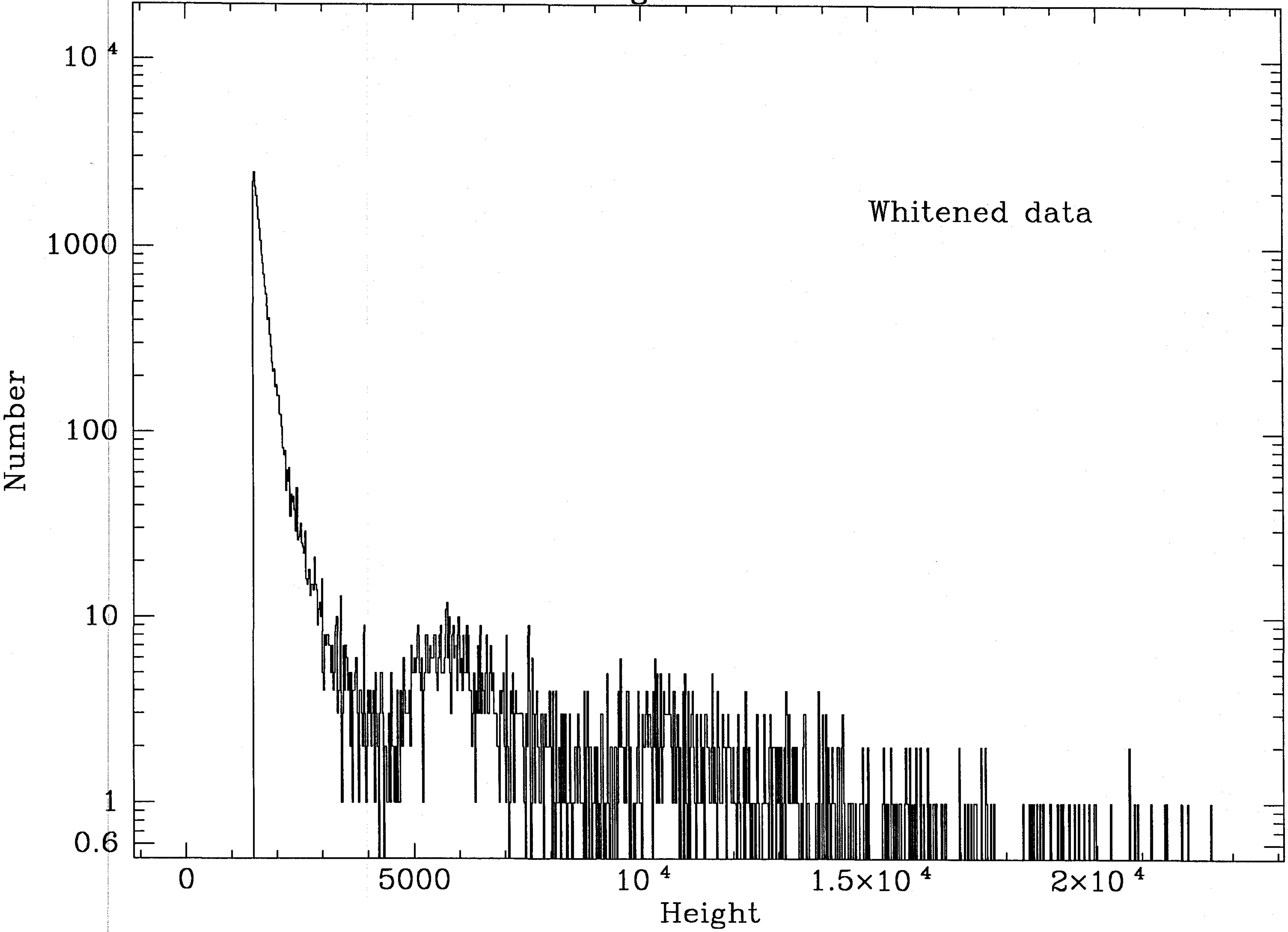
Tape 12/2/93, Section 2

Histogram of Whitened Samples

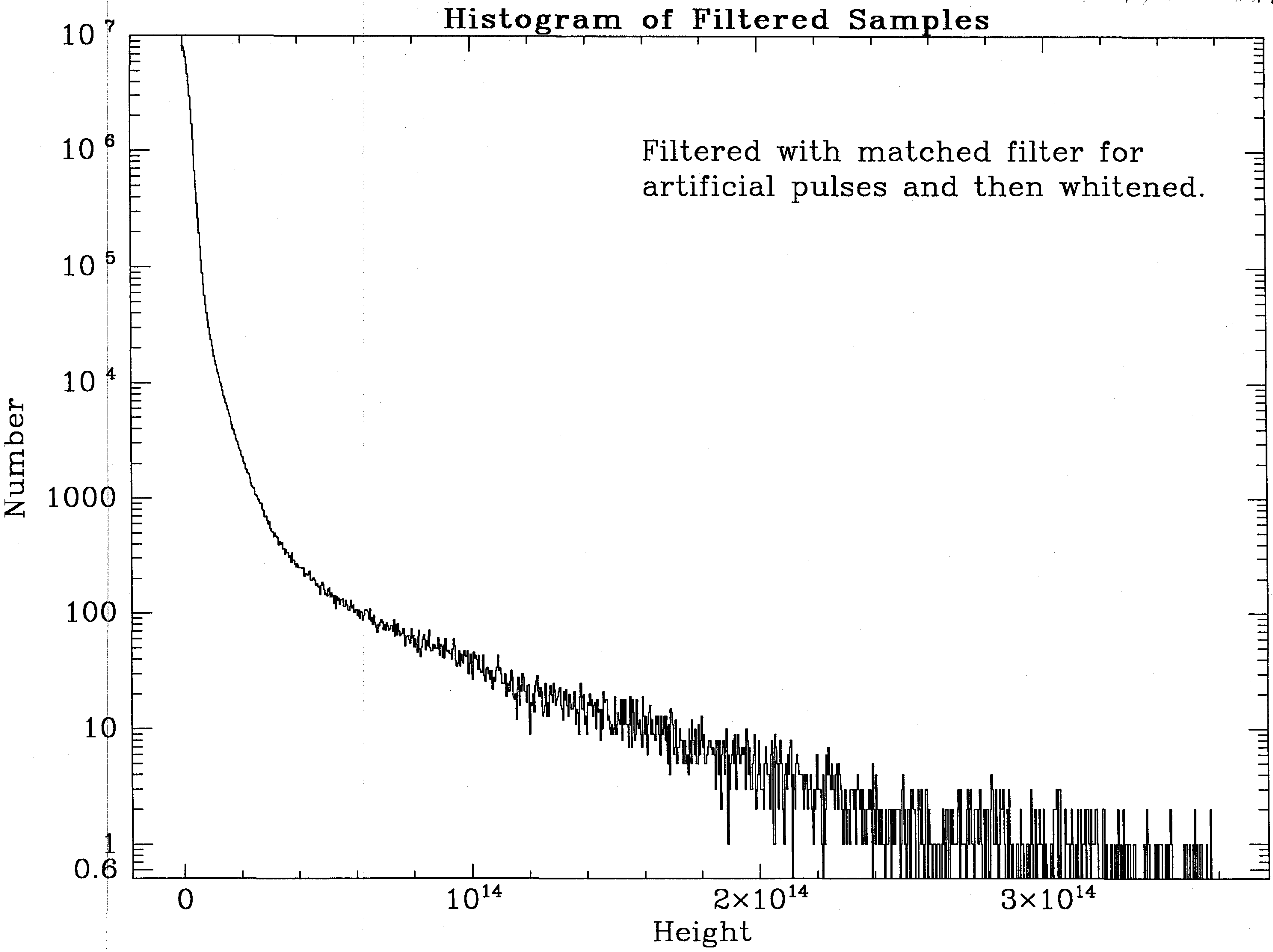


Tape 12/2/93, Section 2

Histogram of Pulses

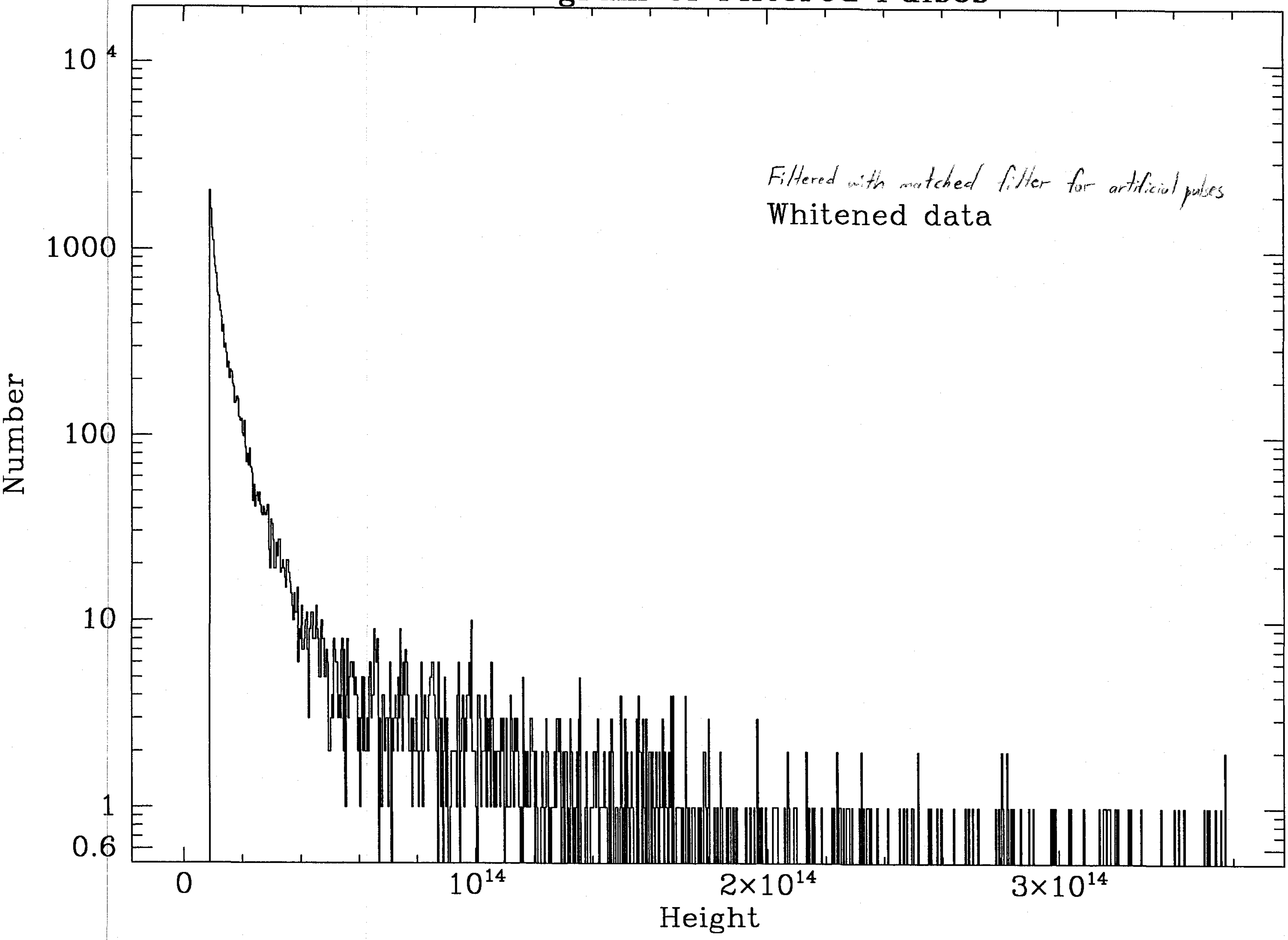


Tape 12/2/93 — Section 2



Tape 12/2/93, Section 2

Histogram of Filtered Pulses



3/30/94, TTL

Analysis of 3/2/94 Data

There were 1670 pulses found in section 1 which were all due to the 1670 impressed artificial pulses. (Note that "coincidence.c", ver 1.0 miscounts the output from recent versions of "pulses", i.e. Ver. 1.5.1.) To find artificial pulses I used:

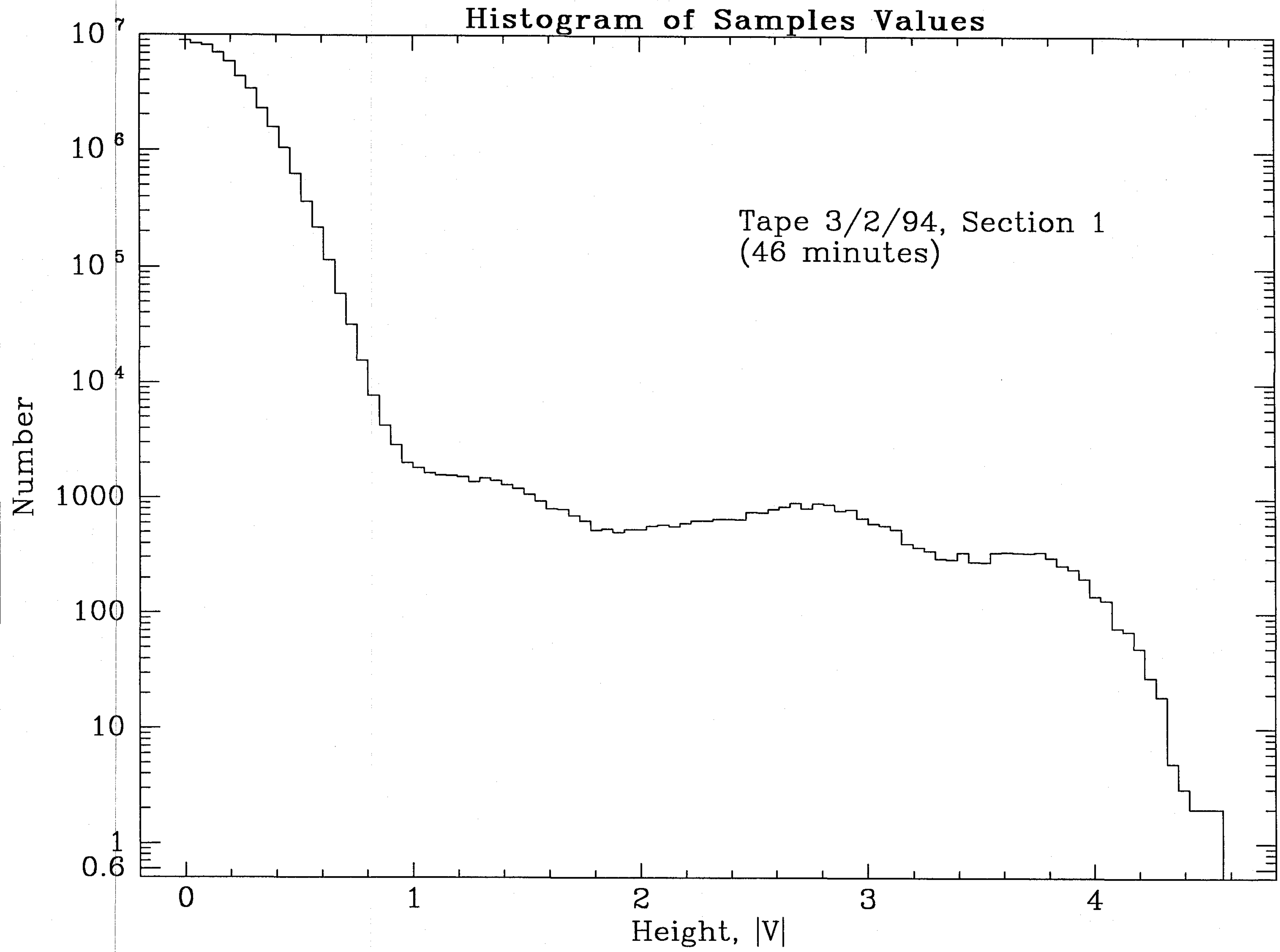
```
prepch c.1.bin 1 ; mv chan chan1
pulses chan1 -pr -t 10 -d 10 -reset
```

Sample and pulse histograms follow.

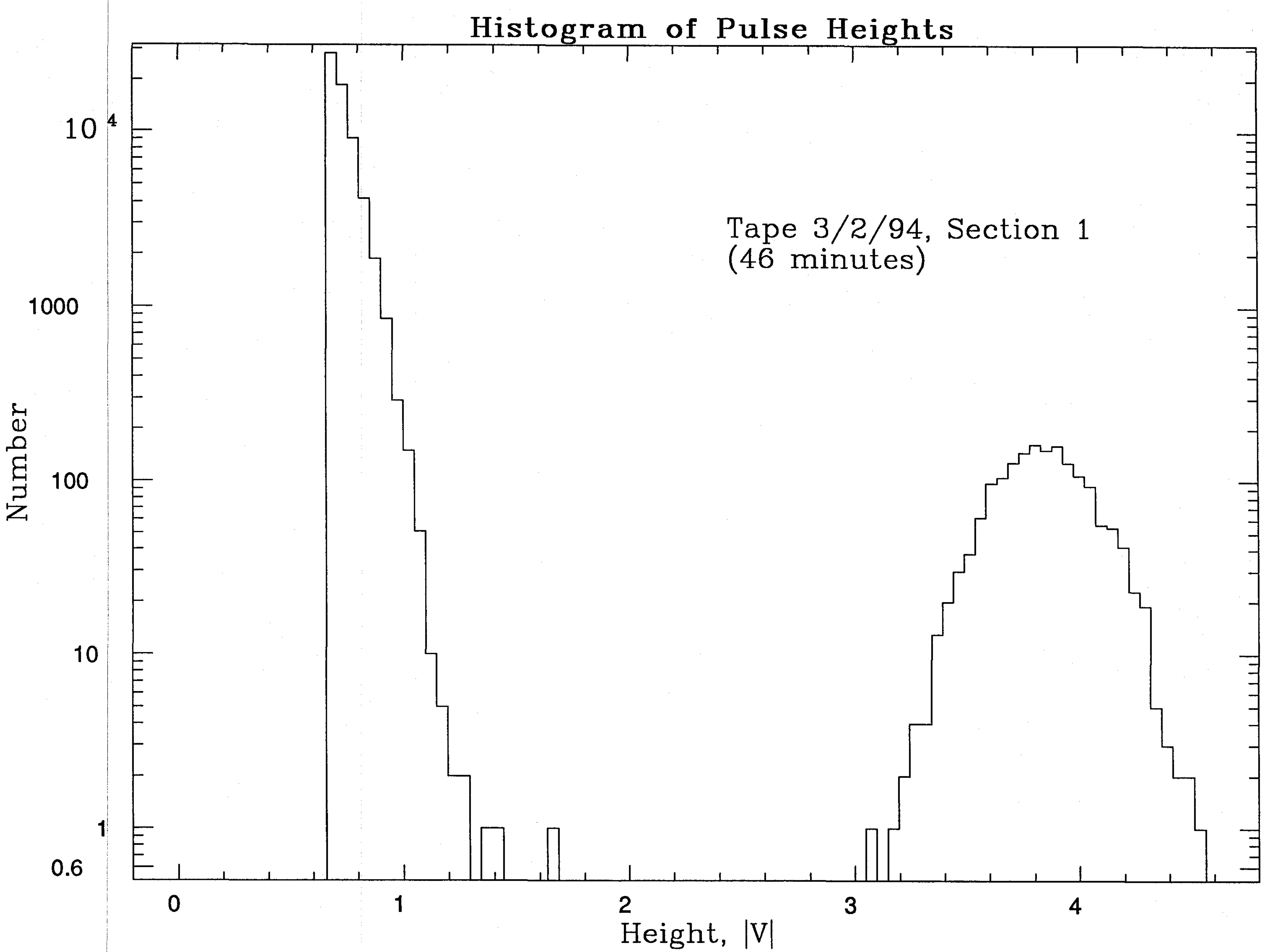
4/1/94, TTL

The whitening procedure greatly changes the rms level of the data. I modified it so that the data after whitening is renormalized so it has the same rms. The rms is calculated in the frequency domain by "rmsfft.c". If $x(t)$ is the original data and $S(f)$ is the power spectrum to divide by the whitened data is

$$\tilde{x}_w(f) = \frac{\tilde{x}(f)}{S(f)} \frac{\left(\int_0^\infty |\tilde{x}|^2 df\right)^{1/2}}{\left(\int_0^\infty \frac{|\tilde{x}|^2}{S^2} df\right)^{1/2}}$$



Histogram of Samples Values
Tape 3/2/94, Section 1
(46 minutes)
Number
Height, |V|
10 7
10 6
10 5
10 4
1000
100
10
1
0.6
0
1
2
3
4


Histogram of Pulse Heights
Tape 3/2/94, Section 1
(46 minutes)
Number
10^4
1000
100
10
1
0.6
0
1
2
3
4
Height, |V|

Data Run "I"

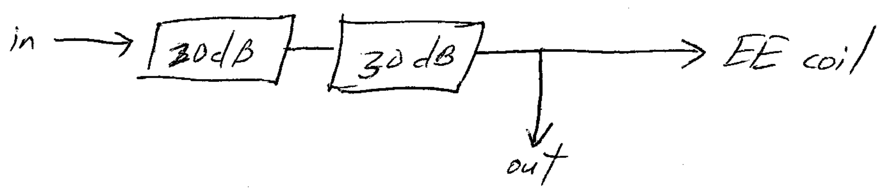
Data channels taken the same as 3/2/94 data run except:

<u>Ch 0:</u> Final Stanford SR560 inserted during data run had a gain of 10 instead of 20 previously.

<u>Ch 1:</u> 30 dB attenuator replaced by 30 dB and 20 dB attenuator in series. Source level of HP 3563A was 3.8 Vrms. Pulses were outputed at manual times ≈ 20 seconds apart. (Used SELECT TRIG ⇒ ARM: MAN & SOURCE TRIG. Then pulses outputted only after pushing ARM.)

Took data:	DRI NØ	Power Spectrum, 0-10 kHz, rms V
on disk	DRISSØ	Swept Sine Freq. Resp., 1-10 kHz
33.02	DRISS1	Coherence of DRISS1
	DRICØ	Calibrated spectrum $= \frac{1}{7133\,(j\omega)^2}\,\frac{DRIN\emptyset}{DRISS\emptyset}$

I measured the transfer function through the 30 dB + 20 dB attenuator loaded with the calibration coil.



It was ≈ 130×10^{-6}. For 30 dB alone it was ≈ 1.42×10^{-3}.

Data Run Events

11:37 pm Laser = 0.40, Vϕ = 78%, V1 = 64%, V2 = 68%
Ganged Switch = 9, Gain = 2.9, phase = 20°

11:43 pm Started data acquisition.

11:48 pm Started occasional pulses

11:50 pm Fell out of lock & reacquired

11:52-11:54 pm Out-of-lock.

12:00-12:03 am Out-of-lock. Set Gain = 3.0.

12:06 am Out of lock.

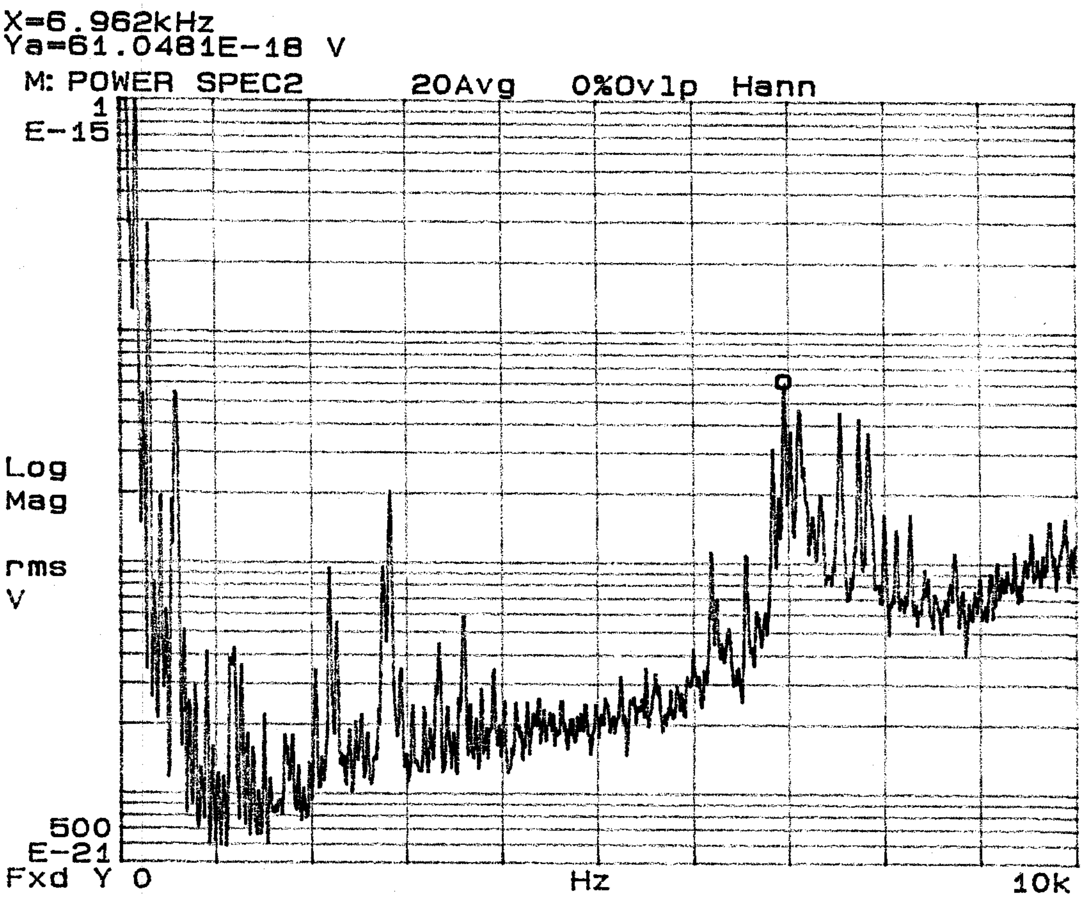
12:14 am " " . Gain = 2.9

12:26 am Out-of-lock & stopped data run.

7/6, 11/1/94

11:11 pm

Calibrated Displacement



"DRIC0"

disk 33.02

I whittened the data of 3/2/94, Section 1 using the rms normalization. The pulse height spectrum follows. Mike explained why the impressed pulses seem to have spread out so much in amplitude. This is due to the fact that our whittening filter notches things out which are $\sim \frac{1}{10}$ Hz wide. Thus the impulse response of this filter is ~10 seconds long. Since the artificial pulses are only seperated by ≈ 0.04 seconds there is significant overlap between them. In fact the time when the pulses occur has a much higher pulse rate at all heights and has some huge spurious events. The total number of pulses with amplitude > 2 V (which represents a clean break between real and artificial pulses in the original spectrum) is 1995 while there were only 1670 artificial pulses.

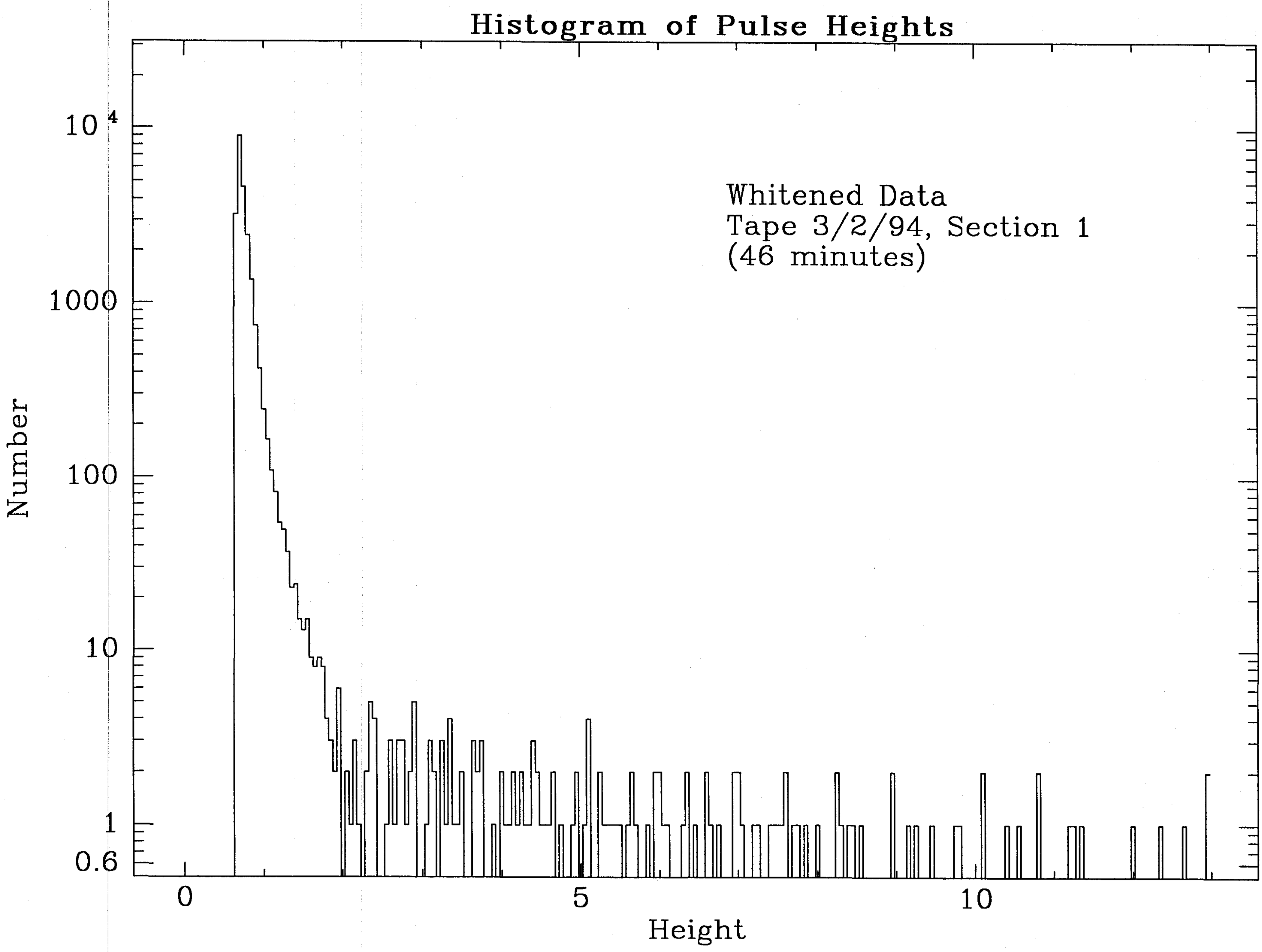
4/8/94, TTL

I wrote a script to calibrate my artificial pulses on channel 1 in displacement units. It uses:

$$\frac{dx^2}{dt^2} = \frac{F}{m} = \alpha V_{A-D}$$

$$(j\omega)^2 \tilde{x} = \alpha \tilde{V}_{A-D} \implies \tilde{x} = \frac{\alpha}{(j\omega)^2} \tilde{V}_{A-D}$$

From Bob's "calbn7.txt" I get β the calibration from voltage on 1Ω to displacement by coil. $\beta = 1.54 \times 10^{-5} \frac{m\ Hz^2}{V_{1ohm}}$


Histogram of Pulse Heights
Whitened Data
Tape 3/2/94, Section 1
(46 minutes)
Number
10^4
1000
100
10
1
0.6
0
5
10
Height

$\alpha = 1.42 \times 10^{-3}\ \beta$ from measurement on 4/7/94.

$\therefore \quad \alpha = 2.19 \times 10^{-8}\ \frac{m\ Hz^2}{V_{A-D}}$

The factor of 1.42×10^{-3} is close to the expected value of

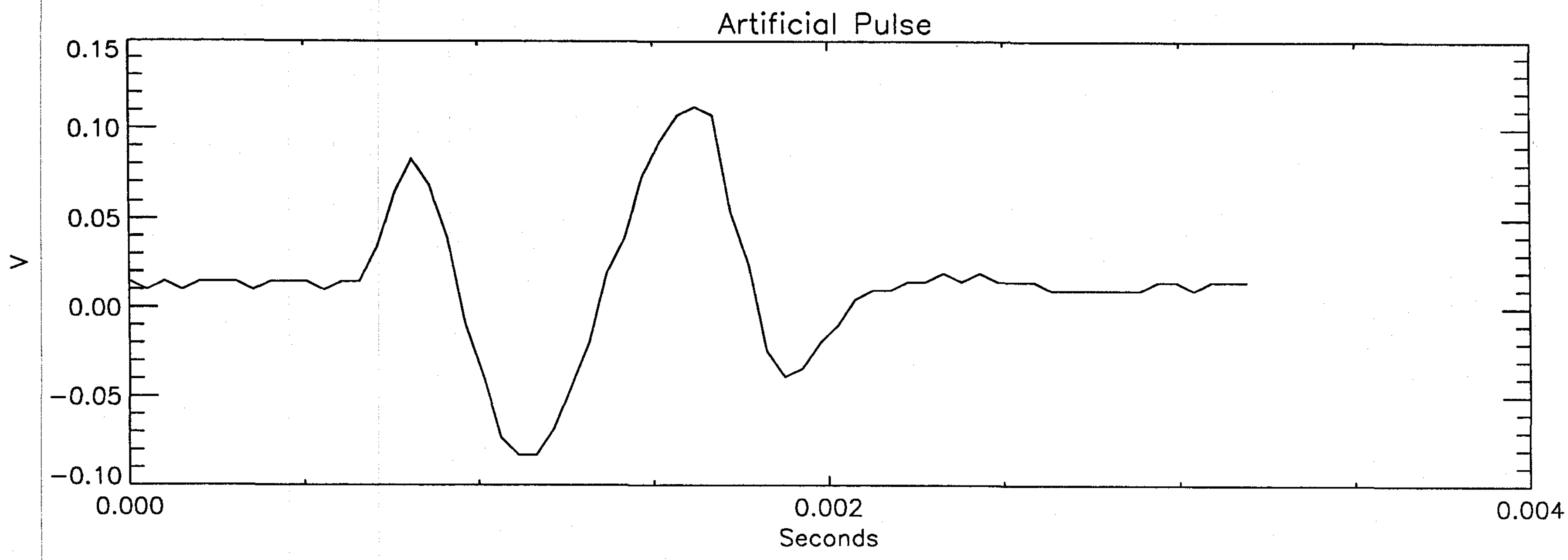
$\frac{2}{31.6}\ \frac{1}{50} = 1.27 \times 10^{-3}$.

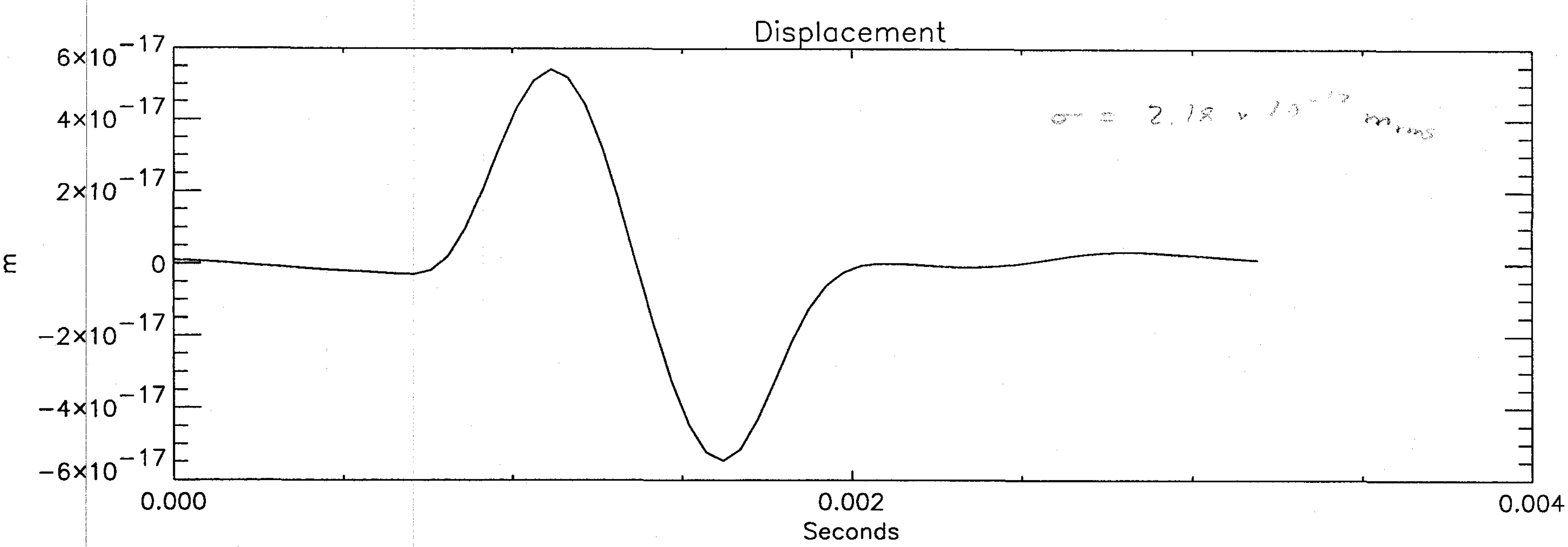
I implemented the calibration in "art_x". A plot of the artificial pulses in voltage and displacement follows.

4/13/94

I finally suceeded in calculating the voltage seen at the coil driver output (strain) due to the impressed pulses. The following proceedure was used:

1. Get the swept sine (1-10 kHz) data file onto the Sun filesystem.
2. Convert the resulting MatrixX file to flat text with my version of "mx-asc-fr". In ~torrey/glitch.
3. Interpolate to 1024 points using the flat10.dat file; example:
   ftm flat10.dat x drhss0.dat -fft -nonorm > tr.fnc.dat
4. Set the DC response in trfnc.dat to 0.
5. Run "art_V" on a 2048 point long section of pulse monitor data.

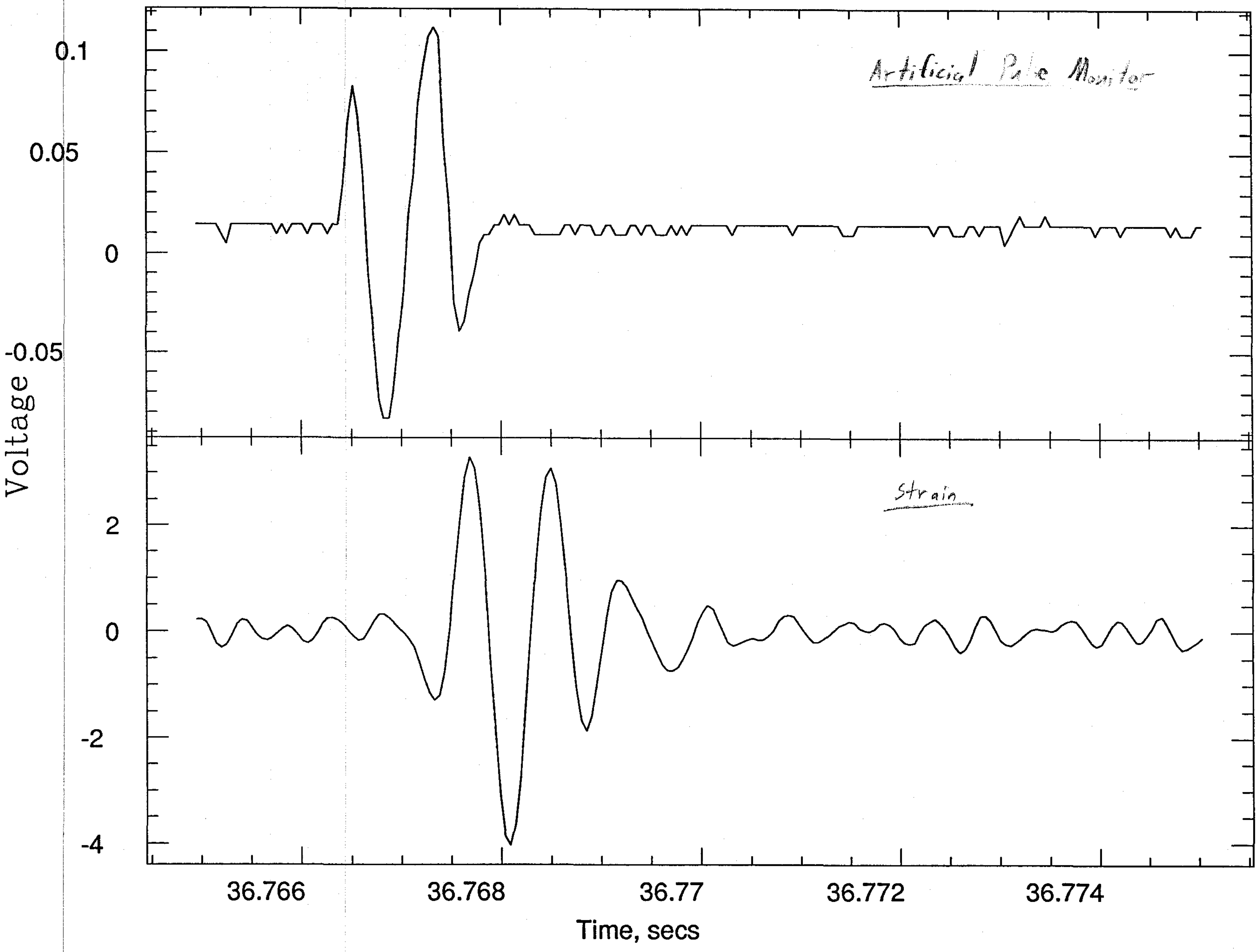

Artificial Pulse
0.15
0.10
0.05
0.00
−0.05
−0.10
V
0.000
0.002
0.004
Seconds

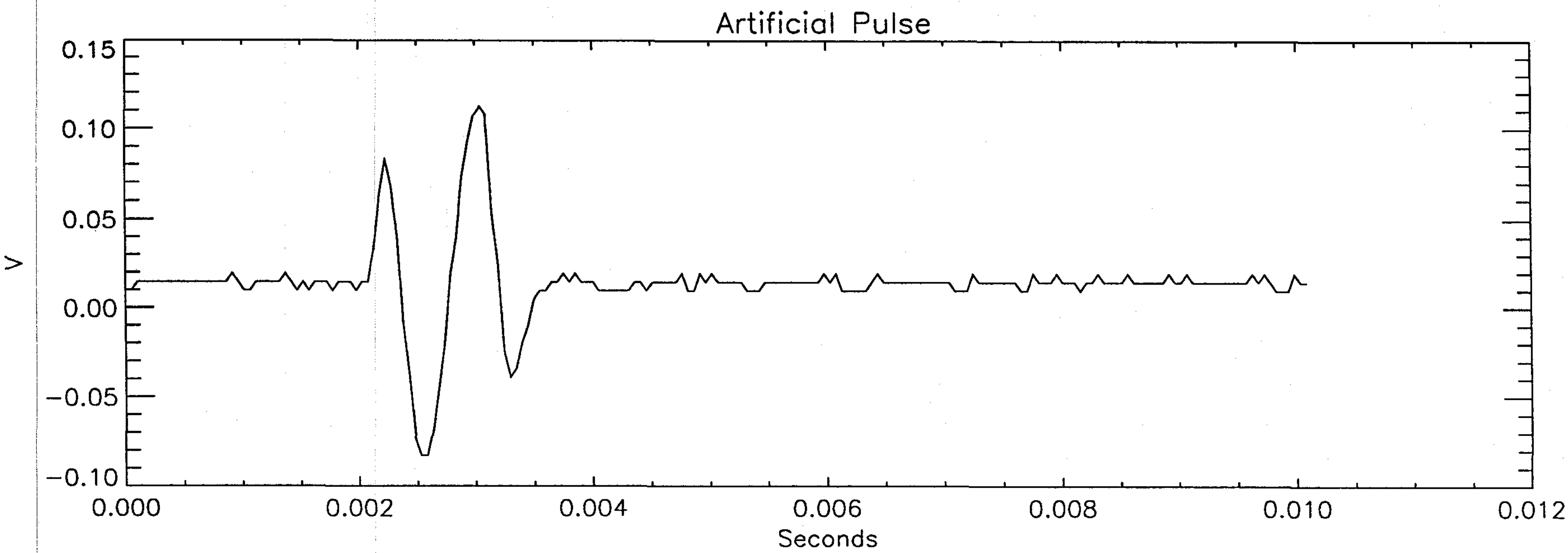

Displacement
6×10^−17
4×10^−17
2×10^−17
0
−2×10^−17
−4×10^−17
−6×10^−17
m
0.000
0.002
0.004
Seconds
σ = 2.18 x 10^−17 m rms

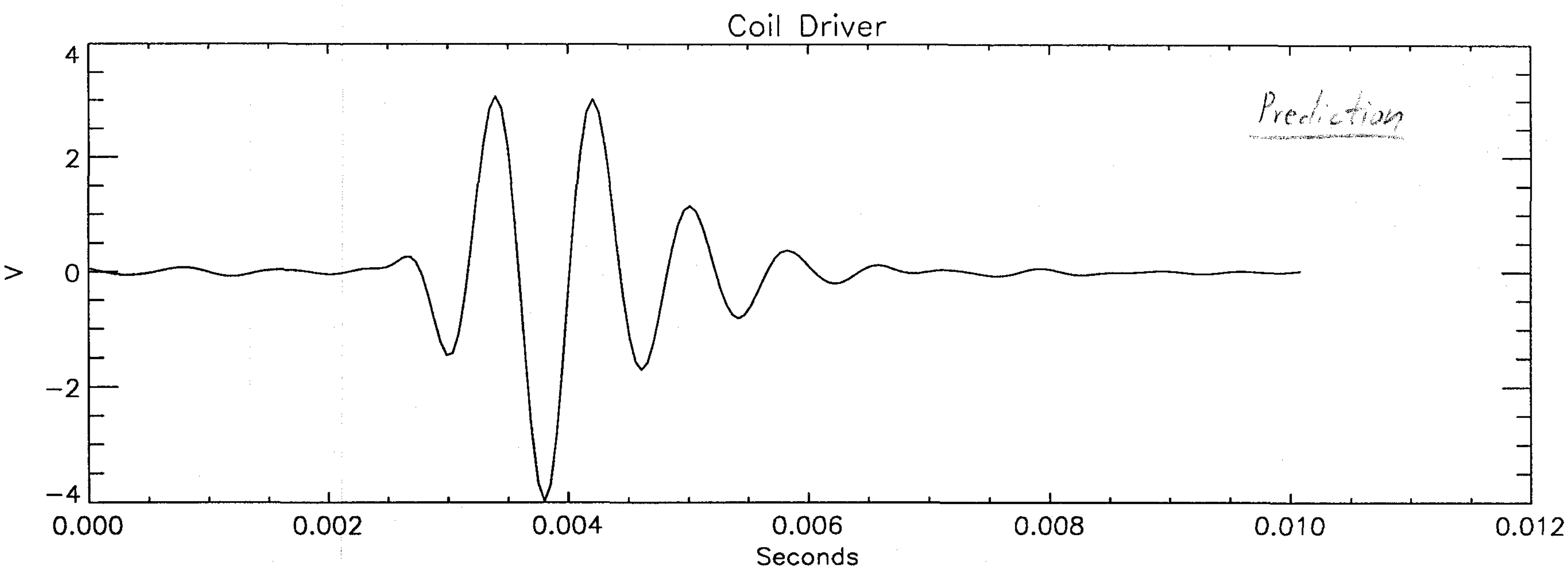
The output is the response seen by the ADC on the strain channel. Strangely to get the algorithm to work correctly I had to complex conjugate trfnc.dat. Otherwise it seemed to have an output with time running backwards. (Pulse on coil driver before pulse monitor.) Bob mentioned that the HP software in conversion makes a factor of $\sqrt{2}$ error in some cases. This does not seem to be the case here. Plots for prediction and measurement are shown. The calibration factor used is the 1.42×10^{-3} measured for the loaded -30 dB attenuator (see 4/7/94 run) times 20 for the additional gain inserted after the swept sine was taken. The agreement is excellent.

TTG, 4/8/94

40m Pulses
(measured)




Artificial Pulse
0.15
0.10
0.05
0.00
−0.05
−0.10
V
0.000
0.002
0.004
0.006
0.008
0.010
0.012
Seconds

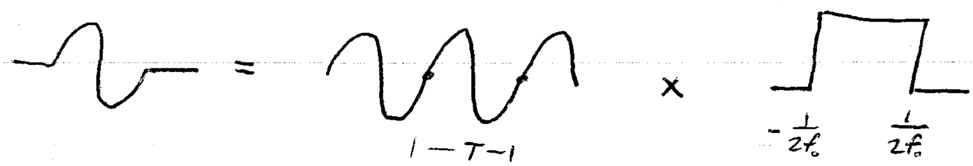

Coil Driver
Prediction
4
2
0
−2
−4
V
0.000
0.002
0.004
0.006
0.008
0.010
0.012
Seconds

4/25/94, TTL

Checking Calibration of Artificial Pulse in Displacement

Original Pulse:

$$x(t) = A \sin(2\pi f_0 t)\, \mathrm{rect}(f_0 t)$$



$$\tilde{x}(f) = \delta(f - f_0) \otimes \frac{A}{f_0} \mathrm{sinc}\left(\frac{f}{f_0}\right)$$

$$= \frac{A}{f_0} \int_{-\infty}^{\infty} \delta(\xi - f_0)\, \mathrm{sinc}\left(\frac{f - \xi}{f_0}\right) d\xi$$

$$= \frac{A}{f_0} \mathrm{sinc}\left(\frac{f - f_0}{f_0}\right)$$

$$|\tilde{x}(f)|^2 = \frac{A^2}{f_0^2} \mathrm{sinc}^2\left(\frac{f - f_0}{f_0}\right)$$

Filtering:

On 2/17/94 (61W of 40m Logbook #32) Mike built the pulse. The proceedure was:

$$x(t) \rightarrow FFT \rightarrow \times j\omega \rightarrow \times LP \rightarrow \times j\omega \rightarrow \times LP \rightarrow FFT^{-1} \rightarrow \ddot{x}(t)$$

The LP filter was 5 real poles @ 5kHz, 3.1×10^{18} gain. It is recorded on disk 32.01 as "5p5kfilt". Thus we need to multiply by this filter squared twice to get the resulting artificial pulse displacement spectrum.

After filtering we need to correctly normalize the spectrum $|\tilde{x}(f)|^2$. We have to keep in mind the fact that for actual calculations we use discretely sampled data **in** MATLAB. We will be comparing $|\tilde{x}(f)|^2$ to the displacement noise spectrum of the 40m. We use "DRHCØ" on disk 32.02.

⇒ Note: In converting from the HP disks to the Suns we must divide the result by $\sqrt{2}$ to correct for a bug Bob found in the rms V power spectra converter.

We then sample $|\tilde{x}(f)|^2$ at the frequencies we have data for in DRHCØ. (1-10 kHz) In doing the double multiplication by the filter function, SP5KFILT, we have to spline interpolate. This gives us $|\tilde{x}_p(f_i)|^2$. Normalization condition:

$$\sum_{i=1}^{N} |\tilde{x}_p(f_i)|^2 \underbrace{\Delta f}_{f_{i+1}-f_i} = \underbrace{\int_{-\infty}^{\infty} |\tilde{x}_p(f)|^2 df = \int_{-\infty}^{\infty} x_p^2(t)\, dt}_{\text{Parseval's Theorem}}$$

$$\int_{-\infty}^{\infty} x_p^2(t)\,dt = \sum_{i=1}^{N'} x_p^2(t_i)\,\Delta t$$

$$\approx \sigma^2 \tau \quad \leftarrow \text{pulse duration}$$

$$\therefore \; |x_p(f_i)|^2_{norm} = \frac{|\tilde{x}_p(f_i)|^2}{\sum_{i=1}^{N} |\tilde{x}_p(f_i)|^2} \; \frac{\sum_{i=1}^{N'} x_p^2(t_i)\,\Delta t}{\Delta f}$$

We have previously calibrated the artificial pulses in displacement units (on 4/8/94) giving us $x_p(t)$. Unfortunately this calibration was incorrect as "ftm.c" divides by $(j\omega)^2$ instead of f^2 as Bob's value for β intended.

$$\alpha = 1.42 \times 10^{-3} \; \beta \; (2\pi)^2$$
$$= (1.42 \times 10^{-3})(1.54 \times 10^{-5})(2\pi)^2$$
$$= 8.63 \times 10^{-7}$$

This is now incorporated into "art_x" and a plot follows. It turns out,

$$\sum_{i=1}^{N'} x_p^2(t_i)\,\Delta t = 2.4087 \times 10^{-33} \; m^2 s$$

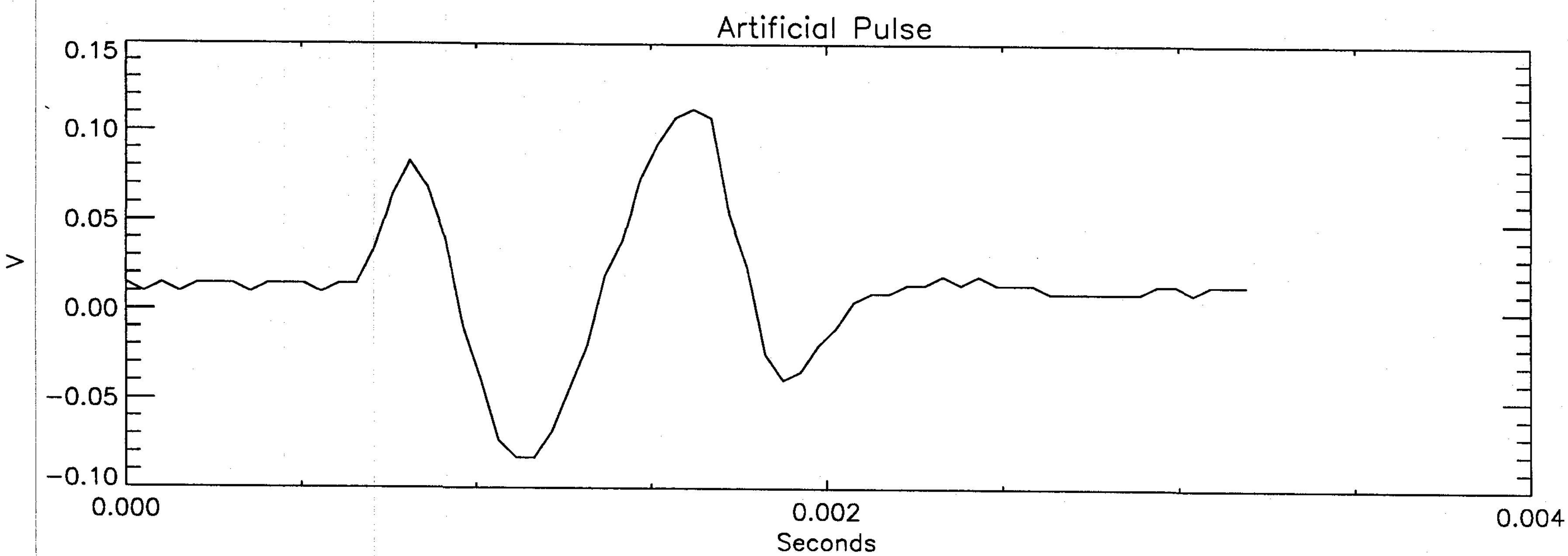
The signal to noise ratio can be found by;

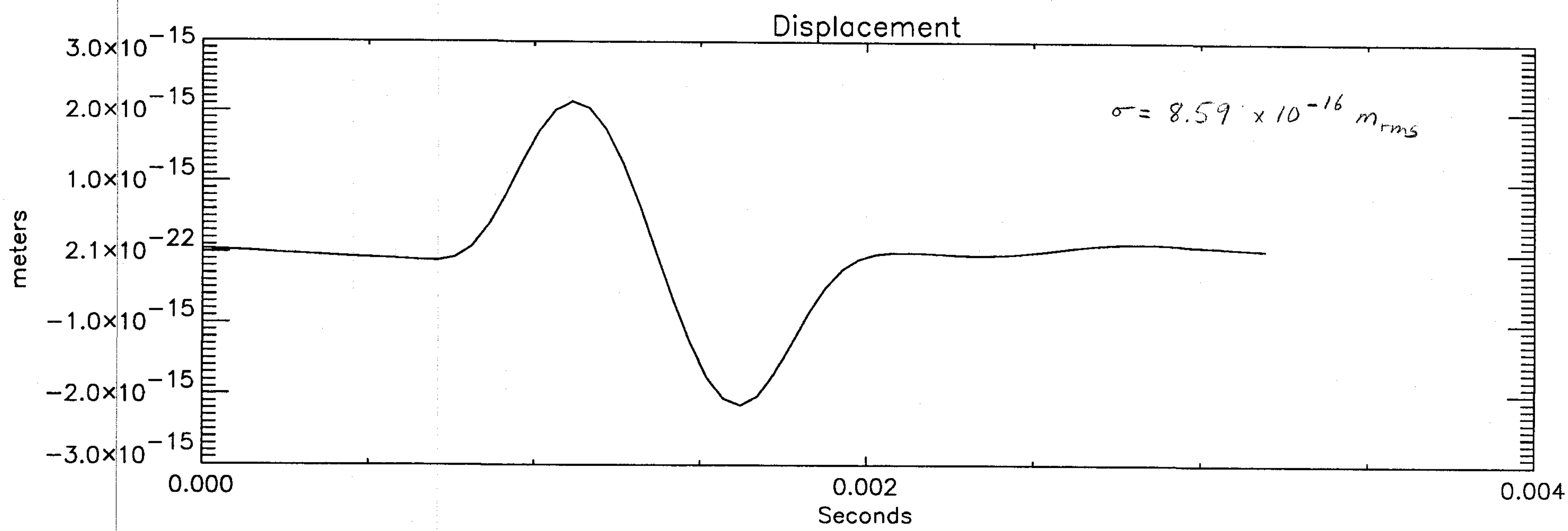
$$\left(\frac{S}{N}\right)^2 = \int_0^\infty \frac{|\tilde{x}_p(f)|^2}{S_y(f)}\,df = \sum_{i=1}^{N} \frac{|\tilde{x}_p(f_i)|^2}{S_y(f_i)}\,\Delta f$$

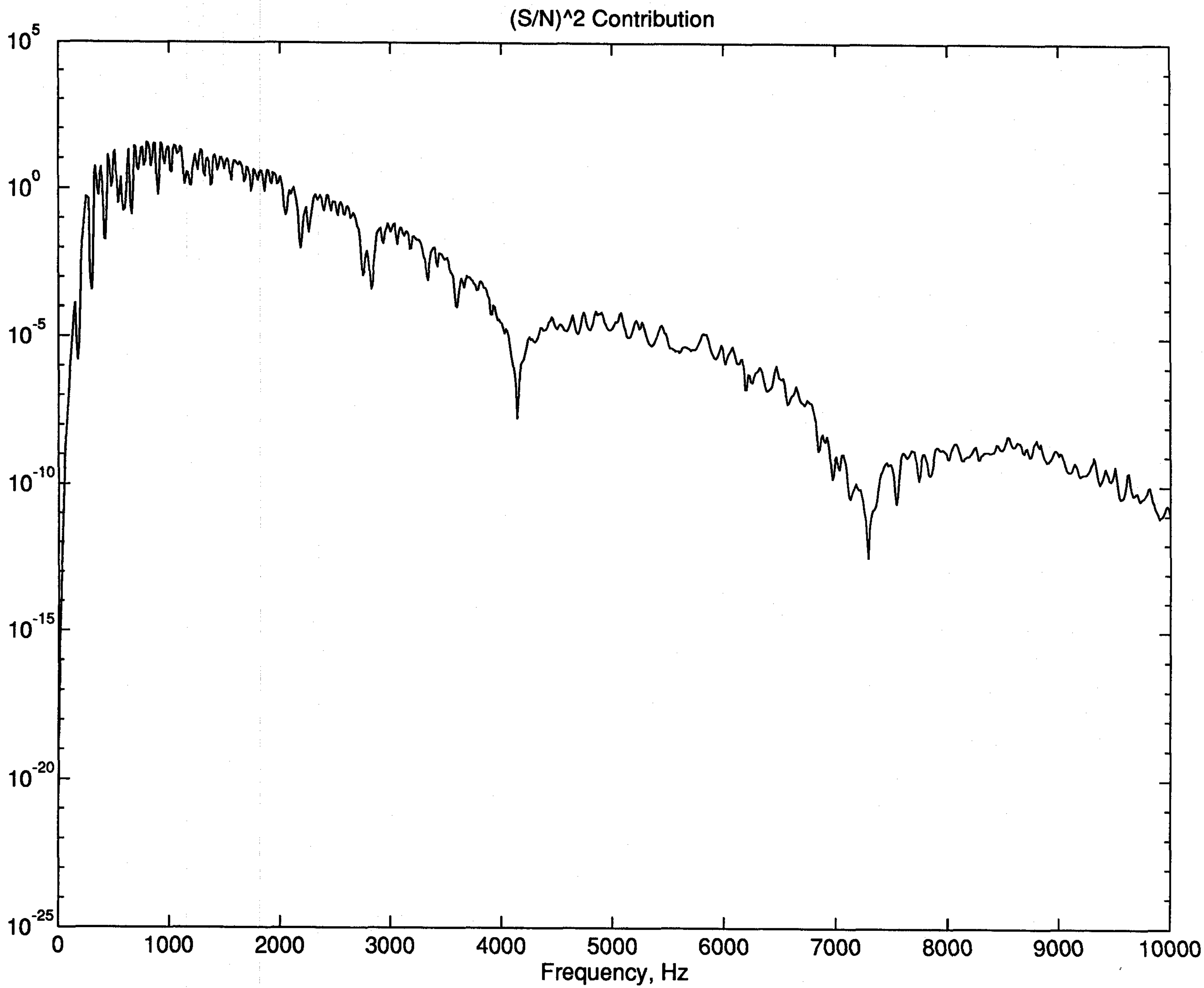
where $S_y(f)$ is the displacement power spectrum of the noise, $(DRHC\,\phi)^2$. A program "art.m" does all this for us and plots $\frac{|\tilde{x}_p(f_i)|^2}{S_y(f_i)}\Delta f$ versus f_i. It gives:

$$\frac{S}{N} = 33.2$$

Plot follows.


Artificial Pulse
V
Seconds


Displacement
meters
Seconds
$\sigma = 8.59 \times 10^{-16}\ m_{rms}$



(S/N)^2 Contribution
10^5
10^0
10^-5
10^-10
10^-15
10^-20
10^-25
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Frequency, Hz

5/12/94

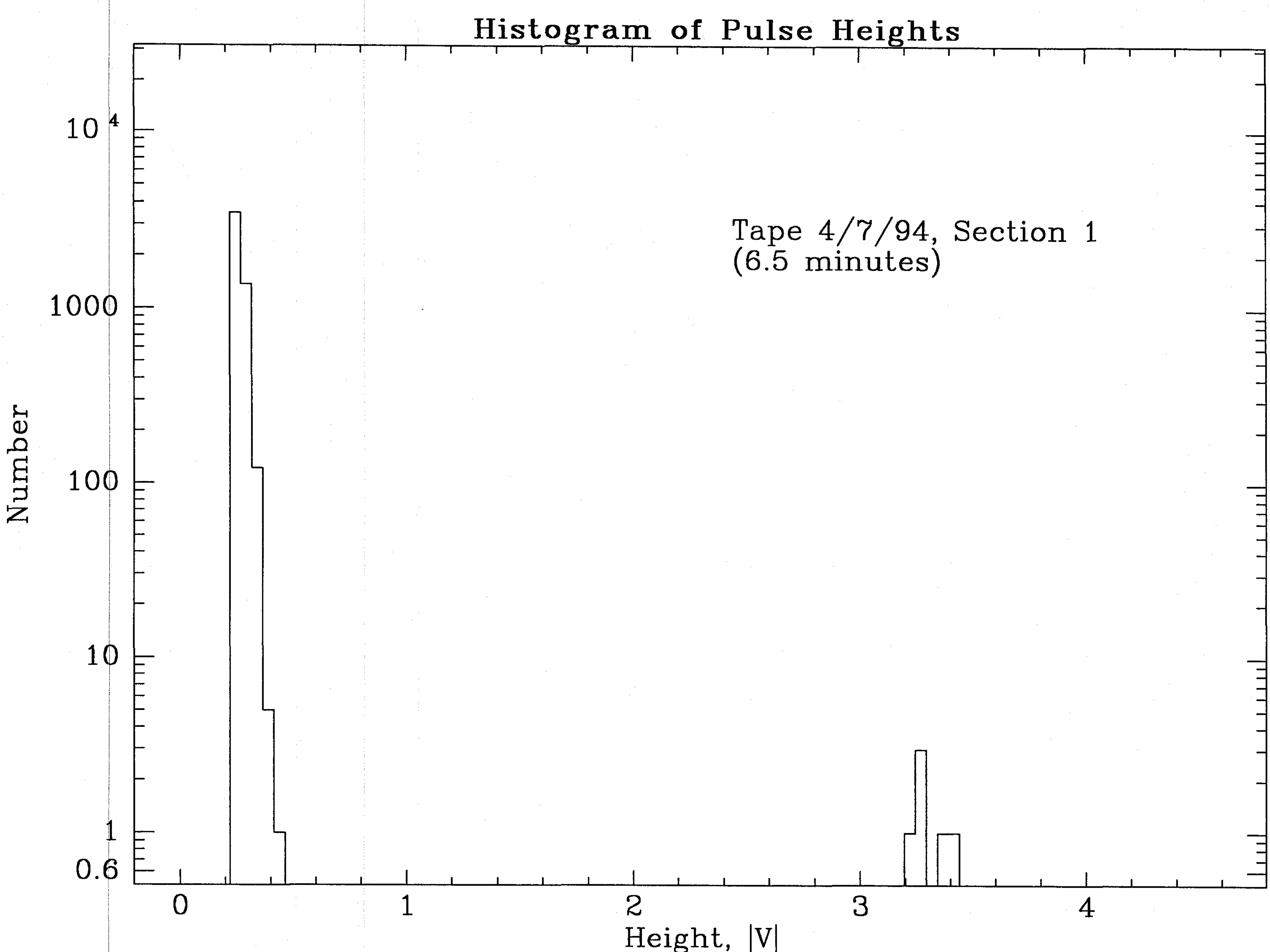
Analysis of Tape 4/7/94

Of the 8 locked sections recorded during 43 minutes of data taking, only 4 were long enough to analyze. No "real" pulses were found. The pulses found were either:

1. Artificial impressed (during section 1)
2. At the very beginning of the section
3. At the very end

All sections had pulses at the beginning except the first which suggests the 1 minute dead time is not long enough. The last such pulse was 7 seconds after the analysis start. All except section 7 had an out of lock transient which was a rail-to-rail oscillation immediately before falling out of lock. On the two sections I spot checked (sections 1 & 8) the oscillations were at ≈1.3 kHz and the behavior immediately after falling out of lock was different. In both cases both arms fell out of lock simultaneously.

We are primarily interested in section 1 which had the artificial pulses impressed. The were 6 impressed pulses which were all detected. Their minimum spacing was 12 seconds.


Histogram of Pulse Heights
Tape 4/7/94, Section 1
(6.5 minutes)
Number
10^4
1000
100
10
1
0.6
0
1
2
3
4
Height, |V|

To whiten the data we need a power spectrum. I use my standard $m = 131072$ and $k = 100$ power spectrum with Hann windowing of data from 60 seconds onward. (≈ 22 minutes are used!) Unfortunately we only have ≈ 200 seconds available in section 1 so I used $m = 131072$, $k = 15$, starting at the beginning of the (analyzed) data. This still avoids the impressed pulses. Looking at the spectrum that above 5 kHz and below a few 100 Hz that the spectrum in voltage is dominated by digitization noise. With our data rate with this many points the output of "powspc" in volts will have 12-bit digitization noise at $\approx 4.4 \times 10^{-5}$ V.

5/13/94

After trying to whitten the dat I again got spurious large very fast pulses in the output. The explaination Mike used that this was due to the artificial pulses being too closely space due to the long impulse response (≈ 10 sec) of the whitehing filter, does not seem to be true. I believe that the digitization noise at higher frequencies is being amplified by the whitening filter so that we sometimes get a spurious large high frequency pulse.

The way to get around this seems to be to use the full optimal filter. Unfortunately on the computer the order of operations for filtering becomes important. That is:

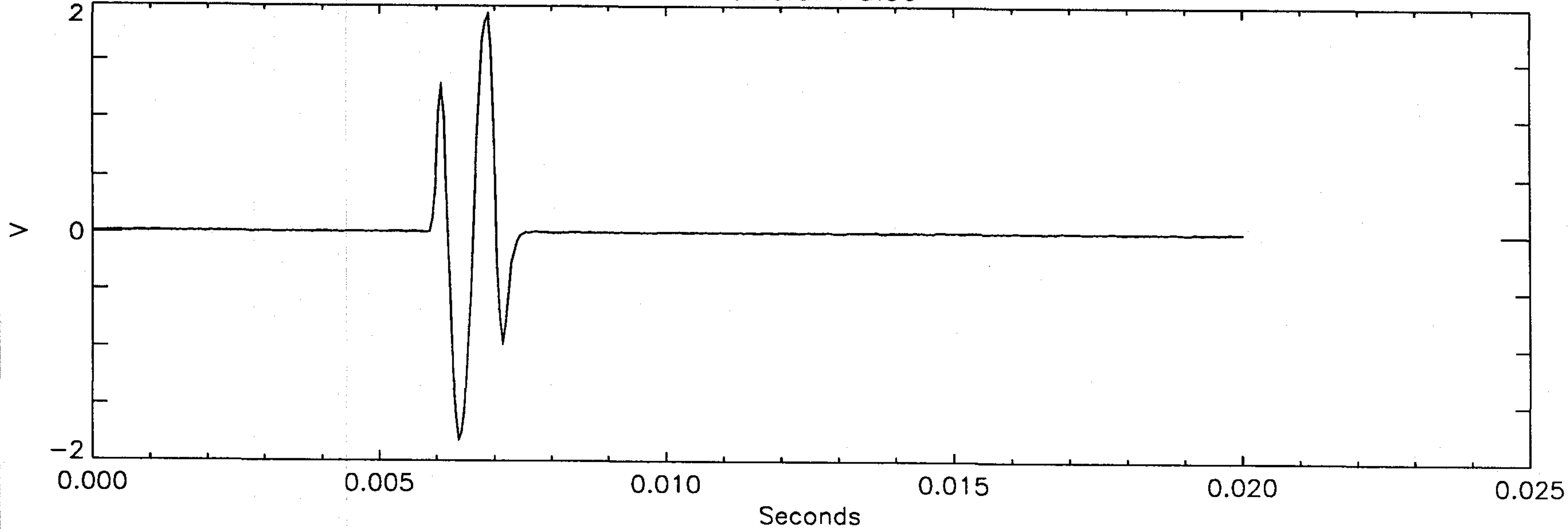
(0) Convolution by Optimal Filter = Correlation with signal + Whitening output (1)

= Whitening data + Correlation with signal (2)

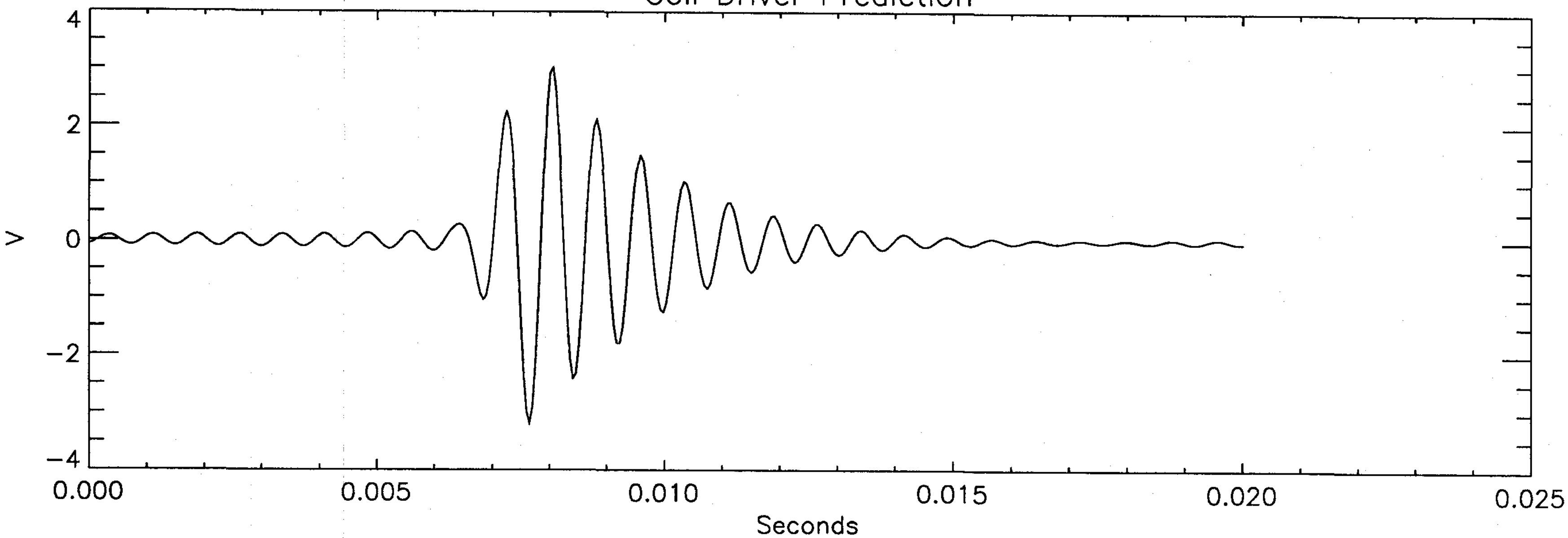
Unfortunately the option we use (1) has the same problem as it will accentuate digitization error left over from the correlation. From now on I will do (0) in one step which is computationally most efficient since we must whiten in the Fourier domain anyway.

I modified art_V and art_x to use the correct attenuation constant for future data runs of 130×10^{-6} from the 20 dB + 30 dB attenuators loaded by the EE coil. Also needed to change final Stanford pre-amp gain setting in art_V from 20 to 10. The results of these two are plotted following. Unfortunately the interpolated swept sine filter is slightly acausal.

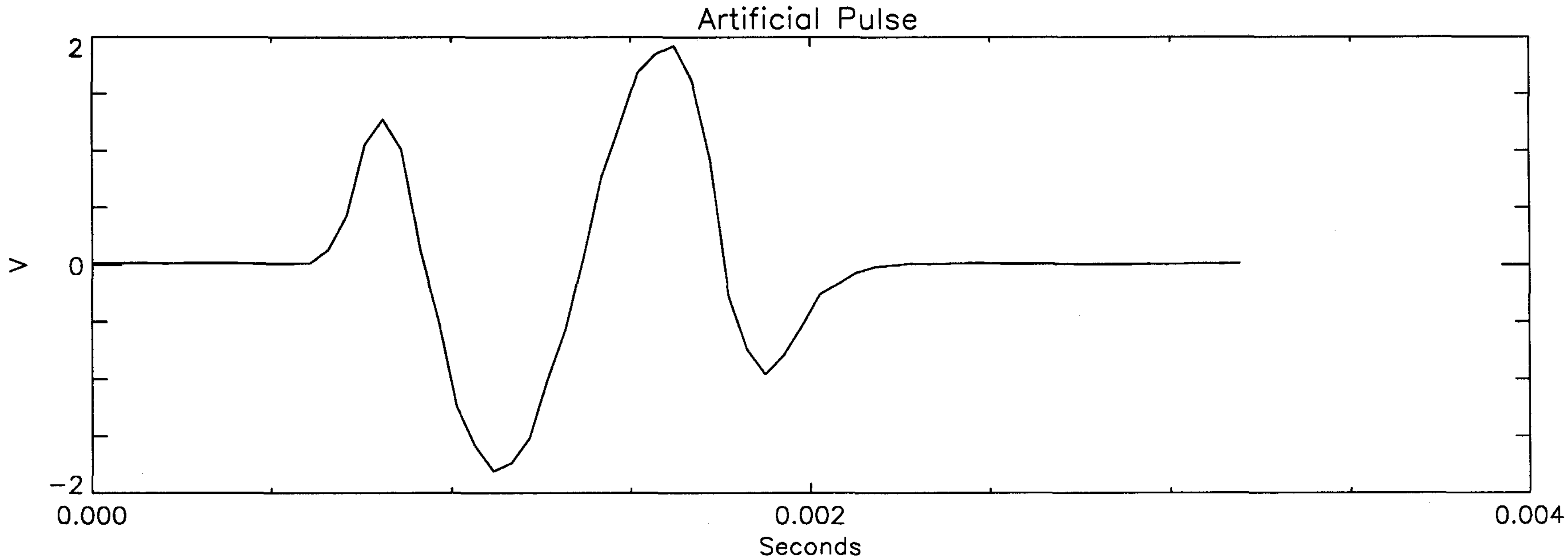
Artificial Pulse

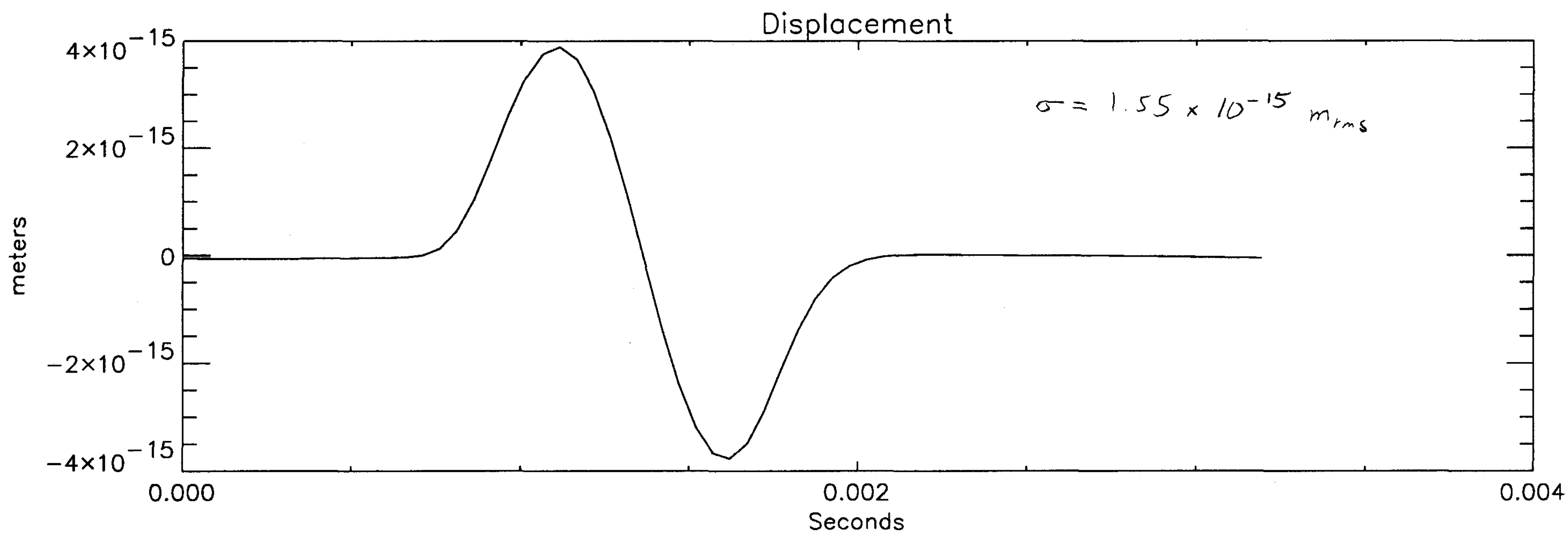


Coil Driver Prediction



1TL, 5/15/14


Artificial Pulse
V
2
0
−2
0.000
0.002
0.004
Seconds


Displacement
meters
4×10^{-15}
2×10^{-15}
0
-2×10^{-15}
-4×10^{-15}
0.000
0.002
0.004
Seconds
$\sigma = 1.55 \times 10^{-15}\ m_{rms}$

BATCH START

Option Filtering

STAPLE OR DIVIDER

5/16/94

I found a general problem with interpolating a Fourier transformed signal using "ftm". The inverse transform of the resulting data is longer but the pulse will show up right at the beginning and may even overlap so part of it is at the end. Zero padding the original time domain data seems to be the way to go. Thus for optimal filtering purposes I have to modify the directions of 4/13/94 for generating a template to make the last step:

5. Run "art_V" on a 262144 point long section of pulse monitor data.

Recipe for Optimal Filtering:

1. Generate artificial pulse template using modified directions from 4/13/94. (Use 262144 points.) Output is stored in 'coil.flp.'

2. Generate a V^2 power spectrum of interferometer output with m = 131072. Call it 'bigspc2.flp.'

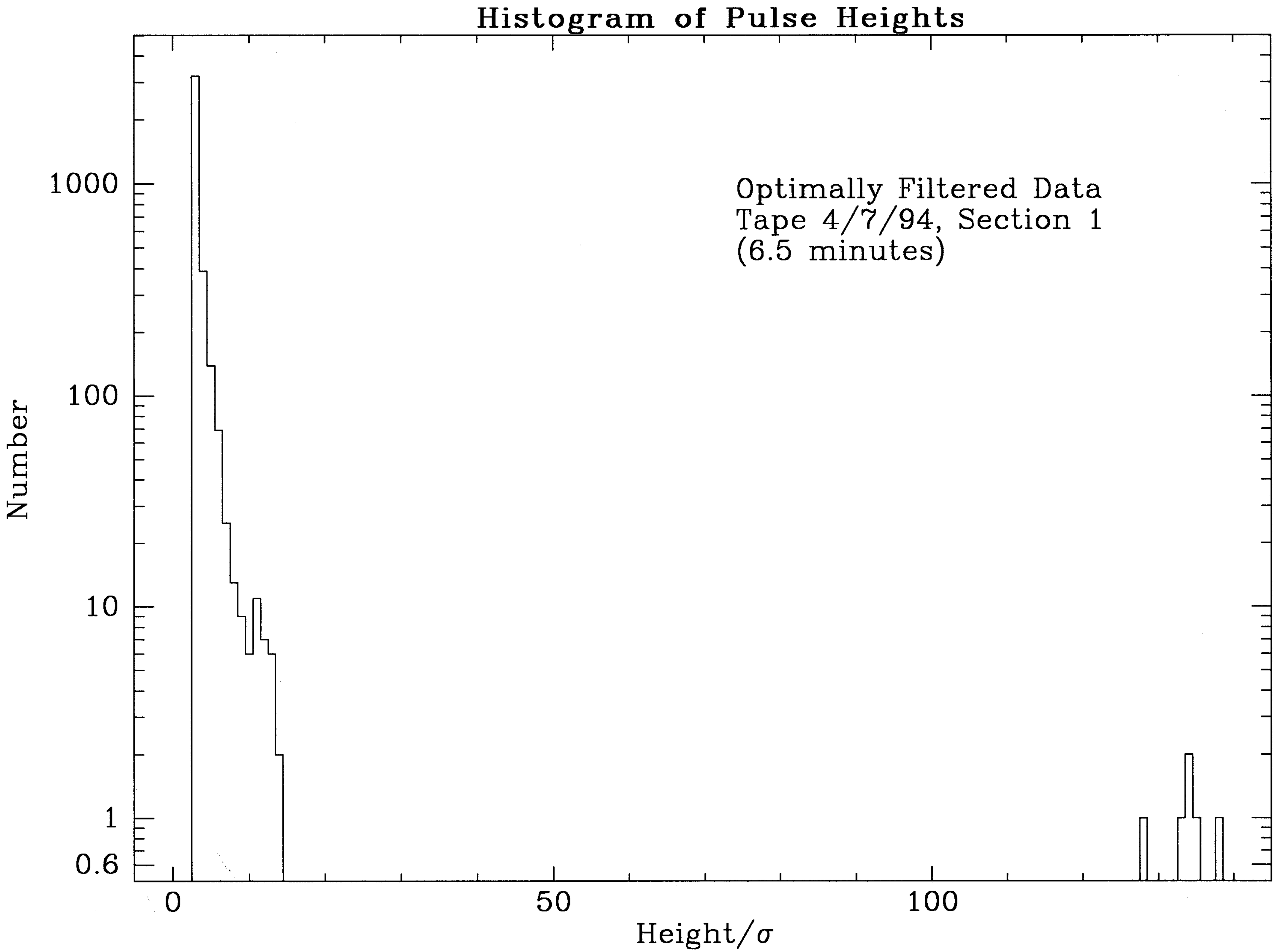
3. Run "make_opt coil.flp". This will generate the optimal filter for this template. Output is in 'filter.flp.'

4. Run "opt_filt" on interferometer data. Output is in 'time.flp.'

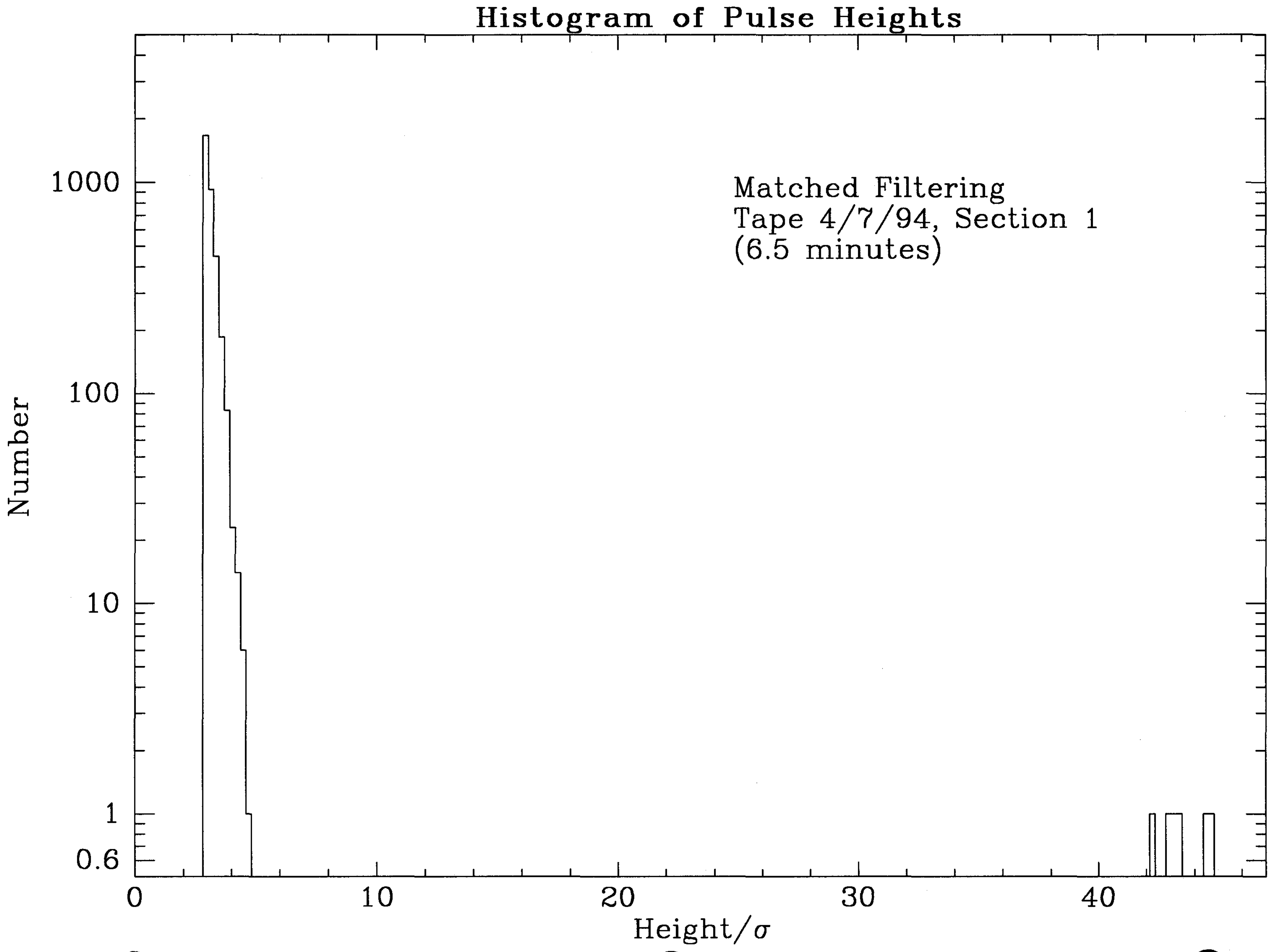
I checked the standard deviation of the resulting optimally filtered data from 4/7/94, section 1 and found it was 1.068611. This is good as it was supposed to be normalized to 1. Running the optimal filter on all 6.5 minutes of data took 24.4 minutes on flogger, a SPARC 1.

5/14/94

I did a matched filtering of the same data. That is a correlation without any whitening. The pulse height histogram follows.


Histogram of Pulse Heights
Optimally Filtered Data
Tape 4/7/94, Section 1
(6.5 minutes)
Number
1000
100
10
1
0.6
0
50
100
Height/σ

TTL, 5/17/94


Histogram of Pulse Heights
Matched Filtering
Tape 4/7/94, Section 1
(6.5 minutes)
1000
100
10
1
0.6
Number
0
10
20
30
40
Height/σ

5/20/94

Predicting $\frac{S}{N}$ from optimal filtering: Correct formula is

$$\left(\frac{S}{N}\right)^2 = 4\int_0^\infty \frac{|\tilde{m}(f)|^2}{S_n(f)}\,df$$

where, $S_n(f)$ is the one-sided PSD of the noise and $\tilde{m}(f)$ is the Fourier transform of the signal.

Using the old program called 'art.m', which I have renamed 'sn_opt_old.m' one gets $\frac{S}{N} = 134$. To run this version requires the following files to be in the same directory:

'caldisp.dat'	Calibrated displacement noise spectrum
'p5kfilt.dat'	Filter used on HP 3562
'disp.dat'	Signal in displacement units

First one must run 'art.m' which calculates the normalization constant from the signal. 'sn_opt_old.m' then builds $\tilde{m}(f)$ from a sinc function as described before. I am uncertain, however, about a factor of 2 in the normalization. This $\frac{S}{N}$, however matches up perfectly with the pulse height spectrum.

Correction: I solved the factor of 2 discrepancy and found another error. My $\frac{S}{N}$ now is 112.

A new version of this program, 'sn-opt.m', simply calculates $\tilde{m}(f)$ from the data. This will work for arbitrary pulse shapes. It gives $\frac{S}{N} = 117$.

It requires: 'caldisp.dat' Displacement noise spectrum
'displ.dat' Signal in displacement units

Note that in doing these calculations with dric0.dat, it has a 0 at DC. I set this somewhat arbitrarily to 1e-7 to avoid errors in semi-log plots.

6/7/94

Analysis of Tape 3/2/94, Section 2

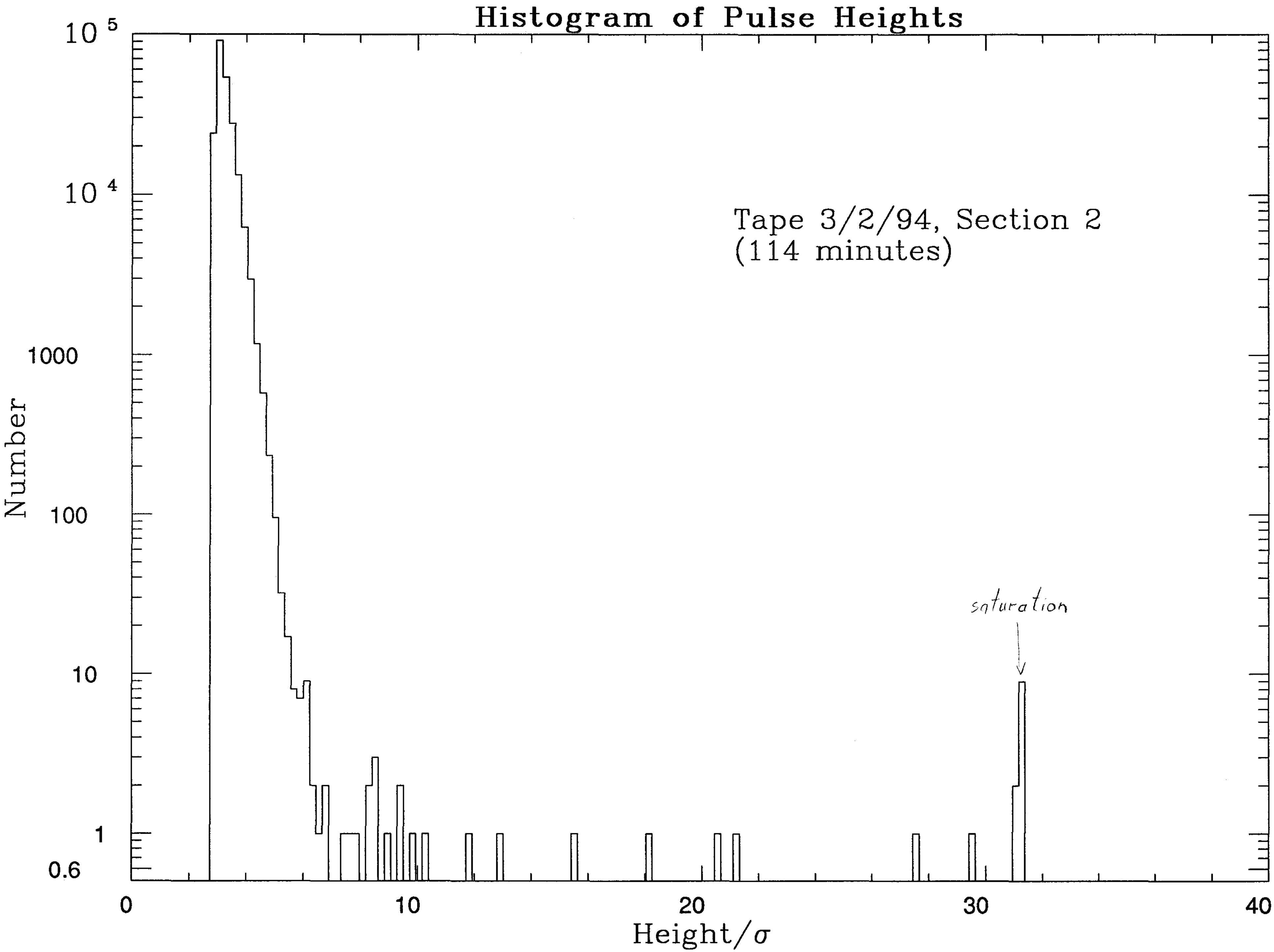
Many large pulses occur in the 1st ≈ 20 seconds of analyzed data. This is probably because I belatedly switched the Ganged Switch from 9 to 10 as recorded in the event log. To be safe I will cut off and ignore an additional 60 seconds from the beginning of the run. From now on I will ignore the 1st 2,400,000 points of data.

6/9/94

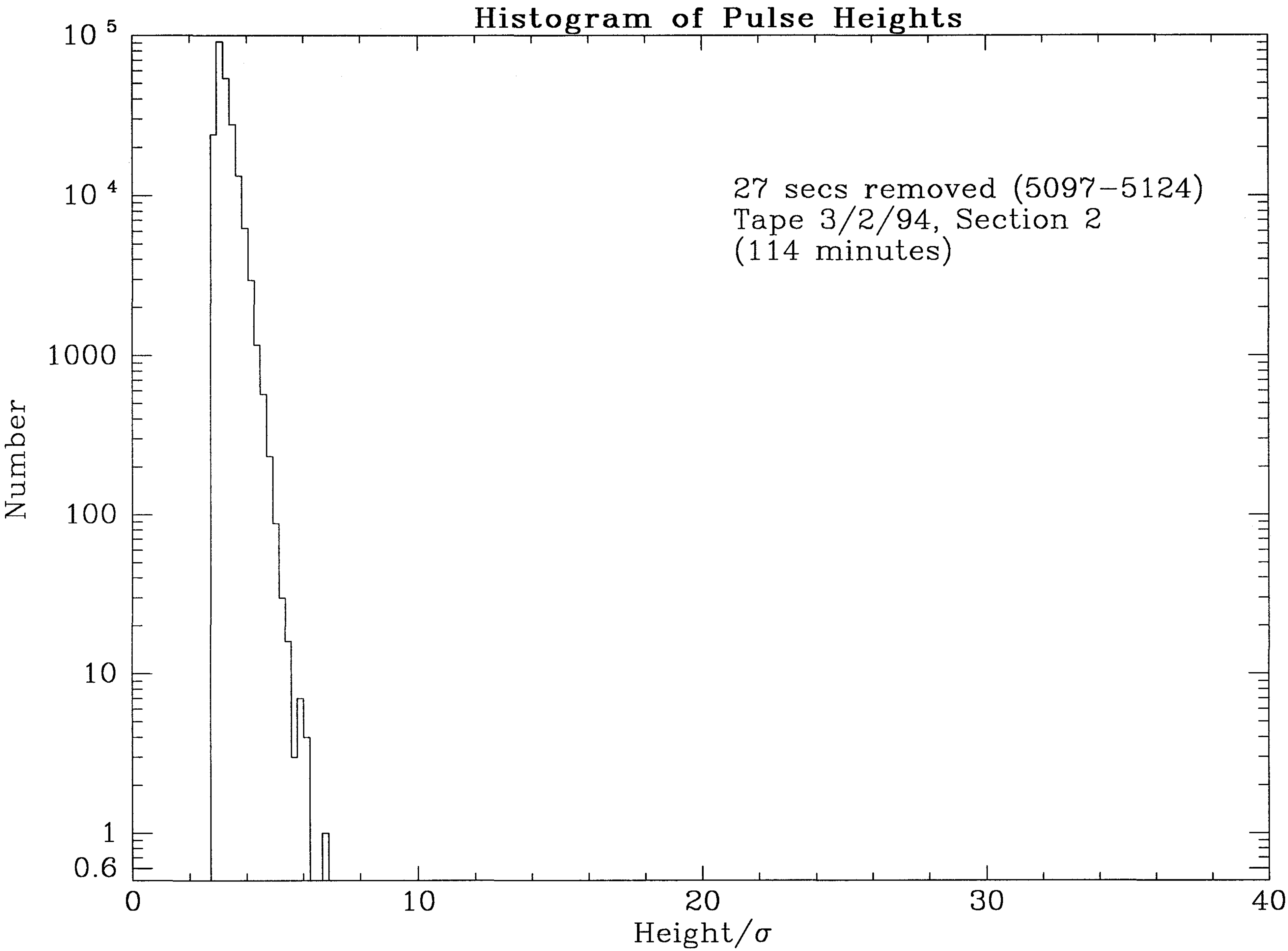
To get the template for matched filtering I reloaded off the tape 4/7/94 the first impressed pulse. To estimate the noise power spectrum I used powspc with m = 131072, k = 100 starting at the beginning of the analyzed data.

As can be seen from the Pulse Height Histogram, 37 8σ pulses were found in the raw data. All of the occured in the 27 second period between 5097 - 5124 seconds. Another histogram with this time period exised shows very gaussian behavior.

776, 6/7/94


Histogram of Pulse Heights
Tape 3/2/94, Section 2
(114 minutes)
saturation
Number
Height/σ
10 5
10 4
1000
100
10
1
0.6
0
10
20
30
40

-72, 6/9/94


Histogram of Pulse Heights
27 secs removed (5097–5124)
Tape 3/2/94, Section 2
(114 minutes)
Number
Height/σ
10 5
10 4
1000
100
10
1
0.6
0
10
20
30
40

6/15/94

In attempting to optimally filter section 2 for our canonical impressed pulse (single cycle of 1kHz sine wave) we run into disk space and time limitations. I overcame these by writting a faster filtering routine, "fast_filt.c", dividing the work among several Sparc 10's and binning the data after each 262144 point block so the raw data doesn't have to be saved.

Timing / block:

Computer	method	time elapsed	% cpu time	
flogger	old	1:04.82	93.6	(Sparc 1)
alleycat	old	58.48	25	(Sparc 10)
flogger	fast	57.11	96.4	
alleycat	fast	37.68	34.7	
puma	fast	38.23	40.1	(Sparc 10)

Thus we can see that each block is filtered in about 3 times as long as its real time length on a Sparc 10 with fast_filt. (Old refers to the old 3 step algorithm of fft ; ftm ; fft-inv used previously which fast_filt replaces.)

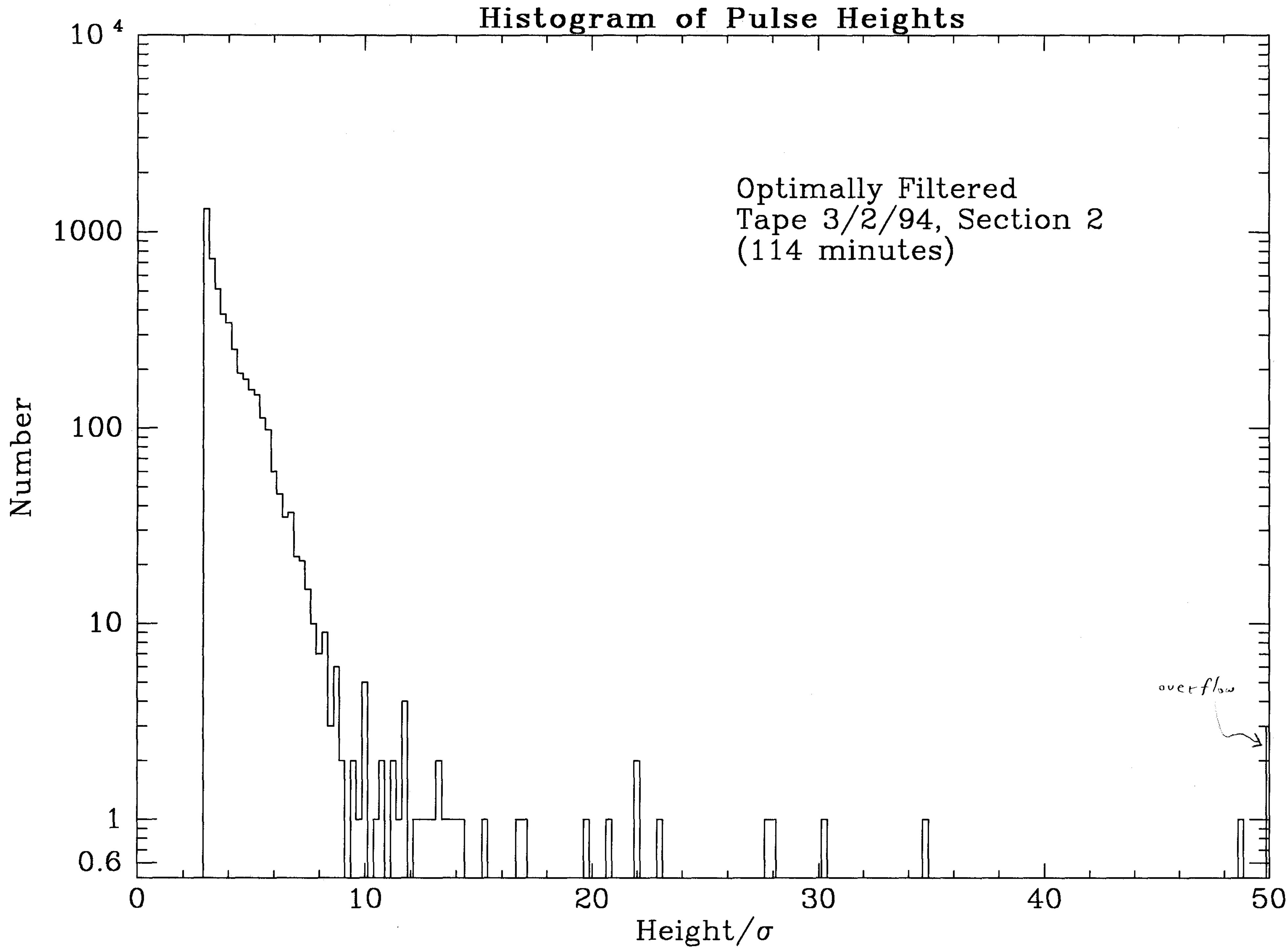
The entire section 2 is 270,723,822 bytes long.

This means it is 516.4 blocks of 262,144 points long. (Each point is 2 bytes.) I will assign this to 2 Sparc 10's. (In fact I mistakenly assigned 2 other Sparc 10's to non-existant data.) They were:

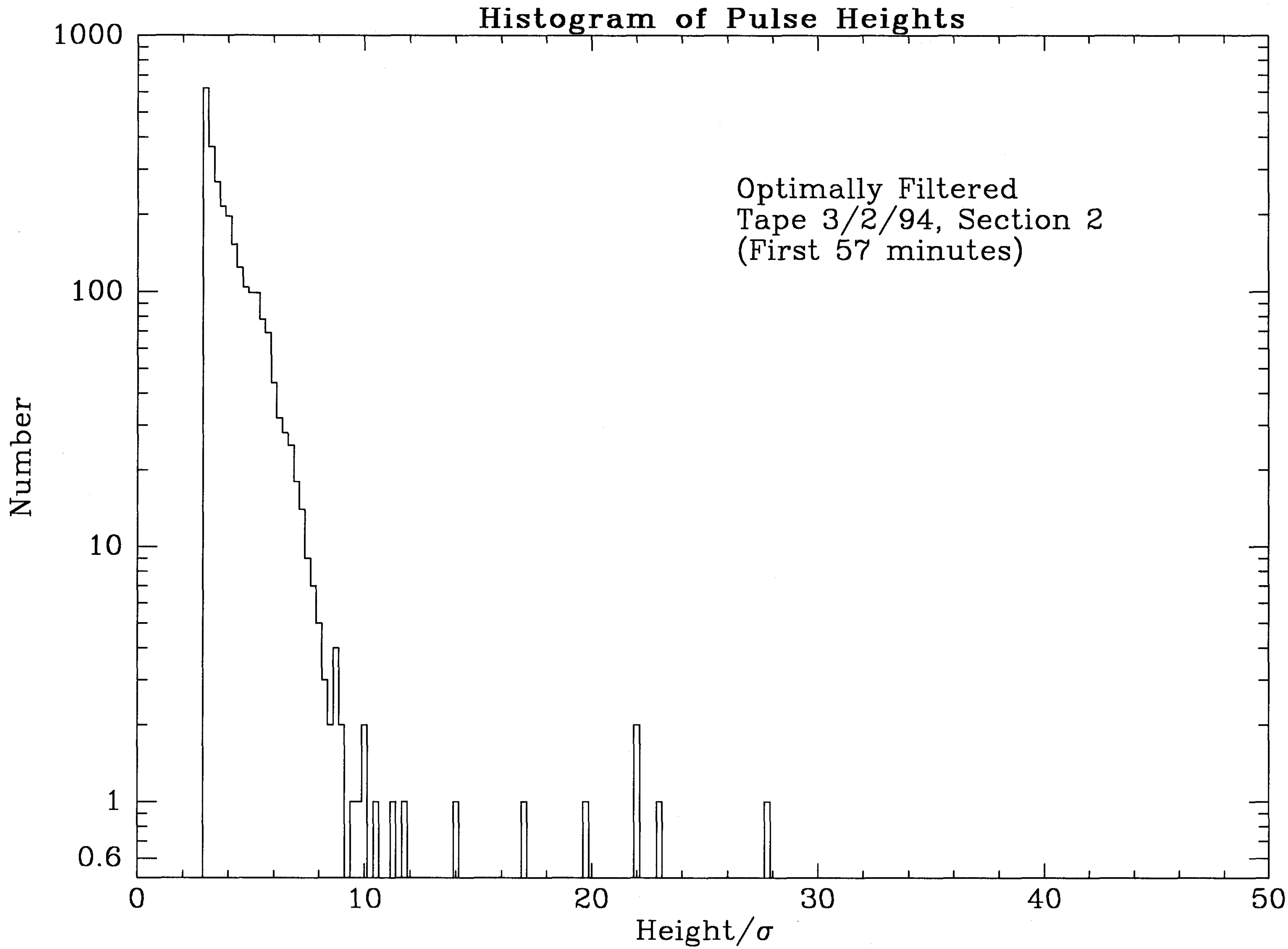
~/glitch/work/	Computer	Blocks	Time	% cpu
a	alleycat	0 - 257	3:02:11.5	36.8%
b	panther	258 - 515	2:59:50.3	33.7%

The output is histogramed pulse heights and sample values. A plot of the combined pulse height histograms for the entire section follows. The large non-gaussian component is troubling. Even the 1st half of the data (without the troubling 27 seconds) shows some large pulses, although they are smaller.

TTL, 6/16/94


Histogram of Pulse Heights
Optimally Filtered
Tape 3/2/94, Section 2
(114 minutes)
Number
Height/σ
overflow
10 4
1000
100
10
1
0.6
0
10
20
30
40
50

TTL, 6/16/94


Histogram of Pulse Heights
Optimally Filtered
Tape 3/2/94, Section 2
(First 57 minutes)
Number
Height/σ
1000
100
10
1
0.6
0
10
20
30
40
50

BATCH START

Probability

STAPLE
OR
DIVIDER

6/17/94

Thoughts on Probability:

Height/σ	$1-P$	Average Time Between Events (ATBE)
1	0.317310	160 μs
2	0.045510	1.11 ms
3	2.6998×10^{-3}	18.8 ms
4	6.3344×10^{-5}	0.80 sec
5	5.7343×10^{-7}	1:28 min
6	1.973175×10^{-9}	7:08:00 hours
7	2.559647×10^{-12}	229 days
8	1.244199×10^{-15}	1291 years

$$P = \frac{1}{\sqrt{2\pi}} \int_{-x}^{x} e^{-\frac{1}{2}t^2} dt \qquad ATBE = \frac{1}{1-P} \frac{1}{\text{data-rate}}$$

Assumed data-rate = 19736.8 samples/sec

In fact for a non-white random process the number to use for data-rate is less than the actual data rate. This is because they will have non-zero correlation times so that adjacent samples will be correlated. If we define:

$$2S(0)\Delta\omega = \int_{-\infty}^{\infty} S(\omega)\, d\omega \qquad 2R(0)\Delta\tau = \int_{-\infty}^{\infty} R(\tau)\, d\tau$$

Then, $\Delta\omega \Delta\tau = \frac{\pi}{2}$

If T = total time of data run

then, n = effective number of samples $\approx \frac{T}{\Delta\tau}$.

The probability of getting an event of height $\geq h$ in time T is $P_T(h)$. Let $P(h)$ be the probability of getting such an event on a single sample. (Shown above.) Then,

$$P_T(h) = P(h) \sum_{i=0}^{n-1} (1 - P(h))^i \approx n P(h) \text{ if } P_T(h) << 1$$

$$= P(h) \frac{1 - (1 - P(h))^n}{1 - (1 - P(h))}$$

$$= \boxed{1 - (1 - P(h))^n}$$

Aaron made the observation that it is stupid to have digitization noise dominant in any part of the spectrum. This is because it is non-gaussian. (Hence the problem with whitening.) He pointed out that I should just allow some signal aliasing and then only use the lower 70-80% of the frequency bins. (The HP spectrum analyzers take 1024 points and only use 812.)

6/20/94

Remaining questions from section 2 of 3/2/94:

1. Where do the non-gaussian pulses on the optimally filtered data come from?

2. Where do the non-gaussian (>6σ) pulses in the raw data come from?

Answers:

1. From comparison of 1st half of filtered output with "chan ∅."
   a) Output of optimal filter oscillates @ ~500 Hz so there can be multiple counting of pulses @ 10σ or lower threshold.
   b) There is a ≈20 Hz envelope around the noise in channel 0. early in the locked section. Strangely the pulses in the filtered output seem to occur at the nodes of the envelope.
   c) All ≥10σ pulses at < 4000 secs except one occur at ≤ 126 secs.

Most probably the non-gaussian pulses are a result of amplifying the non-gaussian noise.

2. The non-gaussian pulses in the raw data do not appear to be correlated with any other data channels. These were: Laser slow PZT monitor, seismometer, X laser pointing, Y laser pointing.

Data Run "J"

Data Channels:

0 Grav. Wave Signal. Output of 2nd arm Coil Driver →
2 pole 100 Hz HP in Pomona Box. →
SRS Model SR560, A coupling: DC, 6dB/oct. HP 0.3 Hz,
6dB oct. LP 100 Hz, Low Noise, x 200, Line Power, < 150mA output →
Ithaco 4213 Elec. Filter, BP 100 - 8000 Hz, Normal Mode →
EG&G Parc, A input: AC couple, LF roll-off: 100 Hz,
HF rolloff: 10 kHz, x 100, → A - D

1 Pulse Monitor. HP 3563A Source → 20 dB atth. → 30 dB atth. →
EE coil & A - D

2 1st Arm TTL In Lock

3 2nd Arm TTL In Lock

4 Laser Slow PZT $\frac{1}{100}$ Monitor

5 Ranger Seismometer → PAR/13, BP 0.[illegible] - 100 Hz, x100, AC couple

6 East End Global X

7 East End Global Y

Aaron helped me setup for this data run. The primary purpose for this data run is to check that my optimal filtering programs really work if given data where digitization noise does not dominate a section of the spectrum. We spent a long time ensuring this would be true as can be seen from the plot of "DRNJ1". Note digitization noise is at

$$\frac{\Delta^2}{12} = 0.00141\ V_{rms} \longrightarrow 1.41 \times 10^{-5}\ V/\sqrt{Hz}$$

or -97 dB

Somehow Aaron and I were fooled into thinking digitization noise for 12-bits was at $-57 dBV/\sqrt{Hz}$. Thus the gain for this data run is very high. Even as it is our aliasing is such that the aliased noise will be atleast 20 dB below the signal at frequencies below 8 kHz.

The data taken on disk 34.01 of the HP3562A was:

DRNJØ	10 kHz span power spectrum of noise in rms V.
DRNJ1	20 kHz span power spectrum of noise in rms $V/\sqrt{Hz}$.
DRSSJØ	10 kHz span swept sine ~~freq resp.~~ coherence.
DRSSJ1	10 kHz span swept sine freq. resp.
DRCJØ	Calibrated displacement noise $= \frac{1}{(4.5)(6695)} \frac{1}{(j\omega)^2} \frac{DRNJØ}{DRSSJ1}$

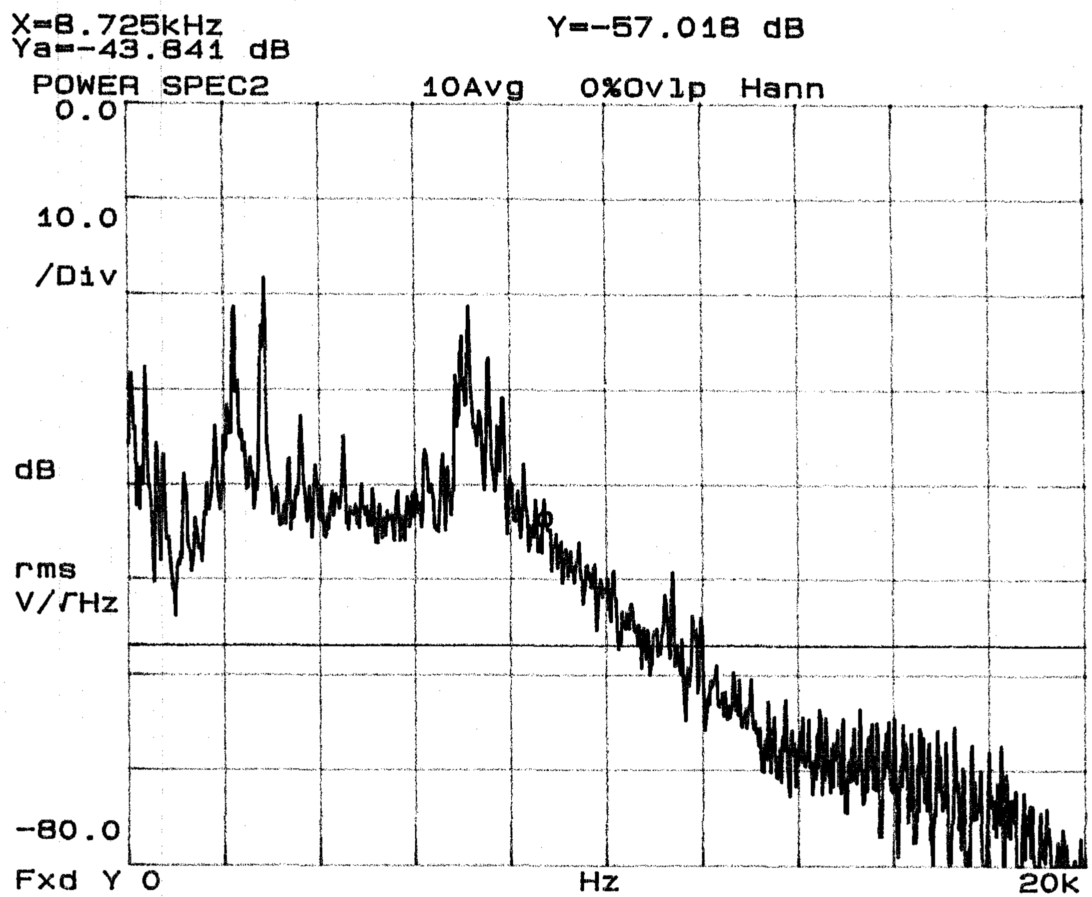
Data Run Events

5:14 pm	Started data acquisition
5:16	Started continuous 1 ms pulses
5:18	Stopped pulses
5:18	Out-of-lock
5:21	Out-of-lock
⋮	Out-of-lock
	Stopped

7/28/94, TTL

"DRNJ1" on disk 34.01

Noise power to show aliasing.



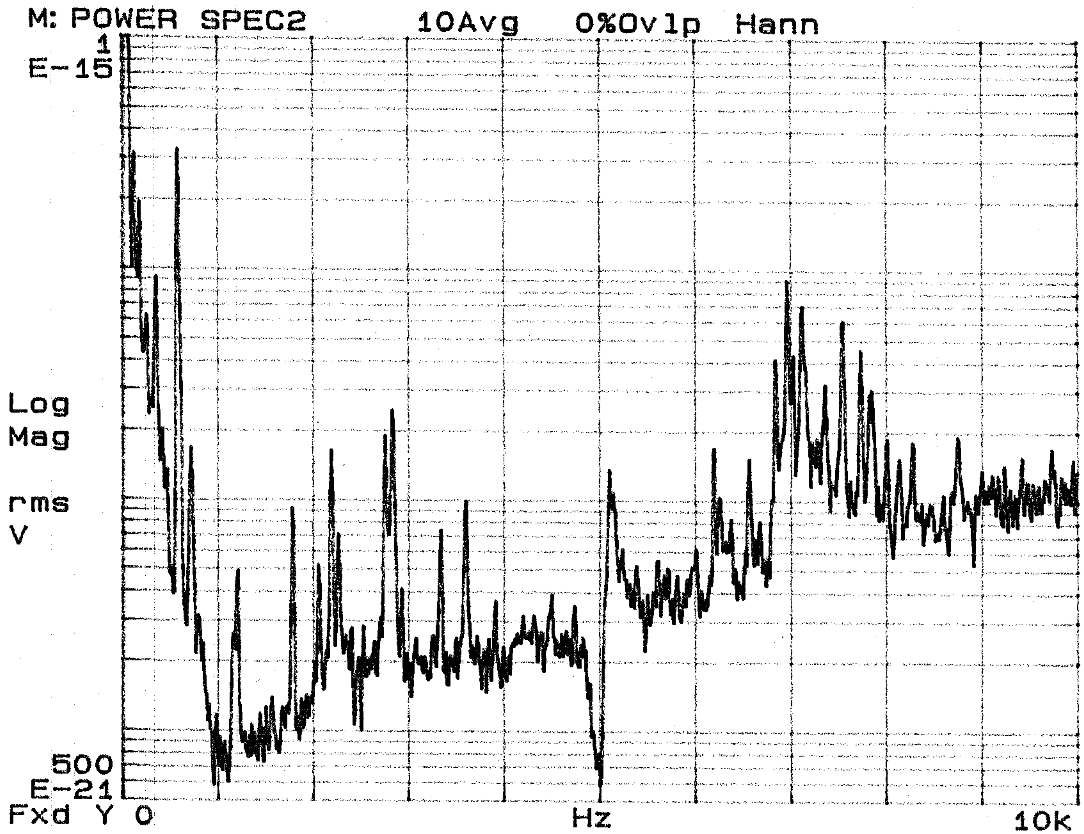
↑

Nyquist Freq.

7/28/94, TTL

"DRCJØ" on disk 34.01

Calib. Displacement Spectrum



8/1/94, TTL

Analysis of 7/28/94 Data, Section 5

1. Estimation of voltage PSD:

```
powspc chan∅ -V -pr -m 131072 -h 30 -Hann
    -bin > bigspc.flp
```

2. Whitened binary data: whiten chan∅
3. Find σ of whitened data, should be same as unwhitened, σ = 1.7 V.
4. Find 3σ pulses:

```
pulses time.flp -float -pr -t 5.1 -d 1 -reset
```

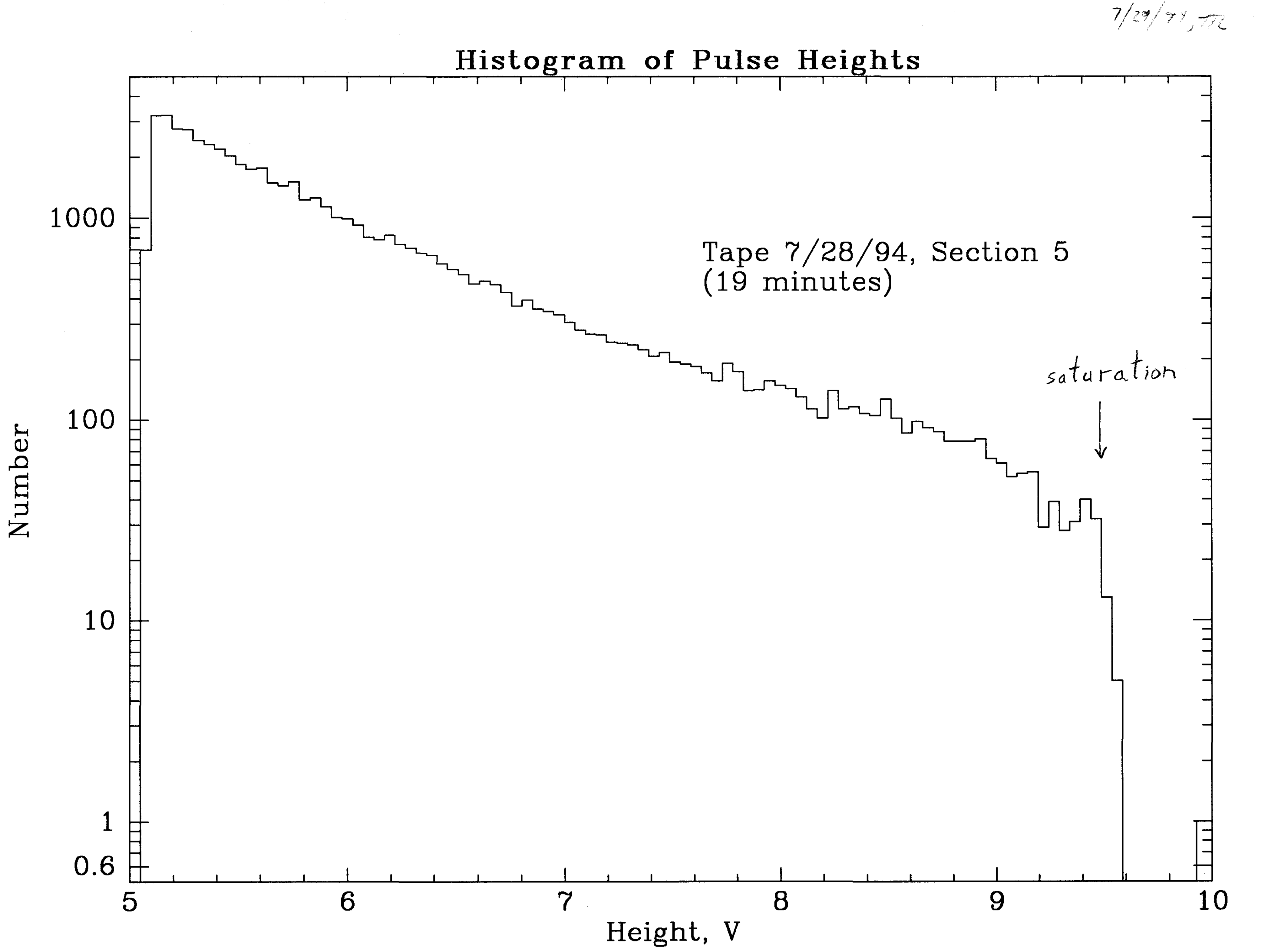
5. Bin data:

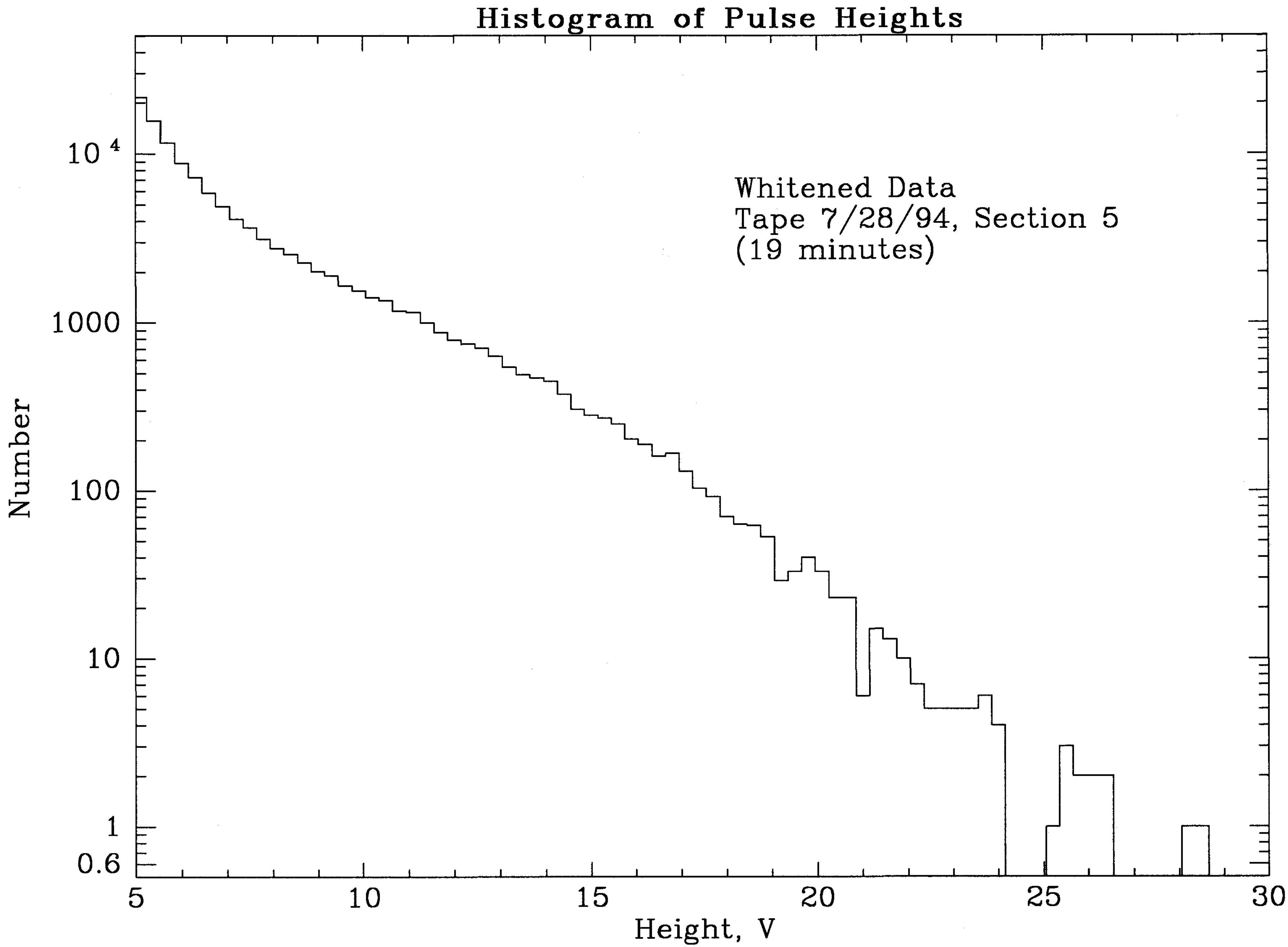
```
hext = `cut -f2 -s pulses.out | grep -v Height > pul0.dat`
binner pul∅.dat -l 0 -h 30 -abs -n 100
```

6. Confirm σ: mean -float time.flp

$\bar{x} = 0.001983 \qquad \sigma_x = 1.939342.$

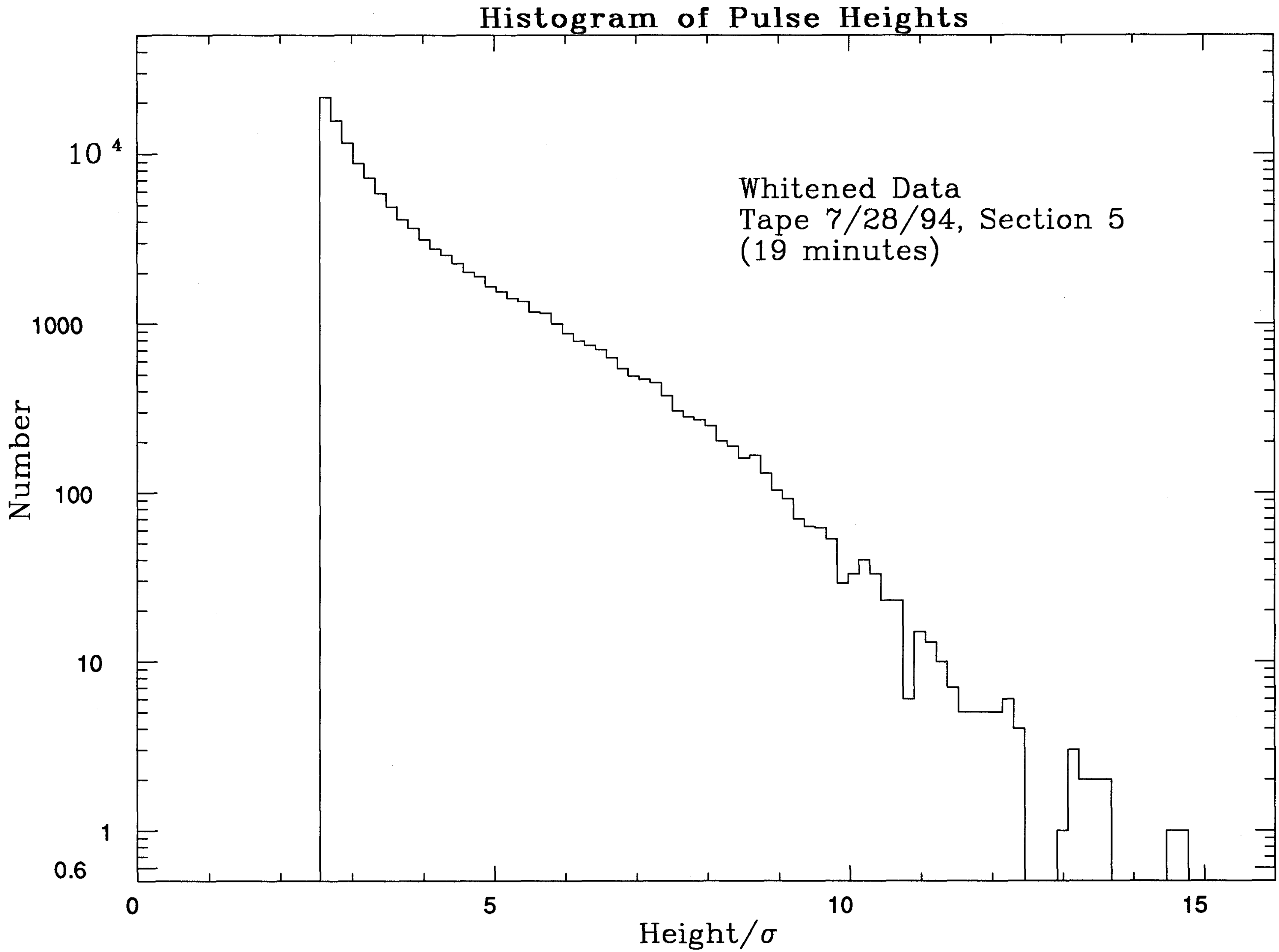
Plots of binned pulses follow and seem to show excess non-gaussian noise, both by themselves and compared to the unwhitened pulse height histogram.


7/29/94, TTL
Histogram of Pulse Heights
Tape 7/28/94, Section 5
(19 minutes)
saturation
Number
1000
100
10
1
0.6
5
6
7
8
9
10
Height, V



Histogram of Pulse Heights
Whitened Data
Tape 7/28/94, Section 5
(19 minutes)
Number
10^4
1000
100
10
1
0.6
5
10
15
20
25
30
Height, V

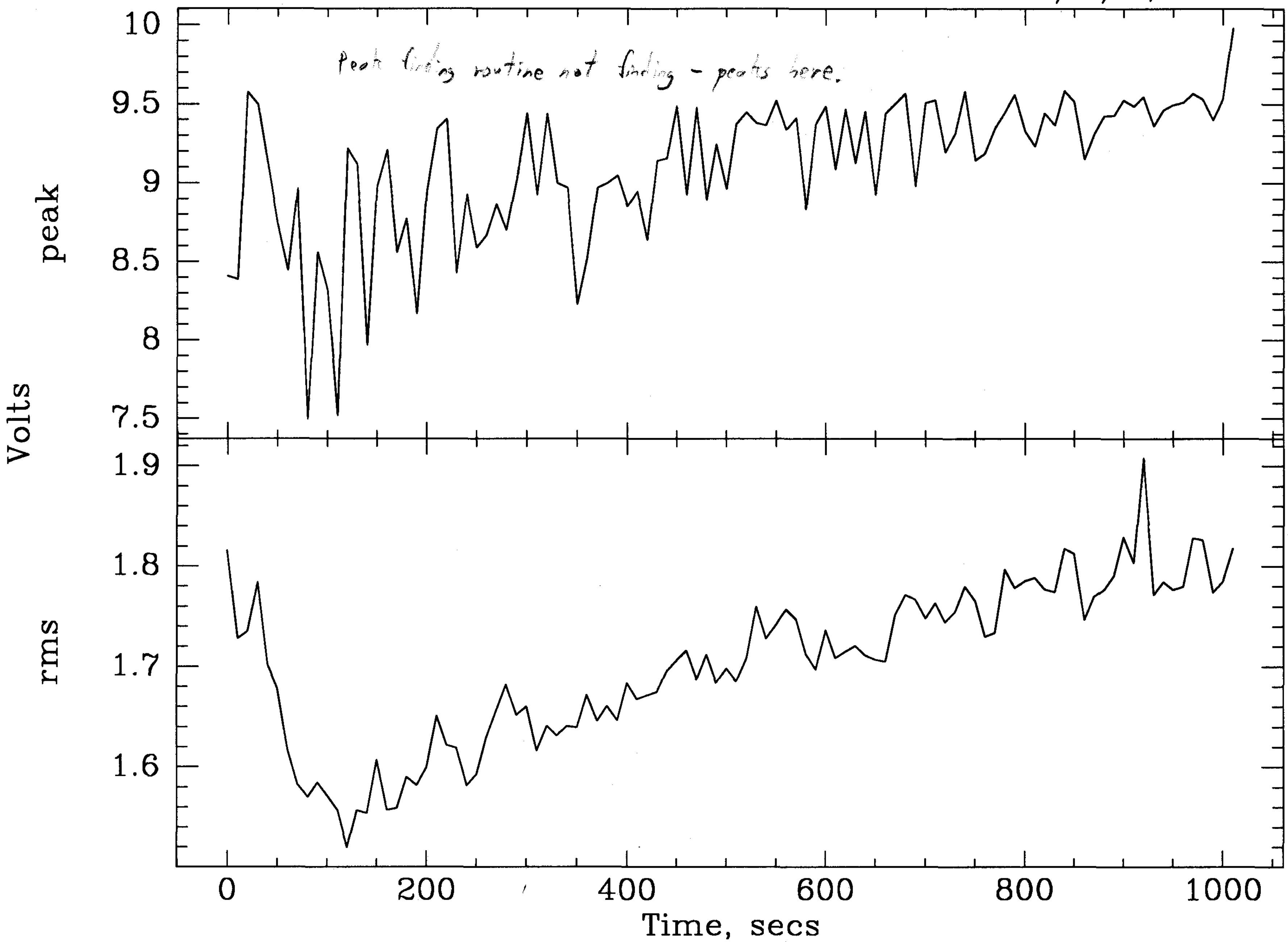
7.72, 8/1/94


Histogram of Pulse Heights
Whitened Data
Tape 7/28/94, Section 5
(19 minutes)
Number
10 4
1000
100
10
1
0.6
0
5
10
15
Height/σ

40m Data Peak and RMS

(10 second average)

7/28/94, Section 5



Data Run "K"

Data Channels:

0 GW Signal Output of 2^{nd} Arm Coil Driver →
2 pole 100 Hz HP in Pomona Box →
SRS Model SR560, A coupling: DC, 6 dB/oct. HP 0.3 Hz,
6 dB/oct. LP 1 kHz, Low Noise, x 0, Line Buer, <150 mA output →
Ithaco 4213 Elec. Filter, BP 100 - 8000 Hz, Normal Mode →
EG&G Parc, A input: AC couple, LF rolloff: 100 Hz,
HF rolloff: 300 Hz, x 20 → A - D

1 Pulse Monitor HP 3563A Source → 20 dB attn. → 30 dB attn. →
EE coil & A - D

2 1^{st} Arm TTL In Lock

3 2^{nd} Arm TTL In Lock

4 Laser Slow PZT $\frac{1}{100}$ Monitor

5 Ranger Seismometer → PAR 113, BP 0.1 - 100 Hz, x 60, AC couple

6 East End Global X

7 East End Global Y

Data taken w/ Spectrum Analyzer ⇒

DRKN∅ 20 kHz span power spectrum of noise in rms $V/\sqrt{Hz}$.

DRKN1 10 kHz span power spectrum of noise in rms V.

DRKSS∅ 10 kHz span swept sine freq. resp.

DRKSS1 10 kHz span swept sine coherence

DRKC∅ Calibrated displacement noise $= \frac{1}{30263.36} \frac{1}{(j\omega)^2} \frac{DRKN1}{DRKSS\emptyset}$

(Bob's new calib., 8/3/94, Book 34, p. 74 W

Steps for setting up HP3563A to generate pulses:

1. Get disk 32.01.
2. MEASUREMENT MODE: LINEAR RESOLUTION
3. FREQ: 20 kH span, ZERO START
4. Load "ACCELT1" and save it to register #2.
5. SOURCE: SOURCE TYPE: MORE TYPES: USR SAVE 2, SINGLE
6. SELECT TRIG: ARM = MAN, SOURCE TRIG
7. Start a measurement running continuously.
8. Press ARM to get a pulse.

Events, 8/23/94

4:32 pm Started tape writing

4:34 - 4:36 Impressed pulses once every ~30 secs.

4:36 Out of lock.

4:37 out of lock, twice.

4:41 Out of lock.

4:46 Out of lock.

4:53 Out of lock.

4:55 Back in lock, otherwise it has been pretty quick. Disconnected scopes to cut down line spikes.

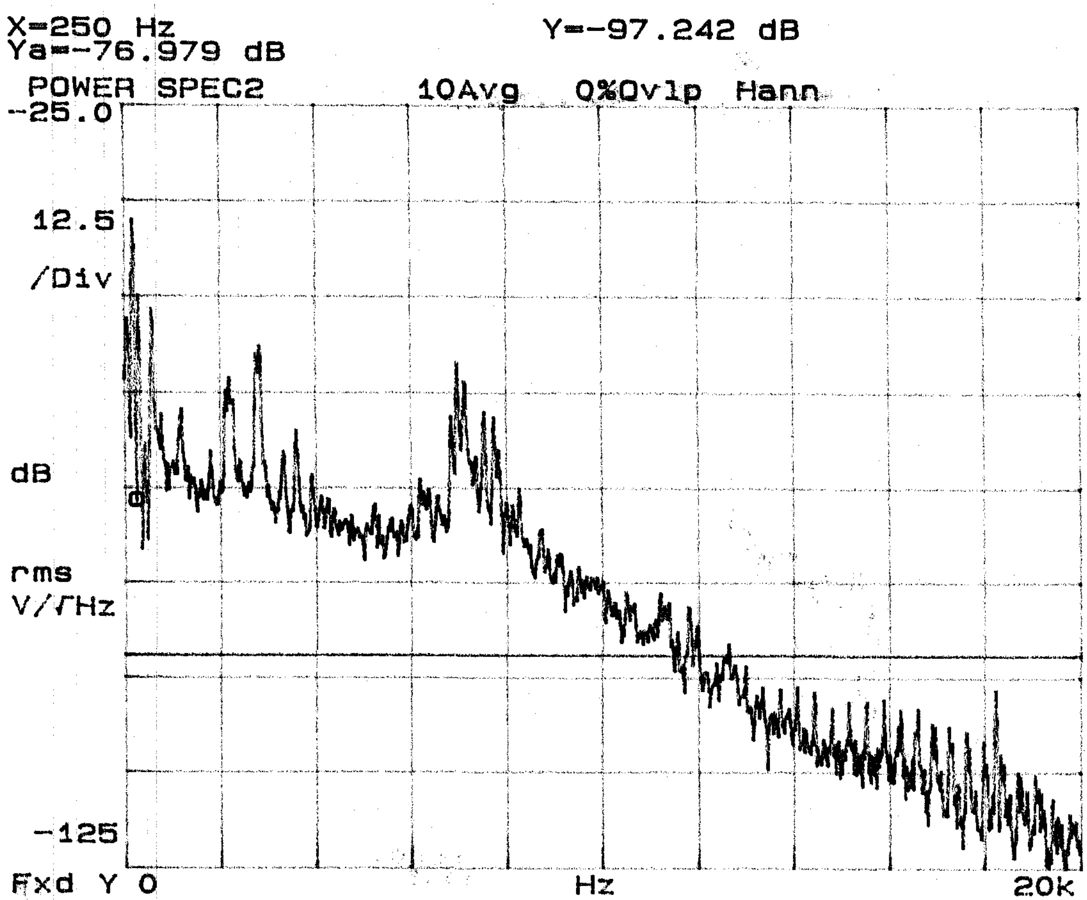
5:00 - 5:04 Out of lock. Mode cleaner was very misaligned. TEM_{00} V ≈ 30%. Now back up to 70%.

5:08 out of lock.

5:09 stopped tape.

3:03pm, 8/23/94
TTL

Noise Spectrum Sent to A-D

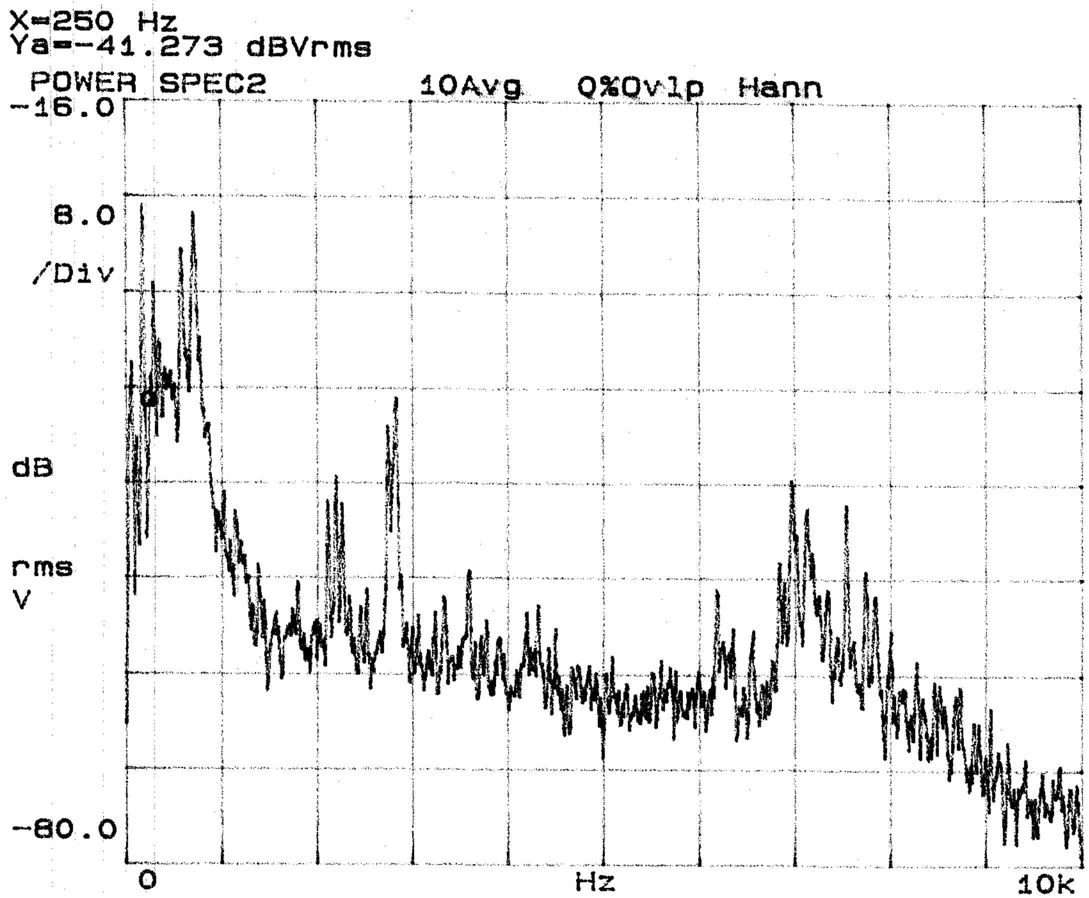


← digitization noise

Saved on disk 34.02
DRKN∅

3:13pm, 8/23/94
TTL

Noise Spectrum, uncalibrated



Disk 34.02

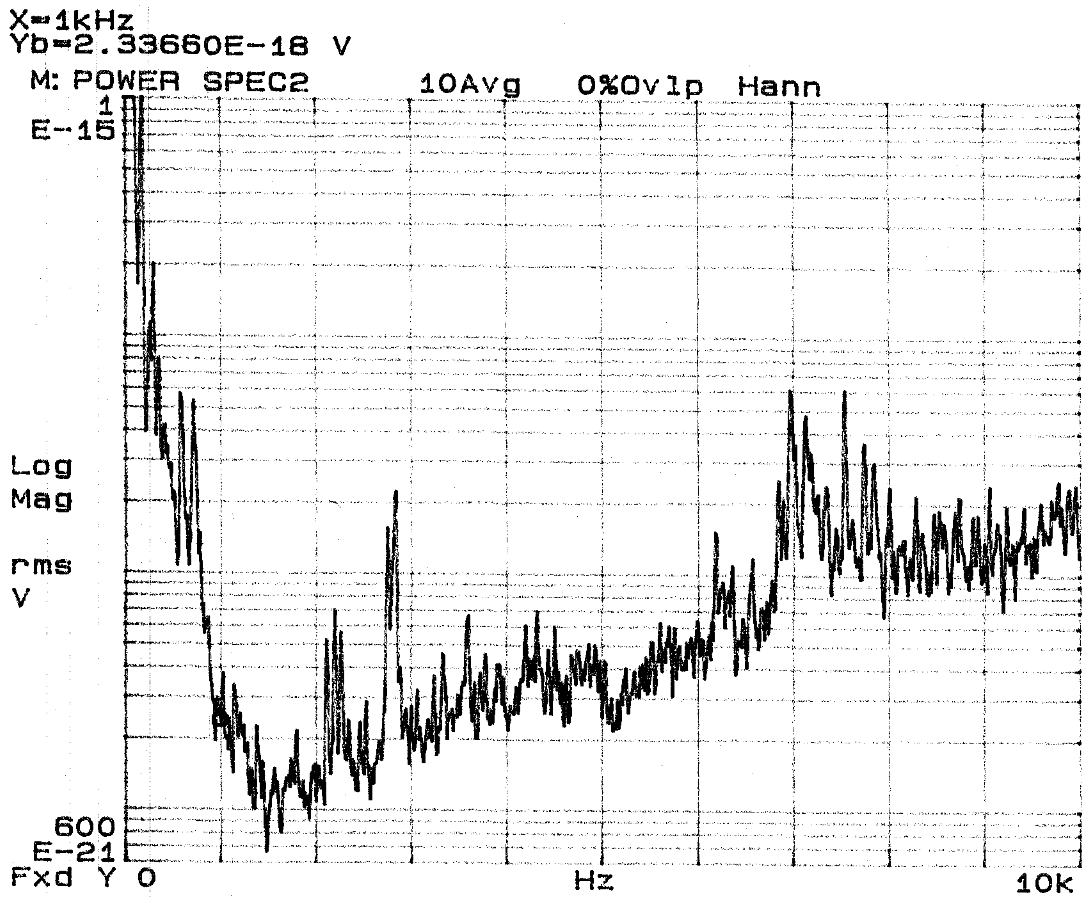
DRKN1

8/23/94, TTL

Calibrated Noise Spectrum

Saved in 34:02:

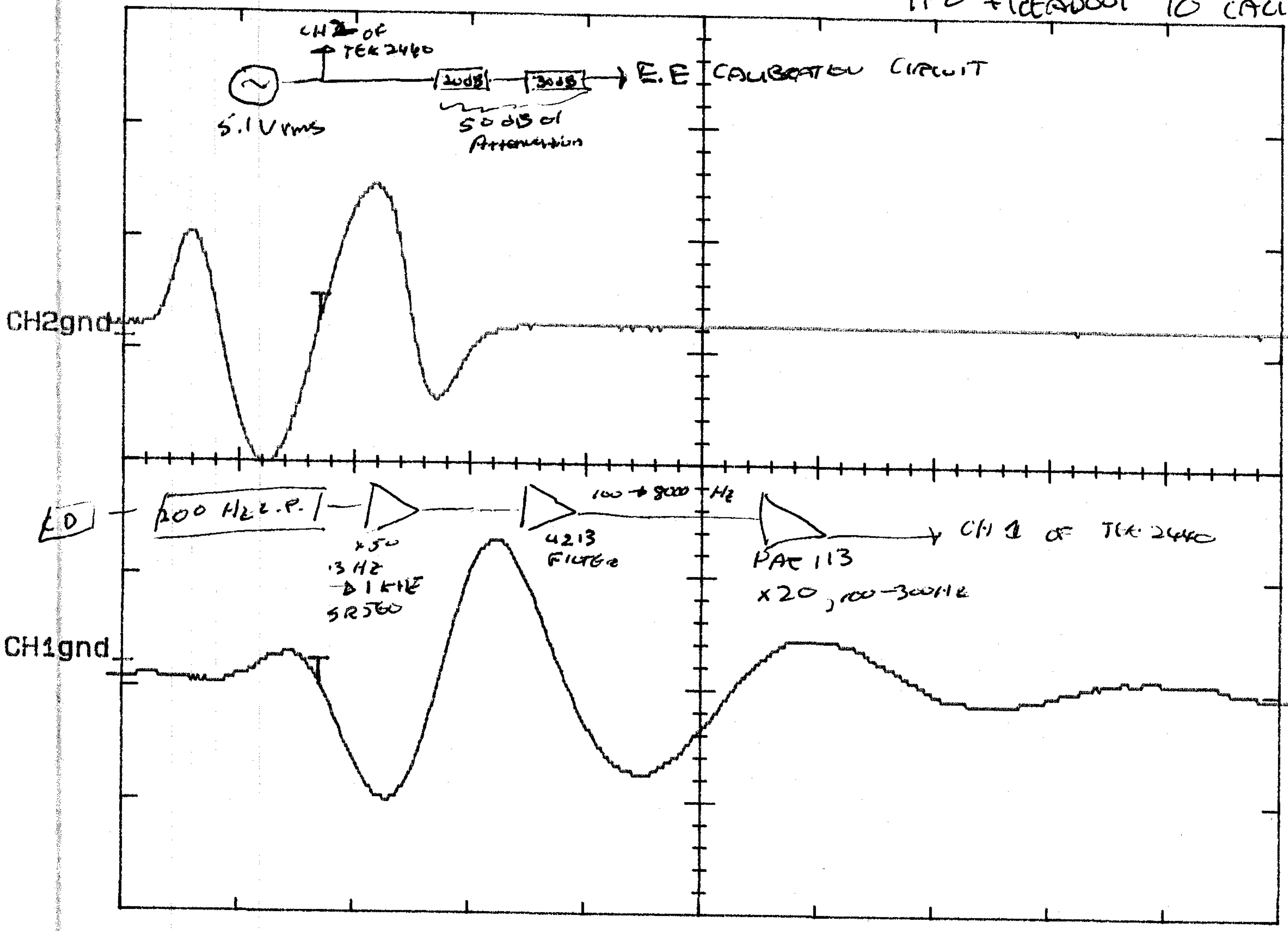
DRKC Ø



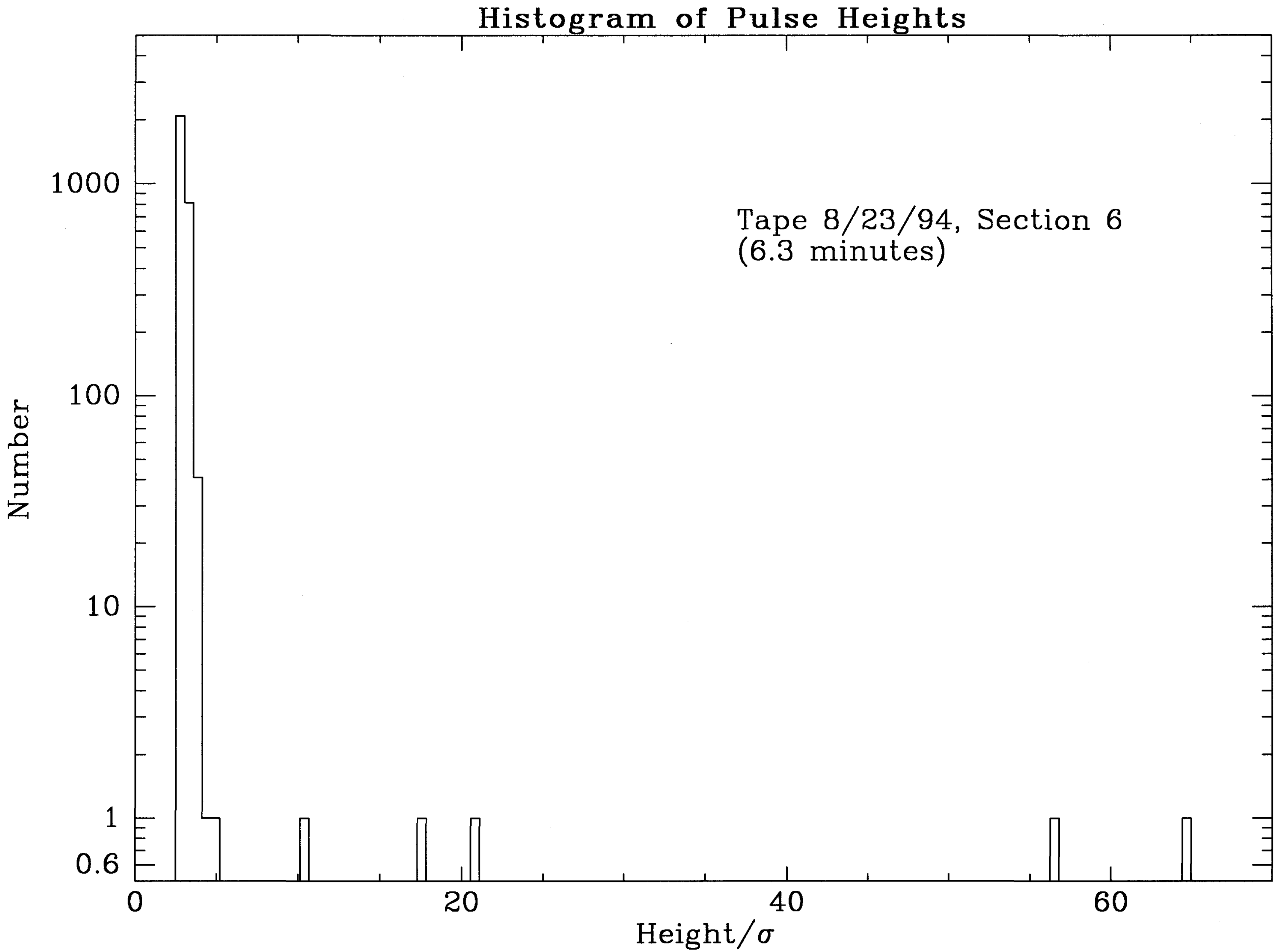
CH1 200mV Bw A 500µs 7.81mV CH2
CH2 2V

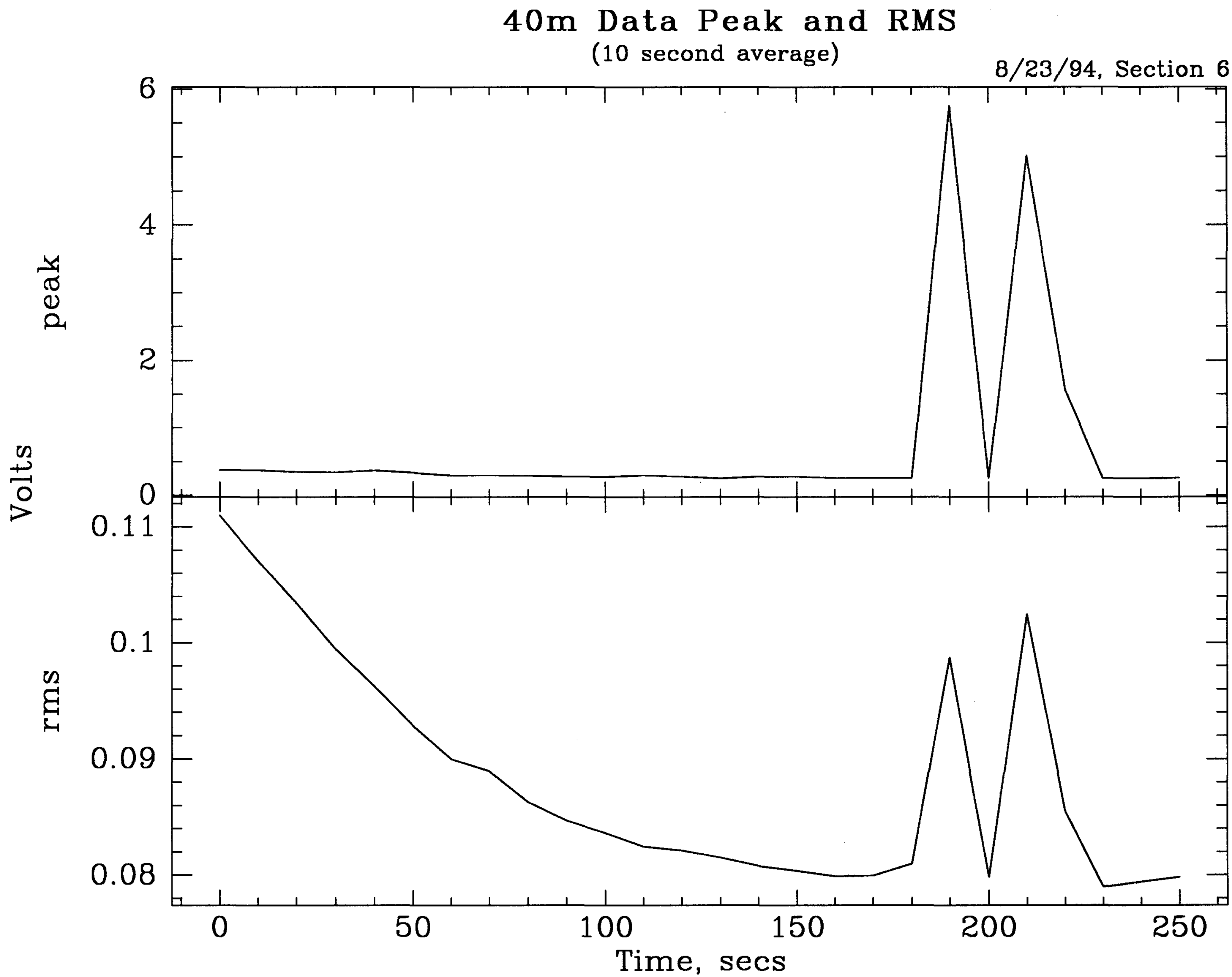
23 AUG 94 16:20

TIME-DOMAIN RESPONSE OF IFO + READOUT TO CALIBRATION PULSE

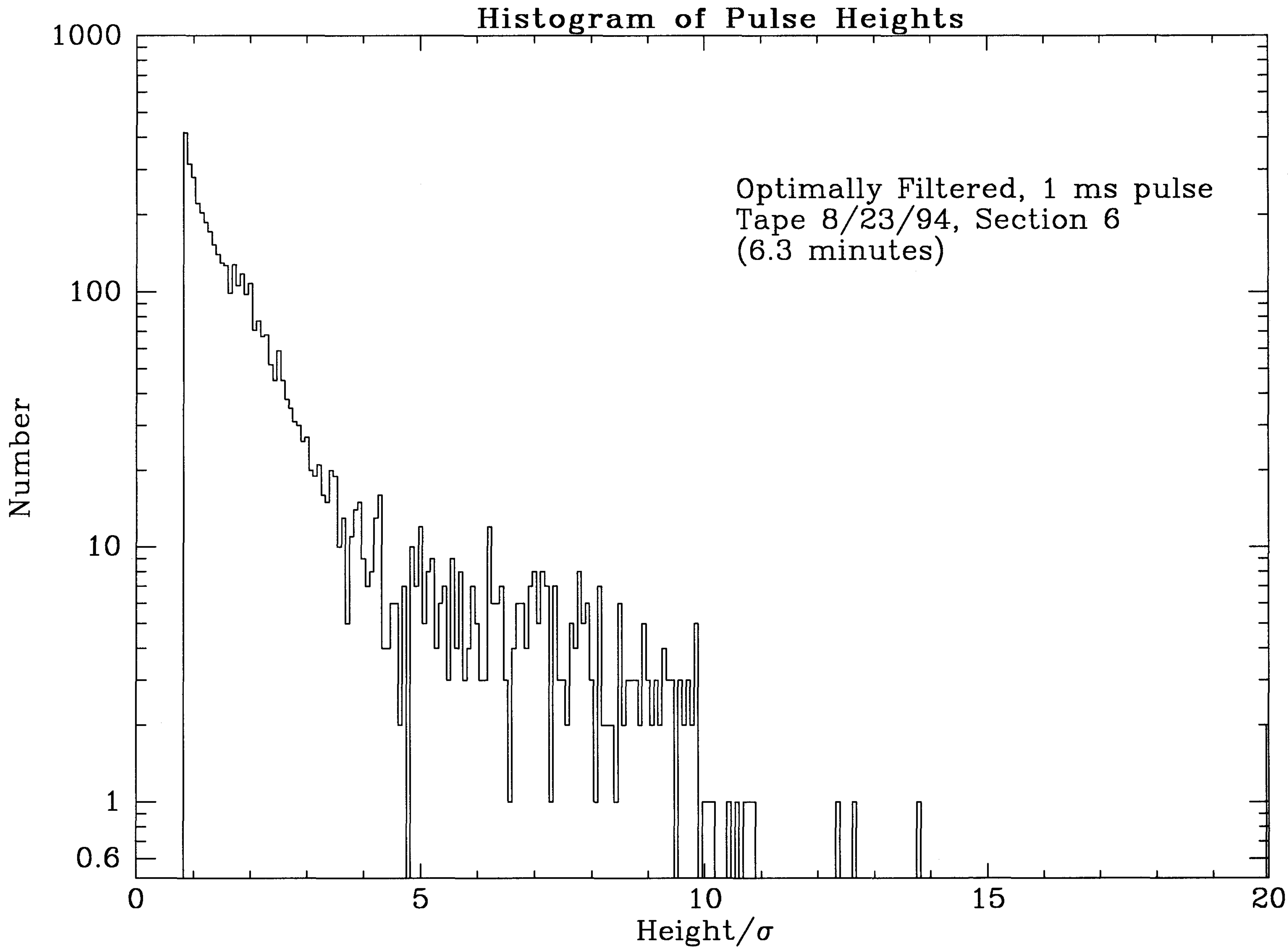


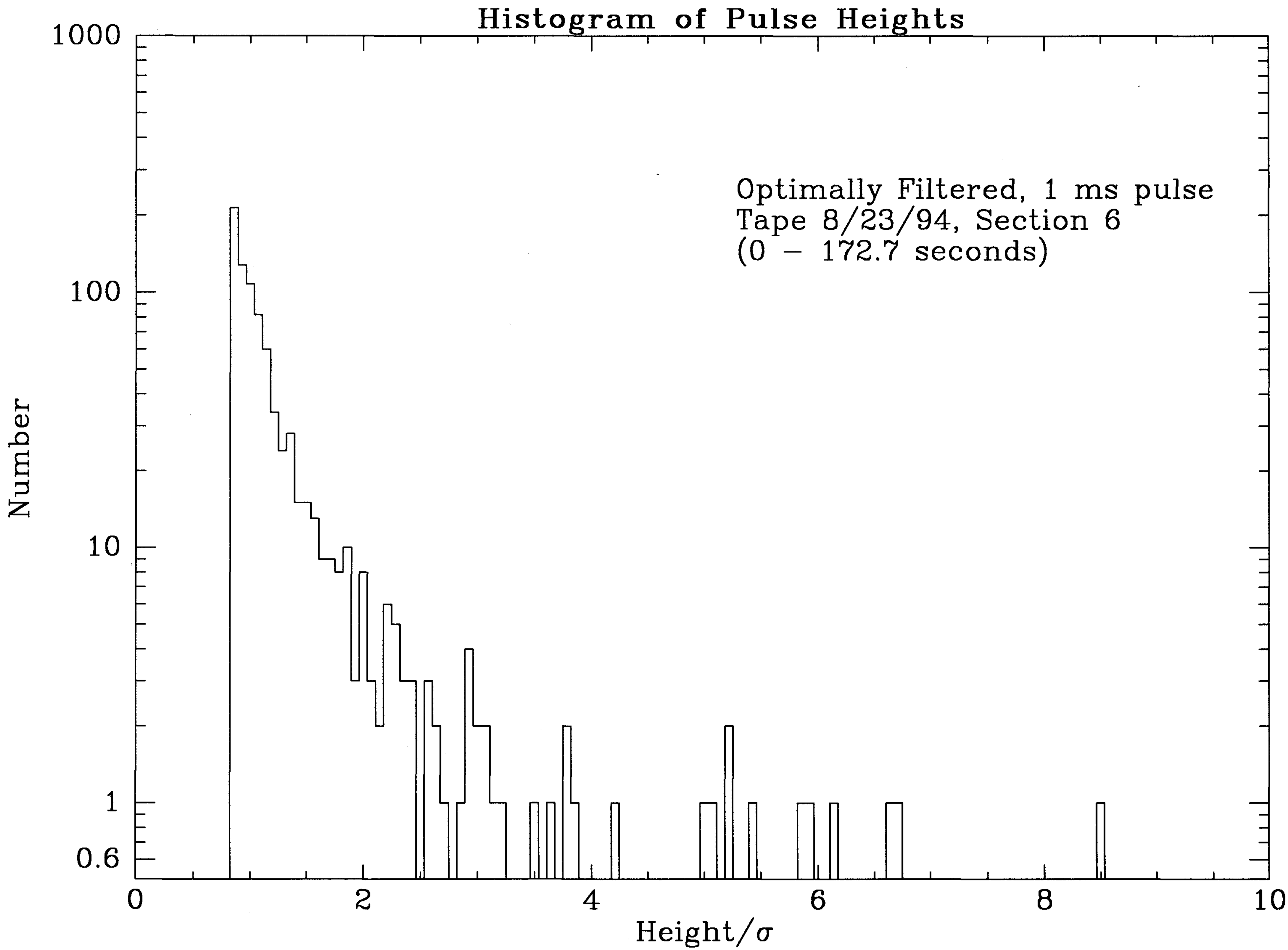
TTL, 8/24/94


Histogram of Pulse Heights
Tape 8/23/94, Section 6
(6.3 minutes)
Number
1000
100
10
1
0.6
0
20
40
60
Height/σ



40m Data Peak and RMS
(10 second average)
8/23/94, Section 6
Volts
peak
rms
6
4
2
0
0.11
0.1
0.09
0.08
0
50
100
150
200
250
Time, secs


Histogram of Pulse Heights
Optimally Filtered, 1 ms pulse
Tape 8/23/94, Section 6
(6.3 minutes)
Number
1000
100
10
1
0.6
Height/σ
0
5
10
15
20


Histogram of Pulse Heights
Optimally Filtered, 1 ms pulse
Tape 8/23/94, Section 6
(0 – 172.7 seconds)
Number
Height/σ
1000
100
10
1
0.6
0
2
4
6
8
10

TTL, 8/24/94

Analysis of 8/23/94 Data — Section 6

I extracted the first of 4 artificial pulses from the pulse monitor.

clip c.l.bin -pr -ct 69.473625 -n 262144 -bin > sig.bin

Constructed optimal filter template following directions from 5/16/94. Run filter. Pulse search in filtered data.

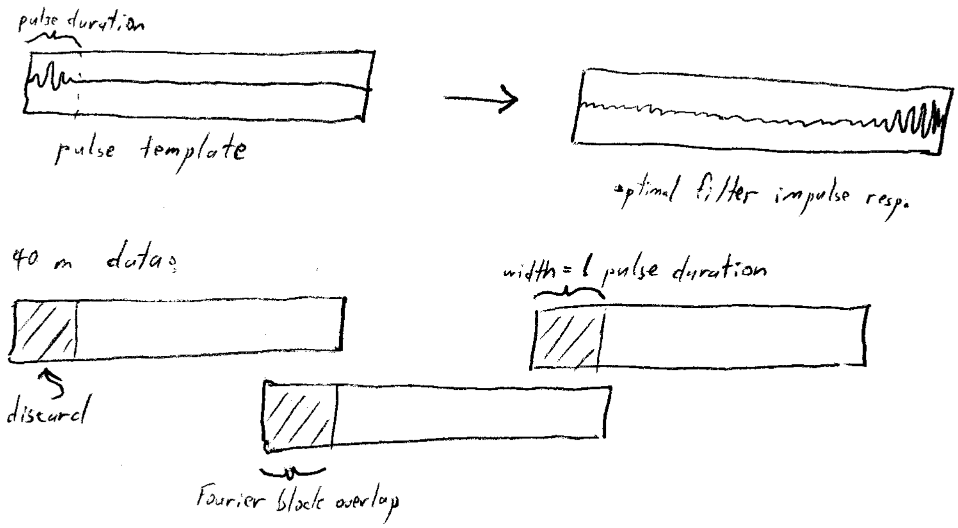
pulses time.flp -float -t 3 -d 1 -reset -pr

In trying to compare original and filtered data there is a delay in the filtered data. The 1/2 width of the template is 6.640981 seconds. From the data it appears the filtered data lags the original data by this time. A histogram of filtered pulse heights is shown. The large non-gaussian component is largely due to the very noisy section of data between 180 - 230 seconds. (See Peak/RMS plot.) Taking only data from 0 - 172.665515 seconds (This is the nearest 262144 point block boundary to 180 seconds) we get another histogram. There are still non-gaussian events. These seem to be due to edge effects when the edge of a 262144 point block is reached. I tried to Fourier tranform filter.flp back to the time domain (in binary ints) and do a correlation instead of Fourier filtering. Unfortunately 40,960 points took ≈ 19 hours on flogger to process.

TJL, 8/25/94

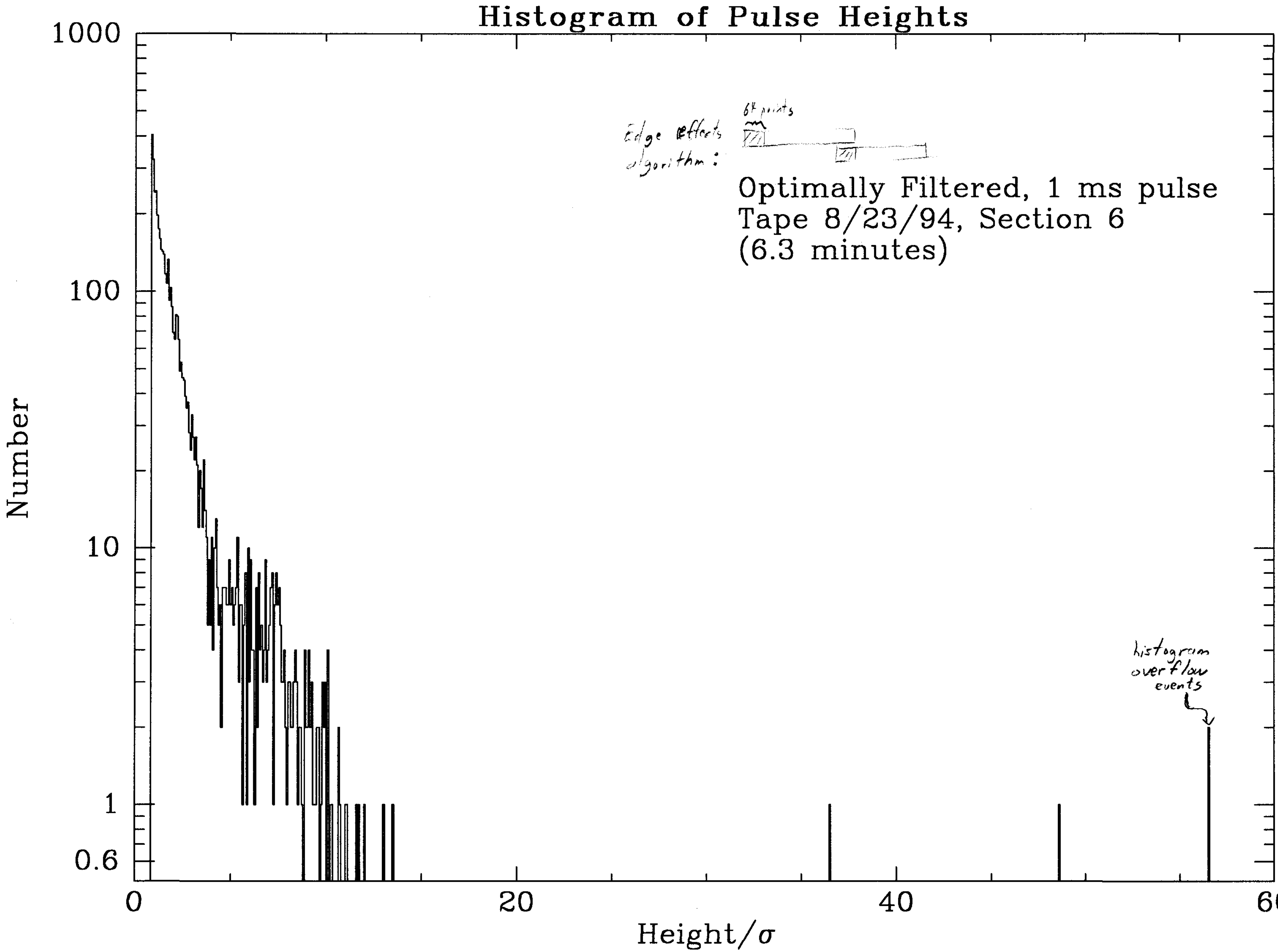
Aaron convinced me that I should discard data at the edges of Fourier transform blocks. The data discarded should be the same length as the signal we are looking for. My signal in 2^{nd} arm coil voltage is 2 ms long so I will discard 64 points. Unfortunately I have to use a different input pulse template with the pulse at the beginning of the

This looks like:



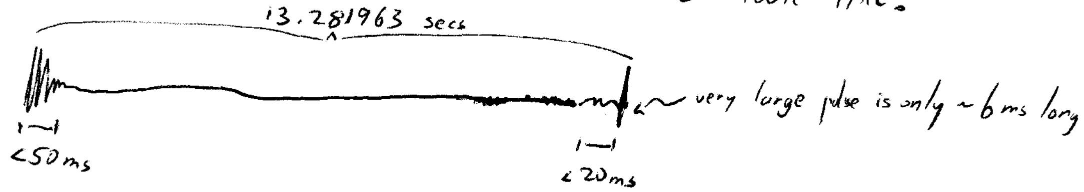
I realized that my pulse duration in 2^{nd} arm coil voltage is actually ≈ 6 ms long, (It is 2 ms long at the calibration coil.) thus I will overlap 128 points. Flogger took 18 minutes to filter 6.3 minutes of data in this way.

8/26/94, TL

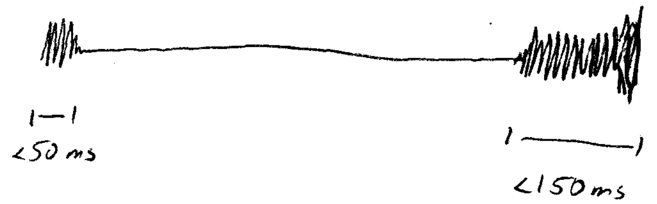

Histogram of Pulse Heights
Edge effects algorithm:
64 points
Optimally Filtered, 1 ms pulse
Tape 8/23/94, Section 6
(6.3 minutes)
histogram overflow events
Number
1000
100
10
1
0.6
0
20
40
60
Height/σ

8/27/99

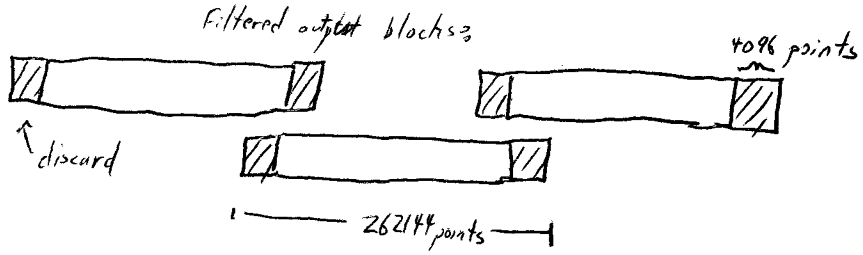
Unfortunately even after overlapping 128 points/block I still get significant non-gaussian noise due to edge effects. The impulse response of the filter seems to look like:



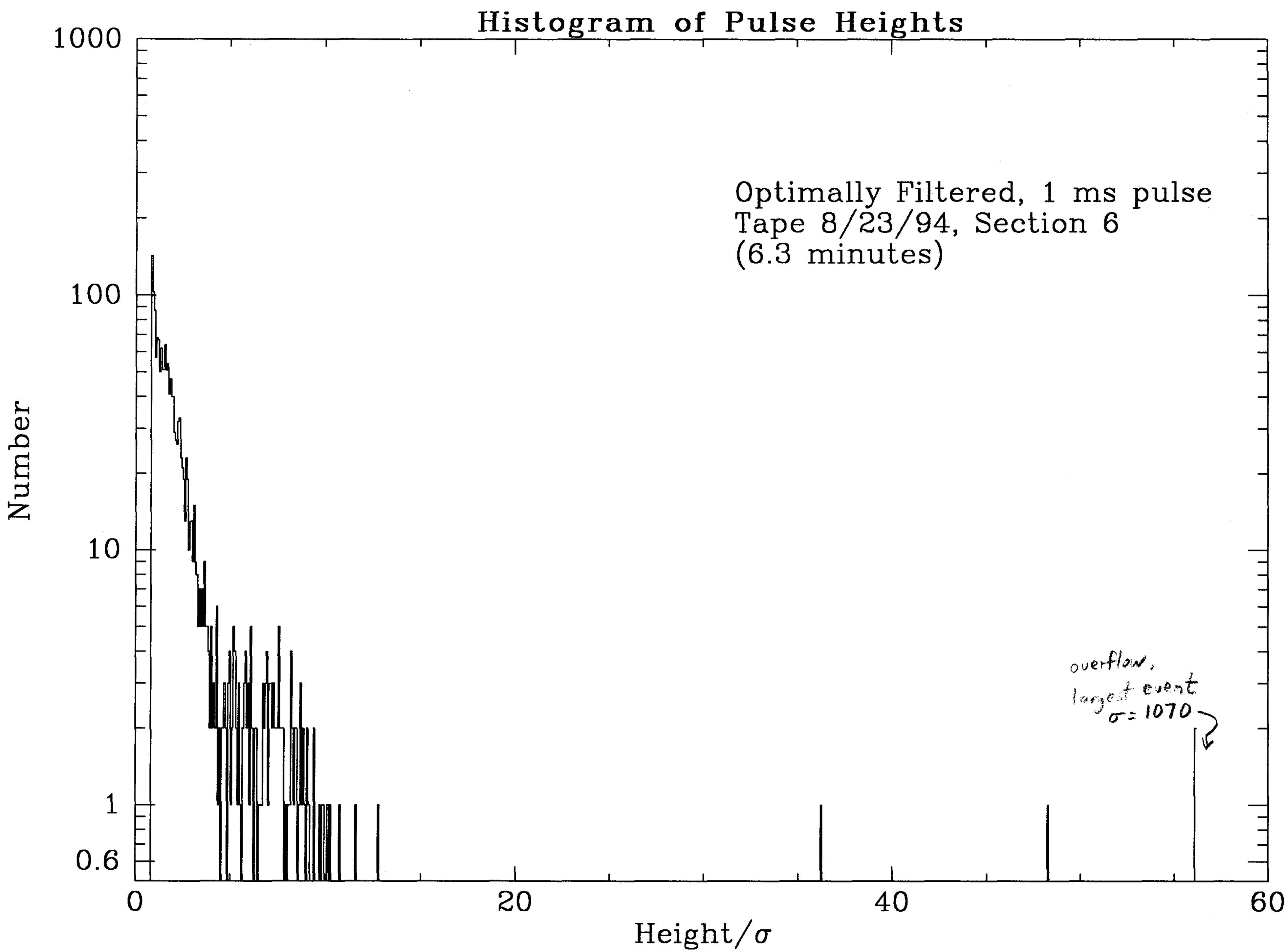
Typical block of filtered output data:



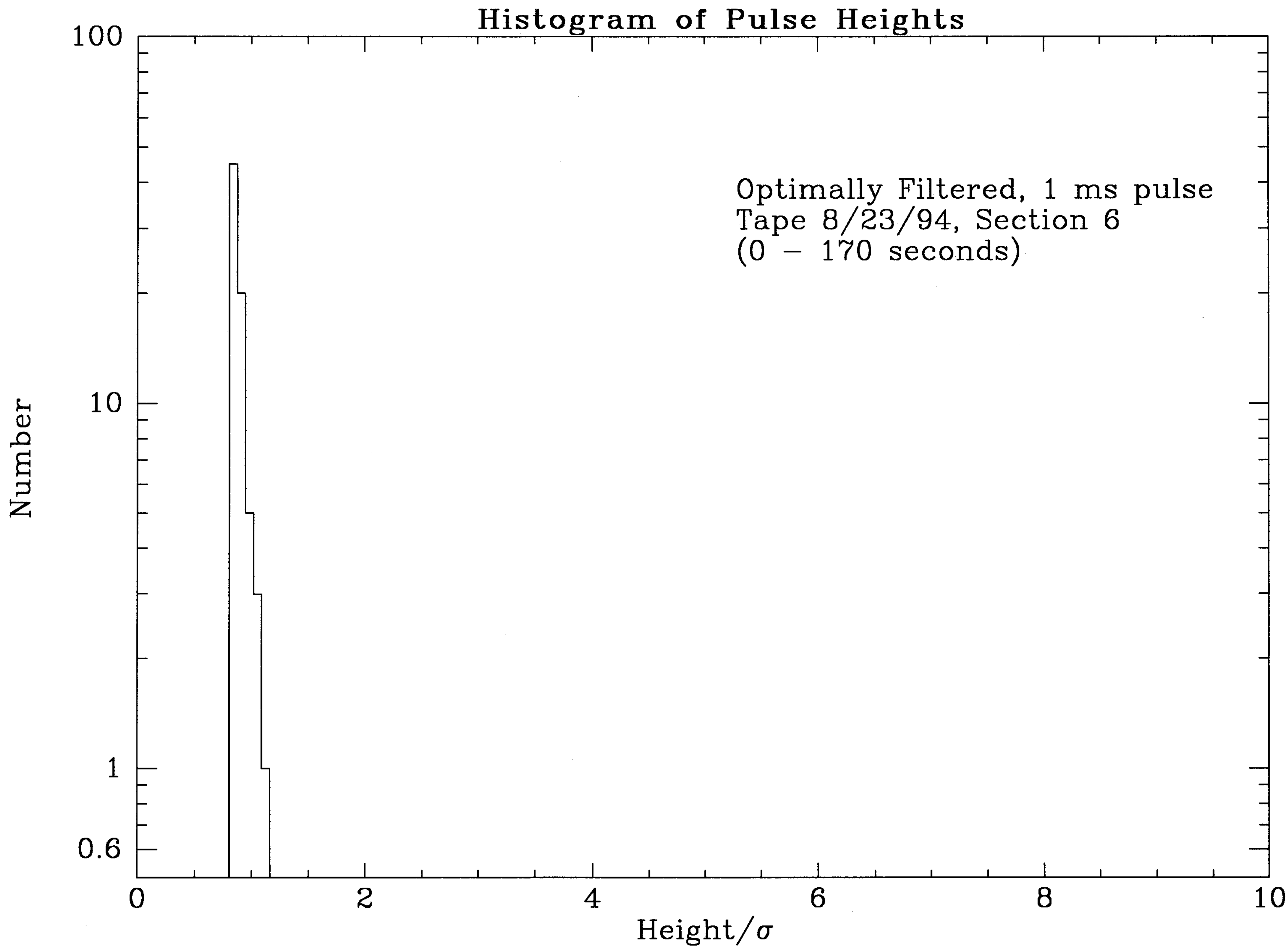
I don't understand why the filtered output looks this way. Nonetheless I will overlap a conservative 4096 points = 207.531ms at the beginning and end of Fourier blocks. They are overlapped like so:



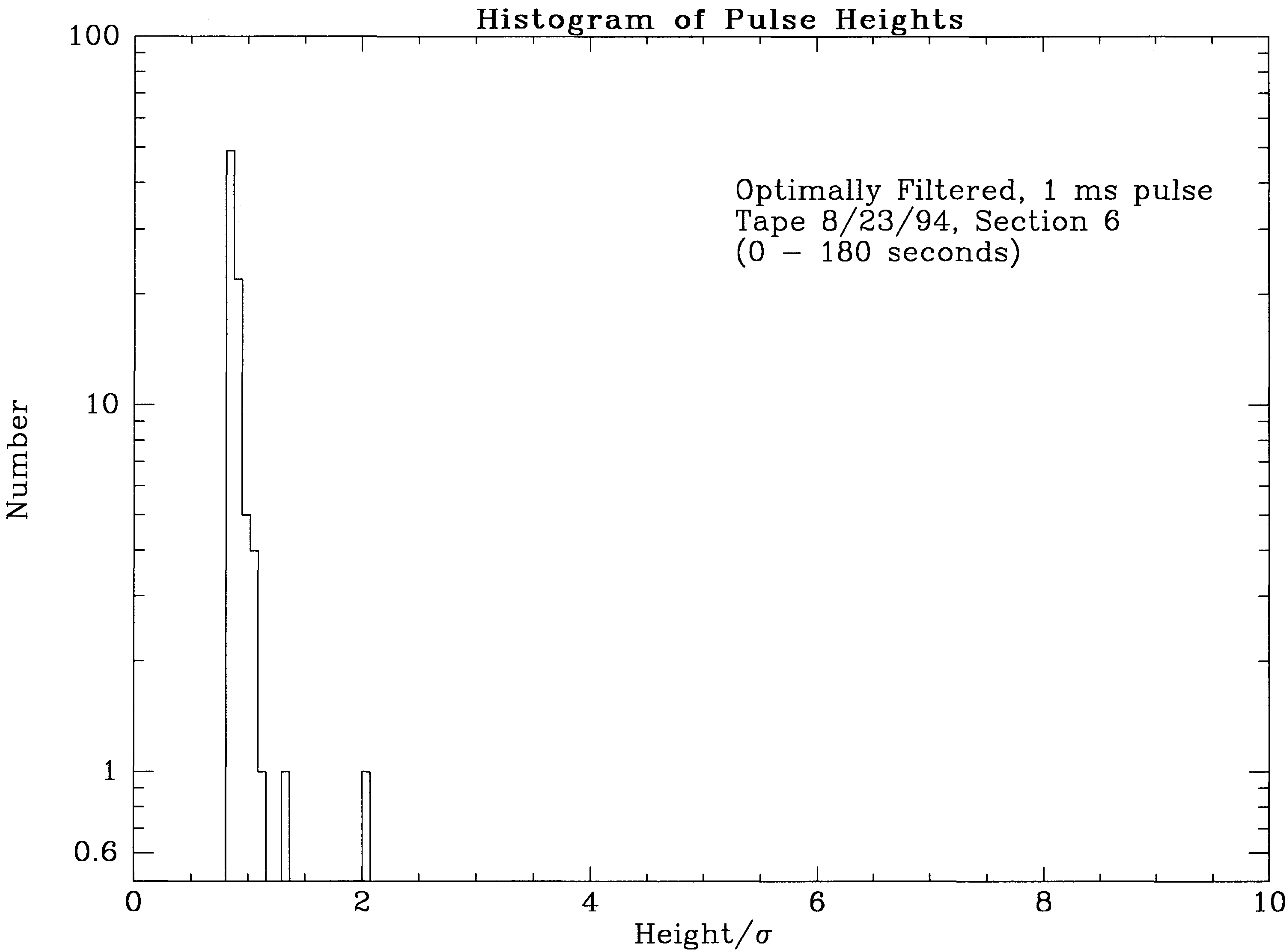
With this method I get no excess non-gaussian noise, particularly when I excise the noisy part from the record.


Histogram of Pulse Heights
Optimally Filtered, 1 ms pulse
Tape 8/23/94, Section 6
(6.3 minutes)
Number
1000
100
10
1
0.6
0
20
40
60
Height/σ
overflow,
largest event
σ = 1070

TR, 8/27/94


Histogram of Pulse Heights
Optimally Filtered, 1 ms pulse
Tape 8/23/94, Section 6
(0 – 170 seconds)
Number
Height/σ
100
10
1
0.6
0
2
4
6
8
10

TTL, 8/27/94


Histogram of Pulse Heights
Optimally Filtered, 1 ms pulse
Tape 8/23/94, Section 6
(0 – 180 seconds)
Number
100
10
1
0.6
0
2
4
6
8
10
Height/σ

9/1/94, TTL

As per Fred's suggestion I tried analyzing the data using just the signal from the coil as the filter. (Ie. $\tilde{S}^*$ instead of $\frac{\tilde{S}^*}{S_x}$.) This gave no apparent supurious pulses at the edge of the filtered output. (Or anywhere for that matter.)

9/4/94, TTL

Procedure for constructing SE coil waveform from EE

(Updates instructions given on 4/13/94.)

1. Get 1-10 kHz swept sine data file onto Suns.
2. Run "mx-asc-frt" on file and redirect output.
3. Copy processed swept sine output to "/tmp/torrey/trfnc.dat."
4. Run "art_V" on 262144 point long section containing SE coil waveform. Output is in coil.f/p.

Comments: There appears to be no reason to spline interpolate the swept sine first to 1024 points and set DC response to 0. The results are almost identical with this method.

Re-analyzing Tape 3/2/94, Section 2

Unfortunately I didn't read the tape correctly so I only got the first 70 minutes of this locked section. (This avoids the very noisey section towards the end.) Looking at the peak/rms plot we can see that it is still noisy at the beginning. Thus I do the power spectrum estimation after the first 200 seconds.

```
powspc chest -k 100 -m 131072 -V -Hann -bin > bigspc.flp
ftm bigspc.flp x bigspc.flp -float -bin -noint -pr > bigspc2.flp
```

9/7/94

Optimally filtering a few 13.3 secs sections of data I found similiar edge effects to those observed previously. Strangely, however, very large pulses were seen at regular 5 second intervals. These were roughly 5σ events. This is probably what provided so many excess 5-10σ pulses in previous analysis of this locked section. Could this be due to digitization noise? In fact the blocks of data written to the tape are 5.066667 secs long. This is almost certainly the cause of the extra pulses, but how the tape switching causes noise and what type eludes me.

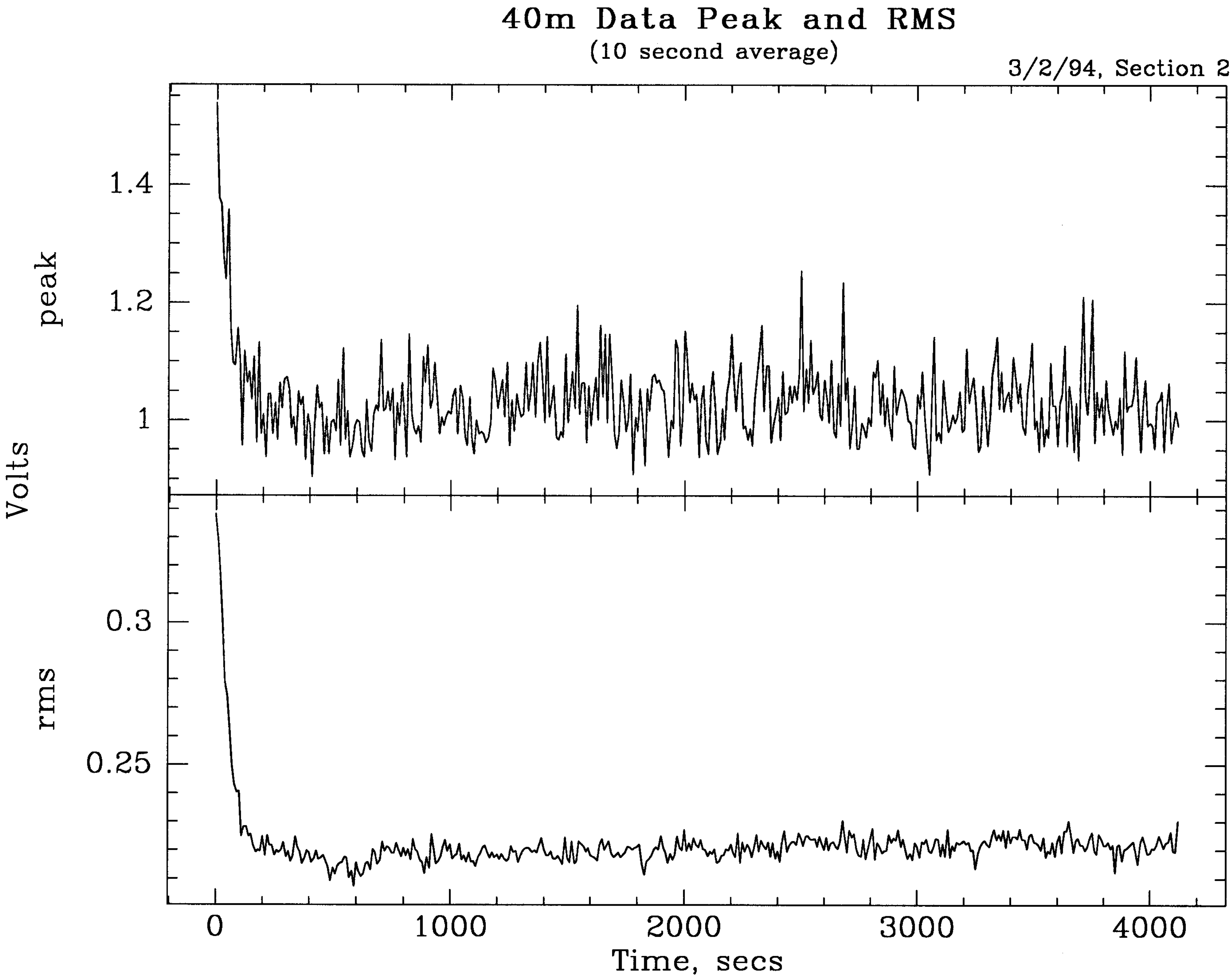
BATCH START

40 m Data Peak & RMS

STAPLE

OR

DIVIDER


40m Data Peak and RMS
(10 second average)
3/2/94, Section 2
Volts
peak
rms
1.4
1.2
1
0.3
0.25
0
1000
2000
3000
4000
Time, secs

TTL, 10/20/94

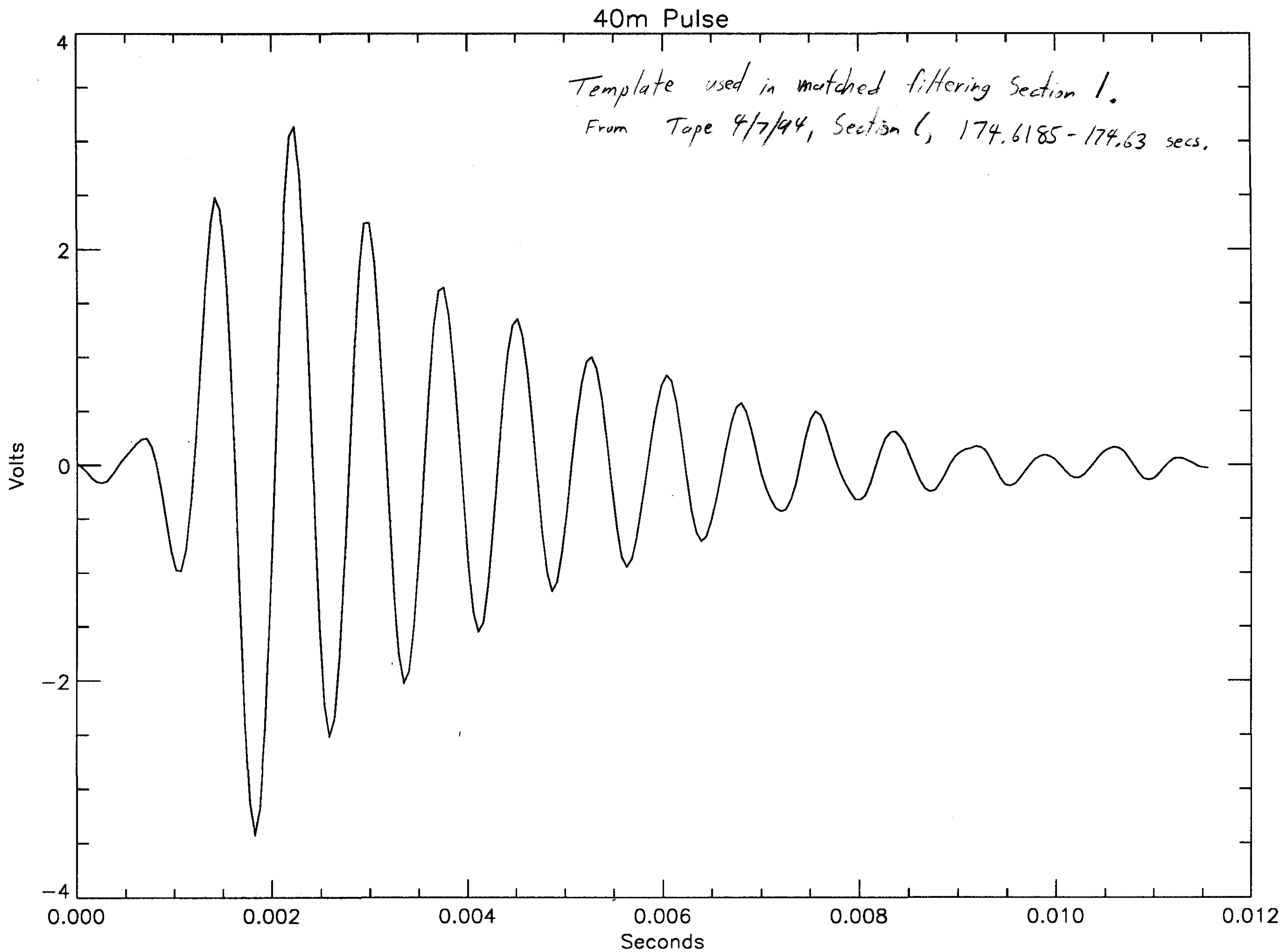
Fred wants me to reproduce the plot of the pulse height histogram for matched filtering of Tape 4/7/94, Section 1. This plot was done originally on 5/17/94. I followed the following procedure:

1. Loaded first 400 seconds of Tape 4/7/94 & analyzed.
2. Got first 0.003 seconds of sig.bin from ~/glitch/results/23aug94.
   This is the pulse template.
3. "correlate chanØ sig.bin -pr -bin > match.flp"
4. "mean -float match.flp"
   Output gives: $\sigma = 82641.44022 \rightarrow \frac{1}{\sigma} = 1.210047 \times 10^{-5}$
   peak = 3675590.0
5. "ftm match.flp -x 1.210047e-5 -float -bin -pr > matchn.flp
6. "pulses matchn.flp -float -pr -t 3 -d 1 -reset"
7. "cut -f2 -s pulses.out | grep -v Height > pulØ.dat"
8. "binner pulØ.dat -l 0 -h 50 -n 250 -abs"
9. Results plotted with histpul.sm.

Oopps! I realized that sig.bin is template of voltage applied to calibration coil. I need to convert. Instead I will clip a piece out of the real data. I do:

1. Clip from chanØ 174.6185 – 174.630 secs. Plot follows.
2. "correlate chanØ coil.bin -pr -bin > mch.flp"

TTL, 10/20/94


40m Pulse
Template used in matched filtering Section 1.
From Tape 4/7/94, Section 1, 174.6185 - 174.63 secs.
Volts
Seconds
4
2
0
−2
−4
0.000
0.002
0.004
0.006
0.008
0.010
0.012

Now, $\sigma = 218020.890625 \rightarrow \frac{1}{\sigma} = 4.586716425 \times 10^{-6}$

peak = 9216201

Results were plotted and included in Stan's R&D Plan. The results we were trying to duplicate looked much more like the wrong version using the calibration coil voltage as the template. I suspect I made the same mistake before. Unfortunately with the right template the impressed pulses appear at slightly lower S/N.

11/1/94, TTL

Tape Switching Noise? (see 9/4/94)

I took a dummy data run with the Channel 0 input terminated in 50Ω at the panel next to the Concurrent. The same number of channels, data rate, etc. were used. The data shows no evidence of pulses. The largest events were 5 counts with an average of 2.6 counts and $\sigma = 0.6$ counts. The 5 count events seemed to occur at random times. If tape switching is causing noise it is not in the A-D. It could be inductive pickup in the long cable to the A-D or noise on the line. Approximately 100 seconds of data were taken.

Tape Writing Speeds

Aaron and I tried writing in various channel configurations to select one for our data runs.

Channels:	Result:
4@10ks, 0@1ks	OK
4@10ks, 6@1ks	"
4@10ks, 8@1ks	memory error before starting
4@10ks, 12@1ks	OK
5@10ks, 6@1ks	OK
" , 8@1ks	memory error
" , 10@1ks	" "
" , 11@1ks	failure after start
6@10ks, 0@1ks	OK
6@10ks, 10@1ks	failure
3@10ks, 8@1ks	OK
3@10ks, 10@1ks	memory error
3@10ks, 13@1ks	OK

We will probably use 4@10ks with 12@1ks.

Data Run "L"

This data run we will take data with:
4 channels @ 10 ksamples/s
12 channels @ 1 ksamples/s

Data Channels

0 2^{nd} arm coil driver output → 2 pole 100 Hz HP in Pomona box
→ SRS 560, A coupling: AC, BP: 100-300 Hz, 6dB/oct.,
low noise, x1000, <150 mA output
→ Ithaco 4213, BP $1.25 \times 10^2 - 1.25 \times 10^3$, normal mode
→ EG&G Parc, A input coupling: AC, BP: 100-10 kHz, x20
→ A-D

1, 2, 3 Nothing

4 TTL Arm 1 & 2 in lock (arm 2 set incorrectly so meaningless)
5 Laser Slow PZT $\frac{1}{100}$ Mon.
6. Arm 1 visibility mon: Meter Mon. Output (-5V to +5V = 0% to 100%)
7 Arm 2 visibility mon: " "
8, 9, etc. Nothing
15 50Ω terminator

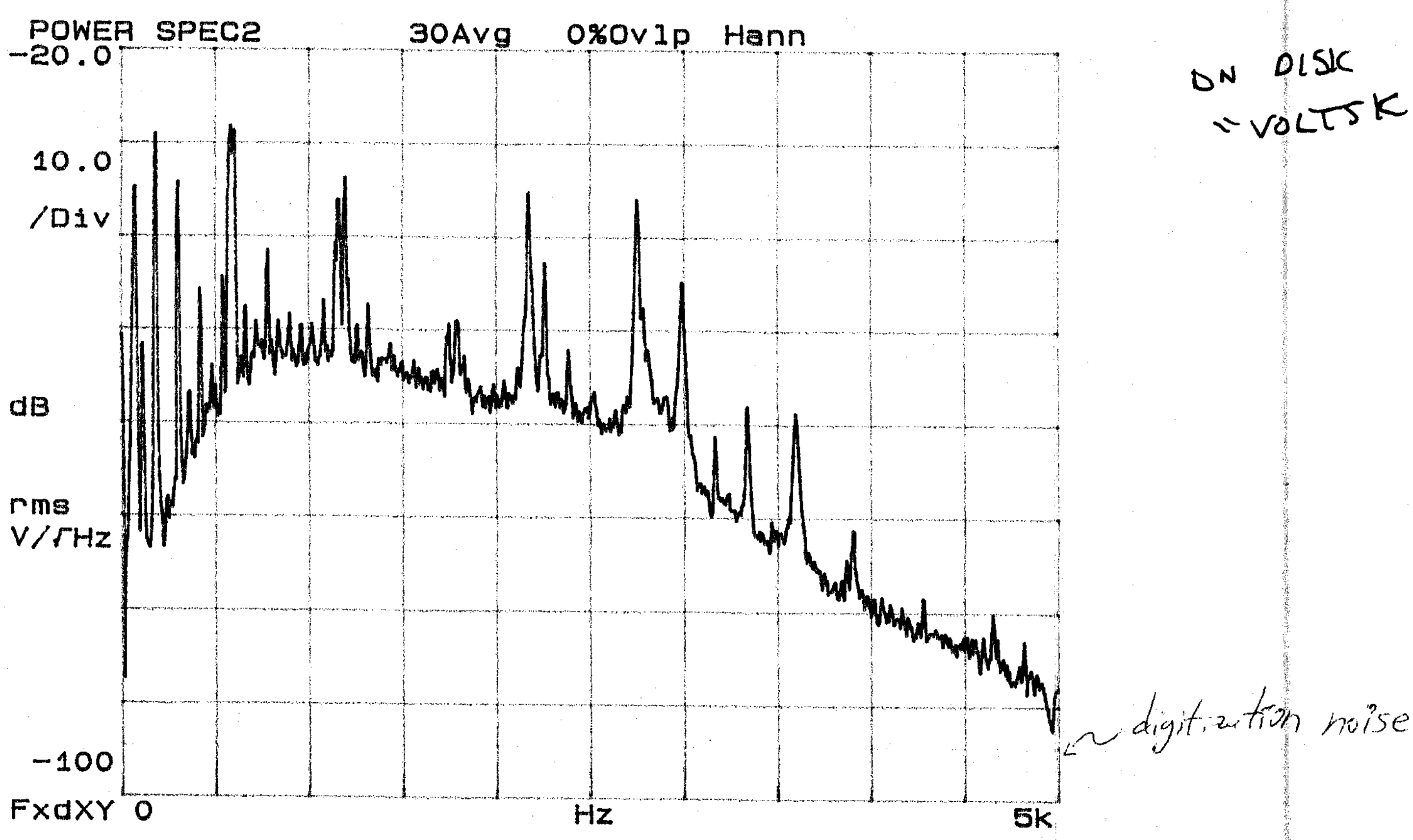
Saved on disk 35.04:
VOLT5k 5 kHz span power spectrum of noise in rms V/√Hz
VOLT1k 1 kHz " "
SS5k 5 kHz span swept sine freq. resp.
SS1K 1 kHz " "
NouZe 5 kHz span calibrated noise spectrum

Started @ 7:20 pm. Out of lock 7:29 pm. In lock 7:35 pm.

11/2/94
TBrrayt
Aaro
18:45

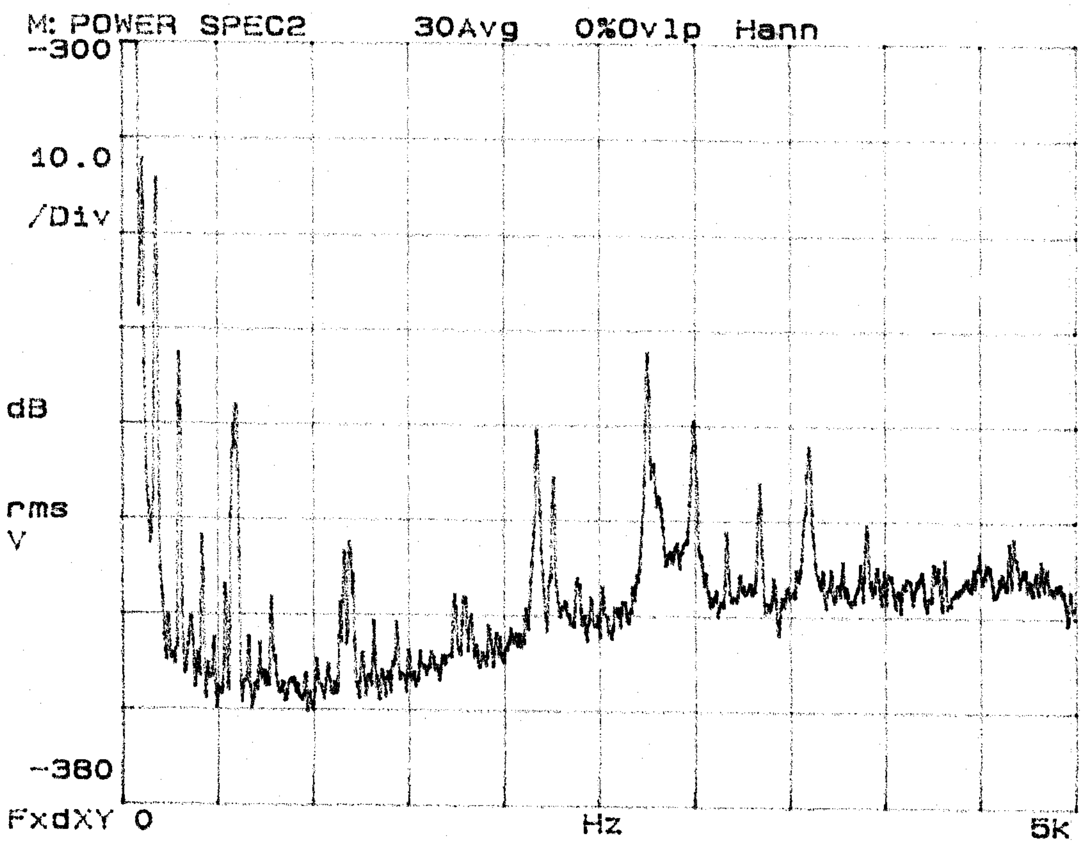
Raw Voltage output

ON DISK
"VOLTSK"



11/2/94 TTC, AG
7:12 pm

Calibrated Displacement Spectrum



On disk "Nov2c"

3/15/95, TTL

Locking Statistics of 11/14/95 - 11/20/95 Data Run

Read tape 19NOV1. On channel 10 (TTL In Lock) I found in lock was 5-6 counts, out of lock was 1037 - 1041 counts and tape dead time was 0 counts.

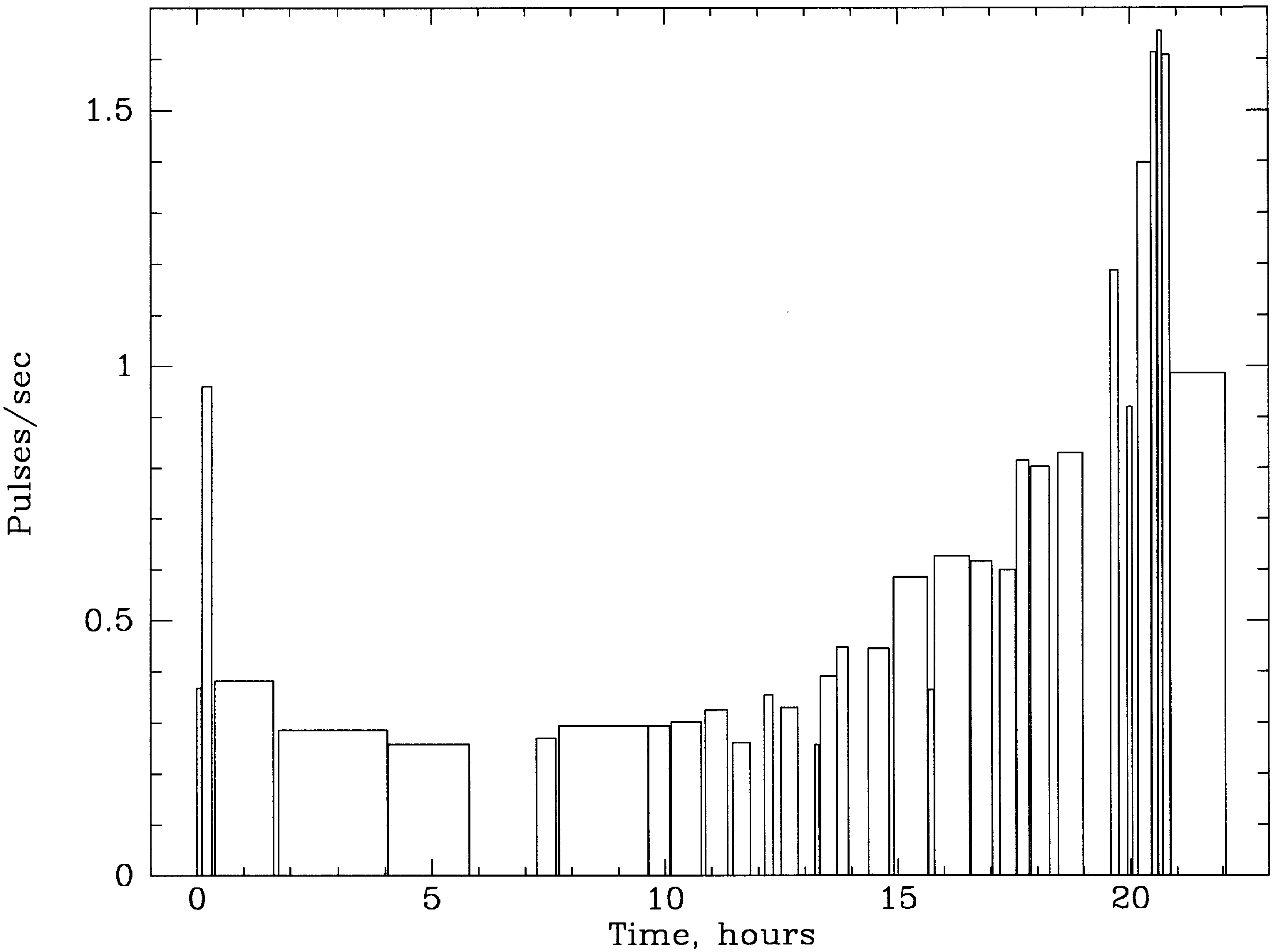
BATCH START

Pulse Rates

STAPLE
OR
DIVIDER

TTL, 1/11/92

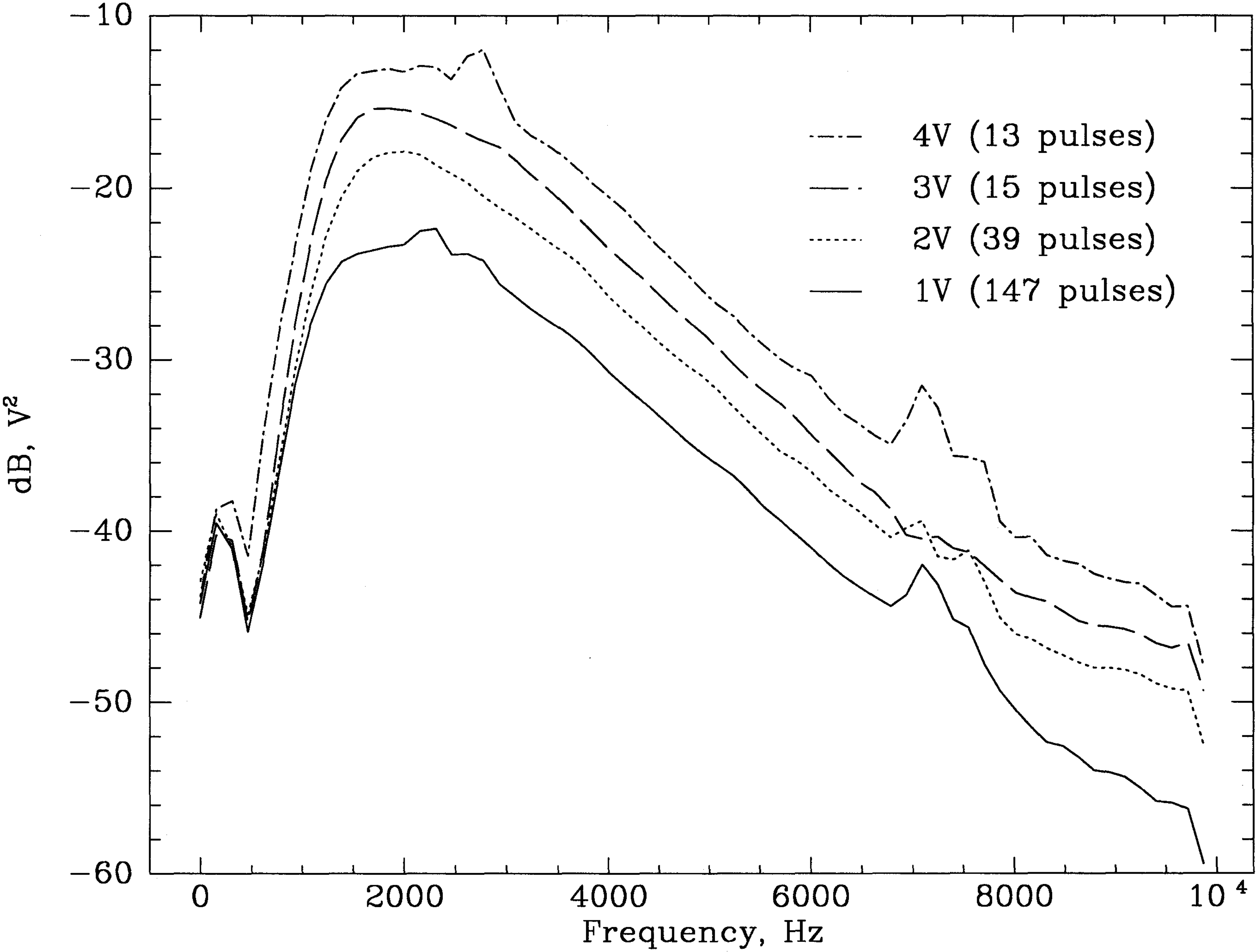
Pulse Rates for 8/24–25/92 Data Run



TTL, 1/28/93

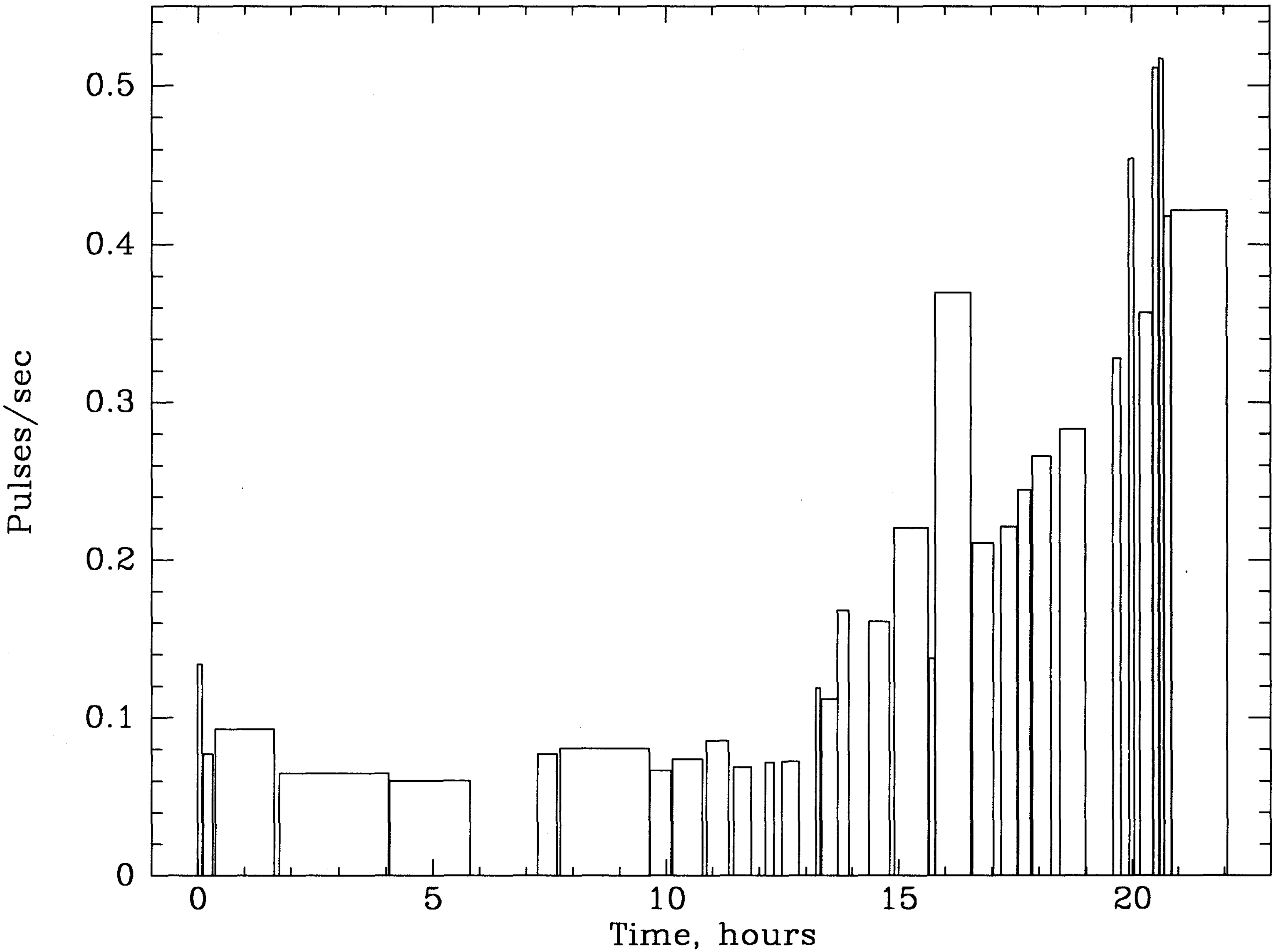
Pulse Power Spectra, Tape 2, Section 14

(Uncalibrated)



TTL, 1/11/92

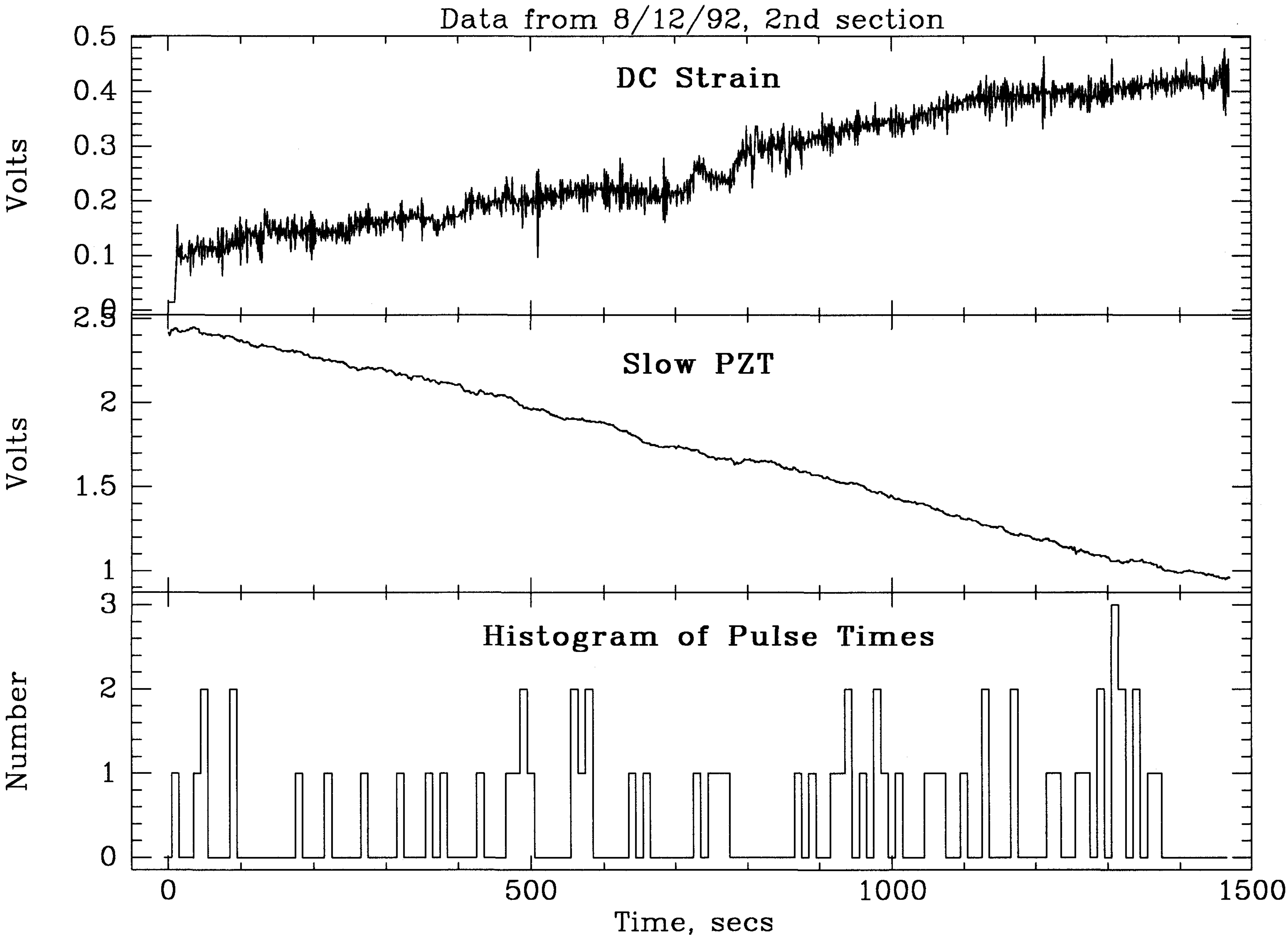
2.0 V Pulse Rates for 8/24–25/92 Data Run



Data from 8/12/92

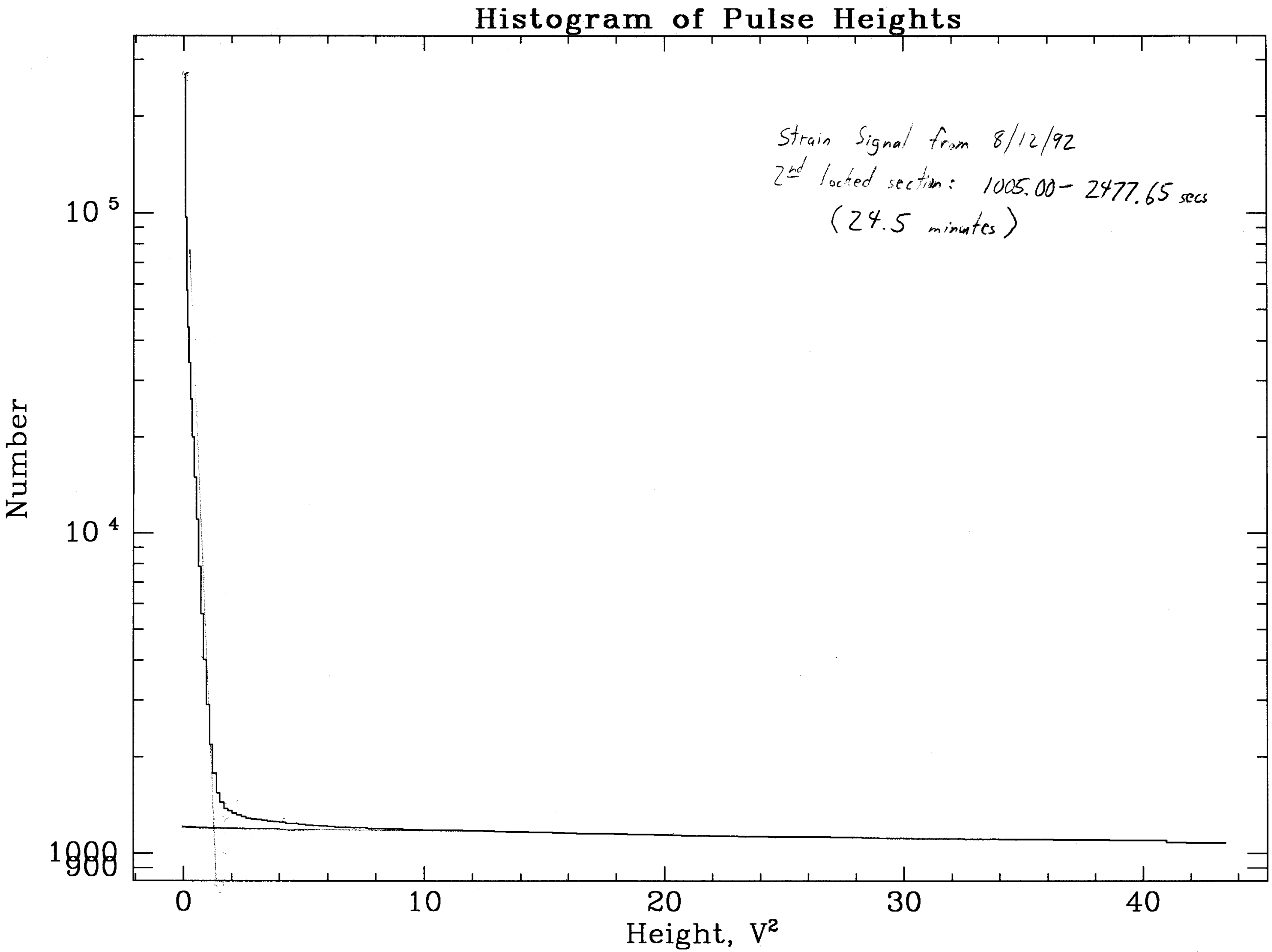
Analysis of 40m Interferometer data by program LOCKED, ver. 1.0.
Data rate = 1973.699951 samples/sec. Locked range = -44 , -24.

Time, sec	Stop, sec	Start, count	Stop, count	
0.000000	943.478760	0	1862144	
1004.995239	2477.650146	1983559	4890138	1472.654907
2546.954590	2614.294922	5026924	5159834	
2634.808838	3546.638428	5200322	7000000	

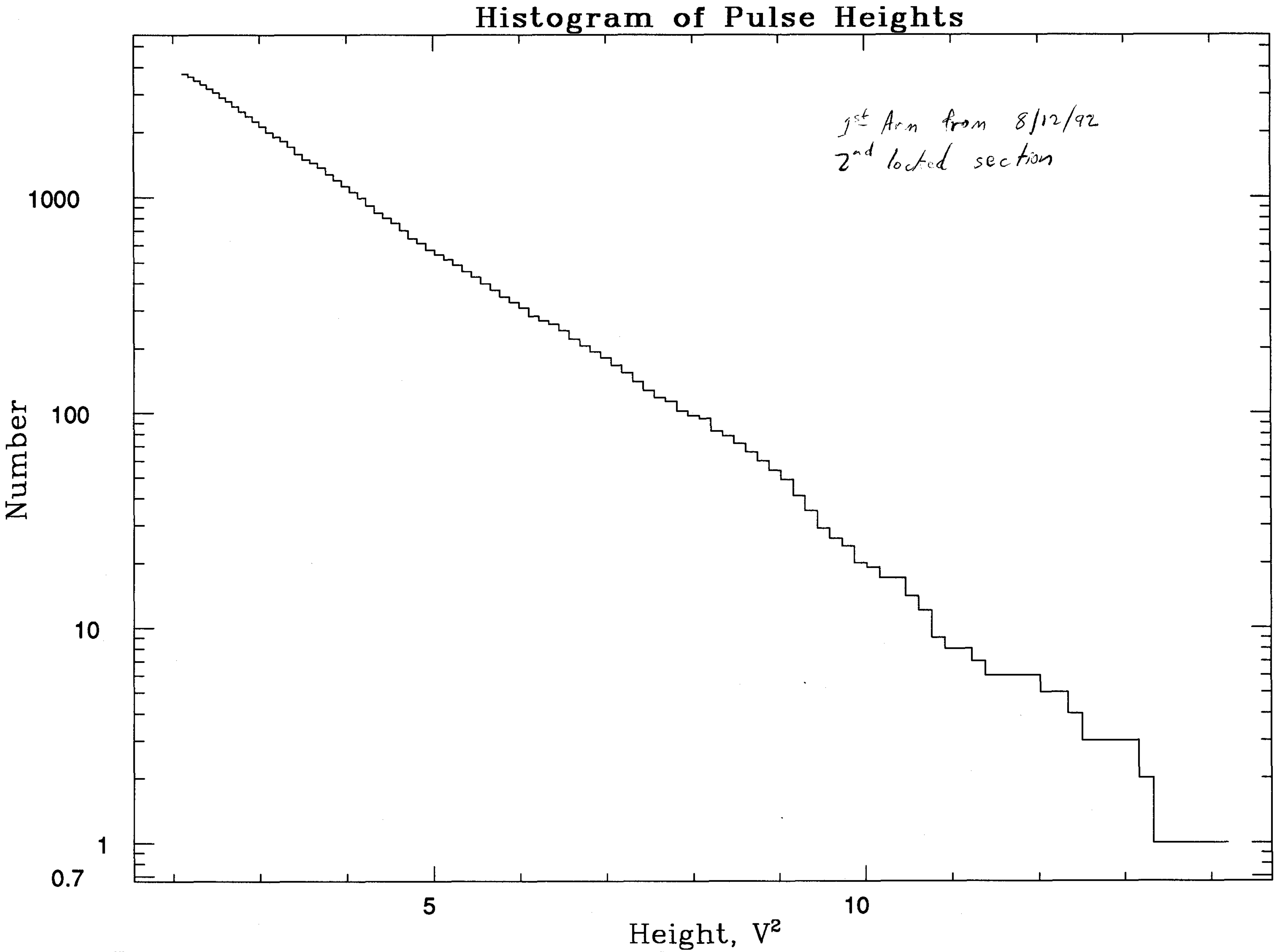


Data from 8/12/92, 2nd section
DC Strain
Slow PZT
Histogram of Pulse Times
Volts
Volts
Number
0.5
0.4
0.3
0.2
0.1
0
2.5
2
1.5
1
3
2
1
0
0
500
1000
1500
Time, secs

8/20/92 TTL



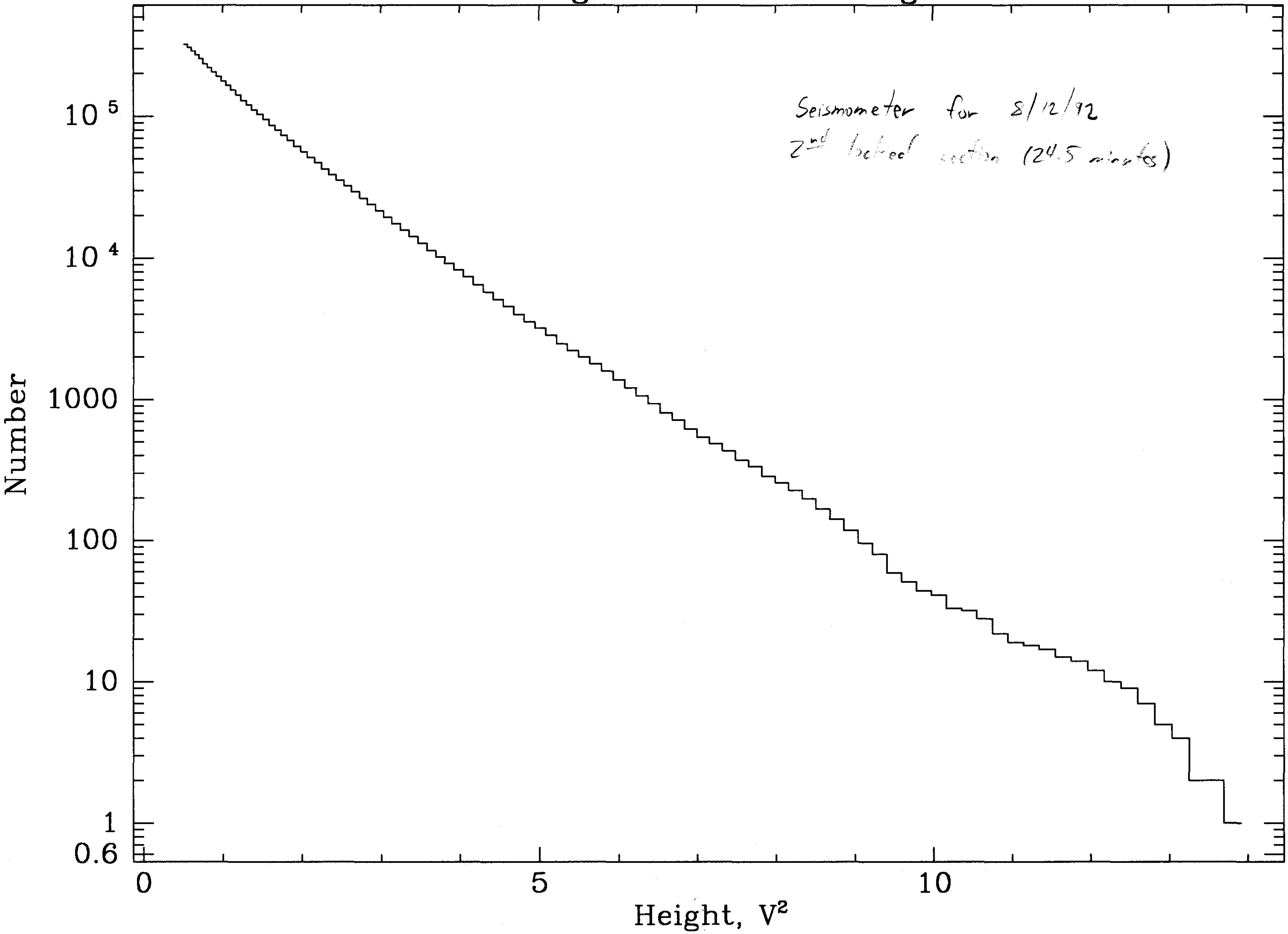
Histogram of Pulse Heights
Strain Signal from 8/12/92
2nd locked section: 1005.00 – 2477.65 secs
(24.5 minutes)
Number
10 5
10 4
1000
900
0
10
20
30
40
Height, V²



Histogram of Pulse Heights
1st Arm from 8/12/92
2nd locked section
1000
100
10
1
0.7
Number
5
10
Height, V²

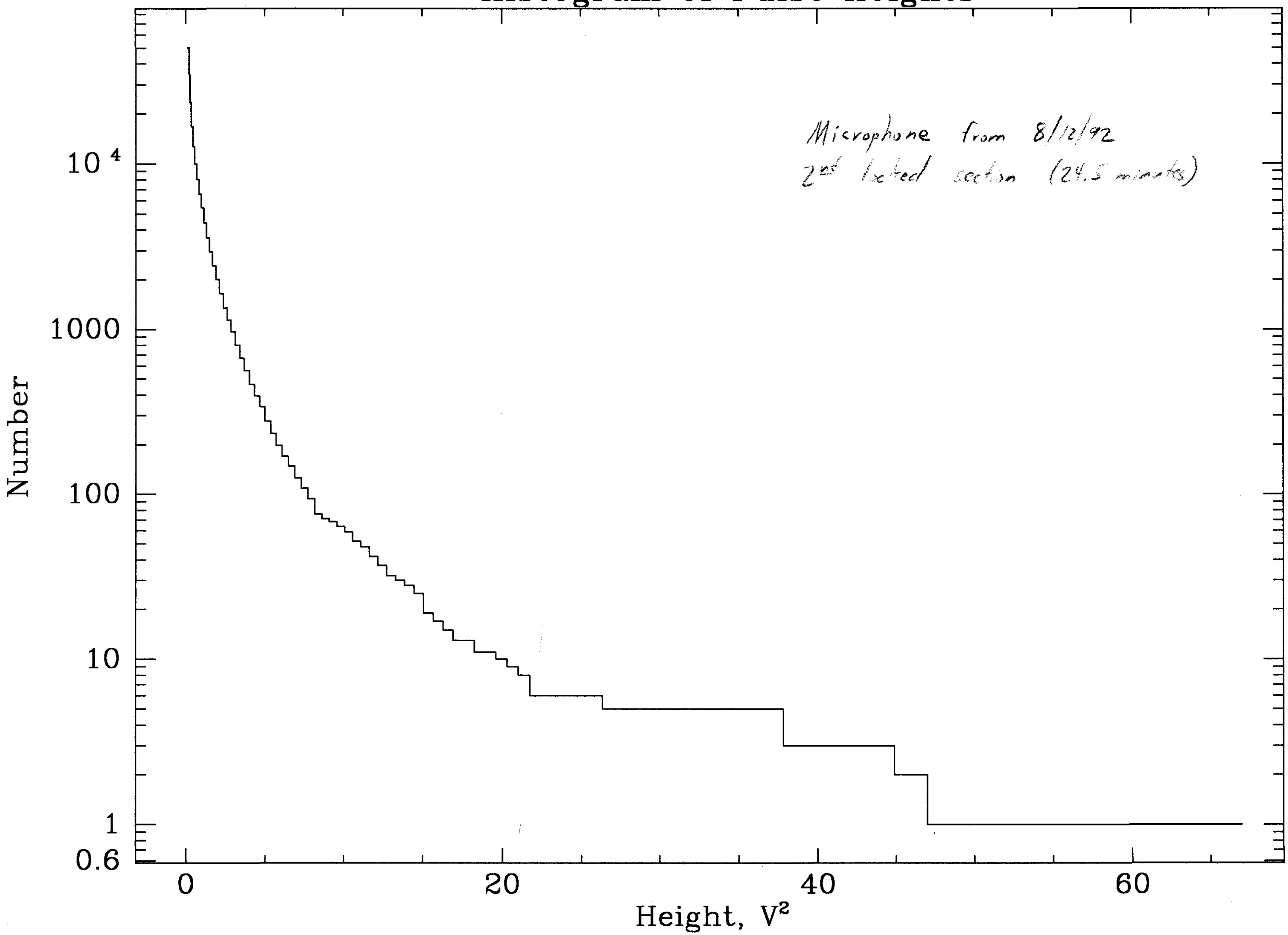
8/20/92 TTL

Histogram of Pulse Heights

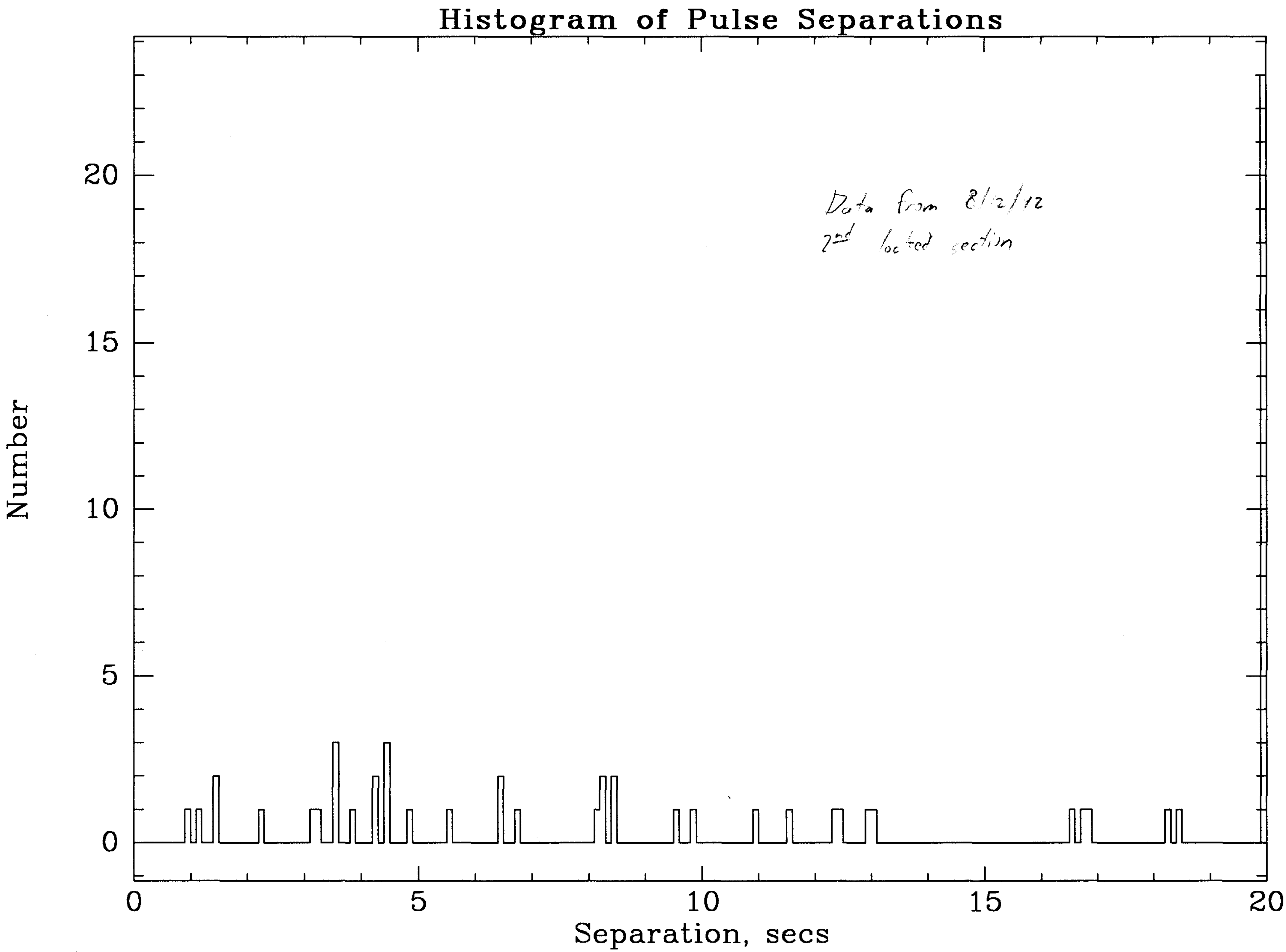


8/20/92 TTC

Histogram of Pulse Heights



9/8/92 TTL


Histogram of Pulse Separations
Number
0
5
10
15
20
Separation, secs
Data from 8/2/92
2nd locked section

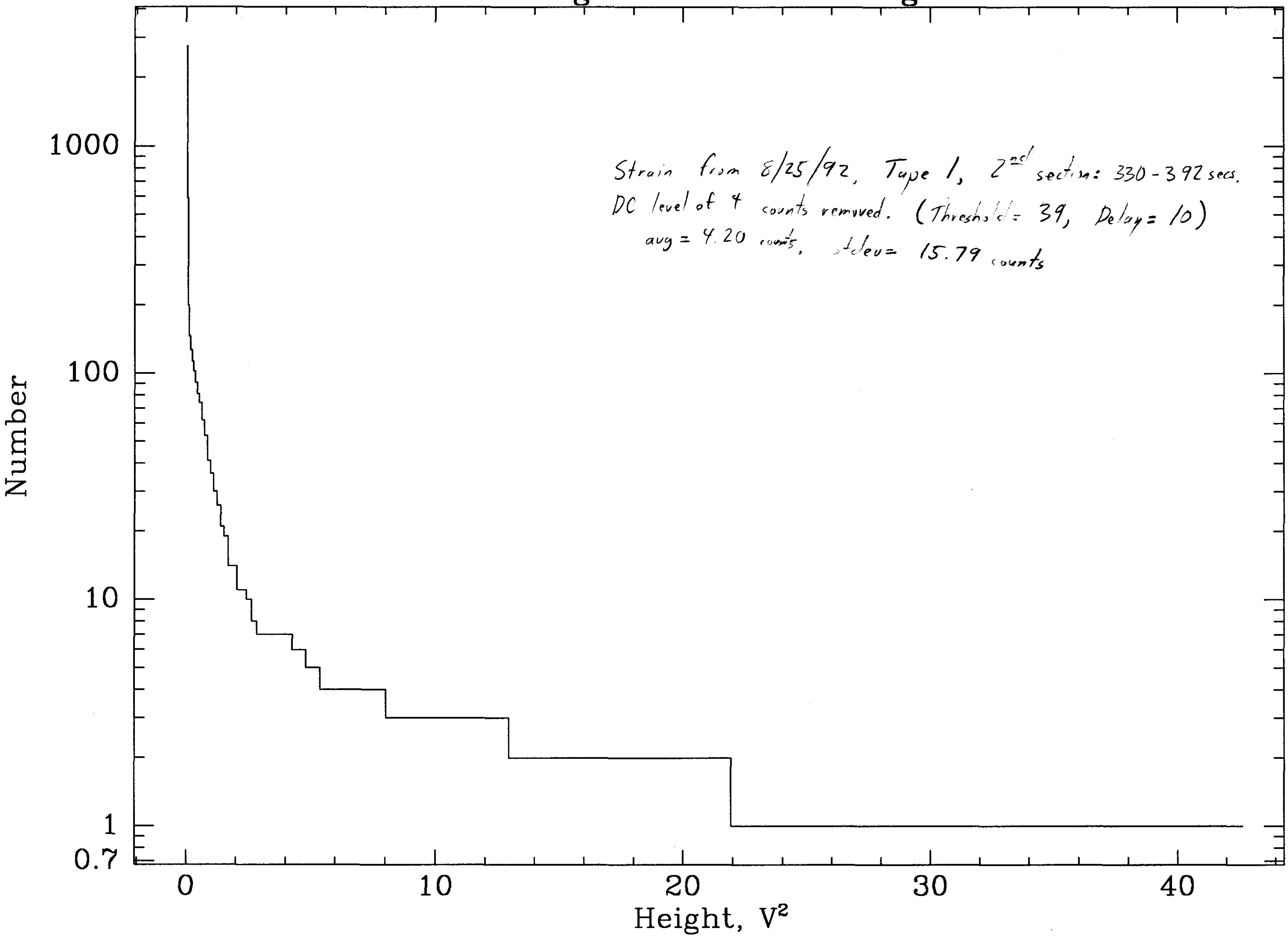
Data from 8/24/92, Tape 1

Analysis of 40m Interferometer data by program LOCKED, ver. 1.3
Data rate = 1973.684204 samples/sec.
Locked range = -45 , -24 (primary) -60 , -34 (secondary).

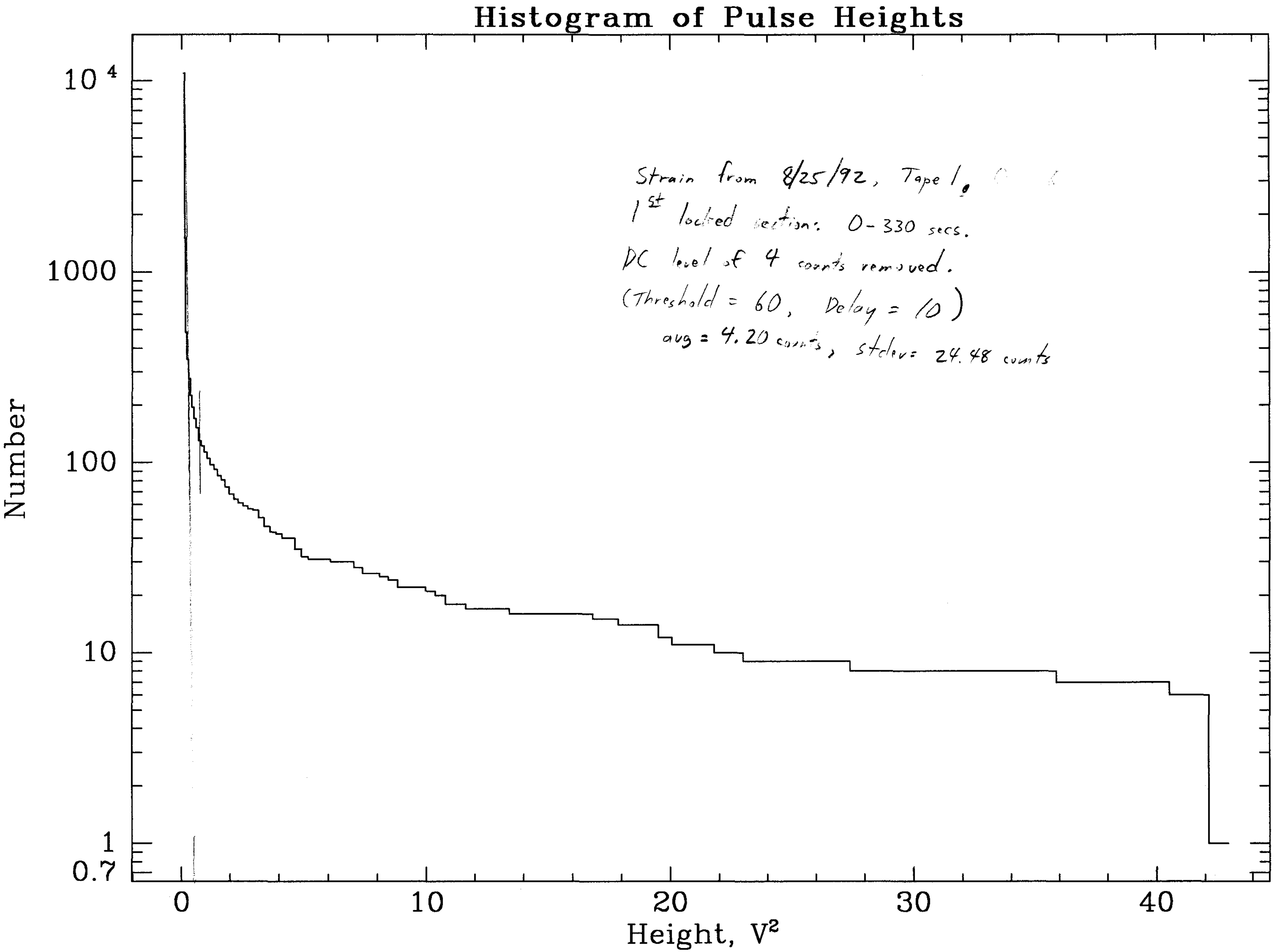
Start, sec	Stop, sec	Start, pos	Stop, pos	Duration, sec	
0.000000	329.822784	0	650966	329.822784	1
329.845581	391.908691	651011	773504	62.063110	2
391.935547	427.512177	773557	843774	35.576630	3
432.474457	1155.360596	853568	2280317	722.886139	4
1372.964355	5923.450684	2709798	11691021	4550.486328	5
5944.506348	6100.024414	11732578	12039522	155.518066	6
6203.212891	6286.549805	12243183	12407664	83.336914	7
6300.503418	14593.189299	12435204	28802347	8292.685882	8
14662.840666	20874.192158	28939816	41199062	6211.351499	9

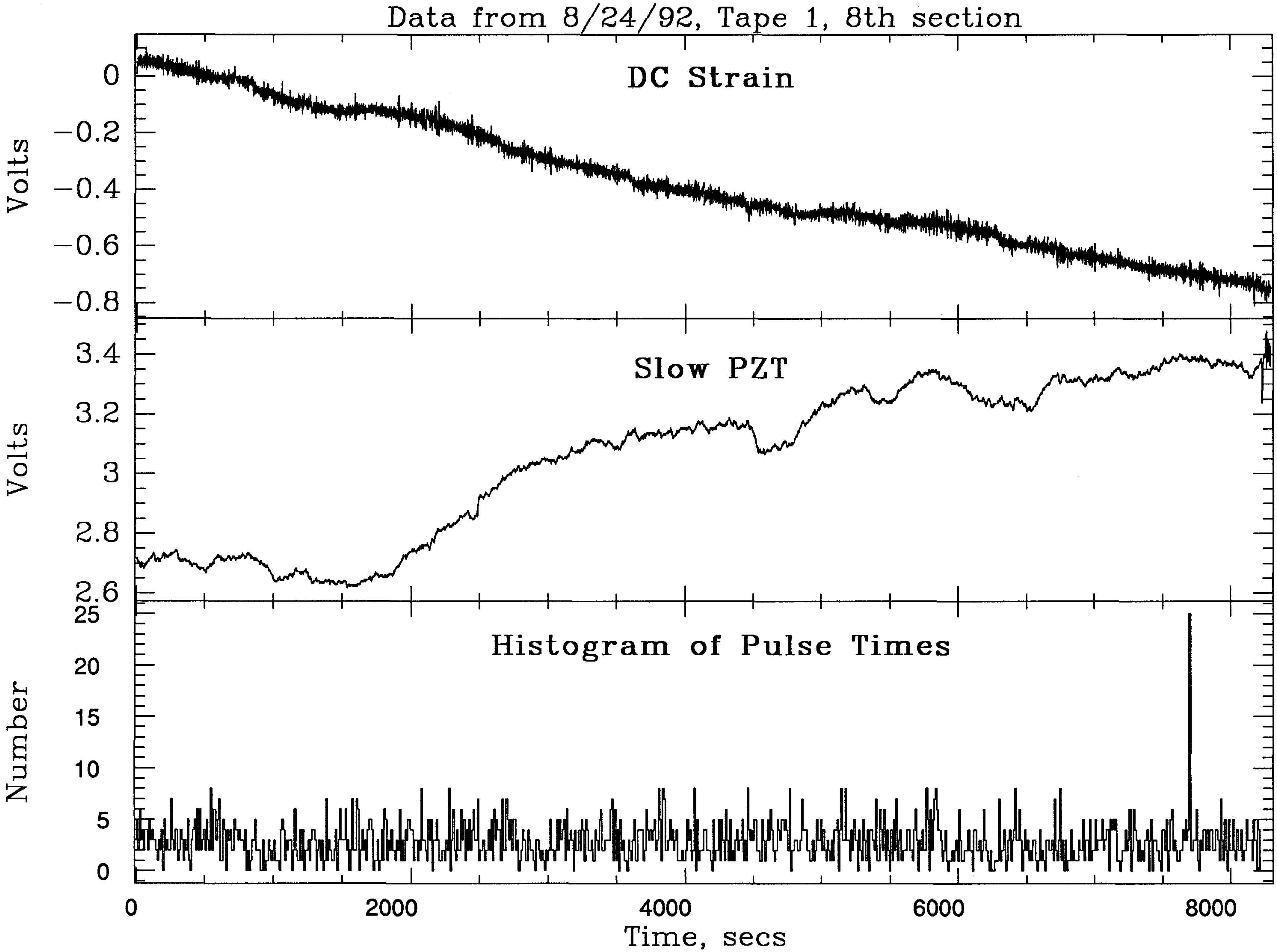
TTL, 11/2/92

Histogram of Pulse Heights

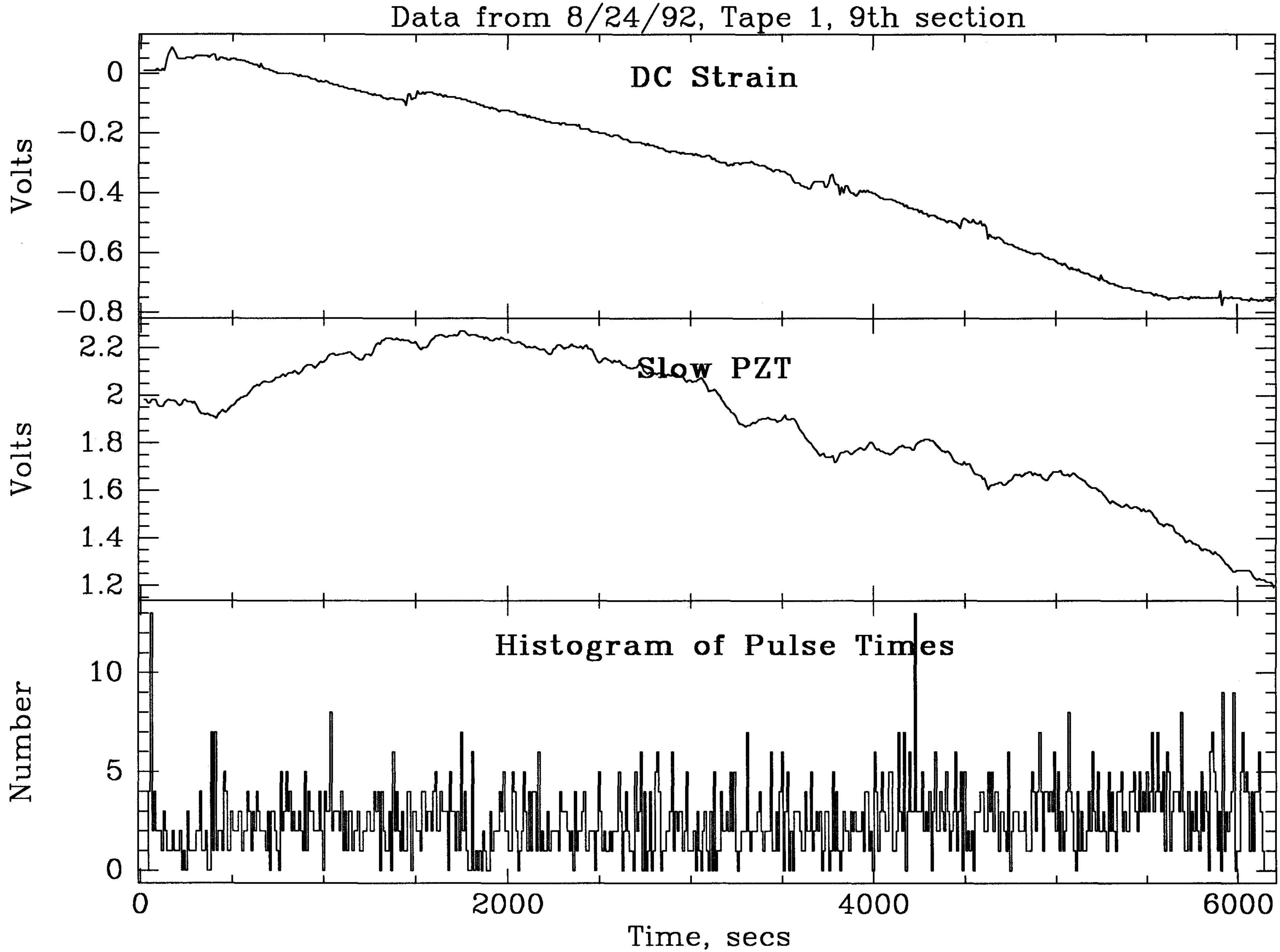


TTL, 10/30/92


Histogram of Pulse Heights
Number
Height, V²
10 4
1000
100
10
1
0.7
0
10
20
30
40
Strain from 8/25/92, Tape 1,
1st locked section: 0-330 secs.
DC level of 4 counts removed.
(Threshold = 60, Delay = 10)
avg = 4.20 counts, stdev= 24.48 counts



Data from 8/24/92, Tape 1, 8th section
DC Strain
Volts
0
−0.2
−0.4
−0.6
−0.8
Slow PZT
Volts
3.4
3.2
3
2.8
2.6
Histogram of Pulse Times
Number
25
20
15
10
5
0
0
2000
4000
6000
8000
Time, secs


Data from 8/24/92, Tape 1, 9th section
DC Strain
Volts
0
−0.2
−0.4
−0.6
−0.8
Slow PZT
Volts
2.2
2
1.8
1.6
1.4
1.2
Histogram of Pulse Times
Number
10
5
0
0
2000
4000
6000
Time, secs

Data from 8/25/92, Tape 2

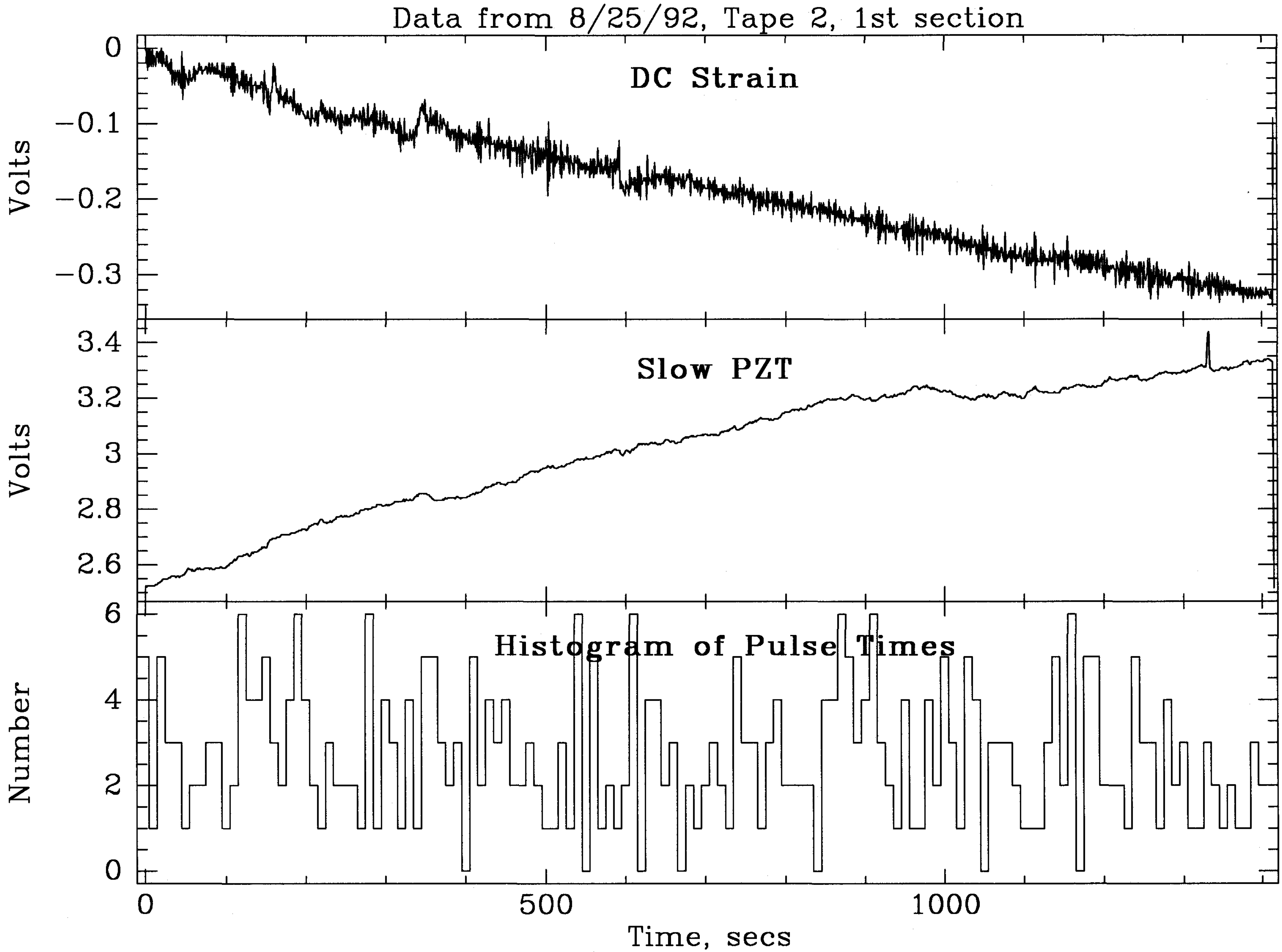
Analysis of 40m Interferometer data by program LOCKED, ver. 1.3
Data rate = 1973.684204 samples/sec.
Locked range = -45 , -24 (primary)   -60 , -34 (secondary).

	Start, sec	Stop, sec	Start, pos	Stop, pos	Duration, sec
1	0.000000	1475.867798	0	2912897	1475.867798
2	1578.068115	1647.003662	3114608	3250665	68.935547
3	1719.692017	8607.356068	3394129	16988203	6887.664051
4	8659.190541	10291.318359	17090508	20311813	1632.127808
5	10408.197266	12718.231445	20542496	25101773	2310.033691
6	13059.246094	14756.470703	25774829	29124613	1697.223633
7	15157.324219	16483.910156	29915771	32534034	1326.586426
8	16563.539062	16603.814453	32691198	32770688	40.274902
9	16603.841797	16720.062500	32770742	33000125	116.220703
10	16960.957031	17177.720703	33475576	33903400	216.764160
11	17369.037109	17460.126953	34281000	34460782	91.089539
12	17587.660156	18260.781250	34712493	36041021	673.120789
13	18487.814453	18666.976562	36489112	36842721	179.161865
14	18848.628906	20168.521484	37201244	39806298	1319.894043

= Analyzed section.

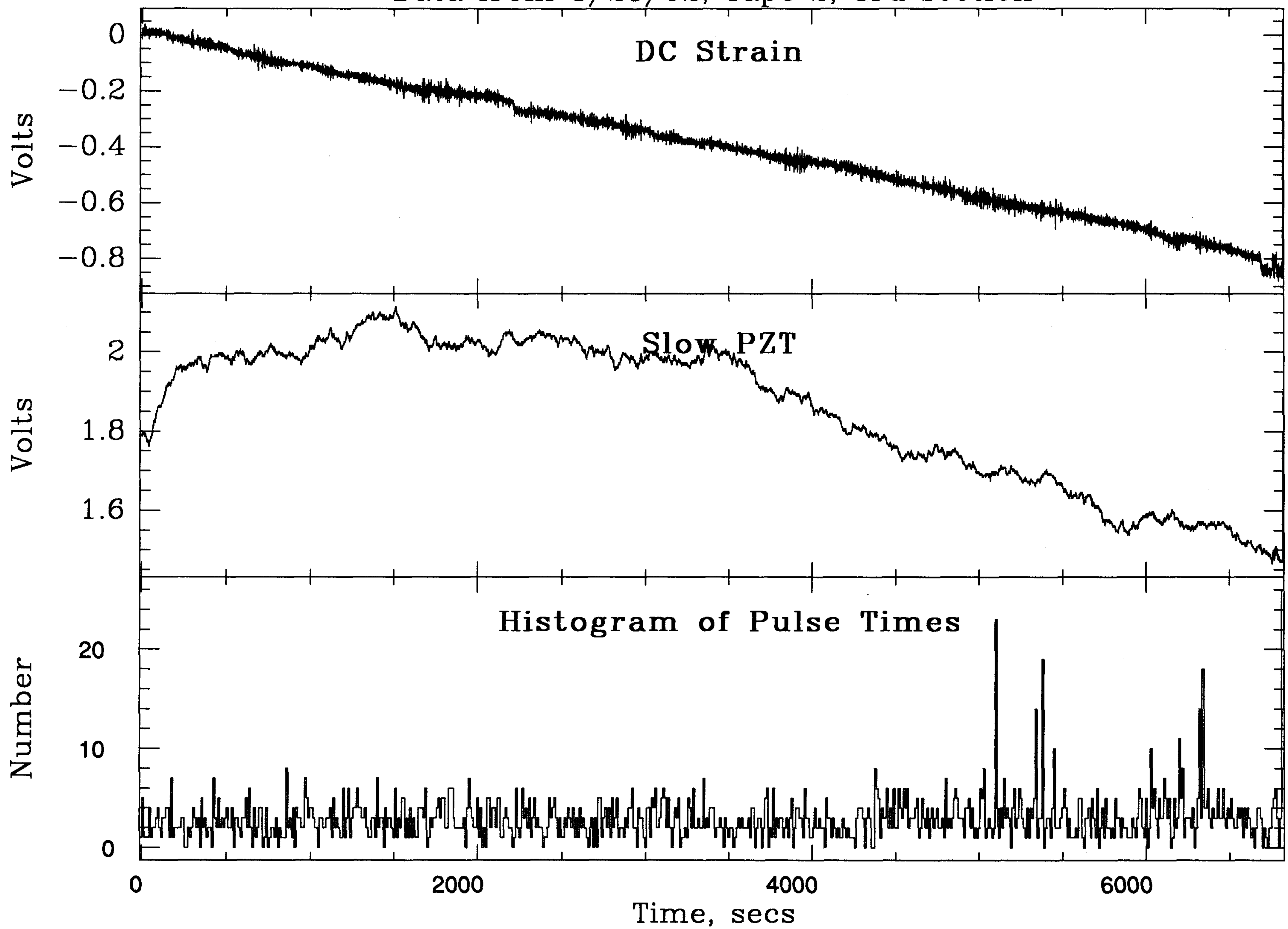
Tape 2 starts 7 hours and 15 minutes (= 26,100 seconds) after the start of the data run.

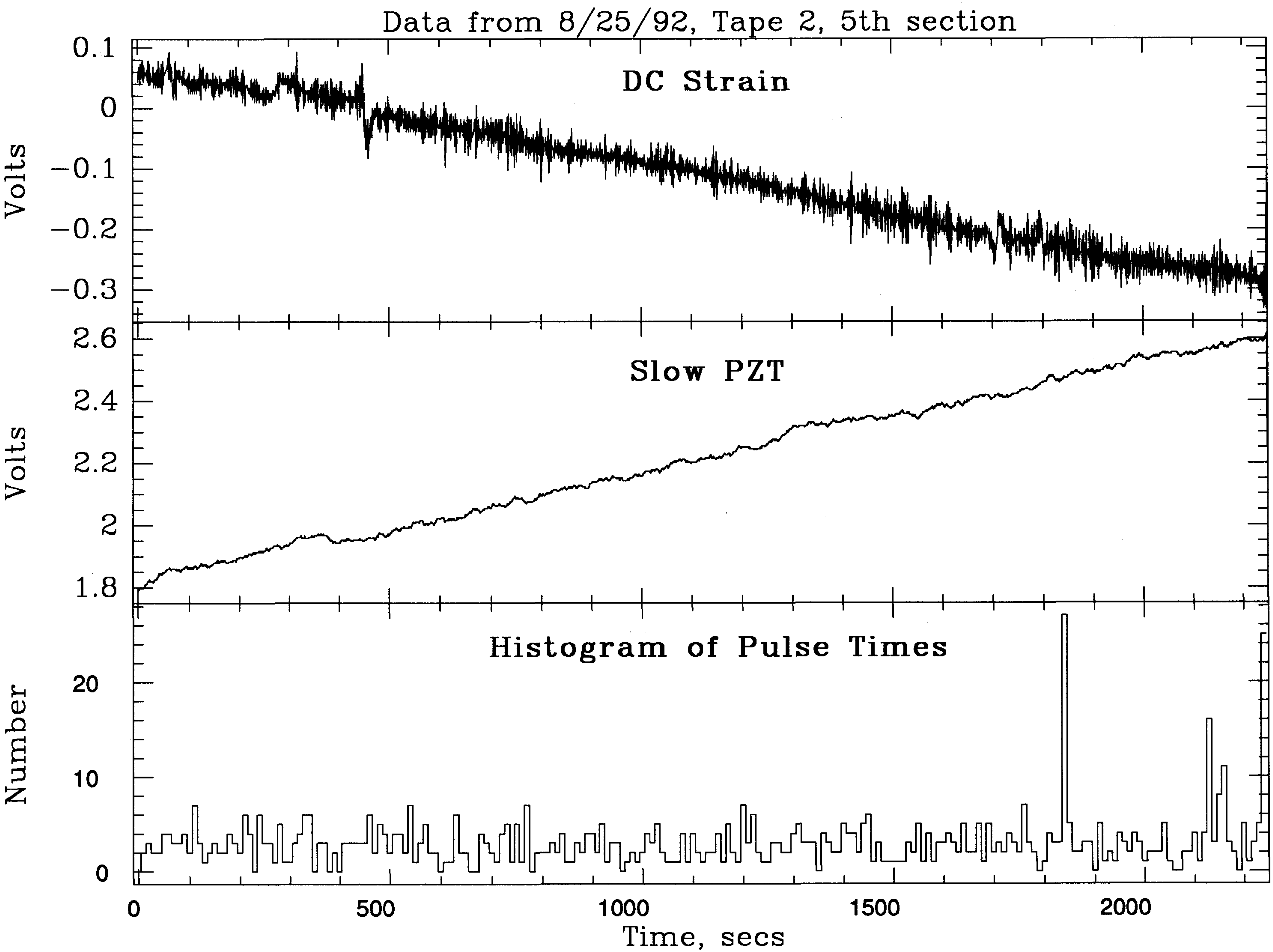
TTL, 1/6/93


Data from 8/25/92, Tape 2, 1st section
DC Strain
Volts
0
−0.1
−0.2
−0.3
Slow PZT
Volts
3.4
3.2
3
2.8
2.6
Histogram of Pulse Times
Number
6
4
2
0
0
500
1000
Time, secs

TTL, 1/7/92

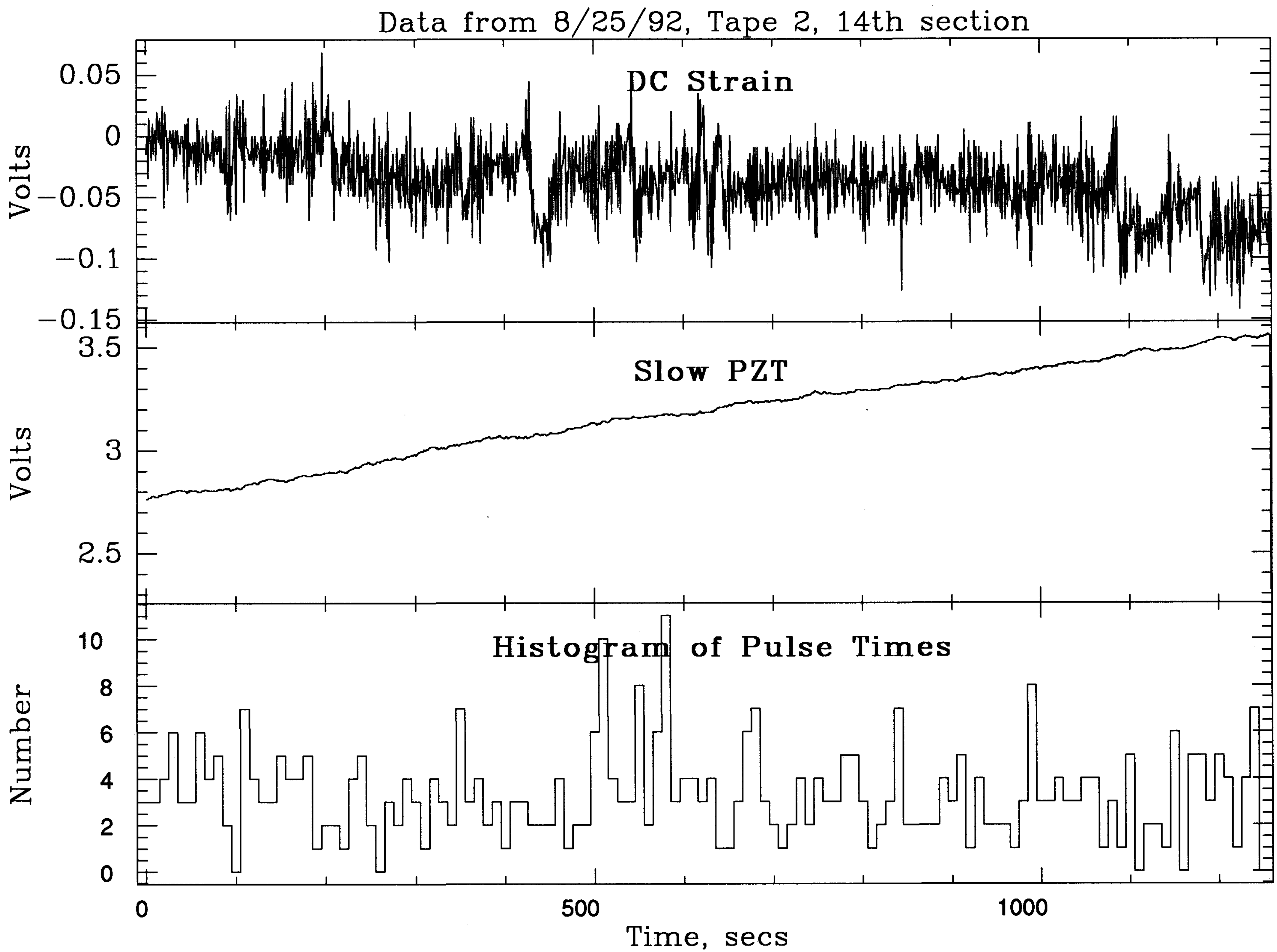
Data from 8/25/92, Tape 2, 3rd section





Data from 8/25/92, Tape 2, 5th section
DC Strain
Slow PZT
Histogram of Pulse Times
Volts
Volts
Number
Time, secs
0.1
0
−0.1
−0.2
−0.3
2.6
2.4
2.2
2
1.8
20
10
0
0
500
1000
1500
2000

TTL, 1/11/92


Data from 8/25/92, Tape 2, 14th section
DC Strain
Volts
0.05
0
−0.05
−0.1
−0.15
Slow PZT
Volts
3.5
3
2.5
Histogram of Pulse Times
Number
10
8
6
4
2
0
0
500
1000
Time, secs

Analysis of 40m Interferometer data by program LOCKED, ver. 1.3
Data rate = 1973.684204 samples/sec.
Locked range = -45 , -24 (primary) -60 , -34 (secondary).

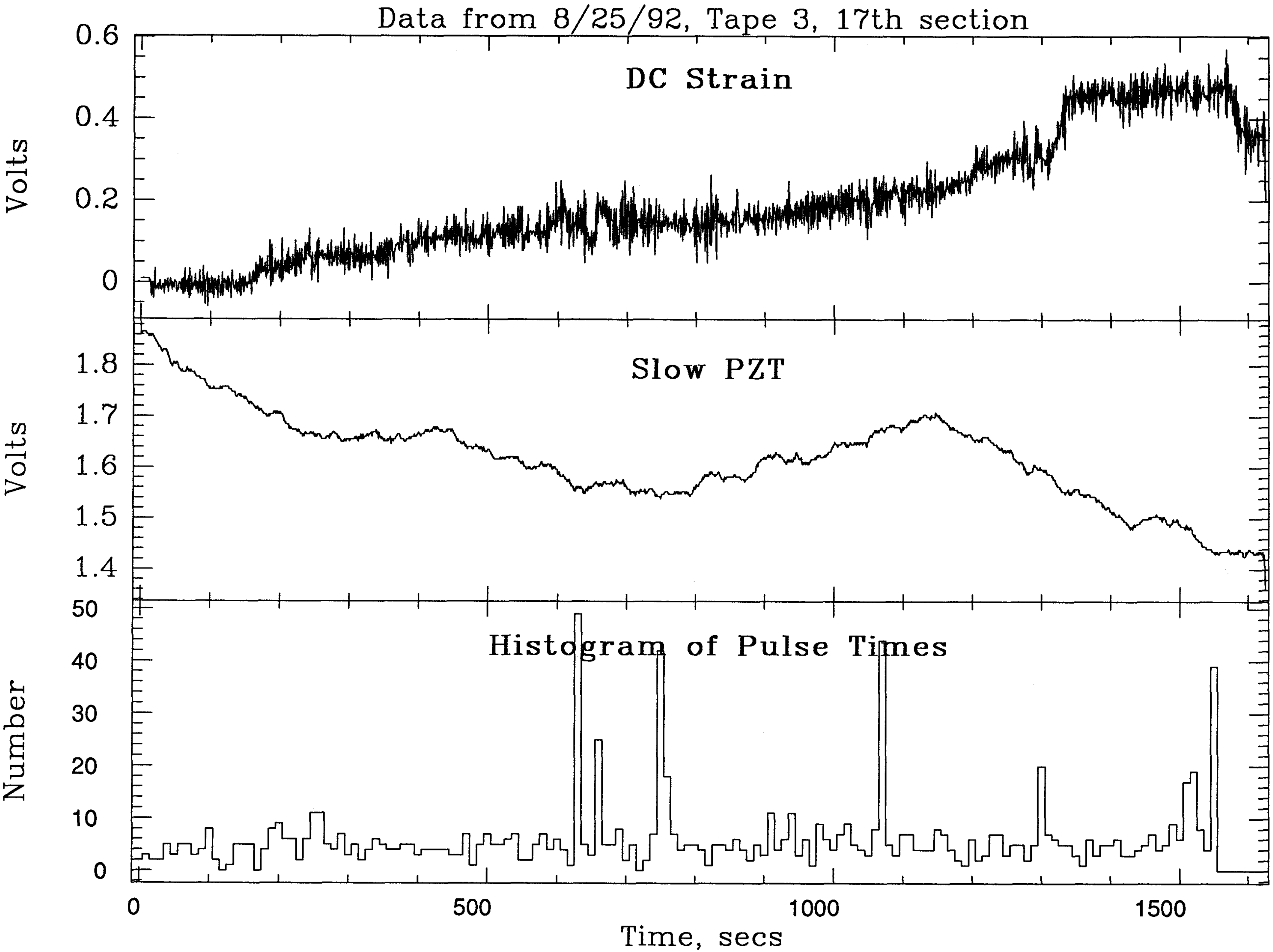
	Start, sec	Stop, sec	Start, pos	Stop, pos	Duration, sec
1	0.000000	322.099152	0	635722	322.099152
2	422.121216	1708.310303	833134	3371665	1286.189087
3	1708.316895	2566.895020	3371678	5066240	858.578125
4	2567.330078	2569.084229	5067099	5070561	1.754150
5	2569.148193	2571.291260	5070687	5074917	2.143066
6	2571.730957	2572.862061	5075785	5078017	1.131104
7	2572.863525	2597.547852	5078020	5126739	24.684326
8	2597.549316	2600.702881	5126742	5132966	3.153564
9	2601.328613	2609.697754	5134201	5150719	8.369141
10	2610.210449	2611.500244	5151731	5154277	1.289795
11	2611.844482	2647.651123	5154956	5225627	35.806641
12	2898.634521	2907.416992	5720989	5738323	8.782471
13	4160.178711	5749.639648	8210879	11347973	1589.460938
14	5773.671387	8708.216326	11395404	17187269	2934.544939
15	8784.291278	9237.928240	17337417	18232753	453.636963
16	9280.131610	12017.150408	18316049	23718060	2737.018799
17	12125.041016	13750.264648	23931002	27138681	1625.224121
18	14008.727539	14061.481445	27648804	27752924	52.754150
19	14065.236328	14088.815430	27760336	27806873	23.578735
20	14089.167969	14093.129883	27807568	27815389	3.962646
21	14111.227539	14114.168945	27851107	27856913	2.941772
22	14142.293945	14146.972656	27912423	27921657	4.678589
23	14146.974609	14148.054688	27921660	27923793	1.080688
24	14157.221680	14174.856445	27941886	27976691	17.634644
25	14178.301758	14181.542969	27983491	27989887	3.240479
26	14195.618164	14212.128906	28017668	28050254	16.510254
27	14213.140625	14214.147461	28052252	28054239	1.006592
28	14215.535156	14218.402344	28056978	28062636	2.866699
29	14219.742188	14220.775391	28065282	28067320	1.032715
30	14321.797852	15549.734375	28266707	30690266	1227.936523
31	15651.861328	16579.927734	30891831	32723542	928.066895
32	16710.513672	18143.972656	32981277	35810472	1433.458496
33	18174.720703	18338.265625	35871159	36193945	163.544922
34	18385.621094	18673.328125	36287411	36855253	287.706543
35	18827.136719	20767.613281	37158825	40988710	1940.475586

= Analyzed section.

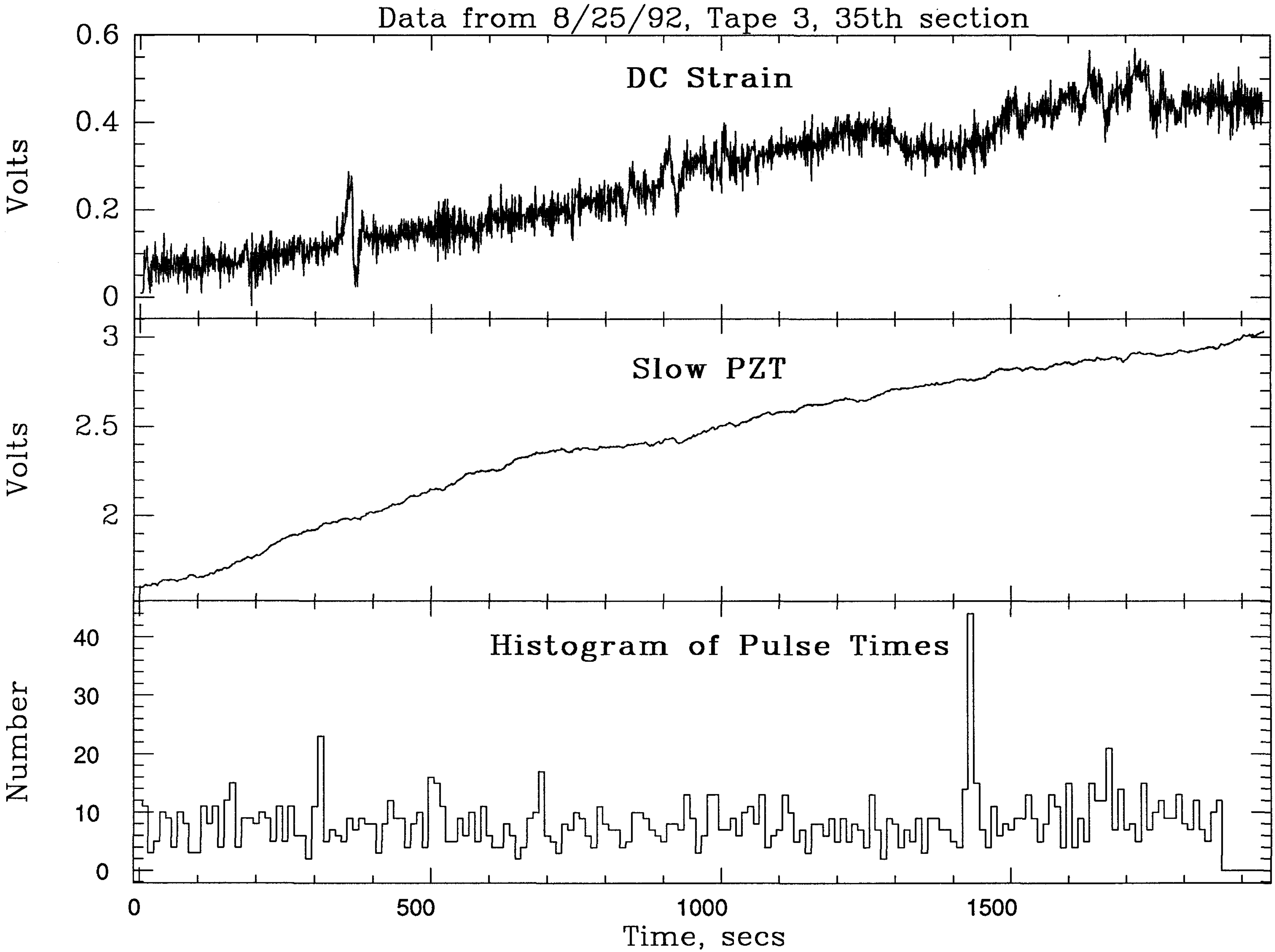
= During the beginning of this section a swept sine was taken. To skip this part of the data, analysis of this section was started 8,000,000 fast samples (405.333335 seconds) in instead of 1,200,000 (60.800000 seconds) as usual.

Tape 3 starts 13 hours and 13 minutes (= 47580 seconds) after the start of the data run.

TTL, 12/2/92


Data from 8/25/92, Tape 3, 17th section
DC Strain
Volts
0.6
0.4
0.2
0
Slow PZT
Volts
1.8
1.7
1.6
1.5
1.4
Histogram of Pulse Times
Number
50
40
30
20
10
0
500
1000
1500
Time, secs

TTL, 12/2/92


Data from 8/25/92, Tape 3, 35th section
DC Strain
Volts
0.6
0.4
0.2
0
Slow PZT
Volts
3
2.5
2
Histogram of Pulse Times
Number
40
30
20
10
0
0
500
1000
1500
Time, secs

Data from 8/25/92, Tape 4

Analysis of 40m Interferometer data by program LOCKED, ver. 1.3
Data rate = 1973.684204 samples/sec.
Locked range = -45 , -24 (primary)   -61 , -34 (secondary).

	Start, sec	Stop, sec	Start, pos	Stop, pos	Duration, sec
1	0.000000	407.426880	0	804132	407.426880
2	456.770142	1069.330688	901520	2110521	612.560547
3	1108.706787	1343.232056	2188237	2651116	234.525269
4	1388.624878	1449.056519	2740707	2859980	60.431641
5	1722.356079	2126.798096	3399387	4197628	404.442017
6	2181.925049	2188.101807	4306431	4318622	6.176758
7	2249.187012	2436.215576	4439185	4808320	187.028564
8	2450.605713	2460.465576	4836722	4856182	9.859863
9	2494.113281	2499.715576	4922592	4933649	5.602295
10	2526.924561	2594.274170	4987351	5120278	67.349609
11	2594.468750	3611.391846	5120662	7127747	1016.923096
12	3648.848145	4087.103271	7201674	8066651	438.255127
13	4139.372070	4478.683105	8169813	8839506	339.311035
14	4508.681152	5062.773926	8898713	9992317	554.092773
15	5101.512207	9417.473633	10068774	18587119	4315.961426
16	9417.476562	9689.378906	18587126	19123774	271.901367
17	9689.384766	9812.351562	19123787	19366485	122.966797
18	9812.368164	9955.210938	19366516	19648442	142.842285
19	9955.240234	9980.490234	19648502	19698337	25.250000
20	10239.665039	10304.511719	20209866	20337851	64.846191
21–23	[redacted]				
24	14392.195312	14525.334961	28405650	28668425	133.139404
25	14525.337891	14528.085938	28668430	28673854	2.748047
26	14613.980469	14615.708008	28843383	28846793	1.727783
27	14783.486328	14784.613281	29177935	29180159	1.126953
28	14796.706055	14798.393555	29204026	29207356	1.687256

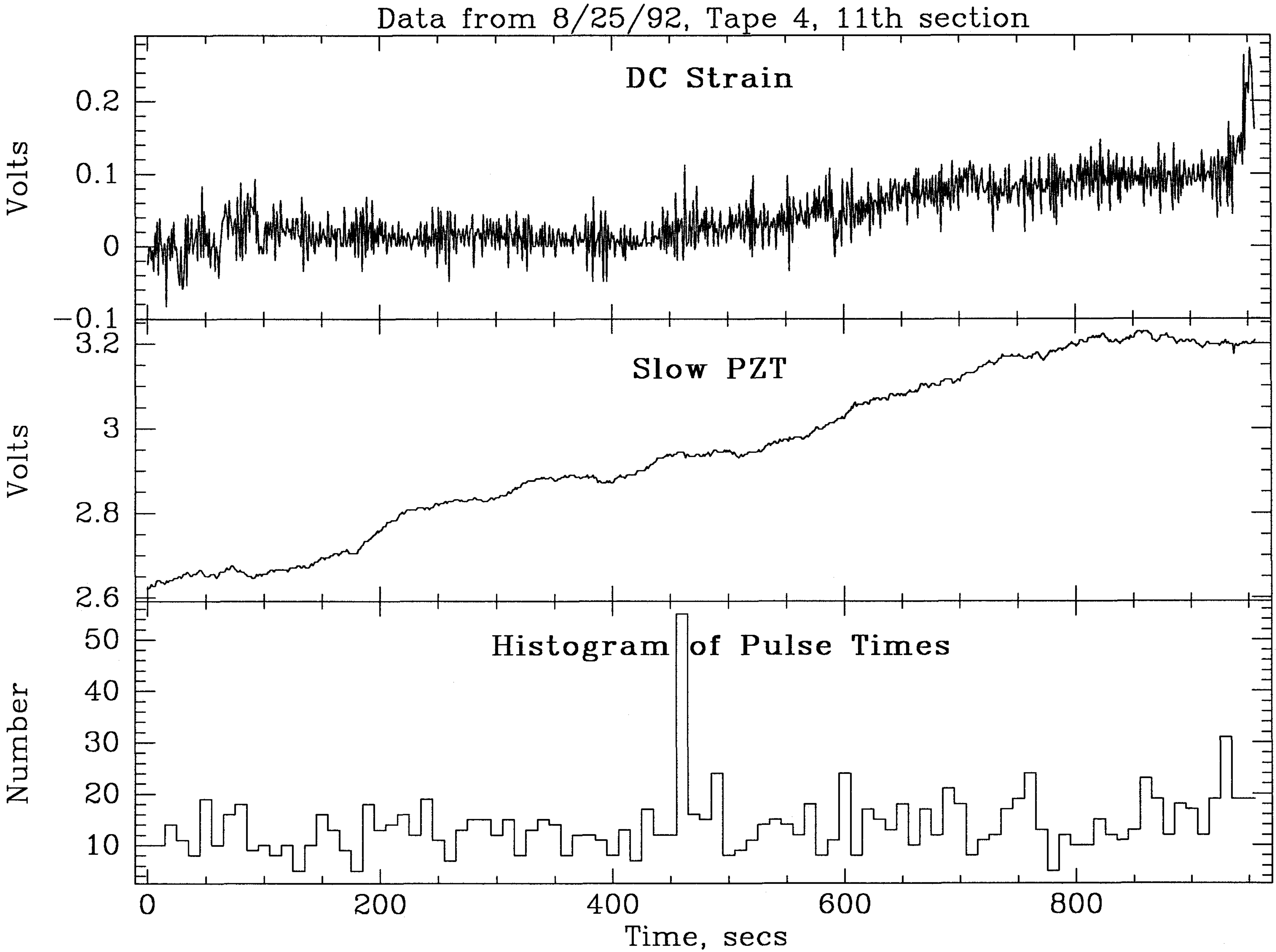
= Analyzed sections.

= A calibrated sine was fed in during this section. It was analyzed, but will not be used for pulse statistics.

= Power dependent relaxation oscillations caused masive pulses in these sections, which were analyzed, and for rest of tape. They will not be used for pulse statistics.

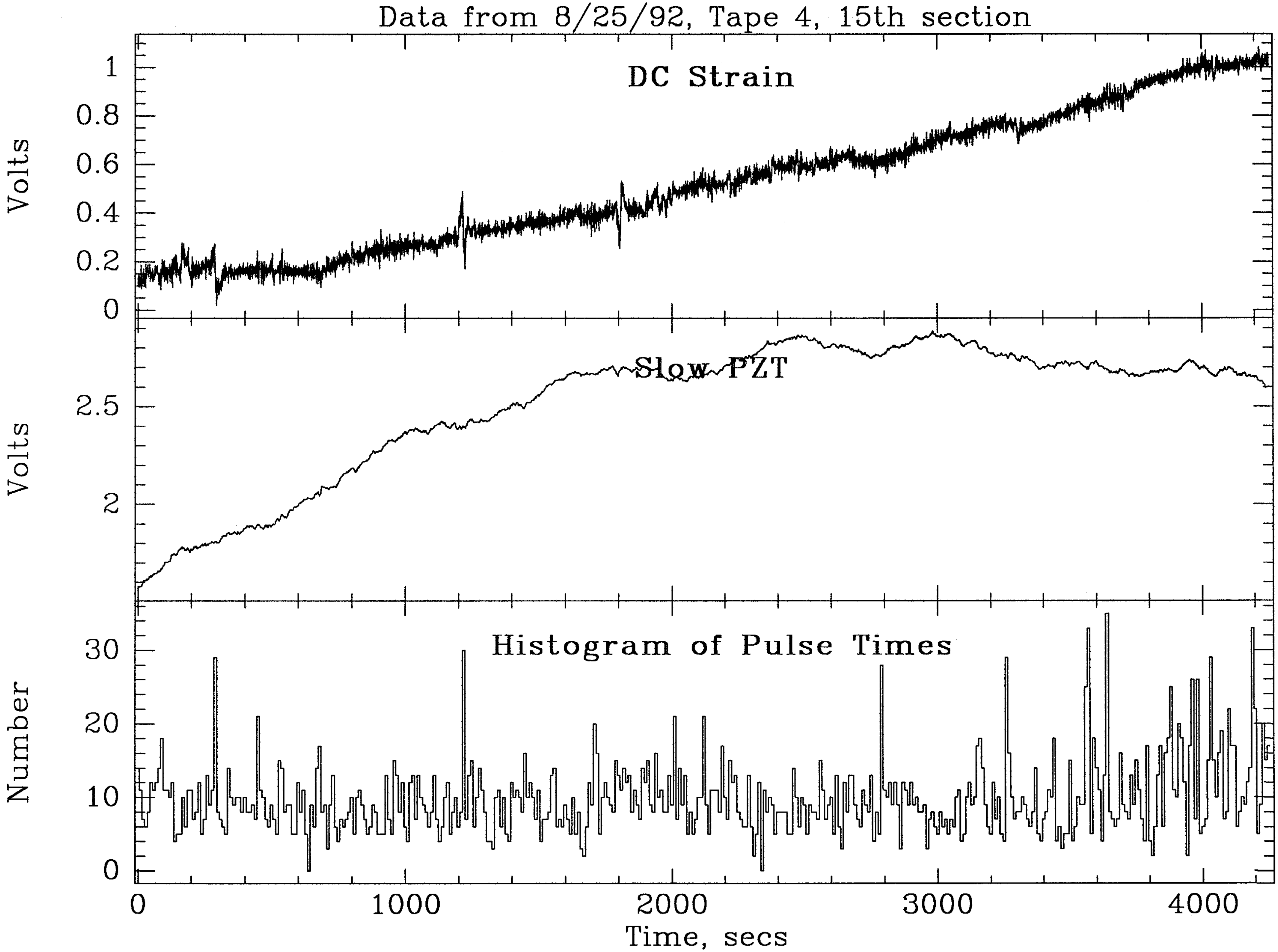
Tape 4 starts 19 hours and 27 minutes (= 70,020 seconds) after the start of the data run.

TTL, 12/14/92



Data from 8/25/92, Tape 4, 11th section
DC Strain
Volts
0.2
0.1
0
−0.1
Slow PZT
Volts
3.2
3
2.8
2.6
Histogram of Pulse Times
Number
50
40
30
20
10
0
200
400
600
800
Time, secs

TTL, 12/15/92

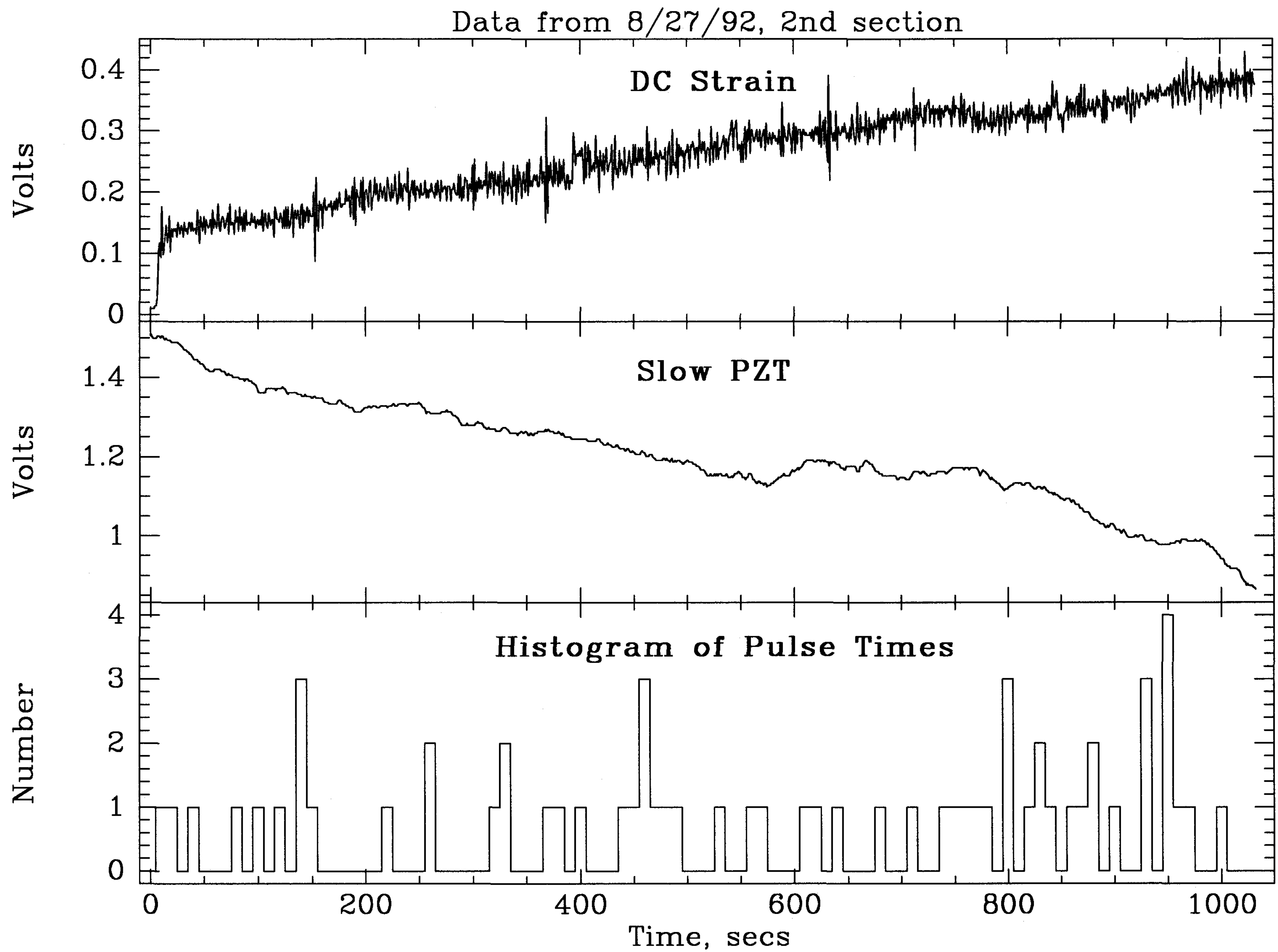

Data from 8/25/92, Tape 4, 15th section
DC Strain
Volts
1
0.8
0.6
0.4
0.2
0
Slow PZT
Volts
2.5
2
Histogram of Pulse Times
Number
30
20
10
0
0
1000
2000
3000
4000
Time, secs

Analysis of 40m Interferometer data by program LOCKED, ver. 1.2
Data rate = 1973.684204 samples/sec.
Locked range = -17 , -9 (primary) -22 , -14 (secondary).

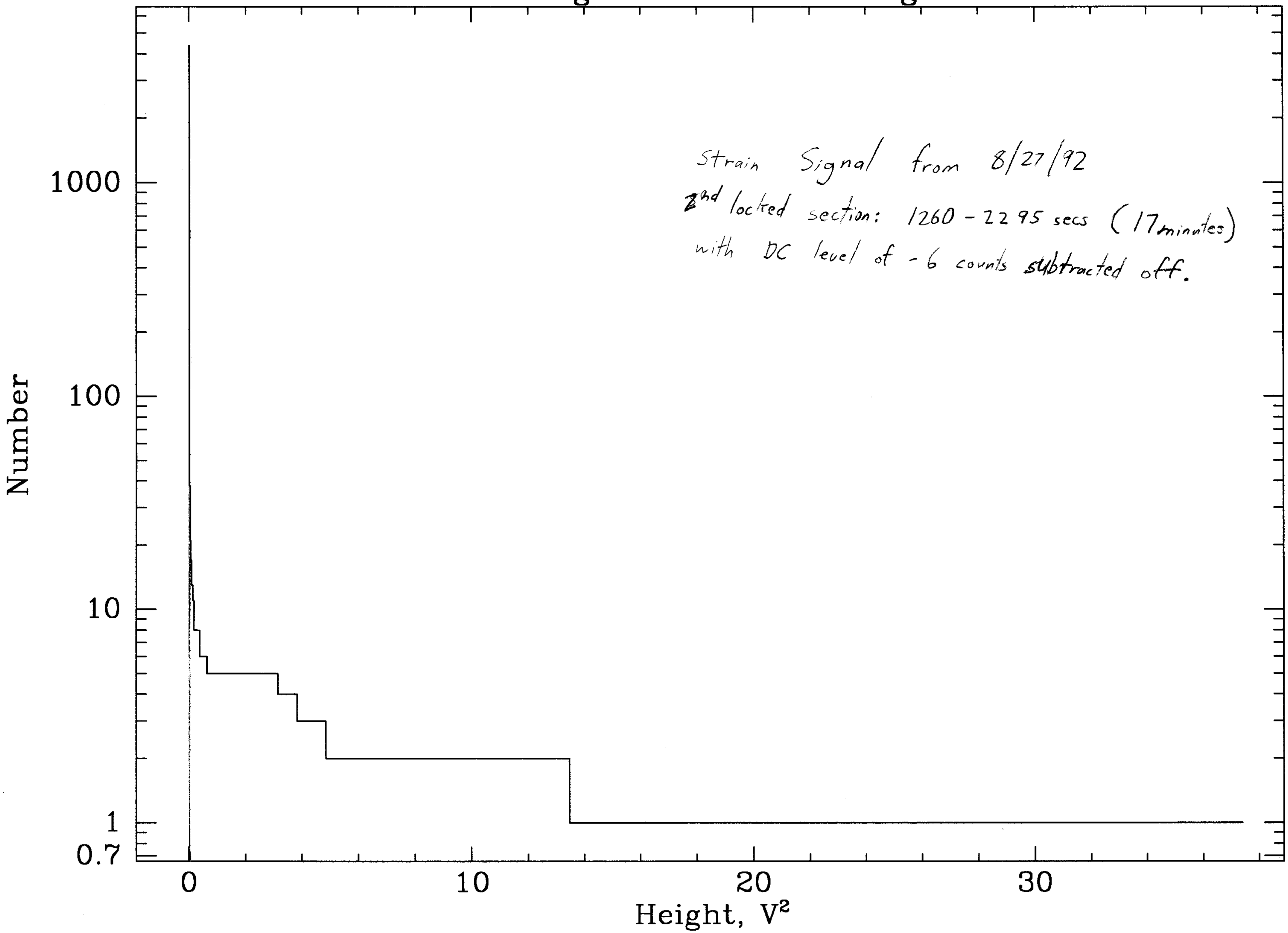
Start, sec	Stop, sec	Start, pos	Stop, pos	Duration, sec	#
0.000000	1146.872437	0	2263564	1146.872437	1
1260.318115	2295.381836	2487470	4530359	1035.063721	2
2336.537354	2343.392090	4611587	4625116	6.854736	
2365.413330	2488.975586	4668579	4912452	123.562256	3
2493.544922	2493.557373	4921470	4921495	0.012451	
2493.580322	2493.589355	4921540	4921558	0.009033	
2493.634033	2499.384766	4921646	4932996	5.750732	
2500.301270	2500.306396	4934805	4934815	0.005127	
2500.322021	2536.024170	4934846	5005311	35.702148	
2537.530029	2548.080322	5008283	5029106	10.550293	
2548.584961	2550.613770	5030102	5034106	2.028809	
2552.457520	2552.464600	5037745	5037759	0.007080	
2552.473145	2552.496094	5037776	5037821	0.022949	
2552.505127	2552.510254	5037839	5037849	0.005127	
2552.511230	2600.907471	5037851	5133370	48.396240	
2660.131348	3502.881592	5250259	6913582	842.750244	4
3563.256348	3571.790771	7032743	7049587	8.534424	
3573.952148	3587.273926	7053853	7080146	13.321777	
3589.940674	3590.864746	7085409	7087233	0.924072	
3591.106445	3591.112061	7087710	7087721	0.005615	
3591.228516	3591.255371	7087951	7088004	0.026855	
3592.099365	3592.118652	7089670	7089708	0.019287	
3592.286865	3592.299561	7090040	7090065	0.012695	
3595.531738	3598.070068	7096444	7101454	2.538330	
3599.981201	3599.987305	7105226	7105238	0.006104	
3599.988770	3599.995361	7105241	7105254	0.006592	
3600.003906	3600.014160	7105271	7105291	0.010254	
3600.020752	3600.049561	7105304	7105361	0.028809	
3600.118408	3600.400635	7105497	7106054	0.282227	
3604.103027	3604.343506	7113361	7113836	0.240479	
3660.558838	3660.563721	7224787	7224797	0.004883	
✓ 3723.896240	6314.479004	7349795	12462787	2590.582764	5
6370.100098	7093.333496	12572566	14000000	723.233398	6

(Useful) Locked Sections

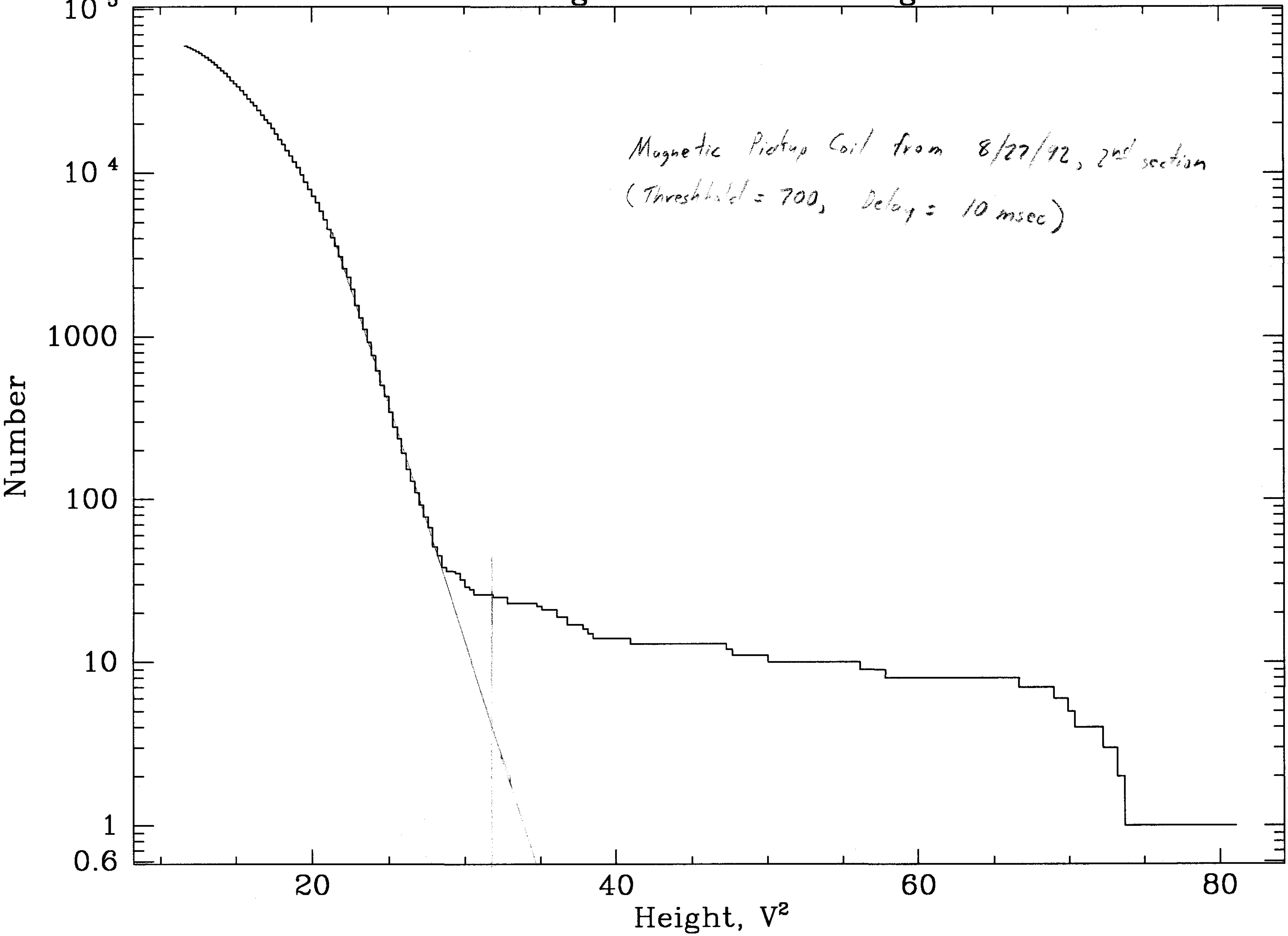
#	Time (nom.)	Comments
1	17:20 - 17:40	Calibrated sine at 17:26.
2	17:42 - 17:59	
3	18:00 - 18:04	
4	18:05 - 18:20	Cryo pump off.
5	18:24 - 19:06	
6	19:08 - 19:11	Calibrated sine.


Data from 8/27/92, 2nd section
DC Strain
Volts
0.4
0.3
0.2
0.1
0
Slow PZT
Volts
1.4
1.2
1
Histogram of Pulse Times
Number
4
3
2
1
0
0
200
400
600
800
1000
Time, secs

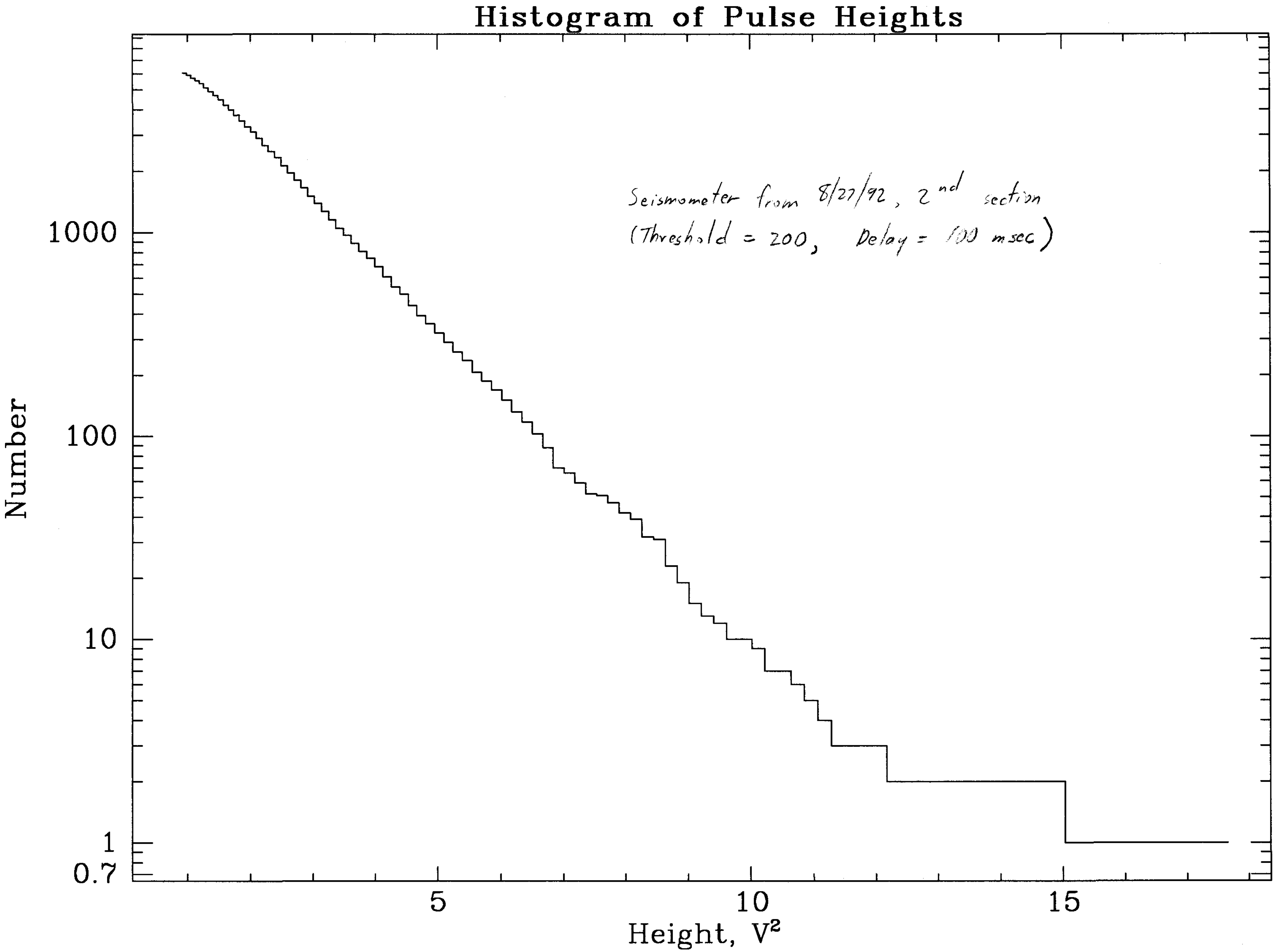
Histogram of Pulse Heights



Histogram of Pulse Heights

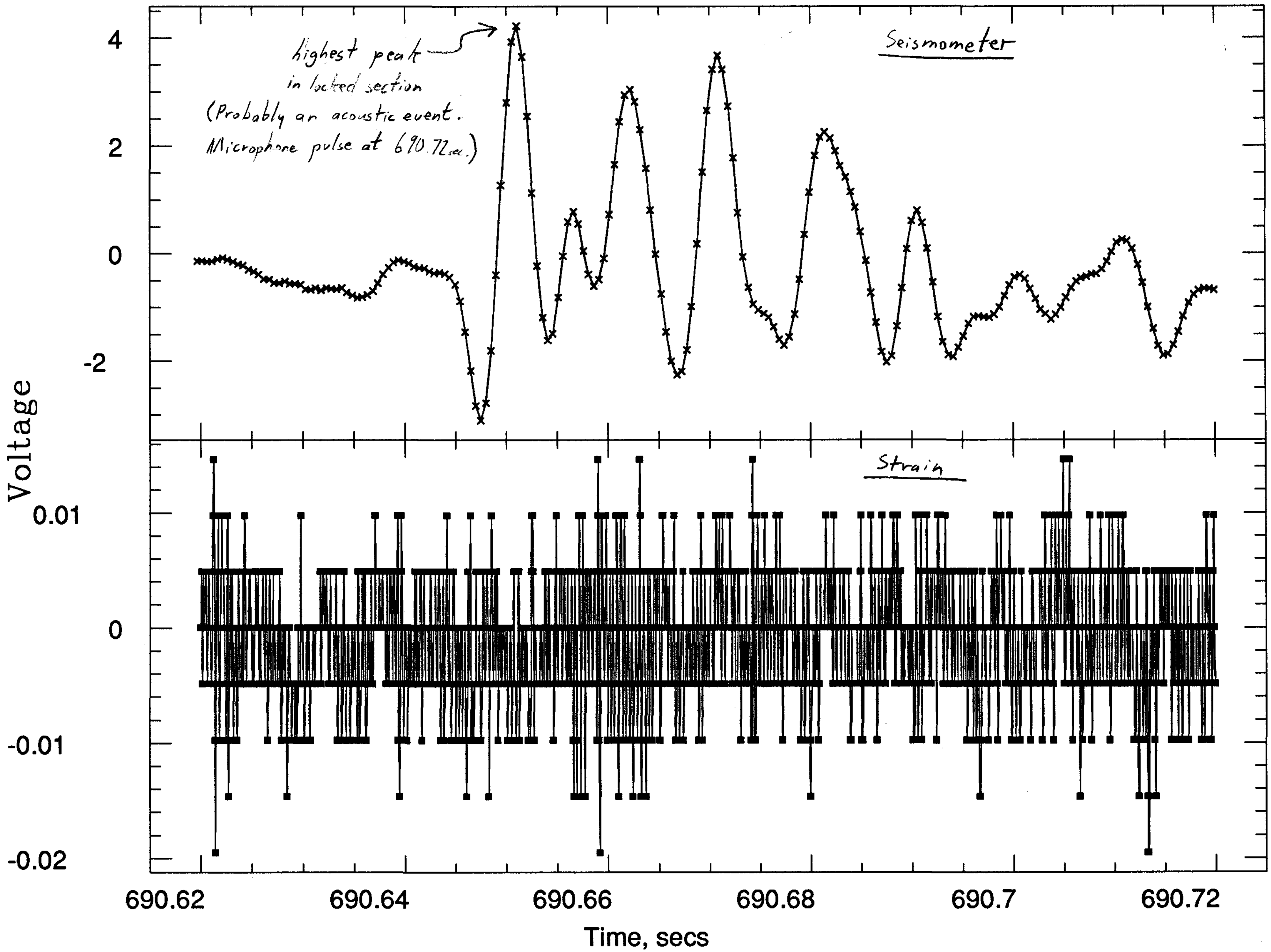


TTL, 10/28/92


Histogram of Pulse Heights
Seismometer from 8/27/92, 2nd section
(Threshold = 200, Delay = 100 msec)
Number
1000
100
10
1
0.7
5
10
15
Height, V²

Example from 8/27/92, 2nd section
TTL, 10/20/92

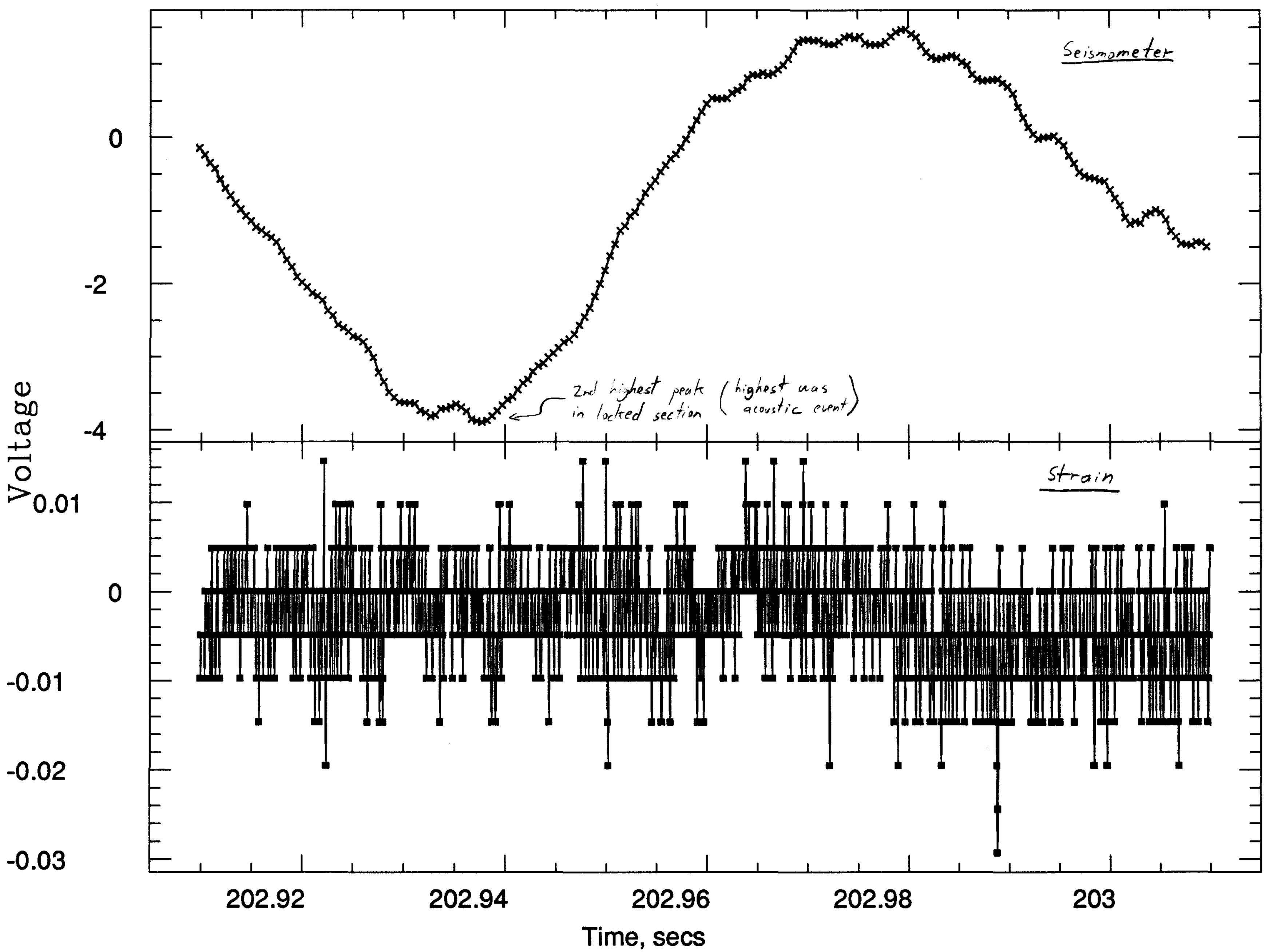
40m Pulses



No coincidence between seismometer and strain.

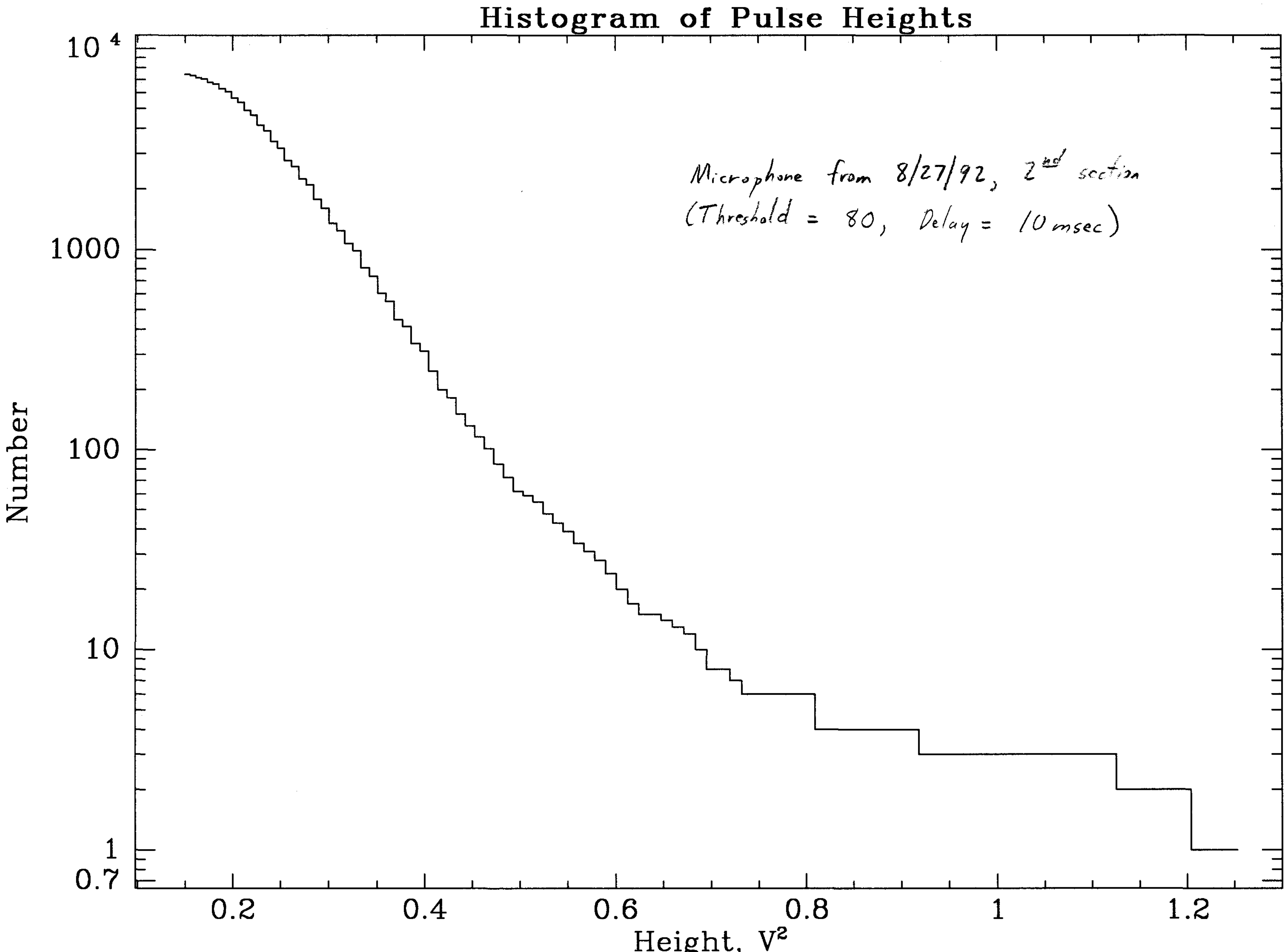
TTL, 10/23/92
Example from 8/27/92, 2nd locked section

40m Pulses



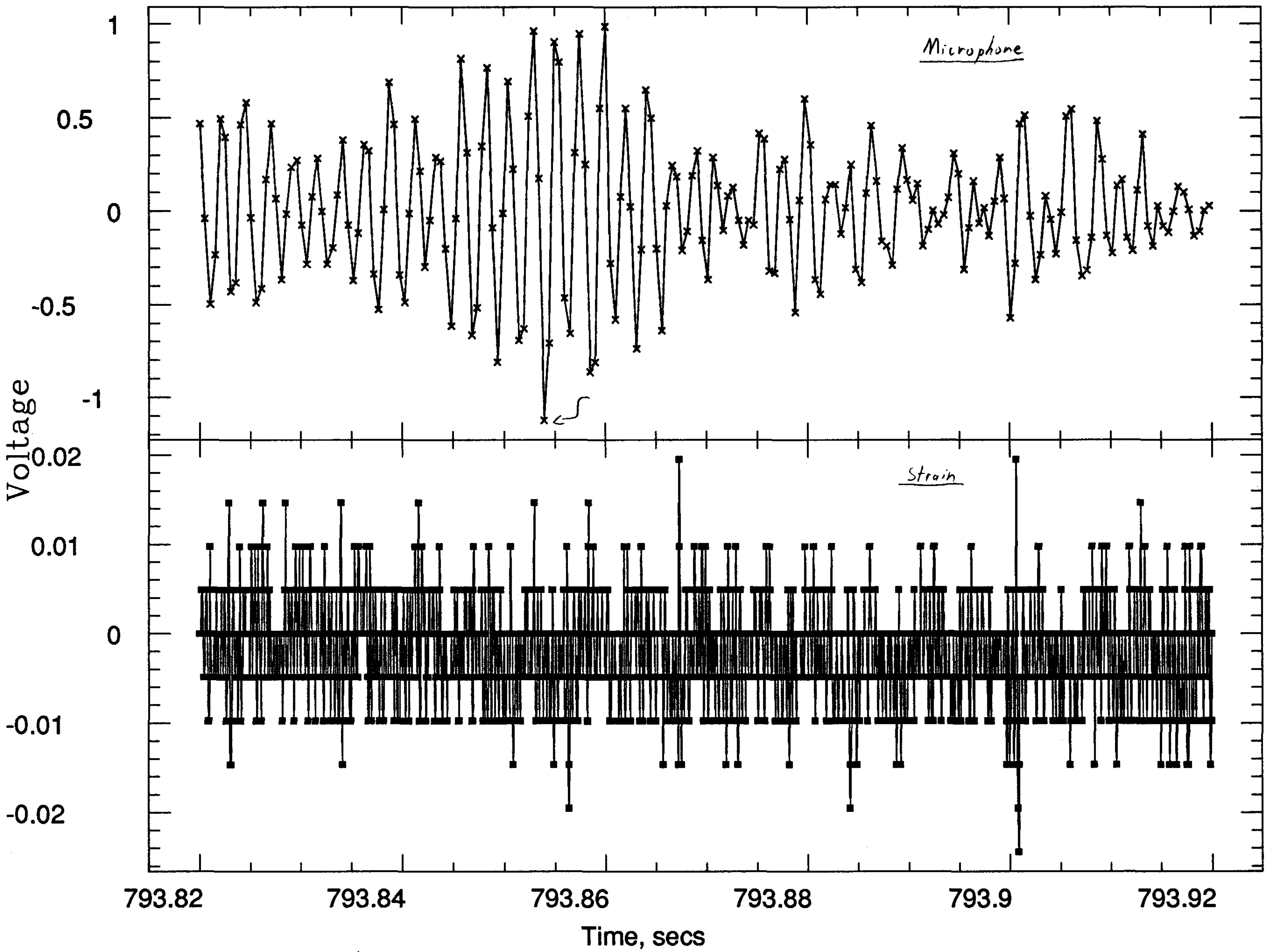
No coincidence between seismometer and strain.

TTL, 10/22/92

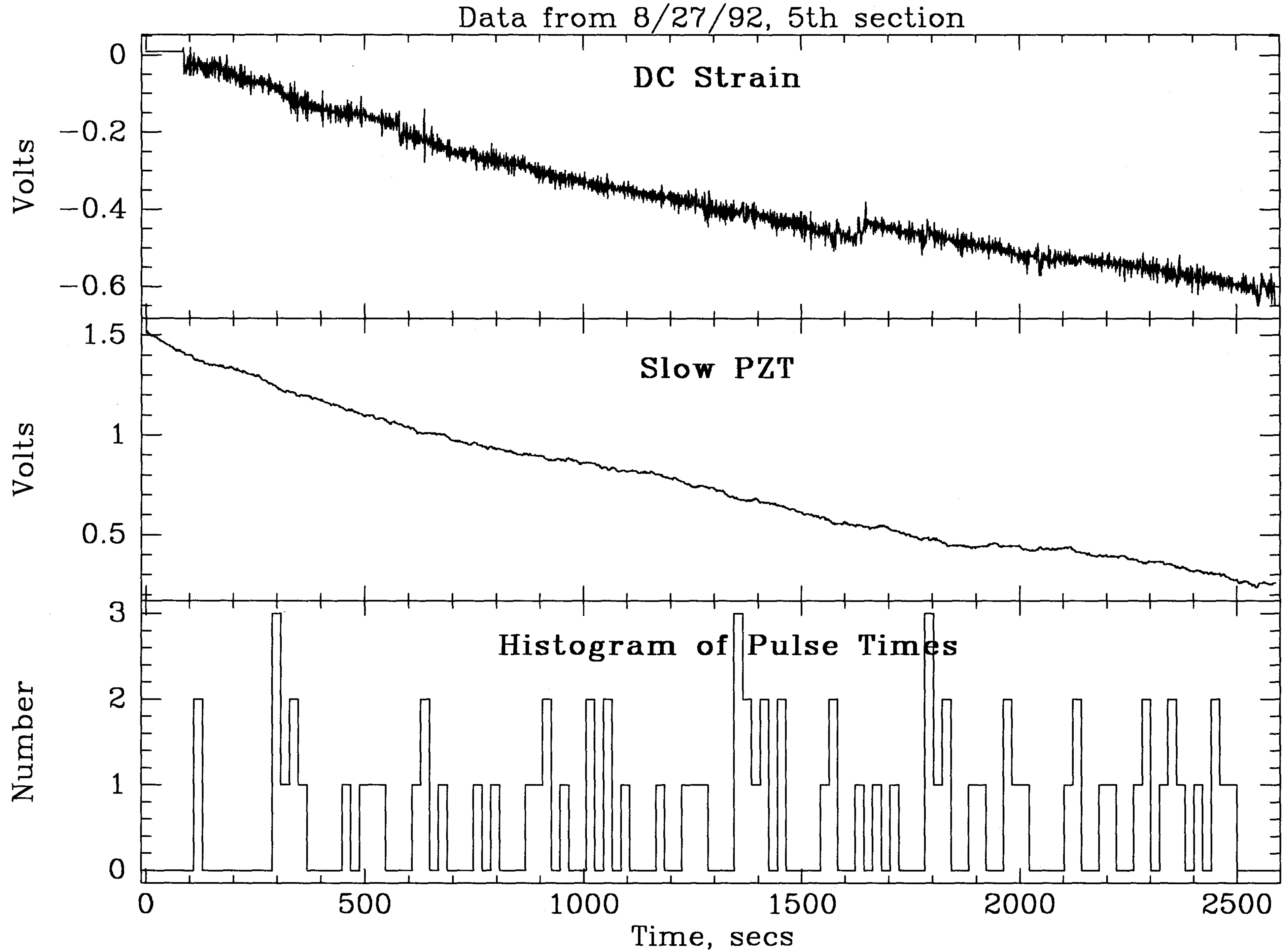

Histogram of Pulse Heights
10^4
1000
100
10
1
0.7
Number
0.2
0.4
0.6
0.8
1
1.2
Height, V²
Microphone from 8/27/92, 2nd section
(Threshold = 80, Delay = 10 msec)

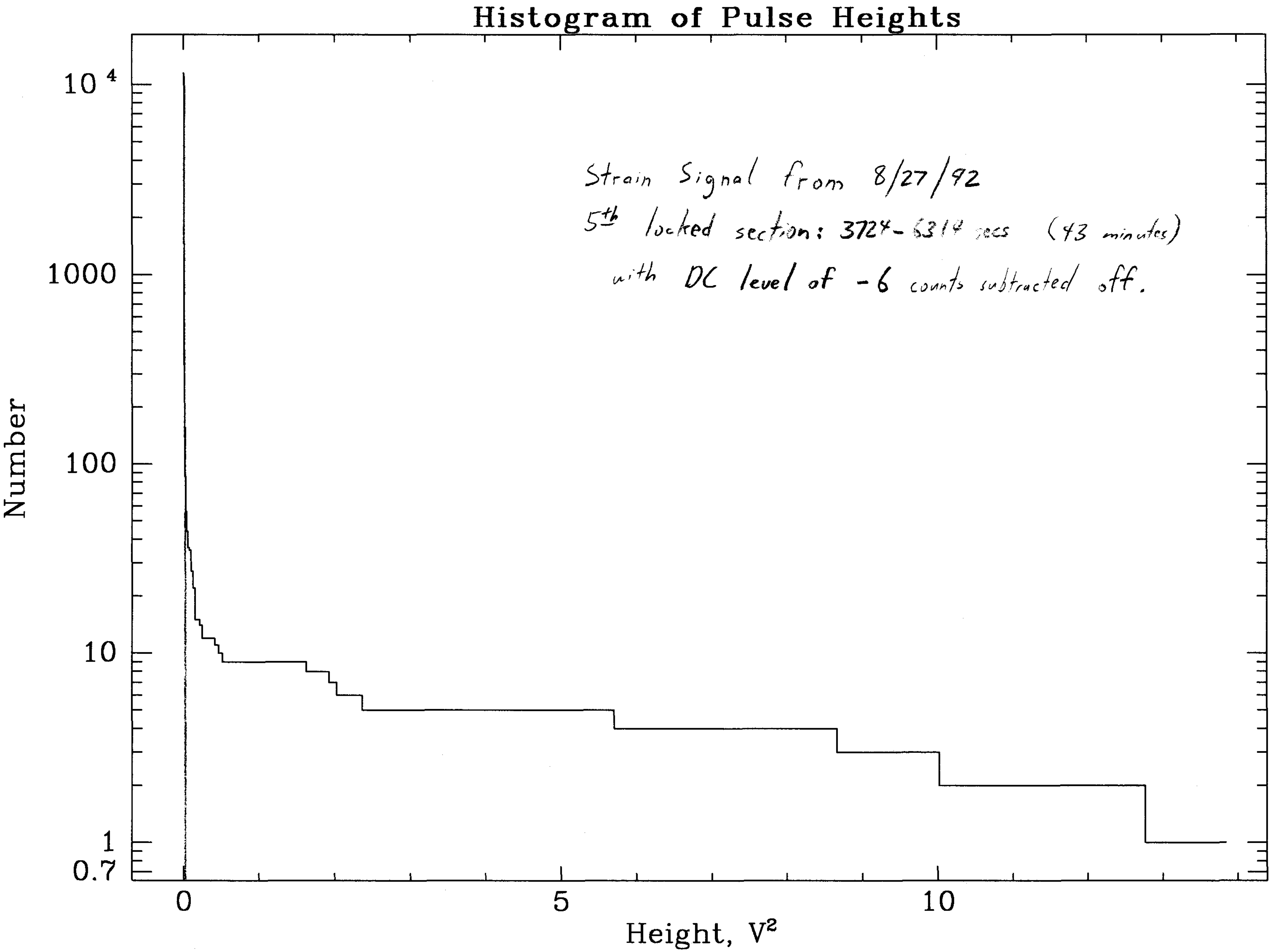
TTL, 10/23/92
Example from 8/27/92, 2nd locked section

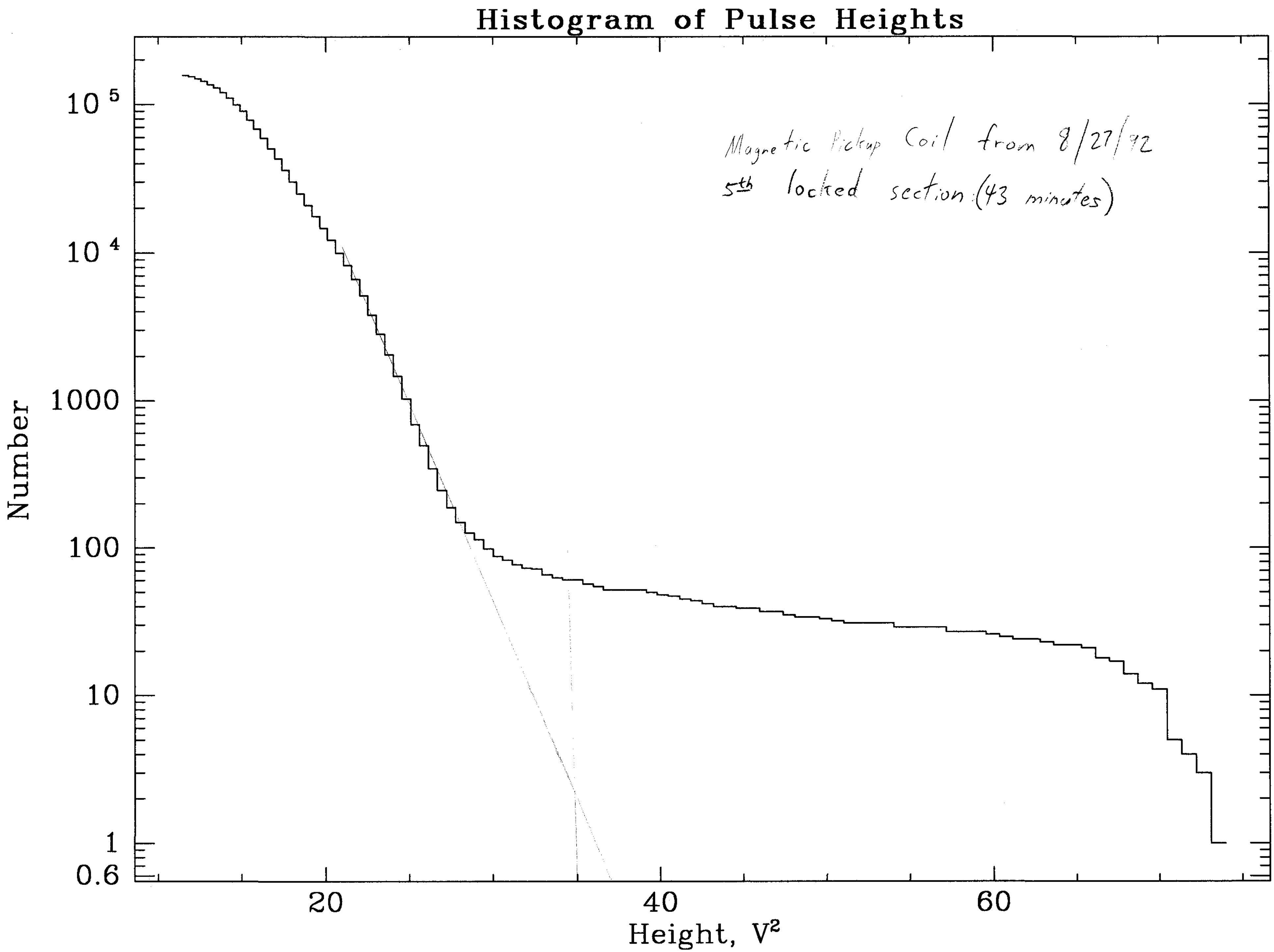
40m Pulses



No coincidence between microphone and strain.

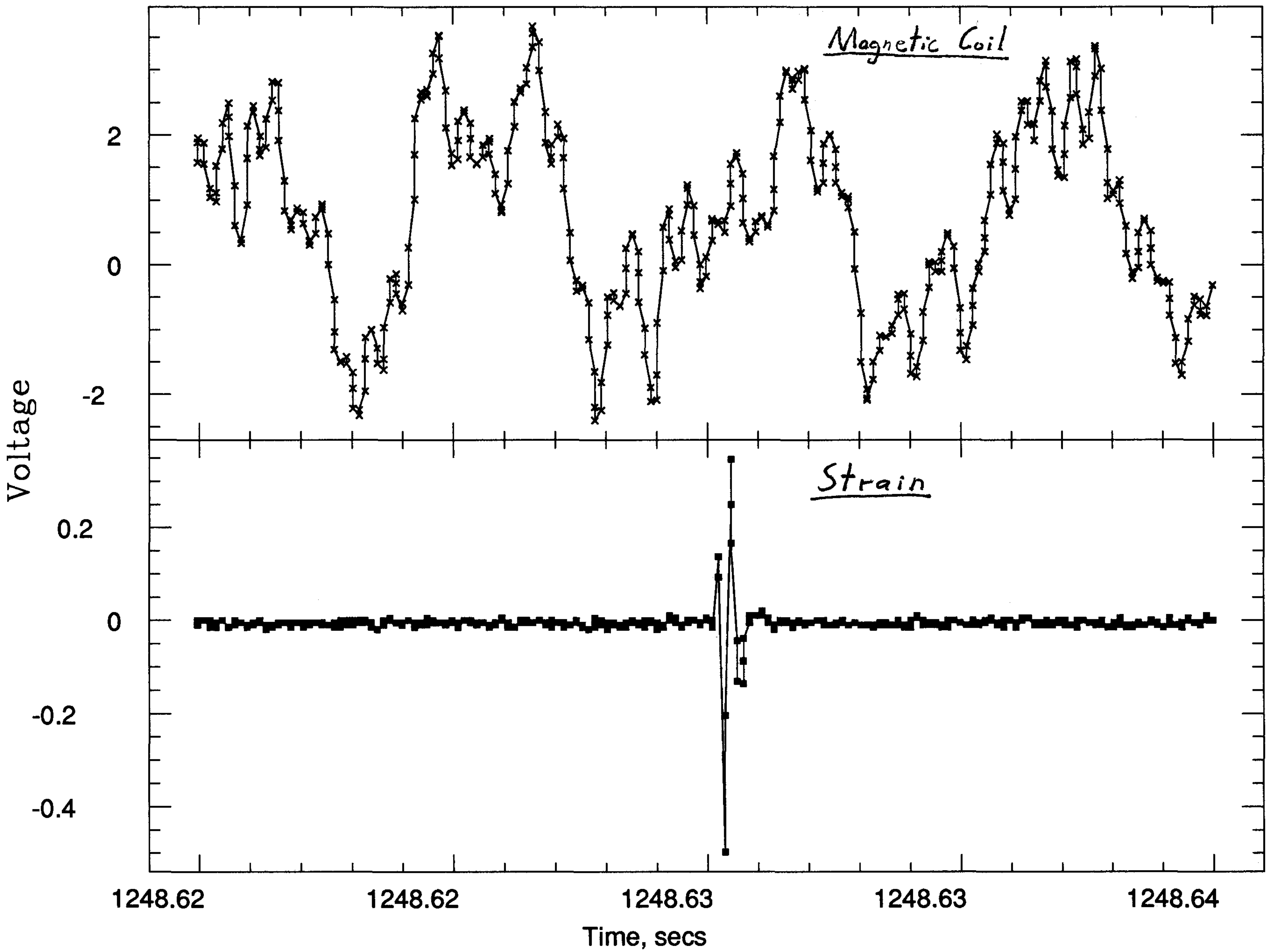

Data from 8/27/92, 5th section
DC Strain
Volts
0
−0.2
−0.4
−0.6
Slow PZT
Volts
1.5
1
0.5
Histogram of Pulse Times
Number
3
2
1
0
0
500
1000
1500
2000
2500
Time, secs


Histogram of Pulse Heights
Number
Height, V^2
Strain Signal from 8/27/92
5th locked section: 3724-6314 secs (43 minutes)
with DC level of -6 counts subtracted off.

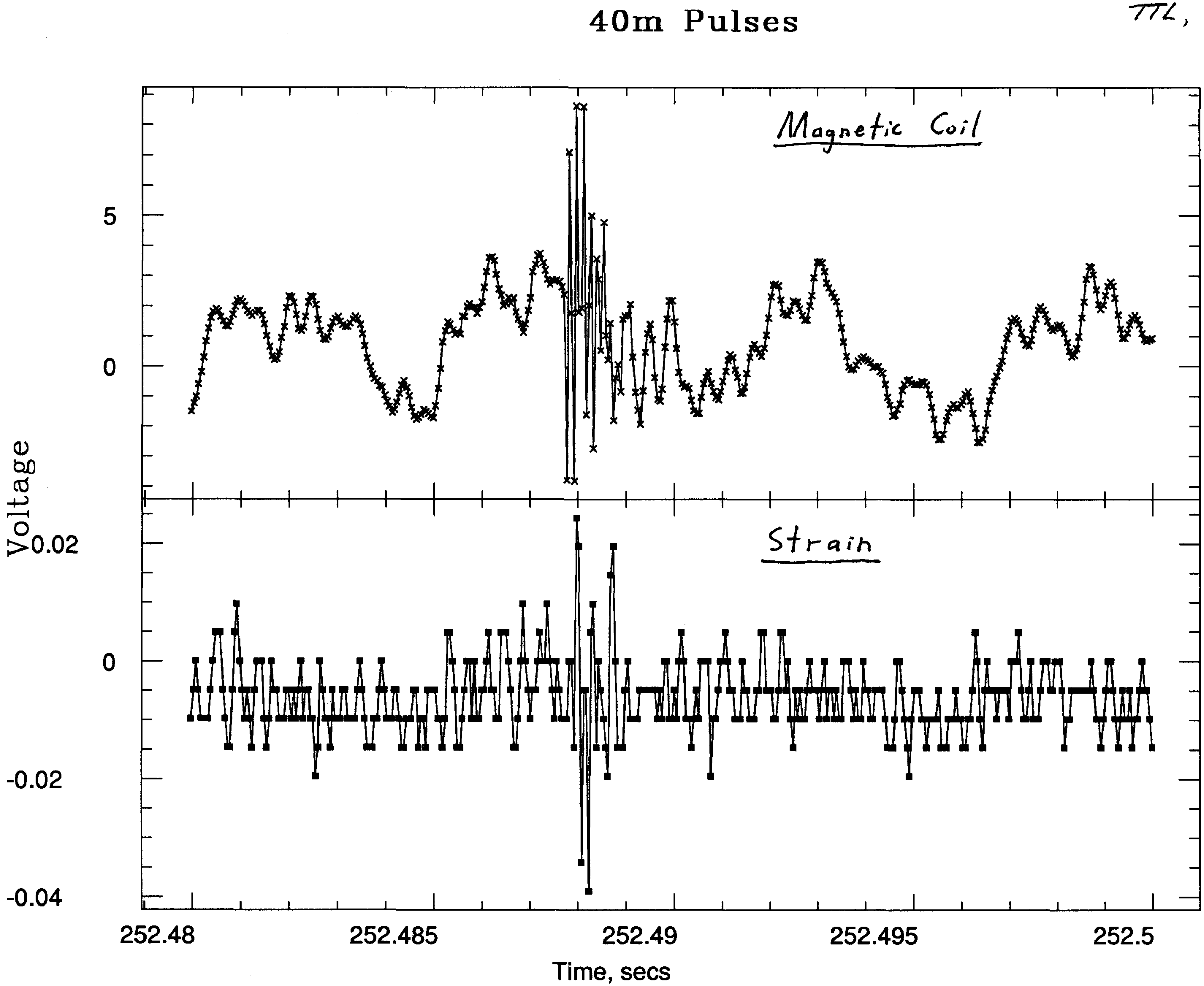

Histogram of Pulse Heights
Magnetic Pickup Coil from 8/27/92
5th locked section (43 minutes)
10 5
10 4
1000
100
10
1
0.6
Number
20
40
60
Height, V²

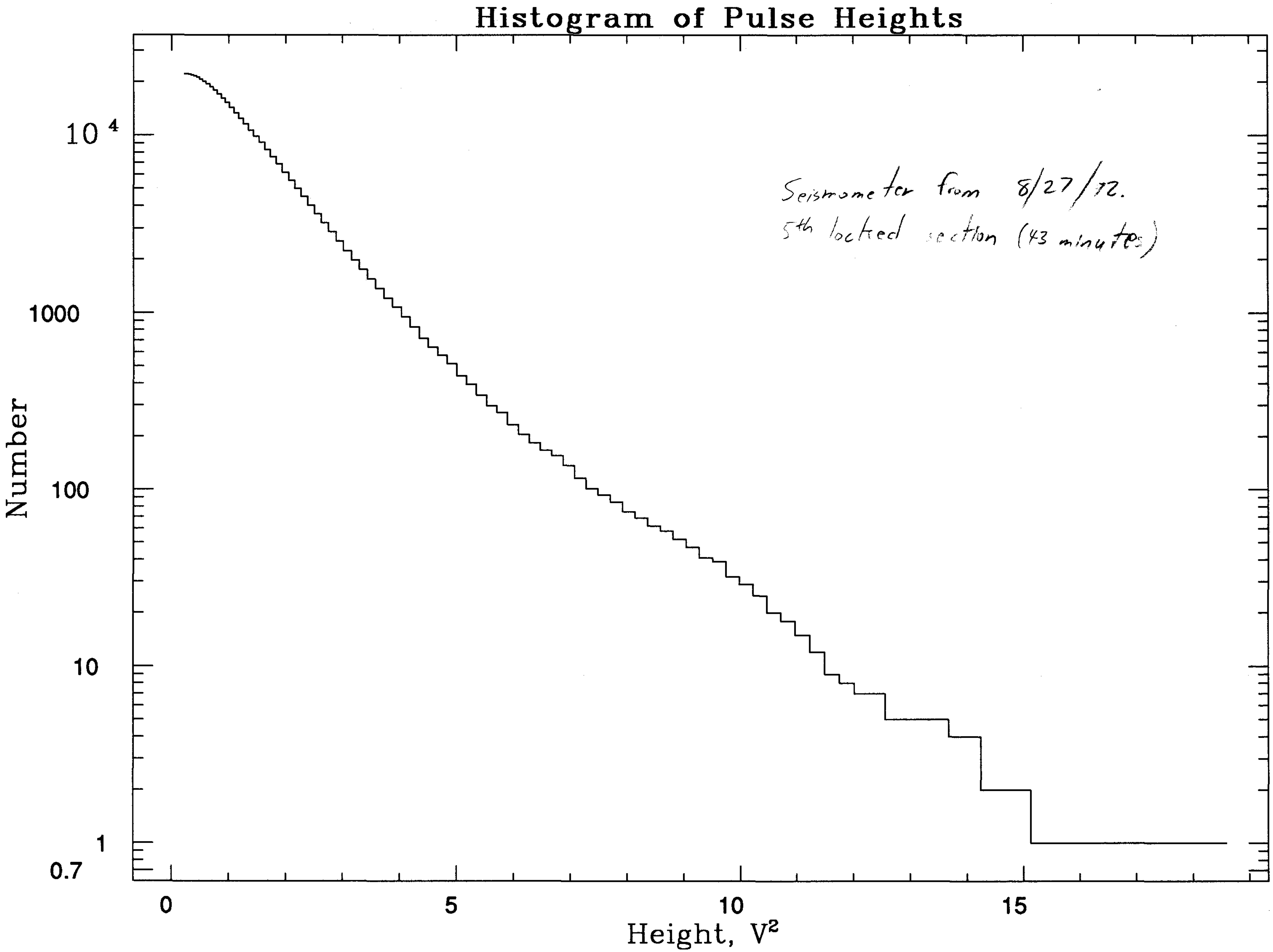
Example from 8/27/92, 5th section
TTL, 10/14/92

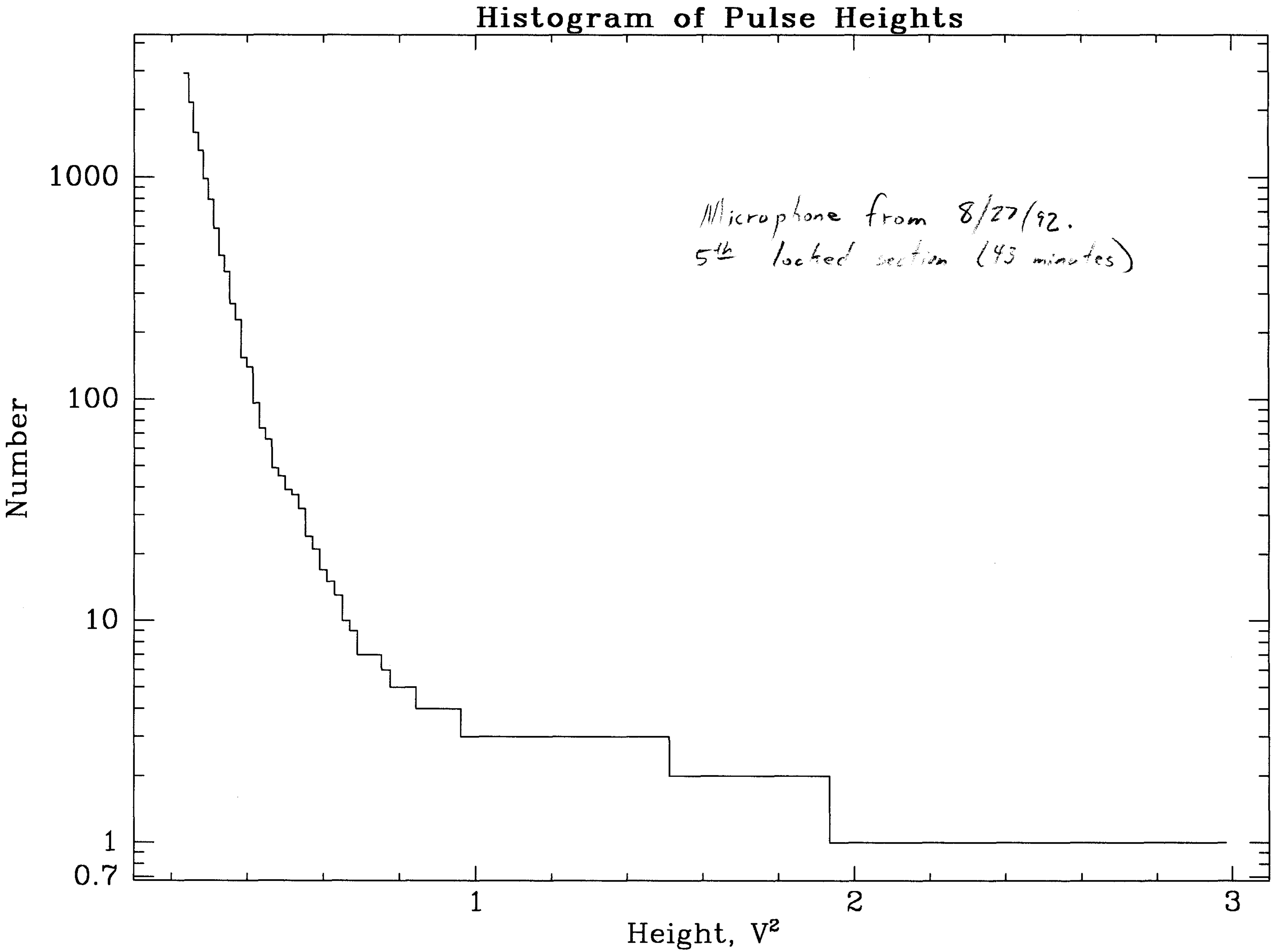
40m Pulses



Example from 8/27/92, 5th section
TTL, 10/14/92




Histogram of Pulse Heights
Number
Height, V²
10 4
1000
100
10
1
0.7
0
5
10
15
Seismometer from 8/27/72.
5th locked section (43 minutes)


Histogram of Pulse Heights
Number
Height, V²
1000
100
10
1
0.7
1
2
3
Microphone from 8/27/92.
5th locked section (43 minutes)

NAME

tapesave – a program to save a-to-d data on an exabyte tape drive

SYNOPSIS

tapesave [-vegt] -f FREQUENCY -n NUMCHAN -p NUMPRIM -s SKIPRATE

DESCRIPTION

tapesave is a program designed to write incoming data to the exabyte in real time. As such, a format has been adopted to keep only the minimal amount of data. This is done by allowing the user to specify the number of channels, and then to subdivide these into primary and seconday channels. Secondary channels are stored at a rate less than primaries.

Channel numbering is from zero to the number of channels minus one. Primary channels are those from zero to the number of primaries minus one. These channels are sampled at the frequency divided by the toal number of channels. Remaining channels are secondaries, and are written at the rate of the primary channels divided by the skip rate.

After the program configures and locks memory, the user will be prompted to start data aquisition. A special header file will be written every time data aquisition starts to get the tape drive ready; this sometimes takes a bit of time.

During data aquisition, the user may either pause or halt aquisition. After pausing, user is once more prompted to start the program.

OPTIONS

-v Verbose mode. Extra information.

-e External clock. Internal clock default.

-g[0-3] Gain. Applicable only to ADV1226.

-t EF12M card wanted. ADV1226 default.

SEE ALSO

extract(l), collapse(l)

AUTHORS

Version 2.0: Myke Hoskins. Version 1.5: Preston Pfrarner, Tom Renner, Michael Hoskins. Version 1.0: Yekta Gursel. LIGO Project, Mail Stop 130-33, California Institute of Technology, Pasadena, California 91125

BUGS

The program often has difficulty locking the required amount of memory against swapping.

NAME

extract – takes an exabyte tape produced by **tapesave** and separates out a single channel or multiple channels over a given block of time.

VERSION

2.1

SYNOPSIS

extract [-v] -c [number of channels] [channel list] -t START END [-o filename]

DESCRIPTION

extract is meant to separate out a given channels from multiple channel data written by tapesave. The output file is formatted, not a simple binary dump. Start and end times are in seconds relative to the start of the data run on the tape. Non-integer values may be specified.

OPTIONS

-v Verbose mode. Extra information.

-o filename Outputs will be directed to named file, with an extender appropriate for each channel, as in "output.3".

SEE ALSO

tapesave(l), collapse(l)

AUTHOR

Myke Hoskins, LIGO Project, California Institute of Technology, Pasadena, California 91125

NAME

collapse – produces a straight binary dump from a formatted file produced by **extract.**

SYNOPSIS

collapse [-fov]

DESCRIPTION

collapse Takes the formatted file, and outputs a binary dump. The dump is composed of two byte words. The main point of this program is that during data aquisition, the user may stop and restart at any time, leaving gaps iin the data. Collapse removes all information bearing headers from its input, replaces all gaps with the appropriate number of null values, and writes the result to its output.

OPTIONS

-v   Verbose mode. Extra information.

-f filename   Input is taken to be named file. Default is stdin.

-o filename   Output will be directed to named file. Default is stdout.

SEE ALSO

tapesave(l), extract(l)

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BUGS

None known.