LIGO-G990079-36-M

PROGRESS IN NOISE CHARACTERIZATION

BERNARD WHITING

(GROUPS AT ANU & UFL)

PREPARATION

COMPUTATION NOISE

DIGITIZING NOISE

SPECTRAL UNIFORMITY

NOISE IDENTIFICATION

DIGITAL FILTERS ...

EXAMINING DATA

FREQUENCY MISMATCH

NOISE UNIFORMITY

A-D UNIFORMITY

LINE INTERFERENCE

DISTRIBUTIONAL DIVERSITY...

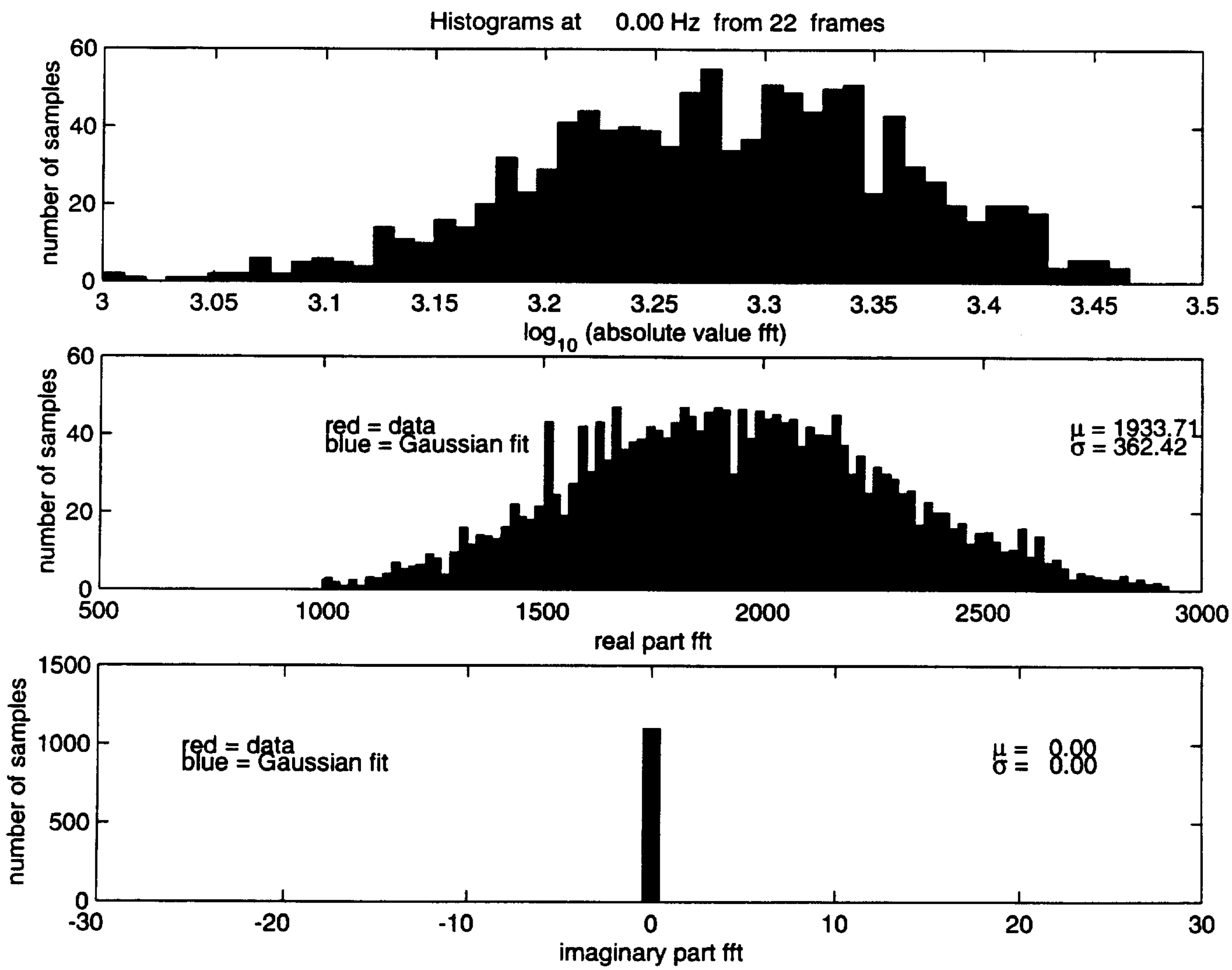
Examining 40 M data
Computational Noise
Frequency Mismatch
Digitization Noise / Uniformity
Random Noise Uniformity

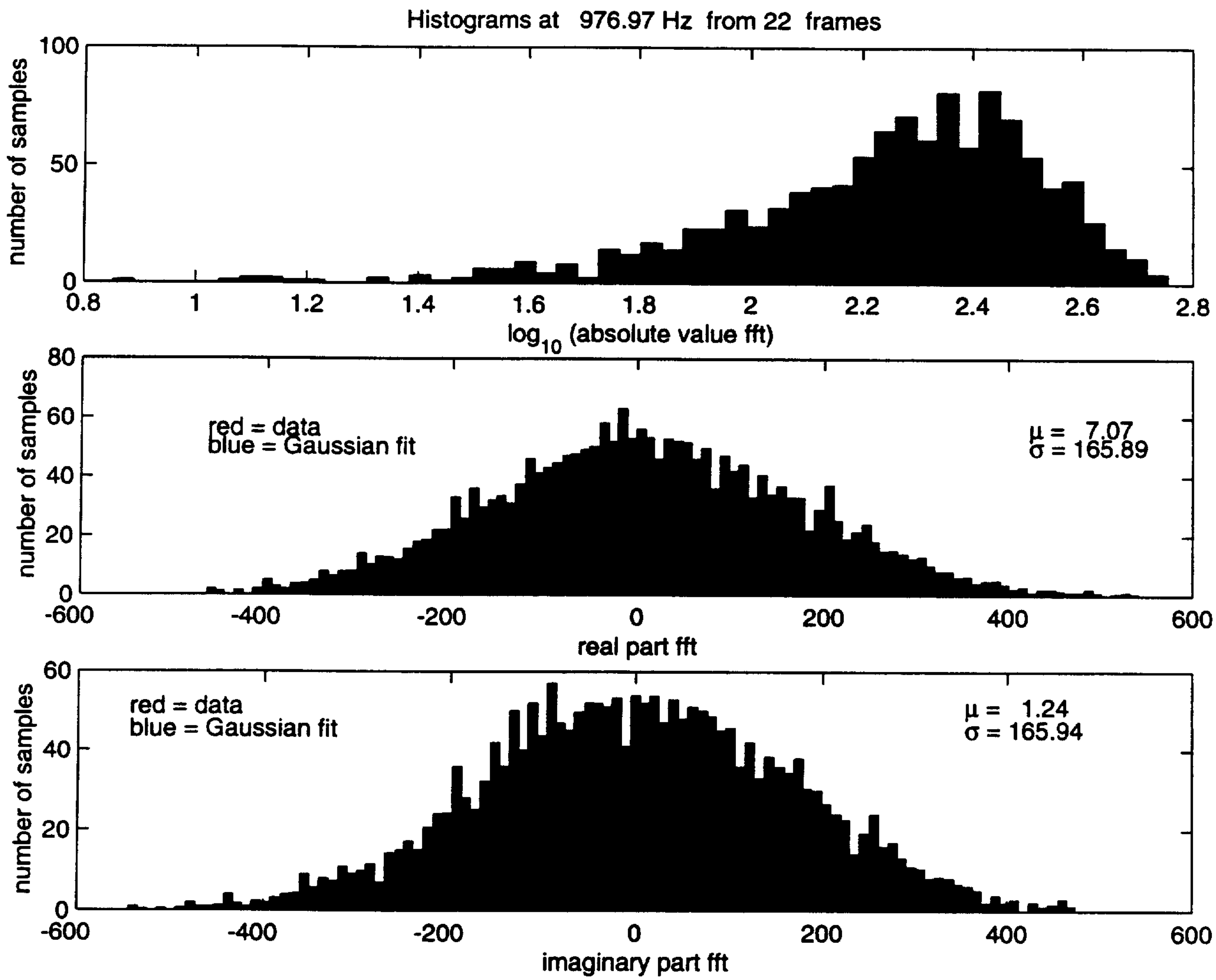
Examining frequency mismatch
Annealing

Noise scaling with sample length
Averaging techniques
(Establishing confidence techniques)
A-D uniformity.

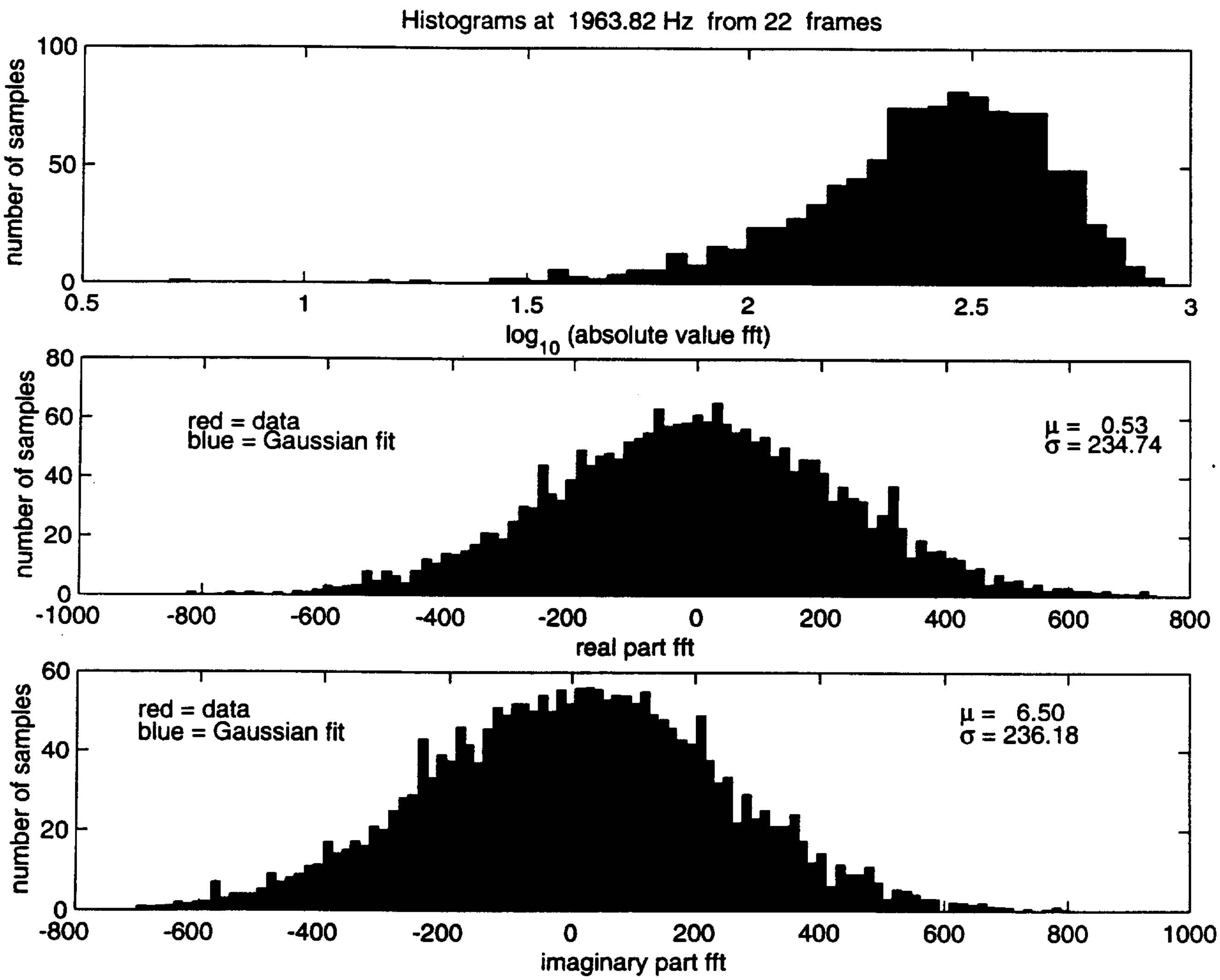
Spectral Uniformity
Line Interference
FFT time vs length
Digital filtering / smoothing
Distribution diversity.

SPECTRAL UNIFORMITY

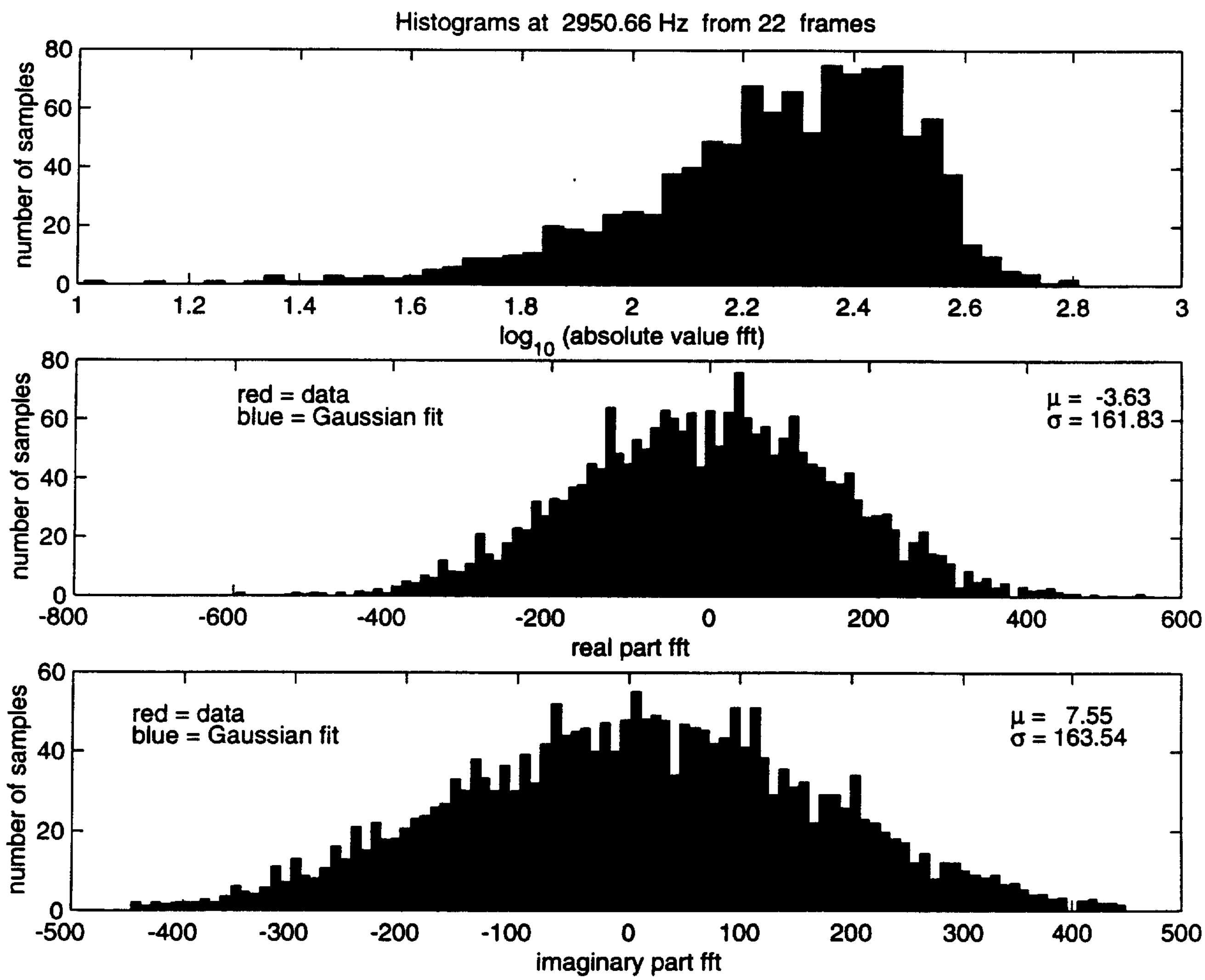


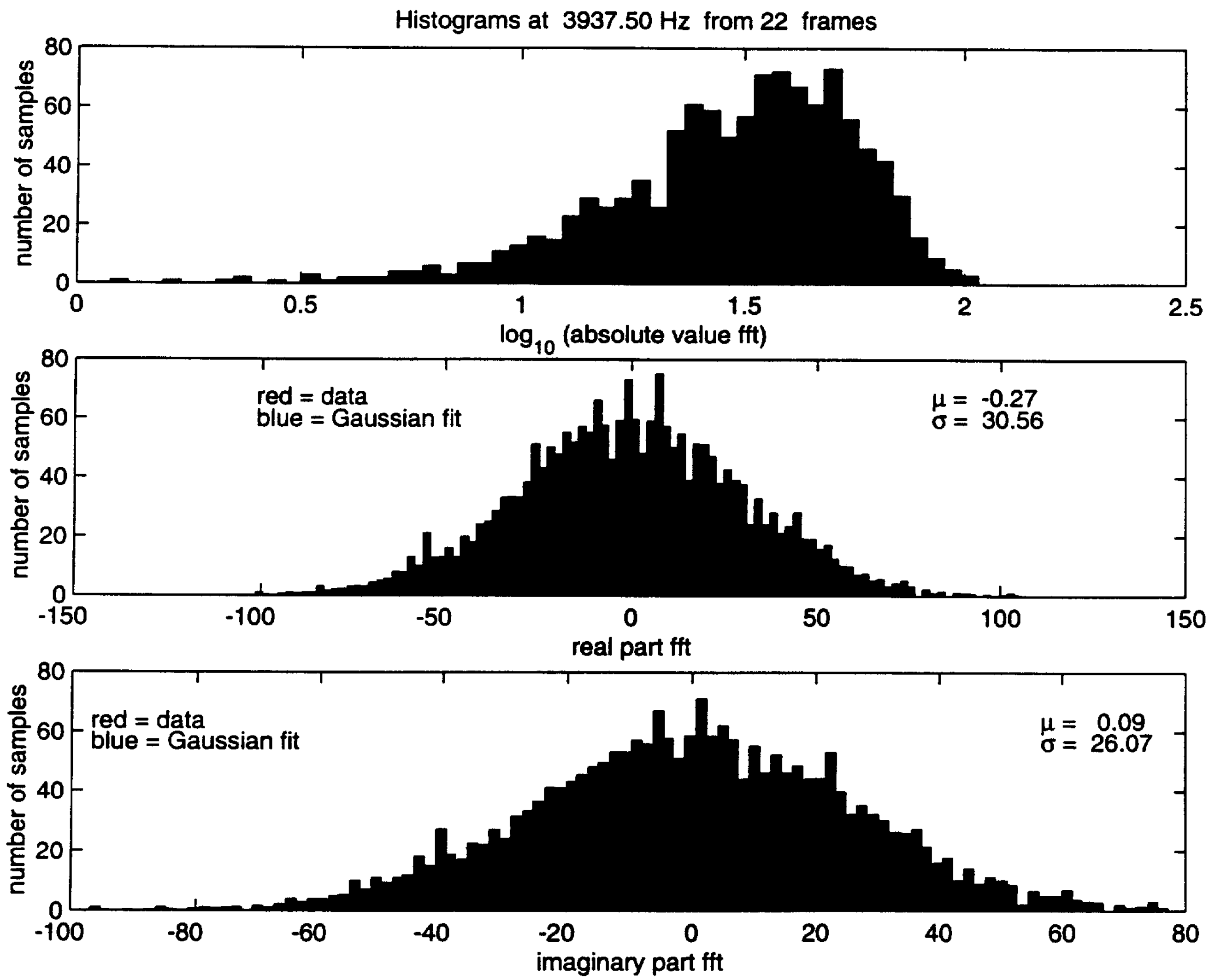


Histograms at 976.97 Hz from 22 frames
number of samples
log$_{10}$ (absolute value fft)
red = data
blue = Gaussian fit
μ = 7.07
σ = 165.89
real part fft
red = data
blue = Gaussian fit
μ = 1.24
σ = 165.94
imaginary part fft

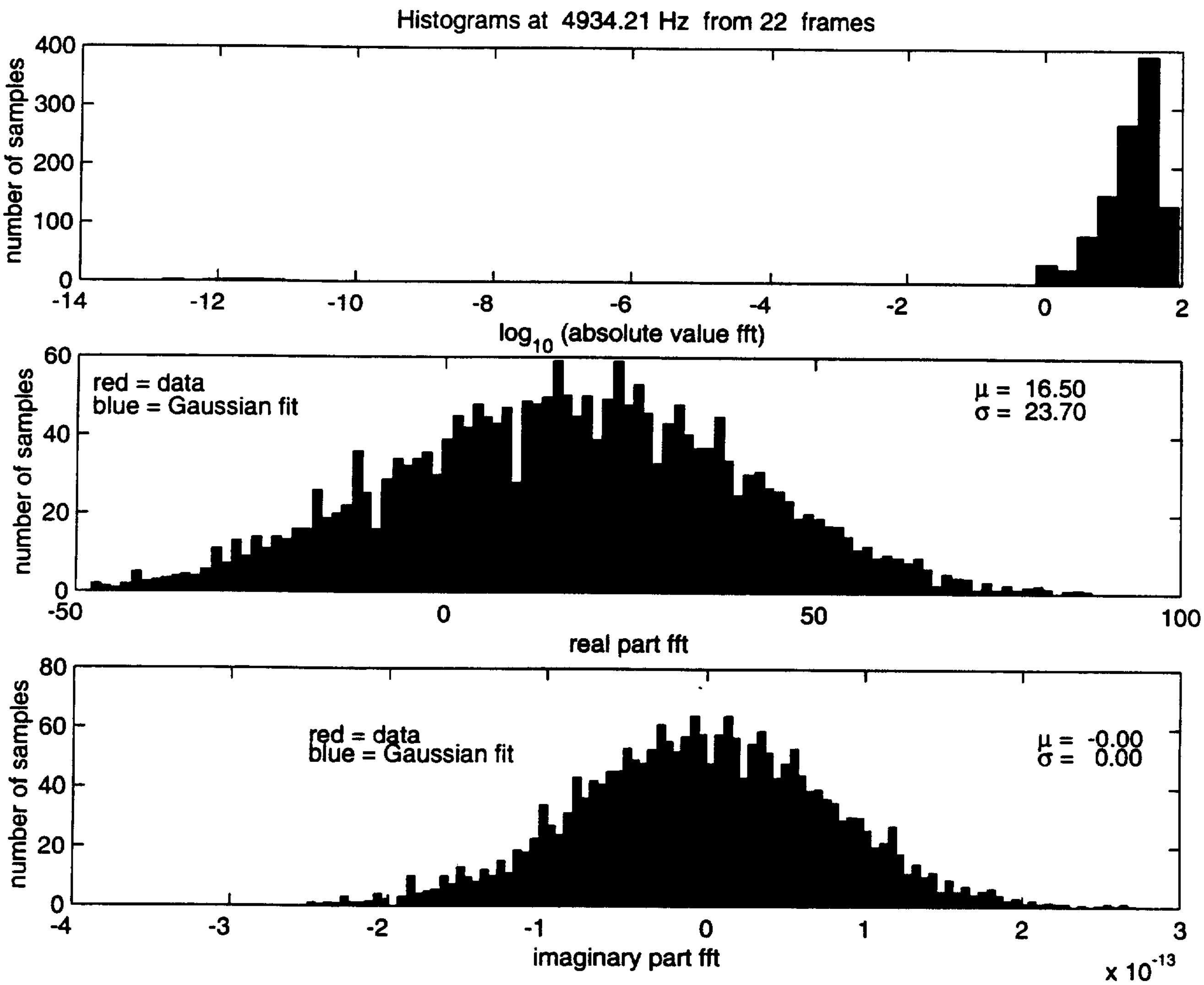


Histograms at 1963.82 Hz from 22 frames
number of samples
log10 (absolute value fft)
red = data
blue = Gaussian fit
μ = 0.53
σ = 234.74
real part fft
red = data
blue = Gaussian fit
μ = 6.50
σ = 236.18
imaginary part fft


Histograms at 2950.66 Hz from 22 frames
number of samples
80
60
40
20
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
log10 (absolute value fft)
red = data
blue = Gaussian fit
μ = -3.63
σ = 161.83
-800
-600
-400
-200
0
200
400
600
real part fft
red = data
blue = Gaussian fit
μ = 7.55
σ = 163.54
60
-500
-400
-300
-200
-100
0
100
200
300
400
500
imaginary part fft

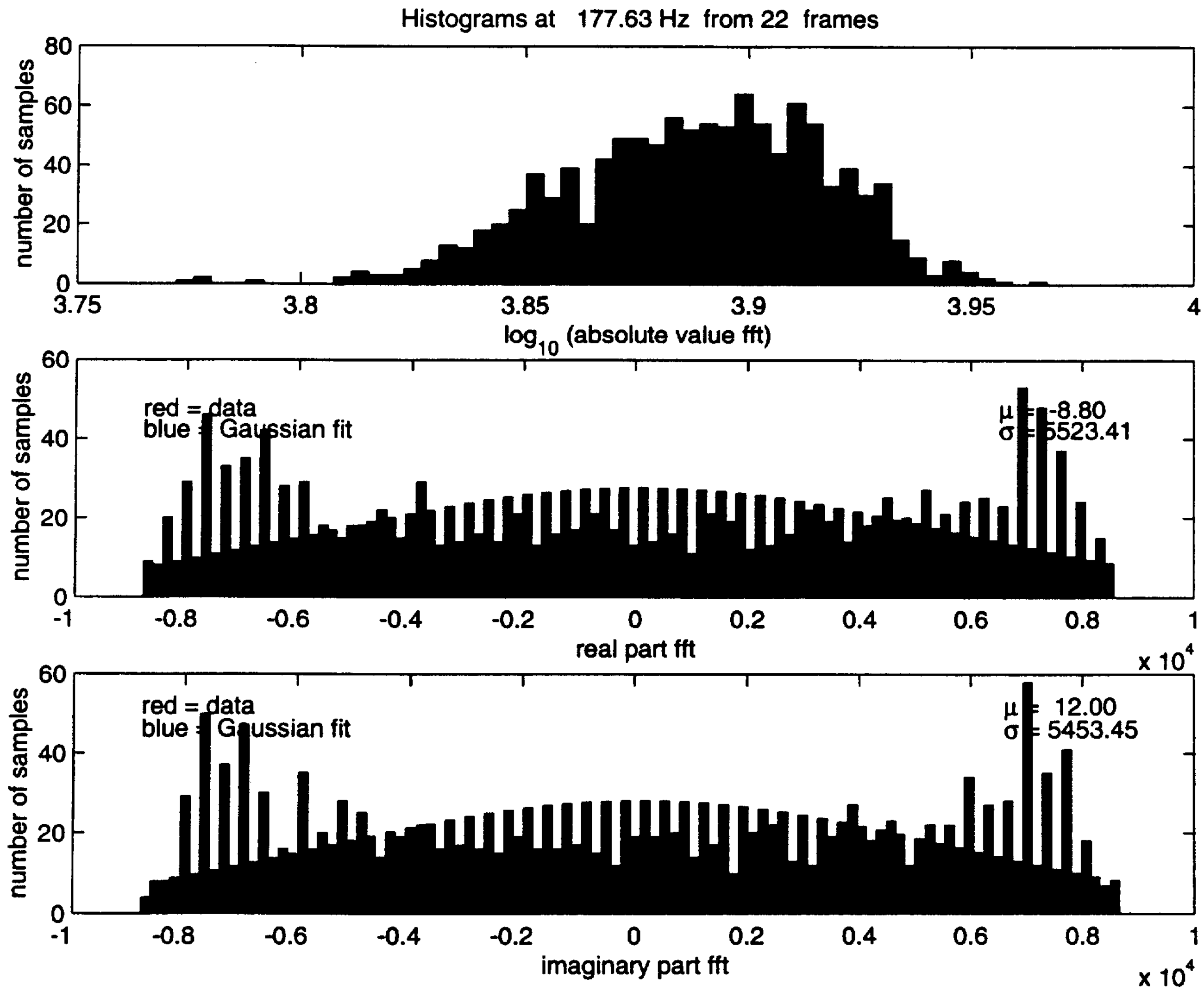


Histograms at 3937.50 Hz from 22 frames
number of samples
log10 (absolute value fft)
red = data
blue = Gaussian fit
μ = -0.27
σ = 30.56
real part fft
red = data
blue = Gaussian fit
μ = 0.09
σ = 26.07
imaginary part fft



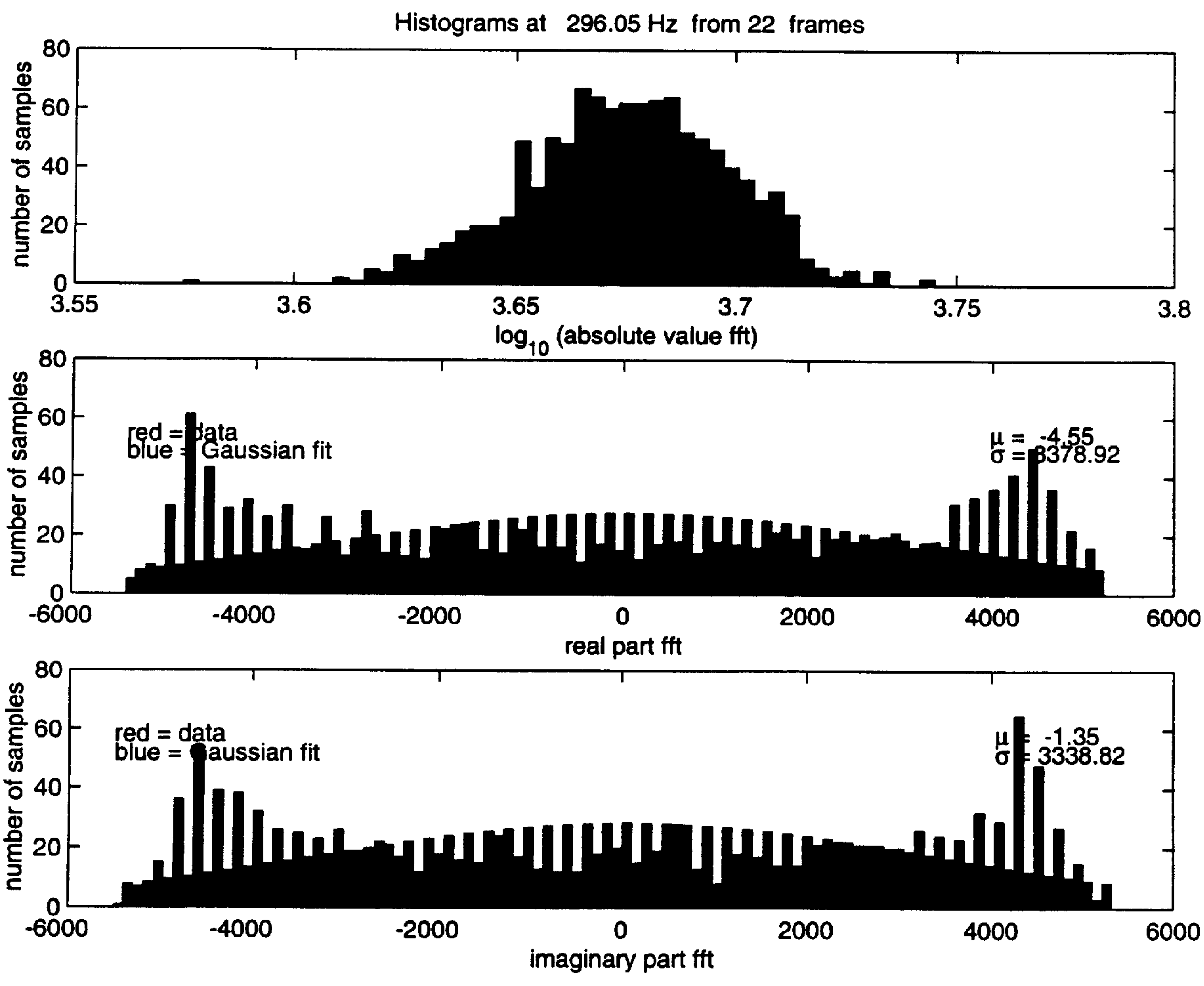
Histograms at 4934.21 Hz from 22 frames
number of samples
400
300
200
100
0
-14
-12
-10
-8
-6
-4
-2
0
2
log10 (absolute value fft)
60
40
20
red = data
blue = Gaussian fit
μ = 16.50
σ = 23.70
-50
50
100
real part fft
80
red = data
blue = Gaussian fit
μ = -0.00
σ = 0.00
-3
-1
1
3
imaginary part fft
x 10^-13

LINE INTERFERENCE NOISE (180 Hz)

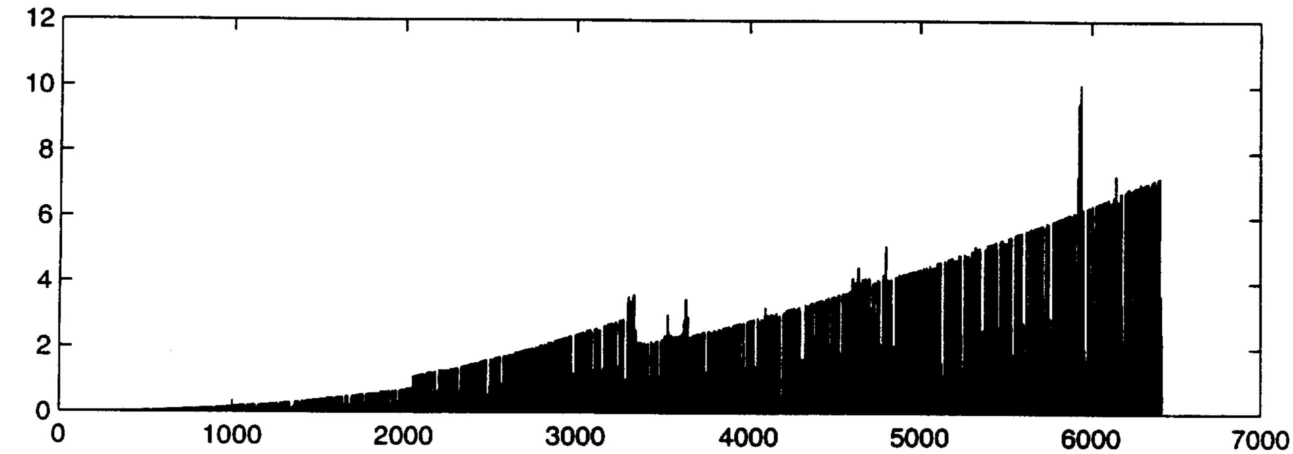


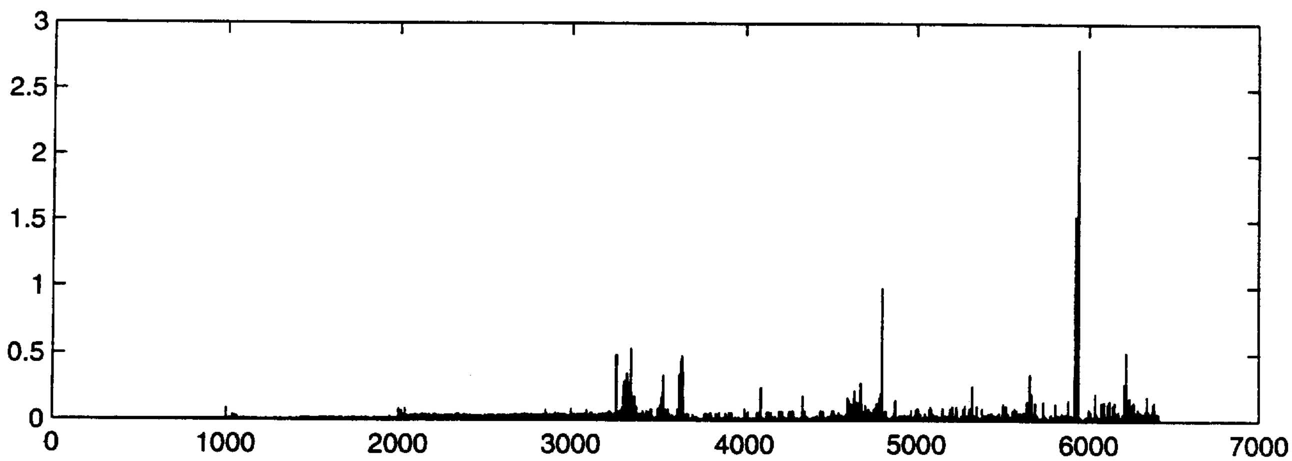
WISH TO RE-EXAMINE AFTER LINE REMOVAL!

LINE INTERFERENCE NOISE (300 Hz)



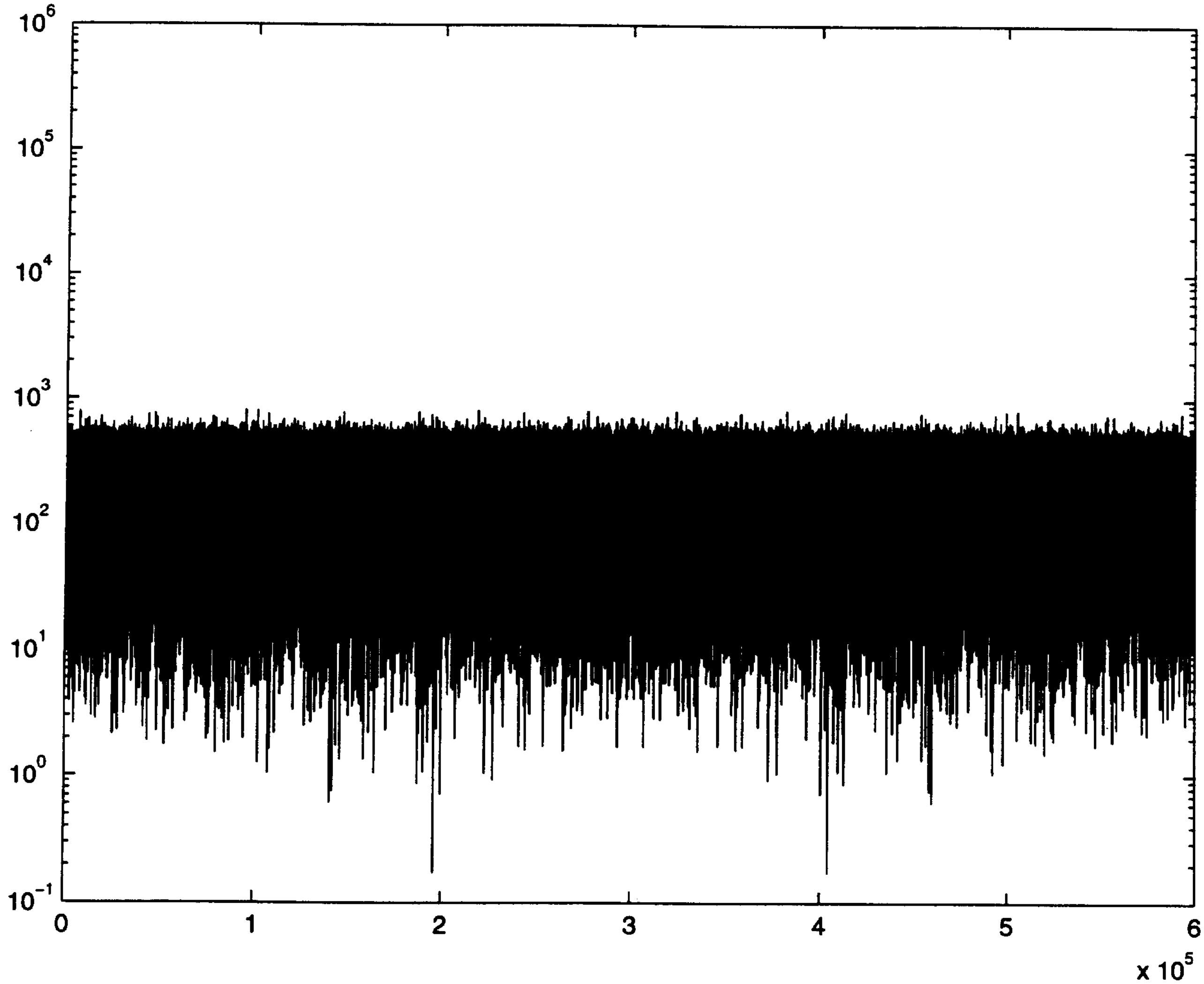
TRANSFORM LENGTH vs FFT TIME

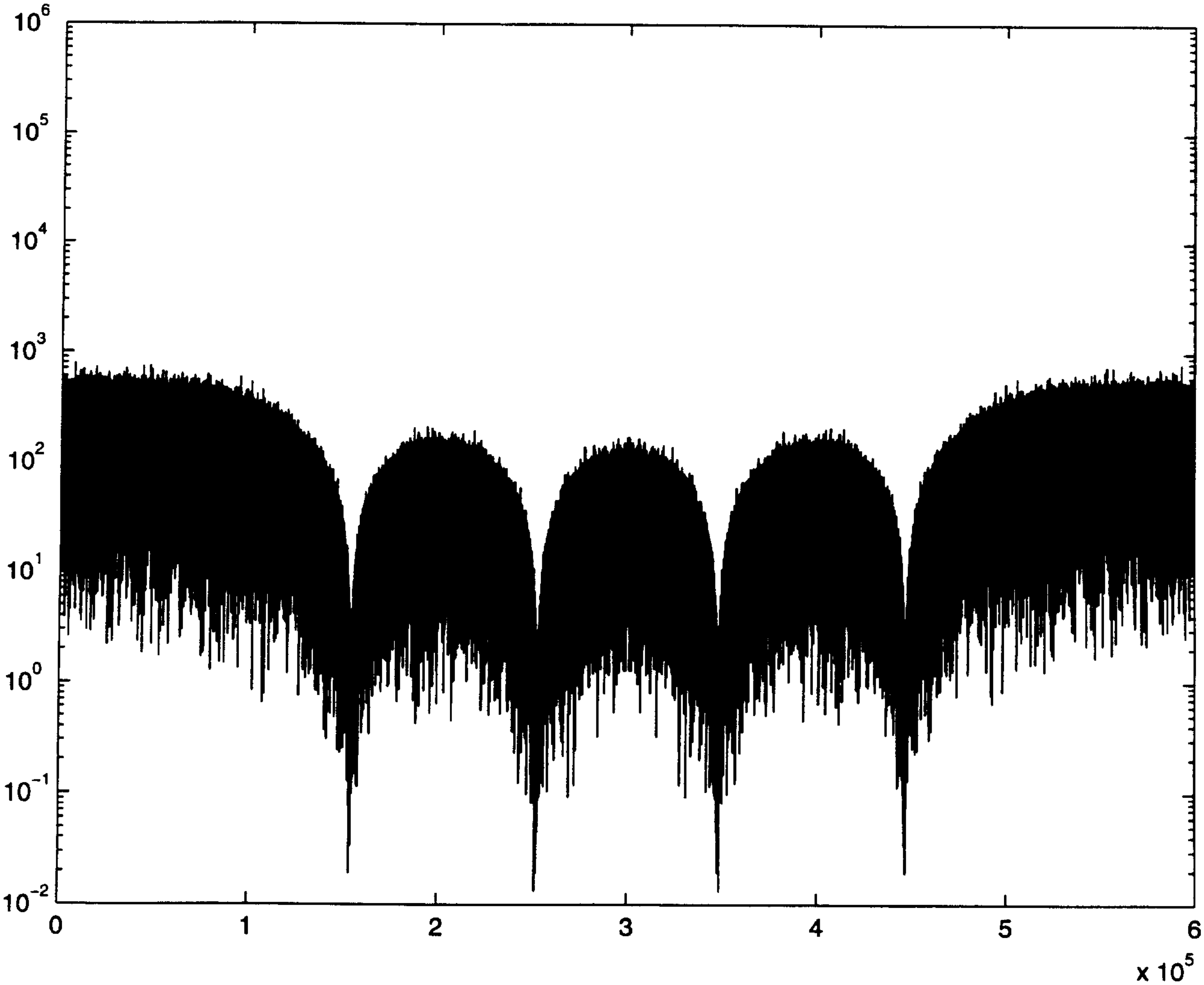




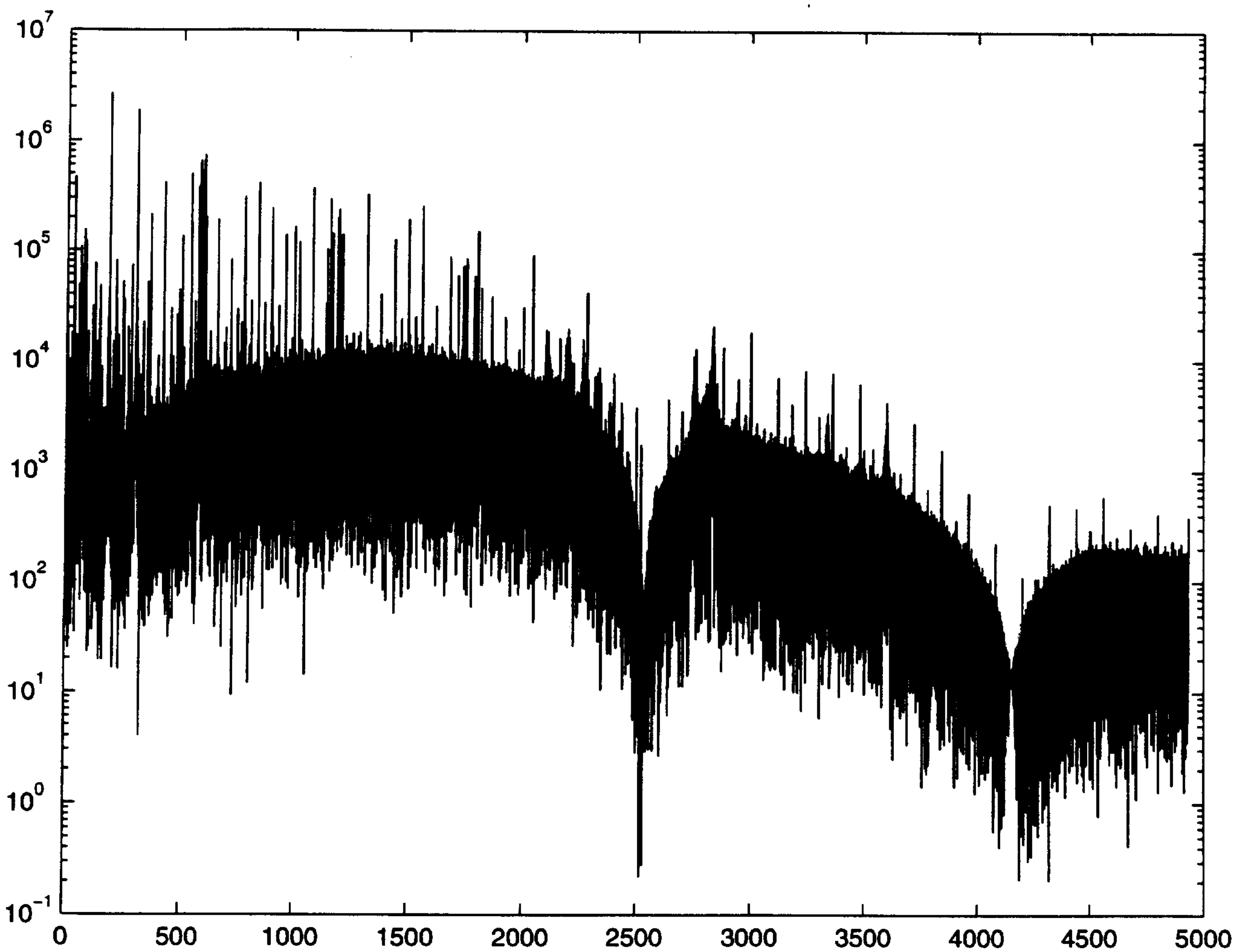
EFFICIENT METHODS FOR MANY FACTORS!

DIGITAL FILTERING / SMOOTHING



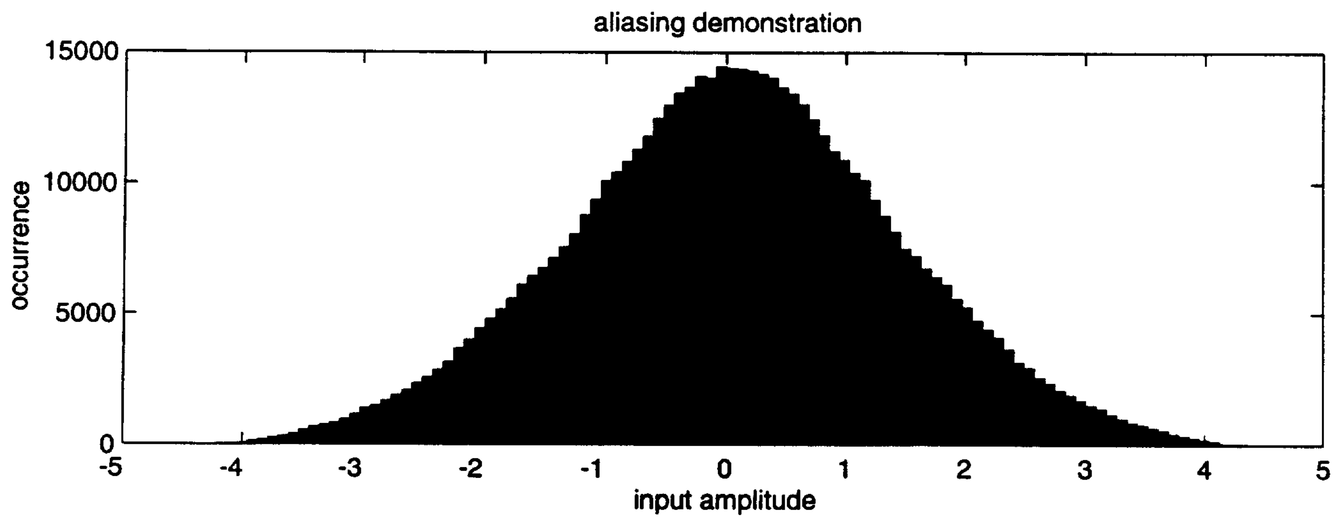


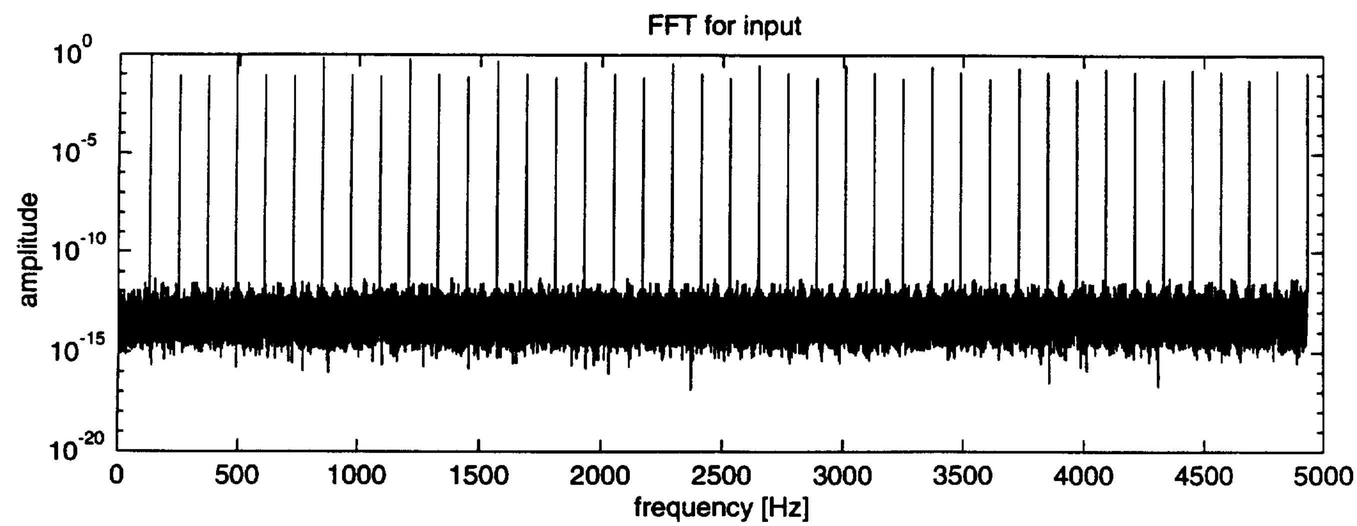
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
0
1
2
3
4
5
6
x 10^5

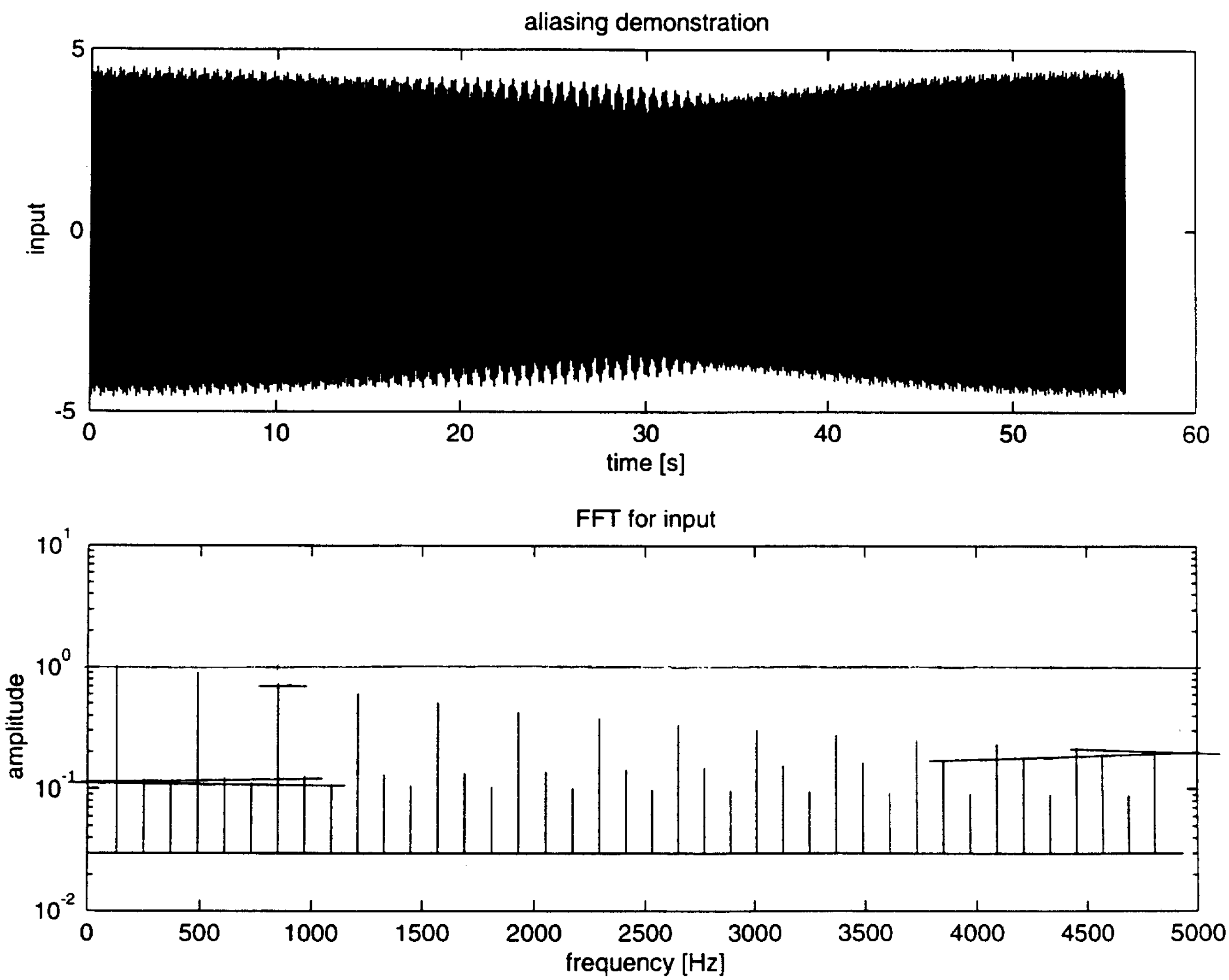


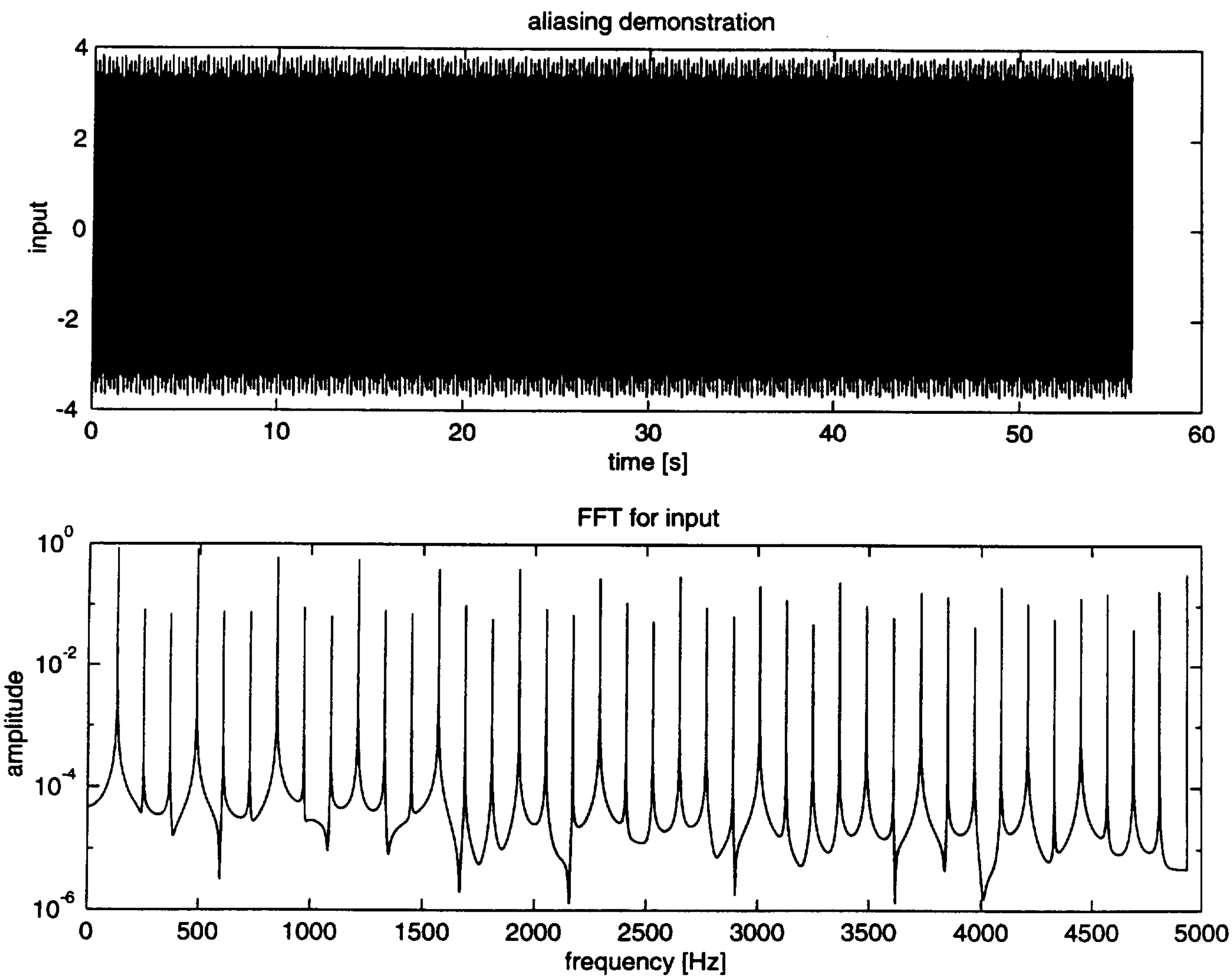
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

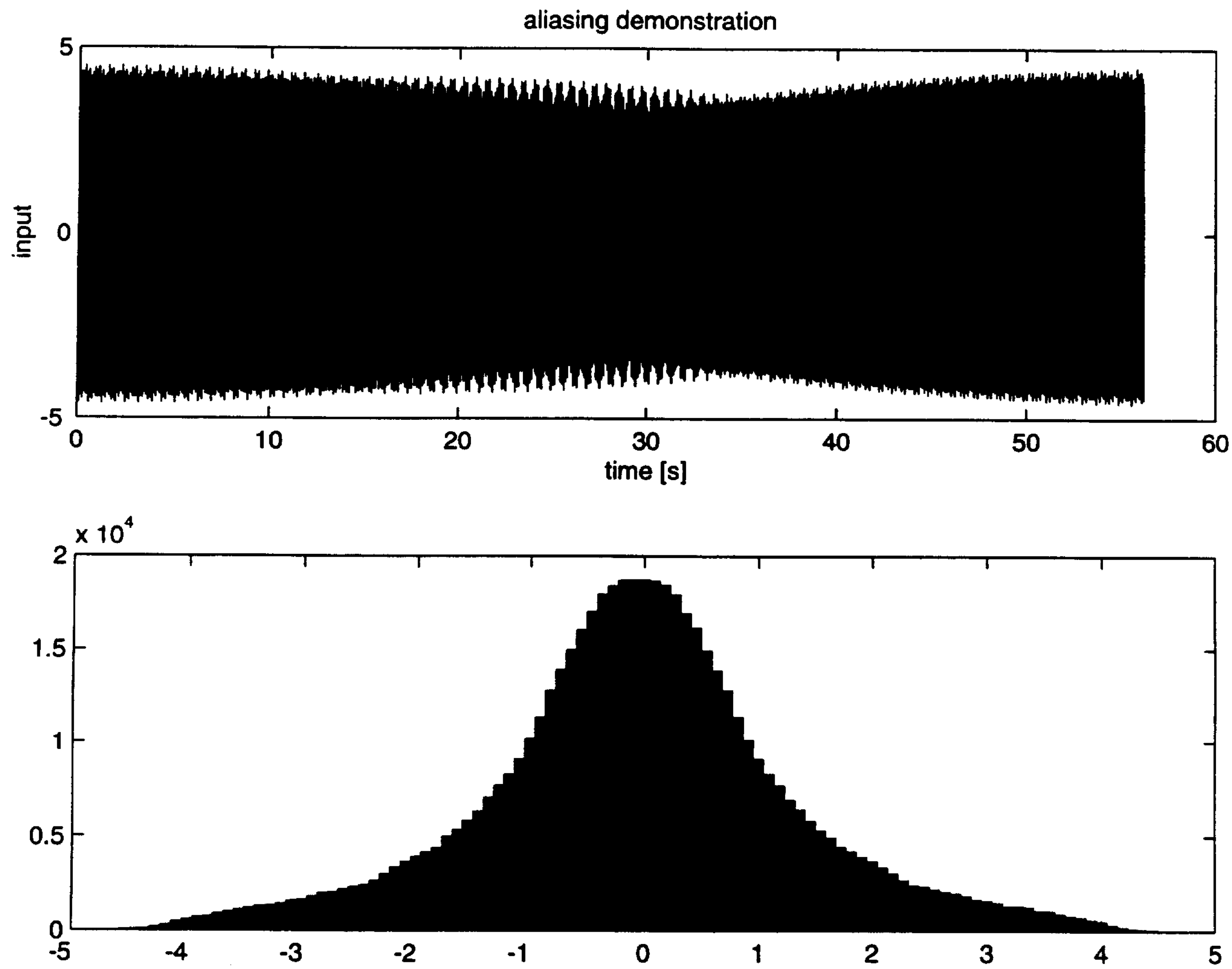
DISTRIBUTION DIVERSITY



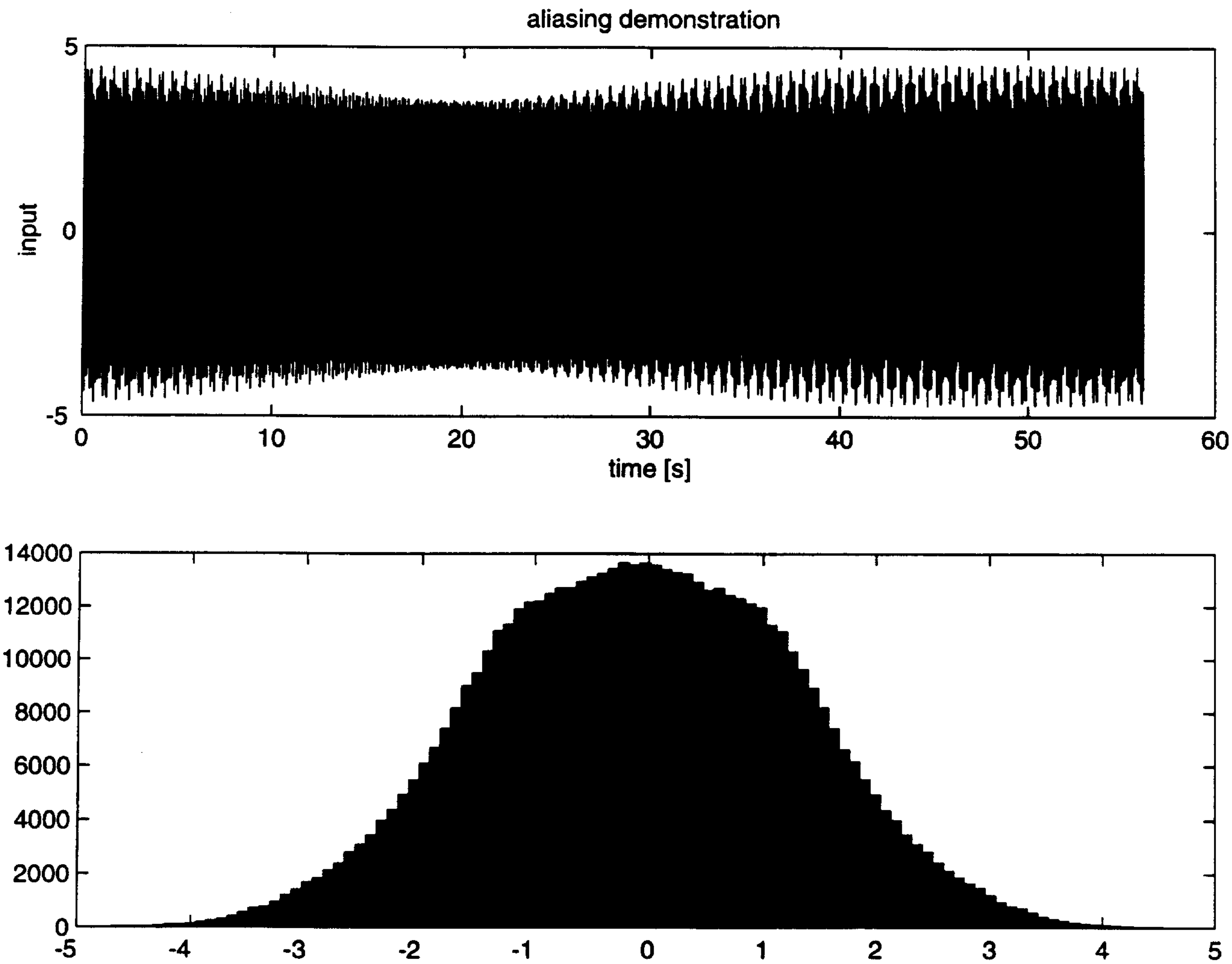


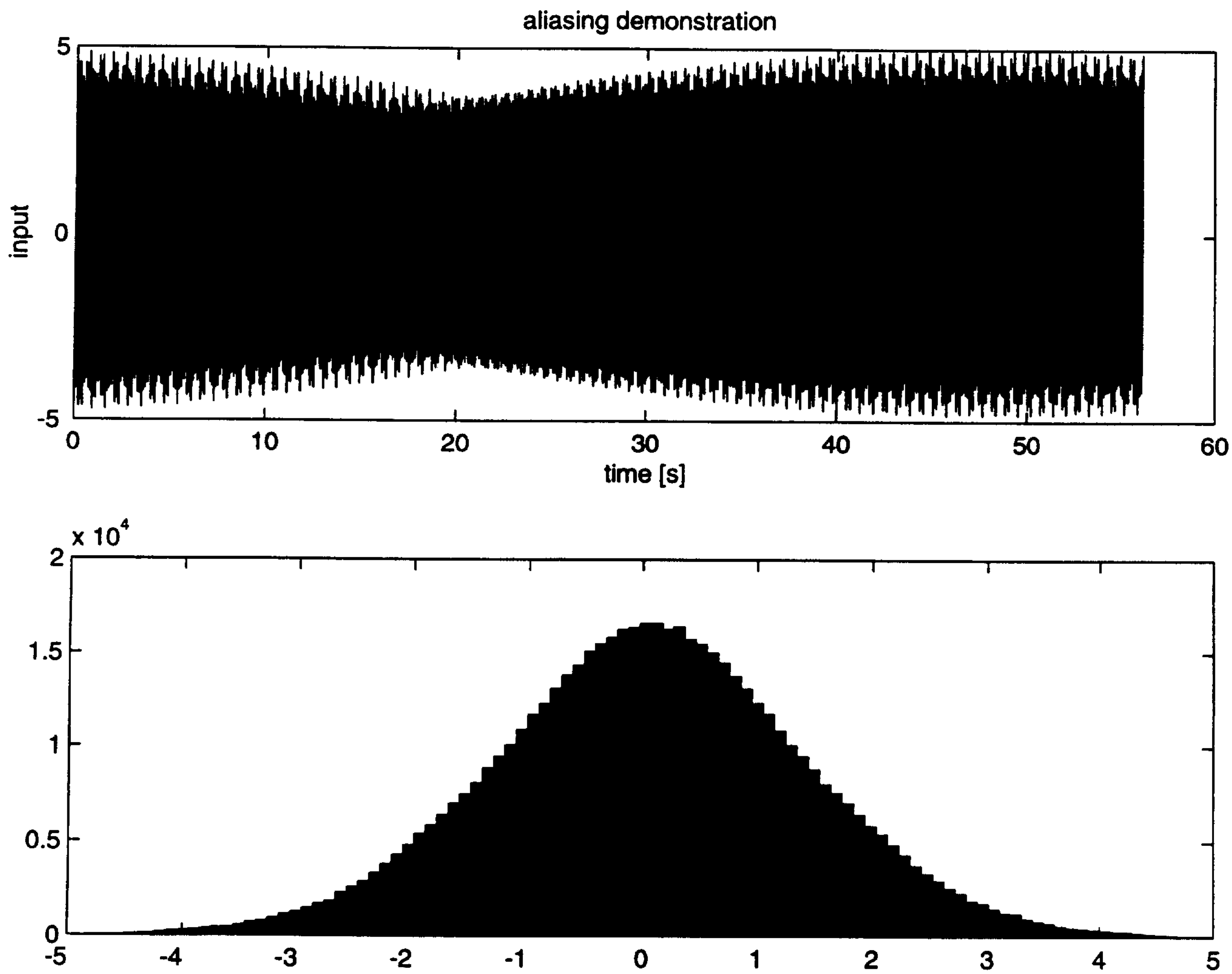

aliasing demonstration
5
0
-5
input
0
10
20
30
40
50
60
time [s]
FFT for input
10^1
10^0
10^-1
10^-2
amplitude
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
frequency [Hz]

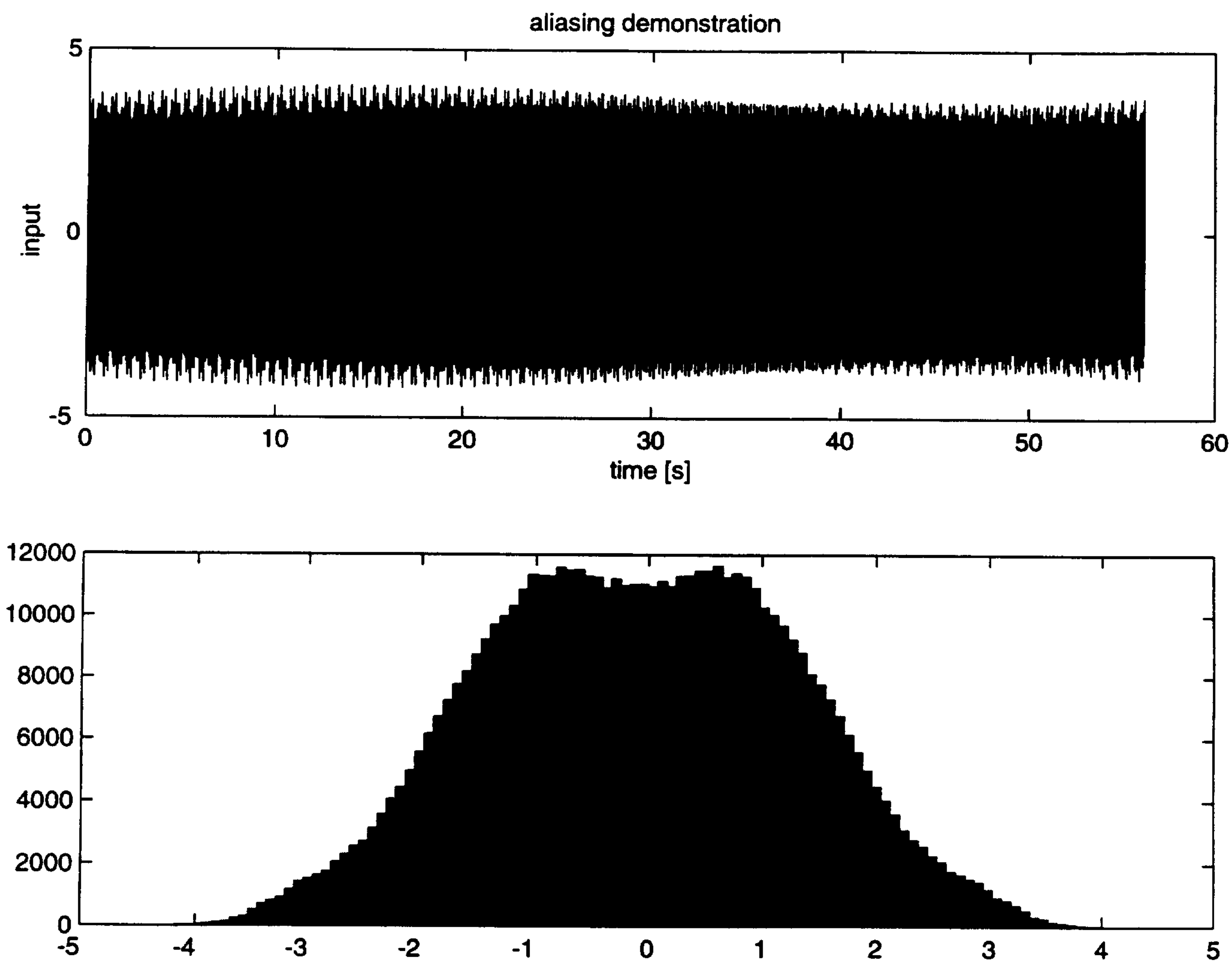

aliasing demonstration
input
time [s]
FFT for input
amplitude
frequency [Hz]

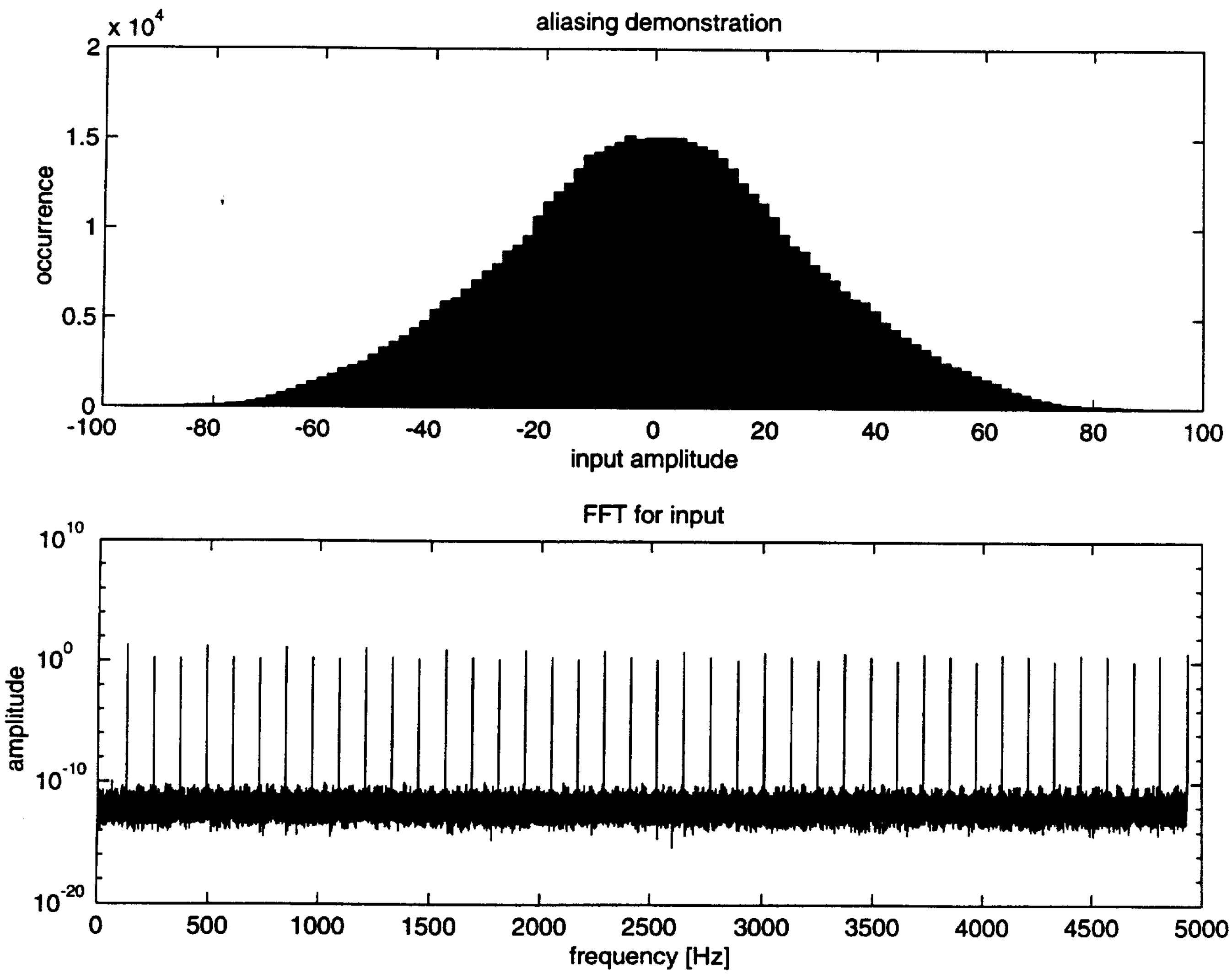


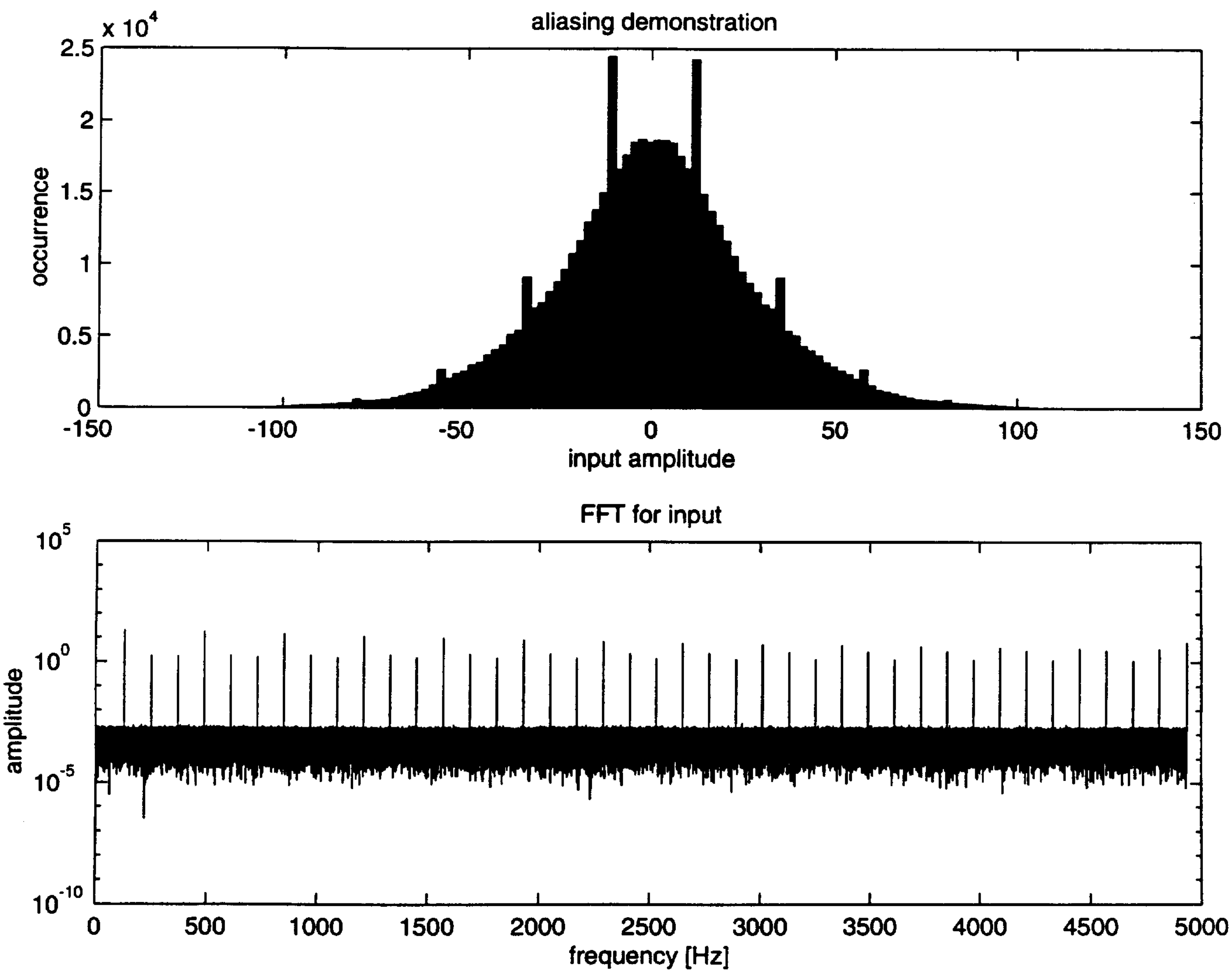
aliasing demonstration
input
time [s]
x 10^4


aliasing demonstration
input
time [s]
5
0
-5
0
10
20
30
40
50
60
14000
12000
10000
8000
6000
4000
2000
0
-5
-4
-3
-2
-1
0
1
2
3
4
5


aliasing demonstration
input
time [s]
x 10^4


aliasing demonstration
5
0
-5
input
0
10
20
30
40
50
60
time [s]
12000
10000
8000
6000
4000
2000
0
-5
-4
-3
-2
-1
0
1
2
3
4
5


aliasing demonstration
x 10^4
occurrence
input amplitude
FFT for input
amplitude
frequency [Hz]



aliasing demonstration
x 10^4
2.5
2
1.5
1
0.5
0
occurrence
-150
-100
-50
0
50
100
150
input amplitude
FFT for input
10^5
10^0
10^-5
10^-10
amplitude
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
frequency [Hz]

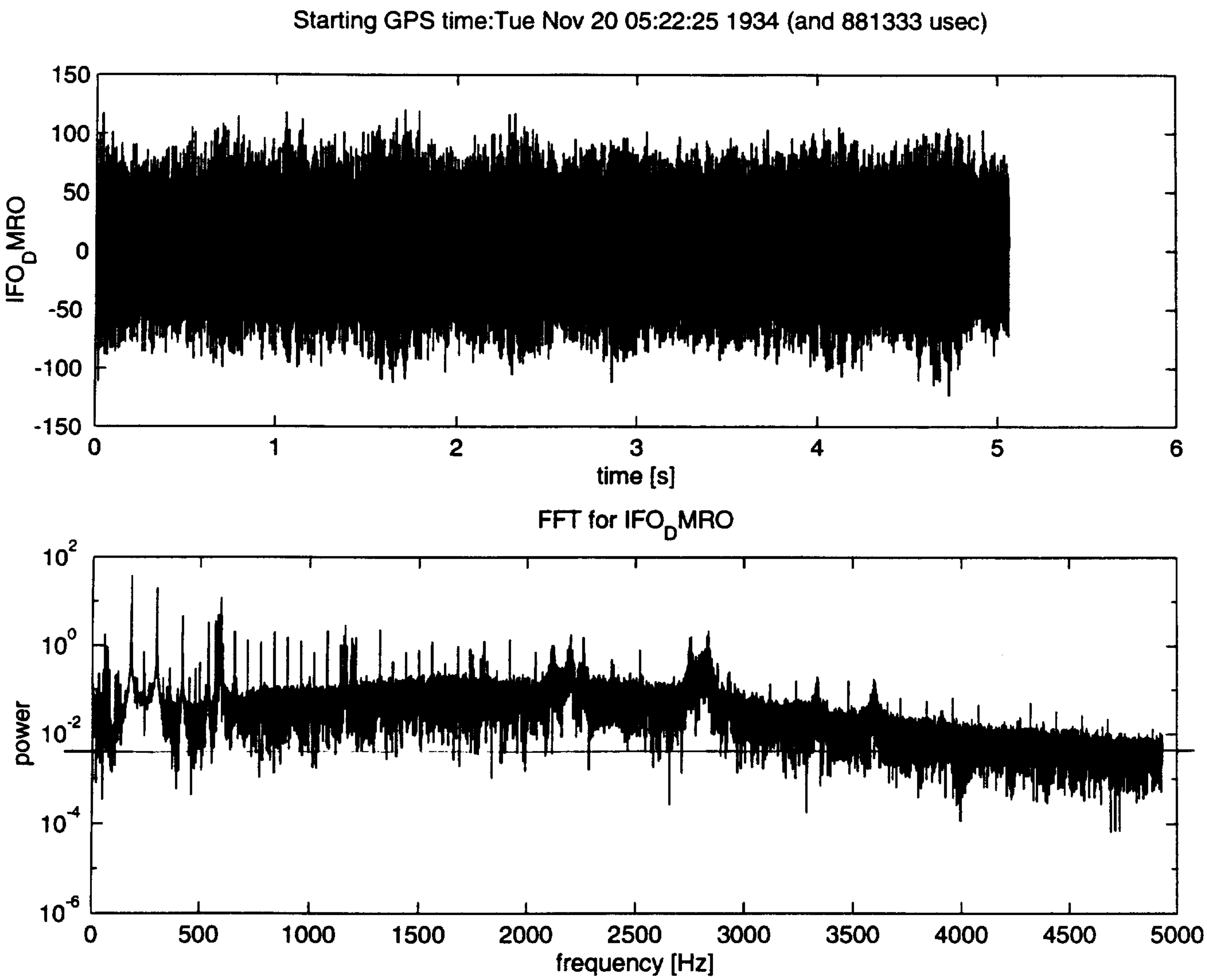
BERNARD WHITING.
(ANU & UF)

DATA ANALYSIS

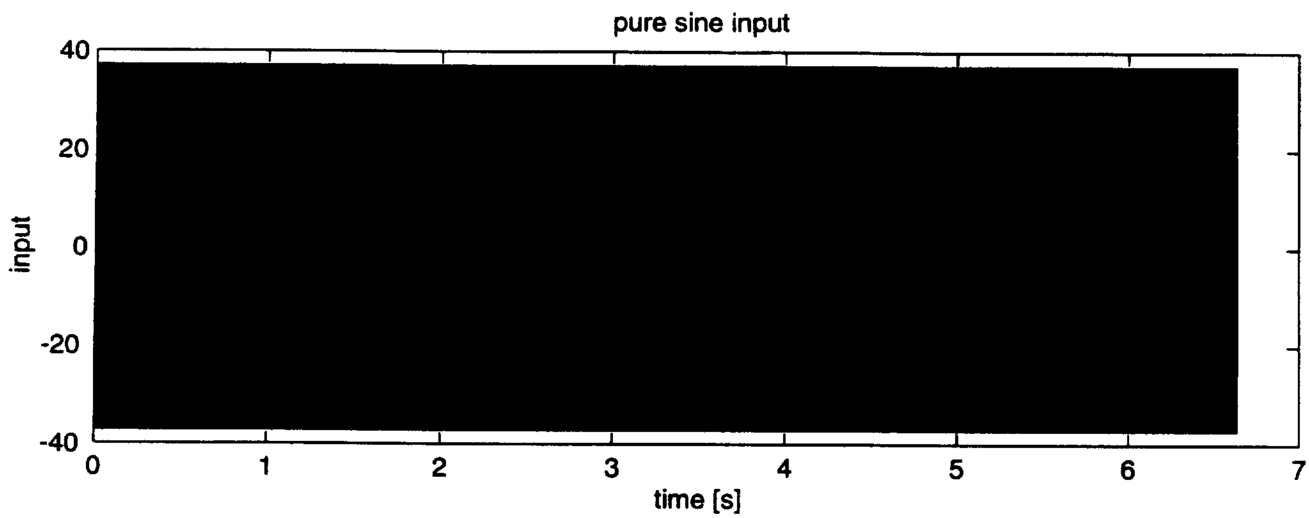
bernard@phys.ufl.edu.

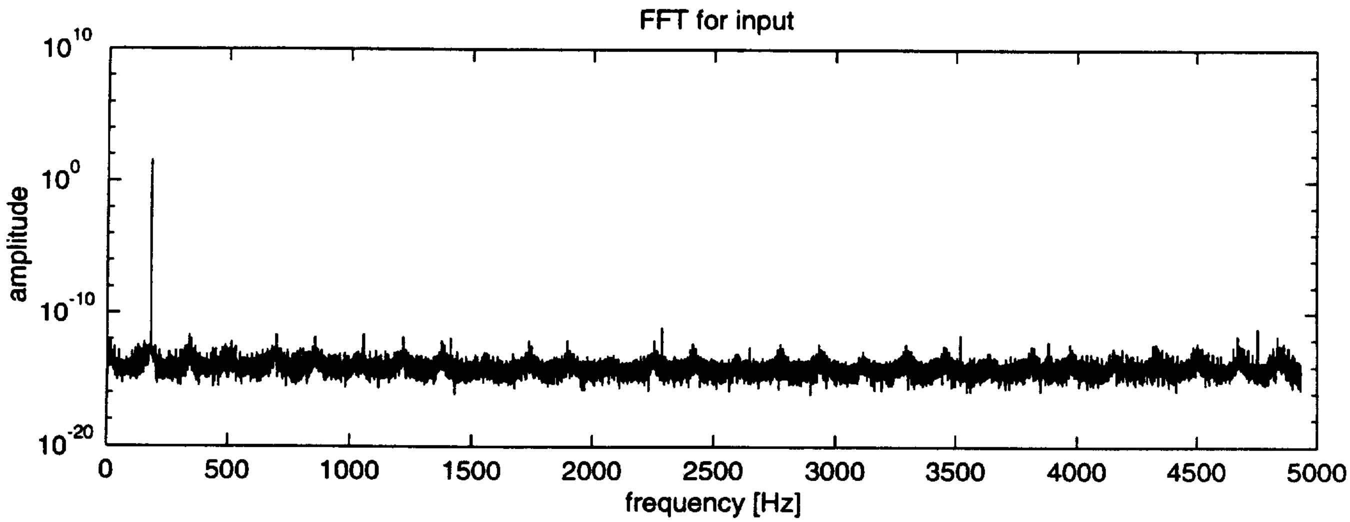
Detector Characterization

EXAMINING 40 METER DATA

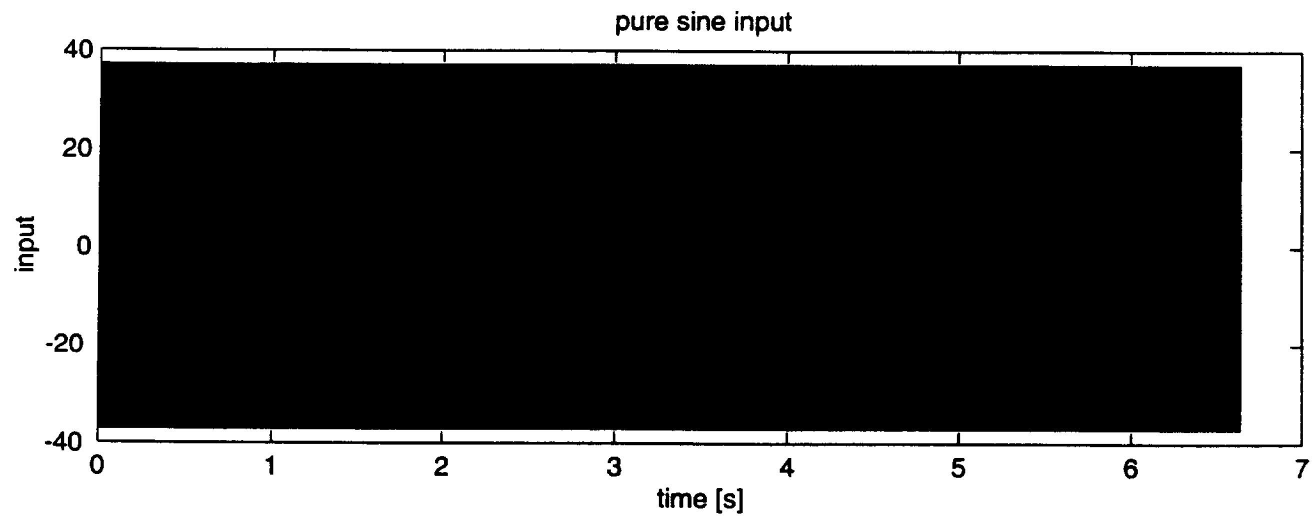


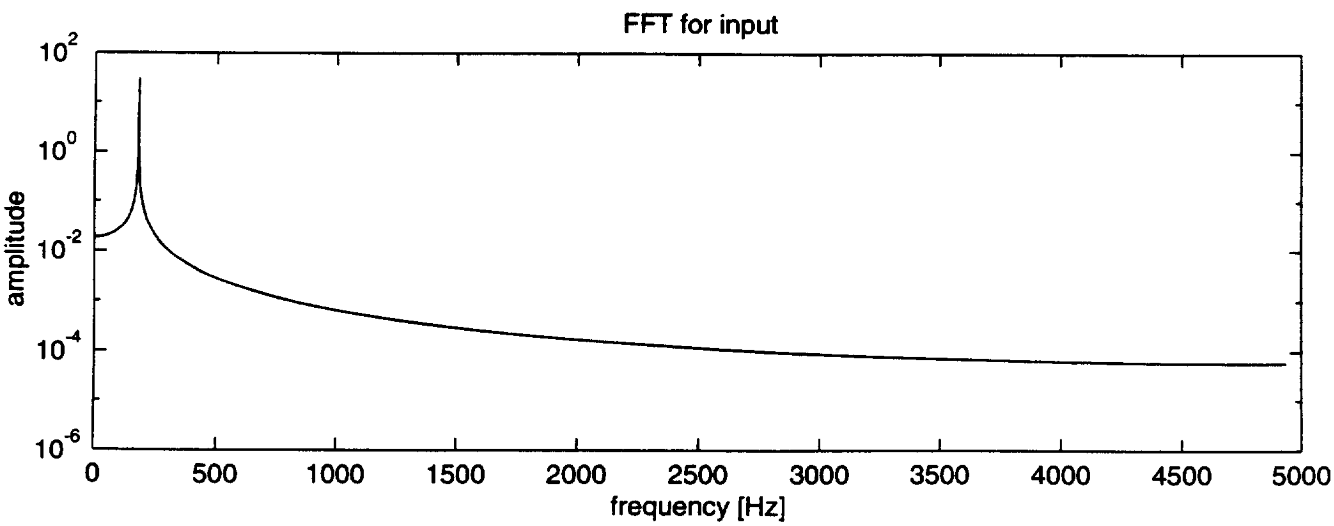
COMPUTATIONAL NOISE





FREQUENCY MISMATCH





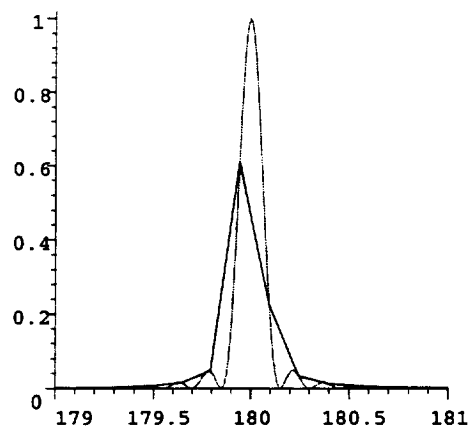
```
> n1:=round(n0);
```

$$n1 := 1195$$

```
> f1:=n1*df;
```

$$f1 := \frac{56015625}{311296}$$

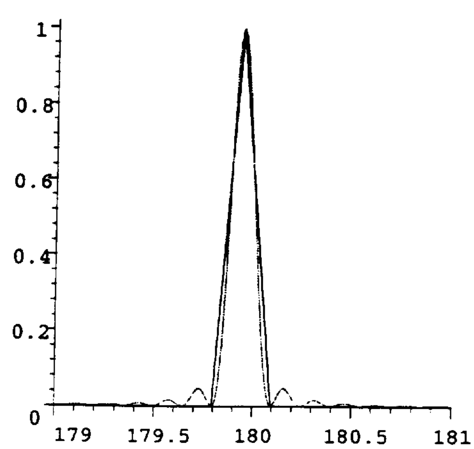
```
> y1:=plot((sin(Pi*(f0-f)/df)/sin(Pi*(f0-f)/sr)/n1)^2,f=179..181):
> with(plots):
> y2:=pointplot([seq([n*df,(sin(Pi*(n0-n))/sin(Pi*(n0-n)/n1)/n1)^2
  ],n=round(179/df)..round(181/df))],style=line):
> y0:={y1,y2}:
> display(y0,insequence=false);
```



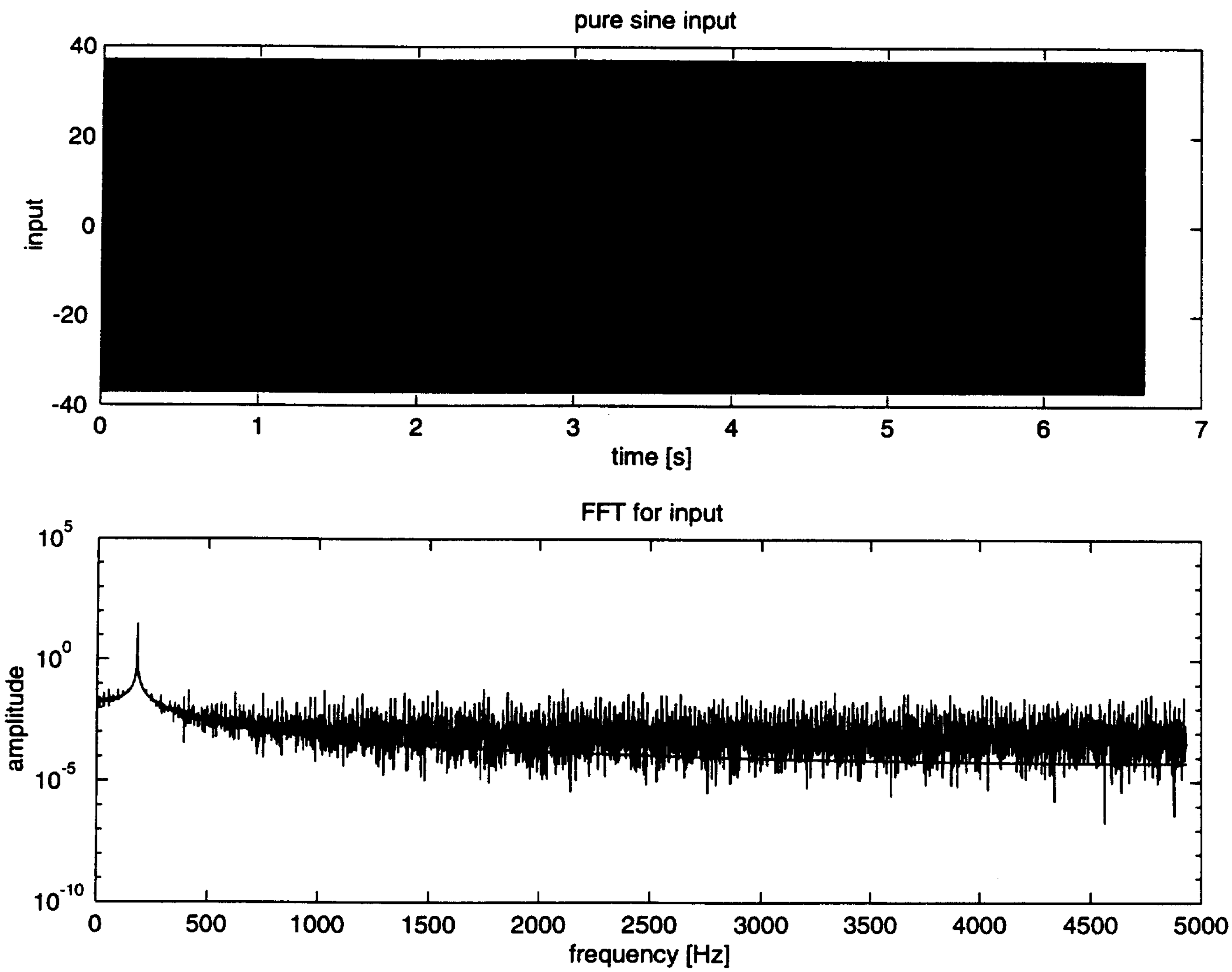

```
> y3:=plot((sin(Pi*(f1-f)/df)/sin(Pi*(f1-f)/sr)/n1)^2,f=179..181):
> y2:=pointplot([seq([n*df,(sin(Pi*(n1-n))/sin(Pi*(n1-n)/n1)/n1)^2
  ],n=round(179/df)..n1-1),[n1*df,1],seq([n*df,(sin(Pi*(n1-n))/sin
  (Pi*(n1-n)/n1)/n1)^2],n=n1+1..round(181/df))],style=line):
```



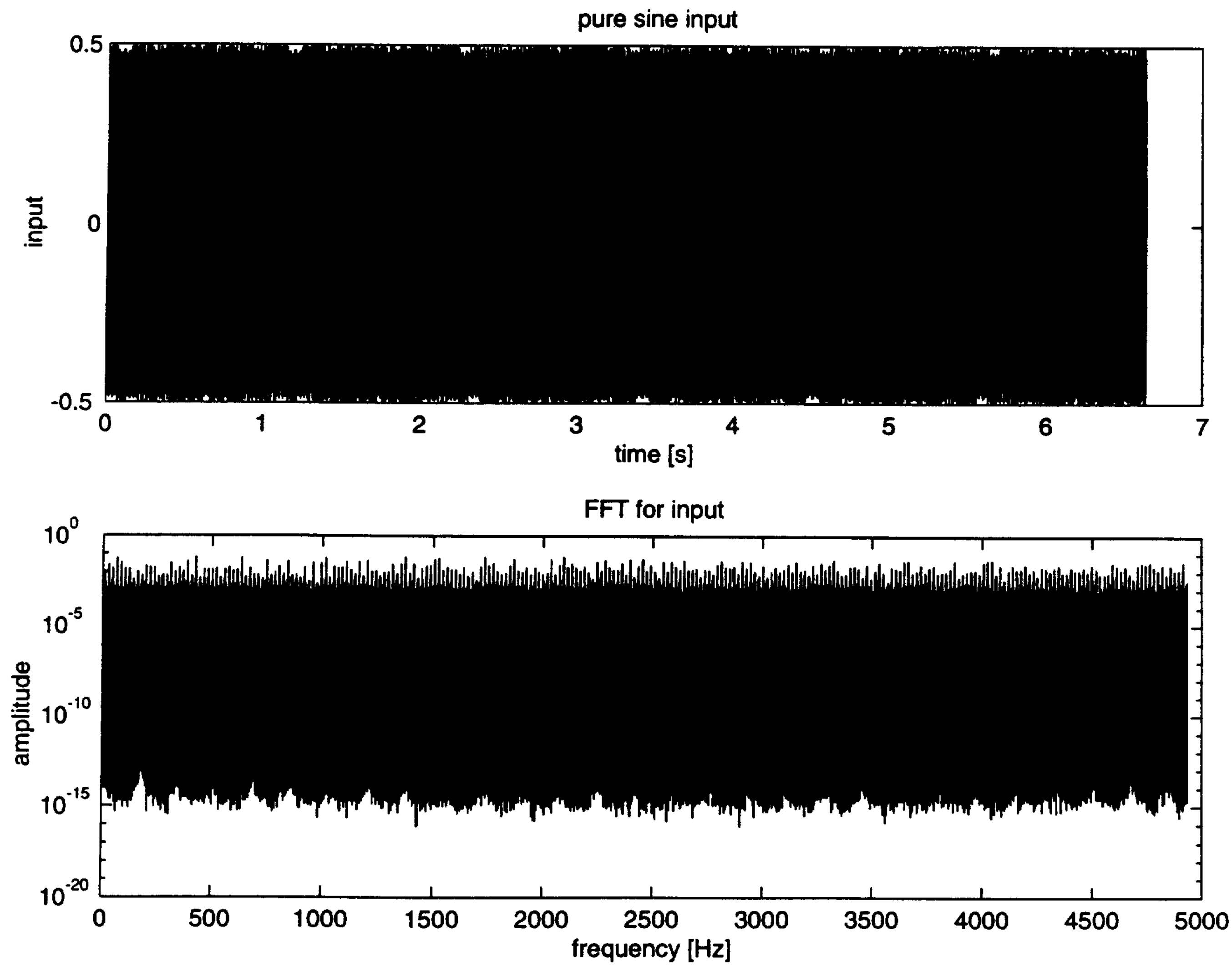
```
> y4:={y2,y3}:
> display(y4,insequence=false);
```



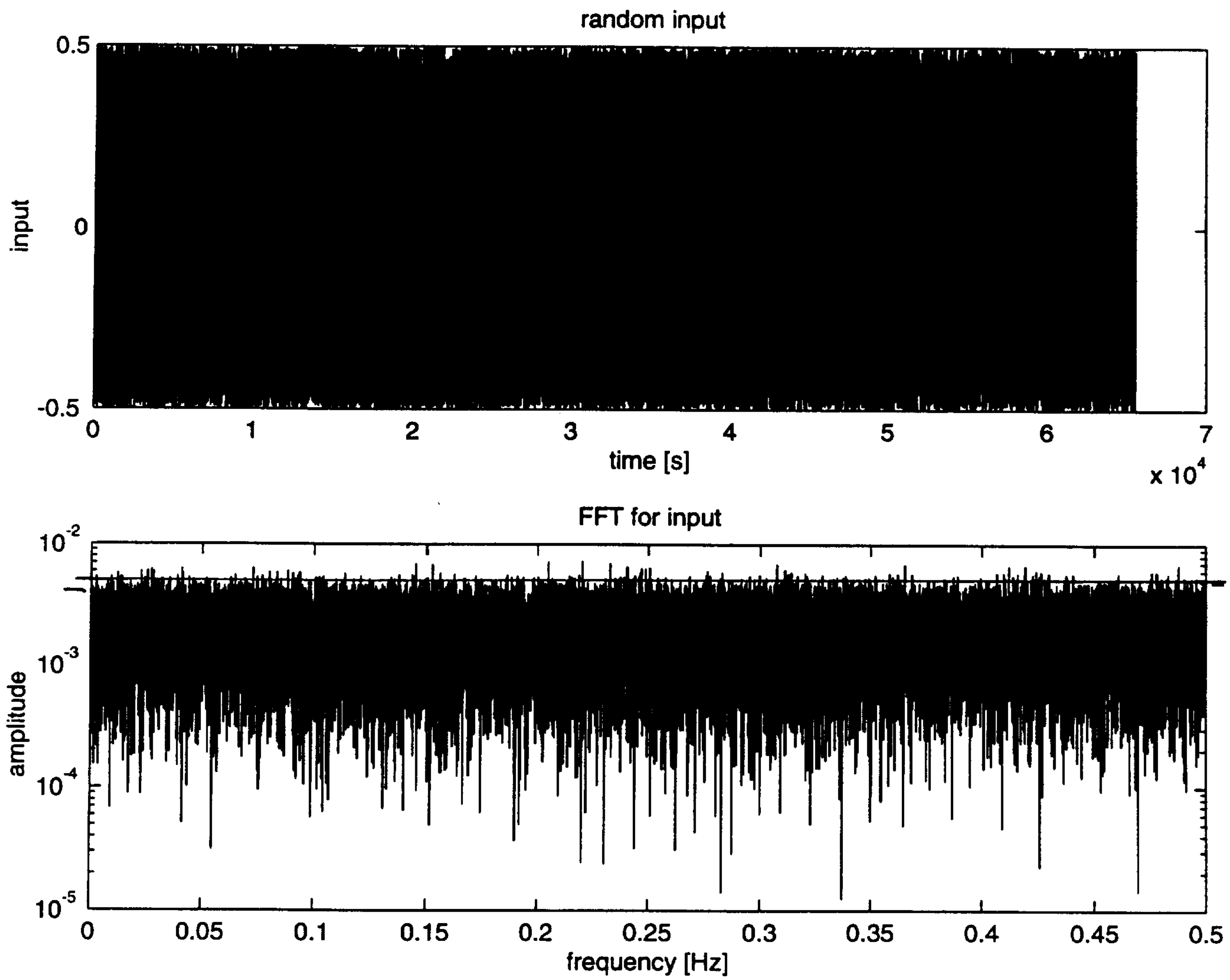
DIGITIZATION NOISE

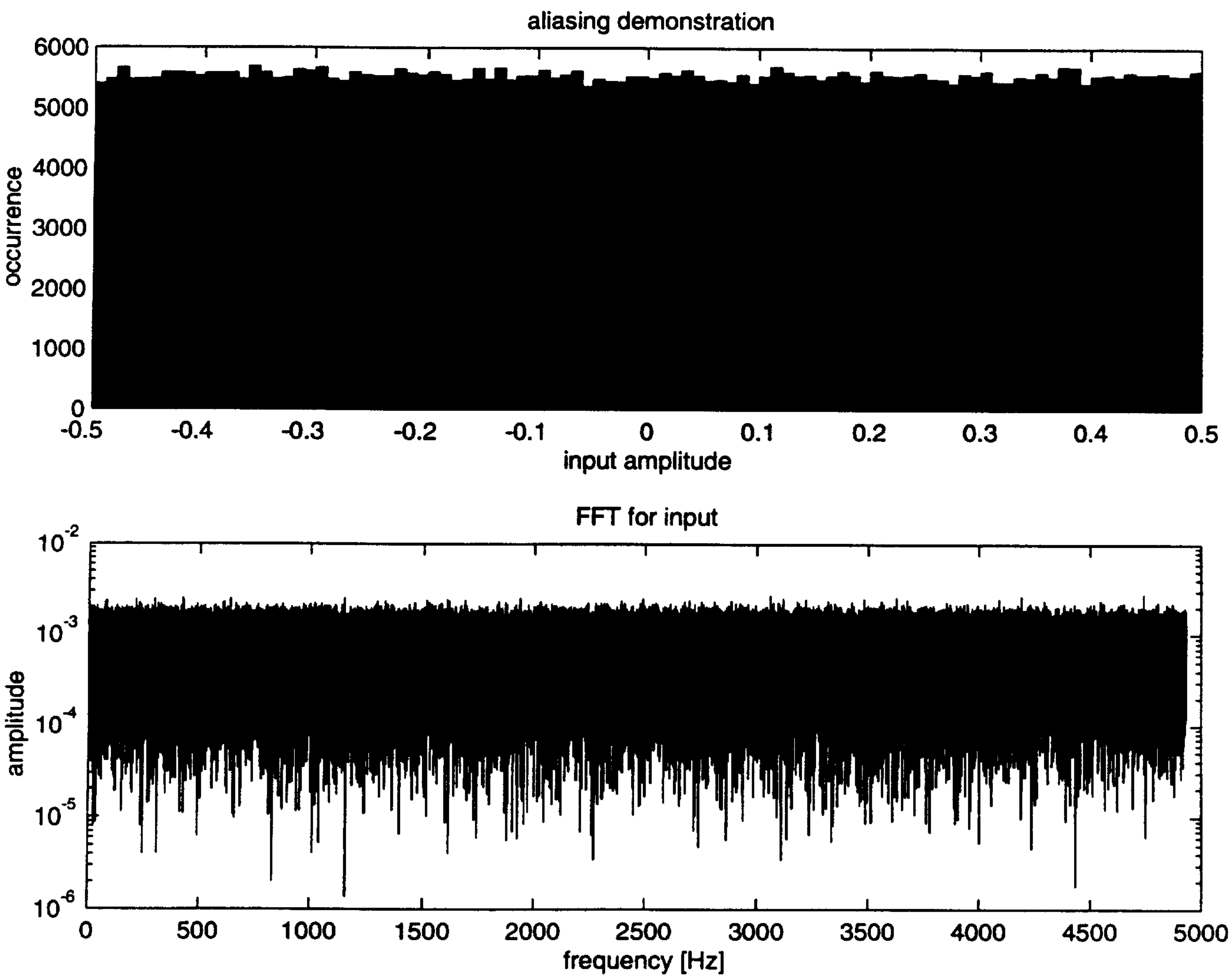


DIGITIZATION NOISE UNIFORMITY



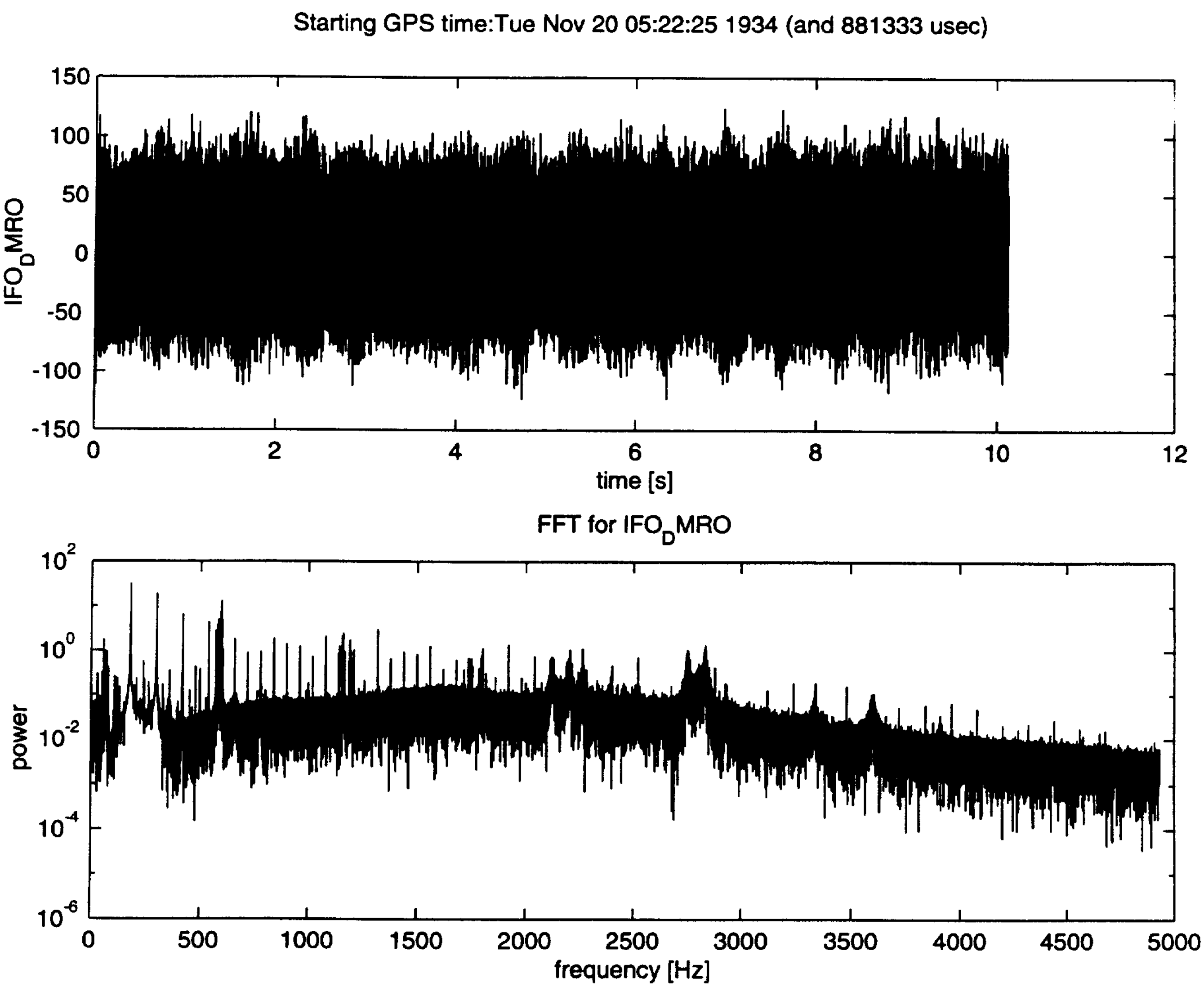
RANDOM NOISE UNIFORMITY



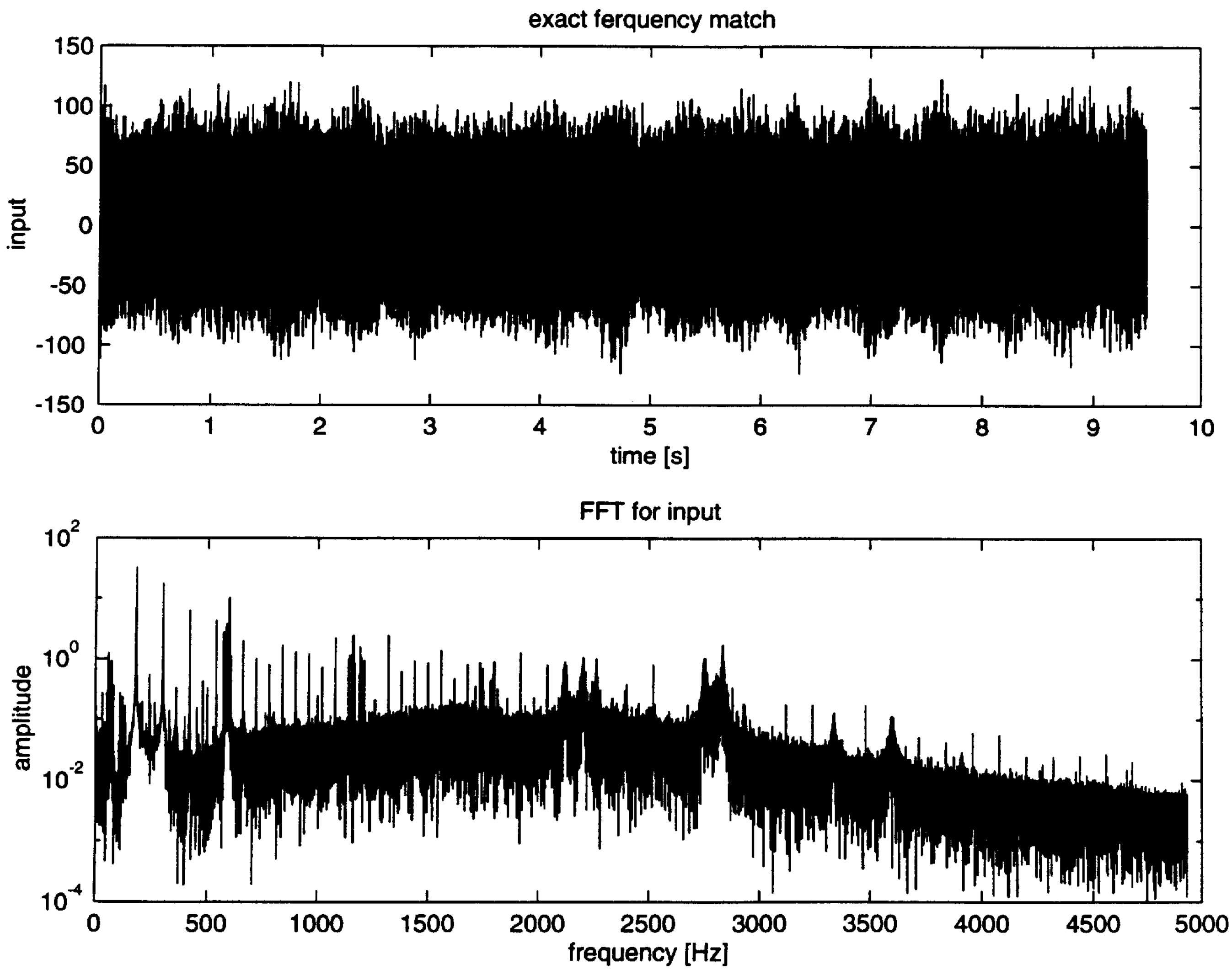


aliasing demonstration
6000
5000
4000
3000
2000
1000
0
occurrence
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
input amplitude
FFT for input
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
amplitude
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
frequency [Hz]

EXAMINING FREQUENCY MISMATCH

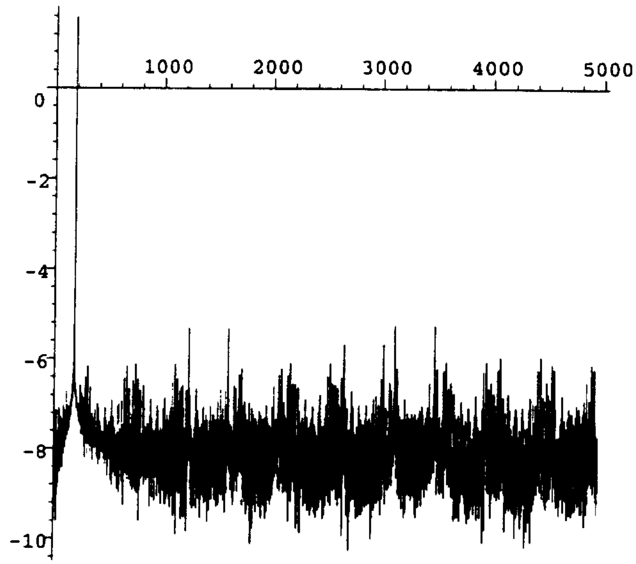


AVOIDING FREQUENCY MISMATCH



$$sqi := i \rightarrow r2_i^{\,2}$$

```
> b2:=vector(nl,sqi):
> rr:=evalm((b1+b2)):
> with(plots):
> pointplot([seq([f0[i],.5*log10(rr[i])],i=1..nl/2)],style=line);
```

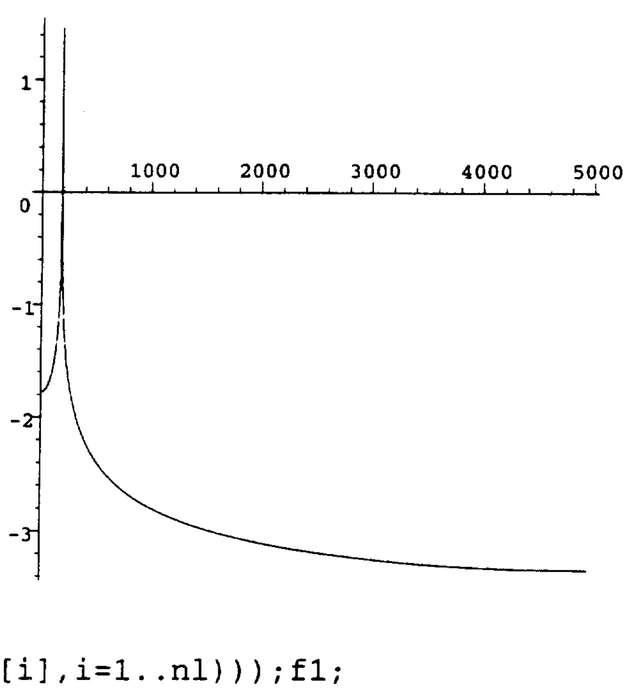



```
> sqrt(max(seq(rr[i],i=1..nl)));f1;
```

37.17500000

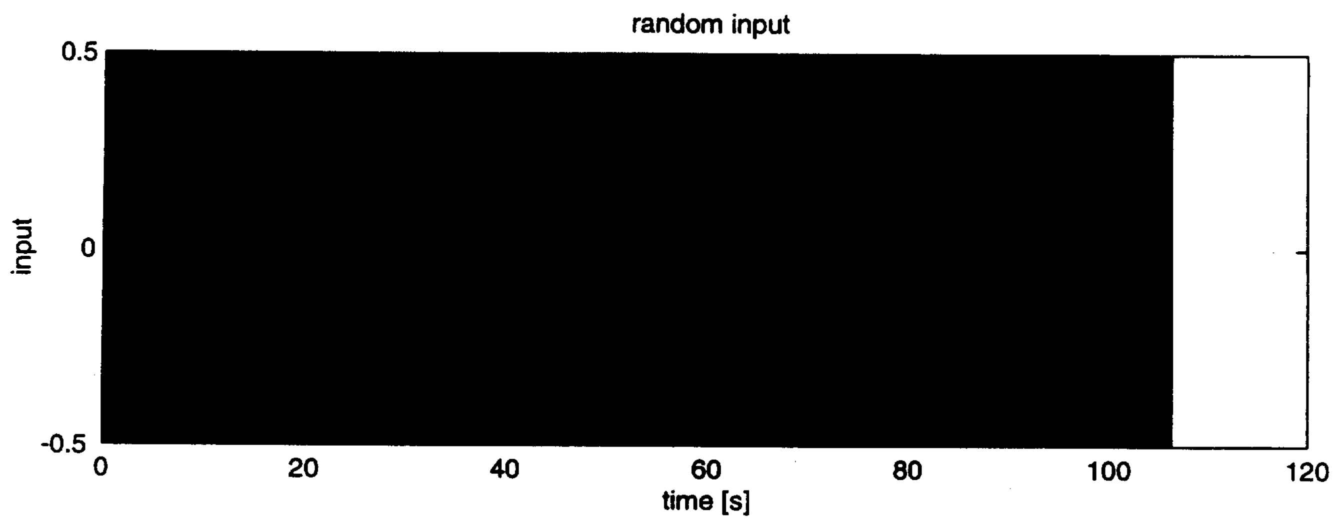
179.9432855

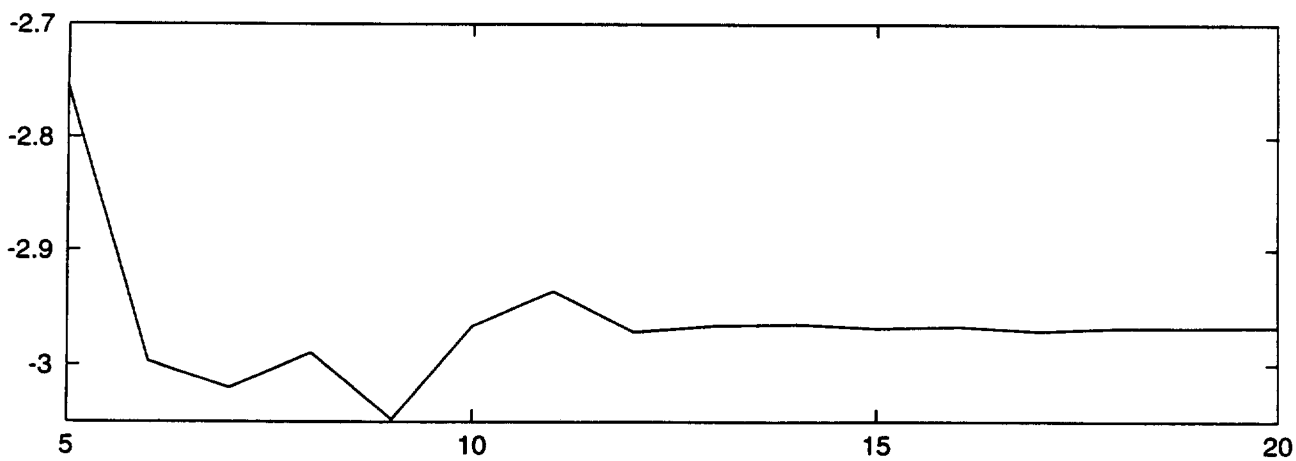
```
> pointplot([seq([f0[i],.5*log10(rr[i])],i=1..nl/2)],style=line);
```



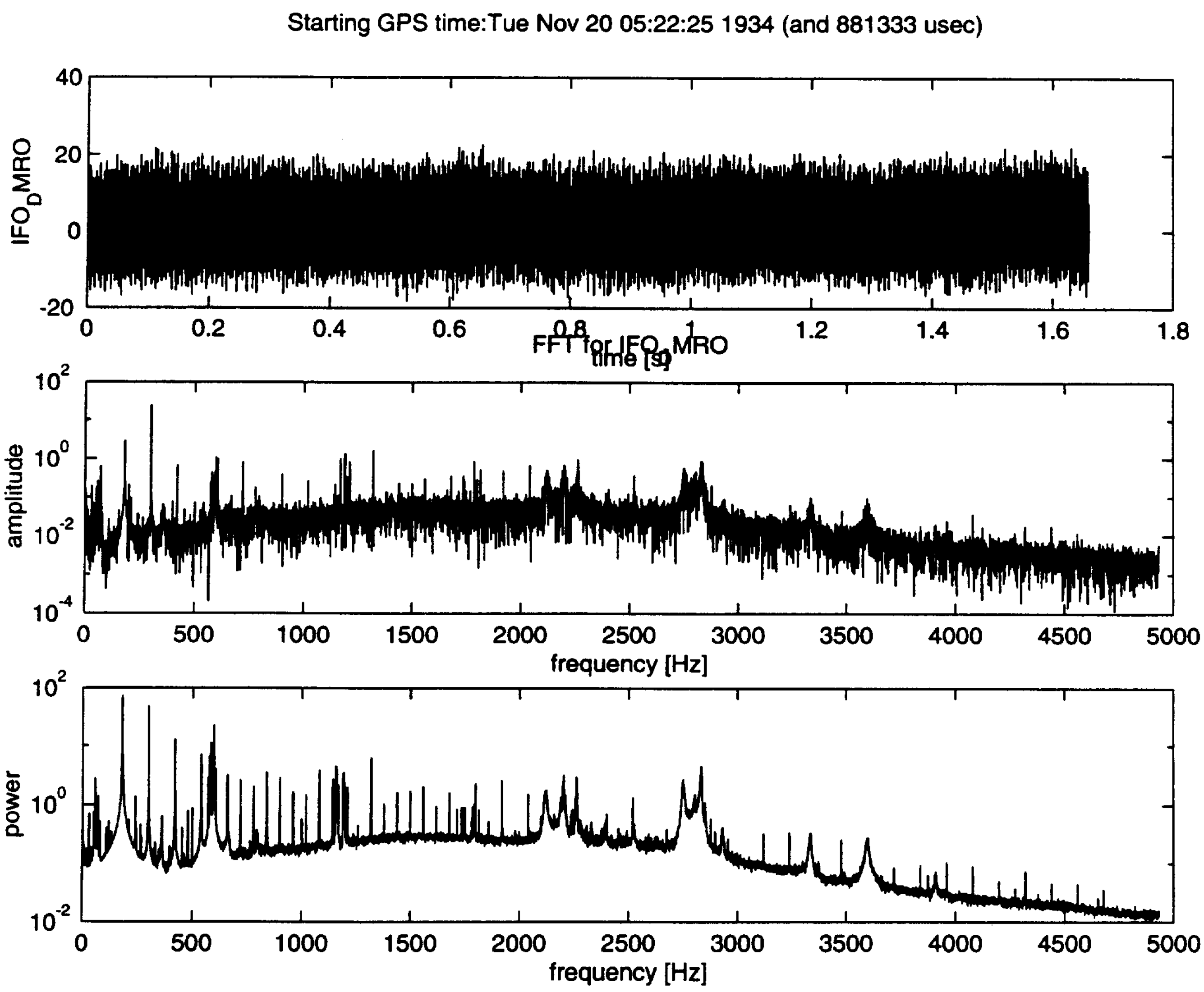

```
> sqrt(max(seq(rr[i],i=1..nl)));f1;
```

NOISE SCALING (WITH SAMPLE)

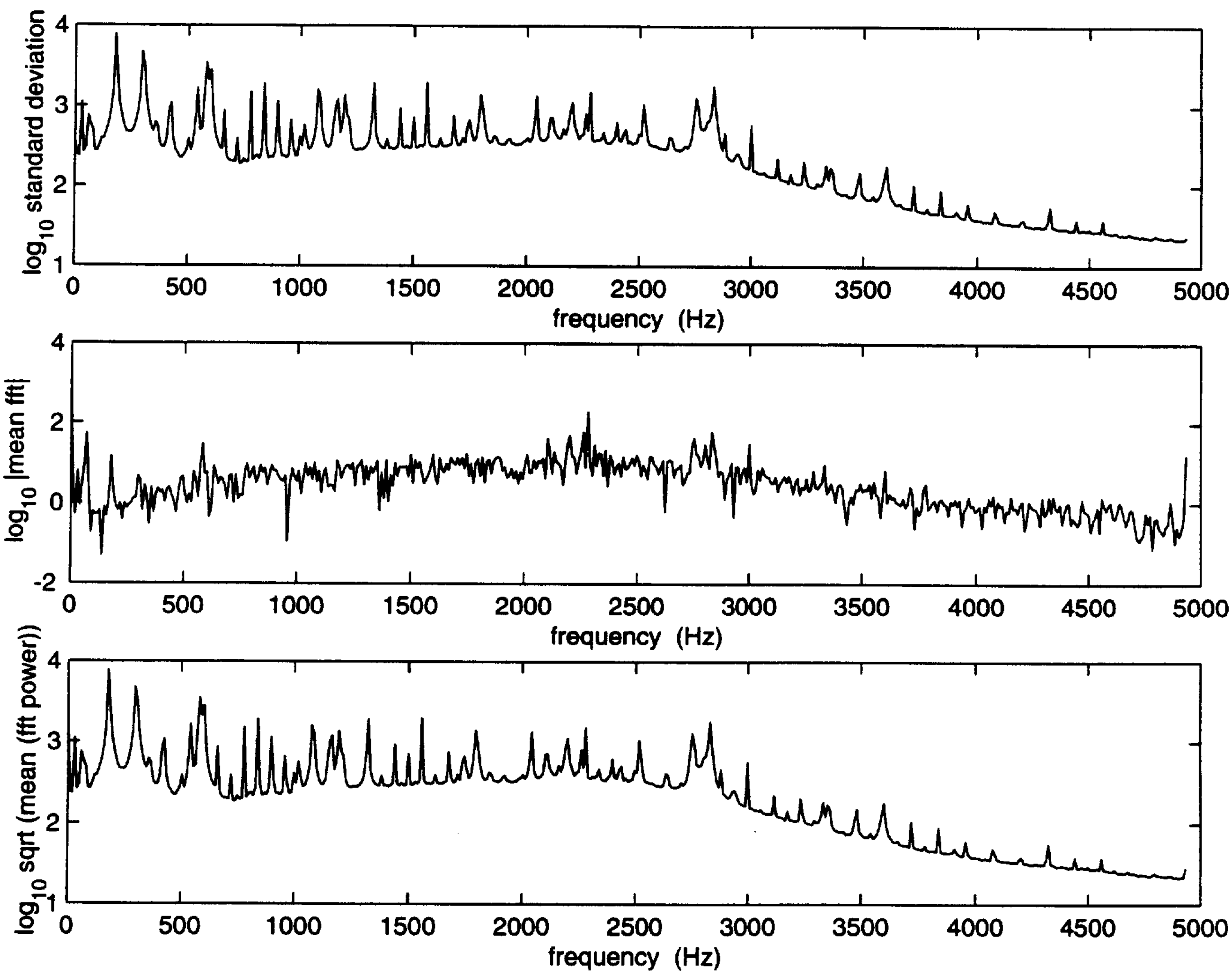




AVERAGING TECHNIQUES



AVERAGING TECHNIQUES



ESTABLISHING CONFIDENCE LIMITS

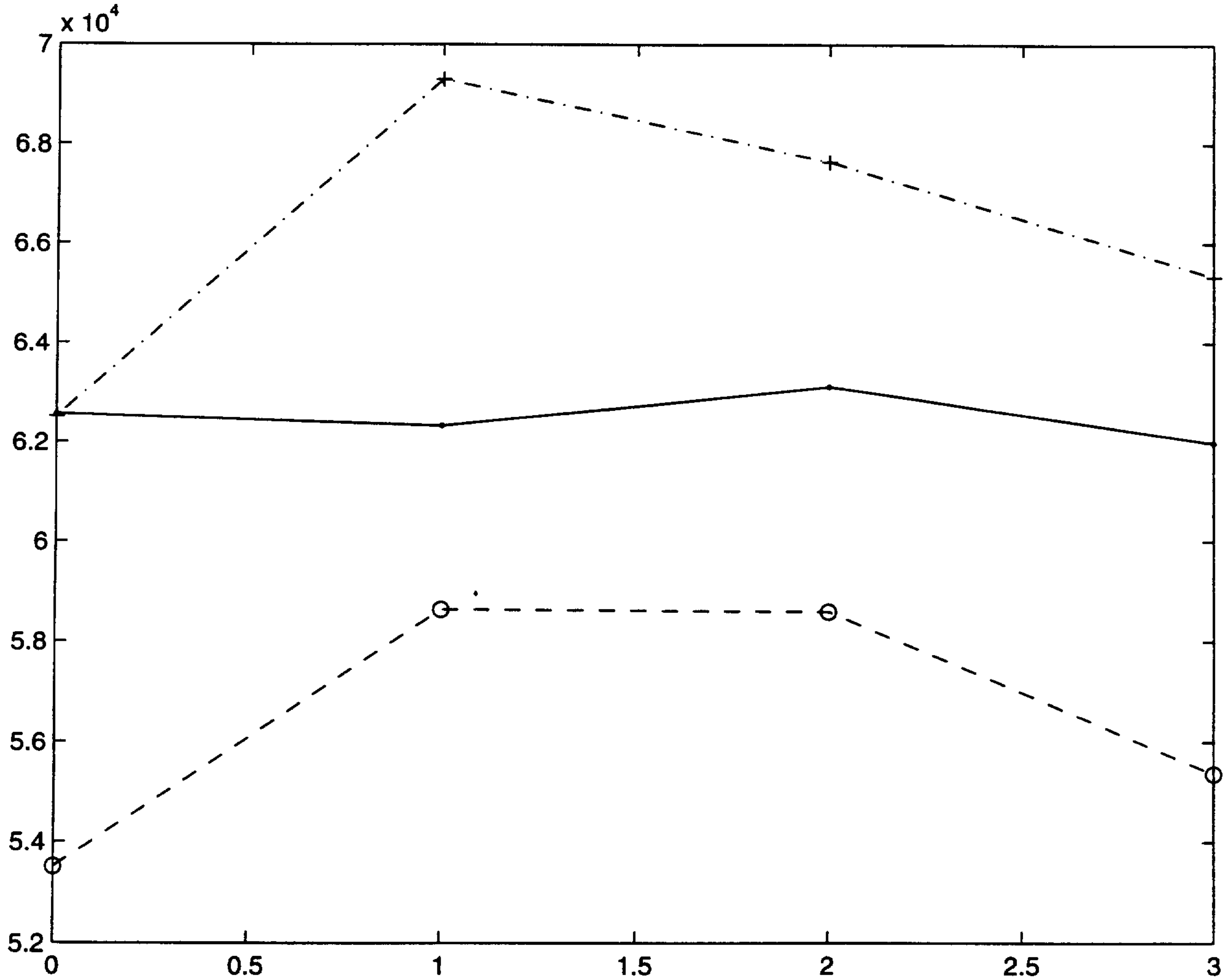
25 Hours good data.

$25 \times 3600 \times 9868.42 = 888157894.7 \sim 9 \times 10^8$ pts

54209 samples at 16384 points.

or 8 sets of 105418 samples at 1024 points.

A A₀ D UNIFORMITY (4 BITS)



A to D UNIFORMITY (64 BITS)