Receiver Design and Electrode Noise Considerations

Perth ASEG 2015

Why Electrode Noise?

Possibilities are:

Increasing Signal

- goes up with square root of Power

Stacking

- goes up with the square root of time

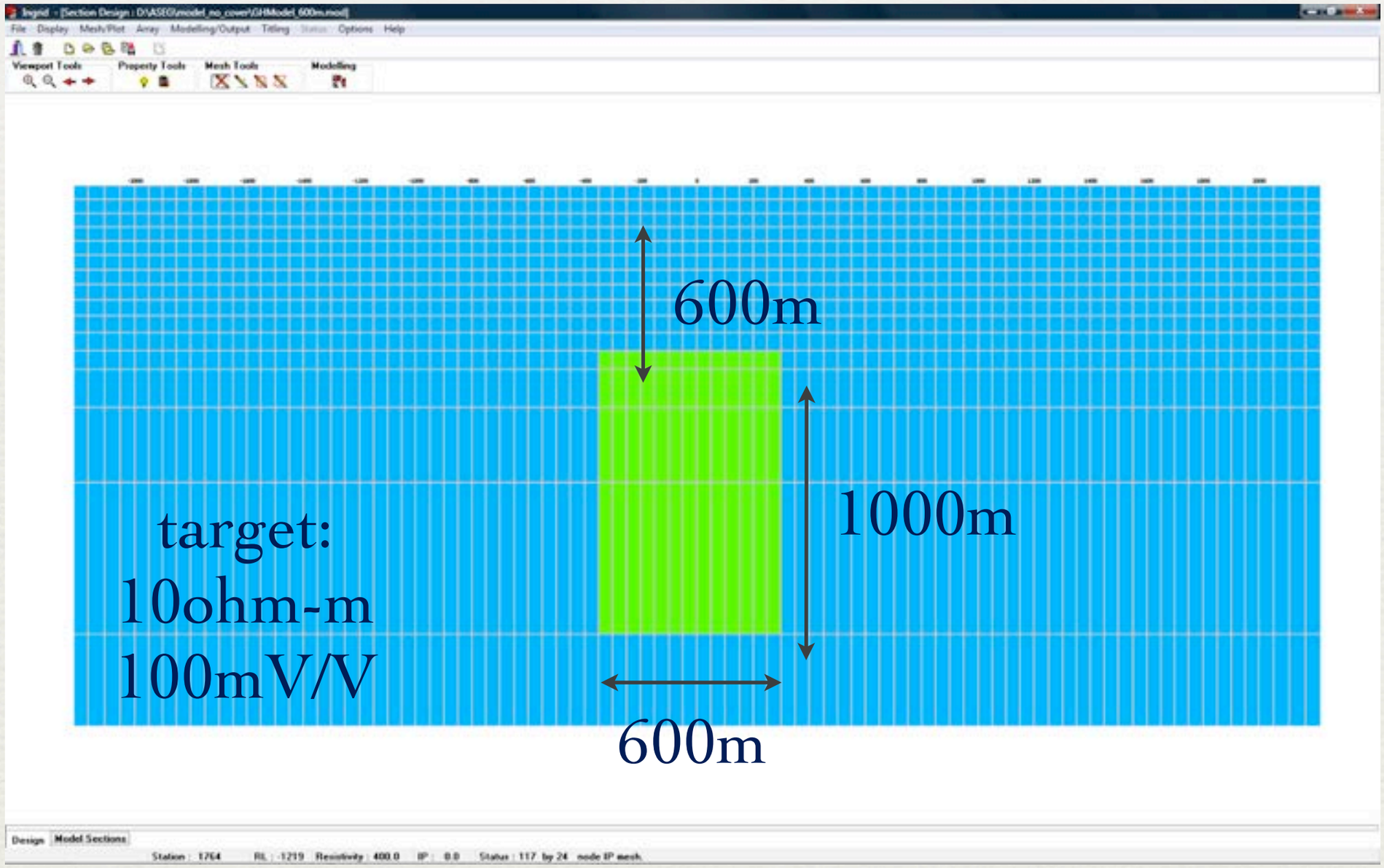
Reducing Noise

-reducing electrode noise

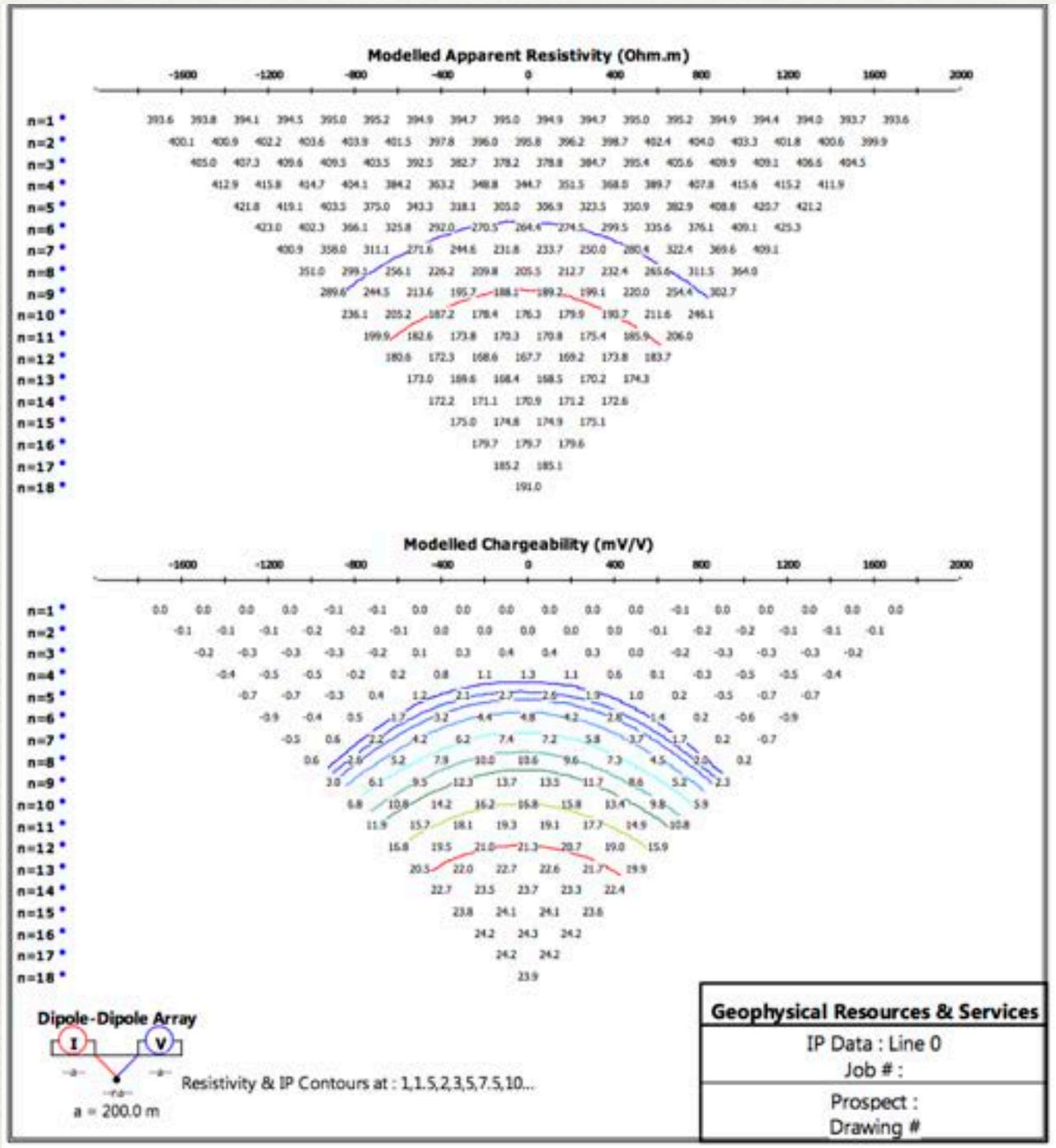
-reducing telluric noise

- essentially linear

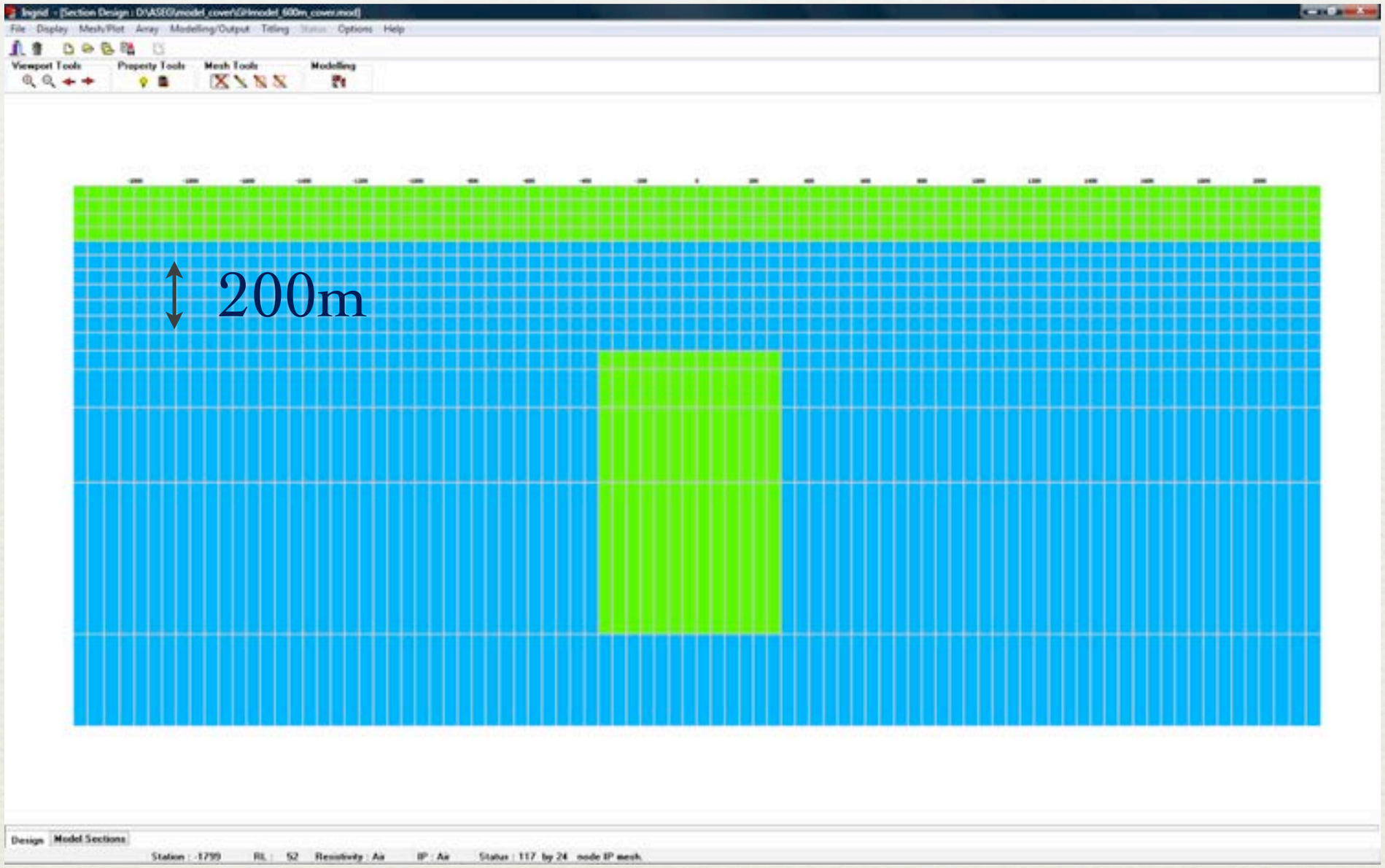
Why Electrode Noise?



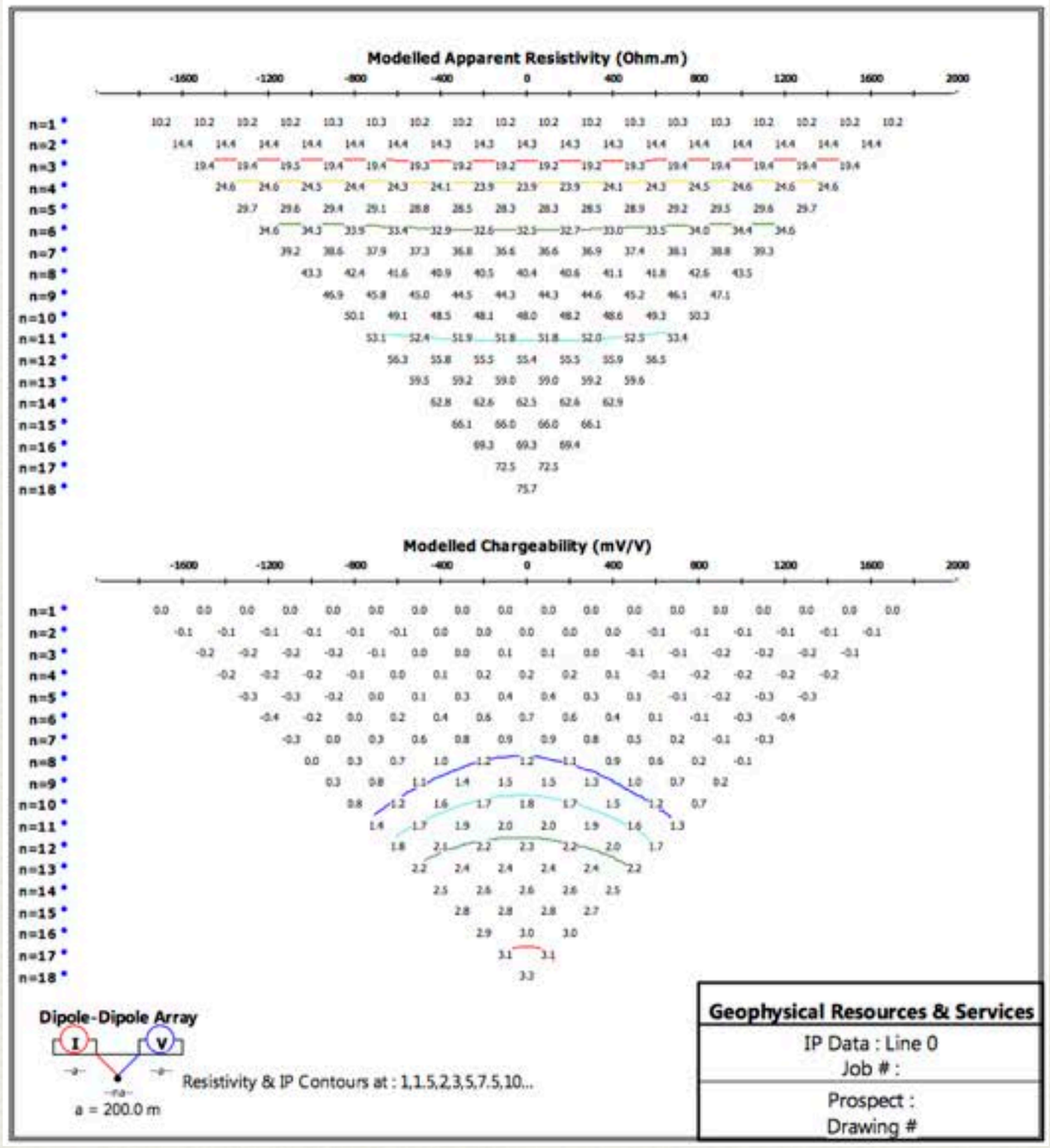
not for targets like that



but if there is cover



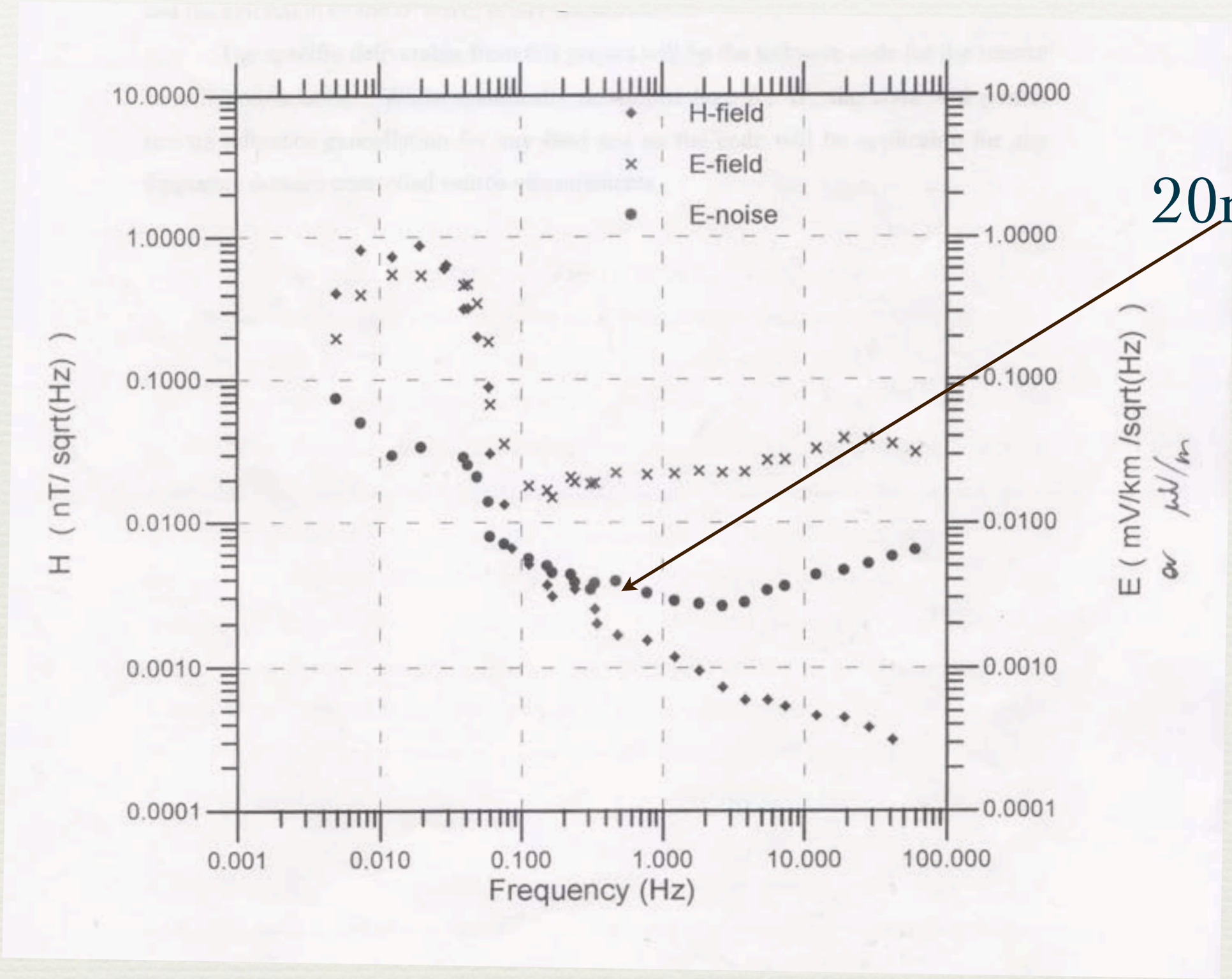
but for targets like that



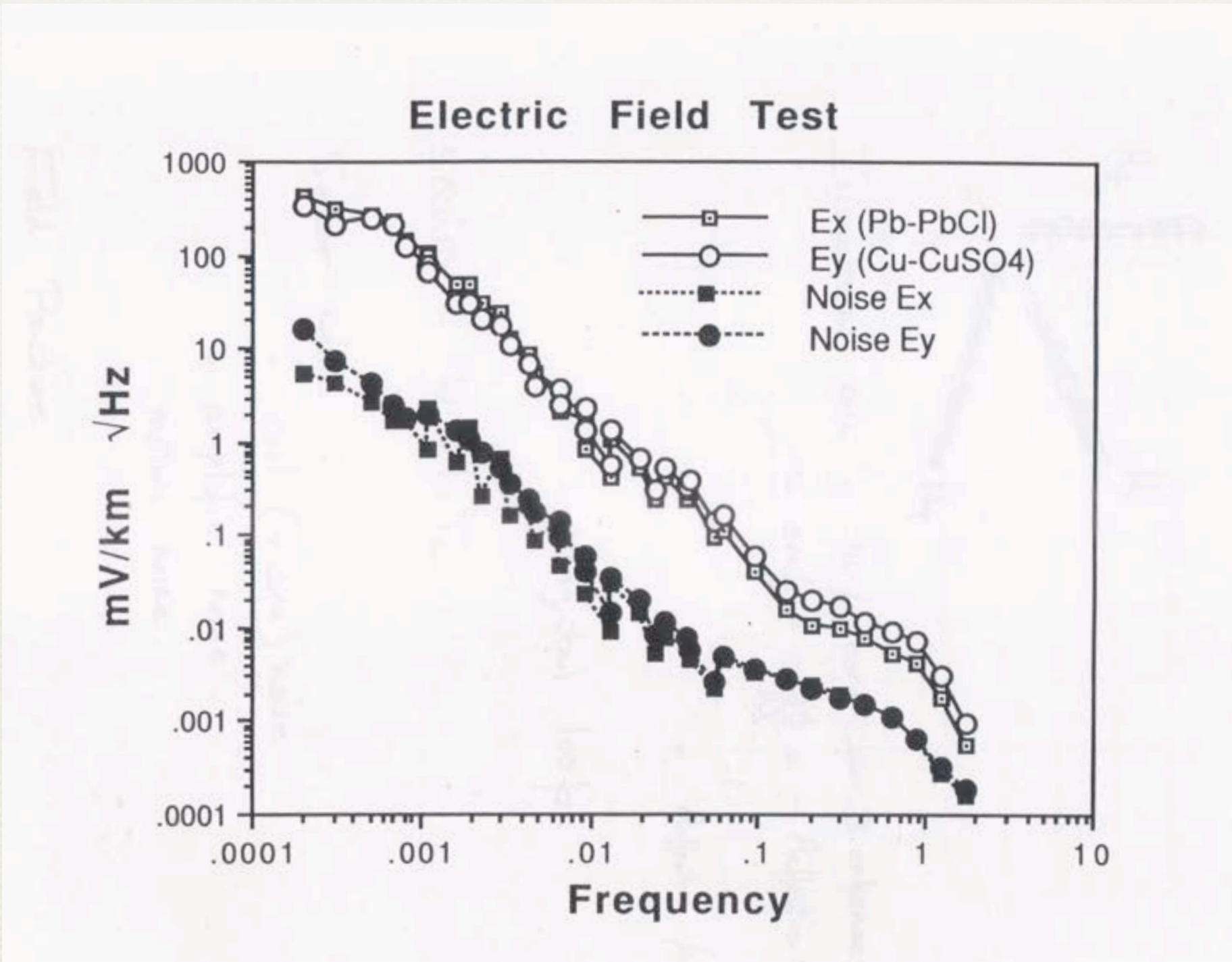
Electrode Noise

- Some (ugly) numbers might be
- Apparent chargeability ~ 3.5 mV/V
- Signal (Vs) at n=12 is ~ 0.1uV/A
- So with 10A will measure 1uV
- Want our noise at least 10 times smaller

Electrode Noise



from Frank Morrison



Also from Frank Morrison

Electrode Noise

- The good news is that it is possible
- The bad news is that Pb-PbCl, and most other metal-metal salt electrodes are a nuisance to handle in numbers...
- .. and100 may be required

Electrode Noise

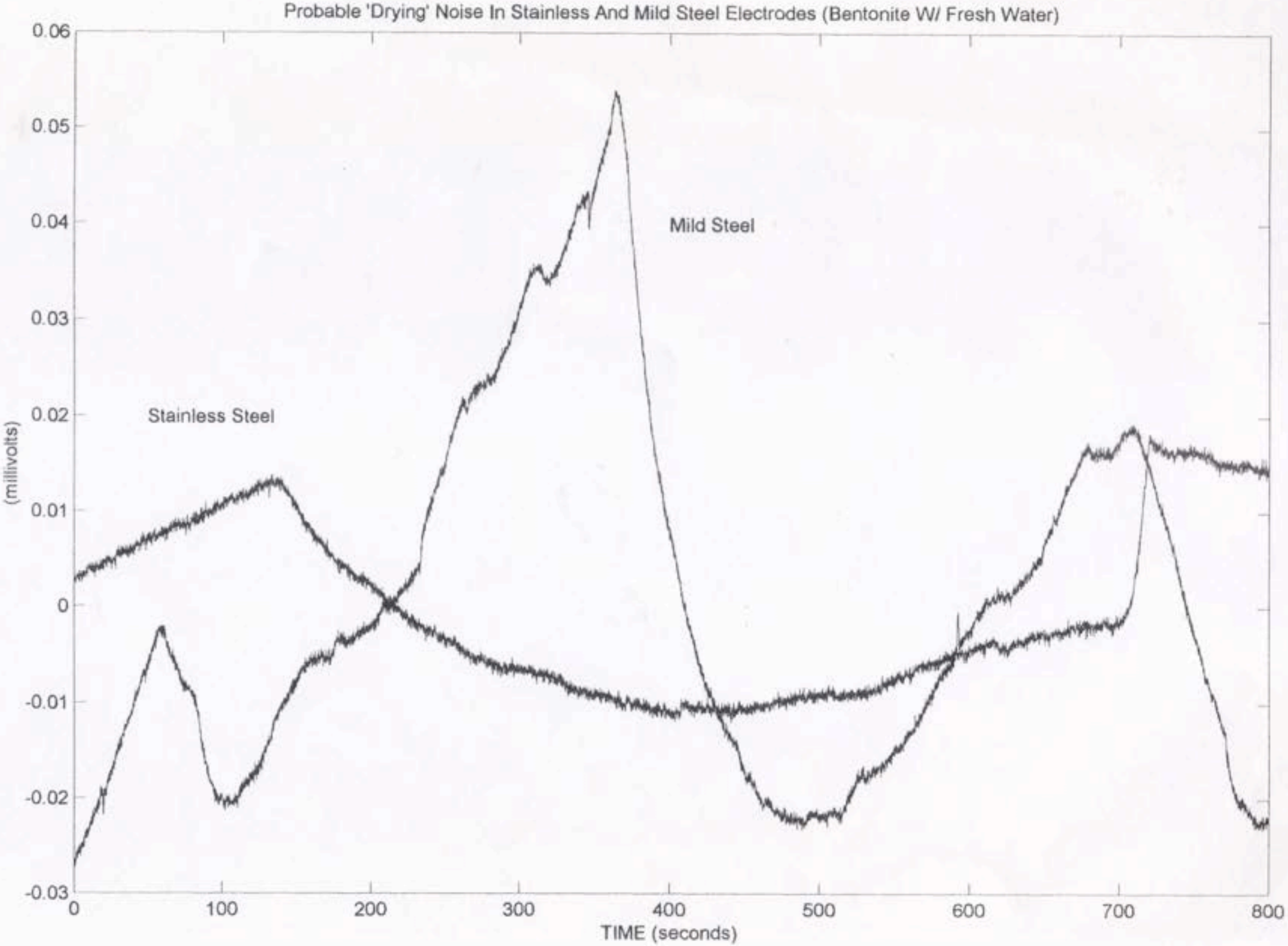
- Metal electrodes, especially stainless steel very common
- Knew that Ananconda and later ARCO had used metal electrodes for very low frequency IP (decays out to 300 seconds)
- but they never test very well in experiments like the Garcy Electrode Experiment, at **low frequencies**

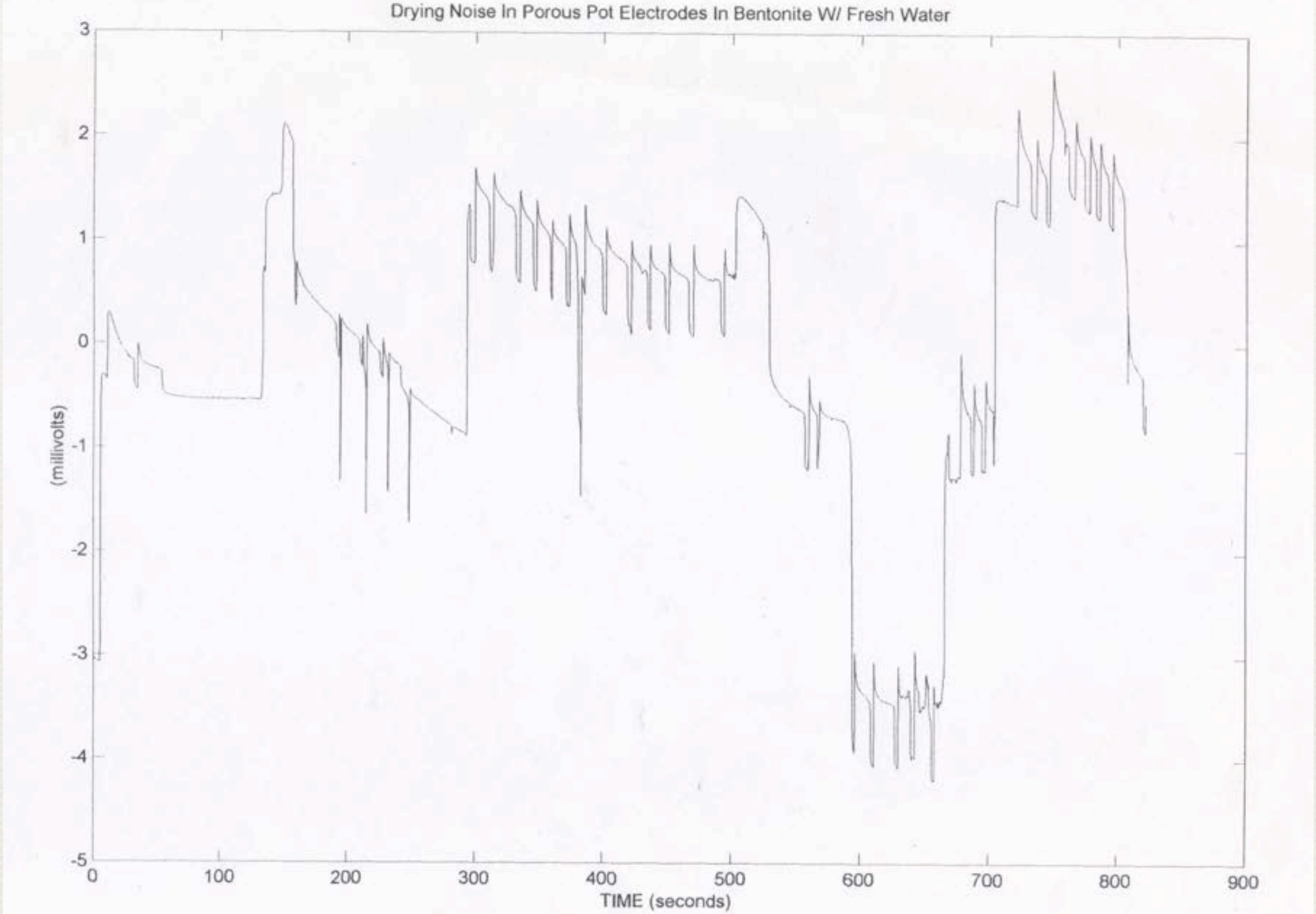
Electrode Noise

- Stainless steel plates in fresh/salt water/mud
- Cu-CuSO4 pots in fresh/salt water/mud
- Mild steel plates in fresh/salt water/mud
- Galvanised iron plates in fresh/salt water/mud
- Copper sheet plates in n fresh/salt water/mud

Electrode Noise

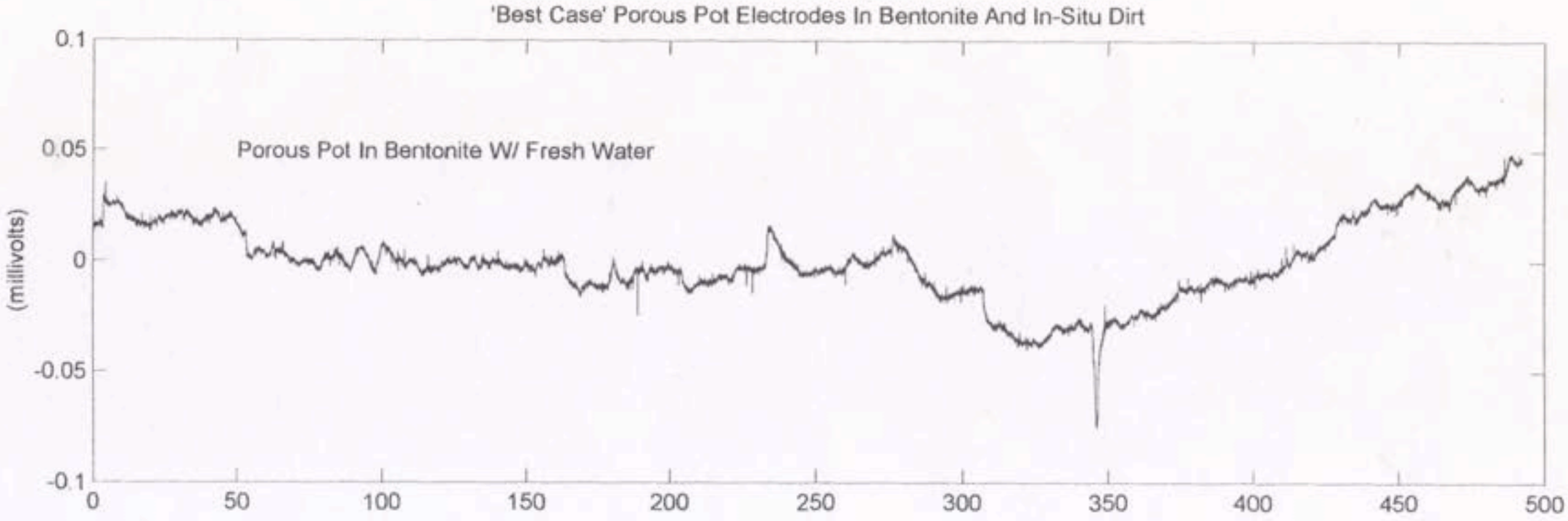
- Just some of the observed odd behaviours

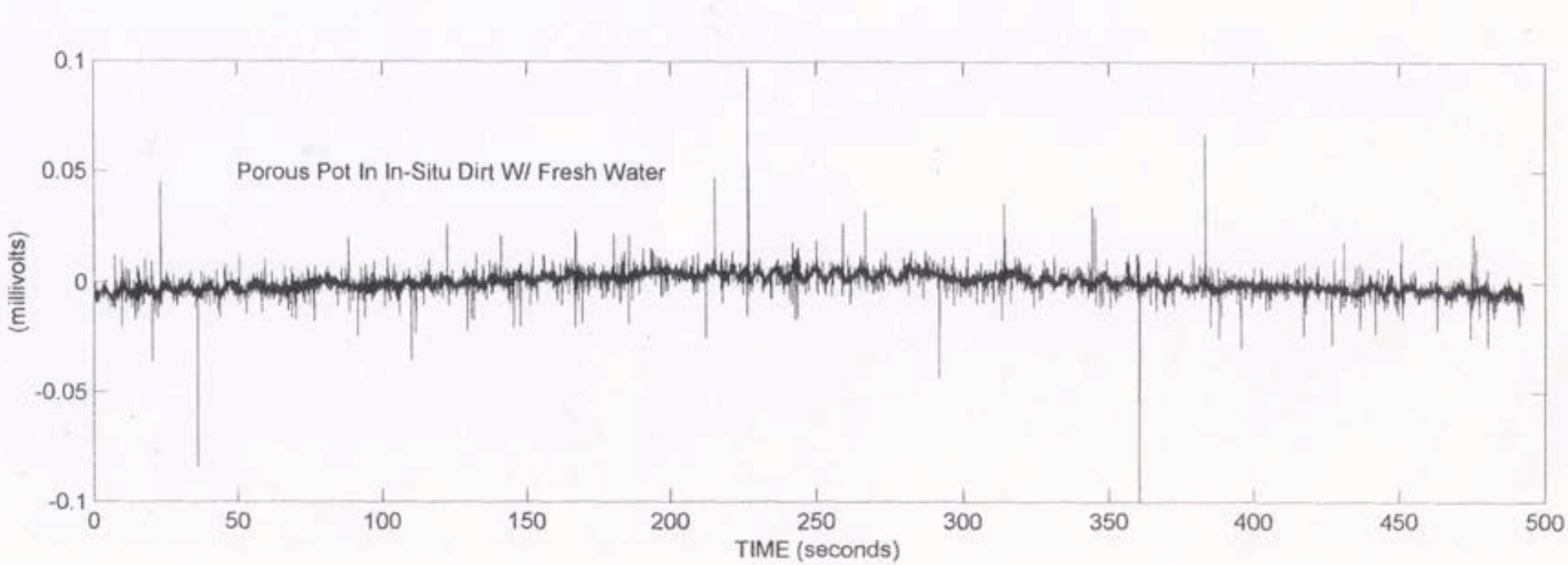

Probable 'Drying' Noise In Stainless And Mild Steel Electrodes (Bentonite W/ Fresh Water)
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
(millivolts)
Stainless Steel
Mild Steel
0
100
200
300
400
500
600
700
800
TIME (seconds)

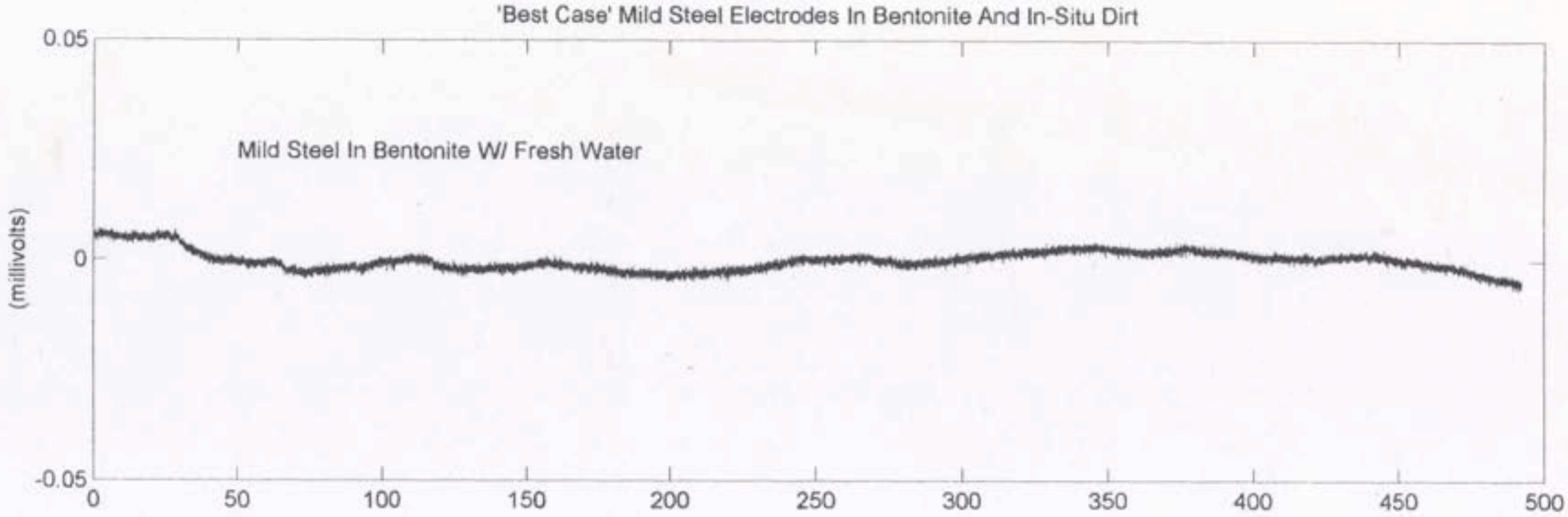

Drying Noise In Porous Pot Electrodes In Bentonite W/ Fresh Water
(millivolts)
3
2
1
0
-1
-2
-3
-4
-5
0
100
200
300
400
500
600
700
800
900
TIME (seconds)

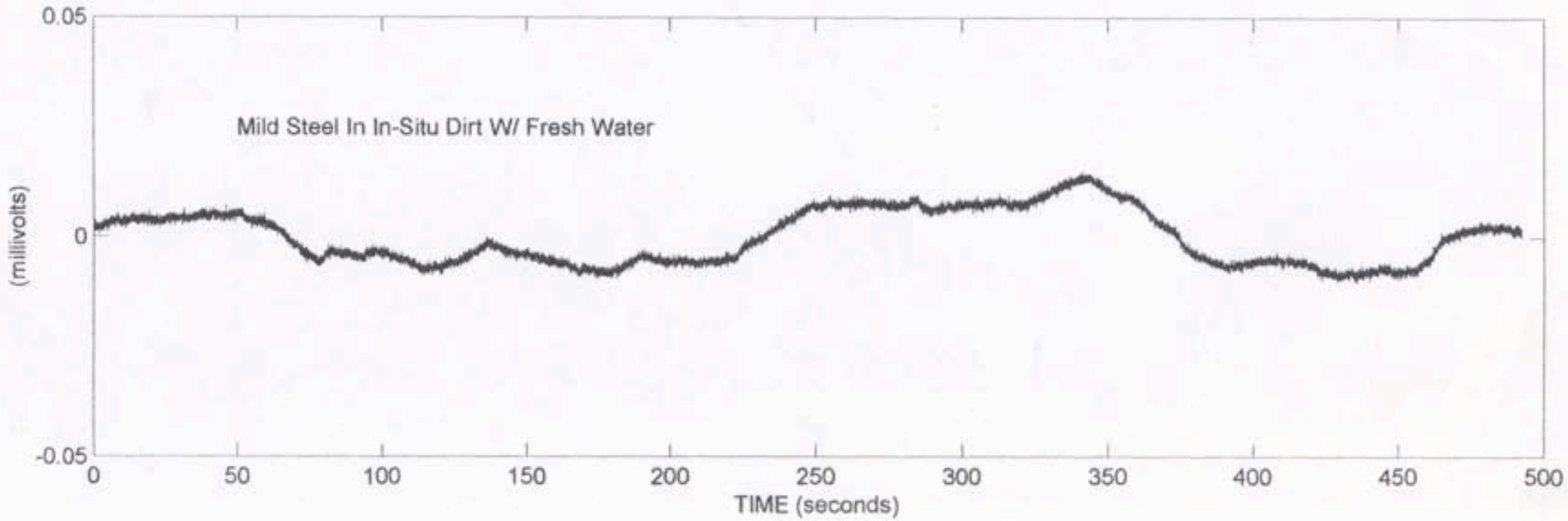
Electrode Noise

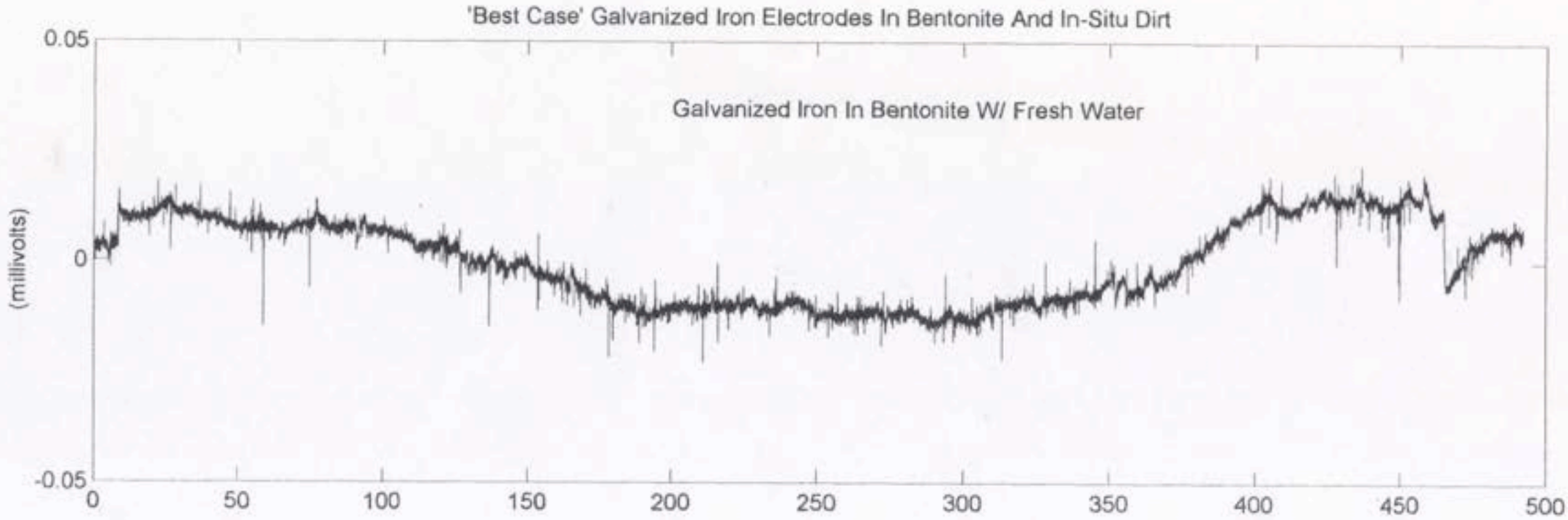
- Summary of Results

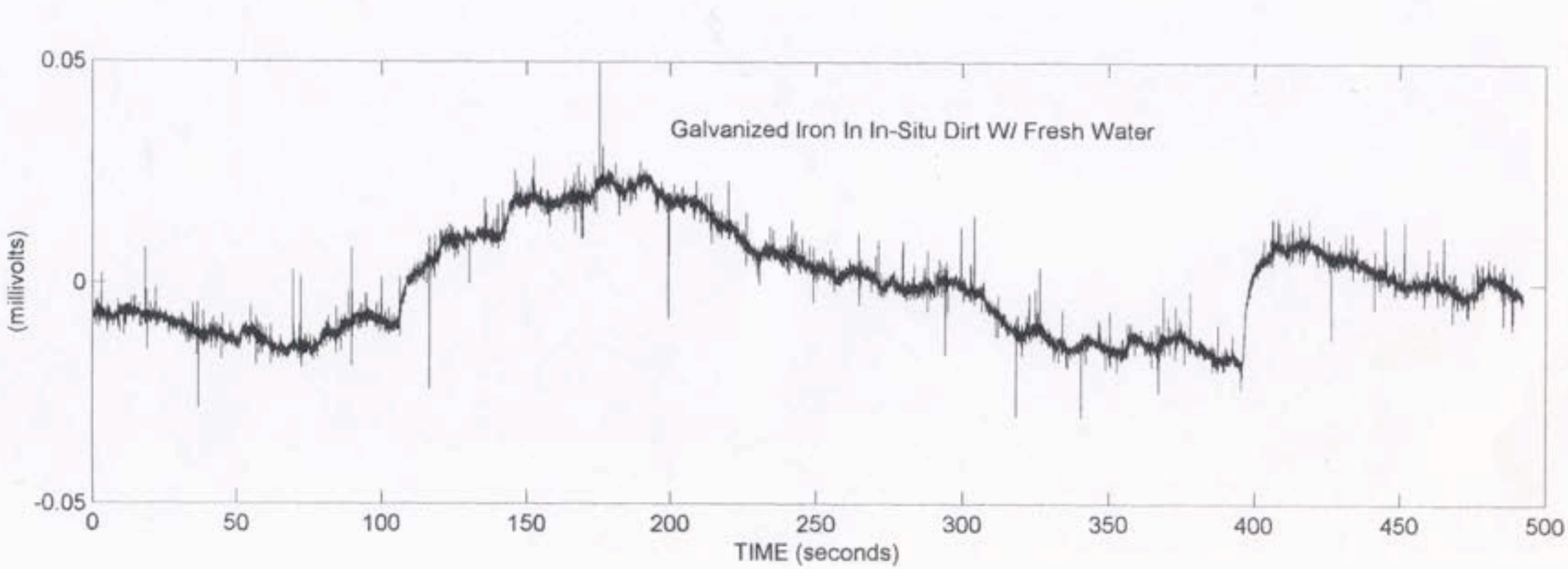

'Best Case' Porous Pot Electrodes In Bentonite And In-Situ Dirt
Porous Pot In Bentonite W/ Fresh Water
(millivolts)
0.1
0.05
0
-0.05
-0.1
0
50
100
150
200
250
300
350
400
450
500

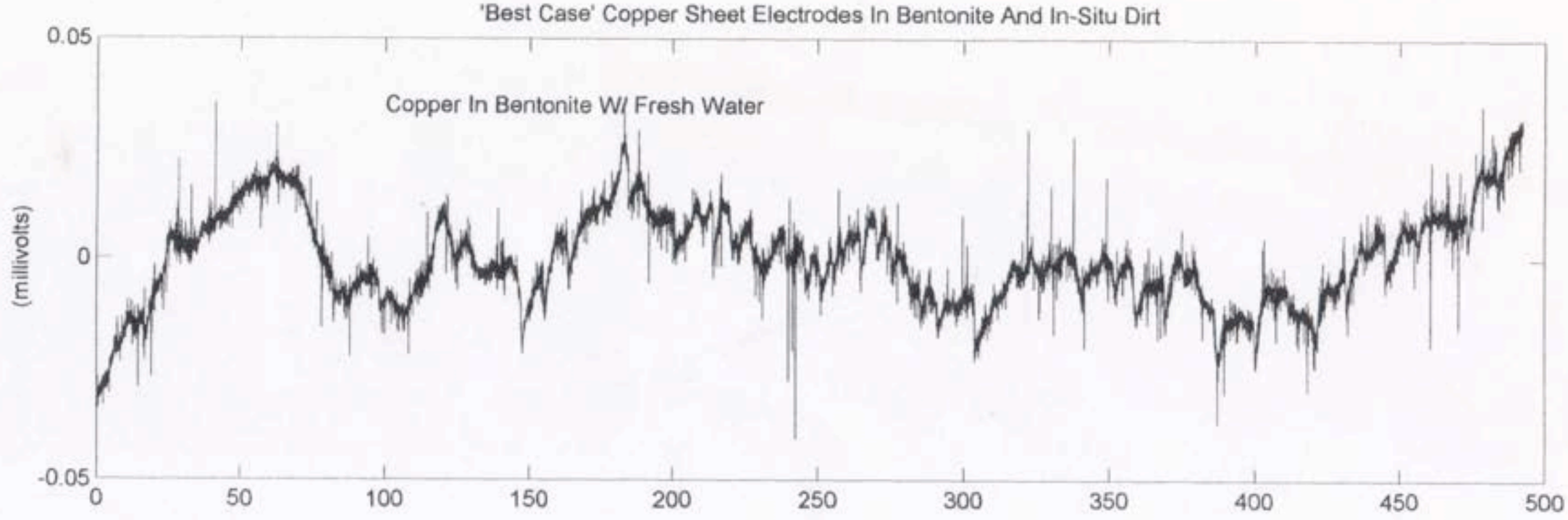

Porous Pot In In-Situ Dirt W/ Fresh Water
(millivolts)
0.1
0.05
0
-0.05
-0.1
0
50
100
150
200
250
300
350
400
450
500
TIME (seconds)


'Best Case' Mild Steel Electrodes In Bentonite And In-Situ Dirt
Mild Steel In Bentonite W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500


Mild Steel In In-Situ Dirt W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500
TIME (seconds)


'Best Case' Galvanized Iron Electrodes In Bentonite And In-Situ Dirt
Galvanized Iron In Bentonite W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500


Galvanized Iron In In-Situ Dirt W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500
TIME (seconds)


'Best Case' Copper Sheet Electrodes In Bentonite And In-Situ Dirt
Copper In Bentonite W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500

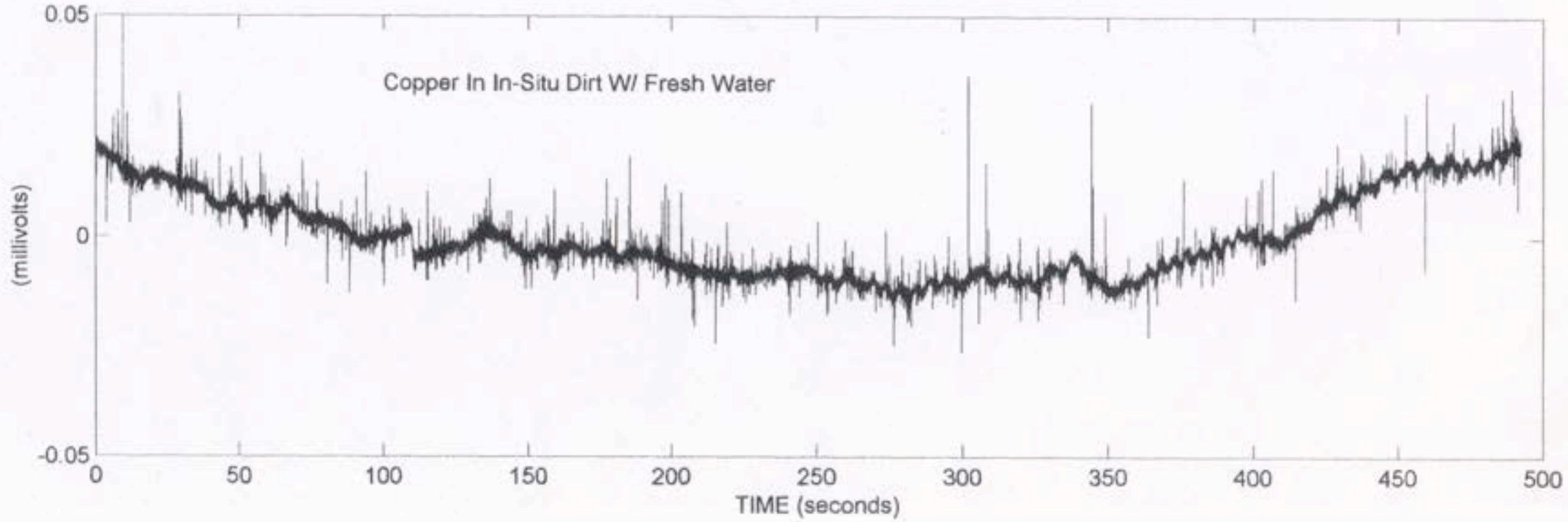
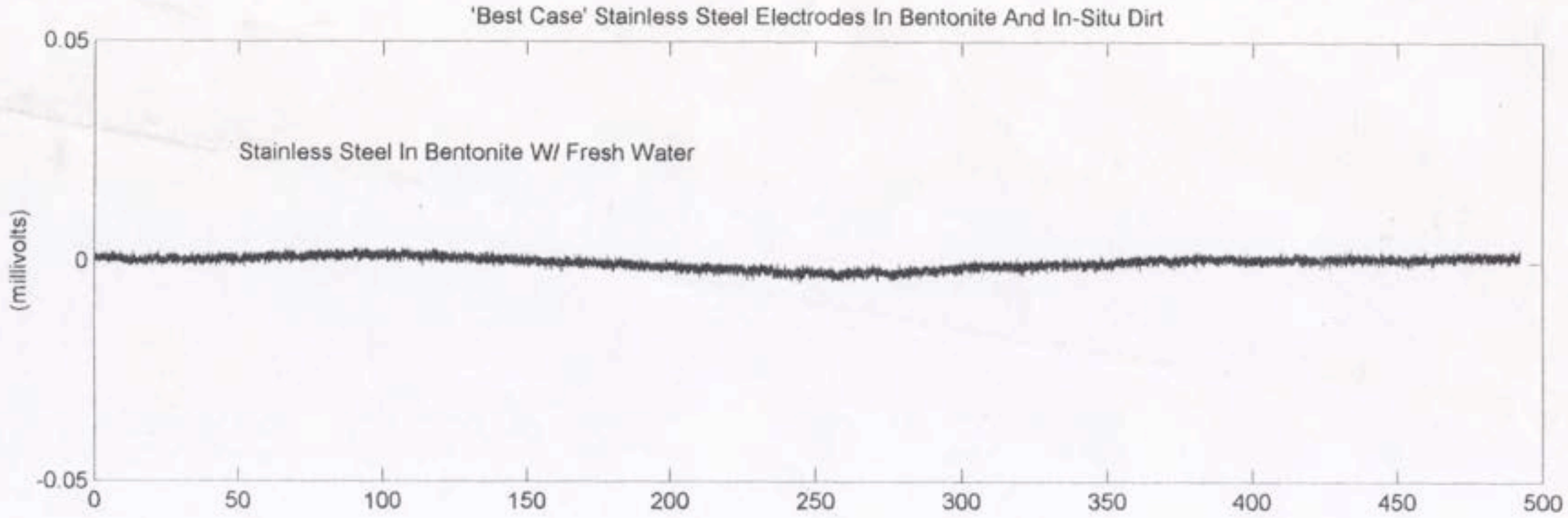
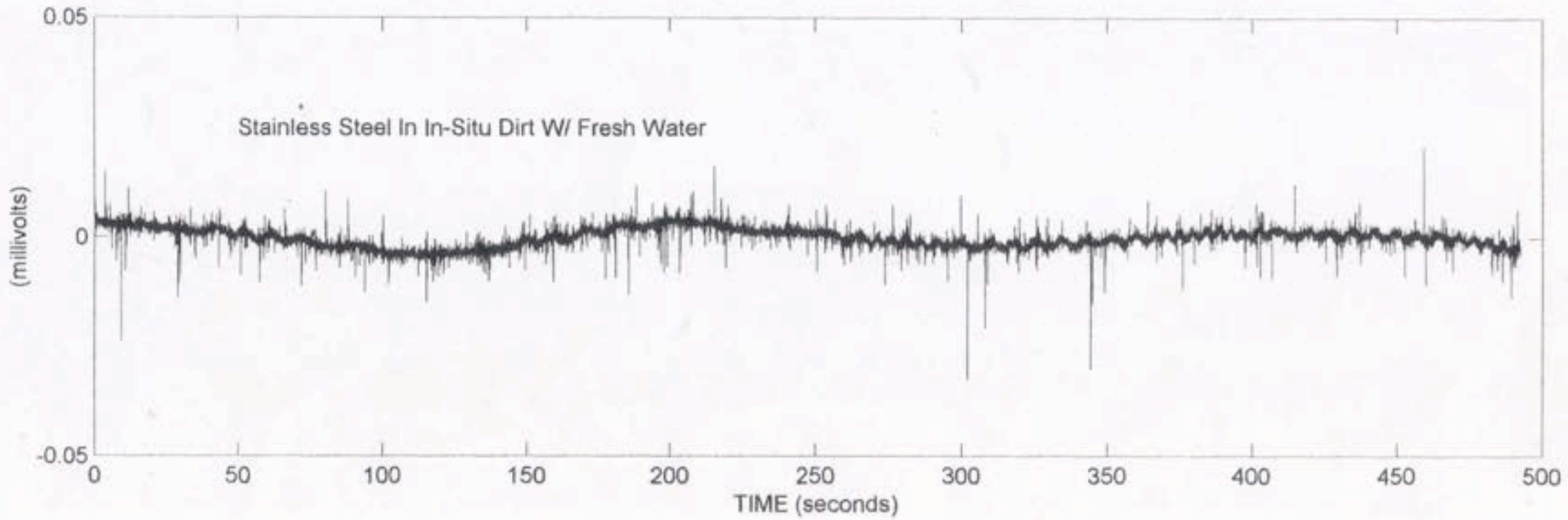
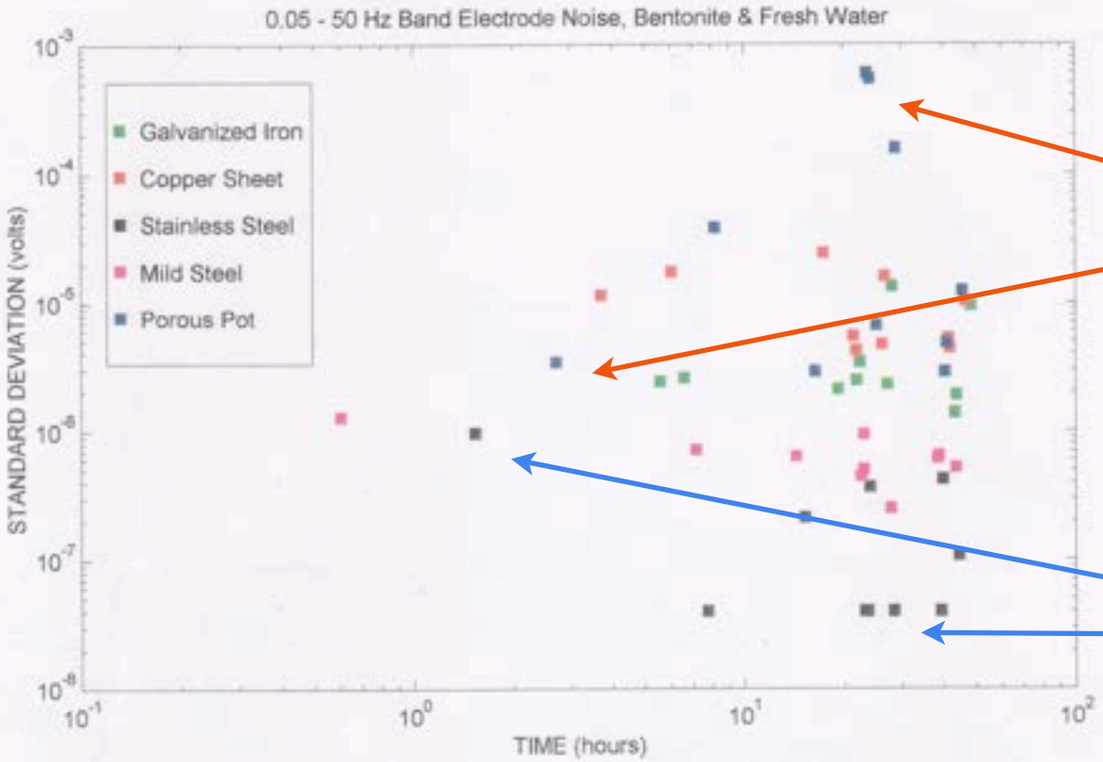

Copper In In-Situ Dirt W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500
TIME (seconds)

Figure 29


'Best Case' Stainless Steel Electrodes In Bentonite And In-Situ Dirt
Stainless Steel In Bentonite W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500


Stainless Steel In In-Situ Dirt W/ Fresh Water
(millivolts)
0.05
0
-0.05
0
50
100
150
200
250
300
350
400
450
500
TIME (seconds)



porous pots

stainless steel

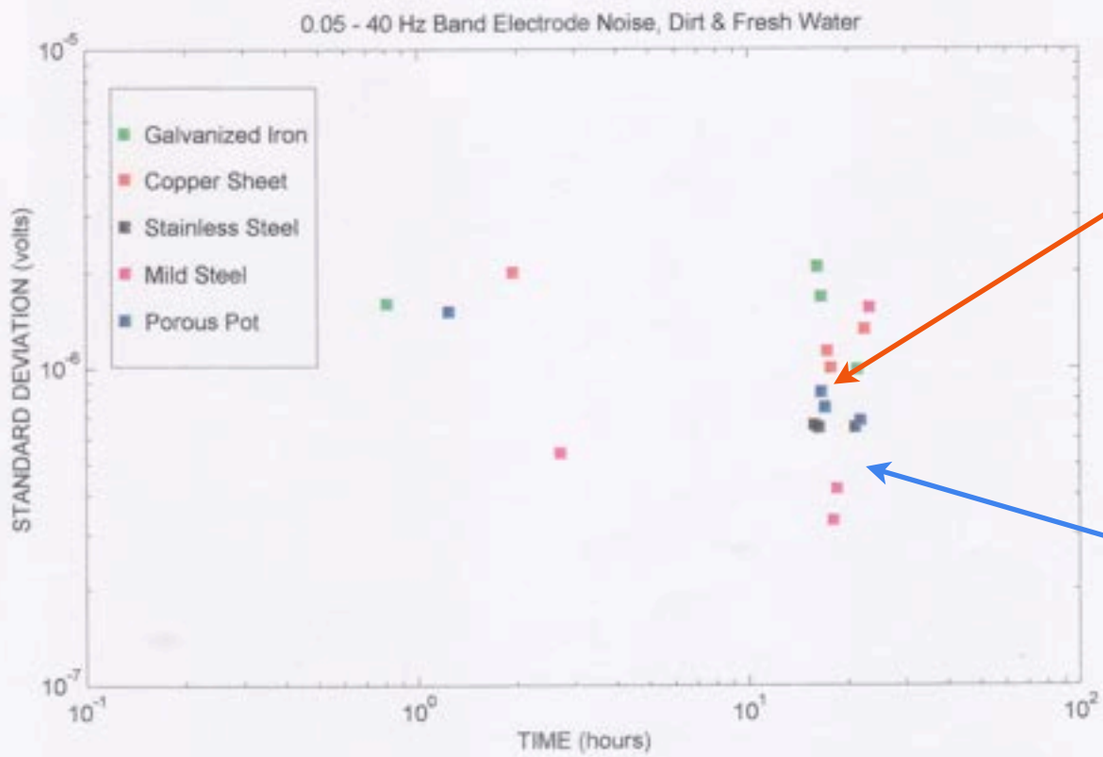
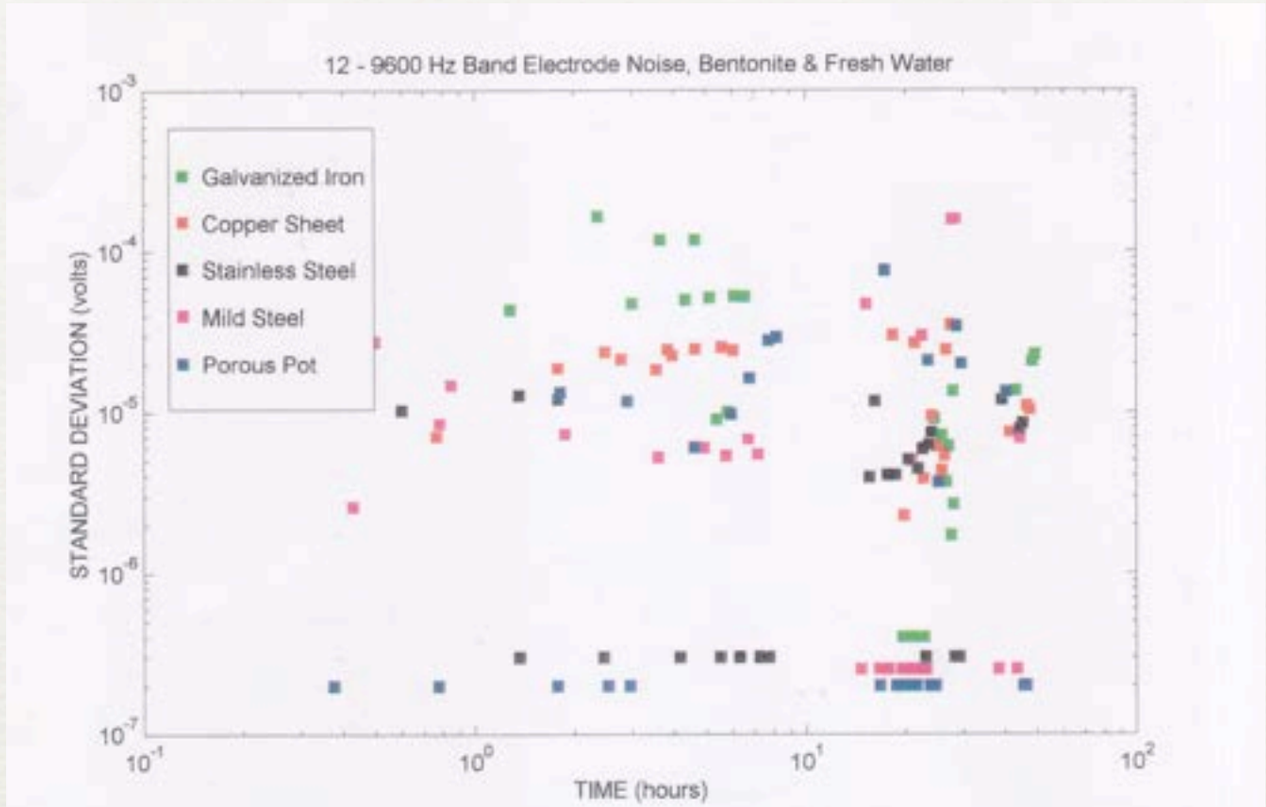


Figure 35

porous pots

stainless steel


12 - 9600 Hz Band Electrode Noise, Bentonite & Fresh Water
Galvanized Iron
Copper Sheet
Stainless Steel
Mild Steel
Porous Pot
STANDARD DEVIATION (volts)
TIME (hours)

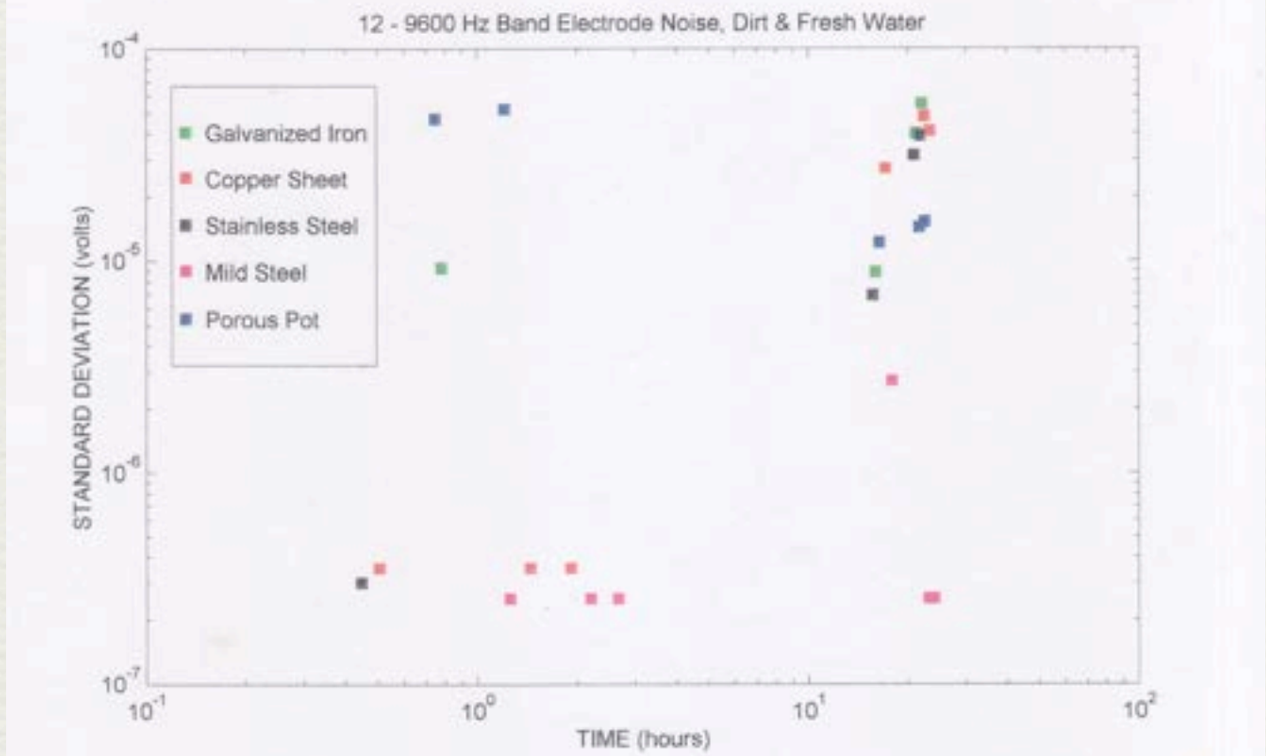
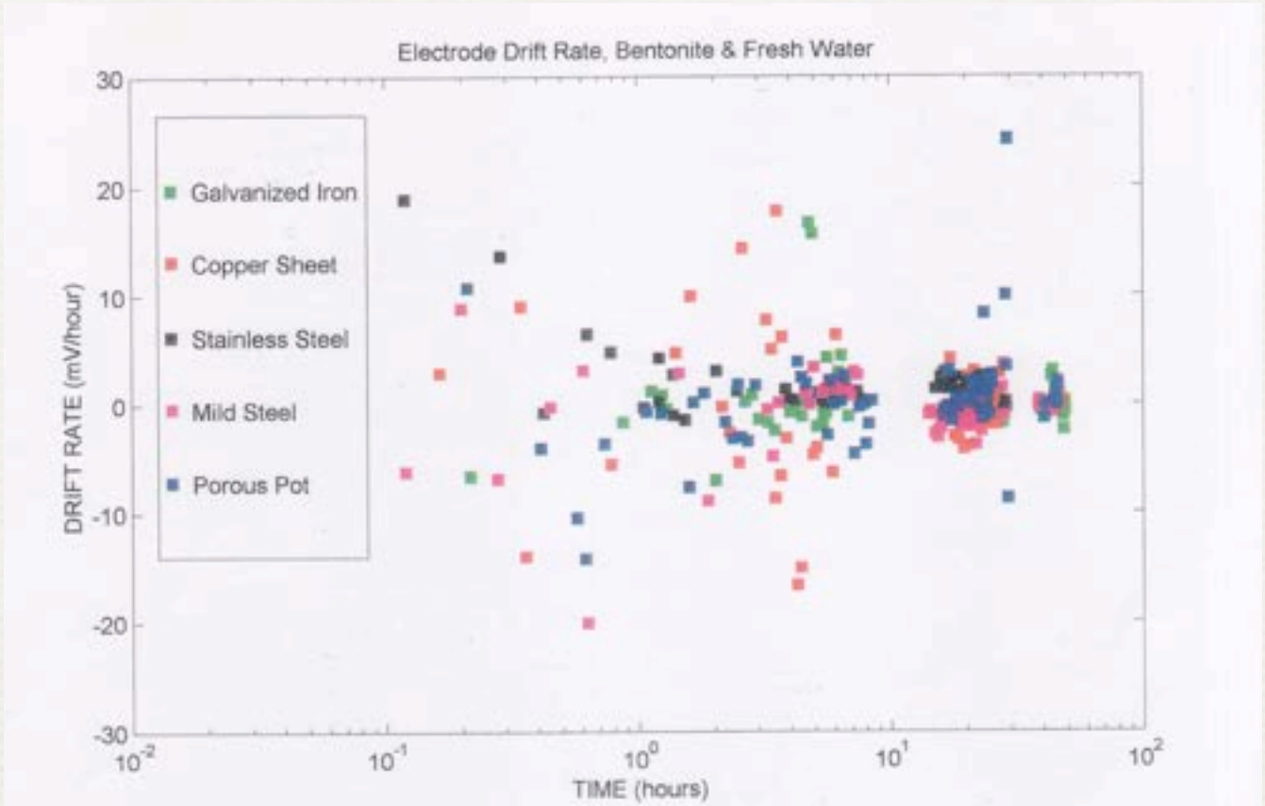
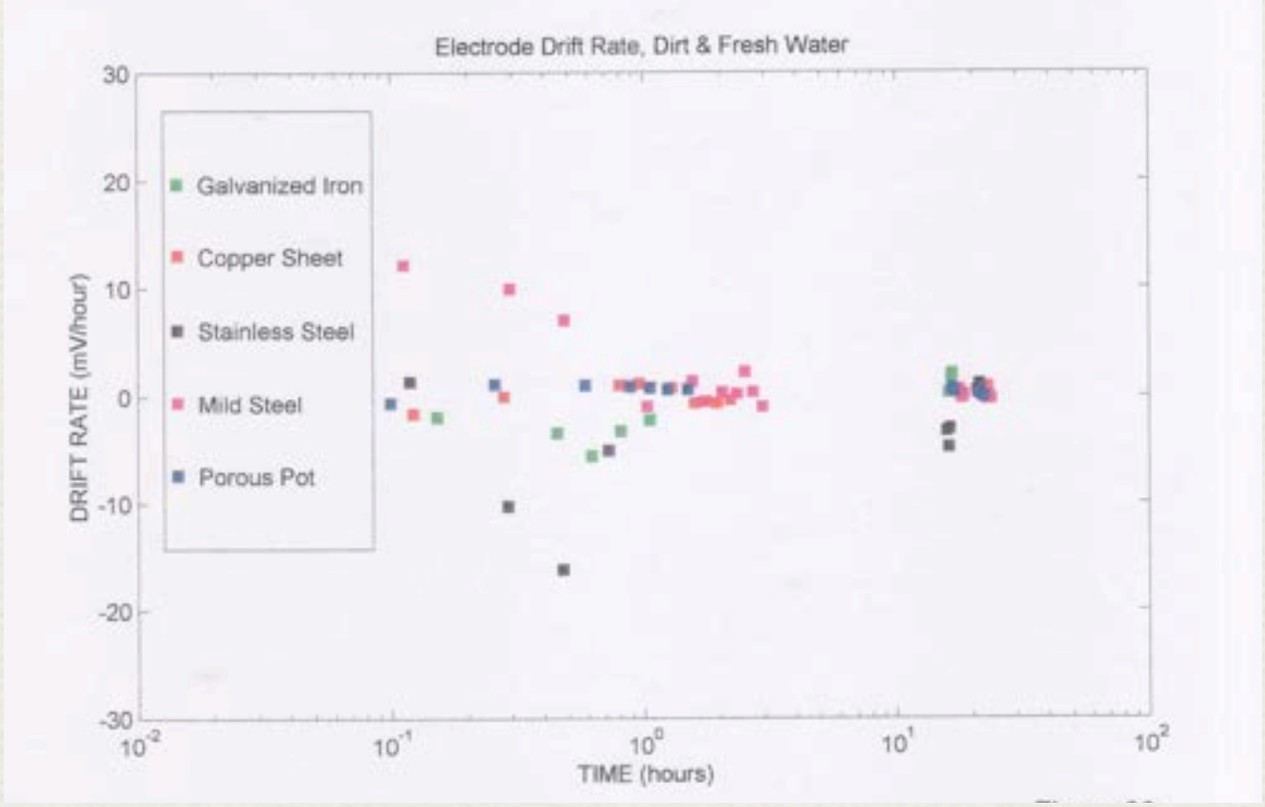
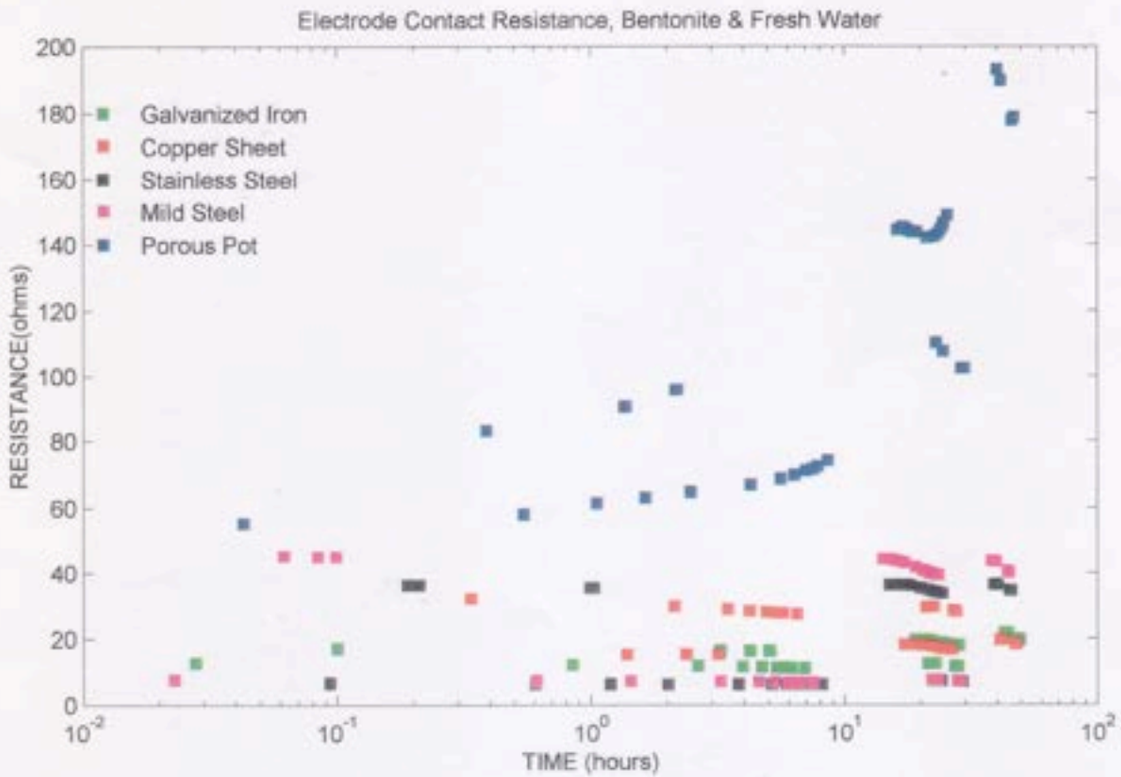

12 - 9600 Hz Band Electrode Noise, Dirt & Fresh Water
Galvanized Iron
Copper Sheet
Stainless Steel
Mild Steel
Porous Pot
STANDARD DEVIATION (volts)
TIME (hours)

Figure 37


Electrode Drift Rate, Bentonite & Fresh Water
DRIFT RATE (mV/hour)
TIME (hours)
Galvanized Iron
Copper Sheet
Stainless Steel
Mild Steel
Porous Pot
30
20
10
0
-10
-20
-30
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}


Electrode Drift Rate, Dirt & Fresh Water
DRIFT RATE (mV/hour)
TIME (hours)
Galvanized Iron
Copper Sheet
Stainless Steel
Mild Steel
Porous Pot
30
20
10
0
-10
-20
-30
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}



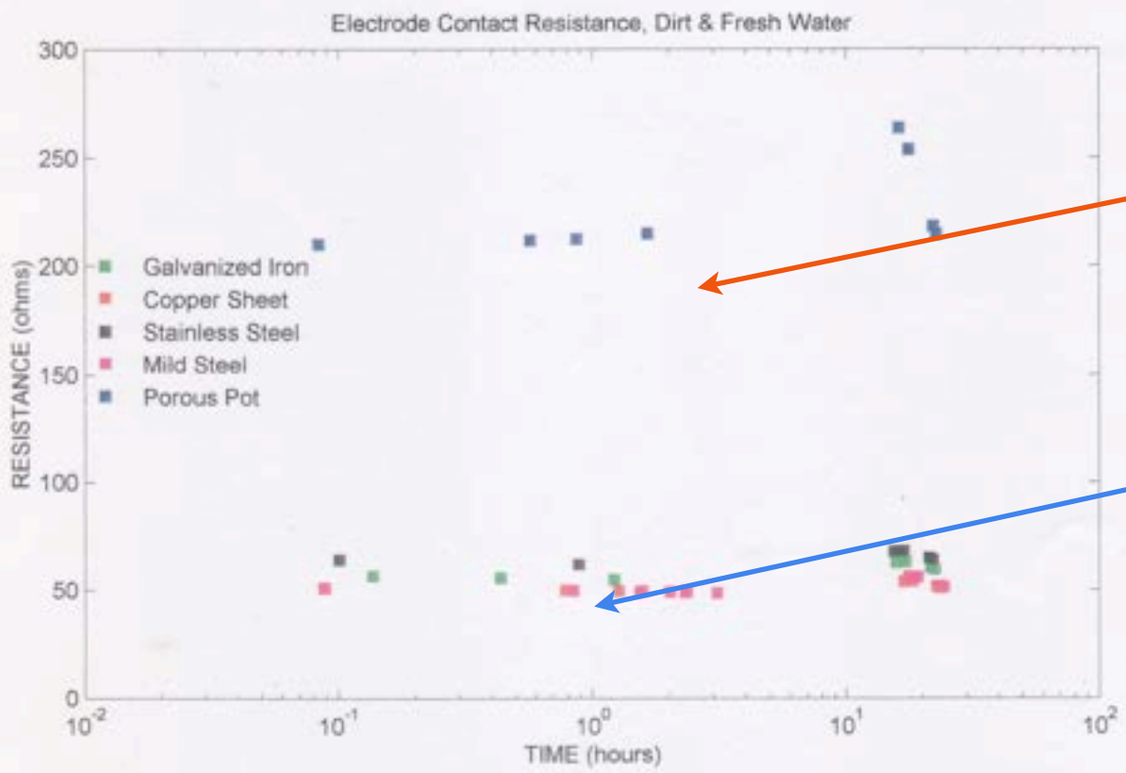


Figure 41

porous pots

stainless steel

Electrode Noise

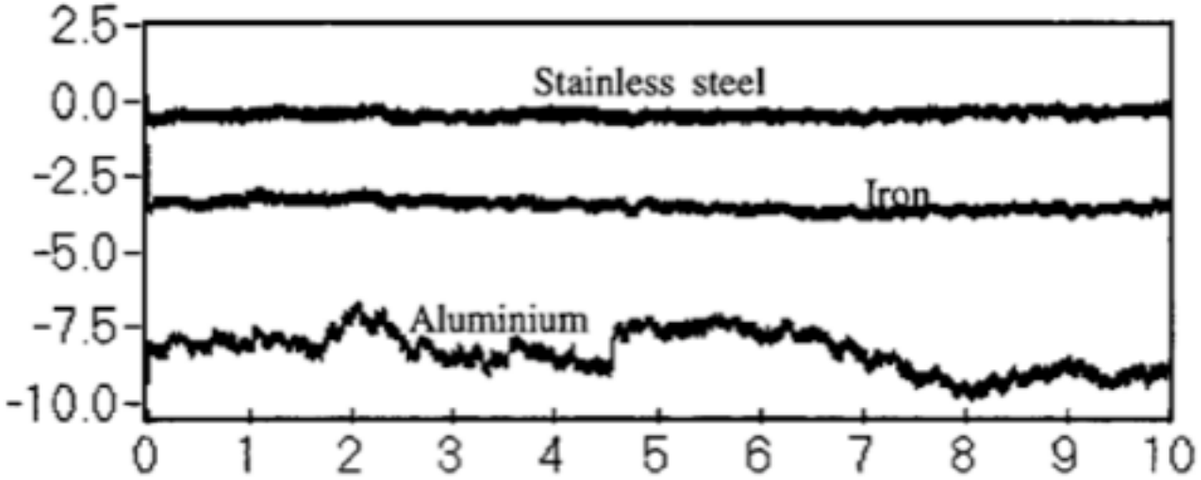


Figure 7. Comparison of the stability of metal rod electrodes.

from Lu & Macnae

Electrode Noise

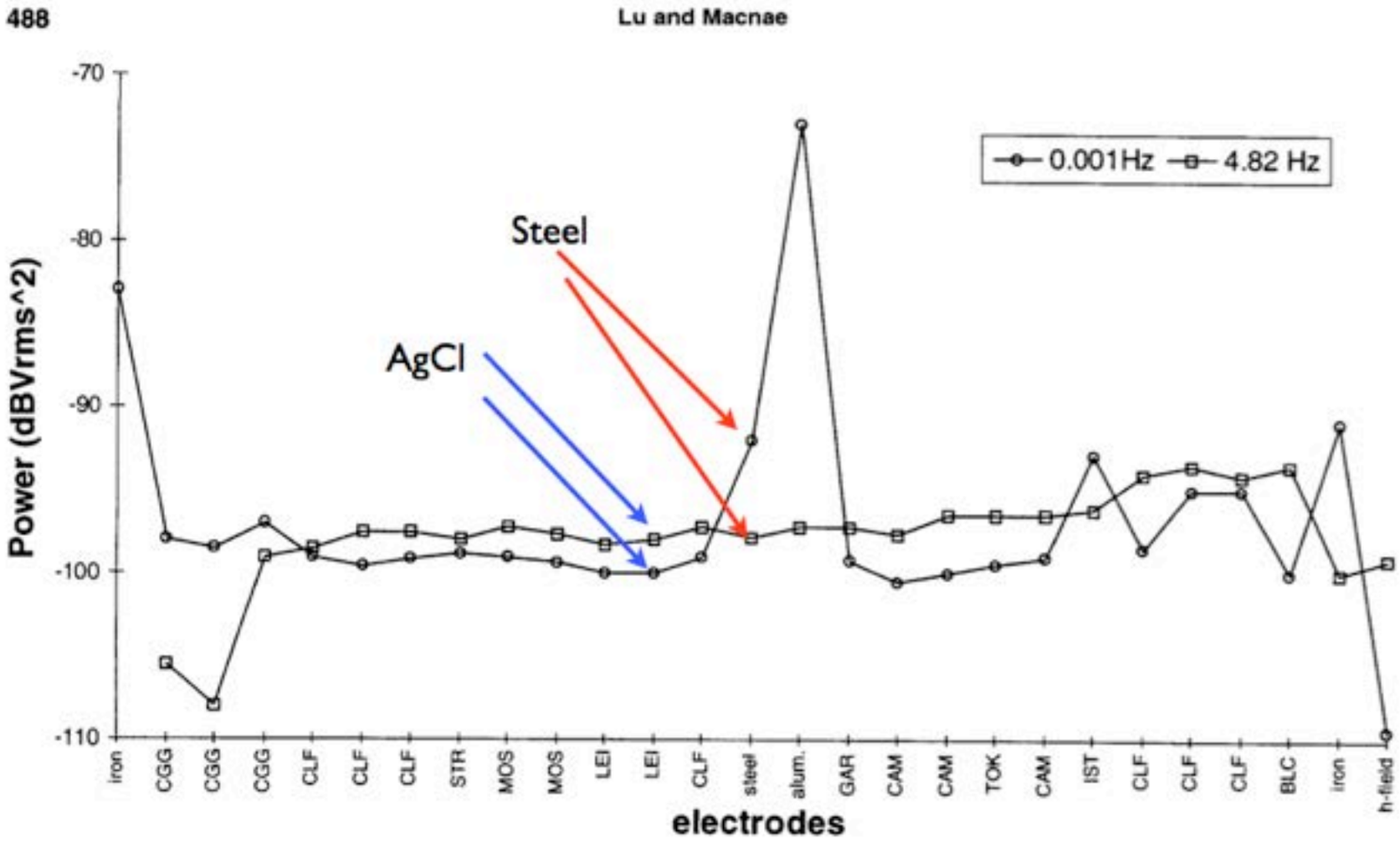


Figure 8. Noise comparison in the power spectrum with 10Hz acquisition (electrode codes in Table 1).

Electrode Noise

- As long as linear or low frequency drift is not a problem, metal electrodes (stainless steel, iron) are pretty good AND very easy to handle and transport, very easy to source

Electrode Noise

- But
- Not a single ‘recipe’
- Seem to be differences in behaviour for different soil types, salt/fresh water and mud

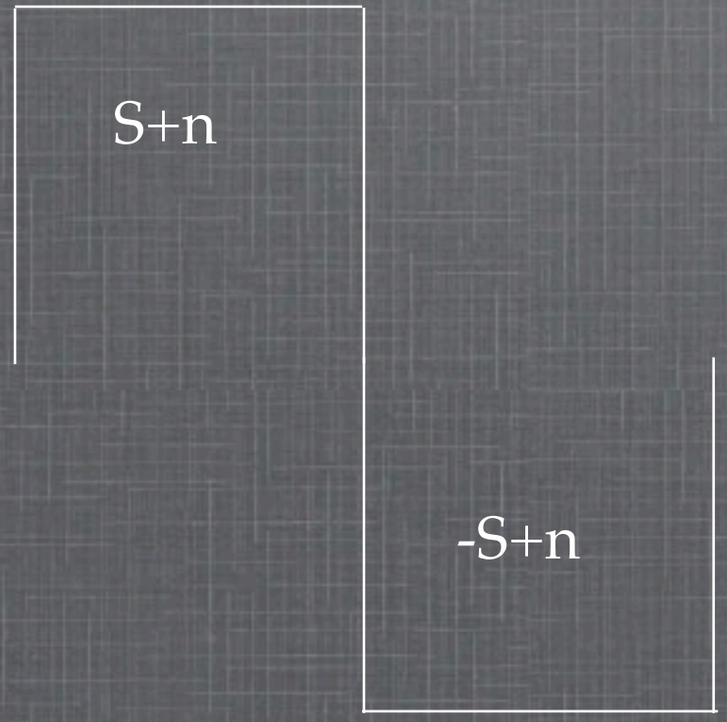
PROCESSING

- Stacking
- Selective Stacking
- Telluric Cancellation

PROCESSING - 1

Stacking

Most stacking is or has been simple bipolar



Adding half periods gives 2*n

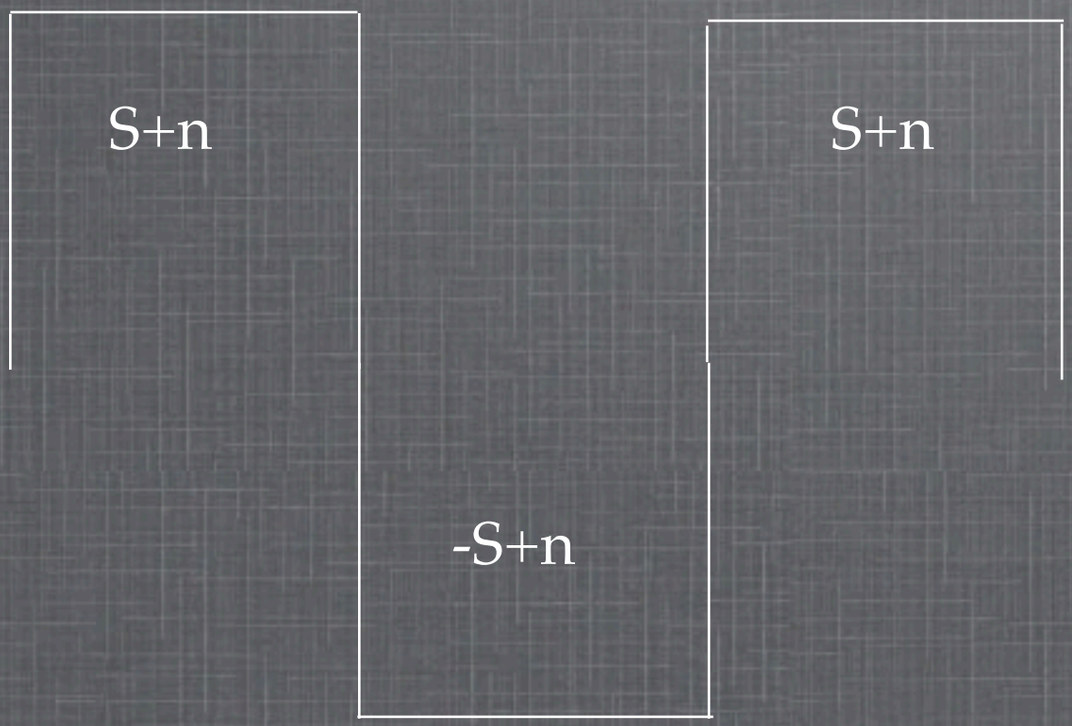
Subtracting half periods gives 2*S

- Emphasises Signal
- Reduces Noise
- Removes DC

PROCESSING - 1

Stacking

Halverson Stacking

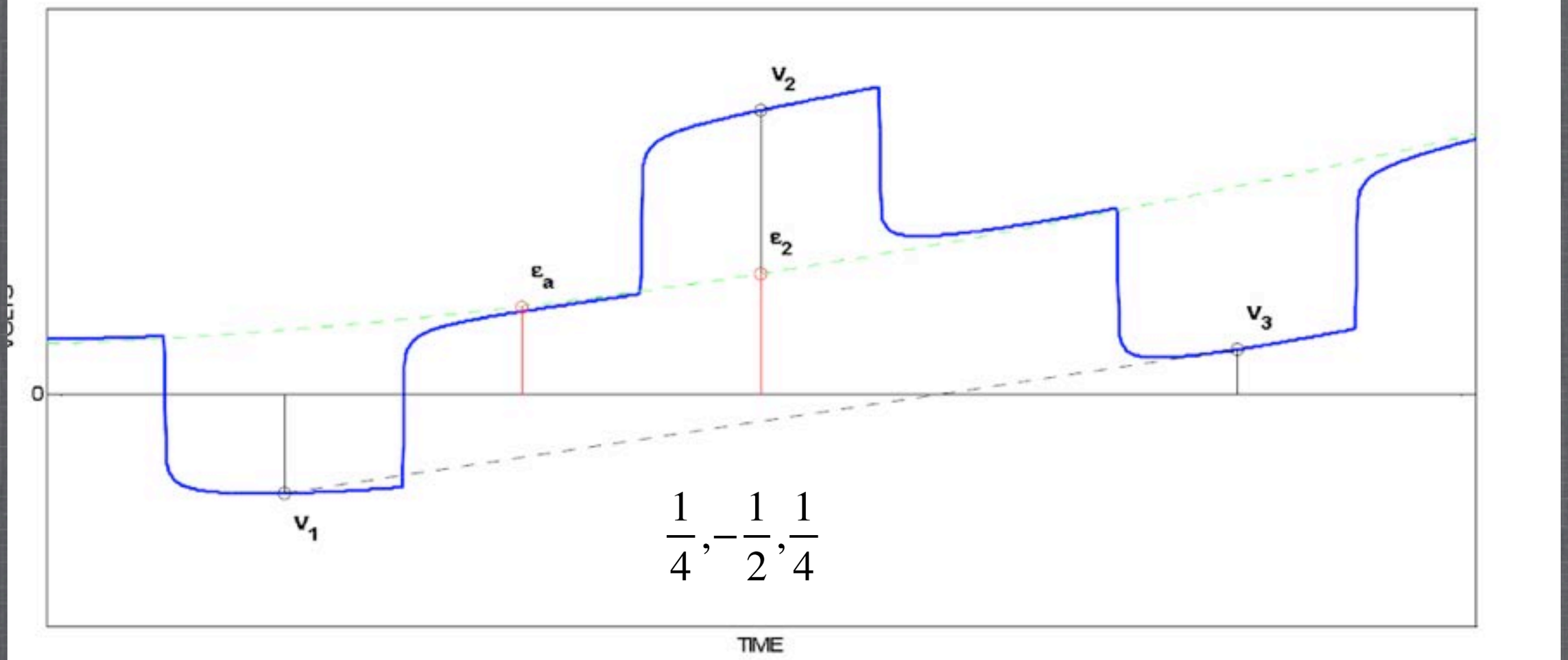


Weighted addition of half periods gives Signal

- Emphasises Signal
- Reduces Noise
- Removes DC
- Removes linear trend

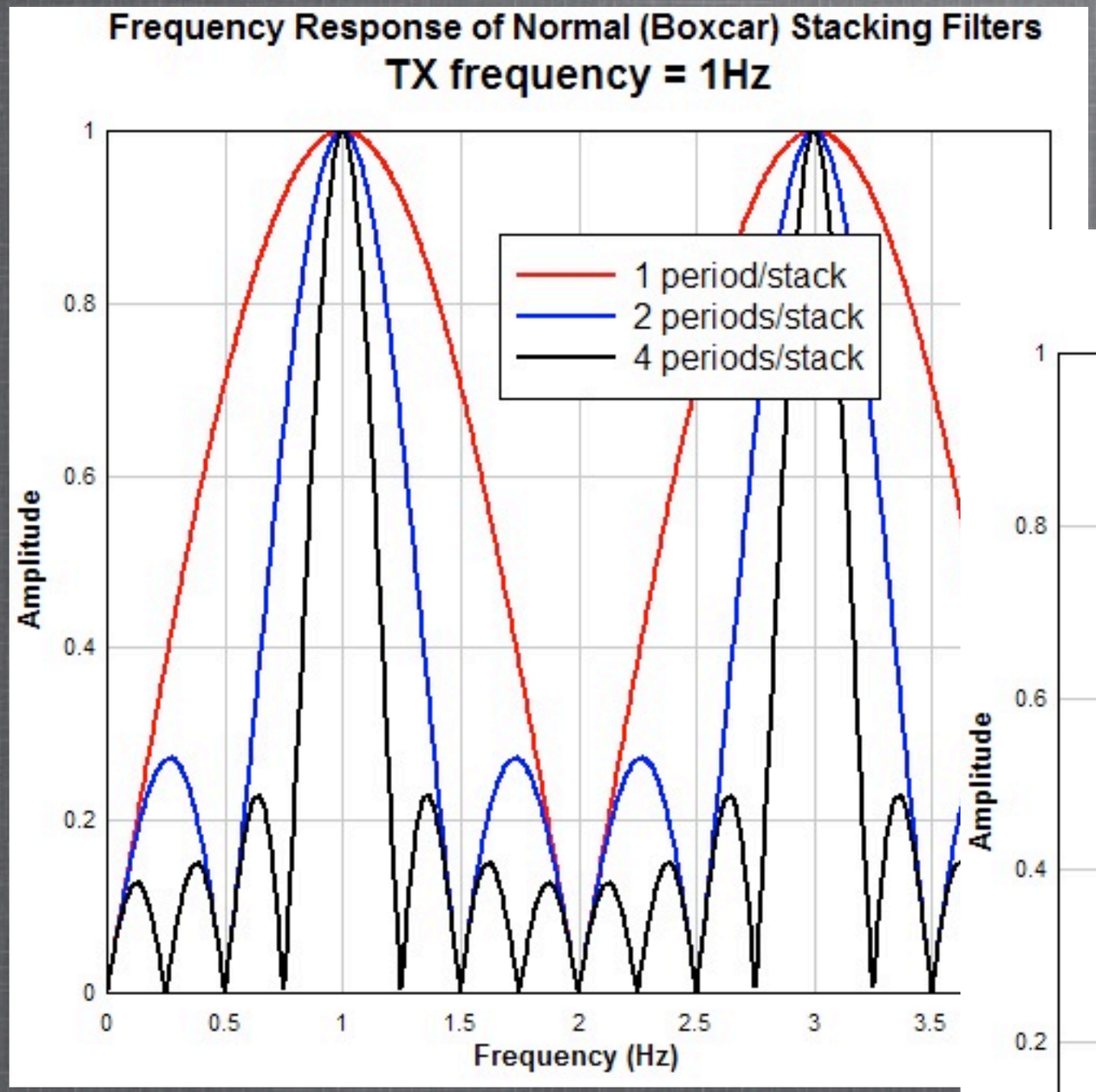
PROCESSING - 1

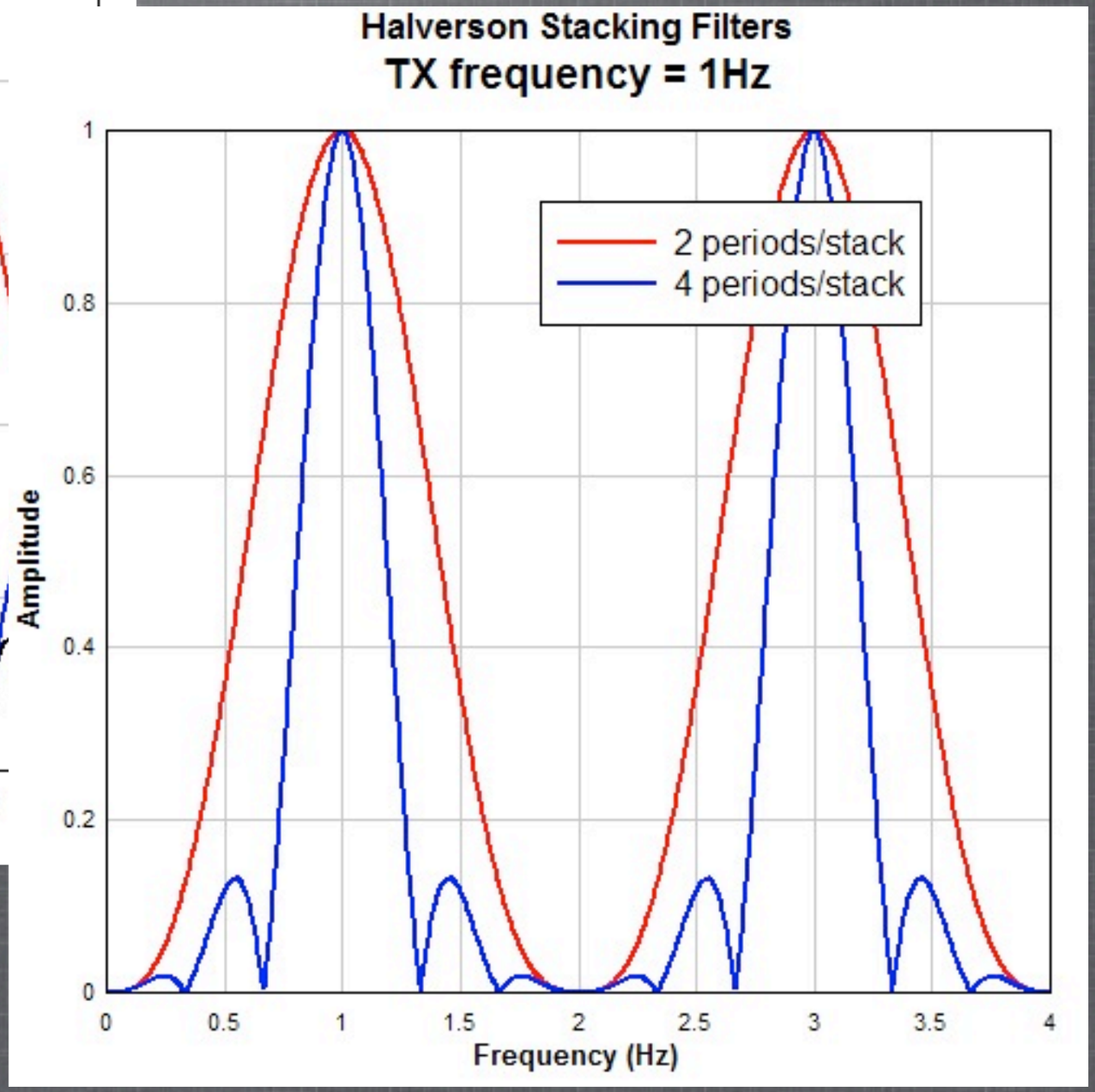
Halverson Stacking



$$\frac{1}{4}, -\frac{1}{2}, \frac{1}{4}$$

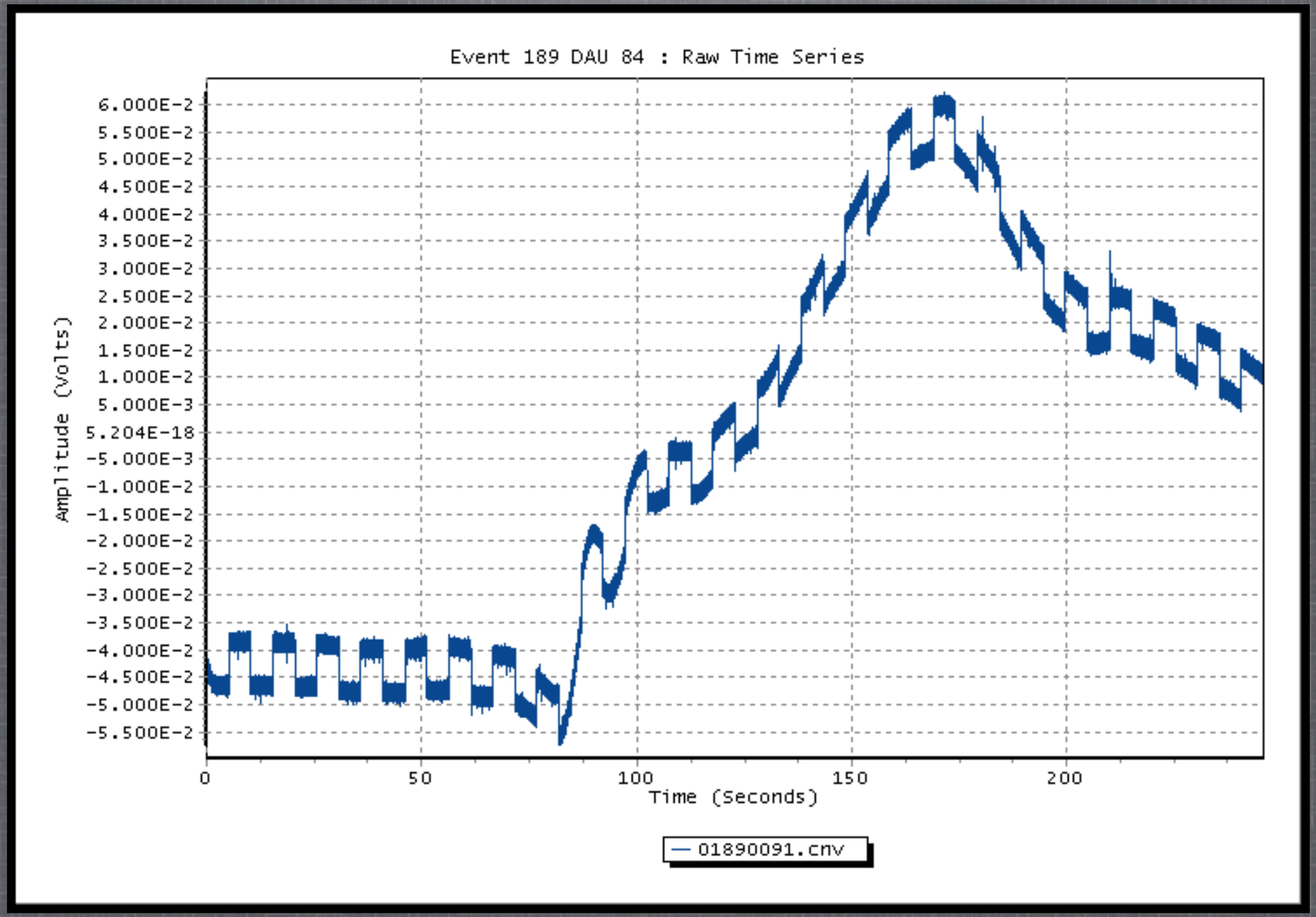
PROCESSING-1



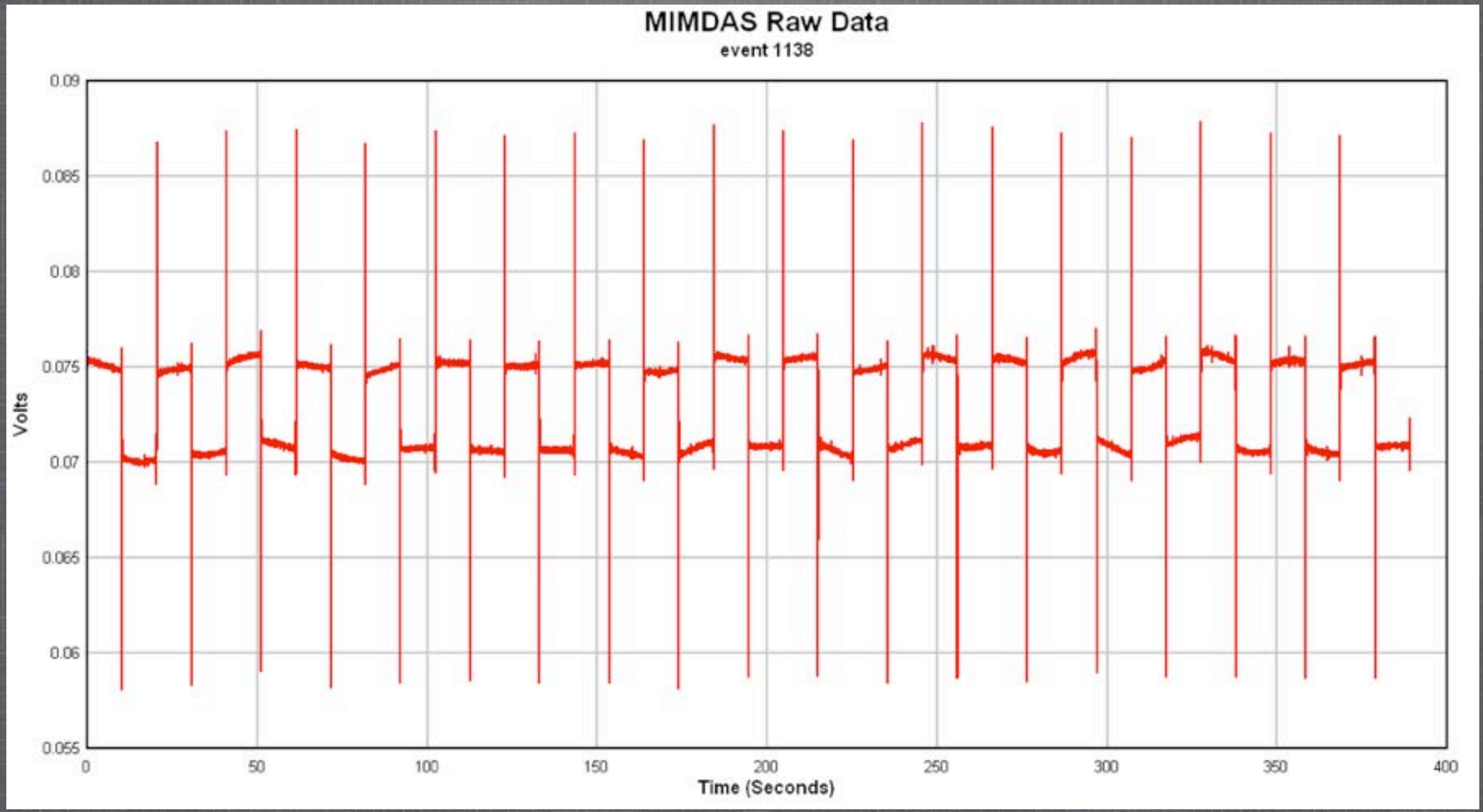


PROCESSING

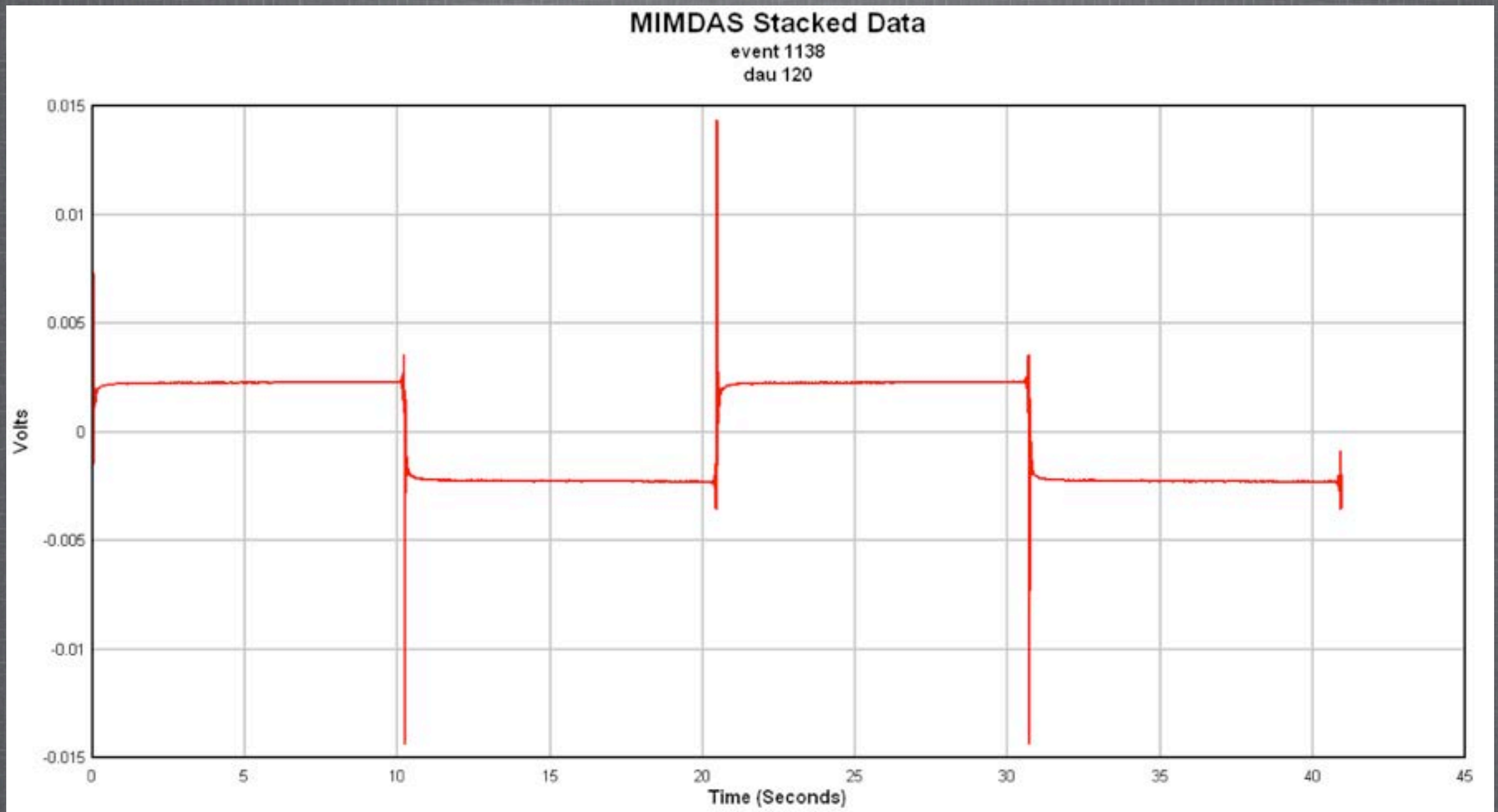
why linear drift removal is important



PROCESSING - 1



PROCESSING -1



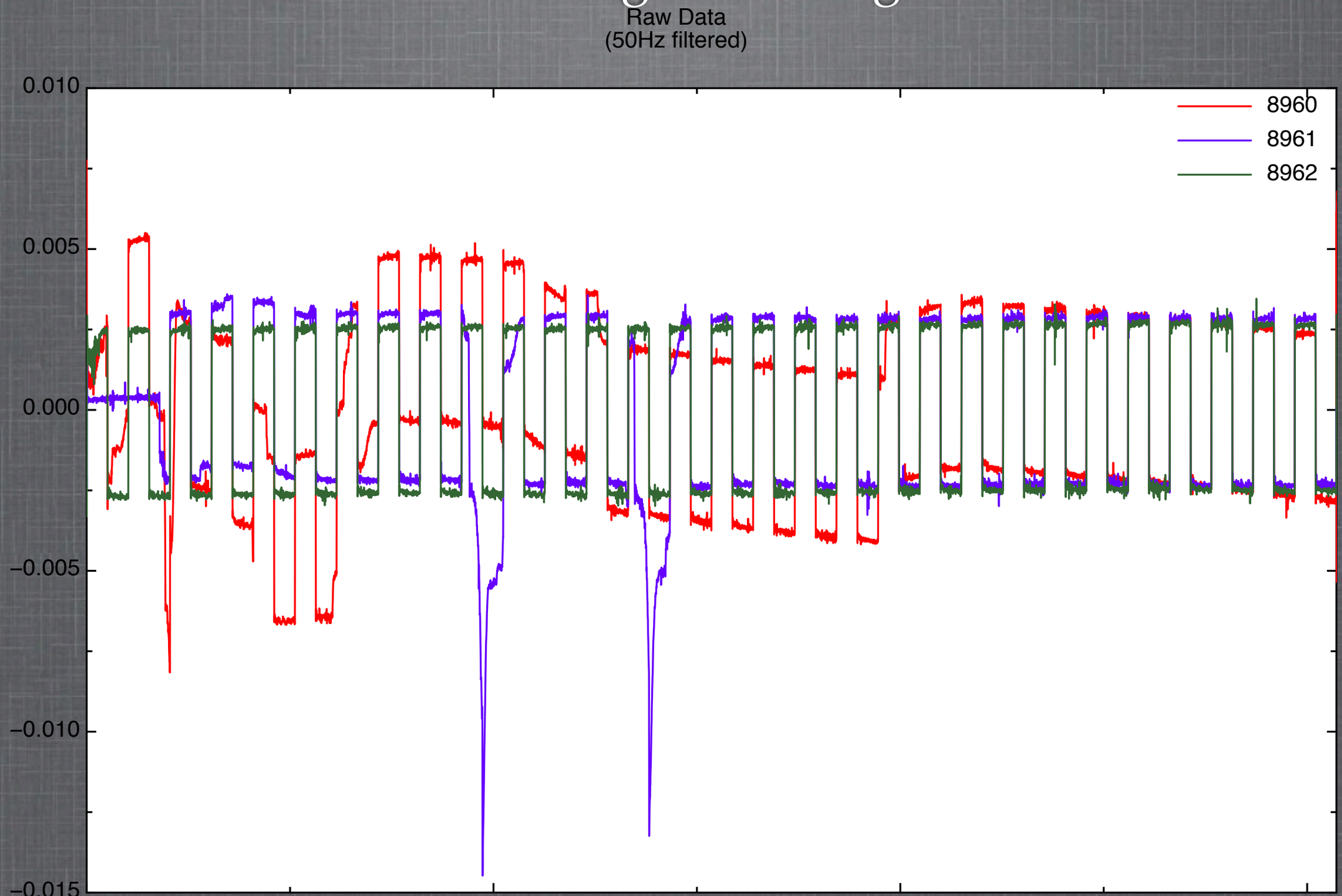
PROCESSING

This can provide a s/n increase of root n, so if we average 100 periods we should get a s/n increase of 10 and that might be enough...

.....But if we have the wrong sort of noise

PROCESSING - 1

Processing - Stacking

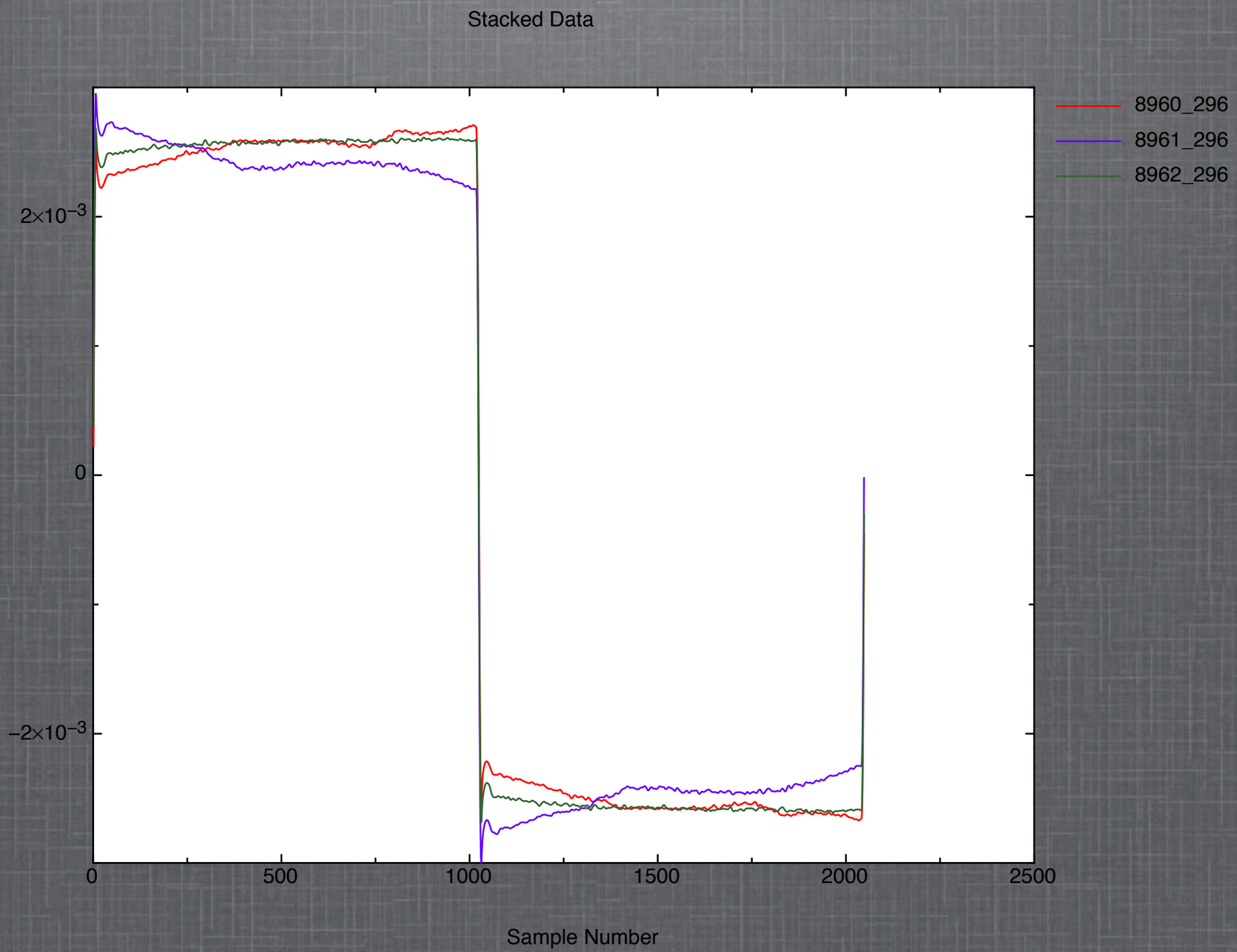


PROCESSING

So even though we have three events with ~ 30 periods each, just averaging the results won't improve the s/n by a factor of ten

PROCESSING -1

Selective Stacking



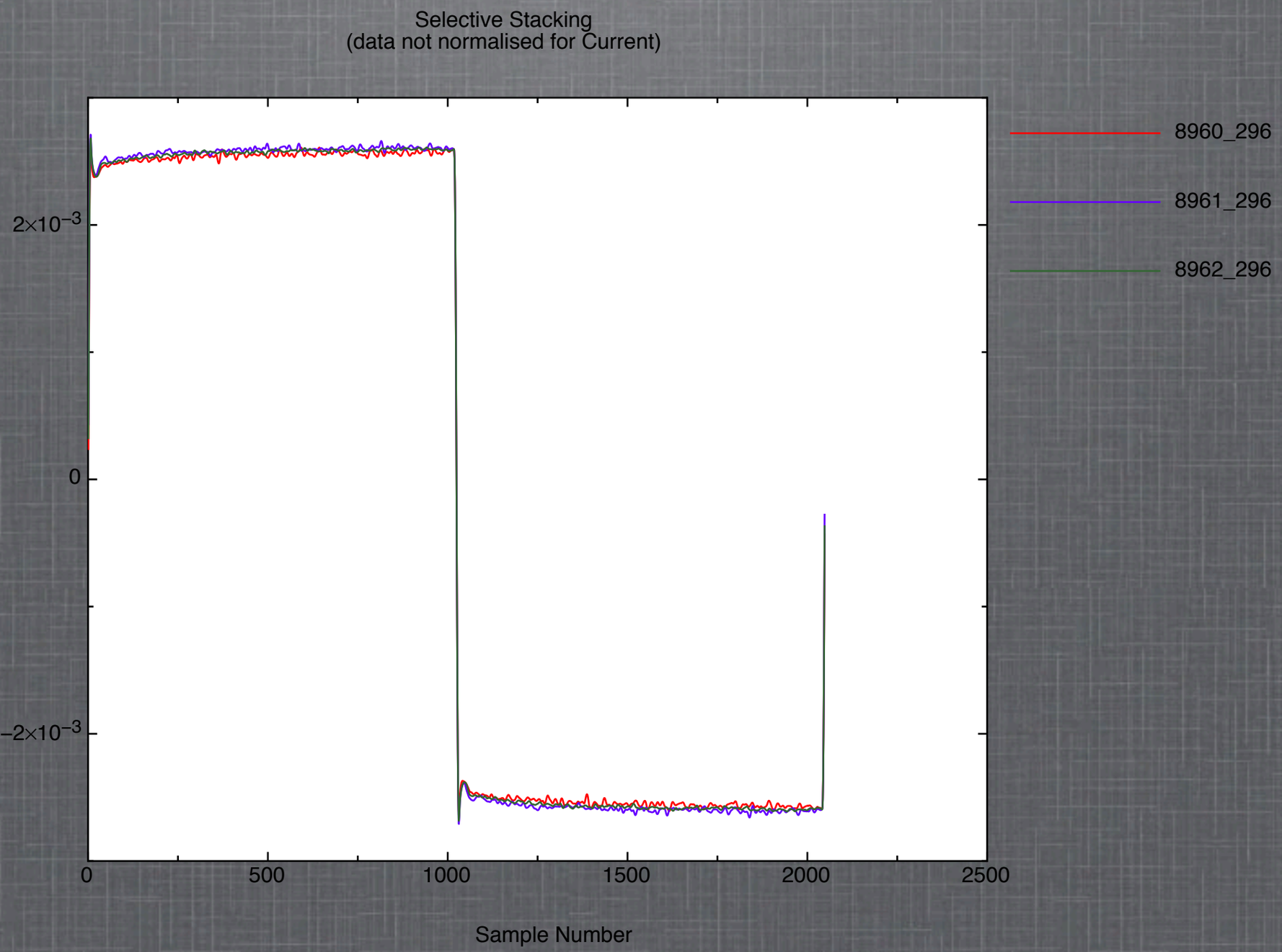
PROCESSING-1

Selective Stacking

If we subset the data then collect statistics on stacked half periods, then select those that suit our criteria...

PROCESSING -1

Selective Stacking

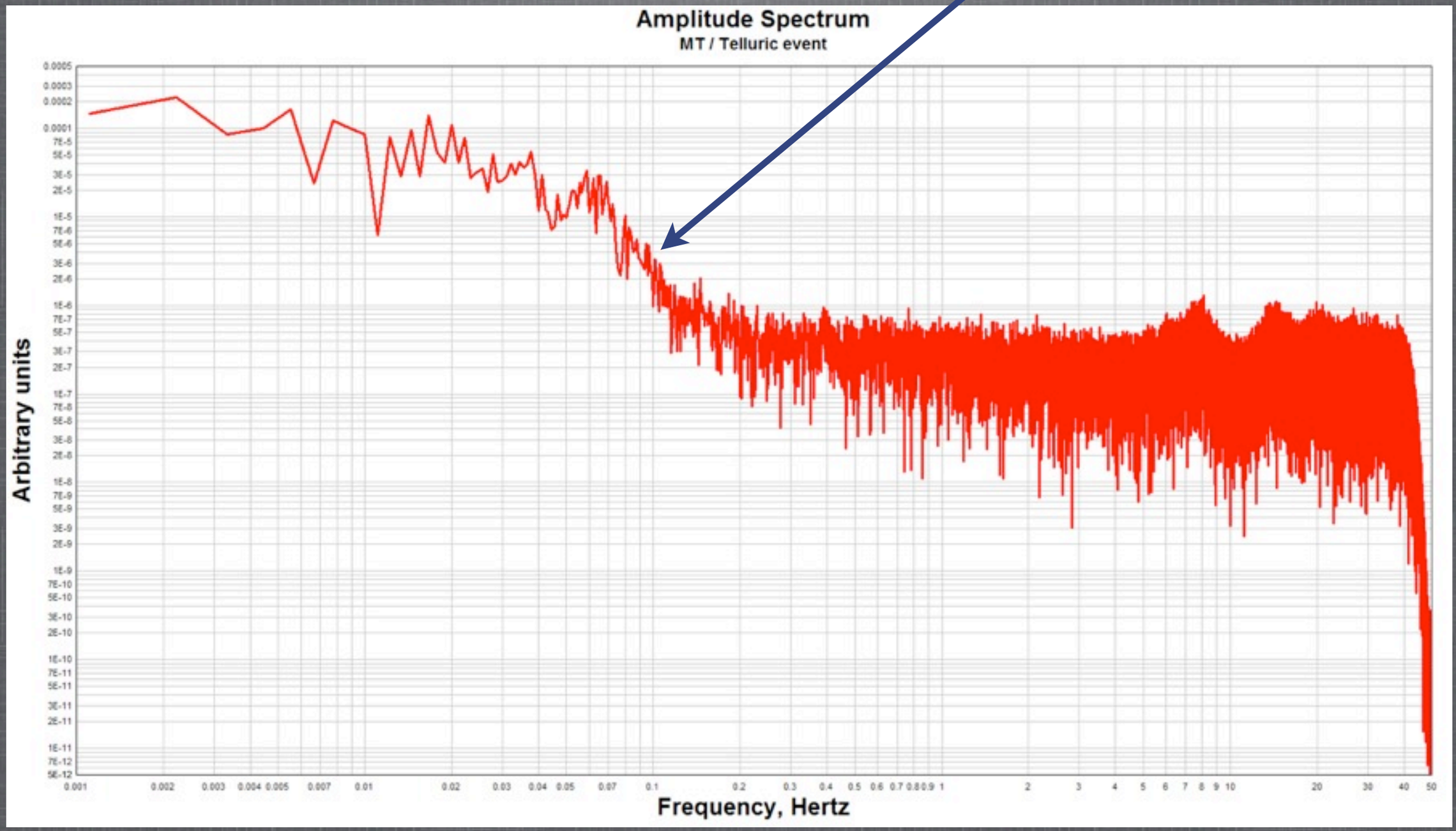


PROCESSING

and that might be enough if telluric noise is ‘normal’

PROCESSING - 5

Telluric Cancellation

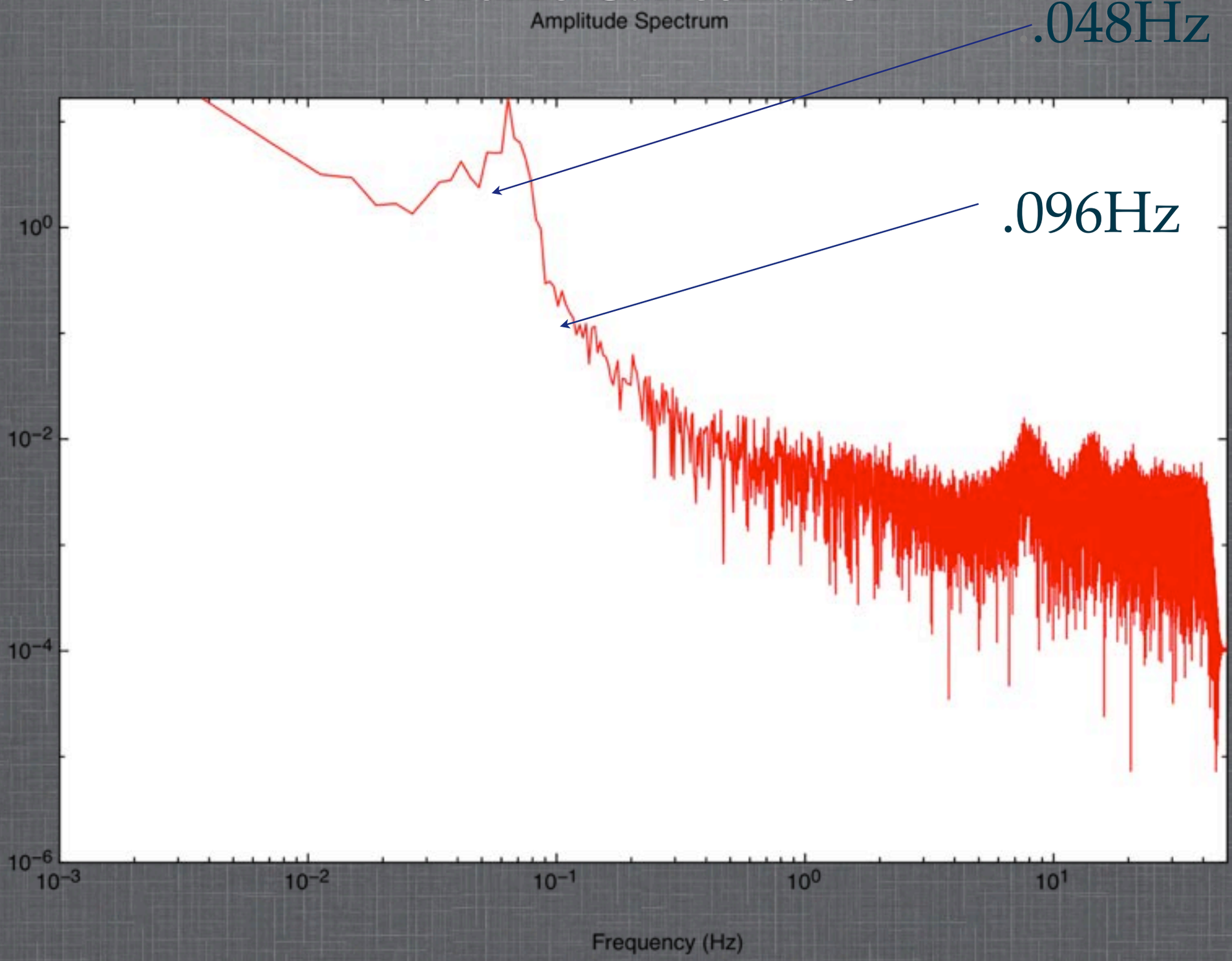


PROCESSING

BUT if we have telluric noise right on the fundamental…

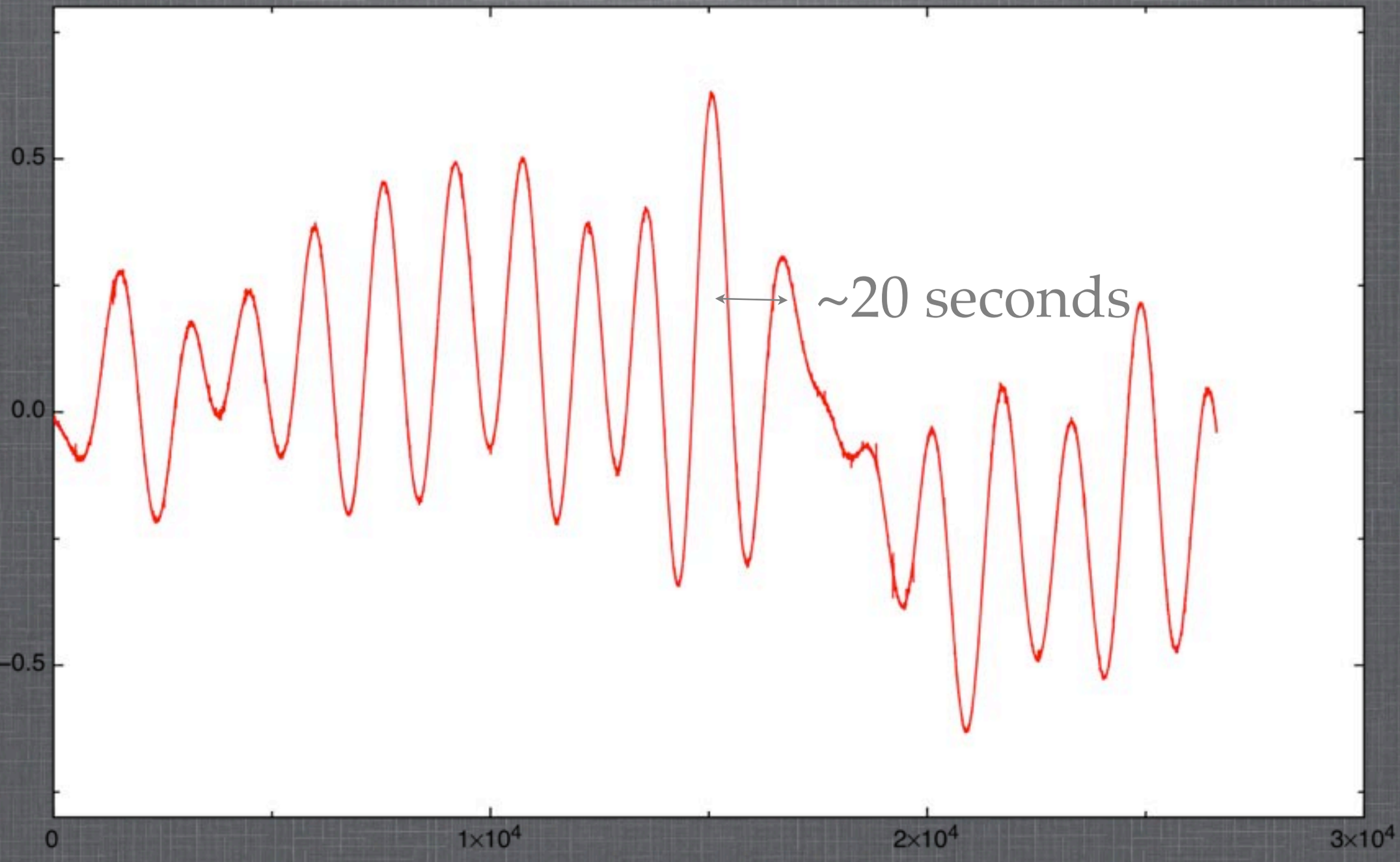
PROCESSING - 5

Telluric Cancellation



PROCESSING - 5

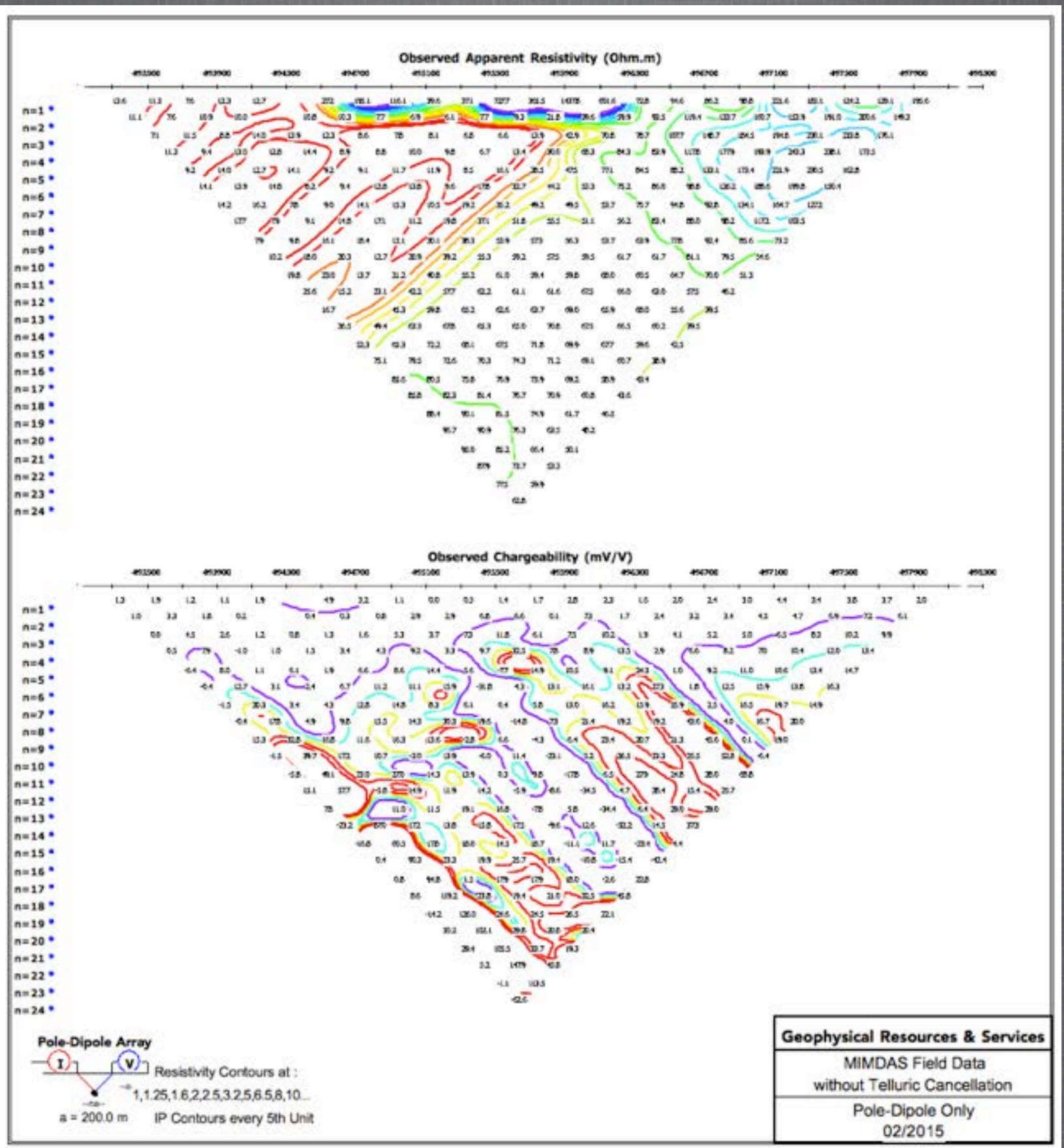
Telluric Cancellation

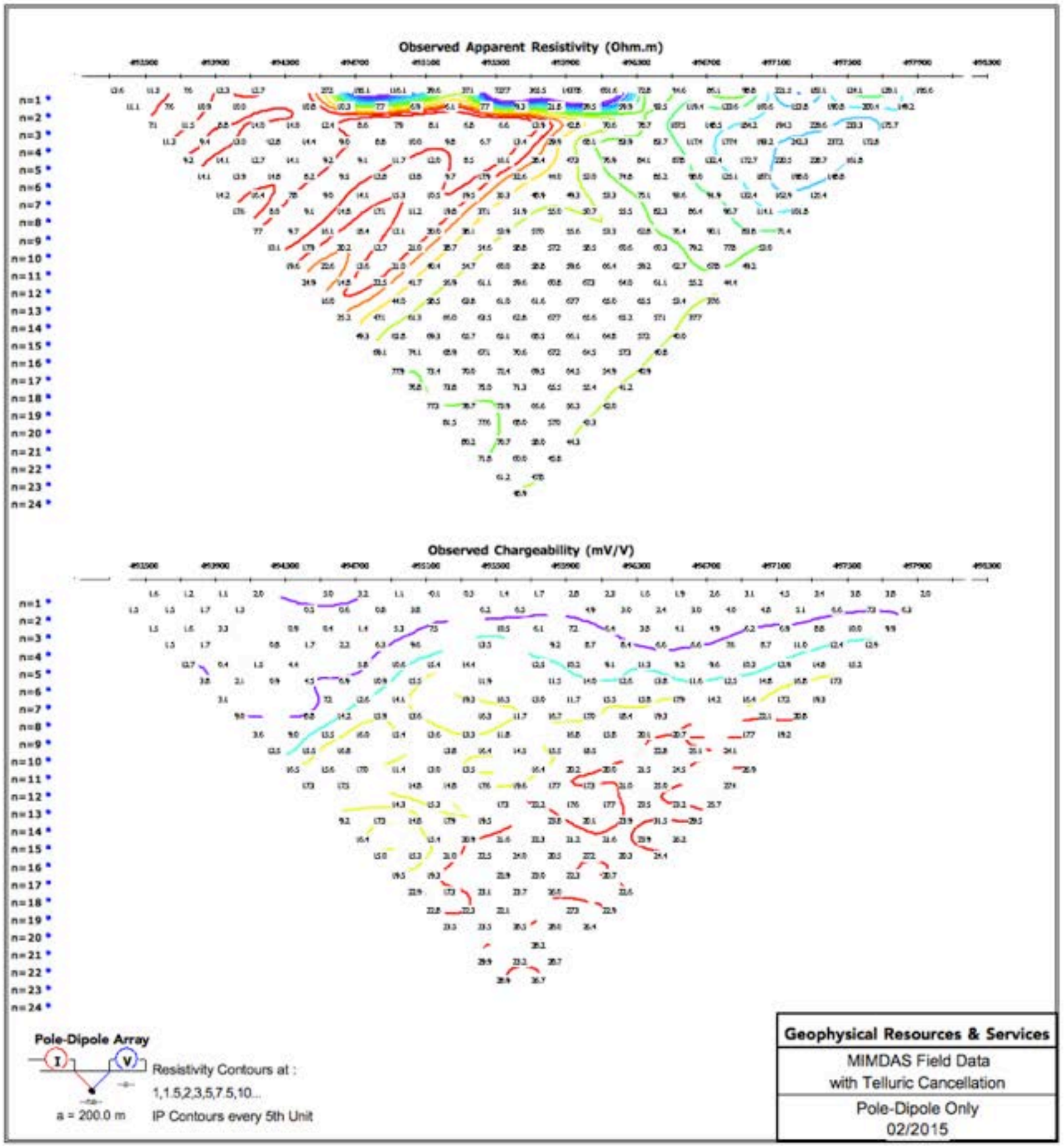


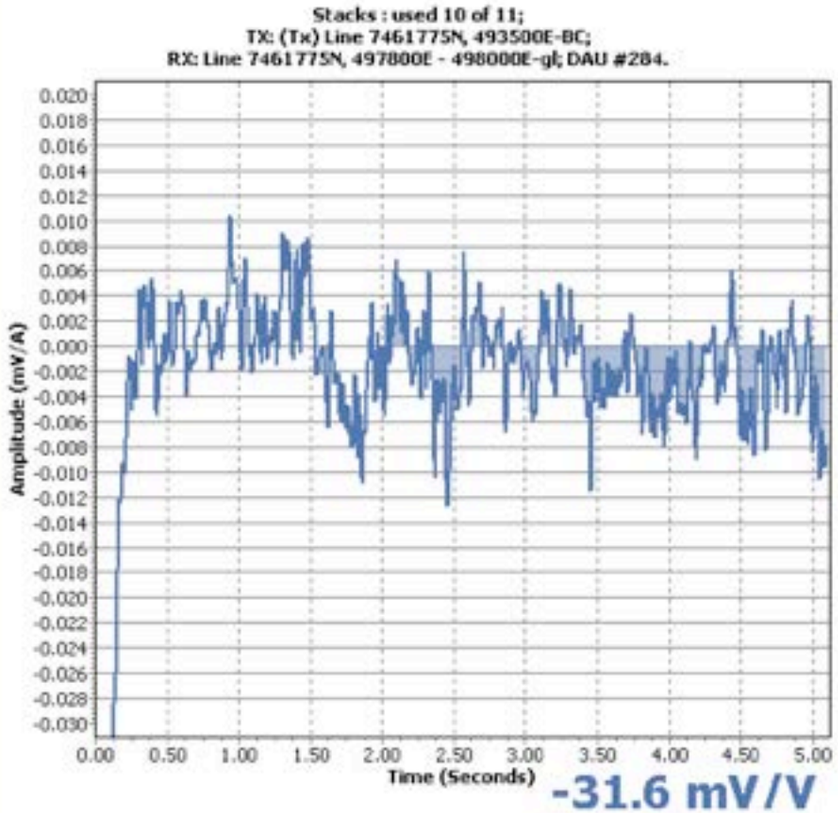
PROCESSING

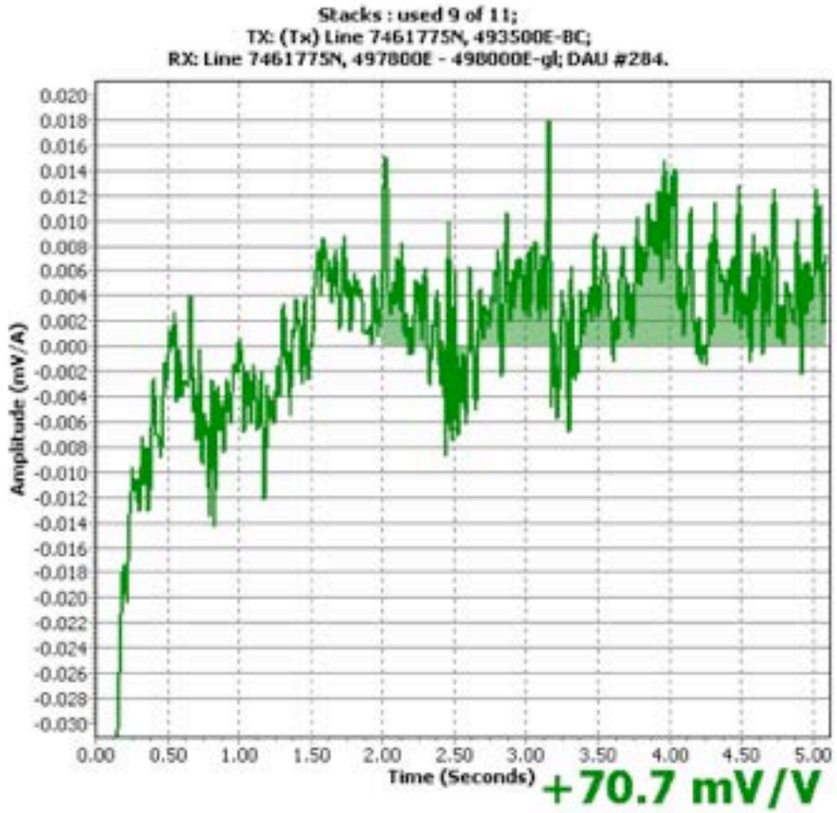
with an increase of noise by a factor of twenty the choices are

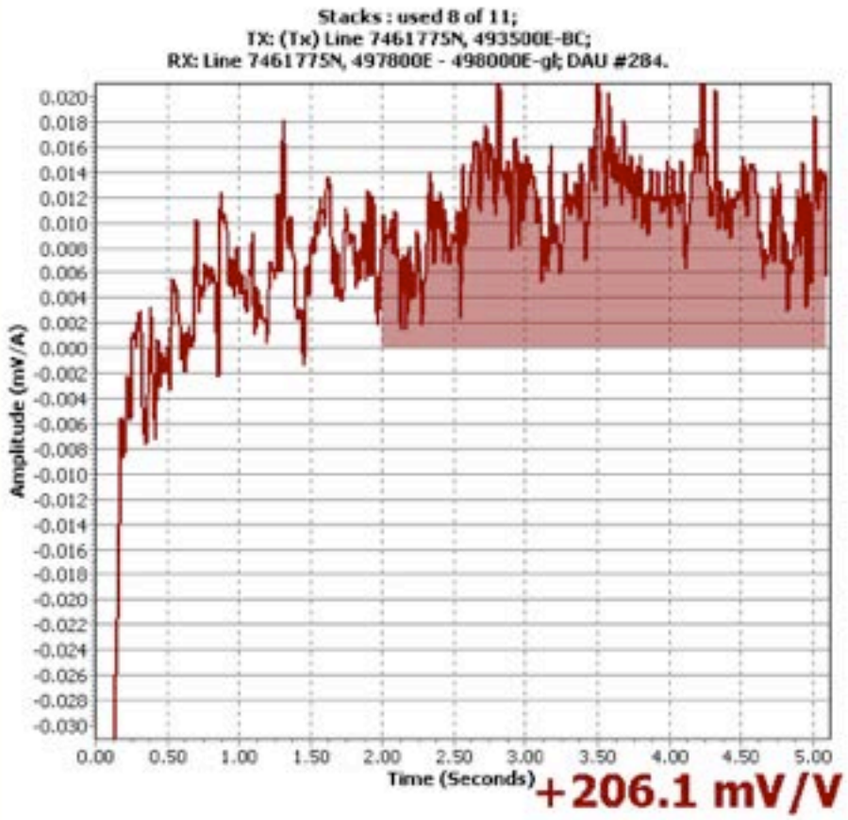
1. increase amount of data (time) by 400
2. increase current by 20 or Power by 400
3. telluric cancellation

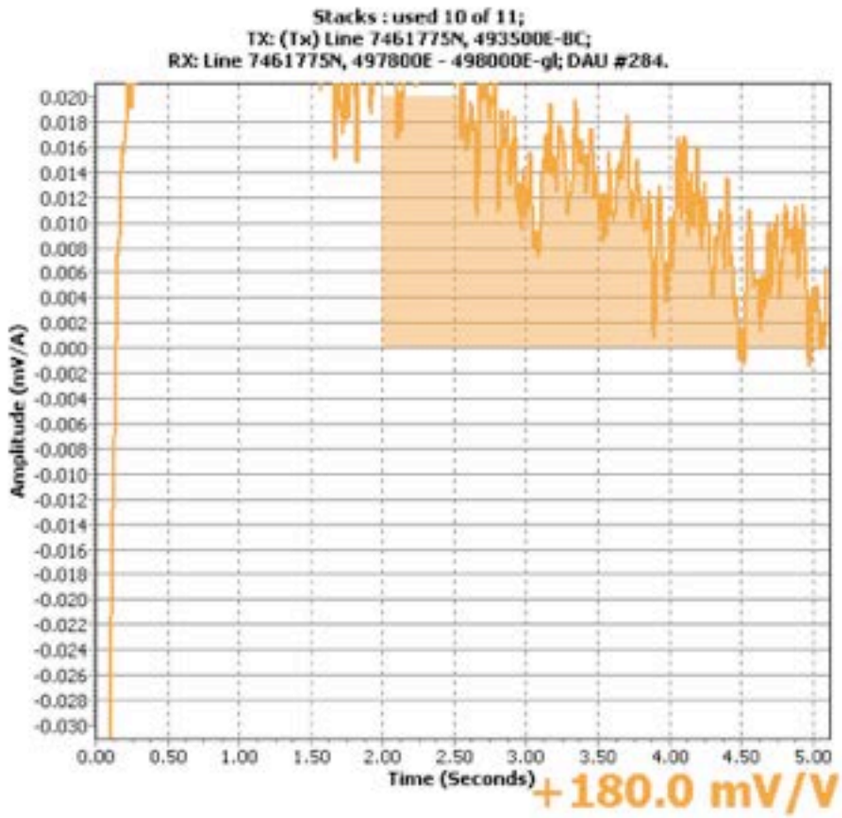

Observed Apparent Resistivity (Ohm.m)
n=1
n=2
n=3
n=4
n=5
n=6
n=7
n=8
n=9
n=10
n=11
n=12
n=13
n=14
n=15
n=16
n=17
n=18
n=19
n=20
n=21
n=22
n=23
n=24
Observed Chargeability (mV/V)
Pole-Dipole Array
I
V
Resistivity Contours at :
1,1.25,1.6,2,2.5,3.2,5,6.5,8,10...
a = 200.0 m
IP Contours every 5th Unit
Geophysical Resources & Services
MIMDAS Field Data
without Telluric Cancellation
Pole-Dipole Only
02/2015


Observed Apparent Resistivity (Ohm.m)
n=1
n=2
n=3
n=4
n=5
n=6
n=7
n=8
n=9
n=10
n=11
n=12
n=13
n=14
n=15
n=16
n=17
n=18
n=19
n=20
n=21
n=22
n=23
n=24
Observed Chargeability (mV/V)
Pole-Dipole Array
I
V
a = 200.0 m
Resistivity Contours at :
1,1.5,2,3,5,7.5,10...
IP Contours every 5th Unit
Geophysical Resources & Services
MIMDAS Field Data
with Telluric Cancellation
Pole-Dipole Only
02/2015


Stacks : used 10 of 11;
TX: (Tx) Line 7461775N, 493500E-BC;
RX: Line 7461775N, 497800E - 498000E-gl; DAU #284.
Amplitude (mV/A)
Time (Seconds)
-31.6 mV/V

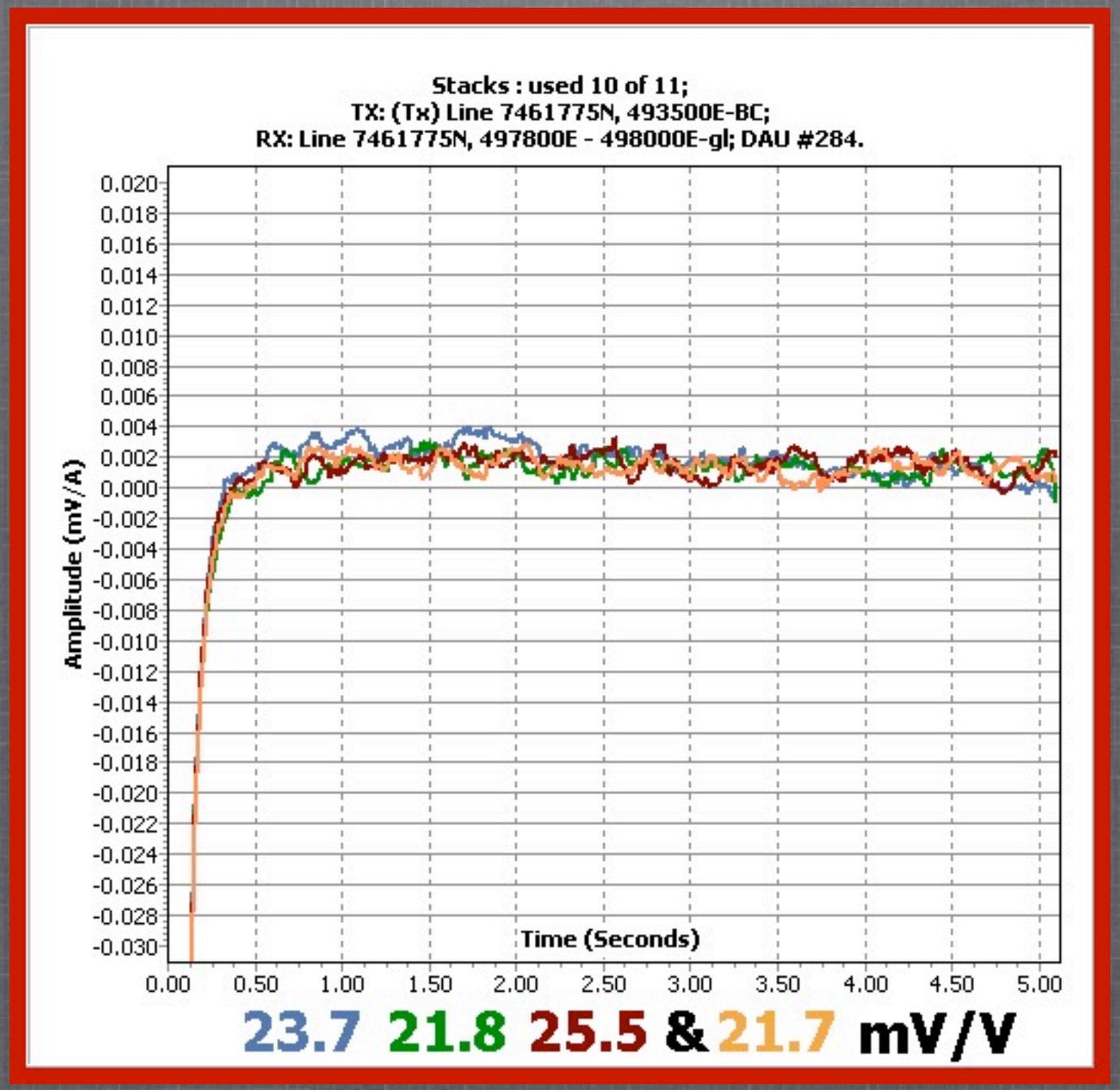

Stacks : used 9 of 11;
TX: (Tx) Line 7461775N, 493500E-BC;
RX: Line 7461775N, 497800E - 498000E-gl; DAU #284.
Amplitude (mV/A)
Time (Seconds)
+70.7 mV/V


Stacks : used 8 of 11;
TX: (Tx) Line 7461775N, 493500E-BC;
RX: Line 7461775N, 497800E - 498000E-gl; DAU #284.
Amplitude (mV/A)
Time (Seconds)
+206.1 mV/V


Stacks : used 10 of 11;
TX: (Tx) Line 7461775N, 493500E-BC;
RX: Line 7461775N, 497800E - 498000E-gl; DAU #284.
Amplitude (mV/A)
Time (Seconds)
+180.0 mV/V

PROCESSING

Telluric Cancellation



SIGNAL TO NOISE

It's as much about noise as it is signal!