IP with SMARTem24

ELECTRO MAGNETIC IMAGING TECHNOLOGY

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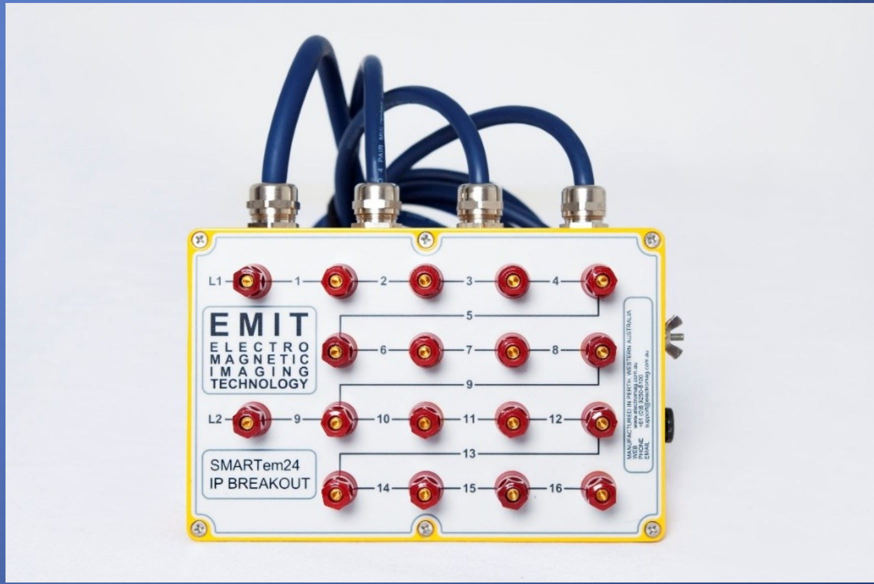
SMARTem24 Receiver System

SMARTem24

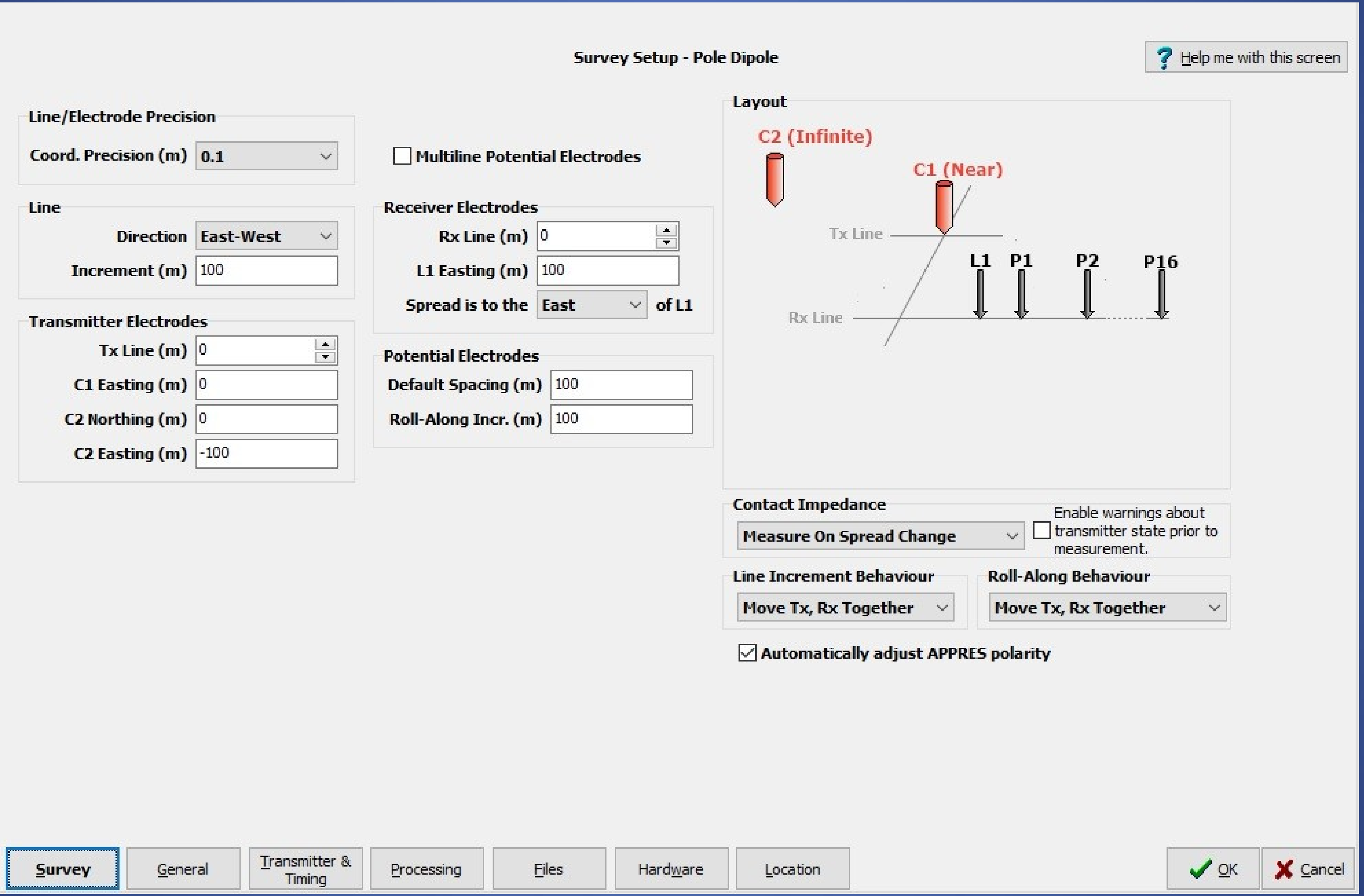
- Designed to interface to a range of transmitters and sensors.
- Multi-purpose, 24-bit, 16-channel receiver system.
- Integrated with a rugged Windows PC (Windows 10).
- GPS/crystal synchronisation or asynchronous operation.
- Sample rates … up to 120 ksps.
- Asynchronous transmitter operation for IP.
- We’ve been collecting full time series electrical geophysical data since 1995.
- First SMARTem IP surveys in 1996.
- Designed to operate with a range of transmitters and sensors.
- The software used in the field is the same as used on a PC for QC/processing.

SMARTem24 IP

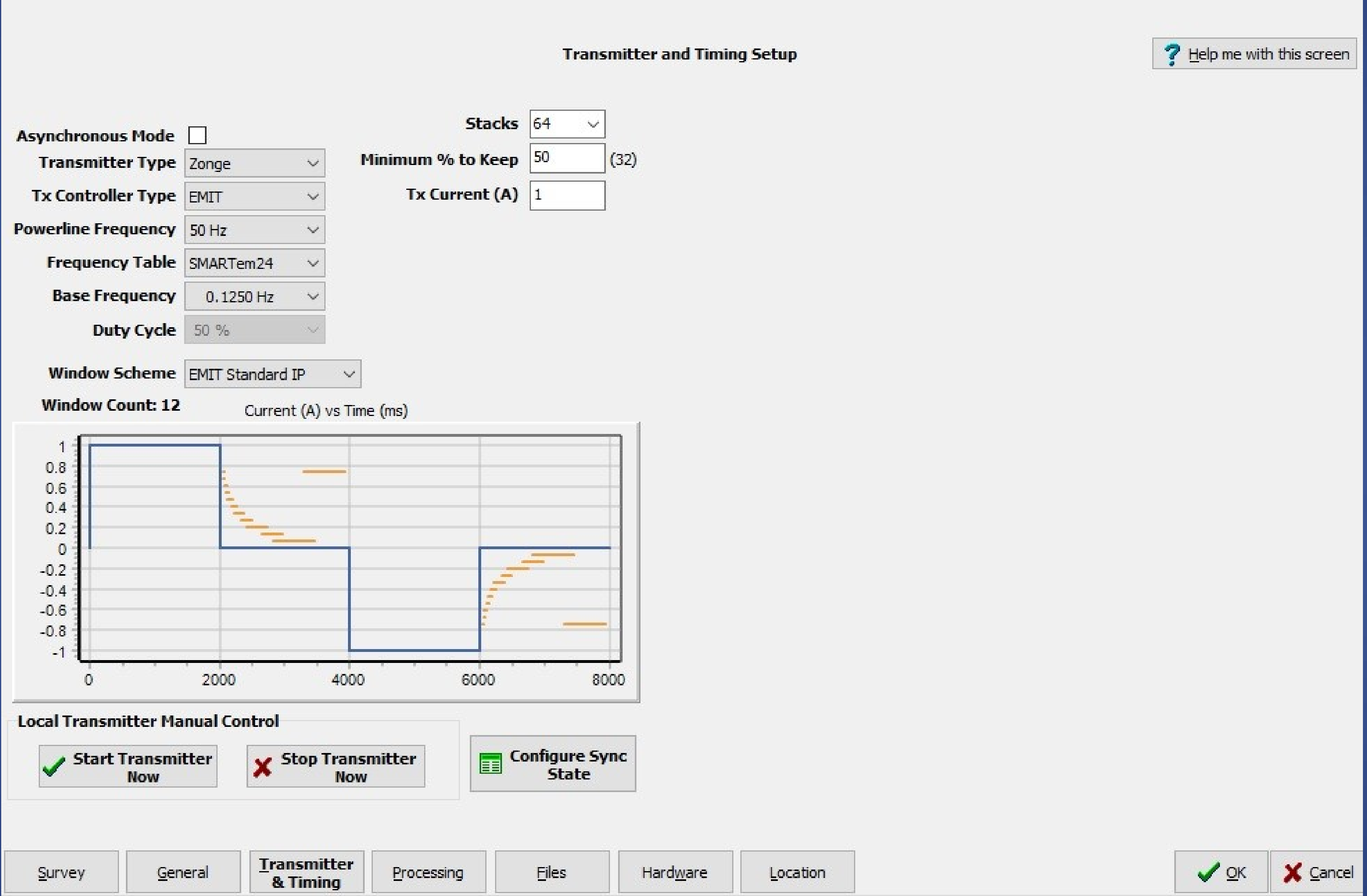
- Display of raw time series, stacked time series, decays, spectra, pseudosections.
- Decimation … 12 ksps decimated to desired lower frequency.
- A separate patch panel with infinite or dipole reference and choice of 1 (16 channel or 2 (8 channel) separately-referenced lines.
- Lightning/surge protection.
- Dipole resistance check.



SMARTem24 IP Software – Survey Setup



SMARTem24 IP Software – Transmitter Setup



SMARTem24 IP Software – Channel Setup

Hardware Setup

? Help me with this screen

✔ Refresh

Enabled Channels: 16

Sampling Rate: 1200

Power Feed: On

Group	Ch	Comp	Gain	Spacing	Electrode 1	Electrode 2
Group 1-4	1	On	Auto	200	*(L1: 100 mE, 0 mN)*	*(P1: 300 mE, 0 mN)*
	2	On	Auto	200	*(P1: 300 mE, 0 mN)*	*(P2: 500 mE, 0 mN)*
	3	On	Auto	200	*(P2: 500 mE, 0 mN)*	*(P3: 700 mE, 0 mN)*
	4	On	Auto	200	*(P3: 700 mE, 0 mN)*	*(P4: 900 mE, 0 mN)*
Group 5-8	5	On	Auto	200	*(P4: 900 mE, 0 mN)*	*(P5: 1100 mE, 0 mN)*
	6	On	Auto	200	*(P5: 1100 mE, 0 mN)*	*(P6: 1300 mE, 0 mN)*
	7	On	Auto	200	*(P6: 1300 mE, 0 mN)*	*(P7: 1500 mE, 0 mN)*
	8	On	Auto	200	*(P7: 1500 mE, 0 mN)*	*(P8: 1700 mE, 0 mN)*
Group 9-12	9	On	Auto	200	*(P8: 1700 mE, 0 mN)*	*(P9: 1900 mE, 0 mN)*
	10	On	Auto	200	*(P9: 1900 mE, 0 mN)*	*(P10: 2100 mE, 0 mN)*
	11	On	Auto	200	*(P10: 2100 mE, 0 mN)*	*(P11: 2300 mE, 0 mN)*
	12	On	Auto	200	*(P11: 2300 mE, 0 mN)*	*(P12: 2500 mE, 0 mN)*
Group 13-16	13	On	Auto	200	*(P12: 2500 mE, 0 mN)*	*(P13: 2700 mE, 0 mN)*
	14	On	Auto	200	*(P13: 2700 mE, 0 mN)*	*(P14: 2900 mE, 0 mN)*
	15	On	Auto	200	*(P14: 2900 mE, 0 mN)*	*(P15: 3100 mE, 0 mN)*
	16	On	Auto	200	*(P15: 3100 mE, 0 mN)*	*(P16: 3300 mE, 0 mN)*

Survey | General | Transmitter & Timing | Processing | Files | **Hardware** | Location | ✔ OK | ✘ Cancel

Processing Raw A/D Samples to Useful Numbers

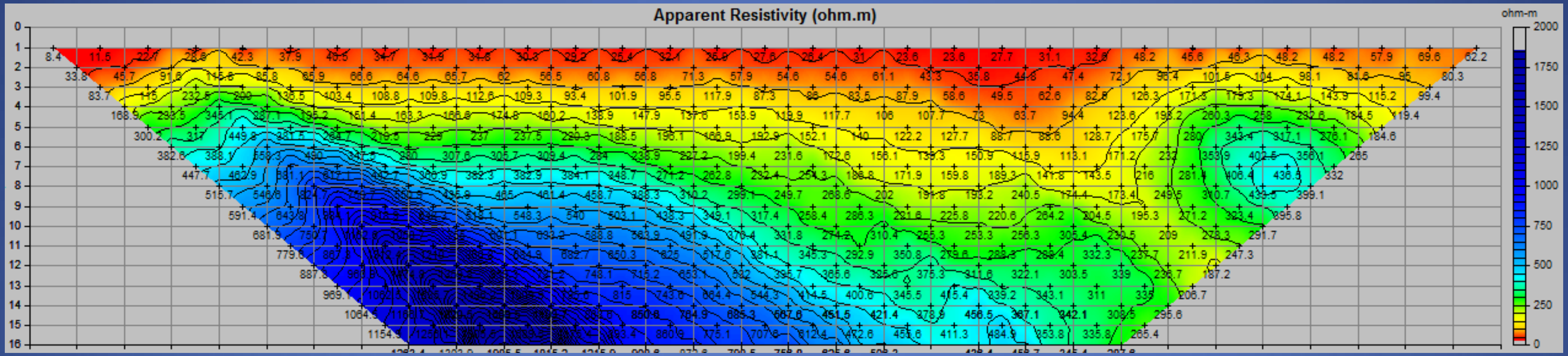
- Sample 24 bits (12 ksps)
- Filter and decimate (Dolph Chebyshev 120 dB, 1200 sps)
- Convert 24 bit A/D outputs to a calibrated voltage
- Stack (tapered stack) (***** most important stage *****)
- Window a decay
- Compute VP, M windows
- Normalise
- Generate stats while collecting data
- Ancillary parameters – powerline monitor, SP, APPRES

General Comments on Stacking

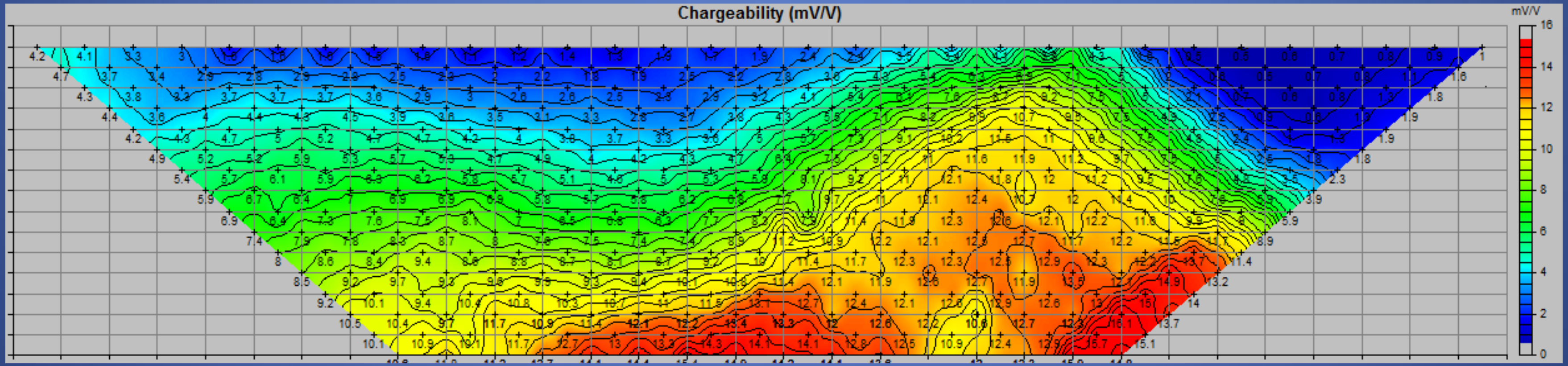
- A stacking filter has a passband only at odd harmonics of the fundamental frequency – 'comb' filter
- A taper to the stack (start and end of the reading) makes a huge difference to data quality when noise is not white (and it never is)
- If your instrument doesn't use a tapered stack then get one that does
- Usually only a small (say, 10% of the duration of the reading) taper is required and its main role is to remove low frequency noise from raw IP signals
- A longer taper can be very useful where powerline or other similar interference dominates, BUT with a small number of periods in a typical IP reading, the scope is limited
- Double precision arithmetic can be handy

Data Set – Pole-Dipole 200m n=16 roll-along

Apparent Resistivity

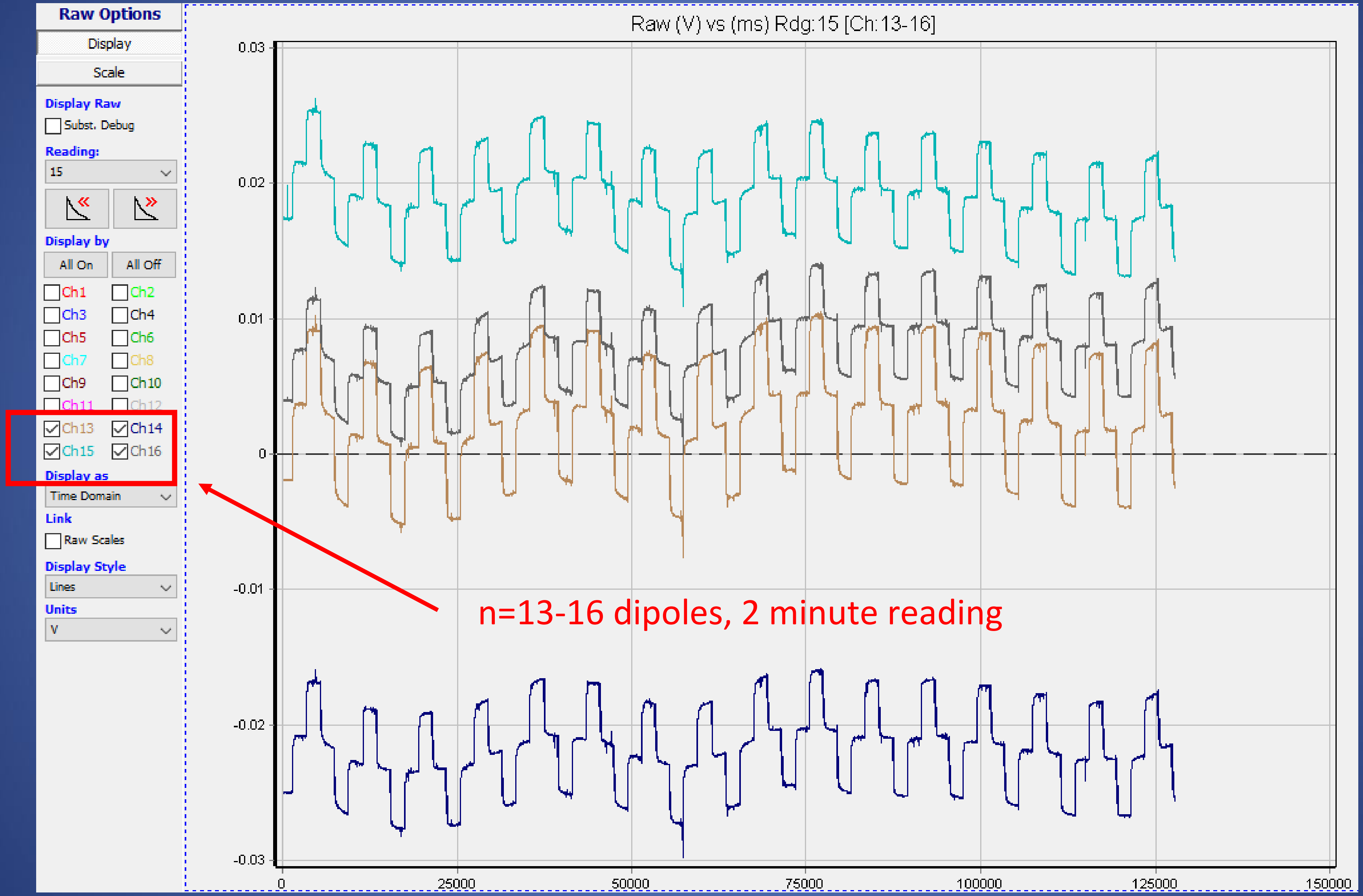


Chargeability



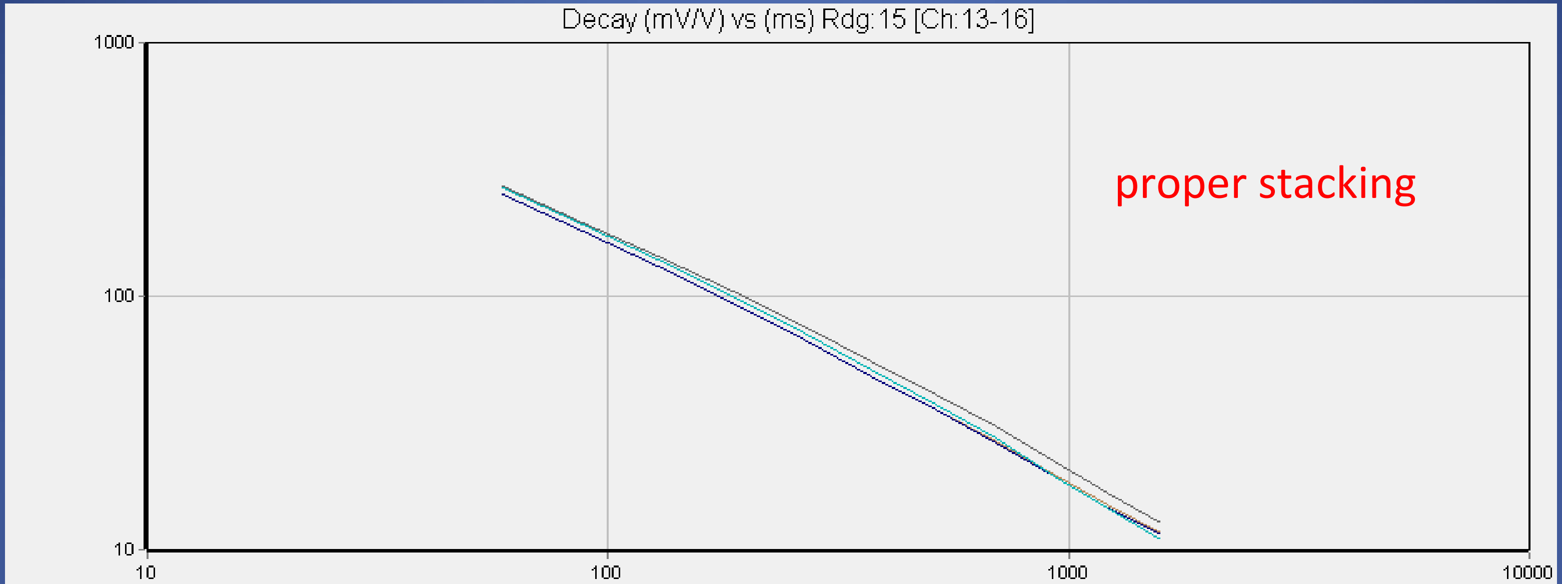
Collected by Moombarriga Geoscience using SMARTem24 Receiver and Search Exploration Services Transmitter

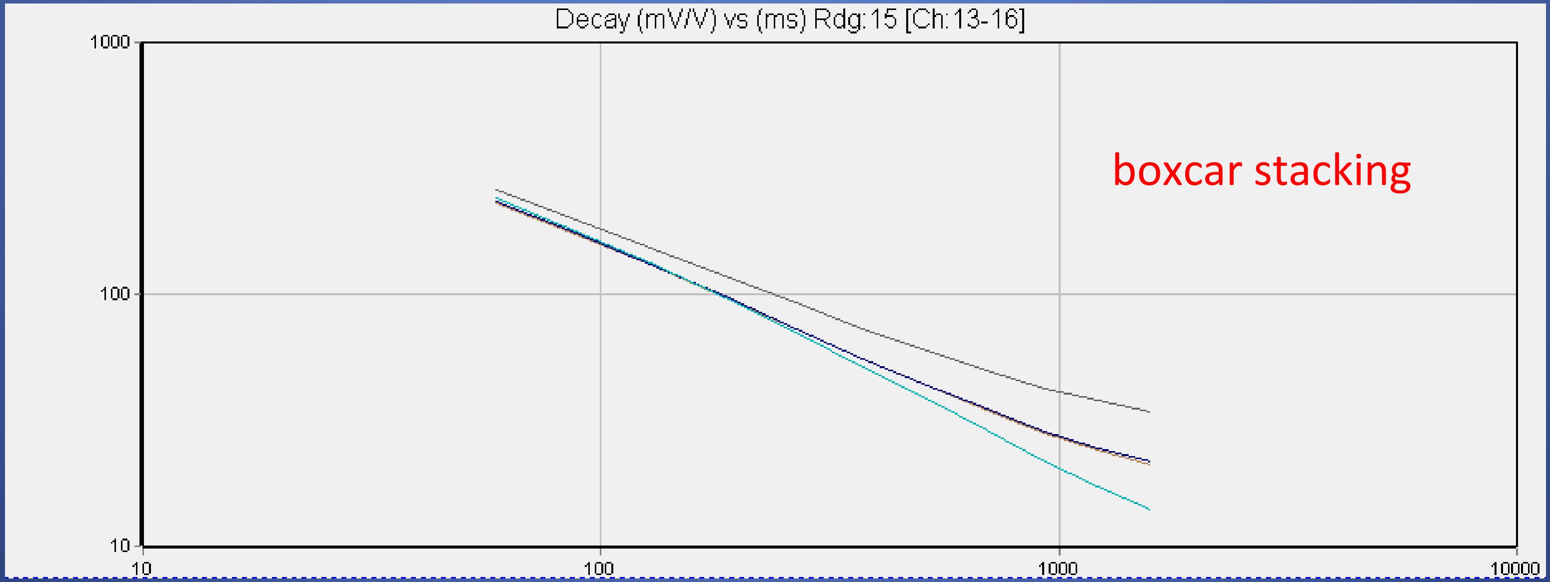
Raw Signals



Raw Options
Display
Scale
Display Raw
Subst. Debug
Reading:
15
Display by
All On
All Off
Ch1
Ch2
Ch3
Ch4
Ch5
Ch6
Ch7
Ch8
Ch9
Ch10
Ch11
Ch12
Ch13
Ch14
Ch15
Ch16
Display as
Time Domain
Link
Raw Scales
Display Style
Lines
Units
V
Raw (V) vs (ms) Rdg:15 [Ch:13-16]
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
25000
50000
75000
100000
125000
150000
n=13-16 dipoles, 2 minute reading

Resulting Decays





General Comments on Windowing

- Windowing is a low pass filter used like an integration window or moving average
- There is no point using a narrow window at late-time
- Strictly-speaking, overlapping windows are required to avoid aliasing of the decay
- My preference is to use windows that are overlapping
- SMARTem window schemes are user-selectable during or after a survey

Windows

Default settings:

•VP window: 52-98% of on-time

•M window: 52-98% of off-time

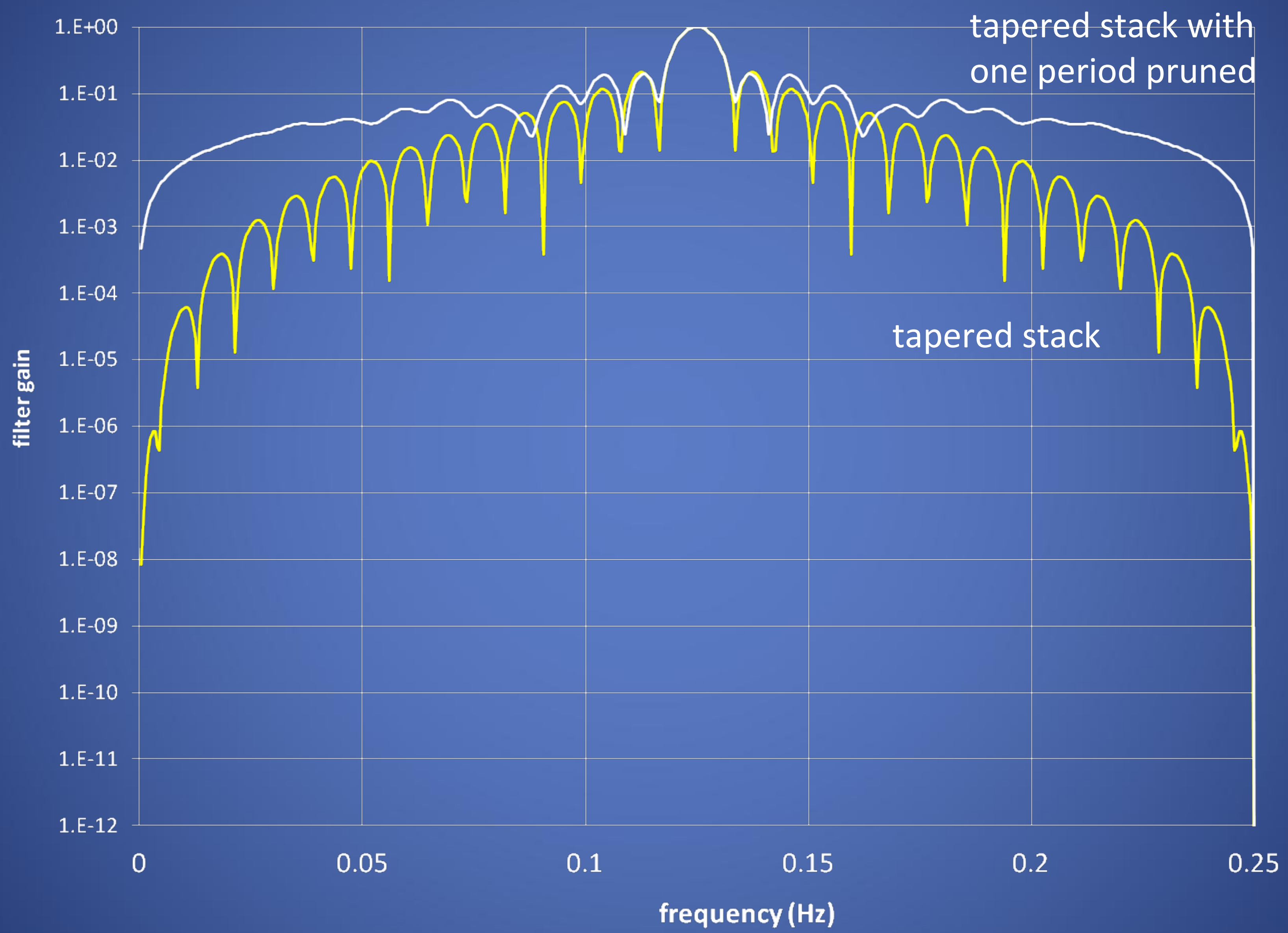
Windows for measured decay are selectable. Users can enter their own schemes into a configuration file, then the scheme becomes available for windowing during data collection or processing afterwards.

Archiving stacked waveforms is all that is required to re-window a data set. Not a hefty storage job.

Non-Linear Filtering/Processing

- Clipping, paring, deleting, outlier removal, de-spiking
- My opinion: if noise sources are continuous, systematic, predictable or well-separated in frequency from our frequencies of interest then non-linear techniques to remove them are probably not a great idea
- Deleting segments of data from the stack *may* have unintended consequences
- A remote reference technique probably offers more promise than a non-linear processing step

Stacking Filter Performance - 16 periods at 0.125 Hz (8 s)



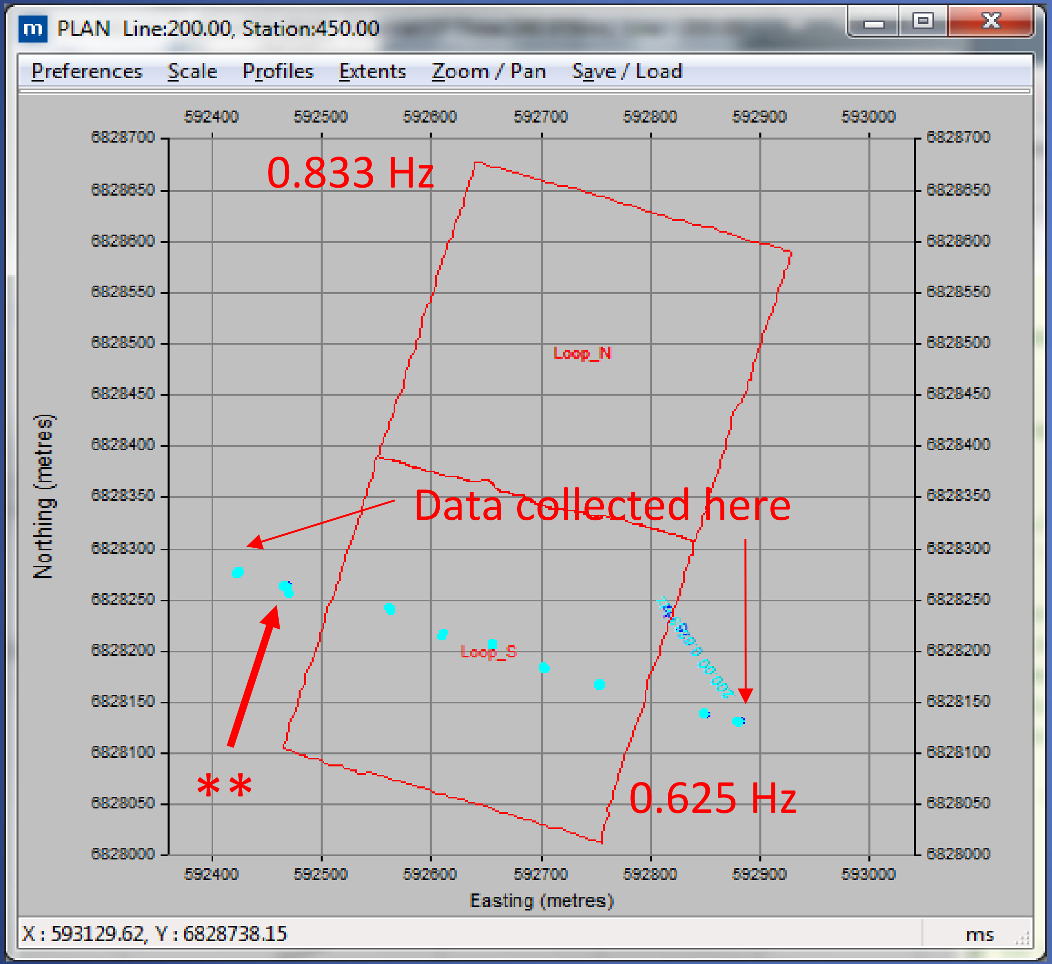
Why Record Time Series?

- Better signal processing
- Test a range of processing options
- Additional filtering or deconvolution
- Remote reference processing
- Re-stacking or re-windowing

Collecting IP Data from Multiple Sources Simultaneously

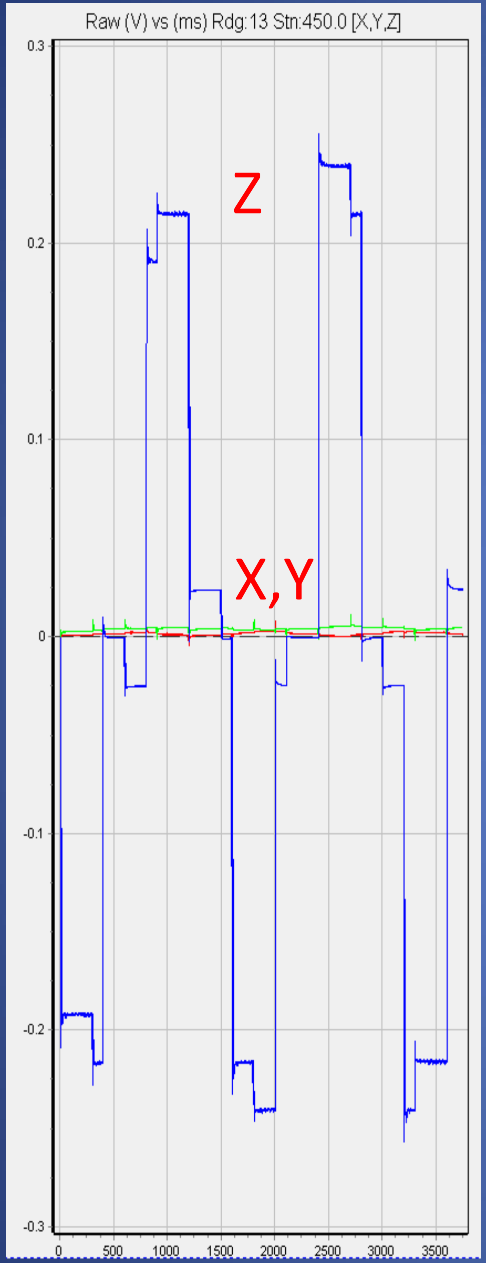
- Most useful in a survey that you want done quickly and don't want to re-occupy receiver sites for an additional transmitter setup
- Use transmitter frequencies that have odd harmonics that don't overlap
- Stack the signal *properly* at each transmitter frequency
- The larger the separation in frequency the better – within limits
- You need more transmitter gear!
- It presents an interesting processing problem!

An EM Example to Illustrate This

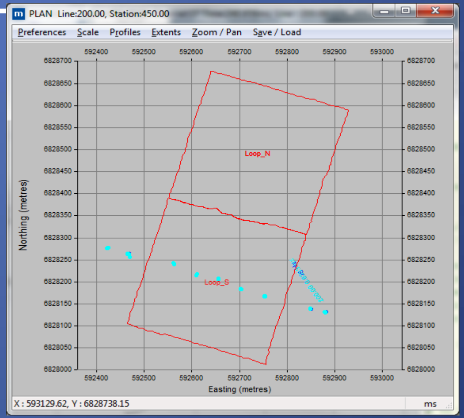


- This illustrates the processing problem
- Low frequency EM data collected from two 300m x 300m loops transmitting simultaneously.

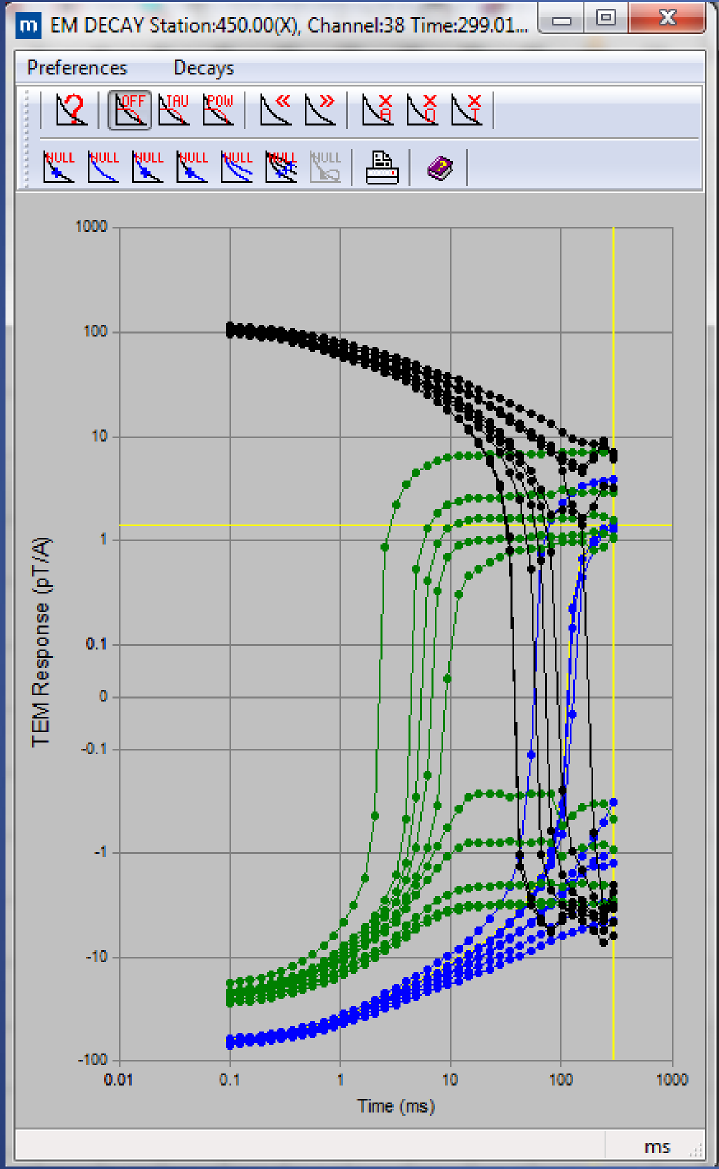
- Collected by Discovery Geophysics using a 3-component HT SQUID, Phoenix TXU-30 transmitters both at 40A.
- 4-10 readings at each station, each of 50s duration

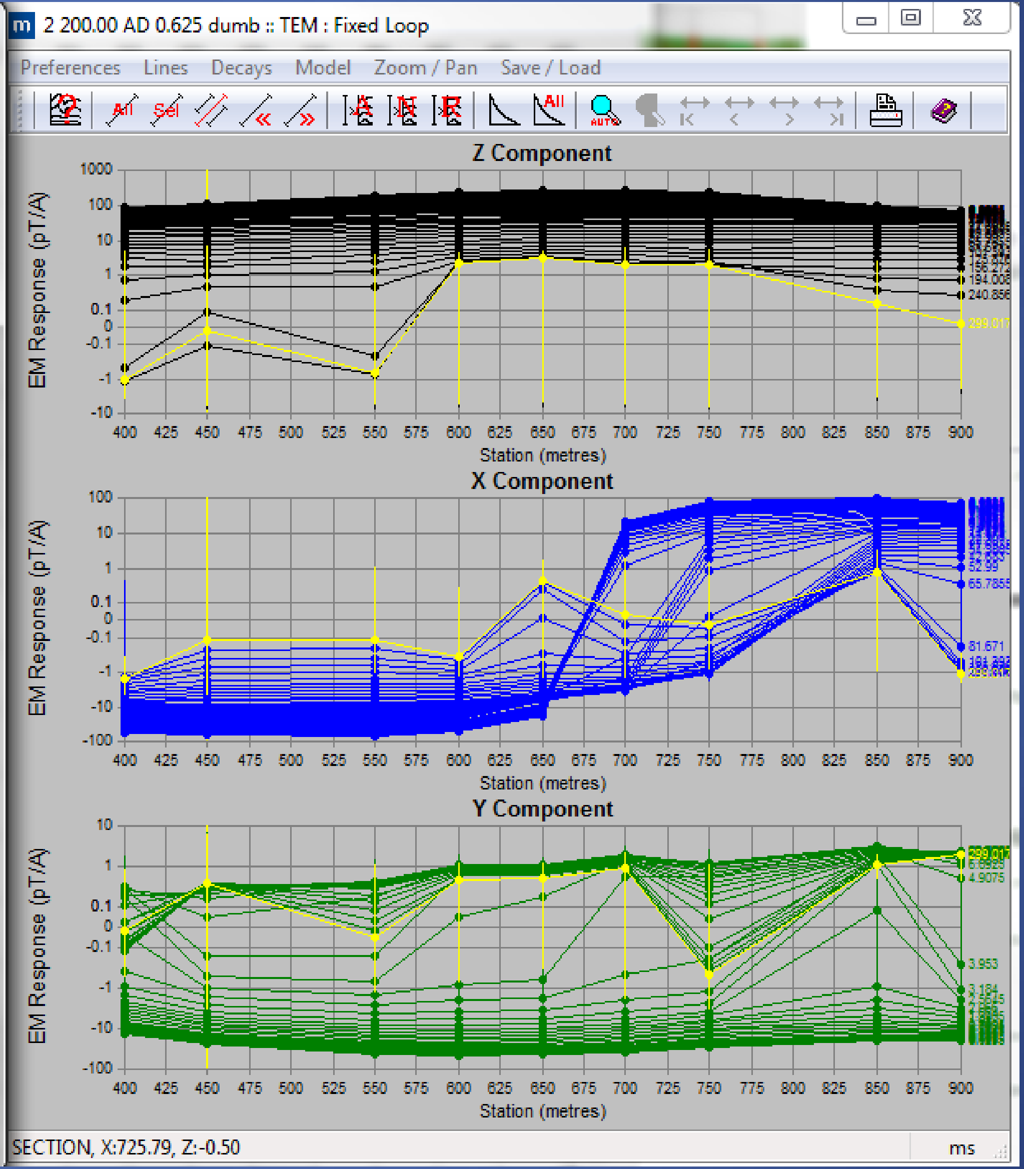


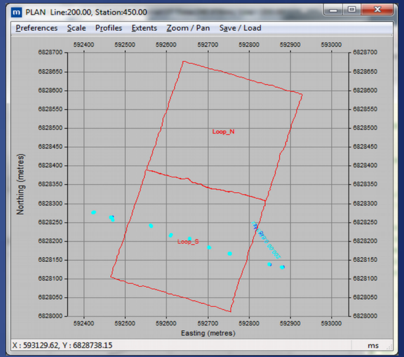
- First station west of the loop (as shown)
- Large response from nearby southern loop (0.625 Hz), smaller response from northern loop (0.833 Hz).
- For a normal off-time EM survey, the field of the 'other' transmitter is a noise source
- At this station, vertical primary field from the nearby loop is approximately 113 nT, primary field from the distant loop is approximately 11 nT



Boxcar Stacking @ 0.625 Hz (nearby loop)





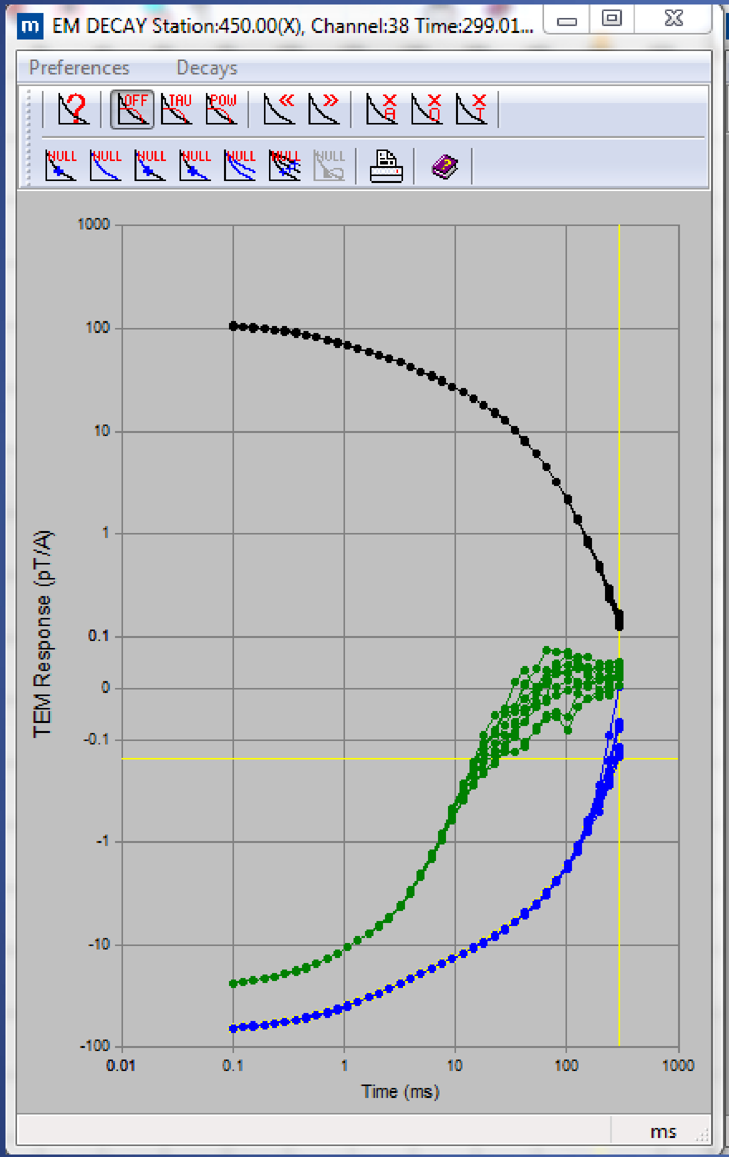


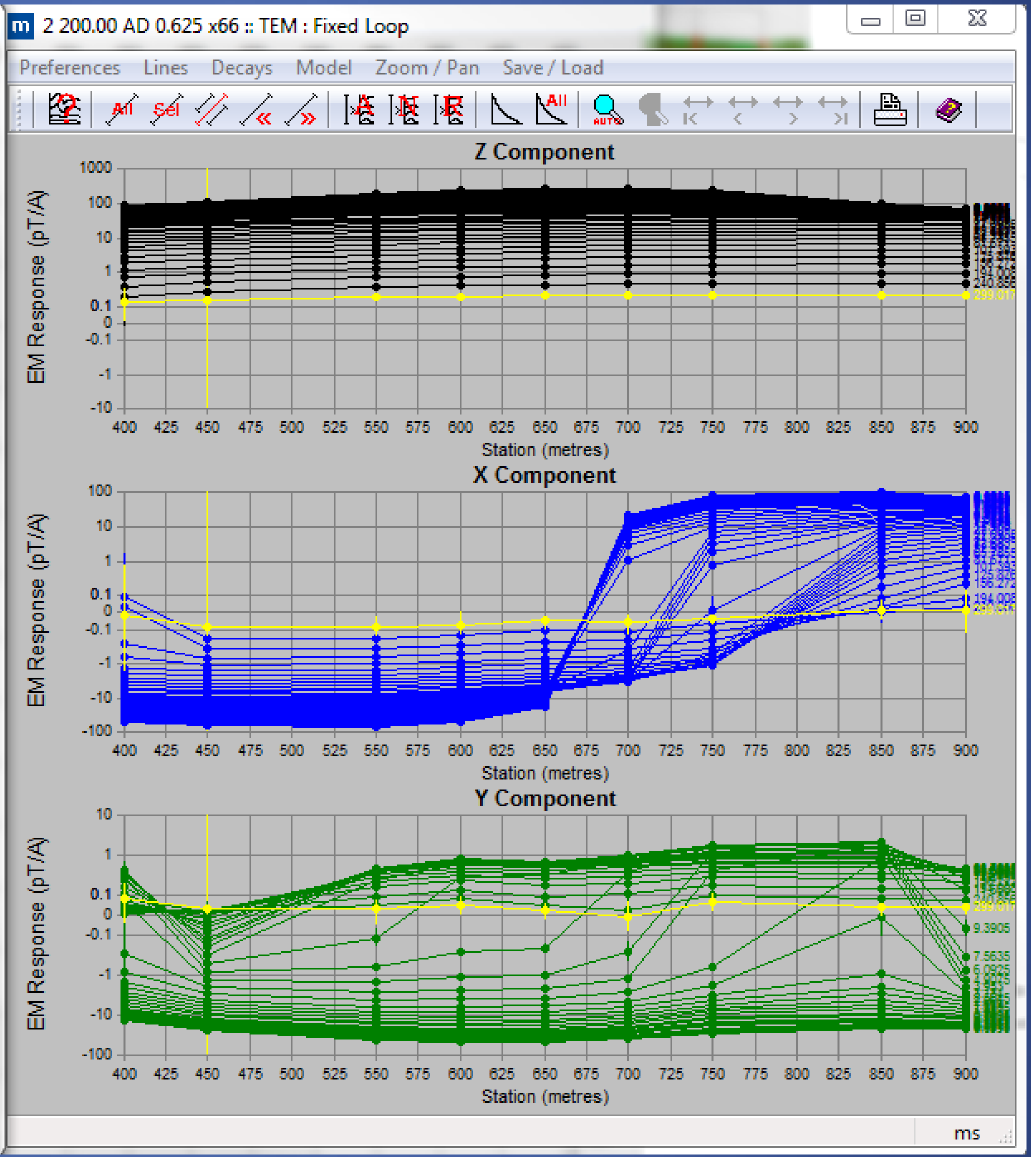
EMIT – 21 years

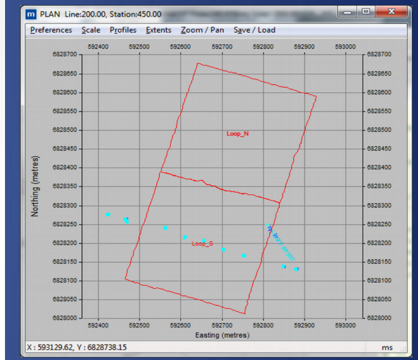
ASEG 2016

Aug 2016

Proper Stacking @ 0.625 Hz (nearby loop)





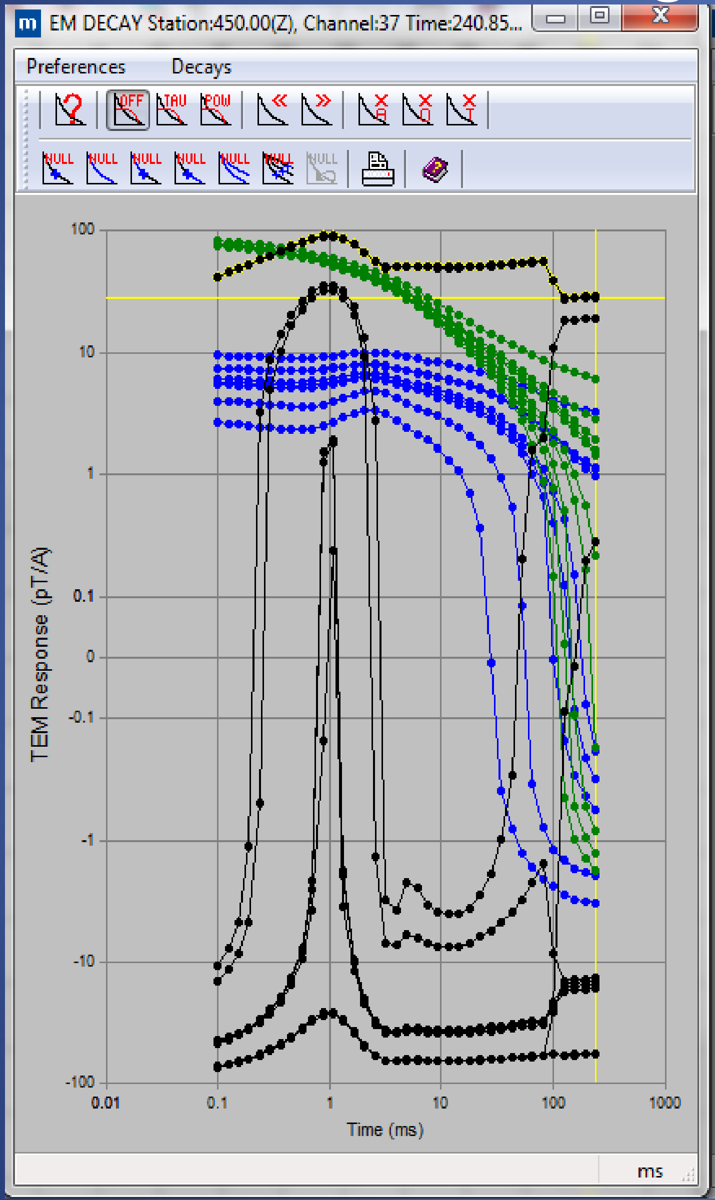


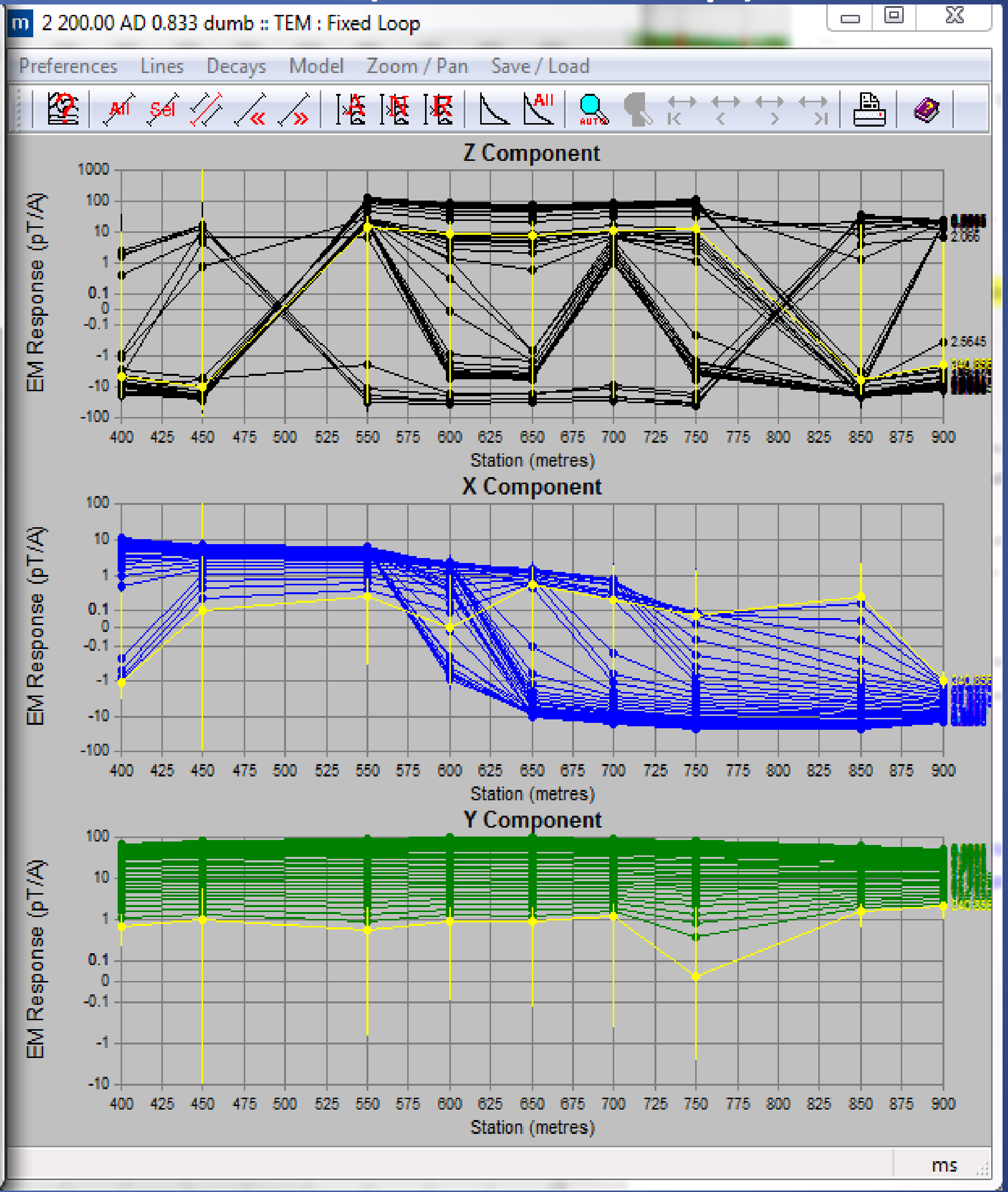
EMIT – 21 years

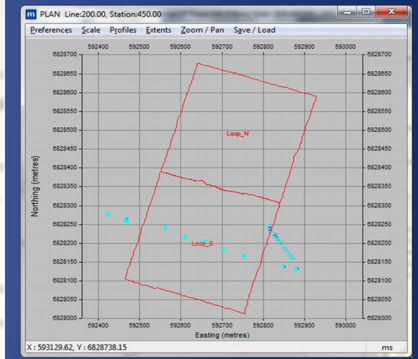
ASEG 2016

Aug 2016

Boxcar Stacking @ 0.833 Hz (distant loop)





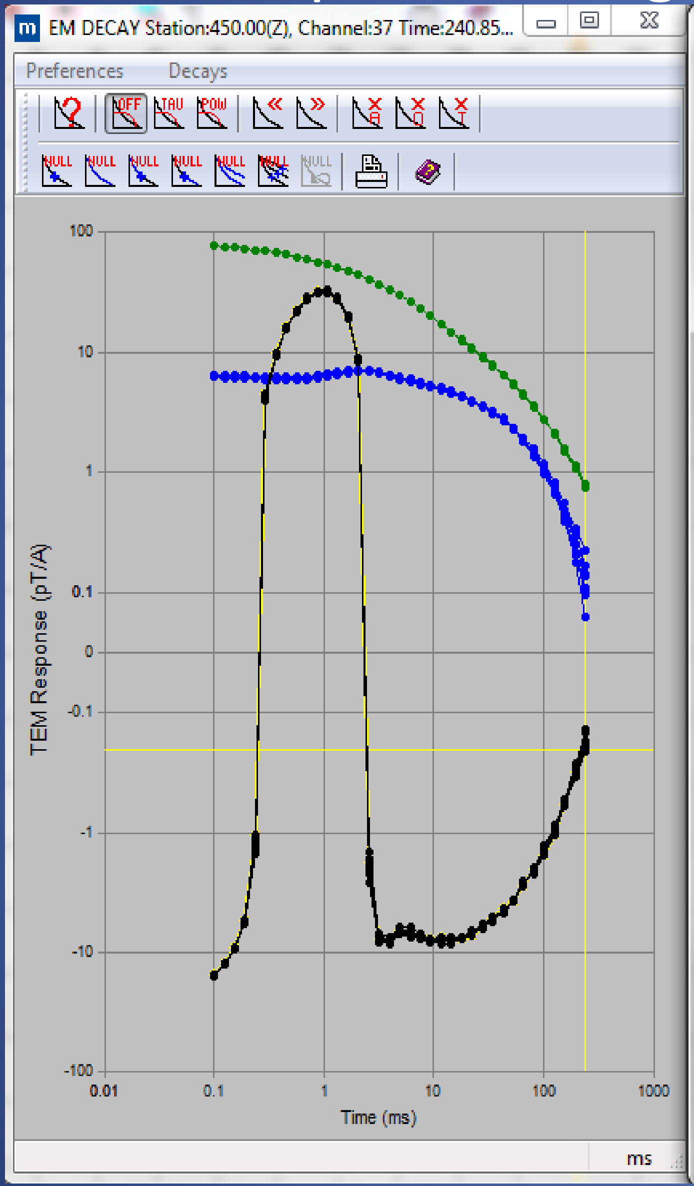


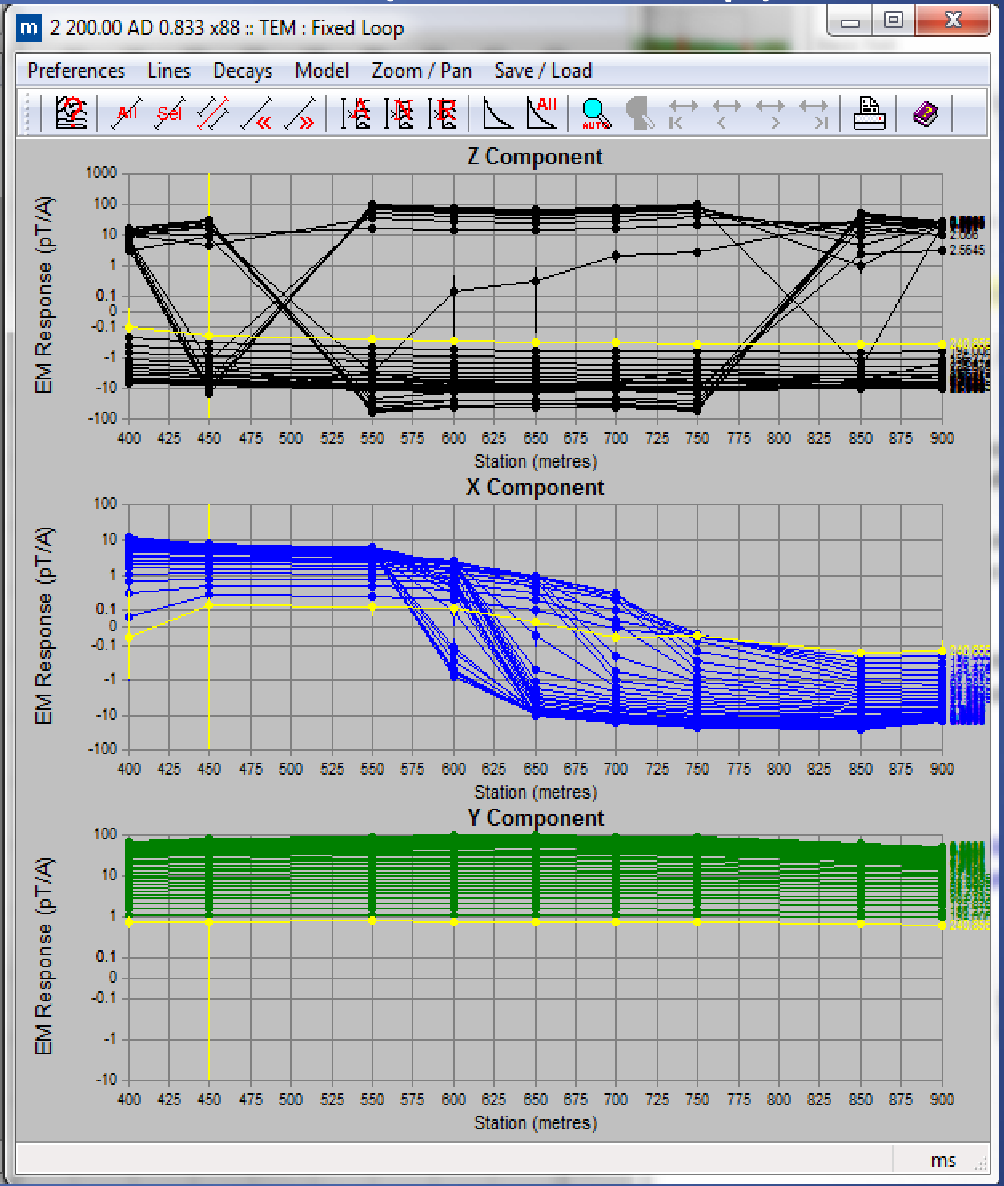
EMIT – 21 years

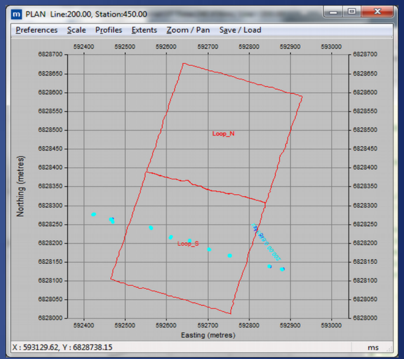
ASEG 2016

Aug 2016

Proper Stacking @ 0.833 Hz (distant loop)







EMIT – 21 years

ASEG 2016

Aug 2016

Summary – Multiple Simultaneous Transmitters

For the data from the northern loop (distant, 0.833 Hz):

- Interference from the 0.625 Hz transmitter was 113 nT on vertical field measurements
- Secondary fields processed to a precision of approximately 0.1 pT/A = 4 pT in each 50s worth of data
- This is noise reduction by a factor of roughly 30,000 in each of the 50s readings, *just by stacking and windowing it*
- I'd suggest that this is far more than would be required to make this work in IP surveys – with the right processing
- NB: this kind of noise rejection is only possible with a coherent noise source

Summary

Using good signal processing practices results in higher quality results and productivity improvements

The stacking filter is the most important issue to consider in the design of signal processing software

Good signal processing is not a new idea, but modern hardware makes it easier

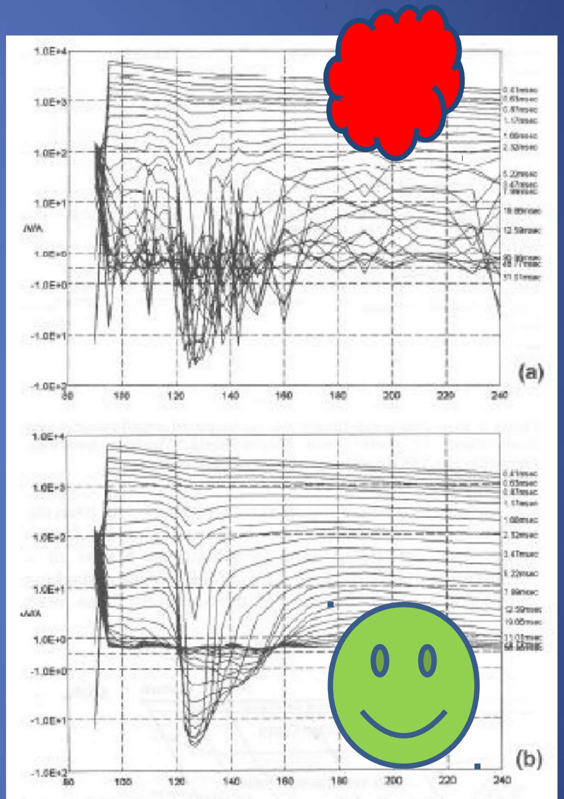


Figure 5. Profiles of TEM data from surface borehole at Leinster. Interference from PED system evident in (a) has been removed by processing, resulting in (b) which shows a well-defined off-hole anomaly.