The Volterra System

Syd Visser

ASEG 2016
Adelaide, Australia

SJ GEOPHYSICS
Science on Target

Acknowledgement

- Ross Polutnik
- Kalen Martens

GEOPHYSICS
Science on Target

VOLTERRA

Outline

- The Approach
- The Volterra System
- Development of the Volterra System
- Borehole (IP)
- Data Processing Concepts
  - 50% vs 100% Duty Cycle
  - Timing
  - Telluric Cancellation

The Approach

- Apply an integrated approach to acquire superior data and provide the best possible targeting

Survey Evaluation & Design "SED" → **Acquisition** → **Modeling & Interpretation**

Survey Evaluation & Design "SED"

- Define the client's objective
- Custom survey design

Acquisition

- Utilize state of the art instrumentation & signal processing with optimized parameters

Modeling & Interpretation

- Full value from data
- Inversion & 3D visualization
- Integrated interpretations (geophysical + geological + geochemical data)

GEOPHYSICS
Science on Target

VOLTERRA

AQUISITION
The Volterra System

- Untethered, distributed data acquisition system
- Suitable for:
  - IP, EM, CSAMT, MT, MMR/MMIP, etc.
- Two components
  - Hardware: data acquisition units
  - Software: advanced signal processing

GEOPHYSICS
Science on Target

VOLTERRA

Volterra System: Hardware

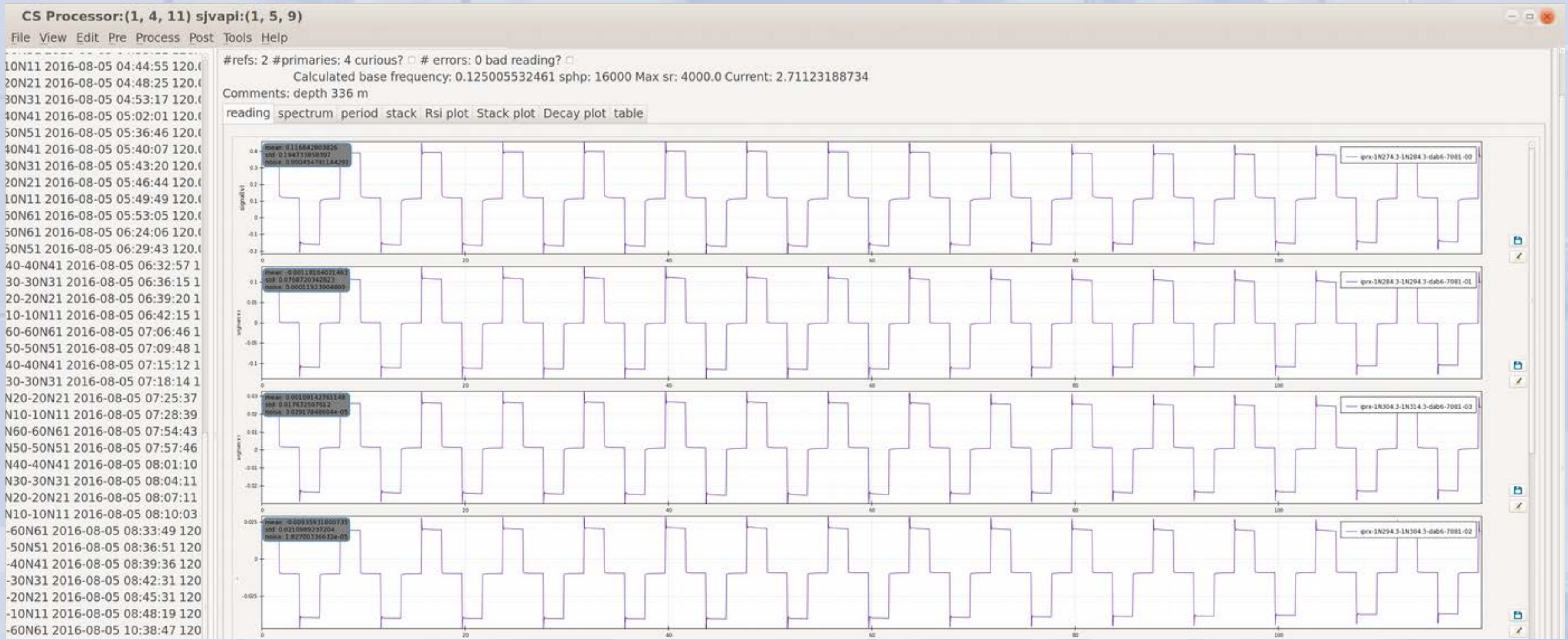
- Built around the Volterra data acquisition unit
  - 4-channel, 24-bit full-waveform recording
  - Sample rates up to 128,000 samples/second
  - Integrated GPS timing
  - Lightweight & low power consumption

Volterra System: Hardware

- Controlled and monitored from Android devices via Bluetooth
  - Tablets
  - Cellphones

Volterra System: Software

- In-house developed advanced signal processing software package
- Written in Python utilizing SciPy and NumPy



SJ GEOPHYSICS
Science on Target

VOLTERRA

The Volterra System in Action

Volterra-3DIP
In Arizona

Volterra-3DIP & GDD
TxII Transmitter

Borehole-EM
in Australia

Volterra-3DIP in
British Columbia

Borehole-EM in
Saskatchewan

GEOPHYSICS
Science on Target

VOLTERRA

Development of the Volterra System

- Parallelization of the UBC DCIP3D software code
- Hardware evolution – Induced Polarization
  - SJ-24
  - Dabstix
  - Dabtube
  - Borehole

Parallelization of UBC DCIP3D

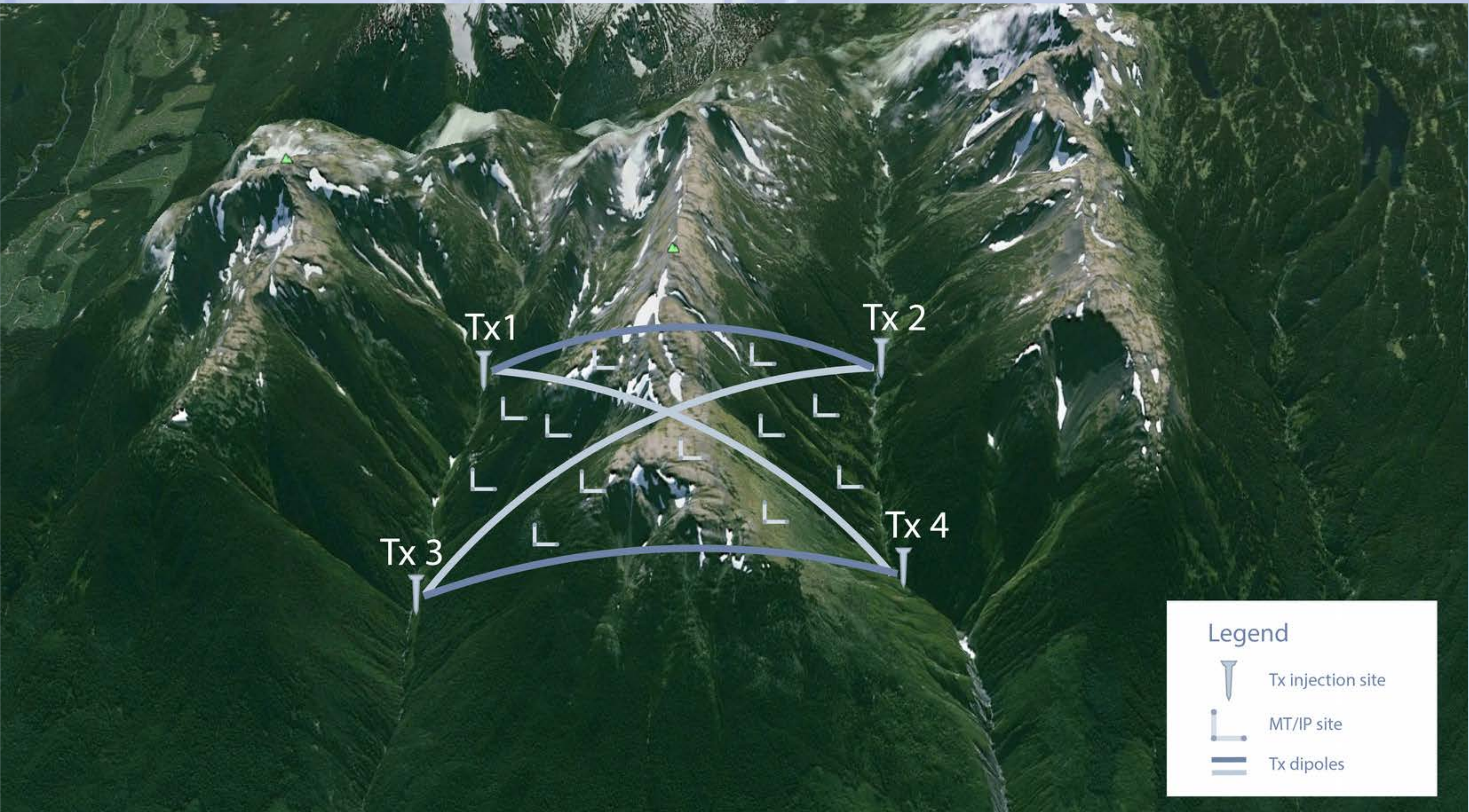
- Completed in 2003

GEOPHYSICS
Science on Target

VOLTERRA

- Allowed rapid development of 3DIP surveys.
  - Reduced inversion time
  - No longer restricted to line based arrays

Reconnaissance IP/MT



SJ-24

- Released in 2004
- Full-waveform receiver
  - Real-time signal processing
  - Raw data saved
  - Ability to re-process after a survey is completed

SJ GEOPHYSICS
Science on Target

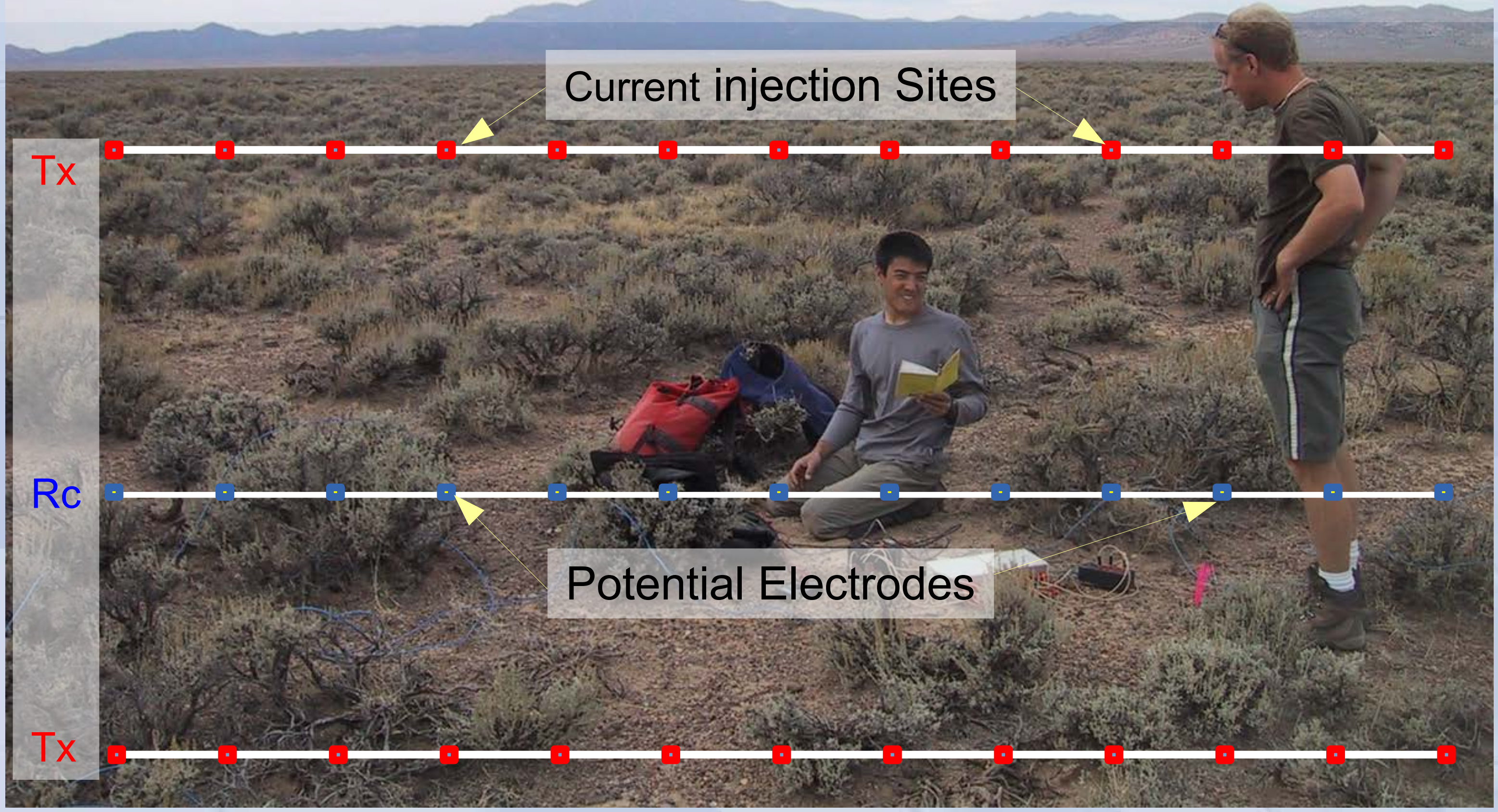
VOLTERRA

SJ-24

- 16 channel system
  - 4 channels per acquisition box with up to 4 boxes connected together
- Sample rate of 1000 samples/second
- Simple signal processing methods

SJ-24

- Suitable for IP data acquisition only
- Data acquired using 2D arrays and early 3D arrays (offset pole-dipole, ie. 3 line Tx-Rc-Tx configuration)

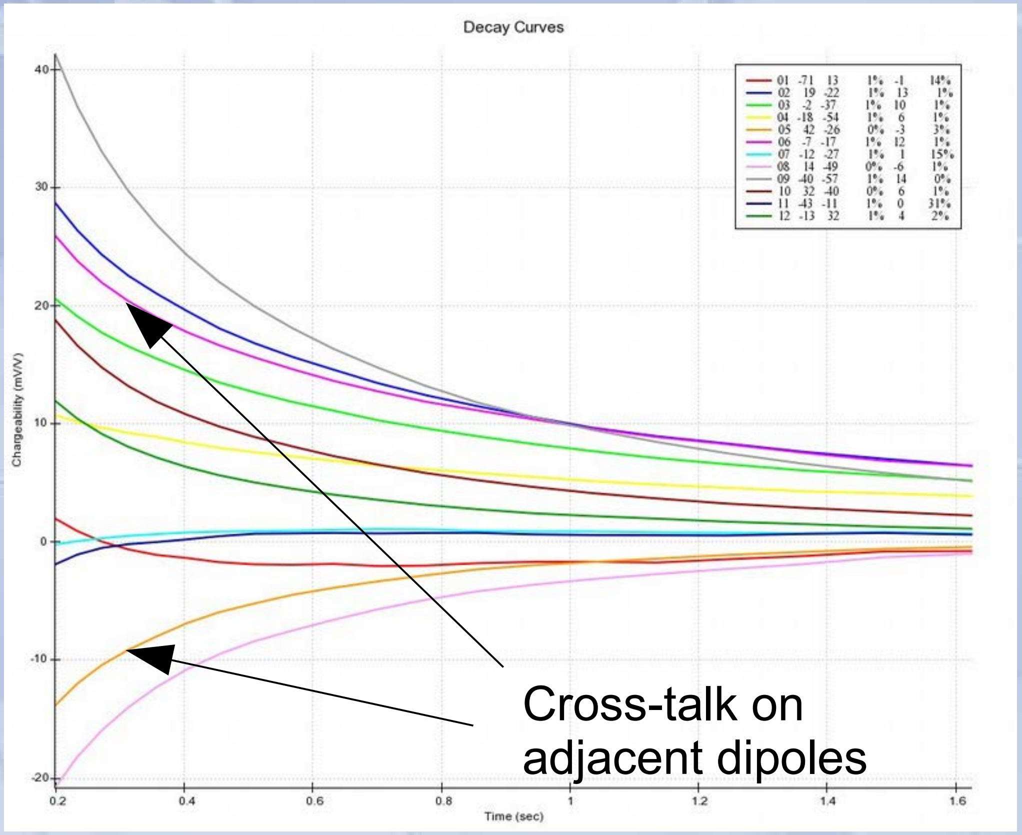


SJ-24

- Tethered acquisition system
  - Multi-conductor cables

Changes Required: Why?

- Cross-talk issues between channels
  - A big issue in wet, cool environments (British Colombia, Tazmania)
  - Needed to eliminate multi-conductor cables.
- Create a distributed system



GEOPHYSICS
Science on Target

VOLTERRA

Change Required: Why?

- Timing Issues
  - Quality was not good enough
    - Worked well to trim data to reading windows (start-end)
    - Edge detection methods had to be used for finer timing
  - Move to GPS timing

Change Required: Why?

- Sample Rate
  - Too low
    - Wanted the ability to also acquire EM, MT, CSAMT, etc with the same acquisition system
    - Significantly higher sample rates needed

Dabstix

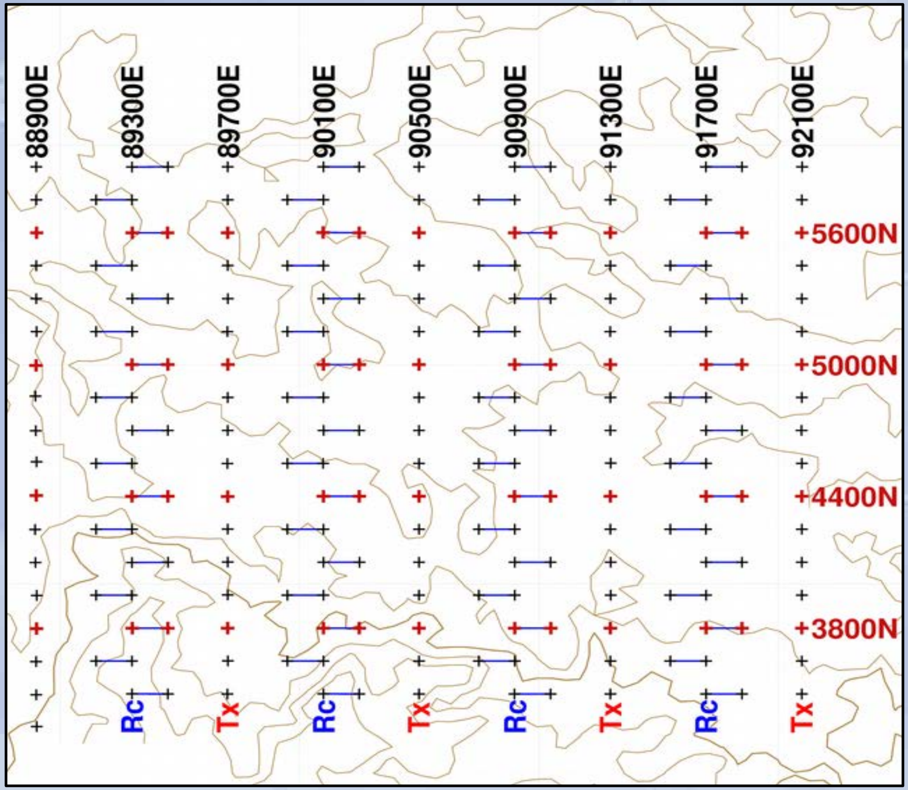
- Released in 2010
- Full-waveform acquisition unit “Dabstix”
  - Raw data stored on internal memory
  - Signal processing at the end of each survey day on a personal computer
- Fully Distributed acquisition system (untethered)

Dabstix

- Single channel per acquisition unit
- Sample rate of 4000 samples/second
- Capable of acquiring IP and AMT data

Dabstix

- Individual wires (Eliminated multi-conductor cables)
- Number of channels limited only by the amount of resources



- 400m line spacing
- Cross dipoles every 150 m

Upgrades Still Required

- Next generation hardware needed
- Why?
  - Each acquisition unit powered by a 12V gel cell battery
    - Weight issue
  - Desire to create a surface and borehole EM and IP system
    - Require higher sample rates for EM
    - Slim design
  - Improve timing

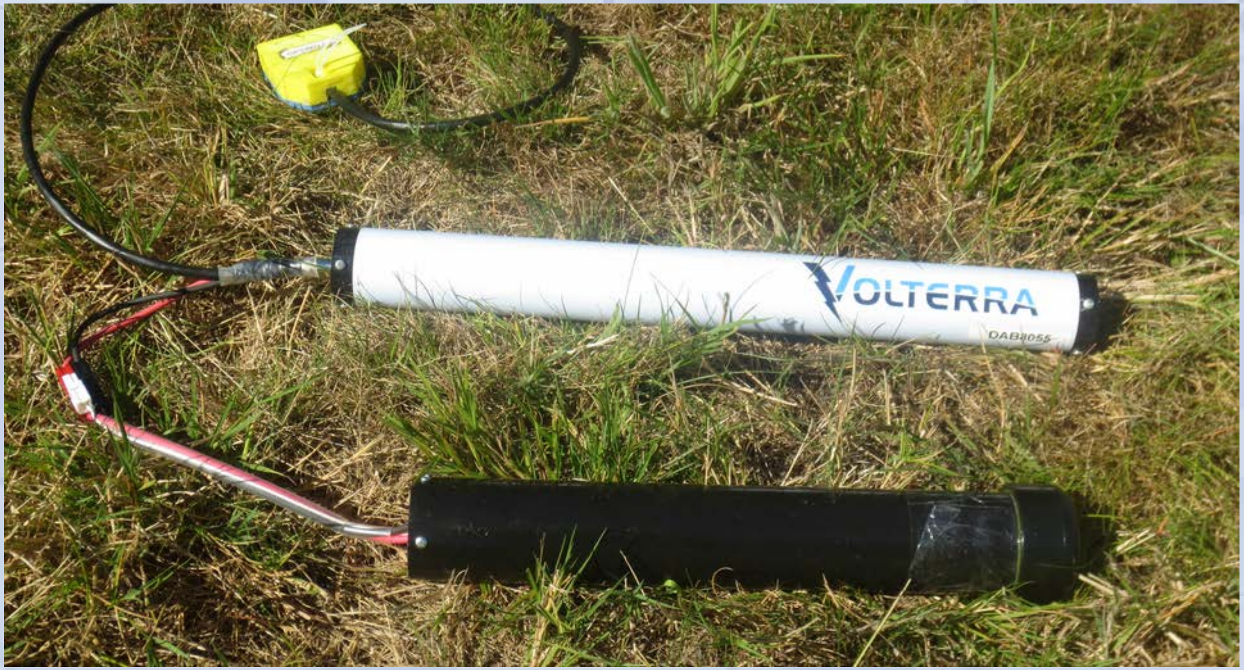
Dabtube

- Released in 2013
- Full-waveform acquisition unit "Dabtube"
- Fully distributed
- 4 channel per acquisition unit
  - Weight decreased
  - Simplified use
  - cost
- 1,000 – 128,000 samples per second

Dabtube

- Current monitor to record voltage with time
  - Used during signal processing

- Each acquisition unit is powered by a 5V NiMH battery pack.
  - Lighter weight
  - Can be flown using aircraft (versus lithium-ion)
  - A more efficient system



Dabtube

Battery

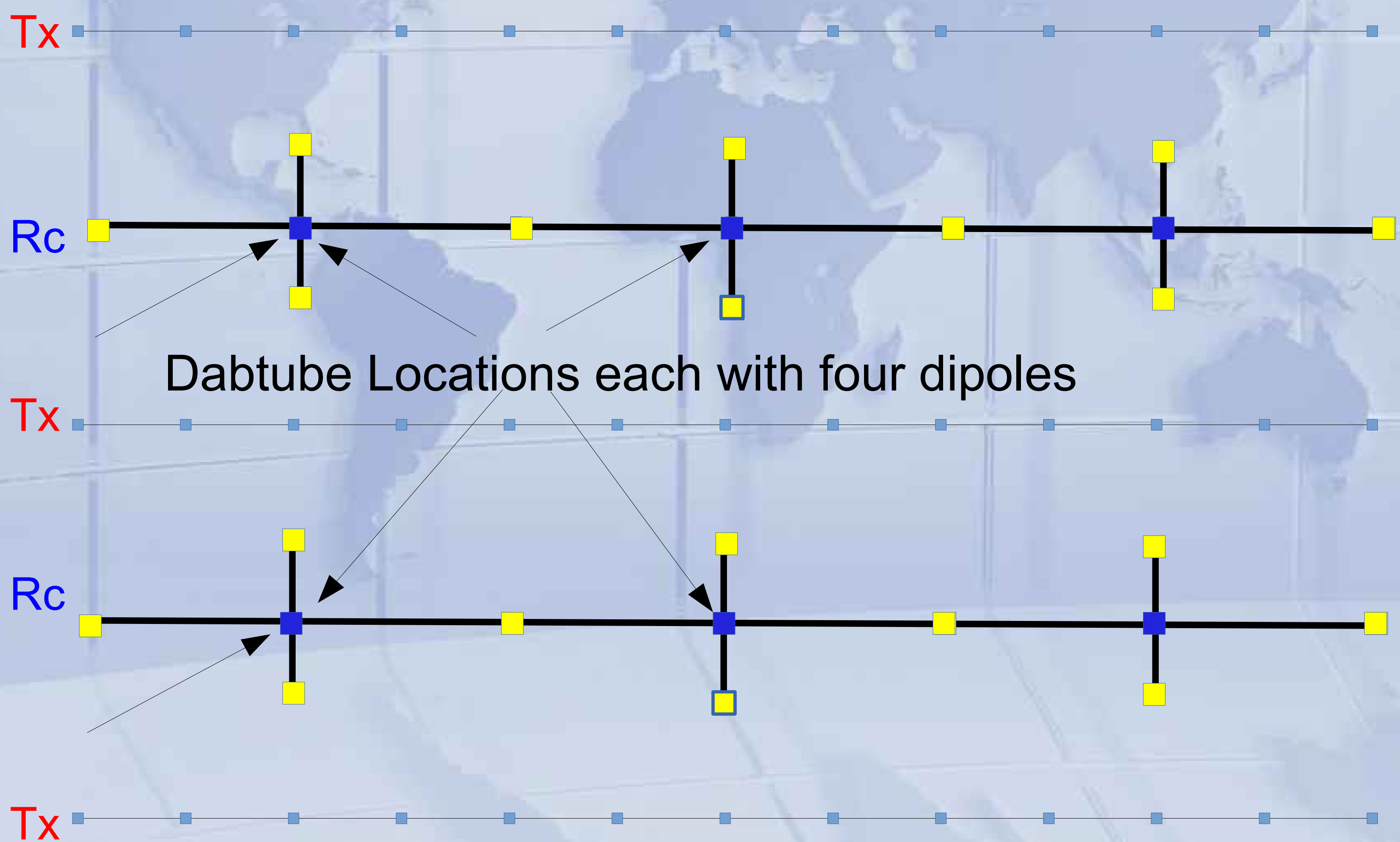
GEOPHYSICS
Science on Target

VOLTERRA

Dabtube – Survey Designs

- Array designs from simple to complex. Limited only by imagination
  - Inline arrays
  - Cross-dipole arrays
  - Diamond arrays
  - Interlaced arrays
  - Etc.

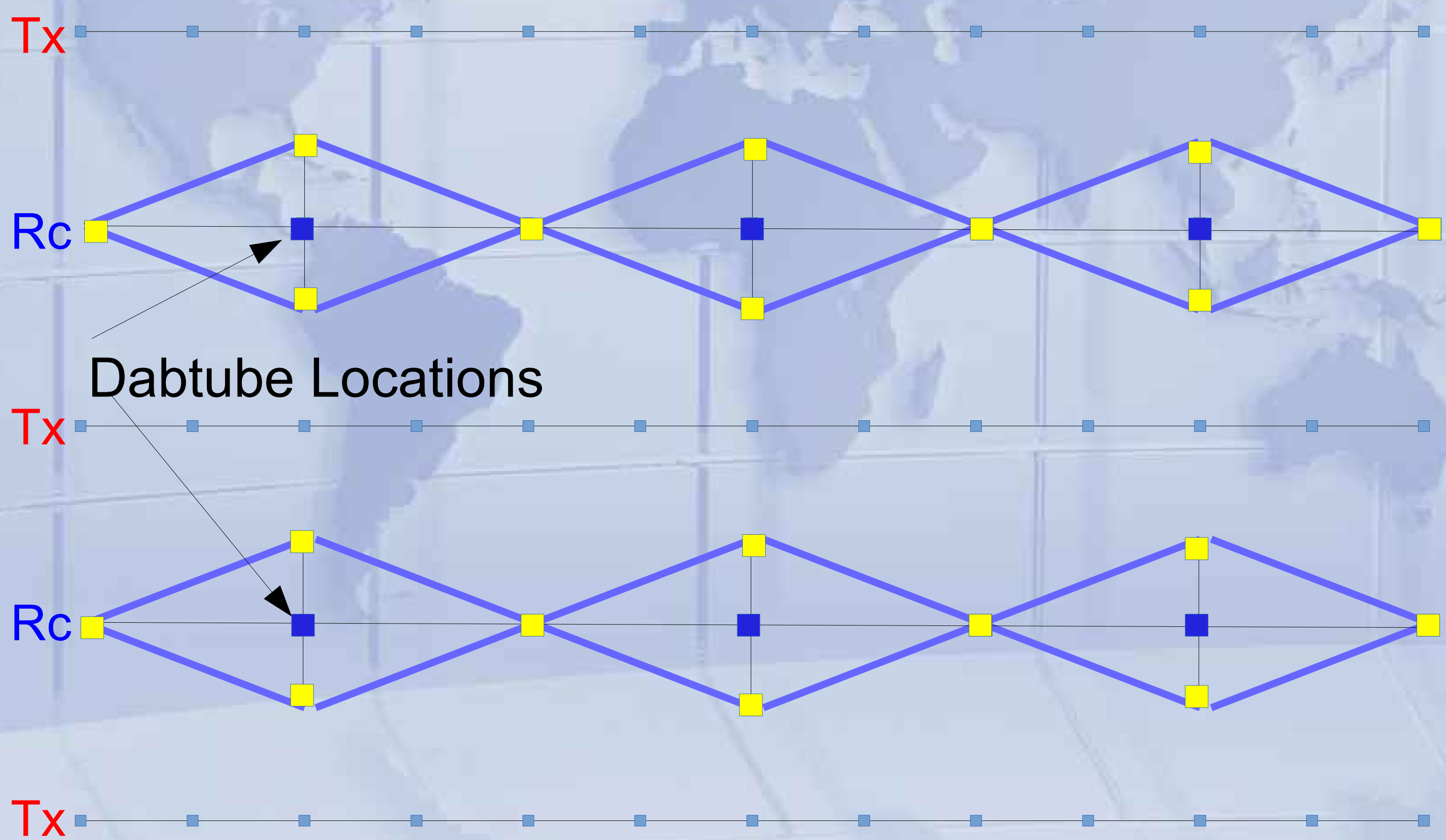
Volterra Distributed Receiver Array: Cross-Dipole



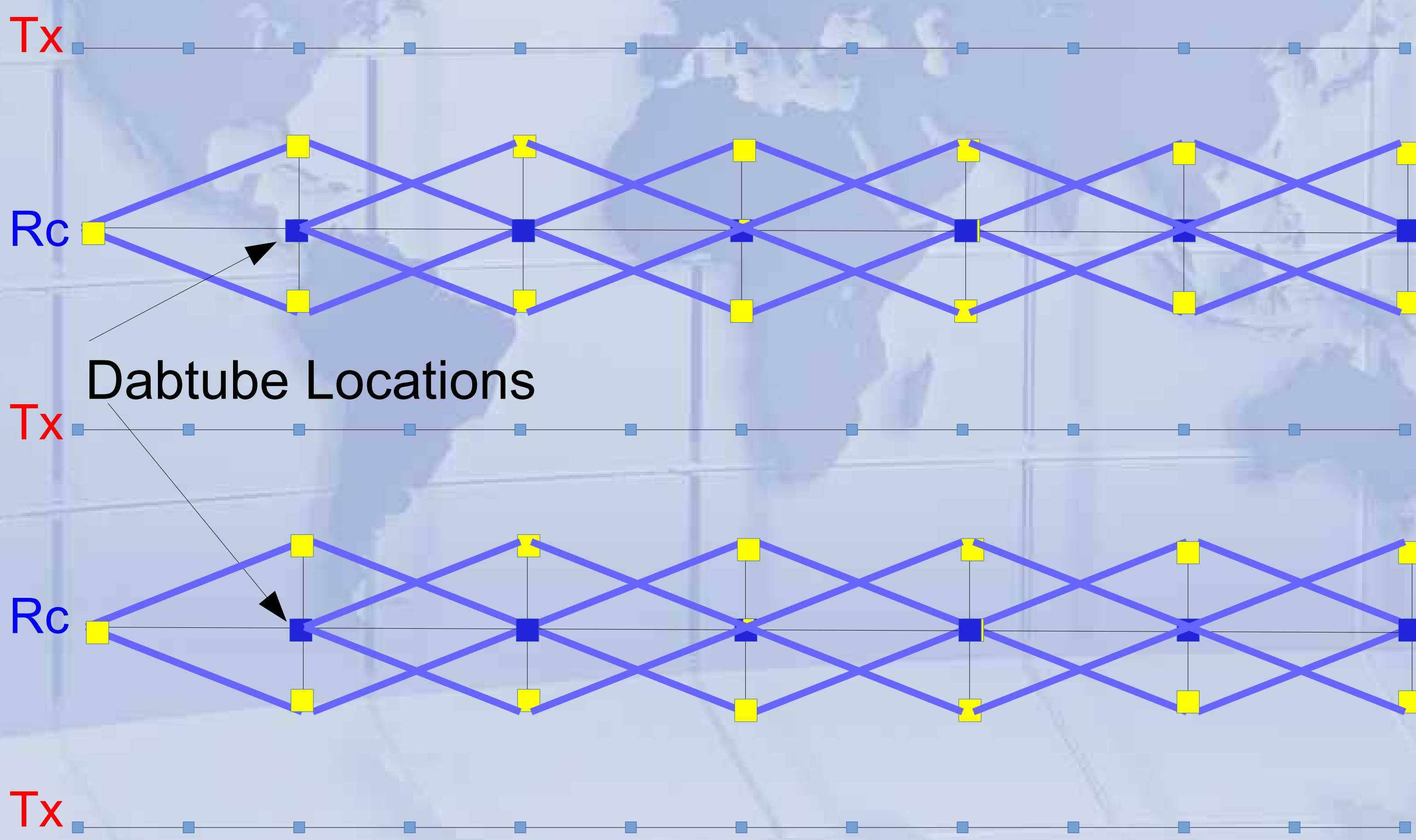
GEOPHYSICS
Science on Target

VOLTERRA

Volterra Distributed Receiver Array: Diamond Array



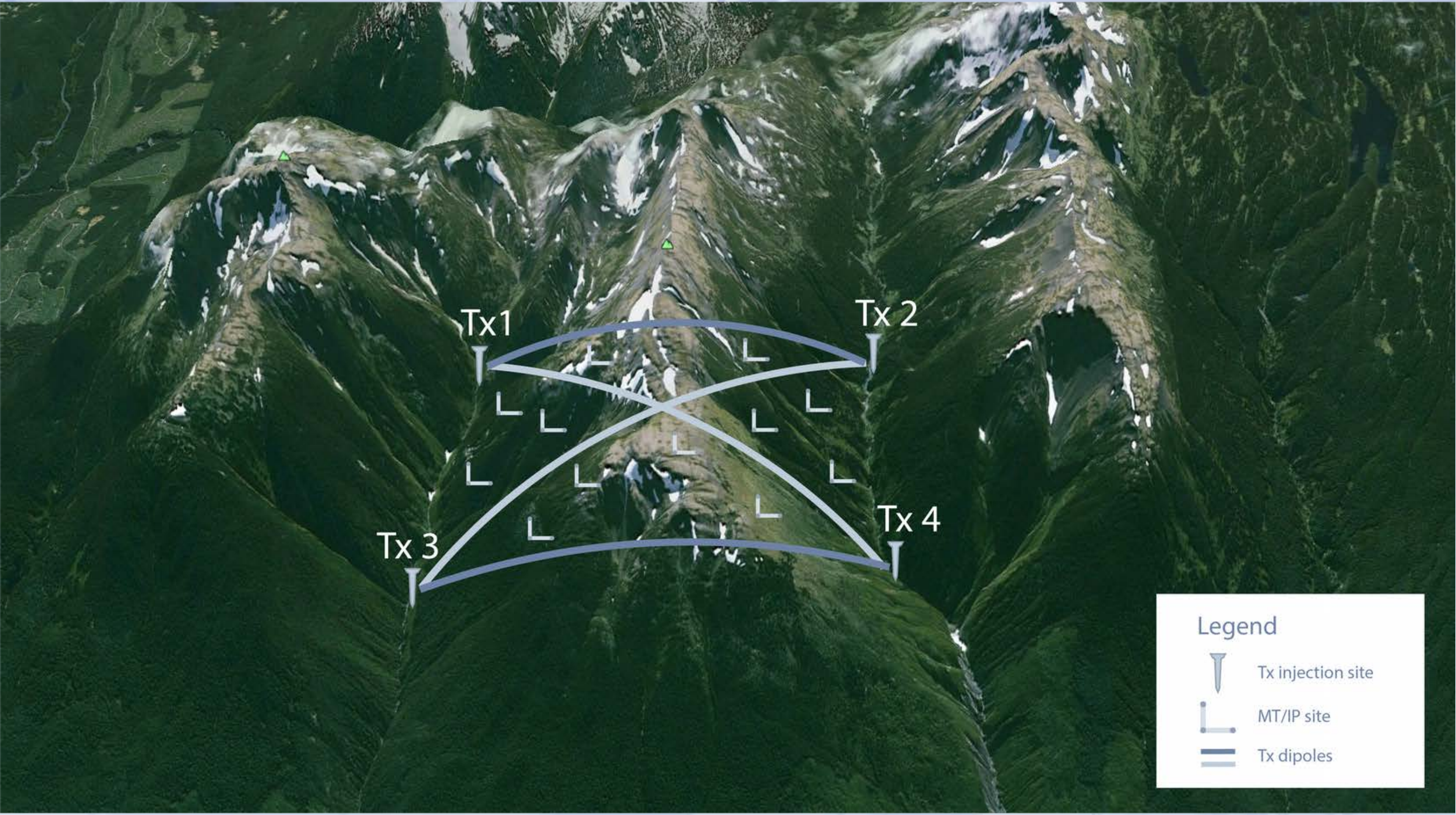
Volterra Distributed Receiver Array: Interlaced Diamond Array



GEOPHYSICS
Science on Target

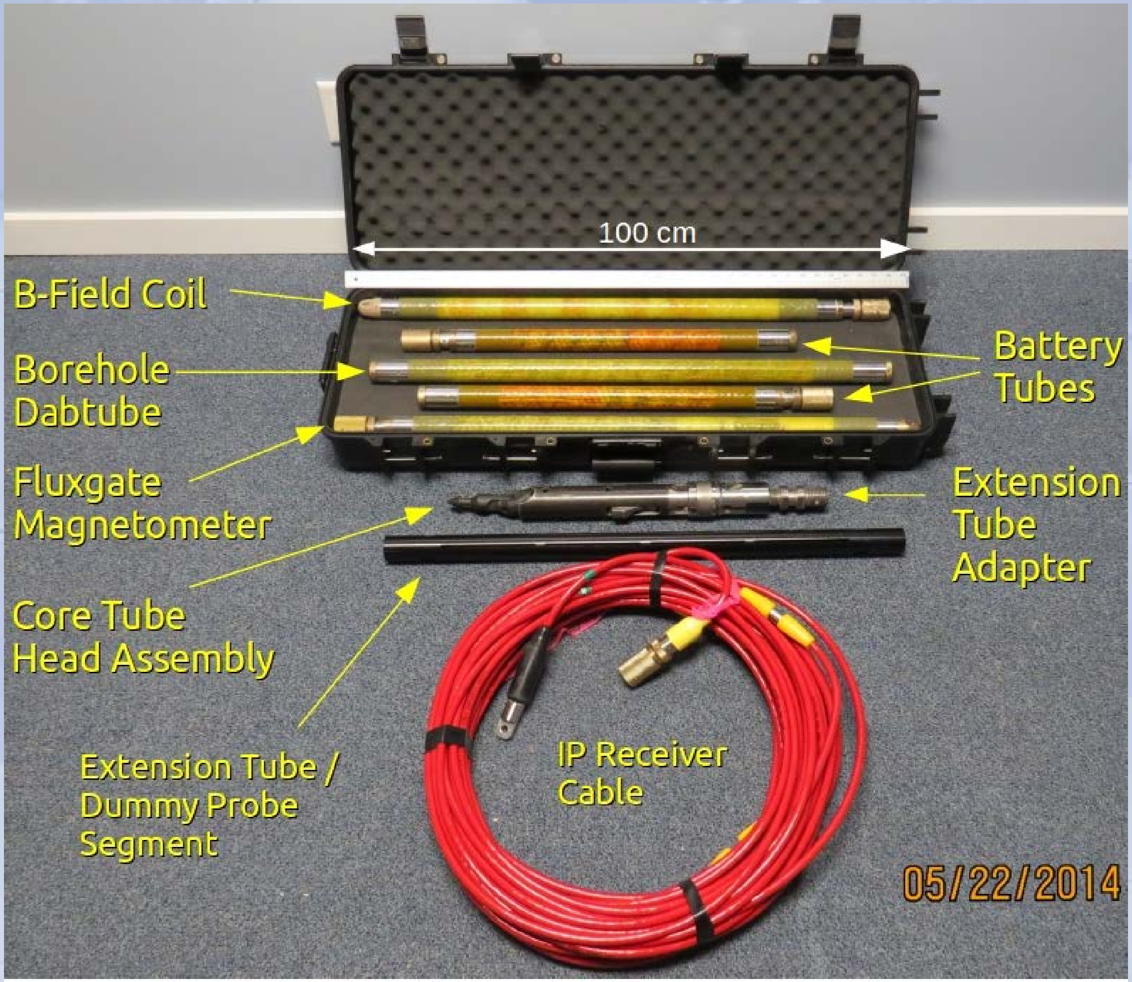
VOLTERRA

Reconnaissance IP/MT



Borehole IP & EM

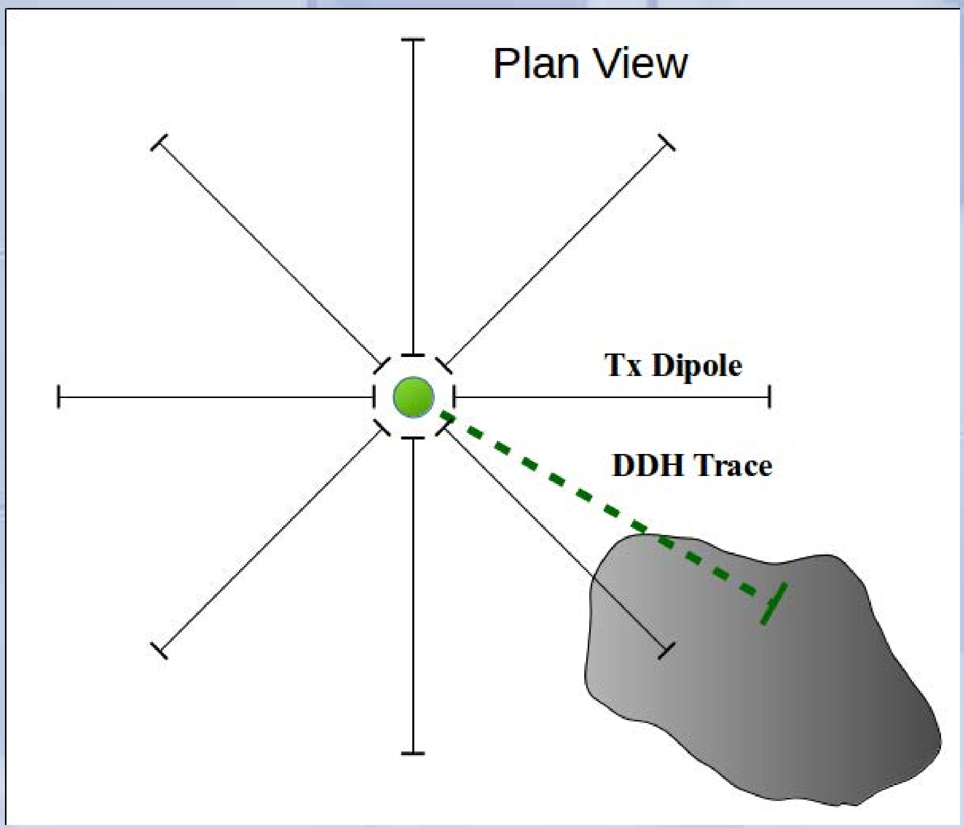
- Volterra Dabtube technology within a borehole probe

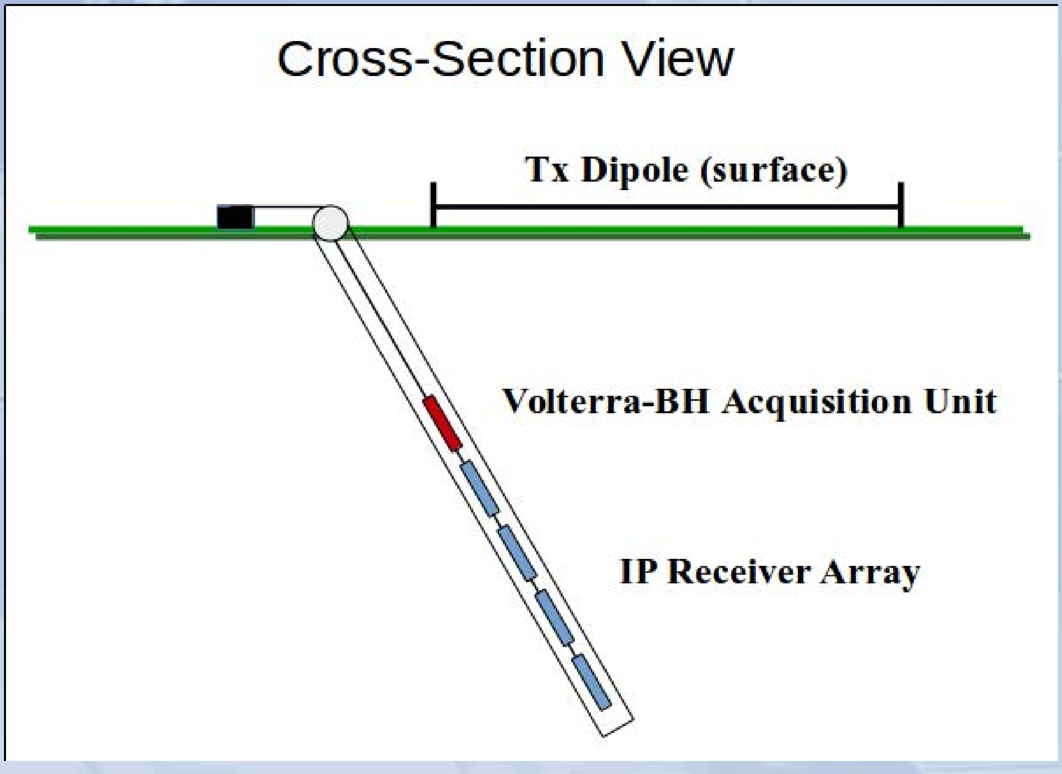


GEOPHYSICS
Science on Target

VOLTERRA

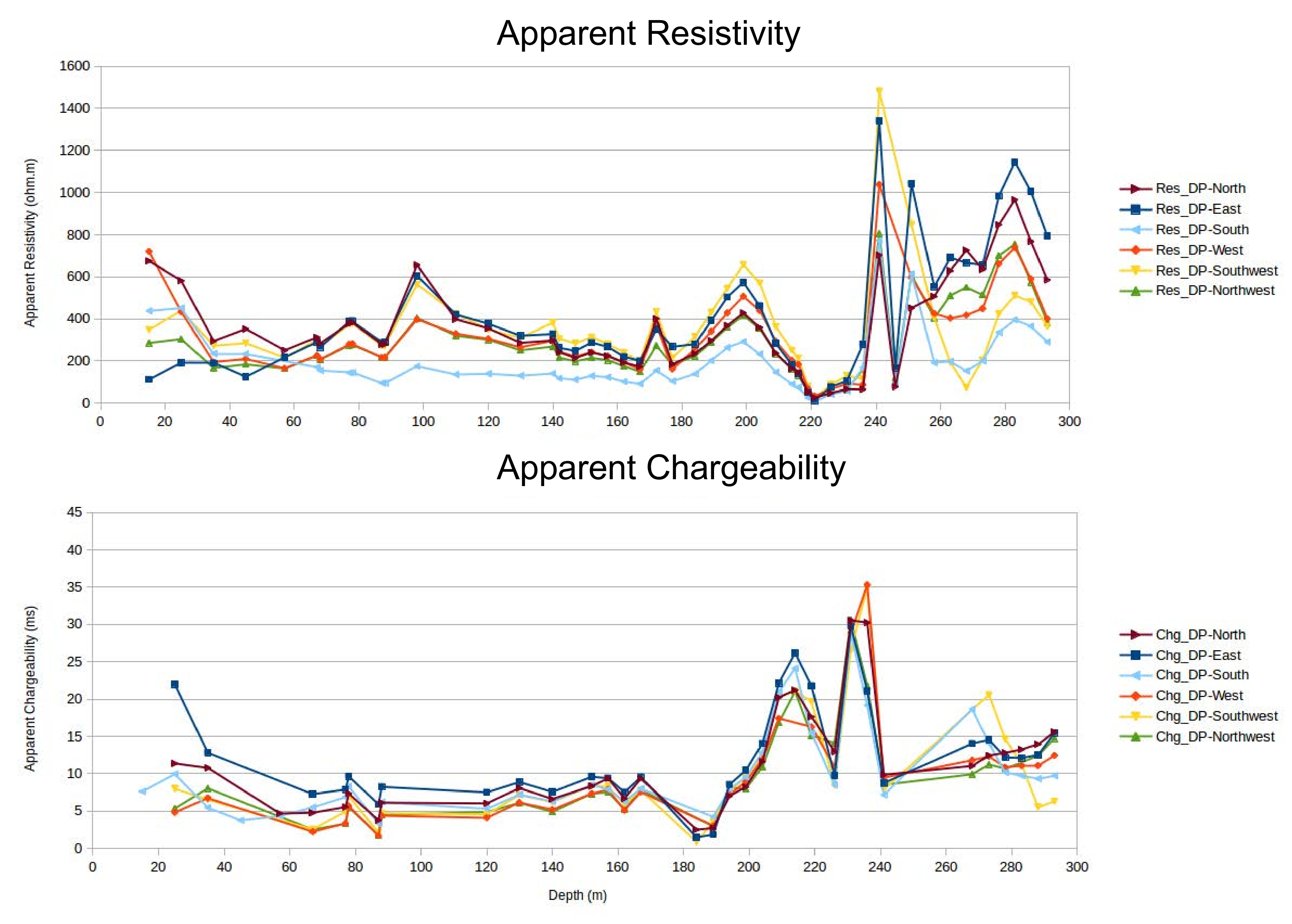
Borehole-IP Survey Design





GEOPHYSICS
Science on Target

VOLTERRA



SJ GEOPHYSICS Science on Target

VOLTERRA

Combined Borehole IP/Mag survey in northern BC

SJ GEOPHYSICS
Science on Target

VOLTERRA

IP Data Acquisition

- Timing application at the transmitter to record start and stop time for each reading
  - Accurate to within a few seconds
- GPS timing integrated into each data acquisition unit
  - Very accurate time
  - non-trivial to implement
- In the event of bad GPS timing rely upon old edge detection technique
  - Each data acquisition unit is independent If signal is weak or noisy, edge detection techniques may fail.

IP Data Processing

- Data processing techniques used are likely pretty typical for time-domain IP systems with our own proprietary part

End of the Commercial

GEOPHYSICS
Science on Target

VOLTERRA

IP Data Processing

- Instead of running through standard processing techniques I will try to make some comments and ask some question which I hope with lead to more discussions.

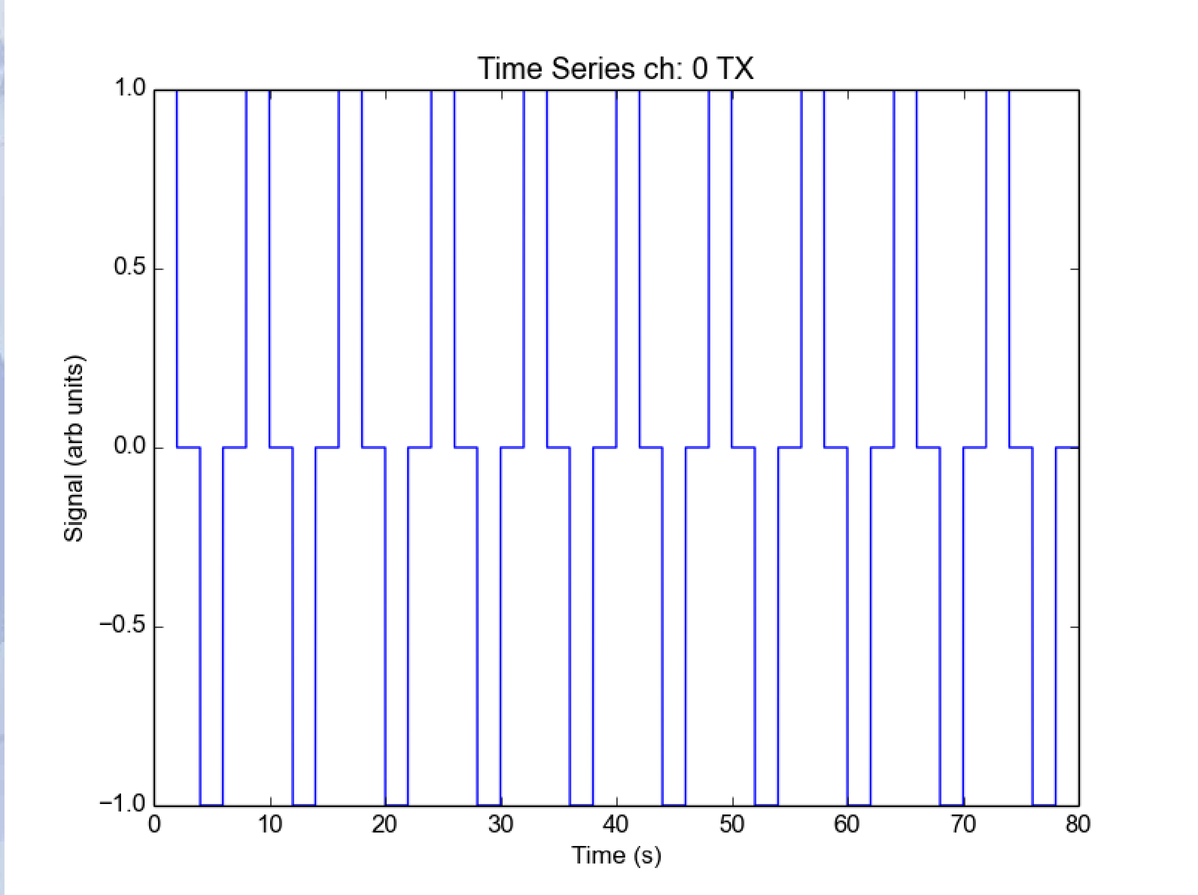
IP Data

- Examples using synthetic data
  - 50% duty vs 100% duty cycle
  - Time domain vs frequency domain
  - Timing issues
  - Telluric cancellation

Time Domain

50% Duty

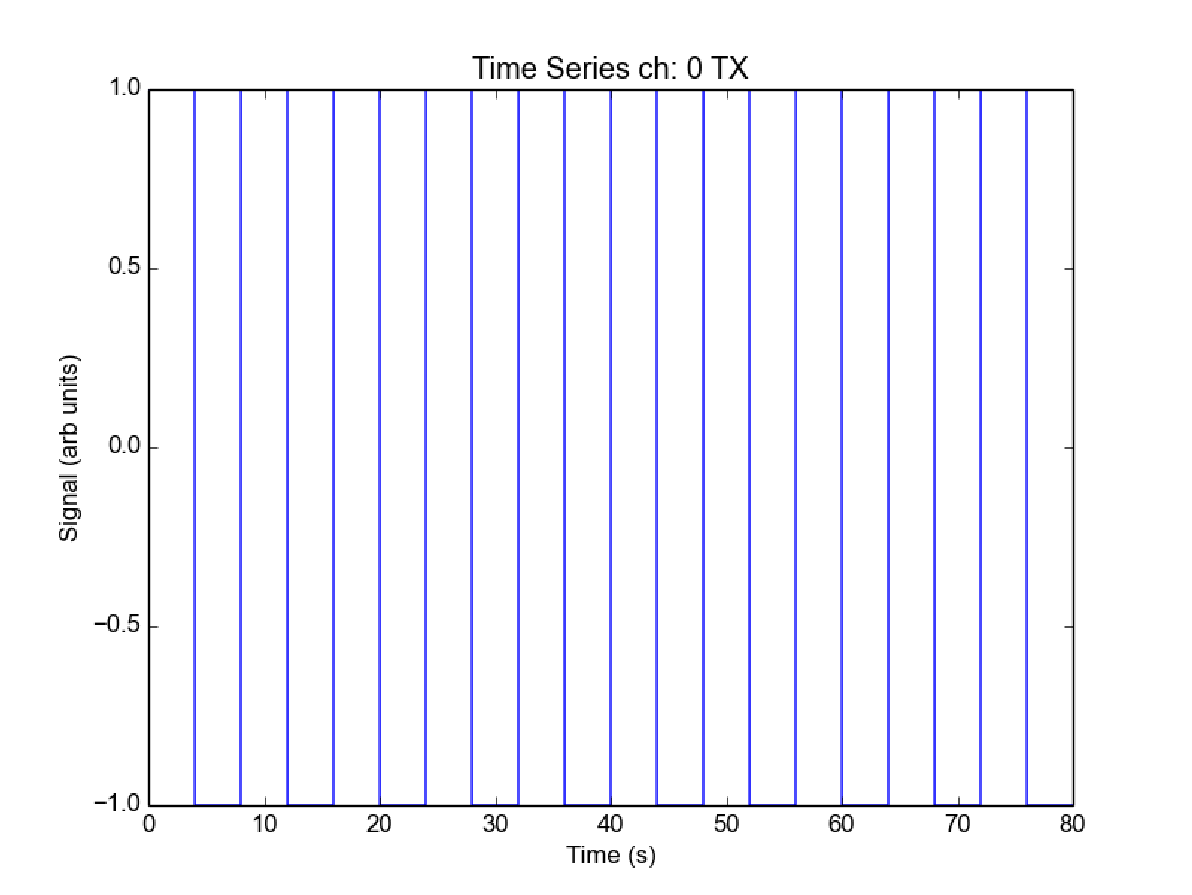
2 Sec on positive
2 Sec off
2 Sec on negative
2 Sec off



Time Domain

100% Duty

4 Sec possitive
4 sec negative



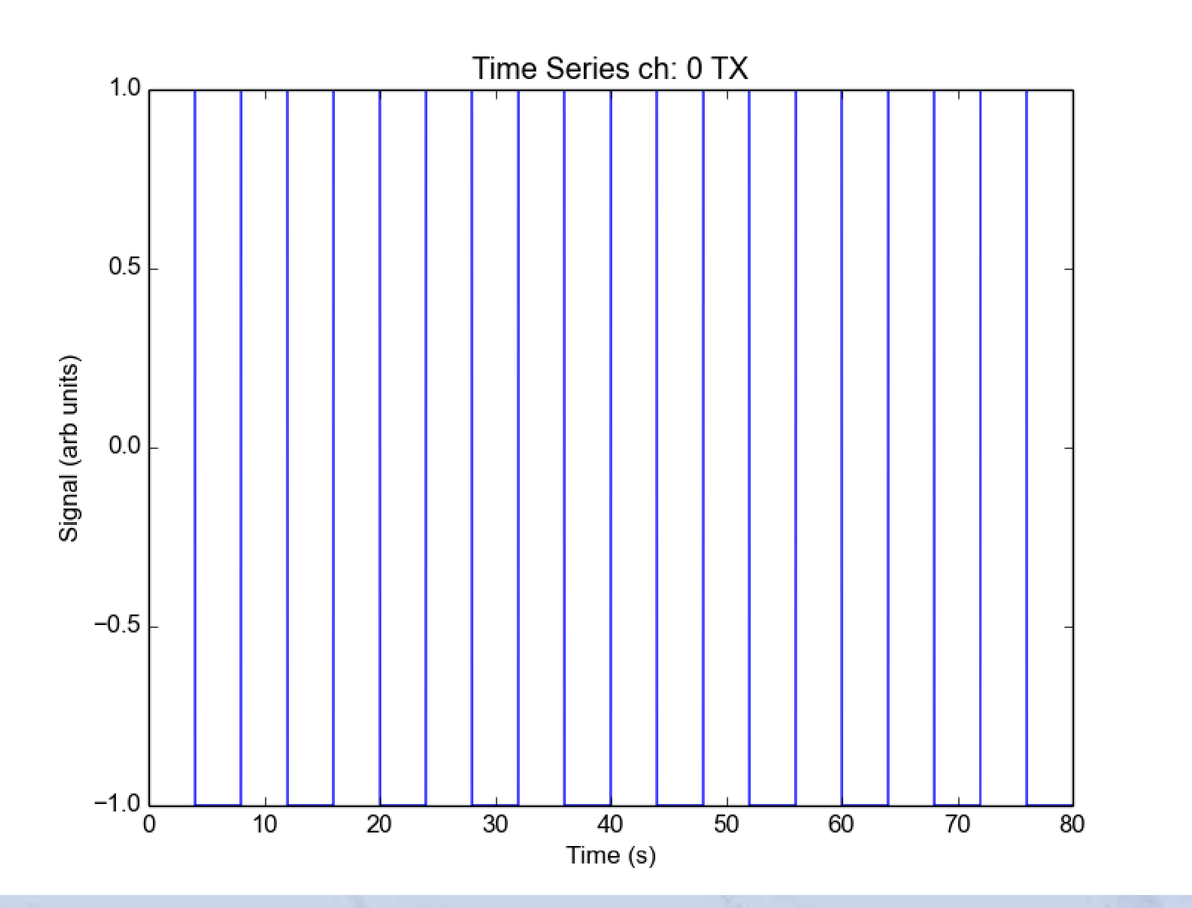
GEOPHYSICS
Science on Target

VOLTERRA

Frequency Domain Transmitter

100% Duty

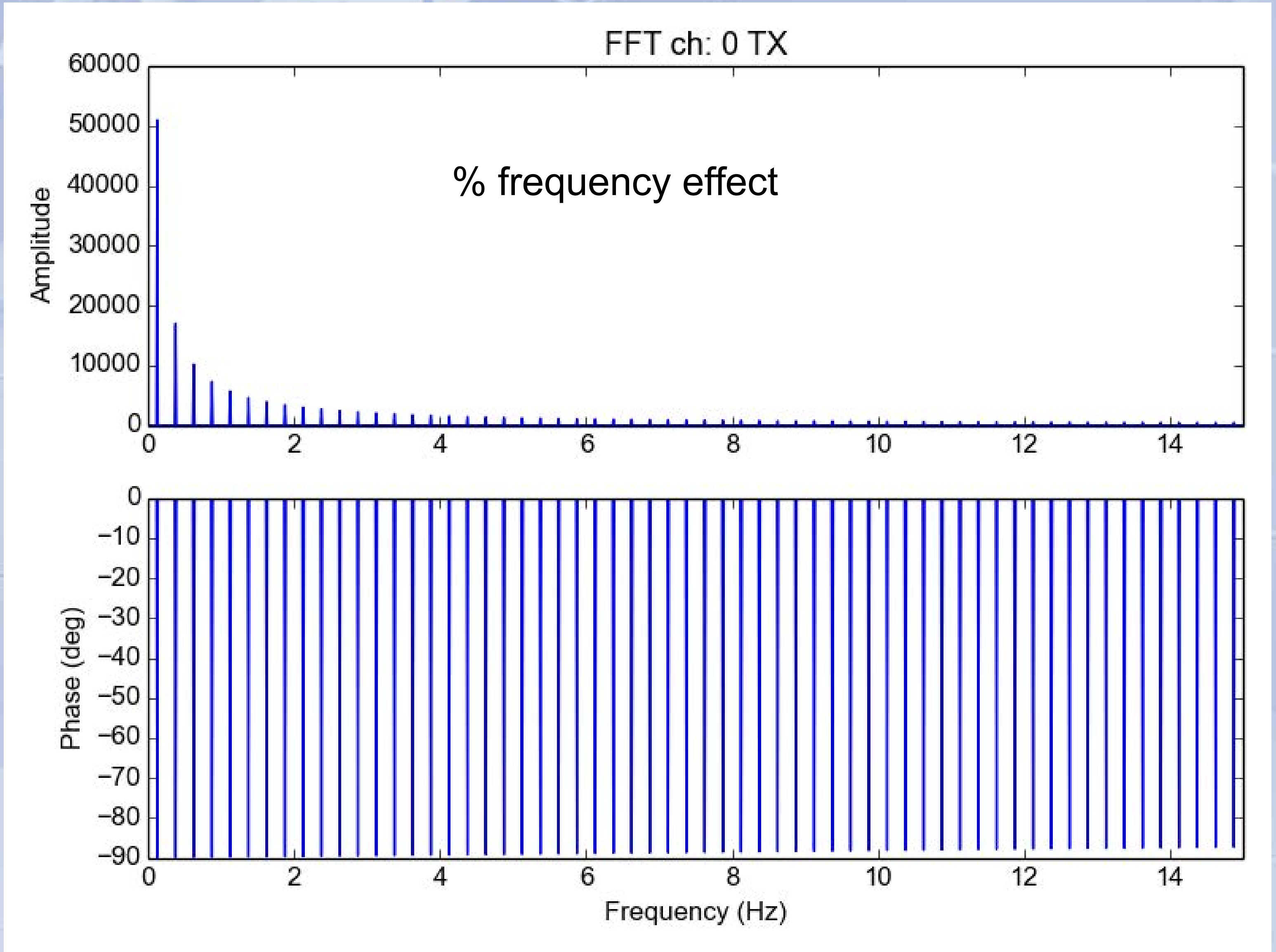
4 Sec possitive
4 sec negative



Frequency Domain

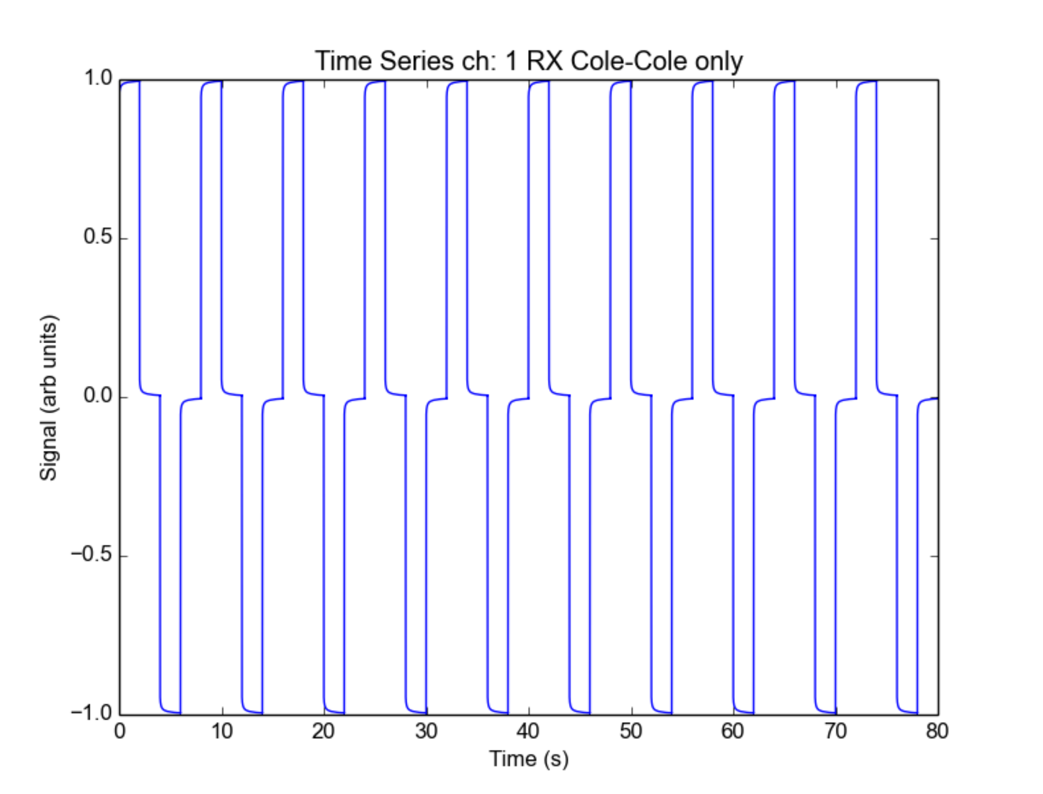
100% Duty

4 Sec possitive
4 sec negative

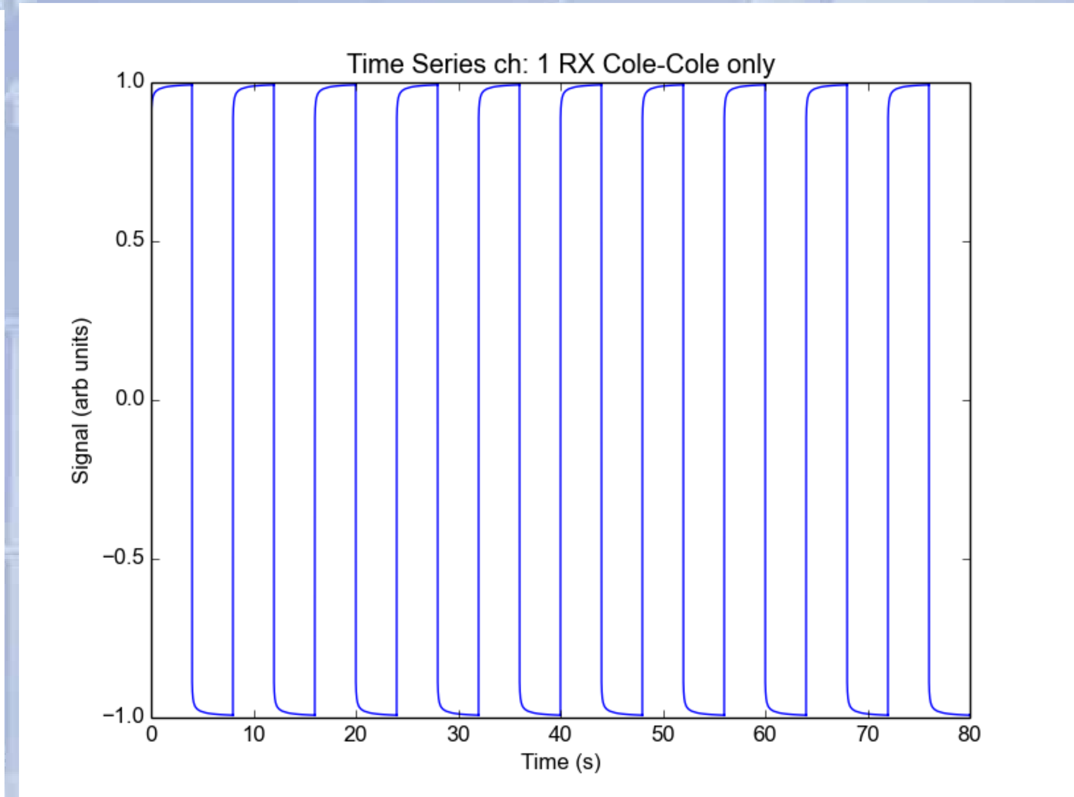


Phase IP

Time Domain or frequency domain??



Transmitter waveform for time domain

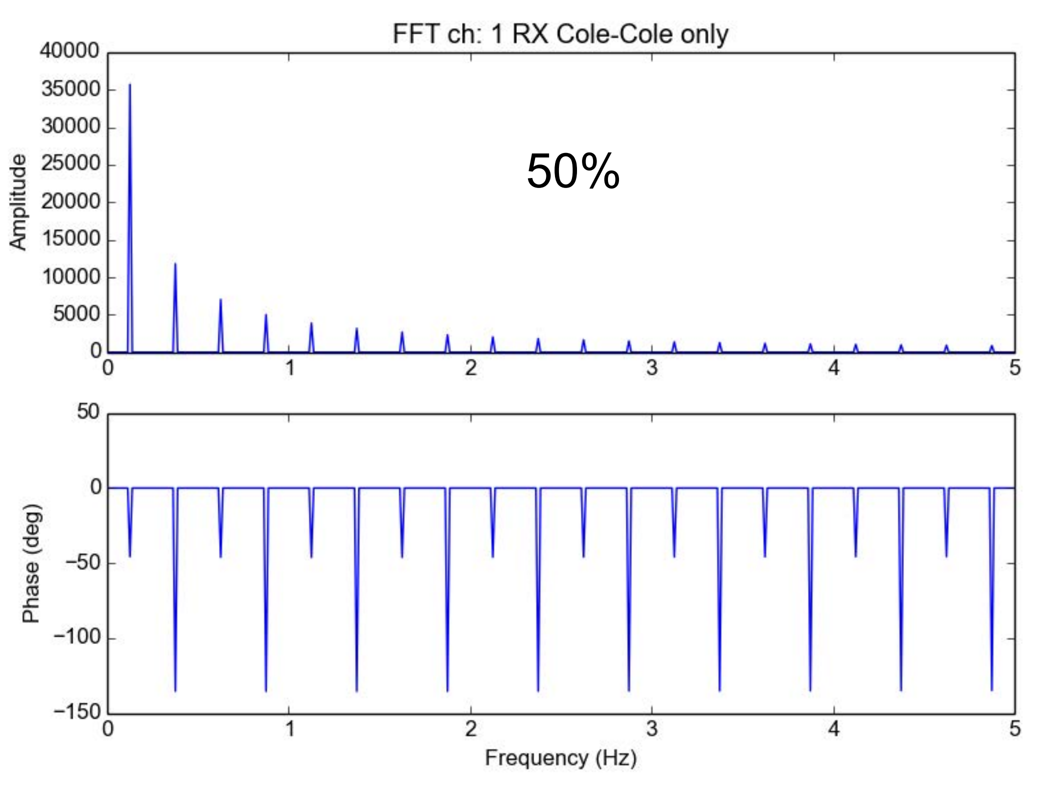


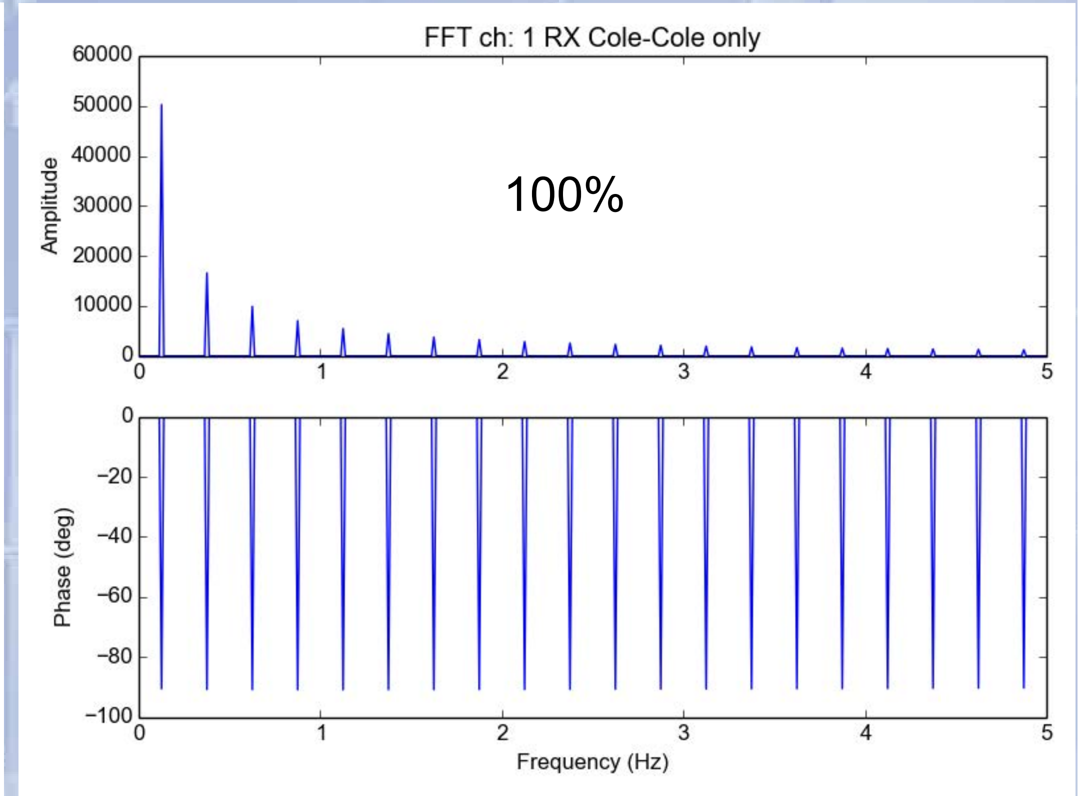
Transmitter waveform for frequency domain

SJ GEOPHYSICS Science on Target

VOLTERRA

Time Domain or frequency domain??





GEOPHYSICS
Science on Target

VOLTERRA

IP Data: Transmitters 100% Duty Cycle

- Significant advantages
  - Current is doubled – Not shut down 50% of the time
  - Can survey at half the time-base of base frequency to get the same number of time windows
  - Can stack 4 times as much in the same period of time – 2 times the signal/noise
  - Transmitter can be almost 6 times smaller to get same s/n data as 50%

IP Data: Transmitters 100% Duty Cycle

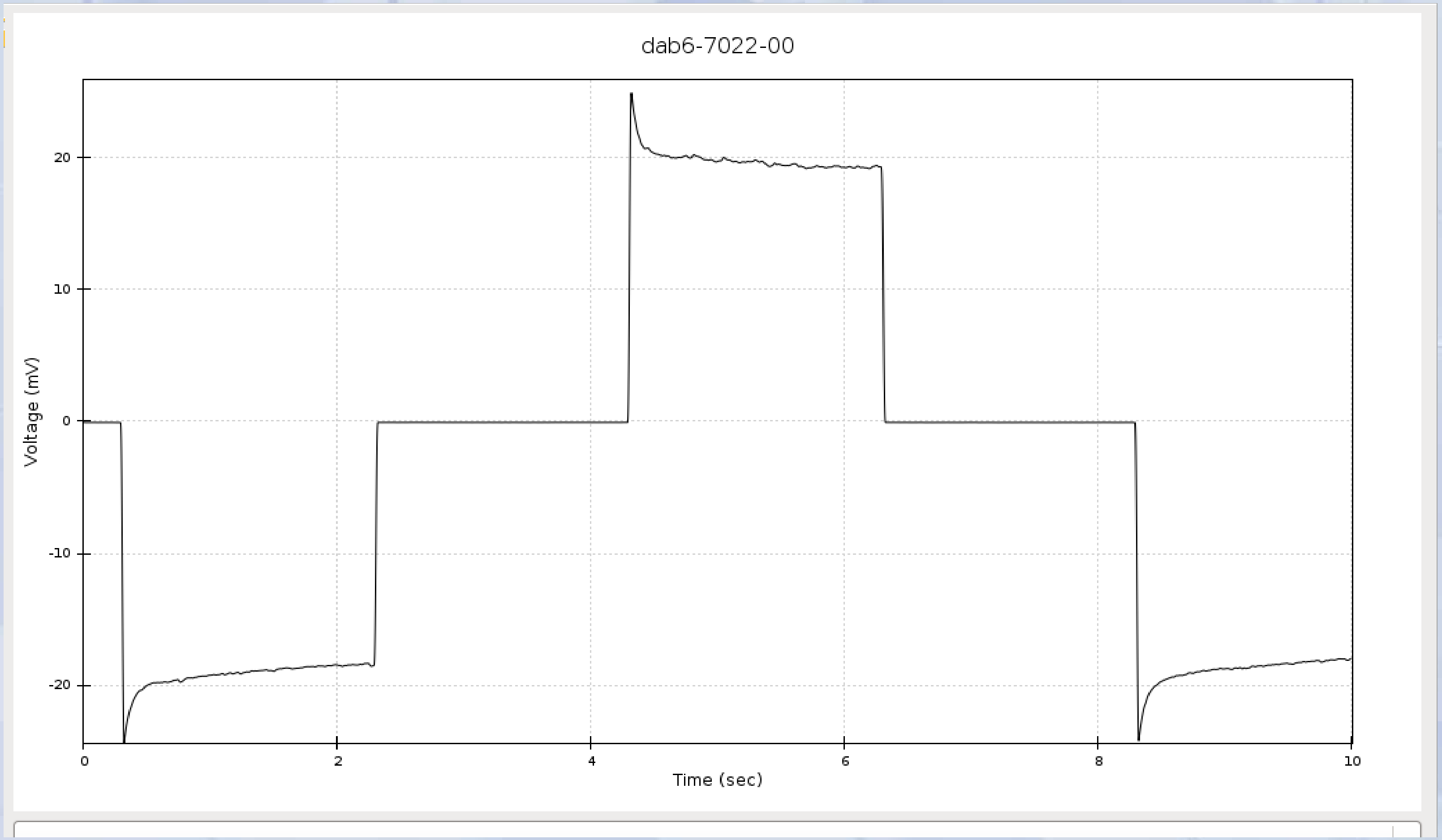
- Issues
  - Difficult to calculate the primary field to subtract versus easily done in EM.
- Possible solutions
  - Convolve with a 50% duty cycle signal. Gives the same time gates as 50%, but lose advantage of longer time
  - Acquire frequency-domain IP and look at the phase
    - FFT of time-domain IP = frequency-domain IP
  - Other ways not yet known or accepted

IP Data: Transmitters 100% Duty Cycle

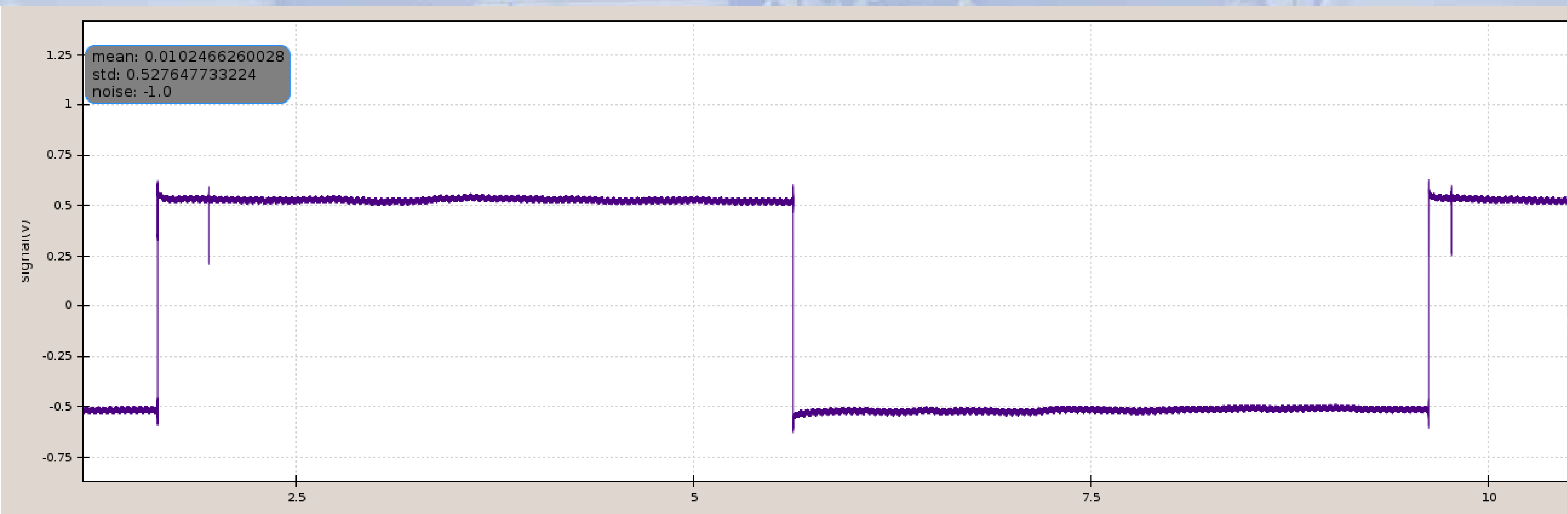
- Why do people only collect 50% duty cycle data?
  - Because the transmitters are so noisy during the on-time therefore can't collect data there ?

IP Data: Transmitters

- Most transmitters are big noise generators



GEOPHYSICS
Science on Target
VOLTERRA



SJ GEOPHYSICS
Science on Target

VOLTERRA

IP Data: Transmitters 100% Duty Cycle

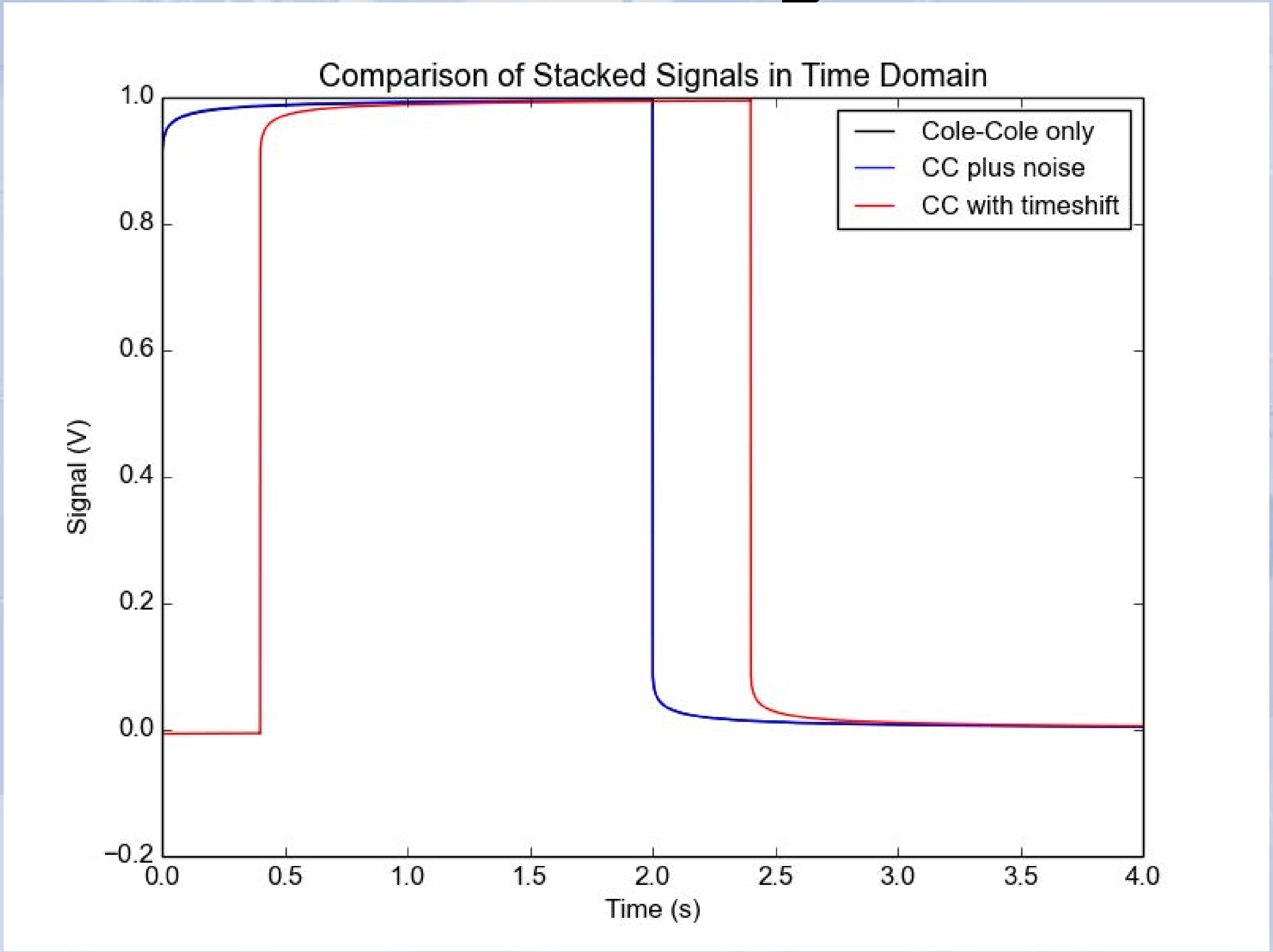
- Maybe it something as simple as this is the way its been done for 50 years
- why change now ?

Timing

SJ GEOPHYSICS
Science on Target

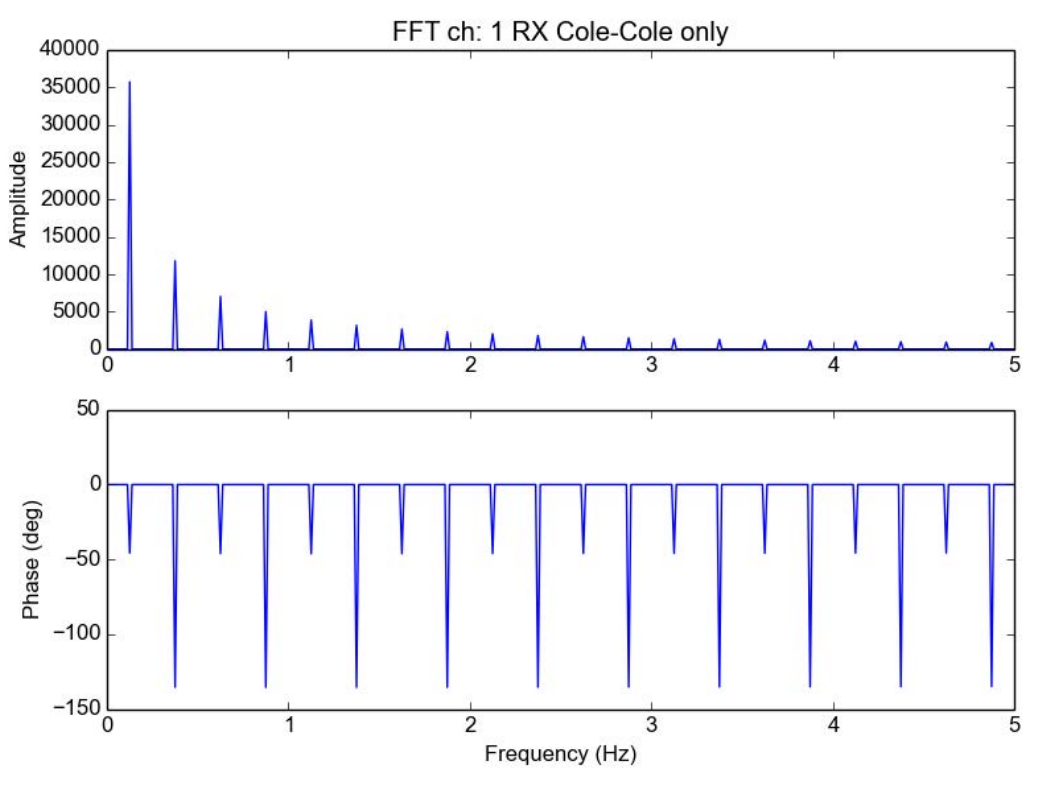
VOLTERRA

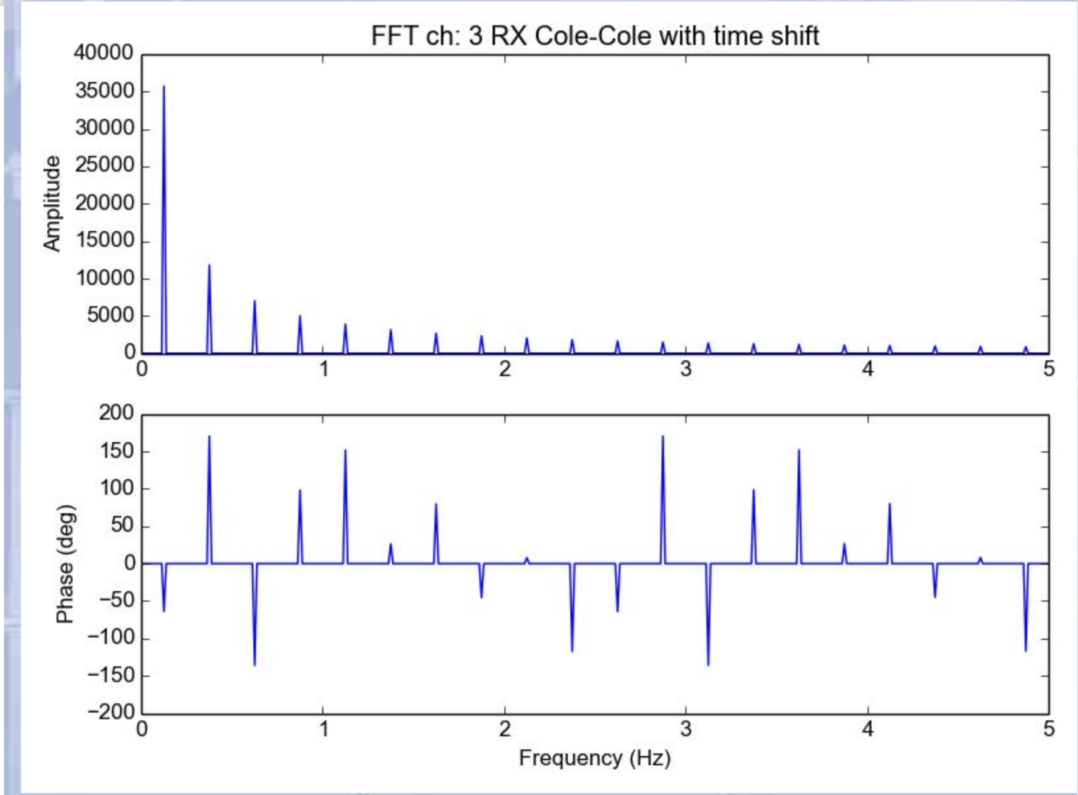
Timing



Comparison of Stacked Signals in Time Domain
Cole-Cole only
CC plus noise
CC with timeshift
Signal (V)
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (s)

Timing





GEOPHYSICS Science on Target

VOLTERRA

Timing

- Solutions
  - Use % frequency effect
  - Time shift
    - By hand
    - Edge detection
    - Good timing by GPS
  - Phase shift

Telluric Cancelation

- Includes
  - Reading length
  - Stacking
  - filtering

Telluric Cancellation

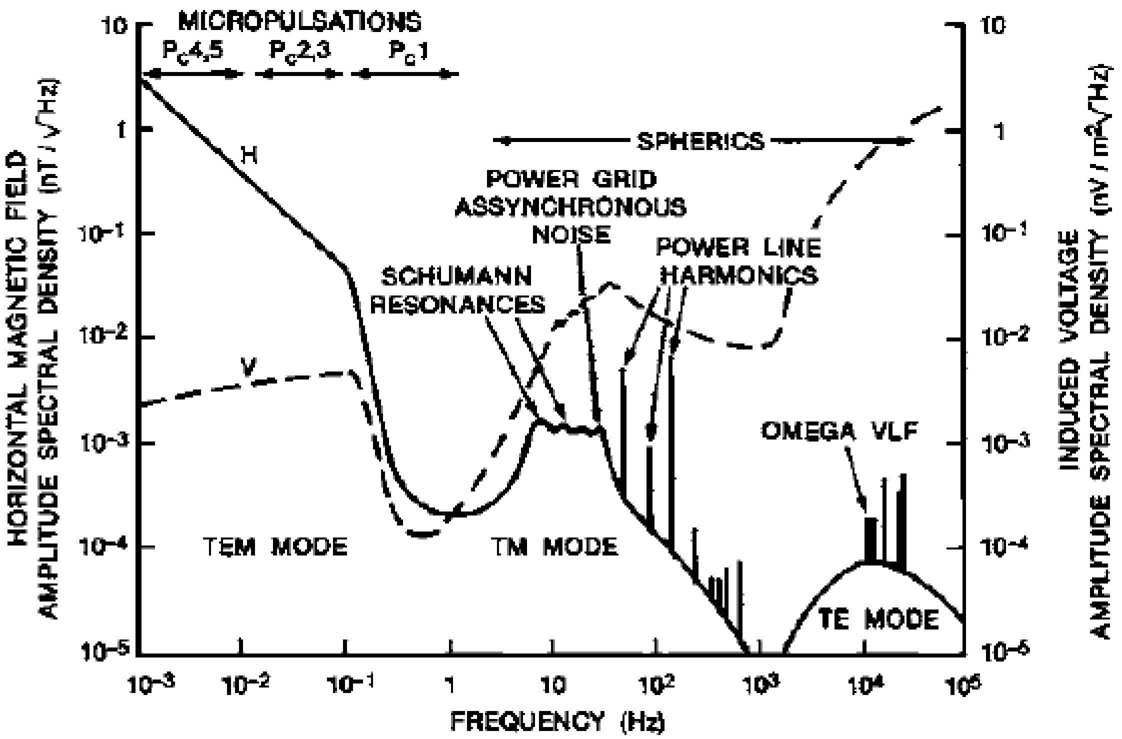
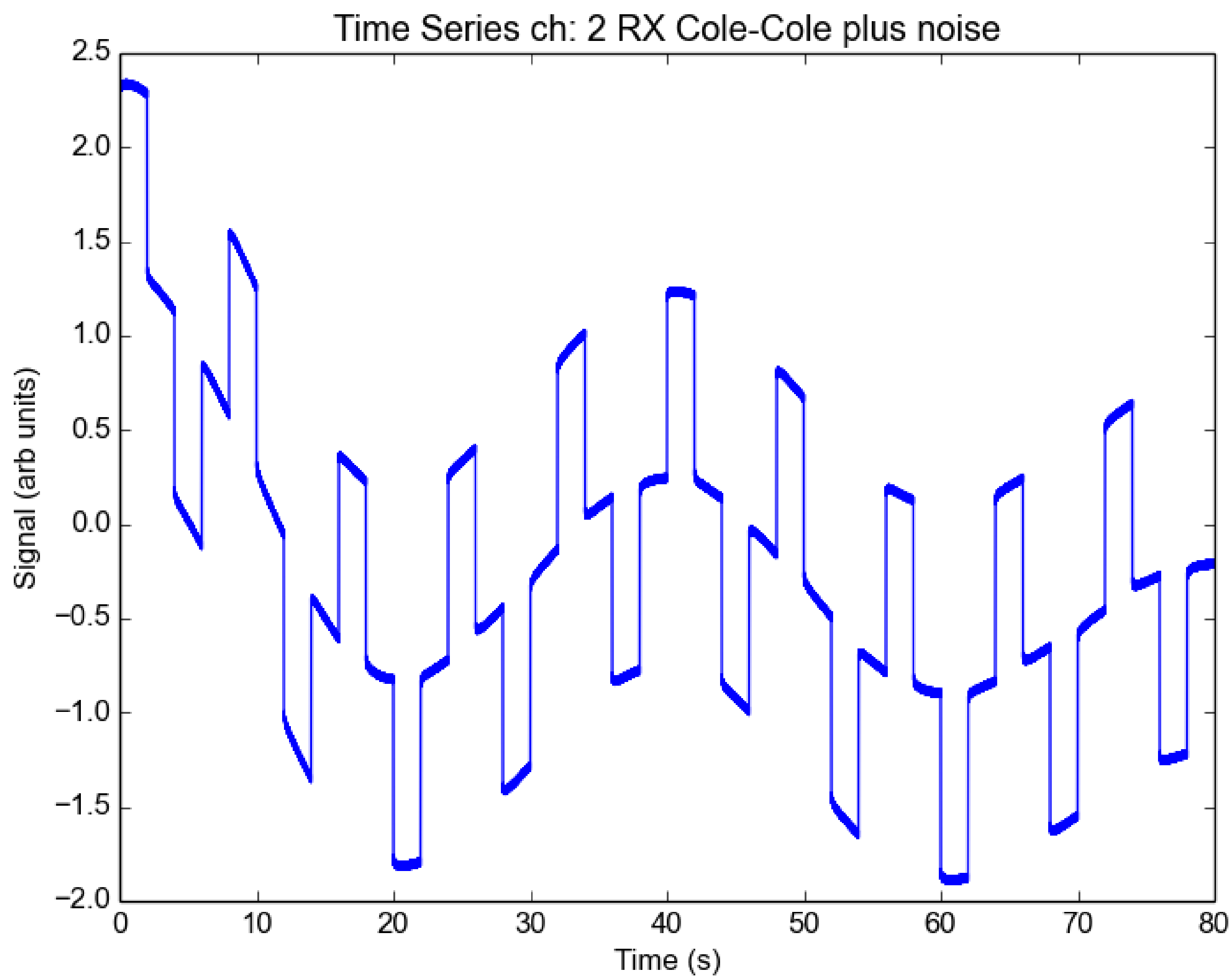


Fig. 27. Generalized geomagnetic spectrum for horizontal magnetic field (H) and induced voltage (V) measurements.

SEG_IG_EM_Vol2

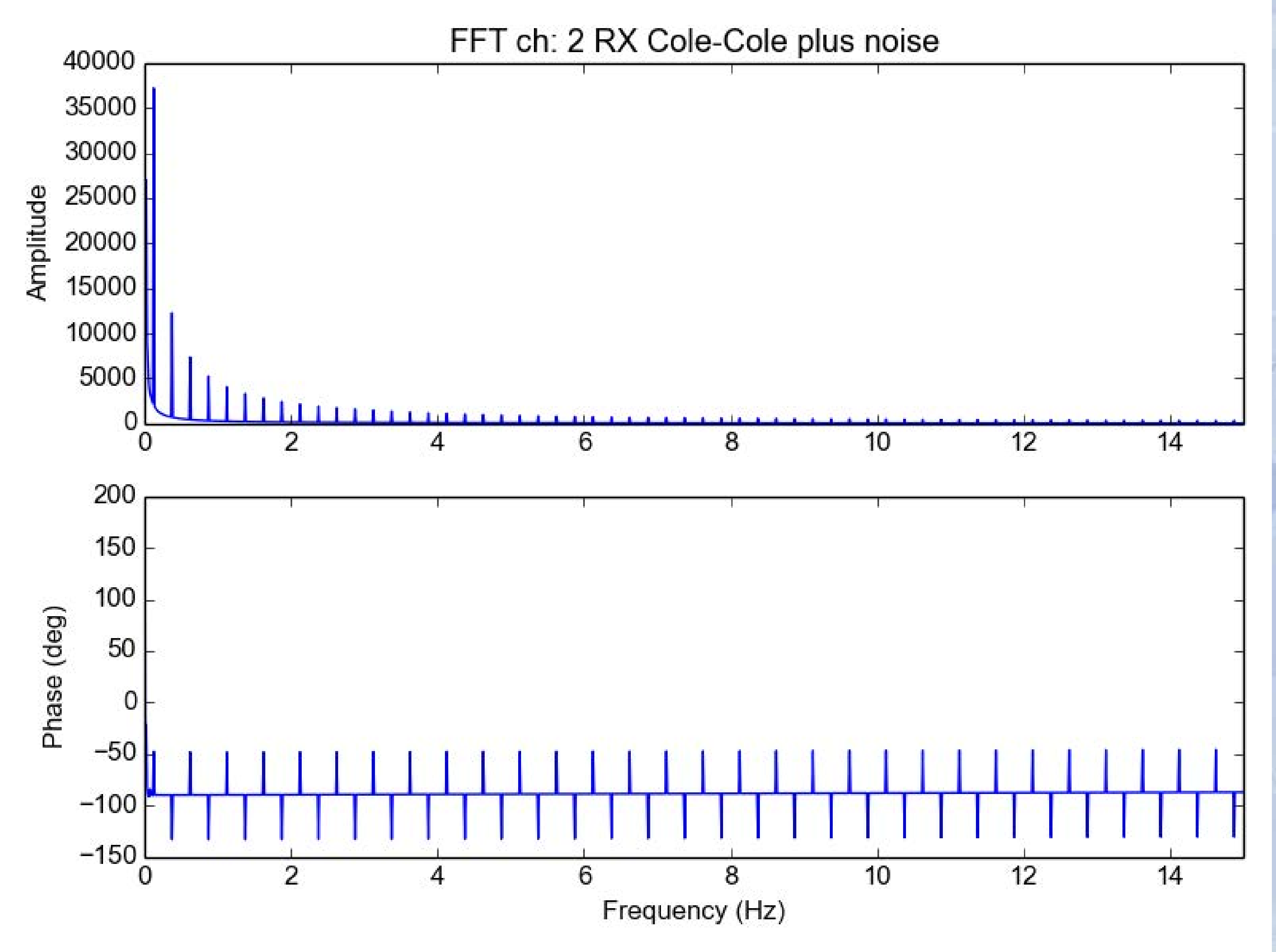
10 cycles with noise



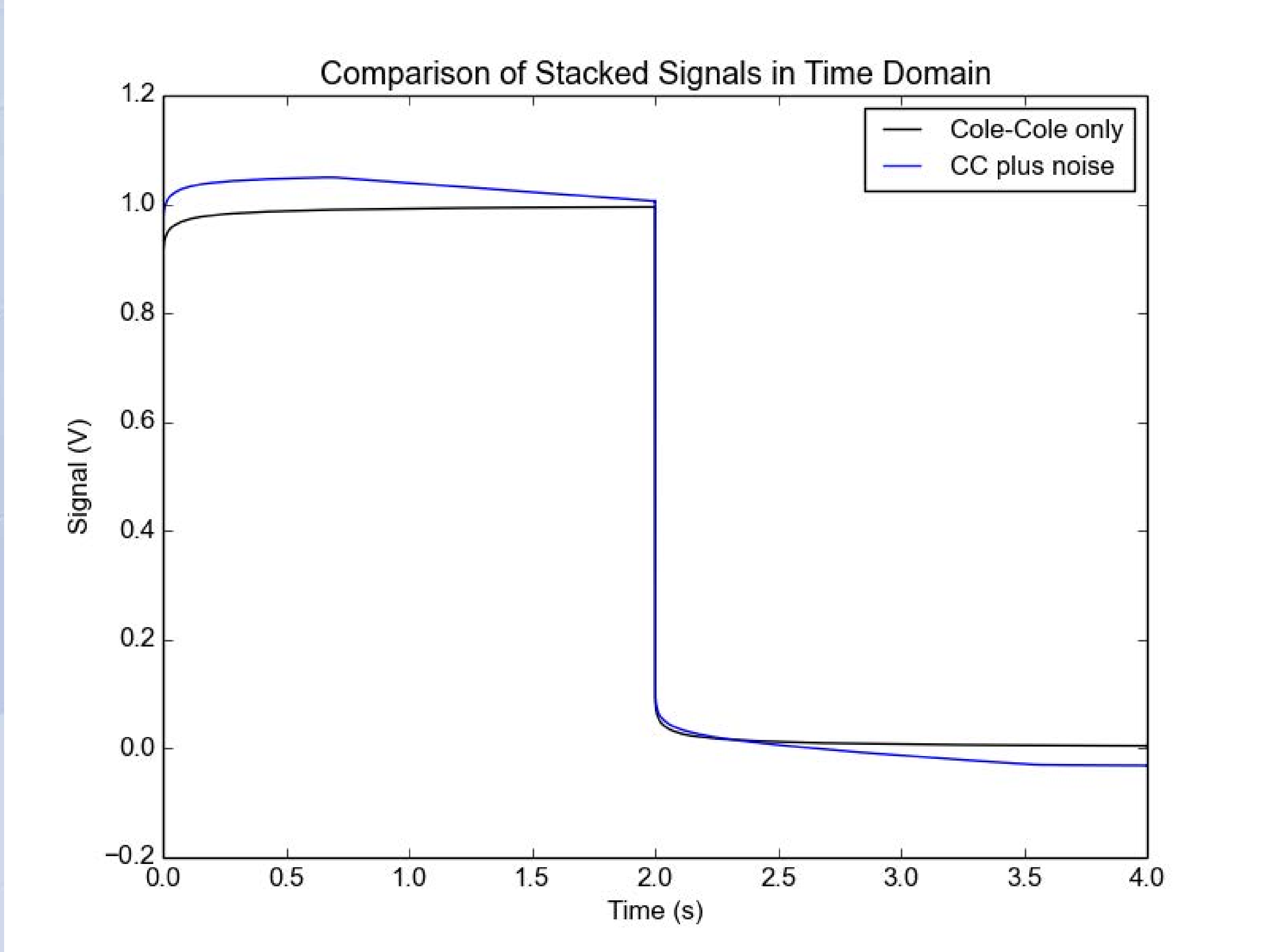
GEOPHYSICS
Science on Target

VOLTERRA

Telluric Cancellation



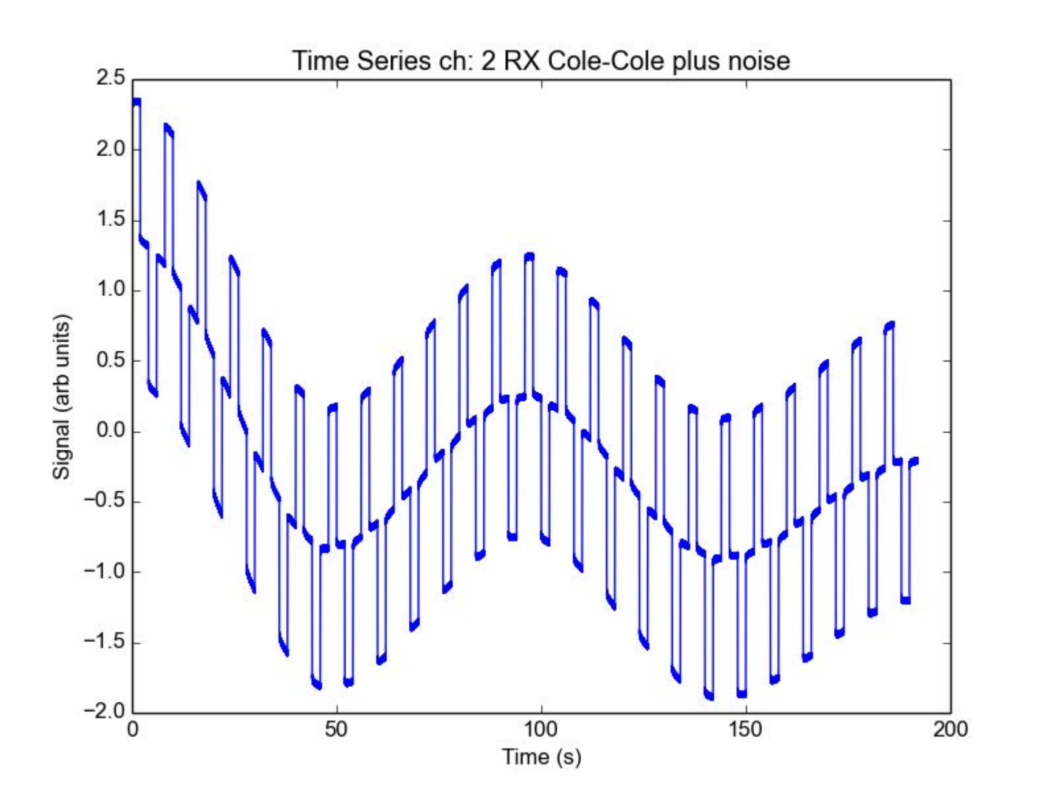
Simple stacking (averaging) 20 stacks, 80 sec

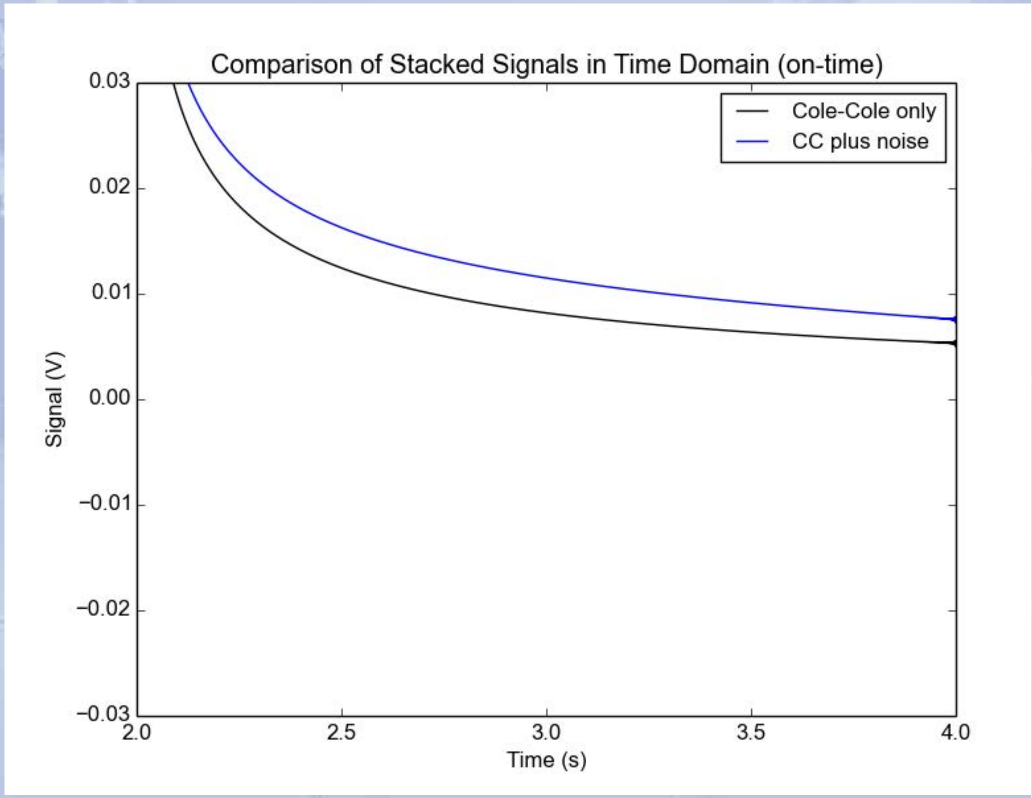


GEOPHYSICS
Science on Target

VOLTERRA

Simple stacking 48 stacks, 192 sec

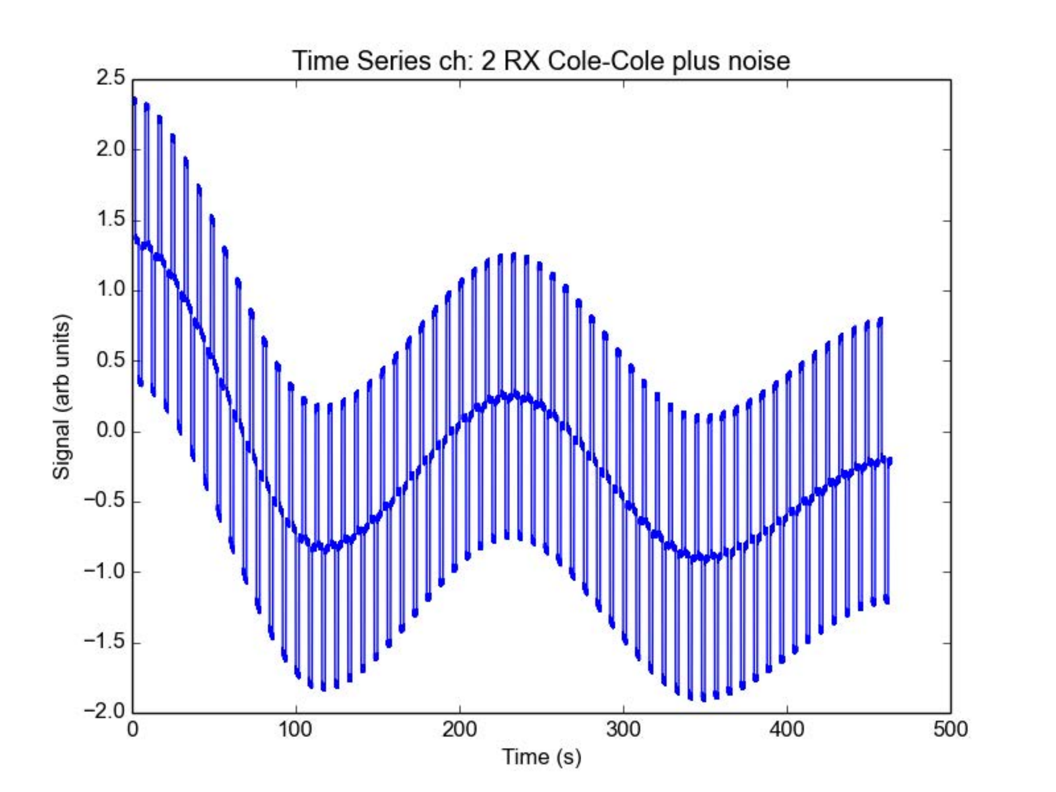


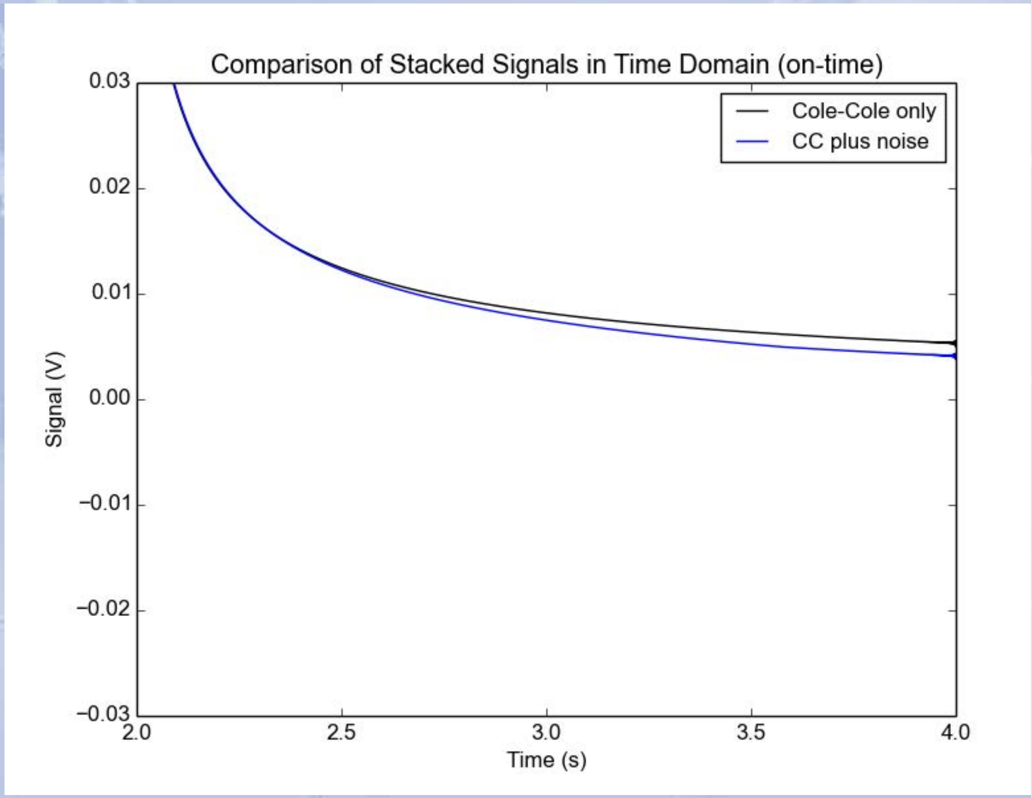


GEOPHYSICS Science on Target

VOLTERRA

Simple stacking 116 stacks, 464 sec



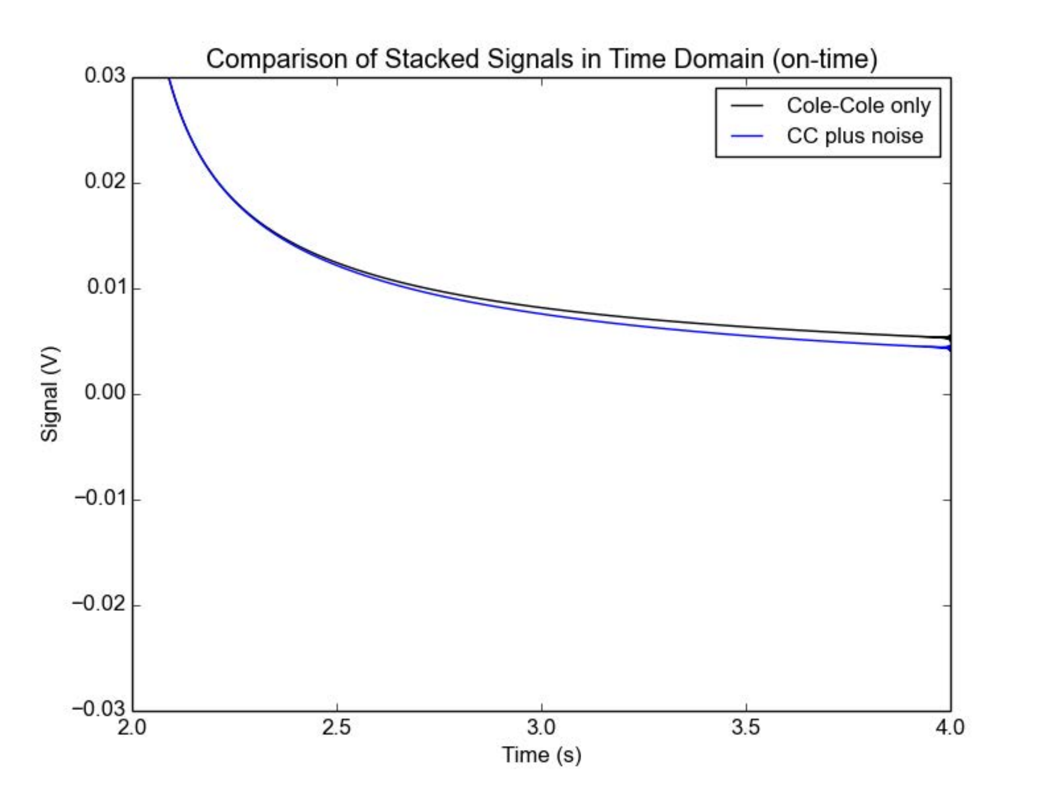


GEOPHYSICS
Science on Target

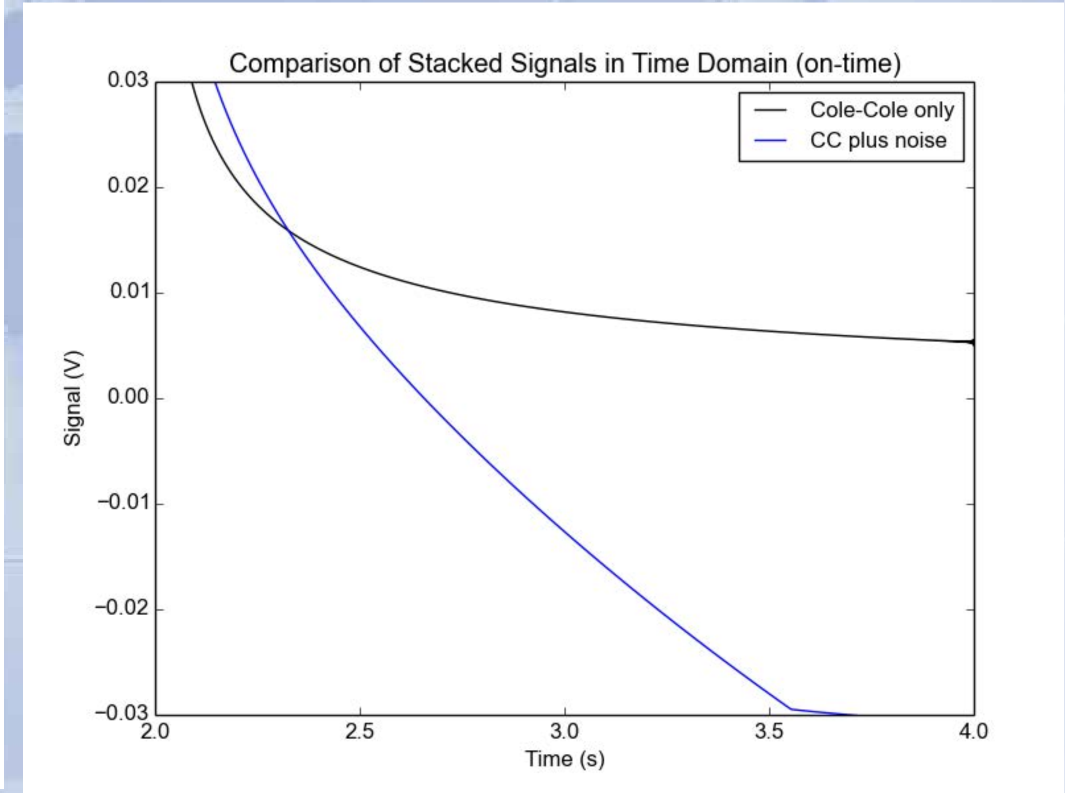
VOLTERRA

20 stacks, 80 sec

Filtered Stacking



Simple Stacking

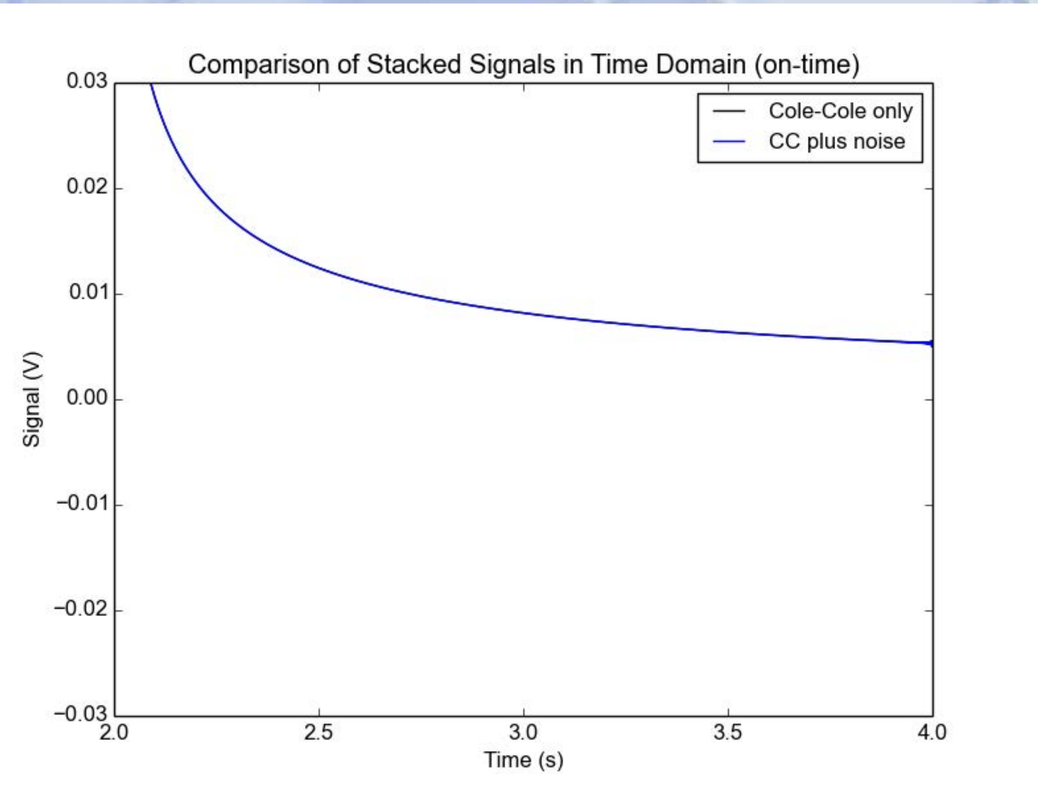


SJ GEOPHYSICS
Science on Target

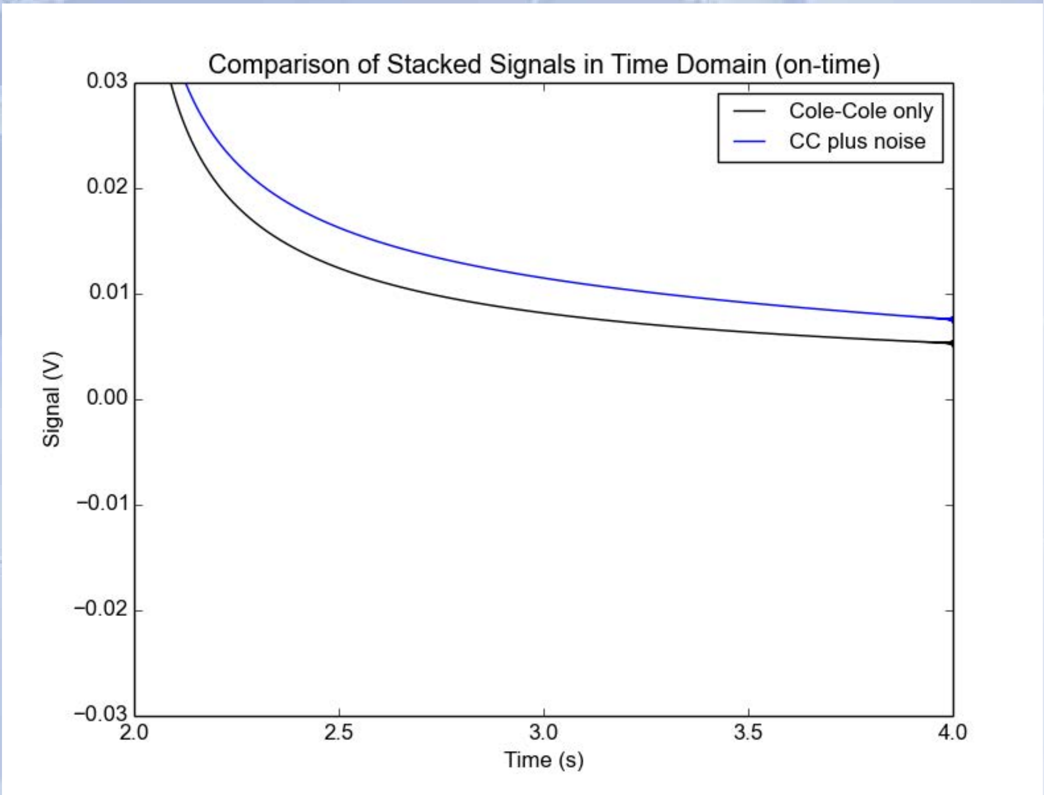
VOLTERRA

48 stacks , 192 sec

Filtered Stacking



Simple Stacking



GEOPHYSICS
Science on Target

VOLTERRA

IP Systems

- Most systems are hardwired to 2s on, 2s off or 4s on, 4s off
- Not enough work is being done on studying base frequencies and there relationship to noise
- In EM, noise readings are taken at the start of the job and the base frequency is adjusted to eliminated any beating with local noise sources
- 10 stacks is simple not enough to do good stacking
  - Remember multiple reading and then averaging is like simple stacking
- Build good transmitters not simply a bigger hammer.

Telluric Cancelation

- conclusion
  - Longer reading length proper stacking and filtering in most cases does a better job then “telluric cancellation“
  - My experience shows telluric cancellation improves the precision (lower rms error) of a reading but not the Accuracy.

Accuracy vs. Precision

Low Accuracy, Low Precision

Low Accuracy, High Precision

High Accuracy, Low Precision

High Accuracy, High Precision

IP

- We have to get away from the we have done it like this for the last 50 years approach including simply getting bigger hammers

There are much more elegant ways to get better S/N