An Application of LOTEM around A Salt Dome near Houston, Texas

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Outlines

- Background
- Methodologies
- Data processing
- Result & discussion
- Conclusion
- Acknowledgments

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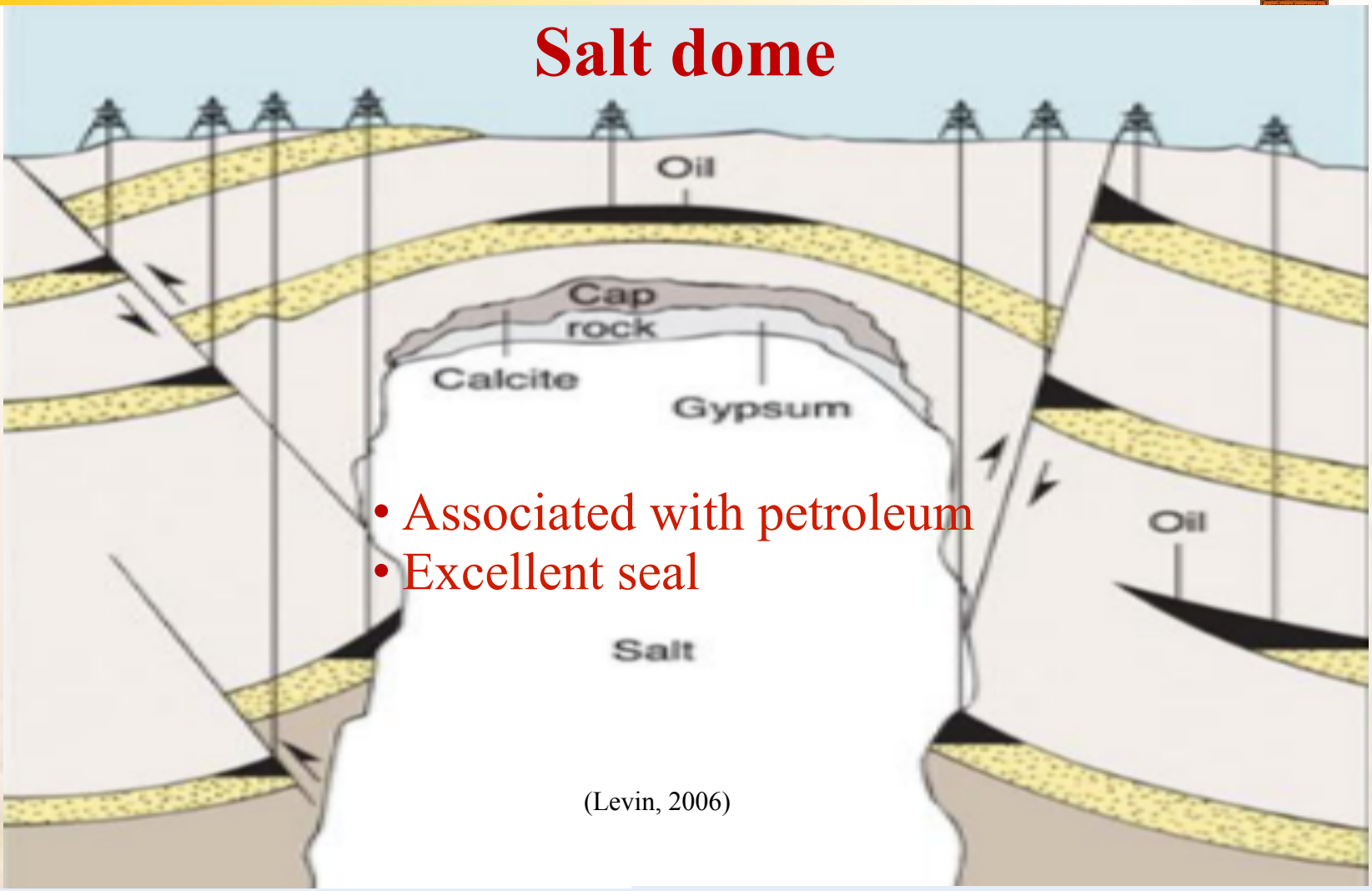
Salt dome

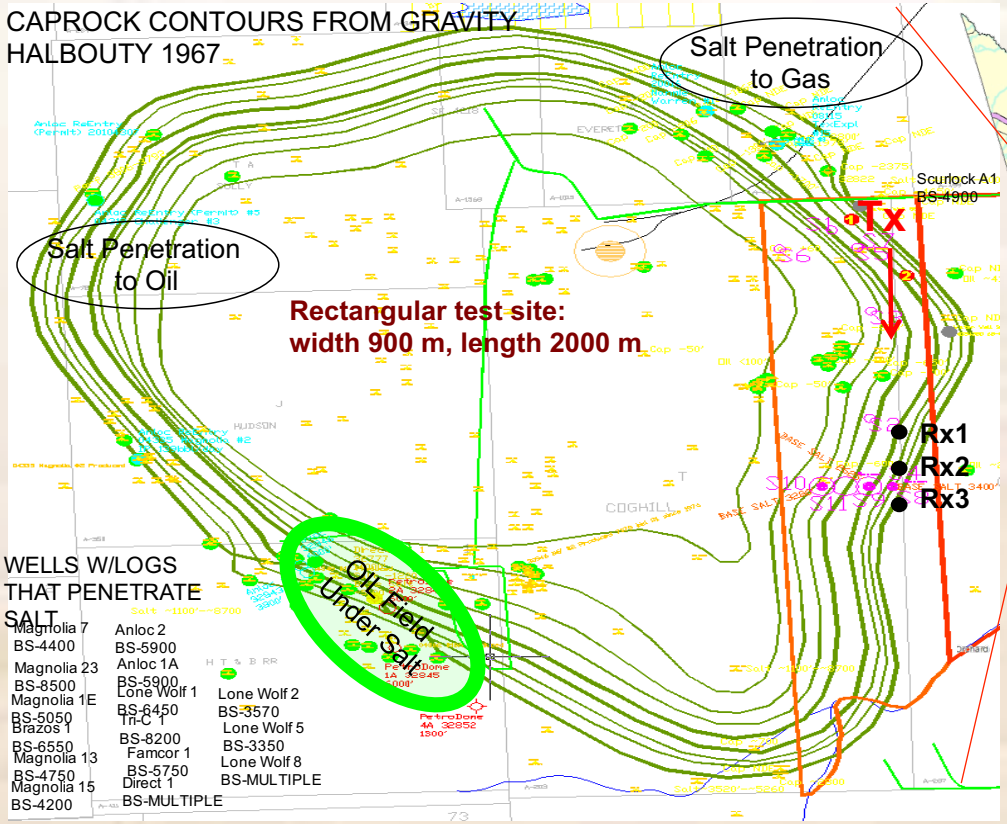


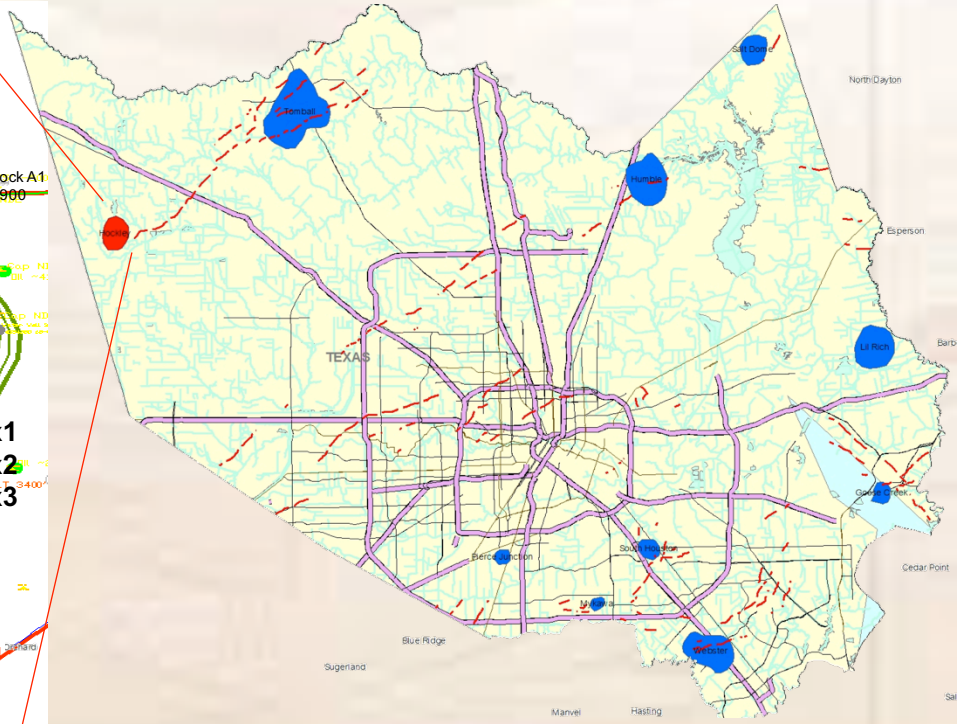
- Associated with petroleum
- Excellent seal

(Levin, 2006)

- Seismic :
  - Hampered by salt bodies
  - High velocity of salt
- Gravity survey (mapping)
- Electromagnetic:
  - Issue: high cultural noise

- **Processing of LOTEM data for confidence to the quality of inversion and interpretation**
- **Preliminary interpretation for overhang**





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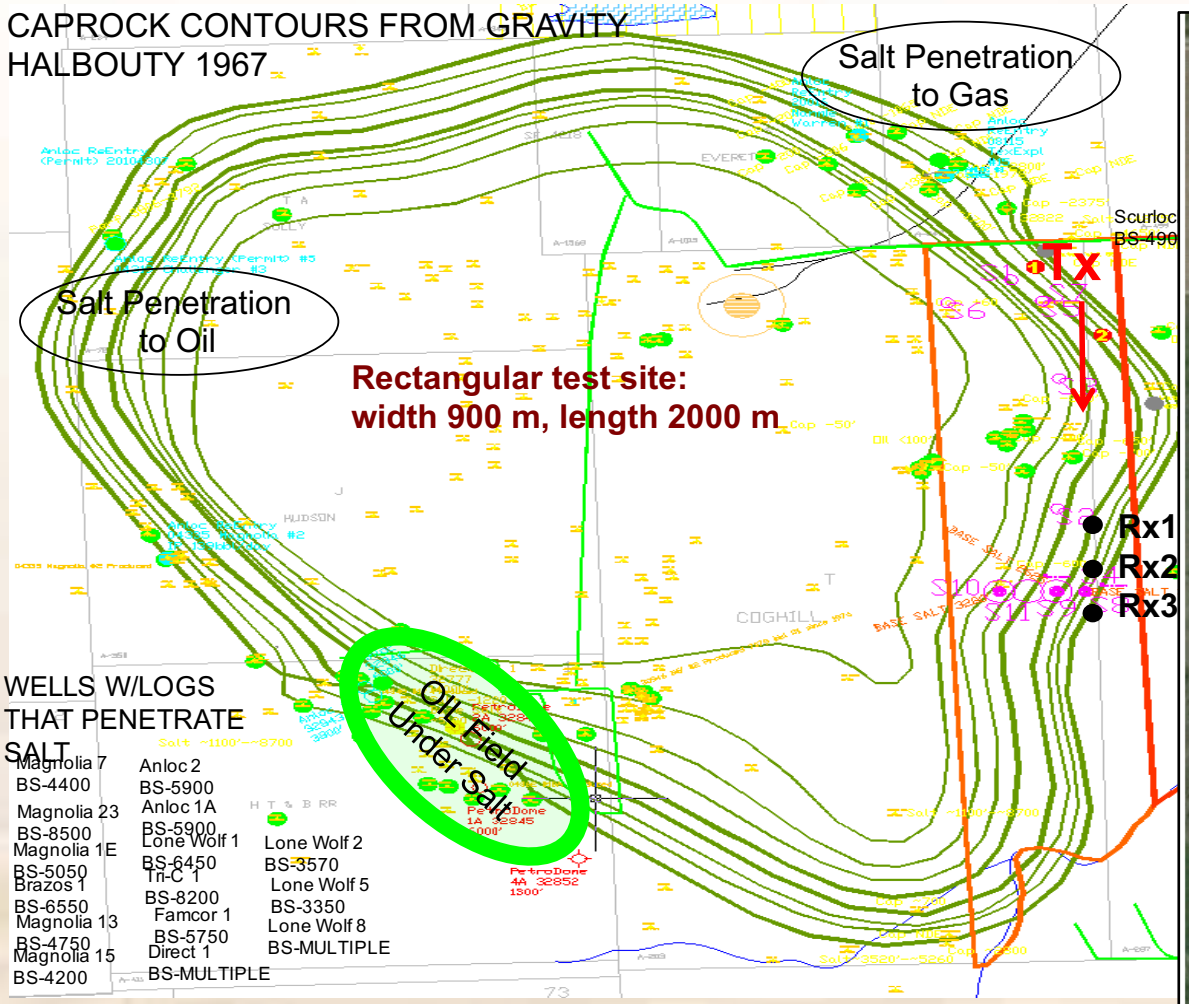
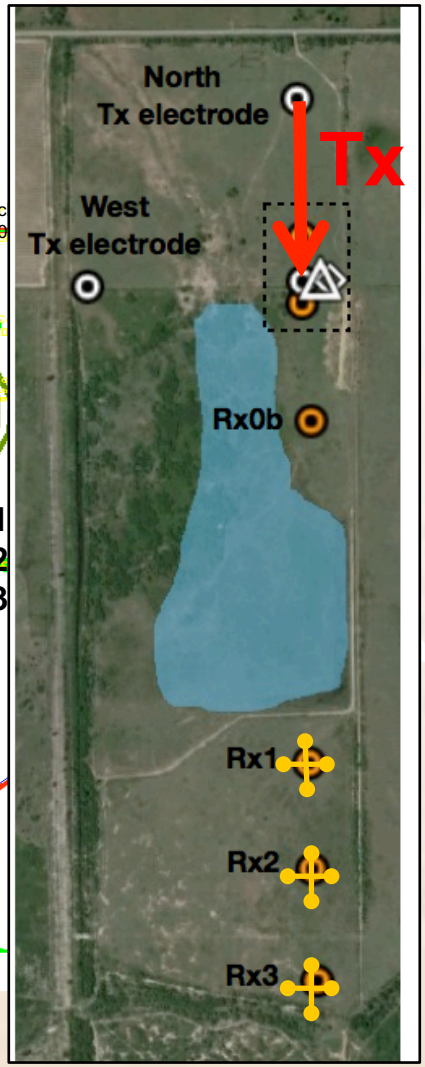
Survey setting





Tx North: -340 m
(29.9659° 95.8274°)

Tx South: 0
(29.9628° 95.8273°)

rea

900 m
(29.9547° 95.8272°)
1100 m
(29.9529° 95.8271°)
1300 m
(29.9510° 95.8271°)

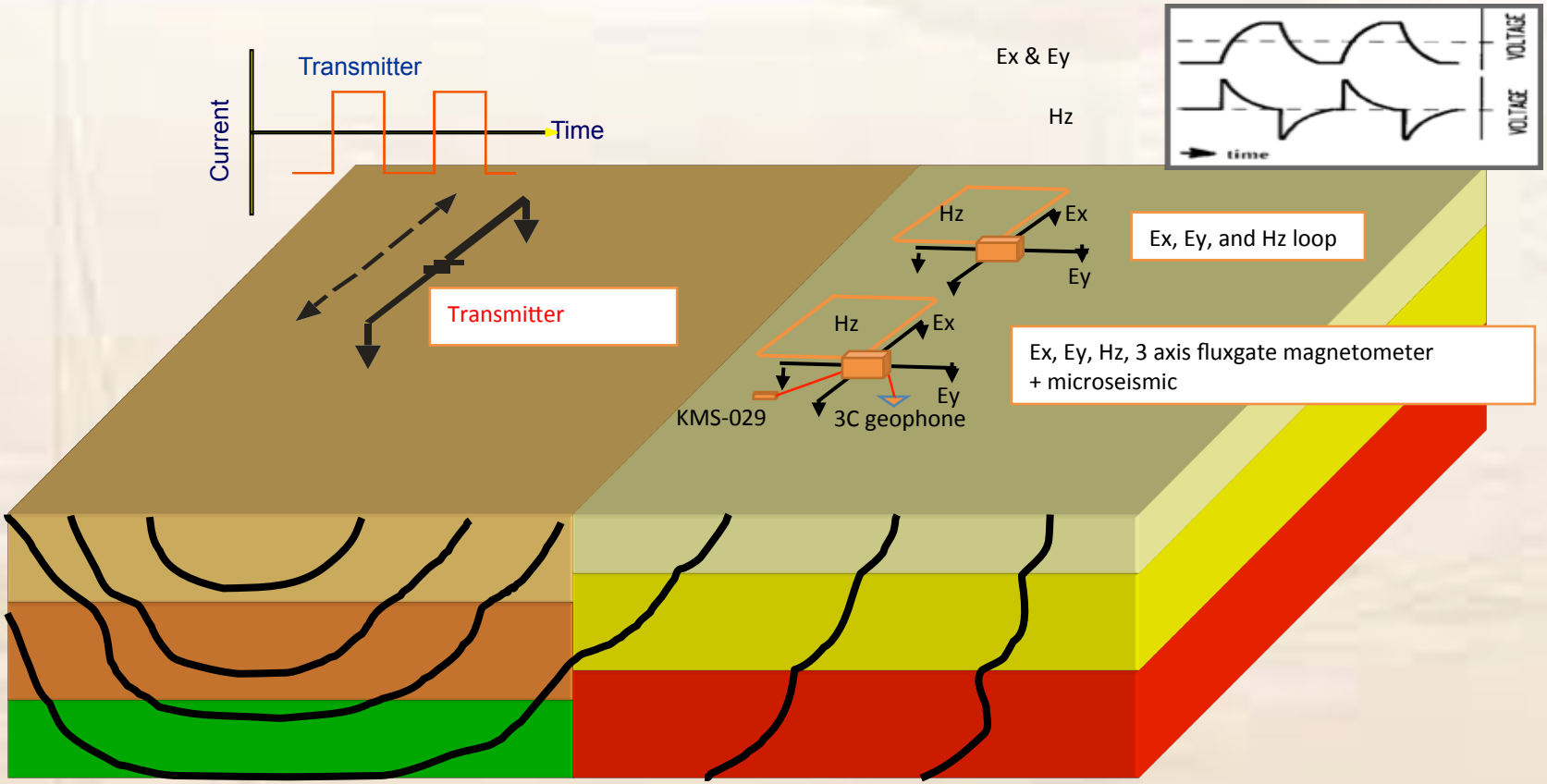
Rx0c = Located between North and South transmitter

Rx0a = Near Offset

Rx0b= Middle offset

Array

- Grounded wire transmitter,
- Receiver :
  - Induction loop and coil for magnetic field
  - Polarized electrode for electric field.



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CSEM: LOTEM & FSEM

LOTEM

- Used with high electromagnetic noise
- Measured electric and magnetic field

Focused Source EM

- Significantly higher spatial resolution
- Provides deeper resistivity data;
- Using the vertical focusing in the electric field;
- Inspired by the resistivity well logging (Laterologs 7).

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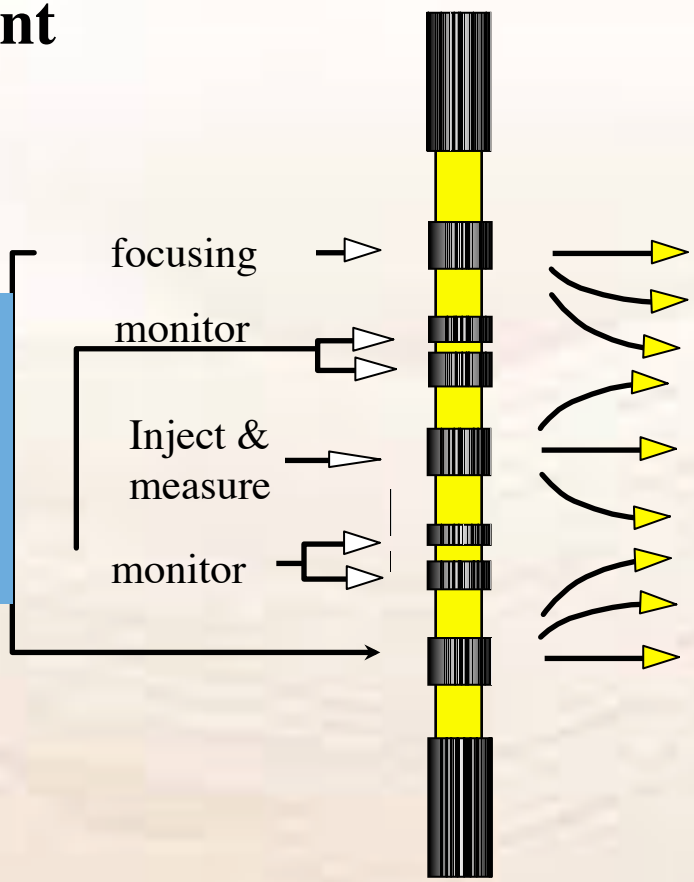
FSEM: Focused log equivalent

- Help keep the central current more focused.
- Adjusted to maintain zero voltage across the monitor electrodes

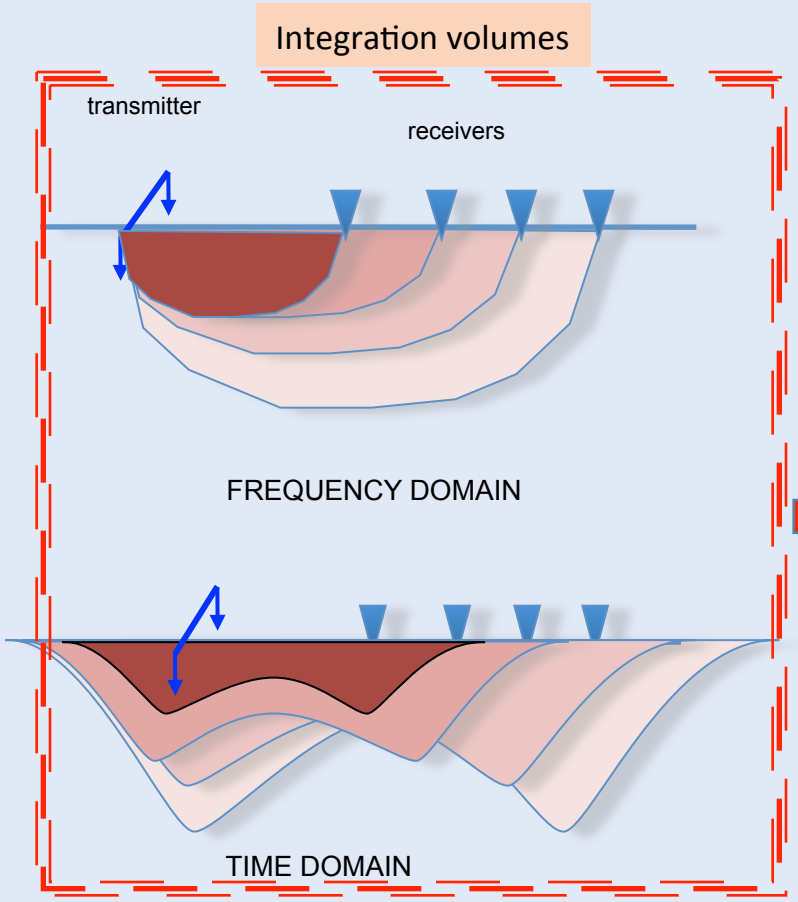


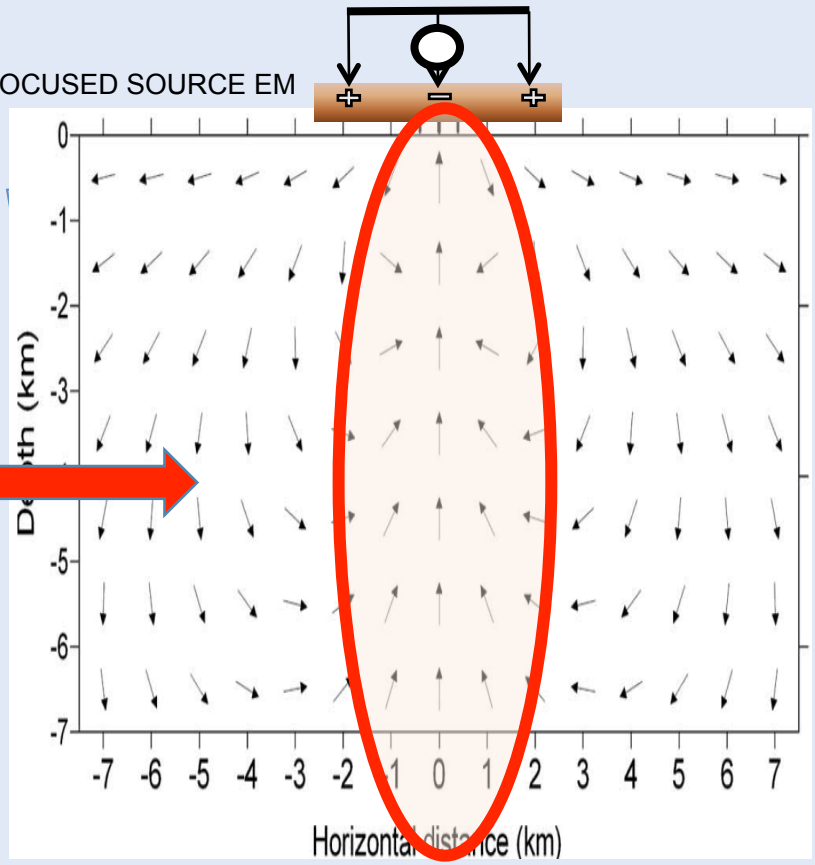
Laterologs 7

The survey current is focused,

- Providing better vertical resolution
- Deeper depth of investigation

CSEM & FSEM





Rykhlinskaya, E., & Davydycheva, S., 2014, U.S. Patent 8,762,062 B2.
Davydycheva, S., 2016, U.S. Patent Application US 2016/0084980 A1.

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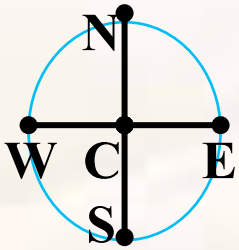
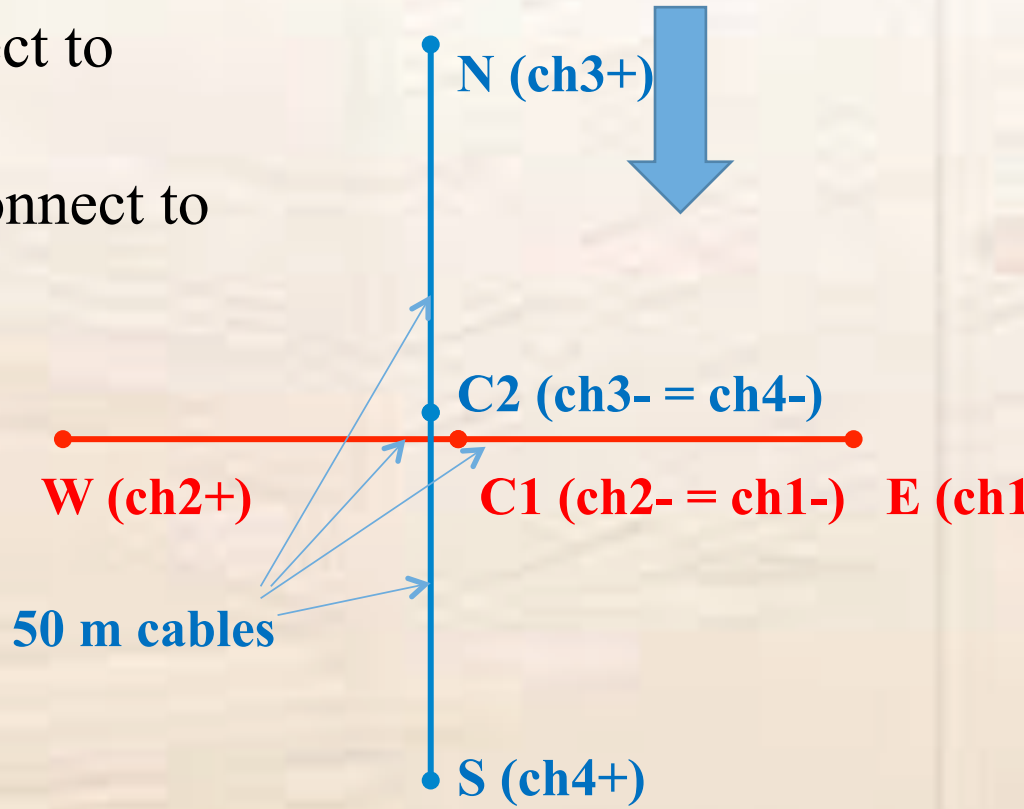
FSEM circular dipole field layout

- Center needs to be split into two: C1 & C2
  - Distance between them ~0.3 to 1 m
- Centers C1 & C2 always connect to "minus" of KMS-820 channels
- Peripheral electrodes always connect to "plus" of KMS-820 channels

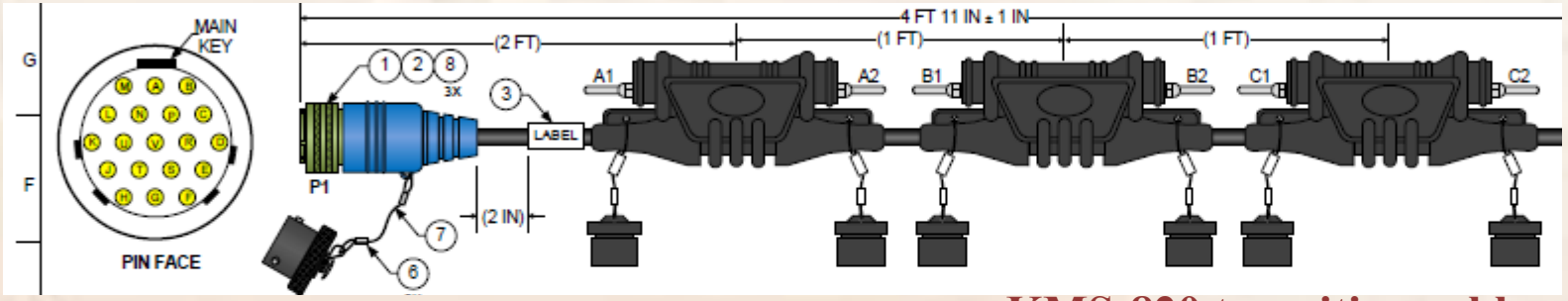




50-m electrode extension cable

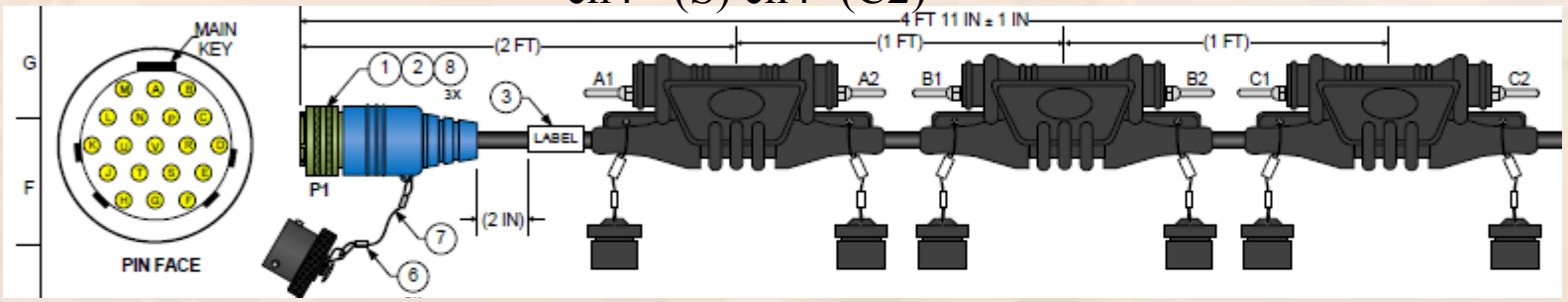
Compatible to grounding electrodes

ch1+ (E) ch1- (C1) ch2+ (W) ch2- (C1) ch3+ (N) ch3- (C2)

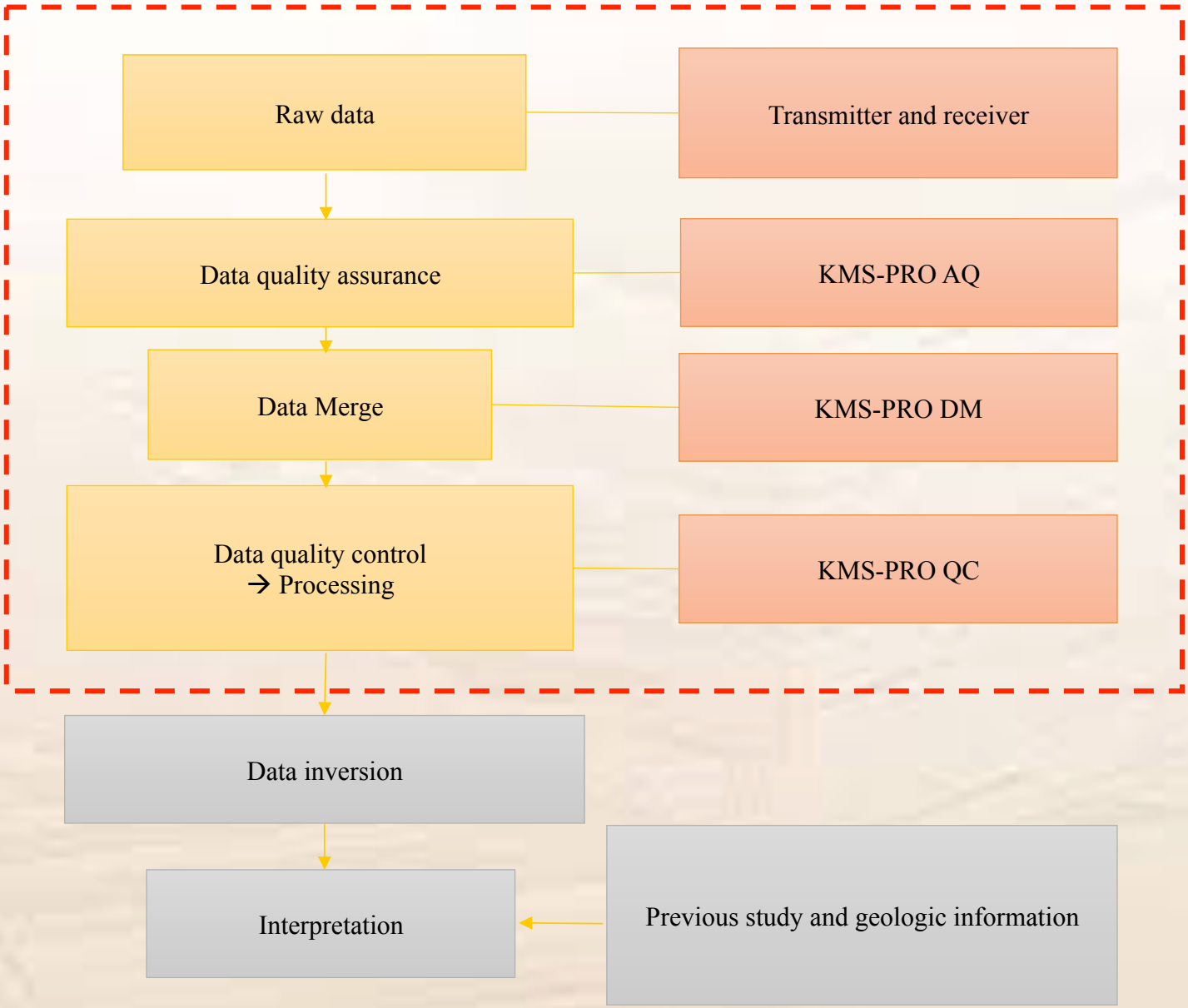


KMS-820 transition cables

ch4+ (S) ch4- (C2)



Work flow


Raw data
Transmitter and receiver
Data quality assurance
KMS-PRO AQ
Data Merge
KMS-PRO DM
Data quality control
→ Processing
KMS-PRO QC
Data inversion
Interpretation
Previous study and geologic information

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Data quality assurance

- To avoid problems in data processing.
- Calibration & header checking
- Amplitude calibration
  - Timing check
  - Header editing

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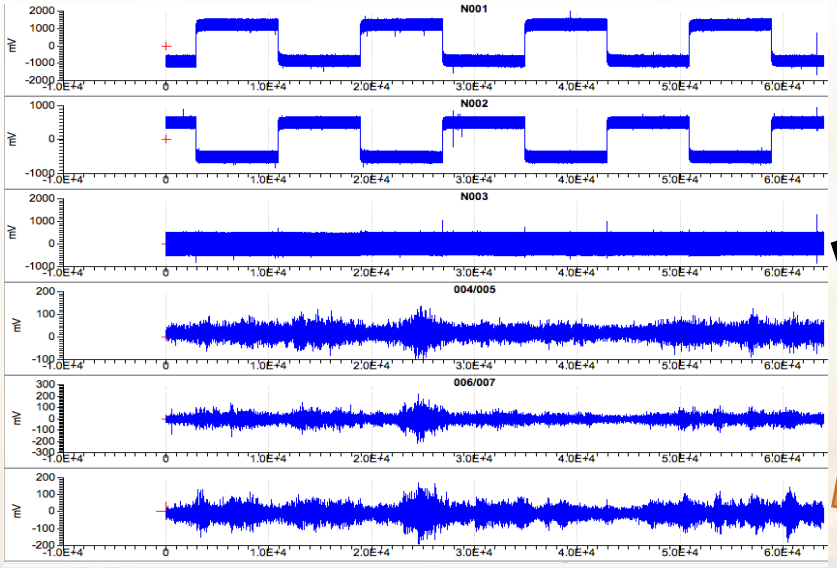
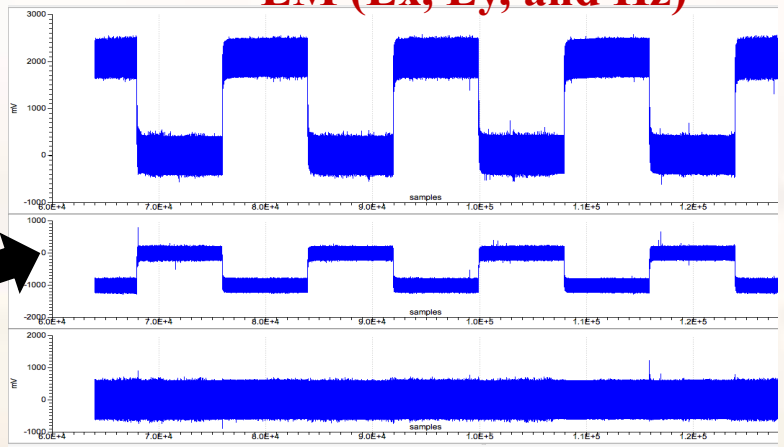
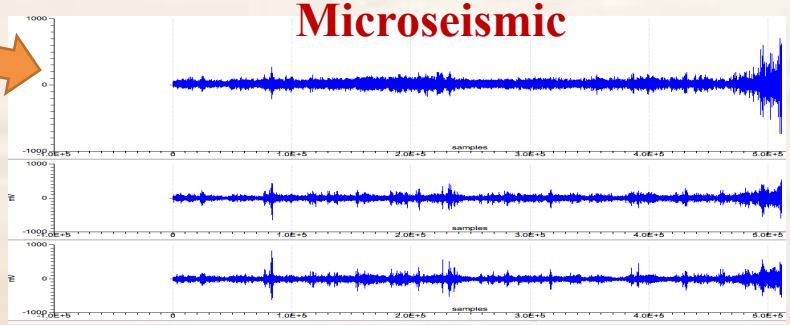
Data Merge



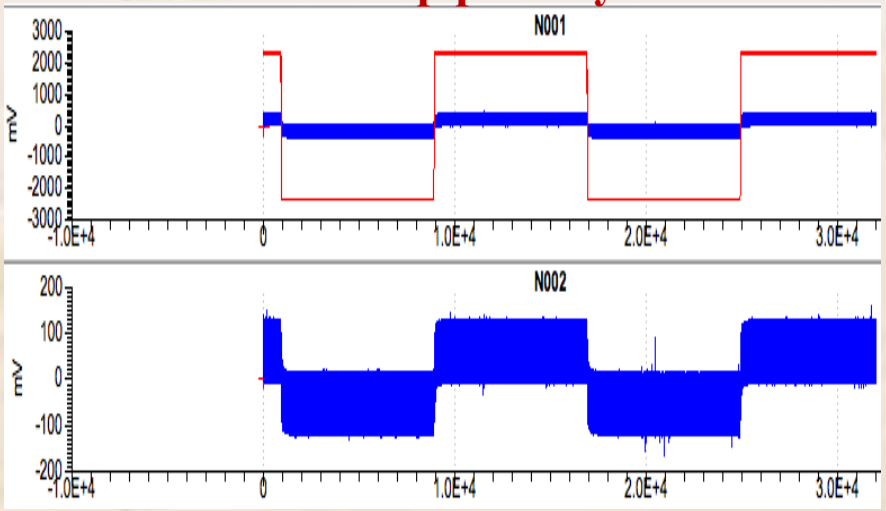
EM (Ex, Ey, and Hz)



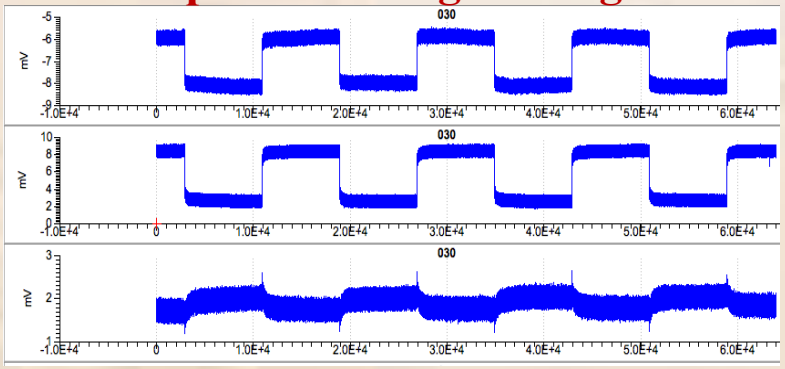
Microseismic



Flip polarity



3-components fluxgate magnetometer



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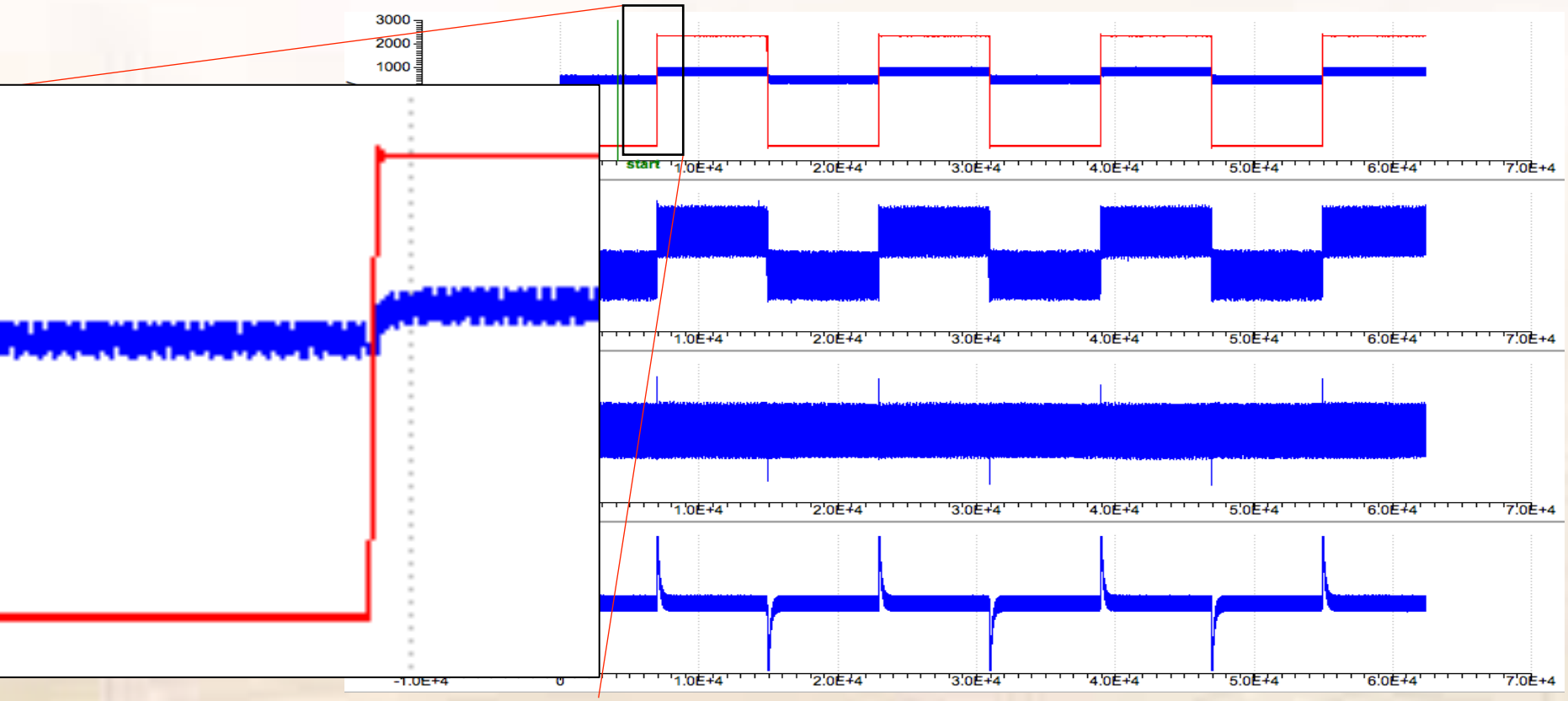
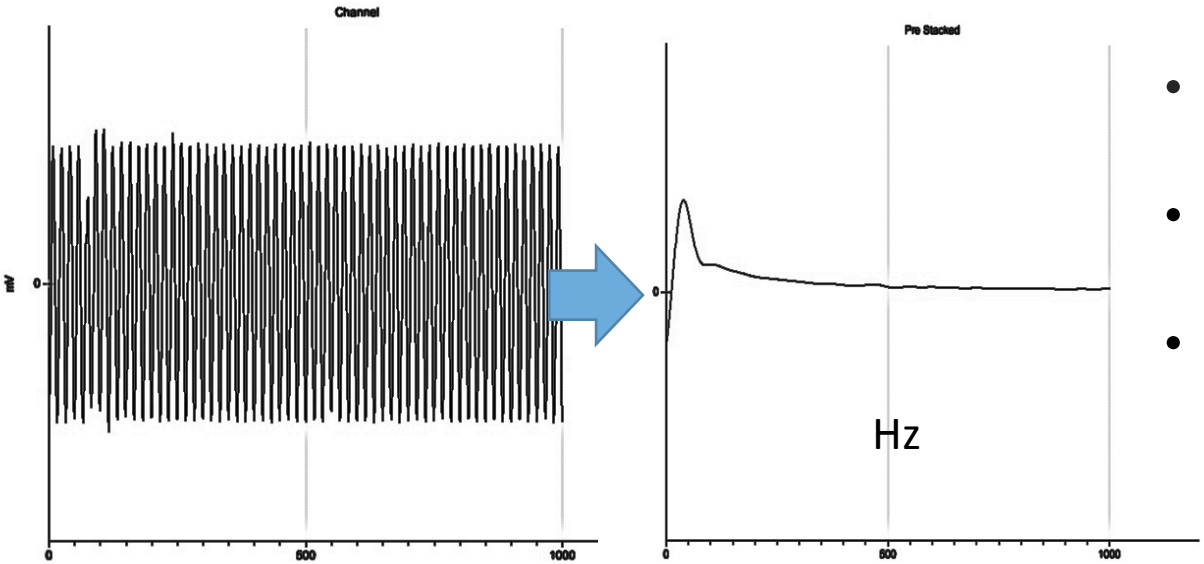
TX & RX alignment

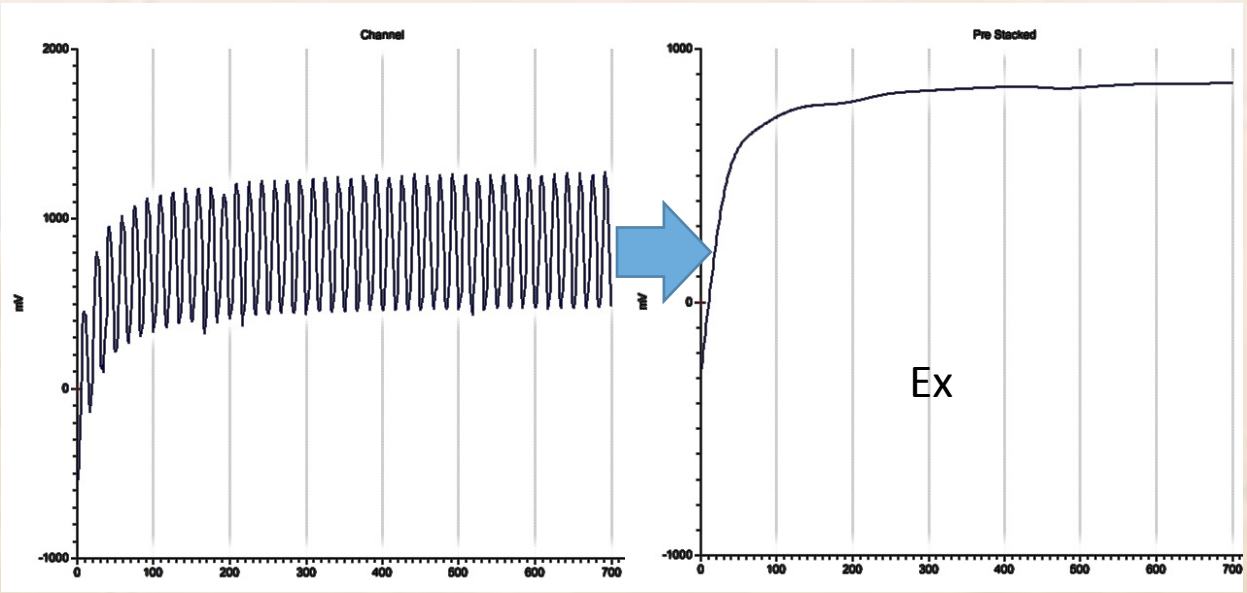


Sample frequency = 1kHz
Duty circle = 100%
Transmitter current = 70 A
Switch time = 8 s
Receiver = Ex, Ey, Hz loop, and Hz coil

Pre-stack : Filtering harmonic noise



- Butterworth low-pass filter
- Power line harmonic 60 Hz
- Center harmonics (60, 80, 120, 180, 300, etc)



Sample frequency = 1kHz
Duty circle = 100%
Transmitter current = 70 A
Switch time = 8 s
Receiver = Ex, Hz loop

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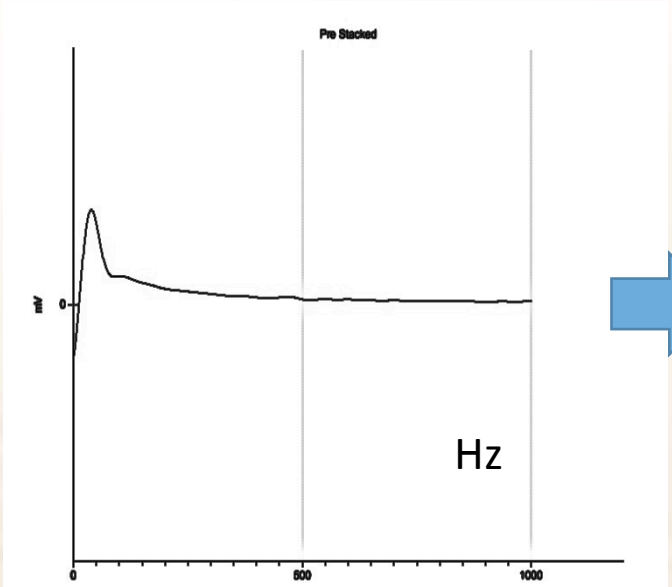
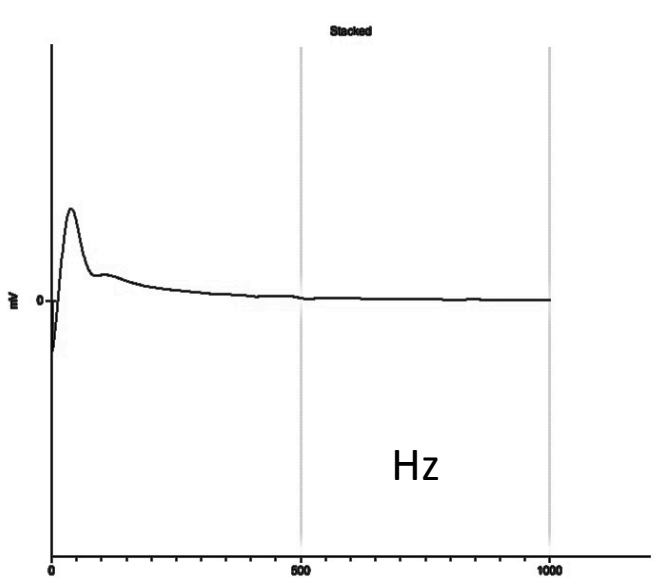
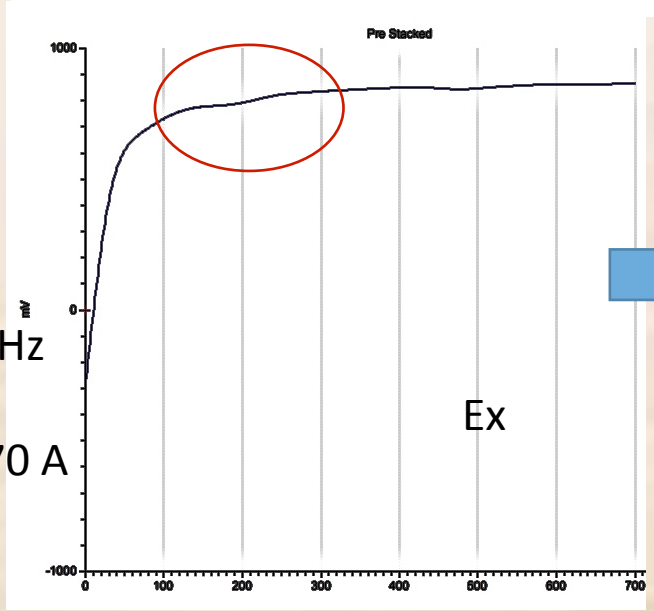
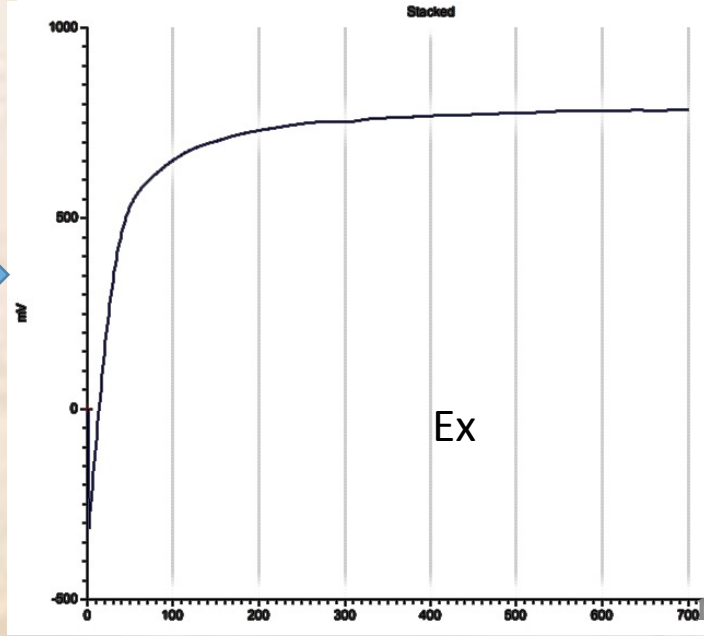
Stacking : Compensate for the unrecognized sporadic noise

- Trimmed mean
- Correct start time in t=0 (Step on)



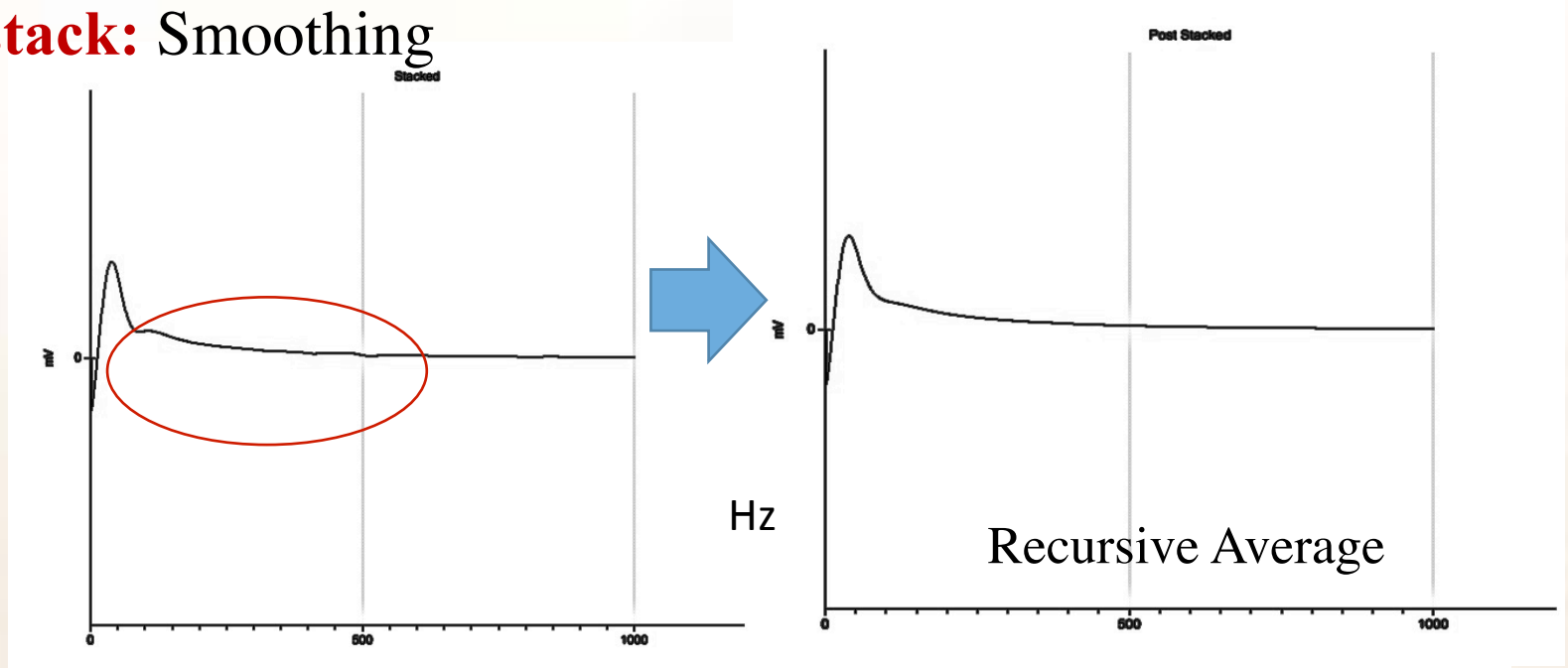


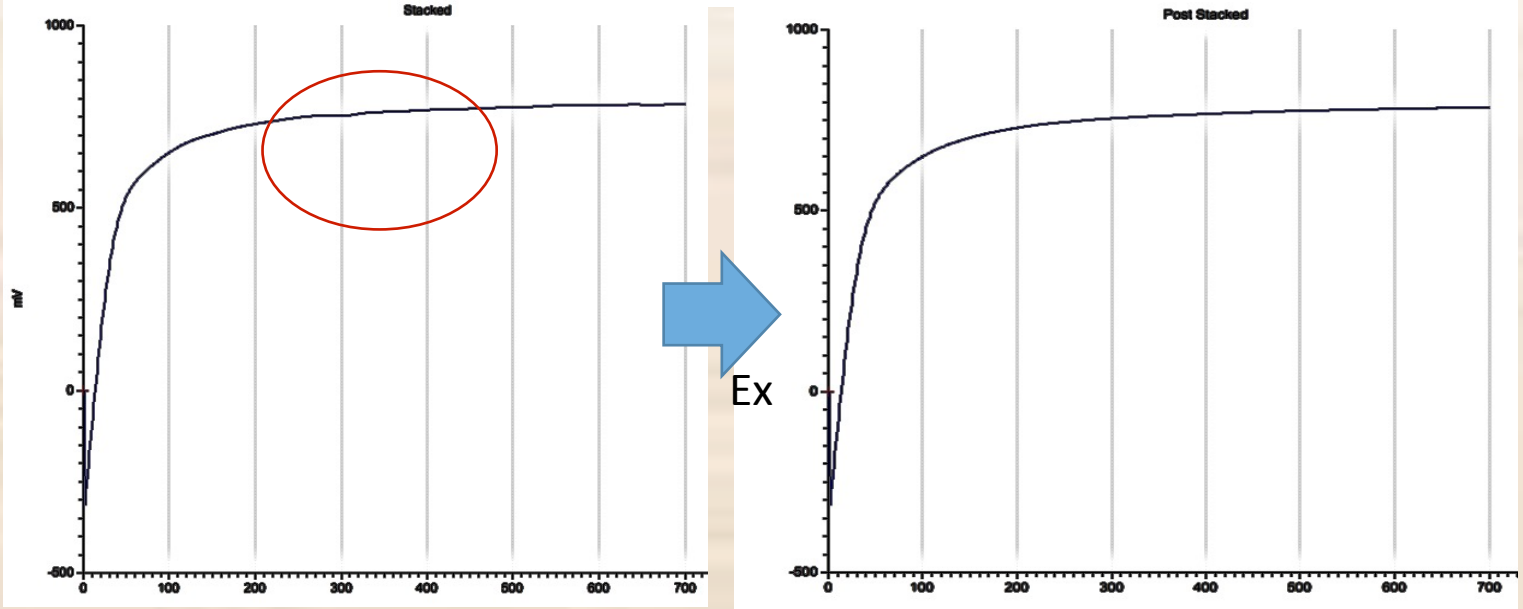




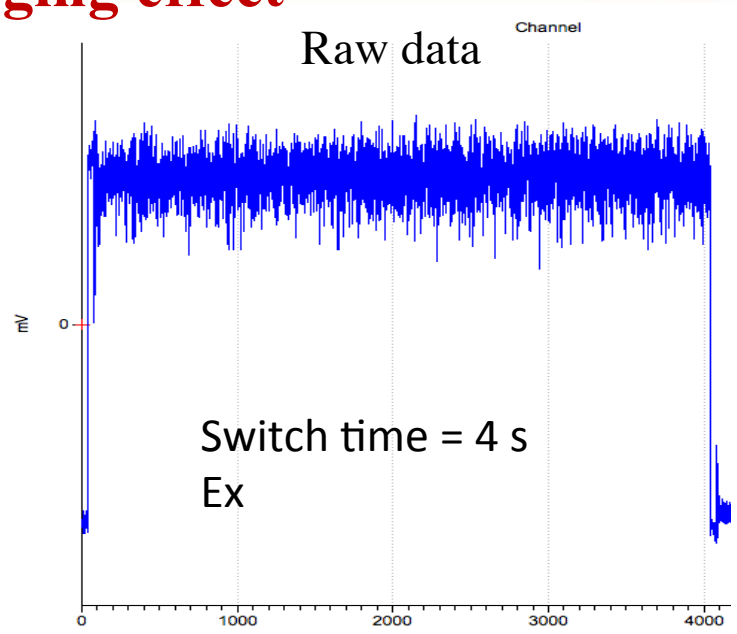
Sample frequency = 1kHz
Duty circle = 100%
Transmitter current = 70 A
Switch time = 8 s
Receiver = Ex, Hz loop

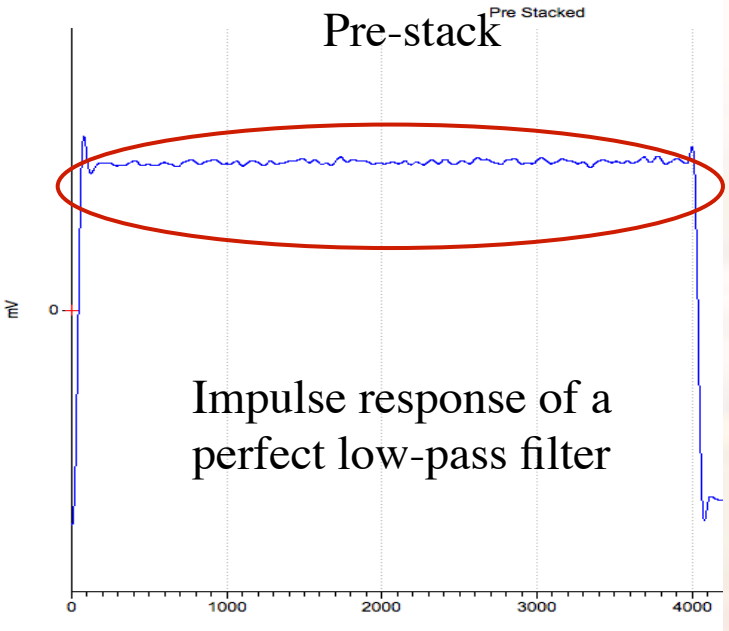
Post-stack: Smoothing

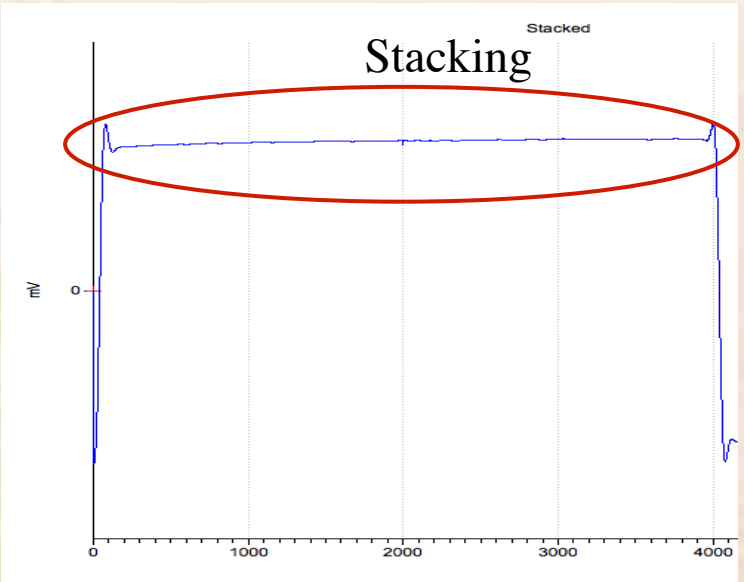


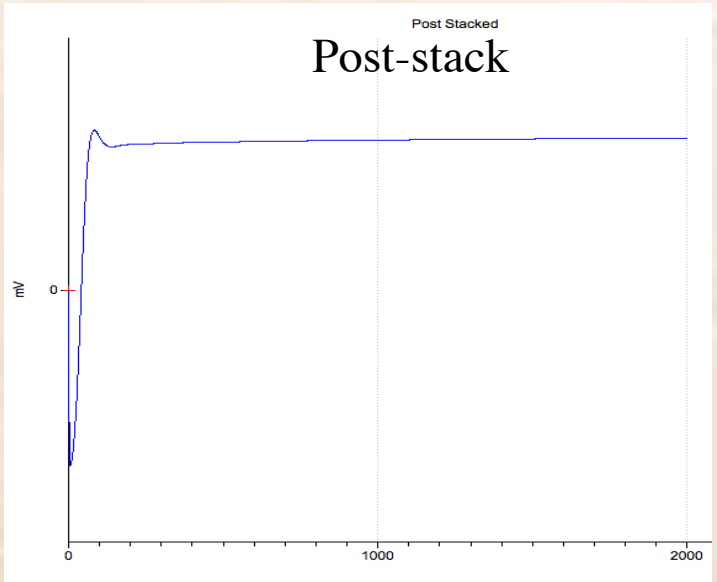


Ringing effect

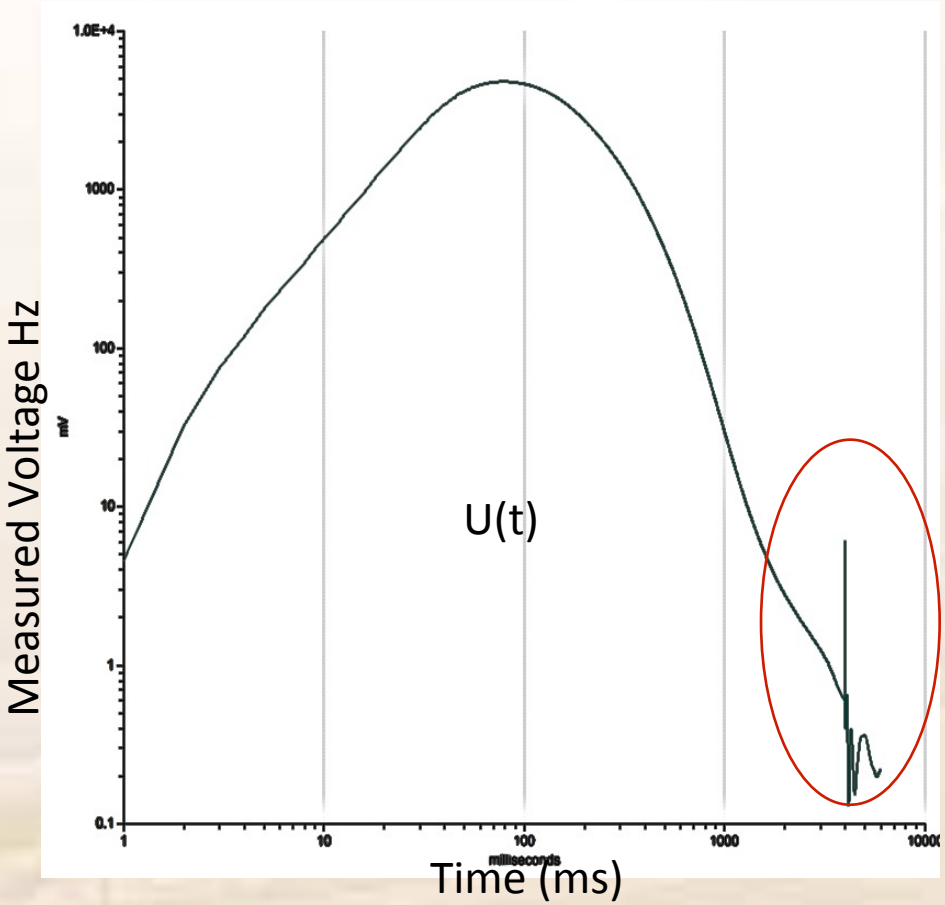


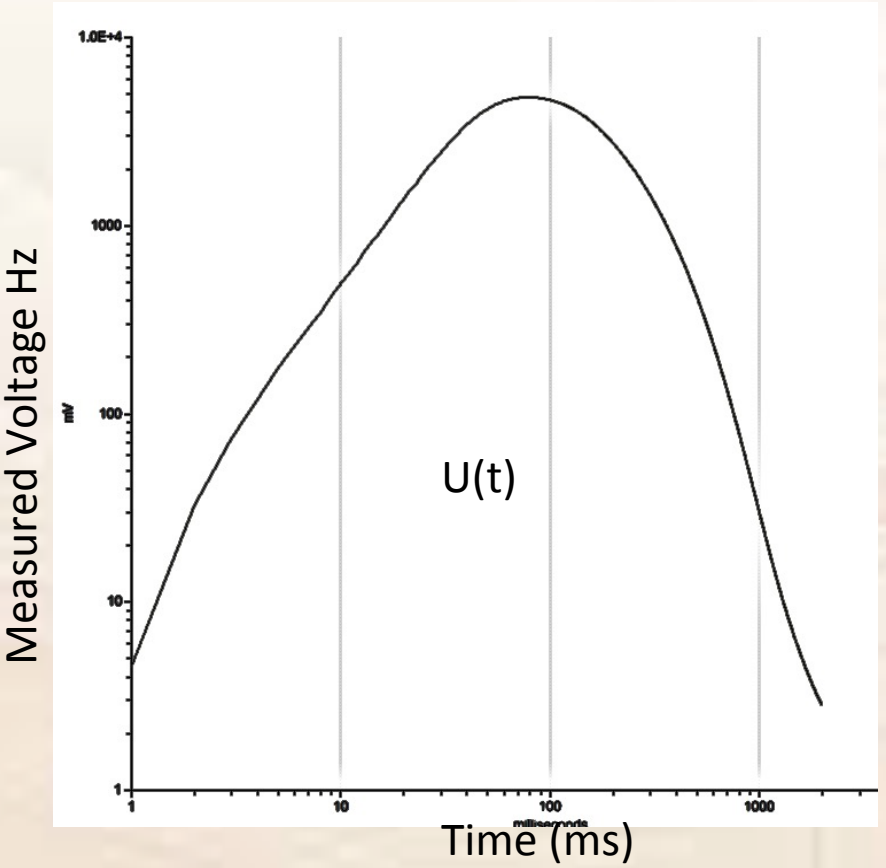






DC-step removal: Hz





Sample frequency = 1kHz
Duty circle = 100%
Transmitter current = 70 A
Switch time = 8 s

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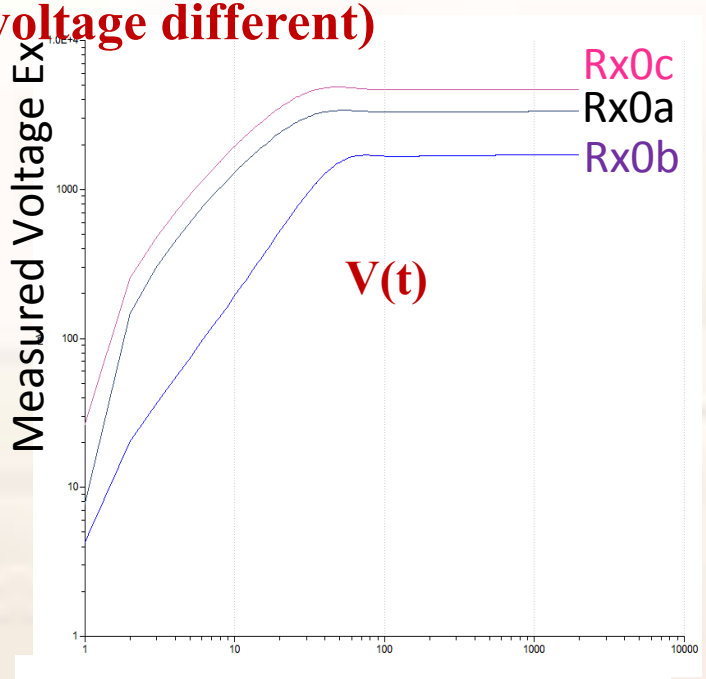
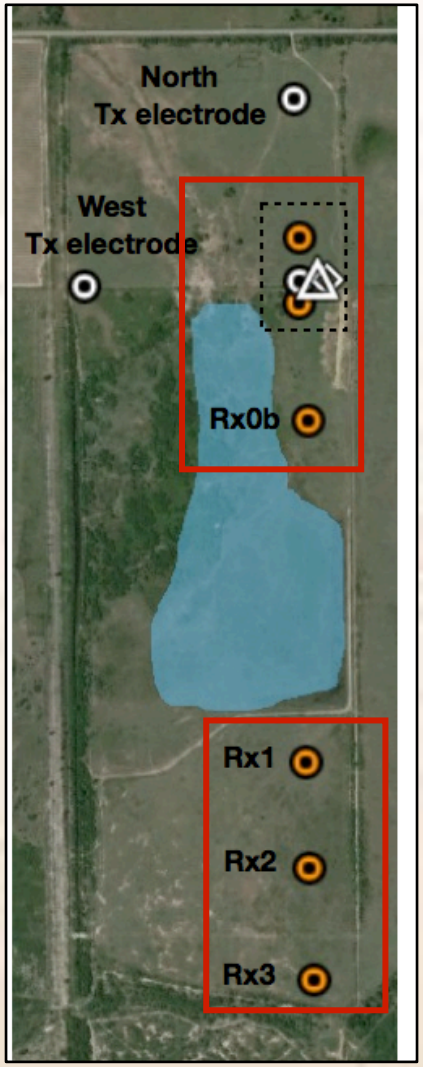
Processed electric field data (voltage different)

Time	Rx0c	Rx0a	Rx0b
0	2.01E+01	1.63E+00	9.08E+00
1	2.65E+01	7.77E+00	4.29E+00
2	2.53E+02	1.47E+02	2.04E+01
3	4.73E+02	3.01E+02	3.65E+01
4	6.95E+02	4.48E+02	5.39E+01
5	9.15E+02	5.98E+02	7.28E+01
6	1.13E+03	7.46E+02	9.50E+01
7	1.33E+03	8.92E+02	1.17E+02
8	1.54E+03	1.02E+03	1.40E+02
9	1.74E+03	1.16E+03	1.64E+02
10	1.94E+03	1.30E+03	1.93E+02
etc	Etc.	Etc.	etc

Time	Rx0c	Rx0a	Rx0b
0	4.51E+01	3.21E+01	1.40E+01
1	1.18E+01	9.00E+00	9.35E+00
2	1.90E+01	1.50E+01	3.23E+01
3	5.13E+01	3.87E+01	5.25E+01
4	8.30E+01	6.20E+01	7.44E+01
5	1.14E+02	8.27E+01	9.59E+01
6	1.42E+02	1.05E+02	1.17E+02
7	1.71E+02	1.27E+02	1.34E+02
8	2.01E+02	1.48E+02	1.54E+02
9	2.29E+02	1.66E+02	1.74E+02
10	2.53E+02	1.86E+02	1.92E+02
etc	Etc.	Etc.	etc





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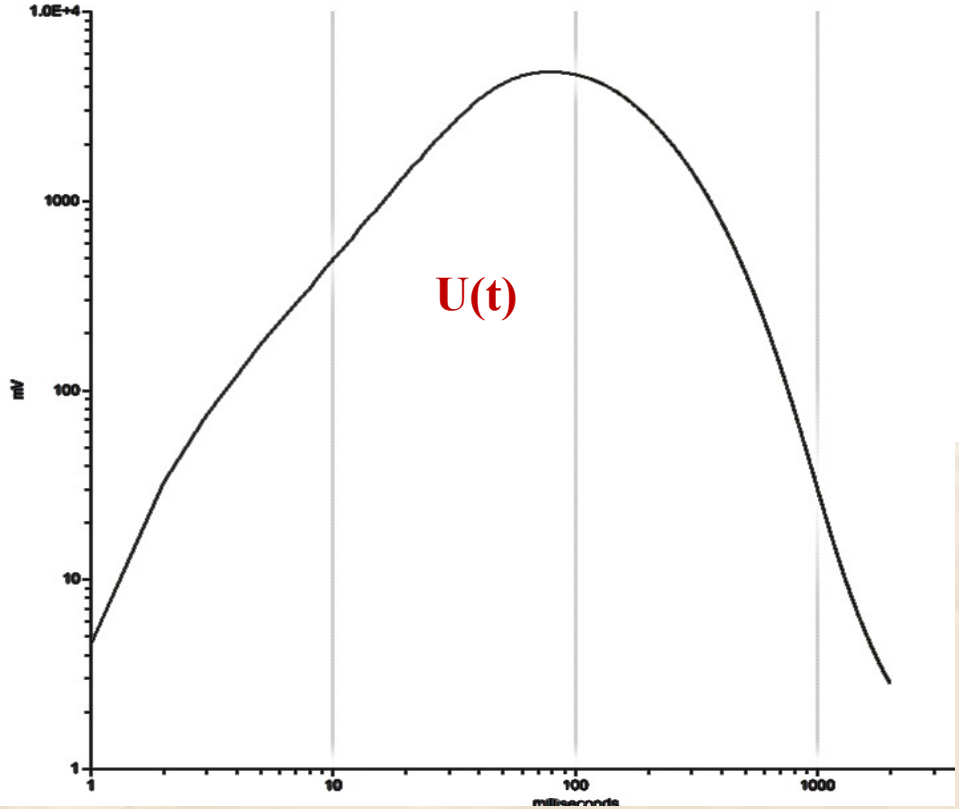
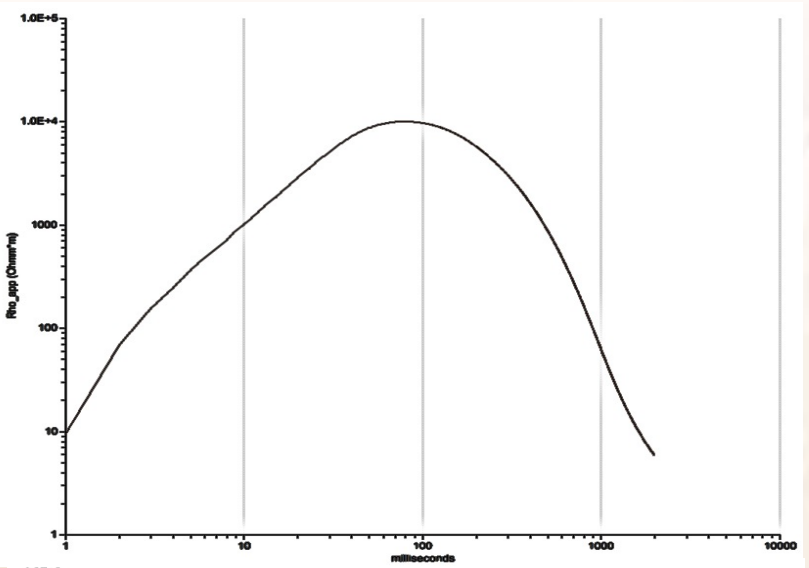
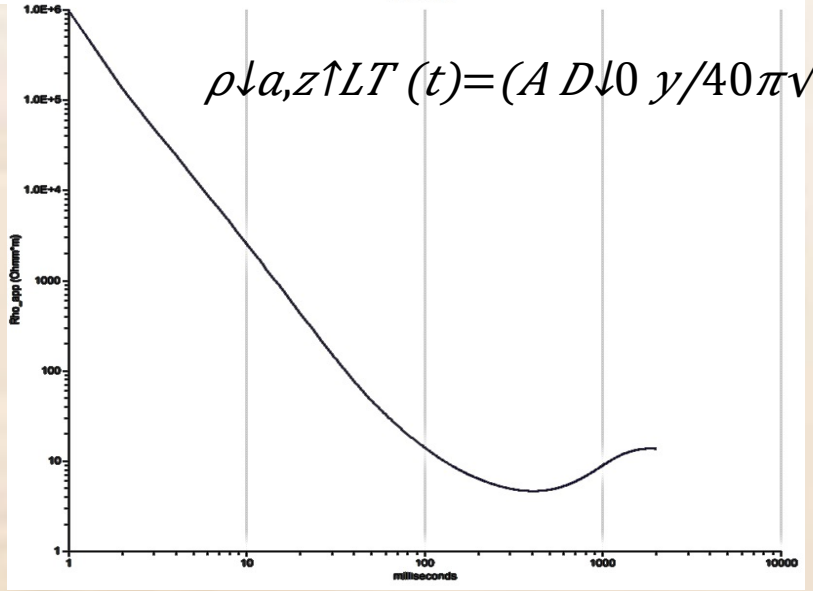
Apparent resistivity (Early and late time)

$$\rho_{a,z}^{ET}(t) = 2\pi r^5 / 3AD_0 y U_z$$





$$\rho_{a,z}^{LT}(t) = (A D_0 y / 40\pi\sqrt{\pi} U_z$$

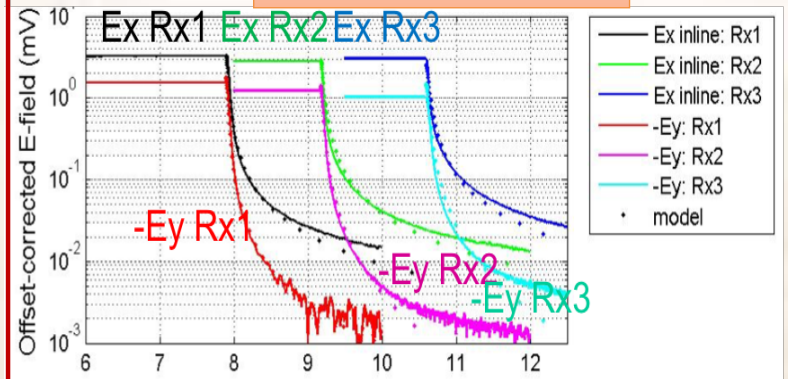


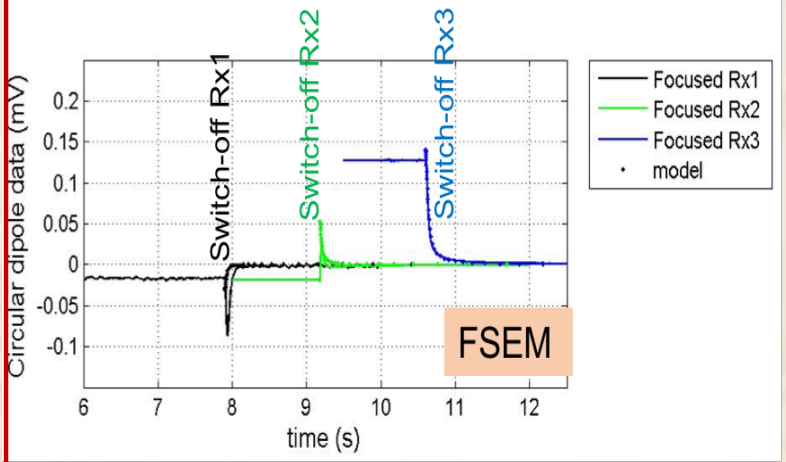
Focused source solution to volume imaging

Duty circle= 50%

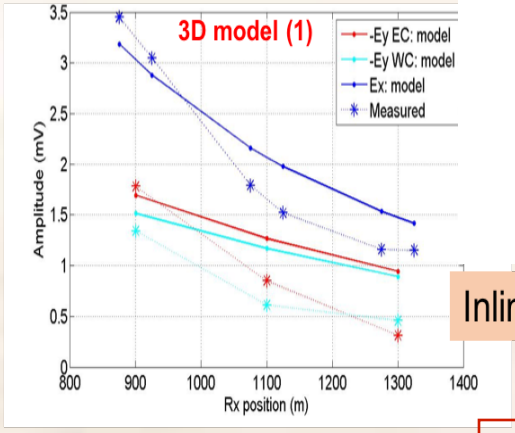
Data & models

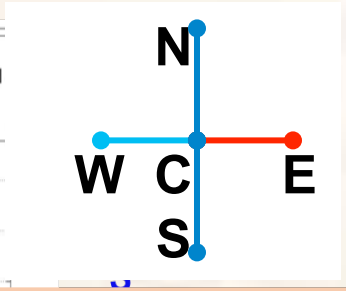
LOTEM



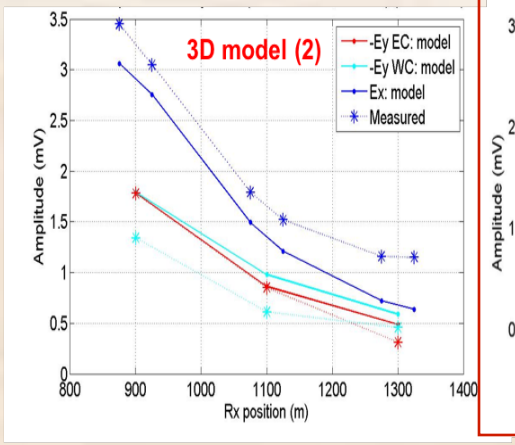


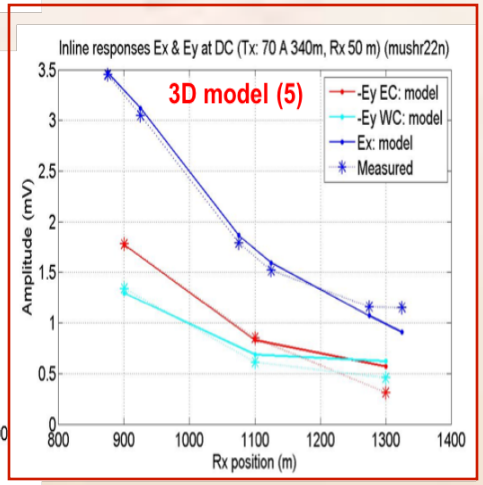
FSEM



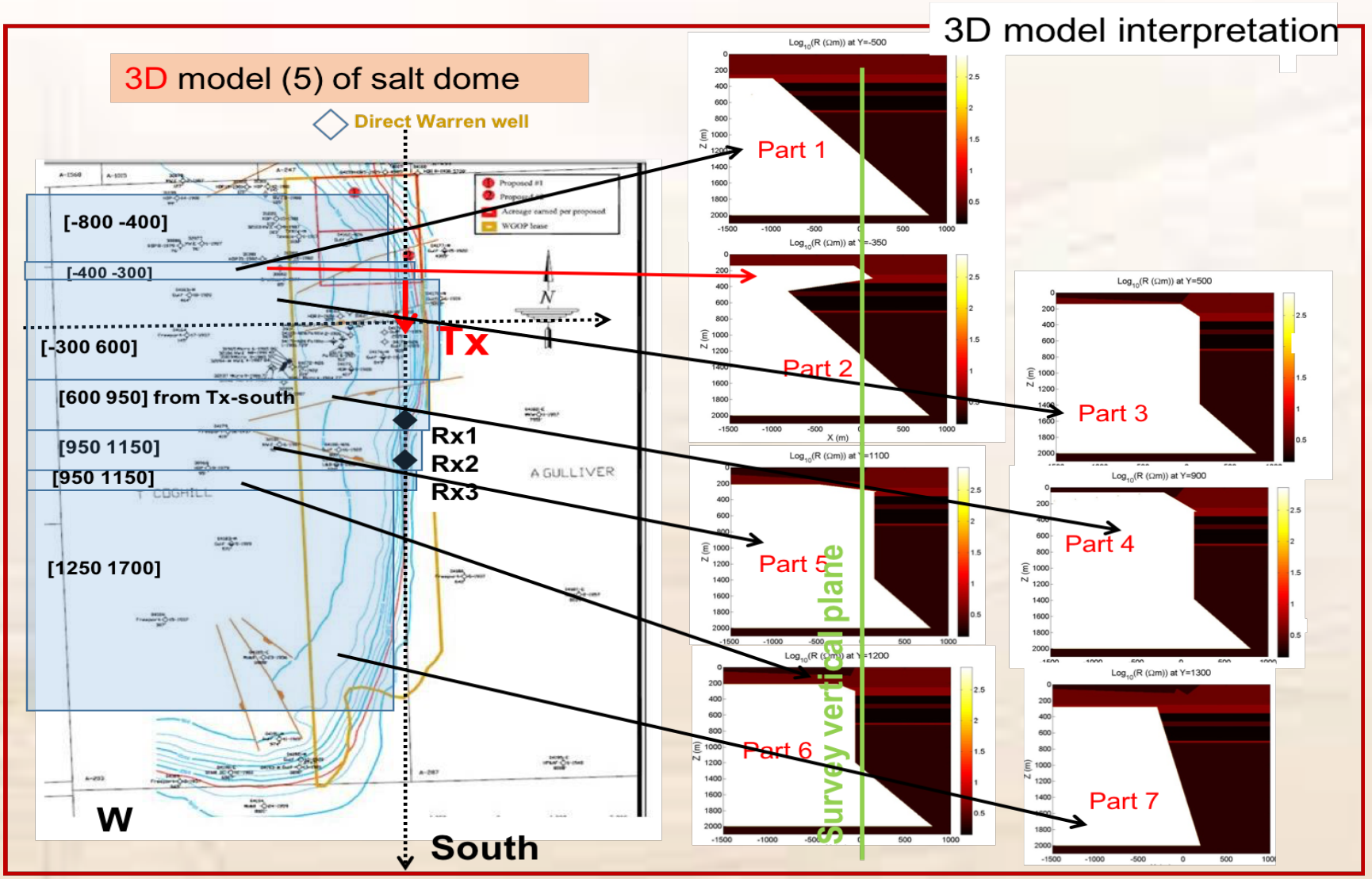


Inline & cross-line DC responses





FSEM: Preliminary result



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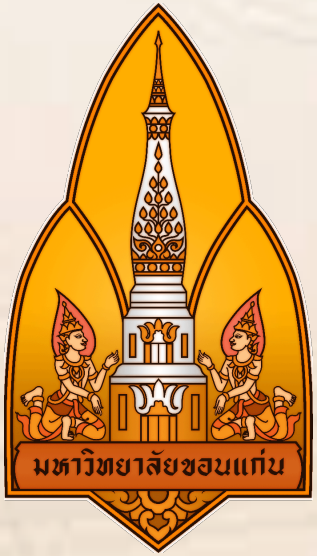
Conclusion:

- Processing pre- & post-stack give confidence to the data quality;
- FSEM method: sensitivity to the area under the salt dome.

Future works:

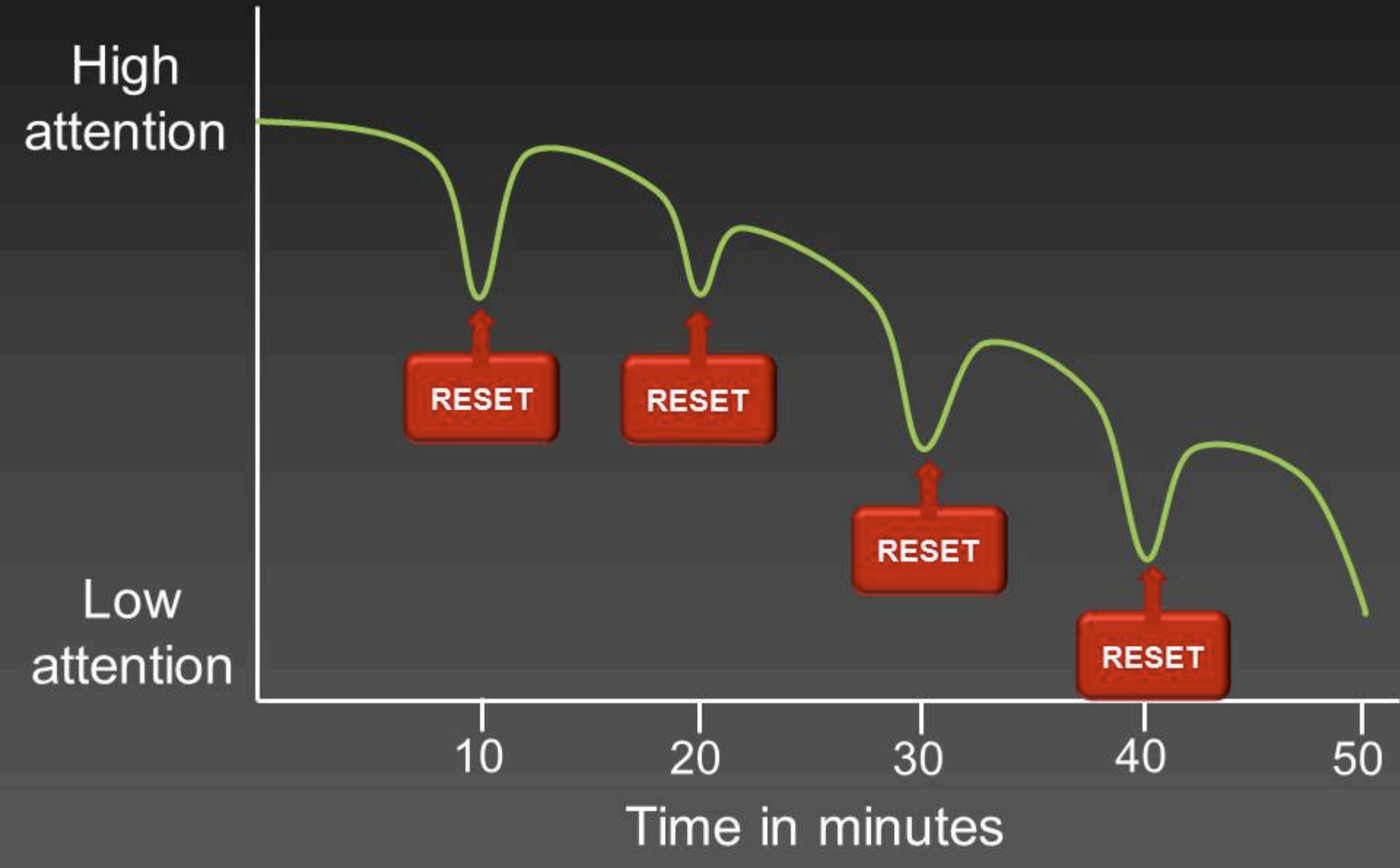
- LOTEM data inversion
- Joint inversion

- KMS Technologies' staff:
  - Data measurement
  - T. Hanstein's support
- Khon Kaen University.



KMS Technologies

Thank you for your attention

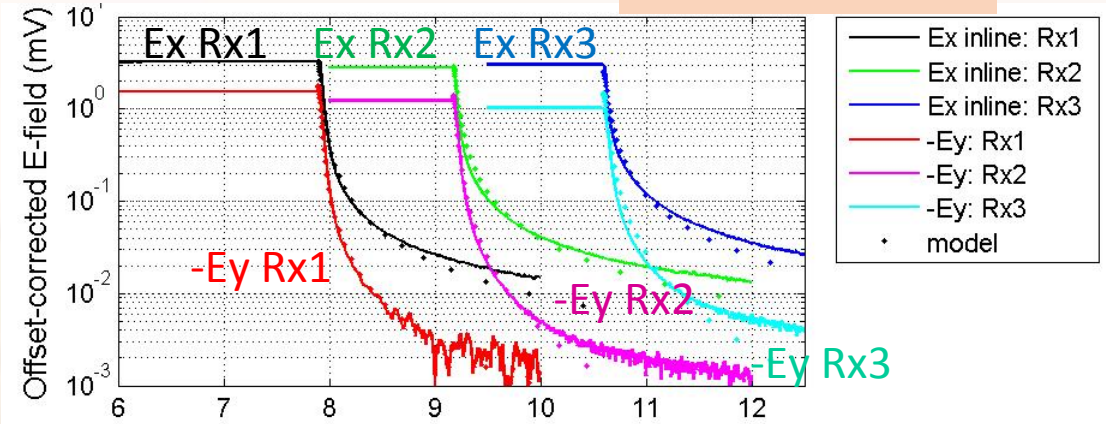


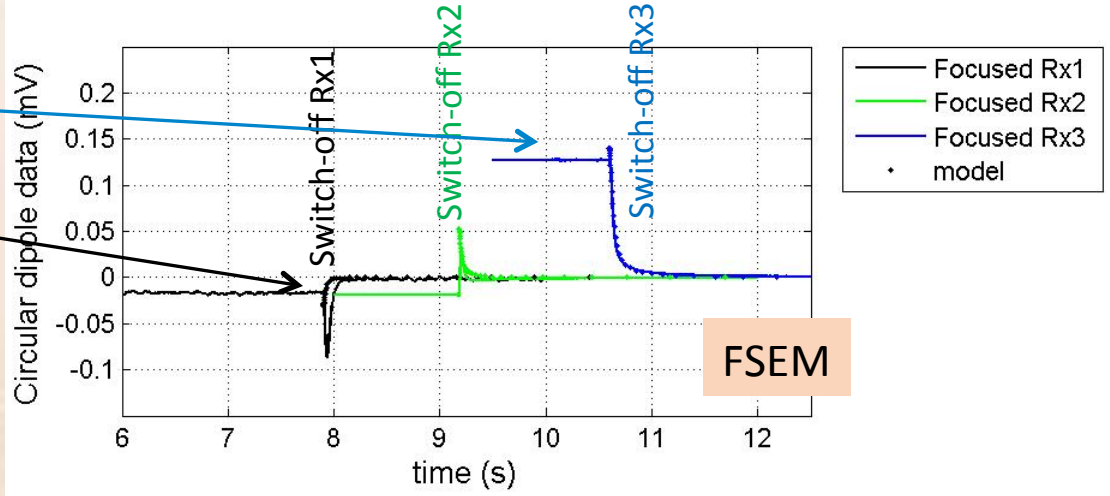
Measurements vs 3D model: transients in receivers

- Offset-corrected data (lines) vs model (dots)
  - DC levels: checked to 1 nV
  - Time-decay curves
- Ex (inline) & Ey (cross-line):
  - In all receivers: similar time-decay
  - Ey is comparable to Ex because at the edge of the salt dome currents tend to turn around its corner(s)
- Circular dipole data:
  - Show focused vertical current
  - All receivers behave different:
  - **Rx3** is NOT above salt: vertical current is positive
  - **Rx2 & Rx1** are above salt: vertical current is negligible (model) or even slightly negative (data)
  - Difficult to match “zero current down” above shallow resistor
  - Difficult to match the data wiggles at early times (shallow effects)

Rx1, Rx2, Rx3

STANDARD CSEM





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