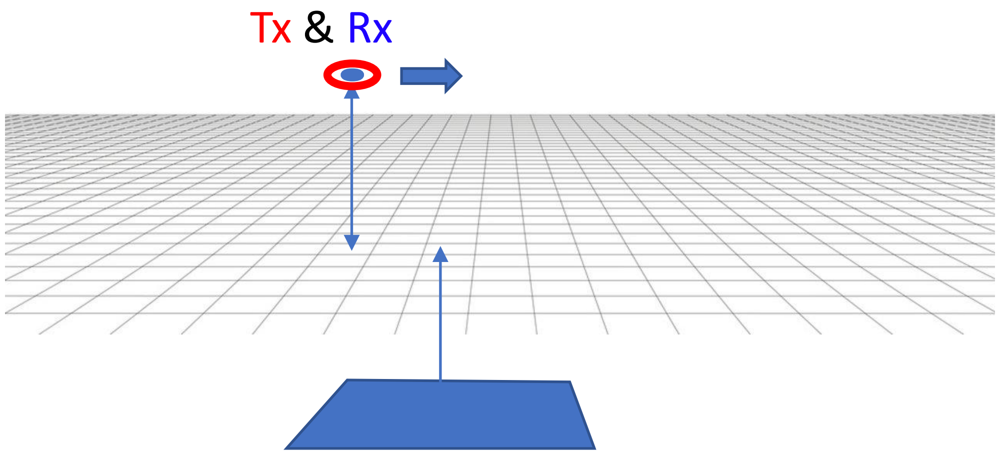
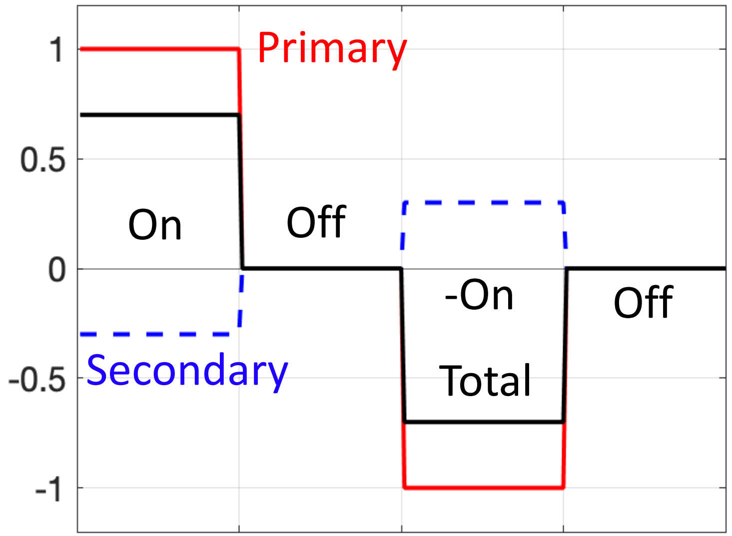
The Perfect Conductor (PerC)
Some fundamental issues

James Macnae

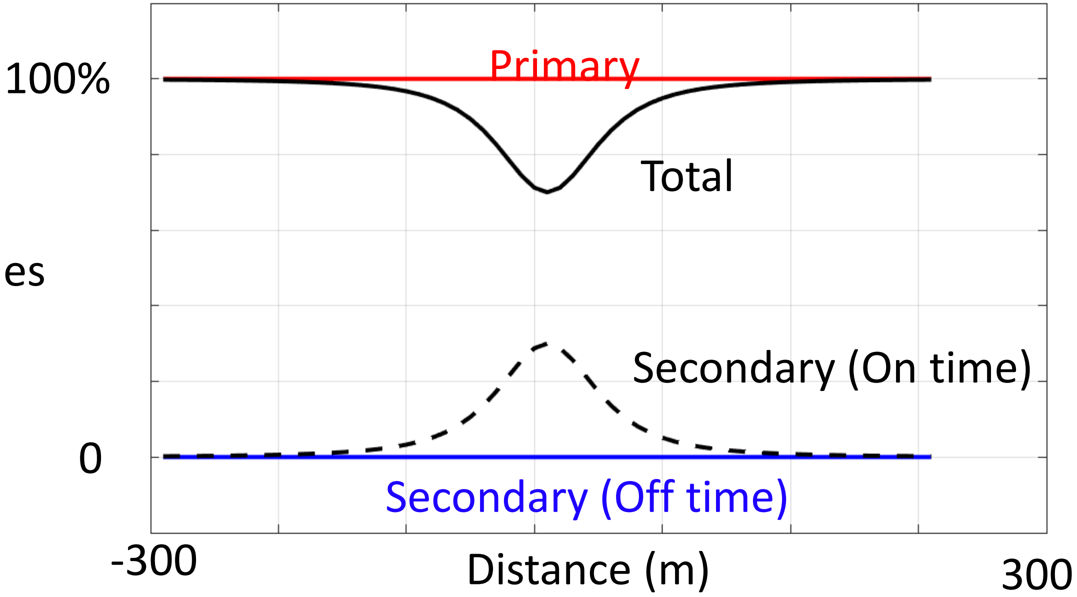
Honorary Professor at
RMIT UNIVERSITY

Method 1: Use “on-time” to detect Perfect Conductor (PerC)





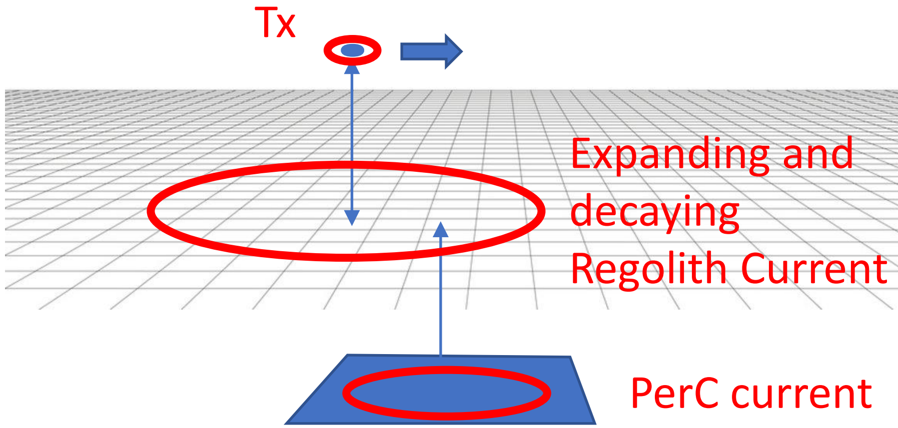
Waveform



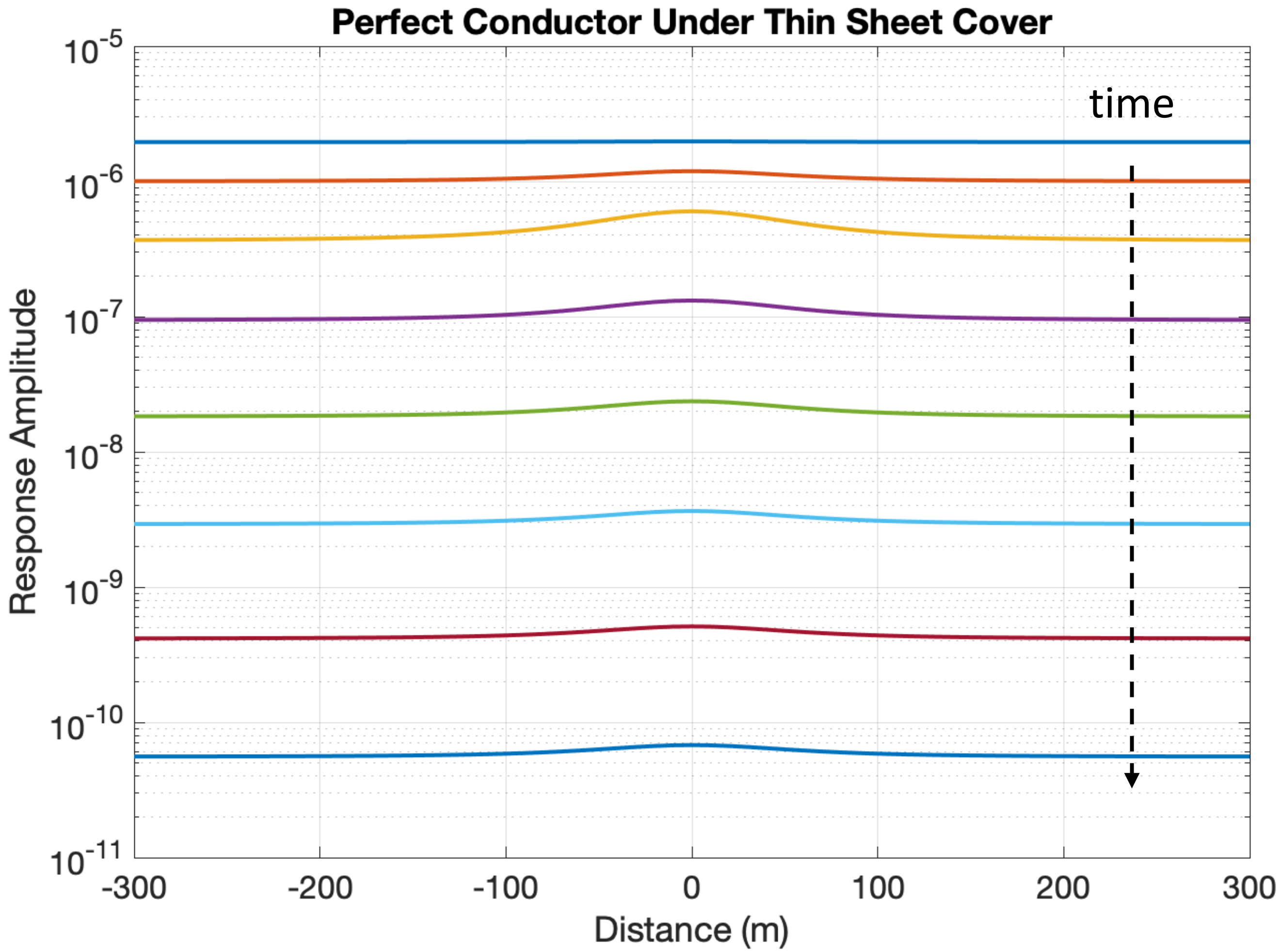
Profiles

PerC sees primary of Tx
Current induced in PerC with exactly same waveform as primary
Rx sees currents in PerC in on-time only

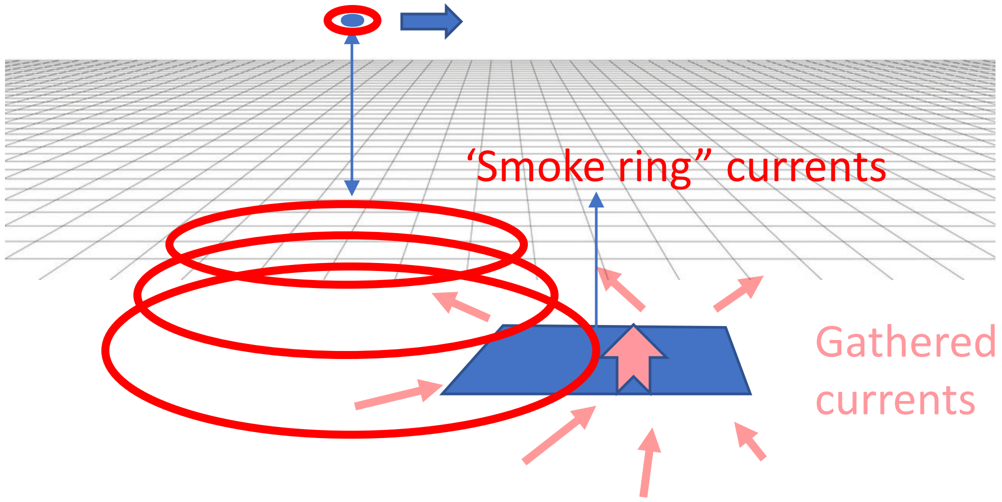
Method 2 (on or off-time): Hide PerC under conductive overburden (alas not discriminatory)



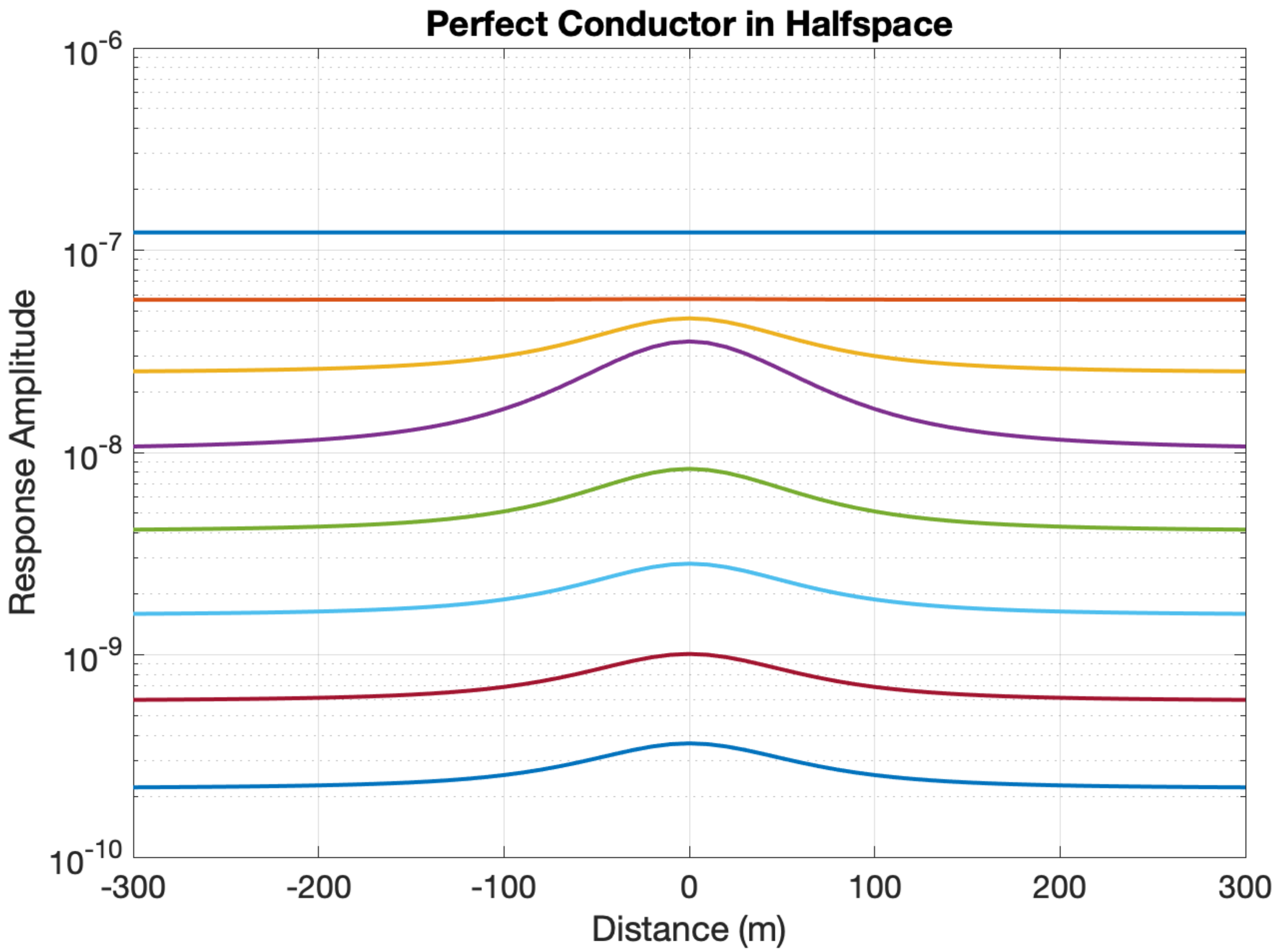
PerC sees delayed primary of Tx under conductive overburden
Current induced in PerC with “background response” waveform
Rx sees overburden plus field of the (further delayed) currents in PerC



Method 3 (on or off-time) : Bury PerC in a conductive horizon. Get current gathering (still not discriminatory)



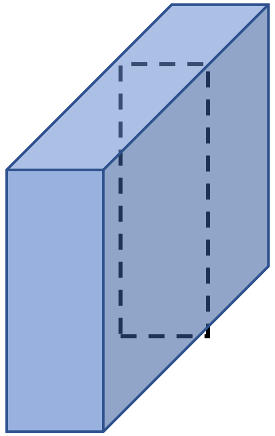
PerC sees delayed primary of Tx
Current gathered into PerC with background response waveform
Rx sees background plus (time-delayed) field of gathered currents in PerC
Bigger response than in method 2.

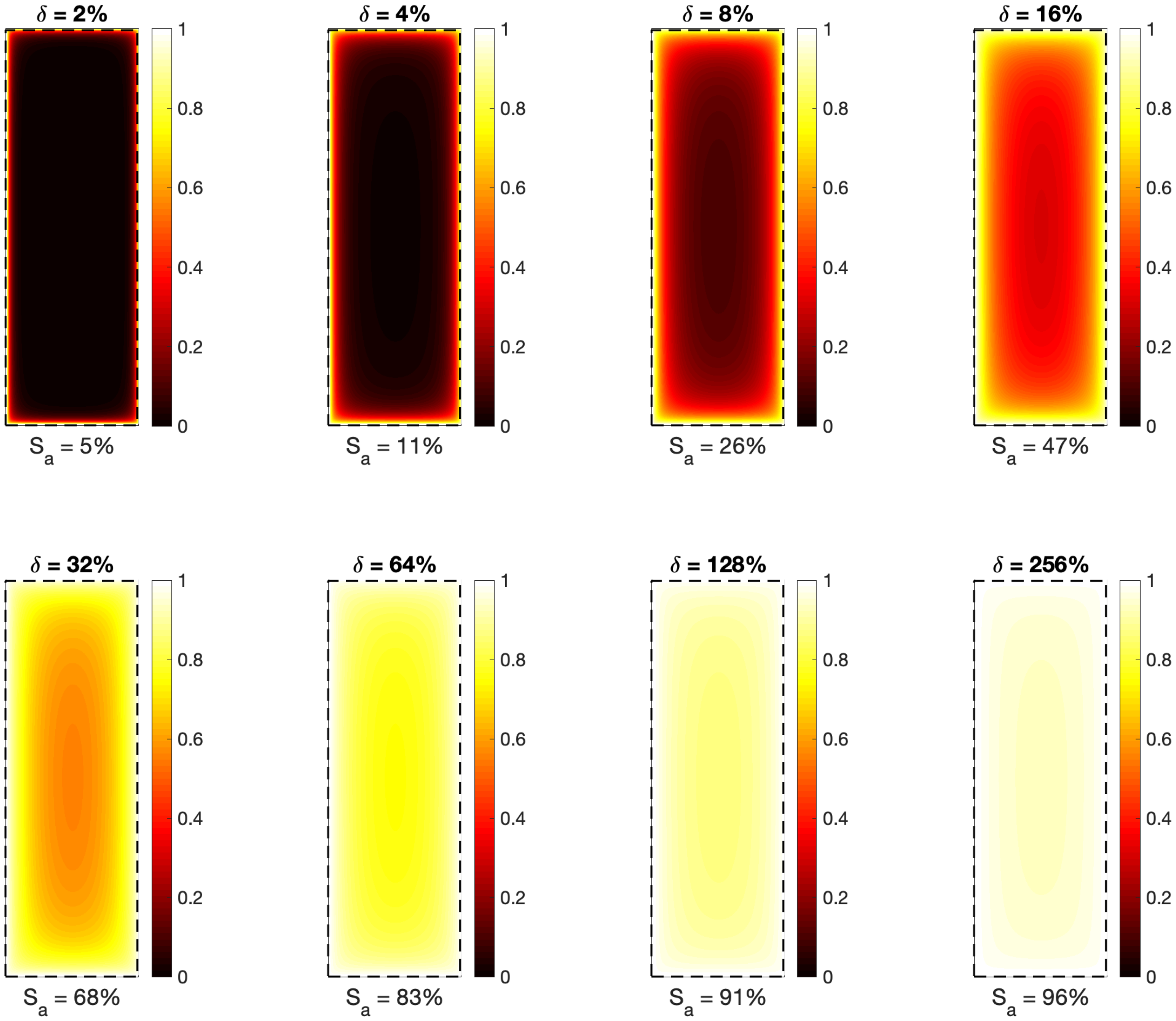


Method 4: Use “Inductive Thickness” for almost PerC

- Other than inside SQUID sensors, there are no perfect conductors in the field.
- Often use Conductance S to describe conductors S = product of conductivity and thickness for targets
- Any geological conductor has finite conductivity
  - Seawater, 5 S/m, Conductance at Marianas trench is 50,000 S
    - **Geometrically thick** since 10 km “thick” (deep) >> survey dimensions
    - **Inductively thick** since skin depth << sea depth at typical survey frequencies
  - 0.5 m wide seam of Pyrrhotite of 100,000 S/m also has conductance 50,000 S.
    - **Geometrically thin** since width << survey dimensions
    - **Inductively thick** since skin depth << width at typical survey frequencies

Skin depth $\boldsymbol{\delta} = \sqrt{(2/\sigma\mu\omega)}$ = 1.6 cm at 10 kHz, 16 cm at 100 Hz and 1.6 m at 1 Hz





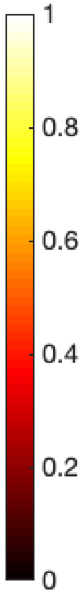
100000 S/m
F = 1 Hz, δ = 1.6 m

If 10 m wide. Then estimated conductance <50% of true value

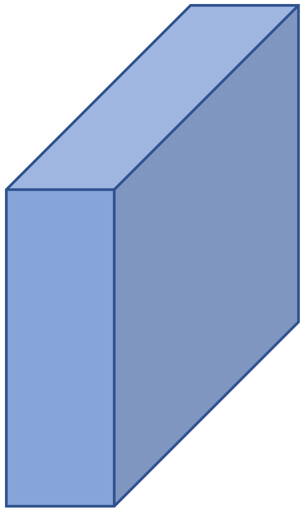
Penetration of field into tabular conductor as a function of skin-depth δ shown as a percentage of the conductor width

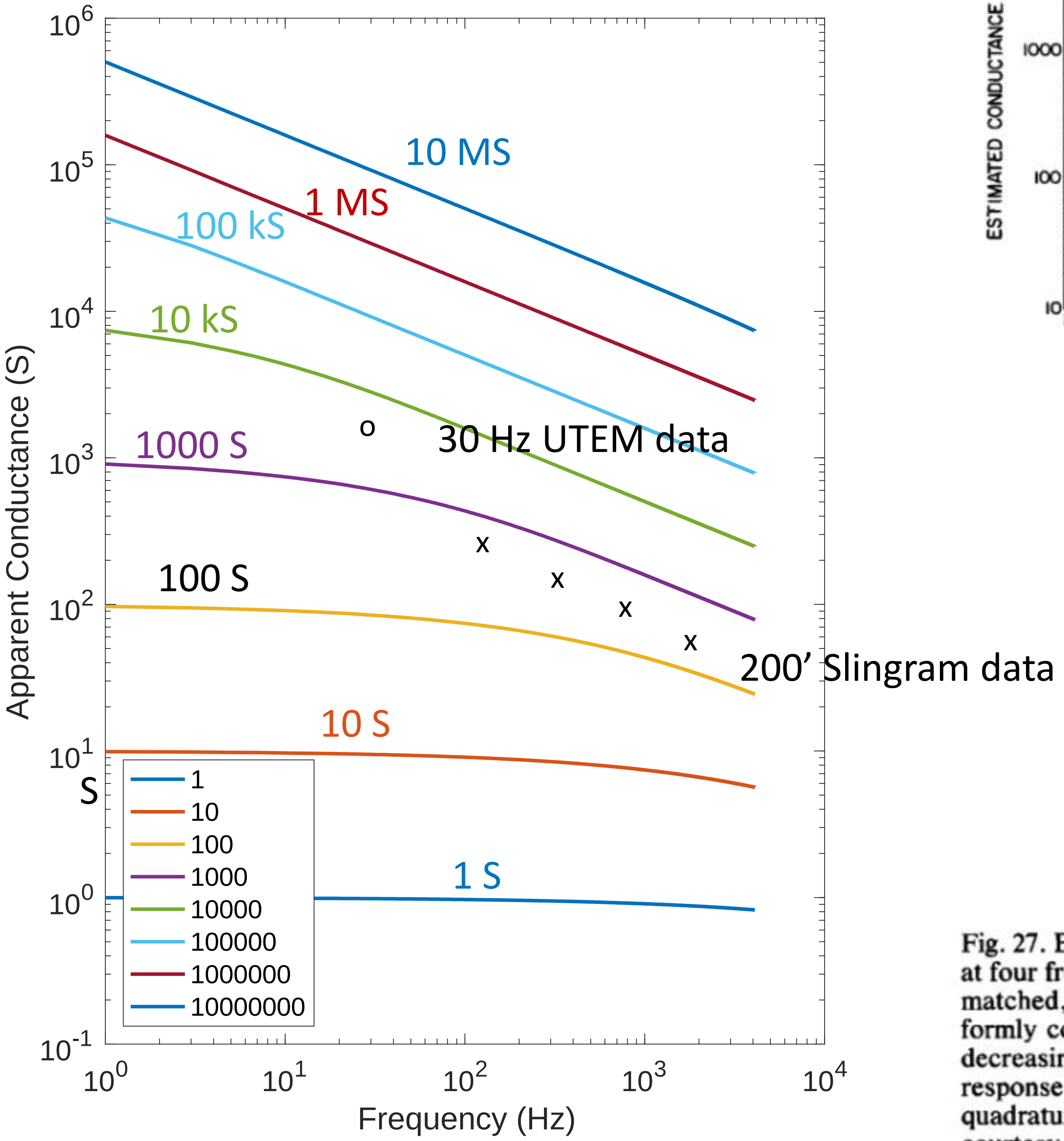
Effective conductance S_a as percentage of true conductance

Amplitude Fraction

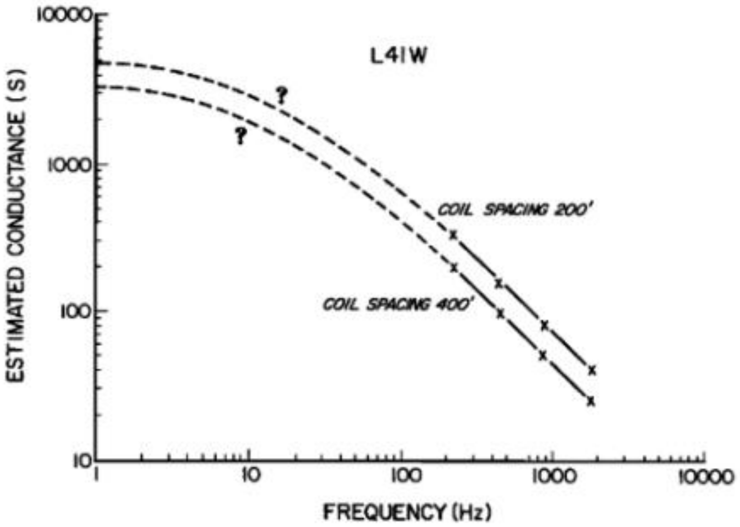


Frequency domain apparent conductance S_a





$S_a = \alpha/(\mu\omega\ell)$



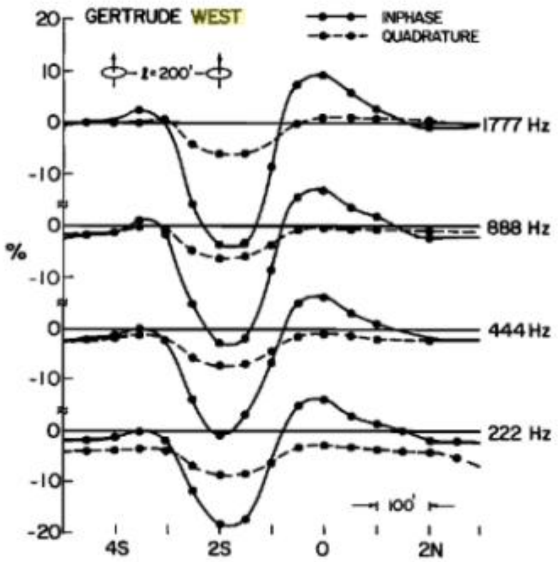
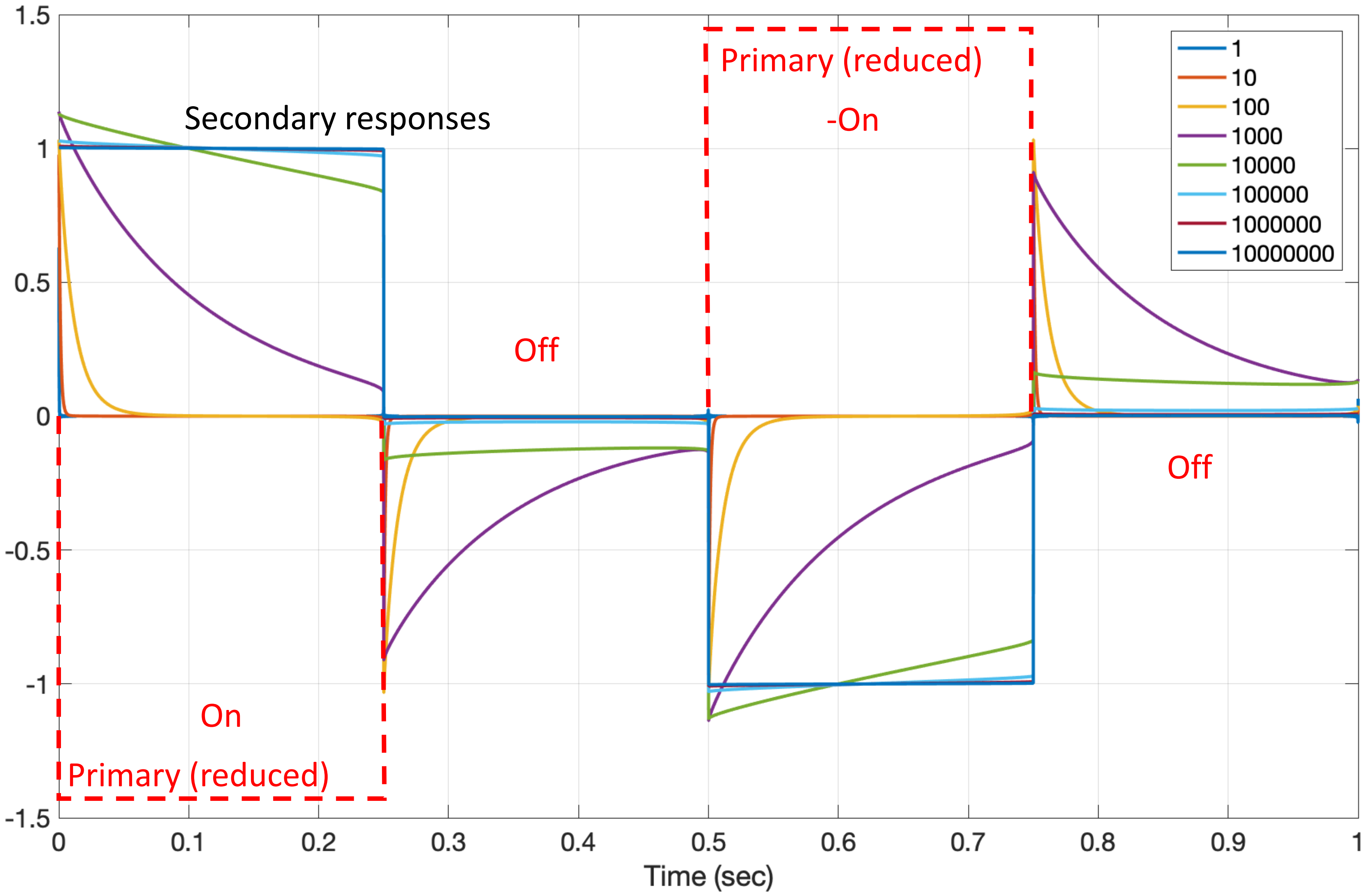
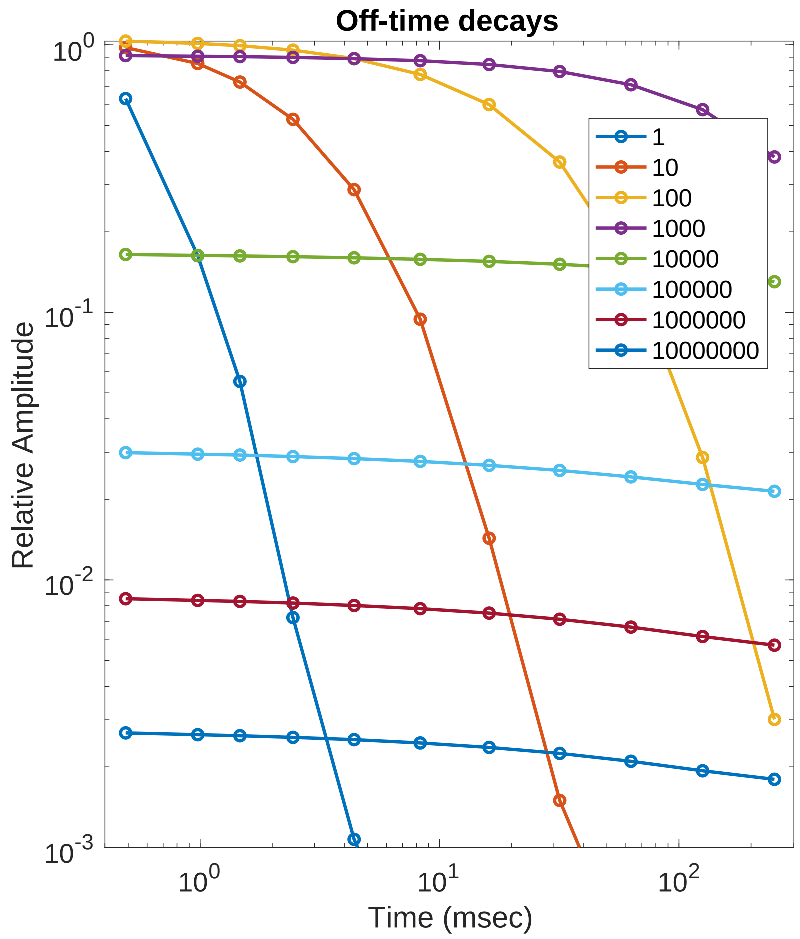


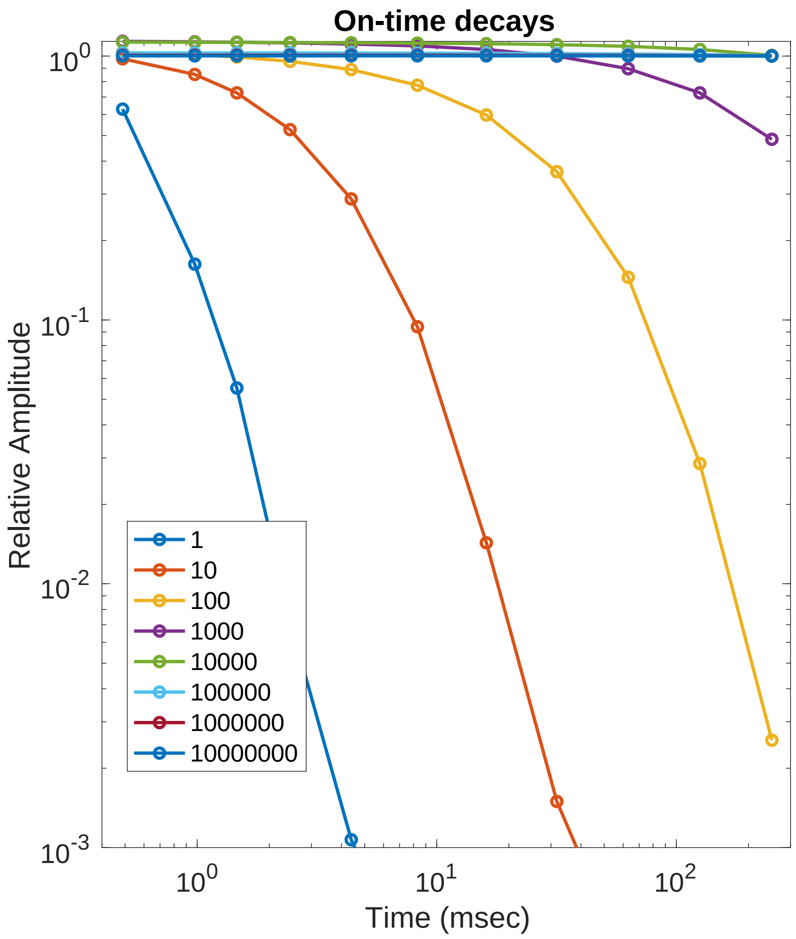
Fig. 27. EM response observed over a massive sulphide zone at four frequencies. When the observed spectral response is matched, frequency by frequency, with any simple uniformly conductive model, the fitted conductivity rises with decreasing frequency. The effect is large unless the induced response is in the resistive limit, i.e., the ratio of in-phase to quadrature response is well below one (HLEM data by courtesy of J. Betz and INCO Limited).

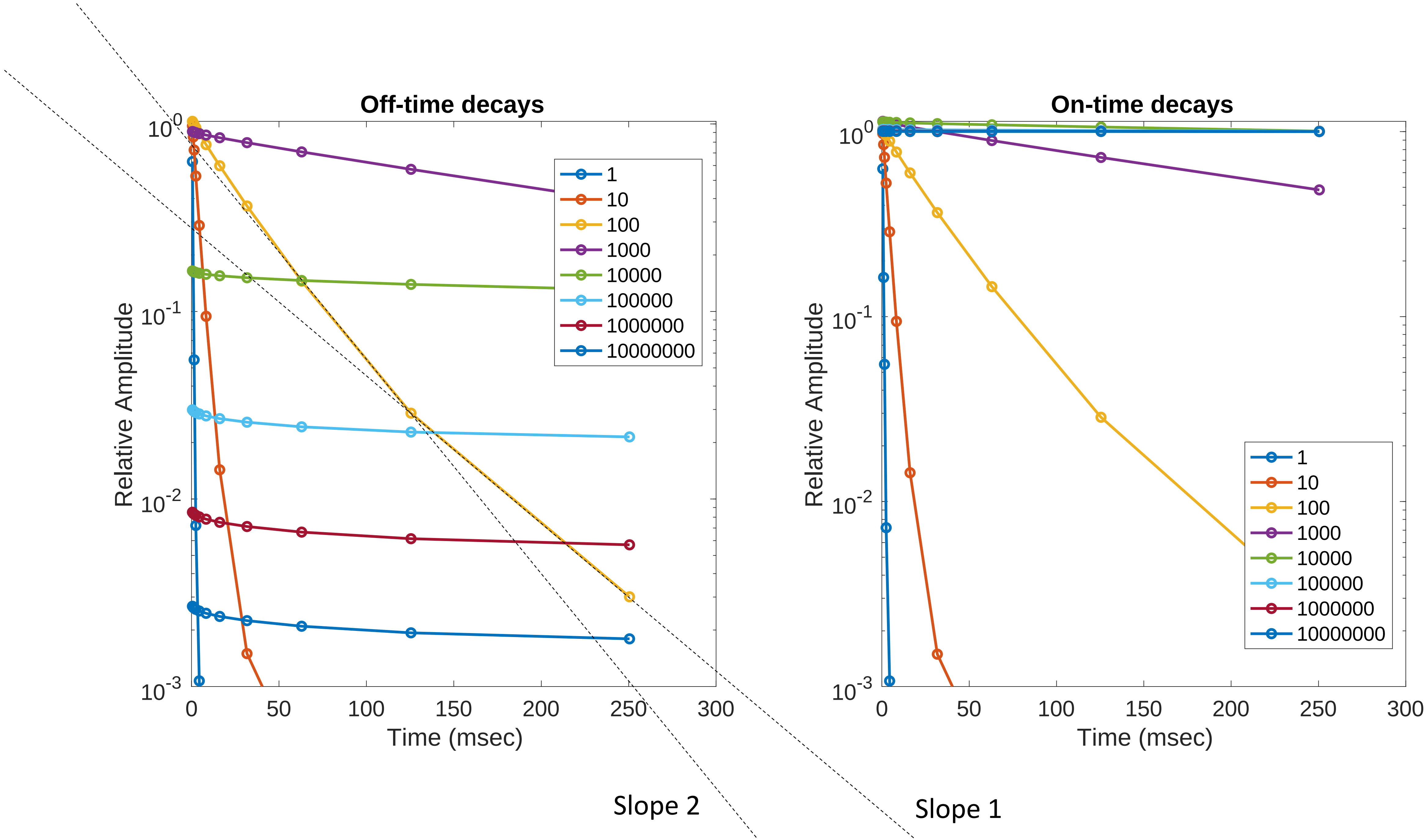
1 Hz 50% duty cycle plane wave, B field



Secondary field decays; Inductively thick target in free space, 1 Hz system







Off-time decays
Relative Amplitude
Time (msec)
1
10
100
1000
10000
100000
1000000
10000000
On-time decays
Relative Amplitude
Time (msec)
1
10
100
1000
10000
100000
1000000
10000000
Slope 2
Slope 1

Summary, 10 m wide conductor, 100 m characteristic system geometry, 1 Hz

Conductor	Predicted S Off-time	True S	Predicted S On-time	Conductor
Weak	1	1	1	Weak
Medium	7	10	7	Medium
Good	55	100	55	Good
Excellent	307	1 000	307	Excellent
Perfect	1 820	10 000	2 444	Superb
Perfect	2 097	100 000	13 803	Amazing
Perfect	1 674	1 000 000	49 535	Astounding
Perfect	1 695	10 000 000	156 250	Astonishing

The UNDERESTIMATE of Conductance S was predicted from the last 2 channels above (numerical) noise

Inductive Thickness Symptoms (B field) to detect almost PerC’s in free space

- Longest tau estimated from data similar to base period (e.g. 1 sec at 1 Hz)
- Estimated tau increases with delay time (double delay time, empirically increase tau by 1.4 to 2), better in on-time (if Tx stable enough or monitored)
- Double Base frequency… estimate 0.5 to 0.7 of the tau value (or 0.5 to 0.7 of the conductance in frequency domain)
- There is a limit on how conductive PerC’s appear to be using off-time data.
- On-time MUCH better than off-time even if geometry uncertain, available from streaming receivers but need current monitor

Effect of cover / conductive host on PerC detection

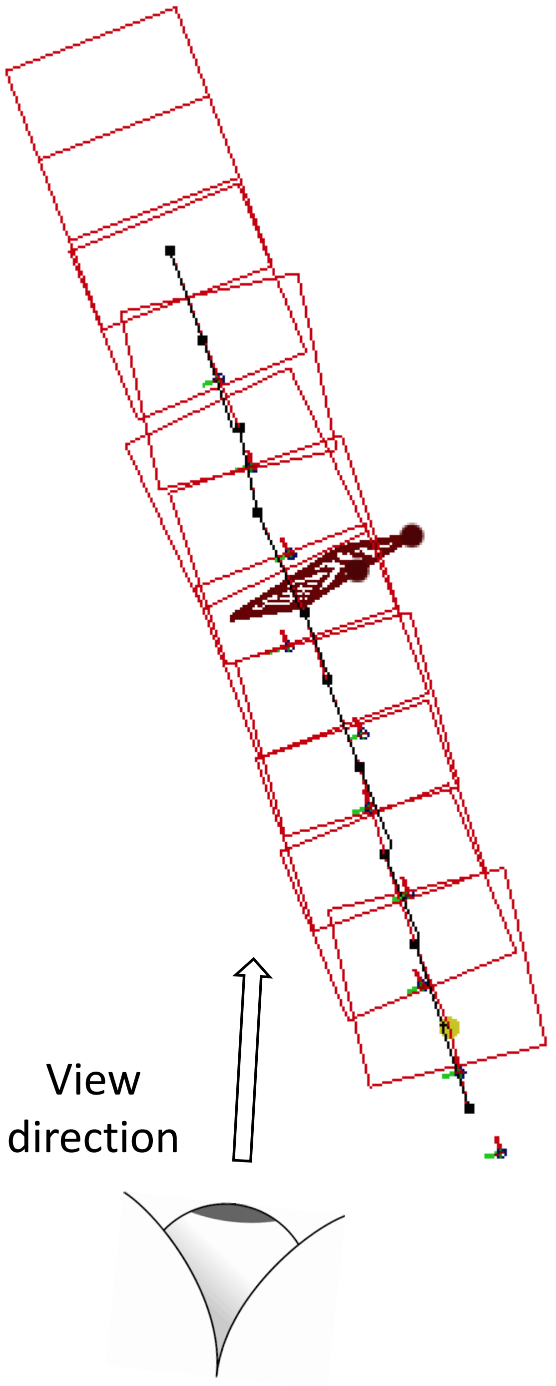
- No time to discuss, example to follow
- Need to minimise deleterious effects in survey design (e.g. use small Tx loops when conductive overburden present)

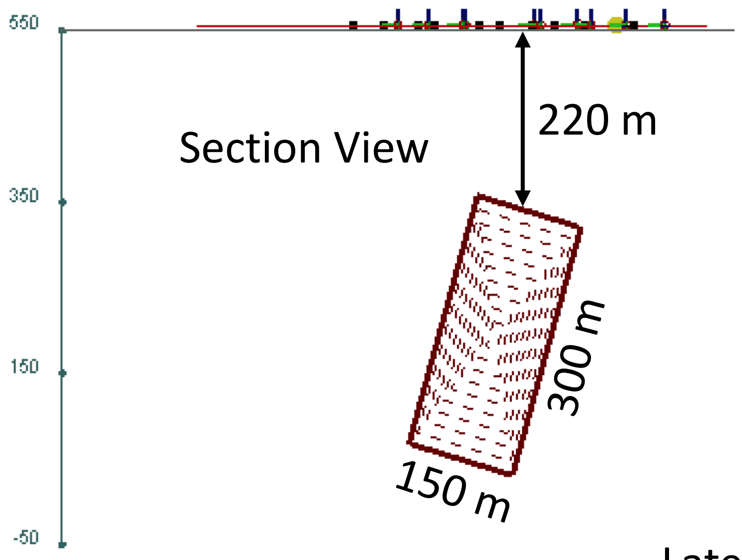
Can we use dB/dt???

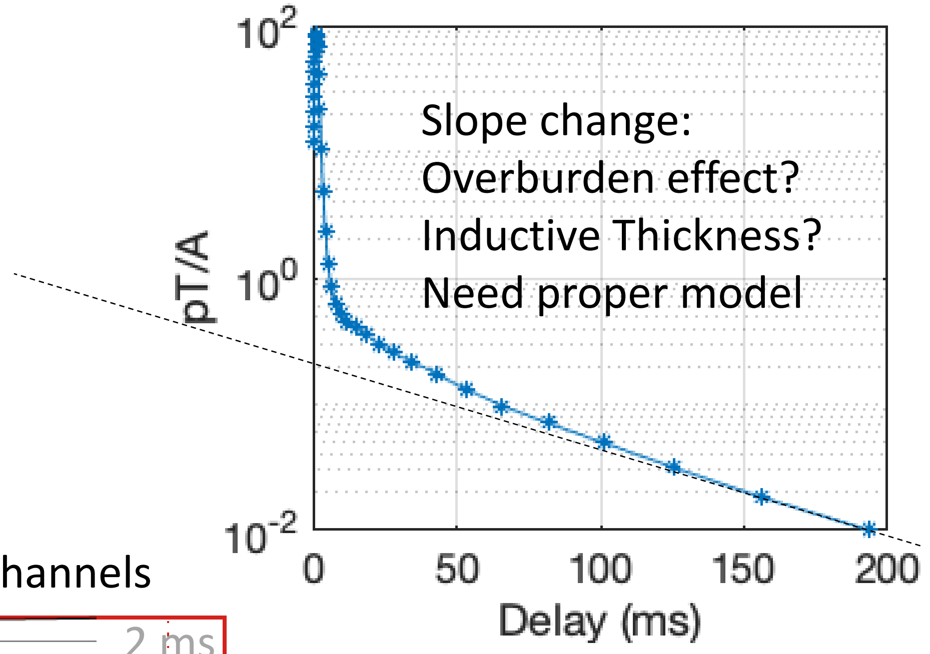
- dB/dt on time can be used with streaming receiver, but not nearly as good as B
- Off time basically forget it… inductive thickness and/or other conductors in vicinity energise non-discriminatory response
- Best case: May detect associated halo sulphides / alteration nearby??

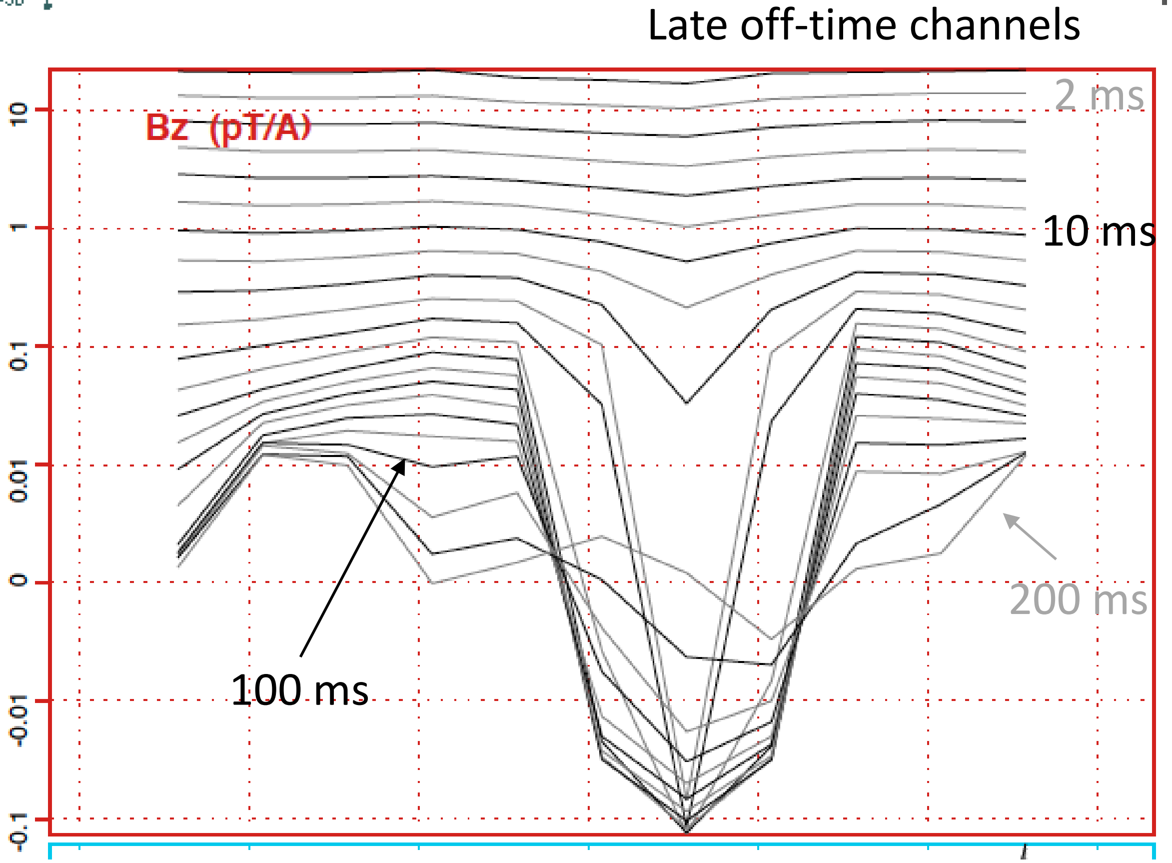
ARMIT field example

Courtesy of Newexco and Sandfire









NEWEXCO
GEOLOGY GEOPHYSICS DISCOVERY

ARMIT v4 sensor
1.04 Hz Base Frequency
150 A current into
300 by 300 m loops
300 m Slingram geometry
Predicted S = 2000 S
220 m deep pyrrhotite
target confirmed by
drilling & DHEM

Acknowledgements

Nick Ebner
BCGS / EMinar

NEWEXCO
GEOLOGY GEOPHYSICS DISCOVERY

Data

SANDFIRE
RESOURCES NL

RMIT
UNIVERSITY

ABITIBI
GEOPHYSICS

ARMIT development