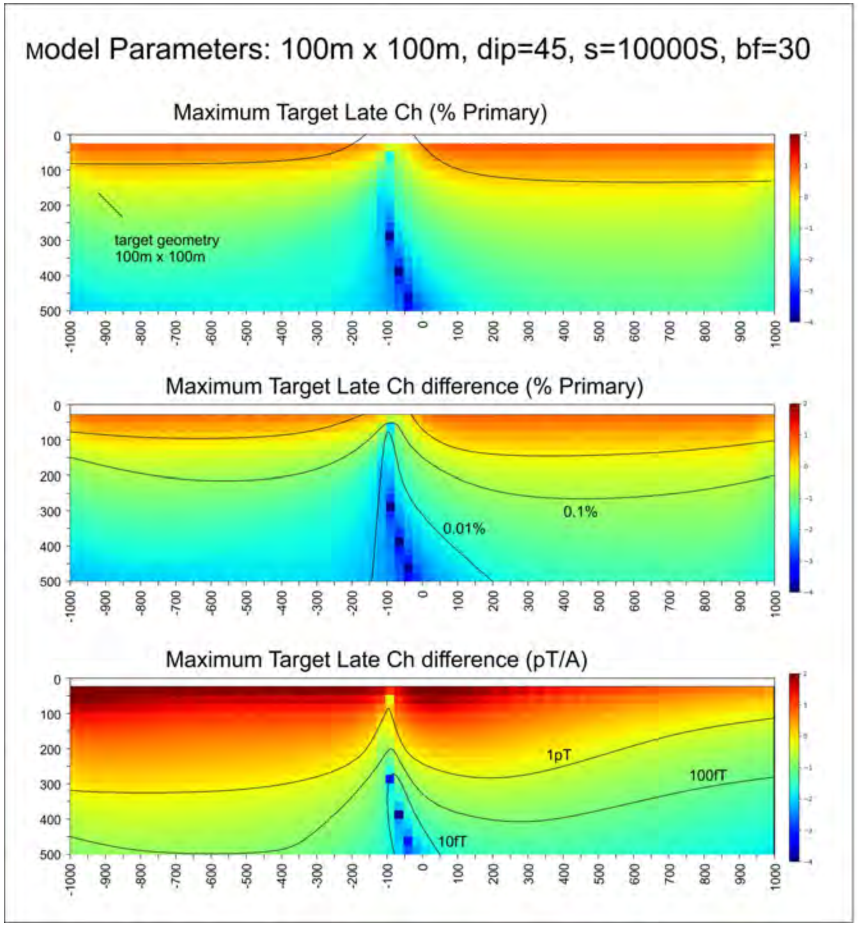
Tools and Concepts for Prediction of EM System Performance for Detection of Long Time-Constant Targets



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Ben Polzer
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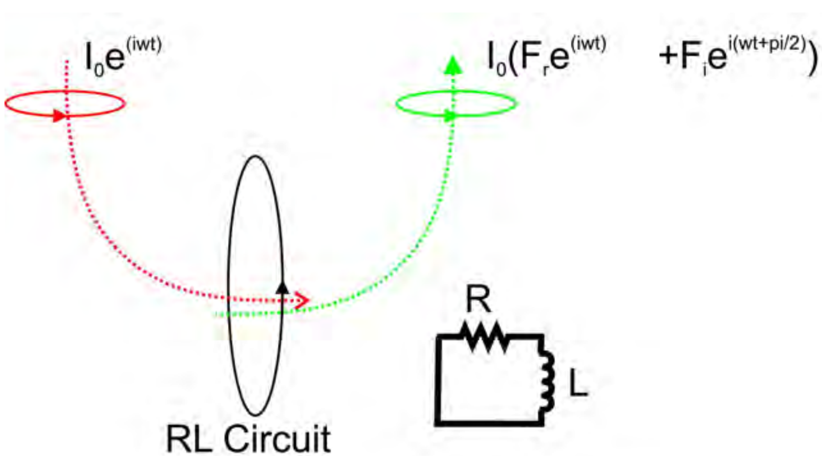
Signal and Noise

- On-time and Off-time approaches have different sensitivities (signal strengths) with respect to target parameters, especially for high conductance targets.
- The detectability of a target depends on the S/N ratio not just the signal strength.
- On-time systems can be more vulnerable to systematic noise sources
- Off-time approaches become more vulnerable to vibration noise in the quest to coax out a decay
- If we are going to study the S/N it is useful to use very simple models and noise estimation techniques to predict system performance

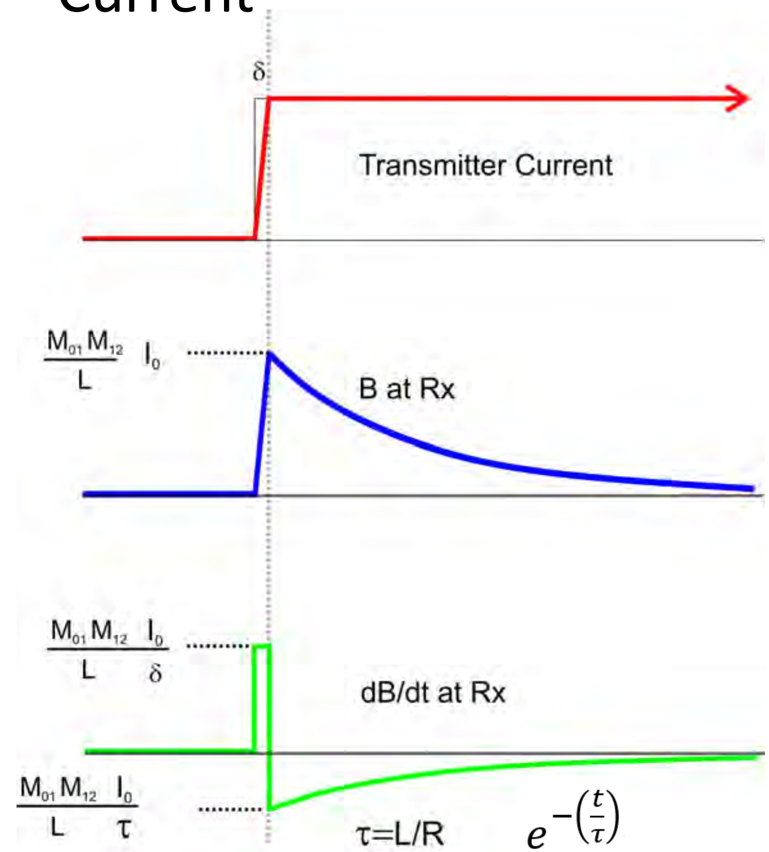
RL Circuit Model For Target

- After Grant and West (1965)

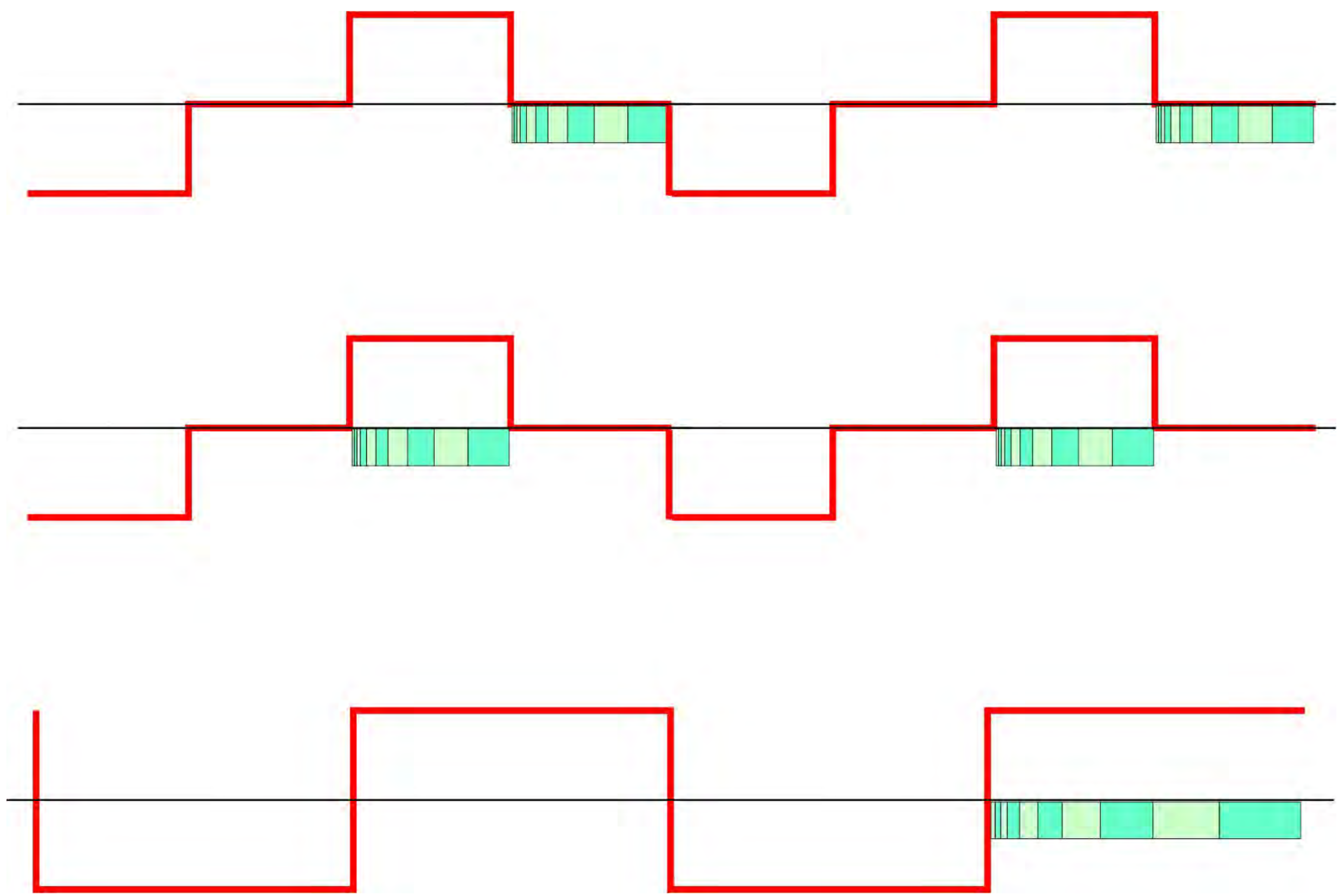
RL Circuit Model



Response to Step Tx Current

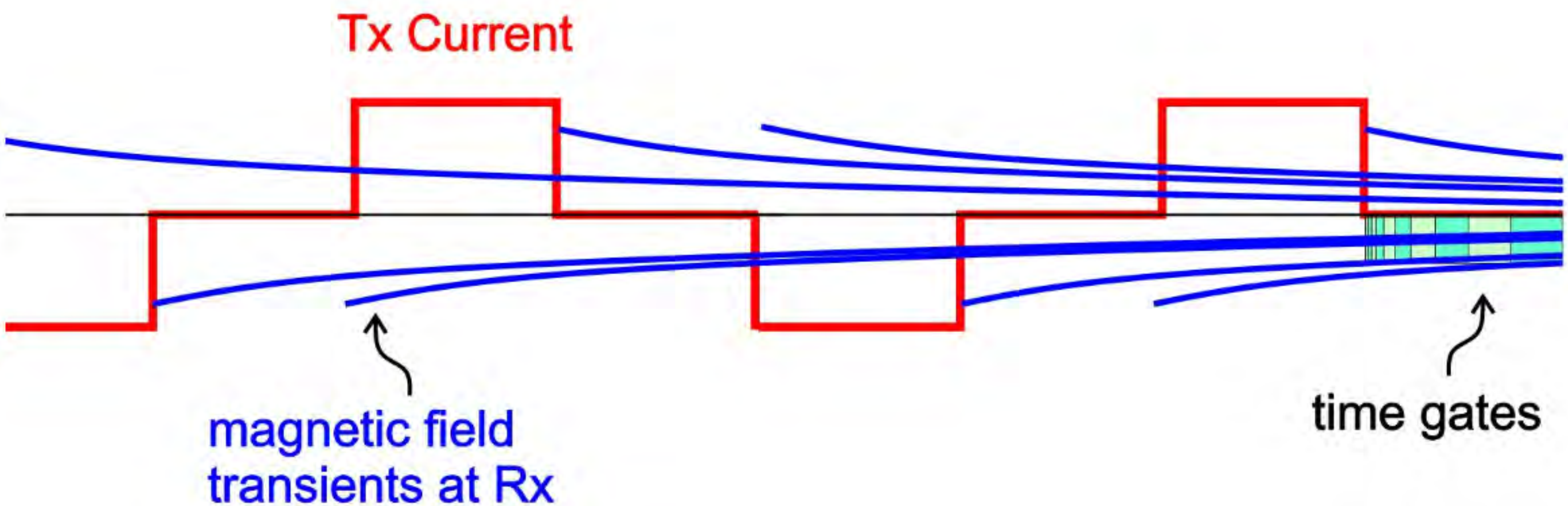


Waveforms and Sampling



Periodic Transient Effect

- EM systems drive a periodic signal with a base frequency.
- Transients from previous half cycles overlap and the effect becomes more significant as the ttime constant of the target gets longer.



Periodicity Factors

- The infinite series of exponential transients can be summed analytically to yield the original transient modified by a Periodicity Factor which is dependent on the tau to base period ratio.

$$e^{-\left(\frac{t}{\tau}\right)} - e^{-\left(\frac{t}{\tau}+\frac{P}{4}\right)} + e^{-\left(\frac{t}{\tau}+\frac{P}{2}\right)} - e^{-\left(\frac{t}{\tau}+\frac{3P}{4}\right)} + e^{-\left(\frac{t}{\tau}+P\right)} - \ldots$$

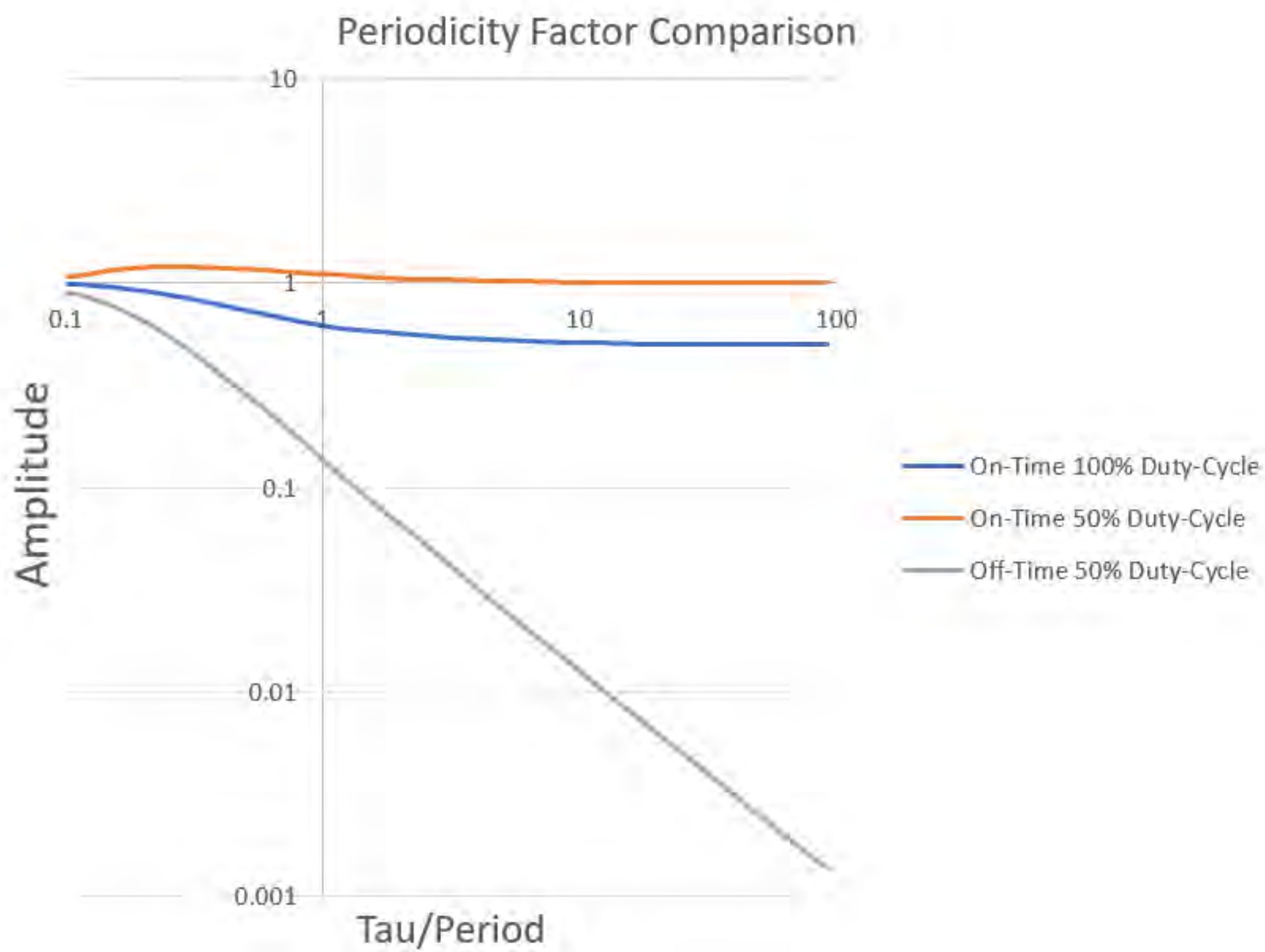
$$= e^{-\left(\frac{t}{\tau}\right)}[1 - X + X^2 - X^3 + X^4 - X^5 + \cdots]$$

$$= e^{-\left(\frac{t}{\tau}\right)}[1 + X]/[1+X^2]$$

original transient   Periodicity Factor

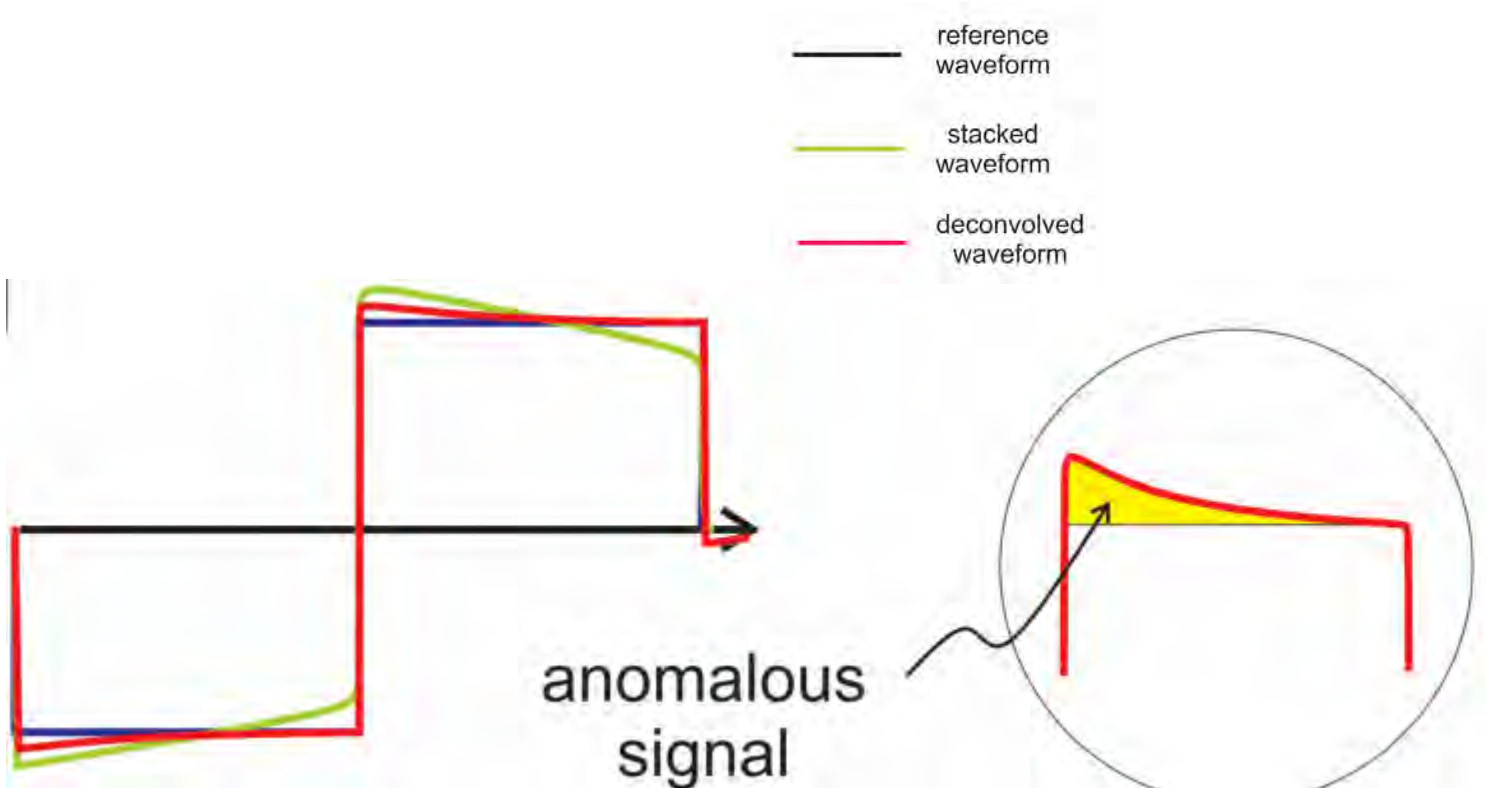
where X= $e^{-\left(\frac{P}{4}\right)}$ and P= $\frac{Period}{\tau}$

Periodicity Factors



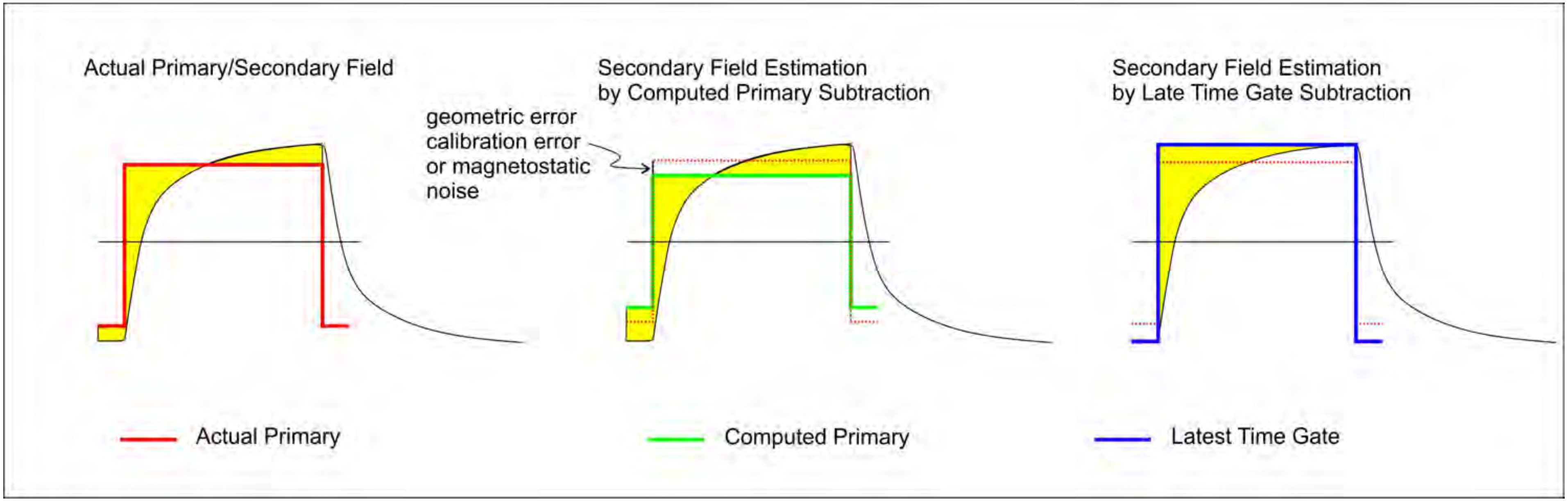
How Are On-Time measurements Done?

- For on-time measurements the anomalous response is deviation of the signal from an expected response curve.
- the response can be deconvolved in post processing to a perfect square wave response



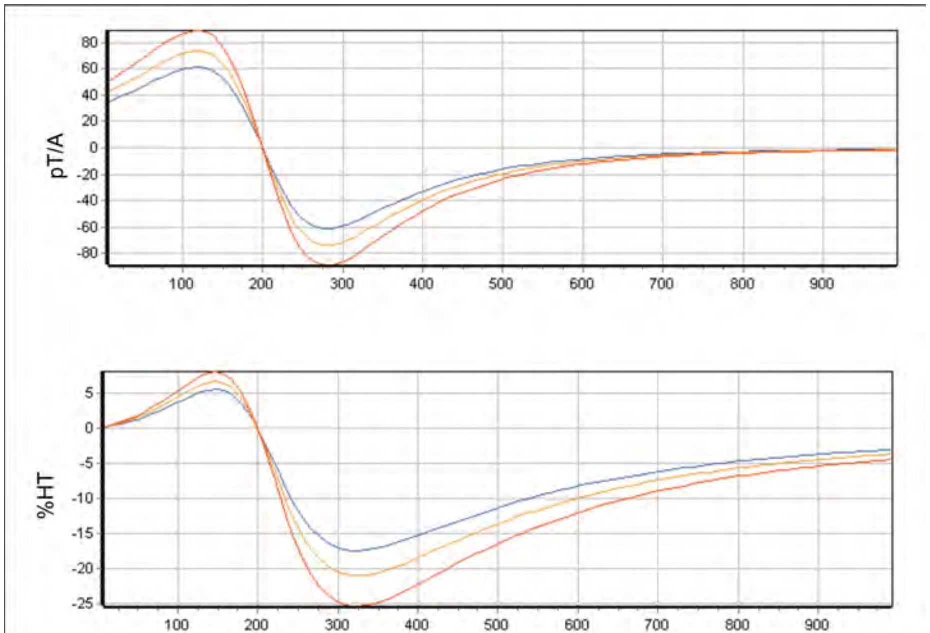
Primary Field Removal

- For off-time system primary field removal is automatic
- For on-time systems removal of primary field requires
  - Subtraction of the computed field
  - Subtracting the late transient as a reference.
  - Usually the late time is referenced to primary field (eg UTEM ch1)
  - Usually the transient is characterized using the late time reference



Filament Model Responses

- Filament modelling useful for analysis of signal for different stacking and averaging schemes and plate parameters
- Generate primary field reference channel and late time referenced transients



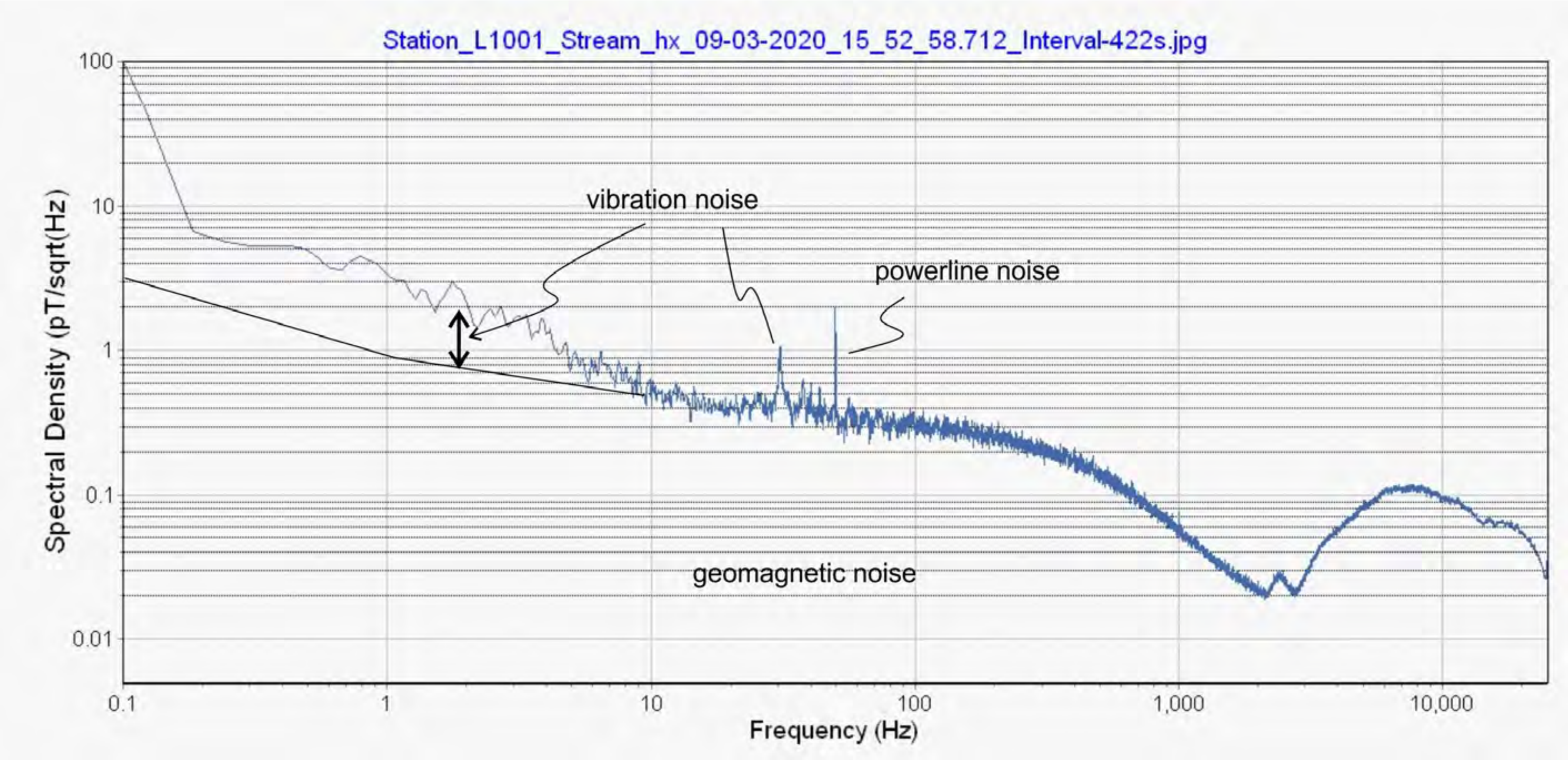
Sources of Noise

- While on-time data are much more sensitive to long tau decays they are also subject to more systematic “noise”
  - Fidelity of the waveform, calibration and deconvolution process
    - 0.1% easy to do
    - 0.01 % hard
    - 0.001% ???
  - Magnetostatics “Noise”
    - Very dependent on geological environment (0.1%-20%) of primary field
  - Geometry errors
    - ~1% at best
    - Very different for Hx a

- Stochastic noise common to both approaches
    - Sensor and system noise
    - Vibration noise

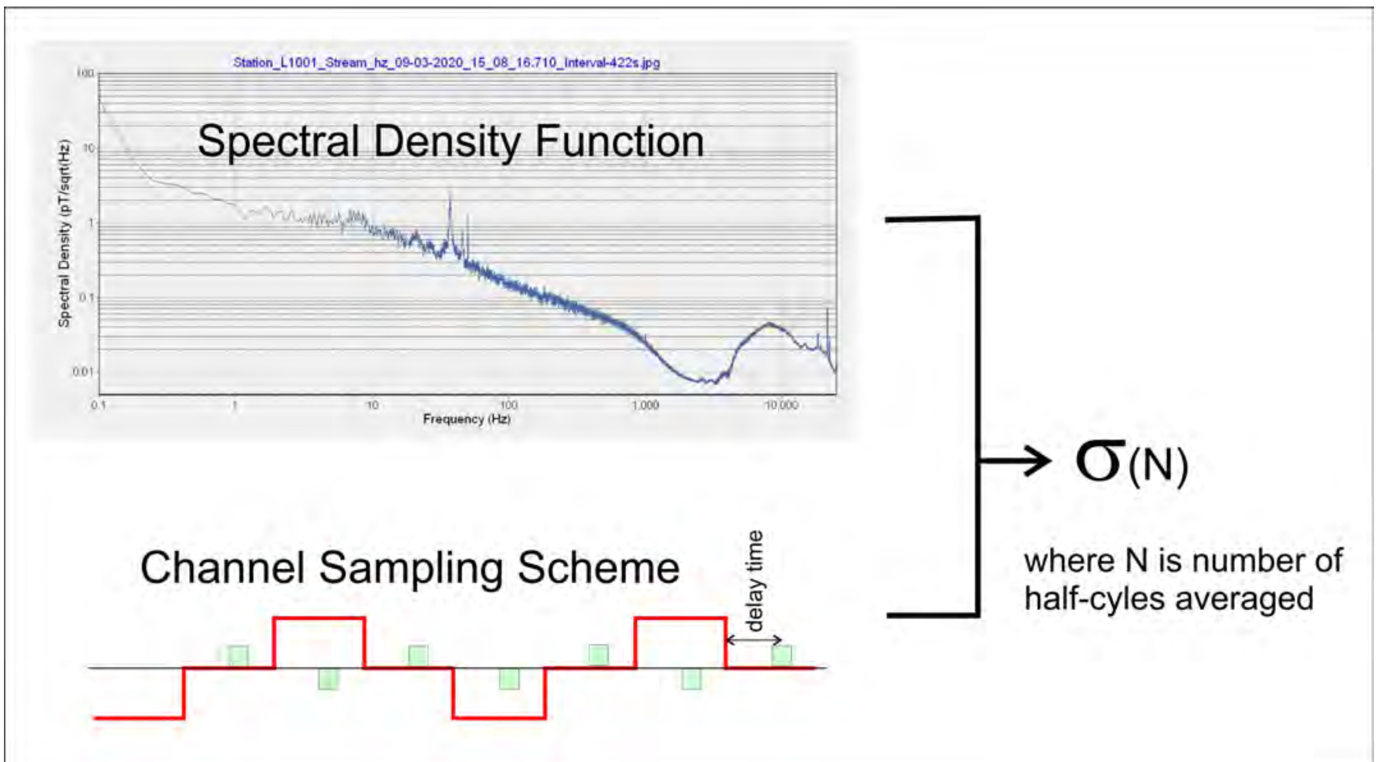
Sources of Stochastic Noise

- Sferics, Powerlines, Sensor vibration
- Time series recording provides a valuable tool for analyzing noise and optimizing survey parameters



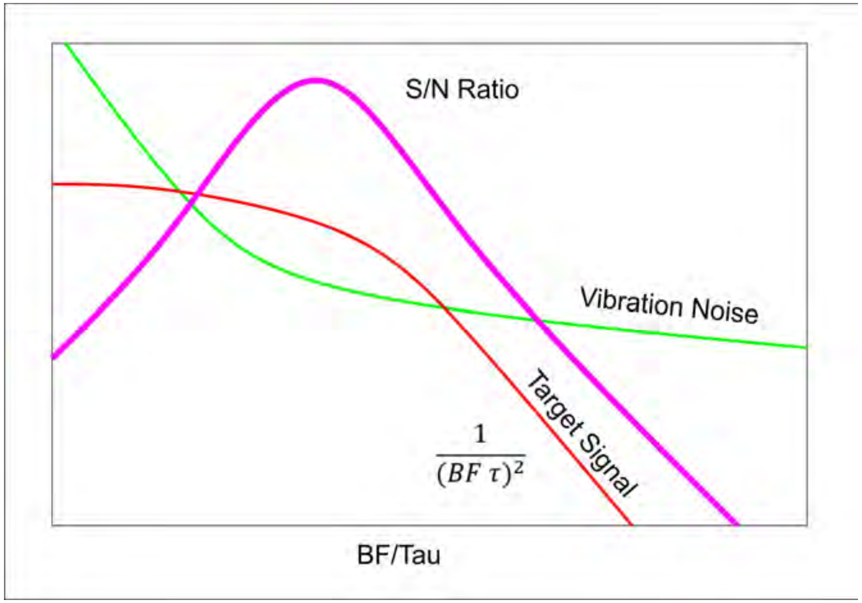
TDEM Gated Channel Noise from Spectral Density Estimates

- Time series recording are potentially useful for determining expected noise in stacked data for different base frequencies and stacking schemes
- Eg Macnae, Noise processing techniques for time-domain EM systems, **GEOPHYSICS, VOL. 49, NO. 7 (JULY 1984);**



Proposed optimization of off-time detection

- Most important parameter is the base frequency
- Based on previous experience in the environment need to estimate channel std deviation as a function of base frequency. Easy to do from time series with or without the loop running.
- For any target plot the expected S/N versus BF based on the noise estimate and the target parameters.

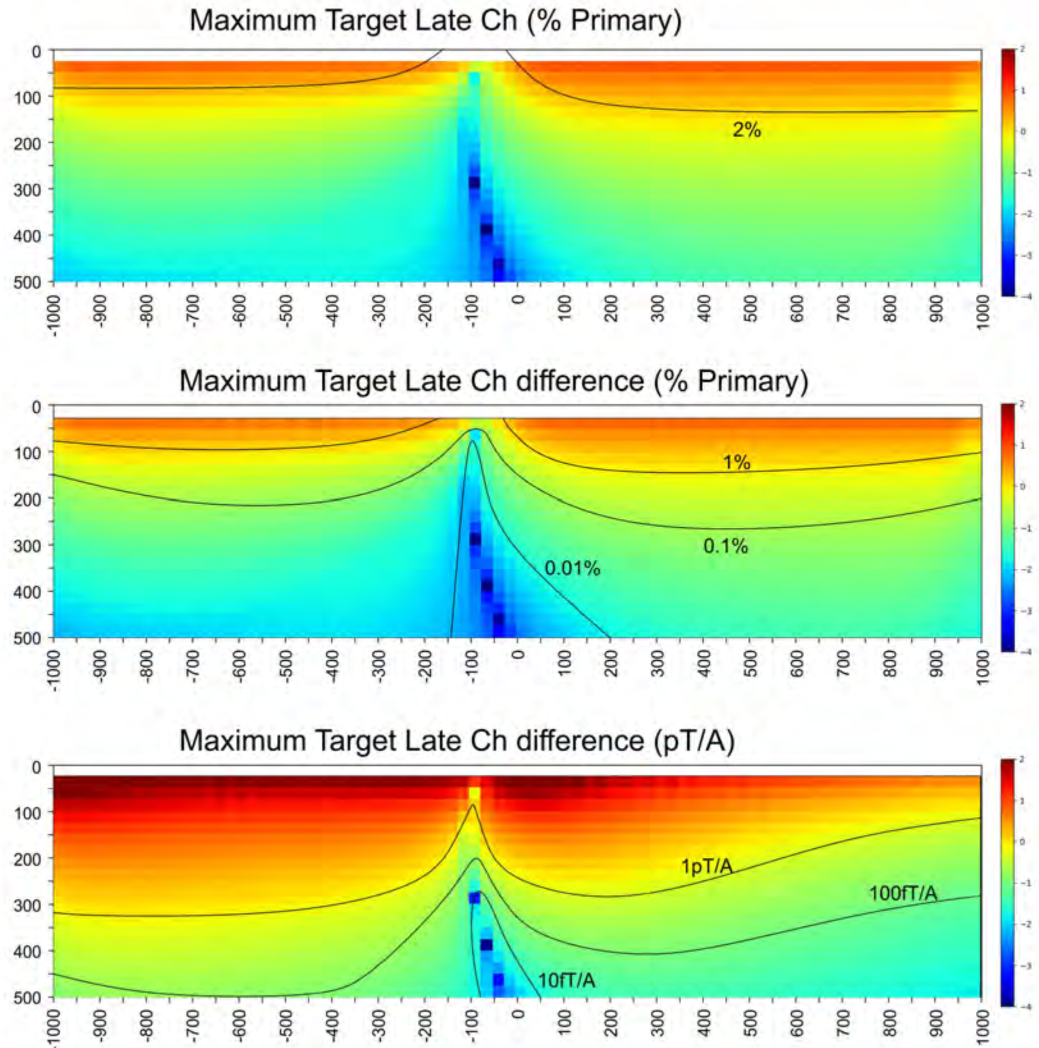


S/N Analysis

- Use the filament model to compute signal as
  - In on time as a late time channel (e.g. UTEM ch1)
    - Expressed as pT/A
    - Expressed as %HT
  - In on time as a late time channel difference (e.g. UTEM ch2-ch1)
    - Expressed as pT/A
    - Expressed as %HT
  - In off time expressed as pT/A
- For any given model: strike length, dip extent, dip, sigma-t, base frequency
  - Compute the responses over an entire grid for each of an ensemble of plate locations, for instance on a vertical plane
  - Plot the maximum (absolute) response observed on the entire grid at position of each plate (centre of top edge referenced).
  - Use the contours of these images at the specified noise limits for the systematic and stochastic noise for the system in question.

S/N Analysis
Locii of Detectability

Model Parameters: 100m x 100m, dip=45, s=10000S, bf=30



Conclusions

- It is possible to use simple models for induction that recreate the sensitivity of a system response to conductance and base frequency.
- All sources of noise should be characterized for any given system
- The two can be combined to form S/N ratio that can be used to predict system effectiveness for a particular exploration target.

Appeals

- To off-time EM practitioners
  - Pay heed to base frequencies that are too low to be useful given vibration noise
  - Get some add-on on-time recording into your systems. Because of the limits of magnetostatic noise and positioning and pointing errors the on-time recording does not have to be very precise to reduce the risk of missing a VB Ovoid at shallow depth.
- To both species
  - Time series data are extremely useful for understanding noise sources and optimizing S/N