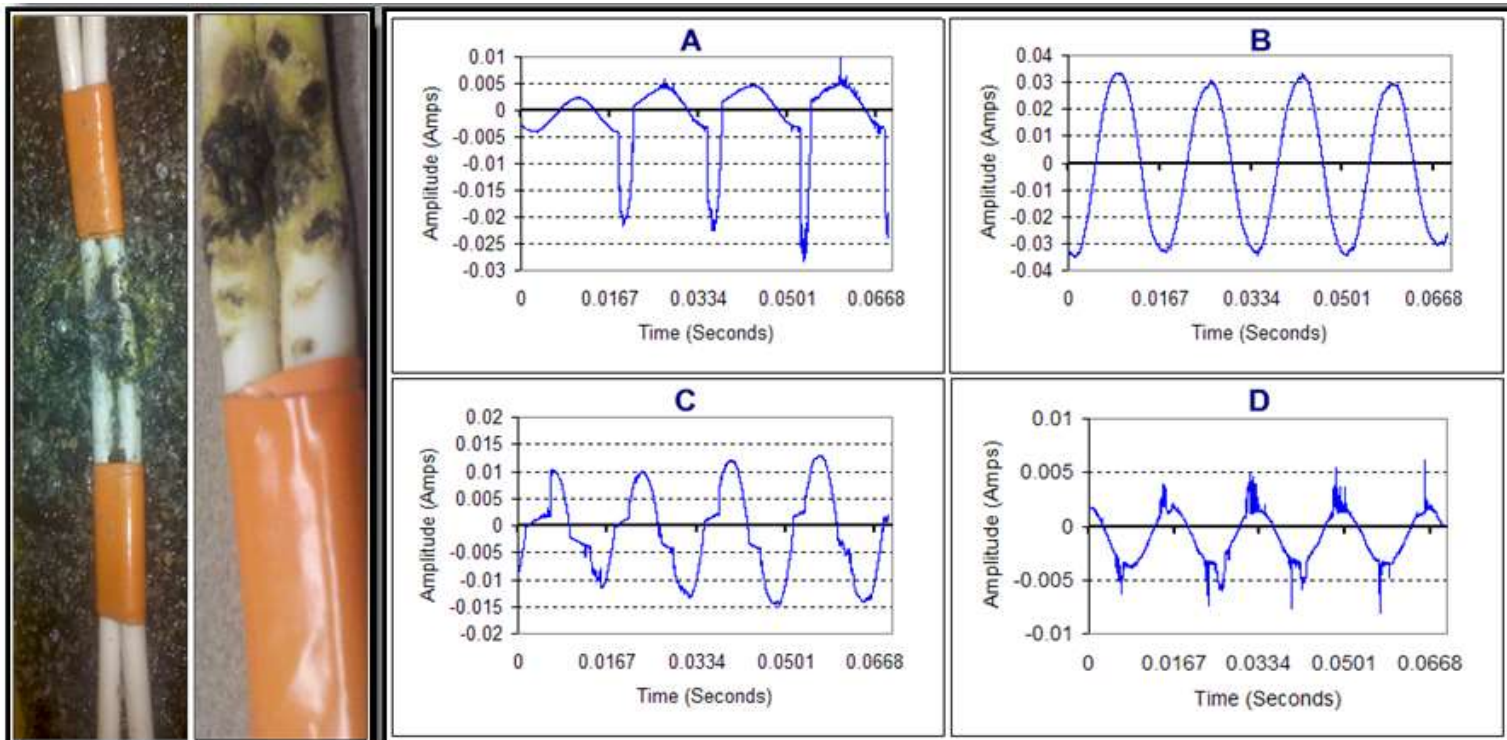


Signatures of Arcing and Incipient Faults from Underground Power Distribution Cables

Thomas Cooke



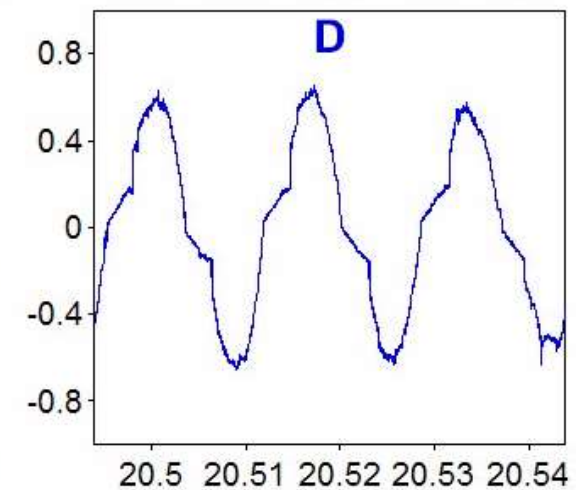
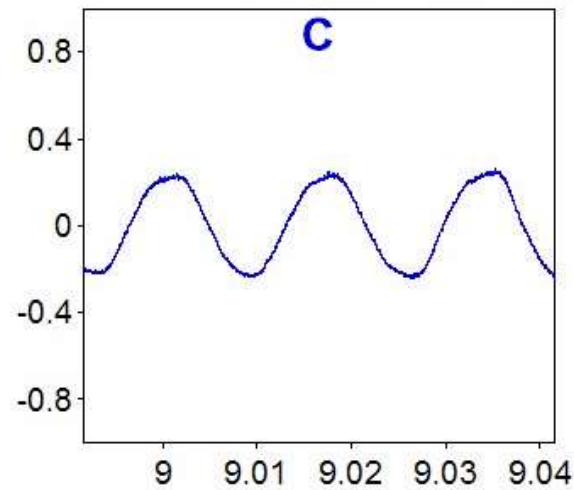
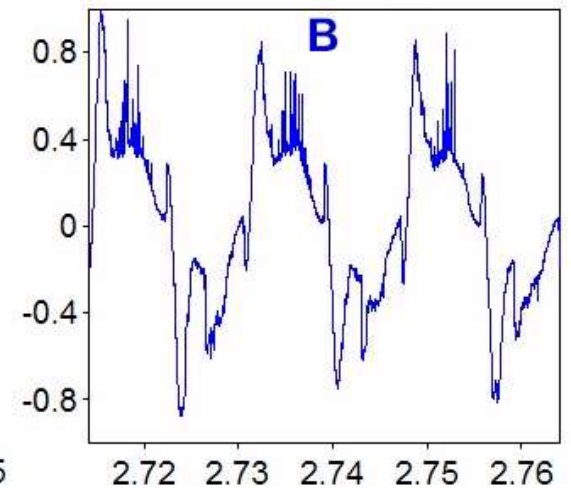
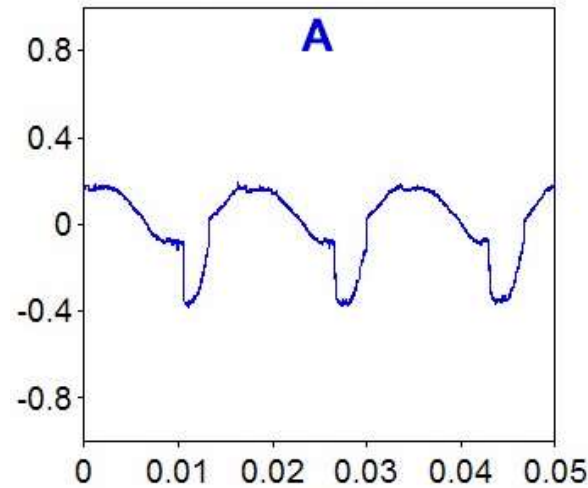
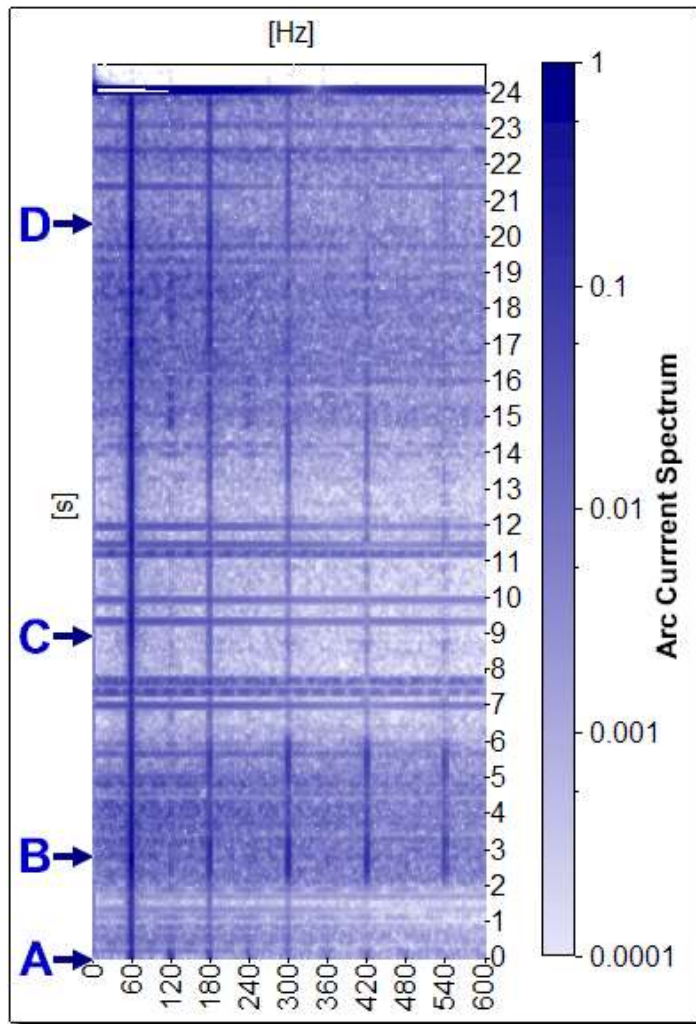
Signature Analysis - 5 Primary Factors



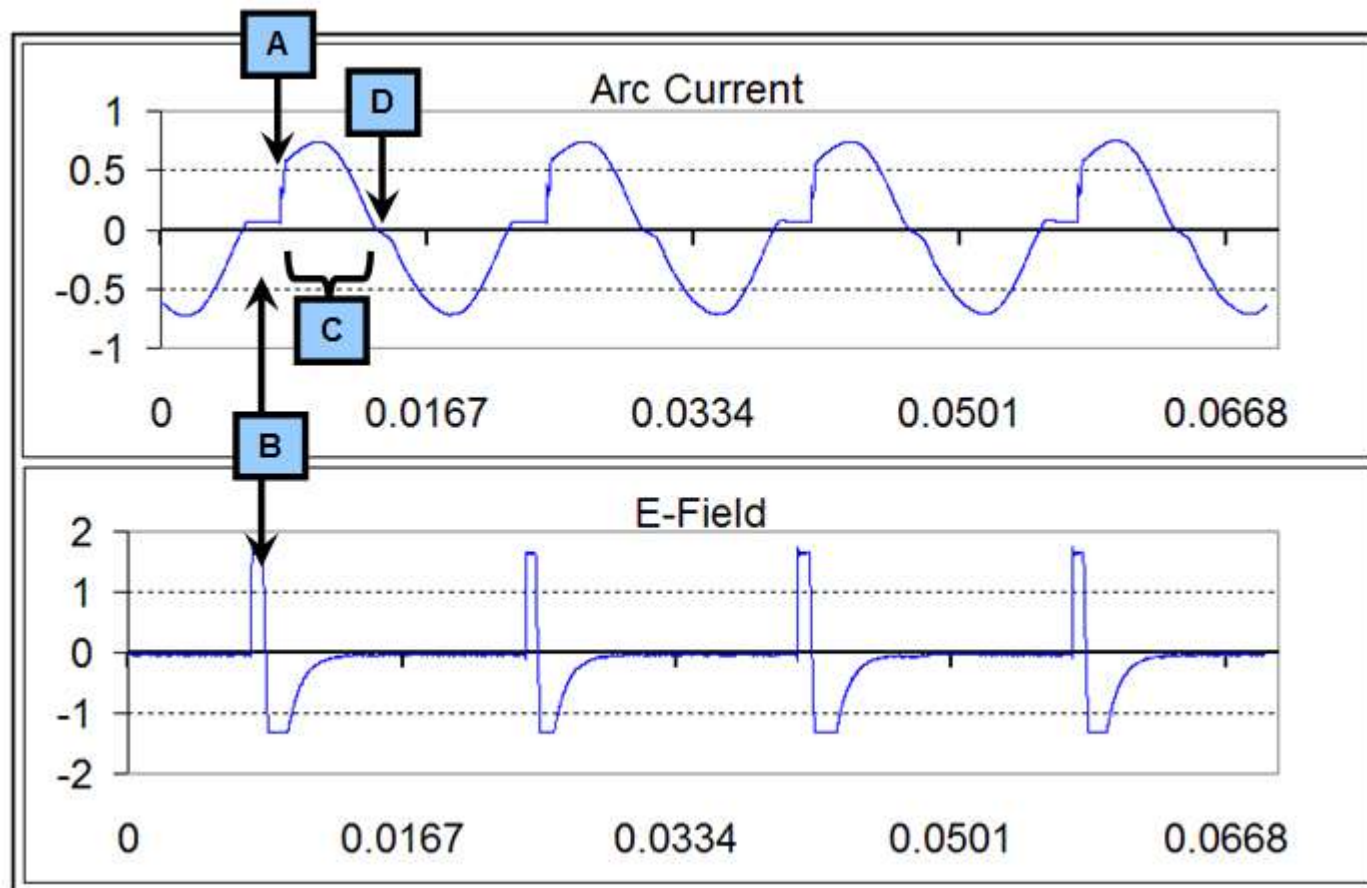
Even Harmonics /

Arcing Indicator	Waveform Characterization	Wave Shapes
Inter-Harmonics	No symmetry in positive to negative 60Hz cycle	A, C, D
Sporadic Changes	Non-repetitive wave shape in a given short period of time. (0.1 to 1 sec.)	(A, B, C, D) Collectively
High Frequency	Sharp rise/fall times, spikes, notching, etc.	D, A, C
120 Hz Repetition	High frequency content at positive and negative peaks of 60 Hz cycle	D, A
High Crest Factor	High peaks, and/or narrow half-cycle	C, A, D

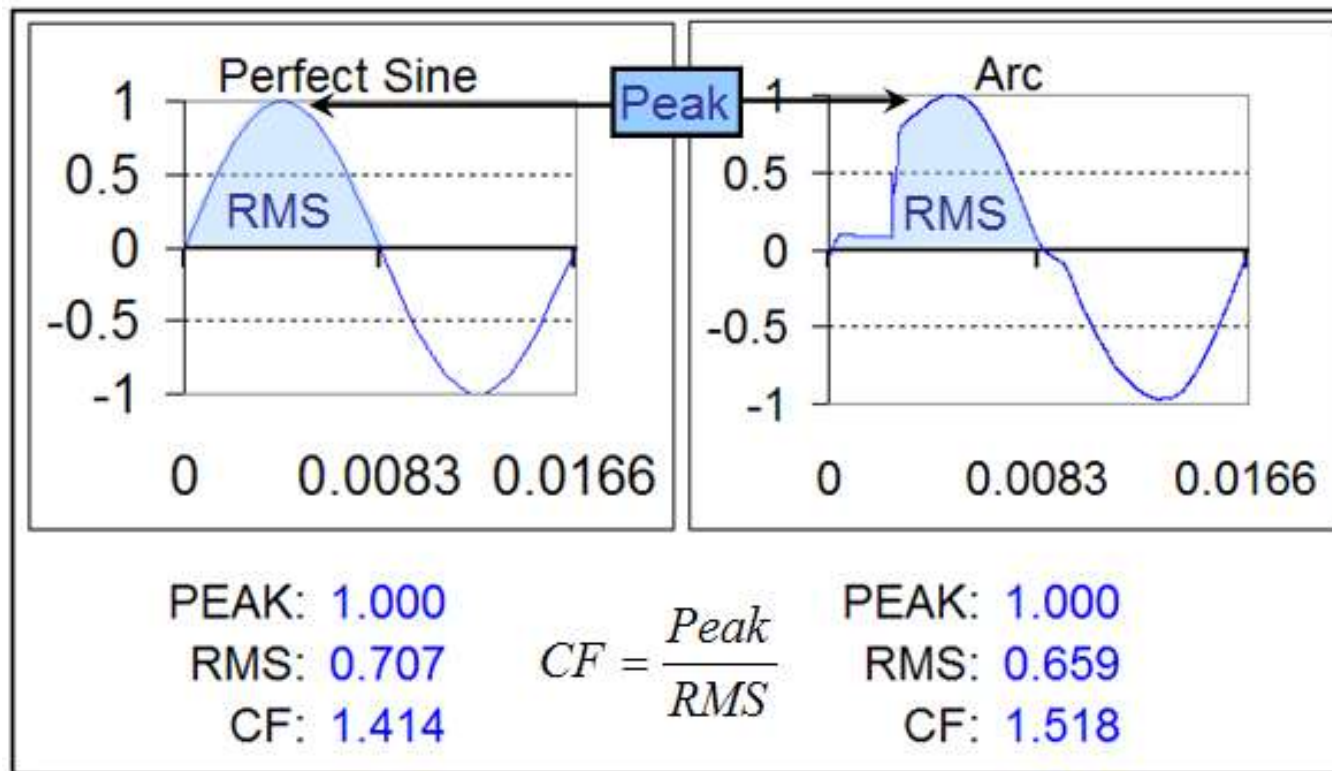
Arcing Signatures



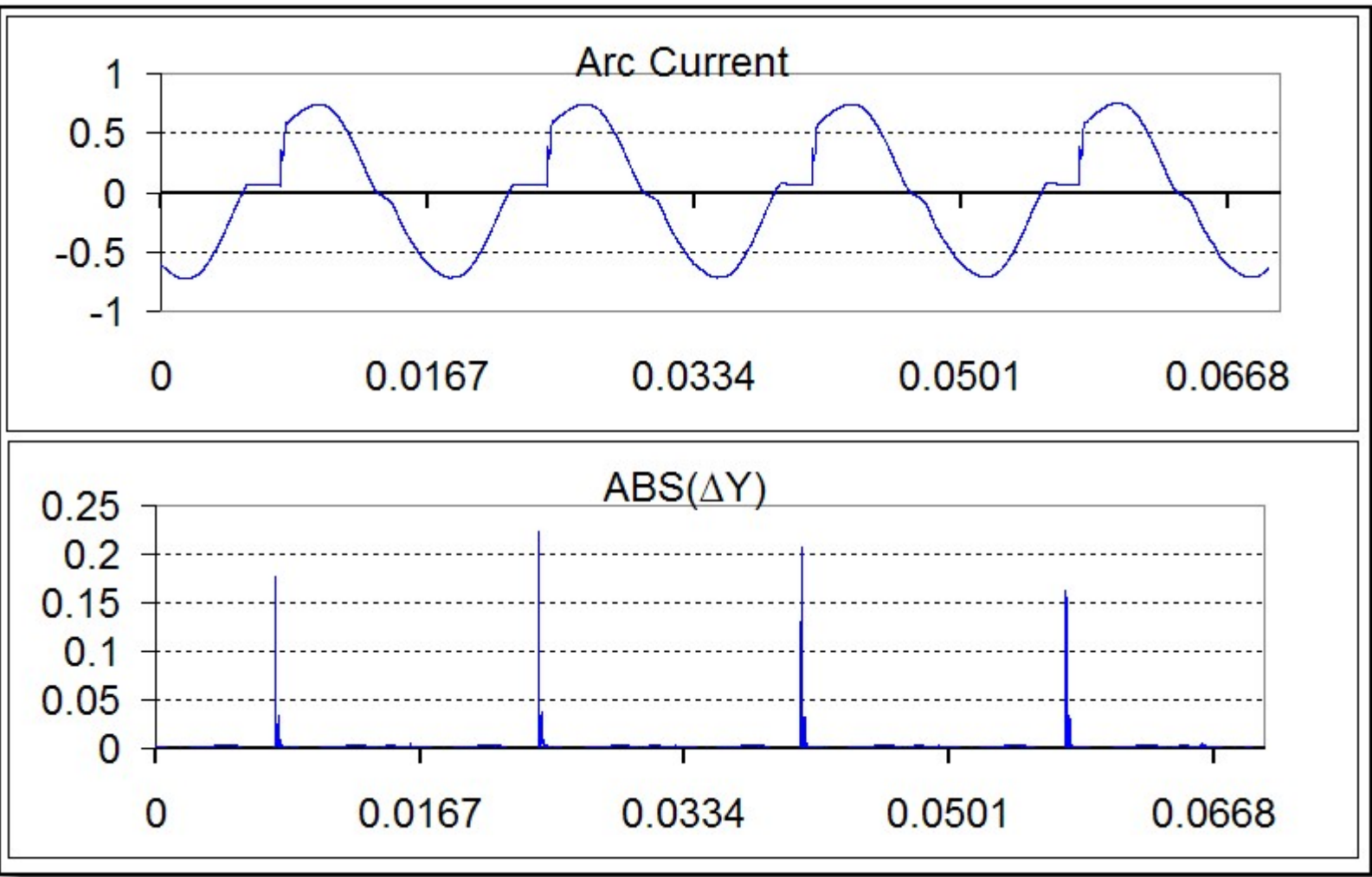
Series Arcing: Current



Series Arcing: Current Crest Factor



Series Arcing: $\Delta I/\Delta t$

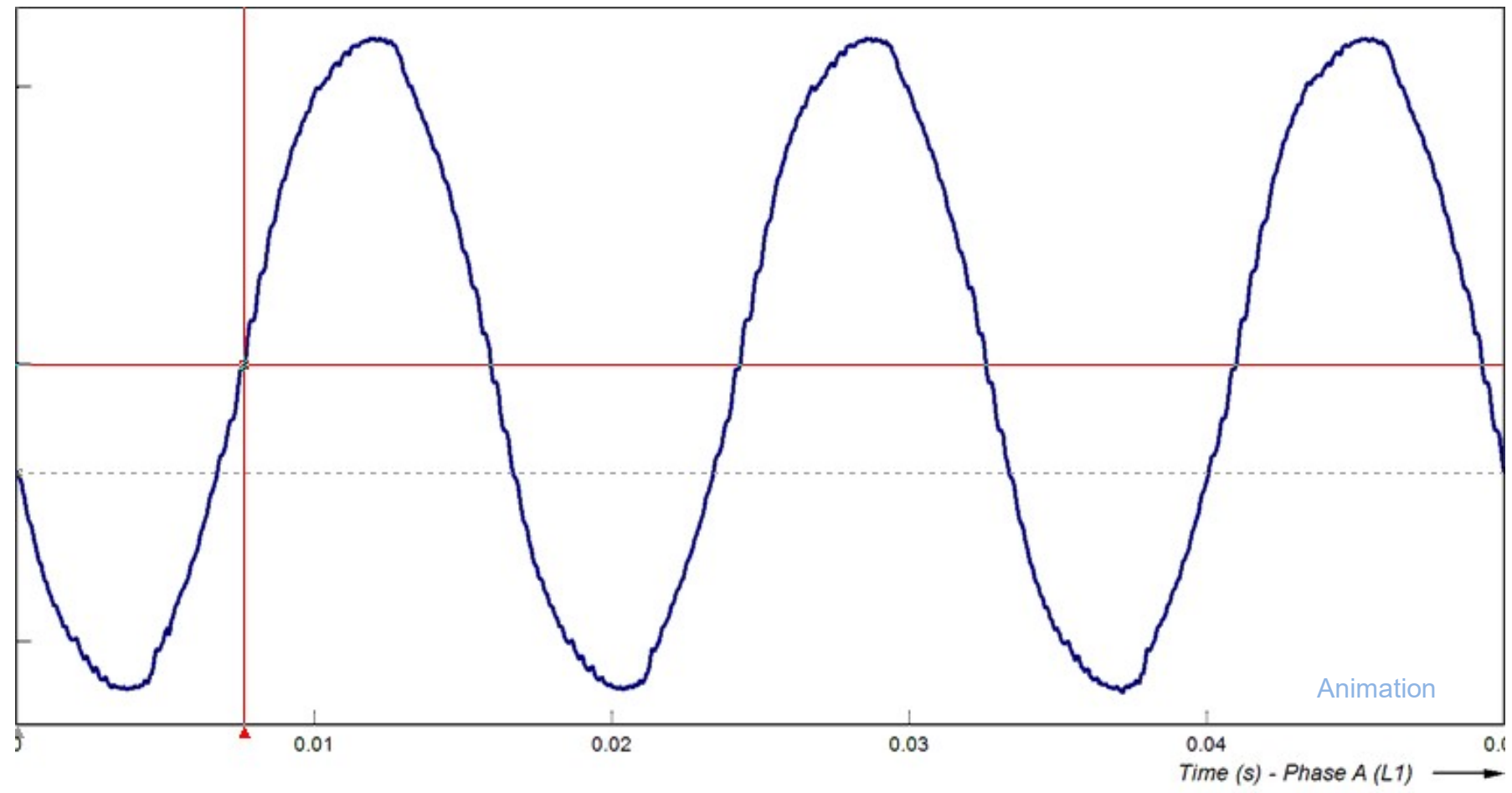


Assessment of PQ Monitors

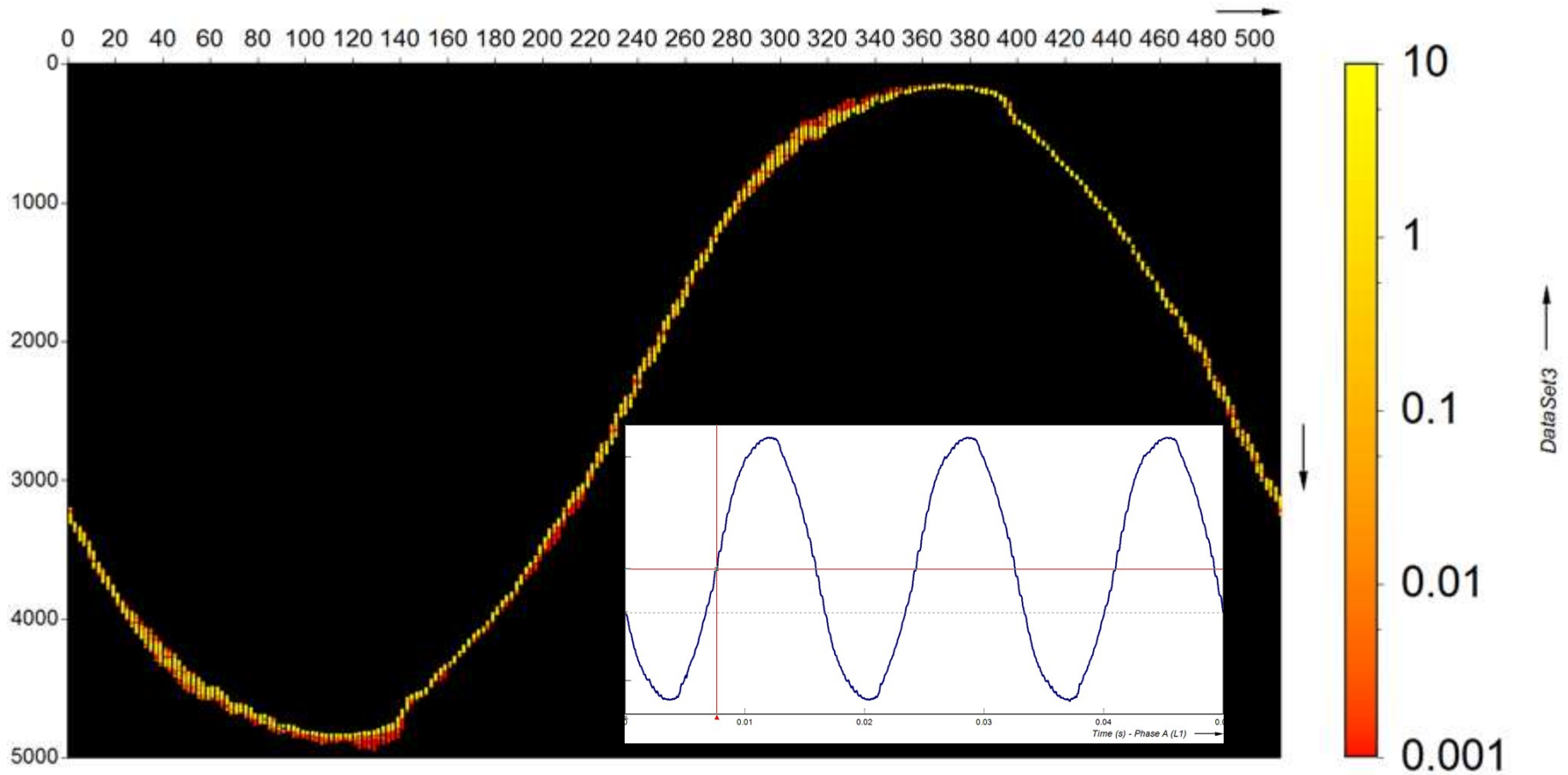
- Although PQ monitors have the bandwidth and ability to measure some of these indicators, the current threshold and **triggering algorithms need improvements**
- For example, increase in interharmonics can be captured through trend data, but triggering can only be obtained through static threshold levels. This is feasible; however, many false positives can result. A dynamic-threshold and **sporadic-occurrence algorithm** will offer a more confident triggering mechanism
- To enhance PQ monitoring capabilities, an **arc-triggering algorithm** needs development for not only triggering a waveform recording but also alerting service personnel



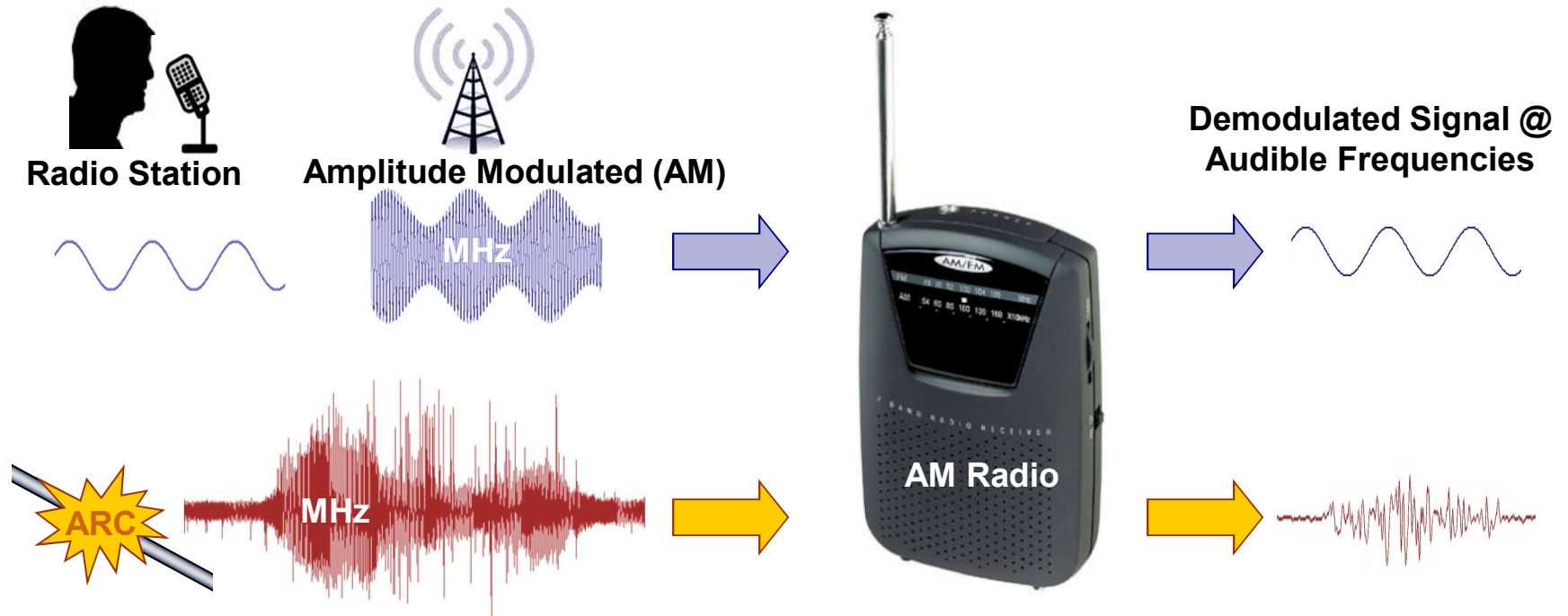
Subtle Waveform Deviation from Arcing



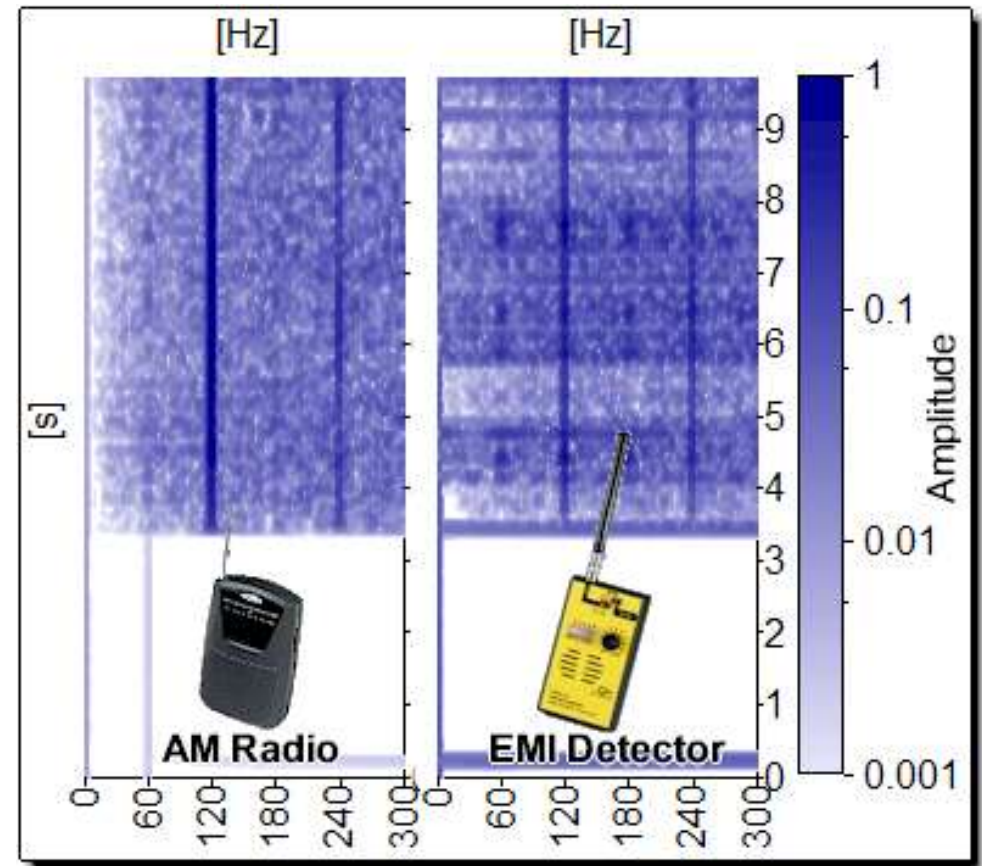
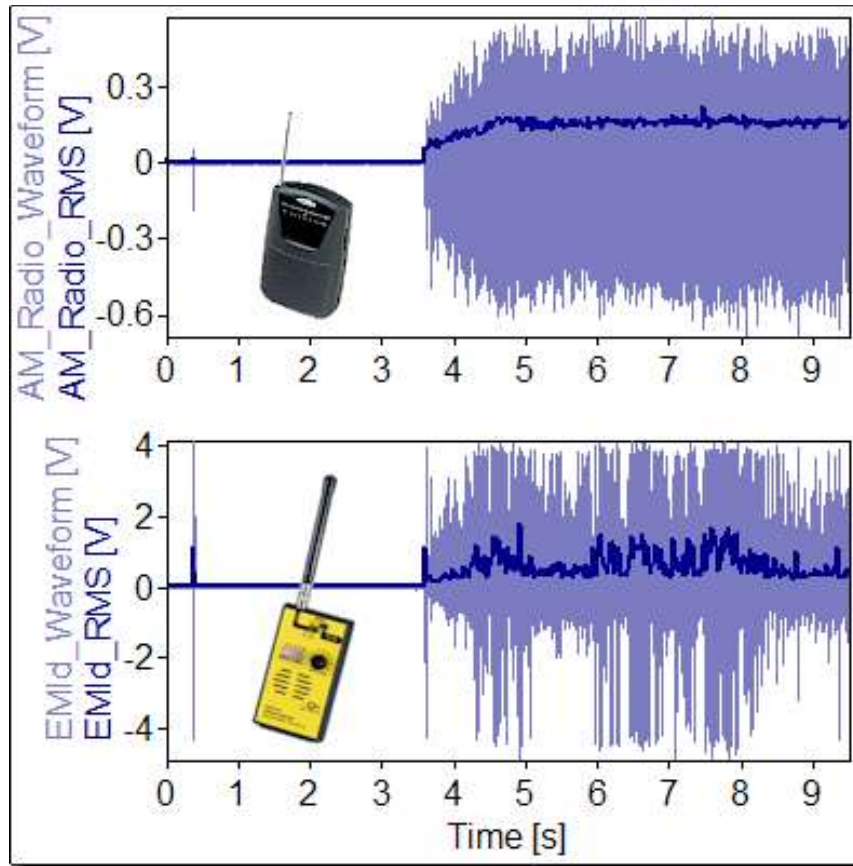
Cyclic Histogram Highlights Deviations



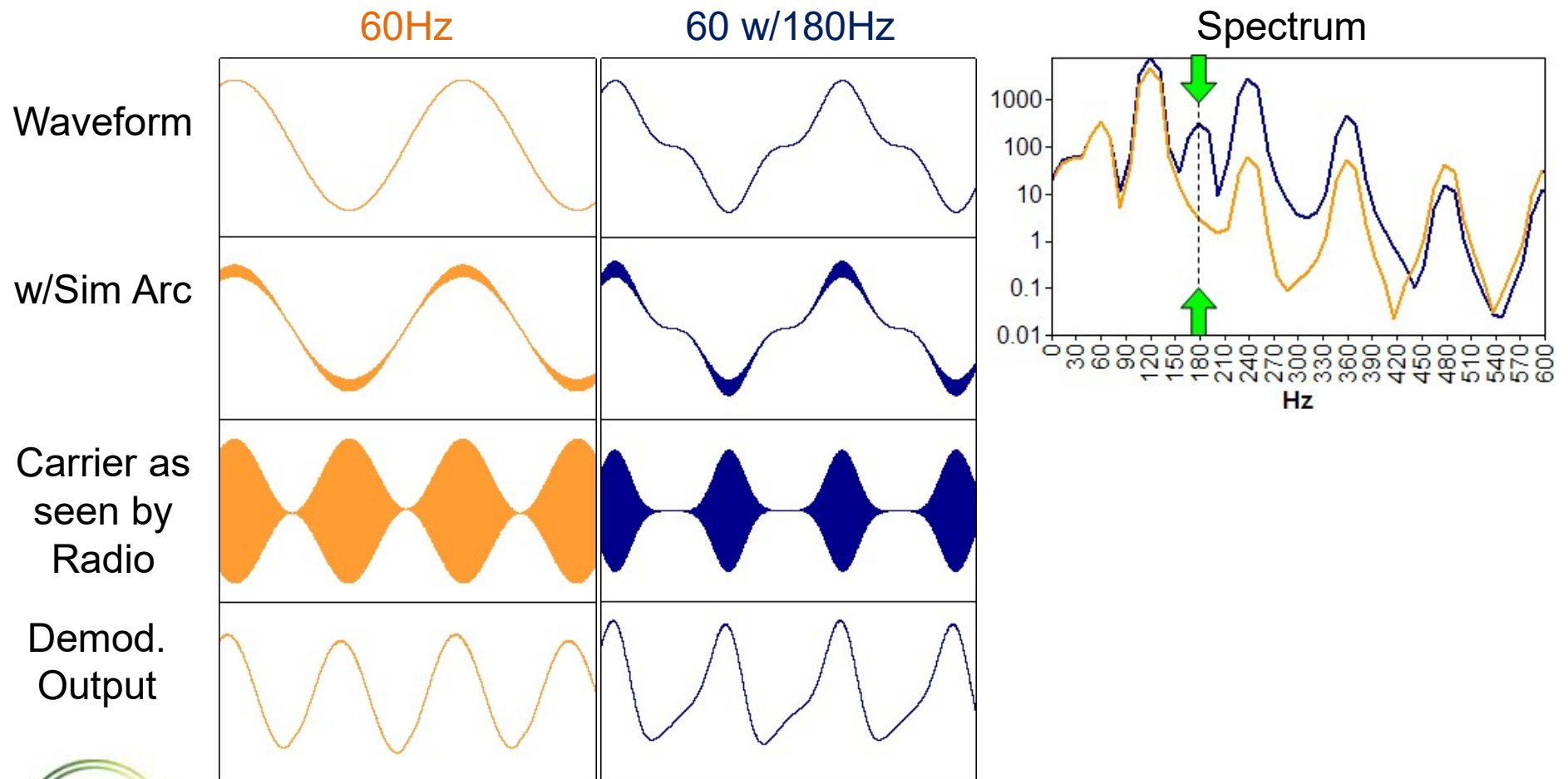
High Frequency PQ Monitoring



Flaws in Using AM Radio for Arc Detection

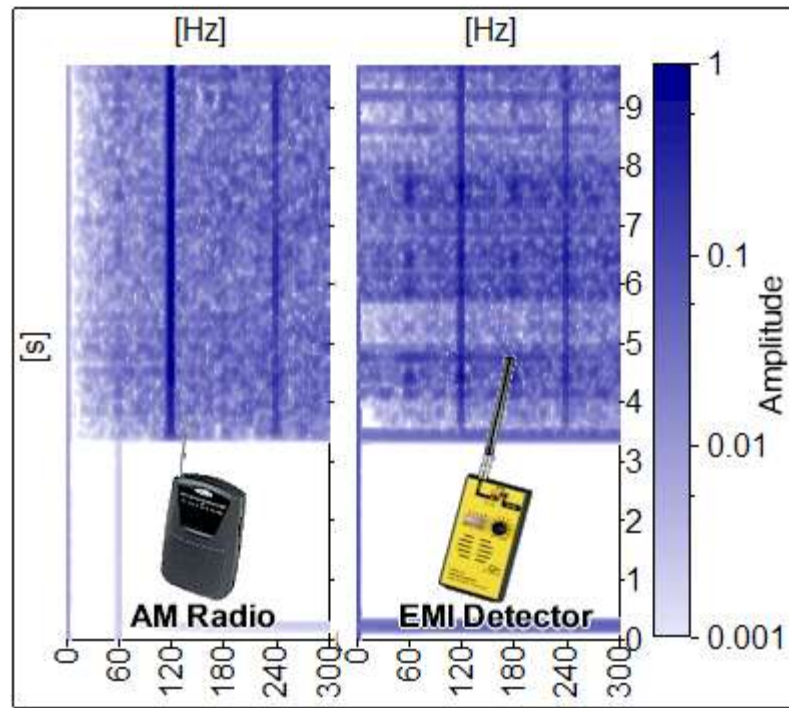


Demodulation Carries the Fundamental & Harmonics Frequencies

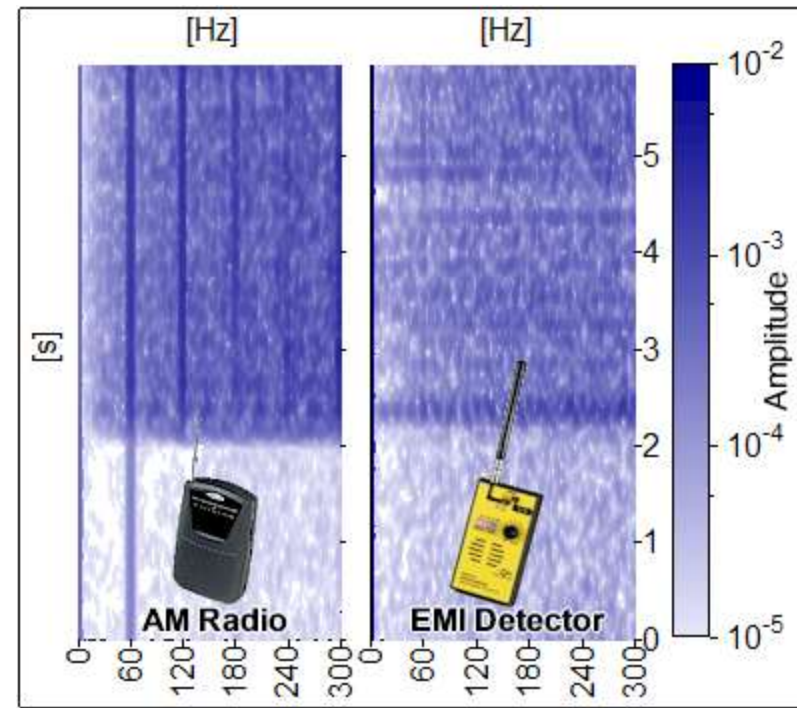


Important to Distinguish False Positives for Cable Arcing

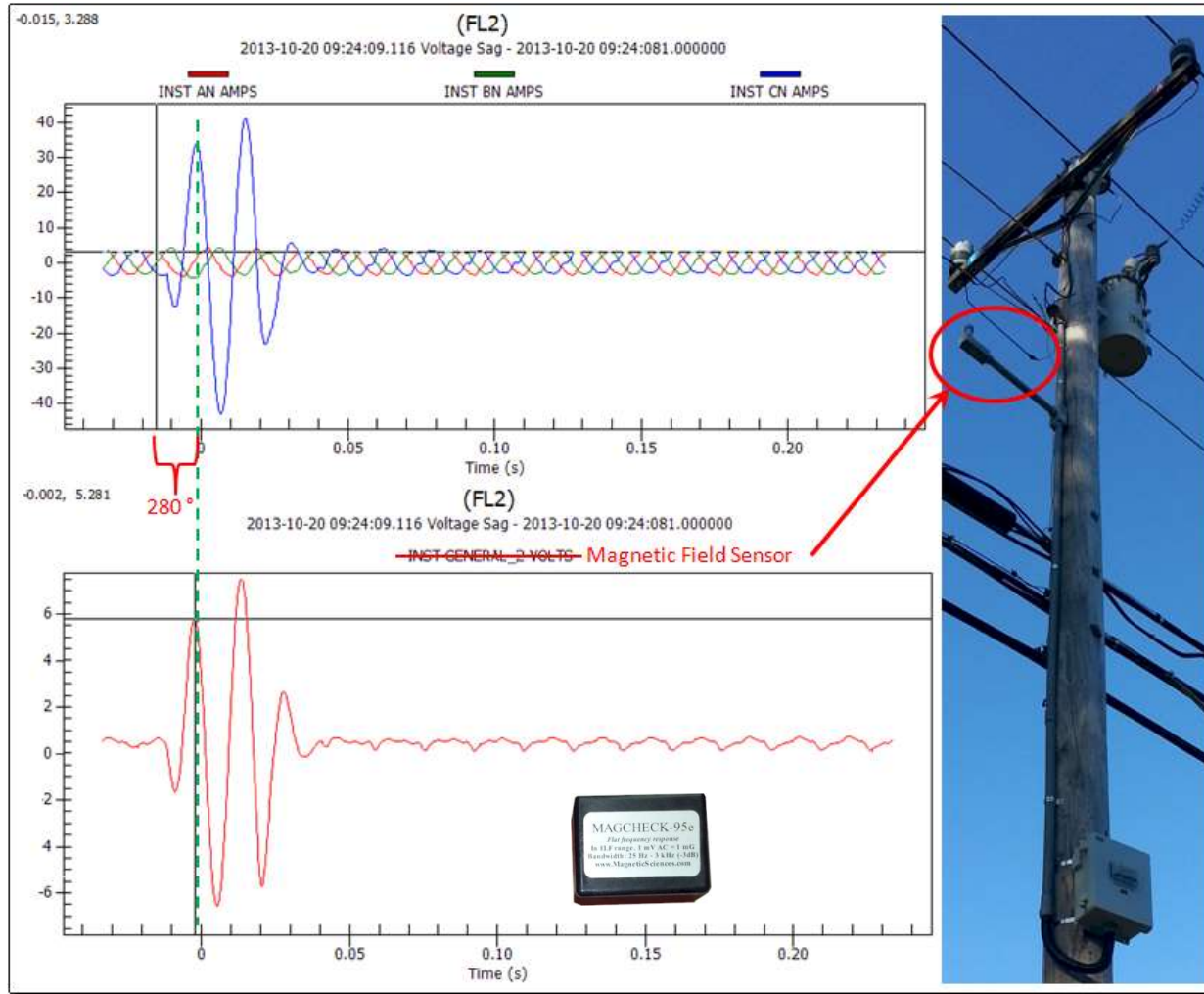
From Cable Fault Arcing



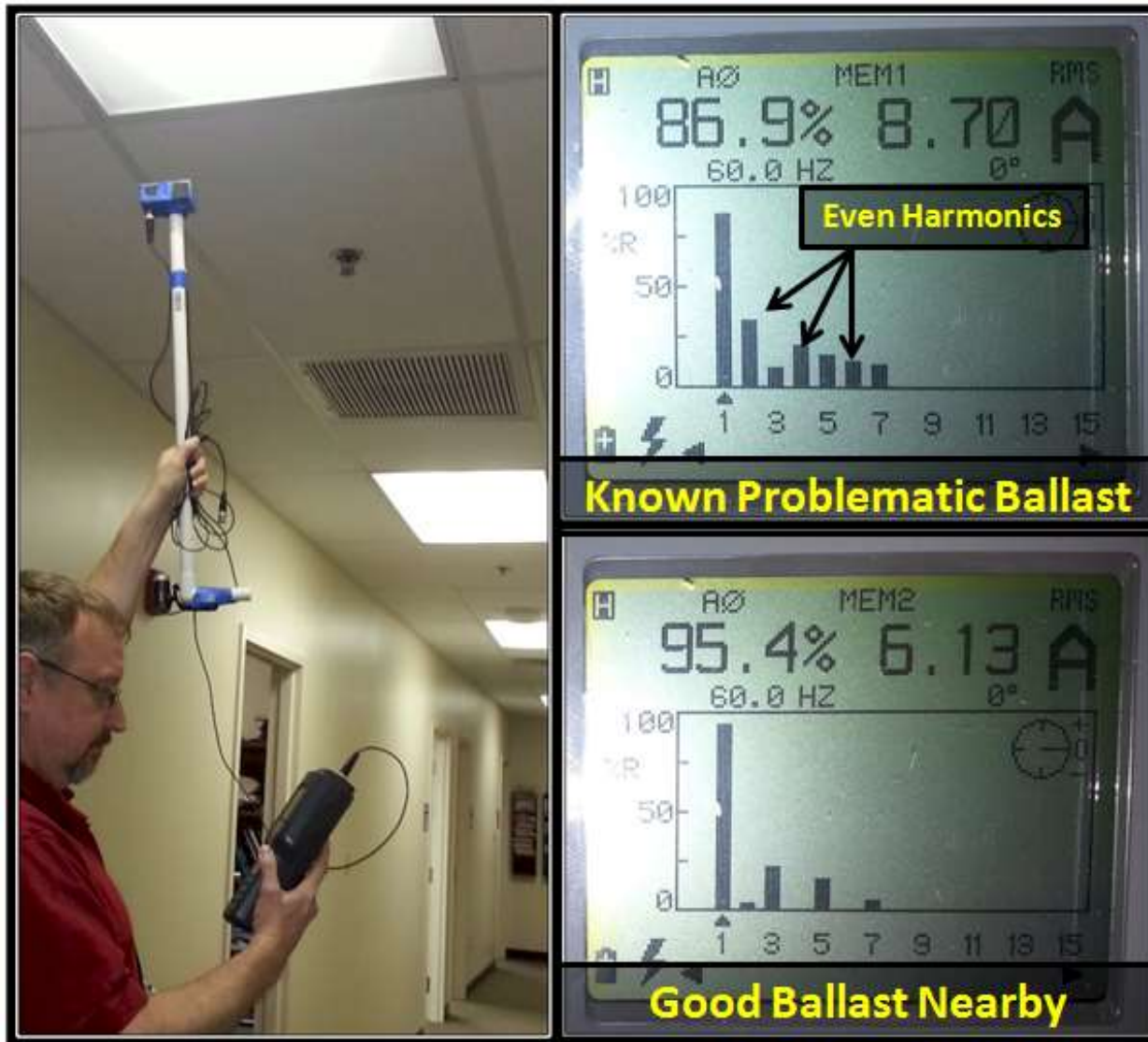
From DC Motor Brush Arcing



Fault Indication / Measurement with Non-Contact Magnetic Field Sensor



Harmonic Signatures



Moving Forward

- Sporadic trigger algorithm for existing PQ parameters
- Consider additional channels on PQ Monitors for Non-Contact Sensors
 - Single low frequency magnetic field sensor that collects residual current of nearby conductors.
 - Demodulated High frequency (1-10 MHz) EMF sensing
- Address the monitoring gap of missing high impedance faults

