Electrical and Acoustic PD sensing

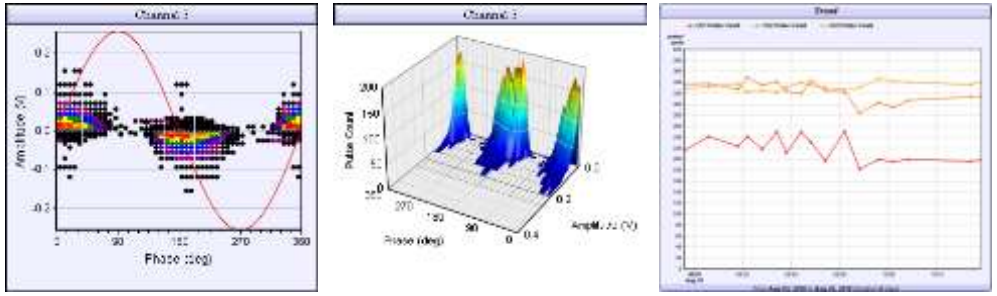
- All below is about in-field measurements!
- Electrical and Acoustic PD are complimentary
- Ideal system (Personal pure speculation)
- Electrical sensing - Problems
- Capacitively coupled and Magnetically coupled PD probes
- Capacitive coupling– frequency band. Where is truth?

Electrical and Acoustic PD are complimentary

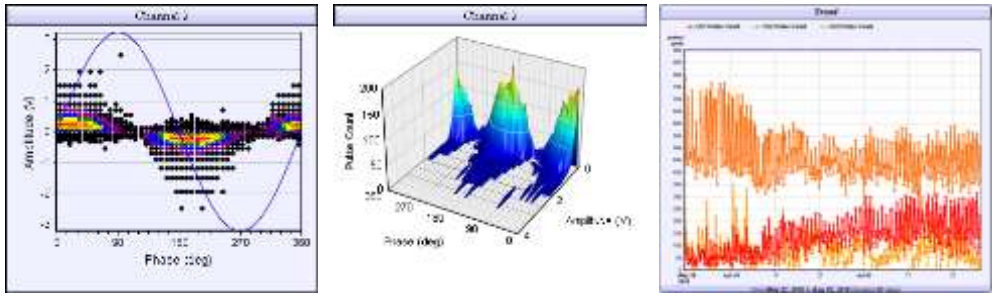
- Acoustic
  - More noise immune, allows for pinpointing location
  - Converting to PD values is problematic
    - Max. value can probably be calculated , but PD power ??
  - Most difficult task is counting pulses and resolving small amplitude PDs.
- Electrical
  - Noise is extremely complex problem
  - Localization is inaccurate
    - Easy to determine Phase
    - Locating where in the winding is much more difficult
  - Biggest advantage – Easy to understand PD values and phase-resolved data
- These are major points and is not intended to be a full list

Limitations with acoustic PD measurements

- **Example1: 110kV CT, 50 Hz, 350 Pulses per cycle,**
- **Mild estimate of time between pluses ~=20mS/350/2=28uS**

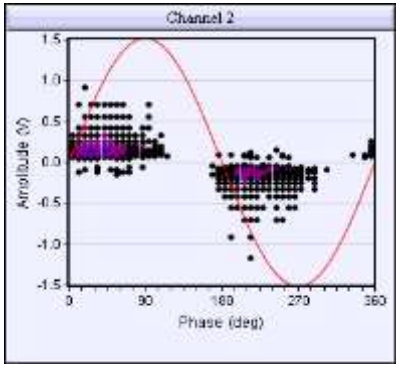


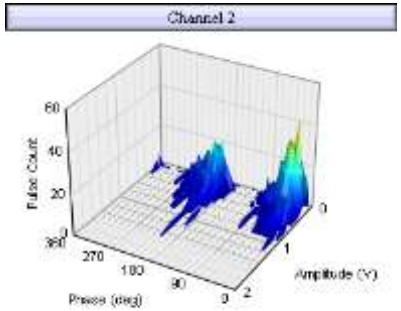
- **Example2: 110kV CT, 50 Hz, 750 Pulses per cycle,**
- **Mild estimate of time between pluses ~=20mS/750/2=13uS**



Limitations with acoustic PD measurements

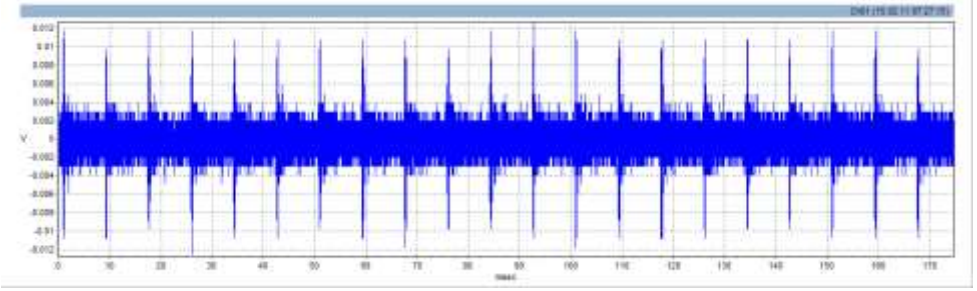
- **Example3: 69kV transformer, 60 Hz, 80 or below Pulses per cycle,**
- **Mild estimate of time between pluses ~=16.7mS/80/2=104uS**



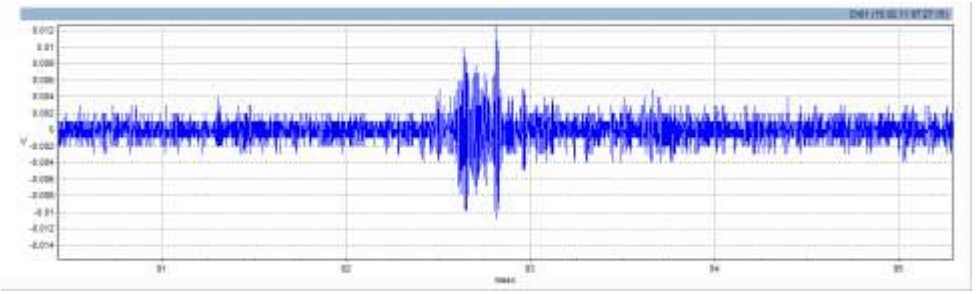


Acoustic Data Example 1

- Minor sparking, Acoustic signal

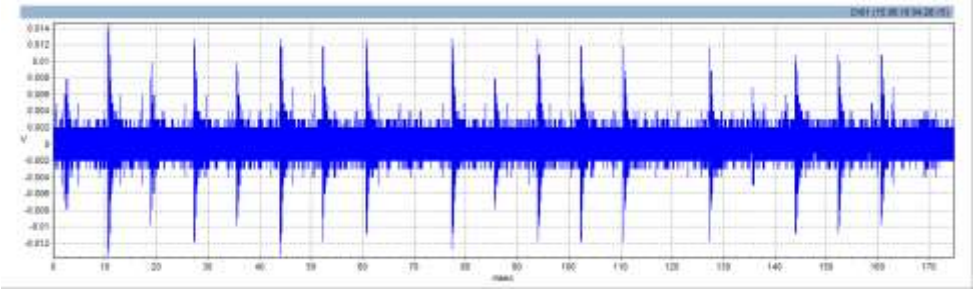


- **Zoom In**
- **250 uS per event**

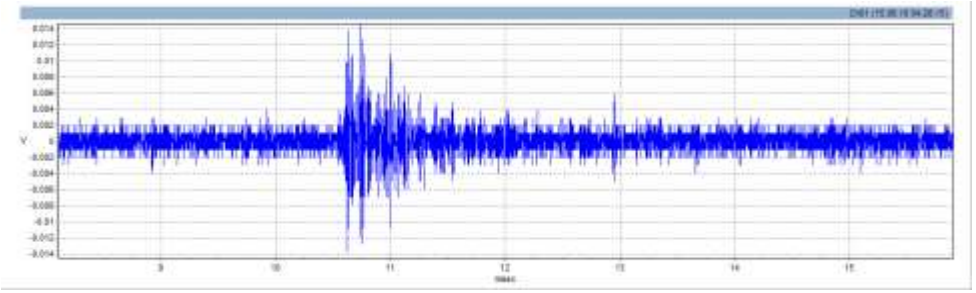


Acoustic Data Example 2

- Minor sparking, Acoustic signal



- **Zoom In**
- **500 uS per event**



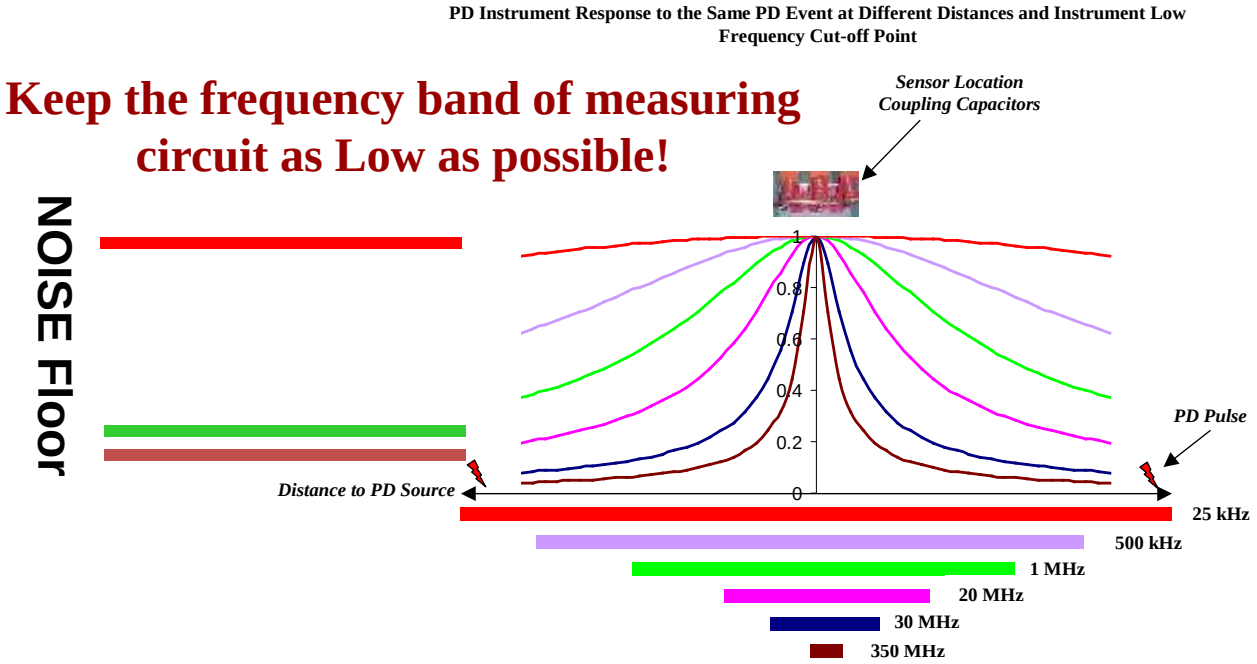
Challenges when using electrical PD in field

- **Signal Attenuation**
  - **Significant problem in rotating equipment and large transformers**
  - **Not as much a problem in switchgear/cables/buses**
  - **Attenuation is lower at lower frequency and pushes to lower frequency band**
- **In Industrial Environments, Noise exists!**
  - **Industrial noise pushes measurements to the higher frequency bands (lower noise)**
- **Traditional Factory Testing uses a lower frequency band (25 kHz - 800 kHz, Classical Band)**
  - **This is not always practical in the field.**
- **Right Frequency band**
  - **The closer to the "Classical Band" the Better and more coverage by each individual sensor.**
- **Equilibrium between Attenuation and Noise provides for greater object coverage and improves ability data quality**

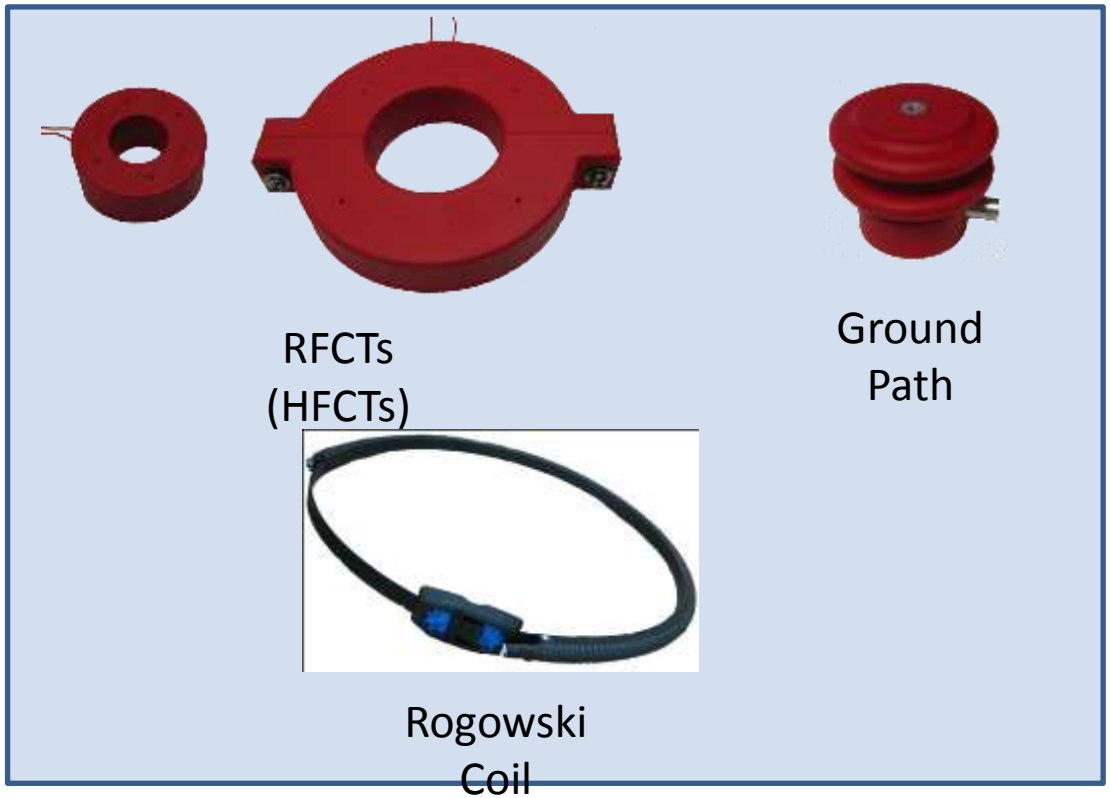
Ideal system - use both technologies

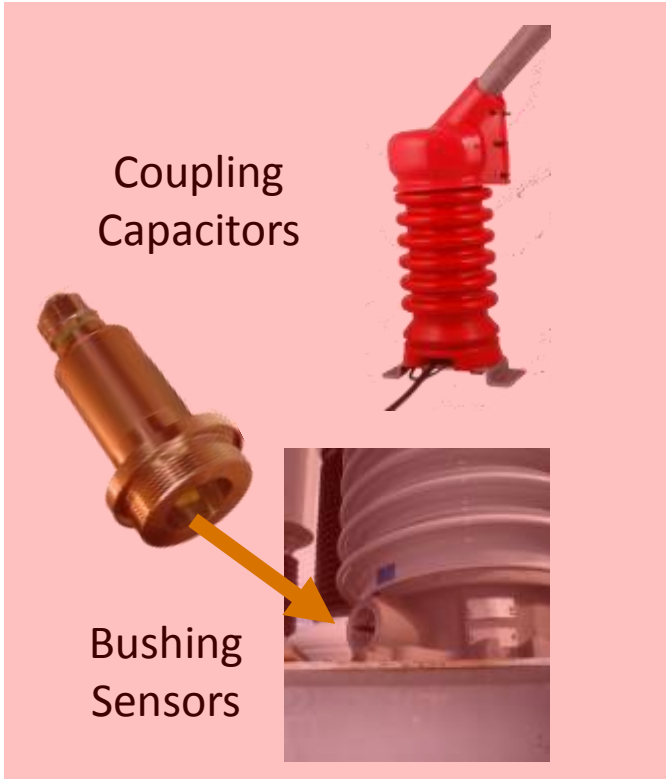
- **Why are they complimentary?**
- **Cross correlation on events**
  - **May improve Electrical PD noise immunity**
  - **May allow for easier PD localization in Acoustic even if few sensors show the event**
  - **Even a single acoustic sensor may provide valuable PD information when synchronized with the electrical data**

Signal Attenuation

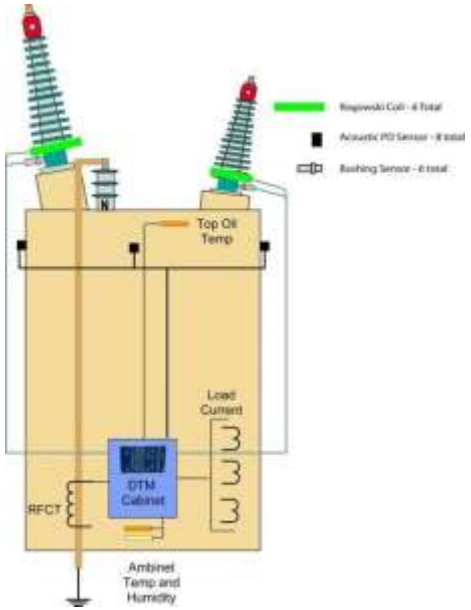


Typical electrical sensors used on transformers

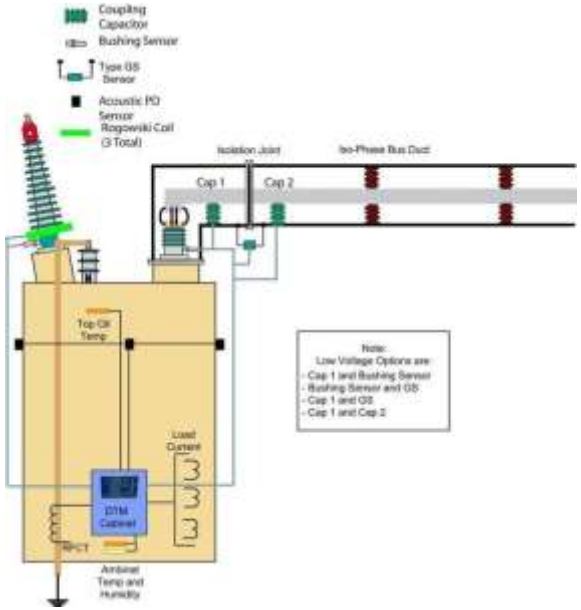




Typical electrical sensor location



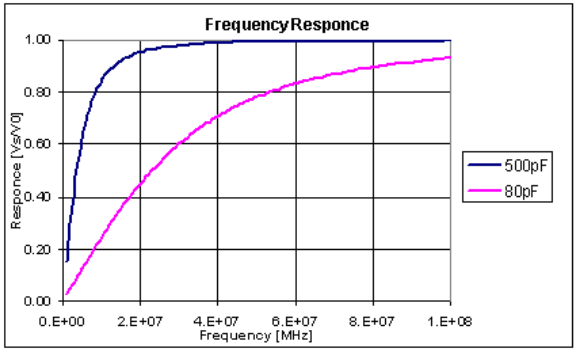
Transmission

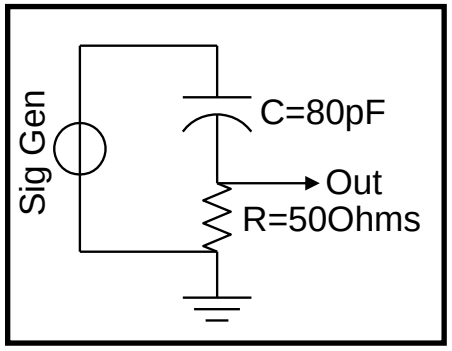


GSU

What is the frequency band of a capacitive sensor and can we control it?

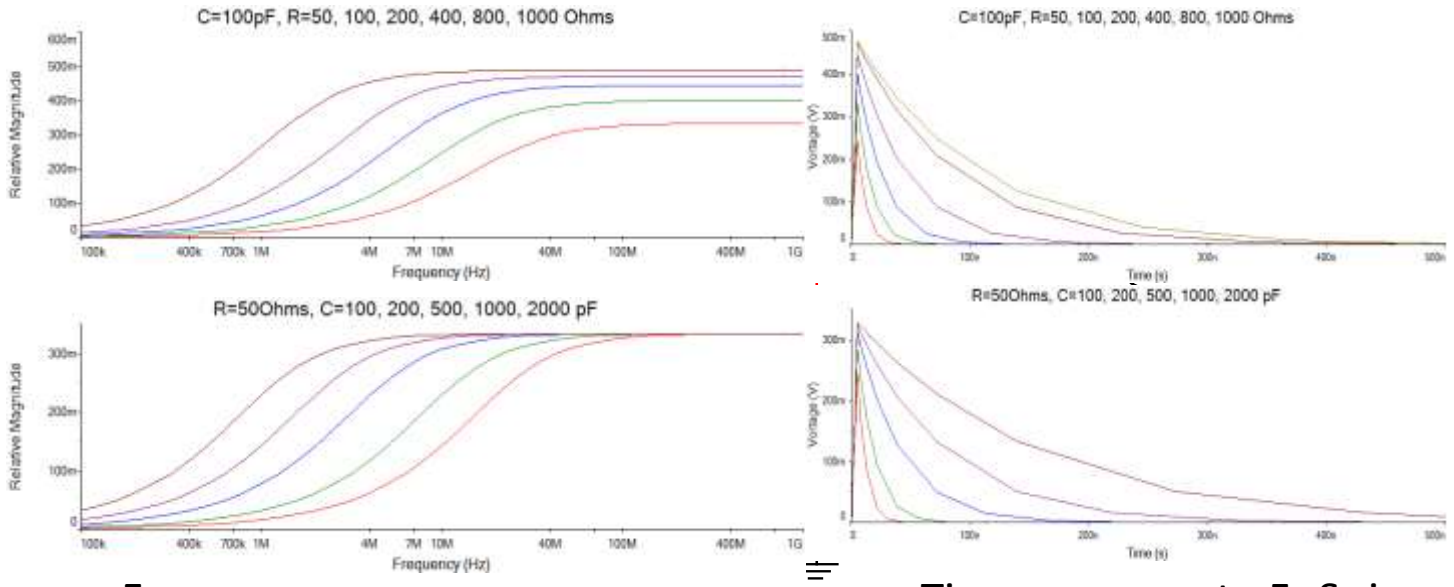
- In reality we have capacitance that is given and impedance is given – 50 Ohms coaxial cable
- What is our sensor circuit frequency band?
- A scientist will immediately estimate the frequency band as simple RC circuit. Is this right?





What is the frequency band of a capacitive sensor and can we control it?

- **A little bit better view on simple circuit**
  - **To give an impression how capacitance and impedance affect frequency band**

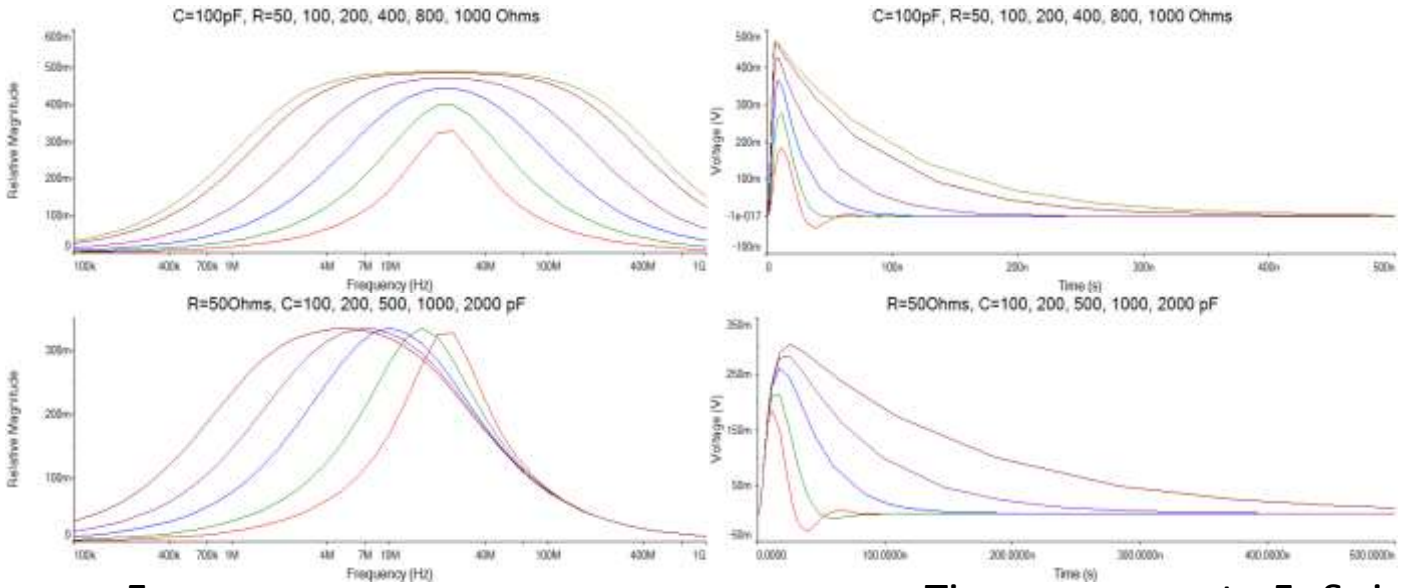


Frequency response

Time response to 5nS rise step voltage

What is the frequency band of a capacitive sensor and can we control it?

- A little bit better view on simple circuit
  - 10cm radius loop has 0.5uH. Important?



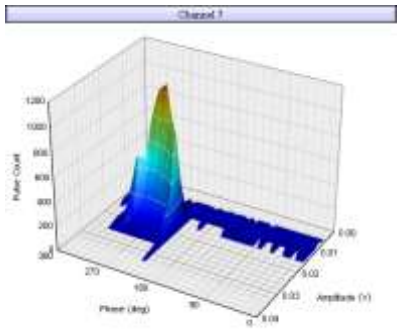
Frequency response

Time response to 5nS rise step voltage

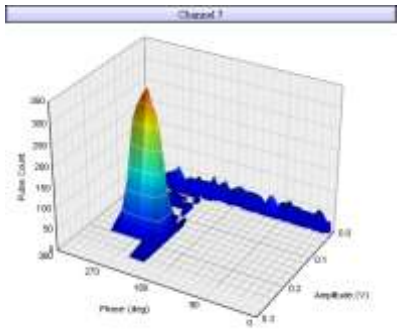
Example of what is possible with 15pF

- **The task was to get PD from cable termination that has 15pF shield electrode**
- **Sensitivity – about 0.3pC/mV**
- **Two negative corona samples with different wire diameters about 10pC and 70pC**

Small corona



Large corona



Both