



10/07/2026

LFHCAL Longboard VN Analysis

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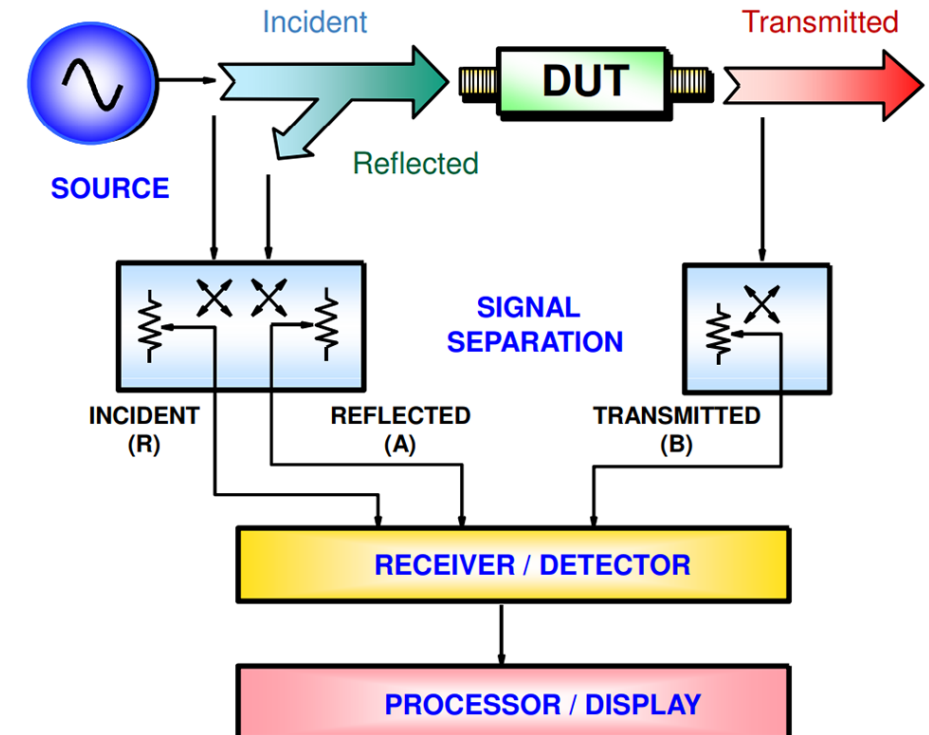
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LFHCAL Longboard Trace Properties

- The LFHCAL longboard have a very high trace density
 - 480 SiPM traces all routed to high density connector on end of board
- We want to know:
 - What is the signal degradation over long traces?
 - How much crosstalk is there between traces?
- A Vector Network Analyzer (VNA) can answer this
 - **S₂₁**: DUT response (magnitude and phase) to a known stimulus signal (usually sine sweep)
 - (**S₁₁**: stimulus signal fraction reflected back to input)
 - (VNAs with >2ports exist for simultaneous determinations)



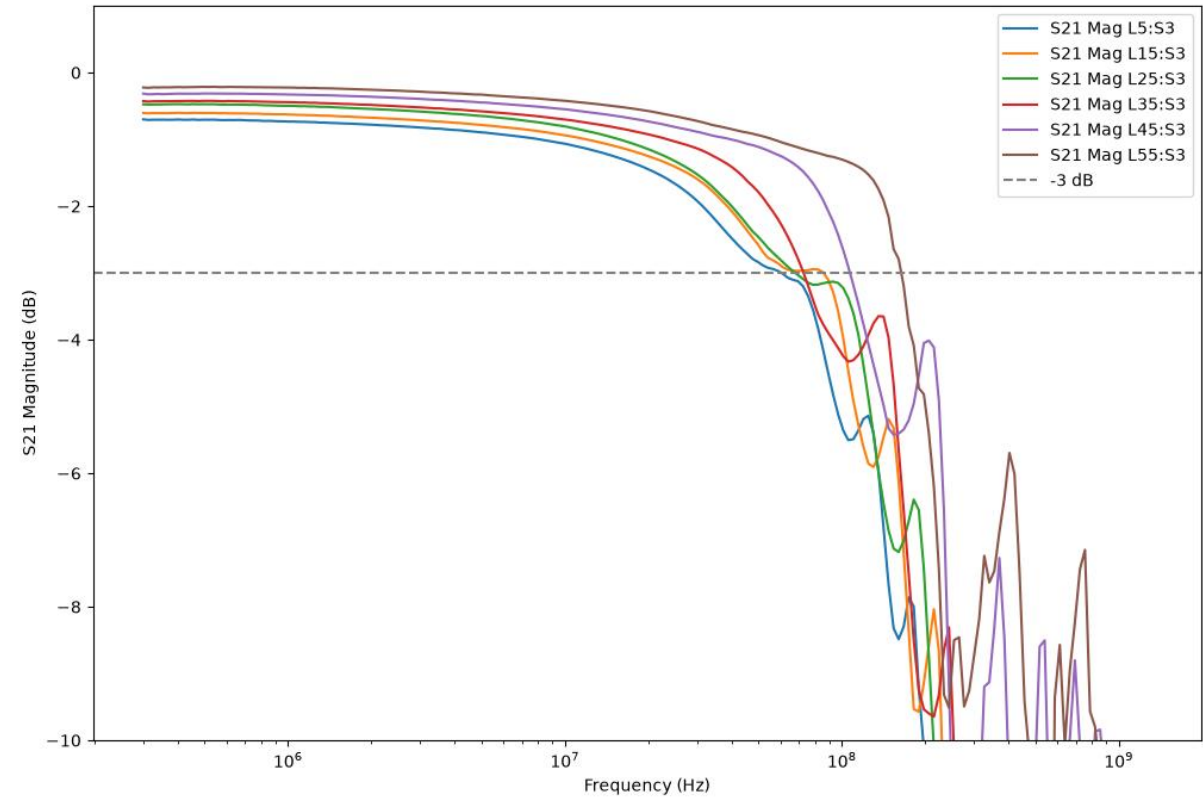
Setup and Measurements I

- Produced adapters to SMA for both sides of longboard
- Measure S21 along a trace:
 - Connect stimulus and receiver on both ends of the same trace
 - Ultimately yields transfer function of specific trace
- Expect some kind of lowpass behavior
 - every physical system not designed to be something else is generally a lowpass filter ;-)



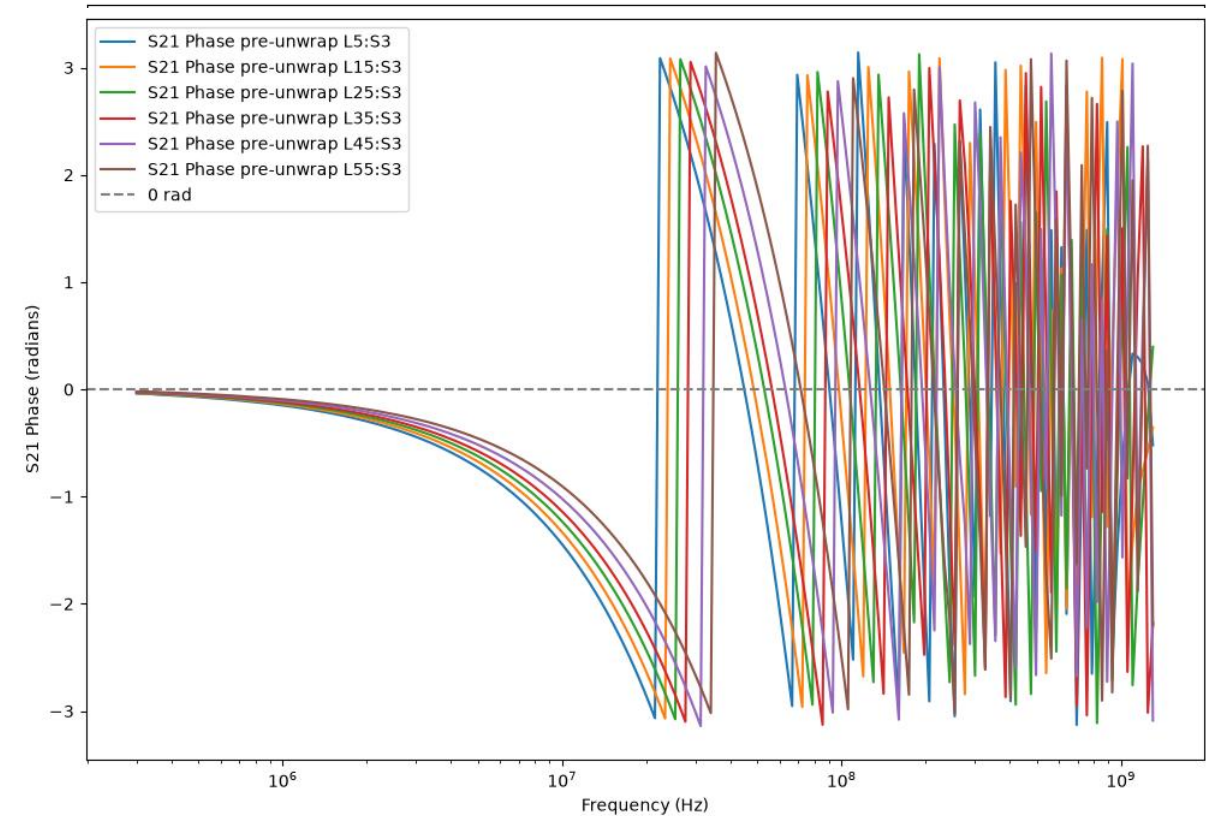
Magnitude Along Trace

- Some DC (ohmic) loss up to -1dB depending on trace length
- ~60-100MHz -3dB lowpass filter
 - Not unexpected



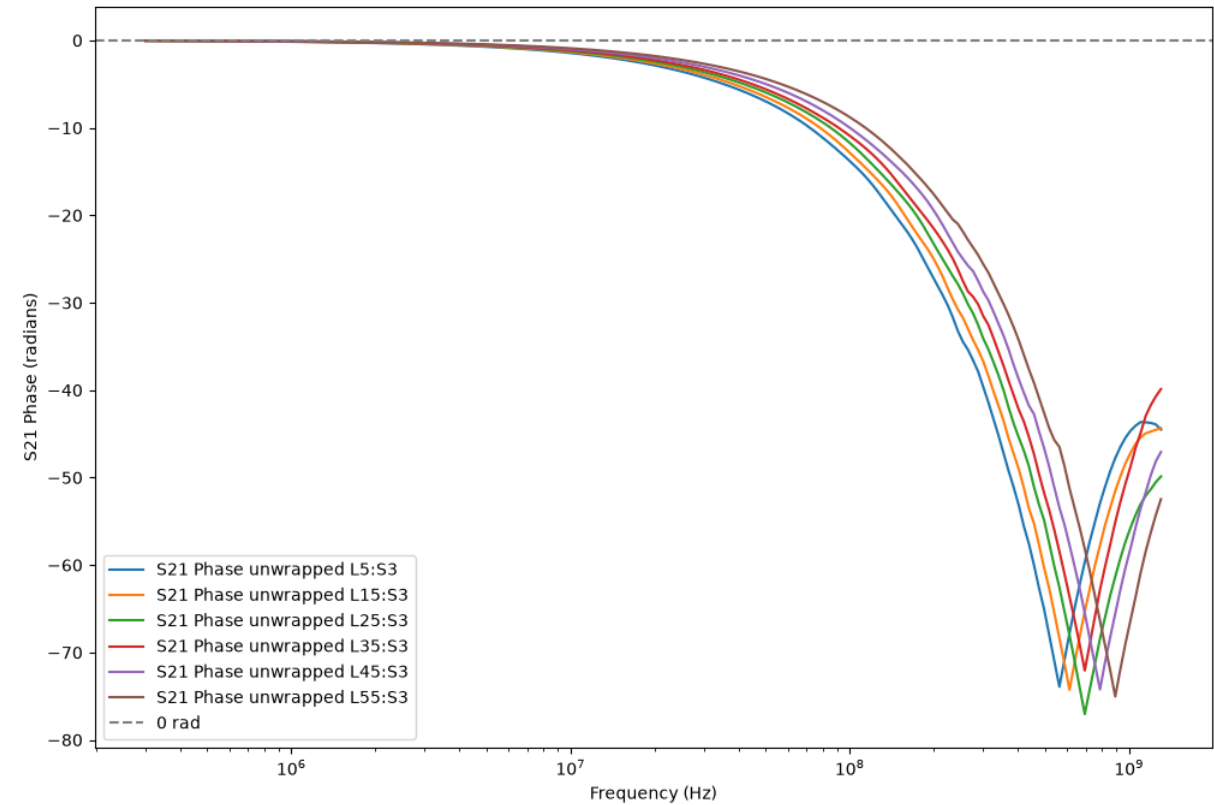
Phase Along Trace

- Phase only measured between $\pm\pi$
- Can be unwrapped though
 - Need more points for correct unwrapping
- OK, but what can we do with this?



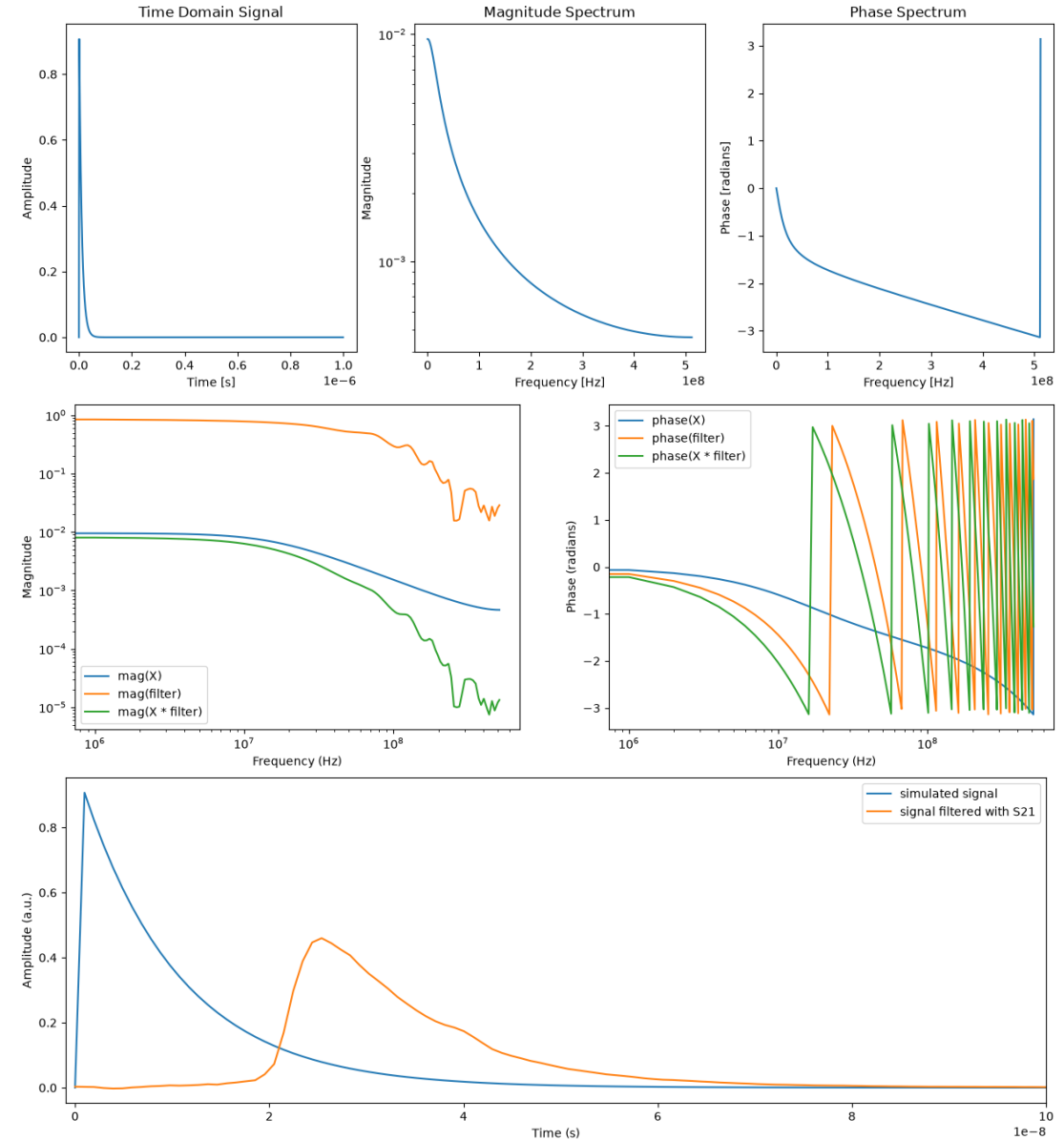
Phase Along Trace

- Phase only measured between $\pm\pi$
- Can be unwrapped though
 - (Need more points for correct unwrapping at high frequencies)
- OK, but what can we do with this?



Applying Measured Transfer Function to Simulated Signal

- Simulate (or measure) raw signal -> get Fourier Transform -> apply measured transfer function -> inverse FT
- Simulated signal: $\exp(-t/10\text{ns})$
- Compute Fourier Transform
- Apply measured transfer function
 - Multiply complex coefficient
 - Multiply signal magnitudes, add phases
- Compute Inverse Fourier transform
- Result: initial signal barely changes except delay
 - The longboard does not meaningfully contribute to signal length on HGCROC

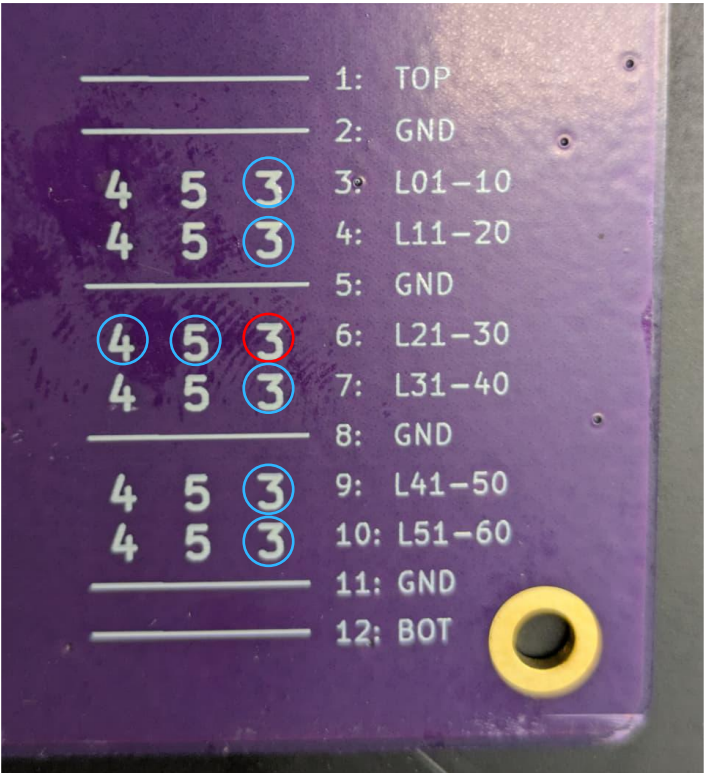
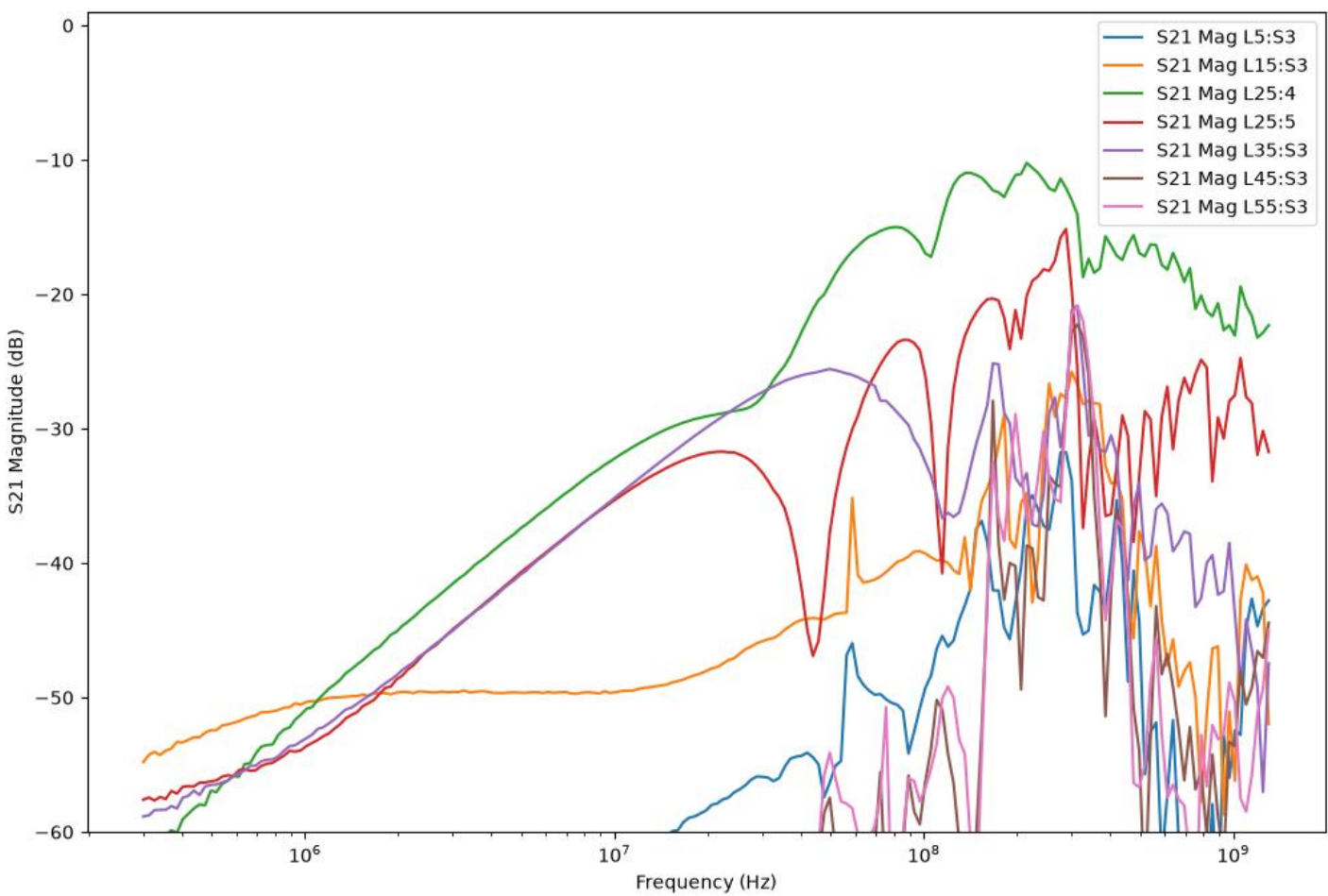


Setup and Measurements II

- Measure S21 between (neighboring) traces:
 - Connect stimulus on trace A, connect receiver to trace B
 - Terminate both open ends with 50R !
 - Yield crosstalk between traces
 - Expect some kind of bandpass
 - No crosstalk for DC signals, no output for very high signals
- Stimulus always in **L25:S03**
- Receiver on **geometrically surrounding traces**

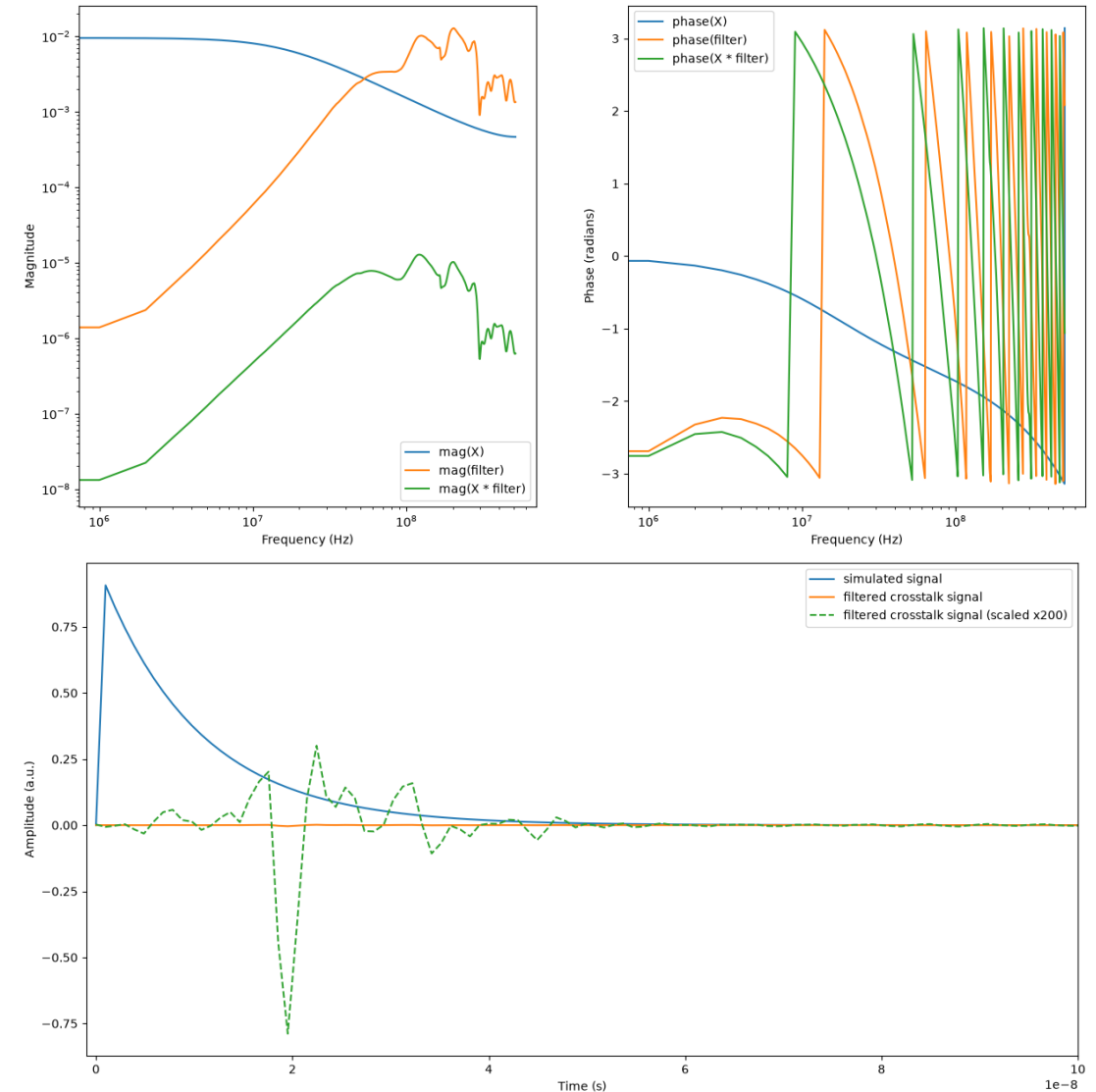


Setup and Measurements II



Applying Measured Transfer Function to Simulated Signal

- Stimulus into L25:S05, xtalk to L25:S03
 - Same layer, neighboring trace
- Simulate (or measure) raw signal -> get Fourier Transform -> apply measured transfer function -> inverse FT
- Result: longboard crosstalk is negligible in practice terms?!



Summary

- Unless we did (or interpreted) something fundamentally wrong:
 - The longboard trace effective lowpass does not meaningfully contribute to the signal length we see on the HGCROC
 - That does **not** mean that the added input capacitance of the longboard trace does not contribute
 - Electrical crosstalk between neighboring traces is up to -15dB (ish), but only in a narrow frequency band.
 - Simulating the effect shows no practical crosstalk.