

# CAT-5: A New Approach

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Intel

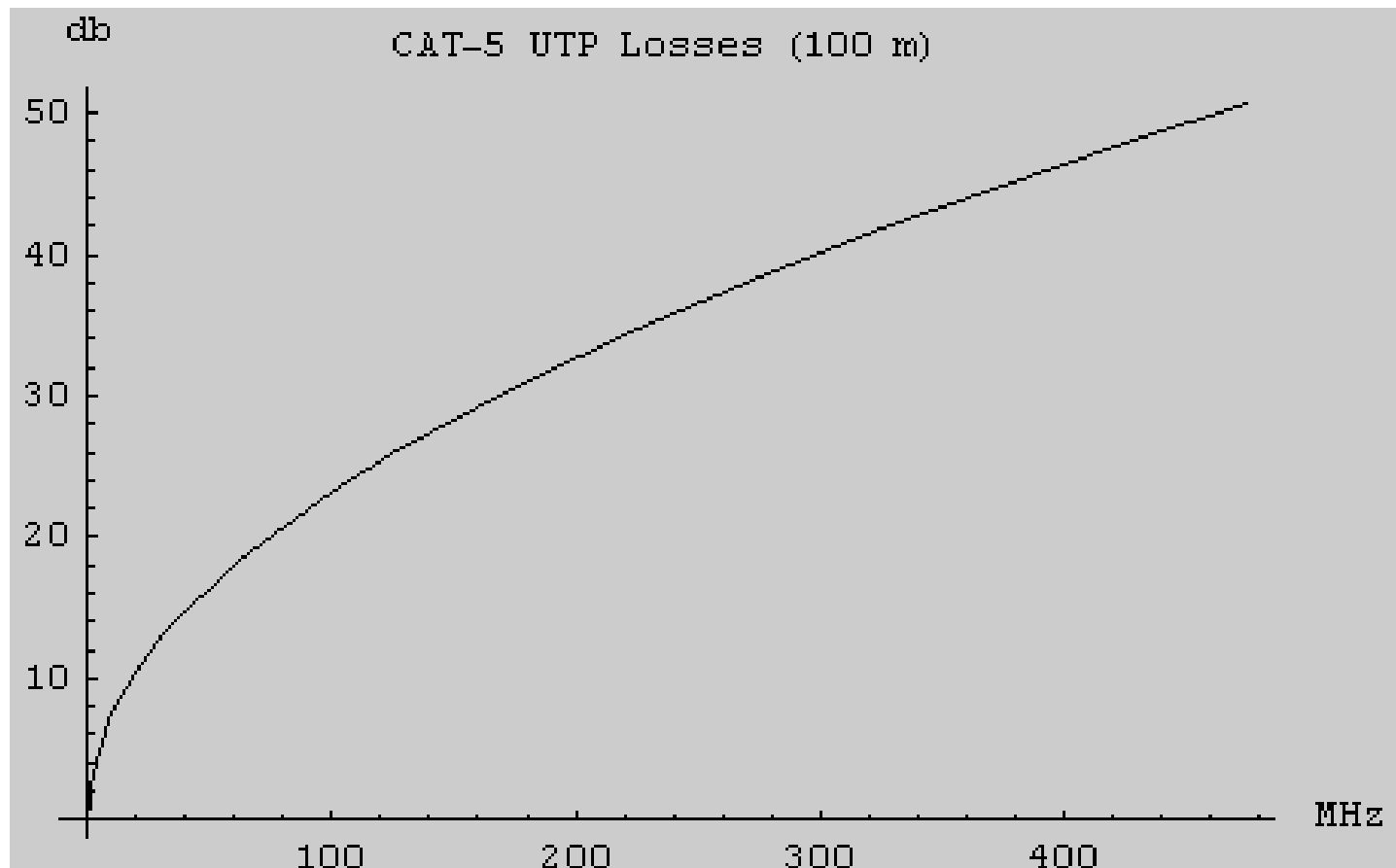
# Overview

- The goal to is define a transmitter that works over 0-100 meters of CAT-5 with a simple receiver
- No adaptive equalizers
- Simplified electrical specification

# Rationale

- NRZ binary level encoding + 8b10b
  - Optimized for eye at 100 meters
    - Amplitude versus  $f$  equalized
    - Phase shift versus  $f$  equalized
  - Allow large ringing at  $\ll$  100 meters lengths
- The receiver must tolerate ringing (e.g., clips the signal)
  - Receiver can have a good termination network

# CAT-5 Loss Characteristics



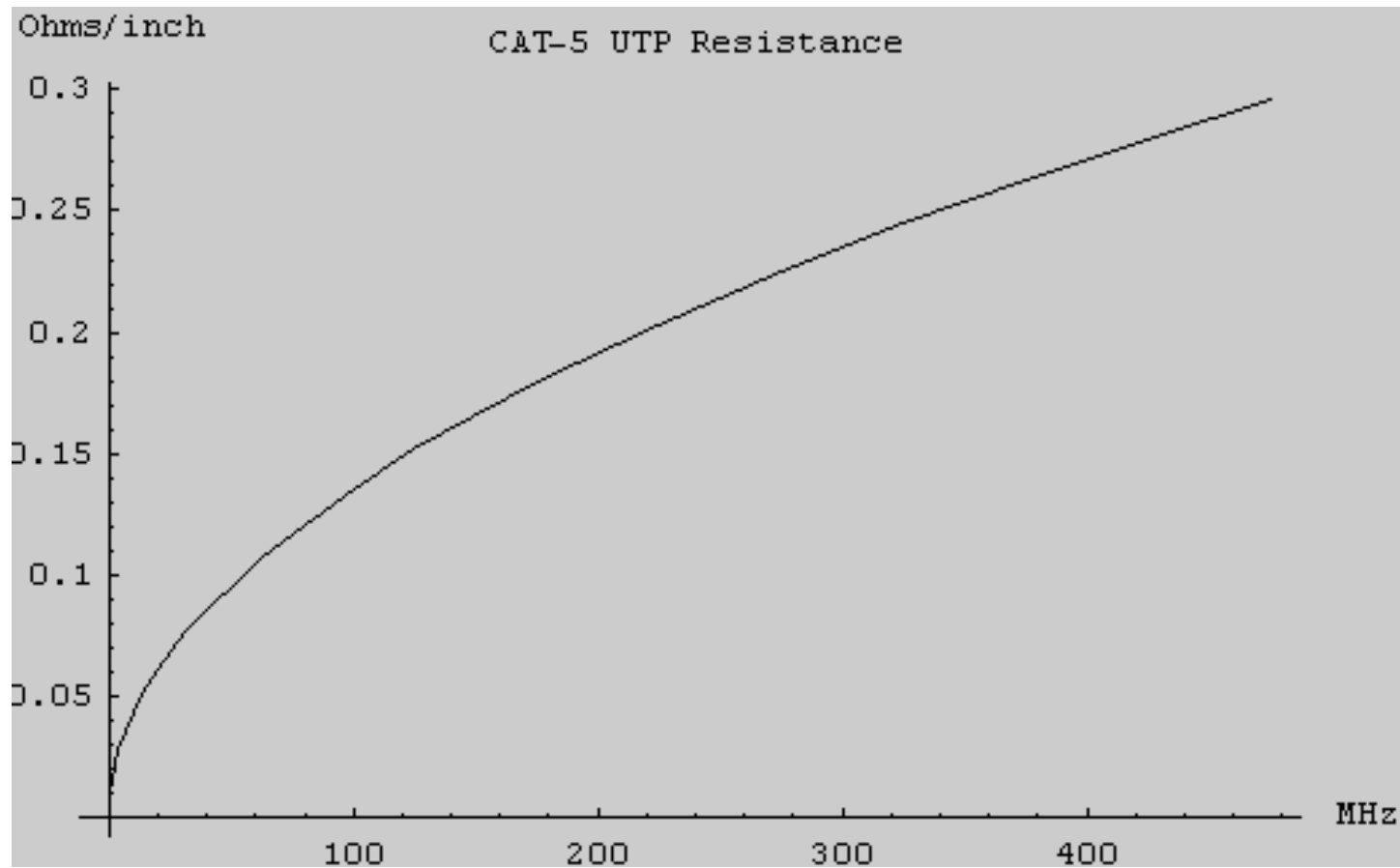
# Cable Equations

$$\partial_z v[z, t] == -r i[z, t] - l \partial_t i[z, t]$$

$$\partial_z i[z, t] == -g v[z, t] - c \partial_t v[z, t]$$

$$r_{\text{internal}} = \begin{cases} r_{\text{dc}}(1 - i f / f_0), & f \leq f_0 \\ r_{\text{dc}} \sqrt{f / f_0} (1 - i), & f > f_0 \end{cases}$$

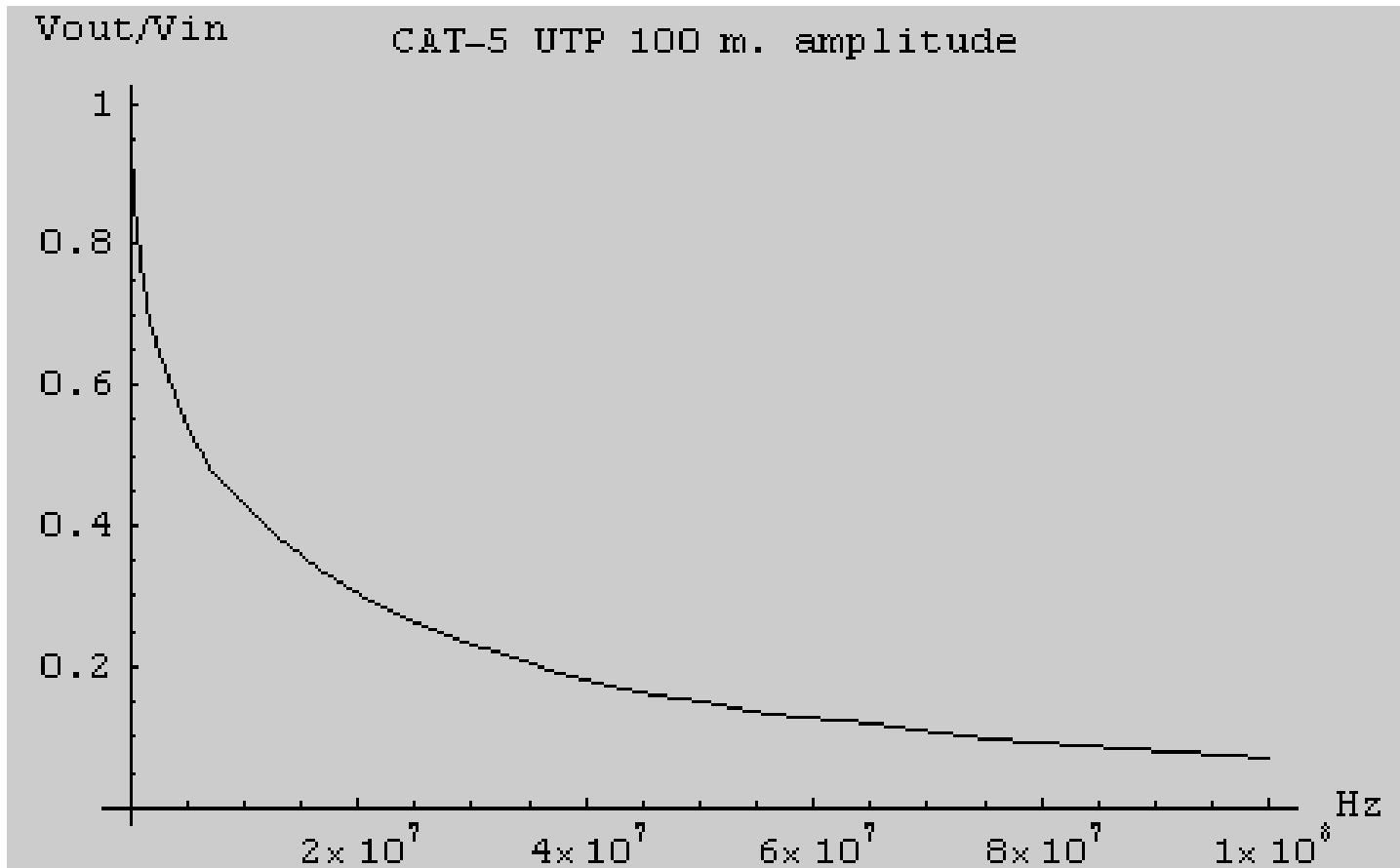
# Loss Parameter



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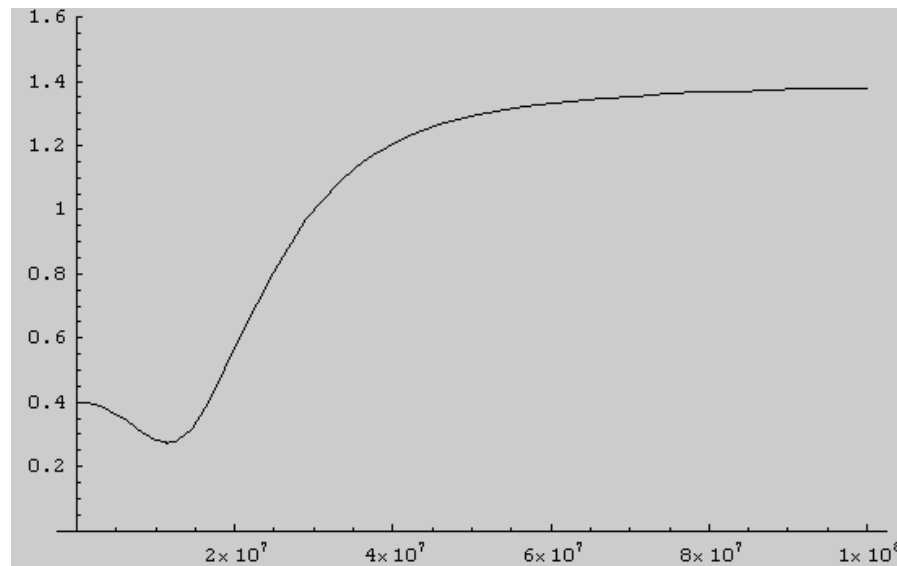
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# Voltage Transfer



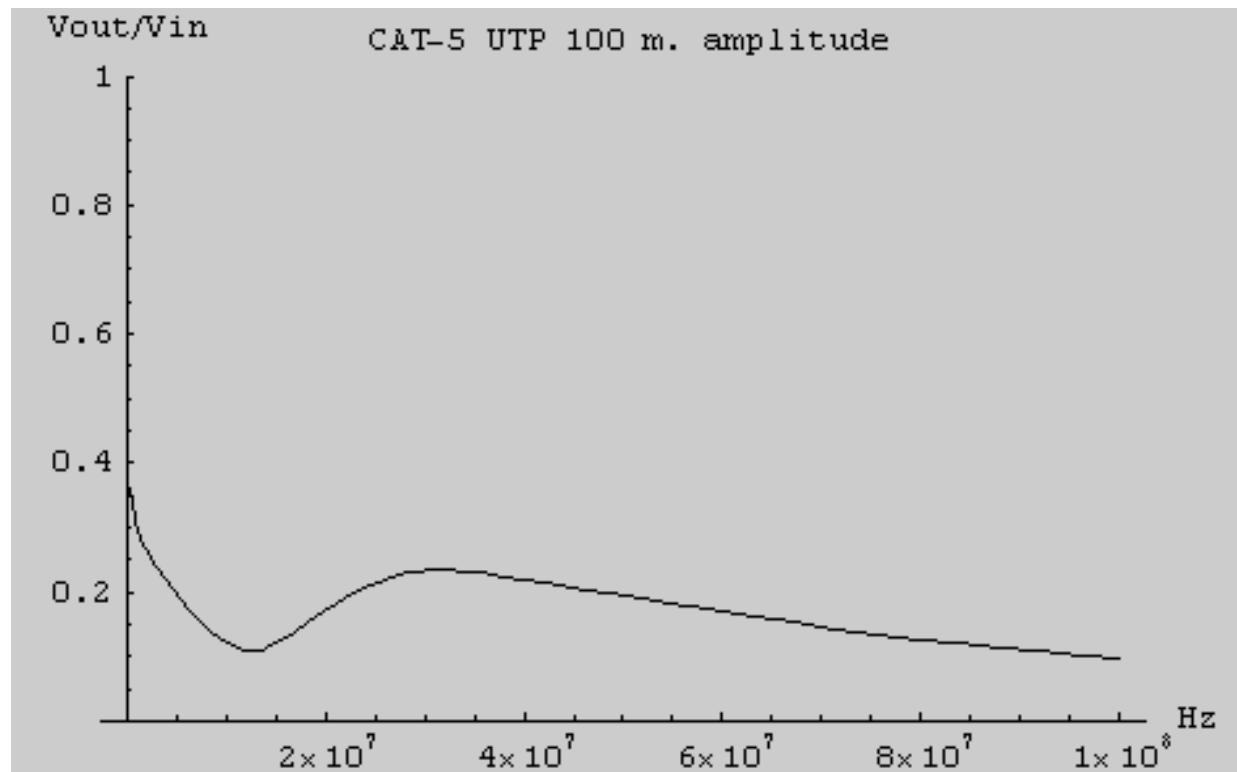
# Amplitude Correction Filter

N=2 Butterworth + 0.4 Leakage Filter

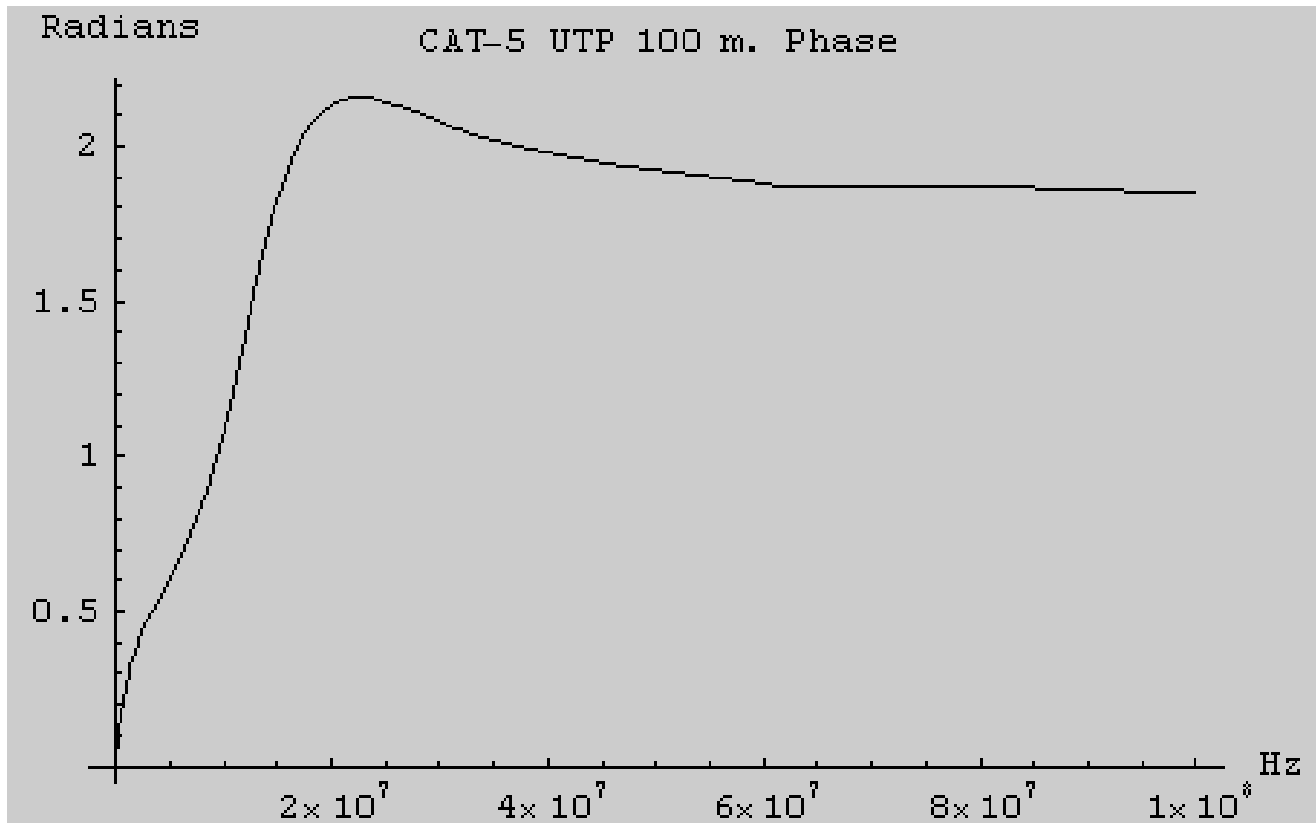


$$\frac{2 + \frac{1 f}{6250000 \sqrt{2}} - \frac{7 f^2}{6250000000000000}}{5 \left( 1 + \frac{1 f}{12500000 \sqrt{2}} - \frac{f^2}{6250000000000000} \right)}$$

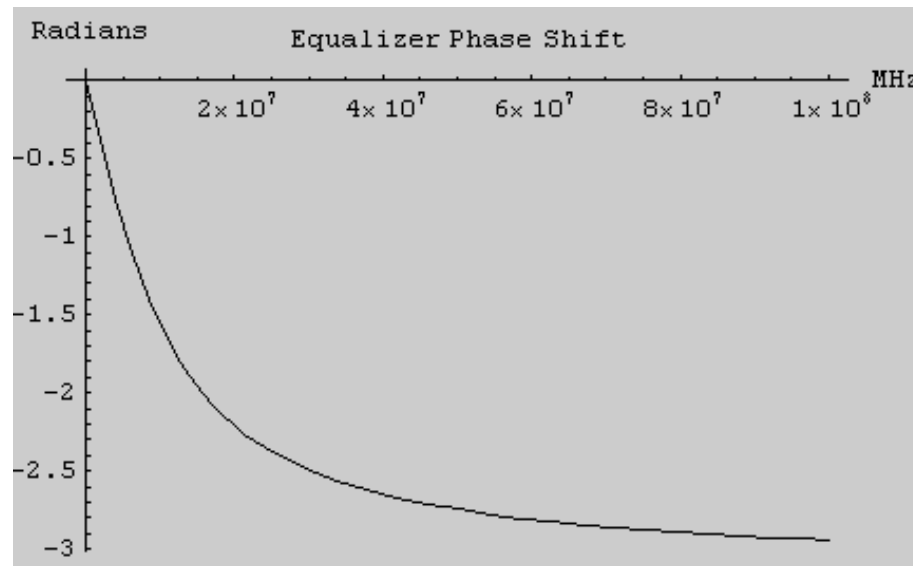
# Post Amplitude Correction



# Phase Problems Remain



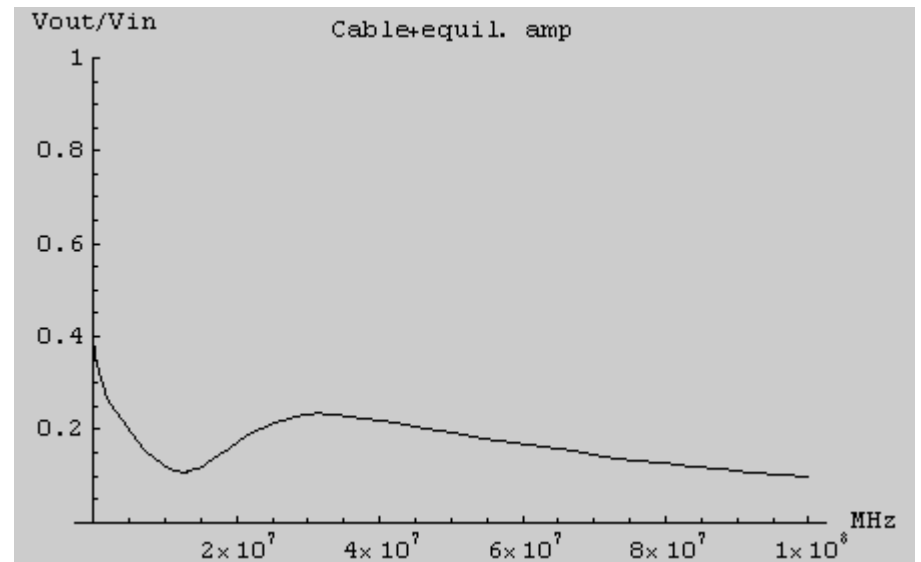
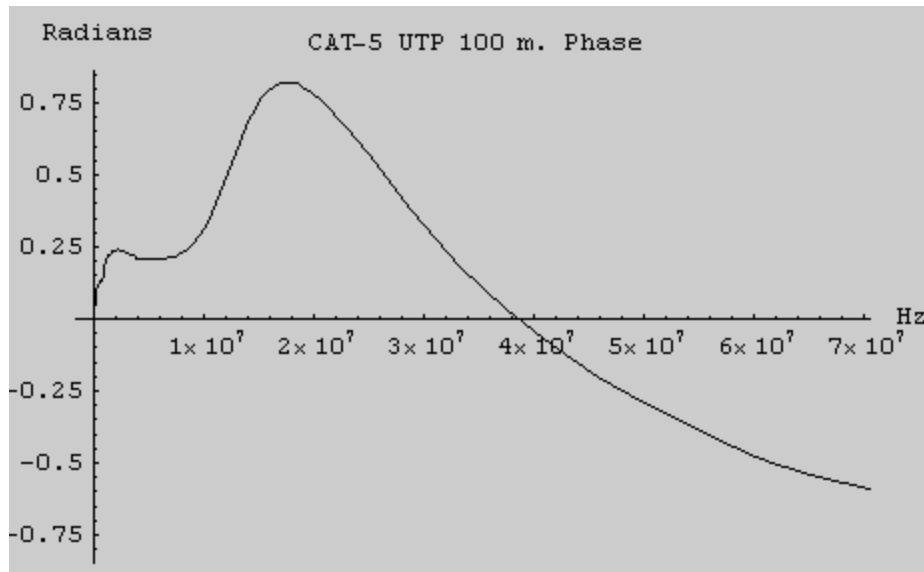
# All Pass Filter for Phase Compensation



$$\frac{\text{cut} - I \omega}{\text{cut} + I \omega}$$

$$\text{cut} + I \omega$$

# Post Amp+Phase Equilization

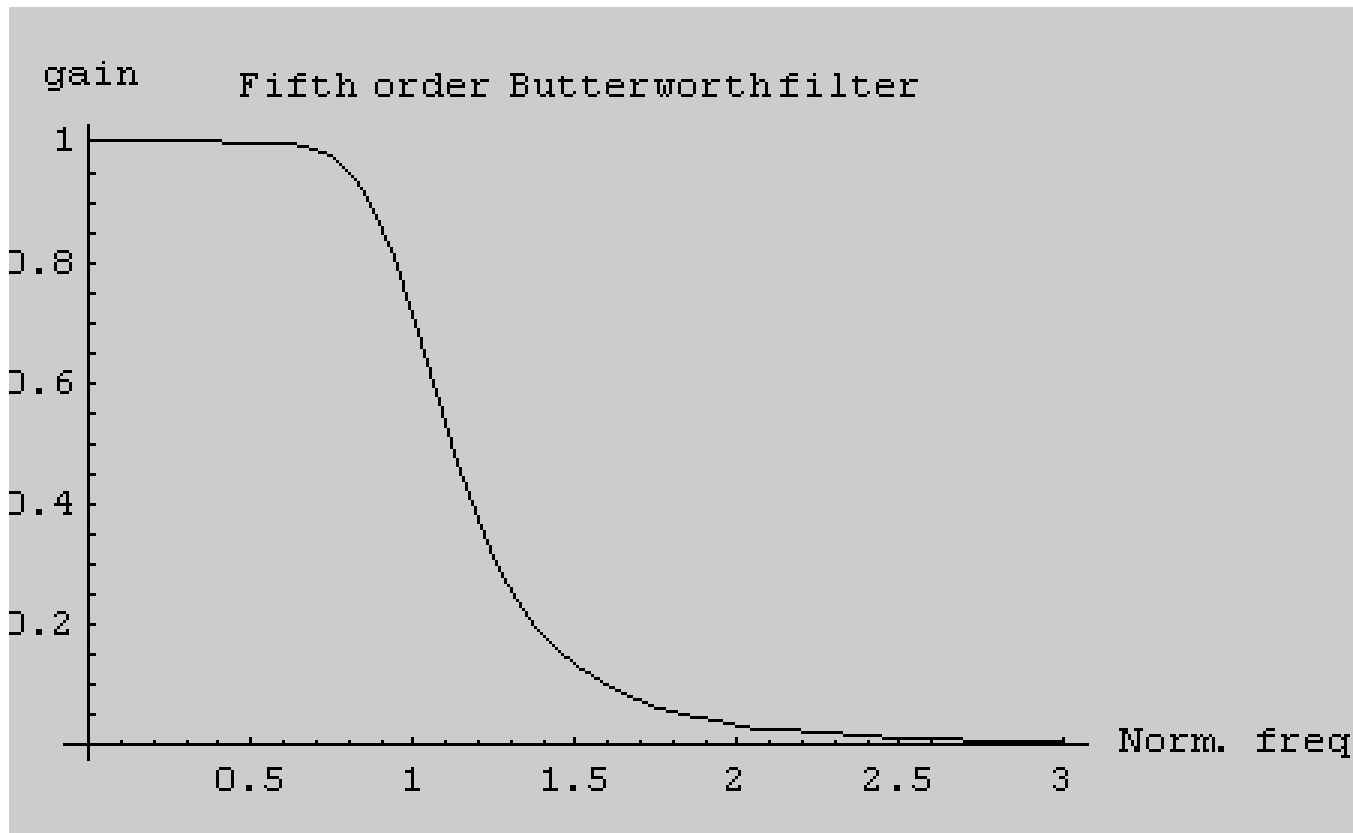


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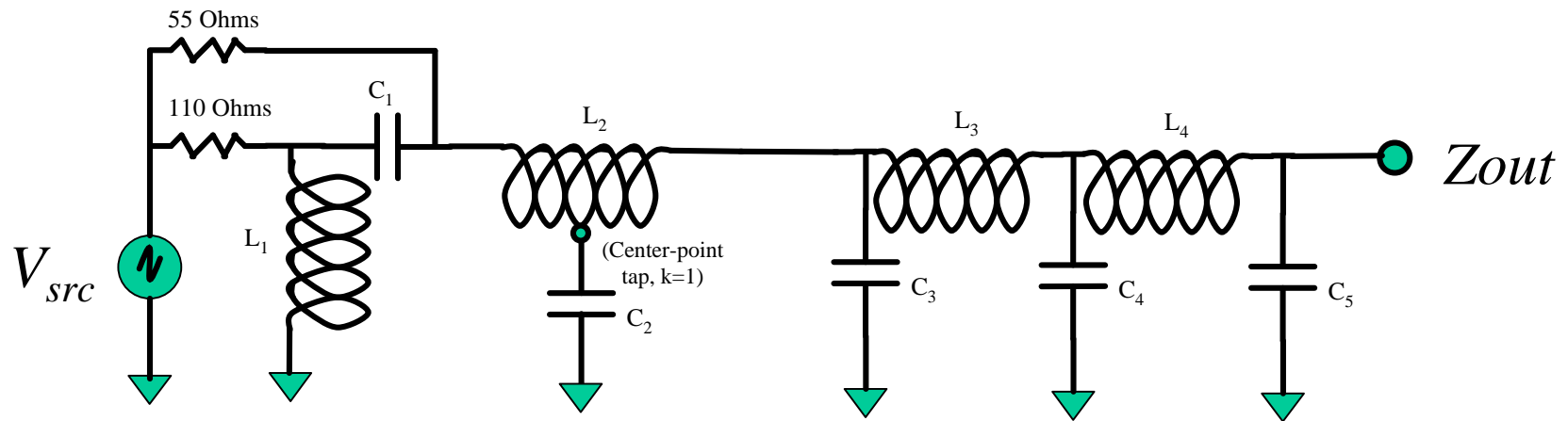
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# Removal of High Frequencies



# Single-ended circuit

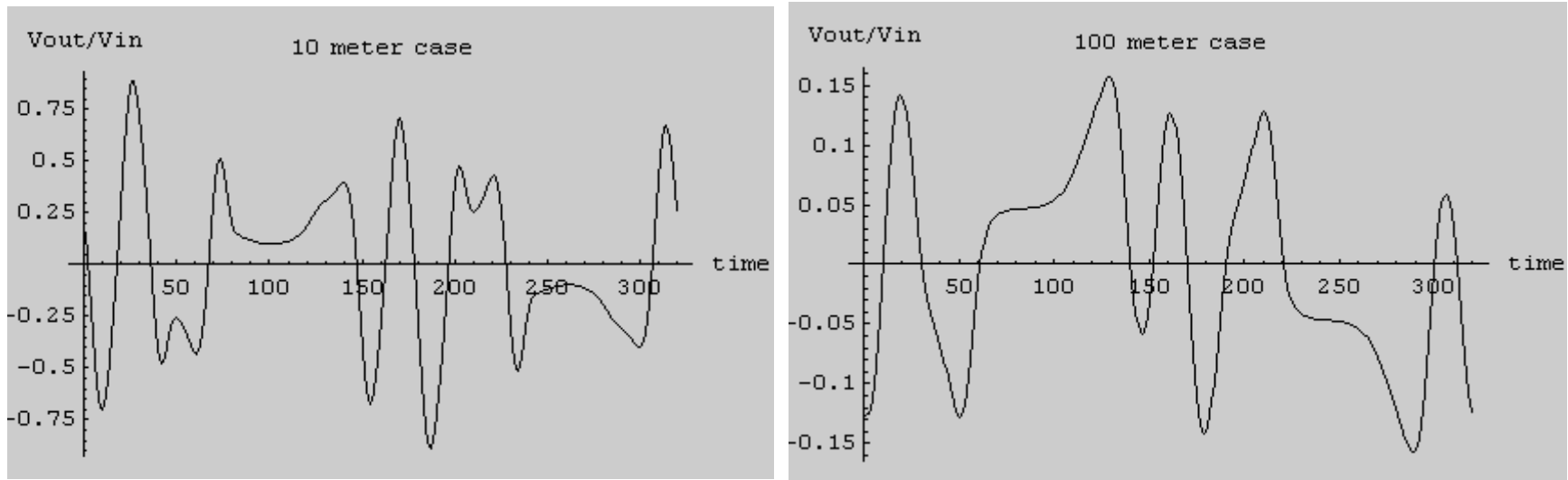


$$\begin{aligned}C1 &= 41 \text{ pF} \\L1 &= 500 \text{ nH} \\C2 &= 120 \text{ pF} \\L2 &= 1.4 \text{ } \mu\text{H}\end{aligned}$$

$$\begin{aligned}C3 &= 7.2 \text{ pF} \\L3 &= 230 \text{ nH} \\C4 &= 23 \text{ pF} \\L4 &= 230 \text{ nH} \\C5 &= 7.2 \text{ pF}\end{aligned}$$

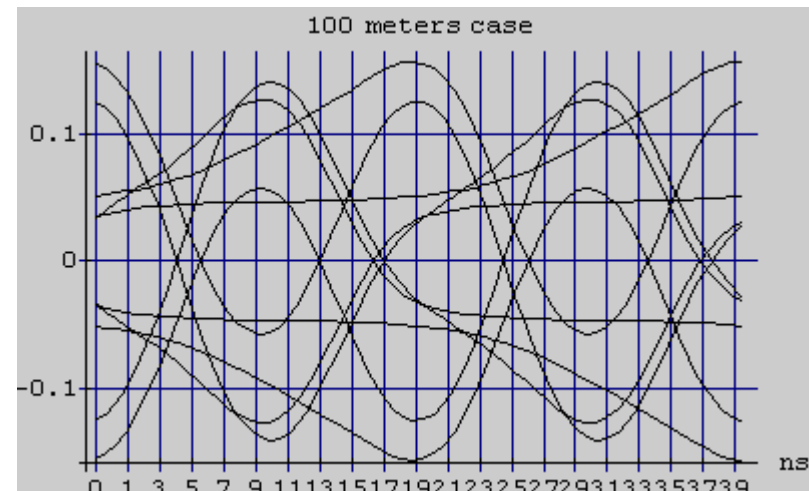
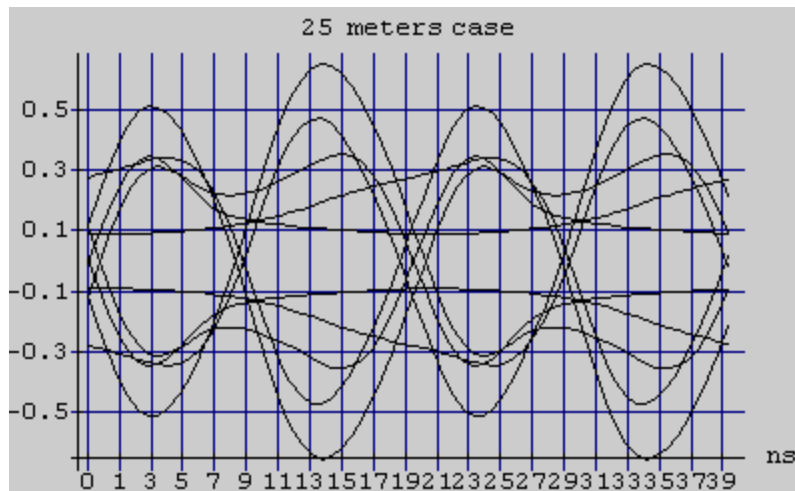
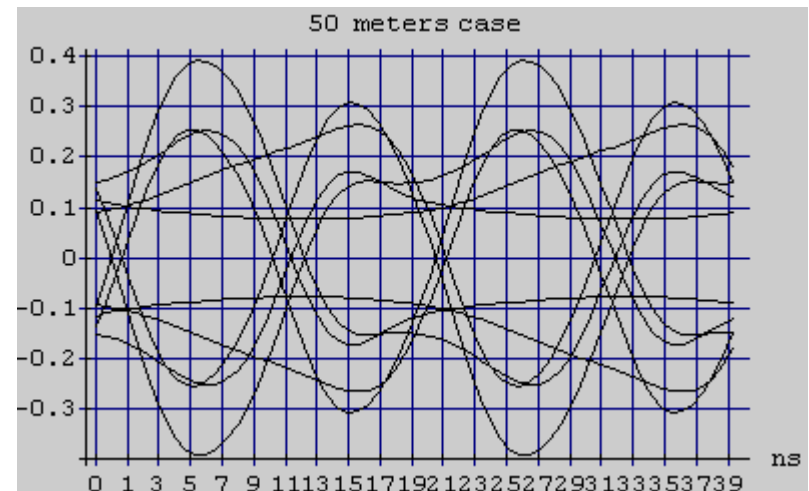
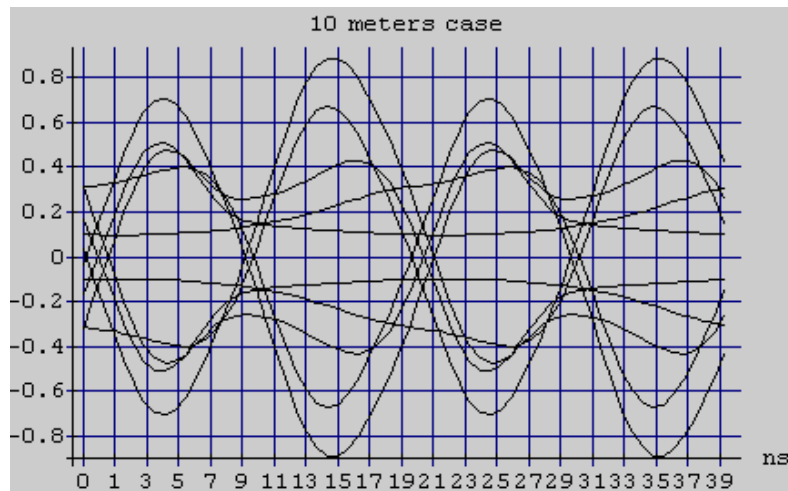
# Test Sequence

{1,1,0,0,0,0,0,1,0,1,0,0,1,1,1,1,1,0,1,0}

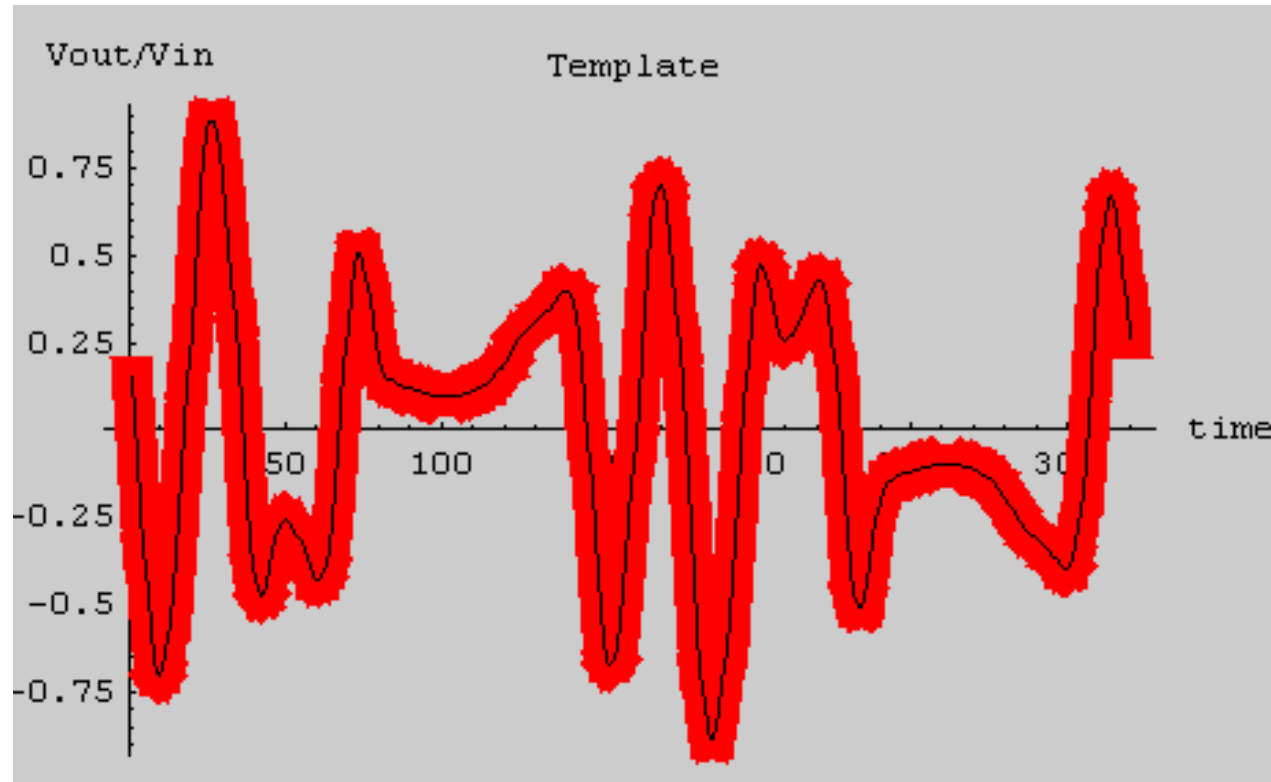


All filters in place, realistic cable transfer function used

# Simulated Eye Diagrams



# Specification via Template



As measured at the end of a 1 meter long stub CAT-5 cable