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Detection of Passive Intermodulation in Drop Wiring by Burst Transmission Analysis

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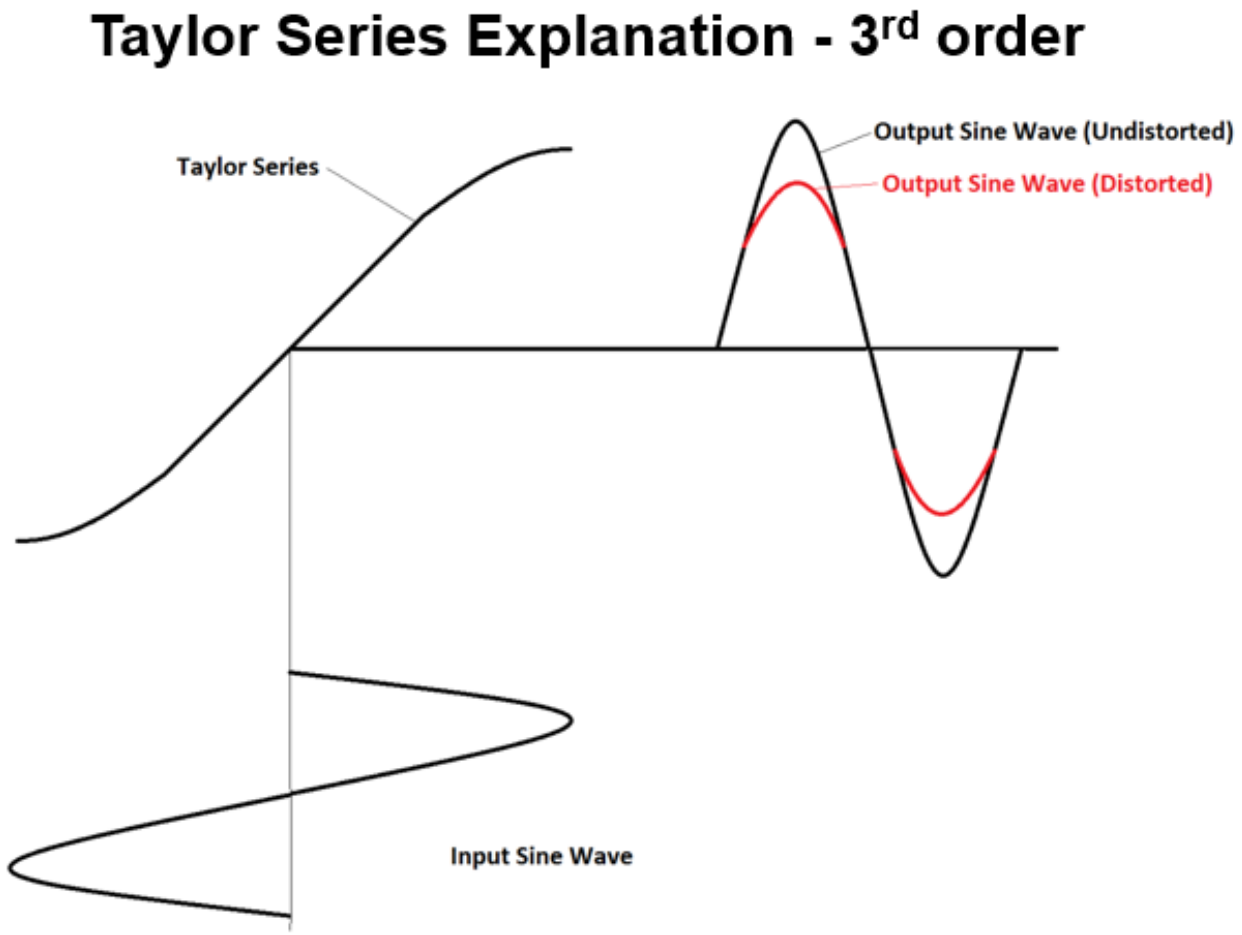
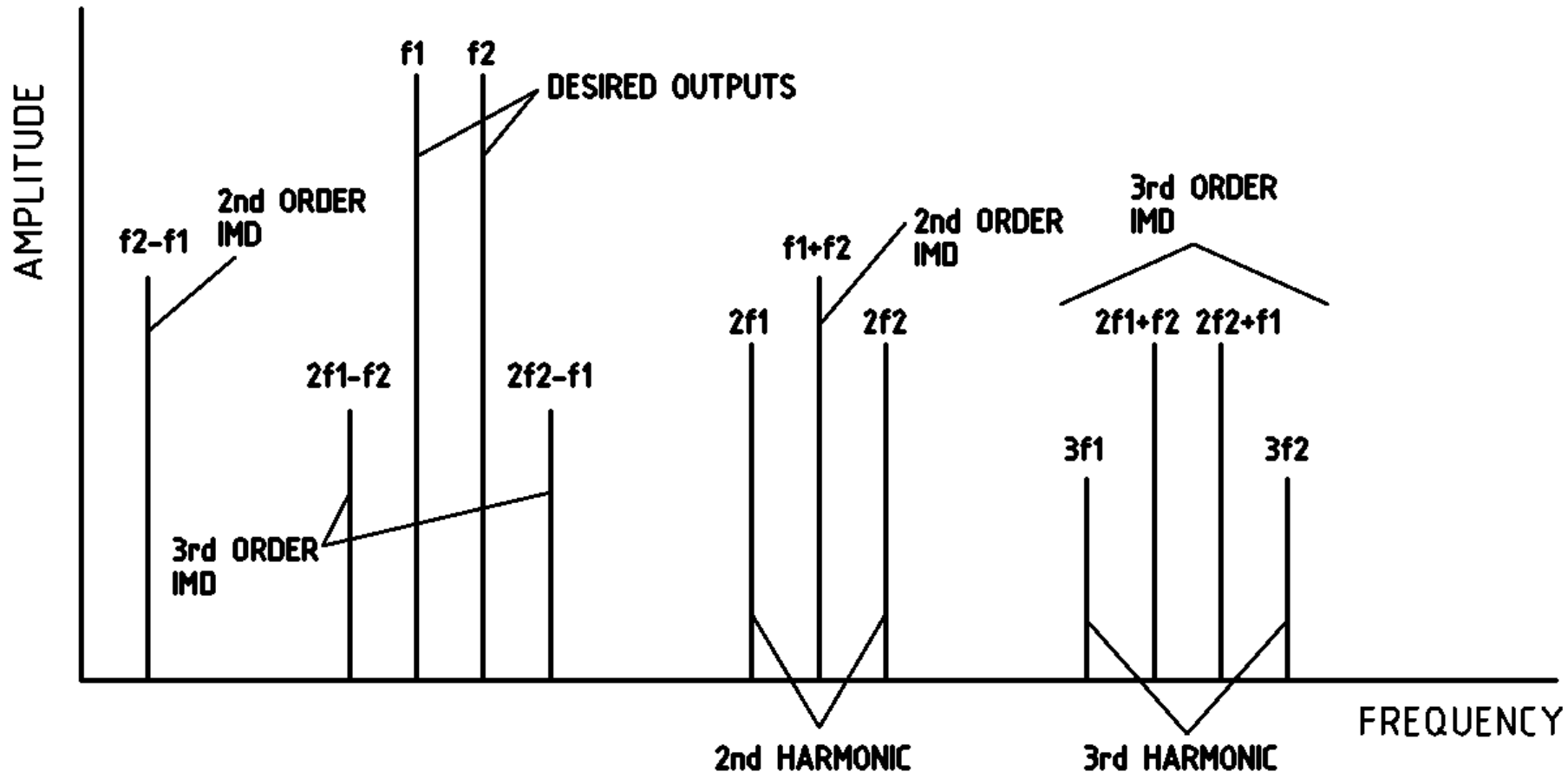
Nonlinear Distortion in Cable Networks

- Cable has linear and nonlinear distortions.
- Linear can be eliminated with an adaptive equalizer
- Nonlinear is very hard to eliminate, and generally it is best not to create it in the first place
  - Push-pull amplifiers make nonlinear distortions, but push-pull design cancels 2nd harmonic. Lowering distortion causes more power consumption in class A amplifiers.
- Taylor series polynomial can be used for analysis:
- $Eout = A \cdot Ein + B \cdot Ein^2 + C \cdot Ein^3 + \ldots$
  - A is gain, B is 2nd order distortion, C is 3rd order distortion

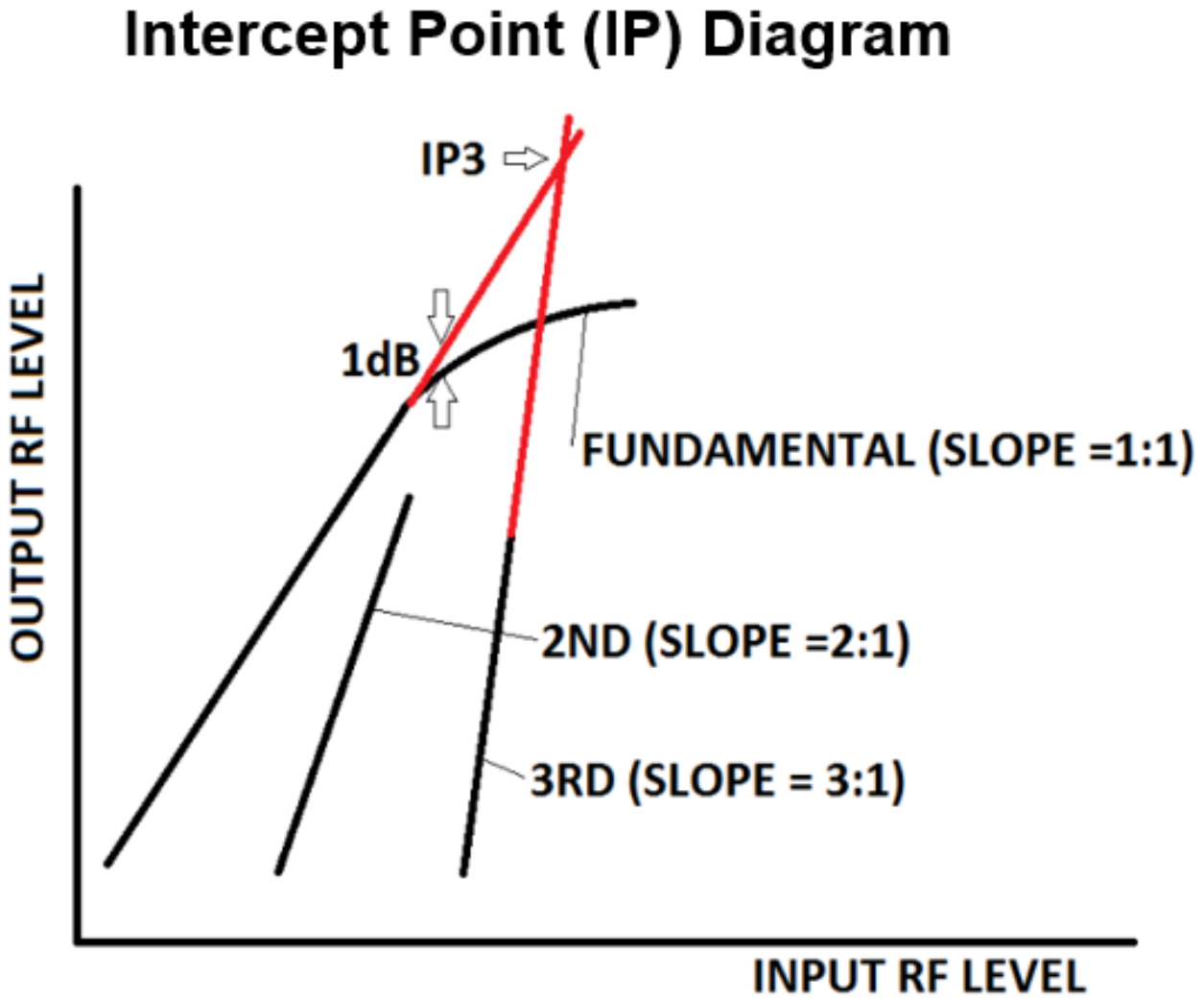
Taylor Series Polynomial Model



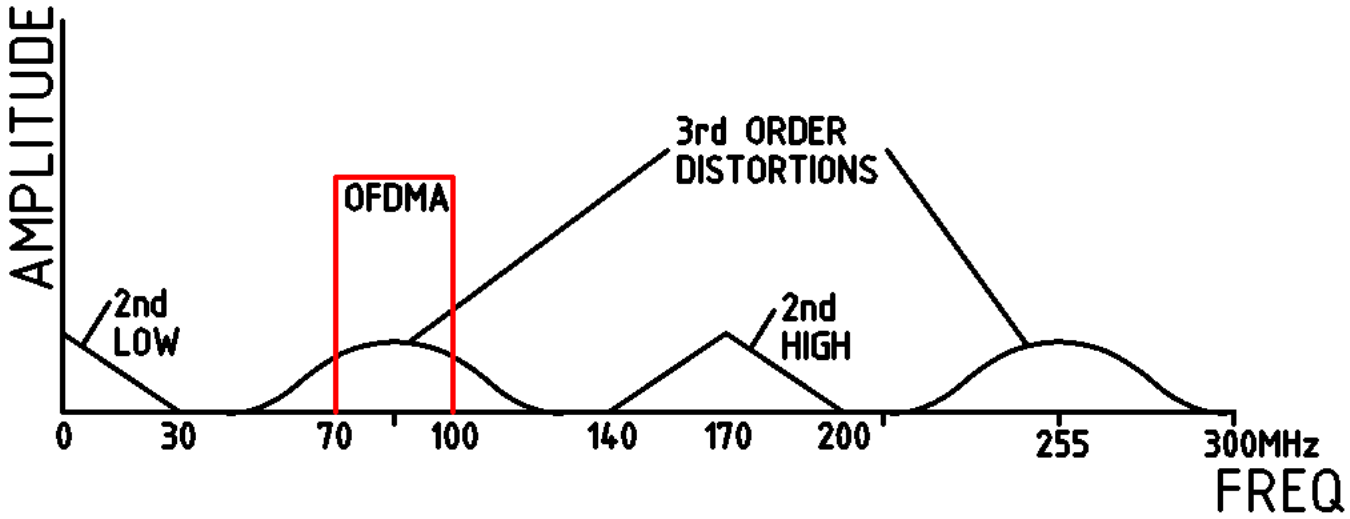
How Two Sines Waves Get Inter-Modulated



Distortion Levels vs. Output Level

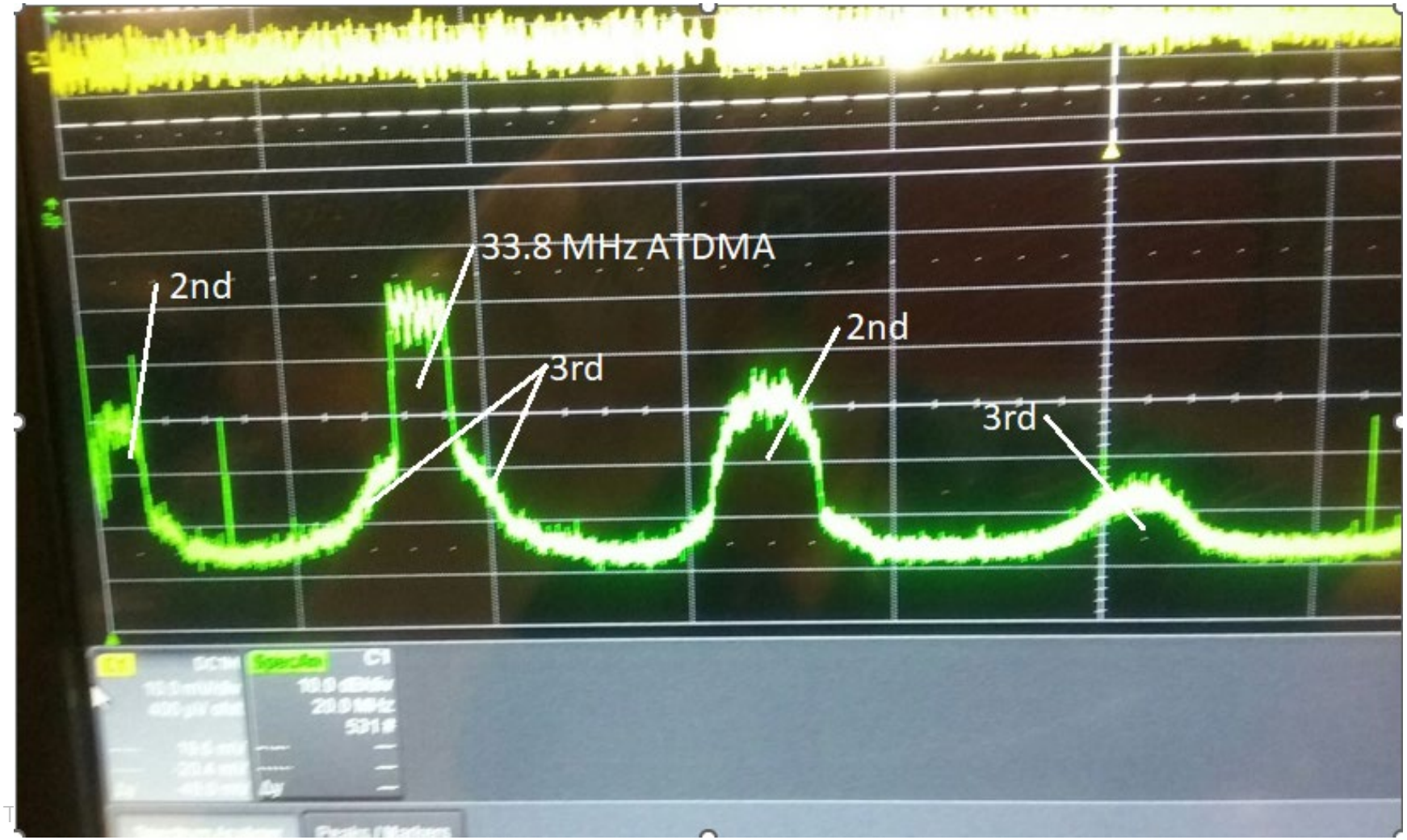


What Distortions We Expect on Upstream Plant

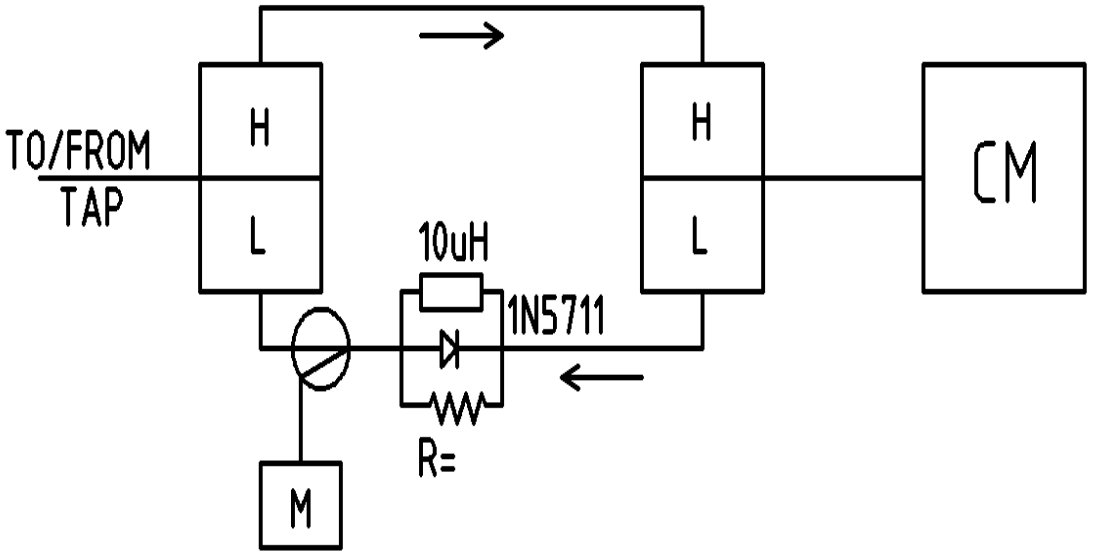


- Rectangular transmitted signal in RED
- 2nd order distortions are convolution of rectangular spectrum with itself. Gives a "triangular" shape.
- 3rd order distortion are triple convolutions of rectangular with itself. Gives a "haystack" shape.
- Higher order distortion are wider and flatter haystacks

What We Measure on Distorted Upstream Plant



Schottky Diode Test Circuit for Lab Tests

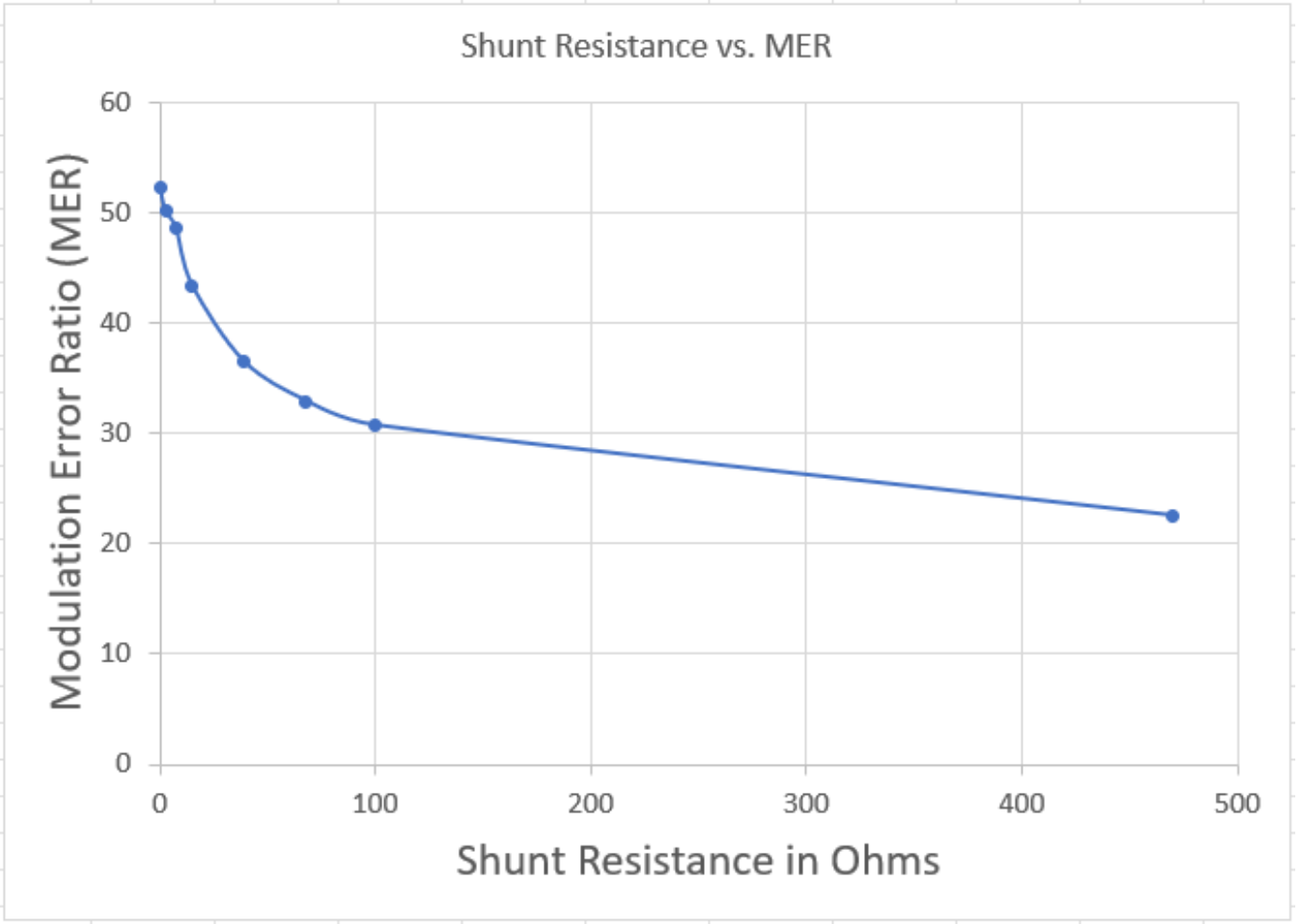


- High split plant was used
- Diplexers are mid-split and used to prevent distortion from affecting CM's downstream reception.
- Corrosion diode put in shield path of simulated ground block
- R=? Is a shunt resistor to simulate low or high contact force. Low force makes higher R
- "M" is measurement point.
- Optional inductor prevents DC on diode

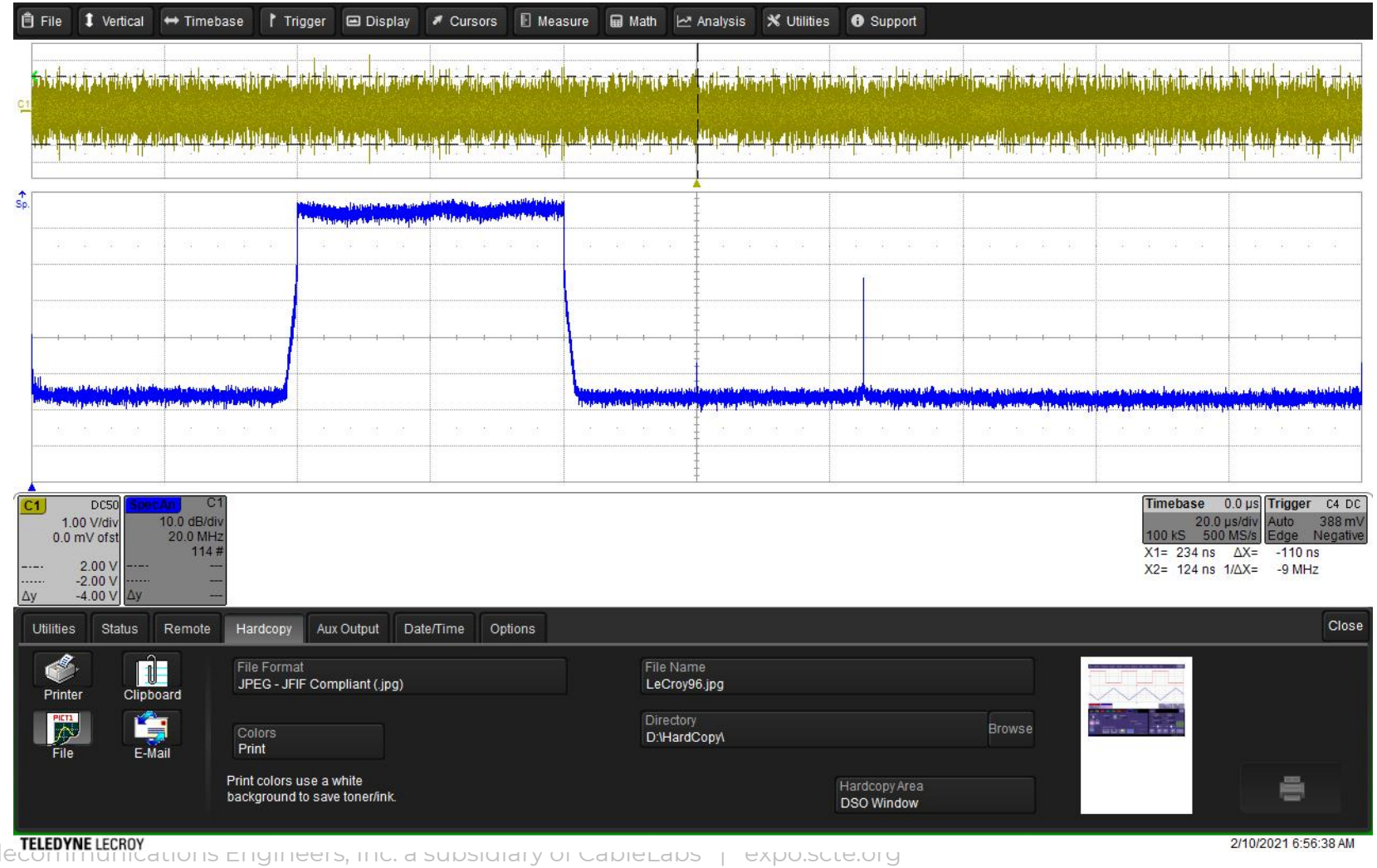
Modulation Error Rate vs. Shunt Resistor

Test with 40-80MHz OFDMA carrier, 64QAM
500 Msamples/sec on LeCroy DSO

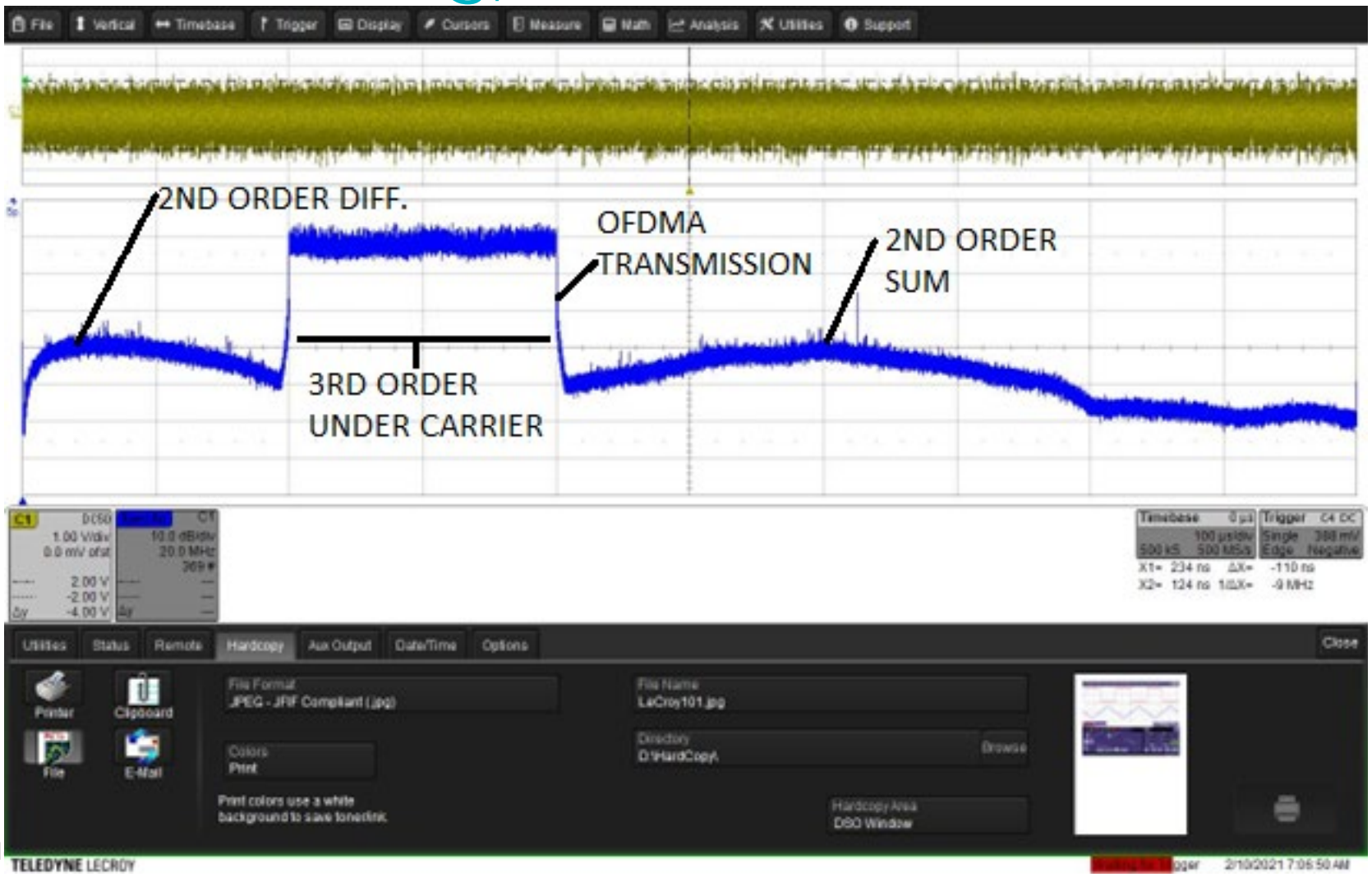
R= ohms	MER	TX power
0	52.3	48.7
2.7	50.1	48.3
7.5	48.6	47.7
15	43.4	47.7
39	36.5	46.95
68	32.9	46.95
100	30.7	46.6
470	22.5	46.4



Clean House Wiring, R=0 Ohms



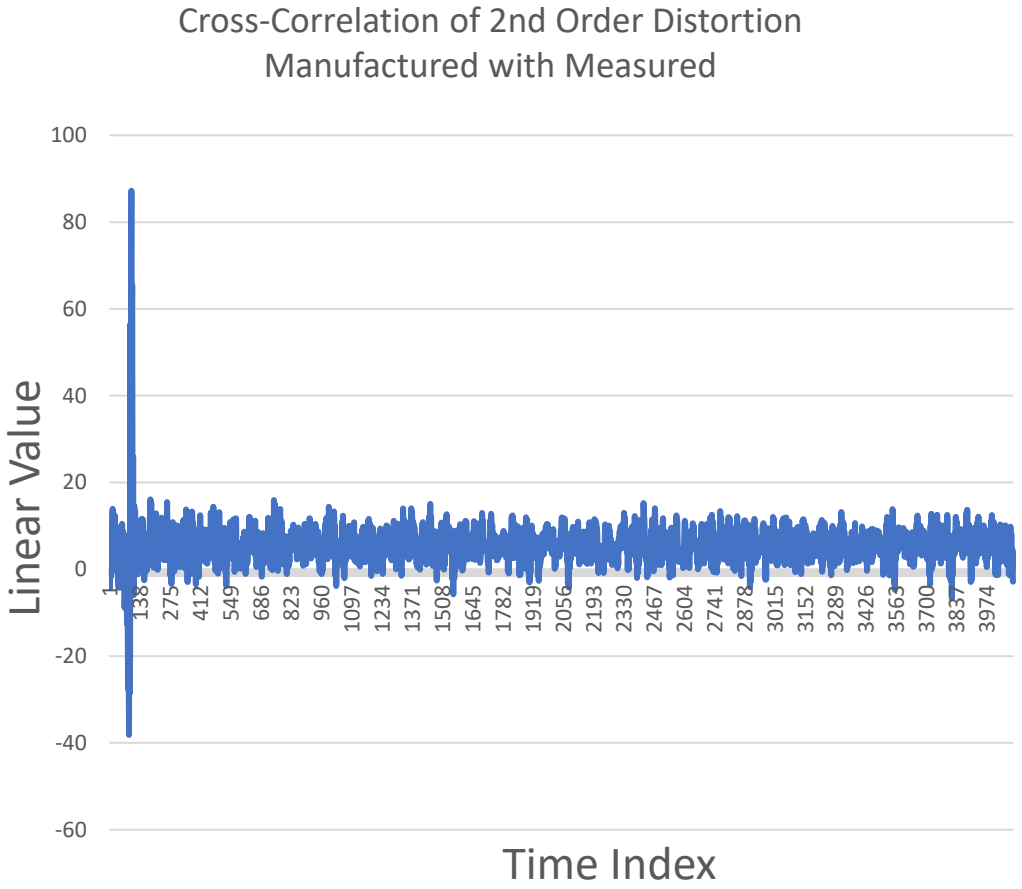
Corroded House Wiring, R = 39 Ohms



Detection of Nonlinear Distortion

- Generally hard to do because
  - High power transmission needed
  - Where was it made?
  - Was burst energy ingress or nonlinear?
  - No transmission, no distortion
- Look for bad upstream Modulation Error Rate, but neighbors measure okay under same test conditions
- Look for Sum F1 + F2
- Look for 2nd order Difference F2-F1
- Digital Signal Processing (DSP) on Upstream Triggered Spectrum Capture (UTSC)

Detection Method Using DSP



- Cross correlation of transmitted signal's measured distortion with mathematically-created distortion signal
- 4096 complex points used
- Works best in vacant band
- Needs complex I and Q time samples from UTSC for processing

Nonlinear Issues with Wide Upstream Bandwidth

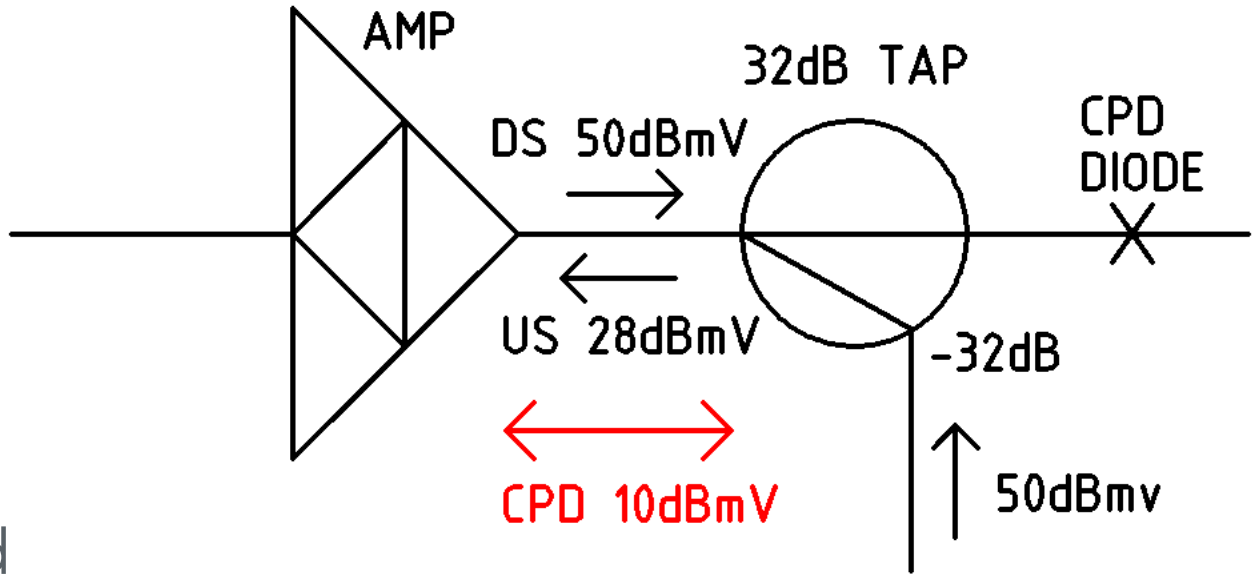
- In sub-split with 6.4 MHz ATDMA bandwidth
  - most of 0-6.4MHz difference product are blocked by 5MHz high-pass filter in amplifiers
  - 2nd and 3rd harmonics are blocked by amps' diplex filters
  - In-house, disruption to downstream signals is usually brief
- With mid- and high-split
  - OFDMA wide signal bandwidth means wider distortion bandwidth, almost appearing "flat"
  - Harmonics are not blocked by diplexer and can propagate upstream
  - With Full Duplex (FDX) the receiver can only cancel linear distortion, not nonlinear distortion

Conclusions

- Where are the corrosion diodes in my plant is a silly question. We build our plant out of corroded metal.
- Better question is where are high values of shunt resistors caused by low clamping force, such as loose seizure screws and loose housing bolts.
- CPD is a subvariant of PIM, where signal is made in downstream and affects upstream
- We need UTSC (required in DOCSIS PHY spec.) to identify which houses are bad.

Downstream CPD

- Why don't you normally observe CPD in downstream?
- In example, CPD is -40 dBc on downstream, but -18 dBc on upstream.
- Upstream spectrum is generally vacant, downstream spectrum is generally occupied.
- Generally, CPD is a wide bandwidth impairment, observed to be relatively flat in the 5-42 MHz upstream spectrum.



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Thank You!

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