

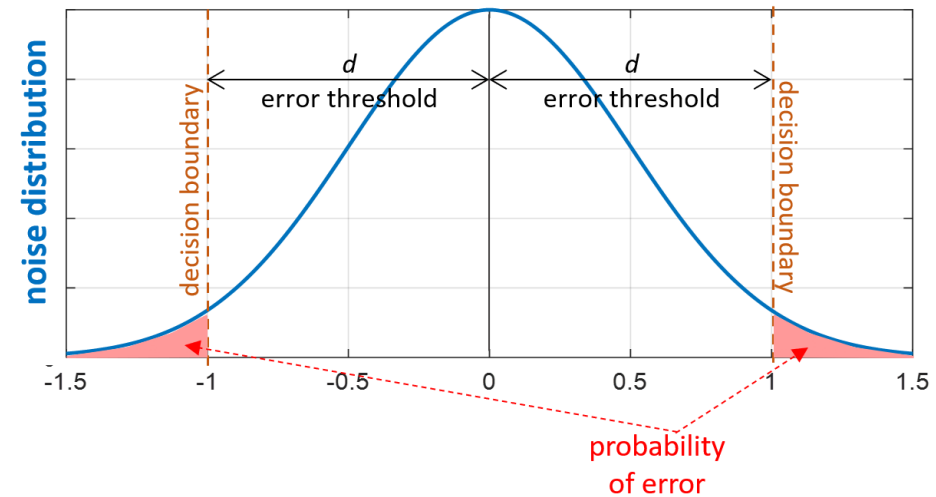
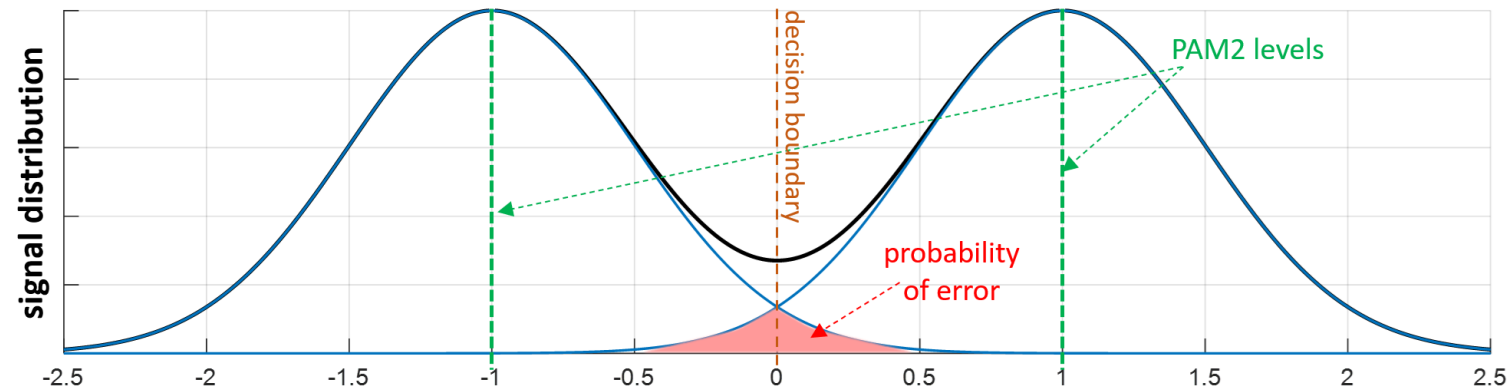
Electromagnetic Sensitivity ACT vs TDD

Hossein Sedarat

Overview

- Electromagnetic (EM) immunity has been identified as one of the more challenging aspect of the automotive PHYs
- Previous contributions have stated the vulnerability of a TDD upstream receiver to electromagnetic interference
 - Wider signalling bandwidth exposes the TDD receiver to a variety of EM interferers over a wide range of frequencies
 - Wider signalling bandwidth results in more signal loss in the channel and lower signal-to-EMI power ratio
- This contribution quantifies and compares the sensitivities of the ACT and TDD upstream receivers

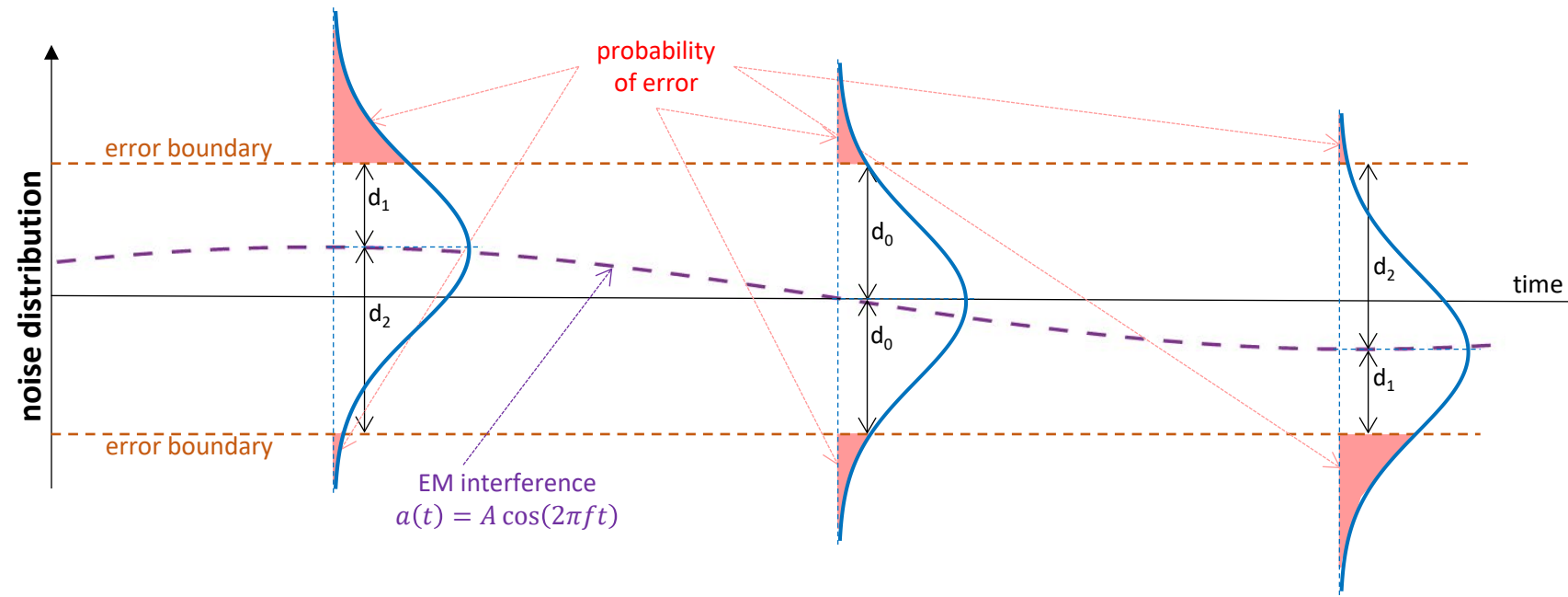
Probability of Error: Gaussian Noise



Probability of Error: Gaussian + EMI

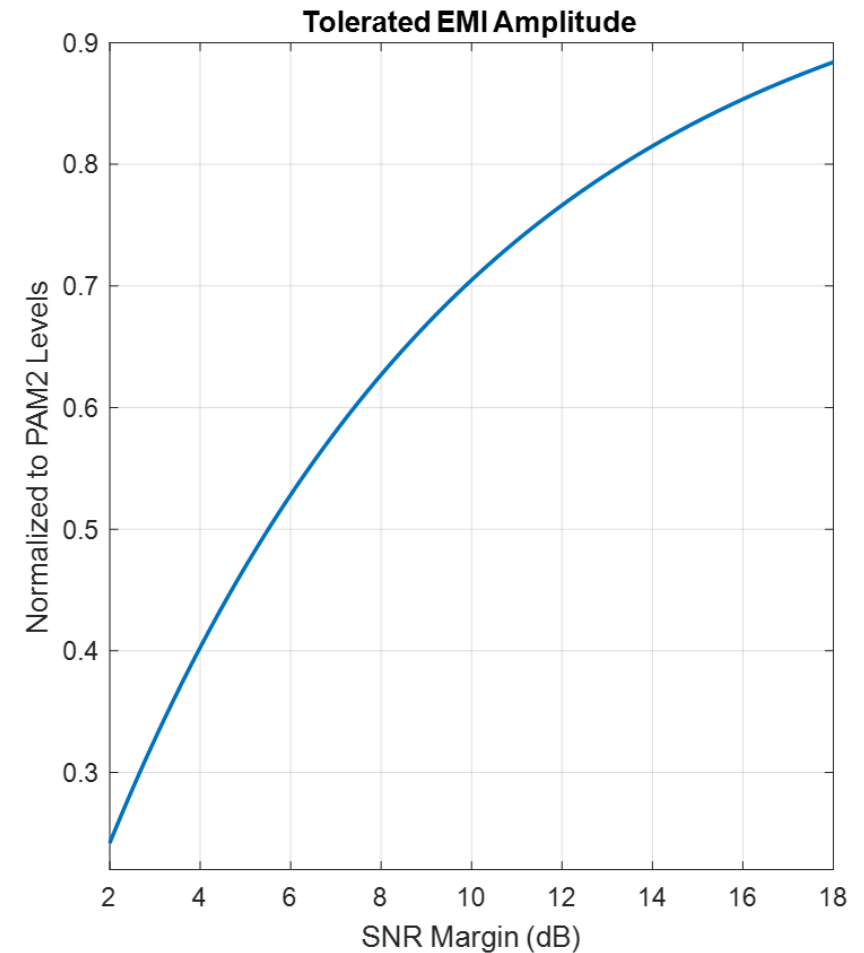
EM interference modulates the mean of the Gaussian distribution, changing the effective error thresholds in time as

$$d(t) = d_0 + a(t)$$



Tolerated EMI Amplitude

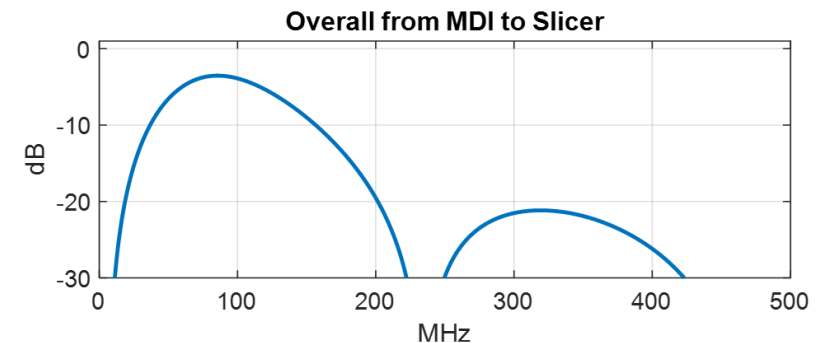
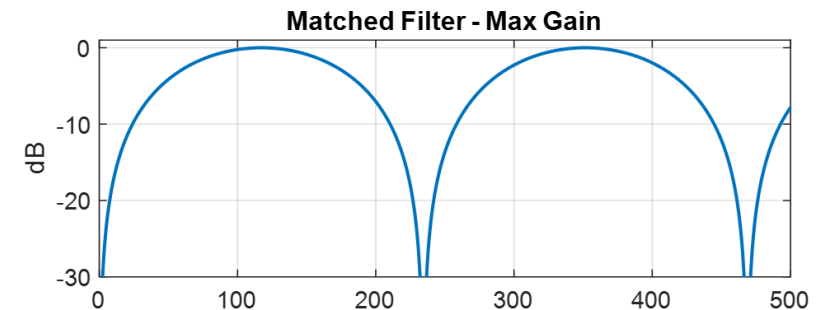
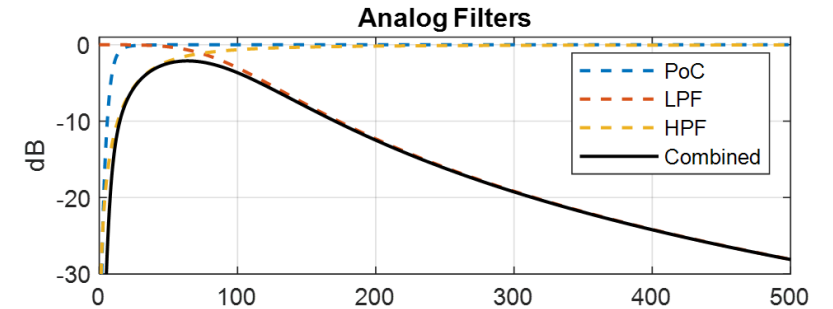
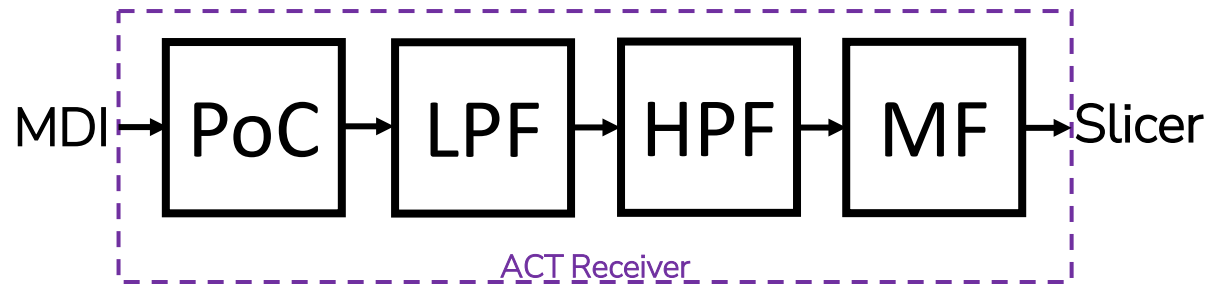
- Error rate analysis integrates the area under Gaussian distribution where its mean follows distribution of a sinewave
 - With typical SNR values, the error rate is mostly limited by EM interferer at its peak
 - Minimum error threshold, where the target BER is still met, is $\frac{d_0}{SNR\ margin}$
- ➔ Tolerated EMI amplitude $\approx d_0 \times \left(1 - \frac{1}{SNR\ margin}\right)$
(at decision point)



* *SNR margin* expressed in linear term and not in dB

EMI Level: From MDI to Slicer

- EM interferer experiences the gain of the receiver signal path as it moves from MDI to the slicer
- The gain of matched filter depends on the phase of EM interferer with a maximum that follows the shape of a sinewave in the frequency domain

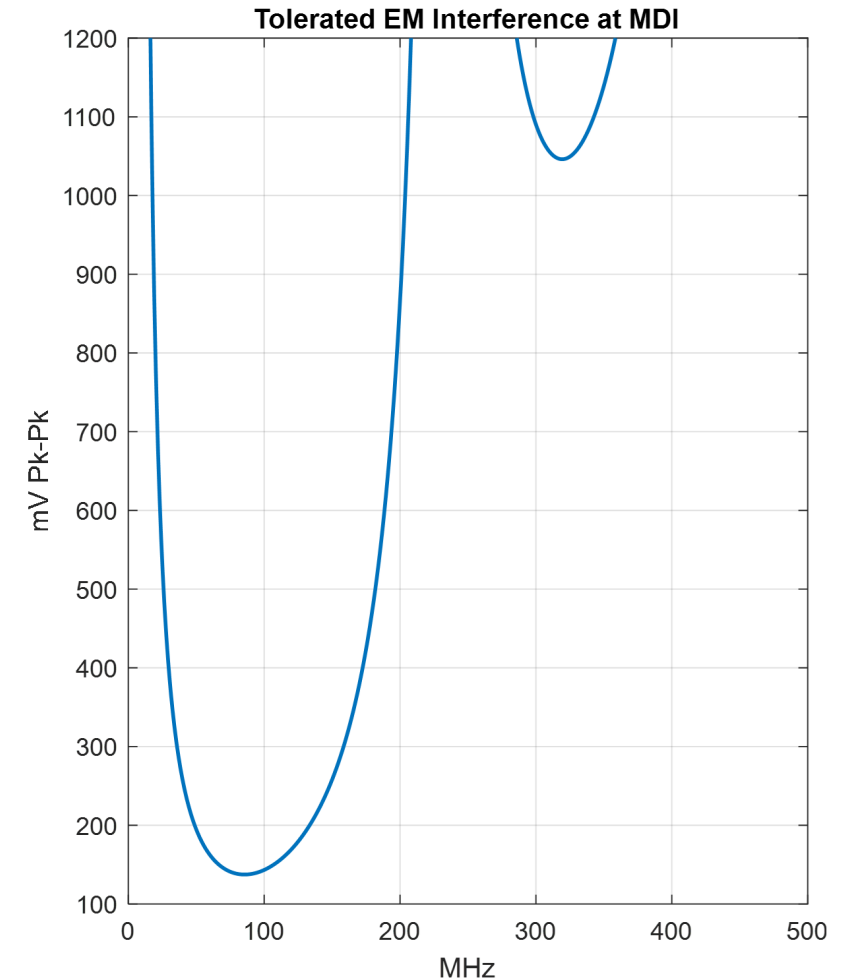


Tolerated EMI Level at MDI

Given an ACT receiver architecture as in [sedarat_202507](#), with the worst-case condition of:

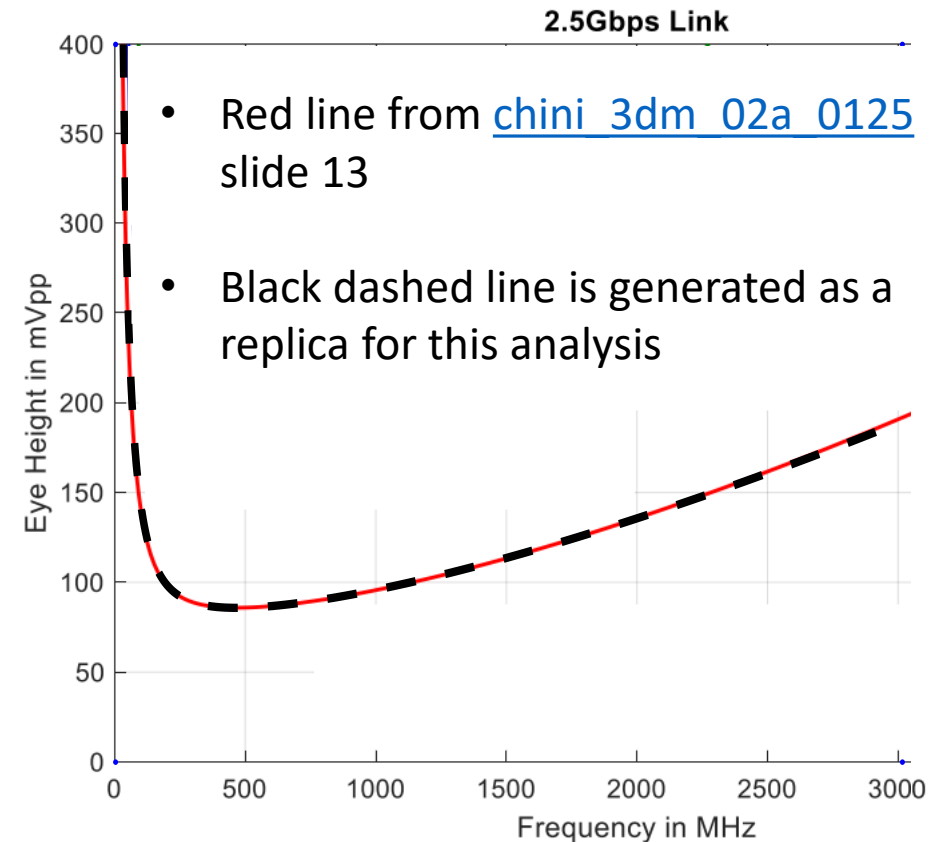
- 28 dB IL at 3 GHz ([cable limit line](#) + PCB)
 - “[Ugly](#)” [echo channel](#) with as low as 14 dB of RL at low frequencies
 - Maximum imbalance in [transmit power](#) for minimum signal-to-echo ratio
- ➔ SNR margin = 5.2 dB
- ➔ Tolerated EMI level at Slicer = 0.48

➔ Tolerated EMI level at MDI > 140 mV



TDD Receiver

- Receiver frequency response is created to match the graph in [chini_3dm_02a_0125](#)
- SNR margin is assumed to be 13 dB as presented in [chini_3dm_02b_0325](#)

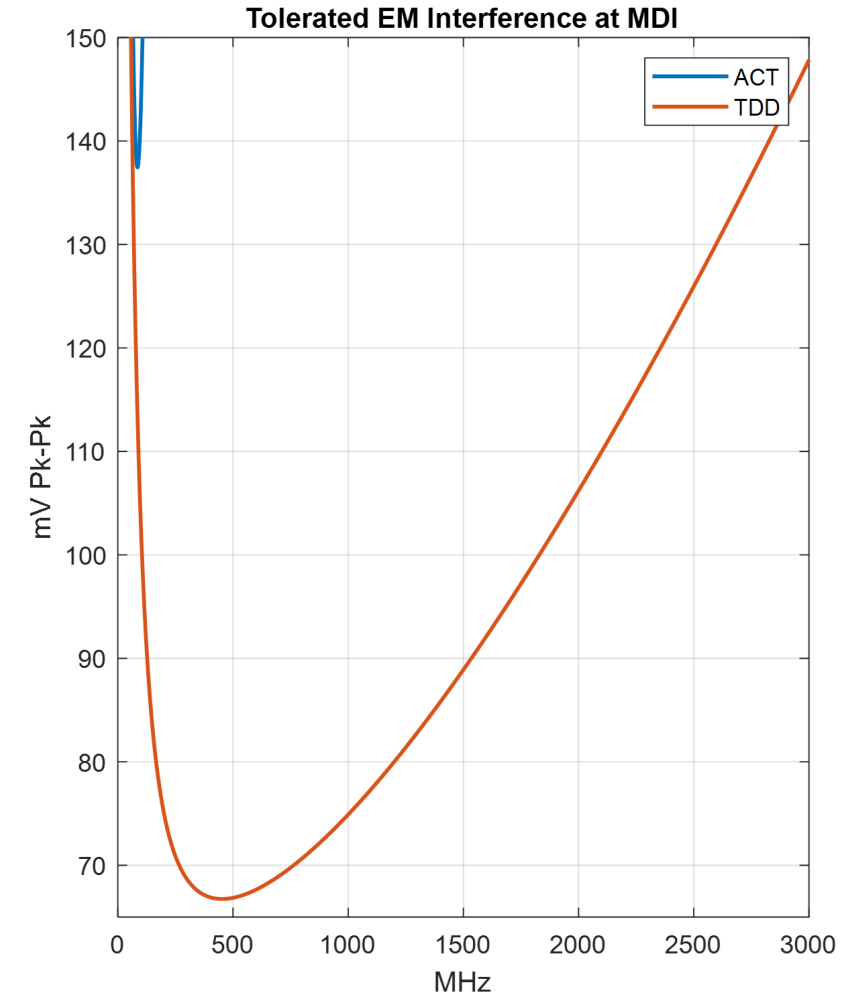


EM Tolerance: ACT vs TDD

	ACT	TDD
Insertion Loss (at 3 GHz)	28 dB	23 dB
Transmit power	-3 dBm	+1 dBm
Noise Environment	Worst Echo	Low noise floor

Even though ACT is analyzed for a much worse operating point:

- ACT still tolerates much stronger EM interference over all frequencies
- Comparing the most sensitive points, ACT still tolerates ~4 times more of EM power

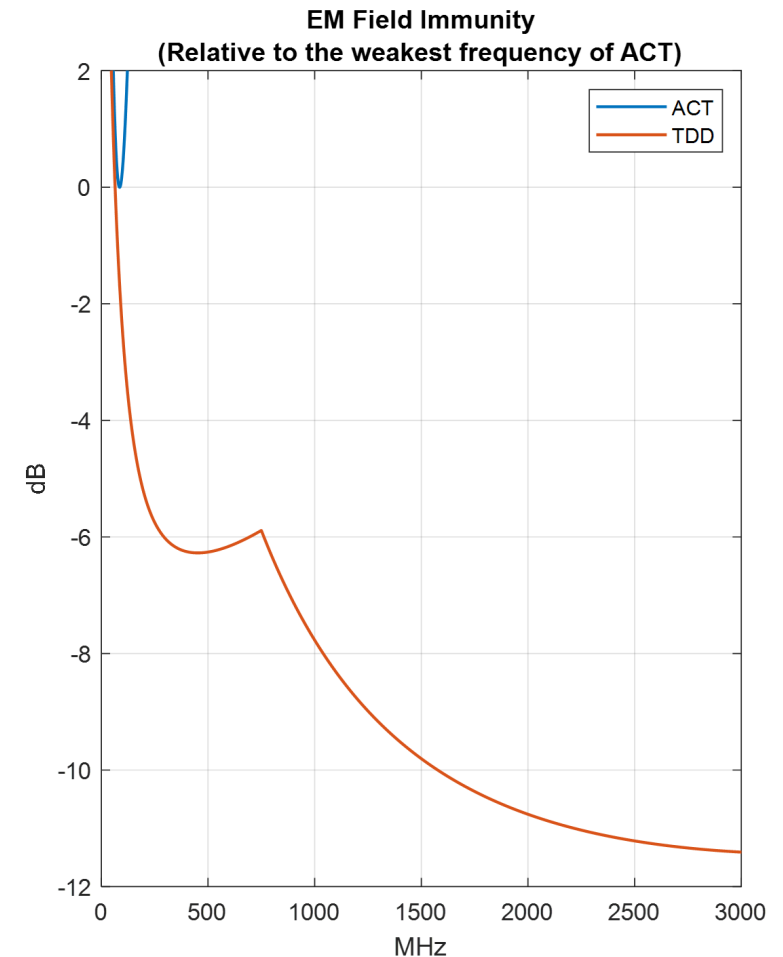


EM Field Immunity: ACT vs TDD

Field coupling into STP cable is stronger at higher frequencies



Compared to the weakest frequency of ACT, TDD is much more sensitive to EM field in almost all frequencies, and by as much as 11.5 dB



Summary

An EMI analysis of ACT and TDD upstream receivers show:

- ACT receiver, even at an artificially worst-case operating point, is virtually insensitive to electromagnetic interference
- TDD receiver, even at a typical/good operating point, can tolerate much less EM power across frequency
- At their weakest frequencies, ACT can tolerate 4 times more EMI power
- TDD receiver is more sensitive to EM field in all frequencies, and by as much as 11.5 dB



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Thank You