IEEE 802.3dm

Electromagnetic Sensitivity ACT vs TDD

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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

EMI: Downstream vs Upstream Receiver

- EMI can be treated very differently in upstream and downstream receivers

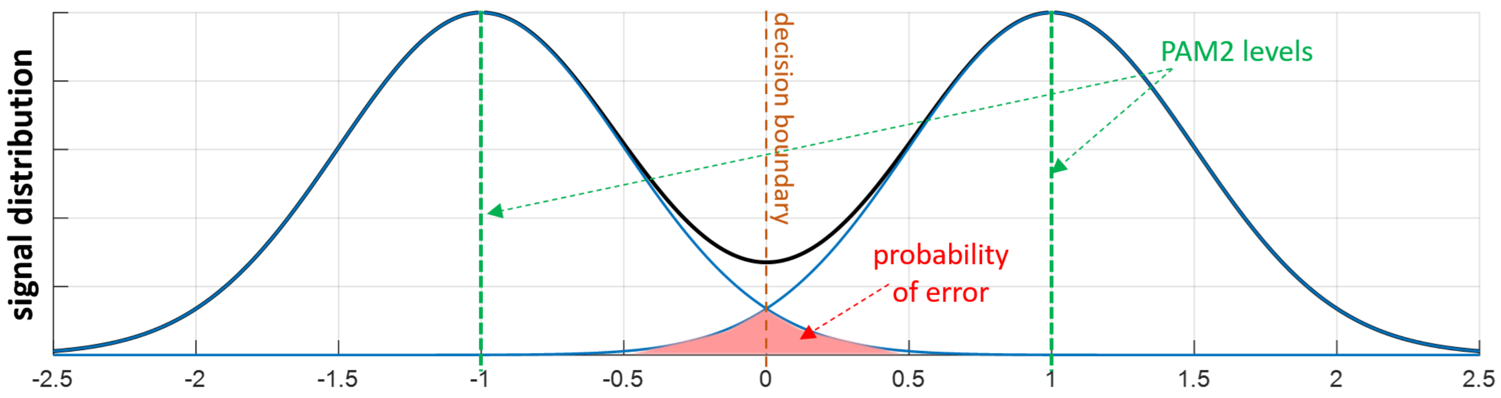
- The downstream receiver is less cost-sensitive

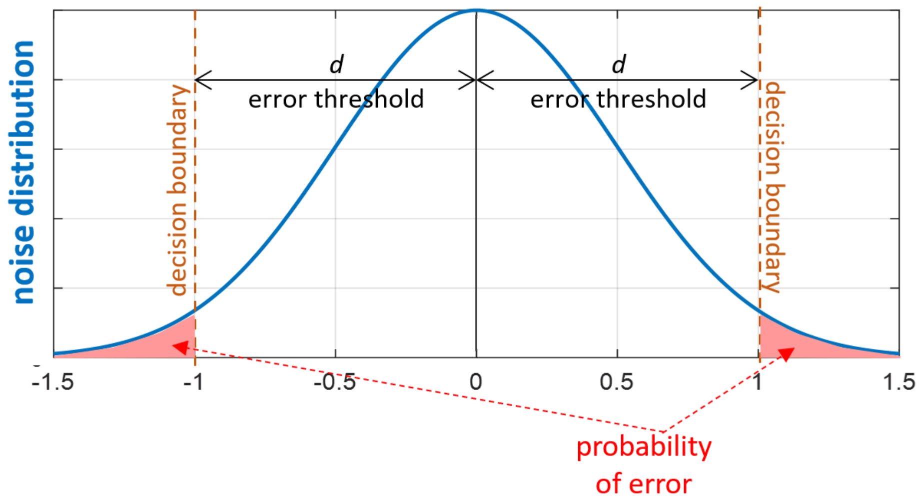
  ➔ It can use advanced DSP techniques to cancel EMI

- The upstream receiver is cost-sensitive with strict limits on power consumption

  ➔ EMI to be accommodated within the operating margin

Probability of Error: Gaussian Noise





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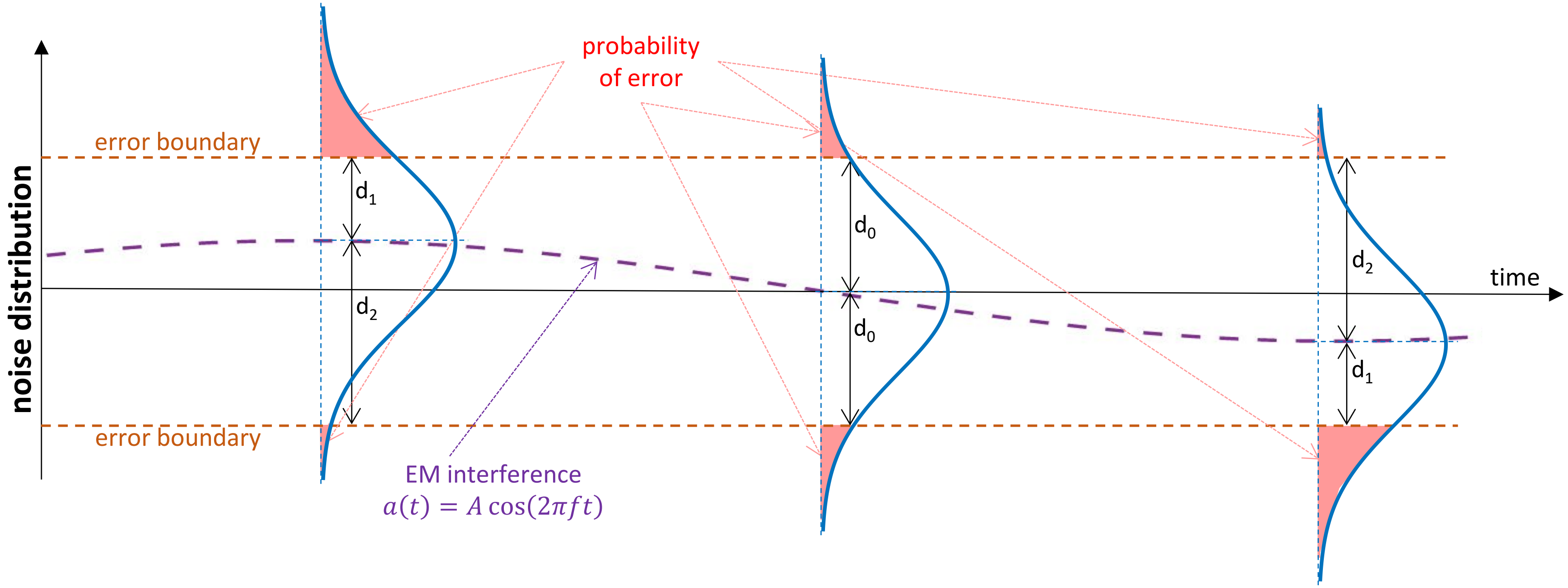
Probability of Error: Gaussian + EMI

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

$$d(t) = d_0 \pm a(t)$$



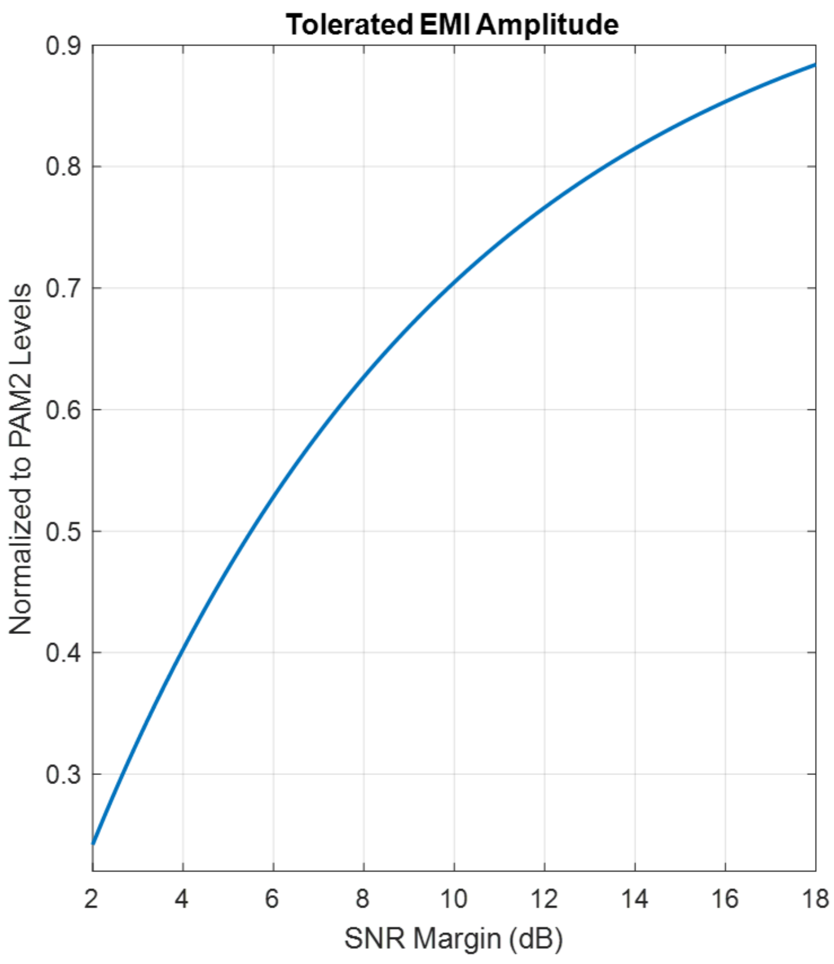
Tolerated EMI Amplitude

- 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

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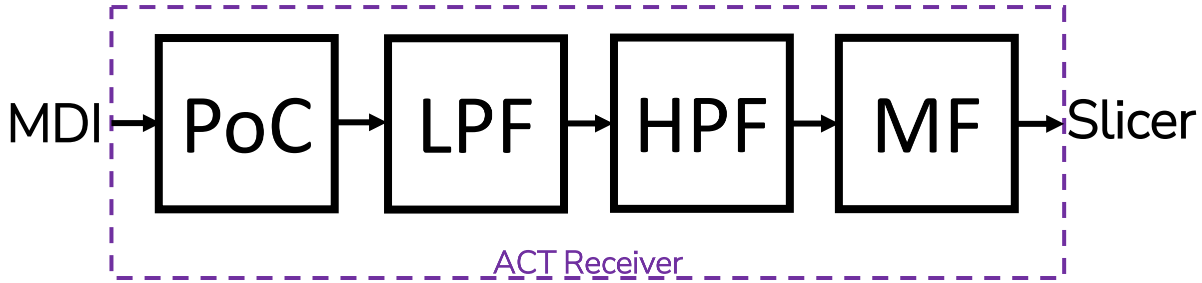
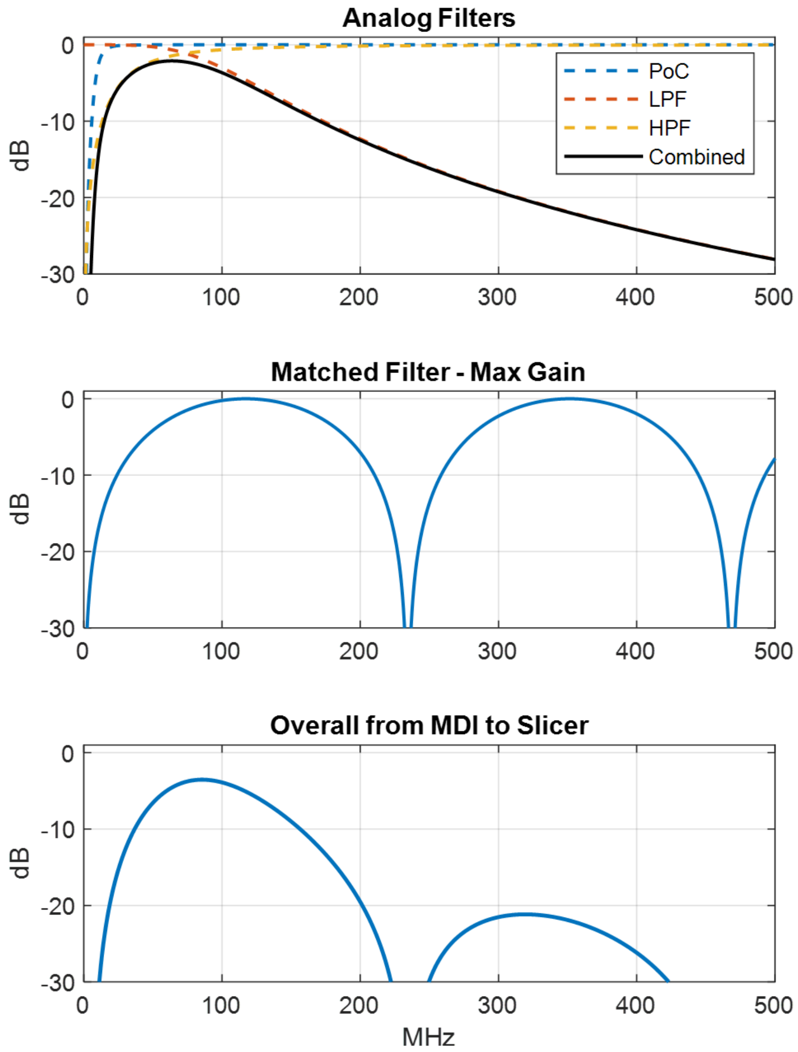
EMI Level: From MDI to Slicer

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





Tolerated EMI Level at MDI

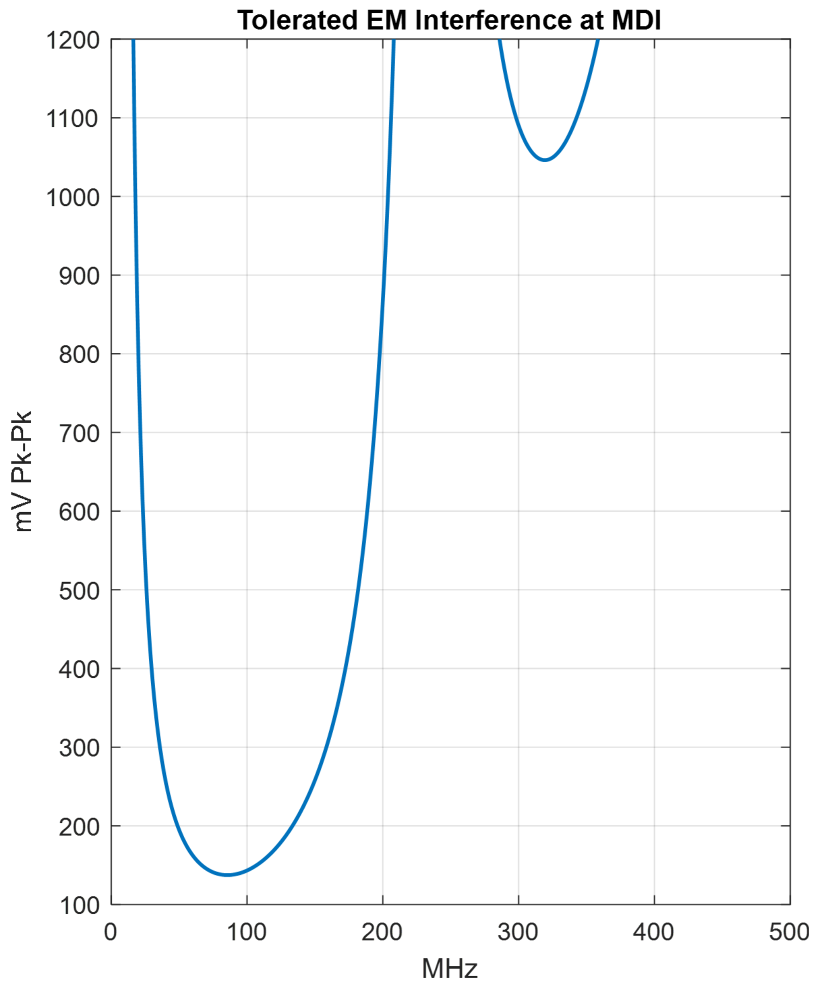
Given an ACT receiver architecture as in sedarat_202507, with the worst-case condition of:

- 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



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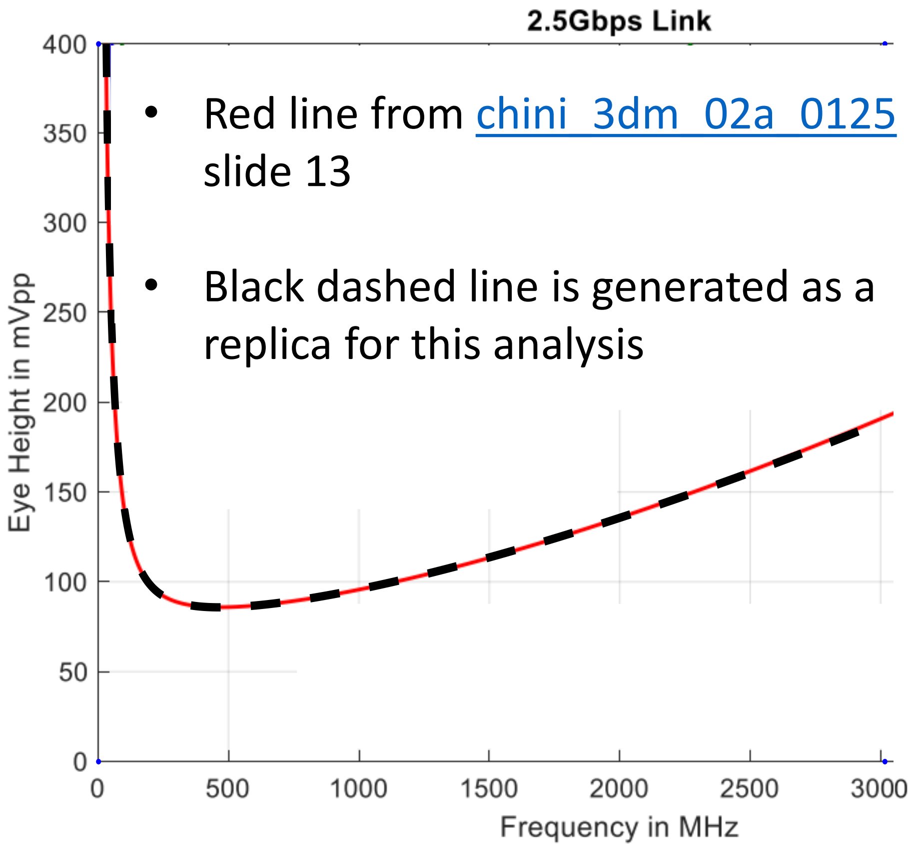
TDD Receiver

- 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



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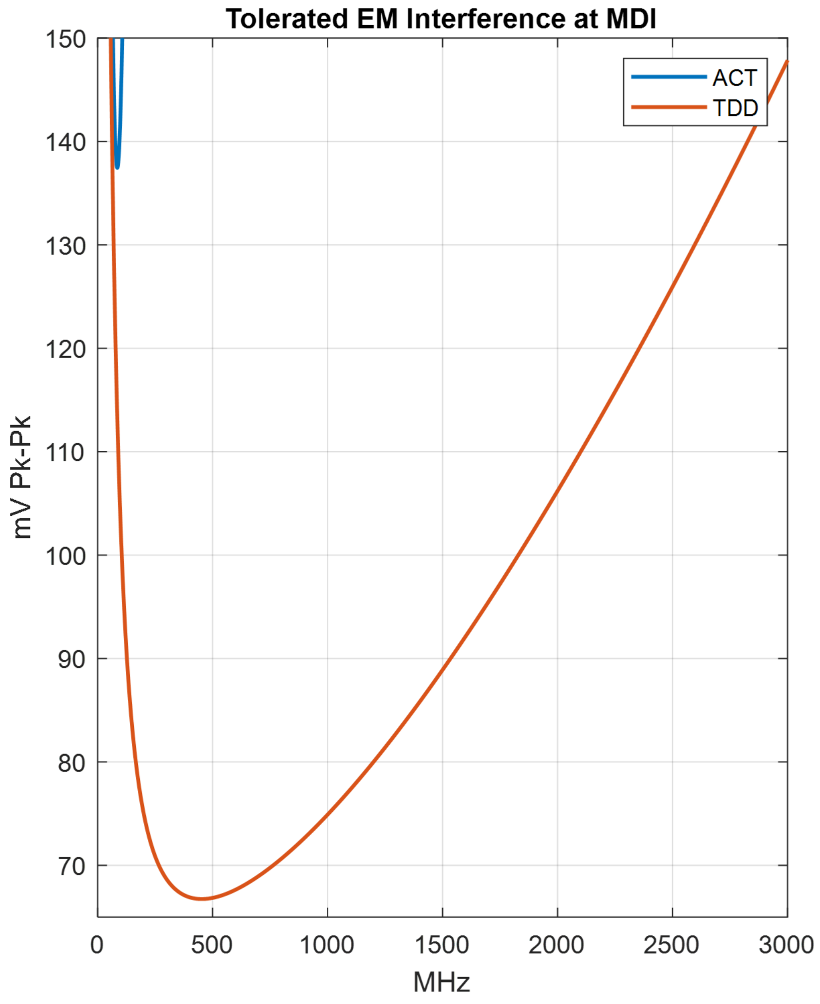
EM Tolerance: ACT vs TDD

	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



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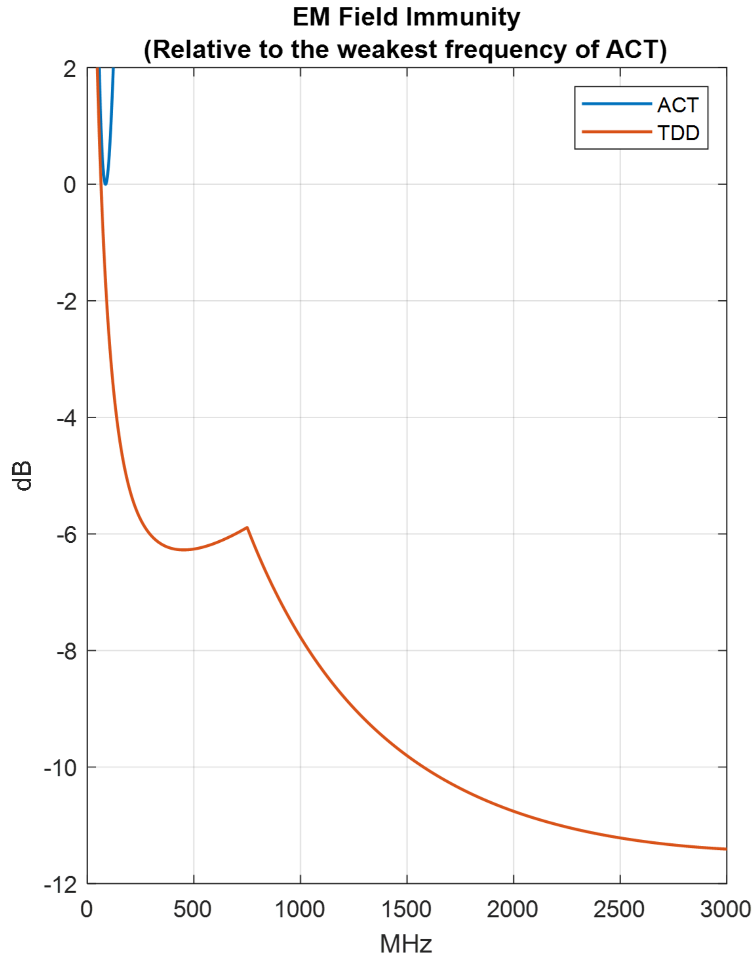
EM Field Immunity: ACT vs TDD

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



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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