Margin and Robustness

GEORGE ZIMMERMAN

CME CONSULTING/(ADI, APL GP, CISCO, MARVELL, ONSEMI, SONY)

7/29/2025

Problem Statements

Does more SNR margin necessarily translate into increased system robustness?

Is there a point where increasing SNR margin only increases complexity?

Is there a point where increasing SNR margin DECREASES practical robustness?

How does this relate to how we evaluate technologies for adoption?

What is margin?

Margin: How much can you increase noise before you have errors.

BUT in every system you have different sources of noise in the mixture.

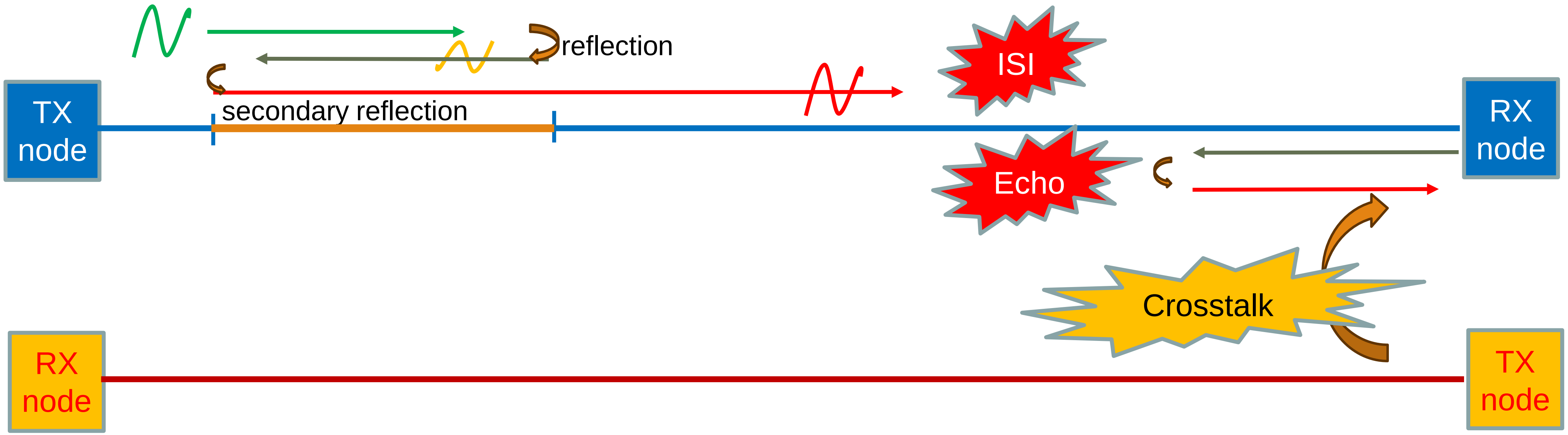
- Internal (e.g., receiver front end) noise
- Noise related to the transmission & reception of the signal under control of the local device (e.g., front-end noise, residual ISI in equalization, echo)
- Noise related to the specified transmit signal outside the control of the local device (e.g., crosstalk, far-end transmit distortion)
- Noise from sources outside the transmission system (e.g., EMI)

How do these margins relate, which noises matter?

This discussion considers a case where hard-decision FEC is used for burst/EMI protection.

Sources of noise dependent on the technology being adopted

Many sources of noise are controlled by the standard or the implementation



Sources of noise dependent on environment

Sources from the environment are independent of signal levels

Observations: Self-noise sources

For internal sources of noise, absolute transmit and received signal levels are less important

- Voltage levels of received signal and noise are similar and often related

Increased SNR margin is often related to increased complexity as these noise levels are often mitigatable with signal processing:

- Equalization: DFEs, FFEs, and CTLEs all Salz SNR and MMSE-DFE simulations often measure residual noise from equalization
- Echo cancellation: Echo noise
- Crosstalk cancellation: Crosstalk noise can often be mitigated
- Baseline wander: Baseline wander effects can be mitigated

These noise levels will be fixed by the design and the link segment specifications

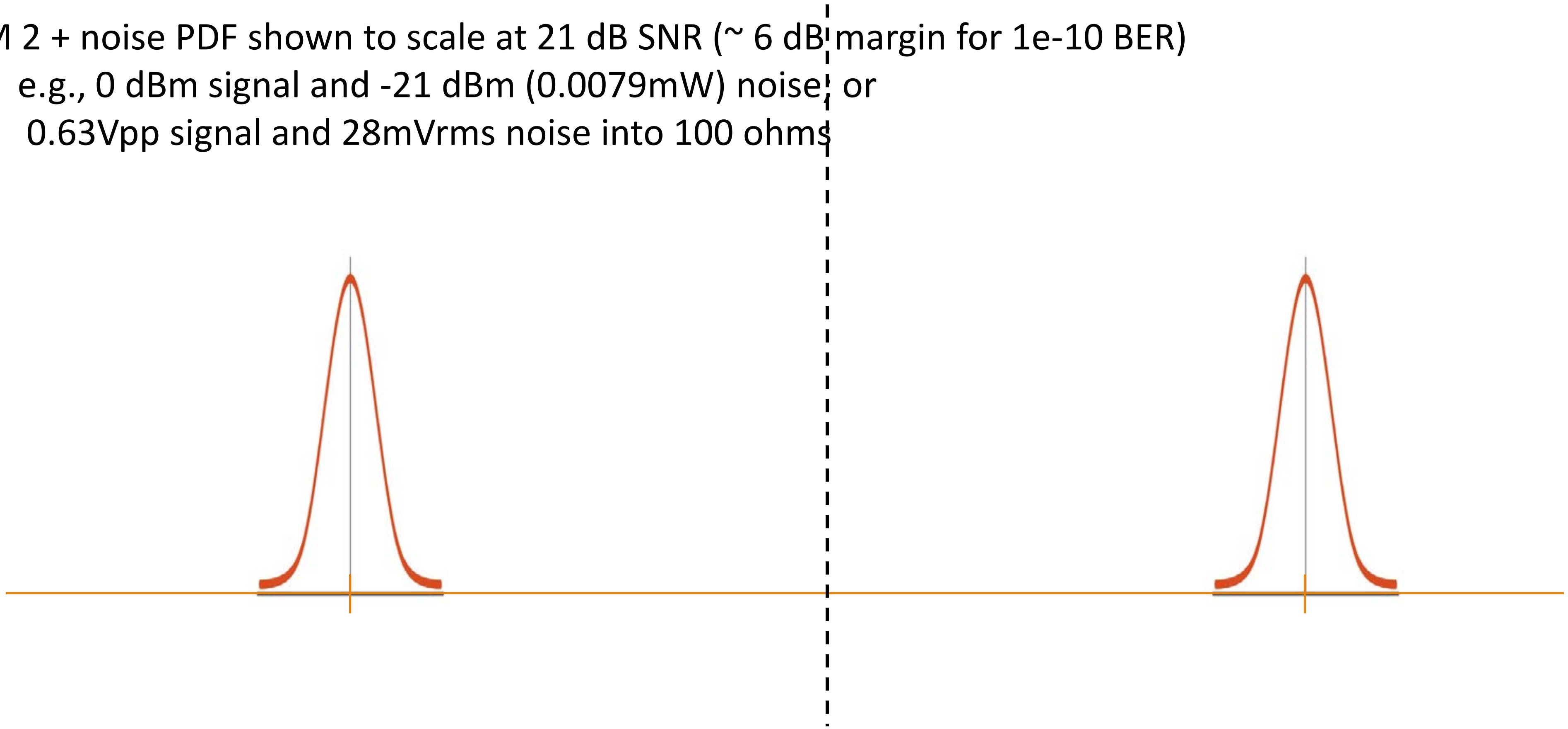
Complexity trade: how small is “small enough”?

Tolerance of additional noise example (1)

PAM 2 + noise PDF shown to scale at 21 dB SNR (~ 6 dB margin for 1e-10 BER)

e.g., 0 dBm signal and -21 dBm (0.0079mW) noise, or

0.63Vpp signal and 28mVrms noise into 100 ohms

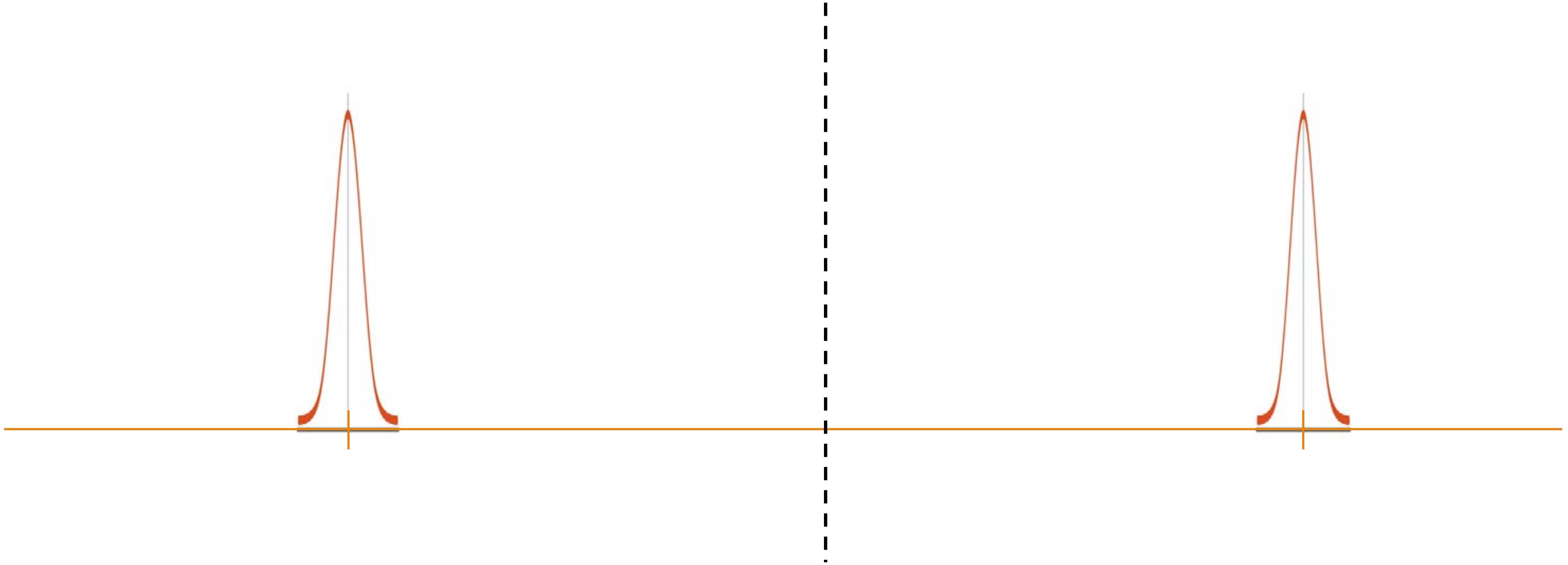


Tolerance of additional noise example (2)

PAM 2 + noise PDF shown to scale at 27 dB SNR (~ 12 dB margin for 1e-10 BER)

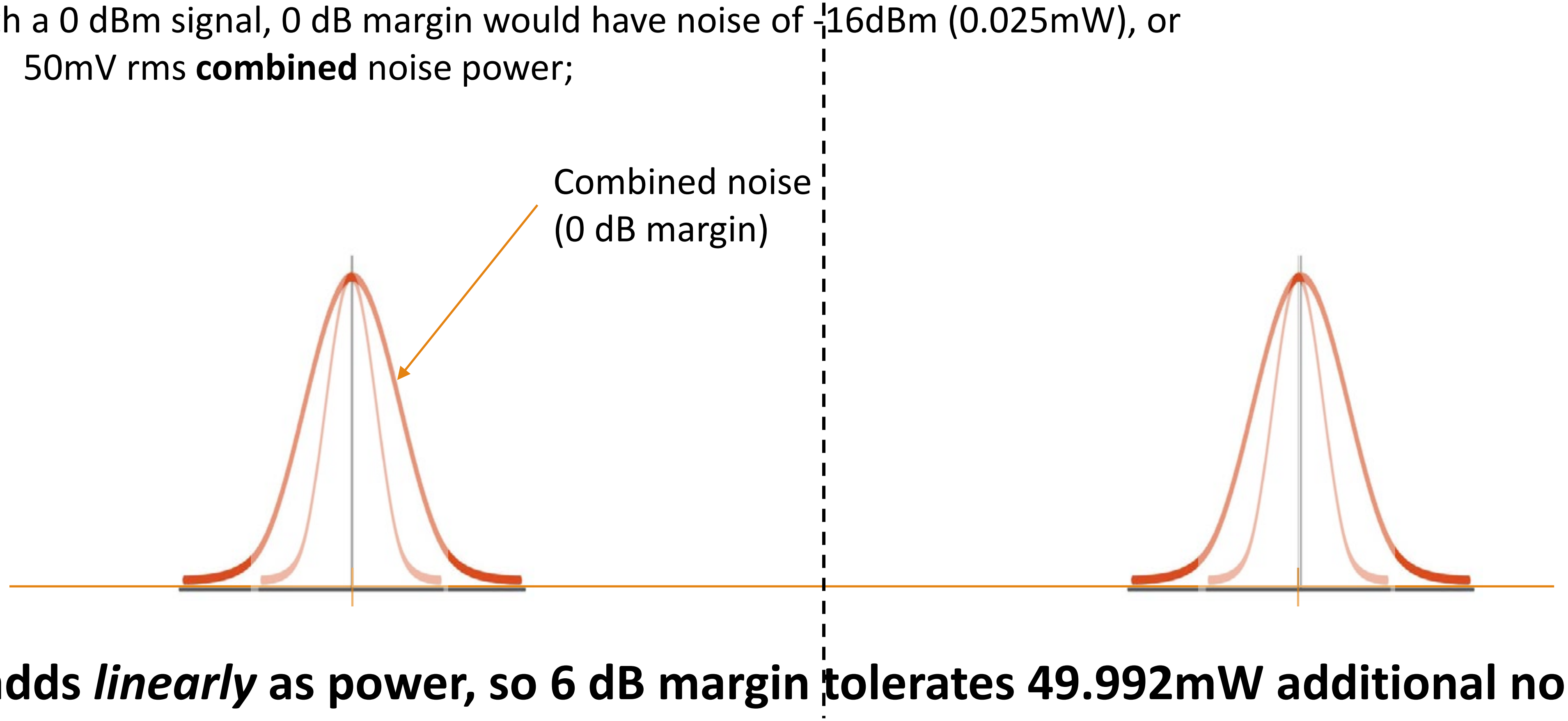
e.g., 0 dBm signal and -27 dBm (0.0020mW) noise; or

0.63Vpp signal and 14mVrms noise into 100 ohms)



Tolerance of additional noise example (3)

With a 0 dBm signal, 0 dB margin would have noise of -16dBm (0.025mW), or 50mV rms **combined** noise power;

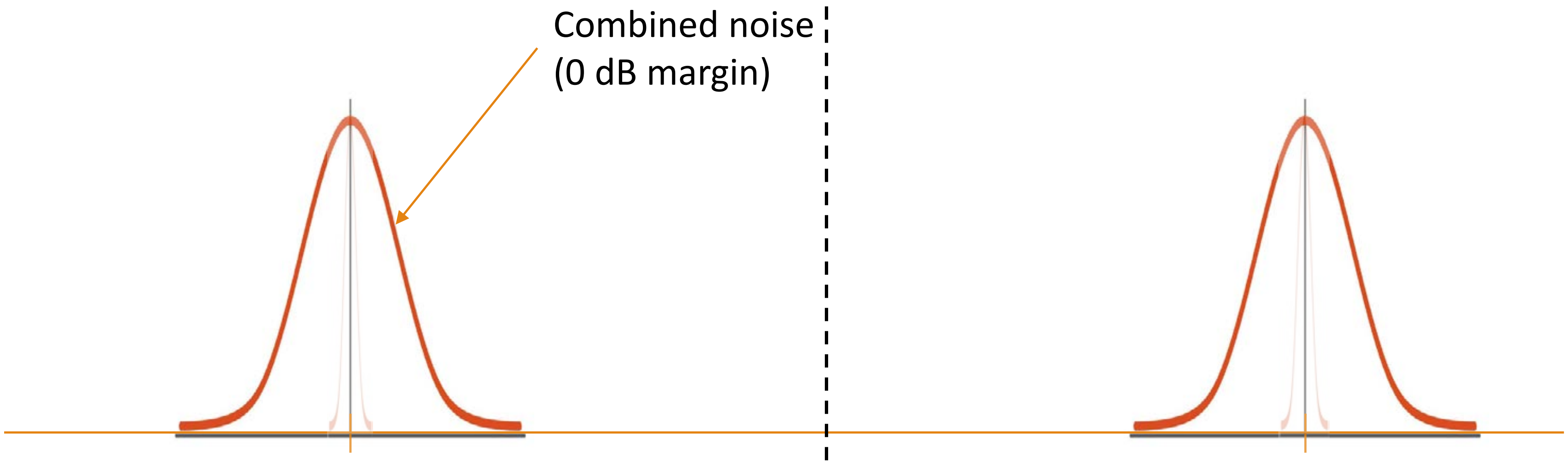


Noise adds *linearly* as power, so 6 dB margin tolerates 49.992mW additional noise
12 dB margin tolerates 49.998mW only 7 *micro*Watts more.

CME Consulting
Experts in Advanced PHYsical Communications Technology

Tolerance of additional noise example (4)

AS THE INITIAL SNR GOES TO INFINITY (initial noise goes to zero), the additional noise doesn’t change much….
Where the entire 50mV is due to the added noise… (vs. 49.99x in the other two cases)



The important thing to consider here for robustness is the actual size (in mV) of the decision distances – ultimately, that controls the tolerable noise level without FEC correction

What if the noise acts as an offset?

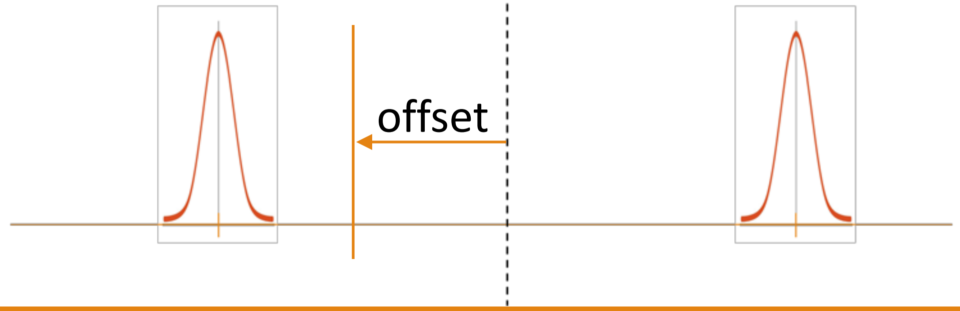
It’s a common simplification, but misunderstanding, that external noise just moves the decision thresholds

- **When it is relatively constant**, it can be easily removed, like with low complexity DC baseline wander compensation (analog or digital) found in most BASE-T designs

Even if not cancelled, increasing the SNR margin by X dB doesn’t increase the tolerable noise level by as much, and eventually goes to zero.

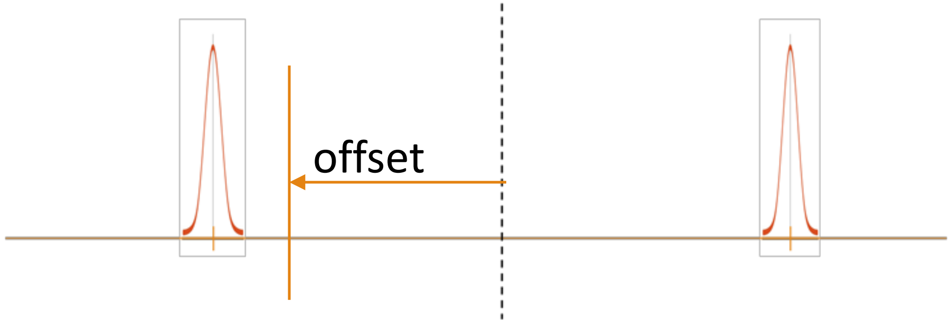
Infinite margin allows only 6 dB more offset than 6 dB margin does

6 dB margin – allows half the distance in offset thresholds



12 dB margin – allows 3/4 the distance in offset thresholds

ONLY 3.5 dB increase in the offset…



CME Consulting
Experts in Advanced PHYsical Communications Technology

Other tradeoffs to consider

Additional complexity may be better spent dealing with improving immunity to slow offsets than increasing margin by reducing internal or other self-noise

Margin is measured relative to the received signal, noise immunity is measured in Volts at the input

- They are related by the received signal level, but REALLY by the received decision threshold level (a function of the signaling speed, the insertion loss, and the number of levels)
- SNR, a ratio, is our common metric when CROSSTALK or ECHO are the dominant impairment
- ***FOR EXTERNAL NOISE: Consider the size of the received decision level relative to the input voltage***

Probability of EMI:

- EMI errors depends on the probability that the EMI is in-band of the receiver

Problem Statements - Answered

Does more SNR margin necessarily translate into increased system robustness?

- NO. *SNR margin only gives relative noise levels. If the received signal detection threshold levels are not identical, more margin doesn't increase robustness.*

Is there a point where increasing SNR margin only increases complexity?

- YES (practically). *After about 6 dB margin, the incremental increase in noise tolerance per dB of margin decreases dramatically, yielding minimal benefit.*

Is there a point where increasing SNR margin DECREASES practical robustness?

- Sometimes. *When increased margin comes with decreased received detection threshold levels or increased probability of interference, increased margin decreases robustness.*

How does this relate to how we evaluate technologies for adoption? – ***You decide.***

Thank you