Test Modes in ACT Downstream Direction

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Overview

IEEE 802.3dm taskforce need to specify test modes

- To define test procedures and test limits to evaluate the
  - Quality of transmit signal
  - Quality of the clock
  - Performance of the receiver
- To ensure interoperability of the PHYs
- To ensure minimum link performance

This document presents a proposal for test modes in the downstream direction of ACT

Test Modes: ACT - Downstream

- ACT transmit signal in the high-speed downstream direction is very similar to that of 802.3ch
- Test setup and procedure can be defined similar to 802.3ch specifications, with some adjustments to
  - Measurement bandwidth for 5G and 2.5G
  - Single-ended measurements for coaxial cables
- The electrical limits may be different due to differences in modulation, bandwidth, signal power and insertion loss
- Test procedure and limits may be different for STP and coax

Test Modes - IEEE 802.3ch

Table 149–17—MDIO management registers settings for test modes

Test mode 1—Setting MASTER and SLAVE PHYs for transmit clock jitter test in linked mode.
Test mode 2—Transmit MDI jitter test in MASTER mode.
Test mode 3—Precoder test mode.
Test mode 4—Transmitter linearity test.
Test mode 5—Normal operation in Idle mode. This is for the PSD Mask test.
Test mode 6—Transmitter droop test mode.
Test mode 7—Normal operation with zero data pattern. This is for BER monitoring.

Measurements and Limits

1. Transmit signal:
   a. Droop (149.5.2.1)
   b. PSD mask, and limits on power and signal swing (149.5.2.4, 149.5.2.5)
   c. Linearity and SNDR limits (149.5.2.2)

2. Clock:
   a. Frequency precision and stability (149.5.2.6)
   b. Jitter: free-running clock, recovered clock, even-odd (149.5.2.3)

3. Receiver: BER target and tolerated alien crosstalk (149.5.3.2)

Transmit Droop

- Transmit droop is the low-frequency signal dynamics due to AC coupling of the transmitter at the MDI
- AC coupling results in baseline wander in the received signal and must be kept within acceptable range for proper operation of a receiver
- Assuming similar PoC circuit with similar low frequency pole as in 802.3ch, the specification in 149.5.2.1 can be used as-is

Clock Precision and Stability

- The precision of clock frequency of the link Leader (Master) determines the capture range of initial clock frequency lock in the link Follower (Slave)

- The stability of the clock frequency of the Leader determines the dynamics of the control loop for phase tracking

- Although the limits of insertion loss in 802.3dm is easier than 802.3ch, the clock specification in 149.5.2.6 is not challenging and may be used as-is (50 ppm and 0.1 ppm/second)

Transmit PSD Mask and Power Limits

Transmit power levels and the PSD mask specified in Sedarat_Cordaro_202505:

Transmit Power (dBm)

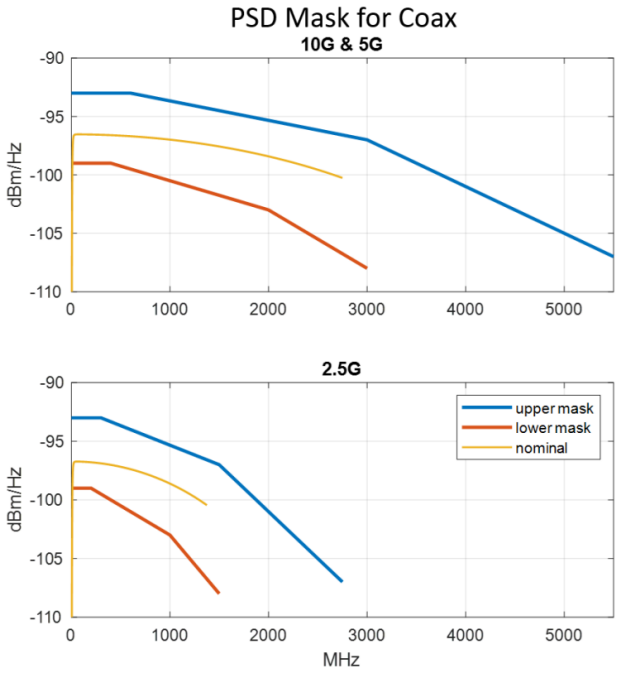
	Coax		STP	
	Min	Max	Min	Max
10G	-4	-1	-1	2
5G	-4	-1	-1	2
2.5G	-7	-4	-4	-1
100M	-6	-3	-3	0

PSD Mask - Downstream

$$UPSD(f) = \begin{cases} P_0 & 0 < f \le 600 \times S \\ P_0 + 1 - \frac{f}{600 \times S} & 600 \times S < f \le 3000 \times S \\ P_0 + 8 - \frac{f}{250 \times S} & 3000 \times S < f \le 5500 \times S \end{cases}$$

$$LPSD(f) = \begin{cases} P_0 - 6 & 5 < f \le 400 \times S \\ P_0 - 5 - \frac{f}{400 \times S} & 400 \times S < f \le 2000 \times S \\ P_0 - \frac{f}{200 \times S} & 2000 \times S < f \le 3000 \times S \end{cases}$$

- P_0 is -93 dBm/Hz for coax, and -90 dBm/Hz for STP
- S is 1 for 10G and 5G, and 0.5 for 2.5G
- f is frequency in MHz



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Transmit Signal Swing

Maximum signal swing for STP cables is deduced from signal power, bandwidth, and modulation:

- **10G** mode signalling is the same as 802.3ch, and the maximum swing may also remain the same: 1.3 V peak-to-peak
- **5G** has the same power and bandwidth as 10G but with PAM2 modulation resulting in roughly 2.5 dB lower swing: 1.0 V peak-to-peak
- **2.5G** is specified with the same modulation as in 5G but with half of the power and bandwidth resulting in 3 dB reduction: 0.7 V peak-to-peak
- Swing for coaxial cables is to be half of what is specified for STP cables

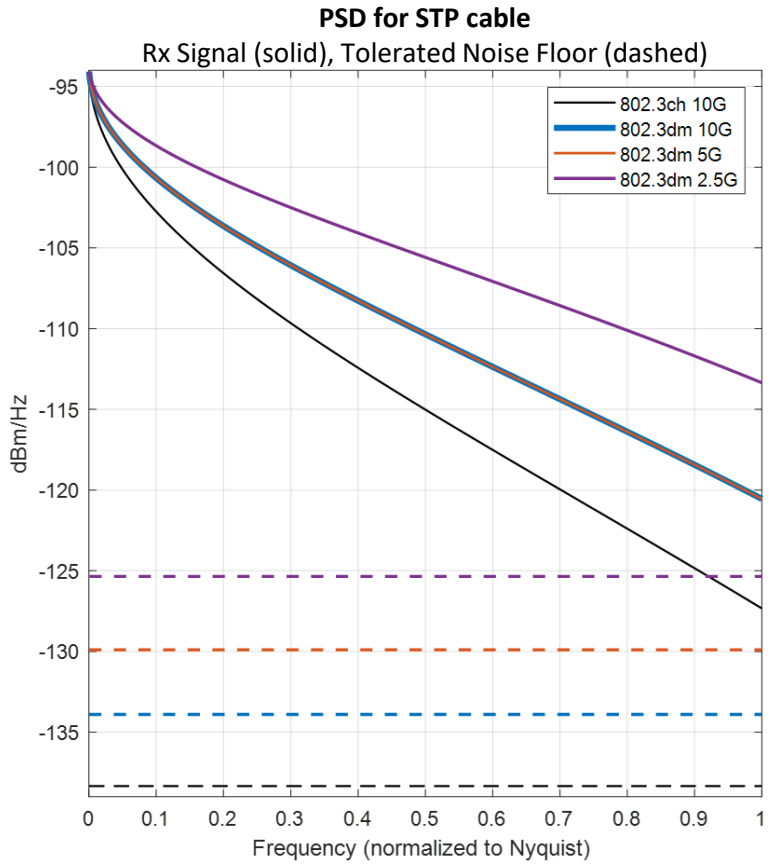
Noise Budget

For the limits on distortion and jitter and injected noise, match 802.3ch for contribution of each component to the overall noise budget

- For BER=10^{-12}, SNR at decision point is 17 dB for PAM2 and 24 dB for PAM4
- PAM2 was adopted to provide more RF immunity
  - consider 3 dB margin for added immunity in PAM2
- Using Salz SNR analysis for input noise budget:

Tolerated noise @ MDI	10G (802.3ch)	10G	5G	2.5G
Noise floor (dBm/Hz)	-138	-134	-130	-126
SNR (dB)	31	29	25	23

- For coax, the noise floor is 3 dB lower



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Transmit Linearity

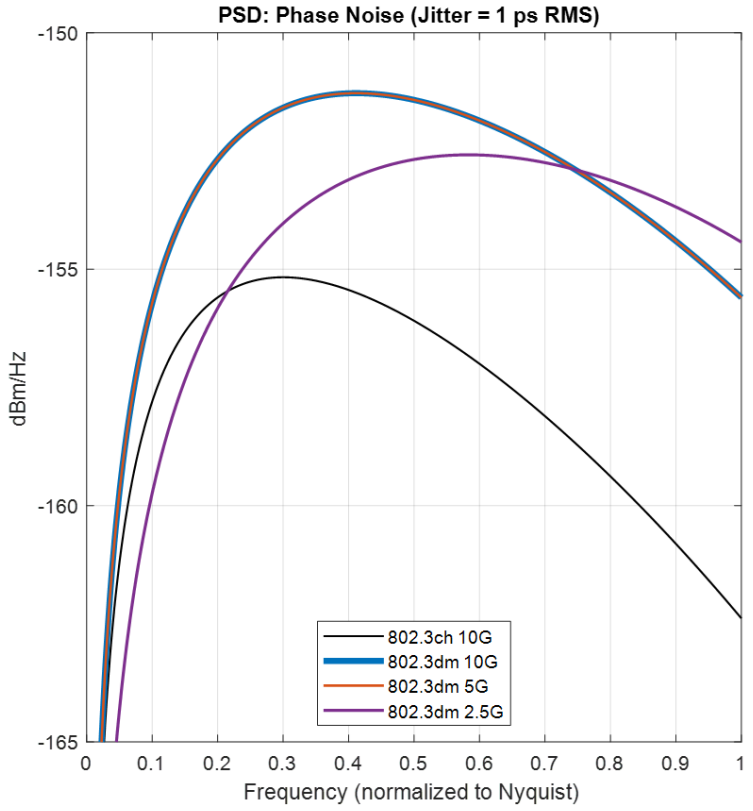
- 802.3ch specifies SNDR=38 dB of linearity for the transmit signal in 10G
- Assuming white spectrum for transmit distortion, the SNR at receiver due to remote transmit distortion remains close to the same level of 38 dB
- This level of distortion is 7 dB lower than the overall tolerated noise
- Choose the limits of SNDR in 802.3dm for distortion to have the same relative contribution to the overall tolerated noise budget:

Tolerated noise @ MDI	10G (802.3ch)	10G	5G	2.5G
Required SNR (dB)	31	29	25	23
Margin	7	7	7	7
Transmit SNDR (dB)	38	**36**	**32**	**30**

Clock Jitter

- Phase noise from clock jitter follows the PSD of signal with an additional term that grows linearly with frequency
- Choose the limits of jitter so that the resulting noise have the same relative contribution to the overall tolerated noise budget as in 802.3ch

	10G 802.3ch	10G	5G	2.5G
Required SNR (dB)	31	29	25	23
SNR due to 1 ps rms jitter (dB)	50	48	48	51
Margin (dB)	19	19	23	28
Relative to 10G .3ch (dB)	0	0	4	9
Jitter Spec (relative to 802.3ch)	1	**1**	**1.5**	**3**



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Alien Crosstalk Noise Level

- Receiver should maintain target BER while white noise, representing alien crosstalk, is injected at MDI

- The injected noise level may be specified so that the margin to tolerated noise floor is the same as what is defined in 802.3ch

	10G (802.3ch)	10G	5G	2.5G
Tolerated noise floor (dBm/Hz)	-138	-134	-130	-126
Margin (dB)	14	14	14	14
Noise injection level (dBm/Hz)	-152	**-148**	**-144**	**-140**

- Injection levels for coax are specified 3 dB lower than STP (table above)

Summary

- ACT test modes for downstream direction are proposed to be based on those defined in IEEE 802.3ch, covering
  - Transmit signal quality: droop, linearity, power, swing, PSD
  - Clock quality: precision, stability, and jitter
  - Receiver performance

- The test limits are derived from 802.3ch to compensate for the differences in
  - Insertion loss
  - Modulation
  - bandwidth


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Thank You