Exploration of SCMR Limits in 802.3ck D2.3

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For IEEE 802.3ck

Outlines

- Background
- Performance impact analysis of CM noise
- SCMR values under different scenarios
- Summary & Proposal

Background – New SCMR (min) in 802.3ck D2.3

- Due to the new adopted TP0v method for 100GEL C2C/KR clauses
  - The original 30 mV, AC common-mode RMS (max), spec is not valid – the value depends on TP0v IL, which is variant
  - Signal to AC common-mode noise ratio, SCMR (min), was adopted in D2.3
    - However, there is no validations yet for 16 dB limit
- Try to analyze what's the appropriate SCMR (min) limit
  - 16 dB is too large, propose 13 dB instead

Recap of SCMR (min) Spec

163.9.2.7 Signal to AC common-mode noise ratio

Signal to AC common-mode noise ratio is calculated using Equation (163–2). The procedure in 162.9.3.1.1 is used to determine the differential-mode linear fit pulse response p(k). The peak-to-peak AC common-mode voltage is defined as the AC common-mode voltage (see 93.8.1.3) range measured at TP0v that includes all except 10^{-4} of the measured distribution, from 0.00005 to 0.99995 of the cumulative distribution. The signal to AC common-mode noise ratio shall meet the specification for SCMR (min) in Table 163–11.

$$SCMR = 20\log_{10}\left(\frac{p_{max}}{V_{CMPP}}\right) \qquad (163\text{–}2)$$

where

$SCMR$	is the signal to AC common-mode ratio in dB
p_{max}	is the maximum value of the differential-mode linear fit pulse response $p(k)$
V_{CMPP}	is the peak-to-peak AC common-mode voltage

- Differential peak signal is compared with pk-to-pk AC common-mode voltage (at prob. of 1e-4)
  - V_{CMPP} strongly depends on components of CM noise – whether it's Gaussian or not?

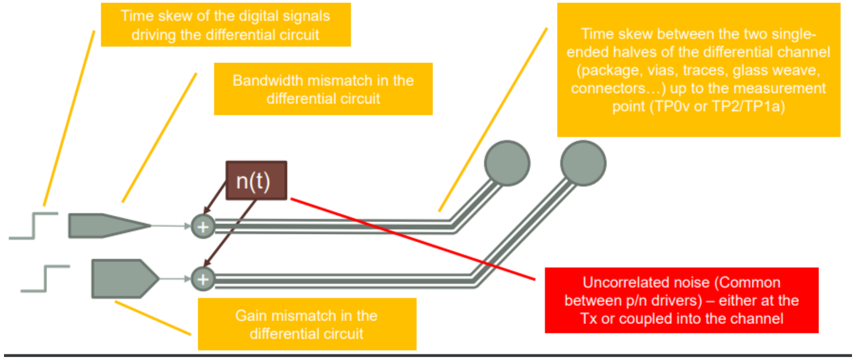
-5—Summary of transmitter specifications at TP0v

meter	Reference	Value	Units
Signaling rate, each lane (range)		53.125 ± 50 ppm[a]	GBd
Differential pk-pk voltage (max)[b] Transmitter disabled Transmitter enabled	93.8.1.3	 30 1200	 mV mV
DC common-mode voltage (max)[b]	93.8.1.3	1	V
DC common-mode voltage (min)[b]	93.8.1.3	0.2	V
Signal to AC common-mode noise ratio, *SCMR* (min)	163.9.2.7	16	dB

- Purpose – explore SCMR values with different scenarios to come out reasonable SCMR limit

Identify AC CM noise sources

- Sources of common mode AC output had been discussed & separated into the following parts in ran_3ck_04_1020

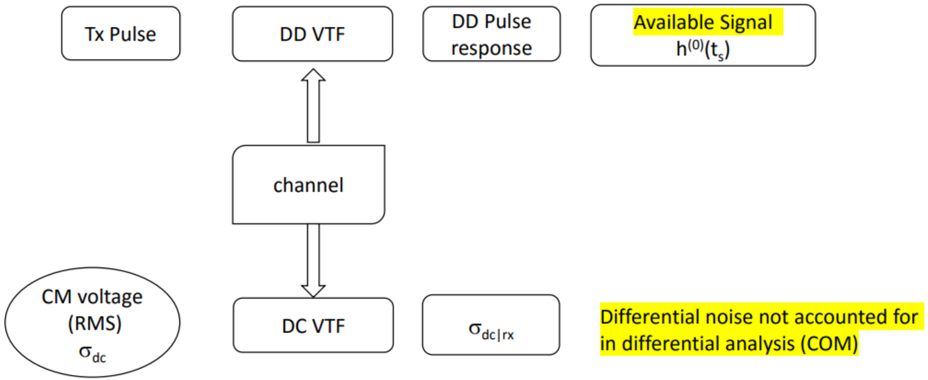


- CM noise (uncorrelated with the desired signal) (**CM1**)
  - High-freq component (**CM1a**), such "supply noise", typically below ~1 MHz (ran_3ck_adhoc_01_063021)
    - Let's model it as dual dirac with pk2pk value as 2*A_{DD1}
  - Wideband components (**CM1b**), let's model it as Gaussian noise with σ_{CM}
- CM signal (correlated with desired signal) (**CM2**)
  - Assumed it can be compensated by RX (ran_3ck_04_1020)
  - Let's model it as dual dirac with pk2pk value as 2*A_{DD2}

Performance Impact of CM1 – SNR_{TX}

- Uncorrelated CM noise (**CM1** with σ_{ucm} by combining A_{DD1} & σ_{CM})
  - $\sigma_{ucm}^2 = (A_{DD1}^2 + \sigma_{CM}^2)$
- Adopted the modified COM code in [mellitz_3ck_adhoc_01_061720]
  - CM voltage (RMS) at TP0 - σ_{dc}=σ_{ucm}
  - Converting by common-mode to differential mode conversion loss of channel (sdc21)
  - Evaluate the impact by SNR_{TX} degradation

Simple First Estimate



Performance Impact of CM1 – SNR_{TX} loss < 0.1 dB

File	AC CM (σ_{ucm}) (mV)	New SNR_{Tx} (dB) 30	17.5	15	**10**	1	sdc21_Peak (dB)
Kateri/Bch2_b7p5_7_		32.0	32.3	32.4	**32.4**	32.5	-38.9931
Kateri/Bch2_b6_7_t		31.9	32.3	32.3	**32.4**	32.5	-38.5647
Kateri/CAch2_a2p5_t		30.4	31.7	31.9	32.2	32.5	**-32.8423**
Heck/Cable_BKP_28dB_0p575m_more_isi_thru1		31.5	32.1	32.2	**32.5**	32.5	-38.3842
Mellitz/CaBP_BGAVia_Opt2_28dB_THRU		32.4	32.5	32.5	**32.5**	32.5	-51.1657
Zambell/Thru_Link_~~9~~10_C1_Pr_14_to_Pr_5		31.7	32.2	32.3	**32.4**	32.5	-40.547
Gore/C2C_PCB/SYSVIA_20dB_thru		31.3	32.1	32.2	**32.4**	32.5	-35.5721
Palkert/THRU_VL5_OD-BP-Channel_16inch_16inch		25.7	28.9	29.6	31.0	32.5	**-30.0389**

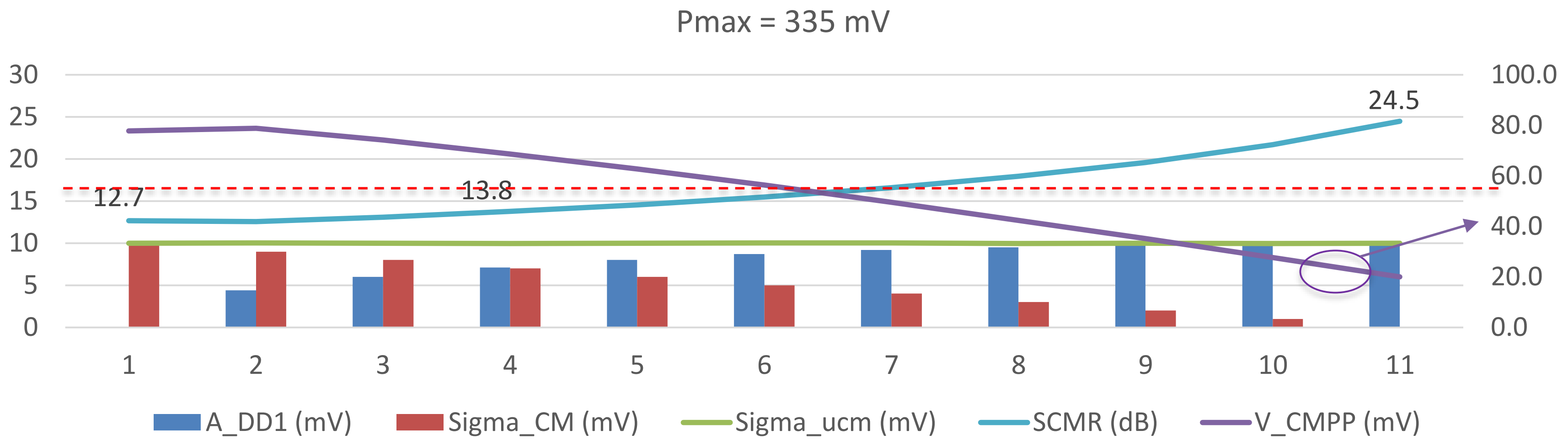
- IEEE 8x baseline KR channels analyzed
- Original SNR_{TX} is 32.5 dB
- By sdc21_Peak <= -35 dB & SNR_{TX} >= 32.4 dB ➔ AC CM (σ_{ucm}) <= 10 mV

Limited Values of Components of CM Voltage

Component	Symbol	Performance impact	Limited value (mV)	Notes
CM1a: Uncorrelated CM noise – high freq.	A_{DD1}	Impact is limited by 0.1 dB SNR_{TX} loss	$\sigma_{ucm} \leq 10$, $\sigma_{ucm}^2 = (A_{DD1}^2 + \sigma_{CM}^2)$	• SCMR strongly depends on ratio of A_{DD1} & σ_{CM} • 10 mV σ_{ucm} results in **SCMR = 13.8 dB (failed 16 dB spec) with** A_{DD1} = σ_{CM}
CM1b: Uncorrelated CM noise – wideband	σ_{CM}			
CM2: Correlated CM signal	A_{DD2}	Assumed no impact	5~10 (50 in mellitz_3ck_01_0921)	Will easily fail SCMR 16 dB spec limit → need to exclude this from SCMR calculation

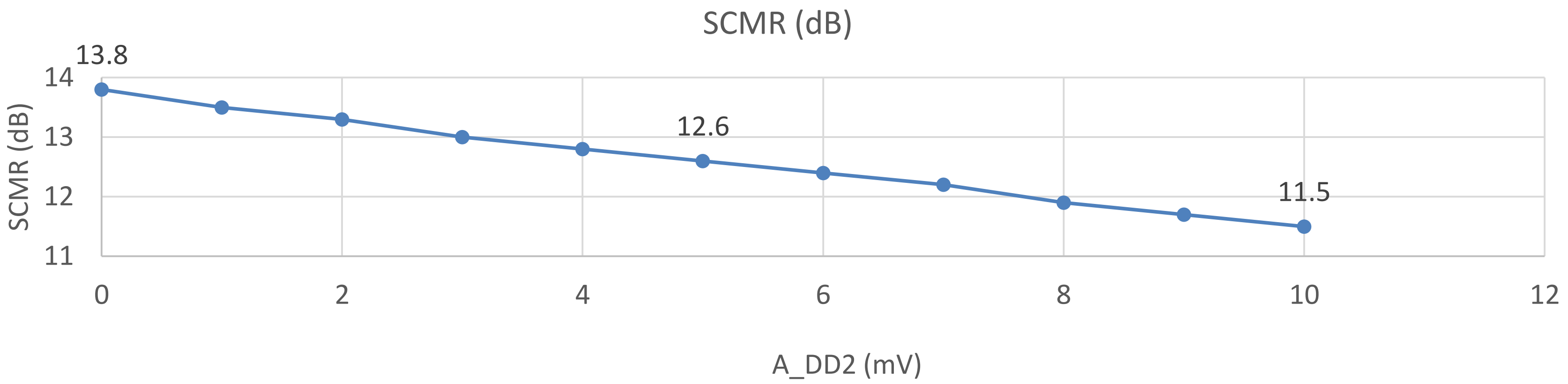
- ❑ σ_{ucm} = 10 mV aligned with mellitz_3ck_01_0921
- ❑ Large value of A_{DD2} doesn't impact RX, but will fail SCMR spec → two options
  - ❖ Option 1 – reduce SCMR limit by considering A_{DD2} component
  - ❖ Option 2 – define CM specs for correlated & uncorrelated (mellitz_3ck_01_0921)

SCMR with $\sigma_{ucm} = 10$ mV sweeping ratio of A_{DD1} & σ_{CM}, with A_{DD2} = 0 mV



- $P_{max} = 335$ mV is derived from referenced TP0v test fixture (163B.3) & scaled up to TP0 (append.)
- Larger σ_{CM} induces larger V_{CMPP}, and therefore smaller SCMR
  - You need to limit $\sigma_{CM} \leq 4.5\ mV$ to meet 16 dB SCMR, even A_{DD2} doesn't count in yet
  - By equal partition in A_{DD1} & σ_{CM}, the appropriate SCMR spec is 13.8 dB

SCMR with $\sigma_{ucm} = 10$ mV, $A_{DD1} = \sigma_{CM}$, by sweeping $A_{DD2} = 0 \sim 10$ mV



- ❑ Although A_{DD2} doesn't have big impact to RX, but contributes a lot to reduce SCMR value
  - ❖ Reduces SCMR with 0.8 ~ 1.7 dB for A_{DD2} in 5 ~ 10 mV
- ❑ It may change too much to D2.3 if excluding A_{DD2} in SCMR or defining CM specs for correlated & uncorrelated (mellitz_3ck_01_0921)
  - ❖ Propose to further reduce SCMR spec limit to reflect this issue, to say 13 dB

Summary and Proposal

- The simulation & analysis of AC CM noise shows
  - $\sigma_{ucm} \leq 10$ at TP0 is the appropriate spec to limit impact to RX
- The SCMR values are calculated by considering
  - Uncorrelated CM noise (high freq. + wideband)
  - Correlated CM signal
- SCMR values strongly depends on ratio of high freq. & wideband components of uncorrelated CM noise
  - Take equal partition, 16 dB is too much a value
- Correlated CM signal further reduces SCMR values, although it only has little impact to RX
  - Need further margin for it
- Propose to change SCMR spec limit from 16 dB to 13 dB
  - Apply both of C2C & C163

Thank You

Information to derive Pmax = 335 mV at TP0

163B.3 Reference Values

For this test fixture, the reference values determined according to the methodology in 163A.3 using the parameters supplied in Clause 163 are listed in Table 163B–1.

Table 163B–1—Summary of transmitter reference values at TP0v

Parameter	Reference	Value	Units
Effective return loss, $ERL^{(ref)}$	163A.3.1.2	12.95	dB
Transmitter steady-state voltage, $v_f^{(ref)}$	163A.3.1.1	0.409	V
Transmitter linear fit pulse peak, $v_{peak}^{(ref)}$	163A.3.1.1	0.237	V
Transmitter pulse peak ratio, $R_{peak}^{(ref)}$	163A.3.2.1	0.580	-

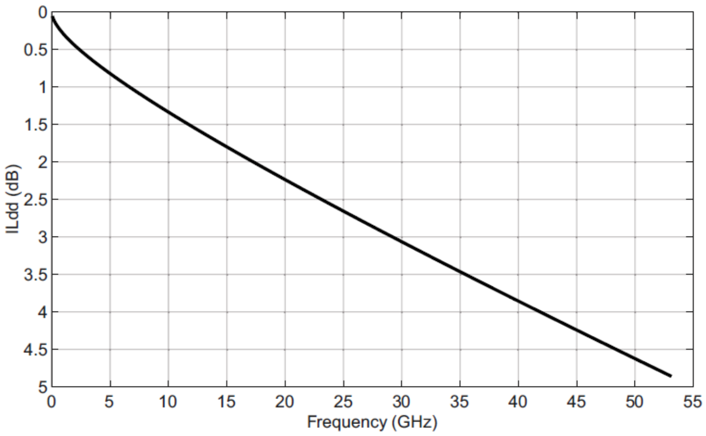


Figure 163B–1—Example test fixture differential-mode to differential-mode insertion loss

- ❑ 237 mV (@ TP0v with ~3 dB IL), simply scaled up by 3 dB (approximately), results in 335 mV @ TP0