Measuring RIN$_{XX}$OMA using an Oscilloscope

IEEE 802.3 Interim Meeting – 802.3dj D1.2 Comment Resolution
Hamburg, Germany

Ahmad El-Chayeb - Keysight Technologies
Ryan Chodora - Keysight Technologies
John Johnson – Broadcom

RIN$_{xx}$OMA - IEEE 802.3dj – Draft 1.1 - Clause *180.9.11*

IEEE 802.3dj – Draft 1.1

➤ IEEE 802.3dj draft 1.1 Cl 180 defines **RIN$_{xx}$OMA** as:

$$RIN_{xx}OMA = 10\,log_{10}\frac{(N_3 + N_0)^2/4}{OMA_{outer}^2 \times BW_N}\left(dB/Hz\right)$$

➤ Comment # 408 suggests changing the numerator from

$(N_3 + N_0)^2/4$ to $(N_3^2 + N_0^2)/2$

➤ This approach uses RSS average to calculate the electrical noise power from the optical noise power of the two levels, RN$_3$ and RN$_0$

RIN$_{xx}$OMA is calculated as defined in Equation (180–1):

$$RIN_{xx}OMA = 10log_{10}\left[\frac{\frac{(N_3 + N_0)^2}{4}}{OMA_{outer}^2 B}\right] \qquad (180–1)$$

where:

— RIN$_{xx}$OMA = relative intensity noise referred to optical modulation amplitude, measured with xx dB optical reflection,
— N$_3$ = Optical noise power of the 3 level,
— N$_0$ = Optical noise power of the 0 level,
— B = Low-pass bandwidth of filter of the reference receiver (Hz).

Cl 180	SC 180.9.11	P 392	L 37	# 408

Ran, Adee   Cisco Systems, Inc.

Comment Type   TR   **Comment Status** X

Equation 180-1 sums N0 and N3 and then squares them and divides by 4 - this seems inadequate. RIN should be a power ratio, so two measured noise levels should be power-averaged, not linearly averaged and then squared.

Also in other optical clauses.

SuggestedRemedy

Change the denominator from (N0+N3)^2/4 to (N3^2+N0^2)/2.

Apply in other optical PMD clauses.

Proposed Response   **Response Status O**

KEYSIGHT

Original RIN$_{xx}$OMA - IEEE Std 802.3ae™- 2002 - Clause *52.9.6.3*

➤ Laser intensity fluctuations can create noise that exceeds the thermal noise of the load impedance and/or the shot noise of the photodetector

➤ The original RIN$_{xx}$OMA was measured on a square wave with an O/E and an electrical power meter

➤ RIN$_{xx}$OMA test procedure was defined in clause *52.9.6.3* in **IEEE 802.3ae™ – 2002**

➤ Some modules' transmitters can't be operated without modulation

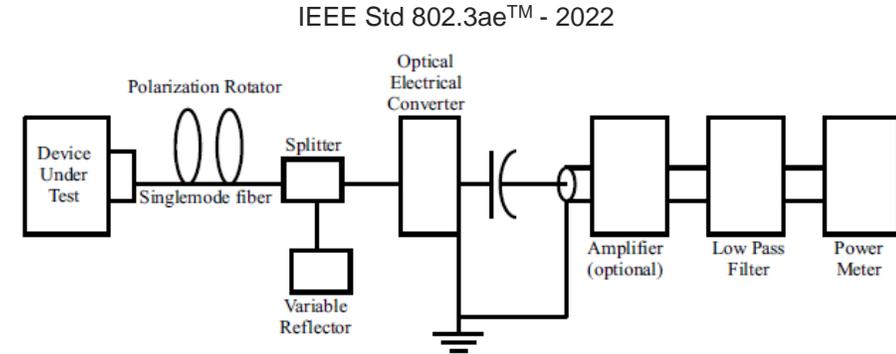➤ Proposal to measure RIN$_{xx}$OMA on the same oscilloscopes used to measure TDECQ in johnson_3j_03a_2405

IEEE Std 802.3ae™ - 2022

Figure 52-7—RIN$_x$OMA measurement setup

$$RIN\ OMA = \frac{P_N}{P_M \times BW_N}$$

$$RIN_{xx}OMA = 10log_{10}\frac{P_N}{P_M \times BW_N}\left(dB/_{Hz}\right)$$

Where:

P$_N$ = Electrical noise power in Watts with ***modulation off***

P$_M$ = Modulation power (observed in the load impedance)

BW$_N$ = Noise bandwidth of the measuring system (Hz)

Measuring the Electrical Noise Power (P$_N$) – Part 1

➢ RIN measurements occur on unmodulated signals

➢ RIN OMA measurements were historically a two-step process measured on both modulated and unmodulated signals

➢ To translate this measurement to a single step process on an oscilloscope, we need to approximate the electrical noise power that would have been measured on the unmodulated signal.

➢ If the unmodulated signal was assumed to be at the average power level (P$_{avg}$) of the modulated signal, then the optical noise power would be approximated as:

$$RN_{avg} = \frac{RN_1 + RN_0}{2}$$
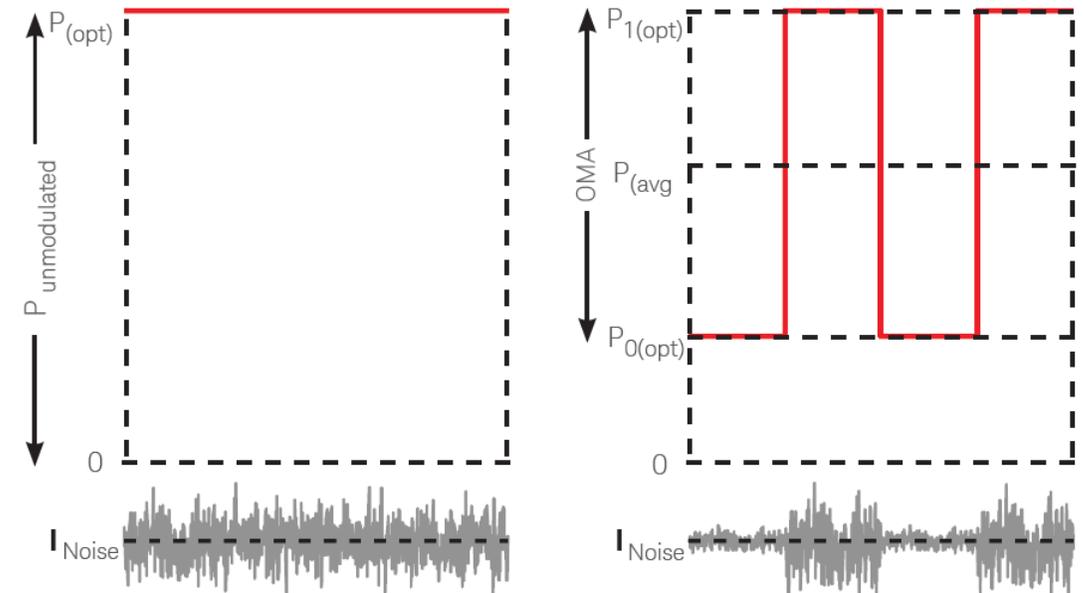
Conceptual difference between RIN (left) and RIN OMA (right)
(Top: Optical signal, Bottom: Noise Current)

KEYSIGHT

Measuring the Electrical Noise Power (P_N) – Part 2

➢ For a PAM4 signal, the RMS of the deviation from the mean optical power for the unmodulated signal (RN_{avg}) can be described as:

$$RN_{avg} = \frac{RN_3 + RN_0}{2}$$

Where:

RN_3 = RMS of the deviation from the mean optical power measured at the P_3 level

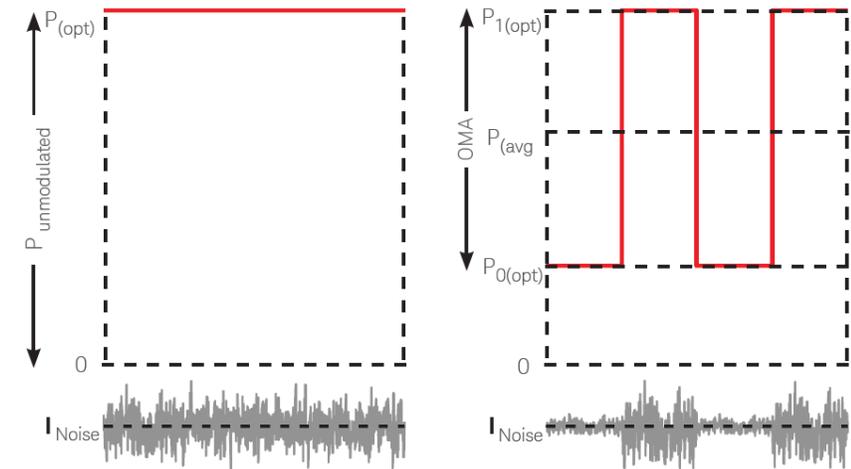RN_0 = RMS of the deviation from the mean optical power measured at the P_0 level

Conceptual difference between RIN (left) and RIN OMA (right)
(Top: Optical signal, Bottom: Noise Current)

➢ This would yield an electrical noise power of:

$$P_N = R_L[r_{pd}\frac{(RN_3 + RN_0)}{2}]^2 = \frac{1}{4} r_{pd}^2 R_L(RN_3 + RN_0)^2$$

Where:

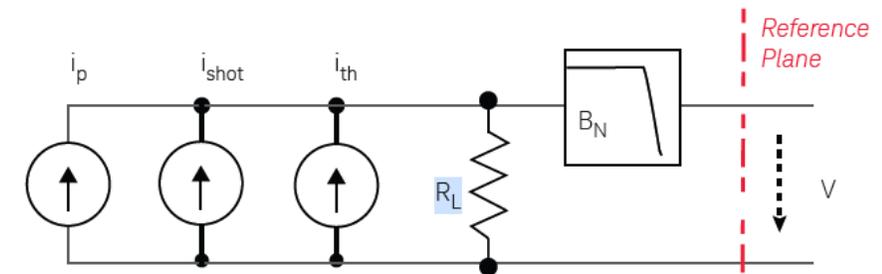R_L = Load resistance, impedance seen by the photodetector.

r_{pd} = Responsivity of photodetector

Measurement Path for Relative Intensity Noise (RIN)

Measuring RIN$_{xx}$OMA using an Oscilloscope – IEEE 802.3 Method

➤ The modulation power is defined as:

$$P_M = \frac{1}{4} OMA_{outer}^2 r_{pd}^2 R_L$$

➤ RIN OMA can then be expressed as:

$$RIN\,OMA = \frac{P_N}{P_M \times BW_N} = \frac{\frac{1}{4} r_{pd}^2 R_L (RN_3 + RN_0)^2}{\frac{1}{4} OMA_{outer}^2 r_{pd}^2 R_L \times BW_N} = \frac{(RN_3 + RN_0)^2}{OMA_{outer}^2 \times BW_N}$$
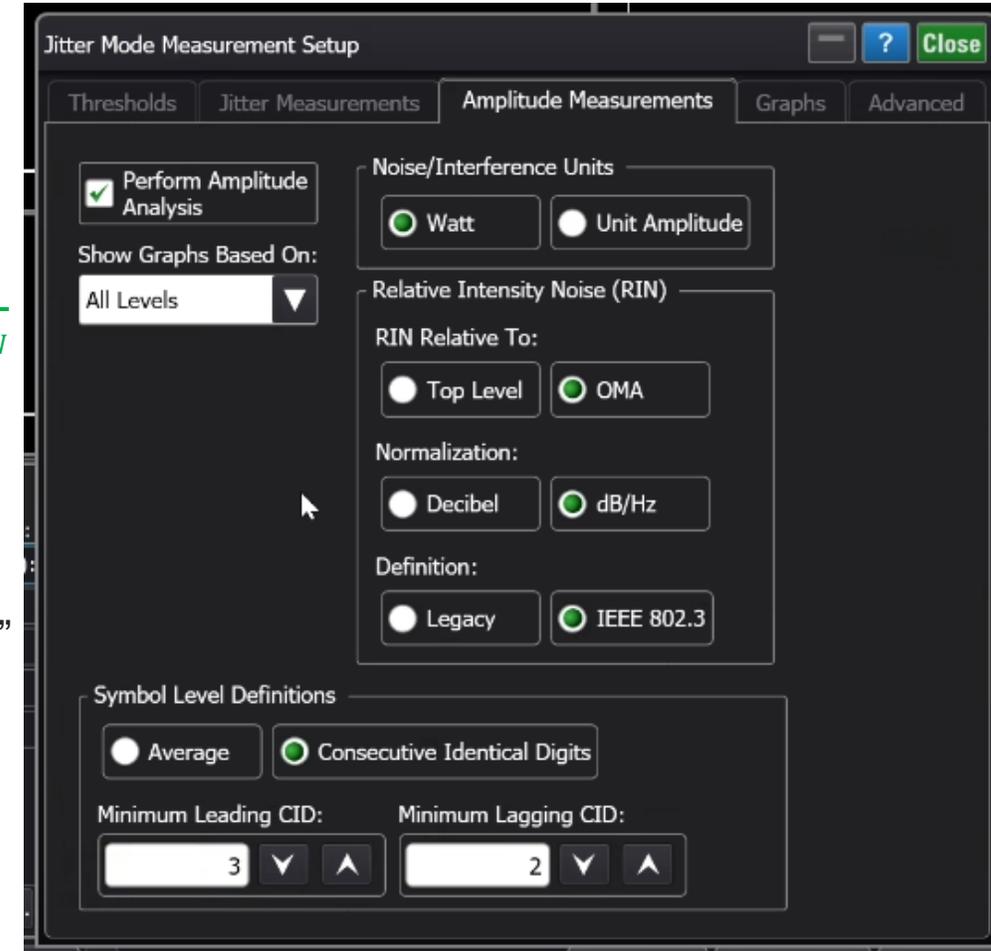
➤ Therefore; RIN$_{xx}$OMA can be defined as:

$$RIN_{xx}OMA = 10\,log_{10}\frac{(RN_3 + RN_0)^2}{OMA_{outer}^2 \times BW_N}\left(dB/Hz\right)$$

➤ This is what is currently implemented in FlexDCA when the "IEEE 802.3" method is selected

➤ This is a factor of 4 different than the current definition of RIN$_{xx}$OMA in 802.3dj draft 1.1 (also legacy method)

$$RIN_{xx}OMA = 10\,log_{10}\frac{(RN_3 + RN_0)^2/4}{OMA_{outer}^2 \times BW_N}\left(dB/Hz\right)$$

Measuring RIN$_{xx}$OMA using an Oscilloscope – Comment Method

➤ Using the RSS average of optical noise is an acceptable approach

➤ This approach does not match the original RIN$_{xx}$OMA measuring P$_N$ on an unmodulated signal

➤ If the electrical noise power is defined as an RSS average of noise, then:

$$P_N = r_{pd}^2 \, R_L \, \frac{(RN_3^2 + RN_0^2)}{2}$$

➤ Modulation power is defined as:

$$P_M = \frac{1}{4} \, OMA_{outer}^2 \, r_{pd}^2 \, R_L$$

➤ RIN OMA can then be expressed as:

$$RIN \, OMA = \frac{P_N}{P_M \times BW_N} = \frac{\frac{1}{2} r_{pd}^2 \, R_L \, (RN_3^2 + RN_0^2)}{\frac{1}{4} OMA_{outer}^2 \, r_{pd}^2 \, R_L \times BW_N} = \frac{2(RN_3^2 + RN_0^2)}{OMA_{outer}^2 \times BW_N}$$

➤ That leads to a RIN$_{xx}$OMA that can be defined as:

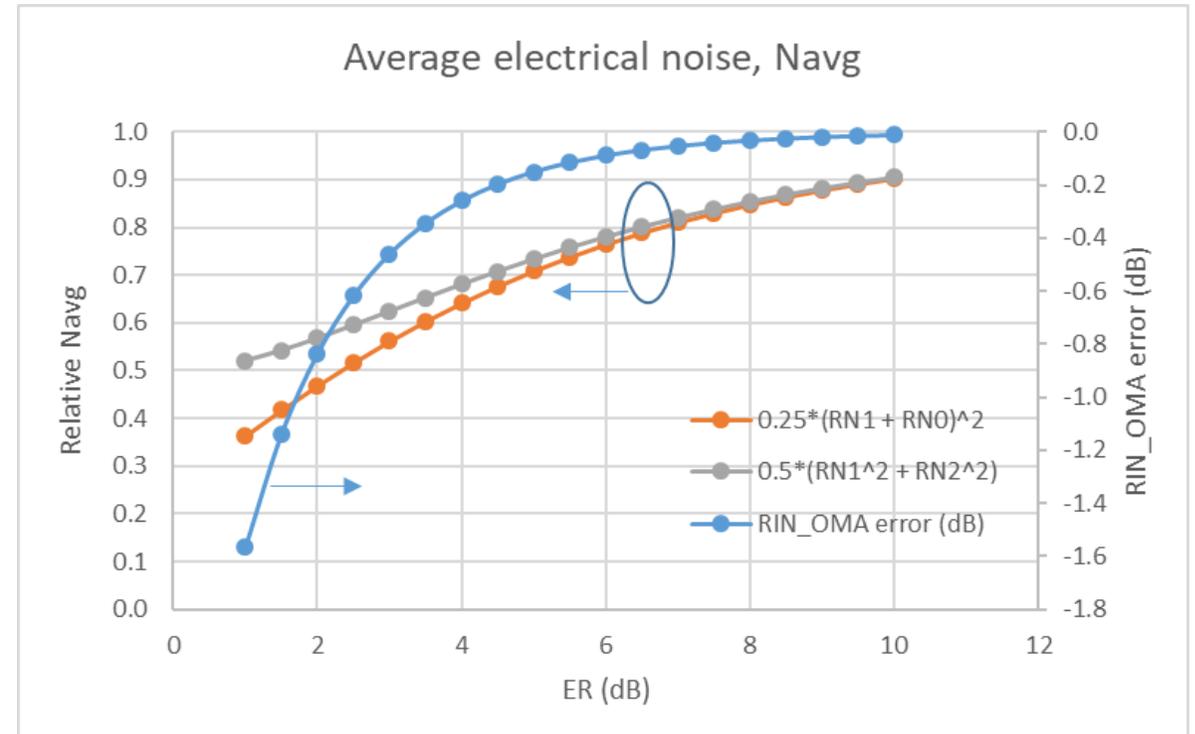$$RIN_{xx}OMA = 10 \, log_{10} \frac{2(RN_3^2 + RN_0^2)}{OMA_{outer}^2 \times BW_N} \, (dB/_{Hz})$$

➤ Therefore, RIN$_{xx}$OMA is a factor of 4 different from the proposed definition in comment #408

CI 180	SC 180.9.11	P 392	L 37	# 408

Ran, Adee   Cisco Systems, Inc.

Comment Type   **TR**   Comment Status **X**

Equation 180-1 sums N0 and N3 and then squares them and divides by 4 - this seems inadequate. RIN should be a power ratio, so two measured noise levels should be power-averaged, not linearly averaged and then squared.

Also in other optical clauses.

SuggestedRemedy

Change the denominator from (N0+N3)^2/4 to (N3^2+N0^2)/2.

Apply in other optical PMD clauses.

Proposed Response   Response Status **O**

KEYSIGHT

Measuring the Electrical Noise Power (P$_N$)

➤ The *RIN$_{xx}$OMA* definition is dependent on the interpretation of the electrical noise power (P$_N$)

➤ Both definitions (averaging and RSS averaging RN$_3$ and RN$_0$) will lead to a very similar RIN$_{xx}$OMA value at the OER range of IEEE 802.3dj (> 3.5dB)

➤ The current definition, using (RN$_3$ + RN$_0$)/2 to calculate the electrical noise power, is a closer match to the original definition of P$_N$ in IEEE Std 802.3ae^{TM} - 2002

➤ Using an RSS average is also an acceptable approach; however, it does not match the historic RIN$_{xx}$OMA measurement used for many years now

➤ We recommend sticking to the current definition and dropping the /4 factor from the current draft

➤ Therefore; *RIN$_{xx}$OMA* should be defined as:

Average electrical noise, Navg

$$RIN_{xx}OMA = 10\ log_{10} \frac{(RN_3 + RN_0)^2}{OMA_{outer}^2 \times BW_N} \left(dB / Hz \right)$$

Thank You