

# Measuring RIN<sub>xx</sub>OMA using an Oscilloscope

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

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# RIN<sub>xx</sub>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<sub>xx</sub>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

$$(N_3 + N_0)^2 / 4 \text{ to } (N_3^2 + N_0^2) / 2$$

➤ This approach uses RSS average to calculate the electrical noise power from the optical noise of the two levels, RN<sub>3</sub> and RN<sub>0</sub>

RIN<sub>xx</sub>OMA is calculated as defined in Equation (180-1):

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

where:

- RIN<sub>xx</sub>OMA = relative intensity noise referred to optical modulation amplitude, measured with xx dB optical reflection,
- N<sub>3</sub> = Optical noise power of the 3 level,
- N<sub>0</sub> = 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.		
<i>Comment Type</i>	<b>TR</b>	<i>Comment Status</i> <b>X</b>		
Equation 180-1 sums N0 and N3 and then squares them and divides by 4 - this seems inadequate. <b>RIN</b> 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.				
<i>Suggested Remedy</i>				
Change the denominator from (N0+N3)^2/4 to (N3^2+N0^2)/2.				
Apply in other optical PMD clauses.				
<i>Proposed Response</i>		<i>Response Status</i> <b>O</b>		

# Original RIN<sub>xx</sub>OMA - IEEE Std 802.3ae™ - 2002 - Clause 52.9.6

- 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<sub>xx</sub>OMA was measured on a square wave with an O/E and an electrical power meter
- RIN<sub>xx</sub>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<sub>xx</sub>OMA on the same oscilloscopes used to measure TDECQ in [johnson\\_3j\\_03a\\_2405](#)

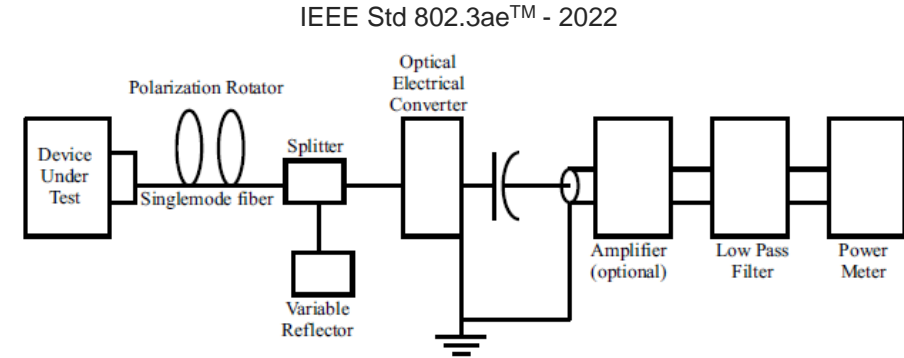


Figure 52-7 – RIN<sub>xx</sub>OMA measurement setup

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

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

Where:

$P_N$  = Electrical noise power in Watts with **modulation off**

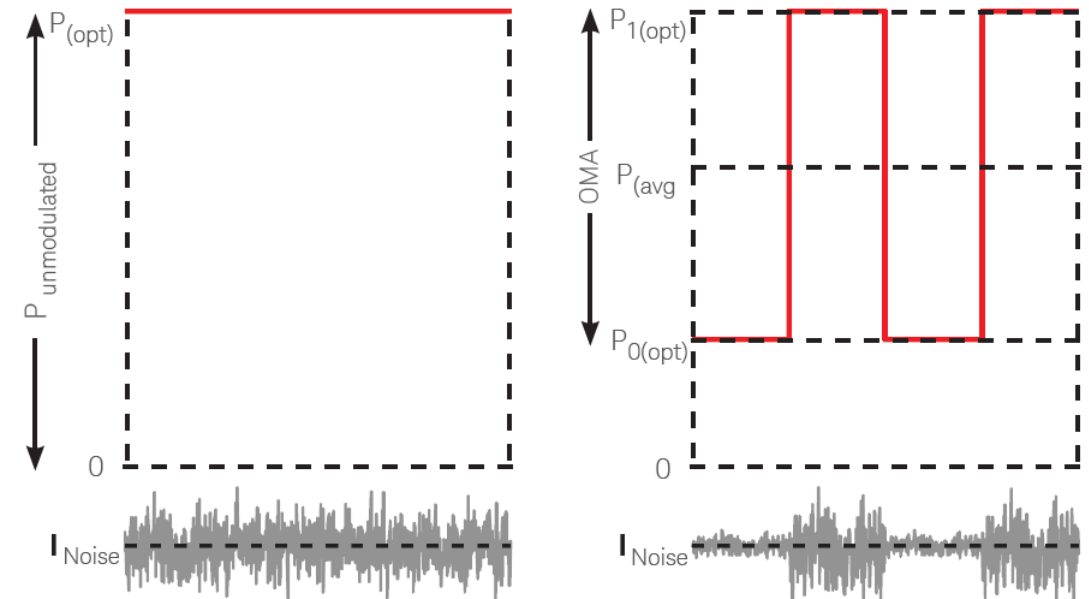
$P_M$  = Electrical noise power in Watts with modulation on

$BW_N$  = 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 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 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)

# Measuring the Electrical Noise Power ( $P_N$ ) – Part 2

- For a PAM4 signal, the unmodulated signal has optical noise ( $RN_{avg}$ ) described as:

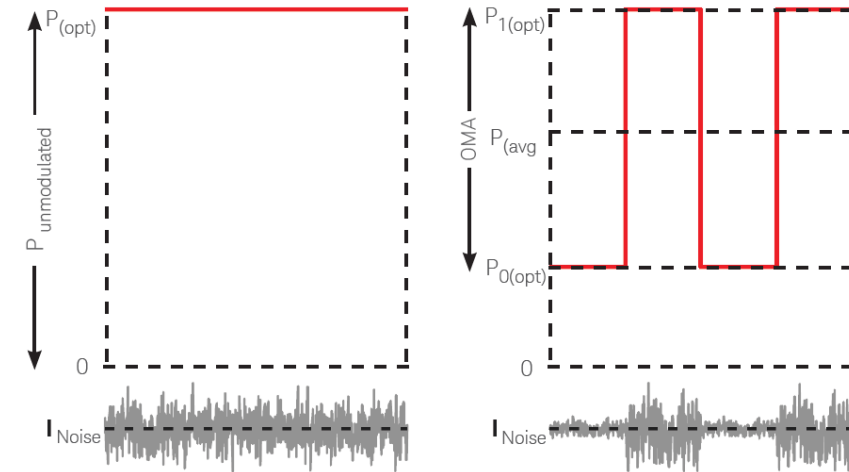
$$RN_{avg} = \frac{RN_3 + RN_0}{2}$$

Where:

$RN_{avg}$  = Average Random Noise (measured optically)

$RN_3$  = Random noise measured at the 3 level

$RN_0$  = Random noise measured at the 0 level



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

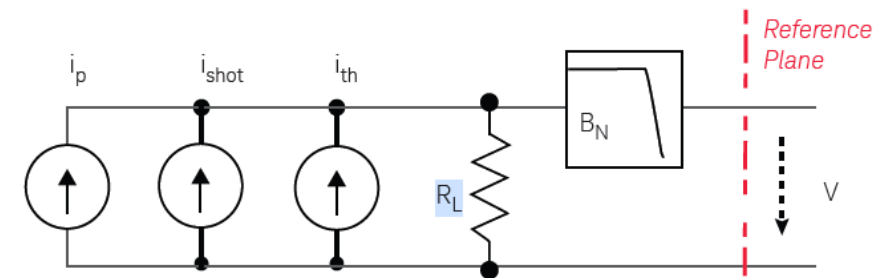
- This would yield an electrical noise power of:

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

Where:

$R_L$  = Load resistance, impedance seen by the photodetector.

$r_{pd}$  = Responsivity of a photodetector



Measurement Path for Relative Intensity Noise (RIN)

# Measuring RIN<sub>xx</sub>OMA using an Oscilloscope – IEEE 802.3 Method

➤ The electrical noise power with modulation on is defined as:

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

➤ RIN OMA can then be expressed as:

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

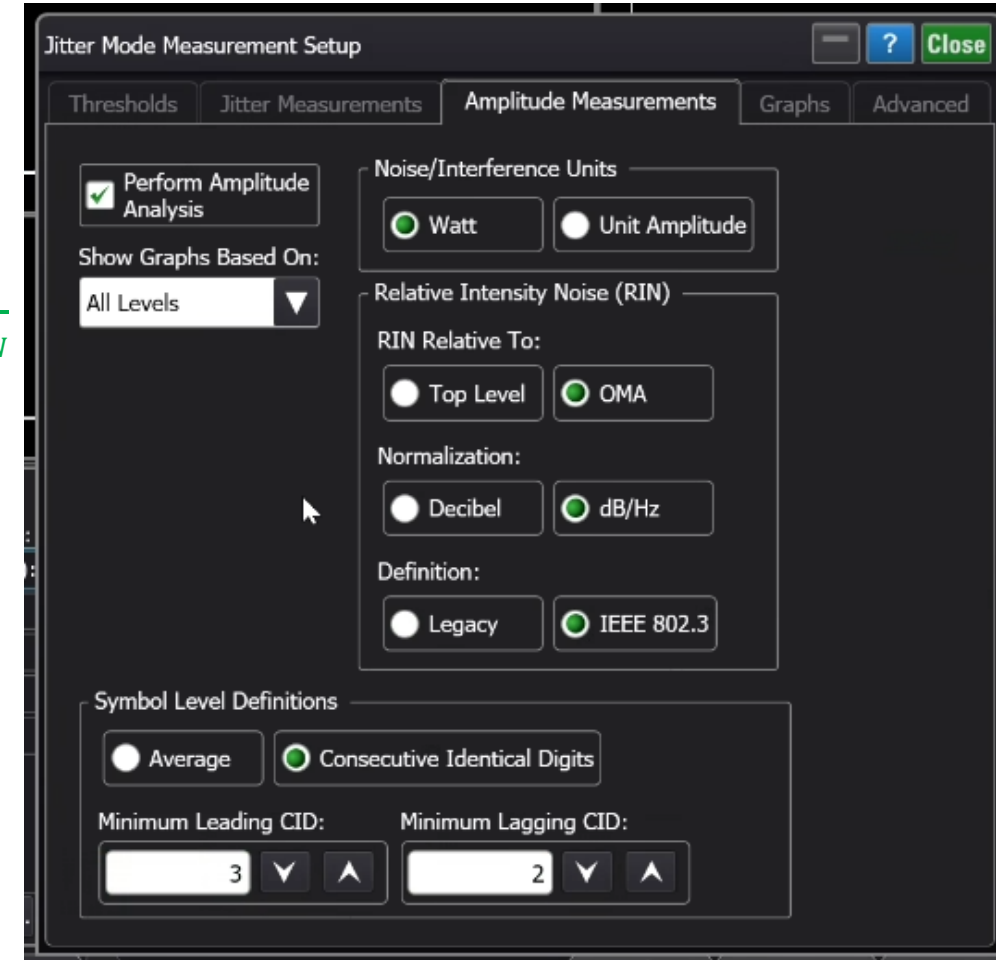
➤ Therefore; RIN<sub>xx</sub>OMA can be defined as:

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

➤ This is what is currently implemented in FlexDCA when “IEEE 802.3” method is selected

➤ This is a factor of 4 different than the current definition of RIN<sub>xx</sub>OMA in 802.3dj draft 1.1 (also legacy method)

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



# Measuring RIN<sub>xx</sub>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<sub>xx</sub>OMA measuring P<sub>N</sub> on an unmodulated signal
- If the electrical noise power is defined as an RSS average of optical power, then:

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

- Electrical noise power with modulation on (P<sub>M</sub>) 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<sub>xx</sub>OMA that can be defined as:

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

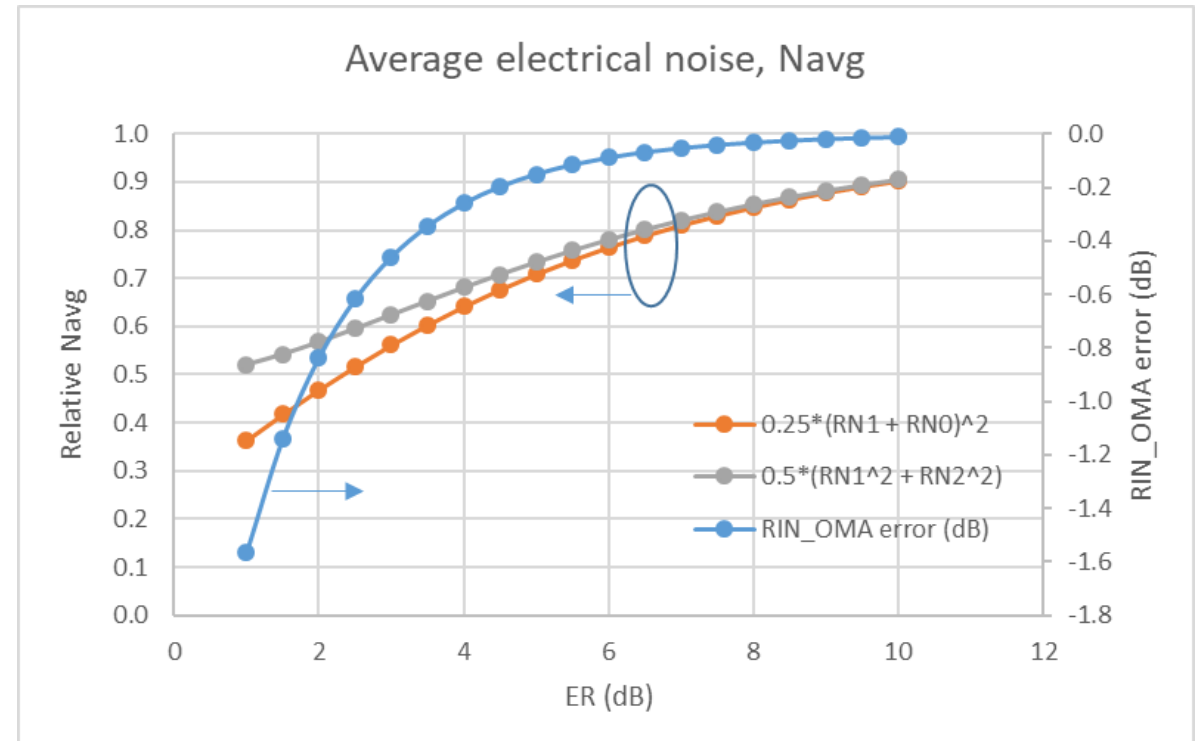
- Therefore, RIN<sub>xx</sub>OMA is a factor of 4 different from the proposed definition in comment #408

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SuggestedRemedy				
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Proposed Response	Response Status O			

# 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 ( $> 3.5\text{dB}$ )
- The current FlexDCA 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™ - 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 FlexDCA definition and dropping the /4 factor from the current draft
- Therefore;  $RIN_{xx}OMA$  should be defined as:

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





# Thank You