

TP2 and TP3 Parameter Measurement Test Readiness

Jonathan King, Sudeep Bhoja,
Jeff Rahn, Brian Taylor

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 - Tx: Eye Mask
OMA, ER, Average Power
Encircled Flux (and CPR)
RIN (and measured SNR (Tx to Rx))
TWDP
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 - Stressed Eye Generator
 - Rx: B-B Sensitivity Performance
TP3 Test Waveforms
Overload

Aim is to show experimental verification of test procedures & compliance to specifications

Summary of Major LRM Parameters at TP2 & TP3

TP2 Parameter		Min	Max	Comments
Tx OMA	dBm	-4.5	+1.5	
Mean Power	dBm		+0.5	
RIN	dBm _{OMA} /Hz		-128	
Eye Mask Margin	%	0		5x10 ⁻⁵ hits in margin
TWDP	dB		4.7	
Encircled Flux		>30% inside 5um radius >86% inside 11um radius		

TP3 Parameter		Min	Max	Comments
Rx OMA Range	dBm OMA	-6.5	+1.5	
Mean Power	dBm	-8.5	+0.5	
Stressed Sensitivity Test	dBm OMA		-6.5	TP3 normative waveforms
Informative Sensitivity Test	dBm OMA		-6.5	TP3 informative waveform
Overload	dBm OMA dBm mean	+1.5 +0.5		TP3 normative waveforms

TP2 Testing

Parameters measured at module level for TP2 Readiness evaluation:

- Average launch power, OMA, ER, Jitter, Eye-mask Margin
 - Test kit required:
 - 2^{31} PRBS data source (eg XAUI, self generated), bit trigger
 - 8x1 8x0 (or similar) data source
 - Digital Oscilloscope with O-E
 - Optical power meter
- TWDP
 - Test kit required:
 - 2^9 Data source, pattern trigger
 - Digital Oscilloscope with O-E
 - Computer
- Encircled Flux
 - Test kit required:
 - IR camera or equivalent method

TP2 tests use conventional equipment and established methods

TP2 Measurement Results

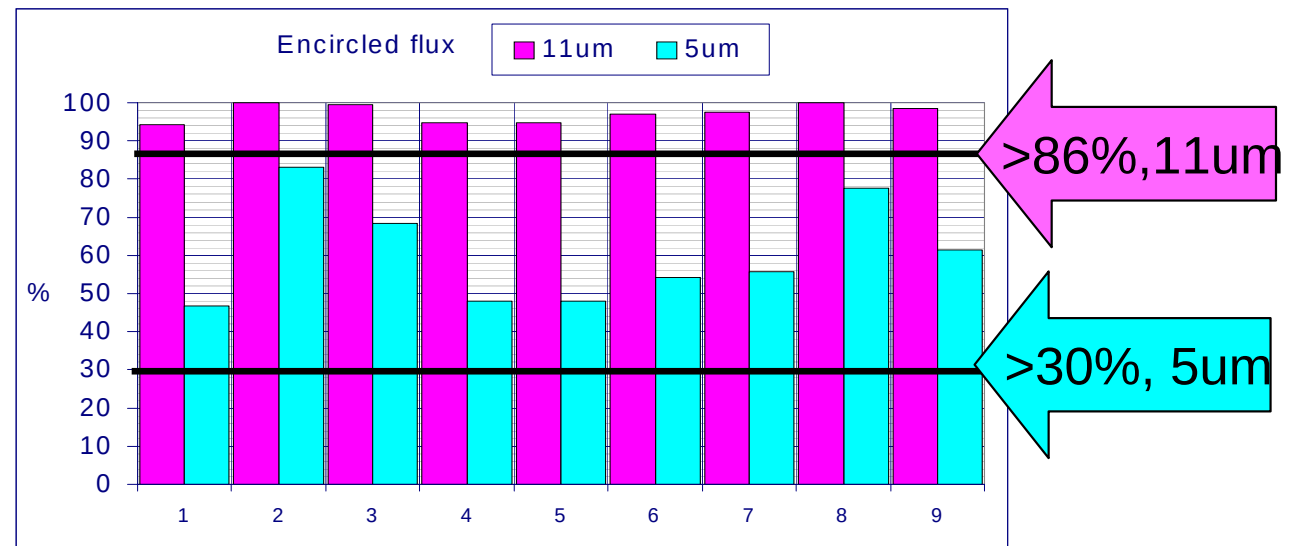
Parameter	Supply, Temp	Average	σ	Spec	Margin to Spec. σ
SMF power, dBm	Min/cold	-1.12	0.26	0.5 (max)	6.2
	Nom/nom	-1.35	0.29		6.5
	Max/hot	-1.64	0.38		5.6
SMF OMA	Min/cold	-1.27	0.27	-4.5 (min)	11.9
	Nom/nom	-1.48	0.25		12.3
	Max/hot	-1.6	0.37		7.9
ER, dB	Min/cold	4.62	0.16	3.5	6.9
	Nom/nom	4.31	0.09		13.3
	Max/hot	4.41	0.16		8.5
Jitter p-p, ps	Nom/nom	25.4	1.52	33	5.0
Eye Margin %	Min/cold	20.0	5.28	0	3.8
NB: 0 hit limit used	Nom/nom	20.6	4.97		4.1
	Max/hot	18.5	4.65		4.0

- Typically $>4 \sigma$ margin to spec
- Confirms TP2 specifications are consistent with high volume manufacture, as required for PAR

TP2 Encircled Flux and CPR Testing & Results

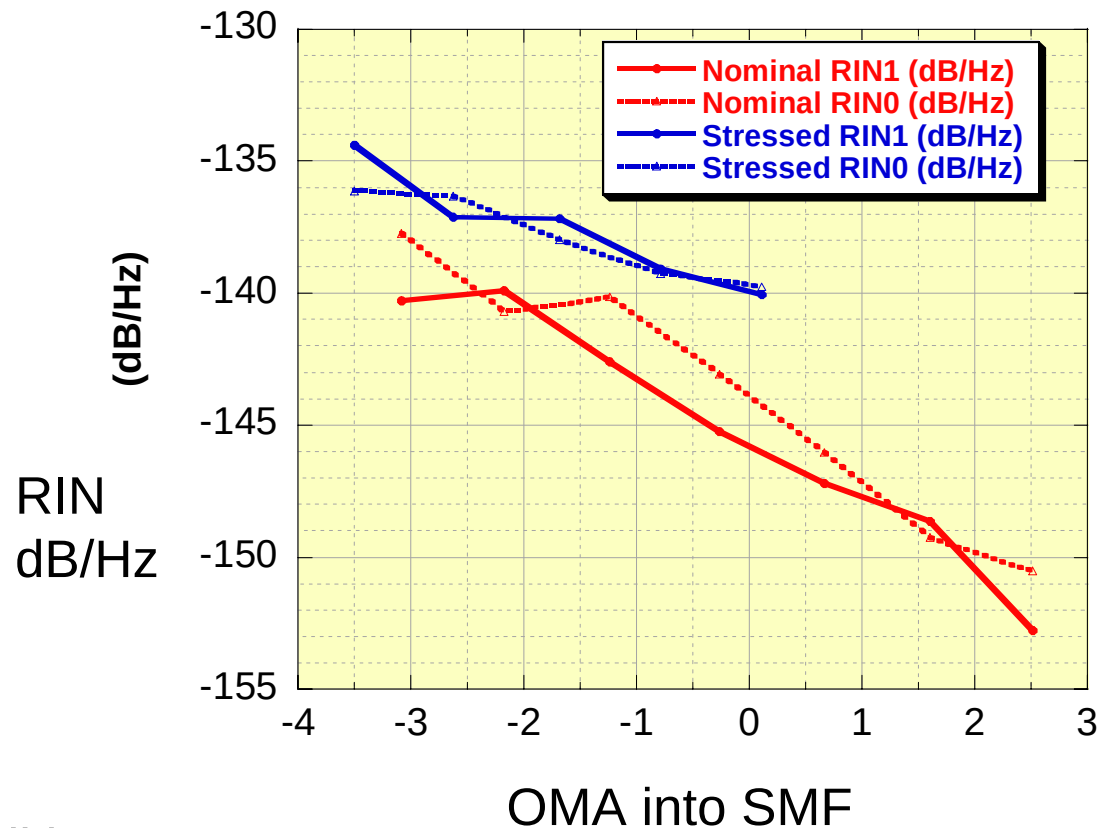
Encircled Flux:

- Non-IEC method used here (scanned SM fibre technique)
- Comparison underway with IR camera approach



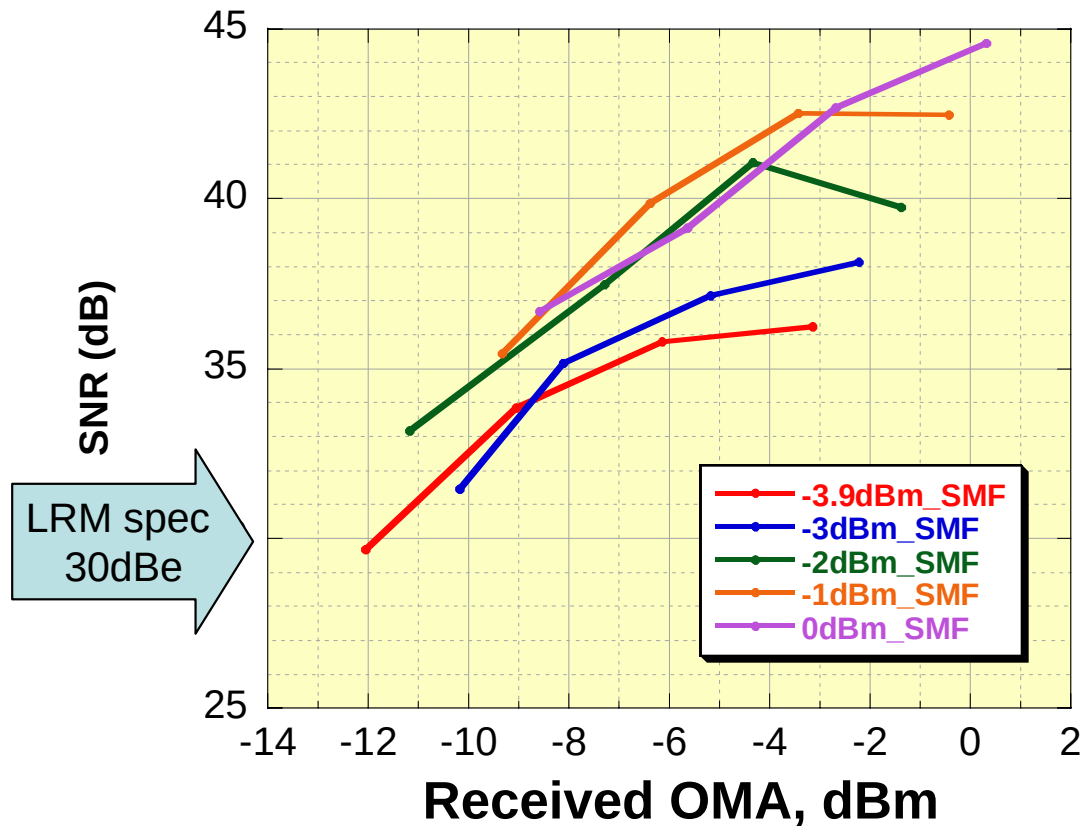
Encircled Flux	Average	Sigma	Spec	Margin to spec
5um radius	60.4%	13.3%	30%	2.3 σ
11 um radius	97.3%	2.32%	86%	4.9 σ
CPR **	0.9dB	0.25dB	2dB	4.4 σ

TP2 Measurements: RIN



- Test conditions
 - Nominal: 30°C, nominal module bias, & nominal back-reflection
 - Stressed: 70°C, low supply (-6%), and 12dB back-reflection
- Nominal Tx OMA -2dBm into SMF
 - Worst case RIN: -140dB/Hz nominal, -137dB/Hz stressed

TP2 Measurements: Example of Tx-Rx SNR



- Test condition
 - TOSA & ROSA: 70°C, low supply (-6%)
- At -2dBm OMA Tx output power
 - SNR > 38dBe at -6.5dBm OMA Rx input

TP2: TWDP

- TWDP measurements here used Draft 2.2 stressors, 100/50 TFF/DFE EDC emulation
 - Normalization of captured waveform to OMA added within code
- 4.7dB test limit, as in Draft 2.2
- Needs repeating with latest finite EDC emulation and latest OMA extraction code

Parameter	Supply, Temp	Average	σ	Spec	Margin to Spec.
TWDP, dB	Min/cold	4.32	0.08	4.7	4.4σ
	Nom/nom	4.31	0.06		6.1σ
	Max/hot	4.41	0.07		3.9σ

- 10 samples typically $>4\sigma$ margin to spec

TP3 Testing

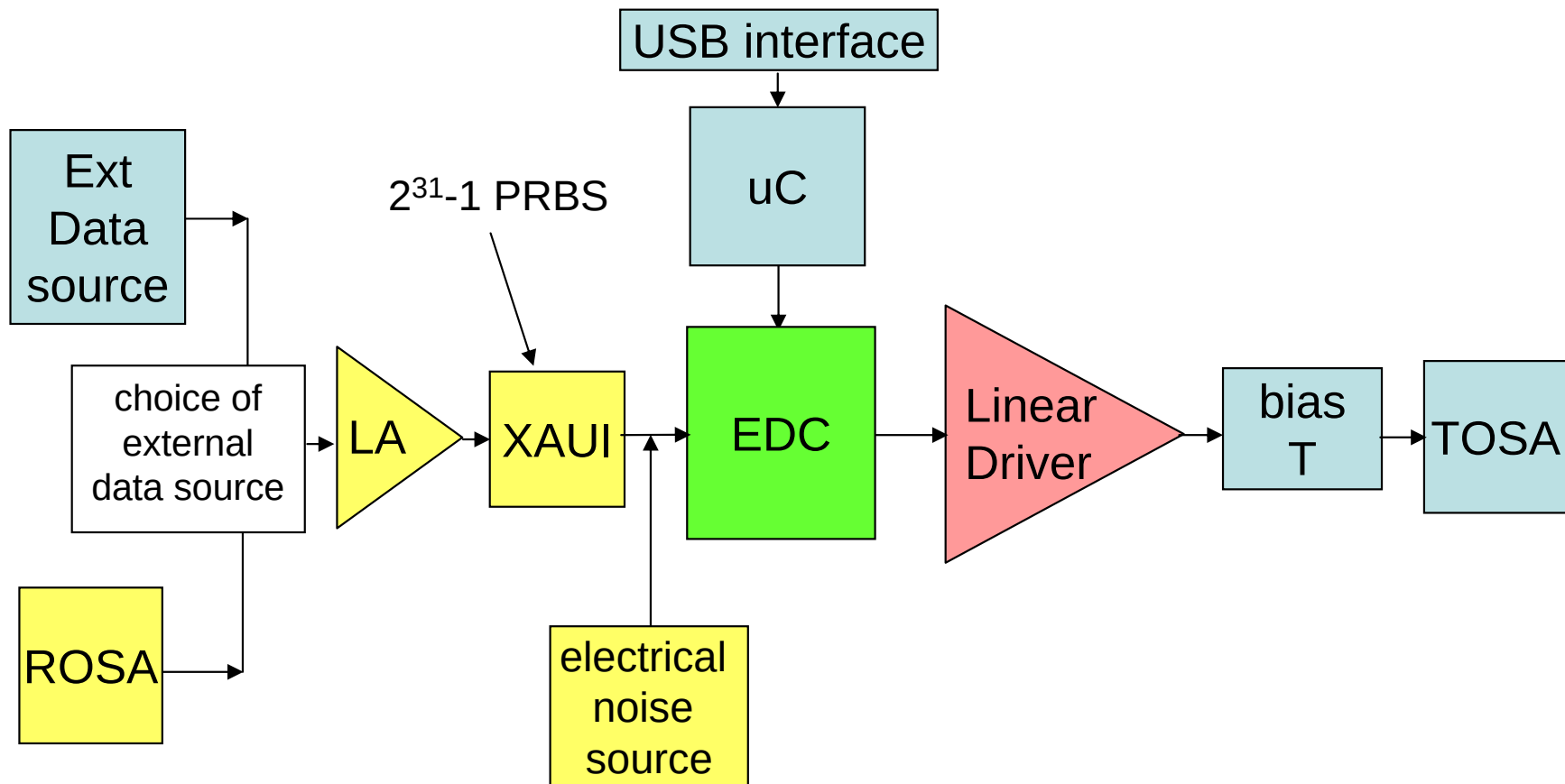
Parameters measured at module level for TP3 Readiness Evaluation:

- Normative sensitivity tests
 - Test kit required:
 - Stressed eye generator (SEG) with E-O (3.5dB ER, 27dB SNR)
 - BER detection
 - Optical power meter
- Overload
 - Test kit required:
 - 2⁹ Data source, pattern trigger
 - Digital Oscilloscope with O-E
 - Computer

TP3 Testing: SEG (Stressed eye generator) for LRM

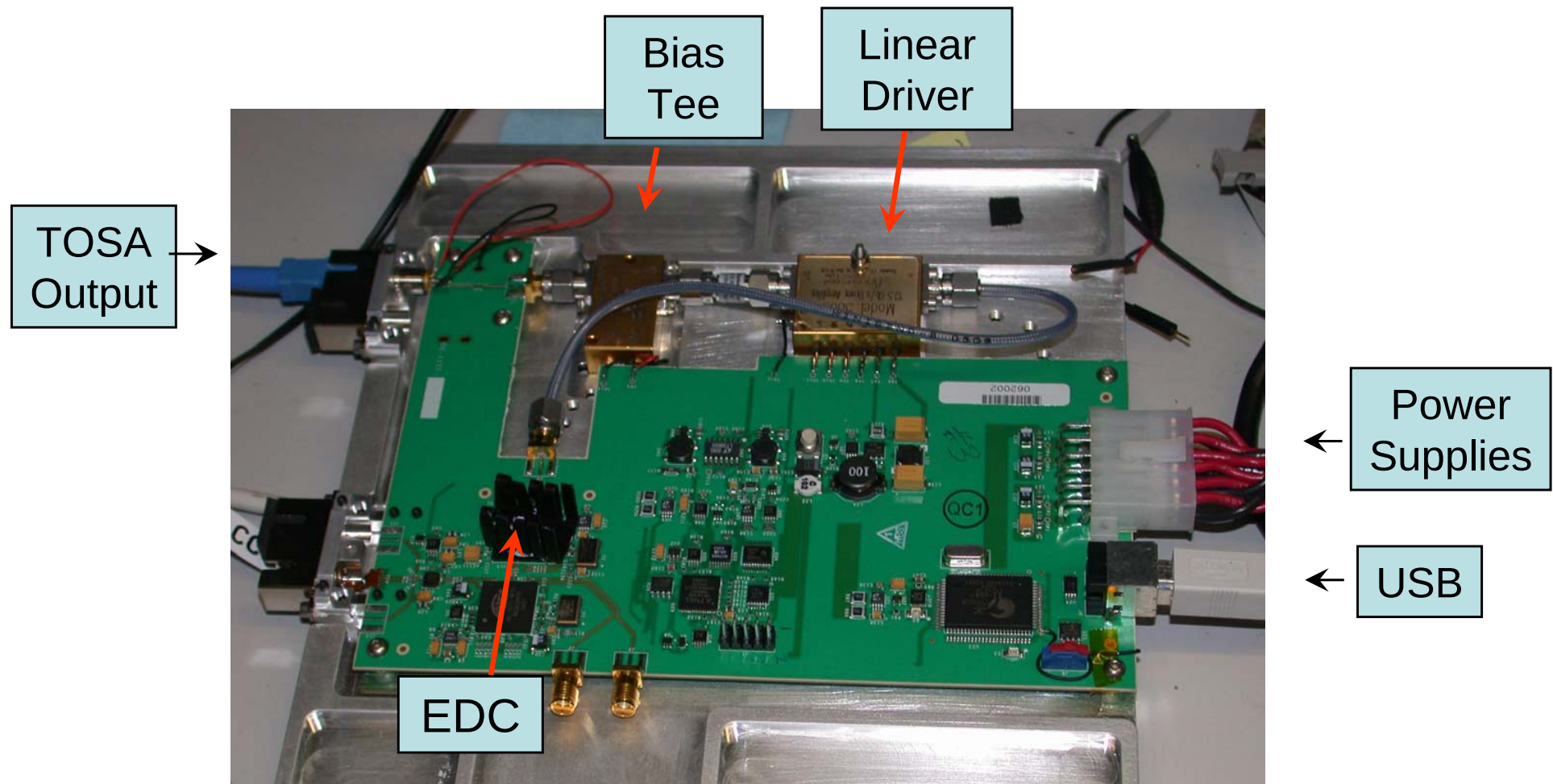
- Creates a stable, stressed channel that can be used to test and compare receiver performance
- ISI generator is based on TFF plus linear E-O
 - Avoids issues with long period reflections associated with lumped element implementations
- On board PRBS generation and error detection
- Large number of taps permits better fits
 - Short period reflections can be compensated for with extra taps
 - DUT sees accurate stressor

SEG Block Diagram



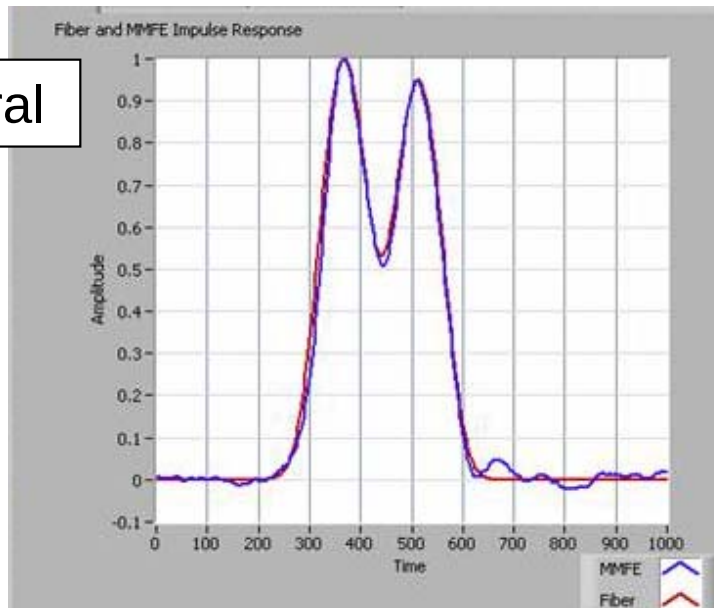
- Like a transponder, but with EDC in Tx chain, linear driver & E-O
- USB interface for easy PC based GUI control
- Implements 802.3aq TP3 Test Waveforms; fiber pulse response emulations are also possible.

SEG Board Photo

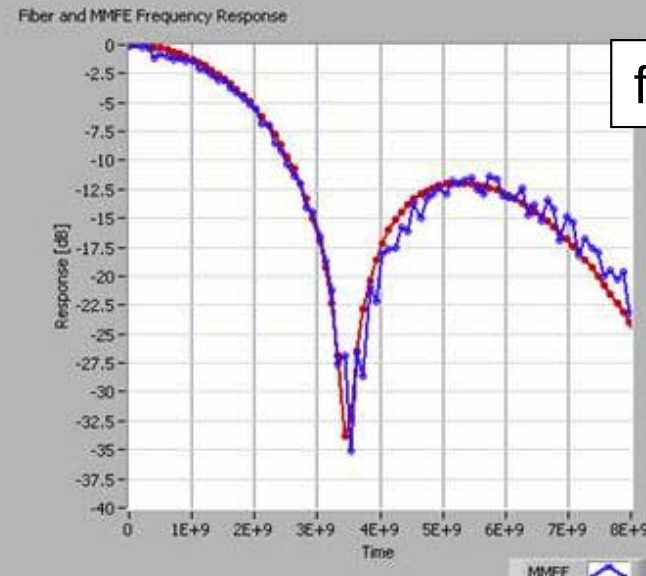


SEG: Symmetric Channel

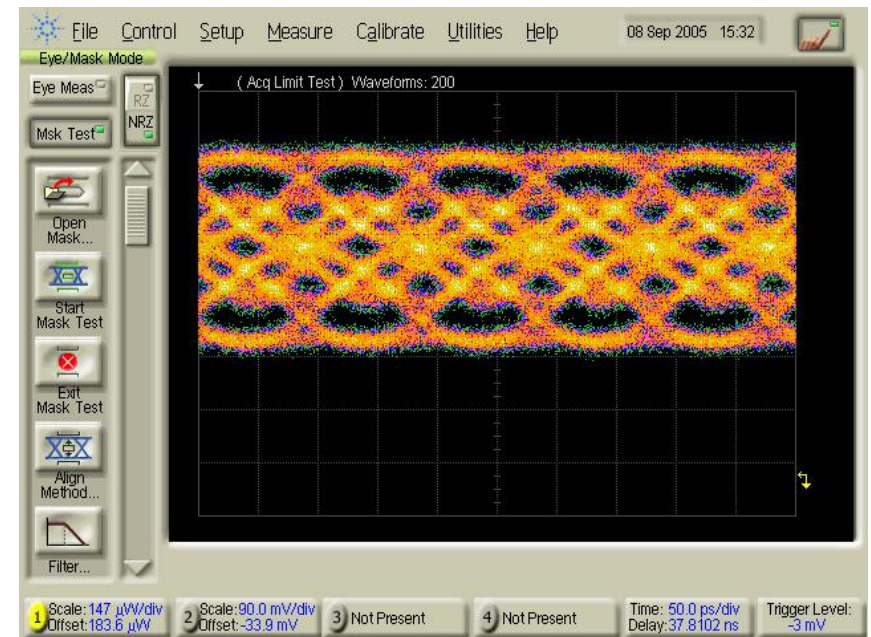
temporal



frequency

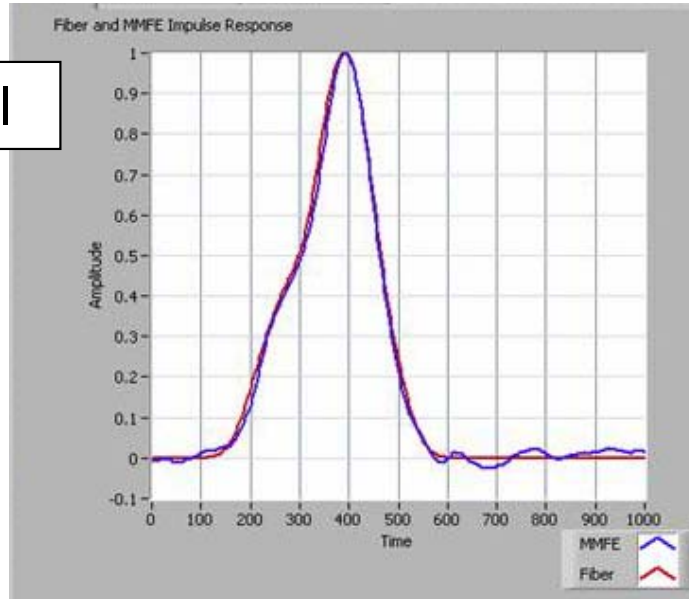


- Blue = SEG fit, Red = Target channel
- PIE-D value 3.85 dB
 - PIE-D error = +0.03dB
- SNR = 30.46dBe
 - SNR error = -0.54dBe
- ER = 3.6dB
 - ER error = +0.1dB
- OMA = -3.0 dBm

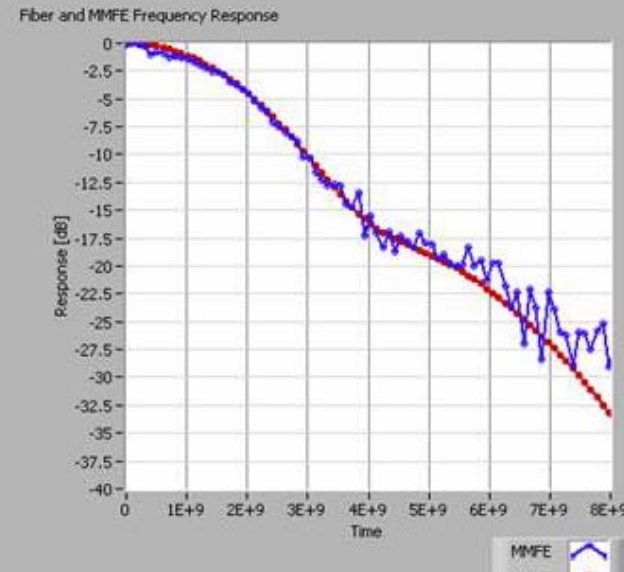


SEG: Pre-cursor Channel

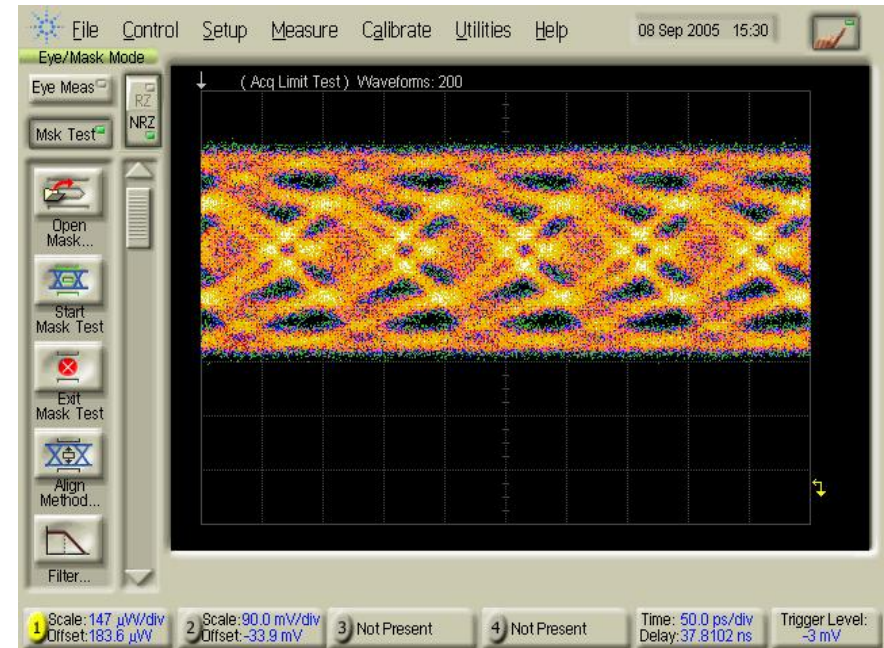
temporal



frequency

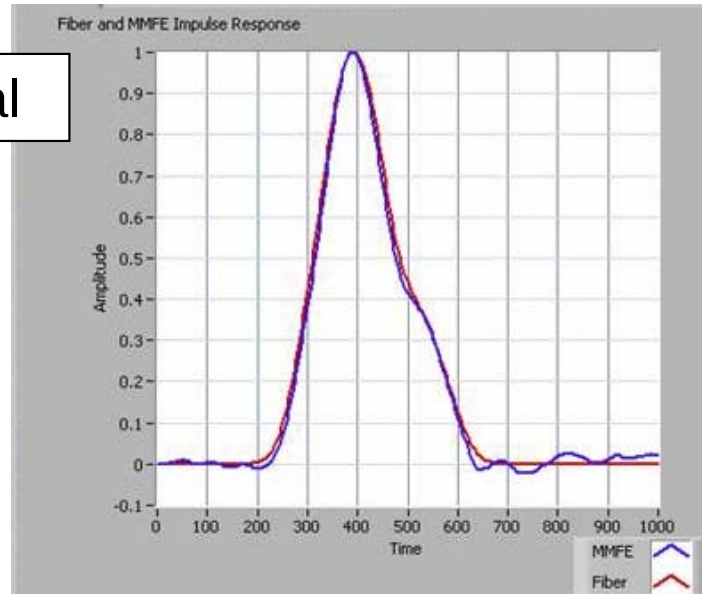


- Blue = SEG fit, Red = Target channel
- PIE-D value 4.1 dB
 - PIE-D error = +0.06dB
- SNR = 30.65dBe
 - SNR error = -0.35dBe
- ER = 3.63dB
 - ER error = +0.13dB
- OMA = -2.96dBm

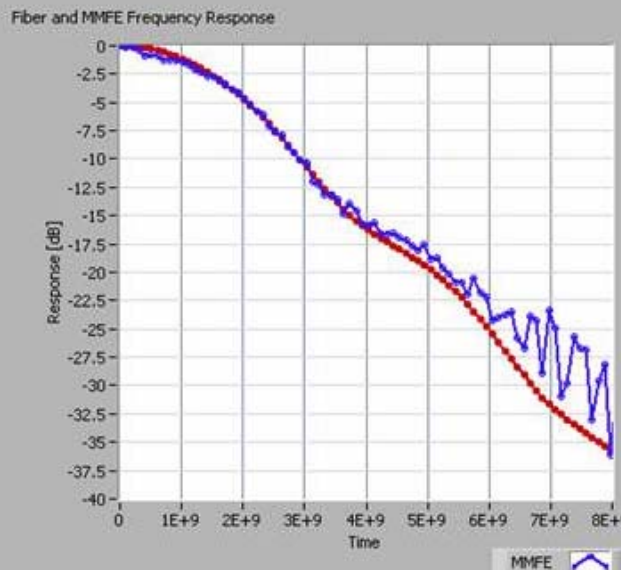


SEG: Post-cursor Channel

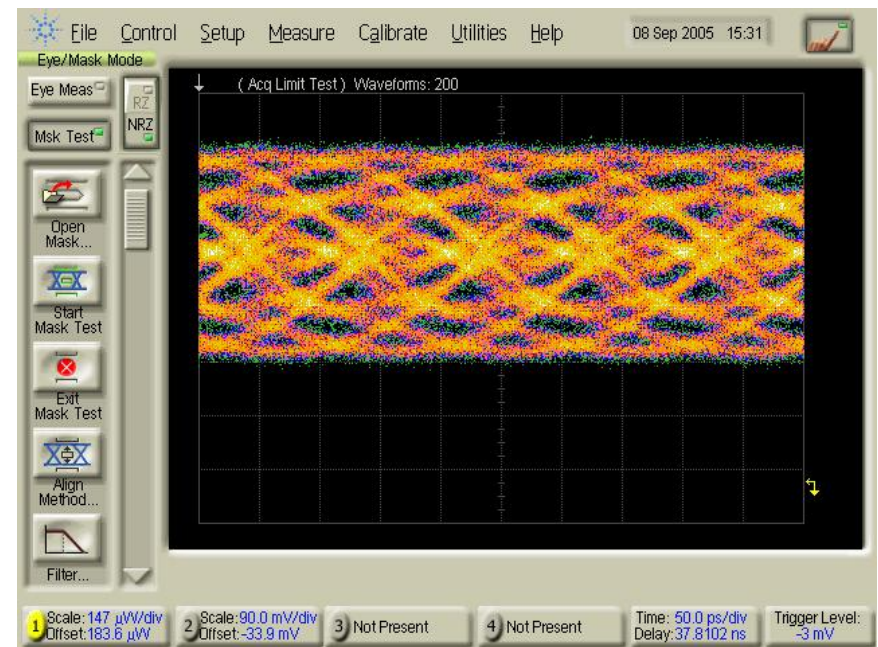
temporal



frequency



- Blue = SEG fit, Red = Target channel
- PIE-D value 4.2 dB
 - PIE-D error = 0.0dB
- SNR = 31.66dBe
 - SNR error = +0.66dBe
- ER = 3.6dB
 - ER error = +0.1dB
- OMA = -2.99dBm



SEG Characteristics*

Item		Min	Typ	Max	Unit
Average Power		-4	-1.5	0.5	dBm
OMA		-4.5	-2.6	TBD	dBm [2]
Extinction Ratio		3.5	3.7	TBD	dB [2]
Signal-to-Noise Ratio		15	16	17	dB (optical) [3]
Transmitter Linearity	dH2		<-40	-	dBc [4]
	dH3		<-38	-	dBc [4]
RIN _{OMA}			-135	-128	dB/Hz
Optical Return Loss		-		-20	dB
Dynamic Repetition Rate		0	-	10	Hz
Pulse Response Fit Error		-	2e-4	4e-4	MSE
PIE-D Error		-0.175	0.08	0.175	dB

[*] Measurements with 62.5µm MCP

[2] Max upper bound is determined by linearity requirements.

[3] Consistent with IEEE 802.3aq D2.2

[4] 500MHz tone

SEG: Calibration

- Measure the step response of the channel using a 128 bit square wave
- Calculate the pulse response
- Calculate PIE-D using the folded frequency method
- Linearity is guaranteed by design bounds
- Combination of SNR, ER, goodness of fit, and PIE-D value used to determine suitability of channel for testing
- Procedure iterates until the target SNR and ER are achieved
- BER tested on reference RX

Test results with SEG

Transponder Measurements: 220m (Draft 2.2) Normative Tests

Stressor	Supply/temp.	Average sensitivity dBm OMA	σ dB	Margin to spec (-6.5dBm)
Post-cursor	Min/cold	-10.6	0.64	6.3 σ
	Nom/nom	-11.2	0.58	7.9 σ
	Max/hot	-11.1	0.55	8.3 σ
Pre-cursor	Min/cold	-10.5	0.85	4.7 σ
	Nom/nom	-10.9	0.69	6.4 σ
	Max/hot	-10.9	0.57	7.7 σ
Symmetric	Min/cold	-9.7	0.72	4.5 σ
	Nom/nom	-10.1	0.79	4.5 σ
	Max/hot	-10.3	0.83	4.6 σ

15 units tested over 3 corners: typically $>4\sigma$ margin to spec

Rx Overload Measurements

- SEG overload test capability recently achieved, enabled with high power cooled DFB used as O-E
 - Max output +3dBm OMA max (2dBm mean, 6.4dB ER)

Stressor	Corner	Overload dBm OMA (Engineering test bed)	Overload dBm OMA (Module)
220m Post-cursor	Min/cold		
	Nom/nom	3.5	>2.6
	Max/hot		
220m Pre-cursor	Min/cold		
	Nom/nom	3.6	>2.6
	Max/hot		
220m Symmetric	Min/cold		
	Nom/nom	3.0	>2.6
	Max/hot		

Summary

- Overview presented of the measurement capabilities & the technical feasibility for many of the 802.3aq 10GBASE-LRM TP2 and TP3 Parameters
 - Test capabilities for TP2 parameters established
 - Test capabilities for TP3 parameters established
- Excellent TP2 and TP3 performance and margins demonstrated
 - Essentially all measurements were completed at the TP2 & TP3 points connected to implementations complying to different industry MSA modules
- Supports the practicality and manufacturability of 10GBASE-LRM PMD for the TP2 and TP3 specifications