TWDP Improvements

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Summary of recommendations

- Adopt offset automation
- Choose OMA normalization
  - Adopt automatic OMA extraction
- Adopt 14,5 finite length DFE EQ
- Maintain present TWDP limit(s) at this time

Presentation topics

1. Automatic extraction of optical power inputs
   - Proposal for optimum waveform offset (SteadyZeroPower)
2. Waveform normalization
   - Proposal for waveform power/strength extraction (MeasuredOMA)
3. EQ length
4. TWDP limits

1. Automatic Extraction of Power Inputs

Automatic extraction

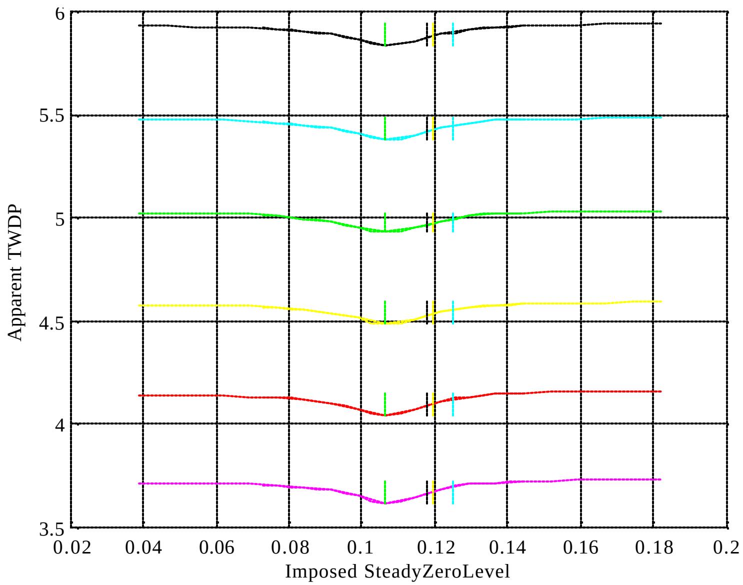
- Why?
  - Improve reproducibility
    - TWDP results are sensitive to input values, and values are sensitive to setup, calibrations and measurement technique;
    - Objective is to provide an automated and uniform method for extraction of input values from waveform within TWDP code;
    - This will eliminate variations in setup, calibrations and measurement technique
    - Method must be consistent with our current definitions
  - Eliminate process steps for manual entry into TWDP

Small range of TWDP requires accurate inputs

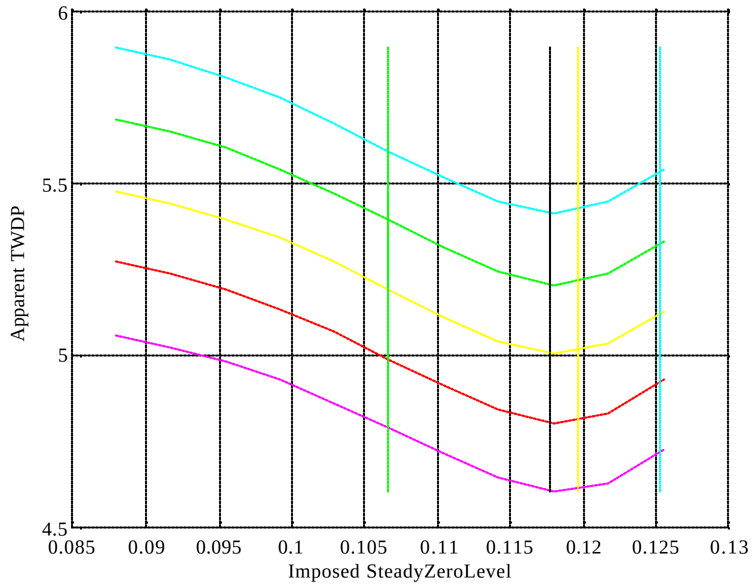
- Fast clean NRZ transmitter 3.6 dB

  Rectangular “1 ps risetime” NRZ (usual Rx filter)
- Spec limit 4.7 dB
- Range from “perfect” to fail only 1.1 dB
- Scope and optical switches optical power cal and reproducibility >~0.2 dB
- To significantly improve accuracy and reproducibility, TWDP code should use just a captured waveform and “calibrate itself” automatically

Example sensitivities to Zero and OMA values



Long EQ (100,50)



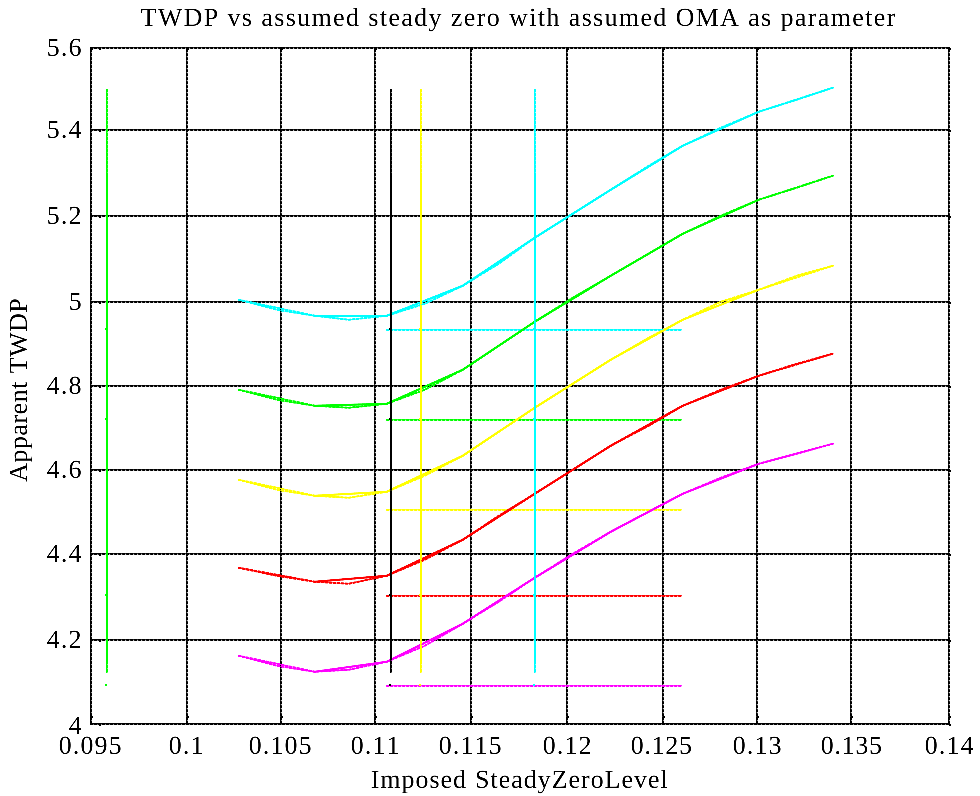
Finite EQ (14,5)

- Curves reflect different imposed MeasuredOMA values
  - 0.5 dB steps on left, 0.25 dB steps on right
- Best SteadyZeroPower does not depend on OMA
- Uses D2.2 code

Automation of optimum offset (SteadyStateZero)

- Technical approach
  - Add constant value through a special “DC” tap
  - Minimize MSE; extra tap optimizes DC offset and frees the other taps to optimize equalization of waveshape

Another example: sensitivities to Zero and OMA values and automatic zero



Finite EQ (14,5)

- Curves: different imposed MeasuredOMA values with SteadyZeroPower per x axis
  - 0.25 dB steps on right
- Horizontal lines: different imposed MeasuredOMA values with automatic code: SteadyZeroPower not used

2. Normalization

Normalization

- Purpose of normalization is to cause TWDP result to be only a function of waveshape
  - Normalization scales all waveforms to minimum power
- Three primary normalization methods have been studied
  - OMA (currently in D2.2)
  - OMSD
  - No normalization

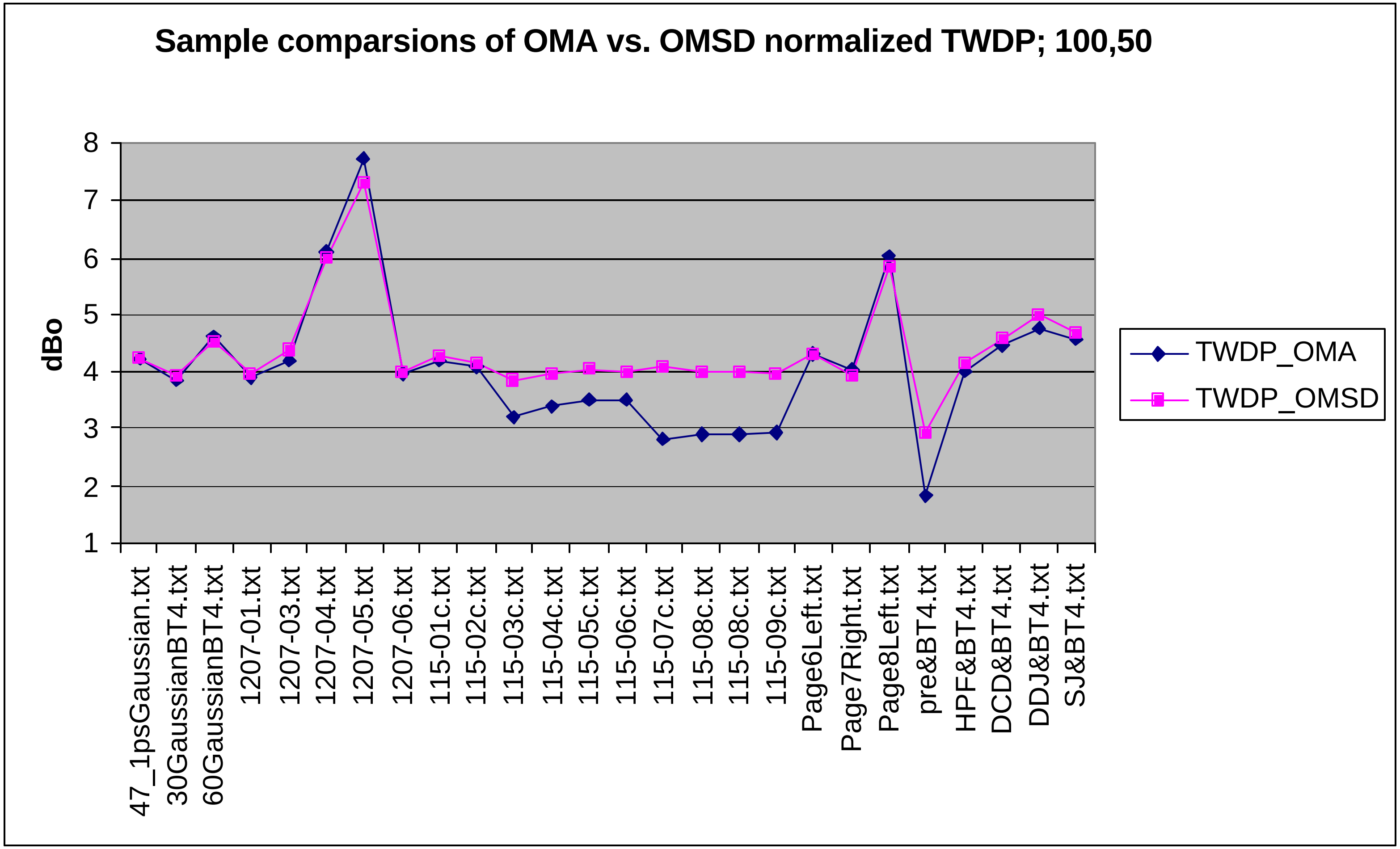
Tradeoffs

	OMSD	OMA	Un-normalized
Status	Proposed/discussed since end of April, but still may be new to some; see Swenson_1_0505	In all revisions including D2.2; familiar	Proposed/discussed since March, but still may be new to some
TWDP basis & protection of receivers	Result dependent only on waveshape at TP3; basis in RF communication theory	Result dependent on combination of waveshape and relative high frequency power not reflected in OMA	Gives credit to extra power as in application; however, may provide excessive freedom to overcome distortion with power; accurate model for signal-borne noises would be needed
Relationship to link budget	Indirect, but in conjunction with OMAmin spec, still assures the budget in conceivable cases that pass TWDP	In conjunction with OMAmin spec, direct tie to link budget	Direct tie to link budget assuming implementation penalty is independent of waveshape
Normalization accuracy	Limited by computing precision (standard deviation of capture)	Typically within 0.1 dB for cases that pass TWDP	Normalization not used
Code complexity	~3 lines	~24 lines	~0 lines

Recommend OMA normalization

- It works to protect receivers
  - Found no cases where good TWDP score due to increased power in non-OMA bits allows unacceptable distortion in practical receivers
    - Revisit if/as appropriate in response to interoperability testing and test-procedure validation
  - Still protects against fear that power can overcome distortion in un-normalized case
- Automation of OMA measurement can sufficiently improve accuracy (to come…)
- It's familiar, it's the basis of D2.2

Results of Normalization

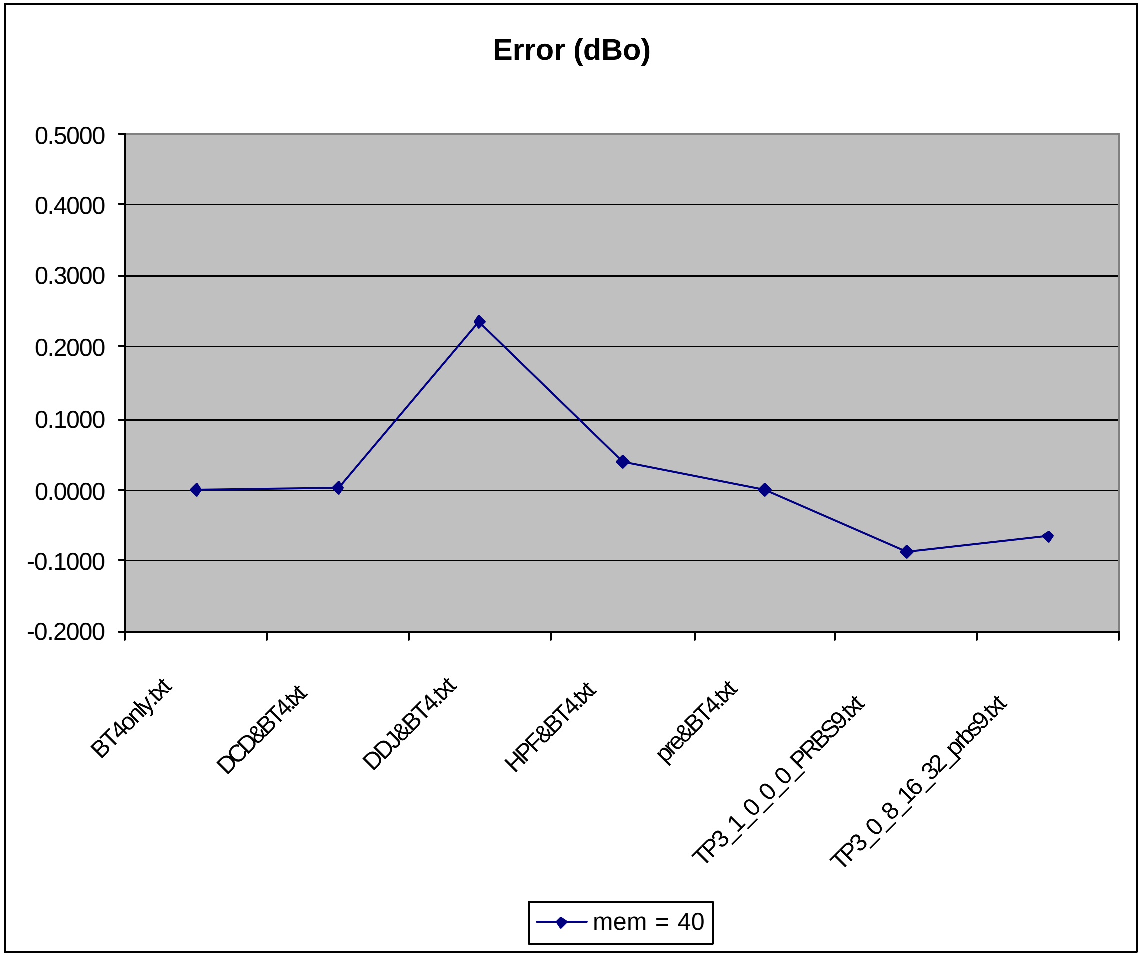


Automatic extraction of MeasuredOMA

- Technical approach
  - Find a pulse shape that best approximates the modulated waveform in a minimum mean squared error sense
  - Synthesize a square wave of period 16*T*
  - Calculate the mean difference between the center 20% of the "one" run and the center 20% of the "zero" run
    - Consistent with OMA measurement in other parts of the standard

Results of OMA extraction

- 5 synthesized test waveforms
  - 1 very clean, 4 with high distortions
  - DDJ&BT4 fails TWDP
- 2 lab waveforms from prototype TP3 stress tester
  - 1 identity channel
  - 1 with stress



3. Finite EQ length

Finite EQ length

- Why?
  - More similar to practical equalizers
  - Less likely to equalize non-linear effects that are artificially converted to time delayed linear distortions (artifact of use of 2^9-1 PRBS sequence)
  - Does not equalize long reflections (particularly important for calibrating Stressed Rx tester)
  - Is less forgiving of pre-cursor impaired transmitters (like practical equalizers)
- These advantages lead to a greater likelihood of system inter-operability

Recommend 14,5 DFE

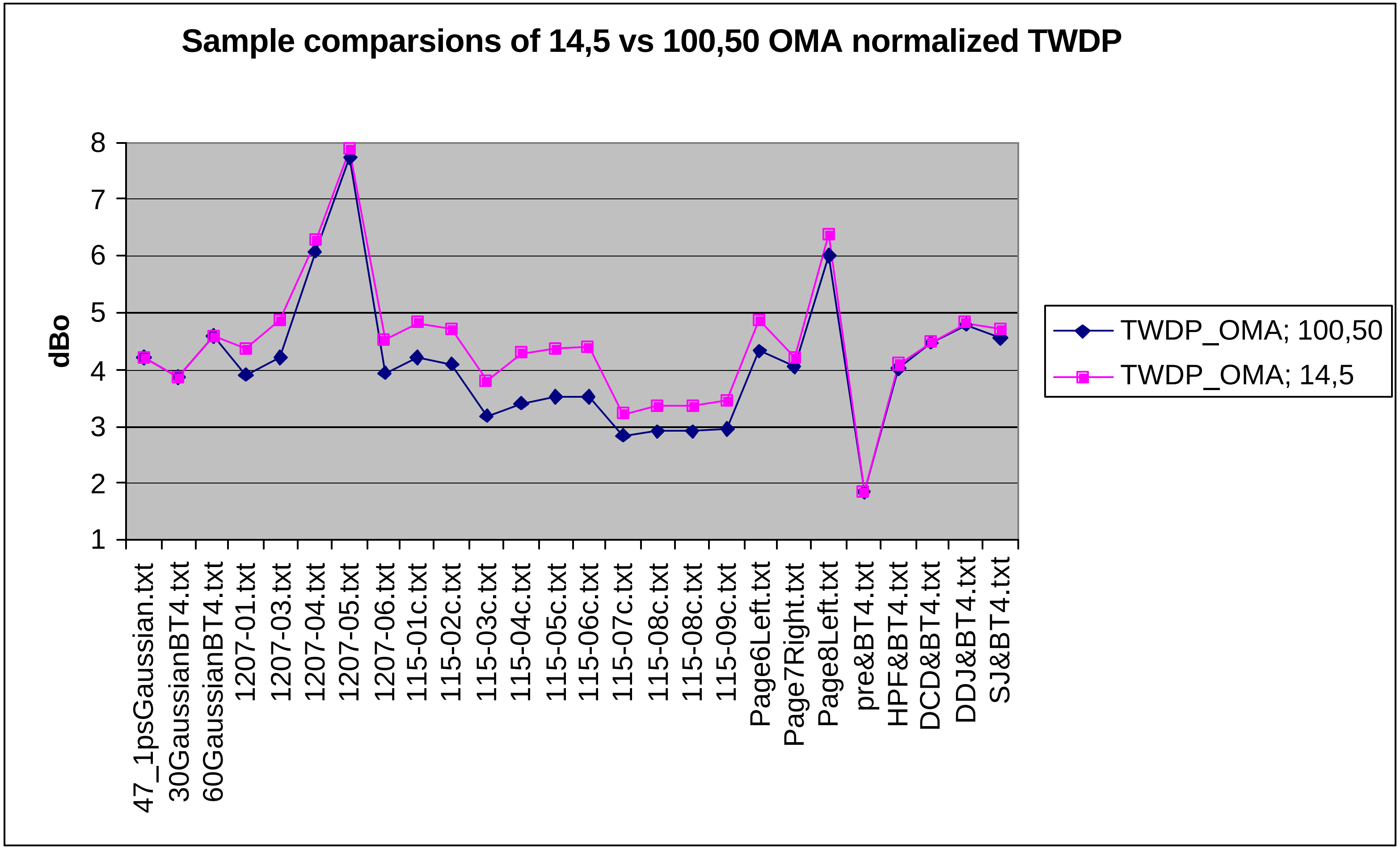
- Results/trends from any finite equalizer are more similar to each other than to the long equalizer
- It is relatively long and not intended to suggest a particular implementation
  - “A 14,5 DFE is used in the determination of TWDP. This 14,5 DFE is not intended to represent the equalizer used within an optical receiver, but is intended to provide uniform measurement conditions at the transmitter.”
- Good familiarity – 14,5 has been included in numerous simulations over many months

Technical approach

- Like long EQ in D2.2, but shorter
- Result is not sensitive to waveform phase with long EQ, but optimization is important for finite length
- Phasing combines
  - Sampling instant
    - 1/16 UI resolution
  - Position of pattern within FFE relative to current bit
  - Exhaustive search
- Speed-up added

- Note - processing time increases ~3.5x; ~2.2 seconds on 2.1 GHz XP test computer

Results of 14,5 length



4. TWDP limits

Pass/fail limit(s)

- D2.2 includes approx 0.5dB Tx implementation penalty in TWDP limit(s)
- Reasons may be able to reduce
  - Automation of baseline and signal strength will reduce error in setups and techniques
  - Discovering “time-tears” in captured waveforms; may be creating measurement error penalties up to 0.5 dB
- Reasons may need to increase
  - Allowance for practical transmitters with 14,5 finite equalizer
- Recommendation – no change to limit(s) at this time
  - More study required - adjust if/as appropriate in response to interoperability testing and test-procedure validation

Summary of Recommendations

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