Framework for EDC based 10GBASE-LRM

Presented by Michael Lawton

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Presentation summary

- **Motivation for EDC based solution for 10GBASE-LRM**
- **Present progress within the EDCSIG**
  - **Framework for standard**
  - **Approach taken**
  - **Observations about the channel**
    - Channel metrics and model, range, implications of launch
  - **Link budget analysis**
    - TP2 specification table
    - TP3 specification table
  - **Progress on demonstration of EDC feasibility**
- **Compliance testing strategy**
- **Conclusions and further work**

Motivation for EDC based 10GBASE-LRM

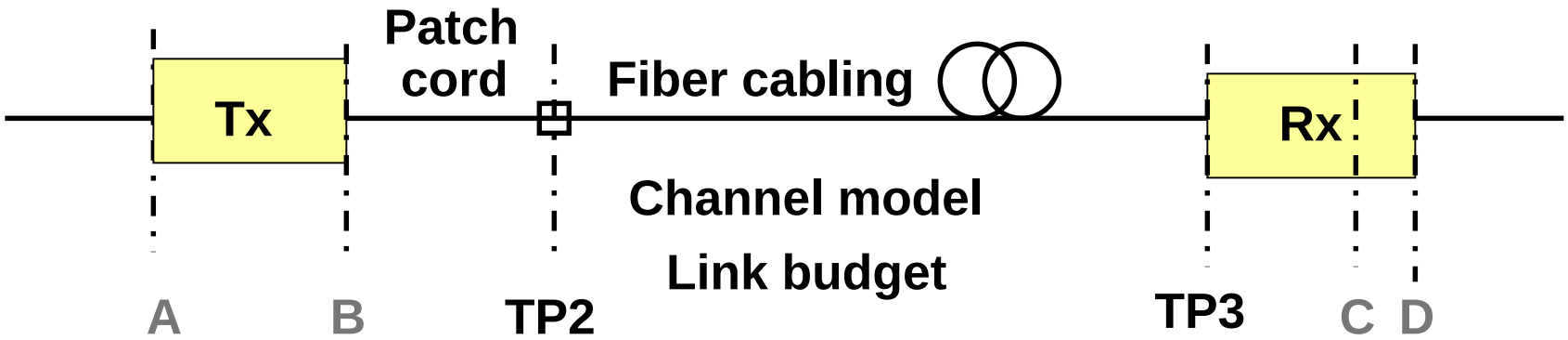
Conventional binary NRZ Tx in 1300 nm band with Rx based Electronic Dispersion Compensation

- **Broad vendor support**
  - **Several vendors (8+ module vendors, 7+ IC vendors) actively involved in EDC Special Interest Group**
- **Large body of work supporting technical feasibility**
- **Technology well suited to supporting an aggressive cost roadmap**
  - **Re-uses much technology from other PMDs**
  - **Economics of IC development**
  - **EDC solution places lowest performance burden on 1310 nm sources (linearity, spectral width)**
  - **Potential for "relaxed" optics being compensated by EDC functionality**
- **Size and thermal characteristics suitable for implementation in small modules e.g. XFP**
- **Market timing is good**
  - **Modules like this proposal already demonstrated by multiple vendors in different form factors: XENPAK, X2, XFP**

Framework for the standard
What the standard needs to provide …

- **10GBASE-LRM specification will involve:**
  - **Link distance of at least 220 m of FDDI-grade MM fiber (300 m on selected MM fibers)**
  - **Set of parameters sufficient to define the optical PHY**
  - **Inter-operability between different vendors supporting the standard**
  - **Channel model to represent the fiber (not actually in standard)**
  - **Compliance testing in support of the specification**
- **10GBASE-LRM specification will not:**
  - **Seek to narrow or limit implementation choices beyond what is required to support the standard**
  - **Address form factor or other specific implementation choices**
  - **Address module power consumption**

Approach taken by the EDCSIG



- **Sufficient to define test parameters at TP2 and TP3 only**
- **Key areas required are:**
  - **Transmitter performance requirements and compliance test spec at TP2**
  - **Channel model (not included in the actual standard)**
  - **Link budget**
  - **Receiver performance requirements and compliance test spec at TP3**

Channel observations

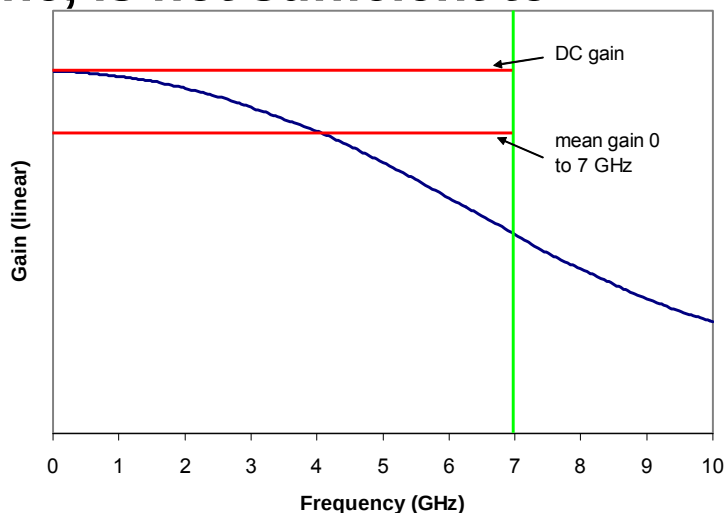
- **The overall channel impulse response is determined by the characteristics of both the fiber and the optical launch technique used**
- **Channel metric requirements**
  - **Some metric is needed to describe "goodness" of channel (launch+fiber)**
    - Required to develop compliance testing and compare different launch techniques and fibers
    - Effective modal bandwidth does not correlate well as a metric for determining equaliser performance (i.e. power penalty required to compensate for dispersion)
    - Nick Weiner will present a proposal for a possible alternative metric at this meeting
    - Other alternatives based on penalty of ideal EDC to be considered – see Nick's presentation and cunningham_1_0104.pdf
- **Fiber Impulse Response Work**
  - **Big Bear and Cambridge have been comparing measured vs modeled performance for different fibers**
    - This work to be continued by the adhoc channel group
  - **Lew Aronson will propose set-up for time varying channel measurements**
    - This is an important area requiring further work

An example channel metric

(subject of presentation by Nick Weiner)

- **1000BASE-LX specified Offset Launch to address modal bandwidth**
  - Modal bandwidths ≥ 500 MHz.km
- **Equalizing receivers make use of the energy across the entire channel spectrum. Modal bandwidth, alone, is not sufficient to predict dispersion penalty**
- **Integrated Frequency Response (IFR): IFR = (Mean gain up to 7 GHz)/(DC gain) (always negative when expressed in dB)**
- **Offset Launch Statistic:**

  99% of 220 m fibers have IFR ≥ -2.6 dB



- **Modal bandwidth and IFR, together, enable us to determine if a new launch is as "good" as offset launch**

Range

- **MMF channel responses are very varied**
- **Analysis and experiment indicates standard can achieve interoperability on (at least) 99% of compliant 220 m FDDI grade fibers by use of receive side EDC**
- **New MMF channel needs more investigation**

Transmitter launch requirements

Goal: determine compliance test at TP2

- **Optical launch characteristics must be specified**
  - **Launch + fiber determine overall channel impulse response**
- **Launch requirements should form part of the compliance test at TP2**
  - **Challenge is to find measurable characteristic at TP2 which can support some guaranteed performance for a defined channel metric when combined with models for the fiber**
    - Previous examples include coupled power ratio (ratio of MM vs SM coupled power) and encircled flux test (min inside 19μm and max inside 4.5μm) – work is needed to show relationship between compliance test and suitable channel metric
- **Why not specify a launch, with associated test, and avoid some work?**
  - **More straightforward to analyze (as the optical path is determined) and test but approach limits ability to support novel approaches**
- **Need to determine appropriate burden of proof and hence support for experimental confirmation vs analytical evidence demonstrating link between launch test and channel metric**

Link budget

(subject of presentation by Piers Dawe)

Link budget (220m FDDI grade MM fiber)		
Parameter (not necessarily spec item)	**Max**	**Units**
Connector losses (4 connectors)	2.0	dB
Fiber attenuation (220 m)	0.4	dB
Modal noise penalty	0.5	dB
RIN penalty	0.4	dB
Corrected distortion	5	dB
Uncorrected distortion*	1	dB
Consequent penalty	0.2	dB
Total	**9.5**	**dB**

* **Allows for un-corrected imperfections in transmitter/receiver and for channel temporal variability.** Split between corrected and uncorrected for further study

- **Link budget requires careful consideration of Tx power ranges and Rx sensitivity**
- **Potential to examine link budget parameters to exploit relaxed optics**
- **Link budget items may change slightly but they seem 75% stable**

Transmitter parameters (TP2)

Transmitter specification		
Parameter	**Value**	**Units**
Signaling speed (nominal)	10.3125	GBd
Signaling speed variation from nominal (max)	+/- 100	ppm
Center wavelength (range)	1260 to 1355	nm
Transmitted Optical Modulation Amplitude (max)	on order of +1	dBm
Transmitted Optical Modulation Amplitude (min)	in range -5 to -3	dBm
Average launch power (max)	0.5	dBm
Launch parameters	TBD	
Launch power of OFF transmitter	in range -30 to -45	dBm
Extinction ratio (min)	3.5	dB
$RIN_{12}OMA_{(max)}$	-128	dB/Hz
Optical return loss tolerance (max)	12	dB
Transmitter reflectance	-12	dB
Transmitter eye mask definition and/or transmitter penalty limit	TBD	

- **How do we specify/measure launch conditions?**

Receiver parameters (TP3)

Receiver specification		
Parameter	**Value**	**Units**
Nominal signalling speed	10.3125	GBd
Signalling speed variation from nominal (max)	+/-100	ppm
Center wavelength range	1260 to 1355	nm
Average receive power (max)	0.5	dBm
Receive OMA (max)	on order of +1	dBm
Receive OMA (min)	in range -7.5 to -5.5	dBm
Indicative receiver sensitivity in OMA (max)	~ -13	dBm
Metrics for distortion of receiver compliance test signal (can't use VECP, jitter if eye is fully closed)	TBD	
Receiver 3dB electrical bandwidth (max)	probably won't use	GHz

- **Additional parameters?**
- **Compliance testing strategy for dispersion performance at Rx?**
  - **Similar strategy to 802.3ae stressed eye test**

Progress on validation of EDC feasibility

- **Several study group presentations have shown simulation results for EDC**
  - **penty_2_0104, bhoja_2_0104, hanberg_1_0304, bhoja_1_0304, ...**
  - **Various channel models and metrics used; 802.3z MBI, Cambridge, measured fiber IPR, …**
  - **Simulation results support a dispersion penalty of 3-6 dB for 220 m of FDDI MMF and 300 m on selected fiber**
  - **Penalty due to jitter, temporal variation of channel & RIN in EDC link requires further study**
- **Open source Matlab model for EDC is currently under development**
  - **Provides transparency into simulation details so that consistent results can be easily obtained**
  - **Currently 5 companies contributing to this effort. A subset of the model will be available for release shortly**
  - **Model described in more detail in multi-company contribution at this meeting**
- **Experimental results supported a TBD dispersion penalty on real FDDI-grade MMF**
  - **(TIA Round Robin, SieCor 05/98, Worst Case SX spool)**
  - **Fully adaptive EDC with no training sequence used**
  - **Similar results obtained across range of optics (including DFB, F-P, LW-VCSELs) and different channel conditions**
  - **Abhijit Shanbhag will present measured results at this meeting**

Compliance testing strategy

- 802.3aq defines the transmitter and receiver
- 802.3 does not define fiber or cable types
- Define transmitted signal quality
  - Power levels
  - Spectral
  - Dynamic (eye shape) and noise – separately or together
  - Define optical launch conditions at TP2
- Propose that we discover and define a select set of “99%-worst” impulse responses at TP3
  - Like 802.3ae’s stressed eye generator but possibly more than one test case
  - Defined powers and distortions
  - Relate these to realistic equaliser architectures to ensure feasibility

Conclusions and further work

- **Broad vendor support for this EDC solution**
- **EDC solution can be developed with cost effective components**
- **Standard framework presented**
- **Significant progress in demonstrating EDC feasibility**
  - **Demonstration of EDC measured performance for different channels**
    - Multiple contributions confirming feasibility by simulation
  - **Link budget analysis that works and appears cost effective**
- **Areas of focus for further work have been identified:**
  - **Compliance test for launch conditions to support flexible development and new launches**
  - **Channel metric to quantify receiver performance requirements**
    - Definition of receiver compliance signal
  - **Characterization of time varying nature of the channel and consequent power penalty**
  - **Channel definition for 300 m**
- **EDC has strong and wide support as the solution with excellent market timing and the opportunity to support an aggressive cost roadmap**