Performance Results: High Gain FEC over DMT

Nov 18, 2014

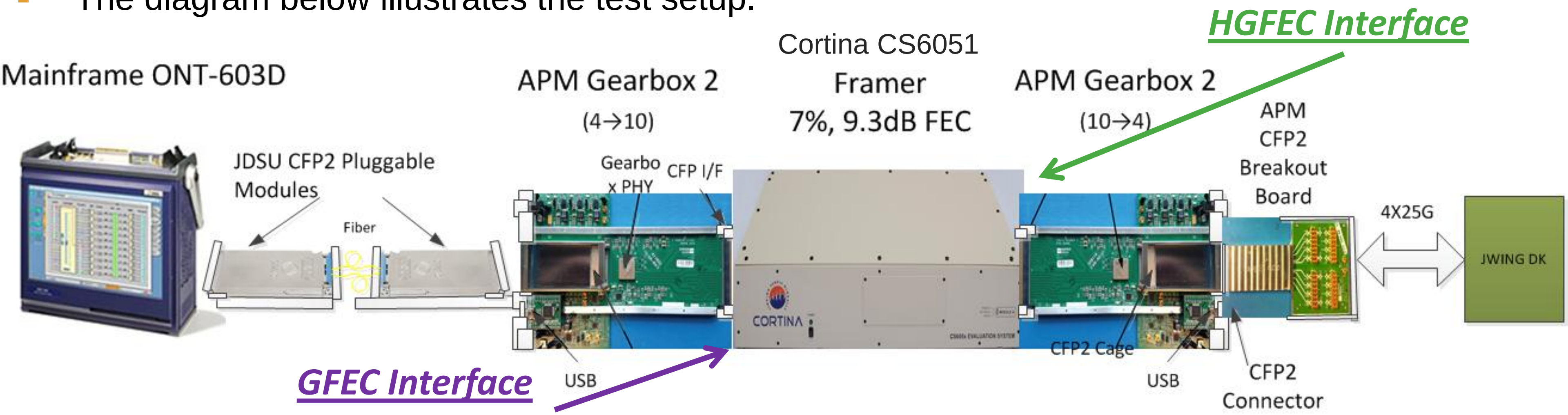
Sacha Corbeil, Shijun Yang

Introduction

- The 4x100G DMT 400GE link proposals for the 500m, 2km and 10km PMD’s rely on Forward Error Correction (FEC) to meet the proposed link budgets
- The DMT transmission protocol can experience bit errors due to thermal noise and RIN, signal clipping, quantization noise, and the finite ENOB of the DAC and ADC
- The proposal would be to incorporate a FEC in the DMT DSP PMD chip inside the module to ensure adequate link budget and an error rate below 1E-15 at the sensitivity limit
- Several different FEC’s are being evaluated for this purpose the one that has been proposed is a 9K BCH FEC with 12.5% overhead, low-latency (300-400ns) and an input BER-threshold of 3.3e-3 for output BER of 1e-15
- Concerns have been raised that higher order modulation approaches could be subject to significant burst error issues and that a BCH FEC may not be optimum for this application
- As a proof of principle we have conducted live traffic transmission at 100Gb/s over a single optical wavelength using a DMT test chip and a commercial framer with a 7% overhead high coding gain FEC
- The framer used was a Cortina CS6051 which has a (9.39dB NCG) staircase FEC with ITU-G.975.1 compatible, 7% overhead a latency of <20us and a 1E-15 FEC threshold of 4.62E-3
- The result demonstrated that we can achieve stable error free operation over an extended period of time even with a fairly high input BER of 9E-4

Test Setup

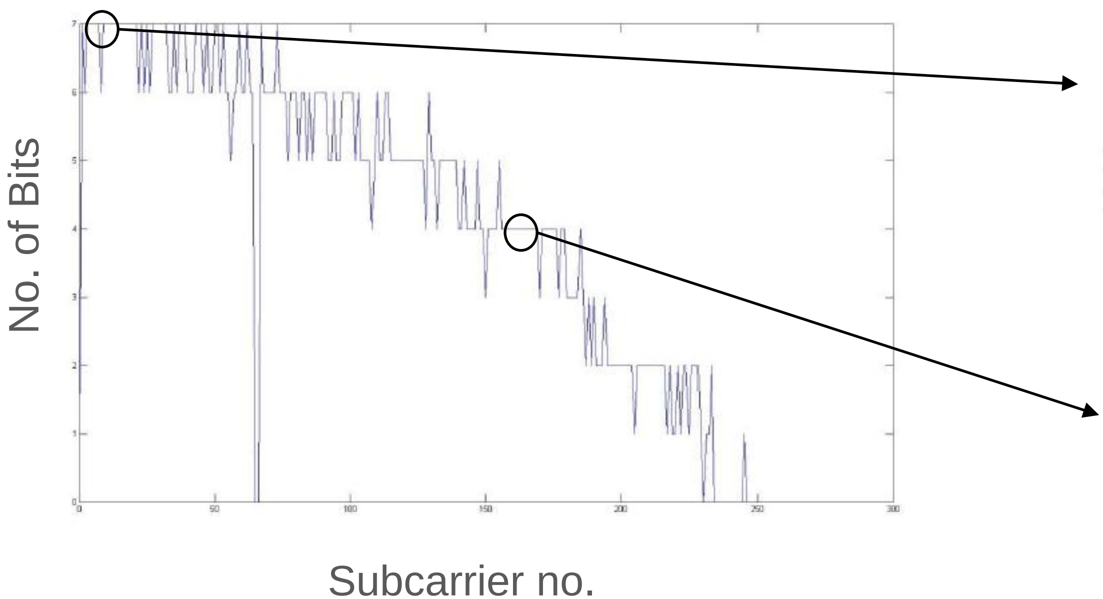
- The diagram below illustrates the test setup.

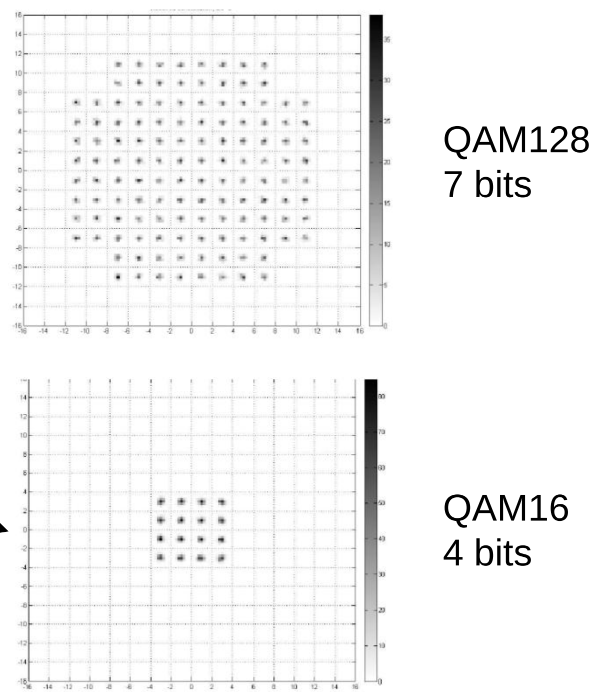


- OTU4 Traffic with a 7% OH GFEC is generated by the JDSU ONT-603D test set
- The OTU4 frames are terminated on the CS6051 framer and regenerated with the 7% HG FEC
- A JWING 100G DMT test chip is used to generate the DMT frames and transmit and receive the DMT data.
- Data is looped back optically, decoded by the CS6051 framer and the corrected frames are passed to the ONT
- A 175MHz clock, synchronous with the data stream, is provided by the Cortina Framer at the HGFEC interface.
- This clock is multiplied up by 5 using the Hittite HMC1035 clock generator, for compatibility with JWING operating rates (data-rate / 128 => 875MHz).
- JWING DAC/ADC are calibrating against this 875MHz clock.

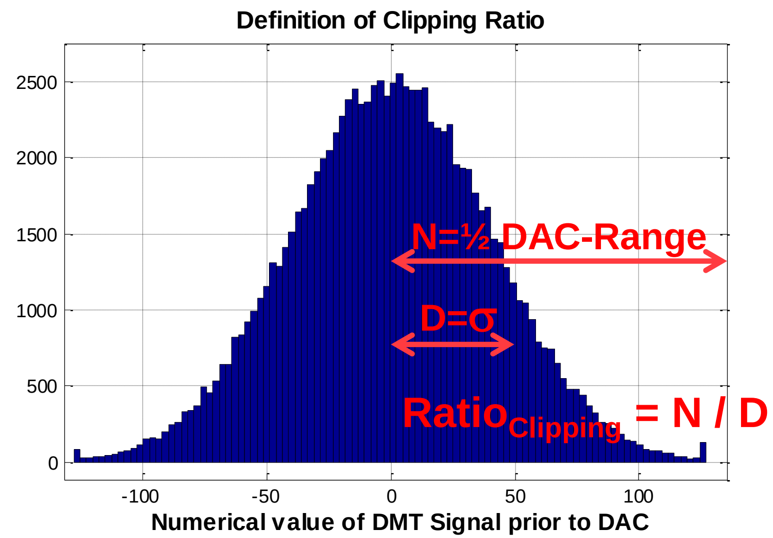
Electrical Back-to-Back DMT Link

- As a first proof of concept, an electrical B2B link was setup from DAC to ADC.
  - No additional attenuation between DAC and ADC
  - Typical BER performance for electrical loopback for the DMT test chip is between 1 and 4E-7
- For these experiments a socketed evaluation board with a DMT test chip was used that had a a raw B2B BER of ~1.7E-5 when used with a DAC clipping-ratio of 3.6
  - As a first test the ONT was run error-free for several days with traffic running through the Cortina and over the Electrical DMT B2B link using the HGFEC
- Example subcarrier bit mapping and electrical constellation is shown below:





Clipping Ratio



- **Clipping Ratio**: Defined here as the ratio to be maintained, by design, at the numerical generation of data at the transmitter, (i.e. prior to conversion to a voltage)

$$\text{Ratio}_{\text{Clipping}} = \frac{Range_{DAC}}{2 \cdot \sigma_{Data}} = \frac{2^{\#bits}}{2 \cdot \sigma_{Data}} = \frac{2^{(\#bits-1)}}{\sigma_{Data}}$$

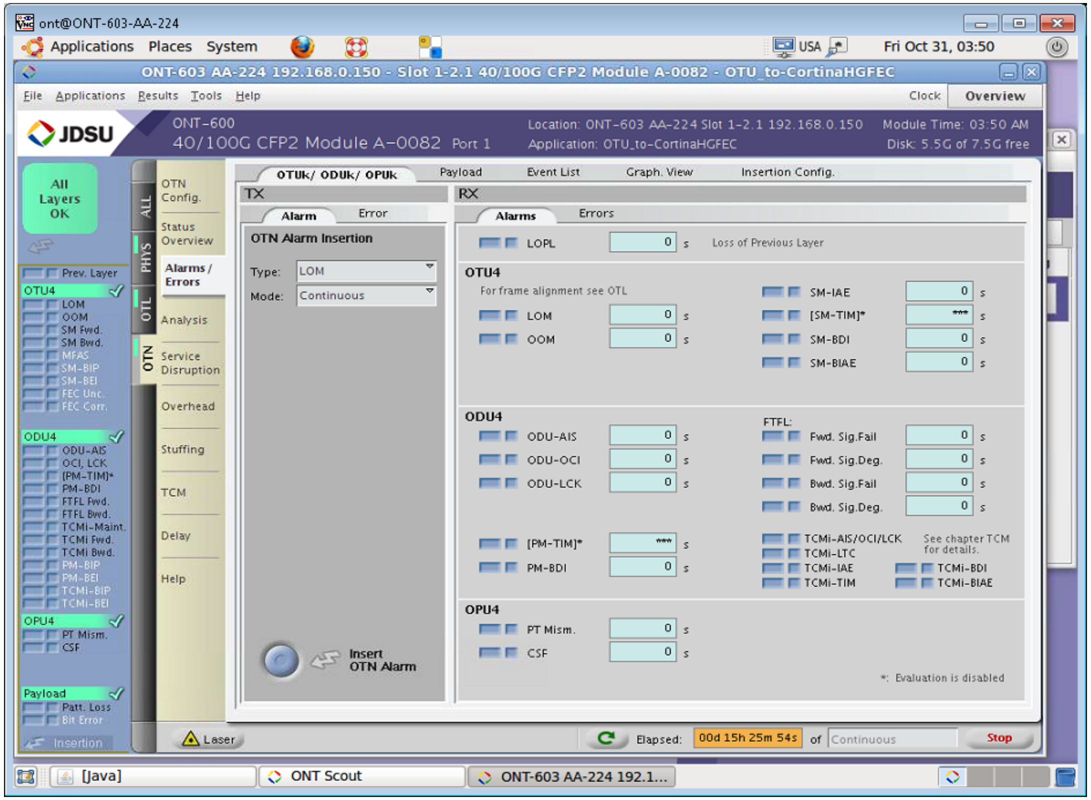
JDSU

Optical Link Test Results

- An optical link was setup using a MAP-ITLA2 as a source and an external MZ modulator the setup is as shown below

  JWING-DAC => Macom3109 => JDSU-LN-MZM => VOA =>Discovery RX => JWING-ADC

- Optical back to back link performance of < 2E-5 BER has been recorded using a similar configuration with the JWING DK
- For this experiment the link was degraded to a B2B BER of ~9E-4 and run overnight in a simple back to back loop
- The ONT did not report any errors for 15 hours (equivalent to 6.2 x 10^{15} bits, or BER < 1.6 x 10^{-16}).



Conclusion

- It's still early to draw any conclusions, but this is what we can say:
  - A high-gain FEC with widespread interleaving is successful in correcting DMT errors over an optical link, at least for a finite duration, and in the absence of any transmission penalties or noise loading
    - *ASE is not expected to worsen the distribution of errors, (only amplify the variance)*
  - We are reminded that, for a bit-rate ~100G, and to test to an output BER of 10^{-15} with a minimum amount of confidence, we need to test for ~3 hours.

- Further testing and investigation:
  - Investigate the effect of clipping-ratio on the effectiveness of FEC. Can FEC still correct to 4.62×10^{-3} over wide range of Tx clipping?
    - This is to test our assumption that burst errors due to clipping are less correctable. Admittedly, the interleaving may mask this, but there's only one sure way to find out.
  - Re-test optical B2B over a longer interval and collect error statistics
  - Propagate optical signal through an amplified link, and re-test over extended duration