DMT measurement considerations part 2: Receivers

IEEE802.3bs 400GbE Task Force

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KEYSIGHT TECHNOLOGIES

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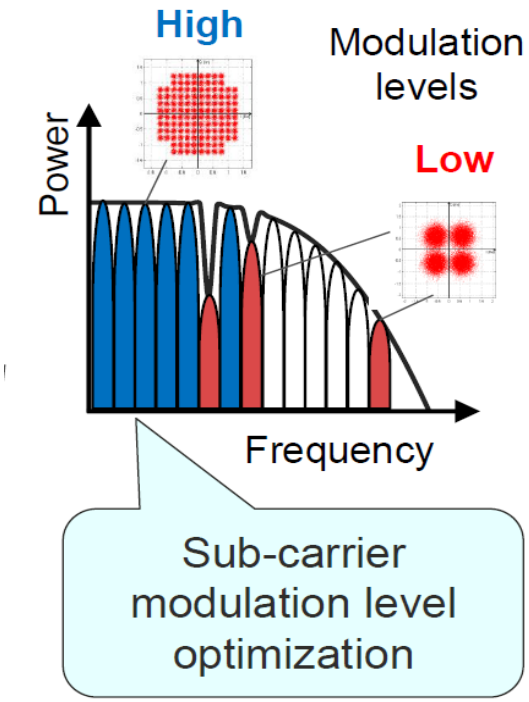
DMT Receiver Test Challenge

- Complete solution includes analysis of both the receiver and the transmitter
- Transmitter test discussed July 2014: http://grouper.ieee.org/groups/802/3/bs/public/14_07/lecheminant_3bs_01_0714.pdf

→ This presentation: ***Focus on generation of electrical test signals***



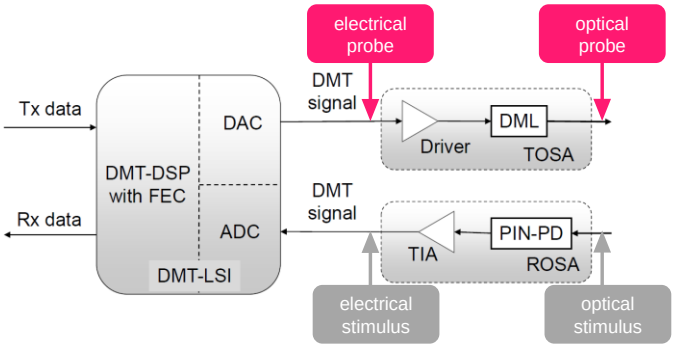
Similar to analysis of DMT signals (required real-time analysis and significant post processing and analysis), generation of DMT test signals requires instrumentation very different from familiar tools used for simple intensity modulated systems

picture source: IEEE302.3 Norfolk interim meeting, Fujitsu presentation

DMT Receiver Test Challenge

- Electrical test signals can be generated using an arbitrary waveform generator (AWG), effectively a digital to analog convertor (DAC)

- Optical signal generation requires an additional directly modulated laser or cw laser in combination with an intensity modulator (see example below for a typical DMT time domain signal)



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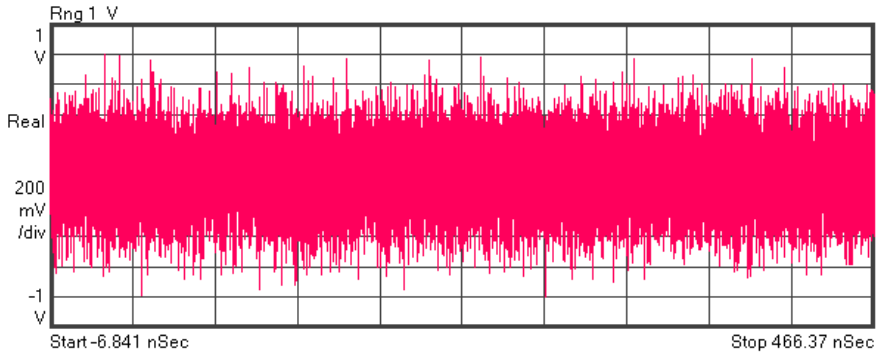


typical DMT signal

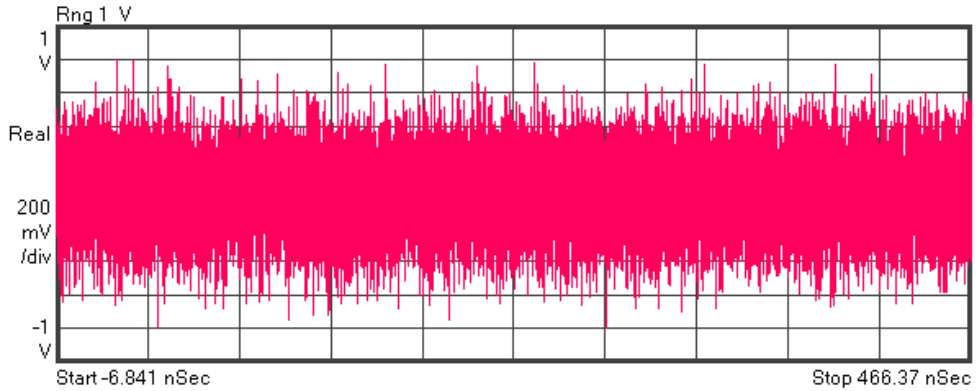
DMT Test Transmitter Requirements

- To generate the signals the bandwidth of the digital-to-analog-converter (arbitrary waveform generator) should be at least the bandwidth of the DMT signal.
- AWG vertical resolution equal to the resolution of the real DMT transmitter considered to be sufficient (typically 8 bit)
- Sampling time to be able to encode n_{Sym} DMT symbols (n_{FFT} = FFT size)

$$t_{sampling} = 1/f_{DAC} \cdot n_{Sym} \cdot n_{FFT} \cdot (1+r_{prefix})$$

- required number of samples

$$n_{sampling} = f_{ADC} \cdot t_{sampling}$$



DMT signal example:

n_{Sym} = 50
n_{FFT} = 512
f_{DAC} = 63 GS/s
r_{prefix} = 16/512

$t_{sampling}$ = 419 ns

f_{ADC} = 63 GS/s
$n_{sampling}$ = 26400

DMT Signal Synthesis Software

- Generation of DMT signals requires knowledge of bit allocation, subcarrier allocation, FFT size, cyclic prefix, system sampling frequency, and other parameters
- Testing of the DMT link start sequence should be carefully defined or even removed from the test requirements to simplify implementation on general purpose arbitrary waveform generators

➢ **Until we have a standard, a general purpose DMT signal synthesis software (e.g. Matlab) in conjunction with an arbitrary waveform generator is used to generate the signals**

DMT Signal Synthesis Fundamentals

- Generate the bit stream (either a PRBS, random data or a special pattern defined in the standard) either per subcarrier or for all subcarriers together
- Convert per subcarrier the digital symbols into the complex amplitudes of each subcarrier, add pilot symbols as defined
- Calculate the inverse Fourier transformation to yield a real valued time domain waveform of the DMT symbol
- Add cyclic prefix to each DMT symbol
- Concatenate the DMT symbols

DMT Signal Measurement

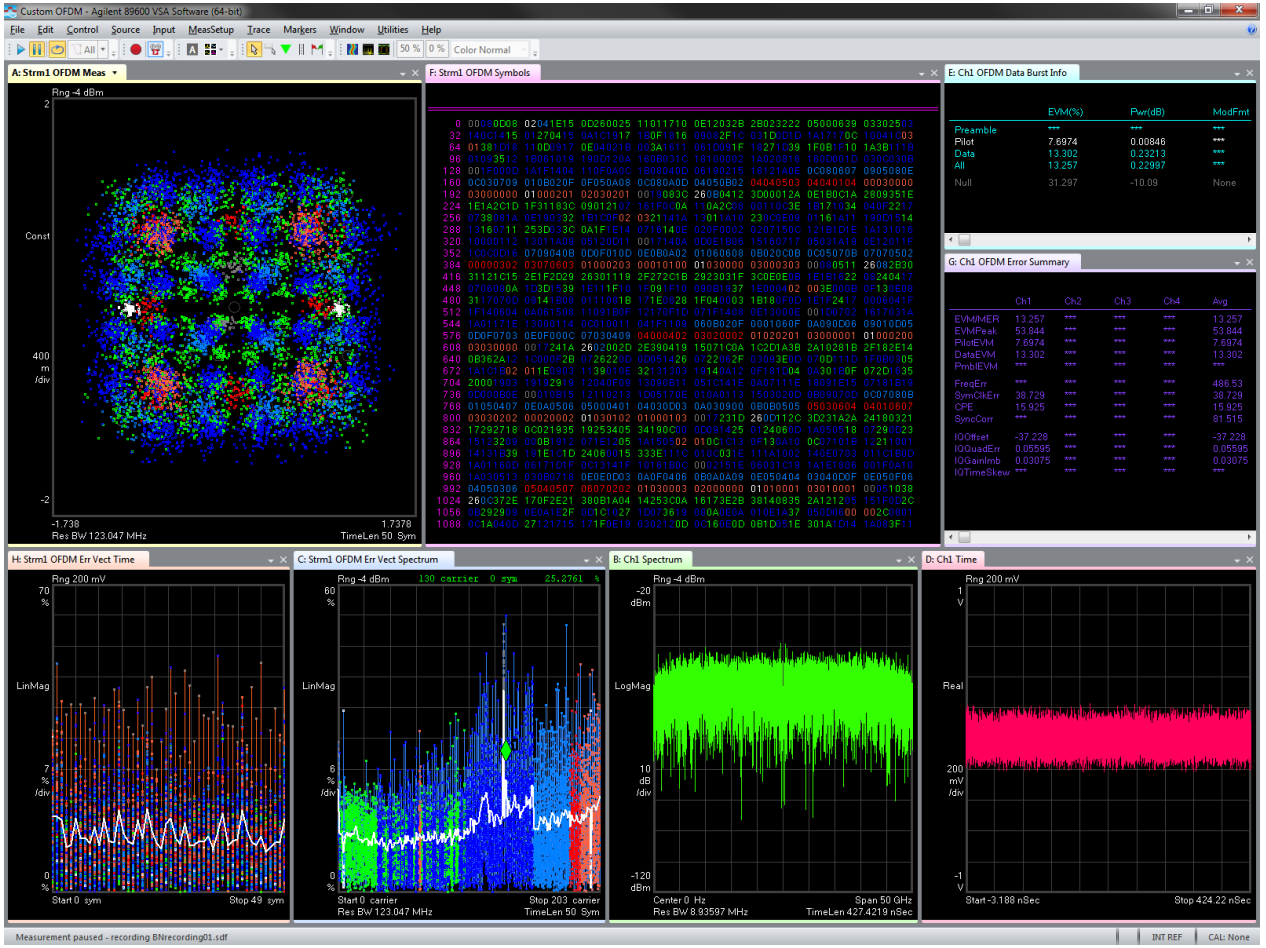
114 Gbit/s electrical single lane back-to-back transmission

Example (Simulation)

- 63 GS/s system frequency
- complex FFT Size 512
- variable bit allocation
- colors encode modulation from QAM 64 (green), QAM 32 (dark blue), QAM 16 (light blue), QAM 8 (red) to QPSK (orange)
- two pilot tones (QPSK, white)
- ADC sampling frequency 80GS/s, 8 bit vertical resolution

Traces (top row)
A: constellation (all SCs)
F: received data stream
E: Data Info
G:Quality Metrics

Traces (bottom row)
H: Error Vector vs. Time
C: Error Vector vs. Frequency
B: Received Spectrum
D: Received Time Domain Signal



DMT Receiver Measurement Conclusions

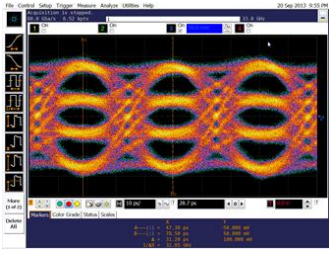
- DMT Signals can be generated using high speed arbitrary waveform generators
- Arbitrary waveform generators with sufficient sample rates for 400 Gb/s DMT are becoming available
- If 802.3bs employs DMT, analysis is simplified if specific test modes are allowed that minimize or do not require link training to achieve a specific transmitter state

Signal Synthesis for PAM-X

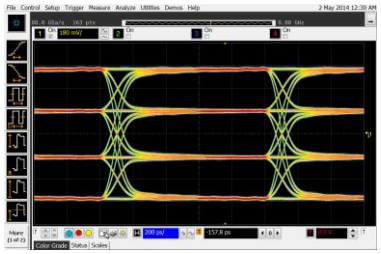
- For PAM-4 and PAM-8 commercial solutions based on high speed BERTs are available, but signals can also be generated using AWG technology
- Generation of PAM-X signals requires knowledge of the number of signal levels, symbol rate, and possibly time domain pulse shaping if applicable
- Transmission of 400 Gbit/s using e.g. PAM-4 requires an aggregate symbol rate of 200 Gbaud or 4 x 50 Gbaud or 8 x 25 Gbaud
- PAM-X signals can be generated using high speed AWG's for symbol rates up to 32 Gbaud today
- Signal impairments like ISI, Jitter, or level interference can be easily added

PAM-X Signal Generation using an AWG

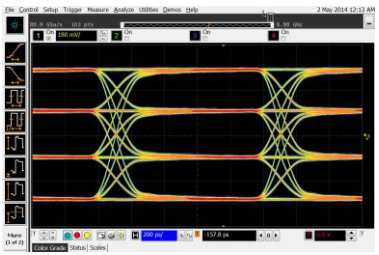
– Adding impairments without external hardware
  - Transition times, ISI, Jitter, DCD, noise, …
– Clean & distorted signals up to 32 Gbaud



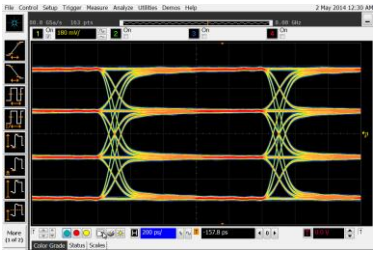
up to 32 GBaud



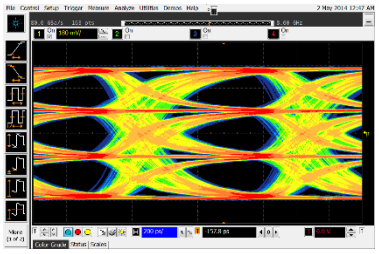
Variable transition times



Variable jitter



Variable ISI



Combination of impairments

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Conclusion

- DMT and for PAM-X signals can be generated using high speed arbitrary waveform generators
- Support will be provided to the standard development to ensure testability of the signals.