Support for a comment proposing better emulation of fiber dispersion for multimode TDECQ

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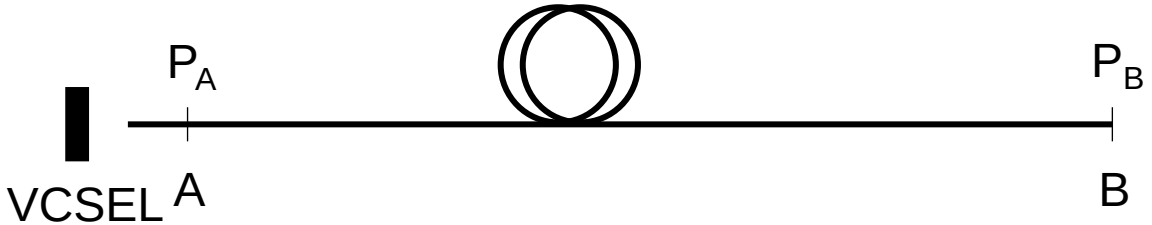
TDECQ review

- TDECQ generally is measured on a TX signal with a half-baud receiver bandwidth
- Currently in draft 1.0 (and earlier multimode standards) rather than place a full span fiber between the TX and the scope to create dispersion, the fiber is emulated by reducing the observation bandwidth
- The above technique is considered valid. However, with current measurement technology, we have the opportunity to better emulate the fiber response and potentially achieve better accuracy in assessing the transmitter dispersion penalty without incurring extra measurement time or cost. This can also simplify the testing of other transmitter parameters
- The end goal is to determine a practical test method that predicts the transmitter eye closure penalty

What is the impact of the fiber channel?

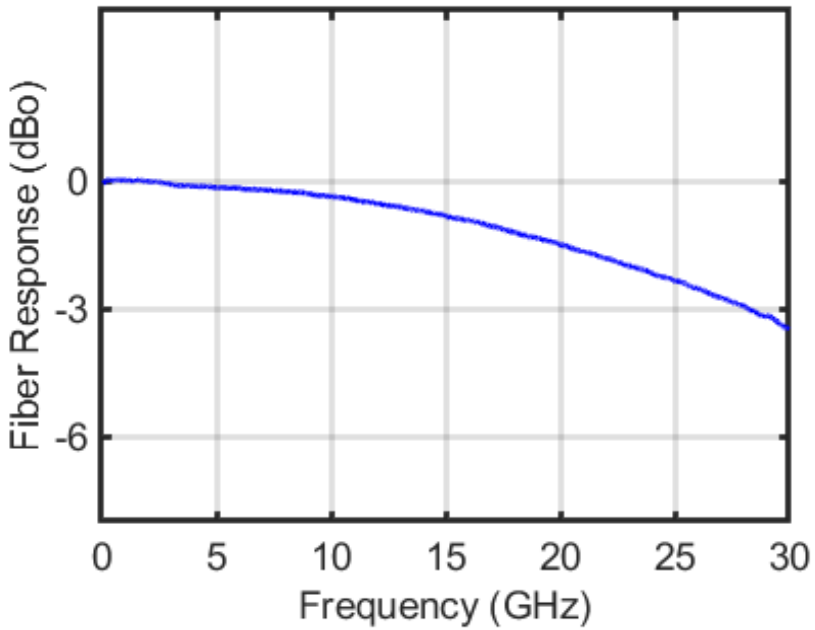
Measured Fiber Frequency Response (courtesy of Ramana Murty)



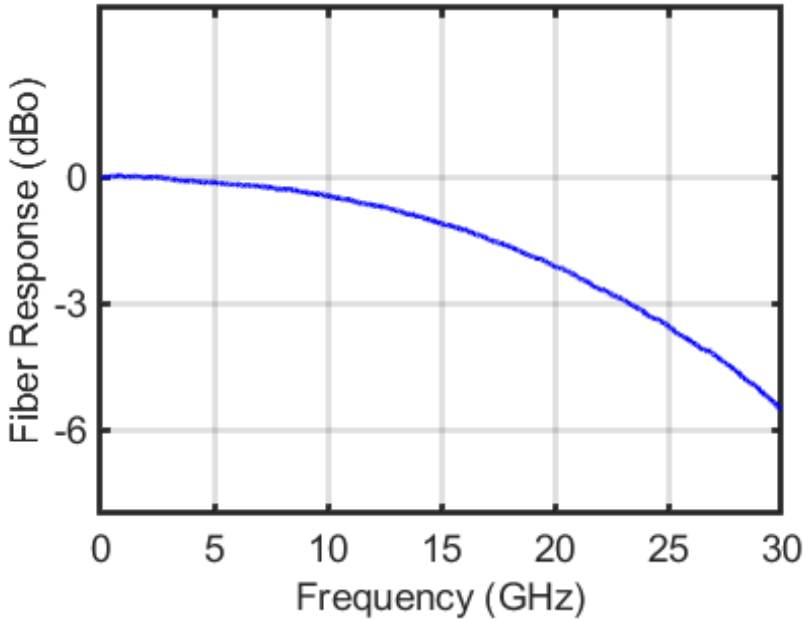
Fiber response

$$\frac{S21(B)-S21(A)}{2} = 10\log_{10}\frac{P_B}{P_A}$$

100m OM4



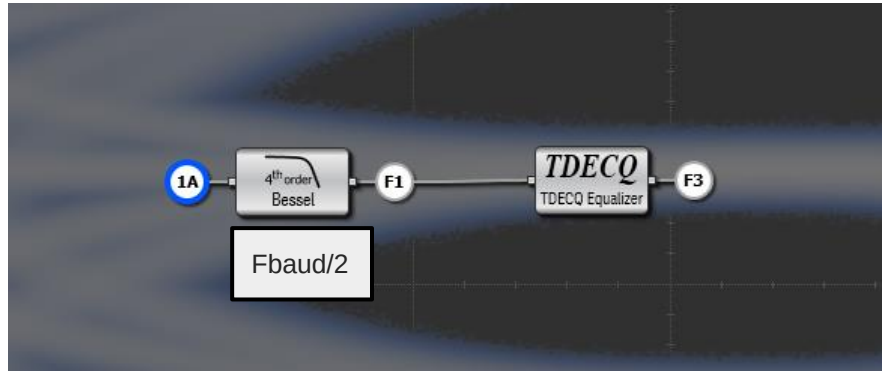
70m OM3

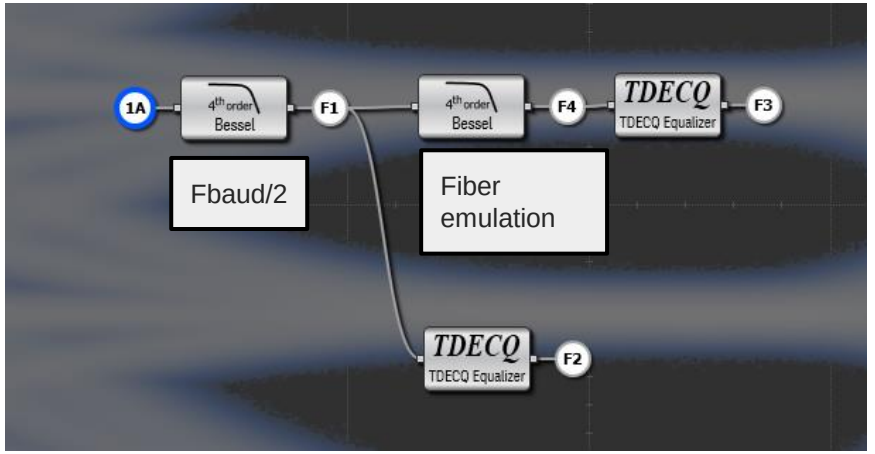


The – 3dBe (not dBo) BW is in the 18 GHz range. Even with a source spectral null at 53 GHz, use of similar data requires extension to ~50 GHz and include phase. Does is represent the worst case allowed condition?

Emulating the fiber dispersion

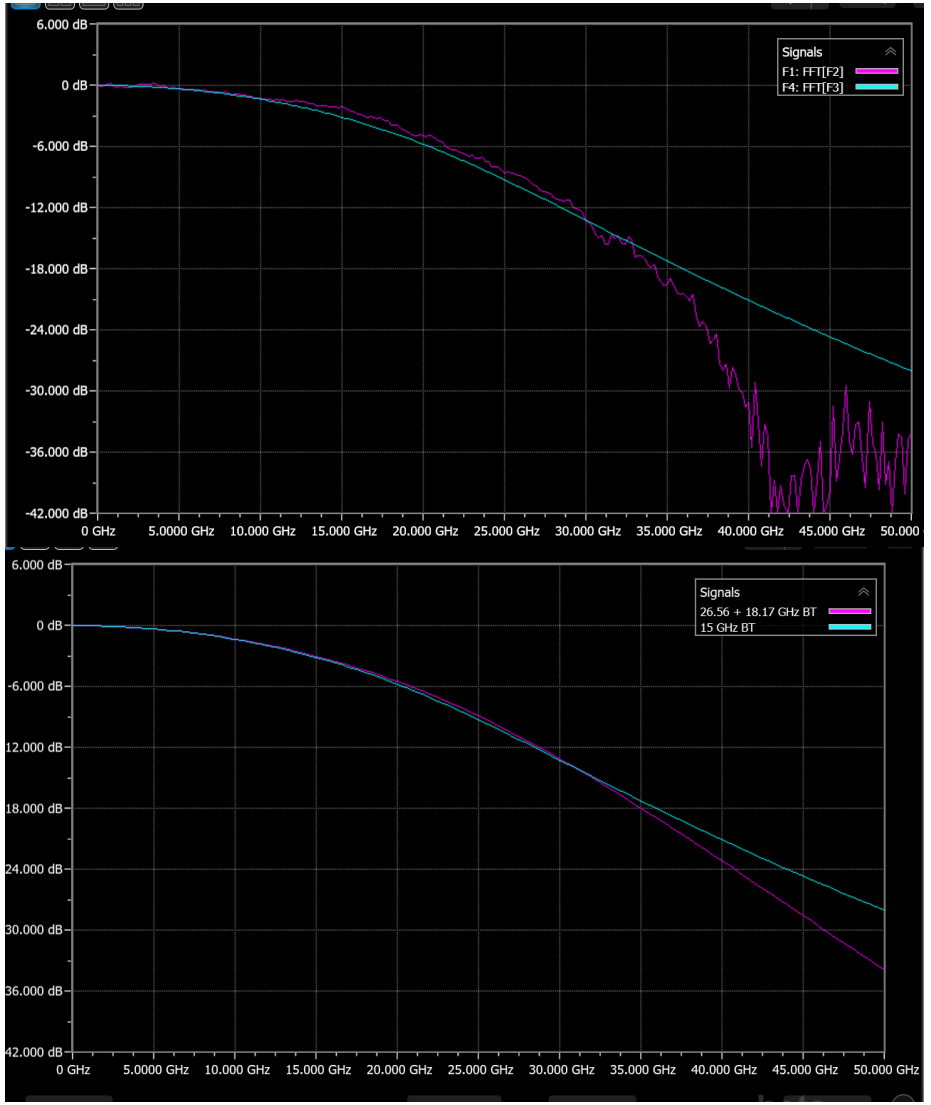
- Today we aggregate the receiver bandwidth with the effective fiber bandwidth created in the scope hardware for a single waveform acquisition
- If we keep the reference receiver bandwidth and the fiber emulation separate, we can acquire one waveform in the half-baud reference receiver bandwidth (used for TECQ and other parameters) and pass the waveform through a virtual function emulating the dispersion to assess TDECQ
- At a minimum, fiber emulation could be a simple BT filter (e.g. 18.2 GHz), but it could be more sophisticated
  - Linear models are good
  - Some form of impulse response?
  - Multiple models could be applied with no extra test time (VR and SR test definitions can differ, but be performed at the same time)





Are the two methods equivalent?

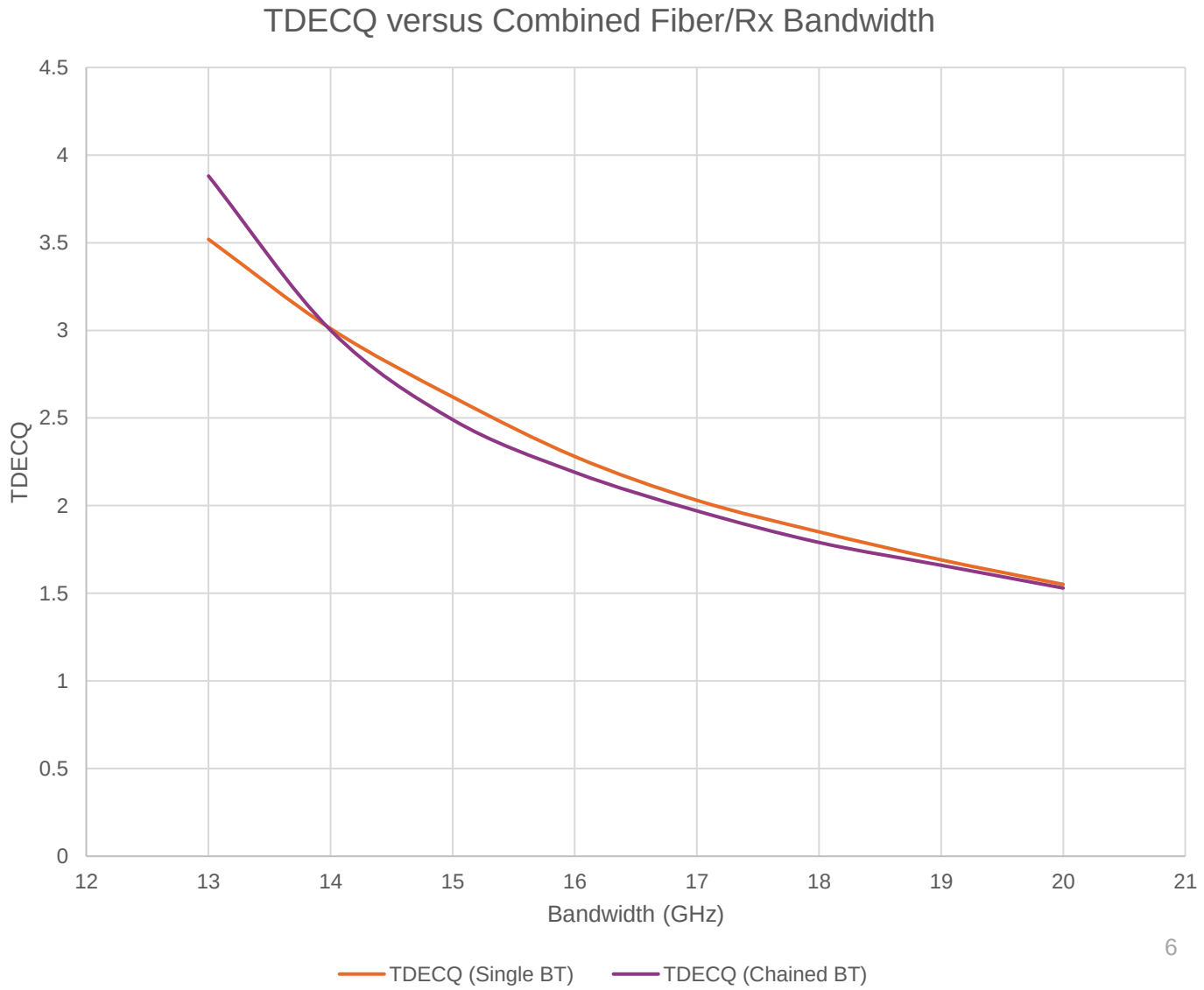
- Yes and no
- In an ideal world they should be equivalent but from a practical perspective it is harder to create an ideal low pass response in hardware compared to having excess bandwidth in the scope hardware and then reducing it mathematically
- Upper: HW tuned to 15 GHz (pink) versus ideal 4th order Bessel
- Lower: HW tuned to 26.6 GHz combined with mathematical 18.2 GHz filter (pink) versus ideal



Comparing TDECQ results

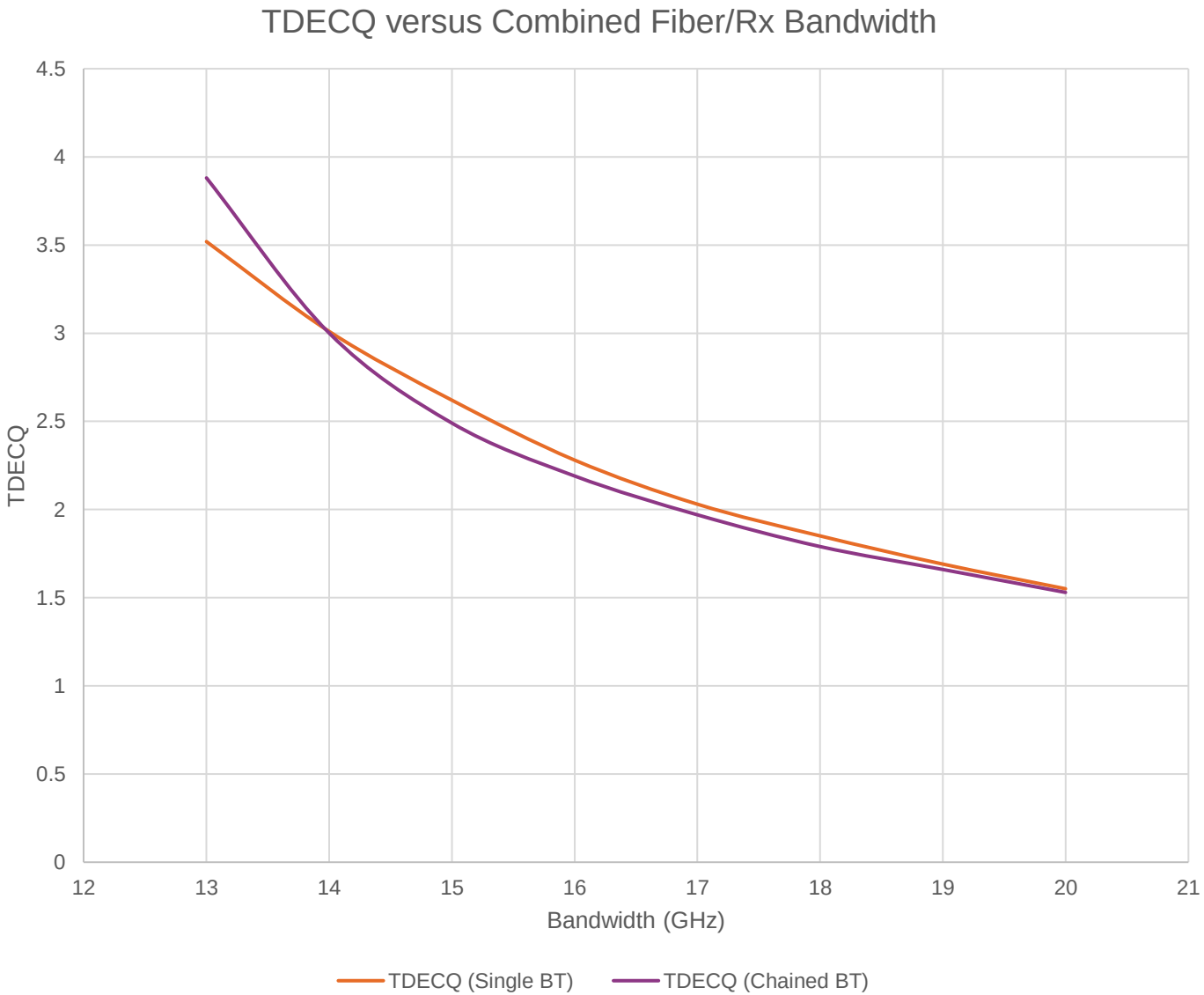
SIMULATION: 53 GBD DEVICES UNAVAILABLE

- TDECQ versus observation bandwidth
- Orange: Aggregated response (scope receiver tuned to desired BW)
- Purple: 26.6 GHz scope bandwidth coupled with a variable fiber BW emulation
- The key observation is that they track. The right answer is whatever we decide best emulates the system



The difference between TECQ and TDECQ is predictable

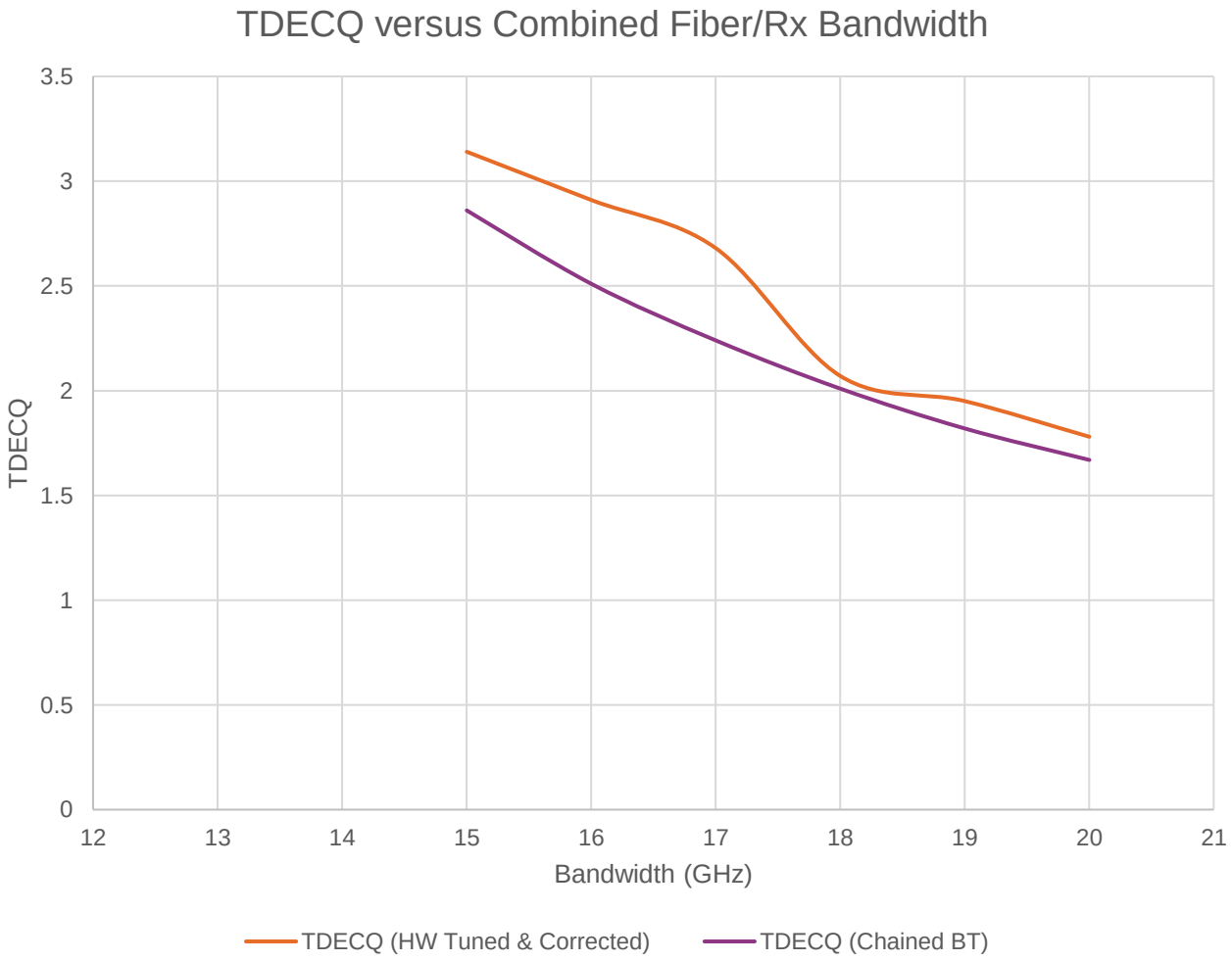
- If the fiber response is fixed, the TDECQ value can be easily estimated from the TECQ measurement (made at 26 GHz)
- Consider that the impact of dispersion can result in high but allowable TDECQ penalties (4.4 dB)
- From a practical view, over 4 dB of eye closure is difficult to measure with high accuracy. An estimate of TDECQ from the TECQ value may be more accurate for high penalty TX, assuming we have the correct model for the fiber



Comparing TDECQ results

SIMULATION: 53 GBD DEVICES UNAVAILABLE

- This example is intended to show the impact of a loosely controlled frequency response
- Orange: Scope receiver tuned to desired BW but with excess rolloff in the 35 GHz region
- Purple: 26.6 GHz scope bandwidth coupled with a variable fiber BW emulation
- Higher performance HW can be built which would yield better agreement, so this type of disagreement should not be assumed



Comment against draft 1.0, clause 167.8.5

SUBTITLE (DELETE IF NOT USED)

- The reference receiver bandwidth for TDECQ analysis is typically at half baud to emulate DSP based receivers with anti-aliasing filters. For multimode transmitter test, the observation bandwidth is reduced further to emulate the dispersion that is created by the fiber span. An alternative approach should be considered. The transmitter waveform is acquired in the half-baud bandwidth. For TECQ, this waveform can be directly analyzed. For TDECQ, the waveform is additionally passed through a second processing block that emulates the fiber. This could be as simple as a low-pass Bessel-Thomson filter, but could be something that better emulates the physical impact of the fiber span, to be determined by the group. This method has the advantage of being able to provide several transmitter metrics, for both SR and VR requirements, with a single oscilloscope acquisition, reducing overall test time and cost, and likely better emulating the true channel response

Proposed remedy

- Change the text of lines 24-34 of page 43 (55 in the overall document) to read: The combination of the O/E converter and the oscilloscope used to measure the optical waveform has a 3 dB bandwidth of approximately 26.5 GHz with a fourth-order Bessel-Thomson response to at least 1.5 × 26.5 GHz. At frequencies above 1.5 × 26.5 GHz, the response should not exceed 24 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response. Prior to TDECQ analysis the waveform is passed through a function that emulates the response of the maximum allowed fiber span. This function is described as a fourth order Bessel response with a -3dB bandwidth of 18 GHz
- The working group should determine what best represents the effect of the fiber, with the 18 GHz value as our best estimate at this time