

IEEE 802.3ca NGEPON Task Force: Calculator for Four-Wave Mixing Products

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Presentation

- What this presentation does <u>not</u> do:
 - Indicate if Four-Wave Mixing is an issue for NGEPON
 - Quantify the impact of Four-Wave Mixing
 - Calculator does not determine the level/intensity of potential FWM products
- What this presentation does do:
 - High-level overview of FWM
 - Show calculator and graphing tool for wavelength locations of potential Partially Degenerate FWM products
 - Summarize of 100GBASE-LR4
 - Show calculator on few example wavelength plans





Four-Wave Mixing Overview



Four-Wave Mixing

- Four-wave mixing (FWM) occurs when two or more frequencies of light propagate through an optical fibre together. Provided a condition known as phase matching is satisfied, light is generated at new frequencies using optical power from the original signals.
- Products from four-wave mixing could be generated on the same wavelength as an optical signal carrying data, thus interfering with the data and increasing errors.







FWM: Partially Degenerate and Non-Degenerate cases



Figure from:

http://www.npl.co.uk/optical-radiation-photonics/optical-comms-and-data/products-and-services/four-wave-mixing-(fwm)





Parameters that impact Four-Wave Mixing

- Wavelength spacing (closer is worse)
- Average Optical Launch Power (higher is worse)
- Fiber distance (longer is worse)
- Chromatic dispersion of the fiber
- Polarization of the light signals





Sources

- "Four-Wave Mixing in an Optical Fiber in the Zero-Dispersion Wavelength Region", Kyo Inoue, JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 10, NO. 11, NOVEMBER 1992
- "Four-Wave-Mixing-Induced Crosstalk and Distortion in Subcarrier-Multiplexed Lightwave Links: Theory and Measurement", Mary R. Phillips, *Member, IEEE*, Kuang-Yi Wu, and F. X. Villarruel, *Member,* OSA, JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 26, NO. 15, AUGUST 1, 2008
- <u>"Four-Wave Mixing (FWM)</u>", National Physical Laboratory | Hampton Road, Teddington, Middlesex





Calculator for Degenerate Four-Wave Mixing Products

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Theory of calculator of potential FWM products

- Assumes only partially degenerate FWM
 - FWM products generated from mixing only two optical signals
 - Formulas for location of potential FWM products:
 - FWM₁₁₂ = $2v_1 v_2$
 - FWM₂₂₁ = $2v_2 v_1$
 - Non-degenerate FWM calculations can be added later if needed
- Definition:
 - λ_1 is wavelength range where optical signal 1 with data (v_1) can be located
 - λ_2 is wavelength range where optical signal 2 with data (v_2) can be located





Calculation of wavelength range for FWM products

- Formulas for location of potential FWM products:
 - FWM_{112 min} = $2v_{1 min} v_{2 max}$
 - FWM_{112 max} = $2v_{1 max} v_{2 min}$
 - $FWM_{221 \min} = 2v_{2 \min} v_{1 \max}$
 - $FWM_{221 \text{ max}} = 2v_{2 \text{ max}} v_{1 \text{ min}}$





Output

- Repeat calculation for FWM wavelength ranges for all combinations of two:
 - λ_1 and λ_2
 - λ_1 and λ_3
 - λ_1 and λ_4
 - λ_2 and λ_3
 - λ_2 and λ_4
 - λ_3 and λ_4





Excel Spreadsheet Calculator

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Examples with FWM Product calculator



FWM Product Calculator: 100GBASE-LR4 Wavelength Plan



Wavelength Range for Potential FWM Product







FWM Product Calculator: TDM 2.0 Upstream



Wavelength Range for Potential FWM Product

Interference with US λ





FWM Product Calculator: WDM 2.1 Upstream



Wavelength Range for Potential FWM Product

Interference with US λ



