Two New Power Penalties for Single-Fiber EFM Links

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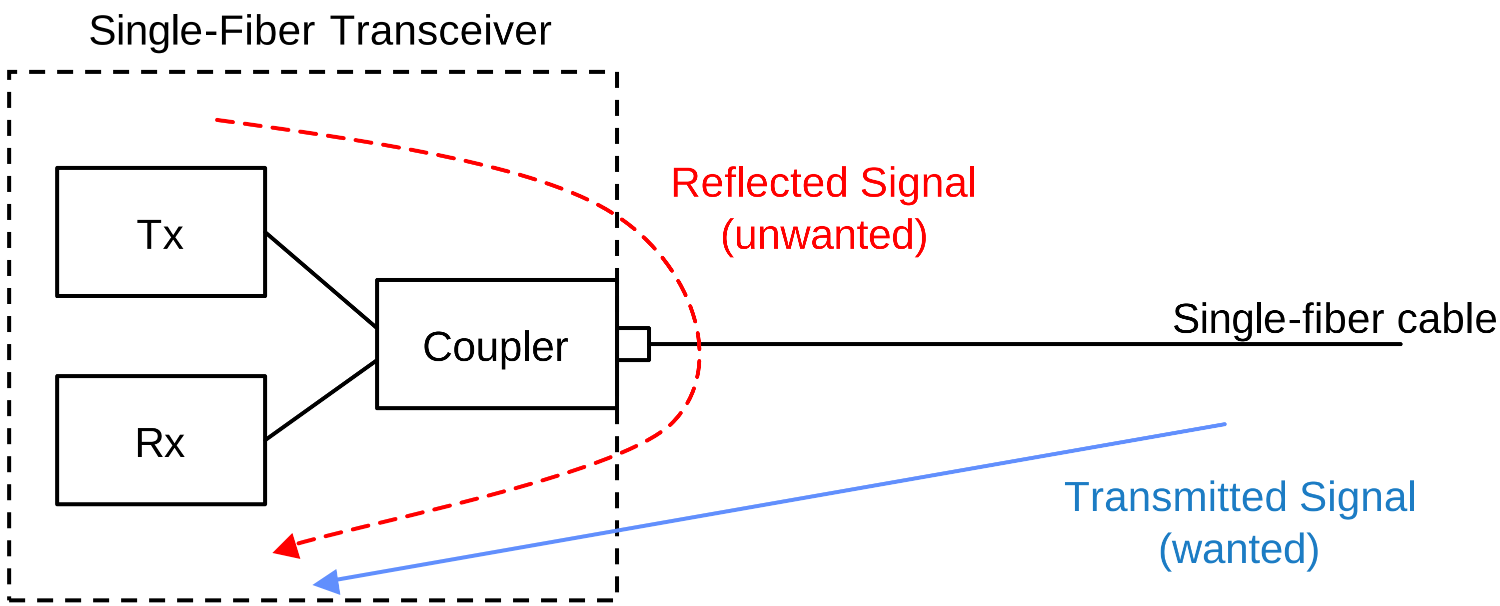
Purpose of this paper…

- …is to describe the basis for adding two new power penalties in the EFM link model.
- These penalties apply only in the case of single-fiber point-to-point and single-fiber PON links, and are large only for single wavelength links with 12 dB return loss.
- Other penalties remain as they are described in the link model: http://grouper.ieee.org/groups/802/3/10G_study/public/email_attach/All_1250v2.xls

Context

- Several co-authors will present a paper on EFM optical power budgets and considerations at the EFM SG Meeting, IEEE Plenary, Portland, July 2001.
- It will refer to two new power penalties described in this presentation.

Reflections in single-fiber links



- The strength of reflected signal depends on implementation – the return loss and whether the coupler is wavelength selective.
- Need a model to quantify the harmful effect of interference from the reflected signal. We propose it in the form of two power penalties.

Two Consequences of Reflections

- First penalty: The reflected signal interferes coherently with transmitted signal. This leads to a noise term and a power penalty.
- Second penalty: The optical powers of reflected and transmitted signals add, causing the receiver threshold to be no longer at the optimum level. Even after adjusting the threshold, a residual power penalty remains.
- Penalties are higher for 12 dB return loss and single-wavelength links.

Interferometric Noise Power Penalty

IN Power Penalty

- Power Penalty caused by Relative Optical Beat Interference Noise [1], [2], [4].
- For 12 dB return loss single-fiber transceivers, light from far-end transmitted signal and near-end reflected signal can coherently interfere. Detector sees it as noise.
- The noise is intermittent, as wavelengths, phases and polarization drift. High when modes are aligned, that is, for each mode pair, the two wavelengths are less than signal bandwidth apart.

Factors that increase the risk of IN Penalty

- Use of DFB lasers with tight tolerances around nominal center wavelength.
- Use of FP lasers with the same mode spacing. If the two lasers in a link end up with a large set of overlapping modes, all pairs of wavelength components that are less than ~2 GHz apart will contribute to this penalty.
- High channel insertion loss and low return loss.

Factors that decrease the risk of IN Penalty

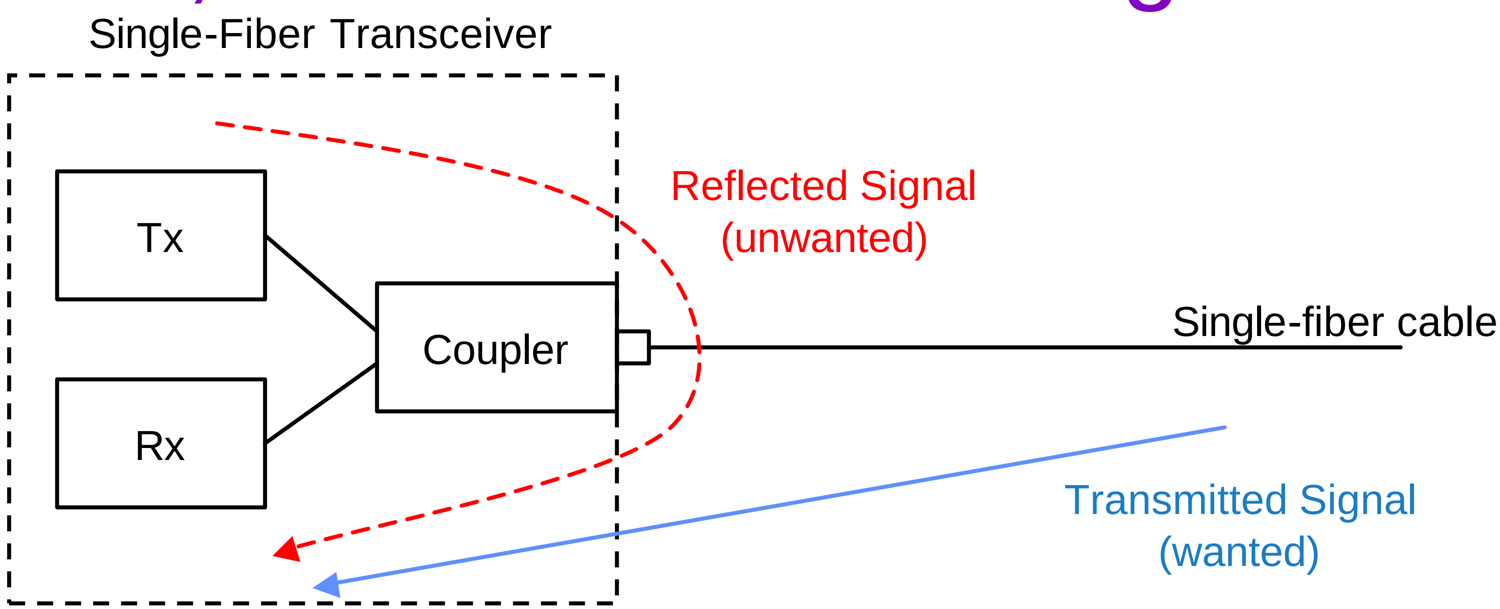
- Higher return loss. (Lower amplitude of the reflected signal.)
- Random polarization of the transmitted signal arriving at the destination receiver.
- Chirp – broadens the linewidth of each laser mode.

IN Penalty value

- Estimates made by various colleagues range from 0.1 dB to 2.0 dB, depending on assumptions.
- Needs analysis and measurements, specific to the EFM cases.

Crosstalk Power Penalty

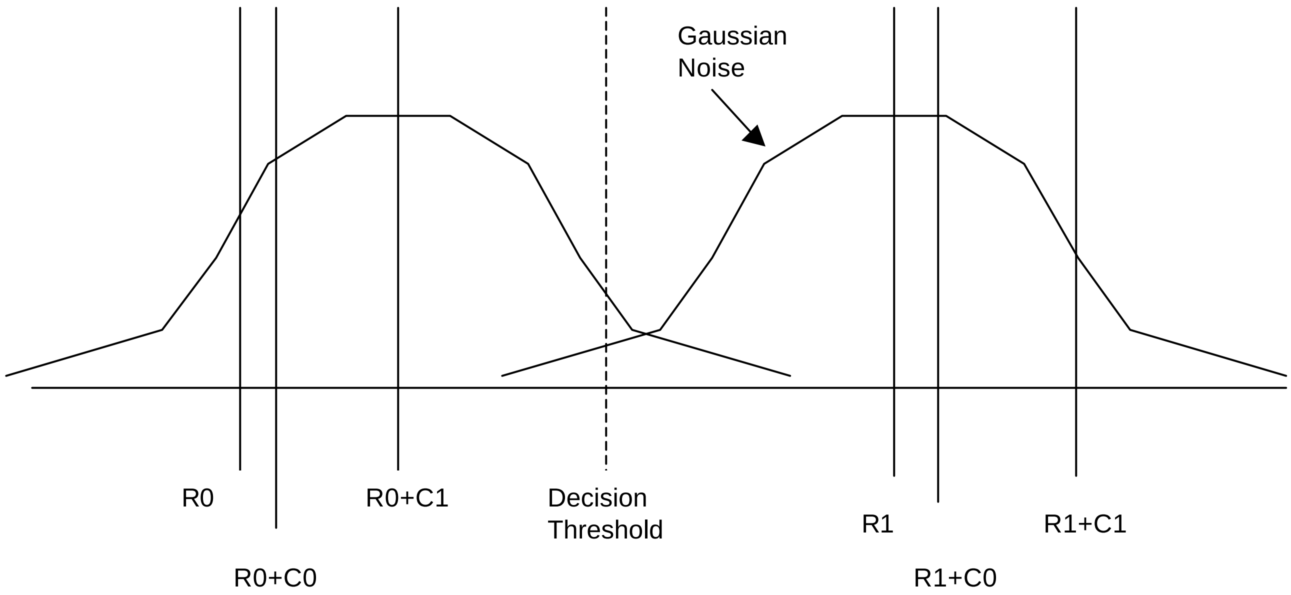
For single wavelength, single fiber links, crosstalk can be significant



- The coupler is a 3-dB power combiner/splitter – not wavelength selective.
- If a 12 dB return loss is desired, the cross-talk resulting from reflections can be significant.

Solution: Adjust the Threshold

A representation of signal, cross-talk, noise and threshold levels



R0 and R1are receive power levels of transmitted signal binary 0 and 1, respectively. C0 and C1 are receive power levels of reflected signal binary 0 and 1, respectively.

- In the presence of crosstalk, moving the threshold up helps.
- Still, a residual power penalty remains. We call it Crosstalk Penalty. For details, please see Reference [3]. Suggested value: 1.6 dB.

Wavelength Plan Affects Penalties

- If two wavelengths are used instead of one, they will be separated far enough to make IN Penalty negligible.
- A two-wavelength filter can be assumed to have sufficient isolation to make Crosstalk Penalty negligible.

Conclusion

- Two power penalties defined – Interferometric Noise Penalty and Crosstalk Penalty.
- Very likely, these penalties are significant only for single-wavelength, single-fiber EFM links with 12 dB return loss.

References

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2. S. L. Woodward et al, "Bidirectional, Subscriber-Multiplexed Transmission Using 1.3 um Fabry-Perot Lasers," IEEE Photonics Technology Letters, VOL. 9, NO. 10, Oct. 1997, pp. 1409-1411.
3. V. Bhatt, “Cross-talk in bi-directional, single wavelength, single fiber Gigabit Ethernet links”, URL: http://www.ieee802.org/3/efm/public/jul01/bhatt_1_0701.pdf
4. C. Desem, “Optical Interference in Subcarrier Multiplexed Systems with Multiple Optical Carriers”, IEEE Journal On Selected Areas in Communications, VOL. 8, No. 7, Sep. 1990, pp. 1290-1295.