



A Furukawa Company

SBS Mitigation in Digital Transmission for 10G EPON Standards Development

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Outline

- Motivation
- SBS in previous contributions on high power
- SBS thresholds and mitigation in digital transmission
 - CW SBS threshold
 - Impact of modulation
 - Suppression by FM dithering
- Strategy for Dealing with SBS in 10G EPON

Need For High Power Tx

CH IL (dB)	Tx Pen. (dB)	Power Budget (dB)	PIN Rx Sens. w/ 3dB FEC (dBm)	Min Launch (dBm)	Max Launch (dBm)
29	~2	~31	-20 (avg) -18.4 (OMA)	11 (avg) 12.6 (OMA)	14-15 (avg) 16.6-17.6 (OMA)
24	~2	~26	-20 (avg) -18.4 (OMA)	6 (avg) 7.6 (OMA)	11 (avg) 12.6 (OMA)

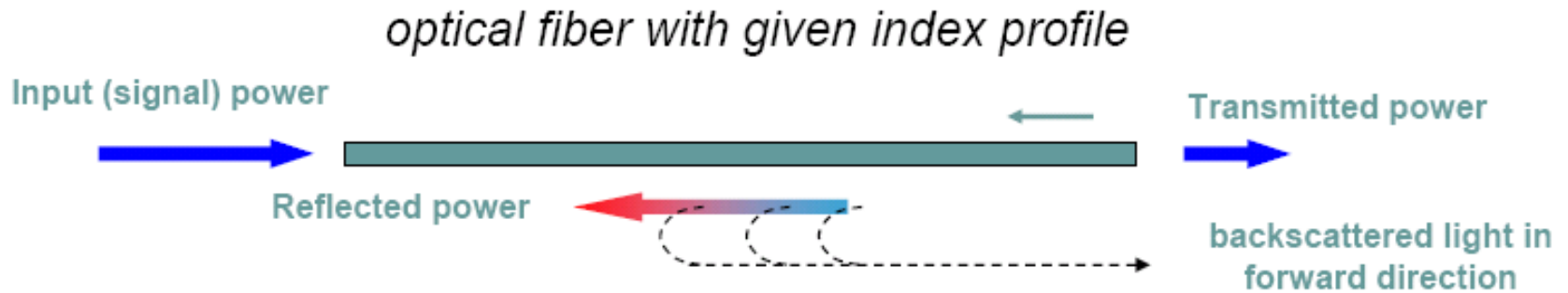
Assume ER > 8.2 dB

Previous Contributions

Contributor	Tx + Amp	Fiber Length (km)	Max Power (dBm) w/o SBS mitigation for ≤ 0.5 dB penalty	Max Power (dBm) w/ SBS mitigation for ≤ 0.5 dB penalty
Murata_1_0706	EML+ EDFA	20	13*	“higher”
3av_0611_doussiere_1	EML + EDFA	25	13	> 17
3av_0701_gokhale_1	EML + EDFA	20	$\sim 12.5^*$	> 17
3av_0701_ten_1	MZM+ EDFA	20	~ 11	

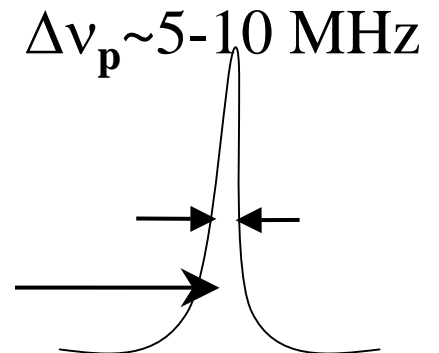
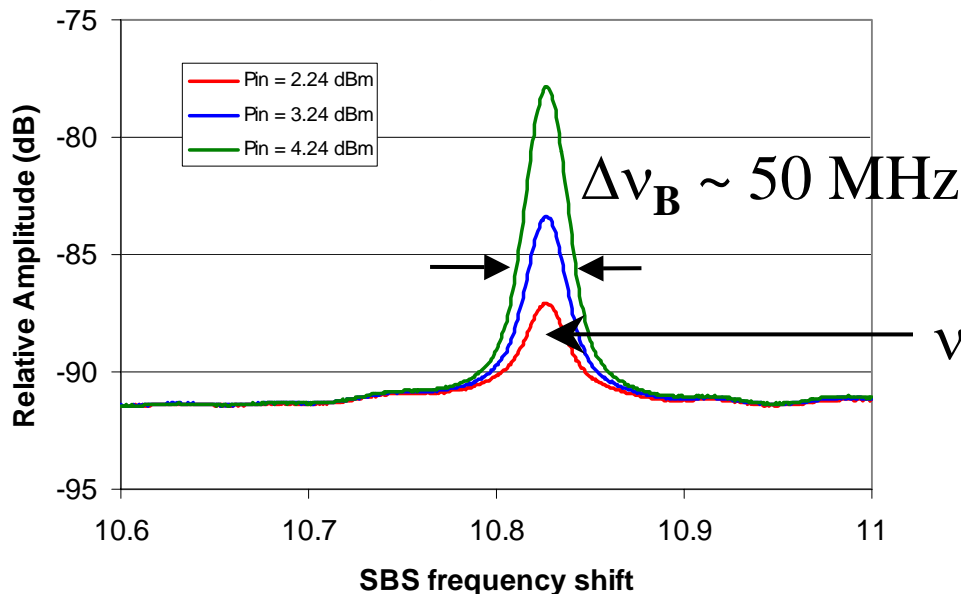
* Estimation, based on conversations with authors

Stimulated Brillouin Scattering



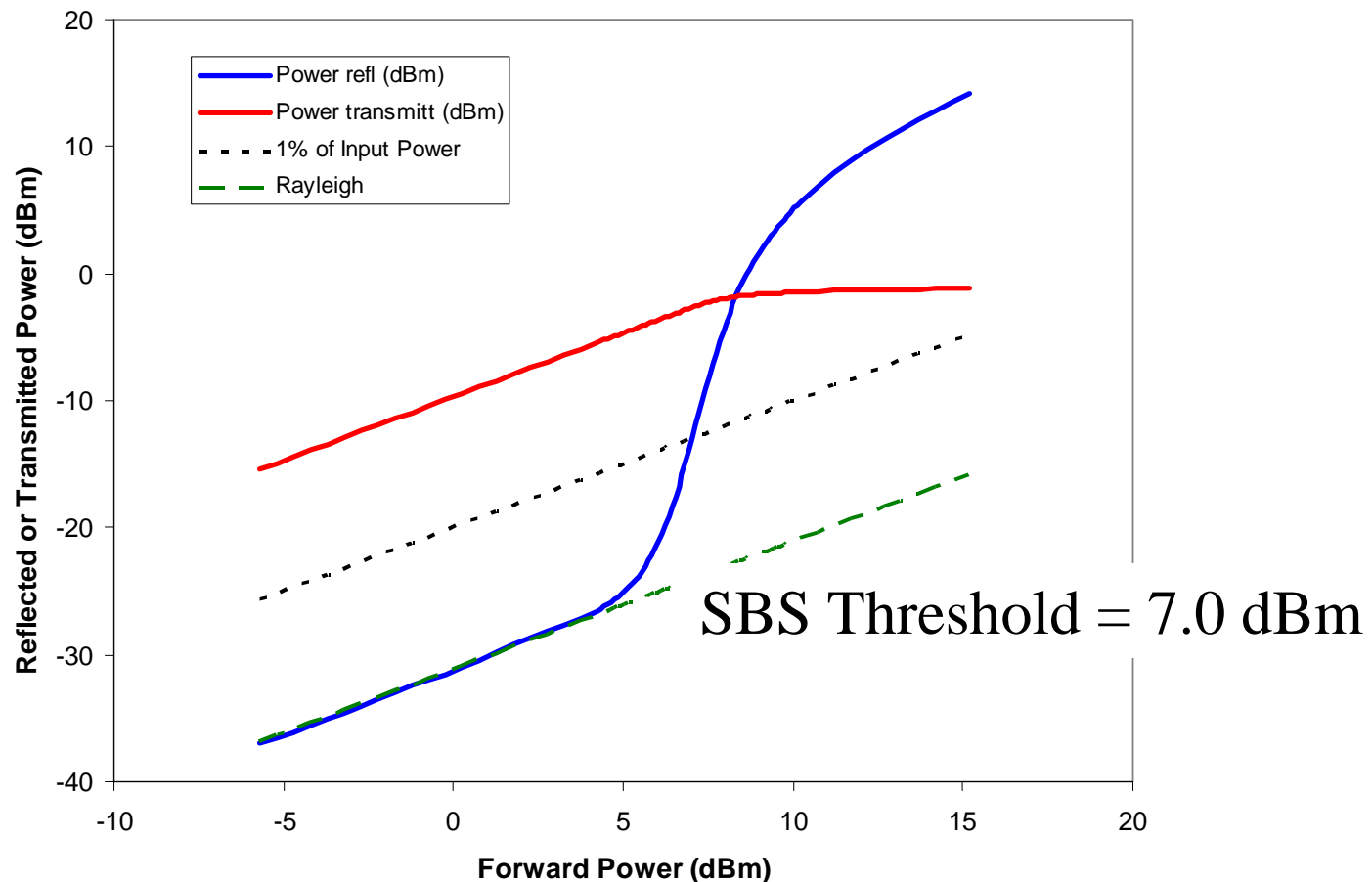
SBS measured on
RF spectrum analyzer

$$P_{thr}^{CW} \approx 42 \frac{A_{eff}}{g_0 L_{eff}} \left(\frac{\Delta \nu_B + \Delta \nu_p}{\Delta \nu_B} \right) \quad \text{Ref: Aoki et al., JLT, v6, p710 (1988)}$$



SBS Threshold Definitions

- Pick some point where the backscatter power is rapidly rising with input power.
- There are advocates for various threshold definitions, but the impact on system performance is what matters.



SBS 1% CW Threshold Power for various G.652 fibers

(values normalized to 20 km length)

Fiber Type	Threshold Range (dBm)	# Tested
A	7.04 – 8.23	≥ 8
B	7.24 – 9.65	≥ 8
C	5.8 – 6.7	3
D	5.91 – 7.2	≥ 8

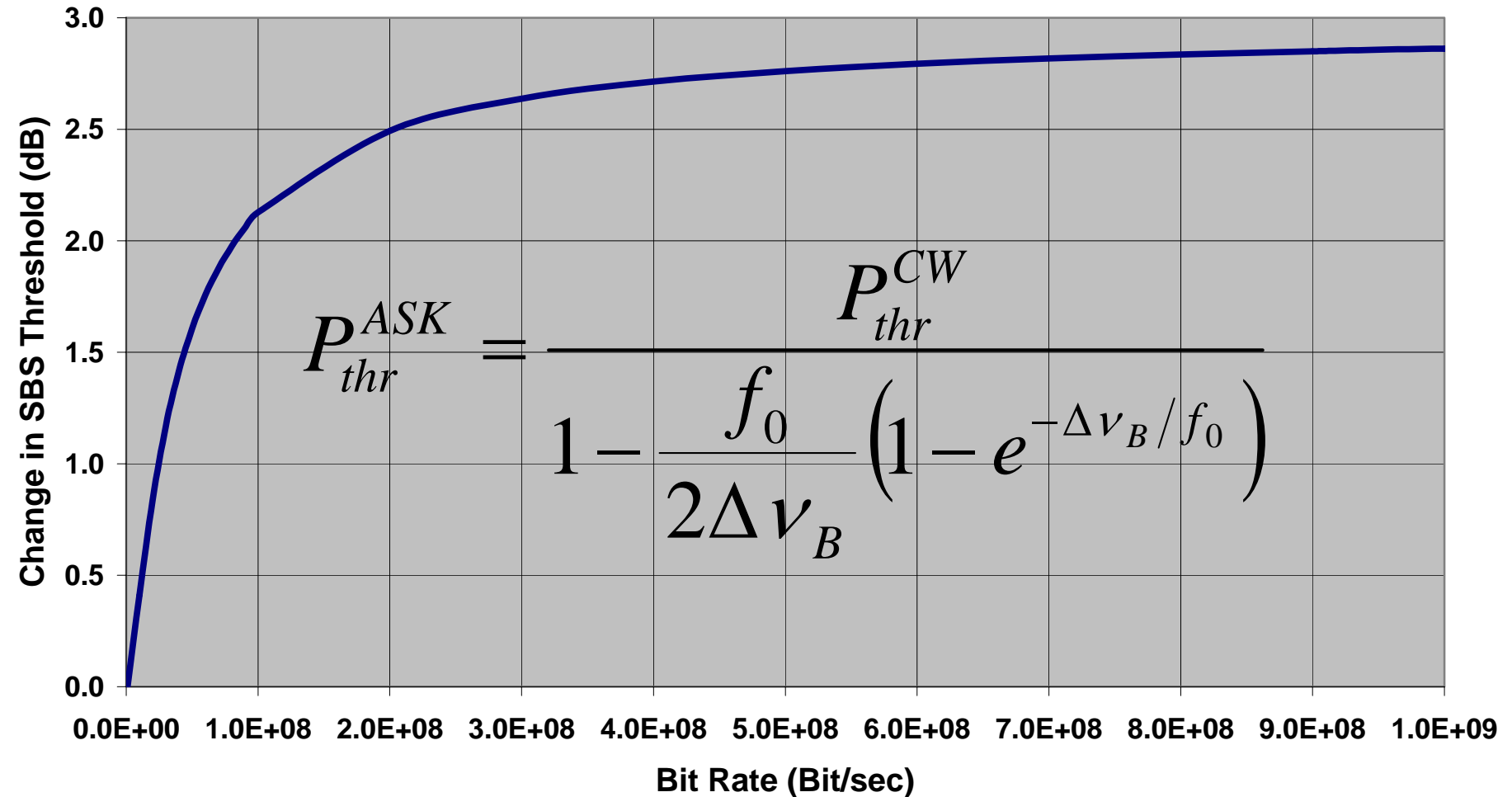
- Measured with ECL, linewidth $\sim 100\text{kHz}$
- Represents different 1) manufacturers, 2) core fabrication technologies, and 3) designs within G.652

SBS Suppression by Data Modulation

- The wider line width of a modulated signal will increase the SBS threshold.
- However, the effect saturates because half the total pump power is contained in the spectrally narrow carrier for ASK.
- Thus the effect saturates at 3 dB, and most benefit is already obtained at a data rate of 500 Mbps .
- Above comments apply to external modulation. SBS can be ignored in the case of DMLs.

Impact of Digital Modulation

Impact of ASK Modulation on SBS Threshold



f_0 is the bit rate, Eq 3 of Fishman & Nagel, JLT 11, p1721 (1993).

SBS Suppression by FM Dither of Tx Center Wavelength

Fishman & Nagel,
JLT, v11, 1721
(1993).

$P_{\text{threshold}}$
mW

FM dithering of the laser wavelength at 10's of kHz broadens the effective linewidth of the source

$$P_{thr} \propto \left(\frac{\Delta \nu_B + \Delta \nu_p^{Eff}}{\Delta \nu_B} \right)$$

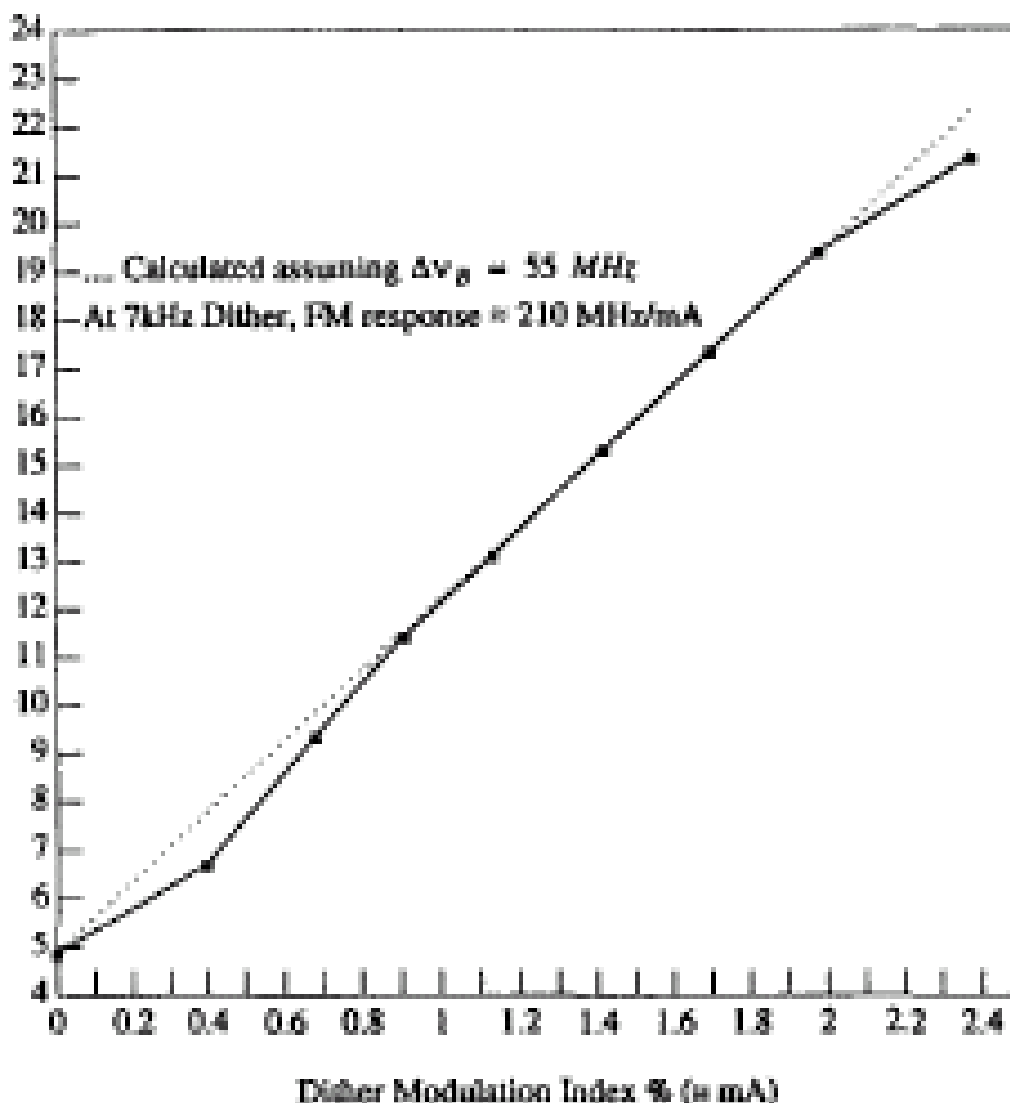


Fig. 9. Plot showing the effect of FM dither on CW SBS threshold. The MQW-DFB laser is biased at 100 mA, with a nominal FWHM linewidth of 25 MHz. The dotted line is a result of the threshold calculated using (2), assuming that $\Delta \nu_B = 55 \text{ MHz}$ and that the dither effectively broadens the linewidth.

FM Dithering of Digital Tx

- It is typical for EMLs for DWDM transmission to have an input for a 1-100 kHz signal to drive frequency dithering for SBS control
- The solution is straightforward, common, and “practically free.”
- Tx dithering can solve any SBS problem that may occur in 10G EPON systems, without adding dispersion penalties.

Suggested Strategy for Handling SBS in 10G EPON

- Determine the limit where SBS suppression is required to keep impairments less than a few tenths of a dB for worst case fiber + amplified EMLs, from experimental data
- Require that SBS suppression be employed for an EML Tx operating in a range that overlaps the determined limit
- If isolation is good at the amplifier, SBS suppression *may* only be an issue for the 29 dB CH IL case