Analog Fiber-Optic Link Technology

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Analog photonic components can be used to overcome the electronic bandwidth limitations in backplane, intra-board, and intra-chip applications. The components of an analog optical link are shown in Figure 1. In order for analog photonic components to be practical and appropriate for optical interconnects, methods have been developed to improve the gain, noise figure, and spurious free dynamic range, the figures of merit of a photonic link as defined in Figure 2. Understanding the link design tradeoffs and the performance of the individual components allows the design engineer to develop a photonic system with optimal performance. The state-of-the-art photonic link performance is shown in Figure 3. During this presentation approaches to improve link performance will be reviewed.

Impedance matching for improved link gain

When impedance-matching to a complex impedance using purely reactive components, the Bode-Fano limit dictates the maximum bandwidth over which a desired return loss can be obtained. We will discuss how impedance matching has been applied to both ends of a photonic link to improve the performance in both narrow bandwidth and broad bandwidth applications.

Methods for decreasing link noise figure

Noise figure is proportional to the noise out of a link and inversely proportional to the gain. In a direct modulation link, the gain is proportional to the slope efficiencies of the laser and detector. In an external modulation link, the gain is proportional to the laser power and slope efficiencies of the modulator and detector. We will show the improvement to noise figure that results from increasing the power in an external modulation link.

Another method to improve noise figure is to not exactly impedance match. The minimum noise figure of a passive lossless impedance matched link is 3 dB. It has been derived and experimentally demonstrated that the noise figure can be<3dB if the components are not exactly impedance matched. This lowering of noise figure comes at the expense of decreasing the gain.

Methods for increasing link dynamic range

The directly modulated laser and the Mach-Zehnder, directional coupler, and electroabsorption modulators available for external modulation have non-linear transfer functions that introduce intermodulation distortion products and degrade the spurious free dynamic range. We will discuss various methods which have been developed using multiple-electrode modulators to linearize the 2nd-order and 3rd-order intermods, or both.

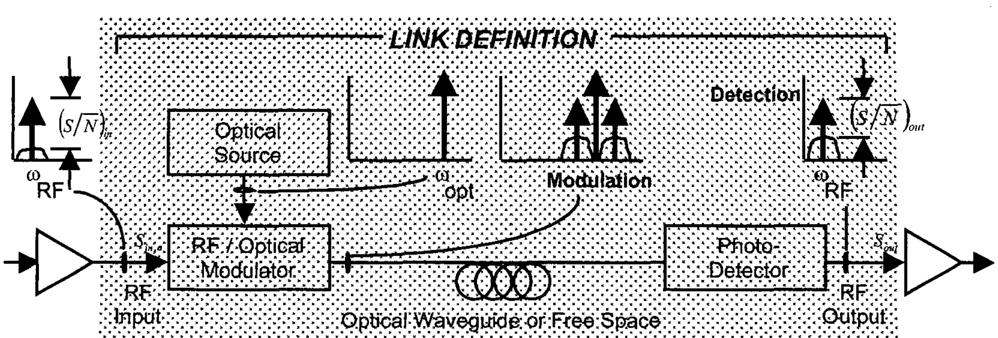

Figure 1: Analog optical link.

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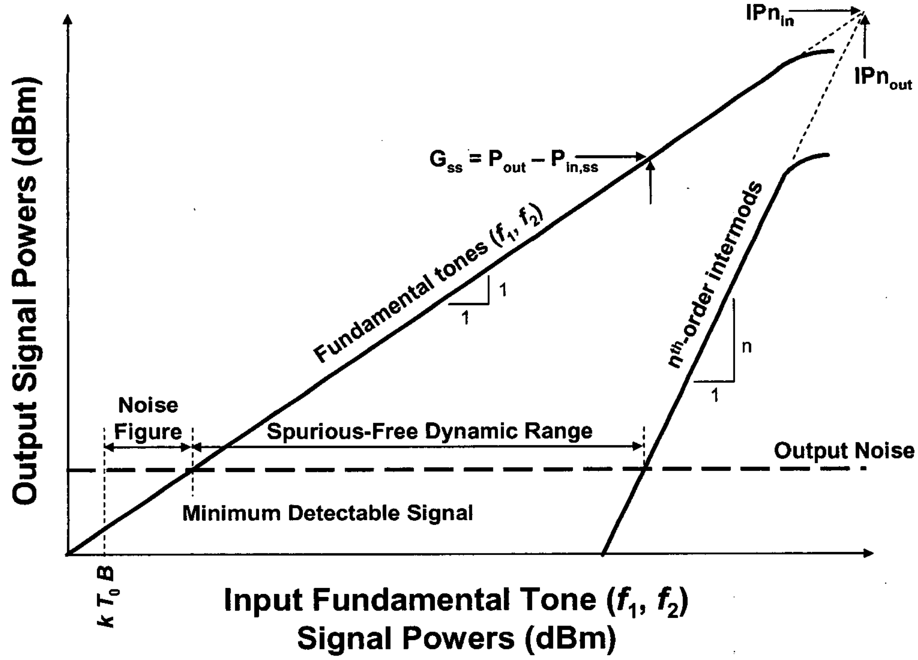

Figure 2: Analog component figures of merit

Parameter	Direct	External
Wavelength (μm)	0.85, 1.3, 1.55	1.3, 1.55
Maximum Modulation Frequency (GHz)	30	100
Link Gain (dB)	-5 to -35	-30 to +38
Noise Figure (dB)	20 to 60	2.5 to 30
IM-free Dynamic Range		
Standard (dB-Hz$^{2/3}$)	100 to 114	112
Linearized (dB-Hz$^{2/3}$)	120	130 (suboctave) 123 (> octave)

Figure 3: Summary of State-of-the-Art IM / DD Link Performance