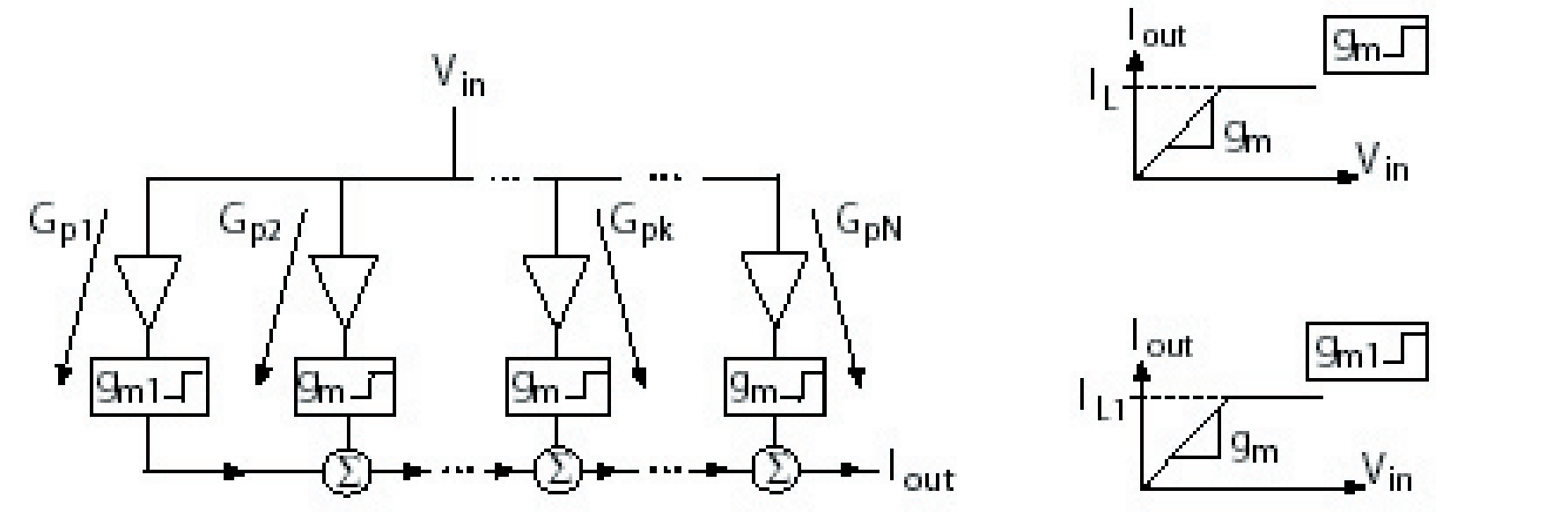


# A 10 GB/S LOGARITHMIC AMPLIFIER FOR OPTICAL SINGLE SIDEBAND

## Logarithmic Amplifier Overview



The sequential limiting of the gain paths provides a piecewise approximate log response.

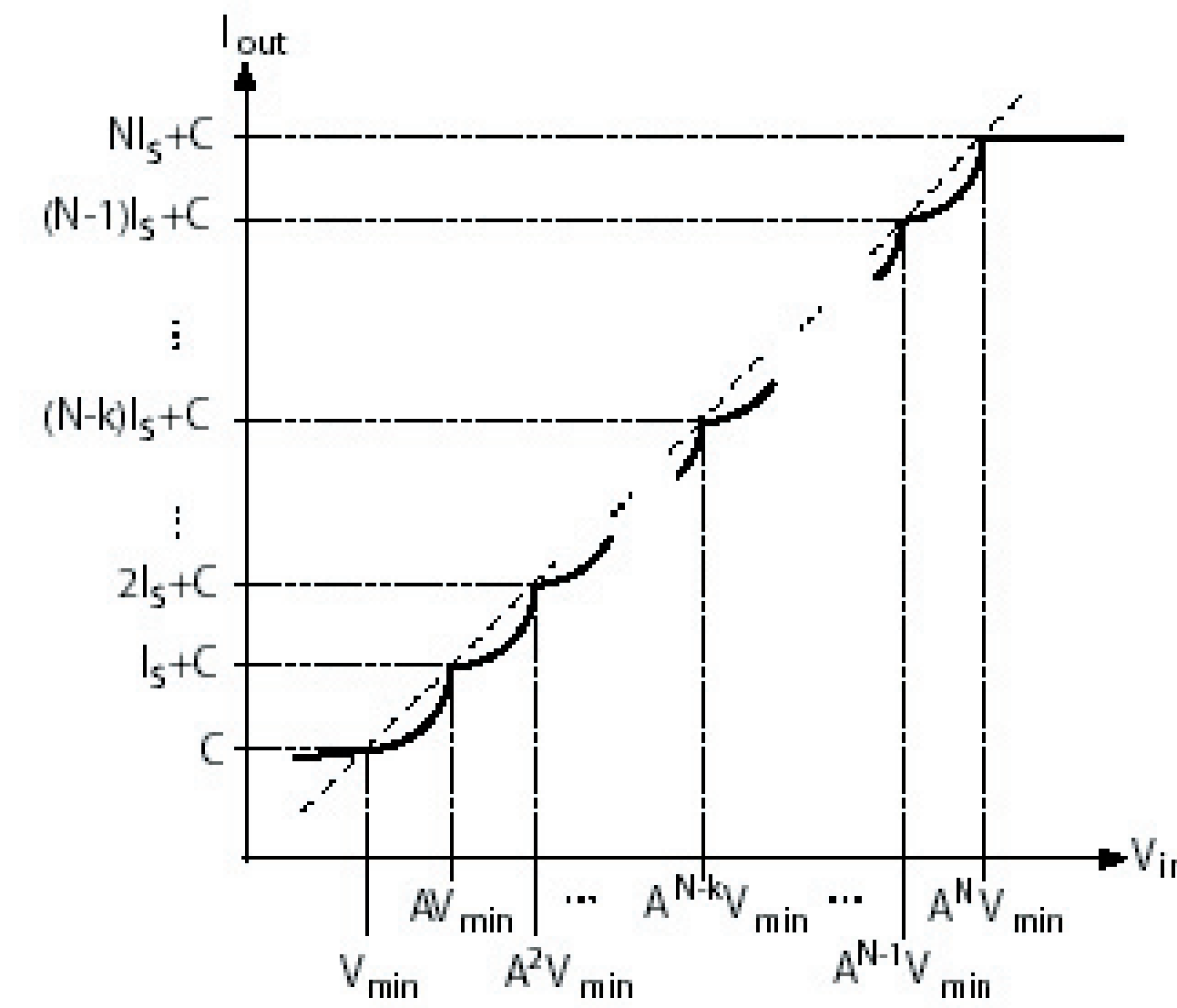


Fig. 1 - Parallel logarithmic amplifier architecture.

Features:

- Fully differential.
- Delay matched.
- Low power.

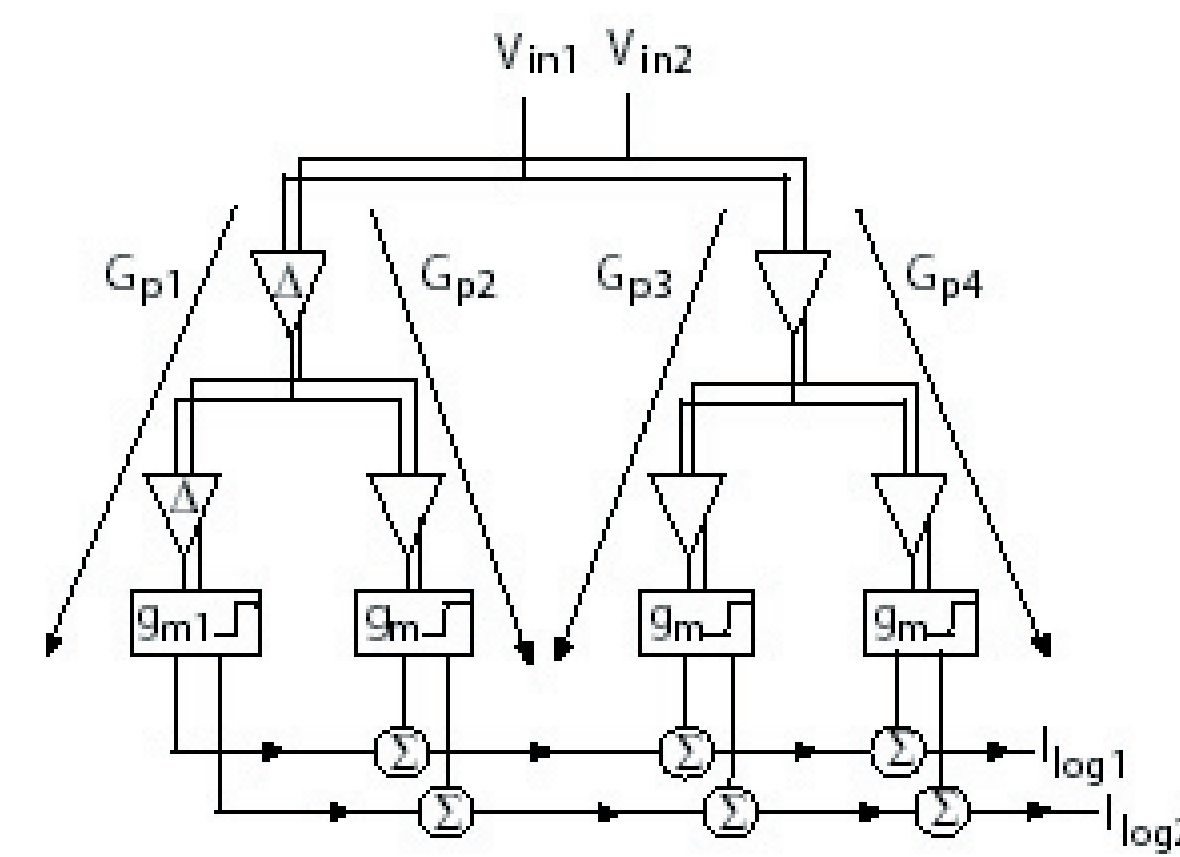


Fig. 2 - Logarithmic amplifier block diagram.

- Fabricated in IBM's SiGe HP5 process.
- -3.3 V, 250 mA
- Second generation of this design.

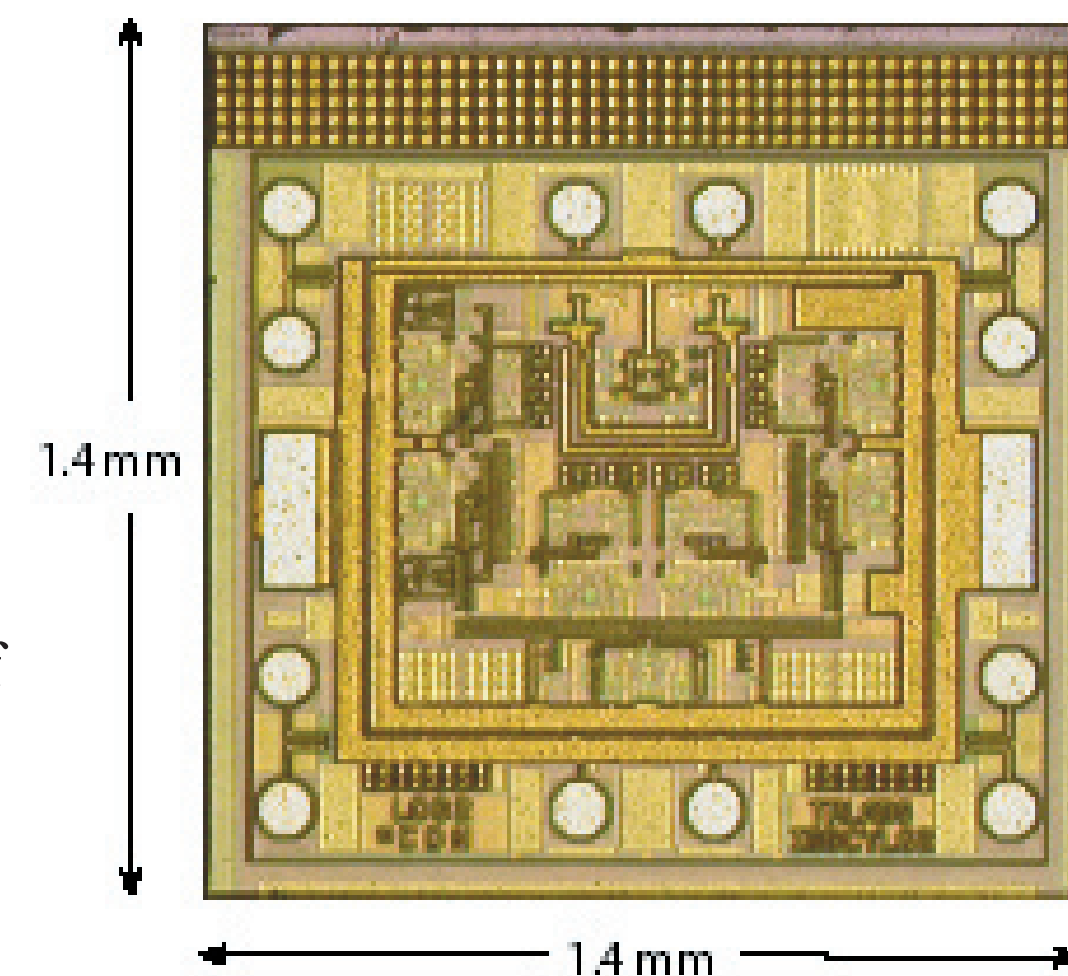
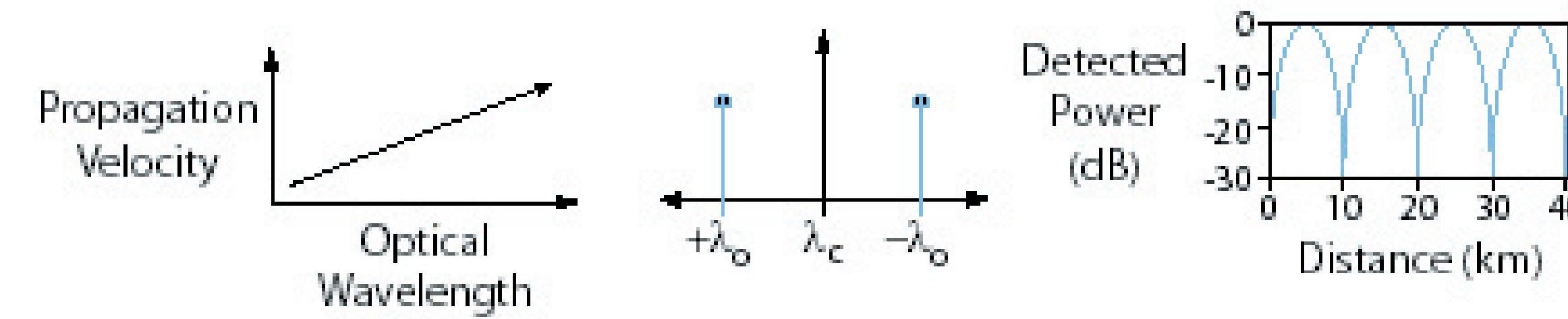


Fig. 3 - Logarithmic amplifier chip photograph.

## Application: Optical Single Sideband

Problem: Power Fading due to Chromatic Dispersion



The sidebands travel at different speeds and interfere with each other.

This results in power fading, with the nulls located differently for each wavelength.

Fig. 4 - Description of chromatic dispersion.

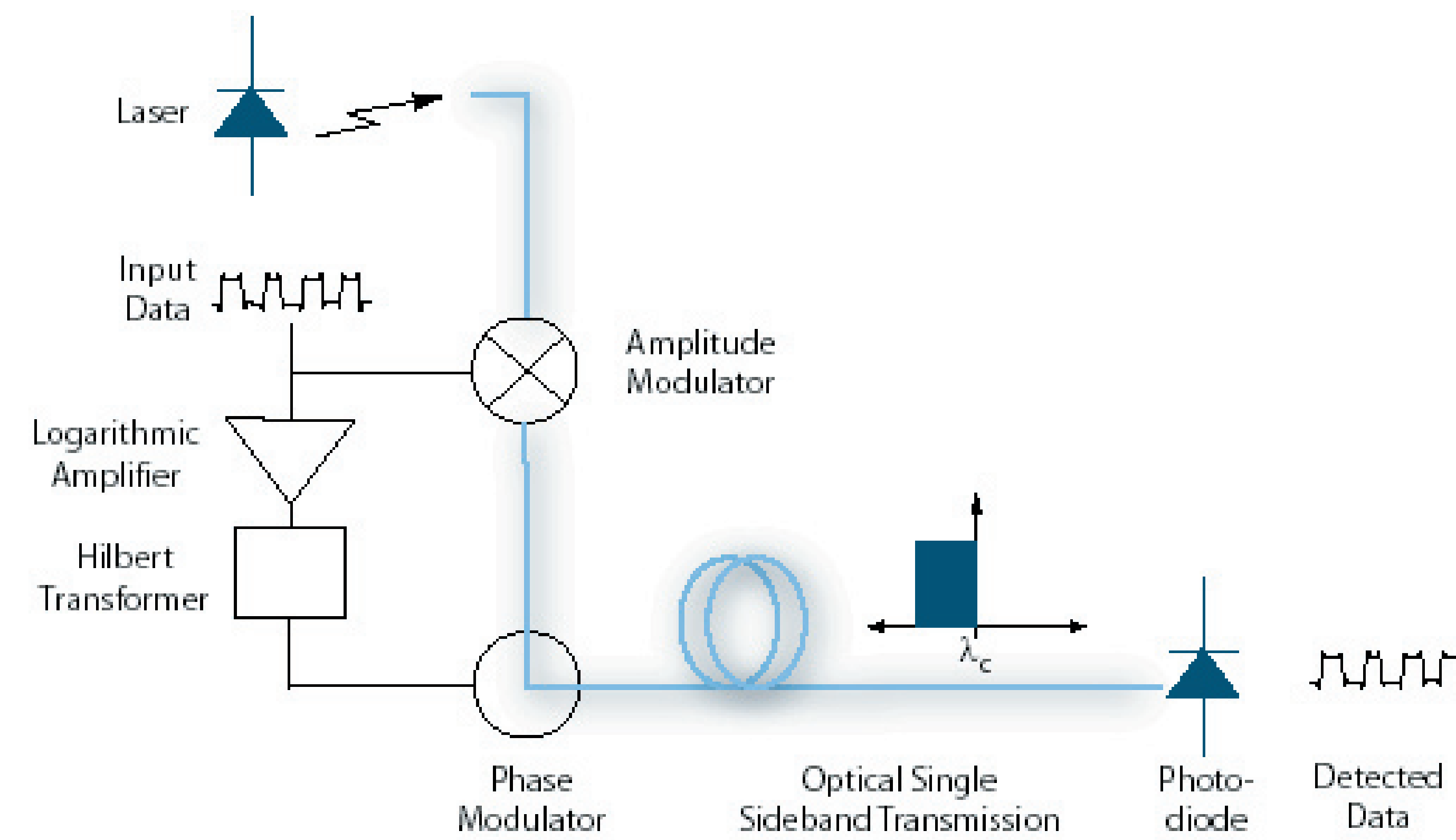


Fig. 5 - Optical single sideband (OSSB) system diagram.

The power fades at the receiver are eliminated when one of the sidebands are removed.

Theoretical basis

The basis of a single sideband signal is the Hilbert Transform pair:

$$a = s + j\hat{s}$$

The form compatible with photodiode (envelope) detection:

$$a = |s| \exp\{j H(\log[|s|])\}$$

where  $H()$  represents the Hilbert Transform operation.

## Logarithmic Amplifier Measurements

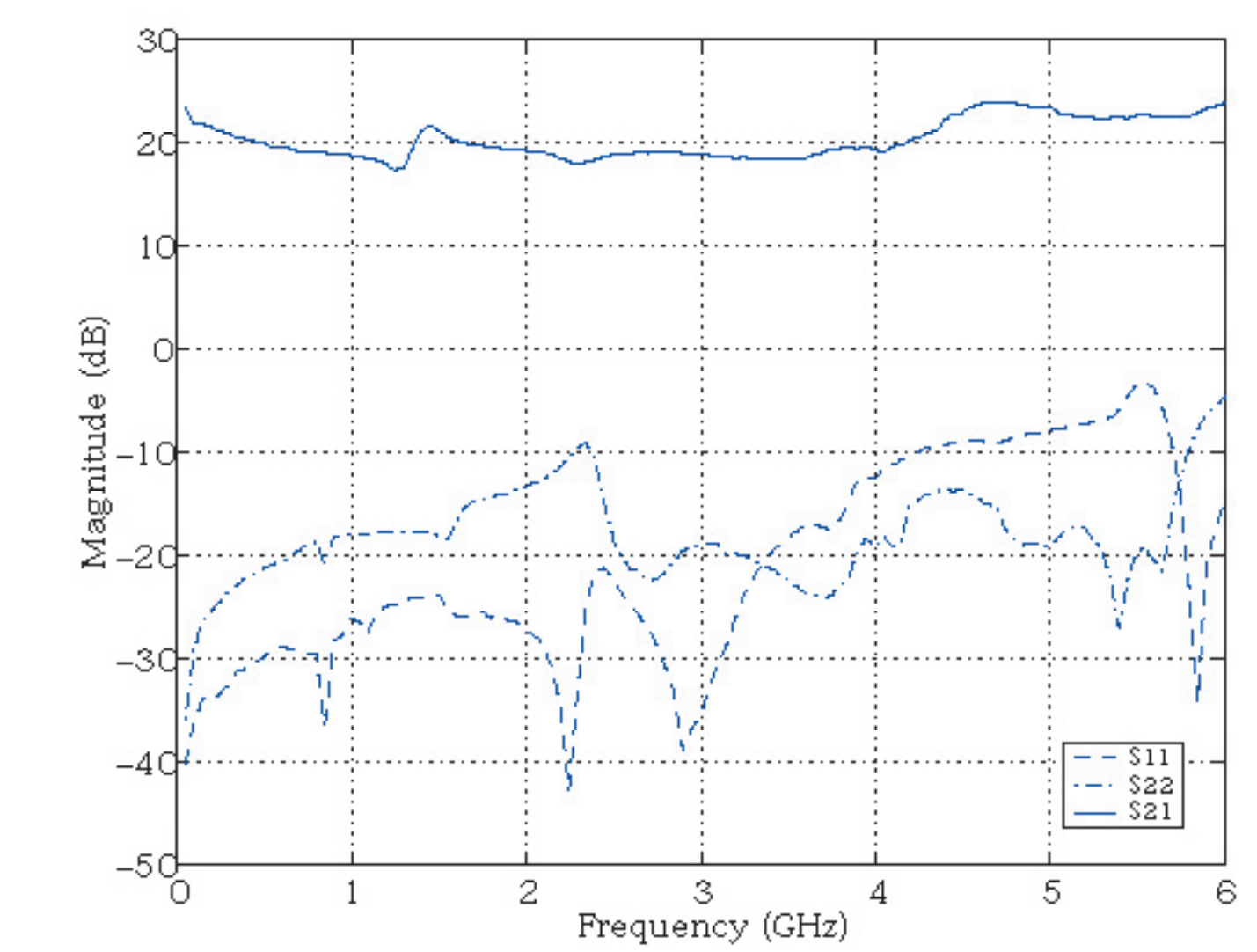


Fig. 8 - Small signal performance.

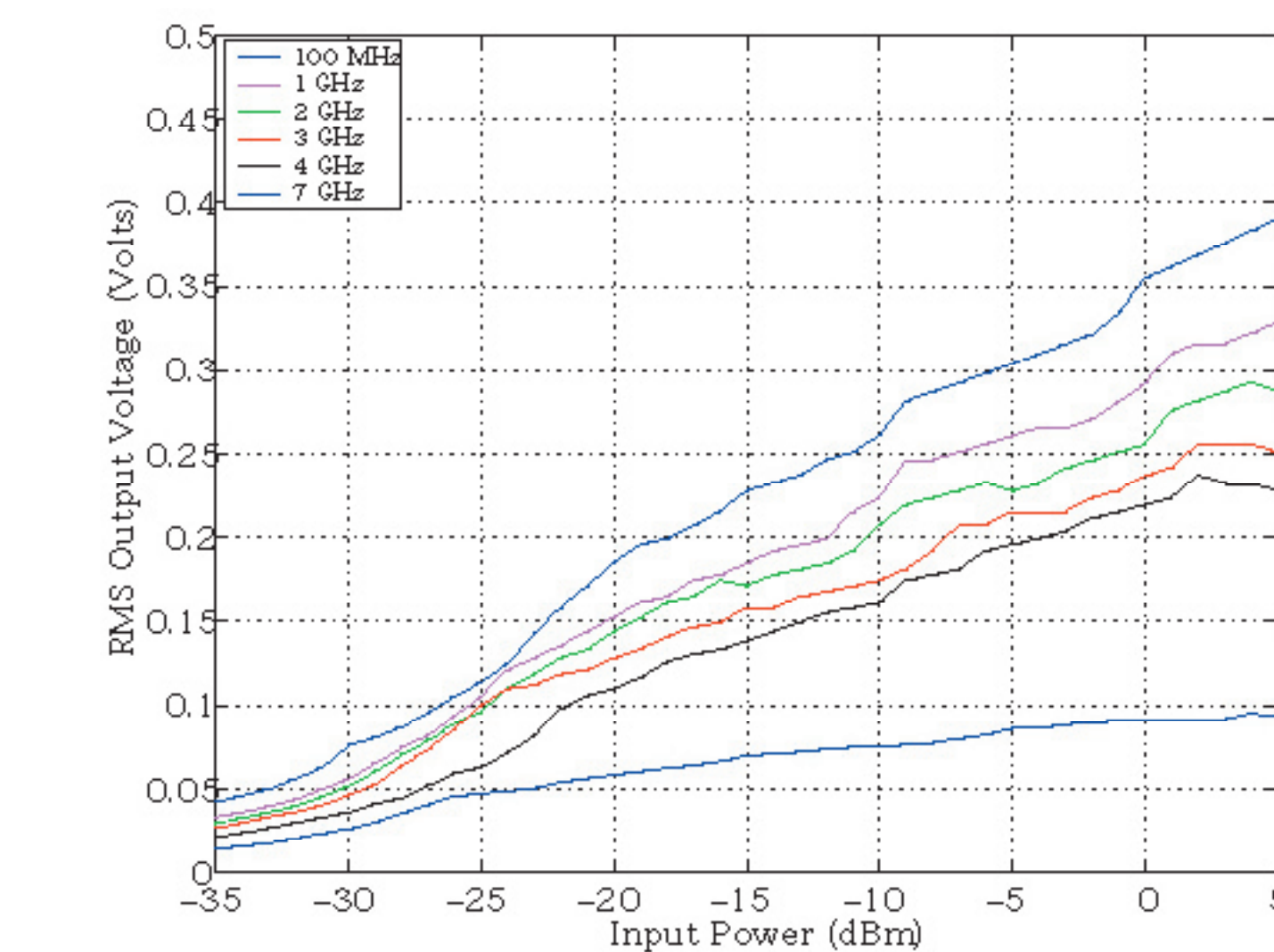


Fig. 9 - Large signal performance.

- DC - 6 GHz bandwidth.
- Measured noise figure of 12 dB

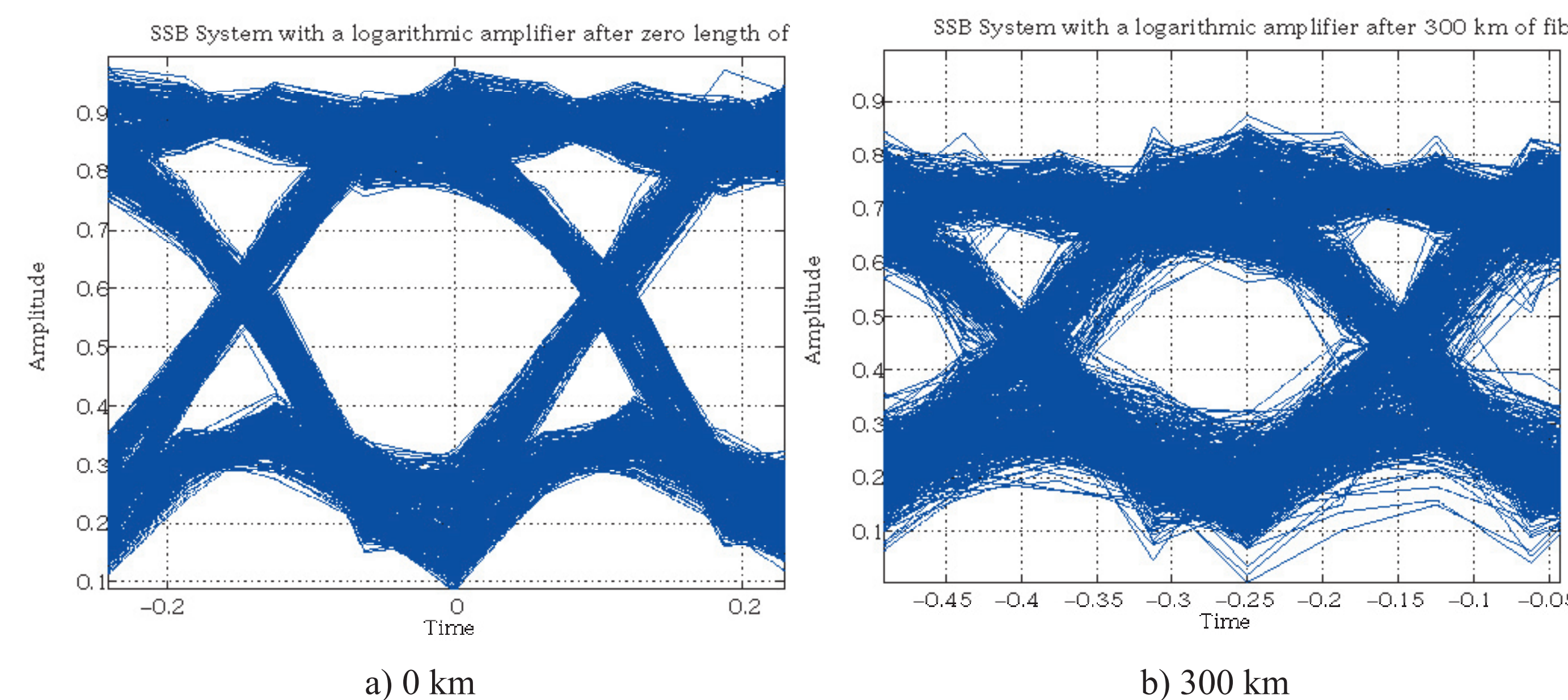


Fig. 6 - 2 Gb/s log amplifier eye diagrams with a 60 ps/nm.km dispersion parameter

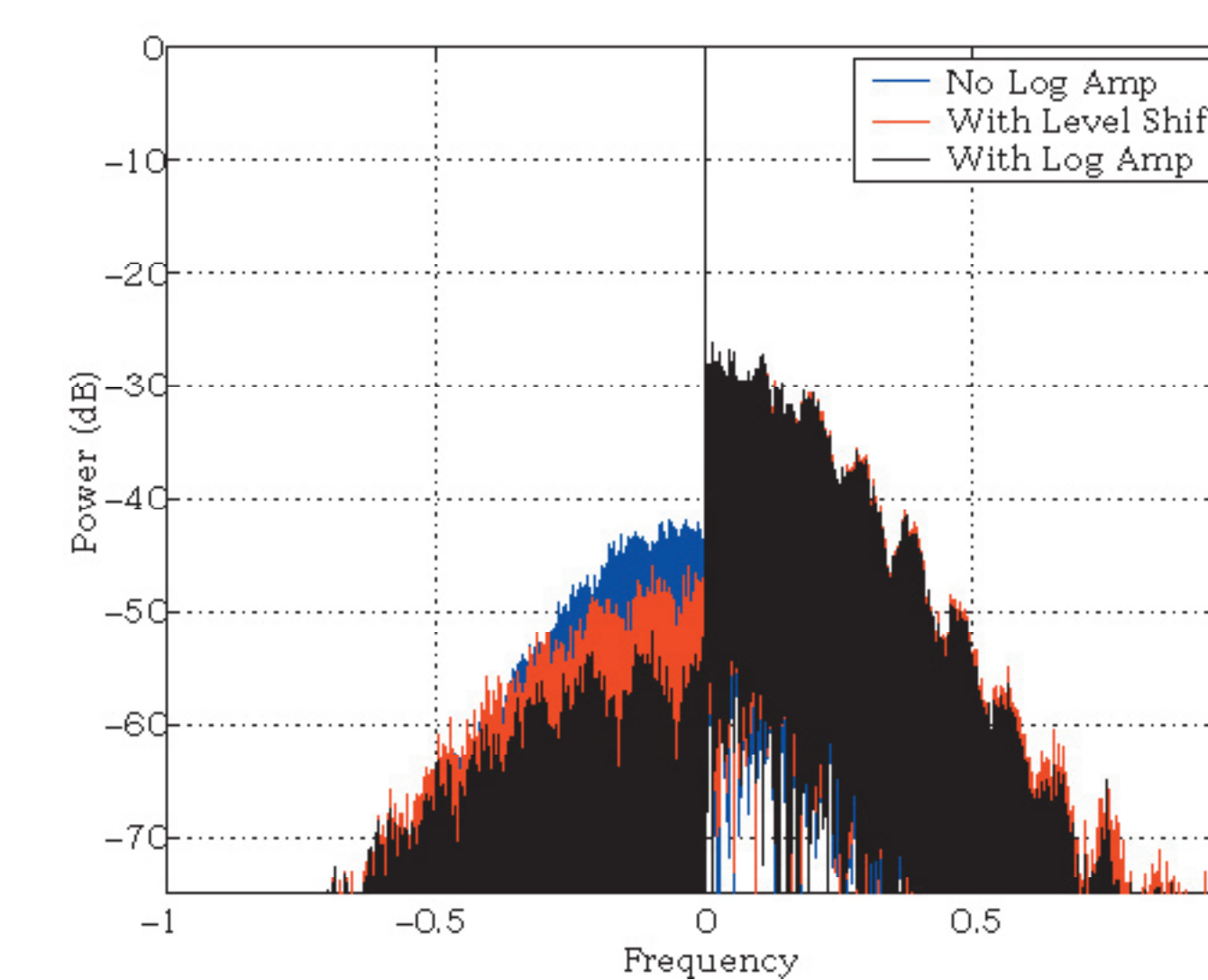


Fig. 7 - Optical spectrum improvement with the log amplifier.

Highest bandwidth log amplifier ever built!

Circuit	Large Signal Bandwidth	Rise/Fall Time
Smith [1988]	0.5 - 4 GHz	500 ps/ 500 ps
Oki [1988]	DC - 3 GHz	400 ps/ 400 ps
TRLabs NT35 Branch Logarithmic Amplifier	DC - 4 GHz	100 ps/ 100 ps
This Work - TRLabs SiGe Branch Logarithmic Amplifier	DC - 6 GHz	50 ps/ 50 ps

Patent Applied For

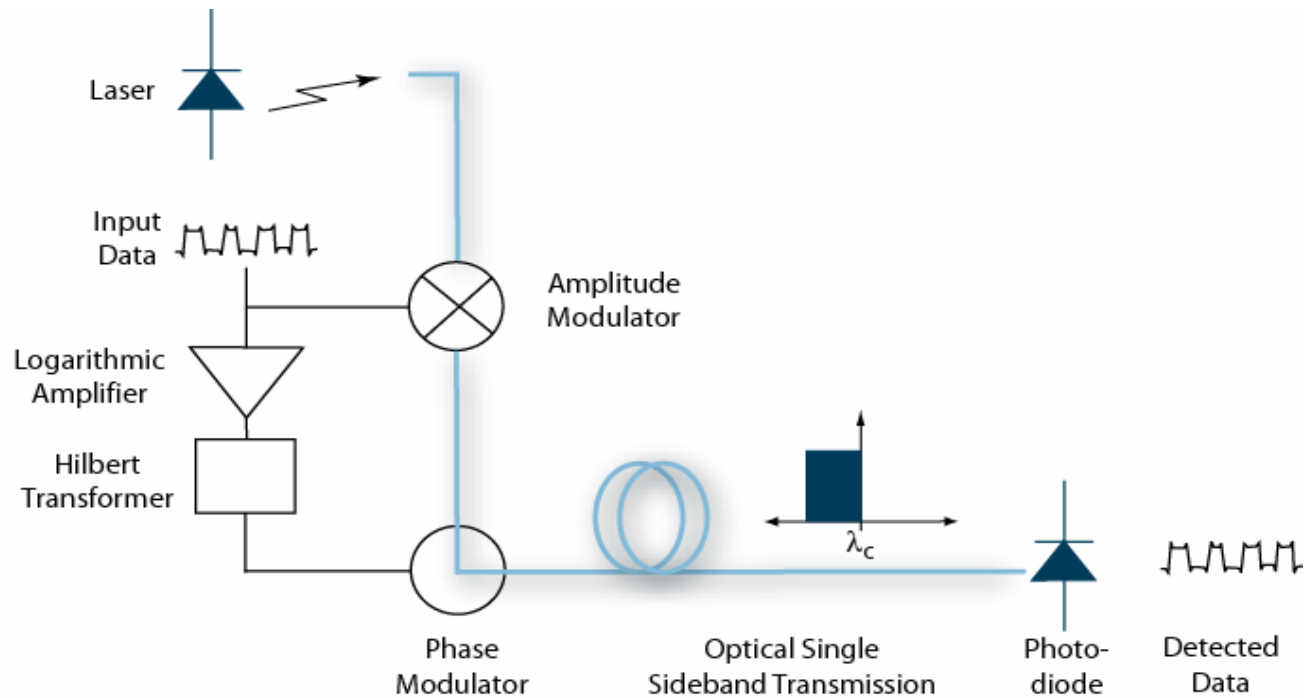
# A 10Gb/s Logarithmic Amplifier for Optical Single Sideband

Chris Holdenried, Jim Haslett, Bob Davies  
TRLabs Calgary

Tech Forum 2002

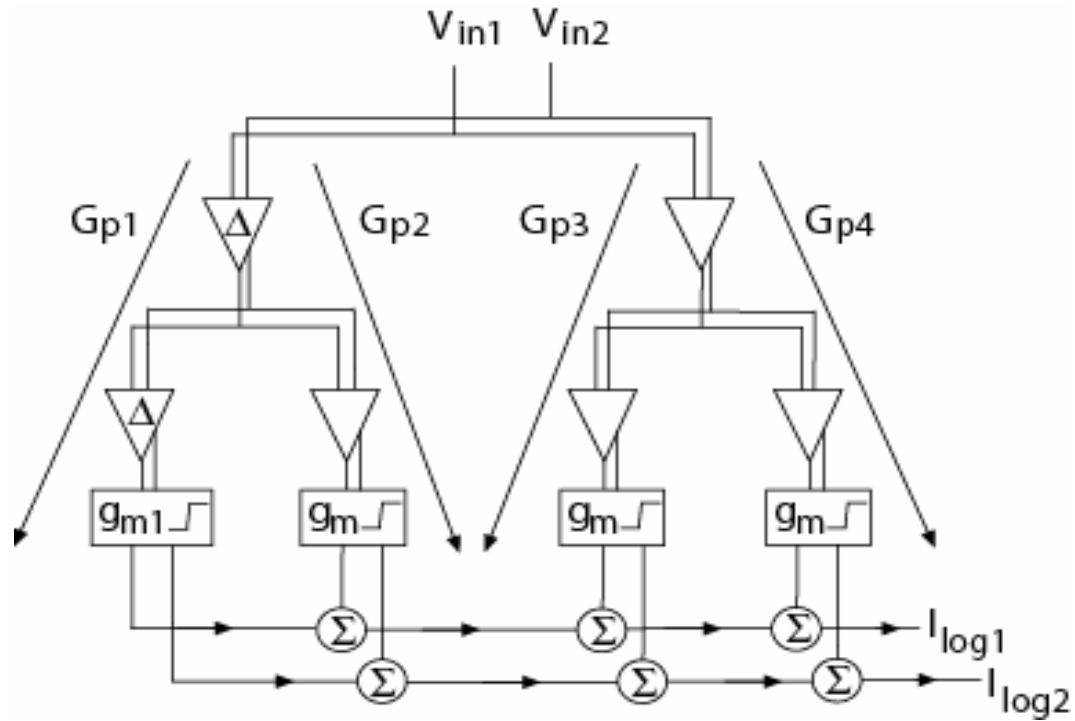


# OSSB System Block Diagram



The logarithmic amplifier generates an electrical signal which is used to phase-modulate the optical signal.

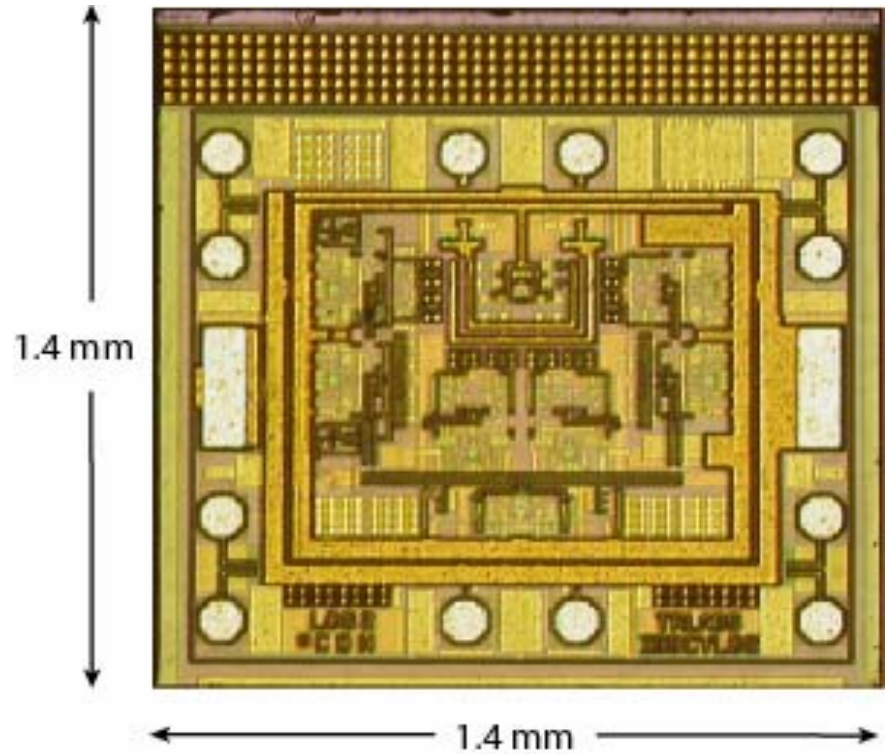
# Logarithmic Amplifier Block Diagram



The logarithmic amplifier uses a parallel architecture developed at TR Labs (patent applied for).

# Logarithmic Amplifier Chip Photograph

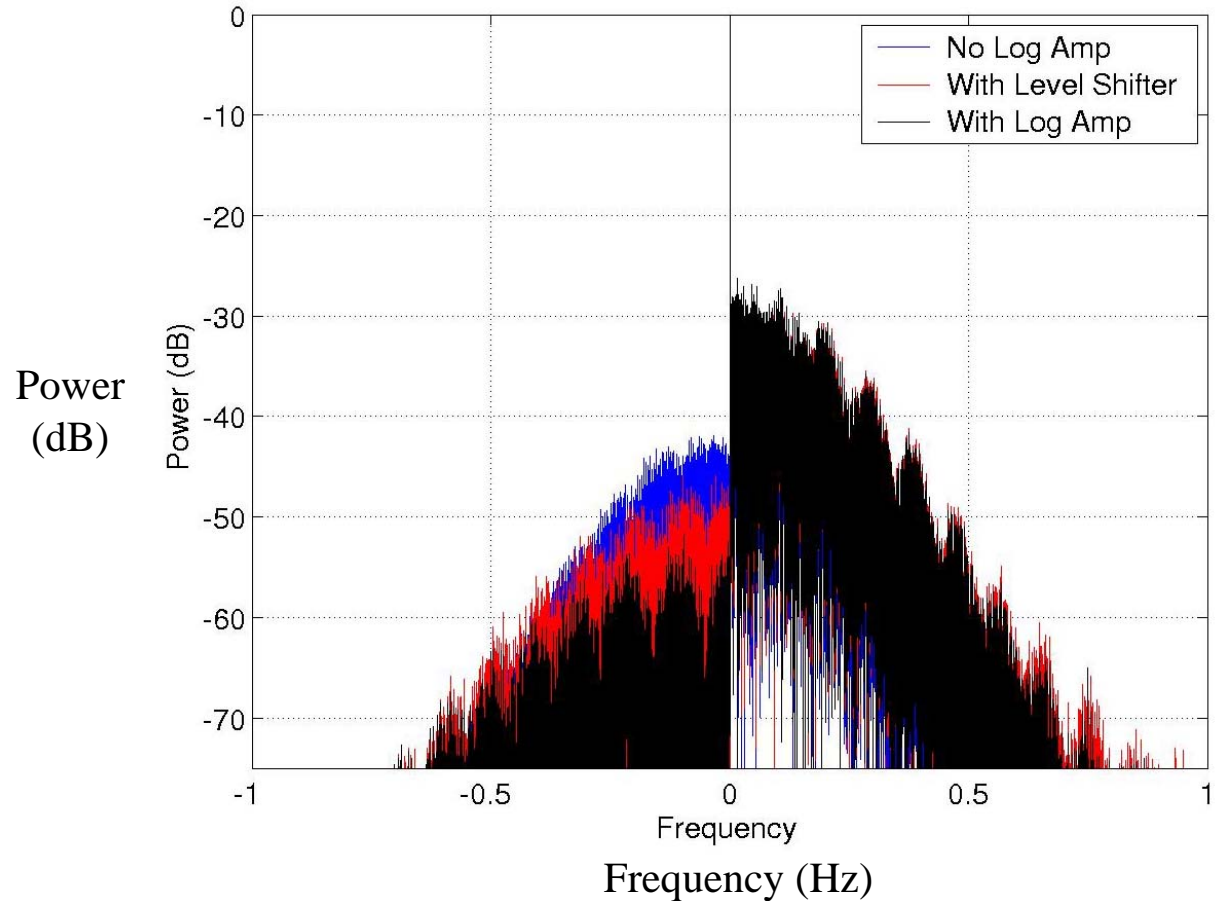
- Fabricated in the IBM Silicon Germanium HP5 process.
- 2 mm<sup>2</sup> area.
- 250mA, -3.3 Volt power consumption.



# 1 Gb/s OSSB Spectrum Plot

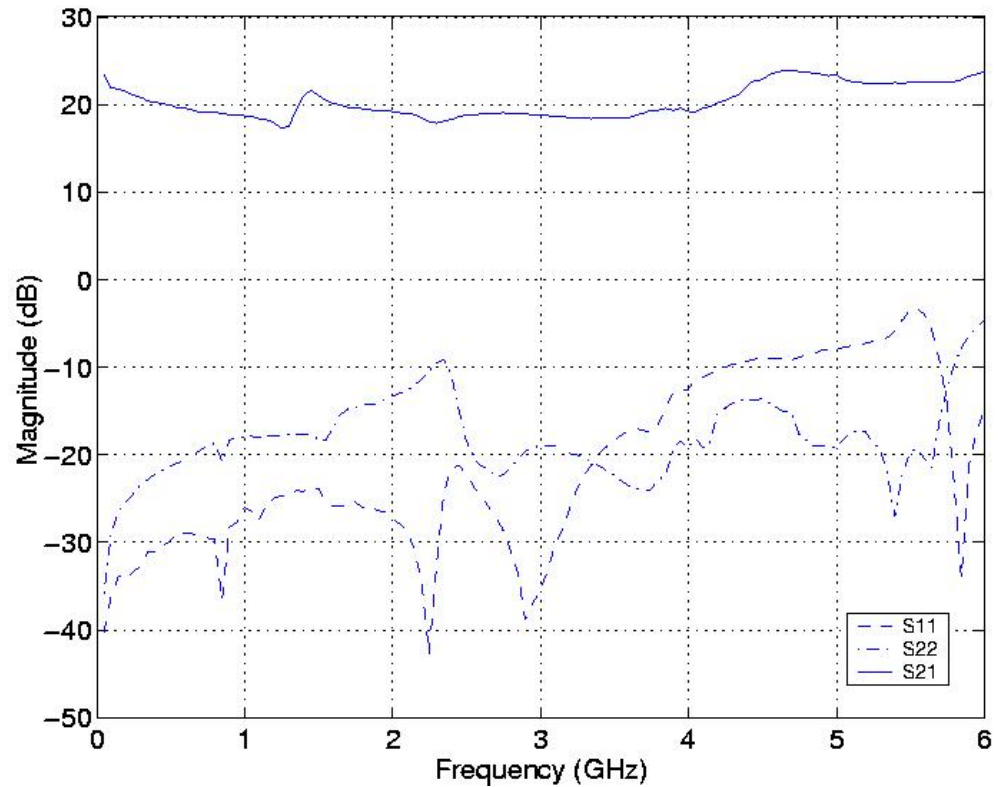
- The logarithmic amplifier improves sideband cancellation.

- This will result in increased transmission distance.



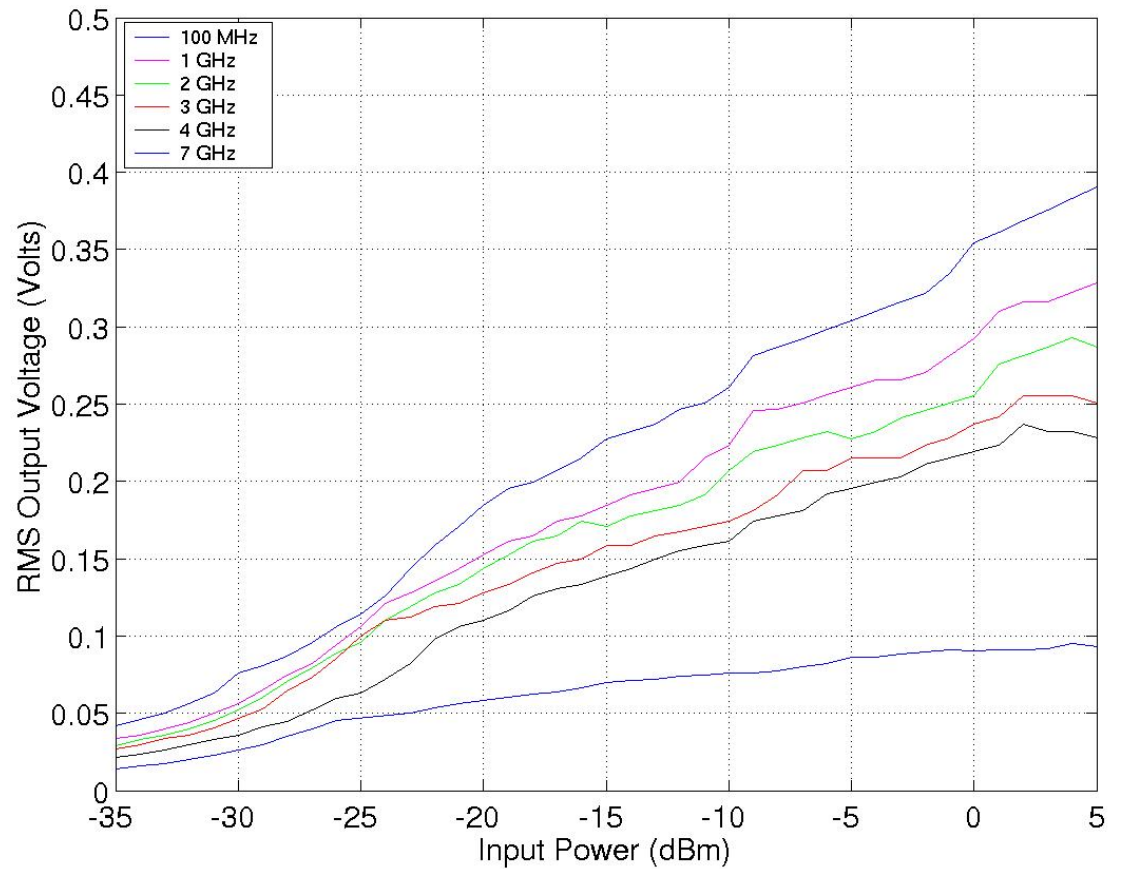
# Measured Logarithmic Amplifier Small Signal Response

- 6 GHz small signal bandwidth.  
This is the highest bandwidth log amplifier ever built.
- 20 dB single ended gain,  
26 dB differential.
- Measured noise figure 12 dB.



# Measured Logarithmic Amplifier One Tone Response

- 9 mV/dB logarithmic slope
- > 1 Vpp output signal (single ended).



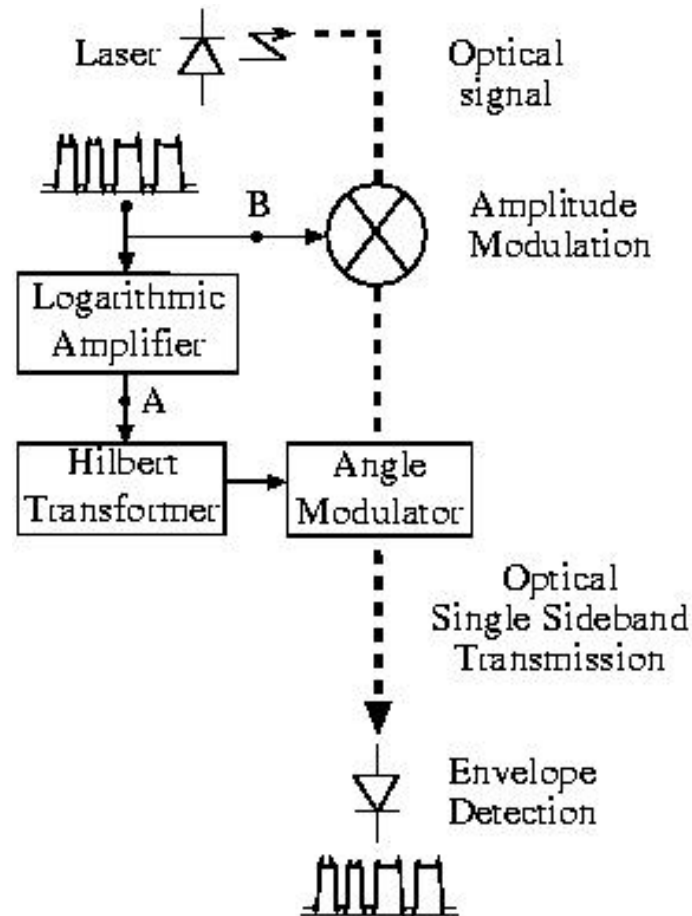
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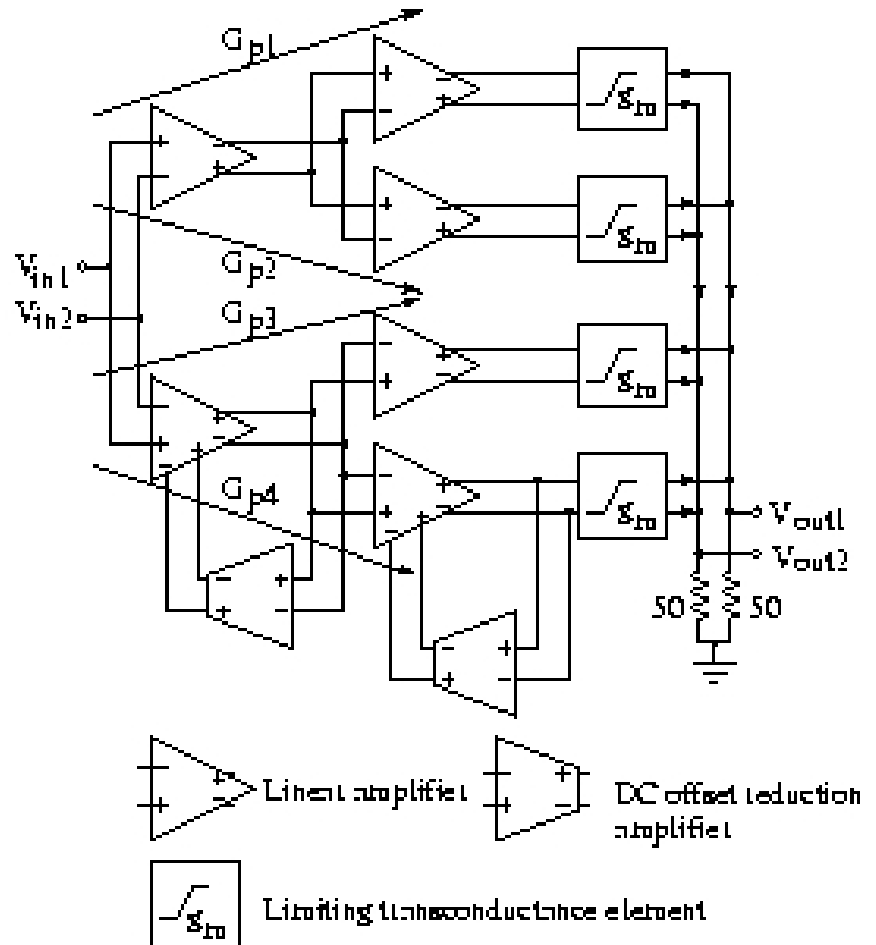
# OSSB System Block Diagram

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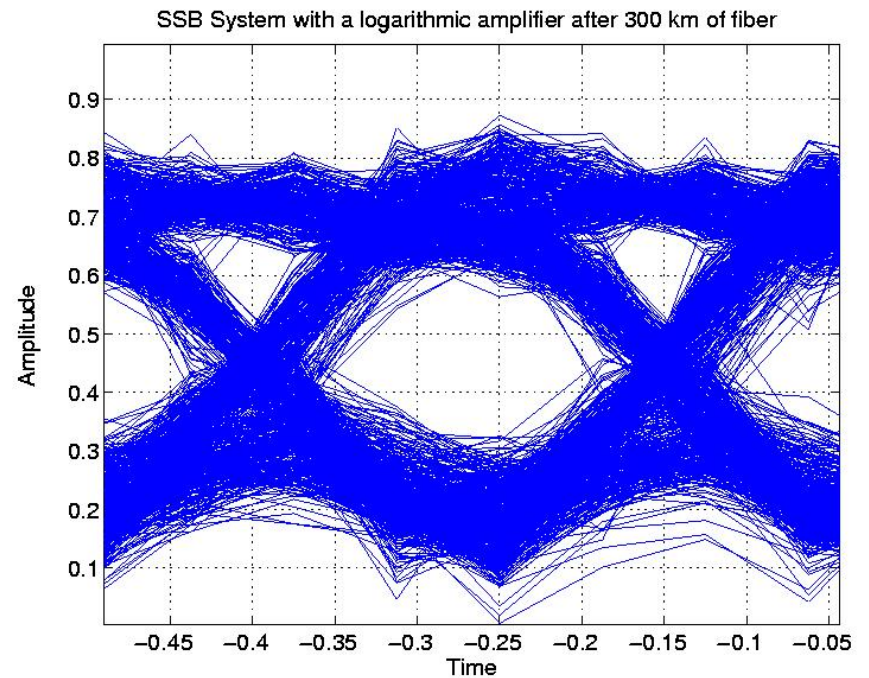
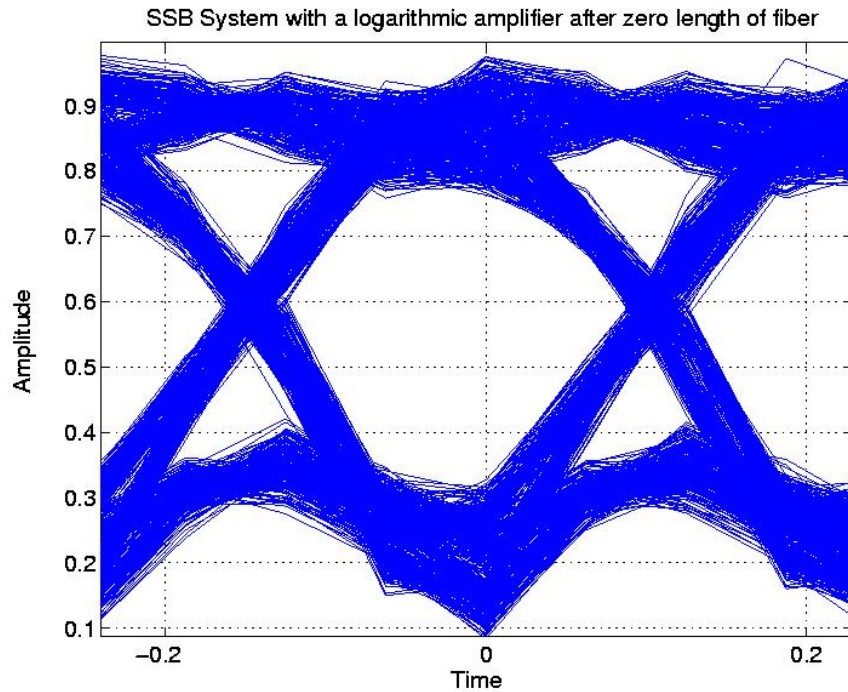


# Logarithmic Amplifier Block Diagram

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## 2 Gb/s OSSB System Eye Diagrams



For this test, measured log amplifier data was combined with a simulation of the optical system.

Patent  
Applied For

Circuit	Large Signal Bandwidth	Rise/Fall Time
Smith [1988]	0.5 – 4 GHz	500 ps/ 500 ps
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