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Highly Linear and Transparent 3-18 GHz Optical Microwave Link

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Abstract

A highly linear optical microwave link transmitter based on heterodyne phase-locked DFB lasers is presented. The transmitter is transparent for FM and PM input signals with carrier frequencies ranging from 3-18 GHz. Distortion-free transmission of a 7.6 GHz FM PAL video signal over 25 km of optical fibre is demonstrated.

Introduction

New types of microwave systems, that require long distance (m-20 km) cable based transmission or extensive signal distribution, are now emerging. Examples are: distributed microwave systems for cellular phone networks [1], feeding of remote antennas, phased array antennas and delay lines.

Standard microwave transmission techniques become increasingly difficult or even impossible to

use in such systems because of high losses. In this case optical microwave links may be the only feasible solution. It is, however, of great importance, that the optical link is capable of transmitting the microwave signals without adding significant distortion. This requirement proves quite difficult to fulfill using conventional optical schemes, especially at high carrier frequencies (>10 GHz), due to the non-linear modulation properties of semiconductor lasers and optical modulators.

Here we present an intrinsically linear optical link based on a novel transmitter scheme using heterodyne phase-locked DFB lasers. This transmitter can presently be operated at carrier frequencies ranging from 3-18 GHz [2] and it has the potential of monolithic opto-electronic integration. The carrier frequency range for the transmitter is only limited by the bandwidth of the

Figure. 1: Linear optical microwave link.

phase detector electronics and could be extended to the 100 GHz range with today's state-of-the-art MMIC processes.

Concept

The link transmitter, as shown in Fig. 1, consists of a free running transmitter laser (Tx-laser), an optoelectronic phase detector, a loop filter and a Current Controlled Oscillator laser (CCO-laser). The microwave signal generated by the beat of the two semiconductor laser signals is compared to the microwave input signal, $x_1(t)$, which may be any angle modulated (analog/digital - PM or FM) signal. The resulting phase error signal is fed back to the CCO-laser which is forced to track the Tx-laser with a frequency and phase offset equal to that of $x_1(t)$.

Loop filter	Passive 2. order
Loop gain at 1 Hz	1.1 GHz
Loop bandwidth	170 MHz
Damping coefficient	0.8
Natural frequency	105 MHz
Propagation delay	400 ps
Lock range	170 MHz
Acquisition range	630 MHz
Phase variance	0.04 rad ²

Table. 1: Parameters of the OPLL

Figure 2: Measured and calculated ratio between FM-index of transmitted and input signal.

The optical phase locked loop (OPLL) simultaneously reduces the phase noise from the beat between the two laser signals and directly transfers the input signal, $x_1(t)$, to the optically transmitted signal, $x_2(t)$.

The wide bandwidth of the OPLL, for which loop data are listed in Table. 1, allows linear transmission of signals with high spectral widths. This has been verified experimentally for a sinusoidal FM input signal by comparing the FM-index of the received signal, $x_2(t)$, with that of the input signal, $x_1(t)$.

Ideally, the ratio between these two indexes equals the closed loop transfer function of the OPLL [3]. As shown in Fig. 2, fine agreement is obtained between measurements and calculations based on the loop parameters in Table. 1. Both calculations and measurements show, that the OPLL transmitter can be used in a highly linear FM link for modulation frequencies of up to around 50 MHz with a FM-index deviation of less than 1.5 dB.

In addition to high linearity, the phase variance (phase noise) of the received signal, $x_2(t)$, must be low. The total phase variance consists of a contribution from laser phase noise and a contribution due to the modulation of the input signal. The phase variance attributed to semiconductor laser phase noise is as low as 0.04 rad² ensured by the wide bandwidth of the OPLL [2]. The modulation induced phase variance

Figure 4: Calculated modulation induced phase variance.

Conclusion

In summary we have presented a highly linear optical microwave link transmitter based on heterodyne phase-locked semiconductor DFB lasers. The link transmitter can presently be used for carrier frequencies between 3-18 GHz and is transparent for angle modulated signals (analog/digital - FM or PM) with modulation frequencies of up to 50 MHz. The link transmitter has been characterized based on standard measurements used for PAL FM video signals and demonstrates that the optical links fulfills the requirements of standard microwave links.

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References

- [1] Ta-Shing Chu et. al.: Transaction on Vehicular Technology, Vol. 40, No. 3, 1991, pp. 599-606.
- [2] U. Gliese et. al.: Photonics Technology Letters, Vol. 4, No. 8, 1992, pp. 936-938.
- [3] U. Gliese et. al.: Journal of Lightwave Technology, Vol. 9, No. 6, 1991, pp. 779-790.
- [4] HP Application Note 175-1, June 1974.
- [5] IBA Technical Review 10, May 1978.