Optical Phase Demodulation of a 10GHz RF Signal using Optical Sampling

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Abstract: For the first time we demonstrate sampling downconversion of a 10GHz phase modulated optical signal using an integrated coherent receiver with feedback. At a downconverted frequency of 100 MHz we measure 19dB improvement in SIR.

OCIS codes: (060.1660) Coherent communications; (130.0250) Optoelectronics; (120. 5060) Phase Modulation

1. Introduction

The need for extreme linearity and low noise figure in certain analog link applications has resulted in an increased interest in optical links that employ phase modulation [1]. However, the challenge in leveraging the potential benefits of such links resides in the receiver architecture where standard interferometer based demodulation of phase generates a sinusoidal response between input phase and output photocurrent. Our effort to generate a linear response uses a feedback loop to a linear tracking phase modulator [2]. Other efforts include linearization of the receiver response using digital signal processing [3]. However, both these approaches suffer from bandwidth limitations when the input frequencies are in excess of a few GHz. In the former approach, even with compact integration of electronics and photonics, physical delays in the feedback path limit the stable loop bandwidth.

In this paper we demonstrate optical down-sampling [4] as a viable technique for extending the input frequency range of a coherent integrated receiver. By downconverting a 10GHz input signal to baseband, we are able to utilize the feedback architecture of the receiver to linearly demodulate the phase of the carrier frequency even though it exceeds the bandwidth of the receiver.

2. Optical Sampling Experiment

In this technique a train of short optical pulses from a high repetition rate pulsed optical source (typically a mode-locked laser (MLL)) is used to sample the optical phase of the input RF signal via an optical phase modulator as shown in Figure 1, right. The input signal is sampled at a rate that's close to its RF period, the pulses are integrated by the detector capacitance and a downconverted frequency component, is obtained. The frequency of this component is the difference between the pulse rate and the input signal frequency (f_{pulse}-$f_{1,2}$). The optoelectronic integrated receiver uses this downconverted signal to linearly demodulate the phase encoded carrier signal as described in [5].

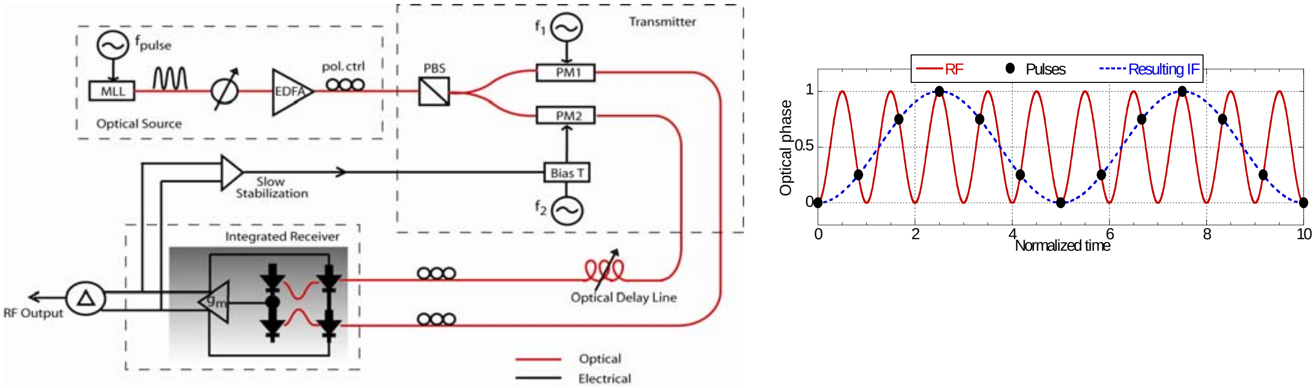

Fig. 1. Left: Experimental link. Right: Optical Sampling of phase modulated signal using pulse source

Figure 1, left shows a schematic of the experimental link used to demonstrate optical sampling. A commercial MLL with f_{pulse}=9.95327GHz and pulse width<1.4ps is used. The path lengths in the two arms of the fiber interferometer need to be accurately matched in order to ensure temporal overlap of the optical pulses from the signal and reference path. Here, an optical delay line is used for path length matching. Polarization maintaining fiber and components are used for stability. Currently, we do not have an optical filter that has high bandwidth and high power handling capability (>26dBm) to filter out ASE noise from the EDFA. Consequently, this limits the noise performance of the receiver. Another limitation to receiver performance arises from the super mode noise generated in the laser cavity about -60dBc.

3. Results

Figure 2, left shows the detected fundamental power and the power of the intermodulation distortion terms as a function of modulator drive power at a downconverted frequency of 100MHz. The input RF tones (f_1=9.852GHz and f2=9.853GHz) are applied to the transmitter phase modulators whose V_π's are 4.4V and 5.5V, respectively. When the receiver is operated without any feedback (open loop) the SIR is measured to be 35dB for an input power of 6.75dBm. When the receiver is operated closed loop with feedback in effect several observations can be made. First, for a higher input power (9.75dBm) the SIR is 19dB higher. This gives a clear indication that the reference phase modulator in the feedback path is linearly tracking the sampled incoming signal phase at a frequency of 100MHz. Second, the output RF power is nearly 20dB lower than the open loop case. This can be explained by noting that when feedback is in effect, there is a net decrease in phase swing across the phase demodulator resulting in a lower output power. Also, the signal is now tapped at the input of the reference phase modulator, not the output of the balanced detectors as in the open loop case. Figure 2, right shows the degradation in SIR at higher downconverted frequencies under closed loop operation. This is consistent with the baseband measurements of [2] where at higher frequencies, the feedback gain decreases resulting in reduced phase tracking.

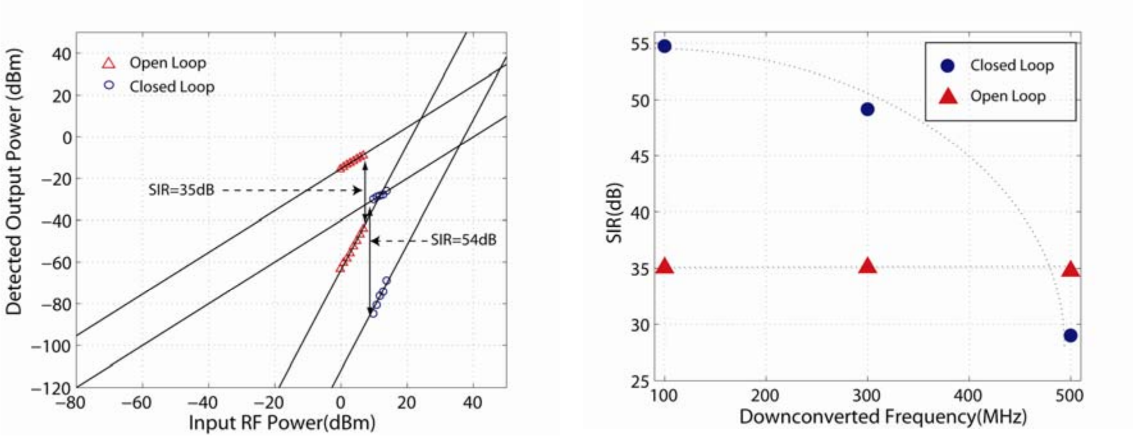

Fig. 2.Left: Measured power of fundamental and IMD3 at 100MHz. Right: SIR as a function of downconverted frequency.

The measured noise (-120dBm/Hz) is relatively high and can be attributed to noise contributions from both the EDFA and the MLL.

4. Summary

In this paper we demonstrate photonic downconversion using an integrated coherent receiver with feedback. The 19dB improvement in SIR realized at 100MHz downconverted frequency suggests that this method can be used for linear optical phase demodulation at carrier frequencies in excess of the bandwidth of the receiver.

Acknowledgment

The authors would like to thank Northrop Grumman Space Technologies for providing the electronic IC. This work was supported by the DARPA PHOR-FRONT program under United States Air Force Contract FA8750-05-C-0265.

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