High Dynamic Range Linearized FM Photonic Link

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Abstract: We present our work on frequency and phase modulated microwave photonic links which achieve linear demodulation using planar lightwave circuits (PLC) optical filtering and balanced detection, showing improvement in spurious free dynamic-range and signal gain.

1. Introduction

Microwave photonic links (MPLs) with high dynamic range are essential for the remoting and processing of radio signals in next generation fiber-wireless systems. Traditional intensity-modulated direct-detection (IMDD) links experience large signal-loss and resulting low noise figures due to the low modulation efficiency of lithium niobate Mach Zehnder modulators (MZMs). On the other hand, directly modulated frequency modulated (FM) lasers have been demonstrated with high modulation efficiency and with modulation bandwidths that are not limited by the laser relaxation frequency [1]. Recent work on multi-section DFB [2] and EML lasers [3] has produced modulation efficiencies two orders of magnitude greater than MZMs. Besides high modulation efficiency, the performance of these devices is also more linear than direct intensity modulation and Mach Zehnder modulators [1], and there is low thermal cross-talk in integrated laser arrays. Phase modulation (PM), using lithium niobate modulators, is also a promising modulation technique for MPLs because it is very linear and uses similar demodulation techniques as FM.

Although the frequency or phase modulation may be linear, distortion is introduced in the demodulation process, especially with coherent and interferometric demodulation techniques. There are electronic means for improving link distortion by compensating for modulation and detection nonlinearity, including pre-distortion [4, 5], feed-forward linearization techniques [6], and feedback linearization [7]. However, these techniques require fast electronics to perform the linearization. At the present time, they are not useable for very high frequency microwave photonics beyond a few GHz. Therefore, we have proposed direct detection using PLC discriminator filters tuned to achieve linear conversion of modulation to AM (FM-DD and PM-DD links), which is scalable to high frequencies.

2. Link architecture

In the PM-DD and FM-DD links, authors have proposed various discriminator-filters to optimize the demodulation for low distortion, including networks of birefringent crystals [8], asymmetrical Mach Zehnder interferometers (a-MZI) [9,10], Fabry-Perot filters [11], fiber Bragg gratings [12] and tunable integrated filters [13,14]. The ideal transfer function is a complementary linear-field demodulation scheme first analyzed analytically in [15]. The power is split between two filters with complementary slope, and detected with a balanced photodetector. Each optical filter is a linear ramp of field-transmission versus offset frequency from the optical carrier, which is a quadratic ramp of power transmission. The ideal filters have linear phase.

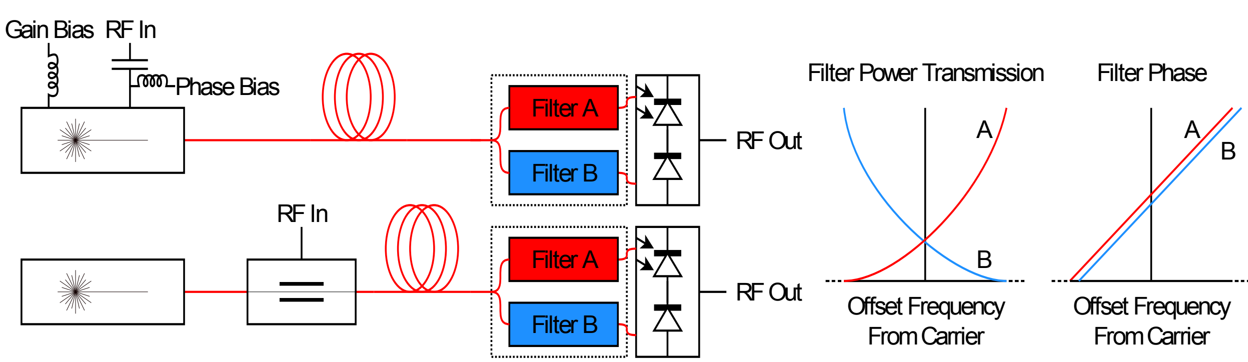

Fig. 1 Diagram of frequency and phase modulated MPLs with direct detection using complimentary linear-field discriminators. The ideal transfer functions for the two filters are shown.

3. Progress to date

Complementary linear-field discriminator filters have been implemented with thermally tunable, silica-on-silicon, planar-lightwave circuit filters fabricated by Alcatel-Lucent Bell Laboratories. We previously reported PM link measurements using a sixth-order cascaded MZI FIR lattice filter [16]. This filter architecture can instantiate any arbitrary transfer function, including control of linear-phase, and has been used for a variety of microwave photonics applications including dispersion compensation [17]. The fabricated filter had only 7 dB optical insertion loss due to low waveguide loss of silica. Measured at 2 GHz, the system showed a factor of 6.7 dB improvement in the third-order output intercept point (OIP3) over an MZM for a fixed photocurrent. We used a spectrum-based optimization routine to tune the sixth-order filter's coefficients to minimize the signal distortion of the link [16].

Additional experiments have been performed using IIR filters based on a cascaded ring-assisted MZI architecture [18], also implemented in planar lightwave circuits. Measurements have been made showing greater than 6 dB improvement in OIP3, low second-order distortion, and improvements in signal compression. Improvements in linearity over the MZM were measured up to 10 GHz. In addition, we demonstrate high dynamic range frequency modulation by replacing the lithium niobate phase modulator with a multi-section DBR laser, also designed by Alcatel-Lucent Bell Laboratories. We demonstrate link signal gain for small photocurrents of less than 6 mA per detector, and similar linearity to the phase modulation experiments within the bandwidth of the FM laser.

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