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Computer-aided Characterization of a Novel Subcarrier De-multiplexing Scheme for SCM Optical Communication Systems

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Abstract

Computer-aided characterization of a subcarrier de-multiplexing scheme for SCM optical communication has been done. Here the baseband signal included in one of the subcarrier is directly detectable from the photodiodes without a subcarrier filter and discriminator. Optimization of the phase-lock loop and the use of more than one loop in the scheme is expected to improve the noise performance of the system.

1. Introduction

Subcarrier multiplexed (SCM) optical communication [1] is very attractive because it permits multiple access when one desires to transmit a variety of information using master carrier at optical frequency. One of the major problems of SCM system is the interference of channels (subcarriers) due to intermodulation occurring in the course of subcarrier signal processing. To solve this problem Greenhalgh et.al [2] proposed the filtering of a desired sub-carrier in the optical range using Febry-perot (FP) etalon placed in front of the photodetector. Such a scheme need highly stabilized optical source and also mechanical tuning of FP structure for each subcarrier. Nakajima et.al [3] proposed a novel homodyne de-multiplexing scheme where a pair of light modulators excited at microwave subcarrier frequency is used. It does not need bulky FP resonators and also tuning is easier at subcarrier microwave frequency rather than at optical frequency.

In this paper we have carried out computer-aided characterization of the scheme proposed by Nakjima et. al [3] on the basis of the analytical model equations of the scheme. It is found that baseband signal included in one of the subcarrier is directly detectable from the photodiode. Noise that may be introduced by the non-linearity in the system might affect the locking characteristics of the phase-lock loop so PLL optimization is done. Also use of more than one loop in the PLL is expected to improve the phase-noise of the de-modulated signal output.

2. Sub-carrier Homodyne De-multiplexing Scheme

The block diagram of the scheme is shown in Fig. 1. The subcarrier modulated light wave P_{in} is divided into two parts with a branched waveguide and injected into a pair of electro-optic (Mach-Zehnder) modulator. The said modulators are excited in reverse polarity with a local oscillator signal provide by the VCO of the phase-locked loop. The output lightwave from each modulator is injected into each of the photodiodes, vide Fig.2.

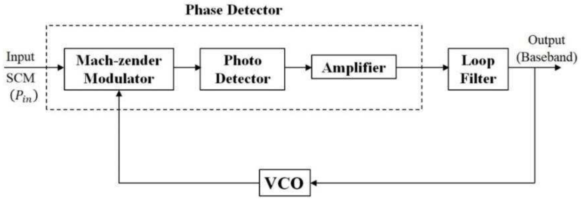

Figure 1. Block diagram of the de-multiplexing scheme

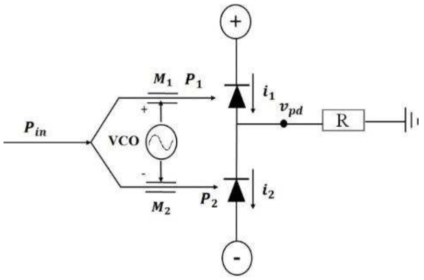

Figure 2. Phase detector part of the scheme

This balanced phase demodulation cancels the DC current at the output of the photodiodes due to the lightwave. The intermodulation distortion does not affect the scheme because of selective homodyne detection at the subcarrier frequency level. Further, additive noise of stationary Gaussian type, if any, has no effect on the scheme due to balanced phase demodulation.

3. Model Equations for Computer-aided Characterization

The output at the photodiodes is given by [3]:

$$v_{pd} = \dot{\eta} * P_1(t) - \dot{\eta} * P_2(t) \qquad (1)$$

Where $\dot{\eta} = \dot{\eta}_0 h(t)$ with $h(t) = \sin(2\pi f_0 t)/2\pi f_0 t$, h(t) is the transfer function of the filter representing the photodiodes and $\dot{\eta}$ is the conversion factor from the optical power to the current of the photo diode. The symbol * stands for convolution and f_0 is the frequency of the optical carrier.

$$P_{1,2}(t) = [1 + \sum_{n=1}^{N} \sin(\omega_n t + \varphi_n)][0.5 \pm 0.5 \sin\{0.1 \cos(\omega_n t + \varphi_l)\}] \qquad (2)$$

Where ω_n, φ_n are respectively the sub-carrier angular frequency and phase angle of the sub-carrier and φ_l is the phase angle of the local oscillator signal.

Instead of using one loop in the PLL of the de-multiplexer if we use two loops (as the sub-carrier microwave frequency may be in the Ka band, 34 GHz) the phase noise of the output signal will improve which is desired for communication applications. The phase noise improvement of two loop PLL system can be characterized with the following formula [4].

$$\begin{aligned} S_{o,n}(f) = {} & [S_{r,n}(f)\left(M + \frac{N}{R}\right)^2 + S_{DR,n}(f)N^2]\left|H(s)\right|^2 + \begin{bmatrix} S_{MUL,n}(f) + S_{SYS,n}(f)\dfrac{M^2}{N^2} \\ - S_{MI,n}(f) - N^2 S_{DN,n}(f) \end{bmatrix} \left|H'(s)\right|^2 \\ & + \left[\frac{N^2}{{K_d}^2}\left(S_{V_{PD,n}}(f) + S_{V_{F,n}}(f)\right)\right]\left|H'(s)\right|^2 + S_{OSC,n}\left|1 - H'(s)\right|^2 \end{aligned} \qquad (3)$$

Where symbols used are detailed in reference [4].

4. Results and Discussion

The input P_{in} and output v_{pd} of the de-multiplexing scheme is shown in Fig. 3 and 4 respectively. It may be observed that the baseband signal is directly detected at the output of the de-multiplexer. Typical baseband frequencies used are 10 MHz, 20 MHz, 30 MHz, and 40 MHz, the subcarrier frequency is 34 GHz and optical master carrier is 5 THz. The phase noise improvement of the detected signal when two loops are used instead of one is expected to improve; the details of which will be given in actual presentation of the paper in the conference.

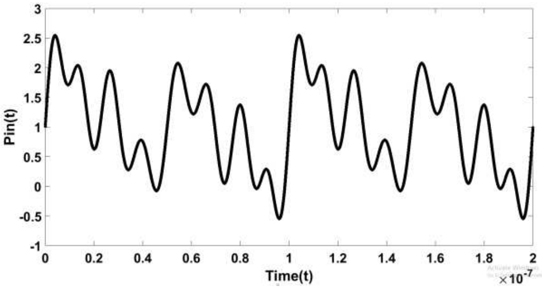

Figure 3. Input P_{in} to the de-multiplexer

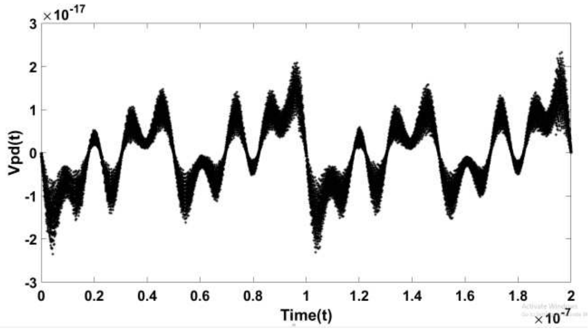

Figure 4. Output v_{pd} of the de-multiplexer

5. References

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