COMPENSATION OF FIBER DISPERSION IN AN OPTICAL MM-WAVE SYSTEM IN THE 60 GHZ-BAND

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Abstract

In a 60 GHz fiber optic microwave transmission system the fiber dispersion of the link is compensated with a length adjustment in the dual wavelength source. The required precision of the length differences lies in the cm-range.

Introduction

The combination of fiber optics and millimeter wave techniques offers advantages for broadband mobile communication systems as well as for the remote control of phased array antennas [1, 2]. Additionally to the long distance low loss transmission and large bandwidth of the fibers, the remote generation of the millimeter wave signals is a powerful advantage. It is expected that the system costs can be reduced if the optical components of the feeder links e.g. laser diodes and photodiodes are also used for generating the millimeter-wave signals in radio links. No millimeter-wave oscillators and modulators are required in the numerous base stations of a mobile communication system or at the numerous transmit/receive modules of a phased array antenna.

In general there exist two main families of optical techniques for transmission and generation of microwave signals: a) direct or external modulation of the optical laser signal with the microwave signal or b) coherent mixing of at least two optical waves on the optic/microwave converter (OMC). The frequency spacing of the optical waves corresponds to the desired microwave frequency. In priniple the two or more optical waves can be generated by use of different arrangements. With the different generation methods the generated microwave signal shows different properties concerning e.g. applicable modulation formats, phase noise and tunability [1]. In this paper we report on the analysis and experiment of the influence of a path imbalance in a sideband injection locked two frequency source.

Principle

The microwave signal is generated by heterodyning two optical waves generated by the Signal Laser LDS and the Reference Laser LDR on the photodiode in the OMC at the base station (Fig. 1). The two lasers are located in the control station. In the dual frequency source the sideband injection locking technique is used to get a stable microwave signal in the 60 GHz-band with low phase noise [1, 3]. The lasers LDS and LDR are locked to the ±10th modulation sideband of the Master Laser LDM

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which is subharmonically modulated with OSC1. The frequency difference of LDR and LDS is $20 \cdot f_{OSC1}$ = 64 GHz. For data transmission a subcarrier (OSC2), which is phase modulated by the 140 Mbit/s data signal in the OQPSK format modulates the injection current of LDS. The two optical signals are added and feed into a standard single mode fiber.

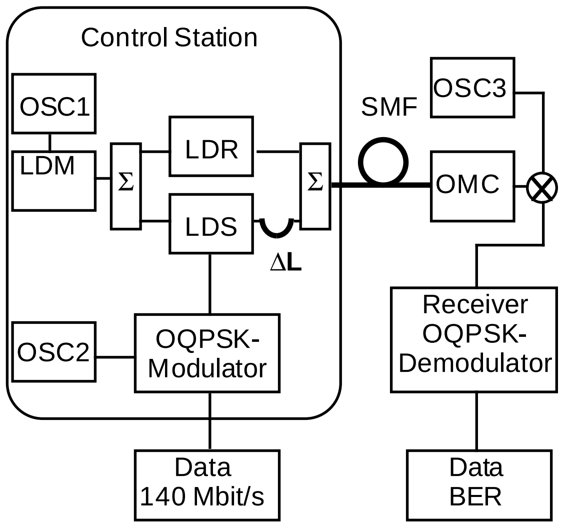

Fig. 1: Experimental Setup: LDM: Master Laser, LDR: Reference Laser, LDS: Signal Laser, ΔL: Path Difference, OSC1: f=3.2 GHz, OSC2: f=1.07 GHz, OSC3: f=63.07 GHz, OMC: Optic/Millimeter-Wave Converter, SMF: Standard Single Mode Fiber.

However, due to chromatic fiber dispersion, the two optical signals experience a differential propagation delay $\Delta\tau$

$$\Delta\tau = D \cdot L \cdot \frac{\lambda^2}{c} \cdot f_{mm}$$

as they travel through the fiber [5]. Where D is the chromatic fiber dispersion, L the length of the fiber, λ the wavelength of the laser and f_{mm} the difference frequency of LDS and LDR (f_{mm} = 64 GHz). It is seen that the delay increases with both distance and difference frequency if a standard single mode fiber is used at $\lambda \approx 1.544$ µm.

This results in a state of partial phase decorrelation of the sideband locked signals. The amount of decorrelation and thus the increase in phase noise on the remotely generated microwave signal depends on the introduced amount of differential delay $\Delta\tau$ and limits the transmission length of OQPSK modulated millimeter-wave signals. The delay induced phase noise is expressed as phase variance

$$(\sigma_\phi)^2 \approx 2\pi \cdot \Delta\upsilon_m B_n (\Delta\tau)^2; \qquad B_n << 1/\Delta\tau$$

where $\Delta\nu_m$ is the full width half maximum linewidth of the power spectrum of the laser signal and B_n is the noise bandwidth of the baseband receiver. In PSK systems the bit error rate (BER) is determined by this carrier phase noise and by additive Gaussian noise [4].

Furthermore, if the two optical signals of LDR and LDS, before they are injected into the same fiber, propagate separate paths whose length difference ΔL can be varied, they also experience a differential propagation delay $\pm\Delta L \cdot n/c$. The path imbalance delay can work in the same or in the opposite direction as the fiber dispersion induced delay. If the path imbalance delay counteracts the dispersion induced delay the dispersion induced phase noise can be reduced for fixed value of difference frequency and transmission distance. This offers the feature of predistortion in a dual wavelength source which must be designed carefully.

In a computer model for analyzing fiber optical microwave transmission systems the de-

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correlation for Lorentzian shaped power spectra was implemented [6]. The influence of the differential delay on the phase noise of the generated signal and on the bit error rate (BER) of the transmitted OQPSK baseband signal was calculated. In Fig. 2 the calculated BER versus a path difference ranging from $-250 < \Delta L <$ 350 mm for a laser linewidth of 2 and 5 MHz is shown. The bit error rate is less than 10^{-10} for a path difference between -100 mm and 75 mm i.e. the fiber dispersion of the 12.8 km long fiber is compensated for a difference frequency of 64 GHz. The results show, that a compensation of the fiber dispersion is possible, if a path imbalance in the source with moderate requirement on the length precision is generated.

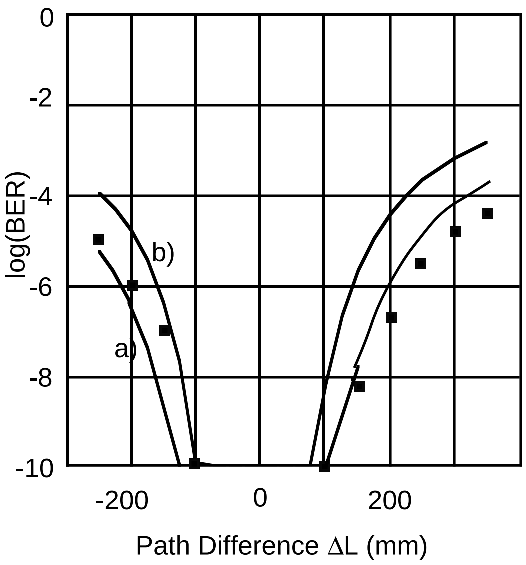

Fig.2: Bit error rate versus the path idifference ΔL in the dual frequency laser source (path of LDS). Calculated values for a laser linewidth $\Delta\nu_m$ of 2 and 5 MHz (curves a) and b)). The squares represent the measured values.

Experiments

The influence of the path imbalance is investigated experimentally in a demonstrator generating mm-wave signals in the 60 GHz-band for use in micro-cellular systems as shown in Fig. 1 [1]. For data transmission, a subcarrier (OSC2: f≈1.07 GHz), which was phase modulated by the 140 Mbit/s data signal in the OQPSK format, modulates the laser diode LDS. The fiber length in one path (LDS) of the two slave lasers is variied in 50 mm steps and the BER of the 140 Mbit/s signal is measured. The squares in Fig. 2 are representing the experimental results. The BER depends strongly on the path difference. For an appropriate differential delay ΔL between 0 and ±75..100 mm the BER is less than 10^{-10}. The length of the transmission fiber between the dual frequency source and the OMC is 12.8 km. The agreement between theory (Fig. 1 curve a)) and experiment is excellent. The results show, that a compensation of the fiber dispersion for a fixed fiber length and millimeter-wave frequency is possible.

Conclusions

The results of our theoretical and experimental investigation show, that an optical two wavelength source can be matched to a given fiber length and a fixed millimeter-wave frequency with the aim to improve phase stability of the generated millimeterwave signal and BER of the baseband signal. The required precision for the alignment of the fiber length lies within a range of several tens of millimeters which is quite easy to handle.

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