OPTICAL MICROWAVE GENERATION AND TRANSMISSION EXPERIMENTS IN THE 12 AND 60 GHz-REGION FOR WIRELESS COMMUNICATIONS

R P.Braun, G.Grosskopf, C H von Helmolt, K. Krüger,
U. Krüger, D Rohde, F. Schmidt

Heinrich-Hertz-Institut für Nachrichtentechnik Berlin GmbH , groskopf@hhi.de
Einsteinufer 37, 10587 Berlin, Germany

ABSTRACT

The optical generation and transmission of microwave radio signals is important for future broadband wireless communications. For the first time, bit error ratio measurements were carried out successfully in optical multichannel and single channel transmission experiments at radio frequencies of 12 GHz and 60 GHz, respectively.

Introduction

The generation and transmission of microwave radio signals by optical means is of importance for future pico-cell broadband mobile communication systems operating at frequencies of 60 GHz [e.g.1, 2, 3, 8, 9] Since a laser diode (LD) and a photo diode (PD) are required anyway for the optical feeder link between the mobile switching center (MSC) and the base stations (BS), the combination of lightwave and microwave techniques is a promising solution for the system implementation. Especially, if the microwaves are generated by optical means the costs of the microwave oscillators and modulators in the base stations can be saved.

Semiconductor lasers in the MSC generate optical waves which are heterodyned at the PD located in the BS. The frequency spacing of the optical waves is equal to the desired microwave frequency

The heterodyne technique enables linear conversion of optical frequency division multiplexed (FDM) signals to FDM-signals in the microwave domain [4]. Due to this linear conversion the laser phase noise may deteriorate the system performance. We distinguish between optical waves with uncorrelated and with correlated phase noise terms. With correlated terms a microwave with low phase noise can be obtained [5]

In the first part of the paper we report on 140 Mbit/s experiments with 2 channels near 12 GHz with uncorrelated phase noise components. While in the second part a 155 Mbit/s transmission experiment with correlated noise terms and a microwave radio signal at 58.25 GHz is described The correlation is obtained by using a mode locked laser (MLL) source

Optical/Microwave Multichannel Experiment

Three DFB-lasers (GEC-Marconi LD 4804) depicted as signal lasers (LD1, LD2) and reference laser (LD Ref) are used for generating the microwave carriers for channels 1 and 2 (**Fig. 1**).

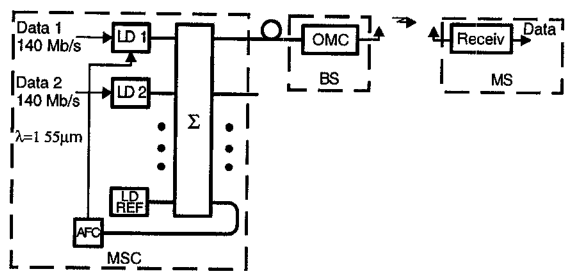

Fig. 1: Principle of the experimental set-up

The optical frequencies of LD1 and LD2 differ to the reference frequency (LD Ref) by the desired microwave frequencies near 12 GHz and can be increased up to each frequency the optic/microwave converter (OMC) allows For the data transmission each signal laser was FSK-modulated by a 140 Mbit/s CMI-signal. The optical waves of the three lasers were combined (Σ) and transmitted via a fiber to the OMC (HP11982A). The resulting radio signal transmitted to the mobile station (MS) comprised both channels **Fig.2a**. An optical input power of -21 dBm at the OMC results in a bit error rate (BER) of 10^{-9}. **Fig. 2b** shows the penalty measurements in channel 1 vs. channel-spacing at a BER of 10^{-9} without radio link. The results reveal that the penalty is caused by crosstalk due to spectral overlap of the modulation sidebands and not by nonlinear distortions of the conversion process. For a 2 dB-penalty a minimum carrier spacing of 1.3 GHz was determined when both signal lasers were modulated (curve 1) and 0.9 GHz (curve 2) when in channel 2 only the unmodulated carrier was transmitted

This experiment was carried out with DFB-lasers depicting linewidths of 2 MHz. To obtain a narrower channelspacing bandwidth efficient modulation formats should be used requiring high spectral purity carriers One method employs optical injection locking, first experiments resulted in sub-Hz linewidths [6]. Another method described in the following applies mode locking [7, 8] of the optical source.

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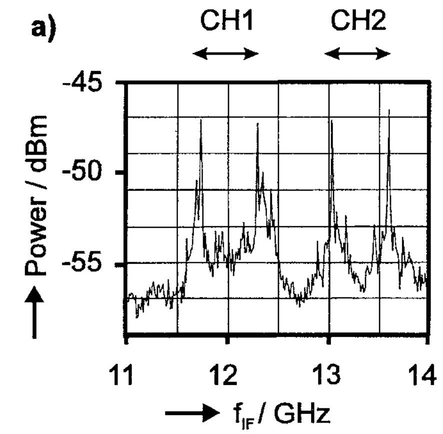

Fig. 2a: Spectrum of two 140 Mbit/s FSK modulated carriers (resolution bandwidth = 3 MHz)

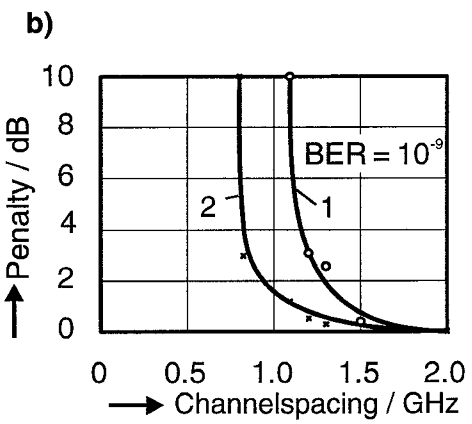

Fig. 2b: Penalty vs. channelspacing
curve 1: carrier in channel 2 modulated
curve 2: carrier in channel 2 unmodulated

Fiber Optic Upconverter Experiment

The MLL emits short pulses yealding several optical lines spaced by 6.25 GHz. The optical pulses generate the microwave signal in the 60 GHz band at the PD. Due to the locking, the modes are strongly correlated, yielding a low phase noise microwave signal (**Fig. 3**, SSB-phase noise = -63 dBc/Hz at 10 kHz for the active locking) The transmission set-up is sketched in **Fig. 4** The information is supplied by the pattern generator feeding a 155 Mbit/s differentially encoded NRZ PRBS sequence to a double balanced mixer. This mixer generates the differentially coherent binary PSK (DBPSK) signal on a 2 GHz subcarrier supplied from a synthesizer. The short pulses of the MLL are intensity modulated (Mod.) with the DBPSK signal and subsequently transmitted over 1 km of dispersion shifted fiber (DSF) to be detected by a fast photo diode (PD) (New Focus 1014) The modulated pulse train at the output of the PD has spectral parts up to frequencies >75 GHz The DBPSK sideband at 58.25 GHz is detected by the V-band receiver and is fed to the error detector after demodulation in the DBPSK demodulator. With this set-up BER-measurements down to 10^{-10} for 155 Mbit/s were performed.

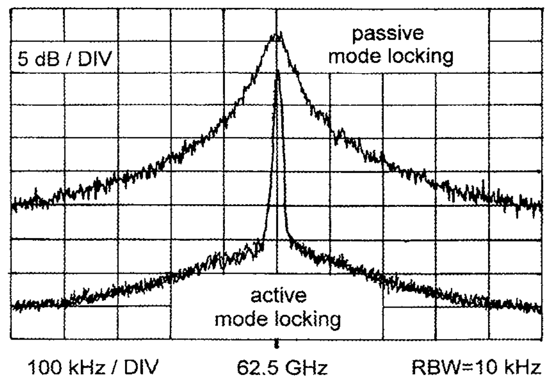

Fig. 3: 62.5 GHz signal for active (MLL locked to a 6.25 GHz synthesizer) and passive mode locking (MLL locked due to an intracavity nonlinearity)

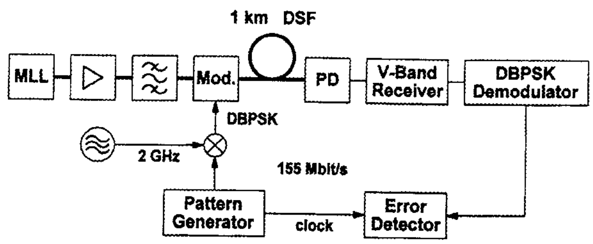

Fig. 4: Transmission experiment with 155 Mbit/s datarate at 58 25 GHz

Conclusion

In this paper two different techniques for generating microwave signals by optical means for future cellular broadband mobile communication systems are investigated. In the first experiment the microwaves are generated by heterodyning the optical waves of three separate lasers. The simultaneous conversion of an optical FDM-signal carrying two 140 Mbit/s signals to the microwave domain near 12 GHz is demonstrated successfully. The second experiment shows the generation of a low phase noise microwave signal in the 60 GHz-band using a mode locked laser This allows in contrast to the first experiment bandwidth efficient modulation techniques The main advantage of both methods is the microwave generation by optical means requiring small additional effort at the optical feeder system and reducing the electronics of the base station. Further cost savings are expected from opto/electronic integration [3]

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