FIBREOPTIC MICROWAVE GENERATION FOR BIDIRECTIONAL BROADBAND MOBILE COMMUNICATIONS

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ABSTRACT

Bidirectional errorfree 140 Mbit/s OQPSK-signal transmission with optically generated microwaves in the 18-19 GHz-band is reported. Two microwave carriers one for the radio link to the mobile receiver (down link) and one for the uplink-microwave mixer in the base station are generated by a simple optical upconversion technique.

I. INTRODUCTION

In future broadband mobile communication systems operating at microwave frequencies laser diodes and photo diodes are required for the optical feeder links between a control station (CS) and a base stations (BS). It is expected that the system costs can be reduced when these optical components are also used for generating the microwave signals in the radio link.

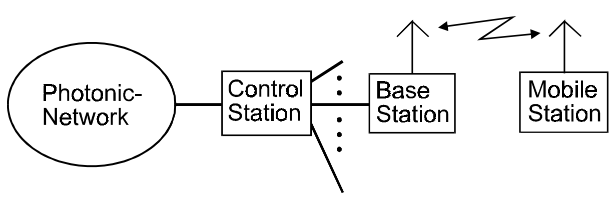

Fig. 1: Architecture of a mobile and photonic network

A further microwave signal is required in bidirectional systems /1/ as LO-signal for the uplink mixer (UM) in the BS (**Fig. 1**). It is used to convert the received uplink microwave signal to a moderate frequency range so that a conventional fiberoptic transmission link from the BS to the CS can be used. Therefore the flexible control of the microwave signals for both the up and the down link should be carried out in the CS while the numerous BS are low-cost modules in which no microwave oscillators and modulators are required. The optical microwave technique is presently subject of world wide research efforts with different approaches e.g. techniques that generate microwaves by direct or by external intensity modulation of the laser in the CS, or dual optical frequency techniques that coherently mix optical waves. Other methods apply frequency doubling /2/ or optical upconversion techniques /3, 5 - 8/.

In this paper we report on experiments with a low-cost method applying an optical upconversion principle in order to generate microwave carriers with high spectral purity in the 18-19 GHz frequency band so that bandwidth efficient modulation formats can be applied. 140 Mbit/s OQPSK-modulated (Offset Quadrature Phase Shift Keying) data signals have been transmitted in up and downstream direction.

II. PRINCIPLE

This very simple optical microwave generation technique yielding low phase noise signals is described in detail in /3/. It applies the nonlinear characteristics of the optical transmission system. A semiconductor laser is directly modulated by a sinusoidal signal emitting an optical spectrum with components spaced by the modulation frequency. The n-tupler function is obtained by choosing those spectral lines which spacing is equal to the desired radio link microwave frequency. In conjunction with a dispersive single mode fiber the relative phasing of the sidebands is altered /4/ so that at the OMC (Optic/Microwave Converter) input in the BS an intensity modulated signal is observed. It is received by the OMC and converted to the electrical domain.

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In general due to the spontaneous emission and absorption of photons in the laser cavity the linewidth of the emitted signal is broadened. In the experiments the lasers were directly modulated thus emitting a line spectrum in the optical domain. The noise terms of the part which was a commercially available digital radio-relay system (Bosch DRS 34(16x2)-155/18700) containing OQPSK-modulating and demodulating modules for 140 Mbit/s data signals as well as microwave components in the 18-19 GHz range. For the trans-

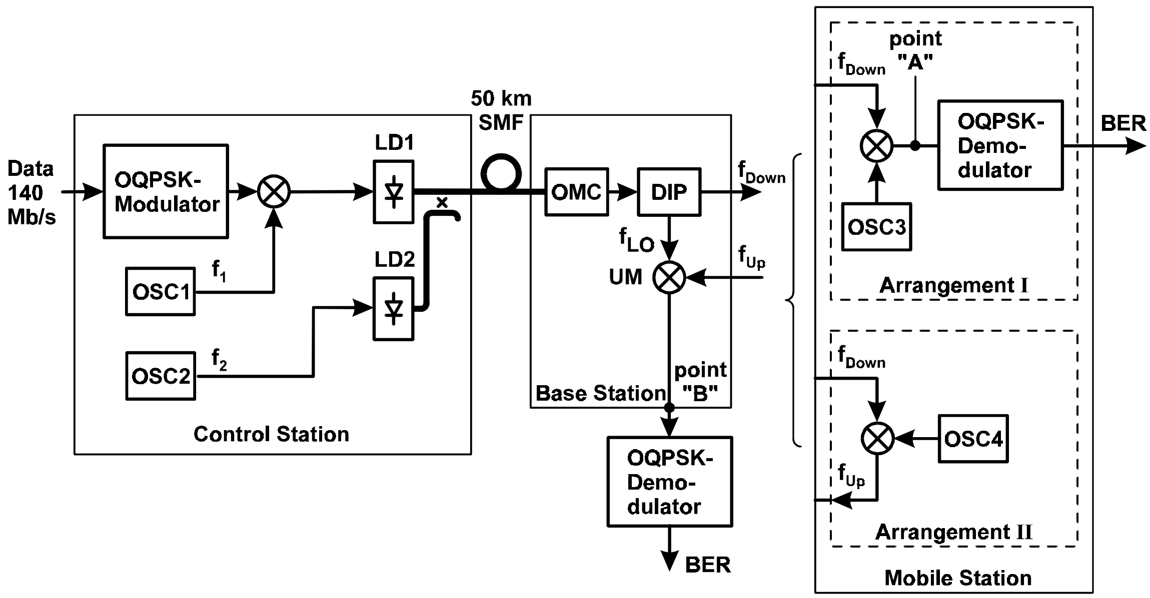

Fig. 2: Experimental set-up: bitrate 140 Mbit/s, PRBS wordlength 2^{23}-1, OQPSK-format, UM: uplink mixer SMF: standard single mode fiber, OMC: optic/microwave converter, DIP: frequency diplexer, OSC: oscillators: OSC1 at 3.744GHz, OSC2 at 2.779GHz, OSC3 at 19.45GHz, OSC4 at 1.01GHz optically generated microwaves: f_{down}=18.58GHz, f_{LO}=19.45GHz, f_{Up}=19.59GHz
Arrangement I: down link transmission, measurement at point „A“
Arrangement II: up and down link transmission, measurement at point „B“

different spectral components of each laser are inherently correlated. Thus the phase noise vanished at the OMC-output. The spectral purity of the microwave carriers was given by the quality of the subcarrier signals. It is theoretically degraded by 6 dB/octave. For the 5th harmonic at 18.58GHz of the 3.774GHz subcarrier we measured -73 dBc/Hz @ 1 kHz carrier offset.

III. EXPERIMENTS

The optical part of the experimental system shown in **Fig. 2** comprizes two DFB-lasers (λ_1 = 1.543µm, λ_2 = 1.540µm), a 50 km standard single mode fiber (SMF), and an OMC (HP 11982A). The electronic

mission experiments we used CMI coded 140 Mbit/s data signals, pseudo random binary sequence (PRBS), word length 2^{23}-1 fed to the OQPSK-modulator. It results in a OQPSK-modulated output signal at a 140 MHz carrier which itself modulates a subcarrier f_1 = 3.744GHz (OSC1). LD1 was directly modulated by this signal while LD2 was modulated by a carrier f_2 = 2.779GHz (OSC2). The optical signals of both lasers have been transmitted via the SMF to the BS. Due to the nonlinear properties of the system the carriers f_1 and f_2 were upconverted to f_{Down} = 18.58GHz ($5 \cdot f_1$ - 0.14GHz) and f_{LO} = 19.45GHz ($7 \cdot f_2$), respectively. At the OMC output, both signals were separated by a diplexer. The modulated down stream signal at f_{Down} was fed to the mobile station (MS)

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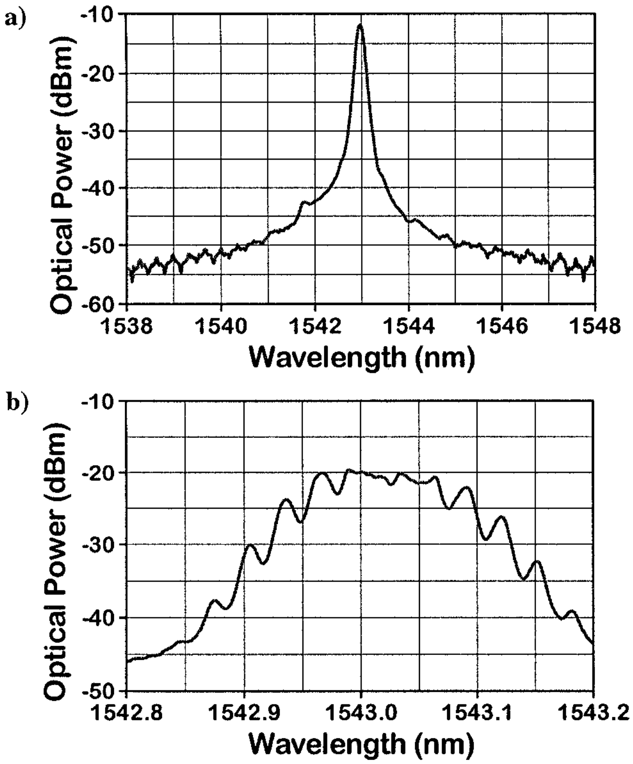

Fig. 3: Optical spectra at the OMC input measured by an optical spectrum analyser
a) wavelength span 10 nm,
b) high resolution mode, span 400 pm

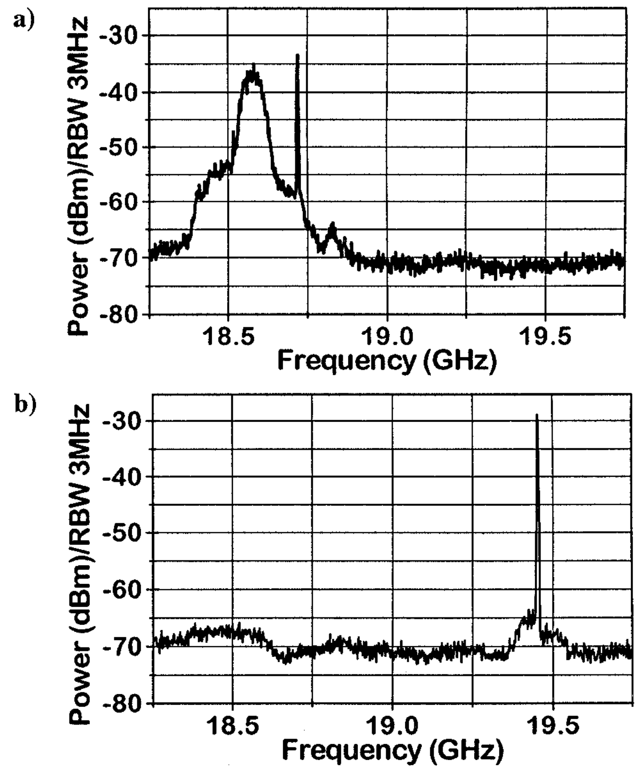

Fig. 4: Optically generated electrical spectra at the diplexer:
a) 140 Mbit/s OQPSK down link data
b) LO-signal for the up link mixer

while the LO-signal at f_{LO} was let to the UM. This LO-signal was used for mixing the received uplink signal at f_{up} down to 140 MHz for the OQPSK-receiver. **Fig. 3a** and **b** show optical spectra of the modulated laser LD1 measured at the OMC-input. The total optical power including all harmonics was approximately -10 dBm. At the diplexer outputs we observed the modulated signal band **(Fig. 4a)** and the LO-signal **(Fig. 4b)** at 18.58 GHz and 19.45 GHz, respectively.

Fig. 5 shows the bit error rate measurements (BER) for different experimental conditions. The measurements have been carried out without radio link. Curve 1 gives the results of a back-to-back BER measurement at 140 MHz when the OQPSK-modulator and demodulator of the digital radio-relay system have been connected directly by a coaxial cable. After transmission via 50 km SMF and conversion to the microwave domain the signal at 18.58 GHz was led to a mixer connected to the 140 MHz-receiver (**Fig. 2** arrangement I). Curve 2 gives the BER-values for the data transmission to the MS measured at point "A". Curve 3 shows the BER-values after transmission via the down and uplink measured at the base station at point "B" (**Fig. 2** arrangement II). In this case the MS contained a mixer which converted the received signal from the 18.58 GHz channel to the uplink channel at 19.59 GHz (channel spacing 1.01 GHz). No signal regeneration was carried out. In the BS this signal was converted to 140 MHz by the uplink mixer fed by the optically generated LO-signal at f_{LO} = 19.45 GHz. In a complete radio-over-fiber system this signal at 140 MHz could be used to modulate the laser of a conventional fiberoptic link back to the CS.

In order to compare the different measurements for all three cases the BER is given versus the electrical power at the 140 MHz-receiver. The results reveal a system penalty of 1 dB at a BER = 10^{-9} and transmission via 50 km SMF when the microwave signals are generated optically (curve 2). A further penalty of 2 dB can be observed after retransmission to the base station (curve 3). The dynamic ranges have been measured to be better than 60 dB and no error floors have been observed for all three cases. In this simple system no optical amplifiers have been required.

IV. CONCLUSION

The combination of fiber optics and microwave techniques offers advantages for broadband mobile communication systems. Additionally to the long distance, low-loss transmission and large bandwidth of the fibers the remote generation of the microwave signals is a powerful advantage of the optical technique. The results of the experiments demonstrate that by applying the optical upconversion principle in the control station components for moderate microwave frequencies can be used. These components in conjunction with commercially available laser diodes provide the microwave signals for both the up and the down link at the base stations. The characteristics of the remotely generated microwave carriers are determined by the equipment in the benign environment of the control station. Hence despite of a possibly rough environment of the base station microwave carriers are optically generated with superior characteristics in terms of frequency stability and setting resolution (Hz-range), wide frequency range (some 10 GHz), spectral purity (SSB phase noise < -70 dBc/Hz @ 1 kHz carrier offset), and simultaneously broadband modulation (> 140 Mbit/s). The changing to higher frequencies is possible /6/. In this centralized concept functions such as upconversion, frequency selection, signal processing, and network management are provided in the central office thus allowing the numerous base stations to be very simple and low-cost.

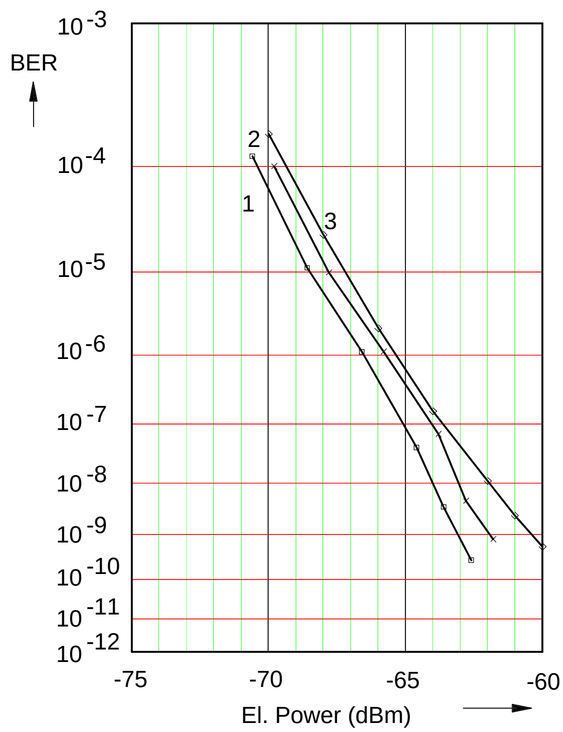

Fig. 5: BER vs. electrical power at the input of the 140 MHz receiver, bit rate 140 Mbit/s, PRBS, wordlength of 2^{23}-1, OQPSK-modulation.
curve 1: back-to-back measurement
curve 2: down link at 18.58GHz (point A) at the output of the mobile receiver
curve 3: down and uplink at the BS (point B) with optically generated LO-signal for the uplink mixer

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