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Fiber Radio Link with Microchip Laser Source

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Abstract* — *This paper describes a fiber radio link, based on a solid-state dual microchip laser source. Experimental results are presented showing T3 rate downstream data transmission over the combined fiber radio and wireless link at 25.65 GHz.

I. INTRODUCTION

This paper describes an optical heterodyne-based hybrid fiber/ fixed wireless access (FWA) radio link. A K-band wireless carrier is generated by a pair of phase-locked tune-able microchip lasers, eliminating the need for an electronic dielectric resonator oscillator (DRO) in the base-station. The fiber link also allows the base-station to be remotely located with respect to the wide area network access point.

In this paper, we report the first demonstration of a 44 Mb/s, T3 connection using a chip-laser-based optical architecture. The system block diagram is shown in Figure 1. T3 connections are provided at both ends of the link. We then used Ethernet to T3 conversion hardware for connection to our existing network. The commercial modems provided link performance metrics including signal to noise ratio and bit-error rate.

A. Downstream Link

Downstream data is modulated onto a 70 MHz carrier using a Raydyne Comstream MM200 microwave modem. The modem supports a variety of modulation formats ranging from QPSK to 256-QAM. QPSK modulation was used for the experiments described in this paper. The 70 MHz modem output then drives a microwave mixer in order to amplitude modulate a 5.325 GHz intermediate frequency (IF). In this demonstration both upper and lower sidebands were retained. The modulated IF signal is then amplified to drive a Mach Zehnder Modulator (MZM). The optical input to the MZM consists of a pair of microchip lasers to be described in Section II. The microchip lasers generate a phase-locked pair of optical carriers that are separated by 20.325 GHz. The optical carriers are then both modulated in the MZM and distributed to the base-station via optical fiber. The mm-wave base-station transceiver detects the optical signals in a high-speed photodetector. The detected photocurrent includes a low frequency, 5.325 GHz, homodyne signal which is rejected by use of a high pass filter. The photocurrent also includes a heterodyne component with a modulated signal at a 25.65 GHz center frequency and an un-modulated 20.325 GHz tone. The unmodulated tone is retained for frequency down-conversion in the upstream link. This eliminates the need for a local oscillator in the basestation.

The modulated 25.65 GHz signal is amplified in the basestation and then transmitted wirelessly to the customer premise equipment (CPE) transceiver. The CPE down-converts this signal to L-band. A second down-conversion translates the L-band signal to the 70 MHz IF required by the modem for demodulation to baseband.

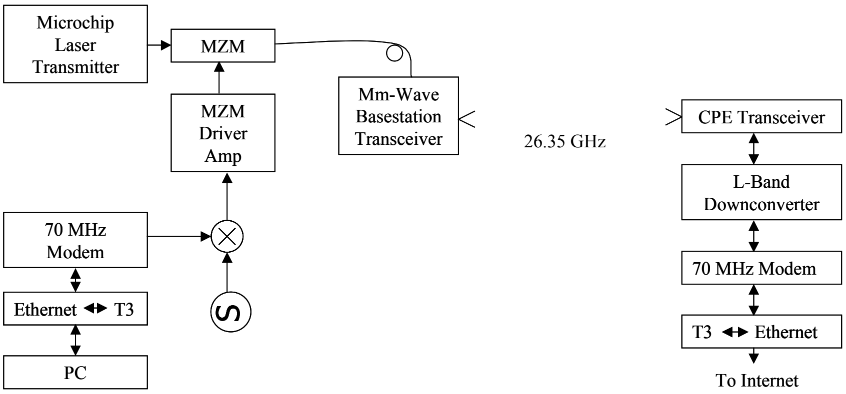

Figure 1. System Block Diagram
(25.65 GHz downstream link; 26.35 GHz upstream link)

B. Upstream Link

The upstream link does not use a chip laser as an optical source, but we discuss it briefly here since it relates to overall system architecture. The upstream (CPE to base-station) wireless link operates at 26.35 GHz. This signal is down-converted to 6 GHz in the base-station using the 20.35 GHz reference signal derived from the microchip laser transmitter. A conventional analog fiber optic link may then be used to transmit this 6 GHz signal back to the optical transmitter where it is mixed down to the 70 MHz IF required by the modem.

II. MICROCHIP OPTICAL TRANSMITTER

The optical transmitter is based on a Nd doped solid state microchip laser described by Li, *et. al.* [1]. A block diagram of the optical transmitter is shown in Figure 2.

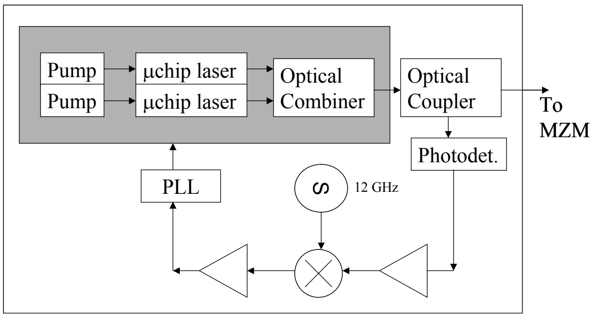

Figure 2. Microchip Optical Transmitter

Two microchip lasers are independently pumped by semiconductor laser diodes. Control of both the pump power control and temperature are used to set the wavelength separation to 20.325 GHz. The two laser outputs are optically combined into a single beam. An optical coupler samples a portion of the beam for use in the transmitter phase locked loop (PLL) while transmitting the rest of the beam to the MZM. The coupled output is detected in a photodiode producing an electrical signal that is approximately 20.325 GHz. This signal is mixed with a low noise 12 GHz reference oscillator to generate an 8.32 GHz input to the PLL. A Type II PLL provides feedback to one of the laser temperature controllers and locks the PLL input to 8.32 GHz. Consequently, the laser output wavelength separation is locked to 20.35 GHz. Figures 3 and 4 show the 8.32 GHz feedback signal and the 20.325 GHz reference signal obtained from the optical transmitter.

The measured single sideband phase noise of the 20.325 reference signal was –74 dBc/Hz at 10 kHz offset and –91dBc/Hz at 1 MHz offset. The optical wavelength is 1.06 µm, but, work is in progress to produce a similar transmitter at 1300 and 1500 nm wavelengths. A phototgraph of the microchip laser source is shown in Figure 5.

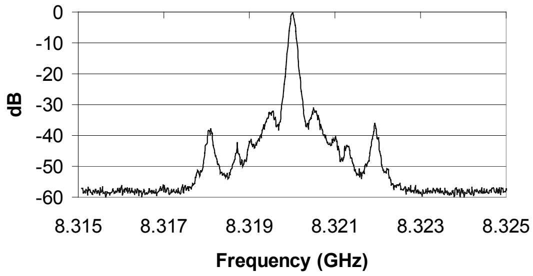

Figure 3. 8 GHz Feedback Signal

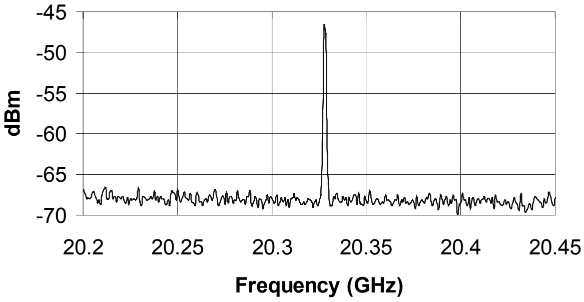

Figure 4. 20.325 GHz Reference Signal

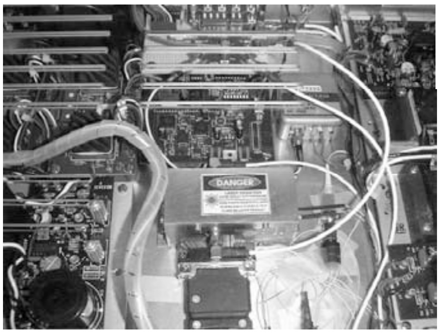

Figure 5. Microchip laser source

III. BASESTATION TRANSCEIVER

A custom basestation transceiver was designed for the system. A photograph of the basestation is shown in Figure 6.

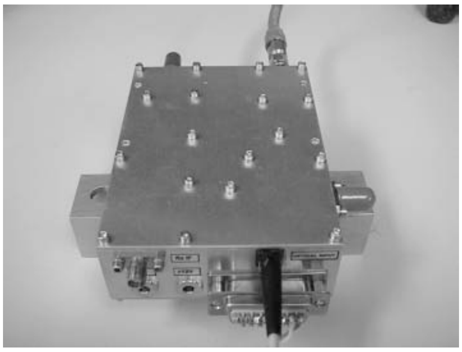

Figure 6. Basestation Photograph – the size is 4.0" x 3.0" x 1.25"

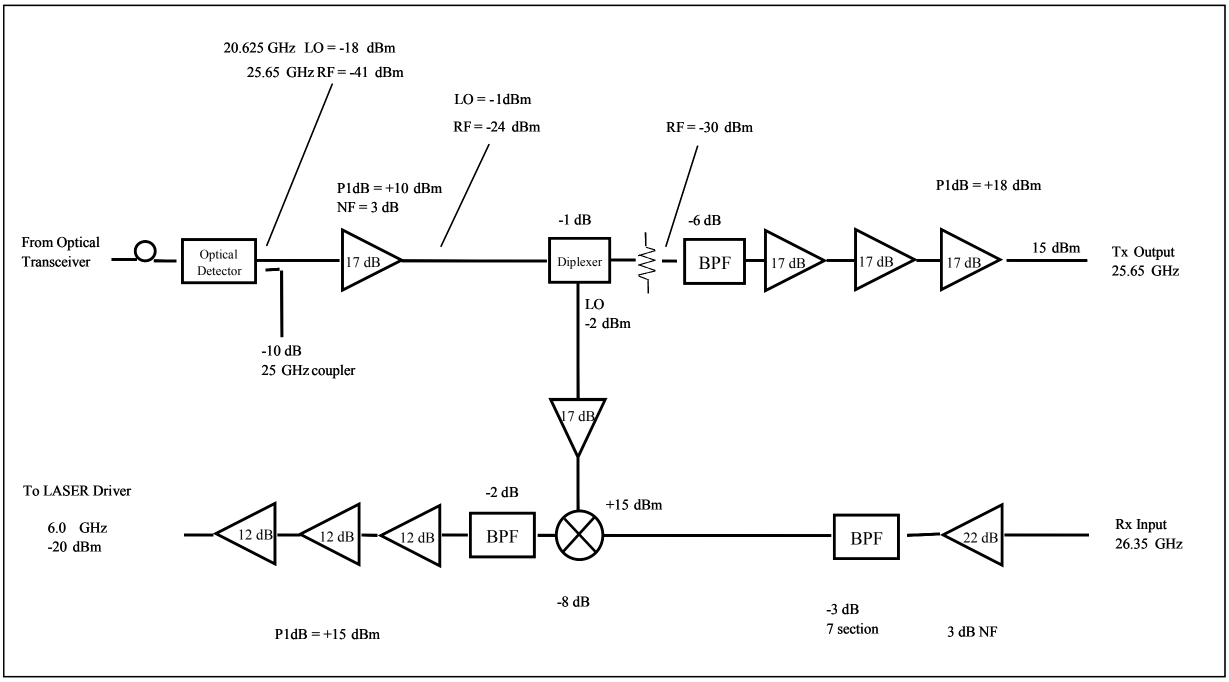

Figure 7. Basestation Block Diagram

The block diagram of the basestation is shown above in Figure 7. The basestation accepts a fiber optic input from the microchip optical transmitter. A high-speed photodetector performs the optical to electrical conversion resulting in a 20.35 GHz reference signal and a 25.65 GHz information signal as described in Section II. These signals are then amplified and then distributed to a custom diplexor. The 20.325 GHz output of the diplexor is amplified and used to drive a mixer for downstream downconversion. The 25.65 GHz diplexor output is amplified to a maximum power level of 15 dBm for wireless transmission. The wireless input to the transceiver is designed to accept a 26.35 GHz upstream signal. The receive signal is amplified and filtered prior to downconverstion to the 6 GHz IF. A 6 GHz analog fiber optic link can then be used to transmit the signal to the optical transmitter. Separate microstrip patch arrays have been designed at 25.65 and 26.35 GHz, however, a waveguide horn was used for initial experiments.

II. CPE TRANSCEIVER

A photograph of the CPE transceiver is shown in Figure 8. The transceiver includes a high-gain dielectric horn antenna and provides up and downconversion to/from an L-band (~ 1 GHz) IF frequency. Both DC power and the L-band IF frequency are distributed on the same coaxial cable to the transceiver. The CPE transceiver was developed for a separate application and, therefore, will not be described in detail.

Figure 8 CPE Transceiver Photograph

V. EXPERIMENTAL RESULTS

The fiber radio system was used for downsteam transmission of Ethernet data at 25.65 GHz. The basic experimental set-up is similar to that shown in Figure 1 with the exception that only downstream operation was used. The data terminal was a personal computer with a standard 10/100 BaseT Ethernet card. The Ethernet data was converted to a T3 data format to be compatible with the modem input. The modem was configured for QPSK operation at an IF output frequency of 70 MHz. The modem uses a quasi-OFDM modulation scheme which processes the serial data into four parallel data streams. Each parallel data stream is modulated onto a separate RF subcarrier. The modem output spectrum is shown in Figure 9.

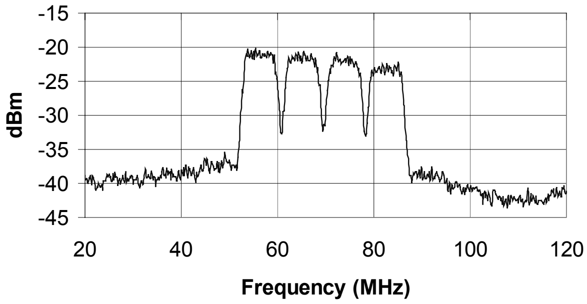

Figure 9. Modem Output

This 70 MHz modem output was then upconverted to 6 GHz and amplified to a nominal level of –6 dBm to modulate the microchip optical transmitter output in the MZM. The basestation output is shown in figure 10.

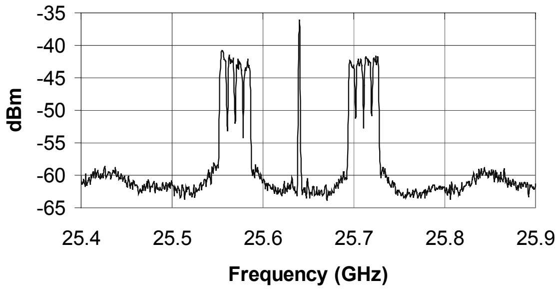

Figure 10 Basestation Output

It should be noted that both upper and lower sidebands are transmitted in this experiment. In he future, a filter could be added at the electrical input of the MZM to eliminate one of the sidebands. It is also noted that the transmitted power kept significantly lower than the maximum design level. This was due in part to maintain safe operating power levels for the indoor wireless transmission used in these initial experiments. The optical power generated by the microchip laser source corresponding to this indoor transmit condition was 0.6 mW. Unfortunately, this optical power level was not adequate to generate enough microwave power at 20.325 GHz to drive the basestation mixer necessary for upstream operation. An increase in optical power is required to this, however, this would also result in higher transmit power that would be inappropriate for indoor testing. In future designs, it would be advisable to add variable gain control in basestation in order to operate both the upstream and downstream channels over a wider range of optical transmitter powers and wireless transmit powers. Nevertheless, the downstream link operated as expected with signal quality that supported high quality data transmission. The upstream SNR and pre and post FEC BER was monitored on each of the four quasi-OFDM modem channels. Table 1 shows these results for a very short link distance (~1 m) where multipath effects were minimal. Table 2 shows results for a longer link distance (~25 m) where there was more significant multipath due to the indoor propagation environment. In both cases the SNR and pre-FEC BER is acceptable for wireless transmission.

Modem Channel	SNR (dB)	Pre FEC BER	Post FEC BER
1	11.1	7.4e-7	1.23e-10
2	10.6	3.3e-6	7.56e-10
3	11.2	1.42e-6	4.63e-11
4	12.4	1.46e-7	0

Table 1. SNR and BER Performance – no multipath

Modem Channel	SNR (dB)	Pre FEC BER	Post FEC BER
1	13.0	1.75e-6	2.33e-8
2	13.3	5.87e-6	2.31e-8
3	13.7	2.4e-6	1.46e-8
4	14.5	3.45e-6	1.84e-8

Table 2. SNR and BER Performance – with multipath

V. CONCLUSIONS

This paper presented preliminary experimental results of a fiber radio link that uses a microchip laser source to generate the required millimeter wave reference signal. These are the first reported experimental results for a fiber radio link using the microchip laser. The signal quality of the mm-wave signals derived from the optical transmitter supported QPSK operation, even at the low optical transmitter power used to keep the mm-wave transmit power low for indoor experimentation.

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[1] Y. Li, S. M. Goldwasser, M. Bystrom, P. R. Herczfeld, "Generation of MSK modulated millimeter wave subcarrier for radio over fiber applications" International Topical Meeting on Microwave Photonics, 2001, pp. 33 –36.