Generation of Optical Microwave Signals using Laser Diodes with Enhanced Modulation Response for Hybrid Radio/Fiber Systems

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ABSTRACT
The authors present the idea of using a laser with improved modulation bandwidth to generate microwave optical signals for hybrid radio/fibre systems. External light injection has been used to enhance the frequency response of the laser and thus greatly improve the overall performance of the hybrid system. Experimental results show an 8 dB improvement in system performance for the externally injected laser in a hybrid radio/fibre system used for distributing 155 Mbit/s data signals on an 18 GHz carrier.

Keywords: external light injection, microwaves generation, bandwidth enhancement, hybrid systems, laser.

1. INTRODUCTION

As the demand for broadband mobile services such as video-on-demand and mobile computing increases, so does the need to develop high capacity mobile communication networks which are capable of delivering broadband signals to remote areas "over the air". High capacity mobile networks of the future will probably use millimetre waves as the access medium (18 – 200 GHz), as this offers a large bandwidth for data transfer.

Future millimetre wave access networks are likely to employ an architecture in which signals are generated at a central location and then distributed to remote base stations using optical fibre, before being transmitted over small areas using millimetre wave antennas (Fig. 1) [1-2]. Such architecture should prove to be highly cost efficient, since it allows sharing the transmission and processing equipment (remotely located in the central control station) between many base stations.

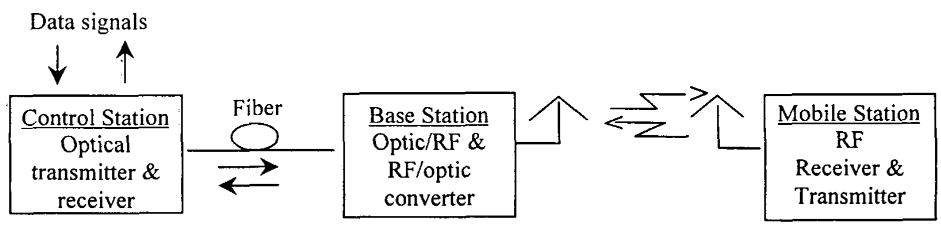

Figure 1. Fibre radio system: basic configuration.

To develop an optically fed microwave wireless network of this type requires the amalgamation of many different technologies. On the transmission side, we need to generate the millimetre wave optical data signals using semiconductor laser diodes. The simplest technique available to generate optical millimetre wave signals involves direct modulation of the laser with the millimetre wave data carrier. However, the limited bandwidth of laser diodes means that we are normally unable to use high frequency RF carriers (> 20 GHz), which could be employed to transmit very broadband data signals. However, it has recently been shown [3], that by using external injection into a laser diode, its modulation response can be significantly enhanced. In this paper we demonstrate that this enhancement of the modulation response allows us to greatly improve the performance of the optically fed millimetre wave system based on direct modulation of laser diodes.

2. SIMULATION SET- UP AND RESULTS.

At this juncture, we introduce the simulation results of the link between the Control Station (CS) and the Base Station (BS), which is the optical part of the hybrid radio – optic system. The schematic of the simulation model is shown in Fig. 2.

The data stream of bit rate 140 Mb/s is mixed at the CS with a 18 GHz sub carrier. The laser diode is then directly modulated with the up-converted data signal. After propagating along the fibre the signal is detected by the p-i-n diode at the BS. In a complete system the output signal of the detector is transmitted through the antenna to the mobile station where the data is received by down-converting the incoming signal using a local oscillator [4]-[7]. However in our simulation we have concentrated on the optical part of the system, hence the down conversion takes place at the BS. The goal of our simulation is to show that by using external injection to enhance the modulation response of the laser diode [8], we can greatly improve the system performance. In our simulation we used two laser models: one for the free running device, and a second for the device with external injection (which gives a 30 dB improvement in electrical response at 18 GHz).

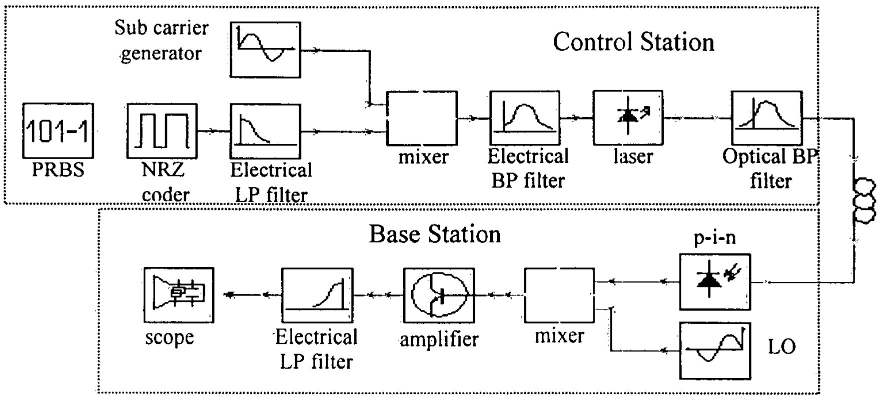

Figure 2. Simulation model.

Figure 3 shows the received eye diagram of the down-converted signals from the free running laser and the laser with the improved modulation bandwidth. One can see that the opening of the eye in the second case is far greater than in the free running case, indicating the improved system performance, which can be obtained using external injection into the directly modulated laser.

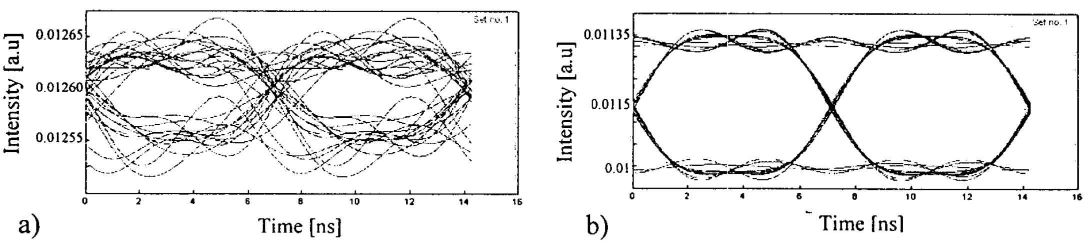

Figure 3: Received eye diagrams from the simulation of the hybrid radio / fibre system using (a) standard laser parameters, and (b) laser with the enhanced modulation response at 18 GHz.

3. EXPERIMENTAL RESULTS.

The initial experimental results of the laser diode bandwidth enhancement were achieved by using external light injection into a commercial single mode laser diode. The experimental set-up (Fig. 4) consisted of a master laser (external cavity tuneable laser), a slave 1.55 μm single mode laser diode, detector (p-i-n diode) and network analyser (HP-8510C). Figure 5 presents the frequency response of the free running laser biased at 60 mA (dashed line), and the laser with external injection (solid line). For external injection, the output power from the external cavity laser was set to 1 mW, and its output wavelength was tuned to the emission wavelength of the single mode laser. As we can see from Fig. 5, the external injection increases the relaxation frequency of the laser to 18 GHz, and gives a greatly enhanced performance at this frequency compared to the free running device.

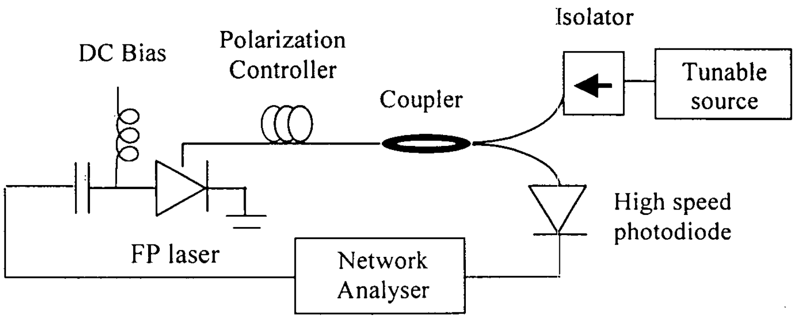

Figure 4: Experimental set-up for examining the modulation bandwidth enhancement.

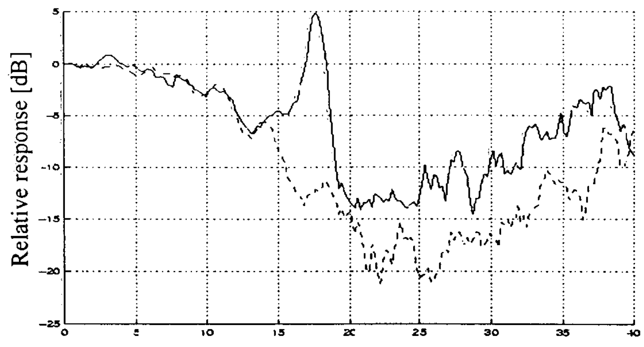

Figure 5: Enhancement of the modulation bandwidth of the laser diode achieved by external light injection.

We then experimentally examined how the enhanced laser modulation response would improve the system performance of an optically fed microwave system. We used an experimental arrangement identical to that described in Fig. 2. Figure 6 illustrates the received eye diagrams after down conversion of the data signal after the detector.

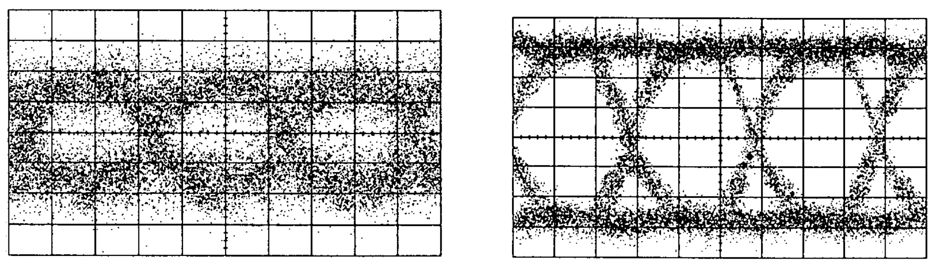

Figure 6: Experimental results: Received eye diagrams from the optically fed microwave system using (a) free running laser diode, (b) laser diode with the external injection.

The improved system performance is clear from the eye openings obtained. The BER vs. received optical power measurements are presented in Fig. 7. From this figure we can see that there is an 8 dB improvement in system performance, for a received BER of 10^{-9}, when external injection is applied to the directly modulated laser. This improvement in optical system performance is slightly less than would be expected (9 dB) from the enhanced electrical frequency response shown in Fig. 5. This is attributed to the fact that the external injection reduces the laser threshold, and thus increases the optical output power from the device.

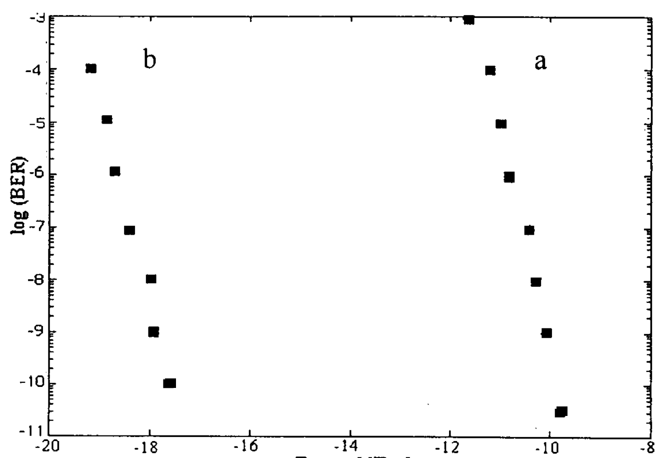

Figure 7. BER vs. received optical power for the signal generated by a) free running laser, b) laser under external injection.

4. CONCLUSIONS.

Radio over fibre systems allows us to combine two different techniques thereby giving us both their merits. Transmission over the air lets us send the broadband data to many mobile users without expensive installation costs, while the fibre provides low attenuation, broadband transmission line, and a EMI immune medium for transmitting the data from control station to base stations, and further (to other networks). The development of hybrid fibre-radio systems strongly depends on the cost of the BS (the high RF carrier implies small size of cells, which requires a large number of BS). This is the main reason for finding remote and cheap ways of generating the optical microwave signal.

In this paper we have shown that by using external injection into a directly modulated laser, we can enhance the modulation response of the laser, such that the system performance of a radio over fibre distribution network is significantly improved. We have demonstrated an overall improvement in system performance of 8 dB when using this technique to distribute a 155 Mbit/s data signal on an 18 GHz electrical carrier.

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