A NOVEL APPROACH TO PRE-SCALED CLOCK RECOVERY IN OTDM SYSTEMS

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Abstract: A new technique for the clock recovery in OTDM transmission systems is demonstrated; it is based on an injected electro-optic hybrid oscillator and offers the advantage of circuit simplicity and frequency scalability.

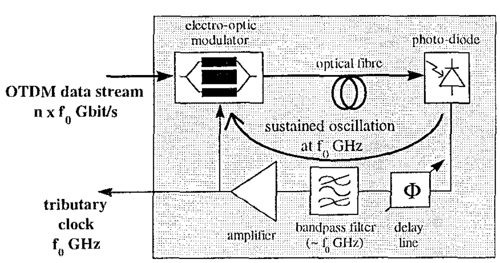
Introduction

In OTDM (Optical Time Division Multiplexing) transmission systems, the receiver sub-system must be able to recover, from the incoming multiplexed data stream, the tributary clock, in order to synchronize the demultiplexing device. Several solutions have been proposed /1,2/, which generally imply high speed components or circuit complexity. The approach presented in this work is a simple, not PLL-based, opto-electronic regenerative circuit, which is based on the electronic frequency divider proposed by Miller /3/ and doesn't require components with bandwidth higher than the tributary rate /4/.

Operation principle

Figure 1 shows the circuit scheme: the modulation frequency at the line rate, carried by the incoming optical stream, is mixed, by the electro-optic modulator, with the oscillating electrical signal and with its harmonics generated by the non-linear modulator transmission characteristic. The resulting beat note, obtained by photo-detection and bandpass filtering, oscillates at the tributary frequency and is synchronous with the data stream. The oscillation condition (unitary gain and phase matching in the loop) makes the device working like an harmonic injected oscillator. With a proper choice of the modulator bias voltage it is possible to obtain the tributary rate recovery from a time-interleaved pulsed data stream.

Fig. 1: Scheme of the pre-scaled clock recovery device for OTDM transmissions



The present implementation of the circuit employs a Mach-Zehnder device as the electro-optic modulator and extracts a 10 GHz clock from a 40 Gbit/s (4x10 Gbit/s) data stream (the polarization dependence of its operation is still an open issue). The RF bandwidth of both the photo-detector and the modulator is about 12 GHz. Due to the working principle, this scheme can easily scale with the tributary rate, if needed.

Experimental results

The 40 Gbit/s implementation has been characterized in three different ways. The first experiment demonstrates the device operation as a frequency divider with an optical input signal sinusoidally modulated at 40 GHz. The optical signal was obtained by a CW semiconductor laser followed by a Mach-Zehnder modulator, driven at 20 GHz near the minimum transmission bias. Input (optical) and output (electrical) signals are shown in Figure 2 and their electrical spectra in Figure 3. The phase jitter of the recovered signal was measured in the time (oscilloscope histogram) and frequency domain (RF noise spectrum integration) and it was found to be about 0.5 ps. Figure 4 shows the RF spectrum near the input line (40 GHz) and the output recovered clock (10 GHz).

Fig. 2: Sinusoidal characterization: input optical signal (40 GHz) and recovered clock (10 GHz)

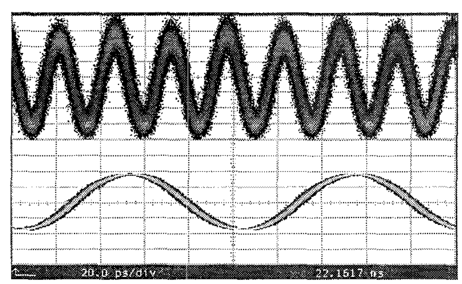
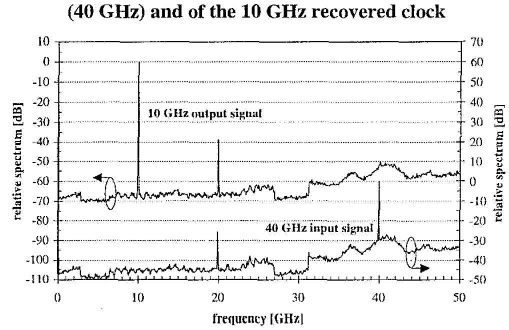
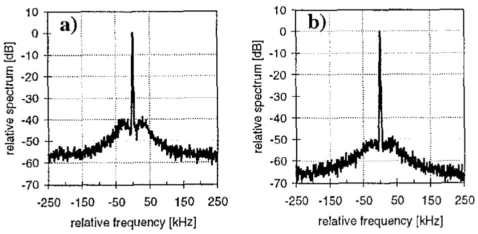


Fig. 3: RF spectrum of the input optical signal (40 GHz) and of the 10 GHz recovered clock



The system typically operates with -5 to 0 dBm input average power and within a 100 kHz locking range (around 10 GHz).

Fig. 4: RF noise around 40 GHz (a) and 10 GHz (b)



In the second experiment the device was used to extract the 10 GHz tributary clock from a 40 Gbit/s pseudo-random OTDM data stream. The OTDM signal was obtained by mode-locking at 10 GHz an Erbium fibre laser, by encoding PRBS data at 10 Gbit/s with an external electro-optic modulator and by passive 4x multiplexing (the OTDM transmitter was developed within the ACTS MIDAS project).

Figure 5 shows the OTDM data stream and the recovered 10 GHz clock (the word length is 2^{23}-1). Figure 6 is an oscilloscope jitter measurement: by taking into account the oscilloscope jitter itself, the recovered clock jitter is 0.3 ps; The RF noise measurements confirm the reported value.

Fig. 5: OTDM input pseudo-random data stream (40 Gbit/s) and 10 GHz recovered clock.

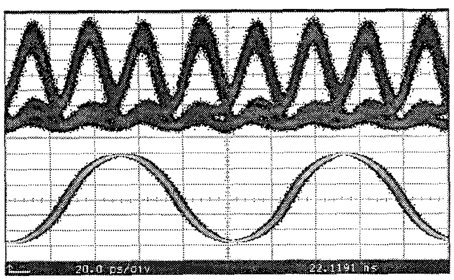
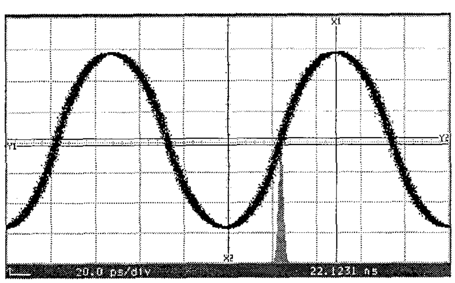


Fig. 6: Recovered clock signal and oscilloscope jitter measurement (histogram)



Finally, the clock recovery device has been utilized in an OTDM receiver, in conjunction with a non linear fibre demultiplexer, driven by a 10 GHz gain-switched DFB laser. The fibre demultiplexer was based on FWM in a dispersion shifted fibre, enhanced by Modulation Instability; a fibre grating notch filter was used, in order to suppress the ASE noise from the amplifiers at the generated wavelength (Figure 7).

Fig. 7: Set-up of the OTDM experiment

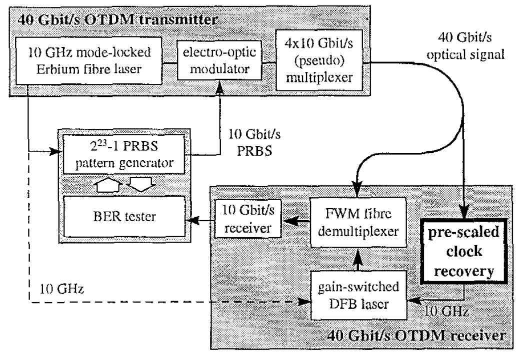
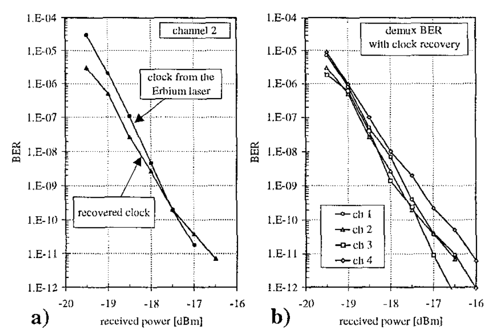


Figure 8a shows a comparison between the BER measurements for one of the four demultiplexed channels (ch. 2), done with different driving signals for the Gain-Switched laser: in the first case the demultiplexer is driven by the clock of the Erbium laser, while in the second case the recovered clock is used, with a negligibile penalty. The BER for the four channels, demultiplexed using the recovered clock, is shown in Figure 8b.

Fig. 8: BER measurements with the recovered clock



Conclusions

The reported measurements demonstrate that the proposed scheme is well suited to clock recovery operation in OTDM transmission systems, with the advantage of circuit simplicity and frequency scalability. A different implementation of this approach, which uses a polarization independent electro-absorption modulator, is under study.

Acknowledgements

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References

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