SIMULATION OF A SUBCARRIER MULTIPLEXED COMMUNICATIONS SYSTEM : A PERFORMANCE ENHANCEMENT TOOL

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Abstract

A 3.9 GHz RF-optical subcarrier multiplexed (OSCM) packet transmission system is simulated and experimentally demonstrated. Simulation results show that integration of the RF subsystem will greatly enhance system performance and require less power to be tapped from the fiber for header detection and processing.

Introduction

The objective of this work is to model an optical subcarrier multiplexed (OSCM) communication network with a commercial CAD tool and study the effects of RF component integration on system performance and network scaleability. High speed optical networks can be used to efficiently integrate data, video, and audio. One class of such networks encodes packet headers on an RF subcarrier while maintaining the payload at baseband[1-3]. This approach has the advantage of simplified header detection and processing. The header is extracted with simple RF filtering reducing the timing requirements and high sensitivity is achieved with coherent RF detection. At each switching node, a portion of the optical signal is removed and the headers are detected and processed in the RF domain in order to route the optical packets. However, previous experimental work has required that a relatively large amount of optical signal be removed (10%) for reliable detection. In order to scale networks to a larger number of nodes and larger internode distances, it is necessary to reduce the amount of signal removed at each node. The simulation approach presented here enables us to study the effect of RF component integration and determine critical design criteria in order to enhance system performance and allow a smaller amount of optical power to be tapped for header processing. Integration of RF/Optical interfaces will allow deeper penetration of RF and lightwave component technology into optical packet networks.

Architecture of OSCM Link

The basic architecture of an OSCM packet link is illustrated in fig. 1. The digital header is upconverted to an RF subcarrier and is combined with the baseband digital payload. The combined electronic/RF signal spectrum is modulated onto an optical carrier through direct modulation of a semiconductor laser or using an

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external electro-optic modulator. The optical packet is transmitted through an optical fiber to a switching node where a portion of the optical signal is tapped off and photodetected. The upconverted header is extracted from the payload and downconverted to baseband for digital processing.

Simulation and Experimental Setups

We have simulated this link using the Communication Suite from Hewlett Packard based on the experiment shown in fig. 2. A schematic of the simulated link is shown in fig. 3. The electrical input is modeled using a mixer, an oscillator, an ideal bandpass filter, two DC shift elements and a summer. Two DC shift elements bias the header and data waveforms to eliminate negative voltages. The mixer upconverts the header to a subcarrier frequency of 3.9 GHz. The complex mixer has three ports connected to three ideal amplifiers to model VSWR and noise figure characteristics. A single 3.9 GHz sinusoidal waveform generator is used as the local oscillator for the transmitter and receiver. An ideal bandpass filter centered around 3.9GHz with bandwidth of 630MHz is used to remove the unconverted header, an effect observed in our experiment.

The simulator models a laser diode (λ=1550nm) directly modulated by the upconverted header and data combination. We assume a fiber loss of 0.2dB/km at λ=1550nm. A 1x2 optical splitter with photodetectors (responsivity = 0.8A/W) at each output port allow the header and payload bit streams to be monitored simultaneously. Specifications of actual components used in the experimental OSCM link shown in fig.2 have been used to supply parameters for the simulation models. Header demodulation and recovery are first modeled using parameters from components used in the experiment: amplifiers with 25dB gain, an ideal bandpass filter centered around 3.9GHz with bandwidth of 630MHz, a mixer, an oscillator and an ideal low pass filter with cutoff frequency at 108MHz. The amplified SCM signal is downconverted to baseband by mixing with the local oscillator. The header is finally recovered using a low pass filter. At the other output port of the optical splitter, the payload data is recovered using a low pass filter with cutoff frequency at 550MHz.

The Signal Fast Fourier Transform test bench is used to verify link performance. This test bench allows one or more input signals assigned to different network input ports, and results in signal measurements, noise measurement and output signal processing measurements at specified network ports[4]. Pseudo-random bit sequence (PRBS) patterns for the header (100Mb/s) and payload (622Mb/s) are used to allow simulation results to be compared with experimentally obtained eye diagrams.

Results

Simulation and experimental results are shown in fig. 4. The simulated signal-to-noise ratio (SNR) for the recovered header and payload is given by the opening of the eye diagrams and agrees reasonably well with the experimental results as can be seen in fig. 5 and 6. Since the simulated optical modulation was achieved using direct modulation of a laser diode and experimental modulation was achieved using an external modulator, amplitudes of recovered header and data stream are different for the simulation and experiment. Experimentally, the output header eye opening was 48%. The simulation shows a 43% output eye opening with an ideal digital waveform generator with 1ns risetime. The experimental results show that the output eye opening was 75%. The simulated result exhibits an output data stream eye opening of 85%. The effects of RF component integration on system performance and network scaleability are tested and shown in fig. 6.

Conclusion

A 3.9 GHz RF-optical subcarrier multiplexed (OSCM) packet transmission system is simulated and experimentally demonstrated. The simulation method itself does not provide the most accurate measurement, but does provide an accurate and efficient design procedure for RF-Optical link systems such as SCM/WDM links. With this simulation method, we plan to optimize the performance of single and multiple channel SCM/WDM links. In addition, we will investigate the performance advantages of MMIC integration in SCM/WDM links.

References

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[2] C. Lu, D. S. Sabido, P. Poggiolini, R. Hofmeister, L. Kazovsky, “CORD-A WDMA Optical Netowrk: Subcarrier-Based Signaling and Control Scheme,” IEEE Photonics Technol. Letts., vol. 7, pp. 555-557, 1995.

[3] A. Budman, E. Eichen, G. Schlafer, R. Olshansky, and F. McAleavey, “Multigigabit Optical Packet Switch for Self-Routing Networks with Sub-Carrier Addressing,” Proceedings OFC’92, Feb. 1992.

[4] Hewlett-Packard - EESOF Microwave & RF System Design, Series IV Manual.

Acknowledgments

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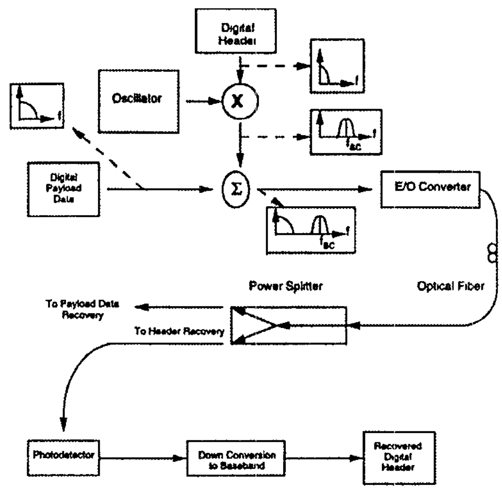


Figure 1. Basic Architecture of an OSCM packet link

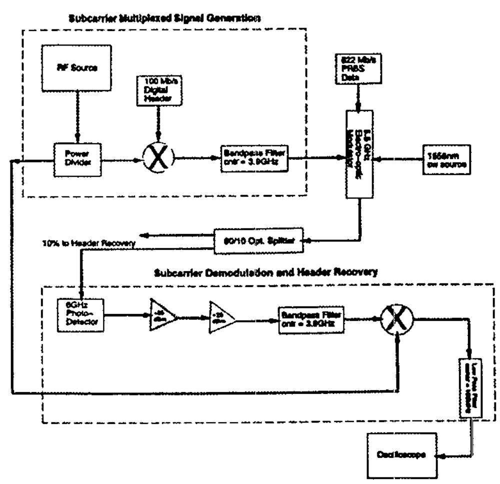
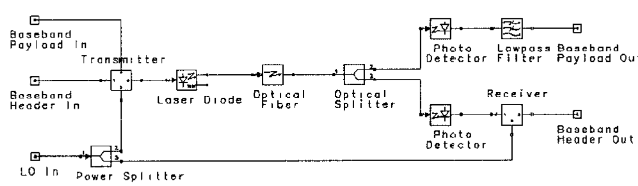
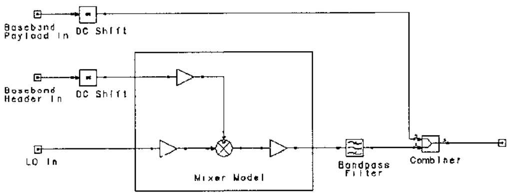


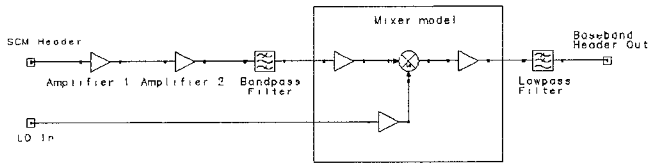
Figure 2. Experimented OSCM link



(a) Entire Link

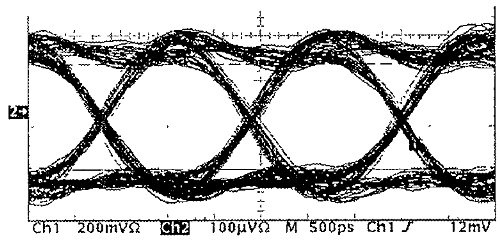


(b) Transmitter

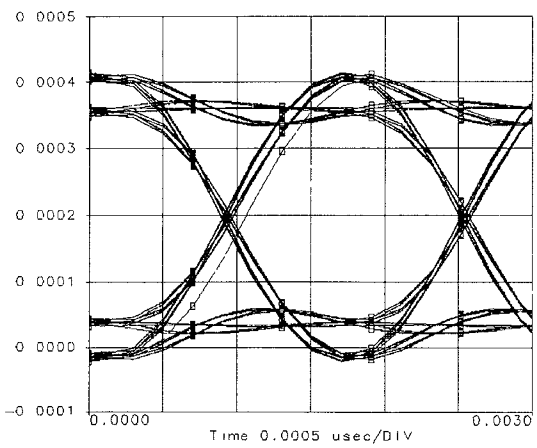


(c) Reciever

Figure 3. Simulated OSCM packet Link

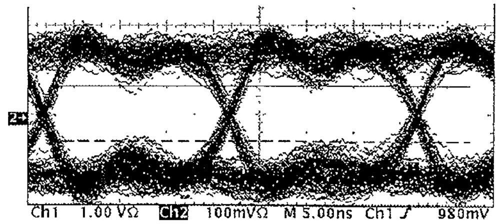


(a) Experimental Result

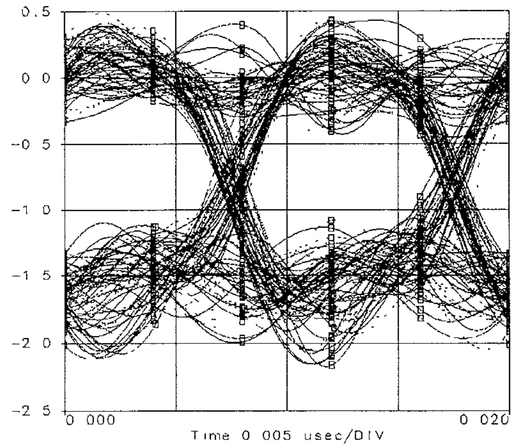


(b) Simulated Result

Figure 4. Eye Diagram of Payload Output

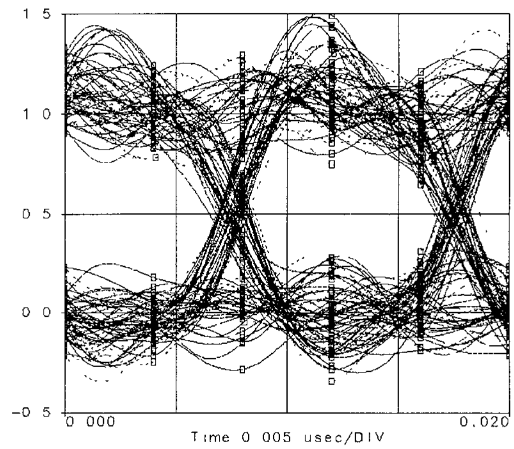


(a) Experimental Result

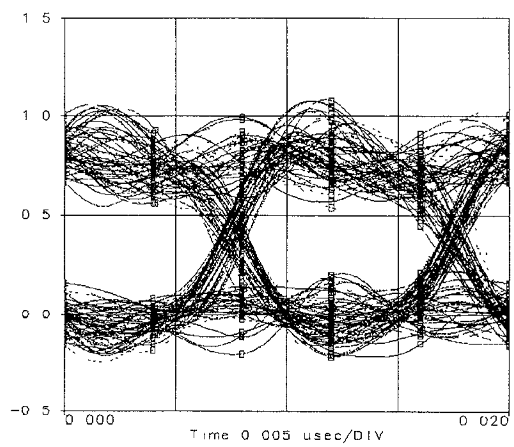


(b) Simulated Result

Figure 5. Eye Diagram of Header Output



(a) With Transmitter Mixer NF=5dB and Amplifier 1 NF=4dB, Gain =28dB



(b) With No Change in Component Characteristics

Figure 6. Eye Diagram of Header Output using 95/5 Optical Splitter