OPTIMIZATION OF RF (MMIC) /OPTICAL SUBCARRIER MULTIPLEXED COMMUNICATIONS SYSTEM

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Abstract

An accurate simulation model which provides an effective method of optimizing an optical subcarrier multiplexed (OSCM) communication network is developed and experimentally demonstrated. Effects of MMIC insertion and two types of header receiver schemes are studied, and the initial performance of MMIC components are presented.

Introduction

The objectives for building a simulation model for OSCM link are to study the effects of monolithic microwave integrated circuit (MMIC) insertion on system performance, to determine the critical design criteria in order to enhance system performance, and to study the network scaleability.

Fiber-optic networks offer the potential for very wideband flexible analog and digital communications for future network applications. Due to the large available bandwidth, multichannel communication can be supported over the fiber using wavelength division multiplexing (WDM) [1], optical subcarrier multiplexing (OSCM) [2], and combination WDM-OSCM techniques [3,4]. Out-of-band signaling using OSCM has several advantages over using WDM for the control channel. One is that the control channel remains "physically attached" to a baseband data channel over longer distances in a dispersive optical fiber. Additionally, OSCM allows for simplified header detection and processing. 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. Therefore, in order to scale networks to a larger number of nodes and longer internode distances, it is necessary to reduce the amount of signal tapped off for header detection at each node. This can be realized by improving the characteristics of RF components through MMIC insertion and by choosing efficient RF detection schemes. Additionally, the realization of MMIC components will reduce the physical size of as well as alleviate the interconnection problems of the receiver and transmitter.

Model Development

This model has been built and simulated using the Series IV communications design suit from HP-EEsof based on the experimental link shown in fig. 1. A schematic of the simulated model is shown in fig. 2. The header input going into one electrical port of the Mach-Zehnder external optical modulator (EOM) is modeled using a mixer with two inputs one being a sinusoidal signal with 5.5GHz frequency and 12dBm power and the other being a pseudo random bit sequence (PRBS) at 100Mb/s. Another input to the EOM is the 2.5Gb/s PRBS payload data which has been band limited by a 1.8GHz SONET filter modeled as a 5th order Bessel lowpass filter. The laser is modeled with laser diode components provided by Series IV. The laser diode characteristics such as the constant optical power output and its wavelength are correlated with the experimental link by changing its bias, average electron density, and data file for the laser diode. The EOM is implemented using equations which model the Mach-Zehnder transfer function and the mismatch information. The attenuator at the header route is modeled by adding its attenuation to the header portion of a 1X2 optical splitter placed after the EOM. The receiver for the payload contains a photodetector and a lowpass filter with cutoff frequency at 2.35GHz. The photodetector is modeled using an ideal photodiode and an ideal unity gain amplifier with the equivalent noise information of the photodetector. The receiver for the header includes one photodetector , two amplifiers, one bandpass filter(BPF), one schottky diode and one lowpass filter (LPF), see Fig. 2b. The amplifiers, BPF, and LPF are modeled using Series IV models. The schottky

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barrier diode is modeled using an ideal halfwave rectifier and a RF envelope detector element to implement its sensitivity.

A discrete time test bench is used to verify the simulation link performance. This test bench processes signals and noise together and outputs the transient-state signal performance [5].

Simulation and experimental results are shown in fig. 3 and fig. 4. The performance of the OSCM link modeled for the simulation can be estimated by evaluating the eye diagram of its header and payload outputs. The eye diagram opening and deviation of the high data and low data from their mean values are evaluated and compared with the experimental link in Table1. As can be seen from Table1, the simulated results agree well with experimental results. The small discrepancy between the simulated and experimental link is due to the imprecise specifications used for optical and RF components of the experimental link and differences in number of input bits.

Effects of MMIC insertion

To see the effects of MMIC insertion into an OSCM link, we apply the simulation model developed above to determine the MMIC specifications. Fig. 5 shows the simulated header output with reduced noise figure from 8dB to 2.5 dB for Amplifier 1 in the header receiver. As can be seen from Table1, the deviation from the mean at the high and low output relative to the eye opening improved from the modeled link simulated above.

In previous experimintal results [6,7], coherent detection with a down converter and an oscillator was used instead of incoherent detection with a Schottky diode. The effect of employing a mixer design for header detection is shown by the eye diagram in fig. 6 and Table1. As seen from Table 2 the simulation accurately predicts that coherent detection is superior to incoherent detection. However, incoherent detection can be implemented with a Schottky diode while coherent detection requires complex phase locking techniques.

We have designed oscillators, up and down converters and power splitters to be inserted into an OSCM network. Up and down converters and power splitters are designed in 60mil X 60mil space to realize input and output mixing of header data in a single chip. Oscillators are designed to operate at frequencies of 3, 4, 5.5, and 10GHz. These frequencies will be used to form a experimental multi-channel OSCM link. Examples of MMICs for the OSCM link are shown in fig. 7.

Summary

An accurate simulation model for a 5.5 GHz OSCM communication network has been developed. This model provides an efficient design procedure which allows the realization of entire electrical portions in MMIC as well as providing a powerful means to capture the use of MMIC in OSCM networks. Detailed experimental results of MMIC/OSCM links will be presented.

References

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This work was supported by grants from the Army Research Office's Young Investigator Award (DAAH04-95-1-0397) and the National Science Foundation Career Award (ECS-9623964). We would also like to acknowledge the processing support from TRIQUINT SEMICONDUCTOR, INC.

	Header output			Payload output		
	eye opening	deviation from mean		eye opening	deviation from mean	
		high	low		high	low
Experiment	10 mV	3.7 mV	1.5 mV	10 mV	3 mV	3 mV
Simulation (incoherent)	9.7 mV	3.2 mV	2.3 mV	12 mV	2.1 mV	2.1 mV
MMIC insertion	11 mV	3 mV	1.7 mV	-	-	-
Coherent Detection	120 mV	30 mV	35 mV	-	-	-

Table 1. Comparison of Experimental and Simulated OSCM Link Eye Diagrams and Comparison of Detector Design Impact Upon OSCM Links

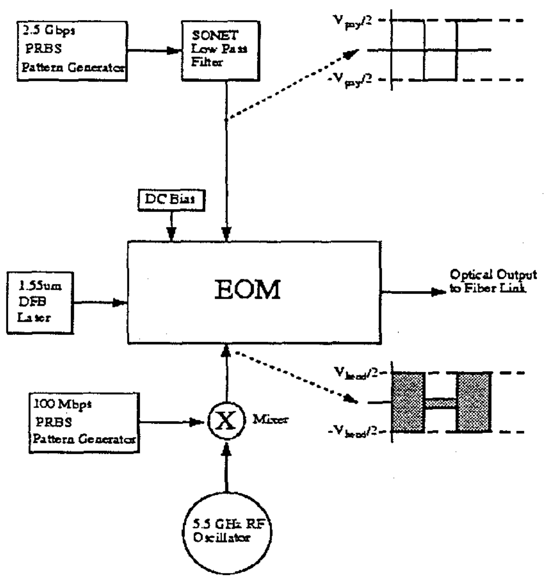

Fig. 1 (a) Experimental Link: Transmitter and EOM

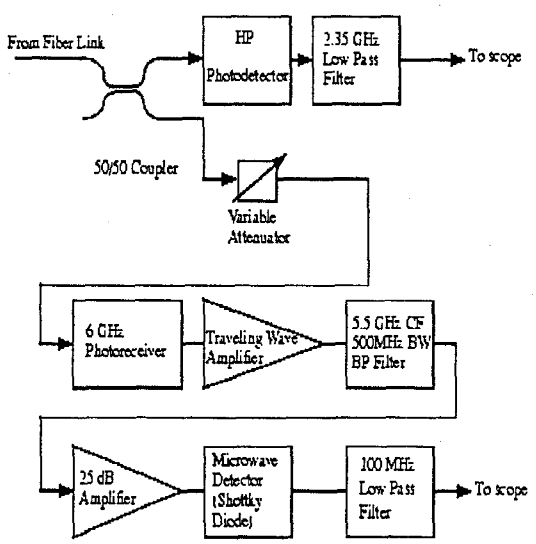

Fig. 1 (b) Experimental Link: Receiver

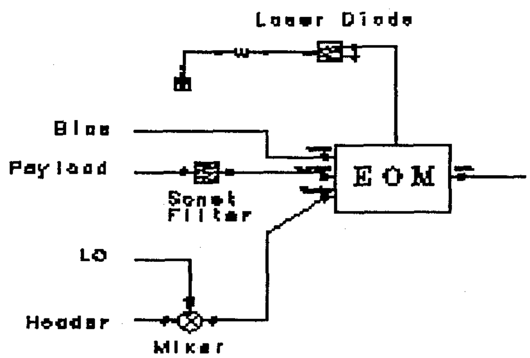

Fig. 2 (a) Simulation Link: Transmitter and EOM

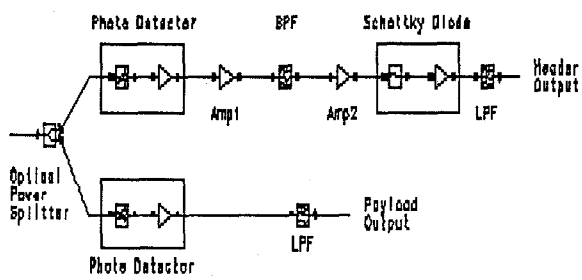

Fig. 2 (b) Simulation Link: Receiver

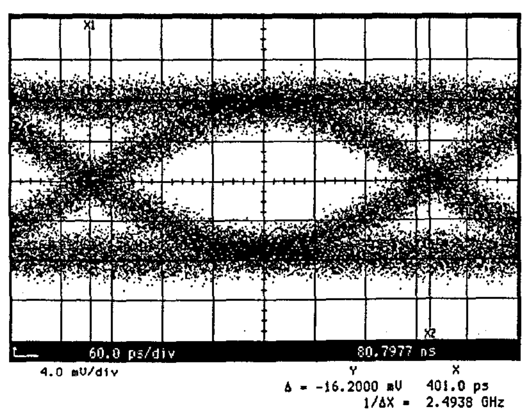

Fig 3 (a) Experimental Results: Payload eye diagram

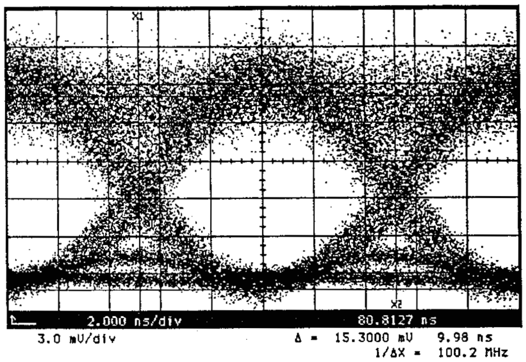

Fig 3(b) Experimental Results: Header eye Diagram

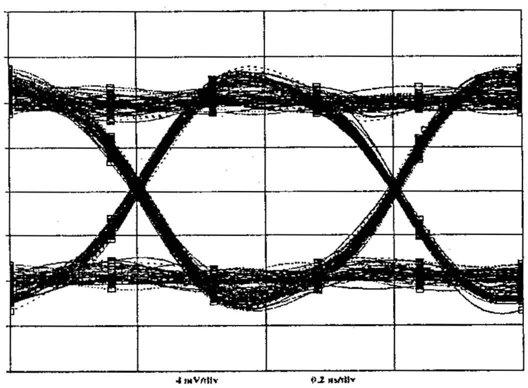

Fig. 4(a) Simulation Results: Payload eye diagram

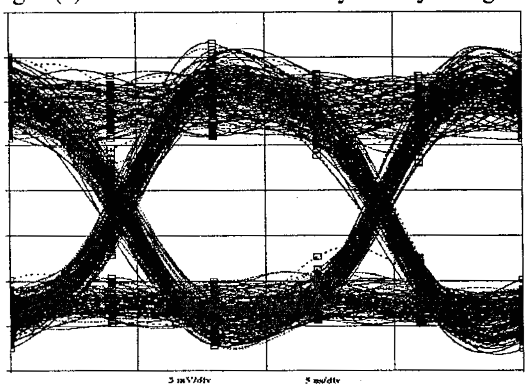

Fig. 4(b) Simulation Results: Header eye diagram

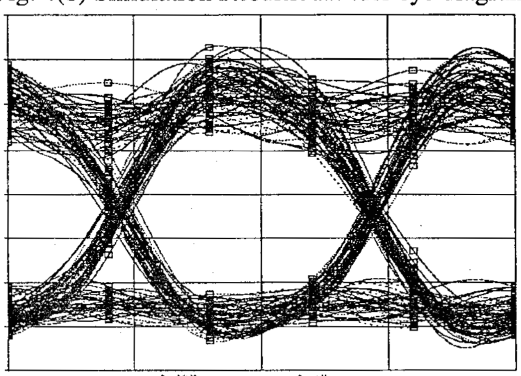

Figure 5. Header eye diagram with improved NF at AMP1

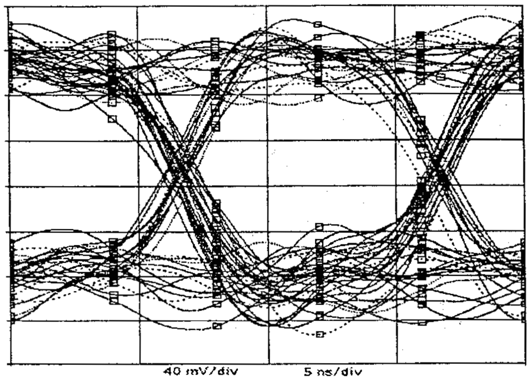

Figure 6. Header eye diagram with coherent detection scheme

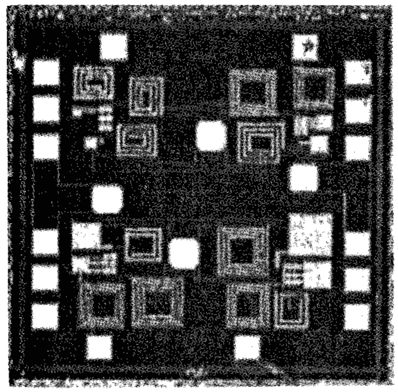

Fig. 7(a) Oscillators

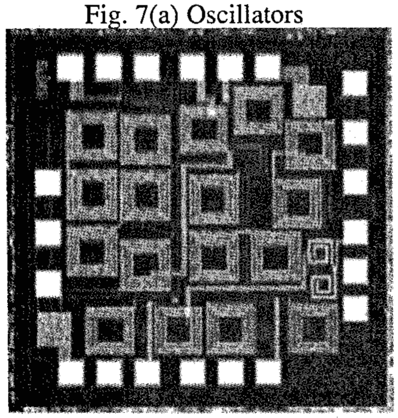

Fig. 7(b) Up and down converter and Power Splitter

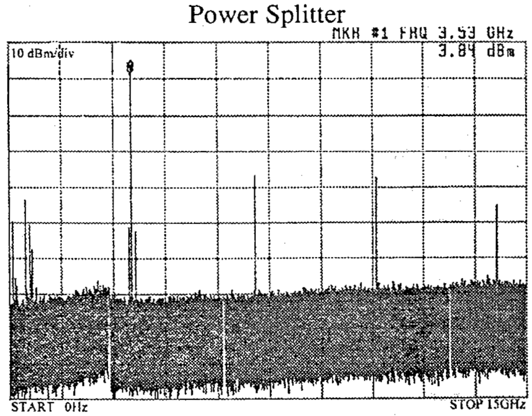

Fig. 7(c) Measured MMIC Oscillator characteristics