FOUR CHANNEL MMIC-BASED TRANSMITTER MODULE FOR RF/OPTICAL SUBCARRIER MULTIPLEXED COMMUNICATIONS

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Abstract

We present a compact four channel RF/optical subcarrier multiplexed (OSCM) transmitter module based on MMIC chipsets and coupled-line filters. The module generates four subcarriers in the 5.2 to 6GHz frequency range and supports up to 50Mbits/s data rate per channel. We present the module design and measured bit-error-rate (BER) performance of the OSCM link. This work is the first step towards fully monolithic implementation of a multi-channel OSCM transmitter module.

Introduction

Multichannel communication can be supported over the fiber using wavelength division multiplexing (WDM) [1], OSCM [2], and combination WDM-OSCM techniques [3,4]. A primary advantage of multiple channel transmission in fiber is that the network interface electronics can be operated at the individual channel rate [5]. OSCM links can support multichannel communications with a single distributed feedback (DFB) semiconductor lasers, and supports simple detection of control channels that carry control or timing information. The transmitter module consists of 4 MMIC voltage controlled oscillators (VCO) with a frequency range of 5.2 to 6GHz for subcarrier generation, 4 MMIC FET switches for amplitude shift keying (ASK) subcarrier modulation, and 4 coupled line bandpass filters to reduce interchannel crosstalk and reject baseband feedthrough. Multi-channel SCM links have been demonstrated [6-11] but to the author's best knowledge this is the first compact MMIC-based multi-channel header transmitter module developed for OSCM communications. MMIC realization is critical because of the advantages over discrete components in terms of size, interconnect losses and ease of integration. The MMIC chipsets were fabricated using Triquint semiconductor TQHiP and TQTRx GaAs MESFET processes. Their performance is demonstrated with output power spectrum and BER test results using a 50Mbit/s control channel rate.

Module Design

The OSCM transmitter module consists of two MMIC double VCOs, four MMIC switches, and four 100MHz bandpass coupled line filters on a 2"x2" ceramic substrate as shown in Figure 1. 16 SMA connectors are used for output, control channel input, and DC controls. This module generates 4 subcarrier frequencies at 5.3, 5.55, 5.75, and 6GHz. Four data inputs are used to modulate the four RF subcarriers on module. Output spurious signal and harmonics are less than –30dBc. All MMIC chipset are ribbon bonded with 75um ribbons. Modulated and non-modulated subcarrier output spectrums are shown in Figure 2.

VCO

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The Double VCO MMIC chipset consists of two identical VCOs with a buffer amplifier as shown in Figure 3(A). For both VCOs, a common gate single FET topology with a varactor diode at the source for frequency tuning is used. The frequency tuning range is 5.2 to 6GHz with an output power of 7±2.5dBm as shown in Figure 4. Harmonics are less than -20dB.

Switch

The switch MMIC chipset consists of two GaAs MESFET source-drain zero current switches in series as shown in Figure 3(B). This FET mixer topology provides low 1/f noise and low unwanted intermodulation product for high RF drive levels [12]. The data input is applied to the gate to ASK modulate the RF subcarriers generated by the VCO chipsets. The conversion loss and extinction ratio are about 5dB and 18dB, respectively, as shown in Figure 5.

Filter

Four 150MHz bandwidth five-stage coupled line filters are designed and fabricated on a 25 mil thick ceramic substrate to reduce aliasing between closely spaced modulated subcarriers and to suppress harmonics and spurious signals. The filter traces are 4um thick gold and the center frequencies of four filters are at 5.27, 5.5, 5.75, and 6GHz. Loss in the passband was 4±0.5dB and return loss is less than 10dB as shown in Figure 6.

Experimental Link Setup

The experimental back-to-back and OSCM link setups are shown in Figure 7 and 8, respectively. To reduce the network and receiver complexity associated with coherent detection techniques, direct detection schemes are used for optical to electrical conversion and RF control channel demodulation. For both test links, two coupled-line bandpass filters are designed and fabricated on a separate ceramic board for control channel selection. Then Schottky envelope detector is used with 100MHz lowpass filter to retrieve control channel information. In the complete OSCM link, outputs of the module are combined and converted to an optical signal by intensity modulation of a 1550nm wavelength DFB laser diode with a $LiNbO_3$ Mach-Zehnder (MZ) interferometer modulator. The optical signal is then converted back to an electrical signal using a photodetector.

Results

Performance of the four-channel transmitter module is measured with back-to-back and complete OSCM link BER tests with 5×10^{10} bits. All four control channel inputs are driven with a 50 Mbits/s pseudo-random bit sequence data with 2V peak-to-peak amplitude generated from three arbitrary waveform generators and BER tester. The BER is measured versus received RF power and shown in Figure 9. Series 1 show the measured result of back-to-back link and series 2 shows that of complete OSCM link. For logarithmic scale, 0 BER is replaced with 1×10^{-11} BER in Figure 9. For the back-to-back link and complete OSCM link, received RF power was varied using electrical attenuators and optical attenuators, respectively. For all four channels, better than 1×10^{-6} BER was obtained for–12dBm received RF power for back-to-back and better than 1.5×10^{-5} BER was obtained at a received optical power of –3.5dBm in the complete OSCM link. As can be seen from the BER test results, the four-channel transmitter is well suited for use in multi-channel OSCM communication link.

Conclusion

A four-channel RF/optical subcarrier multiplexed (OSCM) communication link transmitter module has been developed and demonstrated. VCOs for subcarrier frequency generation and switches for ASK subcarrier modulation are realized in MMIC form to reduce size, interconnect losses, and complexity. Four coupled-line bandpass filters are designed and fabricated on this module to suppress harmonics, spurious signals, and aliasing between adjacent channels. BER test results illustrate that this module is well suited for multi-channel OSCM transmitter and a step towards fully monolithic realization of multichannel OSCM transmitter module.

Acknowledgment

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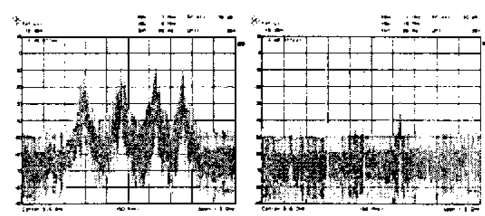
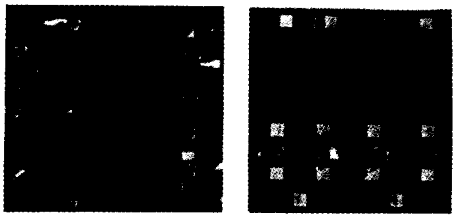
Figure 1. Picture of Designed Module



(A) Modulated (B) Non-Modulated

Figure 2. Subcarrier Output Spectrum



(A) Double VCO (B) Switch

Figure 3. MMIC Chipset

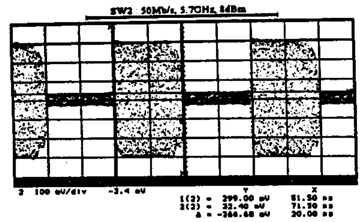


Figure 5. Modulated Output of Switch with $2V_{p\text{-}p}$ 50Mbits/s PRBS baseband and 8dBm 5.7GHz RF inputs

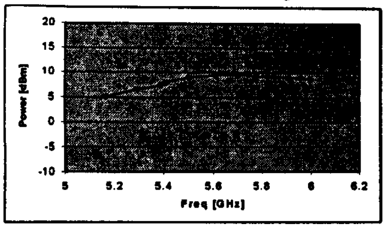
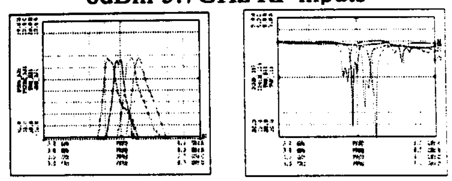


Figure 4. VCO Output Power vs. Frequency



(A) Insertion loss (B) Return loss

Figure 6 Four Coupled Line Bandpass Filter

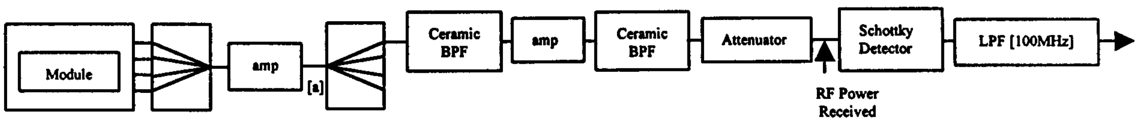


Figure 7. Back-to-Back Link Setup Diagram

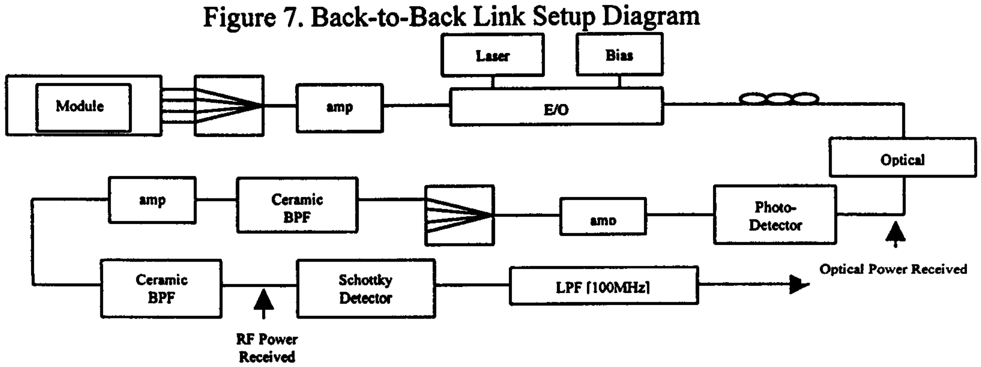


Figure 8. Complete OSCM Link Setup Diagram

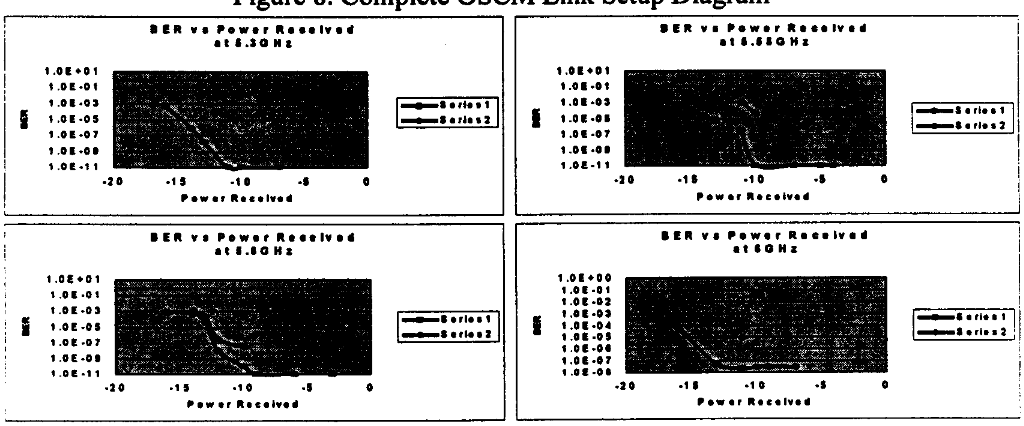


Figure 9 BER Test Results vs RF Power Received