# Fully Monolithic Four Channel Transmitter IC for RF/Optical Subcarrier Multiplexed Communications

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***Abstract*—A compact four channel RF/optical subcarrier multiplexed (OSCM) transmitter MMIC has been implemented in a commercial 0.6-$\mu$m GaAs MESFET process. The designed MMIC consists of four voltage controlled oscillators (VCO) with a frequency range of 3.8–5.5GHz for subcarrier generation and four modulators for on-off keying (OOK) subcarrier modulation. This MMIC supports up to 200 Mb/s data rate per each channel. This transmitter IC occupies a die area of $120 \times 120$ mil$^2$. We present design and characterization of the first fully monolithic four channel transmitter IC for multichannel OSCM link applications.**

***Index Terms*—MMIC, oscillator, subcarrier multiplexing.**

## I. Introduction

DUE TO the large available bandwidth of fiber-optic networks, 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]. These multichannel multiplexing techniques allow the network interface electronics can be operated at the individual channel rate [5]. Two main advantages of OSCM are 1) OSCM link requires only one terminating element, such as a distributed feedback (DFB) semiconductor laser, and a photodetector at each node; and 2) supports simple detection of control channels that carry control or timing information. However, one major problem is the complexity and the cost of the electronics.

The designed four channel OSCM transmitter MMIC consists of four voltage controlled oscillators (VCO) with buffer amplifier which can cover a frequency range of 3.8–5.5 GHz for subcarrier generation and four modulators for on-off keying (OOK) subcarrier modulation. Realization of OSCM interfaces in monolithic technology is very important because it provides circuit simplicity with improved reliability, decreased size, lighter weight, and reduced manufacturing cost compared to using hybrid technology. In addition, monolithically integrated devices have much less parasitic reactance than discrete packaged devices. Circuit flexibility and performance can also be enhanced with little additional cost since it is very easy to fabricate additional FET's in a MMIC design.

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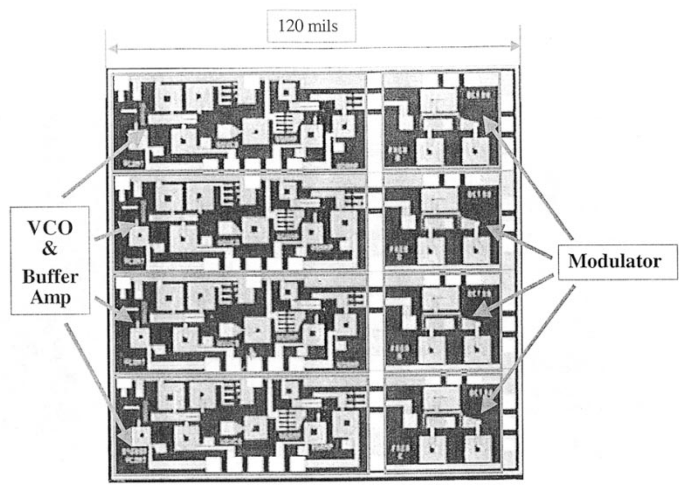


Fig. 1. Picture of four channel OSCM transmitter MMIC.

In this paper, we present the first fully monolithic four channel OSCM transmitter IC design in the TriQuint TQTRx 0.6-$\mu$m GaAs MESFET process. The developed MMIC is fully characterized and demonstrated. This work can contribute to solving major issues with the complexity and cost of multichannel OSCM network by leveraging low cost GaAs MMIC technology.

## II. Circuit Design

The fully monolithic four channel OSCM transmitter IC consists of four VCO's with buffer amplifiers for subcarrier frequency generation and four switch-type FET mixers for OOK modulation in $120 \times 120$ mil$^2$ die as shown in Fig. 1. The designed MMIC has been fabricated using TriQuint semiconductor TQTRx MESFET process. All the functionality of six MMIC chipsets used in four channel MMIC-based multichip OSCM transmitter module work [6] have been combined into this single chip. Dc power consumption has also been reduced by more than 50% from 2.1 W to 1 W. The fully monolithic implementation is critical due to great advantages over multichip solutions in terms of cost, size, interconnect losses, and ease of integration.

All four VCO's have a common gate single FET topology with a varactor diode at the source for frequency tuning as shown in Fig. 2. Depletion mode MESFET's and n$^+$ overlap diodes have been used for active devices and varactor diode, respectively. VCO's are designed to have wide frequency tuning range in order to create more than one combination of four

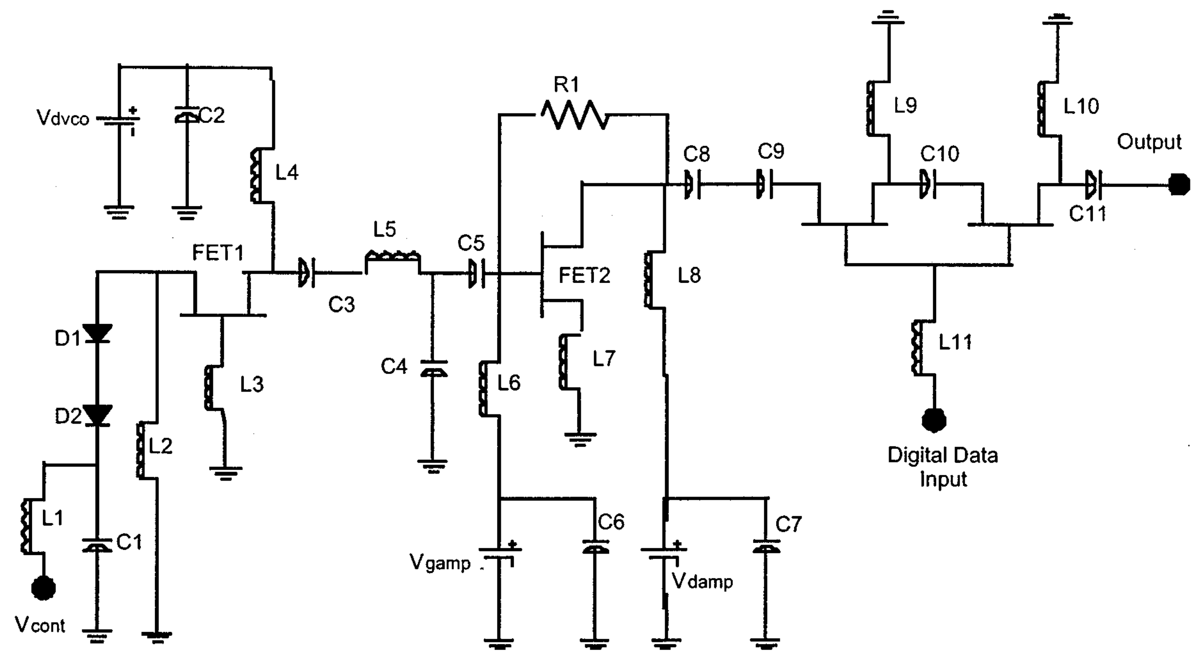


Fig. 2. Schematic of the transmitter IC.

channel transmitter with the same frequency offset between the four subcarriers. This wide frequency tuning range allows to support more than four channel OSCM link applications by using more than one designed MMIC.

The buffer amplifier is designed to facilitate better output matching and desensitize the VCO to the external load impedance. Since the VCO is followed by an OOK modulator, the external load impedance will change greatly between the on- and off-state of the modulator. A simple single-stage common source, class-A depletion MESFET amplifier, using resistive feedback, is designed for the buffer amplifier.

The modulator is a key component in upconverting the digital data onto the subcarrier. The OOK MMIC modulator consists of two GaAs MESFET switch-type FET mixer, which makes use of the gate bias dependence of the FET's channel resistance in series as shown in Fig. 2. The FET is used as a passive device and no drain bias is needed. Hence, the dc power dissipation will be miniscule. This FET mixer topology provides low $1/f$ noise and low unwanted intermodulation product for high RF drive levels [7]. It also provides good inherent isolation between the gate and source as well as between the drain and source in the off-state. The data input is applied to the gate to OOK modulate the RF subcarriers generated by the VCO in the same channel.

## III. Measurements

All four channels of the MMIC have been fully characterized. As summarized in Table I, the frequency tuning range of approximately 900 MHz with an output power of $2 \pm 2$ dBm were measured for each individual channel while the OOK modulator was in the on-state. Harmonic outputs were less than $-15$ dBc. The phase noise was measuredto be less than $-105$ dBc at 1 MHz offset. With 2 V peak-to-peak 50 Mb/s and 200 Mb/s pseudo-random bit sequence input data streams, the conversion loss and extinction ratio were measured to be approximately 7.2 dB and 20.5 dB, respectively, as shown in Fig. 3 and Table II.

TABLE I
MMIC Output Frequencies Tuning Range and Output Power

| | Frequency Tuning Range[GHz] | Power Range [dBm] |
|---|---|---|
| Channel A | 3.78 ~ 4.73 | 0.33 ~ 2.67 |
| Channel B | 3.95 ~ 4.82 | 0 ~ 3.33 |
| Channel C | 4.42 ~ 5.42 | 0.17 ~ 4.33 |
| Channel D | 4.55 ~ 5.48 | 1.33 ~ 3.83 |

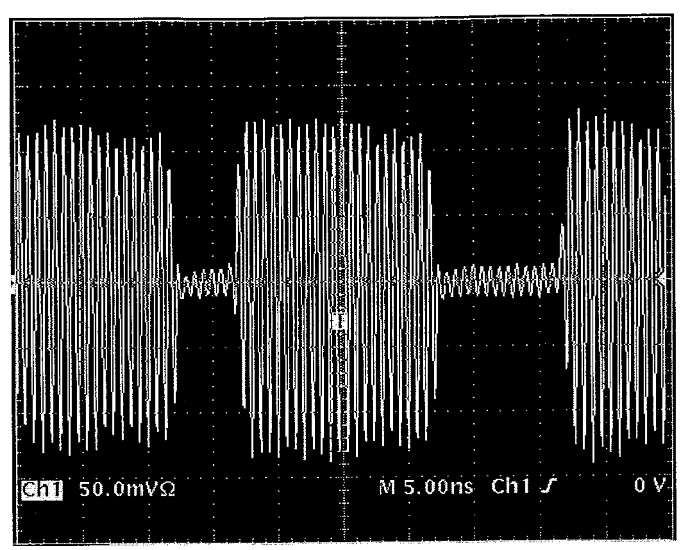


Fig. 3. OOK modulator output from oscilloscope with 200 Mb/s input.

TABLE II
OOK MODULATOR CONVERSION LOSS AND EXTINCTION RATIO VERSUS RF INPUT POWER

| RF Input Power [dBm] | 50Mb/s Data Input | | 200Mb/s Data Input | |
|---|---|---|---|---|
| | Conversion Loss [dB] | Extinction Ratio [dB] | Conversion Loss [dB] | Extinction Ratio [dB] |
| -5 | 7.22 | 20.54 | 7.22 | 20.54 |
| 0 | 7.24 | 20.93 | 7.13 | 21.04 |
| 5 | 7.15 | 20.00 | 7.15 | 20.00 |
| 8 | 7.99 | 20.81 | 8.00 | 20.80 |
| 9 | 8.10 | 20.36 | 8.10 | 20.36 |

The input 1 dB compression point of the modulator was 9 dBm, which can be calculated from Table II.

## IV. CONCLUSION

We presented the first fully monolithic four channel transmitter IC implemented in GaAs MESFET technology. This transmitter MMIC helps to reduce cost, size, complexity and power consumption of the transmitter in multichannel OSCM communication link. The measurements show that this MMIC is capable of generating four subcarriers from 3.8–5.5 GHz. It was also demonstrated that the on-chip modulator could modulate up to 200 Mb/s digital data onto each of the subcarriers. Measured characteristics show that this transmitter MMIC is well suited for multichannel OSCM communications applications.

## ACKNOWLEDGMENT

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