1X8 METAL-SEMICONDUCTOR-METAL PHOTODETECTOR AND HEMT RECEIVER ARRAY WITH 5 GHZ BANDWIDTH

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ABSTRACT

A hybrid integrated three stage HEMT amplifier with a gain of 25 dB and a bandwidth of 5.4 GHz has been designed and constructed. When reconfigurated as an optical receiver by using a linear 1x8 array of GaAs metal-semiconductor-metal photodetectors as the input, 41dBΩ of transimpedance is achieved up to frequencies higher than 5 GHz.

INTRODUCTION

Optoelectronic receiver arrays consisting of an array of photodetectors and an electrical preamplifier have found increased applications for broadband optical signal distributing, switching and processing. The receiver array consists of an array of photodetectors and a wideband preamplifier. Among the different photodetectors used, Metal Semiconductor Metal Photodetector (MSM-PD) array is an attractive candidate due to its low capacitance, simple planar structure, and easy integration with either MESFETs or HEMTs preamplifiers. MSM-PD array used as channel selectors have been demonstrated in wavelength division multiplexing (WDM) optical transmission systems and access networks [1]-[2]. The receiver array can also be reconfigurated as optoelectronic switches by simply varying the bias voltages applied to the photodetectors. An 8x8 optoelectronic switch matrix has been reported using a MSM-PD array for interprocessor switching applications [3]. With optical fiber delay line and a MSM-PD array, a tapped delay line filter has been developed [4]. Broadband variable delay line is an essential component for the phasing radar and other antenna array applications [5].

In order to perform broadband optoelectronic signal detecting, switching and signal processing, very wideband optical receiver arrays must be economically fabricated. In this paper, we present the design and construction of a 5 GHz hybrid integrated optoelectronic receiver array using a 1x8 MSM-PD array and commercially available HEMTs.

DESIGN CONSIDERATONS

A simplified circuit diagram of the optical receiver array appears in Fig.1. The photodetector array used is a 1x8 GaAs MSM-PD array with center output. The spacing between the MSM-PDs is 250 μm. The active area of each MSM-PD is 100x100 μm^2 with finger width of 1.0 μm and spacing of 3.0 μm. The output of the MSM-PD array is connected to the input side of the following preamplifier.

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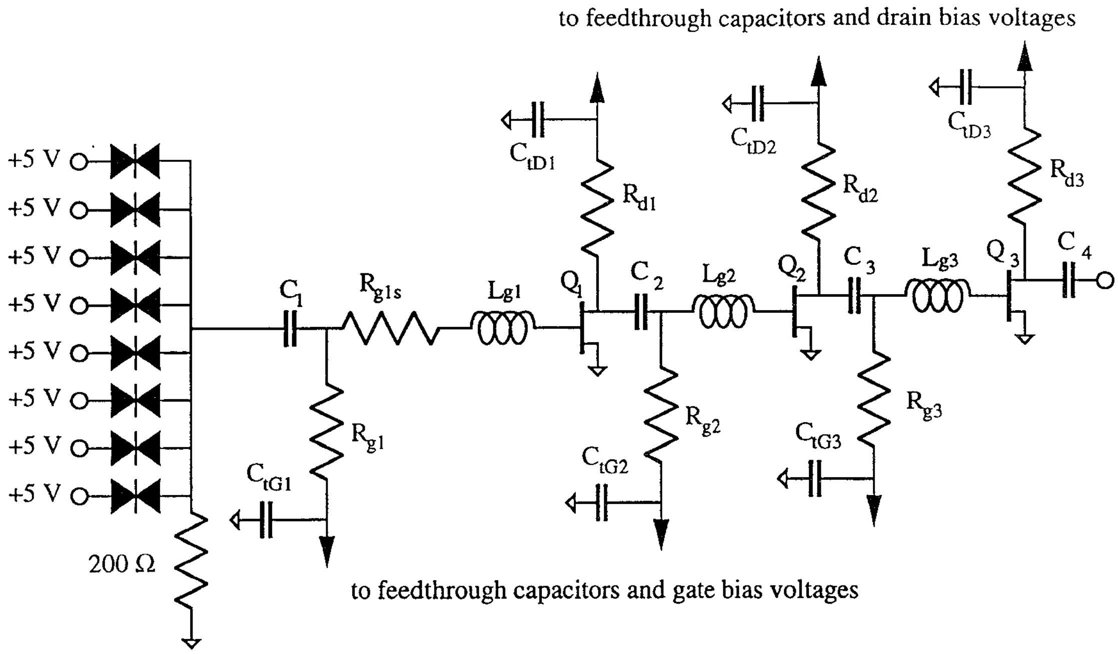

Fig.1 Simplified circuit diagram of MSM-PD and HEMT optical receiver array

In the design of the preamplifier, it was decided to use HEMT chips due to their high transconductance, low noise and wide bandwidth characteristics. The three stage preamplifier is in common source configuration. To meet the wide bandwidth requirement, peaking inductor were included at the gate of each transistor stage [6]-[7]. This relatively simple circuit topology avoids the problem of designing and constructing complicated lossless interstage impedance matching networks. Also feedback was avoided, which would have complicated the design process and possibly caused the circuit to oscillate.

By using Hewlett Packard's Microwave Design System simulation software, the resistor values and three gate peaking inductor values were found to meet flat gain and wideband goals of either the optical receiver array or the preamplifier. The resistors and the capacitors provide a simple interstage impedance matching as well as the flexibility necessary to make the circuit perform as both an electronic preamplifier and an optical receiver. The chip transistors, resistor and capacitors and peaking inductors consisting of 1.25 mil diameter bond wire pairs are all assembled on an alumina substrate and interconnected by 50 ohm microwave traces.

MEASUREMENT RESULTS

Initially, the circuit was assembled and tested only as an electronic amplifier. In this configuration, which initially assembled and tested using the optimal resistor and inductor values determined during the design, the gain measurement didn't result in the desired flat response. However, by adjusting a few of the passive component values, 25 dB of gain with less than 0.75 dB of ripple was achieved, with 3 dB down upper frequency point of 5.4 GHz. The low frequency 3 dB roll-off occurs at about 2 MHz, due to the 1 nF coupling capacitors. Linear phase response was also obtained in the frequency range of interest. The measured amplitude and phase responses of the amplifier are shown in Fig.2 (a) and (b), respectively.

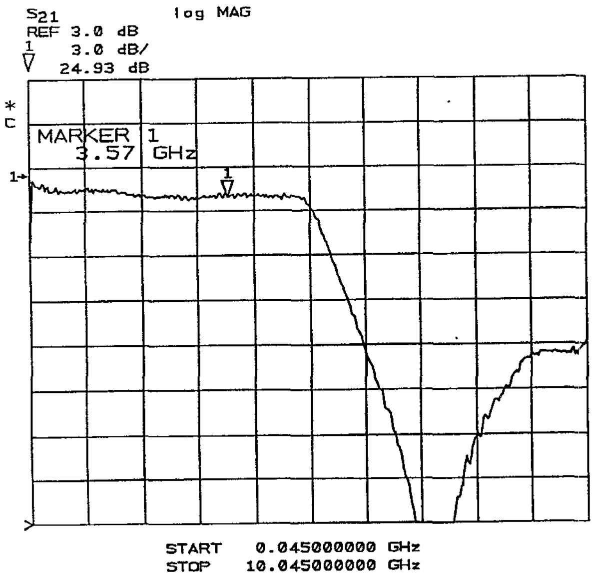

Fig.2(a) Measured amplitude of S_{21} of the preamplifier

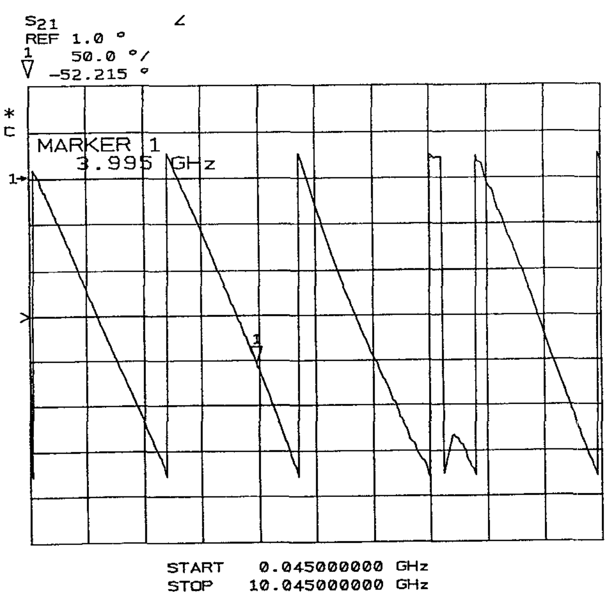

Fig.2(b) Measured phase of S_{21} of the preamplifier

The electronic amplifier was converted into an optical receiver array when the 1x 8 linear array of GaAs MSM-PDs was placed at the amplifier input. The amplifying section was reconstructed with the resistor and inductor design values which would result in a flat gain and wide bandwidth for this circuit configuration. The experimental set-up for testing the optical receiver array is shown in Fig.3. A CW 835 nm laser source was externally modulated by a Mach-Zehnder modulator driven by an amplified signal from port 1 of an HP 8510B network analyzer. Light output from the modulator illuminated an MSM-PD biased at 5 V, and port 2 of the network analyzer was connected to the output of the receiver. An optical power meter was used to measure the optical power incident on the MSM-PDs.

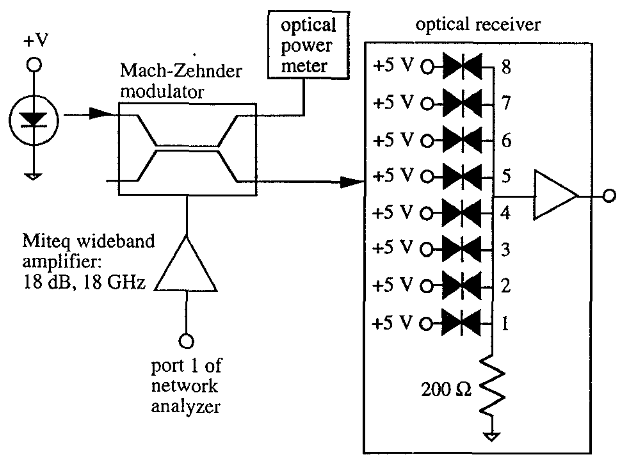

Fig.3 Experimental set-up for optical receiver array measurement

Again, some changes to passive component values had to be made before the frequency responses shown in Fig.4 was obtained. Each of the seven traces represent the frequency response of the optical receiver array with each of the functioning MSM-PD biased and illuminated in turn. The approximately 15 dB gain exhibited by this test set-up corresponds to about 41 dBΩ of transimpedance. The traces exhibiting the highest peak and lowest valley at 5.0 to 4.7 GHz, respectively, result from illuminating the MSM-PDs at the ends of the array, and the one trace that starts lower than the rest is due to a slight misalignment between the output fiber of the Mach-Zehnder modulator and the MSM-PD.

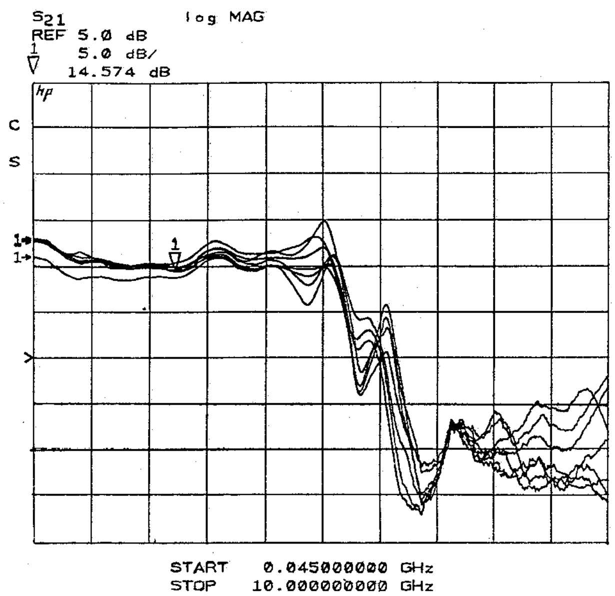

Fig4. Measured gain spectra of the optical receiver array with each of functioning MSM-PDs

This receiver array exhibits about 3 dB of gain ripple up to just over 5 GHz as shown in Fig.4. Up to 10 Gbit/s optoelectronic switching and signal processing should be realizable. The possibility that the electronic amplifier can be reproduced and used to reliably amplify a 10 Gbit/s signal is illustrated in Fig. 5. This simulated 10 Git/s eye diagram was calculated from the measured frequency response of a similarly constructed electronic preamplifier, which had a gain of 24.5 dB with 1 dB of ripple, and 3 dB down upper frequency of 5.1 GHz.

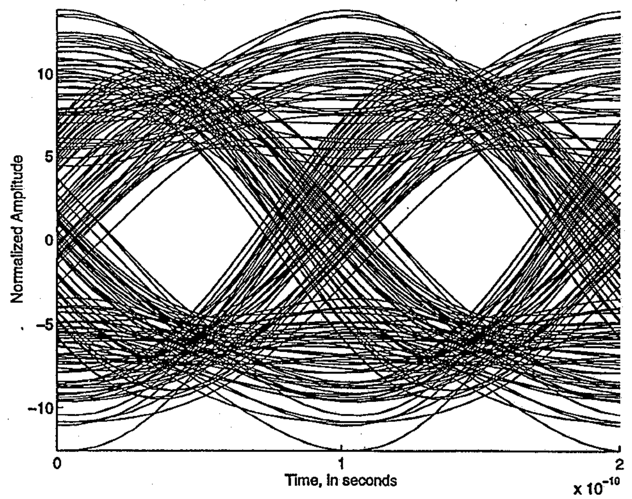

Fig.5 Simulated 10 Gbit/s eye diagram for the preamplifier

REFERENCES

[1] G.K. Chang et al, "A novel electronically switched four channel receiver using InAlAs-InGaAs MSM-HEMT technology for wavelength division multiplexing systems," *IEEE Photonics Technology Letters*, Vol. 3, No. 5, pp. 675-677, 1991.

[2] F. Tong et al, "A four-channel monolithic optical/electronic selector for fast packet-switched WDMA networks," *IEEE Photonics Technology Letters*, Vol. 6, No. 1, pp. 68-70, 1994.

[3] S.R. Forrest et al, "A simple 8 x 8 optoelectronic crossbar switch," *Journal of Lightwave Technology*, Vol. 7, pp. 607-616, 1989.

[4] B.E. Swekla et al, "Optoelectronic transversal filter," *Electronics Letters*, Vol. 27, No. 19, pp. 1769 - 1770, 1991.

[5] I. L. Newberg et al, "Long microwave delay fiber optic link for radar testing," *IEEE Trans. on MTT*, Vol.38, No. 5, May 1990, pp. 662-664.

[6] K. E. Alameh et al, "Tuned optical receivers for microwave subcarrier multiplexed lightwave systems," *IEEE Trans. on MTT*, Vol.38, No.5, May 1990, pp. 546-551.

[7]Q. Z. Liu, "Unified analytical expressions for calculating resonant frequencies, transimpedances, and equivalent input noise current densities of tuned optical receiver front end," *IEEE Trans. on MTT*, Vol.40, No.2, February 1990, pp. 329-337.