DIRECT DIGITAL MODULATION INTRODUCED VIA OPTICALLY-CONTROLLED GAPS IN ACTIVE MMIC on GaAs.

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ABSTRACT

An application of optically controlled gap integrated in an active MMIC is presented. The gap, inserted in a feedback amplifier, can optically modulate the active device. This topology could reduce the design complexity of digital wireless communication systems.

1. INTRODUCTION

Monolithic Microwave Integrated Circuits (MMIC) are very used in Wireless Digital Communication Systems because of the increase of the propagating frequency. Digital modulation is generally introduced via modulating circuits which cause degradation and losses on the modulating signal. Direct modulation introduced by optical technique is better suited for rapid wireless communication systems because of the poor losses and the very large modulation signal band-pass.

We present, in this article, a direct digital modulation introduced by a laser diode lightening a gap designed on a GaAs substrate. This gap can be integrated on an active MMIC like an amplifier or an oscillator which operates at RF frequencies. This kind of topology suppresses the modulating circuit, reducing design cost, consumption and dimensions.

2. OPTICALLY CONTROLLED GAPS : MODELLING AND EXPERIMENTAL RESULTS

The structure of the gap is realized on a GaAs substrate of 200 µm thickness and in a microstrip technology (figure 1). Illumination of this structure by an adequate laser diode creates a conductive plasma in the GaAs substrate between the two 50Ω-lines and increases the transmission of the microwave signal across the gap. These optically controlled microwave structures offer many advantages [Simons and Bhasin (1)] and have been investigated first on silicon substrate. The applications are numerous like switching, phase shifting or modulation [Haidar (2)].

2.1. Modelling

The microstrip gap has been modelized both by electrical and electromagnetic simulations [Merrar et al (3)] and on the ON and OFF states. Due to the particular GaAs technology, the electrical model, based on measurement results on a vectorial network analyzer (VNA) from 0.1 to 40 GHz, is presented on the figure 2. The numerical values of the equivalent circuit components depend on the dimensions of the gap, principally the length which has four different values : 20, 50, 100 and 200 µm.

2.2. Experimental Results

The gap is lightened with an AlGaInP laser diode of 671 nm length-wave coupled to an optical fiber. The maximum power level at the output of the fiber is about 140 mW.

Due to the high-pass response of the microstrip gap, the experimental results showed that gaps produce better ON/OFF ratios at low frequencies than at high frequencies (figure 3). The best ON/OFF ratio has been obtained with the 50 µm-length gap on the entire test frequencies band. This result can be attributed to the intrinsic structure of the gap.

Indeed, a large gap presents a strong isolation between the input and the output. So, the lightening spot of the laser diode (100 µm typically) is smaller than the length of the gap and the transmission gain is not optimal. If the spot covers the entire active region of the gap, the plasma zone is generated between the two electrodes and they are electrically connected : the transmission gain is better. If the gap length is too small, the optical reflections on the two metallizations of the gap are strong and the optical losses, too [Gevorgian (4)]. So, a length of 100 µm for a gap is an appropriate value for our applications.

3. ANALOG MODULATION ON PASSIVE GAPS

Introducing analog modulation via laser diode DC-polarisation, we can show that the modulation is transmitted to the microwave signal which propagates across the gap.

The demonstrating circuit is represented on the figure 4. A CW microwave generator is connected at the input of the gap. A spectrum analyzer on the output visualizes the modulated microwave signal. The generator frequency is 20 GHz and the amplitude modulation frequency is 100 kHz.

Figure 5 shows the measured modulating spectrum at the output of the optical fiber and the measured modulated microwave spectrum at the output of the gap. The AM modulation is recuperated on the microwave signal with an attenuation of the carrier frequency introduced by the frequency response of the gap.

An higher modulation frequency than 500 kHz cannot be introduced on the optical signal because of the cut-off frequency of the DC-polarisation circuit of the laser diode.

4. DIRECT DIGITAL MODULATION ON ACTIVE AMPLIFIER MMIC

Digital modulation at higher frequency can be introduced via optical illumination on the microstrip gap. A cut-off frequency can be very high due to the large frequencies band of both the microwave gap and the laser diode.

Electrical simulations, using envelope method [Yap (5)], of a microwave gap supplied to a digital modulated optical signal has been performed. The equivalent photoconductance has been submitted to an amplitude modulation, synthesizing the physical phenomenon (figure 6). These simulations showed no cut-off frequency of the modulated signal (until 1 GHz) and better results at low microwave frequencies (from 0.5 to 10 GHz).

These encouraging results determined the design of a feedback amplifier at 24 GHz in coplanar technology on GaAs. The CPW gap is introduced between the gate and the drain of a 0.15 µm-HEMT. Adaptative cells have been calculated on the input and the output of the transistor at 24 GHz. The envelope simulation results showed an amplified AM modulated microwave spectrum at the working frequency (figure 7). Other active function can be designed introducing modulated signal via optically controlled gap, like oscillator.

5. CONCLUSION

Rapid digital modulation is well dedicated to wireless applications such as ISM bands like 24 GHz. Due to his high-pass response, a gap is well suited for this application. The modulating frequency could be very high because of the large frequencies response of the laser diode, too. But, the ON/OFF ratio of the gap at the carrier frequency is important : the gap is an attenuator when the light is off and a transmitter when the light is on. So, the carrier frequency should be selected with this criterion.

Envelope simulations on a commercial software showed that high digital modulation applying by optical controlled gap integrated on an active MMIC has good performances. This concept could be introduced both in microstrip and CPW technologies and in various substrates like GaAs, Si and InP.

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(4) S.S.Gevorgian, "*Design Considerations for an Optically Excited Semiconductor Microstrip Gap at Microwave Frequencies"*, IEE-Proceedings-J, vol.139, n°2, pp. 153-157, April 1992.

(5) H.S. Yap, "*Designing to Digital Wireless Specifications Using Circuit Envelope Simulation*", Applied Microwave and Wireless Magazine, June 1998, pp. 84-89.

FIGURES :

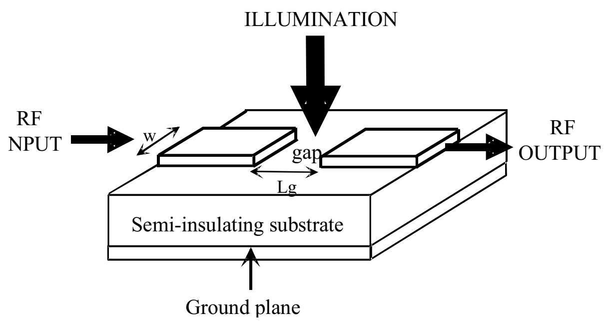


Figure 1 : Illumination of a photoconductive microwave gap.

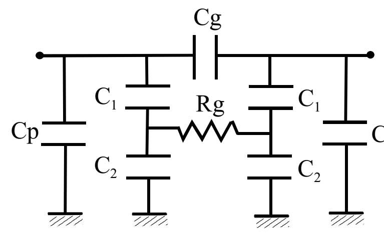
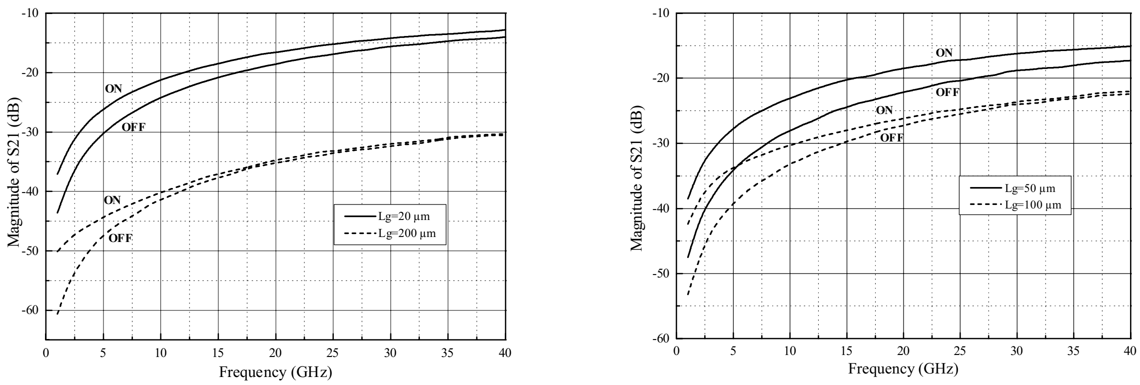


Figure 2 : Electrical model of the lightened microwave gap.



(a) 20 and 200 µm-length gaps

(b) 50 and 100 µm-length gaps

Figure 3 : Measured responses of microwave gaps on ON and OFF states.

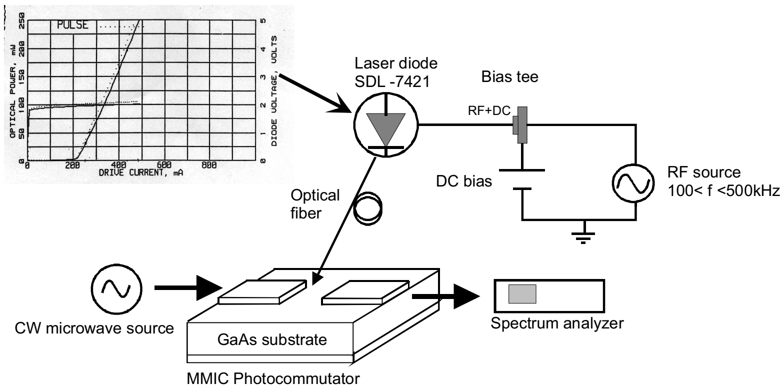
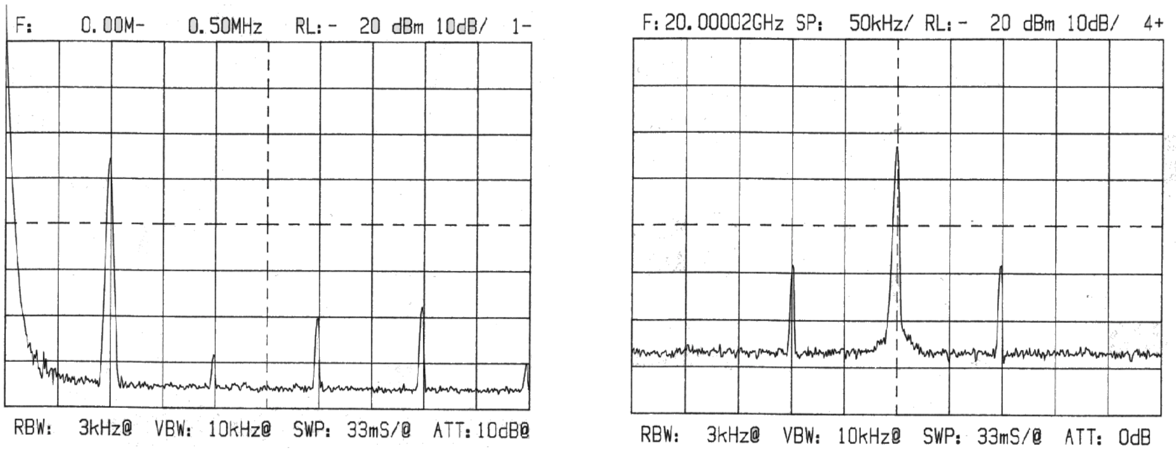
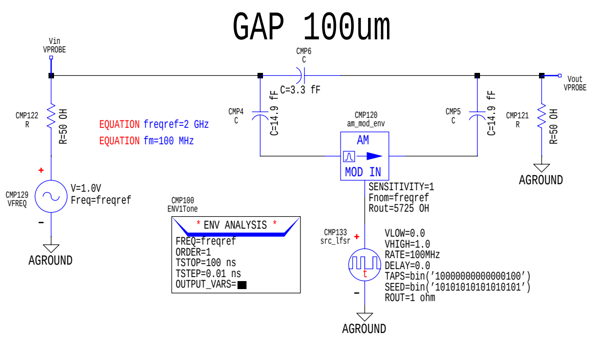


Figure 4 : Synoptic of AM optically modulated gap.



(a) optical spectrum *(b) gap output microwave spectrum*

Figure 5 : Measured modulated spectrums.



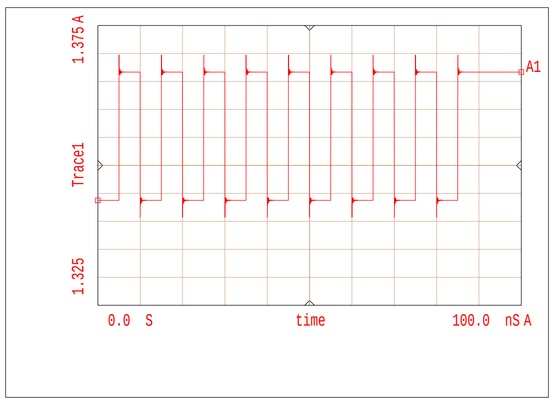


Figure 6 : Envelope circuit simulation of the optically modulated microwave gap.

Figure 7 : Amplifier output AM modulated signal obtained by envelope simulations.