A NEW OPTICAL-MICROWAVE DOUBLE MIXING METHOD

T. Berceli, G. Járó

BME-MHT, Technical University of Budapest, Department of Microwave Telecommunications
H-1111 Budapest, Goldmann György-tér 3, Hungary, Fax: (36)-1-463-3289,
e-mail : berceli@nov.mht.bme.hu, jaro@nov.mht.bme.hu

ABSTRACT

High sensitivity reception is a crucial problem of optical communications. A significant improvement is obtained by a new approach applying a double optical-microwave mixing method for this purpose. The new approach provides 20 dB higher mixing product in a narrow band.

INTRODUCTION

The commonly used optical receivers apply mainly photo-diodes to detect the optical intensity modulated signal. A relatively high sensitivity is achieved by properly matched transimpedance or distributed amplifiers [1].

In another method the modulated optical signal is mixed with a microwave signal in the photodiode producing an intermediate frequency signal [2]. Thus, heterodyne type reception is feasible [3,4]. However the mixing conversion has a higher loss compared to the direct detection.

In the new double optical-microwave mixing approach the conversion loss is much less than that of direct detection offering a significant improvement in the reception sensitivity. The mixing product is even further increased by resonance enhancement providing 20 dB improvement in comparison to direct detection

DOUBLE MIXING PRINCIPLE

The new method utilizes simultaneously two effects : a direct and an indirect mixing of the modulated optical signal and the microwave local oscillator signal. For direct mixing the bias is chosen close to the zero voltage where the photo current is highly dependent on both the illumination intensity and applied voltage. Therefore the mixing product is high. At the same time a detection of the optical signal is also obtained which produces a detected signal in the baseband. If this signal is reflected back to the photodiode it will also be mixed with the microwave local oscillator signal. Thus the output signal is the resultant of two mixing procedures : an optical-microwave and an electrical mixing (after optical detection).

EXPERIMENTAL SETUP

The new double mixing approach is experimentally presented utilizing a 1A358 type CATV PIN photodiode. The setup of the optical-microwave circuit is shown in Fig. 1.

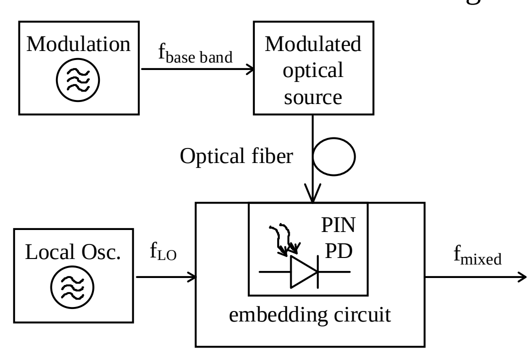

Figure 1. Optical-microwave mixing setup

The embedding circuit can be optimized for detection or mixing. The d.c. characteristics of the PIN photodiode is shown in Fig. 2. Here the detected photocurrent is plotted as a function of the bias voltage for different illumination intensities.

As seen close to the zero voltage bias point the curvature of the characteristics exhibits a maximum [5,6,7]. At this bias voltage the dependence of the photo-current on the light intensity is also maximum. This coincidence ensures the high mixing product in the double mixing approach.

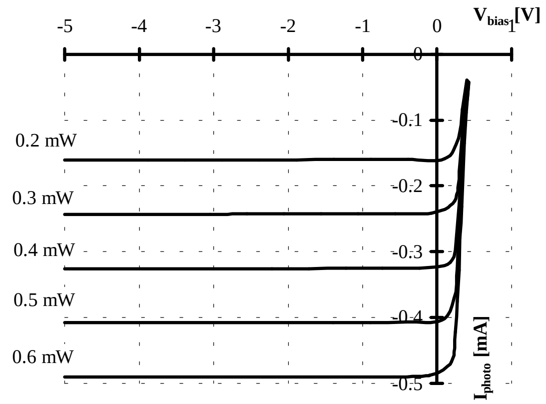

Figure 2. Measured DC characteristic of the pin photodiode (parameter is the incident optical power)

The PIN photodiode is embedded into a microwave circuit (Fig. 1) where the detected baseband signal is reflected. The photo diode is driven by a microwave local oscillator signal and at the same time it is illuminated by an intensity modulated optical signal. The result is presented in Fig. 3.

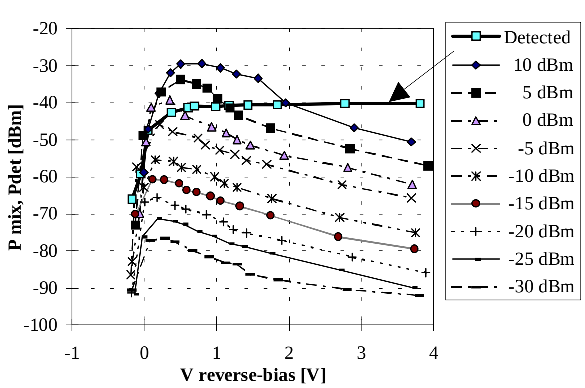

Figure 3 Measured power level of the upconverted signal versus the reverse bias voltage (parameter is the LO power)

Here the mixing product is depicted as a function of the bias voltage. The frequency of the applied local oscillator was 3 GHz and the modulation frequency of the intensity modulated optical signal was 540 MHz. As seen, about 10 dB mixing gain can be achieved biasing the photodiode close to zero voltage.

RESONANT ENHANCEMENT

For further improvement the resonant enhancement method is utilized. The baseband and the microwave band are separated by a branching filter as shown in Fig. 4.

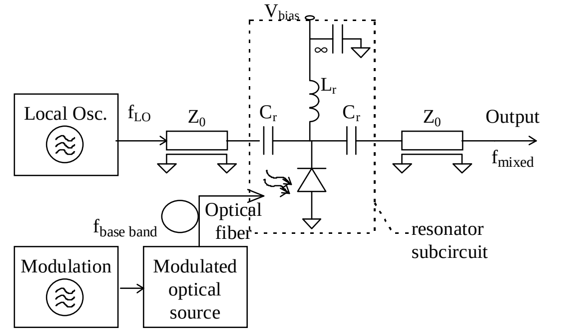

Figure 4 Measurement setup for resonant mixing using a "transmission setup"

The reflection in the baseband can be adjusted using a sliding short circuit (varying inductance). This way the mixing product is enhanced in a narrow band. The spectrum of the upconverted signal is plotted in Fig. 5.

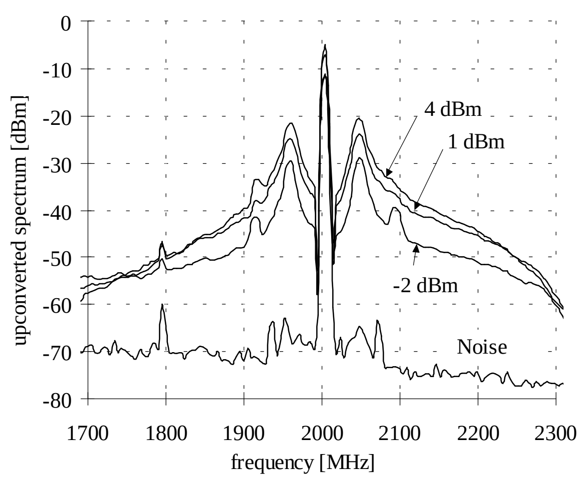

Figure 5 Measured power level of the upconverted signal (parameter is the LO power) (transmission setup)

The frequency of the local oscillator is 2 GHz, the photodiode is biased at -0.2 V (optimum for mixing) and the series capacitor is 4.7 pF. With these settings there is a resonant peak around 50 MHz as shown in the figure.

The resonance can be measured at baseband too. The measured detected spectrum at baseband is shown in Fig. 6 at different bias voltages. The peak of the detected spectrum is only an attenuated signal after the series capacitor (high pass filter) of the resonator.

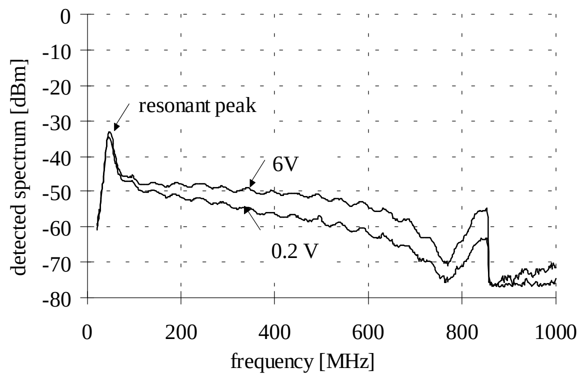

Figure 6 Measured power level of the detected signal in resonant condition (parameter is the reverse bias voltage)

For comparison Fig. 7 shows the upconverted spectrum using the same configuration setup without resonator subcircuit (Fig. 4). In this case the embedding circuit (Fig. 1) was optimized for detection. Comparing the curves of the Figs. 5 and 7 the effect of the resonant can be seen.

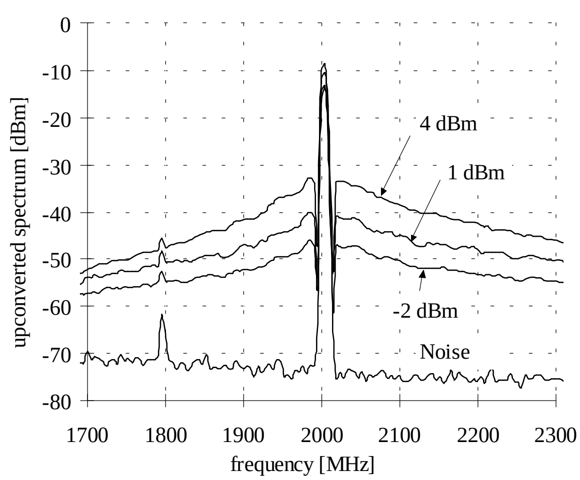

Figure 7 Measured power level of the upconverted signal without resonator (parameter is the LO power)

Without the resonant circuit the detected signal in the baseband is shown in Fig. 8. The parameter of the curves is the reverse bias voltage changed between 0 to 6 V (from the mixing optimum to the detection optimum).

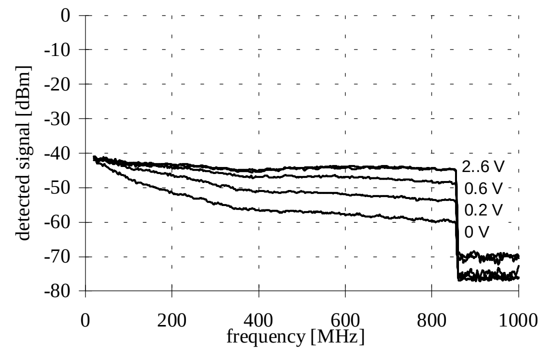

Figure 8 Measured power level of the detected signal (parameter is the reverse bias voltage)

Comparing Figs. 5 and 8 the mixing product is 20 dB higher than the directly detected signal. That is a very significant improvement. The 3 dB bandwidth of the resonance is about 14 MHz.

A resonant mixing using a reflection arrangement was also investigated. The measurement setup is shown in Fig. 9. The circulator separates the local and the mixed signal. In this construction only one capacitor is needed in the resonator.

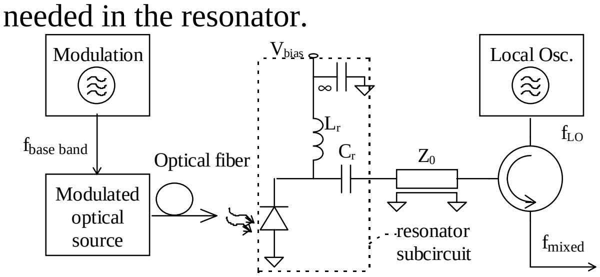

Figure 9 Measurement setup for resonant mixing using a “reflection setup”

Fig. 10 shows a typical upconverted spectrum, where the resonance is set at 105 MHz. The series capacitance is 4.7 pF and the photodiode bias voltage is -0.2 V as it was set in the “transmission setup”. The measured results show again about 20 dB gain compared to the detected baseband signal.

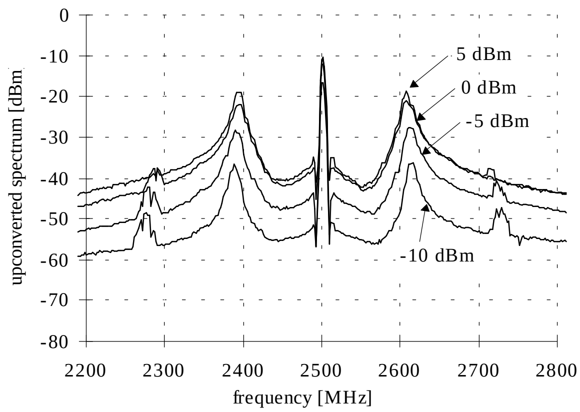

Figure 10 Measured power level of the upconverted signal (parameter is the LO power) (reflection setup)

Mixing of lightwaves and microwaves offers new perspectives for the reception of subcarrier multiplexed optical signals. The received signal can be selected more easily and more efficiently thus the receiver is significantly simplified [8]. In the presently used arrangements the subcarrier channel is selected utilizing either a tunable electrical filter or a tunable electrical local oscillator along with an electrical mixer after direct photodetection.

The new method applying double optical-microwave mixing presented in this paper is very promising because it produces an upconverted signal in a narrow band 20 dB higher than the directly detected signal. Applying this new mixing process the desired subcarrier frequencies can be selected easily by changing the resonance frequency of the electrical resonator.

CONCLUSIONS

Some experimental constructions were investigated for optical-microwave mixing method. A significant increase in the received signal is obtained by applying the new optical-microwave double mixing approach. In a narrow band 20 dB higher mixing product is obtained. The new method can be advantageously used for the reception of subcarrier multiplexed optical signals.

REFERENCES

[1] H. Ogawa, S. Banba, E. Suematsu, H. Kamitsuna, D. Polifko : "A comparison of noise performance between a PIN diode and MMIC HEMT and HBT optical receivers", June 1993, Atlanta, USA, IEEE MTT-S International Microwave Symposium digest, vol.1, pp. 225-228.

[2] Q.Z.Liu, R.Davies, R.I.MacDonald : "Experimental Investigation of Fiber Optic Microwave Link with Monolithic Integrated Optoelectonic Mixing Receiver", September 1995, IEEE Trans. on Microwave Theory and Techniques, vol.43, No 9, pp. 2357-2360.

[3] A. Paolella, S. Malone, T. Berceli and P. R. Herczfeld : "MMIC Compatible Lightwave-Microwave Mixing Technique", March 1995, IEEE Trans. on Microwave Theory and Techniques, vol.43, pp. 518-522.

[4] T. Berceli, B. Cabon, A. Hilt, G. Járó: "Improved optical-microwave mixing process utilizing high-speed photo-diodes" 26th European Microwave Conference Proceedings, Vol. 1, pp. 125-129, Prague, Czech Republic, September 1996

[5] G. Járó, T. Berceli, A. Hilt, A. Zólomy : "New optomixer surpassing photodetection at microwaves", technical digest of International IEEE MTT-S Topical Meeting on Microwave Photonics, pp.143-146, Duisburg, Germany, September, 1997.

[6] K .J. Williams, R. D. Esman, M. Dagenais : "Nonlinearities in p-i-n Microwave Photodetectors", January 1996, Journal of Lightwave Technology, vol.14, No.1, pp.84- 96.

[7] T.Berceli, B.Cabon, A.Hilt, A.H.Quoc, É.Pic and S.Tedjini: "Dynamic Characterization of Optical-Microwave Transducers", May 1995, Orlando, Florida, USA, IEEE MTT-S International Microwave Symposium digest, vol.3, pp. 1295-1298.

[8] T. Berceli : "A new optical reception method using microwave subcarriers", 24th European Microwave Conference Proceedings, pp. 1679-1684, Cannes, France, September 1994.