12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

10A1-5

Properties of Optical Modulator Cascade for Multi-Channel Transmission Systems

Koji Kikushima and Toshihito Fujiwara

Access Network Service Systems Laboratories, NTT, 1-6 Nakase, Mihama-ku, Chiba-shi, Chiba, 261-0023 Japan
e-mail: kikushima.koji@ansl.ntt.co.jp

Abstract: **This paper reports the properties of an optical modulation scheme that uses cascaded external modulators. Calculations show that modulation properties are improved by converting input signal frequency and format prior to optical modulation.**

I. Introduction

We recently reported that cascaded modulation offers better modulation properties than the conventional single modulation approach for multi-channel transmission systems [1]. In the previous paper, we applied the FM and RF conversion to the multi-channel signals prior to modulation.

This previous paper, however, did not fully elucidate the effect of FM and RF conversion on the performance of the cascaded modulation scheme. We rectify this omission by calculations that compare the modulation properties with and without FM and RF conversion.

II. Calculations

The calculations considered the following setups. Fig.1 shows the schematic diagram of the optical modulator and modulation signal frequencies. Fig.1 (a) and (b) are for the test without and with FM and RF conversion, respectively.

FM and RF conversion altered the frequency plan and signal format of the input multi-channel signals as follows.

Input signals, 40 AM and 30 64-QAM CATV (from 91 to 770MHz) signal carriers, were converted into a single wideband FM signal (from 0 to 6GHz) by the FM converter [2]-[3]. This FM converted signal was input to the first EA modulator with optical modulation depth m_1 of 90%.

Pre-emphasis was applied to signal #1 in FM conversion in compliance with recommendation ITU-T J.185 [4] to compensate the triangle noise. Frequency deviation per carrier was set according to Eq. (1).

$$f_{deviation} = 70 \times 10^{\frac{12.9\cdot(f-47)}{16340}} \times 10^{\frac{Vin-85}{20}} \qquad (1)$$

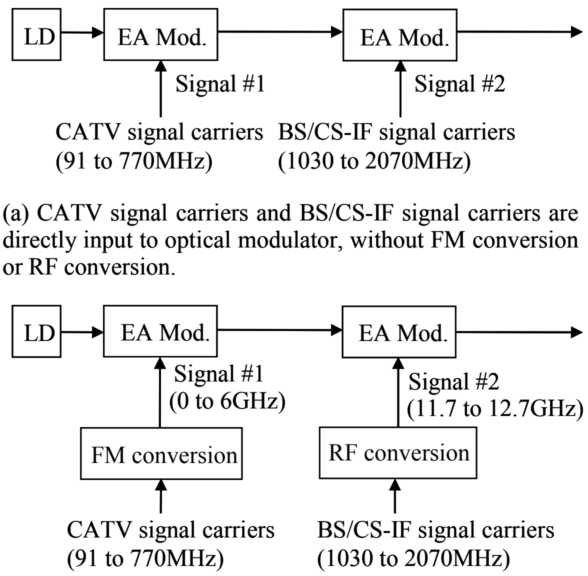
Here, $f_{deviation}$ is the frequency deviation per carrier [$MHz_{0\text{-}p}$/carrier], f is the carrier frequency [MHz], and V_{in} is the signal voltage level input to the FM converter [dBμV/carrier]. In the experiment, the signal voltage level input to the FM converter was 85dBμV/carrier for AM signal and 75dBμV/carrier for 64-QAM signal. Frequency deviation was 126.7$MHz_{0\text{-}p}$/carrier for the highest frequency AM-channel carrier (373.25MHz) and 81.9$MHz_{0\text{-}p}$/carrier for the highest frequency 64-QAM-channel carrier (770MHz).

When FM conversion was not applied, optical modulation depth was set at 3.8%/carrier and 1.2%/carrier for AM and 64-QAM signals, respectively, and so the total optical modulation depth m_1 was set at 25%.

Input signals, 8 broadcast satellite (BS) and 12 communication satellite (CS) intermediate frequency (IF) signal carriers (from 1030 to 2070MHz), were frequency converted to BS and CS radio frequency (RF) signal carriers (from 11.7 to 12.7 GHz) by the up-converter. This up-converted signal was input to the second EA modulator.

For both cases, with and without RF conversion, the optical modulation depth was set at 7.3%/carrier and 4.1%/carrier for BS and CS signal, respectively, so the total optical modulation depth m_2 was set at 25%.

Fig.2 shows the calculated electrical power level of output signal carrier, and second-order intermodulation distortion, for the test without FM and RF conversion.



(a) CATV signal carriers and BS/CS-IF signal carriers are directly input to optical modulator, without FM conversion or RF conversion.

(b) Prior to optical modulation, input CATV signal carriers and BS/CS-IF signal carriers are FM converted and RF converted, respectively.

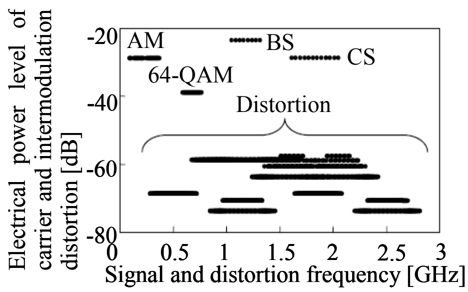
Fig.1 Schematic diagram of the optical modulator and modulation signal frequencies. LD is laser diode.

Fig.2(a) is for the electrical power level of carrier and intermodulation distortion. Distortion is seen in the AM, 64-QAM, BS, and CS channels. Fig.2(b) and 2(c) plot the ratio of carrier to total intermodulation distortion in a channel. In this measurement, the noise bandwidth was 4.2MHz for AM, 5.3MHz for 64-QAM, 28.9MHz for BS and CS signal. The calculated results indicate that unacceptable levels of distortion are created.

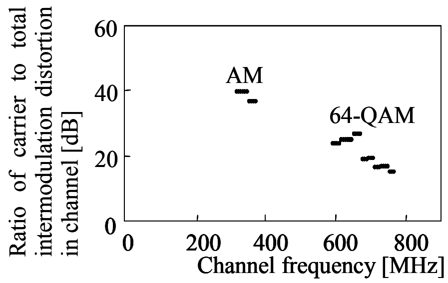
Fig.3 show the calculated results of the electrical power level of output signal carrier, and second-order intermodulation distortion level, for the test with FM and RF conversion. Fig.3(a) shows the electrical power levels of FM converted signal, BS and CS signals, and intetrmodulation distortion. The FM converted signal spectrum has a wideband distribution. This makes distortion also wideband. The distortion, however, is quite low in the FM converted signal band and the BS/CS signal band.

Fig.3(b) shows the ratio of carrier to total intermodulation distortion in a channel. By comparing the calculated values of carrier to distortion ratio shown in Fig.2(c) and Fig.3(b), we can see that the ratio in Fig.3(b) is larger than that in Fig.2(c). The difference is 12dB at the worst values.

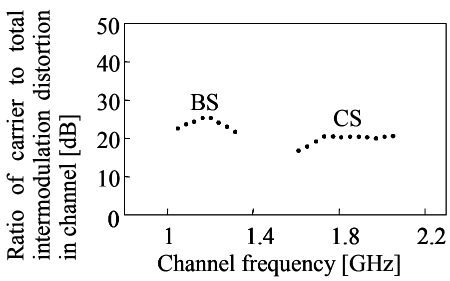
The above calculation indicates that the second-order intermodulation distortion created by the cascaded modulation can be reduced by FM and RF conversion.



(a) Electrical power level of carrier and distortion.



(b) Carrier to total distortion ratio in AM/64-QAM signal channel.



(c) Carrier to total distortion ratio in BS/CS-IF signal channel.

Fig.2 Simulated power values of the output modulated signal and the 2nd-order intermodulation distortion, for the case that CATV signal carriers and BS/CS-IF carriers are directly input to optical modulator, without FM conversion or RF conversion.

III. Conclusions

FM and RF conversion is useful for reducing the second-order intermodulation distortion otherwise present in the cascaded modulation of multi-channel signals.

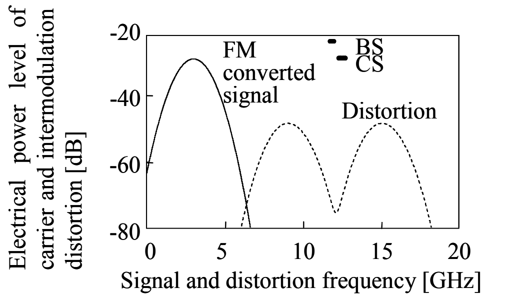
References

[1] K. Kikushima, T. Fujiwara, and S. Ikeda, "Cascaded modulation scheme and its application to optical multi-channel signal transmission systems," IEICE Trans. Commun. vol.E90-B, no.2, pp.195-208, Feb. 2007.

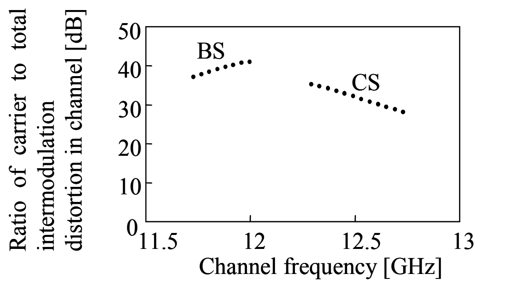
[2] N. Shibata, K. Kikushima, N. Sakurai, and R. Watanabe, "Optical Video Distribution Systems Employing FM Conversion," IEICE Trans. Commun., (Japanese Edition), vol. J83-B, no.7, pp.948-959, July 2000.

[3] M. Fuse, Y. Kudo, Y. Ishii, K. Nojima, and S. Morikura, "Modeling for CNR characteristics under bandwidth limitation on transmission systems employing optical super wide-band FM technique," IEICE Trans. Commun., (Japanese Edition), vol. J84-B, no. 3, pp.496-504, March 2001.

[4] ITU-T Standard J.185, "Transmission equipment for transferring multi-channel television signals over optical access networks by FM conversion," International Telecommunication Union, Geneva, Switzerland, Feb. 2002.



(a) Electrical power levels of FM converted signal, BS/CS-RF carriers and distortions. Resolution is 3MHz.



(b) Carrier to total distortion ratio in BS/CS-RF signal channel.

Fig.3 Simulated power values of the output modulated signal and the 2nd-order intermodulation distortion, for the case that CATV signal carriers are FM converted; BS/CS-IF carriers are RF converted and then input to the optical modulator.