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Externally modulated lightwave CATV transport systems employing negative dispersion fiber

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Abstract: An externally modulated AM-VSB CATV transport system in the 1550 nm region using negative dispersion fiber (NDF) as the transmission medium is proposed and successfully demonstrated. Good performances of carrier-to-noise radio (CNR), composite second order (CSO) and composite triple beat (CTB) were achieved over an-80 km NDF transmission without dispersion compensation. Externally modulated transmitter has a positive residual Mach-Zehnder modulator (MZM) chirp; but, NDF has a negative dispersion property in the transmission fiber. This negative dispersion property overcomes the positive frequency chirp and results in system with better transmission performance.

Keywords: Externally modulated laser, frequency chirp, negative dispersion fiber

Classification: Photonics devices, circuits, and systems

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1 Introduction

To extend the transmission distance is the goal of the lightwave CATV transport systems. However, fiber dispersion effect is one of the most severe limiting factors in long-haul lightwave CATV transport systems. If the fiber transmission length exceeds several tens of kilometers, dispersion effect can cause intolerable amounts of composite second order (CSO) and composite triple beat (CTB) distortions. Recently, nearly all 1550 nm transmitters in operation use external modulation, a technique which provides minimal chirp. Externally modulated laser transmitter, incorporating with a Mach-Zehnder modulator (MZM), has a positive residual chirp which limits the transmission distance [1]. It is necessary to use dispersion compensation devices, such as chirped fiber grating (CFG) or dispersion compensation fiber (DCF) [2, 3], to compensate the dispersion effect and consequently decrease the nonlinear distortions. But, dispersion compensation devices increase the cost and complexity of systems; for a successful deployment of lightwave CATV transport systems, the cost and complexity are obviously considerable concern. In pervious study, negative dispersion fiber (NDF) has been employed as the transmission medium in digital lightwave transport systems [4]. However, its application in analog lightwave transport systems has not seen. NDF, with negative dispersion, is expected to compensate large and positive MZM chirp, and thus to improve the dispersion tolerance in the externally modulated CATV transport systems. In this study, the architecture of an externally modulated AM-VSB CATV transport system in the 1550 nm region using NDF as the transmission fiber is proposed. To the best of our knowledge, it is the first time to transmit externally modulated CATV signals maximum up to 80 km NDF without dispersion compensation.

2 Experimental setup

The experimental system configuration of our proposed externally modulated CATV transport systems using NDF as the transmission medium is shown in figure 1. RF carriers generated from a 77-channel (CH2-78) NTSC Matrix SX-16 signal generator were fed into an externally modulated transmitter with a central wavelength of 1549.4 nm and an optical modulation index (OMI) of ~3.4% per channel. In lightwave CATV transport systems, there is a trade-off between carrier-to-noise radio (CNR) and CSO/CTB performances for different OMI values. Large OMI results in better CNR performance, but degrades the CSO/CTB performances. In order to satisfy the fiber optical CATV requirements (CNR/CSO/CTB >50/65/65 dB), the OMI

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value needs to be set at 3.4% per channel. System link with a transmission length of 0-100 km consisted of two NDF spans (50+50 km, each with an attenuation of 0.212 dB/km, and a negative dispersion of $-2.5\,\mathrm{ps/nm \cdot km}$). In order to transmit optical signal over a 100-km NDF, the optical power was amplified using two stages of erbium-doped fiber amplifiers (EDFAs). The output power level and noise figure of each EDFA are ~17 dBm and ~4.5 dB, at an input power of 0 dBm, respectively. The variable optical attenuator (VOA) was introduced at the start of the optical link, not only to adjust the input power level of optical receiver but also to result in less CSO/CTB distortions since the optical power launched into the fiber would have been less. The optical input power of the optical receiver was adjusted to be 1 dBm using a VOA, with optical receivers' RF output level > 30 dBmV per channel. All CATV RF parameters were measured using an HP-8591C CATV analyzer at various lengths of NDF (0-100 km).

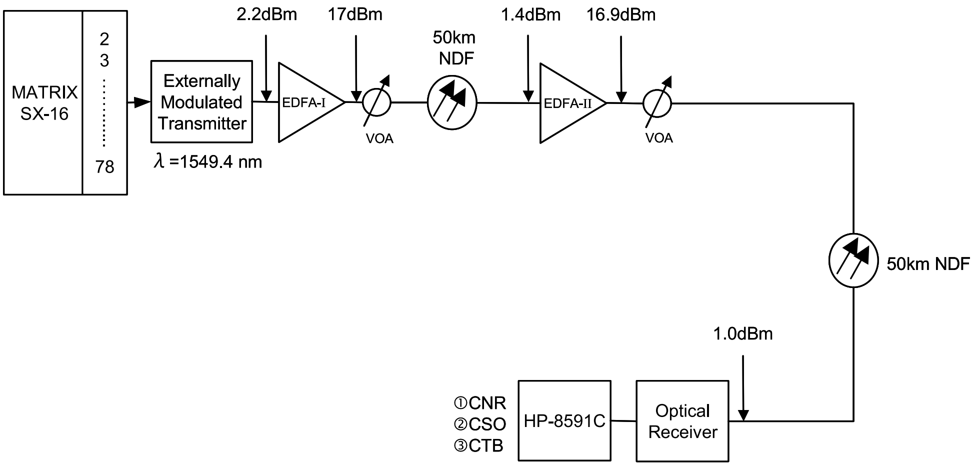

Fig. 1. Experimental system configuration of our proposed externally modulated CATV transport systems.

3 Experimental results and discussions

The measured CSO/CTB values as a function of fiber length is shown in figure 2. Due to the effect of the accumulated negative dispersion, it is apparent that CSO/CTB values improve as the fiber length increases up to 70 km. However, CSO/CTB performances are degraded when the transmission length is more than 70 km. Therefore, it can be concluded that large amount of negative dispersion will degrade systems' performance and limit the transmission distance. As fiber transmission length is 80 km, the measured CSO/CTB values are about 66.3/65.1 dB, both still meet the fiber optical CATV demands (> 65/65 dB). Such results verify that our proposed externally modulated CATV transport systems can transmit optical signal maximum up to 80 km of NDF.

As fiber length is 70 km, the measured CNR, CSO and CTB values under

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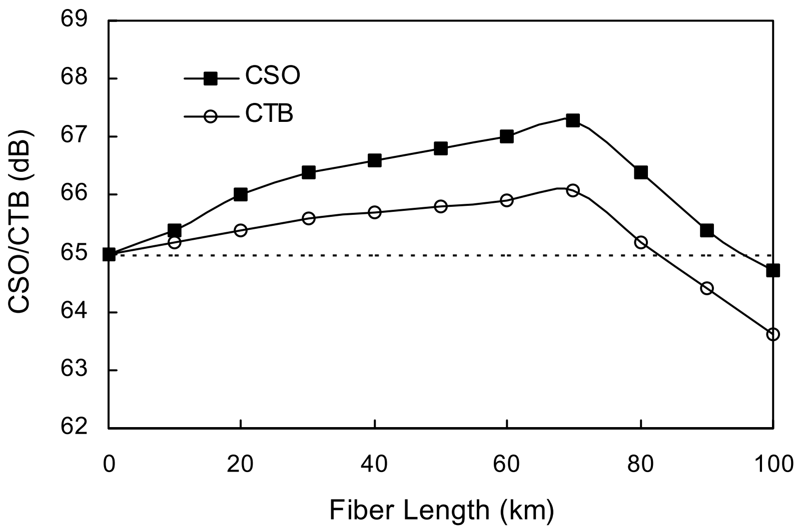

Fig. 2. The measured CSO/CTB values as a function of fiber length.

NTSC channel number are plotted in figure 3. Eight different channels selected from low band (CH2, 12 and 24), middle band (CH30, 40 and 50), and high band (CH60 and 78) represent all CATV channels. Excellent performances of CNR/CSO/CTB (> 50/67/66 dB) were achieved without dispersion compensation. In an external modulation scheme incorporating a MZM with positive chirp parameter α_{MZ}, the second order harmonic distortion to carrier ratio (HD_2/C) and third order intermodulation distortion to carrier ratio (IMD_3/C) can be expressed as [5]:

$$\frac{HD_2}{C} = \frac{1}{4} m\ddot{\beta} z \Omega \sqrt{(4 \cdot \alpha_{MZ})^2 + \left(\ddot{\beta} z \Omega^3\right)^2} \tag{1}$$

$$\frac{IMD_3}{C} = -\frac{9}{32}\left(m\ddot{\beta} z \Omega\right)^2 \left[4 \cdot (\alpha_{MZ})^2 + \Omega^2\right] \tag{2}$$

where m is the OMI, $\ddot{\beta}$ is the second order dispersion coefficient, z is fiber transmission length, and Ω is the RF signal carrier frequency. A direct way to reduce the positive chirp is to introduce a negative chirp parameter into equations (1) and (2). After employing NDF as the transmission fiber, then equations (1) and (2) can be changed into:

$$\frac{HD_2}{C} = \frac{1}{4} m\ddot{\beta} z \Omega \sqrt{(4 \cdot (\alpha_{MZ} + \beta_{NDF}))^2 + \left(\ddot{\beta} z \Omega^3\right)^2} \tag{3}$$

$$\frac{IMD_3}{C} = -\frac{9}{32}\left(m\ddot{\beta} z \Omega\right)^2 \left[4 \cdot (\alpha_{MZ} + \beta_{NDF})^2 + \Omega^2\right] \tag{4}$$

where β_{NDF} is the negative chirp parameter due to NDF. It indicates that the lowest HD_2/C and IMD_3/C values can be achieved when $(\alpha_{MZ} + \beta_{NDF})^2$ reaches the lowest. For a MZM which has a nonzero and positive chirp, optimum transmission length can be obtained by employing NDF with a negative dispersion property. This negative dispersion property overcomes the MZM chirp and leads to a better transmission performance.

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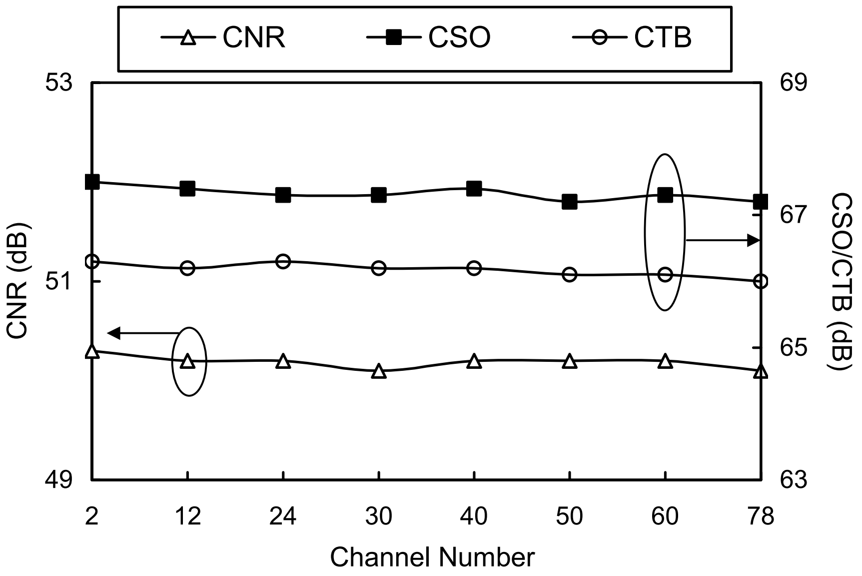

Fig. 3. The measured CNR/CSO/CTB values.

4 Conclusions

We successfully demonstrated an externally modulated lightwave CATV transport system in the 1550 nm region using NDF as the transmission medium. Good performances of CNR, CSO and CTB were achieved over an-80 km NDF transmission. Thus, it is possible to implement a cost-effective lightwave CATV transport system employing externally modulated transmitter and NDF, without dispersion compensation schemes such as CFG or DCF.

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