Employing split-band technique and optical SSB filter to Improve directly modulated fiber optical CATV system performances

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Abstract: A directly modulated AM-VSB CATV EDFA-repeated system that uses split-band technique and optical single sideband (SSB) filter at the receiving site is proposed and demonstrated. Good performances of CNR, CSO and CTB were achieved for the full channel band over a-120 km single-mode fiber (SMF) transport. Our proposed system is suitable for the fiber optical CATV systems in long-haul transport.

Keywords: directly modulated, optical single sideband filter, split-band

Classification: Photonics devices, circuits, and systems

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1 Introduction

Analog fiber optical CATV transmission systems have recently been enhanced by the introduction of 1550 nm technology. However, the maximum transmission distance of fiber optical CATV systems is limited by RF parameters such as carrier-to-noise ratio (CNR), composite second order (CSO) and composite triple beat (CTB). The performance can be seriously degraded due to the stimulated Brillouin scattering (SBS) effect and the self-phase modulation (SPM)-induced chirp. Several compensation techniques have been proposed to improve the system's CSO and CTB performances, but all of them increase the cost and complexity of the system [1, 2]. The transmission of single sideband (SSB) signal has been used in the RF domain of the electrical spectrum to reduce the bandwidth of the signal. If the SSB modulation format could be applied to the optical domain, a dispersion benefit would be obtained due to the optical signal spectrum has been reduced [3, 4]. Optical SSB modulation technique, which can reduce the bandwidth of the optical signal by a factor of two, is expected to have good performances in the fiber optical CATV systems. In this paper, an architecture of a directly modulated NTSC AM-VSB 77-channel erbium-doped fiber amplifier (EDFA)-repeated system that uses split-band technique and optical SSB filter at the receiving site is proposed and demonstrated. Good performances of CNR, CSO and CTB were obtained in our proposed system over a-120 km single-mode fiber (SMF) transport.

2 Experimental setup

Figure 1 shows two optically amplified AM-VSB transmission systems with three cascaded EDFAs. Figure 1 (a) (referred to as system I) shows the conventional 77-channel fully loading externally modulated system. Figure 1 (b) (referred to as system II) shows our proposed split-band directly modulated wavelength-division-multiplexing (WDM) system employing optical SSB filter at the receiving site. In system I, shown in Figure 1 (a), CH2~78 generated from a multiple signal generator (MATRIX SX-16) were fed into an externally modulated transmitter with a central wavelength of 1559.6 nm and an optical modulation index (OMI) of $\sim 3.5\%$ per channel. All CATV RF parameters were measured using an HP-8591C CATV analyzer over a-120 km SMF transport.

In system II, shown in Figure 1 (b), a NTSC Matrix SX-16 signal generator was used to feed 77 RF sub-carriers into four directly modulated transmitters (~ 20 channels per transmitter). The central wavelengths of the four distributed feedback (DFB) laser diodes are 1536.1, 1545.2, 1550.5 and 1557.8 nm, respectively. Over a-120 km SMF transmission, the received optical signal went through an optical SSB filter, in which a fiber Bragg grating (FBG) in combination with an optical circulator (OC), to select the appropriate wavelength. The central wavelengths of the four FBGs are 1536.32, 1545.42, 1550.72 and 1558.02 nm, respectively. In order to maximize the optical carrier power and ensure only one sideband is reflected, the FBG filter

(a)

(b)

Fig. 1. (a) Conventional fully loading externally modulated transmitter system.
(b) Our proposed split-band directly modulated WDM system employing optical SSB filter at the receiving site.

exhibits a sharp cutoff in the transmission spectrum, with a 3-dB bandwidth of 0.3 nm and a 35-dB bandwidth of 0.44 nm. All CATV RF parameters were also measured using an HP-8591C CATV analyzer over a 120 km SMF transport.

3 Experimental results and discussions

Figure 2(a), (b) and (c) show the measured CNR, CSO and CTB values under NTSC channel number for systems I and II, respectively. Figure 2(a)

Fig. 2. (a) Measured CNR values for fiber optical CATV systems I and II.
(b) Measured CSO values for fiber optical CATV systems I and II.
(c) Measured CTB values for fiber optical CATV systems I and II.

indicates that the CNR values (> 50 dB) for systems I and II are almost identical. CNR values depend critically on the EDFA input optical power, EDFA (II and III) input optical power of system I is the same as that of system II, therefore, the CNR values are almost the same for systems I and II.

In contrast, the CSO values (> 71 dB) of system II can be improved significantly. The improved results seen in system II are due to the use of split-band and optical SSB modulation techniques. By using split-band technique, about zero CSO product counts exist in any in-band channels of each split-band region, it results in system with better CSO performance. In addition, originally the directly modulated transmitter possesses a wide spectral width, after the optical signal is coupled into the optical SSB filter, the optical signal possesses a narrow spectral width. The use of an optical SSB filter lets an half of the optical spectrum is eliminated. The second harmonic distortion to carrier ratio ($2HD/C$) is [5]:

$$2HD/C = \frac{1}{4}m\ddot{\beta}z\Omega\sqrt{(4 \cdot \Delta v)^2 + (\ddot{\beta}z\Omega^3)^2} \quad (1)$$

where m is the optical modulation index, $\ddot{\beta}$ is the second order dispersion coefficient in the frequency expansion, z is the optical signal transmission distance, Ω is the RF signal carrier frequency, and Δv is the frequency deviation. By optical SSB filtering, the frequency deviation Δv is decreased

and leads to system with better CSO performance. Optical SSB modulation format not only offers high spectral efficiency but also ameliorates the dispersion by reducing the spectral width of the optical signal.

As to CTB performance, the CTB values (> 63 dB) for system II is degraded about 0.5 dB compared to system I. The CTB performance for system II can be improved by using a CTB RF-predistortion circuit to compensate the insufficient linear characteristic curve of DFB laser diodes.

4 Conclusions

We propose and demonstrate a directly modulated AM-VSB CATV EDFA-repeated system that uses split-band technique and optical SSB filter at the receiving site to improve systems' performance. Good performances of CNR, CSO and CTB were achieved for the full channel band over a-120 km SMF transport. Our proposed system is suitable for the fiber optical CATV systems in long-haul transport.