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Simulation analysis of IMD in multitone analog CATV transmission systems

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ABSTRACT

In this paper we analyze analog CATV transmission system where only one wavelength is used for transmission on which multiple analog RF channels modulated. We analyze different modulation distortions such as composite second order (CSO), composite triple beat (CTB) and intermodulation distortions at different frequencies. Good performance of CSO >−36 dBc and CTB >−41 dBc are obtained at 62.5 MHz, 125 MHz and 187.5 MHz in three tones directly modulated CATV transmission system.

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1. Introduction

During recent years, a cable television (CATV) system has become widespread throughout the cable industry. CATV transmission systems have promoted from coaxial cable based one way broadcast analog video transmission to modern two ways hybrid fiber transmission. In traditional one way transmission several RF amplifiers were used to overcome high losses of the coaxial cables that affect the quality of received signal. The use of optical fiber reduces the RF amplifiers in the CATV transmission. To increase the system link budget, higher transmission power or lower fiber transmission loss are required. The maximum transmission distance of CATV system is limited by the RF parameters such as Composite second order (CSO), and Composite triple beat (CTB). These distortions parameters are degraded by using Stimulated Brillouin scattering (SBS) [1]. In general, CSO and CTB distortions induced by SBS are main limitations in the system [2]. When several numbers of channels in CATV system are amplified simultaneously then there is chance of having intermodulation products which produce distortion in the network. This is mainly due to non-linearity effects in the amplification in the CATV system. To improve the performance of CATV system these parameters should be degraded. Several methods have been proposed to overcome these problems induced by distortions in the CATV system. However, Sophisticated SBS suppression, CTB predistortion, differential detection techniques and expensive externally modulated transmitter are required [4]. It is difficult to obtain good performance of CSO and CTB. Hai-han Lu et al. [3,4] proposed a directly modulated NTSC 80-channel Eribium Doped Fiber Amplifier (EDFA) repeated system using half-split-band (40 channels per transmitter) and wave-division-multiplexing (WDM) techniques to improve the performance of CSO and CTB in fiber optical CATV system. J.Yu et al. [5] proposed an Electroabsorption Modulated Laser (EML). EML can be linearized by emulation and reversal of the nonlinear distortion using a companion EML inside an optoelectronic interferometer. Suppression of composite second order and triple beat signals <−61 and <63 dBc, respectively, have been achieved with a 77-channel loading of CATV carriers. Low distortion lasers are extremely important element in AM-VSB CATV transmission systems. Hai-Han-Lu et al. [6] compared the conventional externally modulated optical fiber CATV system with or without distortion compensation fiber (DCF). Excellent performance of composite second order (CSO) >−78 dBc and Composite tripe beat (CTB) >−65 dBc are obtained by using externally modulated AM-VSB CATV 77-channel erbium doped fiber amplifier (EDFA) repeated systems, which use single mode fiber (SMF) and reverse dispersion fiber (RDF) as a compensation device. Wanjiun Liao et al. [7] proposed an adaptive slot allocation mechanism to improve the performance of Transmission Control Protocol (TCP) in Data-Over-Cable Service Interface Specifications (DOCSIS) based Hybrid fiber Coaxial (HFC) networks. The proposed mechanism is comprised of two parts: Fast Request Transmission (FRT) and Long Packet Deferment (LPD). FRT is designed to handle one way TCP transfers, while LPD targets two way transfers. Here “one way transfer” means all active cable modems perform downloading, while “two way transfers” indicates some perform downloading and some perform uploading. The proposed mechanism has better performance in terms of aggregate downstream throughput, access delay and required

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buffer size as compared to the original control mechanism of DOCSIS. Raffaella Vinzio et al. [8] gave formulas to calculate CSO and CTB in Distributed Feedback Laser (DFL) diodes. Germanov [9] described a new method to calculate the CSO and CTB intermodulation distortions spectrum for fully frequency range of coaxial cable CATV amplifier for any input frequency plan. The calculation takes into account the output level ripple and preemphasis, using frequency dependent intermodulation coefficient. Hai-Han Lu et al. [10] proposed a four wavelength bi-directional Dense Wavelength Division Multiplexing (DWDM) CATV system that uses Chirped Fiber Grating (CFG) as the dispersion compensation device to reduce the fiber dispersion and Cross Phase Modulation (XPM) induced crosstalk simultaneously. Excellent performance of CSO (>72 dB) and CTB (>69 dB) were obtained over a 50 km Single Mode Fiber (SMF) transport. Chia-Hsiung Chang et al. [11] use a repeater less bidirectional wavelength-division-multiplexing (WDM) transmission system for delivery of AM-VSB CATV analog video signals over conventional single mode fiber (SMF). He used and compared two kinds of multiplexers, the optical circulator and the WDM multiplexer configurations, for supporting bidirectional operation. Optical circulator offers satisfactory system performance of CSO >71.2 dBc, and CTB >63.5 dBc. Weissleder et al. [12] analyzed and modified the noise level by using Advanced design Software (ADS) in analog CATV systems. Po-Yi Wu et al. [13] used unconverted technique and a phase modulation technique to reduce noise and distortion and improve the performance of carrier- to-noise ratio, composite second order and composite triple beat (>73/72 dBc). Hai-Han Lu et al. [14,15] proposed and demonstrated light wave transport systems to improve the CSO and CTB performance by using electroabsorption modulator and optical single sideband modulation technique. Here CATV and microwave signals are transmitted simultaneously. The lower frequency side mode injection locked technique used in directly modulated fiber optical CATV transport system largely increases the resonance frequency of laser and improves the CSO and CTB over 100 km single-mode-fiber transmission. We have already achieved good results with in MIMO-OFDM system with OADM recently for optical-OFDM system and Monitoring and Compensation of Optical Telecommunication Channels [16–21].

In this paper, after having comprehensive literature review of System under consideration, we firstly describe the concept of Intermediation distortion for the same. Then experimental cum simulative analysis is made for different tones varies from two to twenty tone systems are analyzed Based on their power spectrums results are concluded in the last.

2. Measurement of intermodulation distortion

The distortion of the signal in CATV transmission is due to the deviation of the signal from the linearity. Which is known as intermodulation distortion such as Composite second order distortion (CSO) and Composite triple beat distortion (CTB). Non-linearity in the propagation characteristics of the fiber transmission produces the new frequencies of the $f_i + f_j$ and $f_i - f_j$. These frequencies lie in the transmission bandwidth and distorted the signal. The power level of the second and third order distortion known as Composite second order and Composite triple beat distortion, for specific channel are normalized to the carrier power of the channel and measured in dBc units.

If f_1 and f_2 are frequencies of two tones, then third order distortion products are occurring in both sides of these tones at $2f_2 - f_1$ and $2f_1 - f_2$. Assuming the power levels of two tones is equal. IMD_3 is the difference of power of fundamental signals and third order products .it is defined as following.

$$IMD_3 = Po - Po_3$$

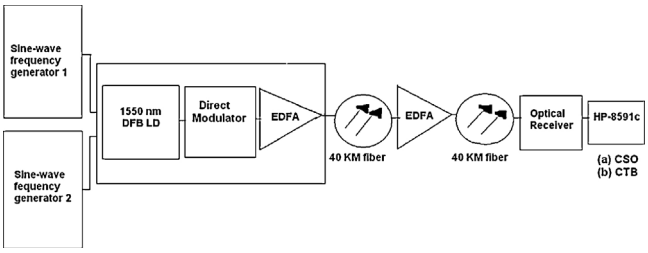

Fig. 1. Two tone direct modulated CATV transmission systems.

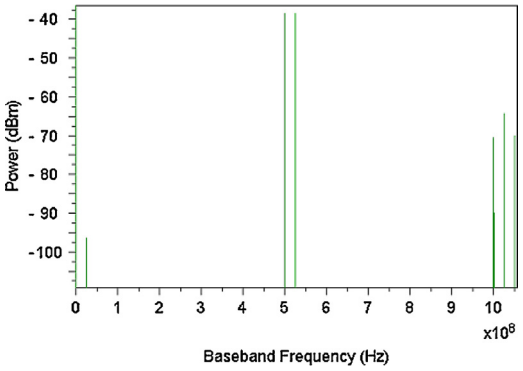

Fig. 2. RF spectra for directly modulated two tone CATV transmission system.

Po_3 is the power level of output third order product. Po is the power level of one the fundamental tone.

Calculate the intercept point of output third order product.

$$\frac{O}{P_3} = \frac{IMD_3}{2} + Po = \frac{1}{2}(3Po - Po_3)(dB)$$

3. Experimental setup and results in fiber optic based catv system

In fiber based CATV transmission system use single wavelength for transmission on which multiple RF analog channels are modulated. In digital communication system BER is the most common performance matric while a distortions measurement is critical matric in analog transmission systems. We can produce these results through simulations in OptSim (Fig. 1).

In the first attempt the two tone direct modulated CATV transmission system is considered. There are two sine-wave frequency generator that generate two frequency are at 500 MHz and 525 MHz and summed. These frequencies are modulated on 1550 nm wavelength by DFB laser diode modulator. Then this is propagated on 80 km single mode optical fiber cable. This is received by PIN based optical receiver. Spectrum analyzer is used to view the RF spectra by which we can measure the distortions such as CSO distortion at new generated frequencies at $f_1 + f_2$ and $f_1 - f_2$. Fig. 2 shows the RF spectra with power at frequency 1025 MHz and 25 MHz as well

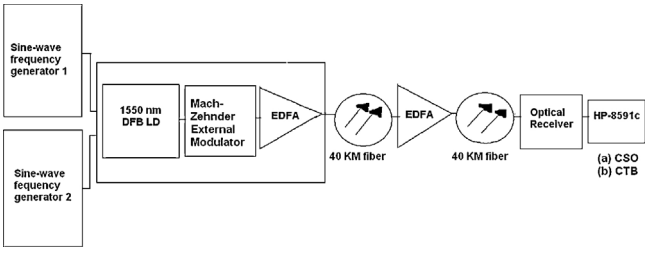

Fig. 3. Two tone externally modulated CATV transmission system.

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