Optical transmission experiment on FM conversion method with wideband phase modulation

Ryo Miyatake a), Toshiaki Shitaba, Akihiro Tanabe, Youichi Fukada and Tomoaki Yoshida
NTT Access Service Systems Laboratories, NTT Corporation, 1-1 Hikari-no-oka, Yokosukashi, Kanagawa, 239-0847, Japan
a) ryo.miyatake.ws@hco.ntt.co.jp

Abstract: In order to transmit BS/CS left-handed IF signals used in 8K4K broadcasting, it is necessary to expand the maximum transmission frequency of the FM conversion system from 2.1GHz to 3.2GHz. Our solution is a new FM conversion optical transmitter using a wideband phase modulator and narrow linewidth LD without frequency divider. In addition, we conduct transmission experiments on a prototype transmitter, and clarify that this transmitter offers long-distance transmission over a relay section of 250 km and access section of 10 km, with some bands excluded.

Keywords: FM conversion method, optical video transmission, phase modulation, broadcasting, 8K/4K

Classification:
Transmission systems and transmission equipment for communications

References
[1] “Transmission equipment for transferring multi-channel television signals over optical access networks by frequency modulation conversion,” ITU-T Rec.J.185,2012
[2] “Schedule for ultra-high-definition television broadcasting by satellite backbone broadcasting,” Ministry of Internal Affairs and Communications, https://www.soumu.go.jp/main_content/000392421.pdf (in Japanese), accessed July 6, 2021.
[3] T.Shitaba, H.Yoshinaga and T.Sugawa, “A study of the left handed circular polarization satellite signal transmission on the FM conversion system,” IEICE Technical Report, Vol.115, No.349, pp.65-69, 2015.
[4] T.Shitaba, T.Yoshida and J.Terada, “Optical Video Transmission Technique using FM conversion,” IEICE Technical Report, Vol.119, No.323, pp.97-101, 2019.
[5] “The government standard for the quality of cable broadcasting.” Ministry of Internal Affairs and Communications, https://elaws.e-
1 Introduction

Our goal is to transmit video signals over a long-distance optical video transmission network with FM conversion method[1]. The video signals are CATV(Common Antenna Television) signals(90~770MHz), BS/CS right-handed IF(Intermediate Frequency) signals(1.0~2.1GHz), and BS/CS left-handed IF signals(2.2~3.2GHz) that are now used for 8K/4K broadcasting[2]. Studies to date show that setting the center frequency of the FM signal to 3.4GHz makes it possible to transmit some BS left-handed IF signals of 2.2~2.7GHz in addition to the existing signals of 90MHz~2.1GHz[3]. However, a method is needed that can transmit existing signals(90MHz~2.1GHz) and all BS/CS left-handed IF signals(2.2~3.2GHz) over one wavelength. Therefore, we develop an optical transmitter capable of transmitting all video signals(90MHz~3.2GHz).

In this paper, we describe a result of a measurement of video signals on the condition of direct connection of the transmitter and V-ONU, in order to clarify the characteristics of this prototype transmitter. We also describe a result of a long-distance optical transmission experiment using this transmitter.

2 Network configuration of FM conversion transmission system

In long-distance optical video transmission networks[4] using FM conversion method, the video signal received by the antenna installed in the broadcaster’s building is input to the optical transmitter via the HE(Headend Equipment). The optical transmitter modulates the input electrical signals and outputs them as optical signals for transmission. Next, the V-OLT’s EDFA(Erbium Doped Fiber Amplifier) in the telecommunications carrier’s building repeats amplification and branching, and transmits relay sections with a maximum total distance of over 300 km. Then, it is received by the V-ONU in each user’s house via the access section of about 10km.

3 Problems and proposed method

Fig.1(a) shows the typical configuration of an optical transmitter (conventional equipment) that uses the conventional FM conversion method[4]. In this configuration, the two FM-LDs(Laser Diodes) are directly modulated in opposite phase by the CATV signals(90~770MHz). The optical signals output from one FM-LD are further phase-modulated by the BS/CS right-handed IF signals(1.0~2.1GHz) input to the phase modulator, and then coupled with the optical signal output from other FM-LD. The coupled signals are converted into a wideband FM signal by a PD(Photo Diode). Here, the center frequency of the FM signal is 6GHz, which is the difference between the optical center frequencies of the two FM-LDs. After that, the center frequency is divided into 3GHz by the
frequency divider installed to reduce the phase noise, and the optical signal from the transmission LD is intensity-modulated by the FM signal, and output. In the conventional equipment, the upper limit of the frequency that can be analog-modulated with high linearity by the phase modulator is 2.1GHz, and the center frequency of the input FM signal of the frequency divider is optimized to 6GHz. Therefore, in the conventional method, if a wideband signal that includes a BS/CS left-handed signal whose frequency upper limit is 3.2GHz is input, the distortion characteristics of the signal are significantly deteriorated, so another method is needed.

Fig.1(b) shows the configuration of the prototype optical transmitter (proposal equipment). In this transmitter, a narrow linewidth LD and a wideband phase modulator are used instead of the FM-LD and phase modulator shown in Fig.1(a). It was necessary to use a frequency divider to compensate for the phase noise performance of the FM-LD at that time in Fig.1(a). This divider was an obstacle to frequency expansion. However, in recent years, LD linewidth has improved. Therefore, by combining a narrow line width LD and a wideband phase modulator, a simple configuration that can modulate a wideband (90MHz~3.2GHz) at once with low phase noise has been realized, see Fig.1(b). All the transmitted signals are input to the wideband phase modulator located after the narrow linewidth LD on one side, and the optical signals are phase-modulated. After that, the wideband FM signal is output by the PD that receives the optical output signals from the two narrow linewidth LDs. The output of the transmission LD is intensity-modulated with this wideband FM signal. The proposal reduces the phase noise by the narrow linewidth LDs and elimination of the frequency divider.

In this transmitter, the FM signal has center frequency of 5GHz.

Fig. 1. Configuration of optical transmitter of FM conversion method
(a) Conventional equipment
(b) Prototyped proposal equipment

4 Experiments
4.1 Back-to-back connection
Back-to-back tests were conducted to evaluate the characteristics of the transmitter
itself, without the effects of the relay section or access section, see Fig.2(a). Frequency-multiplexed multi-channel video signals were input from a signal source simulating the HE to the optical transmitter(proposal equipment). The input signals are the same CATV signals (64QAM/OFDM 36 channels, 256QAM 42 channels), BS/CS right-handed and BS/CS left-handed IF signals (24 channels each) as Fig.1(b). In the optical transmitter, the input signals are converted into a wideband FM signal and then output as an optical intensity modulation signal. The output optical signal is received by the V-ONU via an optical attenuator(ATT). V-ONU converted the optical signal into an electric signal (wideband FM signal) and demodulated the signal by delay-line-detection. The output signal was input to the spectrum analyzer for characterization. Here, the optical receiving power of the V-ONU was set to +1dBm and -12dBm. The optical modulation index of the FM carrier of the output of the optical transmitter was 90.0%, and the relative intensity noise was -147.6dB/Hz.

4.2 Long-distance optical transmission

Next, a long-distance optical transmission experiment was conducted to evaluate the effect of the relay section and access section. Fig.2(b) shows the experimental setup. The input signals to the optical transmitter are CATV signals, BS/CS right-handed and left-handed IF signals, as in 4.1. The output signal from the optical transmitter was transmitted over 250km (11 stages of EDFA for relay) in the relay section, then transmitted over 10km in the access section and received by the V-ONU. The optical receiving power to the V-ONU, the optical modulation index of the FM carrier, and the RIN of the transmitter were the same as those in 4.1. In addition, a 15km single-mode fiber(SMF) is inserted between EDFA1 and EDFA2 in the front stage of the access section, referring to the results of preliminary experiments. This is to suppress the combined effect of the nonlinear optical effect and the wavelength dispersion generated in the fiber in the relay section. Fig.3(a) shows a comparison of transmission characteristics with/without insertion of SMF15km, which was conducted as a preliminary experiment. In Fig.3(a), the government standard [5] was used as the evaluation threshold. This experiment was carried out on the 752MHz channel in the CATV band, and the
characterization was performed using the carrier-to-noise ratio (CNR). From the results of the preliminary experiment, when the SMF15km was not inserted, the characteristic was lower than the government standard at the access section distance of 0 to 12km. However, when SMF15km was inserted, a characteristic offset of 15km occurred, and characteristics exceeding the government standard in Fig.3(a). Accordingly, SMF15km is used in the long-distance optical transmission experiment as shown in Fig. 2(b).

5 Results and considerations

The measured transmission characteristics are plotted in Fig.3(b) for CNR, Fig.3(c) for CSO (Composite Second Order), and Fig.3(d) for CTB (Composite Triple Beat). An enlargement of the 64QAM/OFDM area in Fig.3(d) is shown in Fig.3(e). The government standard was used as the characterization threshold. For some CSO and CTB channels that are not covered by the government standard, the threshold value was set by us. From Fig.3, the CNR and CSO characteristics satisfied the target values at each optical receiving power in both experiments. However, the CTB characteristics in Fig.3(e) were slightly lower than the target in both transmission experiments on some channels of 64QAM/OFDM in CATV. The maximum error was about 0.8dB. This CTB deterioration was found in both long-distance and back-to-back experiments; the difference in CTB between the two configurations is small. This suggests that the deterioration in CTB is due to group delay occurring in the electrical transmission line in the optical transmitter and V-ONU, not by long-distance optical transmission. Therefore, it is expected that CTB characteristics will be improved by adjusting the frequency characteristics of the group delay in the transmitter and V-ONU.

6 Conclusion

In this paper, we prototyped an optical transmitter using a wideband phase modulator and narrow linewidth LDs, and conducted back-to-back and long-distance optical transmission experiments. The results clarified that for relay and access section distances of 250km and 10km, respectively, the transmission characteristics exceeded the target value for all channels from 90MHz~3.2GHz except for a part of 64QAM/OFDM channels. In addition, since the deterioration in these channels occurred in both the back-to-back and long-distance experiments, the cause is deemed to be the electrical transmission line of the transmitter/receiver. In the future, we aim to ameliorate the CTB deterioration and extend the transmission distance from the current 250km to over 300km.
Fig. 3. Experimental results
(a) Preliminary experiment: Comparison of SMF15km insertion
(b) CNR (c) CSO (d) CTB(all channels)
(e) CTB(only 64QAM/OFDM channels)