New Signal Processing Technique Using Optical Phase Modulator and Optical Fiber Dispersion Effect

Naoki Ueda* (1), Yui Otagaki (1), Hiroshi Murata(1)
(1) Mie University, 1577 Kurima-Machiya-Cho, Tsu-City, Mie, 514-8507, Japan

Abstract

In this paper, we propose a new signal processing technique using optical phase modulator and optical fiber dispersion effect. By utilizing a silica optical fiber as a delay line in a RoF link and an optical phase modulator operating with RF wireless signals, detection and processing of RF signals are obtainable. Basic experimental results for 5G wireless band are presented.

1 Introduction

In the future Beyond-5G wireless systems, it will be necessary to develop new signal processing technologies for higher transmission speeds and lower latency, as well as for higher carrier frequencies. Then, we are trying to develop a new signal processing technique based on RoF (Radio-over-Fiber) technology using multiple laser lights and a silica optical fiber dispersion effect. A silica optical fiber is widely used in today's long-haul telecommunication systems. It has a huge bandwidth of over 100 THz and extremely low loss of 0.2dB/km at 1.55μm. In addition, one of the important characteristics is chromatic dispersion. This characteristic causes a slight delay time between optical signals with a different wavelength channel during fiber optic transmission. By utilizing a silica optical fiber as a delay line in a RoF link with an optical phase modulator, detection and processing of RF signals are obtainable. In this paper, we report the basic experimental results.

2 Signal processing using optical fiber dispersion effect

The basic configuration of the signal processing system using wavelength dispersion is shown in Figure 1. Two laser lights (wavelengths λ_1 and λ_2) input to an optical phase modulator from two lasers are simultaneously phase-modulated by a transmitter signal. When the optical signals are transmitted through an optical fiber, the phase modulation is converted to amplitude modulation due to the phase change between sidebands caused by the optical fiber dispersion effect. Then, the optical signal can be detected by using a high-speed photodetector with square-law detection [1].

Due to optical fiber dispersion effect, optical signals have slightly different signal velocities according to their wavelengths. Therefore, when two optical signals with different wavelengths are transmitted through optical fiber, relative time delay appears between the two signals. When the wavelength difference is $\Delta\lambda$ between the two optical signals, the optical fiber dispersion is D, and the fiber optic transmission distance is L, the delay time ΔT is expressed as

$$\Delta T = D \cdot L \cdot \Delta\lambda. \qquad (1)$$

Therefore, by selecting an appropriate wavelength difference $\Delta\lambda$ between the two optical signals, it is possible that this delay time ΔT is to be the same as one-symbol time of the data signal, and to perform correlation operation of the data signal when reconverting it from an optical signal to an electrical signal.

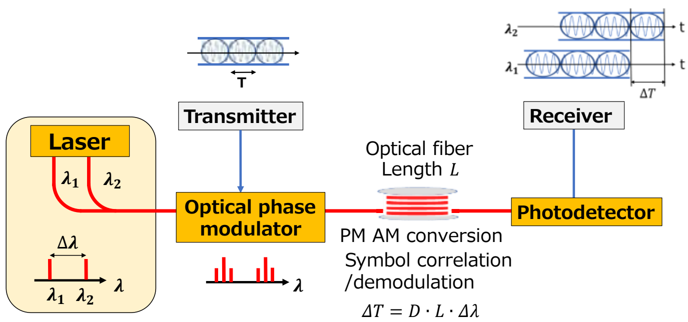

Figure 1. Schematic diagram of signal processing.

3 Experiment

Experiments on wireless signal processing and demodulation were conducted using the experimental set-up shown in Figure 2. In the experiment, 30 GHz wireless signal with 1Gbps BPSK modulation was irradiated to the antenna-coupled electrode EO modulator shown in Figure 3. Antenna-coupled electrode EO modulator is a device to able to directly modulate optical phase by the wireless signal. This device has the advantages of no external power supply, wideband operation, and no bias voltage adjustment [2]. The two optical signals modulated by the optical phase modulator were transmitted by a silica optical fiber, converted to electrical signal by high-speed photodiode, and the waveforms were observed by high-speed oscilloscope.

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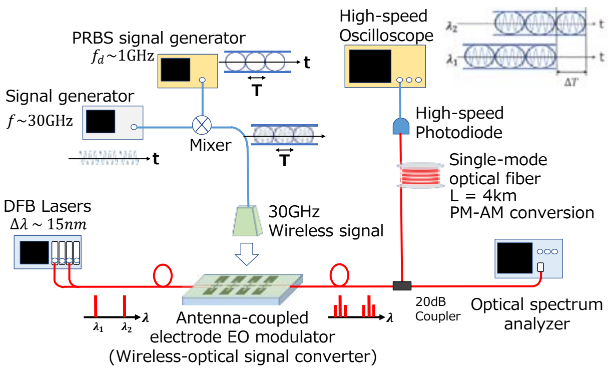


Figure 2. Experimental set-up.

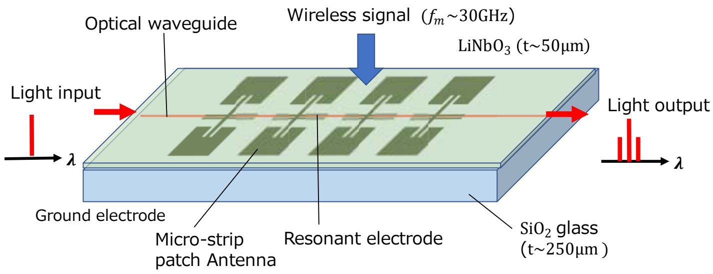
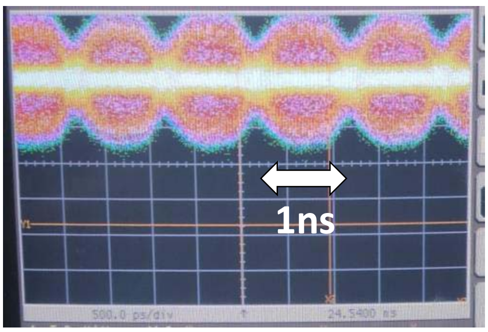
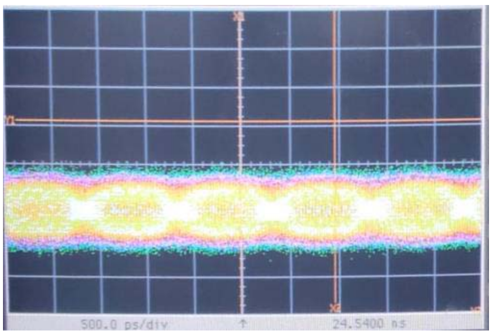


Figure 3. Basic structure of antenna-coupled electrode EO modulator.



(a)



(b)

Figure 4. Measured waveforms of the detected signals. (a) The result of detecting two optical signals with $\Delta\lambda = 15\text{nm}$ ($\lambda_1 = 1539\text{nm}$, $\lambda_2 = 1554\text{nm}$). (b) The result of detecting a single optical signal ($\lambda = 1554\text{nm}$).

If the dispersion of the optical fiber is $D = 16$ ps/(nm · km) and the length of a silica optical fiber is $L = 4$ km, and the wavelength difference is $\Delta\lambda = 15$ nm, the delay time between the two optical signals is approximately 1 ns, which corresponds to the one-symbol time in 1 Gbps signal. As a result, correlation waveform is obtained by superimposing and detecting the two optical signals. The output waveform of the oscilloscope is shown in Figure 4(a). Compared to the case of a single optical signal shown in Figure 4(b), it was confirmed that the amplitude and envelope change according to the data signal based on the proposal technique for two signal detection.

The relationship between the envelope changes in the detected signal and the wavelength difference $\Delta\lambda$ by two optical signal simultaneous detection was analyzed. Figure 5 shows a characteristic in which the ratio of the maximum to the minimum value is plotted for the received signal envelope at each wavelength difference. The envelope amplitude ratio changes as the wavelength difference, peaking at a wavelength difference of 15 nm, where the delay time coincides with the one-symbol time of 1 Gbps. This characteristic shows that the envelope amplitude and wavelength difference for simultaneous detection of two optical signals have autocorrelation characteristics.

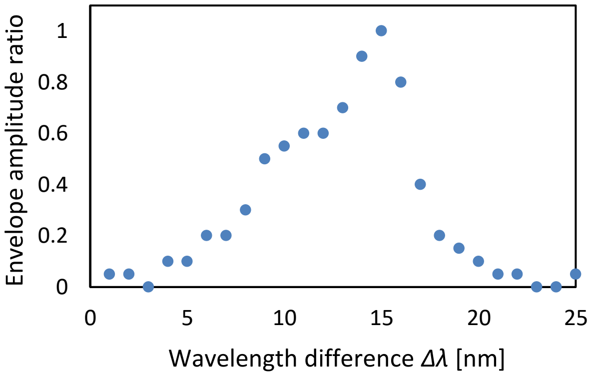


Figure 5. The envelope amplitude ratio at each wavelength difference.

4 Conclusion

Signal processing experiments based on proposed technique using the antenna-coupled electrode EO modulators and wavelength dispersion of optical fibers were reported. This technique is expected to be effective as a new wireless signal detection and demodulation technique in high-frequency bands such as millimeter wave and THz wave. Demodulation of vector-modulated wireless signals is also being investigated.

Acknowledgements

This work was supported in part by the NICT-commissioned research project "Research and development of wireless-optical convergence wireless communication systems for beyond 5G ultra-high-capacity wireless networks" and by the Grant-in-Aid for Scientific Research (B) (20H02205) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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