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Noise Reduction of OCDM Signals by Electrical Time Gating

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Abstract: To reduce the MAI noises from the received OCDM signals, a new electrical time gating method has been designed and evaluated. The results show a bit-error rate improvement of up to over 10^8.

1. Introduction

Recently, OCDM (Optical Code Division Multiplexing) systems using FBG (Fiber Bragg Grating) en/decoders have attracted much attention. The systems allow to prepare multi optical channels with a same wavelength [1, 2]. Therefore, it is easy to increase the number of channels. The systems show a highly secure communication performance because the signals can be recovered only by the corresponding decoders.

The OCDM system we have been studying is shown in Fig.1, where RZ optical signals are spread in the time domain using FBG encoders. The transmitted signals are re-produced by corresponding FBG decoders. The received signals, however, have MAI (Multiple Access Interference) noise due to the cross-correlation among the multiplexed optical signals [3]-[5]. It is desired to reduce the noise to realize a high quality communication.

One of the electrical noise reduction methods we have already proposed is to use peak voltage differences between the recovered signals and MAI noises. The method has shown a good BER (Bit Error Rate) improvement [6]. Other approach using a short time optical gating has been also proposed [7]. Although the optical gating method shows good BER improvement, it has a difficulty in synchronizing signals and the very narrow gate windows precisely. If it is effective for BER improvement to use a time gate after the optical signals are converted to the electrical signals, the synchronization between the signals and gate windows may become easy.

We have designed and fabricated a High Speed Microwave Switch circuit (HSMW) and have evaluated an electrical gating noise reduction method with the switch circuit. This method shows as good BER improvement as the optical gating approach. In this paper, design methods of the HSMSW, the noise reduction configuration and the experimental results are reported.

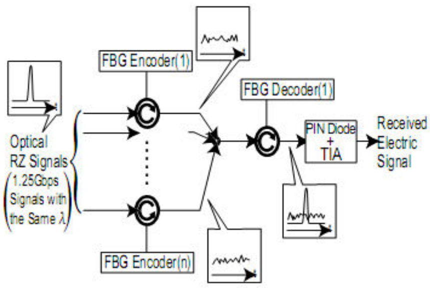

Fig.1 Block diagram of OCDM communication system

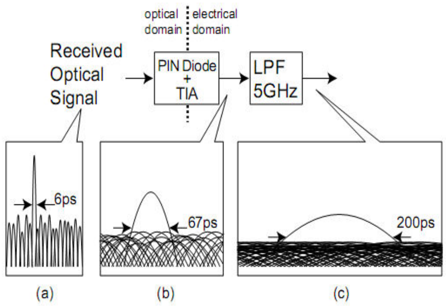

Fig.2 A concept block diagram of a receiver side front end of the OCDM system

2. Noise Reduction Method Overview

In the OCDM system which is studied in this paper, the received optical signal after decoding has 6ps-width data pulses and pulse-like noises with relatively low peaks as shown in Fig.2 (a). The received signal is converted to the electric signal by a PIN photodiode with a trans-impedance amplifier (TIA). In our experiments, the bandwidth of the used TIA is 15GHz. Therefore, the pulse widths of the signal and noises are enlarged about 11 times ($1/6\text{ps} \times 1/15\text{GHz} \approx 11$) by the O/E (Optical to Electrical) stage (Fig.2 (b)). In addition, a low-pass filter (LPF) with a cut-off frequency of 5GHz is inserted between the O/E stage and the subsequent circuits for stable operation. As the result, the pulse widths become about 200ps, consequently (Fig.2(c)).

In the optical gating method which is proposed in [7], an electro-absorption modulator (EAM) is used as an optical gate as shown in Fig.3. By driving the EAM with a narrow pulse of 36ps-width obtained from the clock signal, most part of noises beside the data pulses are suppressed.

Figure 4 shows a concept of the electrical method proposed in this paper. The HSMSW is used as an electrical gate instead of the EAM in the optical approach. Compared with the optical method shown in Fig.3, the electrical method may seem to be inferior on the noise reduction performance because more noises will be included in the gate windows. However, the electrical method is very easier to implement than the other method.

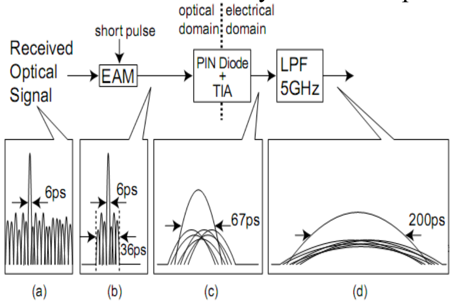

Fig.3 Conceptual block diagram of a receiver side front end of the OCDM system using an optical gating

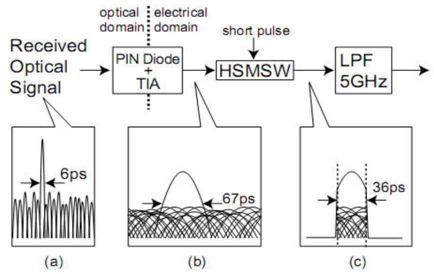

Fig.4 Conceptual block diagram of a receiver side front end of the OCDM system using an electrical gating

3. Circuit Design

A.SPGC

The short pulse generating circuit (SPGC) used for gating pulse is nearly the same one reported in the previous work [7]. The circuit diagram is shown in Fig.5, which consists of three stage FET circuit and is fabricated using discrete packaged HEMTs. In the circuit, as the rising and falling slopes of the input clock are differentiated by the inductor load of the first stage, negative and positive narrow pulses are generated, respectively. Only the negative pulses are selected by biasing the gate of the second stage FET adequately in the experiments. The final stage re-inverted the positive pulses because the HSMSW requires negative pulses for switching operation.

B.HSMSW

Figure 6 shows a circuit diagram of the HSMSW. The circuit is also fabricated using discrete HEMTs. The received signal is introduced to terminal A in the figure and the inverted short switching pulse is to port B. By adjusting the bias voltages of FET 1, Vss and Vgsw, the gate bias of FET 2 can be controlled. It can be set that FET 2 dose not work when no signal is applied to port B, and works only when the negative switching pulse to port B and a positive signal pulse to terminal A are applied simultaneously. As the results, the circuit works as the electrical time gate and most of the MAI noises are eliminated.

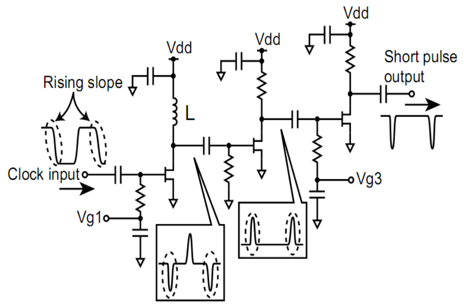

Fig.5 Circuit diagram of the SPGC

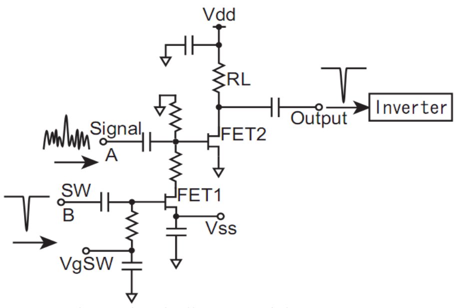

Fig.6 Circuit diagram of the HSMSW

4. Noise Reduction Test

Figure 7 shows a testing system used in this work. A 1.25Gbps optical RZ signal with a narrow pulse width is generated using a mode-locked laser diode (MLLD) and EAM. The optical signal is divided into two lines and each signal is encoded using FBG encoder (1) or (2). By changing the optical power of the signal encoded by encoder (2) before combining the two signals, the multiplicity is changed equivalently. At the receiver side, the received multiplexed optical signal is decoded using the corresponding FBG to the encoder (1), and then converted to the electrical signal. Using this system, 1.25Gbps RZ signals equivalently multiplexed four channels are prepared.

Three configurations: (a) direct (no noise reduction component is used), (b) a pulse peak voltage is controlled and a threshold amplifier is used for deciding the signal pulses, as reported in [6], (c) the electrical time gating mentioned above is used. For these configurations, bit error rate (BER) – received optical power characteristics are measured. The received optical power is changed by using a variable optical attenuator (marked "*" in Fig.7). BERs are measured using an error rate detector for 30 seconds.

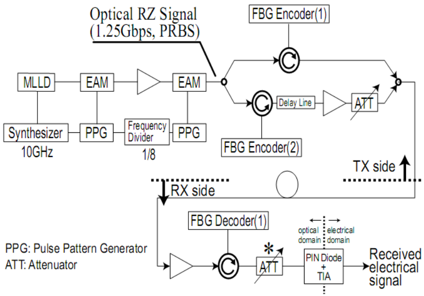

Fig. 7 OCDM signal generation system

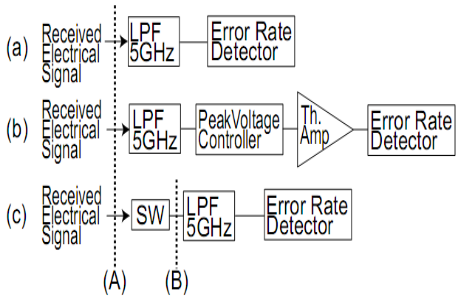

Fig.8 Block diagram of the tested configurations

5. Results and Discussions

Examples of measured waveform of the received electric signal, observed at (A) in Fig.8, and the output signal of the HSMSW, observed at (B), are shown in Fig.9 (A) and (B), respectively. The signal is amplified by switching stage and the MAI noise pulses are compressed effectively compared to the main signal peak. And eye diagram (with the HSMSW) opens more clearly.

Figure 10 shows the measured BER-received optical power characteristics. In the case (c) (using the HSMSW), BERs are significantly improved (>10^8 in the high optical power region) and error-free condition is observed when the received optical power is larger than -4dBm. The BER improvement performance of electrical gating is almost at the same level as that of the optical gating reported in [7], though the other measurement conditions are not completely the same.

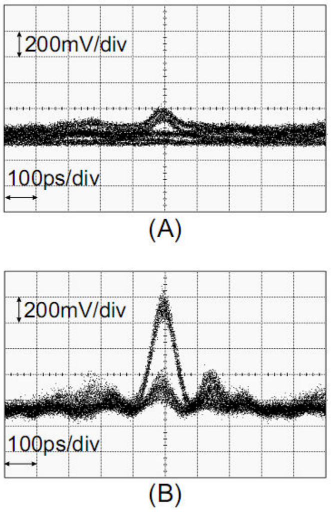

Fig.9 Measured waveforms for configuration (c) in Fig.8
(A): measured at (A), (B): output of the HSMSW

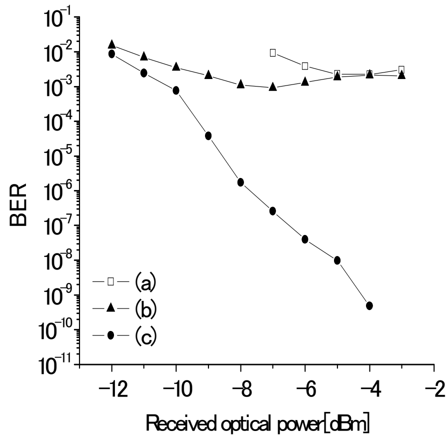

Fig.10 Measured BER-Received optical power characteristics
for three kinds of configurations shown in Fig.8

6. Conclusion

In this paper, an electrical gating noise reduction method of OCDM signals is proposed. The method consists of a Short Pulse Generator Circuit and a High Speed Microwave Switch circuit. The circuits were fabricated and the electrical gating method was evaluated. From the experimental results, BERs are improved significantly, which shows that the electrical time gating is as effective as the optical gating.

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