Research on long distance submarine optical fiber transmission system using MSK downlink signals

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Abstract. The commonly used submarine optical fiber communication system is expected to provide long-distance reliable signals transmission. We present a novel optical fiber submarine system using minimum shift keying (MSK) encoded downstream signals. 10Gb/s MSK coded signals are successfully transmitted over the 100km submarine single-mode fiber (SMF).The optical spectrums, eye-diagrams and bit error rate (BER) before and after transmission of MSK signals in the system were measured and analyzed. The results show that, compared with conventional access methods, this scheme can provide high-speed, stable and secure data communication.

Keywords: Optical fiber communication, Minimum shift keying, Optical spectrum, Eye diagrams.

1 Introduction

The demand for marine communication is increasing with the development of marine resources and human marine activities[1]. Traditional wireless communication methods, marine satellite communication and microwave communication cannot provide fast, stable and reliable data communication since complex weather conditions, and relatively narrow communication bandwidth are limiting factors[2]. In recent years, the advantages of submarine optical cable communication systems such as high bandwidth utilization, long transmission distance, low attenuation, anti-electromagnetic interference, and strong confidentiality have attracted more and more attentions[3]. Submarine optical cable communication system (SOFC) consists of optical cable landing station, submarine optical cable, underwater repeater, splitter and transmission terminal equipment. There are generally two types of submarine optical cable communication systems: One is the repeatered long haul communication system across the ocean, the other is the inshore non-repeatered short haul communication system.

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As we know, a few advanced modulation formats make the optical cable communication system have higher spectrum efficiency, a higher tolerance for fiber dispersion and nonlinearity[4]. These new formats include differential phase shift keying (DPSK), continuous phase frequency shift keying (CPFSK), etc. Minimum shift keying (MSK) is a special case of CPFSK. The end phase of adjacent symbols is equal to the initial phase, which reduces the change of signal bandwidth caused by phase mutation and obtains greater dispersion, tolerance[5]. Various different external modulation schemes to generate optical MSK have been reported, Researchers used these methods to generate optical msk signals with higher bit rates[6-10].These schemes without the use of complex DSP, simplify the signal receiving and sending process, and reduce the cost of system construction.Therefore, it is very suitable for propagation in high-speed and high spectral efficiency submarine optical cable systems.

2 System model

As shown in Figure 1, the transmitter of the system uses a pseudo-random bit sequence (PRBS) generator as the signal source. The generated random binary signal is input the MSK pulse generator to generate a 10Gbit/s MSK electrical signal. The signal is then divided into two paths as I and Q components. One dual-arm Mach-Zehnder modulator (DMZM) is driven by the electrical signal. A continuous wave (CW) signal with frequency of 193.1 THz is launched with a linewidth of 10 MHz into DMZM. The generated 10Gbit/s optical signals transmission over 100-km-long single mode fiber (SMF) and 20-km-long dispersion compensation fiber (DCF). DCF is used to compensate the dispersion accumulated over the length of the 100km SMF. The erbium-doped optical fiber amplifier (EDFA) is placed after SMF/DCF to compensating the transmission attenuation. Optical signals noise is filtered out by using a first-order optical Bessel filter (OBF) with bandwidth of 40Ghz. The optical signal detected by a PIN photo detector for optical-to-electrical conversion. A three-order Bessel low pass filter (LPF) with the cut-off frequency of 7.5 GHz is used for suppressing the electrical noise. The original data is restored by one MSK sequence decoder. Finally, bit error rate tester (BERT) is applied for evaluating system transceivers performance.

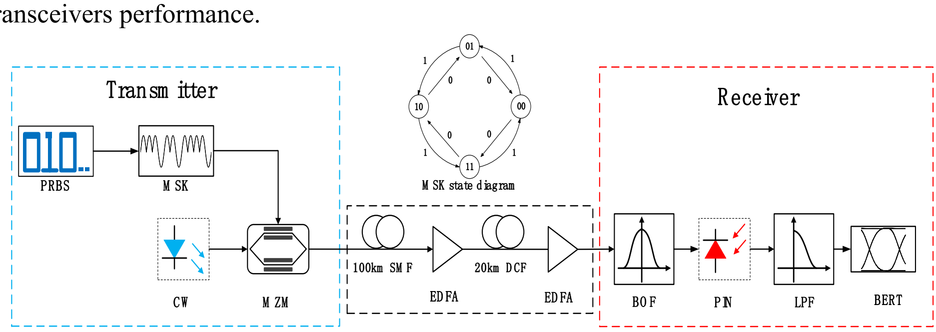

Fig.1. SOFC system using MSK downlink signals.

3 Results and discussion

We evaluated the transmission performance of the system by analyzing the time domain diagrams, spectrum diagrams, eye diagrams and bit-error-rate (BER) curves. The time domain waveform before transmission as shown in Figure 2(a) and Figure 2(b). Figure 2(b) shows that the waveform of the received MSK signal has a slight distortion, and it is clearly to see that the transmitted and received signals have the same change curves. Figure 2(c) and Figure 2(d) show that the optical spectrums of the MSK optical signal before and after transmission, respectively. The peak power of the optical carrier almost have no loss because EDFA compensate the attenuation caused by the signal is transmitted in 100km fiber link.

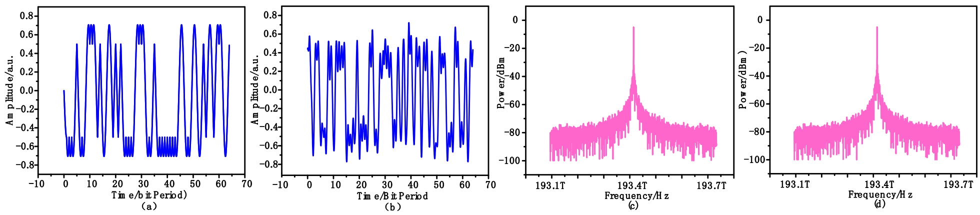

Fig.2. (a) The time domain waveform before transmission; (b) The time domain waveform after transmission; (c) The optical spectrum before transmission; (d) The optical spectrum after transmission.

Figure 3 shows the curves of BER versus received power for MSK signals in back to back (BTB) case and after120-kmlong transmission. The sensitivity of the BTB receiver at BER 10^{-9} is about -18.68 dBm. The inset (a) of figure 3 is the eye diagram of the MSK signal in the BTB case. The decreased signal power in the receiver is due to the transmission attenuation of the signal in the optical fiber link. The inset (b) of figure 3 shows the observed eye diagram of the MSK signal when the BER is measured after 120 km transmission. The eye diagrams in the figure clearly show that, since the use of DCF and EFDA to compensation dispersion and attenuation, even after 120 km, the received optical power is tolerable and the eye diagram is open enough, and the original signal can be restored.

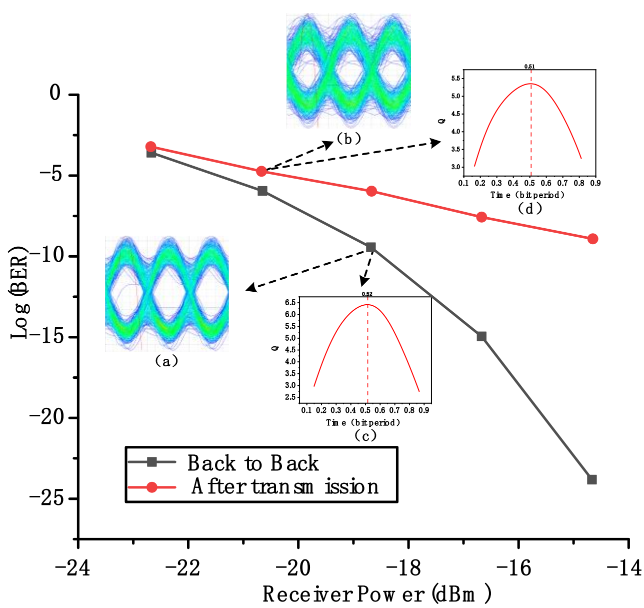

Fig.3. BER performance of MSK signal; (a) The eye diagram in the back-to-back; (b) The eye diagram after transmission; (c) Q factor and 1-bit period relationship curve of back-to-back transmission; (d) IQ factor and 1-bit period relationship curve of after transmission.

Figure 3 (c) and (d) are the Q factor and 1-bit period relationship curves when the MSK signal is demodulated in the BTB case and after 120km fiber channel transmission,. It can be seen from the figures that the optimal demodulation decision points corresponding to the received signal are 0.52 bit and 0.51 bit respectively. There is an inevitable signal-to-noise ratio (OSNR) degradation during signals transmission. It is necessary to select the optimal demodulation decision point within the 1-bit signal period to achieve the best decision detection, so that the transmission data can be recovered better.

4 Conclusion

In this article, we propose a novel submarine optical cable system using 10Gbit/s MSK optical signals to transmit and receive high-speed data over 120km optical fiber. We have evaluated the transmission performance of the system, obtained the time-domain waveforms, spectrums and eye diagrams characteristics before and after the MSK signal transmission, and analyzed the BER performance and the receiver sensitivity. This system omits the complicated DSP process, and in the future it is a potential long distance marine communication scheme.

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