

Investigation of vestigial sideband carrier suppressed return-to-zero formats due to optical filtering in a 40-Gbit/s system

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Abstract. We experimentally investigate the influence of vestigial sideband (VSB) filtering in a 40-Gbit/s optical system. Two kinds of optical filters and different pseudorandom bit sequences (PRBS) are used in experiment. The results show that optical filter ramp and PRBS length will cause different impacts in a VSB carrier suppressed return-to-zero system. © 2006 Society of Photo-Optical Instrumentation Engineers. [DOI: 10.1117/1.2189861]

Subject terms: vestigial sideband; pseudorandom bit sequence length; filtering impacts.

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1 Introduction

Vestigial sideband (VSB) modulation is one important technique to realize high spectral efficiency transmission and improve the fiber dispersion tolerance.^{1,2} There are many techniques to generate VSB or single-sideband (SSB) optical signals.^{3–5} All these techniques use complicated and expensive optical modulators and electrical signal processing devices. In 40-Gbit/s optical systems, optical filtering can be used to generate the VSB signal at low cost for simplicity.^{6,7} Because the optical filter reduces the redundant sideband of the optical signal, there are some distortions of the optical pulses. This paper experimentally shows the VSB filtering impacts on optical signals. Two kinds of bandpass optical filters are used to generate 40-Gbit/s vestigial sideband carrier suppressed return-to-zero (VSB-CSRZ) format with pseudorandom bit sequence (PRBS) lengths of 2^7-1 , 2^9-1 , $2^{15}-1$, $2^{23}-1$, and $2^{31}-1$, respectively. The back-to-back filtering performances are studied. There are bit error rate (BER) floors when the PRBS sequence length increases with both optical filters. The experiment results show that the filter ramp closed to carrier frequency dominates the filtering performance. So in 40-Gbit/s VSB-CSRZ systems, the forward error correction (FEC) should be employed to decrease the BER floor.

2 Experiment and Results

The experiment setup is shown in Fig. 1. In this experiment, the optical signal from the continuous wave laser (CWL) at 1557.36 nm is modulated by a Mach-Zender modulator (MZM1) biased at $V_{\pi/2}$ to generate the 40-Gbit/s non-return-to-zero (NRZ) code. And the second MZM is biased at the minimal intensity-output point and driven with a 20-GHz sine-clock signal. The phase deviation θ of the two modulator arms equals π . Thus the output of MZM2 is the 40-Gbit/s CSRZ code. Tunable optical filters are placed after the amplified signal to generate the VSB-CSRZ code. In order to test the performance, we use a 40-GHz BER tester with an optical preamplifier, after which there is an optical bandpass filter to block amplified spontaneous emission noise.

Two kinds of tunable optical filters are employed to generate 40-Gbit/s VSB-CSRZ signals. The 3-dB bandwidth of filter 1 is 0.3 nm. The transmission spectrum is shown in Fig. 2(a) and its shape is like a Gaussian function. The 3-dB bandwidth of filter 2 is 0.42 nm. The transmission spectrum is shown in Fig. 2(b) and its shape is like a rectangle with a much sharper ramp than filter 1. We tune the center frequency of the two filters in order to filter out one of the main tones of the CSRZ code and suppress the other as low as possible. The spectra of CSRZ and VSB-CSRZ after two separate filters are shown in Fig. 3. It's shown that both of the filters suppress one tone of CSRZ below 20 dB and keep the other dominating tone, which confirms that the VSB signal is more similar to an ideal SSB signal.

In the experiment, we also change the PRBS pattern lengths to 2^7-1 , 2^9-1 , $2^{15}-1$, $2^{23}-1$, and $2^{31}-1$, separately and test the received signal's BER performance. Figure 4 shows the tested BER curves of VSB signals employing different filters. It's obvious that there is a BER floor when the PRBS sequence length increases in both cases. When filter 1 is used, the BER floor rises when the PRBS length increases above $2^{23}-1$ and the BER floor is 10^{-9} . With filter 2, the BER floor rises when the PRBS length increases above $2^{15}-1$ and the BER floor is only 10^{-7} . The VSB filtering impacts can be mainly considered as optical pulse broadening.⁸ The sharper the filter ramp is, the more the optical pulse broadens. Since the ramp of filter 2 is much steeper than that of filter 1 in the close area of carrier frequency, filter 2 has worse BER performance than filter 1, as shown in Fig. 4. At the same receiver power, such as -20 dBm, the BER of filter 1 can be less than 10^{-12} with PRBS order 7, compared to only about 10^{-7} for filter 2. Also the filtering impacts will cause intersymbol interference (ISI) between optical pulses, and the worst case is the single bit "1" and "0" surrounded by different patterns. When the PRBS pattern length increases, the solitary bits are more than the short PRBS length case. Thus long PRBS suffer more distortions with optical filtering and get worse reception performance, which is also shown in Fig. 4(a) and 4(b).

3 Conclusion

The influence of optical filtering in 40-Gbit/s VSB-CSRZ systems is experimentally demonstrated and discussed. By changing the PRBS lengths and employing two kinds of optical filters, the reception performance is studied. The

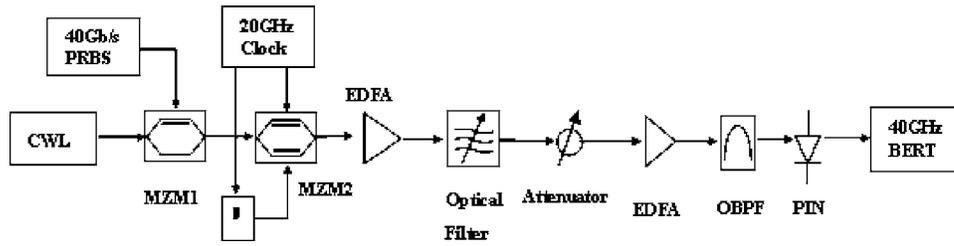


Fig. 1 Experiment setup.

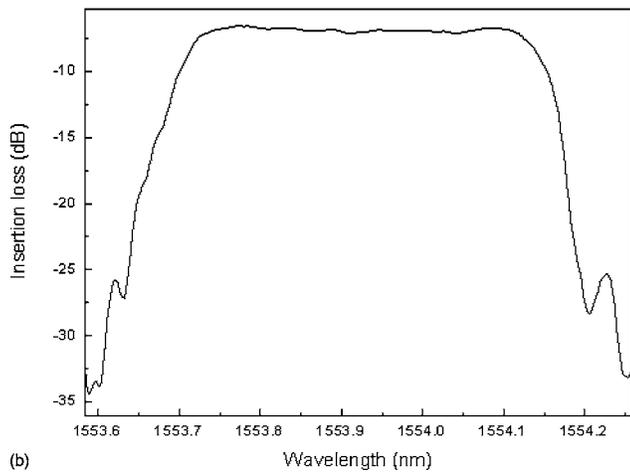
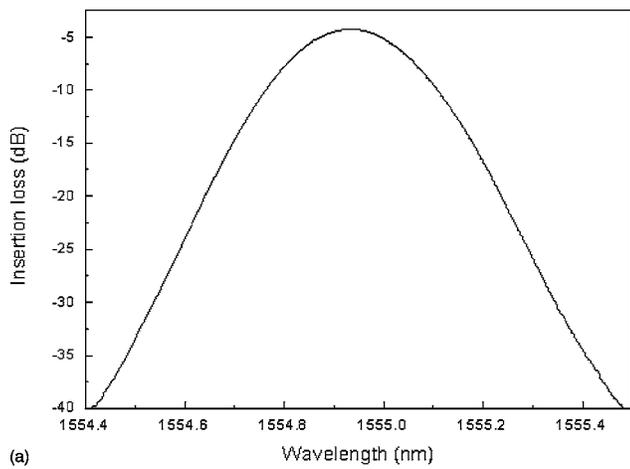


Fig. 2 Transmission spectra of (a) filter 1 and (b) filter 2.

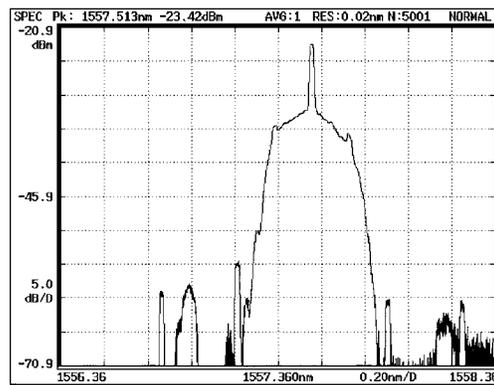
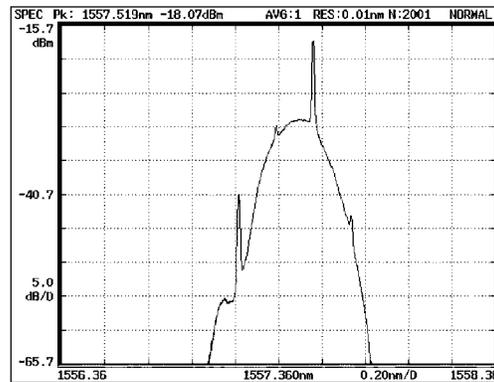
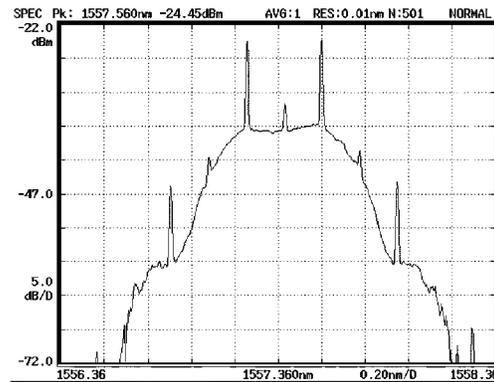
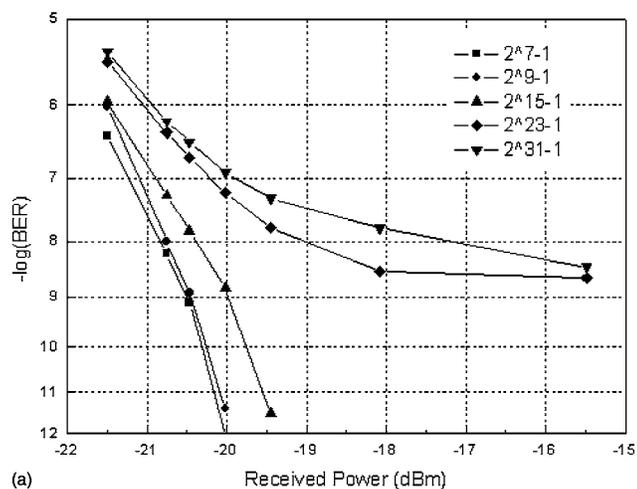
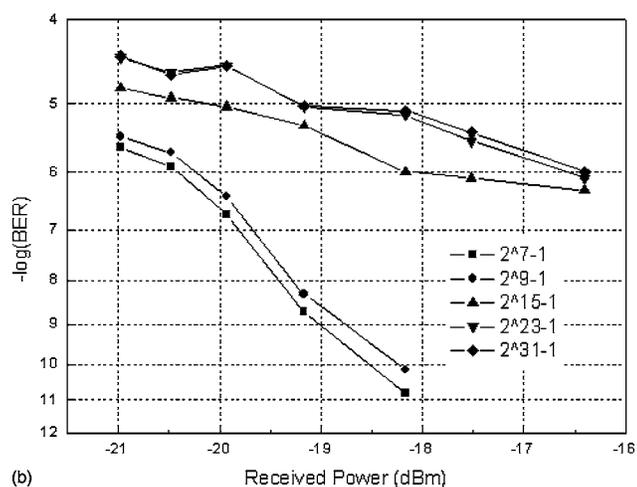


Fig. 3 Spectra of: (a) CSRZ, (b) VSB-CSRZ after filter 1, and (c) VSB-CSRZ after filter 2.



(a) Received Power (dBm)



(b) Received Power (dBm)

Fig. 4 BER curves of VSB signals employing (a) filter 1 and (b) filter 2.

results show that the filter ramp at carrier frequency dominates the performance of different bit sequences. And long PRBS pattern length suffers more than the short ones. So in 40-Gbit/s VSB-CSRZ systems, proper filter and FEC should be used to ensure the transmission performance.

Acknowledgments

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