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Editorial

Mails

Sometimes I wonder how I managed to deal with all the letters and manuscripts in paper form in former (?) times. This was a tremendous effort – and also costly, because most of the correspondence was with Asia and America and therefore I had to spend some money on the postage.

Today is everything is digital and can be sent without too much costs and efforts over the whole world. You may send one information to a lot of addresses – it does not cost more and it does not take more time.

So everything seems to be perfect – seems! Especially in Asia we have a problem which makes it even worse than before with all the paper work: I receive a manuscript by mail and answer the mail to acknowledge that we have received the paper: The mail comes back, because the mail address is invalid or does not work. What to do? Sometimes we have several mail addresses or I have an address of somebody who may work close to the authors. But this is an additional effort. And if this does not work, we have to mail a conventional letter and ask for a valid and working email-address. There are three choices for the answer:

1. There is no answer.
2. The new mail address does not work either.
3. The new address is ok.

These answers are equally distributed.

Sincerely yours

Ralf Th. Kersten

Editor-in-chief

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Modified Duobinary RZ Modulation Format for High-Speed Transmission*

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Summary

A novel duobinary RZ modulation format having a compact spectrum, complete removal of the carrier, and significant suppression of both the side-lobes and discrete components is proposed, with the best immunity to fiber nonlinearities and dispersion.

1 Introduction

A number of different return-to-zero (RZ) modulation formats were proposed recently [1–5]. The most popular among them are chirped RZ (CRZ) and carrier suppressed RZ (CSRZ). CRZ [5] is generated using bit-synchronous phase modulation of the RZ signal. Though highly tolerant to fiber nonlinearities, its spectrum is much broader than conventional RZ. On the other hand, narrower spectrum RZ formats, like CSRZ, are required for higher immunity to residual dispersion. The phase modulation can also be used for high-order dispersion compensation [1]. Recently proposed duobinary RZ (D-RZ) and modified duobinary RZ (MD-RZ) formats [2] are able to significantly suppress (but not completely as claimed by authors [2], see Fig. 2) the discrete components, responsible for creation of ghost pulses arising from four-wave-mixing (FWM). Unfortunately, their spectra, although compact, have very high sidelobes that increases the linear crosstalk, and prevents closer packing of channels for WDM applications. CSRZ has much better suppression of sidelobes, completely suppression of the carrier, but the discrete components remain.

We propose an alternative modulation format, named here as modified duobinary carrier-suppressed RZ (MDB-CSRZ) modulation format, that combine the good properties of both duobinary transmission and CSRZ modulation format. Also the modification of CSRZ by using variable modulation depth, instead of the full modulation depth as earlier proposed [6], allows us to change the duty cycle. It has very compact spectrum, very good suppression of sidelobes, complete removal of the carrier and near-complete removal of discrete components, therefore demonstrates the best immunity to residual dispersion and fiber nonlinearities.

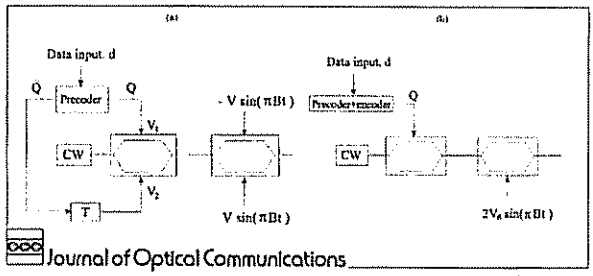

Fig. 1: Schematic diagram of the two variants for the proposed modulation format

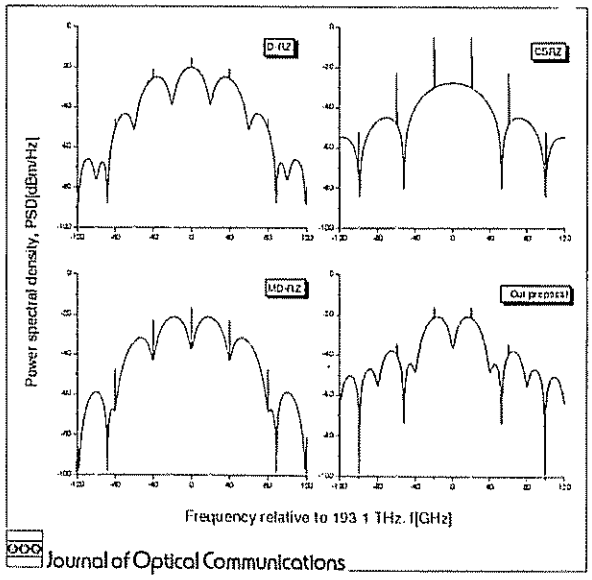

Fig. 2: Power Spectral densities of different RZ signals

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2 Proposed modulation format

Transmitter may be implemented using either push-pull March-Zehnder (MZ) modulators, Fig. 1 (a), or single-drive ones, Fig. 1 (b). The first variant consists of a differential pre-coder, a continuous wave (CW) laser, an electrical delay line and two MZ modulators. One arm of the first MZ modulator is driven by a signal from differential pre-coder ($Q_k = Q_{k-1} \oplus \bar{d}_k$), and the other by one bit period (T) delayed complementary version of pre-coder output. The second MZ modulator is biased at zero transmission point, and driven by sinusoidal signals of the same amplitude V, phase shifted π rad, and frequency equal to the half of a bit-rate. CSRZ results if the amplitude of sinusoid is equal to V_π, otherwise the pulse shape follows the expression $\sin[0{,}5\ \pi\ m\ \sin(\pi Bt)]$, with B being the bit rate and $m = V/V_\pi$ the amplitude depth.

In the second variant the pre-coder performs the same function as in the first variant, while the encoder performs the function $y_k = Q_k + Q_{k-1} - 1$, with y_k being the encoder output and Q_k the precoder output. The second MZ is driven by a sinusoid of frequency B/2 and amplitude $2V_\pi$.

The power spectral density of the proposed modulation format is shown in Fig. 2 for 40 Gbit/s bit rate (and full modulation depth), together with CSRZ, D-RZ and MD-RZ signal formats. The spectrum is the most compact among different RZ formats with the side lobs and the discrete components significantly suppressed, and the carrier is completely suppressed.

To simulate N × 40 Gbit/s WDM system the influence of four neighboring channels on observed channel is taken into consideration [3]. The transmission system consists of four spans of SMF (every 80 km long, giving 320 km of total length), each followed by corresponding DCF section to compensate both dispersion and dispersion slope. Two EDFAs are put after SMF and DCF sections to compensate the fiber loss of previous section.

The proposed modulation format demonstrates superiority over CSRZ in both single-channel, Fig. 3, and multichannel, Fig. 4, environment. The channel spacing was 0.8 nm and 0.5 nm, and the optical filter bandwidth 60 GHZ. Our modulation format significantly outperforms the CSRZ, for 2.5 dB in the second case. (Notice that non-optimal dispersion map is considered and the power at DCF section input is kept strong to demonstrate superiority of the proposed modulation format in the presence of chromatic dispersion, fiber nonlinearities and linear crosstalk over CSRZ.) Results of simulations were obtained using commercially available tool -VPItransmission maker 4.5 [7].

Because the proposed modulation format also has small low frequency components compared to CSRZ, it potentially allows good single-side band transmission that doubles the spectral efficiency.

3 Conclusion

A novel duobinary RZ modulation format with compact spectrum and significant suppression of side-lobes is proposed. Among many recently proposed RZ formats the closest channel packaging for WDM systems is possible with this format. The proposed modulation format suppresses the carrier completely and the discrete components significantly, and demonstrates high immunity to both residual dispersion and fiber nonlinearities.

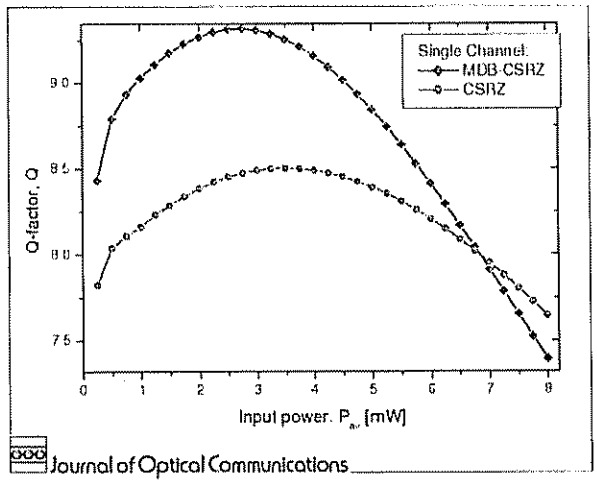

Fig. 3: Novel RZ modulation format vs. CSRZ for single channel transmission

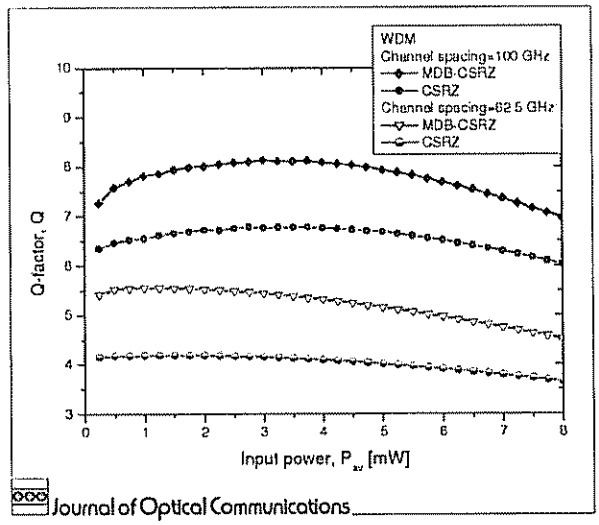

Fig. 4: Novel RZ modulation format vs. CSRZ for multichannel transmission

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