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10 Gb/s 4-PAM optical signal Over SMF Using Direct Detection

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Abstract: In this letter, the use of 4-pulsed amplitude modulation (PAM) in passive optical network (PON) implementations is investigated. The difference between the NRZ and 4-PAM modulation in principle is analyzed. We demonstrate 4-PAM modulation up to 10 Gb/s using direct detection In the meantime, 20-km even 30km transmission at 10 Gb/s with bit-error-rate below the forward-error-correction (FEC) limit can be achieved.

1. Introduction

With the overall expansion of worldwide communications bandwidth and our country scale of arrangement about"replacement of copper cables with optical fiber cables [1-2], universities and research institutions , operators and equipment manufacturers at home and abroad explore actively the feasible technical scheme on the next generation passive optical access network (PON) [3-6]. The optical access system setup is show shown in Figure.1.Next generation access topologies have to provide advanced and customer-oriented network solutions delivering higher data rates and better quality of services through cost-efficient fiber distribution networks [7]. At present, M-ary modulation is widely used in high-speed optical communication system for its high bandwidth efficiency. In this context, the use of advanced modulation formats compatible with intensity modulation direct detection (IM/DD) is an attractive way to achieve high spectral efficiency and faster bit rates maximum reduce the cost of the photoelectric device in the system cost without resorting to costly coherent detection approaches.

In this paper, the superiority of the 4-PAM modulation compared with traditional NRZ modulation signals has been analyzed in principle. We measured optical spectrum curves, and eye-diagrams, and analyzed the receiver sensitivity of 10Gb/s 4-PAM signals before and after transmission over 20 even 30 km SMF by simulation.

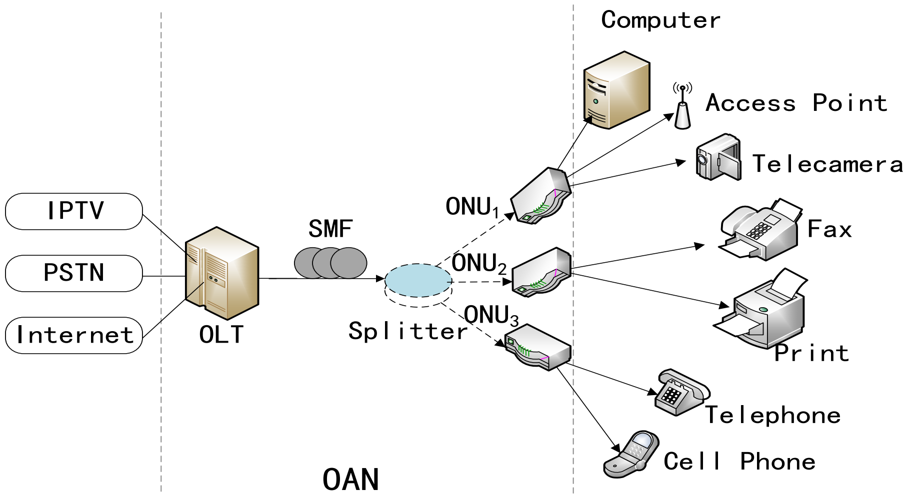

Figure 1: Optical access system setup

2. Materials and methods

When transmitting information, we can vary the amplitude of a signal according to the source symbols. The amplitude values are taken from the set of amplitudes [8]:

$$a_i=(2i-1-M, i=1,2,\cdots\cdots M) \quad (1)$$

In this paper, the M is equal to 4.where M is the number of possible sequences of binary digits, calculated according to:

$$M=2^h \quad (2)$$

Where h is the number of bits per symbol. Using Gray code, the adjacent signal amplitudes that correspond to the binary sequences will differ by only one digit. This model generates pulses according to:

$$k_{out} = \begin{cases} 0 & ,0 \le t < t_1 \\ a_k, & t_1 \le t < t_1 + t_c \\ 0, & t_1 + t_c \le t < T \end{cases} \quad (3)$$

Where a_k is the amplitude of the signal k,T is the bit period, $t_c$is the duty cycle, and t_1 is the pulse position.

Figure. 2 shows the time-domain sequential waveform diagrams of NRZ(a) signal and (b)4-PAM signals, The amplitude values of NRZ(a) signal are taken from 0 ,1,while 4-PAM signals amplitude values have four different values,-3,-1,1,3. So, the 4-PAM signals can bring higher spectral efficiency, compared with traditional NRZ modulation signals. Fig.2 shows the electrical frequency spectra diagrams of NRZ(c) signal and 4-PAM(d) signal. Not hard to find that the spectrum width of 4-PAM signal occupied only is half of NRZ signal within the same bit rate, which can improve the spectral efficiency greatly.

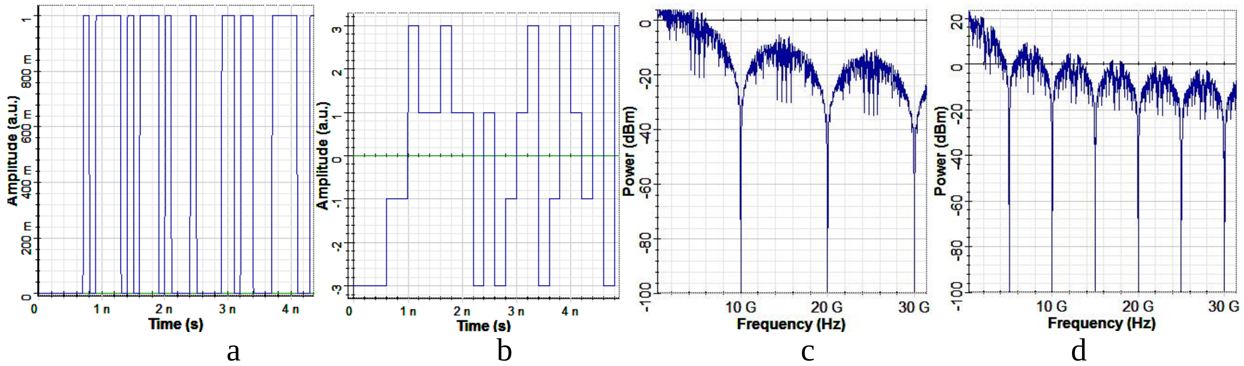

Figure 2: The time-domain sequential waveform diagrams of NRZ(a) signal and (b)4-PAM signals, the electrical frequency spectra diagrams of NRZ(c) signal and 4-PAM(d) signal

3. Results and analysis

In our scheme, two optical spectra diagrams of 4-PAM signals before and after transmission over fiber link are extracted to evaluate the system performance, as show in Figure 3 (c) and (d) respectively. It is clear to see, since the EDFA are used to compensate the transmission attenuation, the peak power of the optical carrier at f_0 =193.1THz almost have no loss. The sideband is aiso suppressed obviously via a optical Bessel filter.

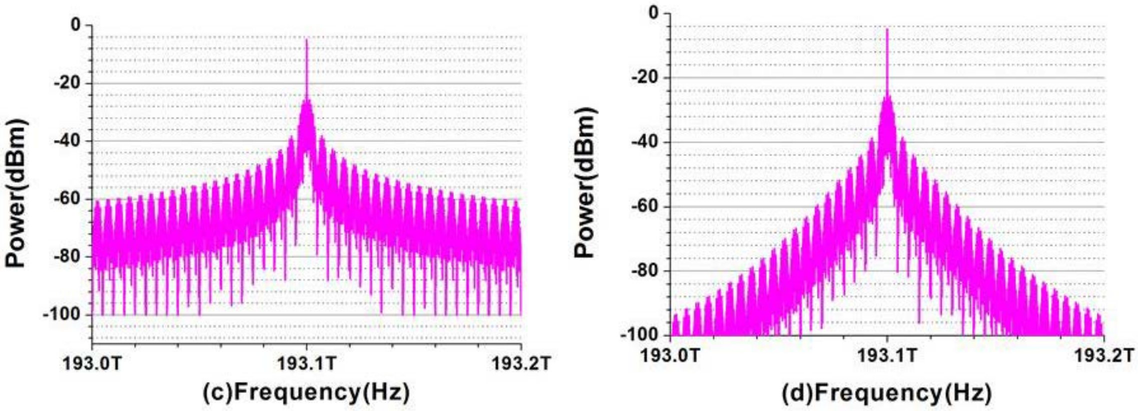

Figure 3: optical spectra diagrams of 4-PAM signals (c) before and (d) after transmission

The BER v/s received power curves for this scheme are shown in Figure.4. The insert picture(a)(g), (b)(f)and(c)(e) are the received signals eye diagram after 0km,20km and 30km SMF transmission respectively. At the end of 20km and 30m SMF, the receiver sensitivity is -9.7dBm and-9.5 respectively(at a BER of 10^{-6}). Compared with the back to back case, the value of the received power penalty at BER = 10^{-6} will be reduced, which is about 2.5dB and 2.7 dB, respectively.

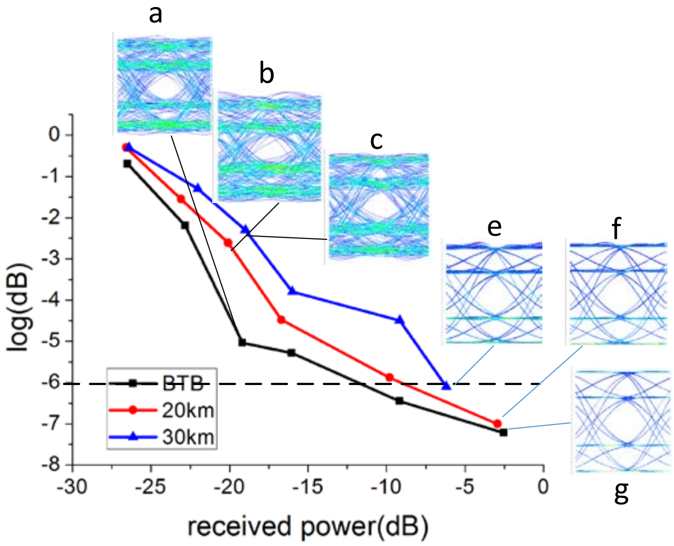

Figure. 4: BER versus received power curves.

4. Conclusions and Discussion

In this paper, the superiority of the 4-PAM modulation compared with traditional NRZ modulation signals has been analyzed in principle. Optical 4-PAM signas are generated, transmitted over 20km even 30km SMF as downlink signals. Simulation results prove the BER performance of 10-6 can be achieved both for 20 and 30km SMF transmission.

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