An 8-dimensional modulation format for Mitigating the NPSE in the polarization multiplexing coherent system

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1. Abstract

- We use an 8-dimensional modulation coding method to reduce the inter-channel nonlinear interference in WDM system.
- The 8-dimensional modulation format can effectively suppressing the nonlinear polarization scattering effect (NPSE) caused by the inter-channel nonlinear interference noise (NLIN).
- Under the same spectrum efficiency , the 8D-16QAM can obtain a nonlinear gain of more than 0.3dB compared with the conventional PDM-QPSK signal in simulation.

2. Principle and Modulation format design

At the transmitter, for 16QAM, we first calculate the corresponding Stokes vector for the 256 four-dimensional symbol combinations (X/Y polarization, in-phase/quadrature component) corresponding to 16QAM, and the calculation formula is shown as below:

$$S_1 = |E_x(t)|^2 + |E_y(t)|^2$$

$$S_2 = 2*\mathrm{Re}\left(\left|E_x(t)\cdot E_y(t)\right|\right)$$

$$S_3 = 2*\mathrm{Im}\left(\left|E_x(t)\cdot E_y(t)\right|\right)$$

where Ex(t) and Ey(t) means the component of the electric field in the X and Y polarization, the"Re" and "Im" denotes the real and imaginary parts, respectively.

TABLE 1 THE OPTICAL FIELD JONES VECTORS FOR THE TWO CONSECUTIVE TIME SLOTS (SLOT-A AND SLOT-B) THAT DEFINE THE 8-DIMENSIONAL X-CONSTELLATION SYMBOLS

Binary Value		0000 0000	0000 0001	0000 0010	0000 0011	0000 0100	0000 0101	0000 0110	0000 0111	……	1111 1000	1111 1001	1111 1010	1111 1011	1111 1100	1111 1101	1111 1110	1111 1111
Slot A	x-pol	-3+3i	-3+3i	-3+3i	-3+3i	-3+3i	-3+3i	-3+3i	-3+3i	……	1-i	1-i	1-i	1-i	1-i	1-i	1-i	1-i
	y-pol	-3+3i	-3+i	-3-3i	-3-i	-1+3i	-1+i	-1-3i	-1-i	……	3+3i	3+i	3-3i	3-i	1+3i	1+i	1-3i	1-i
	$S_A=(S_1,S_2,S_3)$	(0,36,0)	(8,24,-12)	(0,0,-36)	(8,12,-24)	(8,24,12)	(16,12,0)	(8,-12,-24)	(16,0,-12)	……	(-16,0,-12)	(-8,4,-8)	(-16,12,0)	(-8,8,-4)	(-8,-4,-8)	(0,0,-4)	(-8,8,4)	(0,4,0)
Slot B	x-pol	3+3i	3+i	3-3i	3-i	1+3i	1+i	1-3i	1-i	……	-3+3i	-3+i	-3-3i	-3-i	-1+3i	-1+i	-1-3i	-1-i
	y-pol	-3-3i	-3-3i	-3-3i	-3-3i	-3-3i	-3-3i	-3-3i	-3-3i	……	1+i	1+i	1+i	1+i	1+i	1+i	1+i	1+i
	$S_B=(S_1,S_2,S_3)$	(0,-36,0)	(-8,-24,12)	(0,0,36)	(-8,-12,24)	(-8,-24,-12)	(-16,-12,0)	(-8,12,24)	(-16,0,12)	……	(16,0,12)	(8,-4,8)	(16,-12,0)	(8,-8,4)	(8,4,8)	(0,0,4)	(8,-8,-4)	(0,-4,0)
DOP	$\lvert S_A+S_B \rvert$	0	0	0	0	0	0	0	0	……	0	0	0	0	0	0	0	0

For each group of four-dimensional symbols, We find another group of four-dimensional symbol which set of Stokes vectors is opposite. And then we make these two groups of four-dimensional symbols located in two adjacent time slots to form an eight-dimensional symbol with a Stokes vector sum of 0, which means that the DOP of an eight-dimensional symbol is 0.The maintained lookup table is shown in Figure 1.

3. Simulation and results

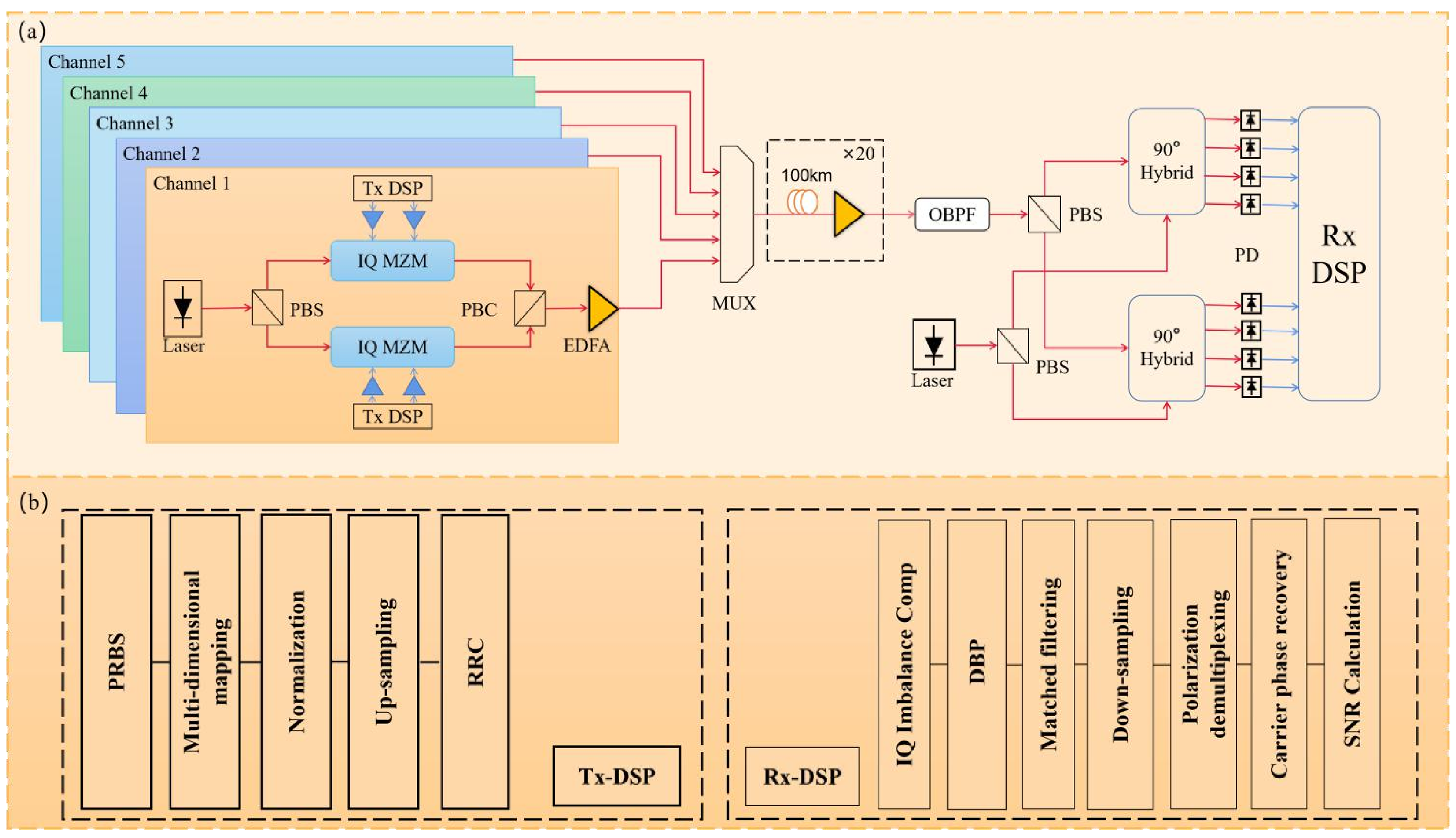

Fig. 1. (a) Simulation setup. (b) Tx DSP and Rx DSP.

We conduct the simulation of five-channel with 30-GBaud 8D-16QAM and conventional PDM-QPSK signals transmission over 2000 km SSMF in the coherent optical fiber transmission system to fairly compare the NPSE tolerance with the same spectral efficiency. Figure. 1(a) shows the simulation setup. Fig. 1(b) shows the transceiver DSP flow.At the transmitter, PRBS are generated to perform 8-dimensional mapping based on the maintained lookup table,which is key part of the simulation.

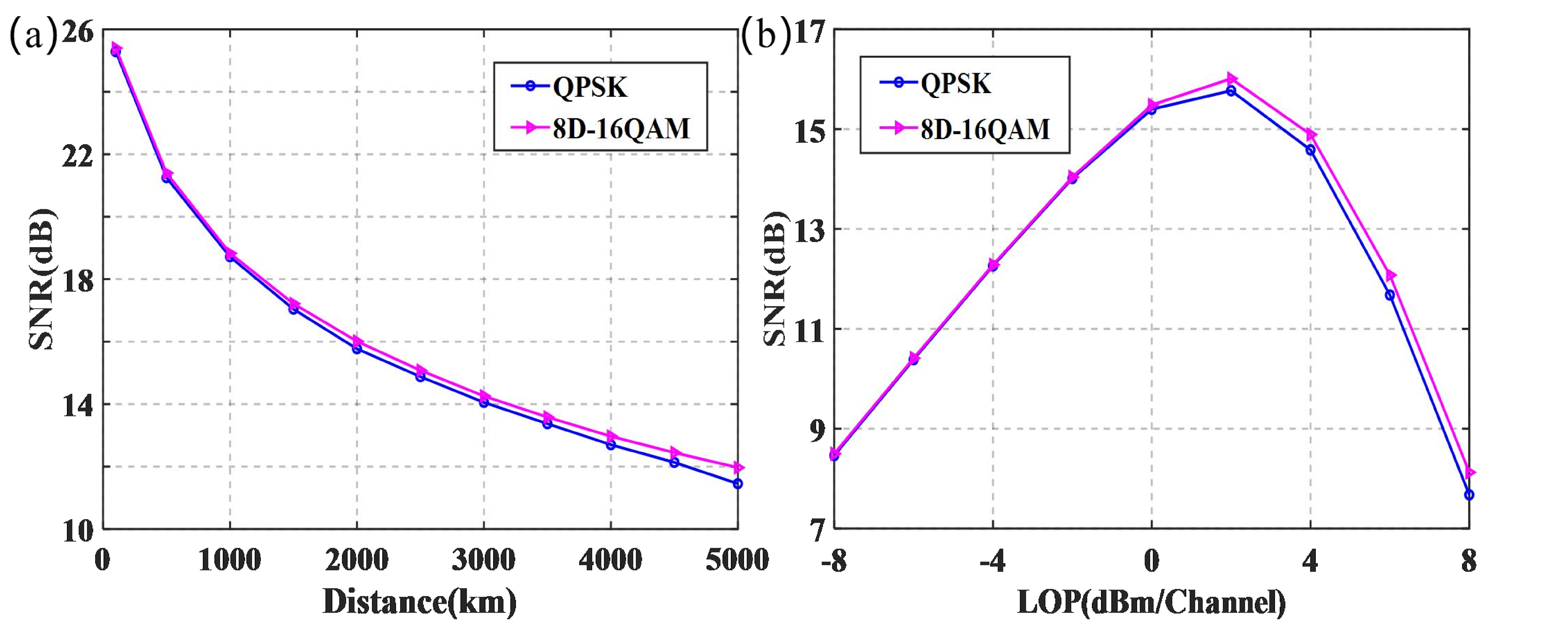

Fig. 2. (a) SNR vs distance for 8D-16QAM based on X-constellation and conventional PDM-QPSK in a 5-channel WDM coherent optical communication system at 30G-Baud; (b) SNR versus LOP for 8D-16QAM based on X-constellation and conventional PDM-QPSK in a 5-channel WDM coherent optical communication system at 30G-Baud over 2000km transmission.

As shown in Fig. 2(a), when the transmission distance is short, 8D-16QAM cannot obtain a significant performance gain. In long-distance transmission, the NPSE becomes the main noise source in NLIN, the 8D-16QAM based on the X-constellation used to suppress the NPSE can be larger than 0.3-dB nonlinear gain compared with the conventional QPSK.It can be seen from Fig. 2(b) that 8D-16QAM and conventional PDM-QPSK have basically the same SNR in the linear region because they are only affected by linear noise. As the increase of fiber LOP, 8D-16QAM gradually shows better nonlinear tolerance compared with conventional PDM-QPSK. At the optimal LOP point, i.e.2dBm, 8D-16QAM achieves a nonlinear gain of 0.3dB.