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New Efficient Four-Dimensional Trellis Coded Modulation Format

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Introduction

With the increasing demand of communication capacity, various new technologies are urgently needed to improve transmission capacity and performance. Four-dimensional modulation has attracted much attention in recent years. Compared with the traditional two-dimensional modulation, the four-dimensional modulation applies the four degrees of freedom composed of the X and Y polarization in phase and quadrature components.

Therefore, new efficient modulation formats 4DTCM-SP-128QAM and 4DTCM-SP-128TQAM are proposed in this paper.

Principle

Set-Partitioning QAM is a new four-dimensional modulation method proposed in 2011 by Coelho and Hanik of the Federal University of Pernambuco, Brazil. 128-SP-QAM is improved based on the traditional modulation format polarization multiplexing(PM)-16QAM. On the basis of the above, the constellation points of SP-128QAM signal are subset and mapped, and 4DTCM-SP-128QAM is realized by trellis coding modulation. In addition, according to 16TQAM signal, 4DTCM-SP-128TQAM modulation format is proposed in this paper. It can be seen that 4DTCM-SP-128TQAM signal has lower average energy per symbol.

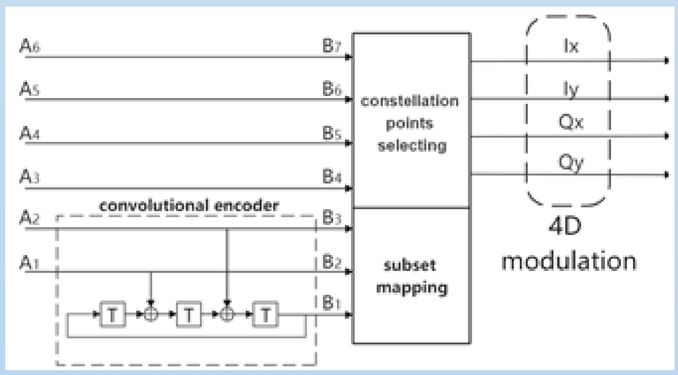

Figure 1. Configuration of 4DTCM-SP-128QAM/128TQAM modulation format.

The basic structure of the 4DTCM-SP-128QAM or 4DTCM-SP-128TQAM modulation format is shown in Fig.1, consisting mainly of convolutional encoder and subset mapping at the sender. The convolutional encoder rate and the constraint length of the encoder are R=2/3 and K=4, respectively. Specifically, two input bits a_1 and a_2 enter the convolutional encoder, while a parity bit b1 is generated by a_1 and a_2 through a convolution process. The newly generated bit b_1-b_3 selects subsets S_0-S_7 respectively. And the choosing rules are depicted in Table 1. After the subset selection, the unencoded bit a_3-a_6 is used to select the constellation points within the subset. Finally, the modulated four-dimensional signal is obtained by diversity mapping. For 4DTCM-SP-128QAM, the subset division of SP-128QAM signal is shown in Fig. 2. The division and mapping of subsets greatly affect the performance of the transmission system and the Euclidean distance of constellation points.

After the first division, the MSED between the constellations did not change. But after the second division, the MSED between the constellations increased twice as much as before. For 4DTCM-SP-128TQAM signal, the set is divided in a similar way. But because of the selection of TQAM constellation points, the MSED will be $3d_1^2$ in case that the minimum distance between constellations is d_1 before subset division.

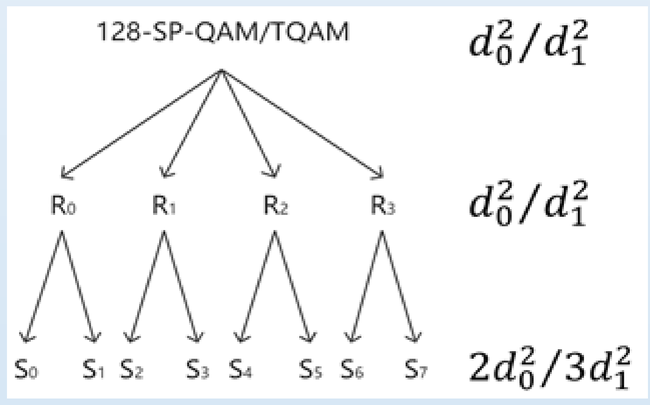

Figure 2. Set partitioning process for 4DTCM-SP-128QAM or 4DTCM-SP-128TQAM.

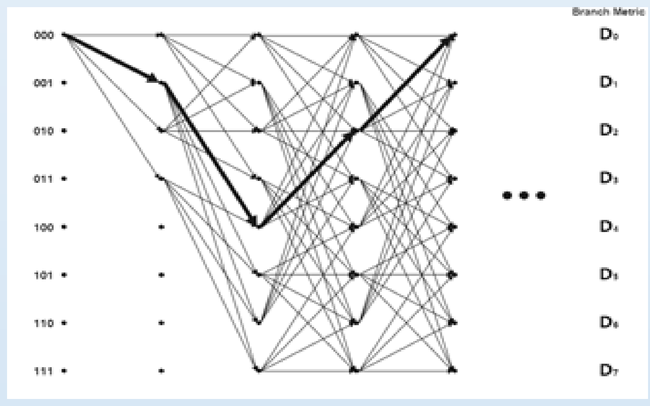

Figure 3. Process of Viterbi decoding.

Simulation and Result

In order to evaluate the performance of the new modulation format 4DTCM-SP-128QAM and 4DTCM-SP-128TQAM, MATLAB is conducted to processes signals and analyze and compare BER performance of 4DTCM-SP-128QAM, 4DTCM-SP-128TQAM and SP-128QAM. The constellations of the X polarization states of these two formats at 18dB SNR are shown in the Fig. 4.

the simulation is performed when the average energy of these modulation formats is fixed in order to fairly compare the performance. The bit error rate is obtained as shown in the Fig. 5. As we can see in the Fig. 5, both of these new modulation formats have improved performance compared to SP-128QAM.

Specifically, 4DTCM-SP-128QAM and 4DTCM-SP-128TQAM obtained the gain of 2.53dB and 1.33dB at $BER=1.0\times10^{-3}$, respectively. And this improvement is enhanced as the SNR increases.

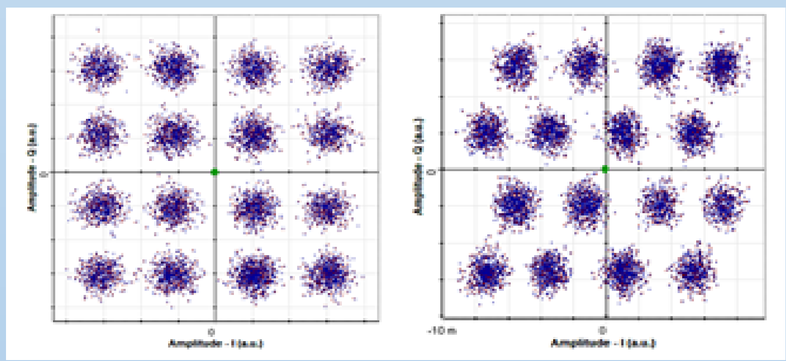

Figure 4. Constellation diagrams.

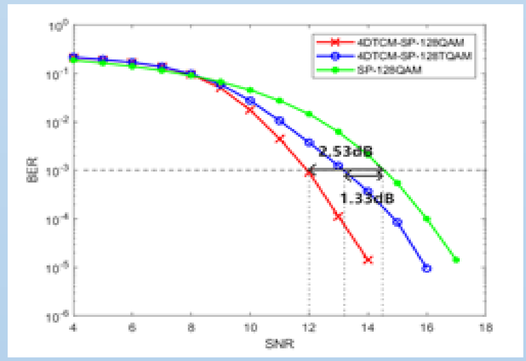

Figure 5. Performance comparison

Conclusion

In this paper, new modulation formats 4DTCM-SP-128QAM and 4DTCM-SP-128TQAM is proposed. Through theoretical analysis and simulation, it is proved that the two modulation schemes are both superior to SP-128QAM. These two modulation formats respectively obtain the gain of 2.53dB and 1.33dB at $BER=1.0\times10^{-3}$ compared with SP-128QAM.

Acknowledgements

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