Research Paper Presentation

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Performance analysis of M-QAM OFDM for satellite laser communication systems

Abstract

1. We will talk about a satellite laser communication system based on M-QAM and OFDM and analyze its performance.
2. The relationship between the link bit error rate and the transmission power under different conditions of atmospheric turbulence and M-QAM modulation.
3. The results have shown that as the turbulence intensity increases, the QAM modulation of order M increases, and the performance of OFDM optical links continues to deteriorate.

Keywords and some definitions

Modulation

It is the process where the properties of a carrier wave such as amplitude, frequency and phase is changed according to the information signal.

Orthogonal Frequency Division Multiplexing Modulation (OFDM):

Method of encoding digital data on multiple carrier frequencies, instead of a single wide frequency bandwidth.

Frequency Selective Fading

Anomaly caused by partial cancellation of a radio signal by itself

Quadrature Amplitude Modulation (QAM):

It utilises both amplitude and phase components that is able to provide high levels of spectrum usage efficiency

Structure Principle

Block Diagram

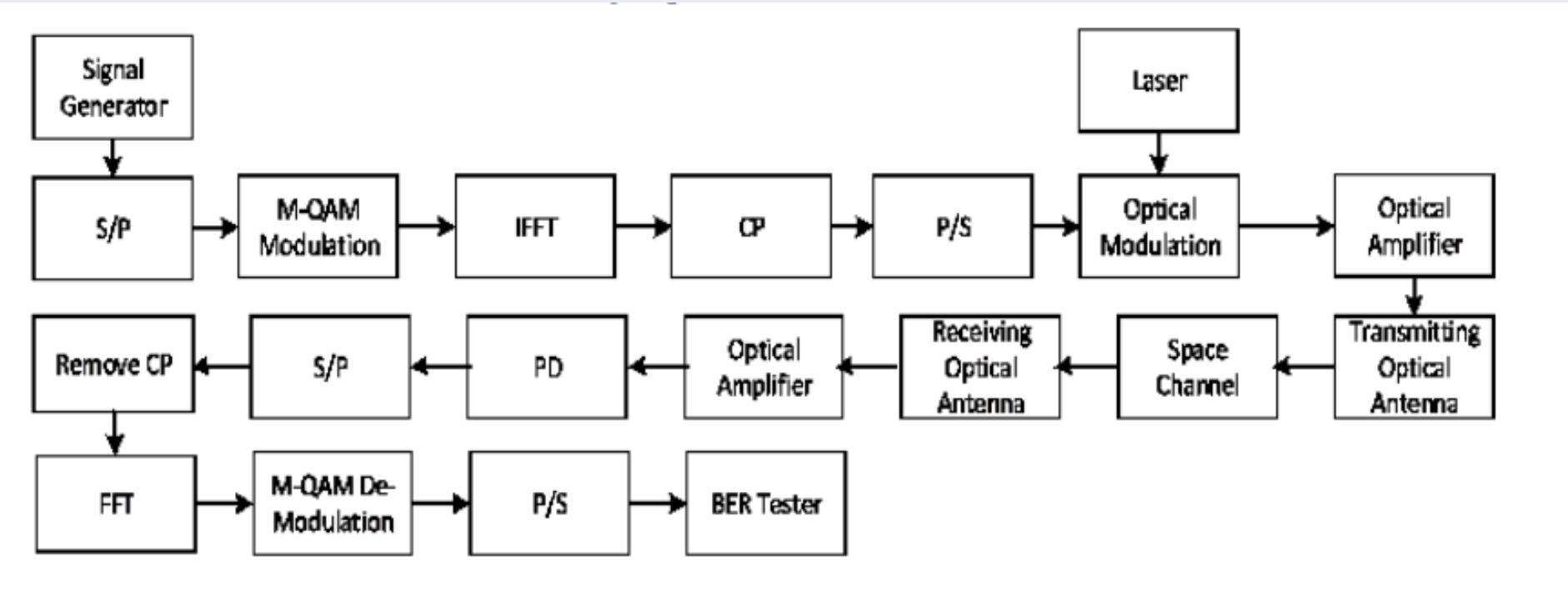

Figure: MQAM OFDM Structure Principle

Structure Principle

Block Diagram Components

1. S/P: Serial to Parallel Converter converts datastream from series to N parallel parts which form each subcarrier for easy modulation and using the frequency spectrum optimally
2. MQAM modulation means *M* symbols are used to represent and transmit data and each symbol is given a certain percentage of amplitude and phase difference
3. IFFT is inverse fast Fourier transform which modulates the info signal onto carrier signal to give modulated signal
4. Space Channel is the medium through which the signal will be transmitted.

Structure Principle

Block Diagram components

1. Optical Modulation allows one to control an optical wave or to encode information on a carrier optical wave.
2. A cyclic prefix is a repetition of the first section of a symbol that is appended to the end of the symbol
3. A Photo Detector detects the required electromagnetic radiation and converts them to electrical signals.
4. BER tester is the Bit Error Rate tester.

Space Channel

About Space Channel

1. It is the medium through which the entire signal is transmitted.
2. There is a lot of interference from other signals, atmospheric turbulence, noise and attenuation.
3. Many different statistical models have been proposed for light intensity flicker caused by atmospheric turbulence. Eg
    1. Negative exponential distribution
    2. Lognormal distribution
    3. Gamma-Gamma distribution model

Gamma Gamma Distribution Model

PDF

$$f_{h_t}(h_t) = \frac{2(\alpha\beta)^{\frac{\alpha+\beta}{2}}}{\Gamma(\alpha)\Gamma(\beta)}(h_t)^{(\frac{\alpha+\beta}{2}-1)}K_{\alpha-\beta}\sqrt{2\alpha\beta h_t} \tag{1}$$

$$\alpha = \left\{\exp\left[\frac{0.49\sigma_0^2}{\left(1+1.1\sigma_0^{\frac{12}{5}}\right)^{\frac{7}{6}}}\right]-1\right\}^{-1} \tag{2}$$

$$\beta = \left\{\exp\left[\frac{0.51\sigma_0^2}{\left(1+0.69\sigma_0^{\frac{12}{5}}\right)^{\frac{5}{6}}}\right]-1\right\}^{-1} \tag{3}$$

Gamma Gamma Distribution Model

PDF

Parameter	Parameter Denotes
$K_{\alpha-\beta}\sqrt{2\alpha\beta h_t}$	Second class modified Bell Function:order $\alpha-\beta$
$\sigma_0^2 = 1.23C^2K^{\frac{7}{6}}z^{\frac{11}{6}}$	Rytov Variance
C_n^2	Atmospheric refractive index structural constant
$K = \frac{2\pi}{\lambda}$	plane wave number
z	speed of light
$\Gamma(\alpha)\Gamma(\beta)$	Gamma function

Table: Parameters

Gamma Gamma Distribution Model

Important Points

1. h_t is our random variable for which distribution is plotted.
2. α and β are defined according to (2) and (3) and depend on σ_0
3. σ_0 depends on the medium through which the wave passes and wave-number of link operating wave.
4. σ_0 also depends on the speed of light which may vary depending upon the atmospheric condition and the medium.

Pointing Error

Pointing error theory

Along with atmospheric turbulence, the pointing errors of the optical links between the platforms affect the fluctuation of the optical signal intensity.

PDF

Probability density function of the pointing error factor of the optical link between platforms:

$$f_{h_p}(h_p) = \frac{\xi^2}{A_0^{\xi^2}}(h_p)^{(\xi^2-1)}, \quad 0 \leq h_p \leq A_0 \tag{4}$$

$$\nu = \frac{\sqrt{\pi r}}{\sqrt{2}w_z} \tag{5}$$

$$\xi = \frac{w_{z,eq}}{2\sigma_s} \tag{6}$$

Pointing error

PDF

Parameter	Parameter Denotes
$w_{z,eq}^2 = \frac{w_z^2 \sqrt{\pi} erf(\nu)}{2\nu \exp(-\nu^2)}$	Equivalent beam width at the receiving end
σ_s	Standard deviation of pointing error offset at receiving end
$erf(\nu)$	Error Function
$w_z = \theta z$	Beam width at distance z
z	distance between transmitter and receiver
θ	Beam emission angle
r	Receiver Radius

Table: Parameters

Demodulator

Performing demodulation

1. The data is converted to parallel and cyclic prefix is removed. FFT is applied.
2. N symbol data is now $N + L$ symbol data, due to IFFT and adding CP.
3. Suppose the required period of an OFDM symbol is T.
4. At the beginning of every OFDM symbol there is a cyclic prefix of length T_g , created by taking last L symbol in a OFDM sysmbol and adding to begining.
5. T_g must be greater than channel impulse response time to be useful.

Subcarrier

Formula

$$\nu(t) = \sum_{k=-N}^{N} C_k \exp\left(2\pi j f_k t\right), \quad 0 \leq t \leq T \tag{7}$$

1. $f_k = \frac{k}{T}$ the frequencies of complex exponential
2. At the receiver it is down converted, timing synchronization is done, cyclic prefix is removed and FFT is applied.

How error occurs?

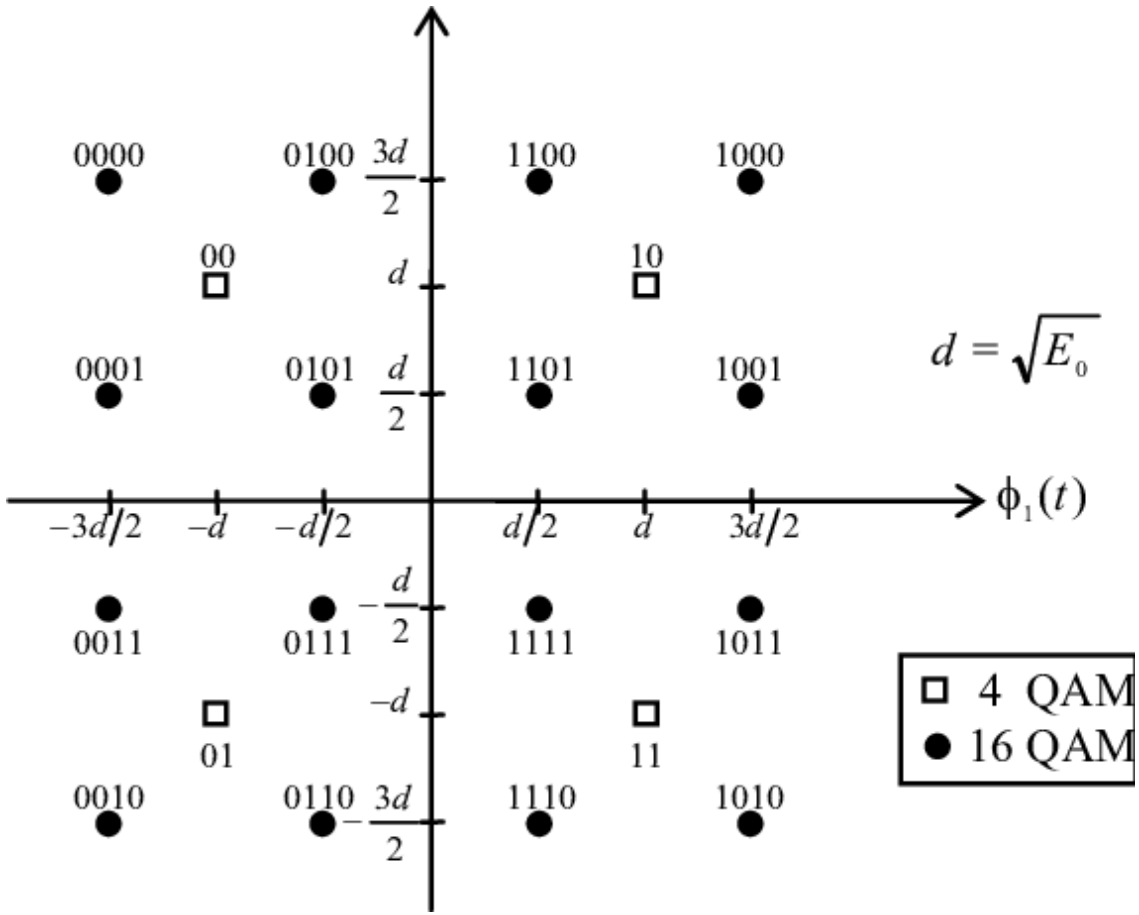

Figure: Mapping symbols in phase and amplitude

Experiment and Results

Case 1

Sub-carrier uses 4-QAM modulation. Turbulence strengths σ_0^2 is taken as 0.4,1.4 and 4.

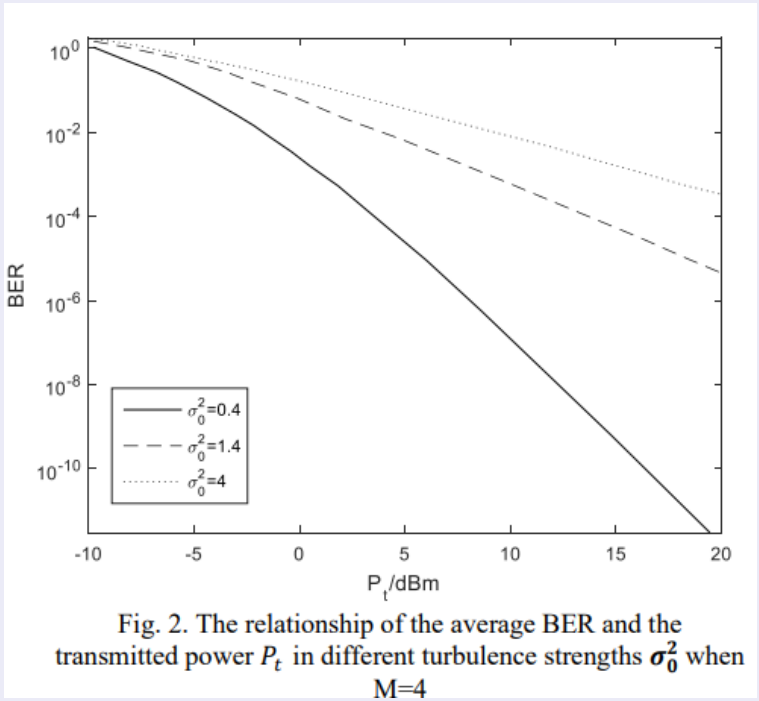

Fig. 2. The relationship of the average BER and the transmitted power P_t in different turbulence strengths $\boldsymbol{\sigma_0^2}$ when M=4

Figure

Experiment and Results

Case 2

Turbulence strength $\sigma_0^2 = 1.4$ and different M-QAM modulations are taken for 4,16, and 64.

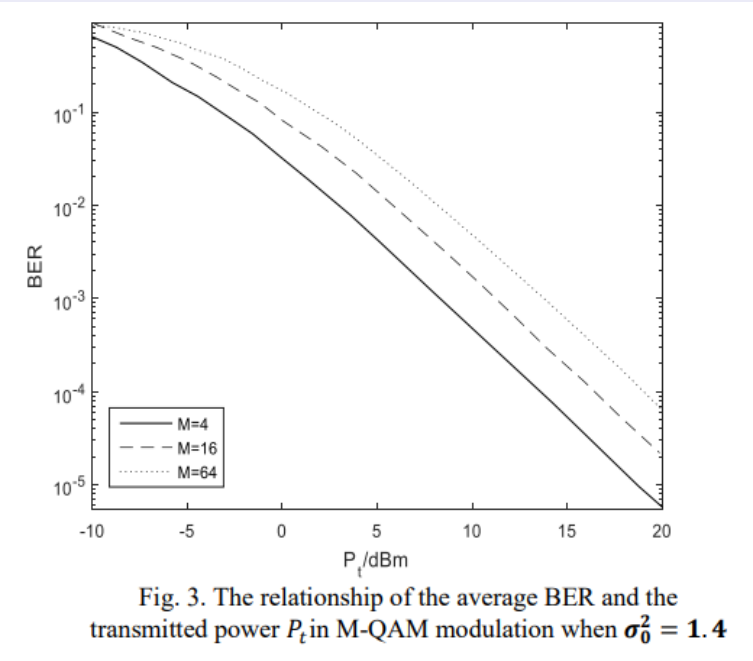

Fig. 3. The relationship of the average BER and the transmitted power P_t in M-QAM modulation when $\boldsymbol{\sigma_0^2 = 1.4}$

Figure

Experiment and Results

Results

1. The relationship between the bit error rate of an OFDM link and the transmit power under different atmospheric turbulence conditions and for different M-QAM modulation.
2. In first case, as the turbulence intensity increases the BER also increases and the performance decreases. By increasing the transmitting power, BER decreases.
3. In second case, as the order M increases the BER also increases and the performance decreases. By increasing the transmitting power, BER decreases.

Conclusion

Conclusions and Inference

1. MQAM OFDM is applied to satellite laser communication.
2. The relationship between the bit error rate of the OFDM optical link and the transmission power is analyzed under different conditions.
3. The results show that as the turbulence intensity increases, the QAM modulation order M increases, and the performance of OFDM optical links continues to deteriorate.
4. This gives us the reference for optimization of OFDM in satellite laser communication.