*2.2 Underwater channel*

For interference in the underwater channel, it is cate-gorized into additive Gaussian white noise and multi-plicative noise. The mathematical expression for the channel model is as follows:

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Among them, represents the information before passing through the channel, represents the in-formation after passing through the channel, represents multiplicative noise, and represents addi-tive Gaussian white noise. In this paper, the multipli-cative noise focuses on the impact of underwater turbulence. Three different distribution functions represent the multiplicative noise to simulate various underwater environments: the generalized gamma distribution, the lognormal distribution, and the Gamma-Gamma distribution.

Weak turbulence is primarily caused by factors such as temperature differences. The generalized gamma distribution, proposed by the Oubei team [11], was specifically designed to describe underwater turbulence induced by temperature variations. Its probability density function is given by:

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There are two shape parameters, and ; the scale parameter is ; represents the beam intensity and Γ is the gamma function.

Strong turbulence is typically modeled using the highly effective Gamma-Gamma distribution. This distribution decomposes the received light intensity into the product of two independent Gamma random processes [12]. These processes represent an adequate number of largescale and small-scale scattering cells. The probability density function is expressed as follows:

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Among them, Γ is the gamma function, *α* and *β* represent the outer scale parameter and the inner scale parameter, respectively, and represents the modified Bessel function of the second kind

The specific range for moderate turbulence remains a topic of debate, with no universally accepted definition. Various distributions can be used to model it; this paper uses the widely adopted lognormal distribution for simulation. Its probability density function is given by [13]:

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Where represents the average received light intensity, while denotes the scintillation index. I represents the beam intensity. The scintillation index can be calculated as the ratio of the standard deviation of light intensity fluctuations to the average light intensity:

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Among them, represents the statistical average and *I* represents the random light intensity of the light beam. This paper initially classifies the strength of turbulence, with serving as the threshold boundary [14], with considered strong turbulence. When , the lognormal distribution is commonly use [15, 16], and when , the generalized gamma distribu-tion performs better, is considered as weak turbulence, while other cases are regarded as moderate turbulence.