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IMPULSE RESPONSE MODEL FOR PERFORMANCE ANALYSIS AND SYSTEM DESIGN OF UWOC SYSTEMS

M.Keerthiga[1], N.Jayanthi[2]
PG Student [Communication Systems], ECE, Mahendra Engineering College, Namakkal, Tamilnadu, India[1]
Assistant Professor, Dept. of ECE, Mahendra Engineering College, Namakkal, Tamilnadu, India[2]

***ABSTRACT*: In underwater wireless optical communication (UWOC) links, multiple scattering may cause temporal spread of beam pulse characterized by the impulse response, which therefore results in inter-symbol interference (ISI) and degrades system error performance. The impulse response of UWOC links has been investigated both theoretically and experimentally by researchers but has not been derived in simple closed-form to the best of our knowledge. In this paper, we analyze the optical characteristics of seawater and present a closed-form expression of double Gamma functions to model the channel impulse response. The double Gamma functions model fits well with Monte Carlo simulation results in turbid seawater such as coastal and harbor water. The channel bandwidth and packet loss, throughput are further evaluated based on this model for various link ranges. Numerical results suggest that the temporal pulse spread strongly degrades the BER performance for high data rate UWOC systems with on-off keying (OOK) modulation and limits the channel bandwidth in turbid underwater environments. The decision feedback (DFE) equalization designed based on our channel model has been adopted to overcome ISI and improve the system performance. It is plausible and convenient to utilize this impulse response model for performance analysis and system design of UWOC systems.**

***Keywords:* Underwater wireless optical communications, Impulse response, Decision Feedback Equalization**

I.INTRODUCTION

Underwater wireless communications has been proposed for submarine communications due to the flexibility and scalability. In recent years, underwater wireless optical communications (UWOC) has attracted considerable attentions as an alternative technology to traditional approach. UWOC systems can provide high security, low time delay and a much higher data rate up to hundreds of Mbps in relatively short ranges (typically shorter than 100 meters). Due to these advantages, UWOC has numerous applications such as real-time video communications, remote sensing and navigation, imaging as well as high throughput sensor network. The absorption and scattering may introduce the effects of energy loss and direction changing for the optical beams, respectively. The multiple scattering effect may spread beam pulse both temporally and spatially, which plays a key role in beam propagation. The spatial beam spreading has been studied in and exerts a positive impact on system performance.

However, the temporal beam spreading will introduce the temporal dispersion and therefore corrupt the receive signal. Prior studies have shown that the optical beam suffers absorption and scattering through propagation in the seawater. The absorption and scattering may introduce the effects of energy loss and direction changing for the optical beams, respectively. In turbid medium especially coastal and harbor water, the transmitted photons are scattered multiple times, which is referred to as multiple scattering. The multiple scattering effects may spread beam pulse both temporally and spatially, which plays a key role in beam propagation. The spatial beam spreading has been exerts a positive impact on system performance. However, the temporal beam spreading will introduce the temporal dispersion and therefore corrupt the receive signal especially for turbid water types.

In this paper, we focus on the impulse response of underwater optical links. Based on the double Gamma functions model, we analyze and evaluate the system performance of inter-symbol interference (ISI), channel bandwidth as well as the bit-error-rate (BER). Without equalization the temporal pulse spread strongly degrades the BER performance. Decision feedback (DFE) equalization is used to enhance the error performance of the high speed UWOC system operating in seawater environment in the presence of ISI. The double Gamma functions model can strongly facilitate the evaluation of BER performance, equalization and 3-dB channel bandwidth due to the simplicity of its closed form expression, which is plausibly beneficial to the design of UWOC systems and link performance analysis. By increasing channel bandwidth we can decrease the packet loss by using equalization.

II. SYSTEM MODEL

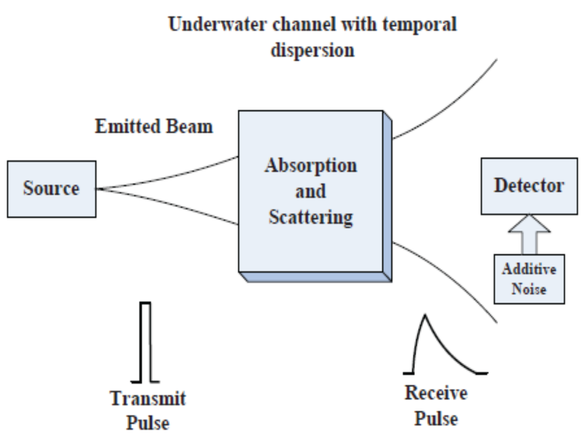

Fig.1. System model of the UWOC link

In this section, we present the system model for UWOC Links. Consider a UWOC system with a precisely aligned line-of-sight (LOS) link and receiver locating on the plane perpendicular to the beam axis. The beam pulse emitted from the source is transmitted through the underwater channel, and then corrupted by the noise in the receiver reception. The noise of UWOC systems depends on the type of receiver. the receiver noise is a combination of background radiation noise, shot noise, dark current noise, and thermal noise, which can be approximated and modeled as additive white Gaussian noise (AWGN). In this paper, with the assumption of AWGN at the receiver, the UWOC system can be modeled as,

$$y(t) = h(t) * x(t) + n(t) \qquad (1)$$

where $x(t)$ and $y(t)$ are the transmit and receive signal, respectively, $h(t)$ is the impulse response of UWOC links, $n(t)$ is the AWGN, and * denotes the convolution operator. Additive White Gaussian noise is the combination of shot noise, thermal noise and dark current noise.

Noise arising in an electric currentbecause of the disc ontinuous nature of conduction by electron, also called schottky noise. Thermal noise arises from the thermal fluctuations in the electron density within a conductor. Dark current noise causes the degradation in signal to noise ratio (SNR). Signal to noise ratio is the measure of signal strength. While packet transmission, due to Additive White Gaussian Noise (AWGN) packet loss may occur. By using zero forcing equalization we can decrease the packet loss and increase the system performance.

III. OPTICAL CHARACTERIZATION OF SEA WATER

The interactions between each photon and seawater contain absorption and scattering through beam propagation. During packet transmission energy of photons lost by interacting with water molecule and other particles. In scattering process, the transmit direction of each photon is changed by the interactions between photons and seawater, which may cause energy loss since less photons are captured by the receiver. The energy loss of the non-scattered light caused by absorption and scattering processes can be evaluated by absorption coefficient $a(\lambda)$ and scattering coefficient $b(\lambda)$, respectively. The extinction coefficient (also known as attenuation coefficient in ocean optics).

$$c(\lambda) = a(\lambda)+b(\lambda) \qquad (2)$$

describes the total effects of absorption and scattering on energy loss. The values of $a(\lambda)$, $b(\lambda)$ and $c(\lambda)$ vary with the water type and source wavelength λ.

The UWOC links encounter a large number of suspended particles such as dissolved salts, mineral components, organic matter and etc, in underwater environment. Then the scattering order of light is typically high in seawater especially in coastal and harbor water. There exist three types of scattering in water such as small scale scattering ($<<\lambda$) caused by density fluctuations due to random molecular motions (also known as pure seawater scattering), particle scattering by large suspended particles ($>\lambda$), and large scale scattering ($>>\lambda$) resulting from turbulence-induced refractive fluctuations. the scattering phase function (SPF) $\beta(\theta, \lambda)$ is introduced to describe the energy distribution of scattering light versus scattering angle θ.

Through the problems of scattering and absorption of pure water belongs to physical chemistry, it is also of interest in optical oceanography. The waters of the open ocean, particularly the deep waters, are o great purity. Consequently the water itself plays an important part in the observed scattering process. Moreover hypothetically pure sea water forms the 'blank' for various optical measurements. Scattering by pure water must be subtracted from the observed scattering to eliminate the role played by the particles.

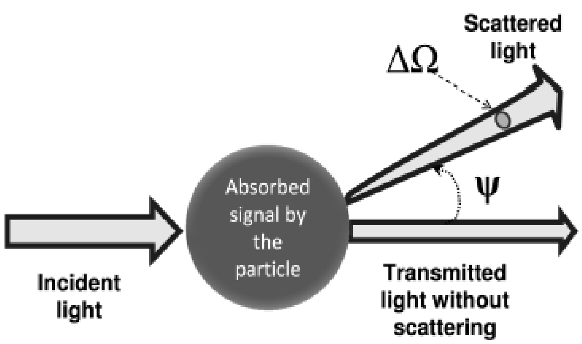

Fig. 2. Light scattering when encountering a particle in water.

We mainly focus on the propagation of blue/green region of visible light,

Water type	a [m^{-1}]	b [m^{-1}]	c [m^{-1}]
Coastal	0.179	0.219	0.398
Harbor	0.366	1.824	2.190

Table. 1. Parameters for blue/green light in coastal and harbor water

IV. IMPULSE RESPONSE MODELING

A. Monte Carlo Simulation

Monte Carlo approach employs the statistical method to evaluate the channel characteristics by generating numerous photons and then simulating the interactions of each photon with the medium. Initially, a set of photons is emitted by the source with specific divergence angle. The interactions for each photon with the medium contain absorption and scattering and can be modeled by changing the basic attributes of each photon such as the position, transmit direction, propagation time and weight during the propagation. These attributes are recorded when the photon reaches the receiver. By collecting and analyzing the basic attributes for all received photons statistically, we can obtain the channel characteristics such as impulse response and path loss.

The photon weight can be updated by

$$W^{i+1} = \left(1 - \frac{a}{c}\right) W^{i} \tag{3}$$

When the photons reach the receiver plane, only the ones within the receiver aperture and with zenith angles less than the half angle of receiver FOV are selected as the detected photons. After repeating the steps above for each photon and recording all the attributes for detected photons, the histogram of received intensity versus propagation time for unit transmit intensity can be estimated by summing the weight of photons with the same propagation time and then normalized by the total transmit weight, which is equivalent to the channel impulse response.

B. Double Gamma Functions Model

In this section, we will present the closed-form expression of the impulse response for UWOC links. Based on the measurement of the energy transportation in UWOC links can be divided into two regions where the non-scattering and multiple scattering.

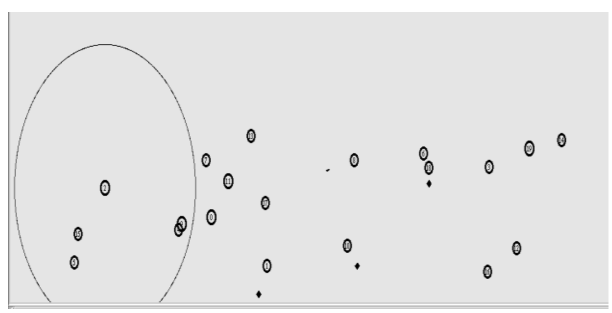

Fig.3. Packet transmission in previous work

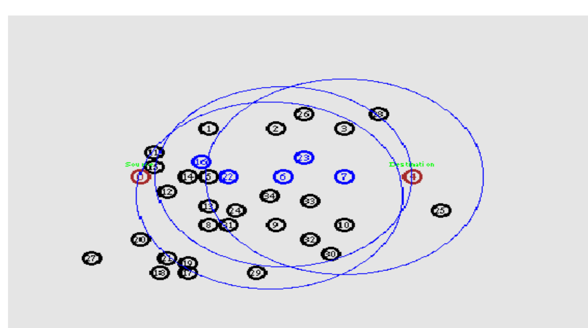

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Fig.4. Packet transmission in present work

Fig.3 and Fig.4 represents the packet transmission of both previous and present work. There is lot of packet loss in previous work. By using decision feedback equalization, the packet loss is decreased in our work and there is an indication of data transmission path and source destination nodes.

The double Gamma functions has been firstly adopted to model the impulse response in clouds where. Although the channel properties of seawater differ from clouds motivated by the dispersive nature of these two medium, we apply the double Gamma functions to model the impulse response in UWOC links with relatively large value of τ where multiple scattering light may dominate. The closed-form expression of the double Gamma functions is

$$h(t) = C_1 \Delta t e^{-C_2 \Delta t} + C_3 \Delta t e^{-C_4 \Delta t}, \quad (t \geq t_0) \tag{4}$$

where $C1$, $C2$, $C3$ and $C4$ are the four parameters to be solved. And $\Delta t = t - t0$ where t is the time scale and $t0 = L/v$ is the propagation time which is the ratio of link range L over light speed v in water. The parameter set ($C1$, $C2$, $C3$, $C4$) can be computed from Monte Carlo simulation results using nonlinear least square criterion as

$$(C_1, C_2, C_3, C_4) = \arg\min \left(\int \left[h(t) - h_{mc}(t) \right]^2 dt \right) \tag{5}$$

where $h(t)$ is the double Gamma functions model and $hmc(t)$ is the Monte Carlo simulation results of impulse response. argmin(·) is the operator to return the argument of the minimum. Then it can be solved by curve fitting approach using scientific computing software.

V. PERFORMANCE EVALUATION

A. Channel bandwidth

We evaluate the BER performance based on decision feedback equalization by using Monte Carlo approach which generates channel bandwidth, packet loss and throughput. The double gamma function model of impulse response provides an easy way to determine the channel bandwidth.

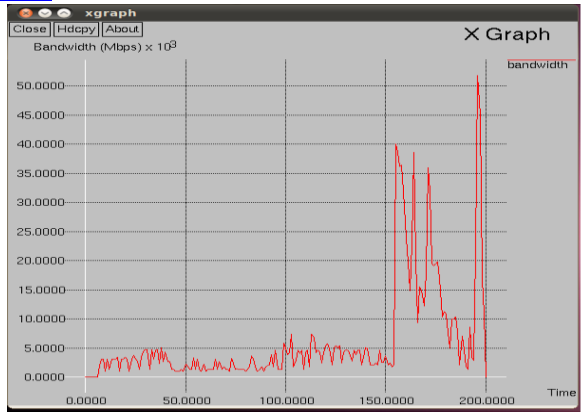

Fig.5.Channel bandwidth versus time

Based on the channel bandwidth performance, the UWOC link can provide higher data rate and large attenuation length. Therefore, equalization technique designed on our model is necessary to be utilized to improve the system performance.

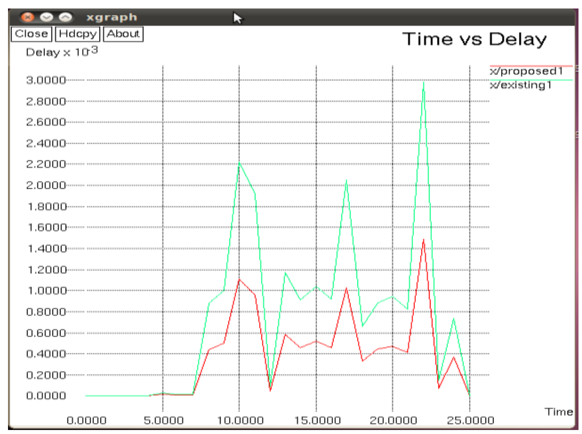

Fig.6. Packet delay versus time

Fig.6 represents the packet delay at the receiver. Compared to previous work, the packet delay in our work has been decreased by using decision feedback equalization. Average energy consumption also decreased in our system. The average energy consumption is illustrated in fig.7. Packet delay and energy consumption plays an important role in system performance. By decreasing delay and energy consumption we can increase the performance of underwaterwireless optical communication system.

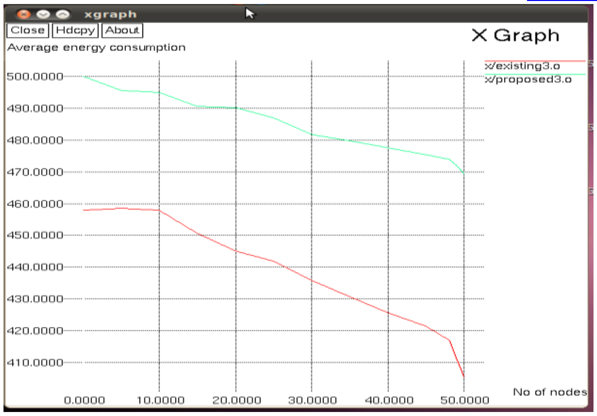

Fig.7. System energy consumption

B.Packet loss

The packet loss performance will be designed based on the channel bandwidth performance. By increasing channel bandwidth the packet loss will be decreased. The packet loss performance is illustrated in following figures.

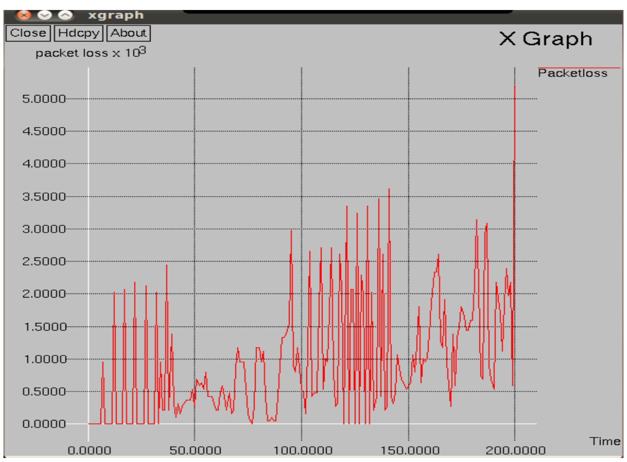

Fig.8. Packet loss versus time

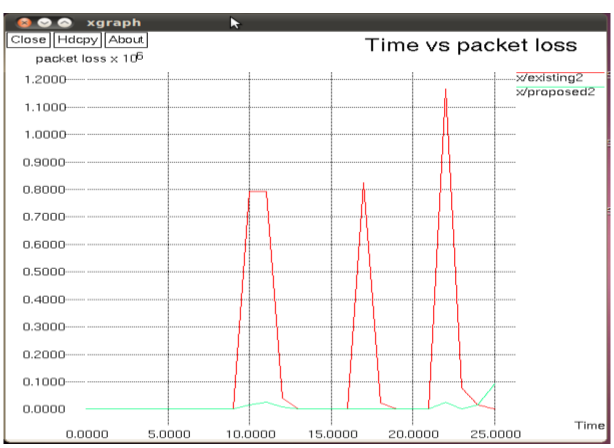

Fig.9. Comparison of packet loss

Packet loss is also identified as inter-symbol-interference which means additive white Gaussian noise appears at the receiver. Shot noise, thermal noise and dark current noise are approximated as AWGN.

C.Throughput

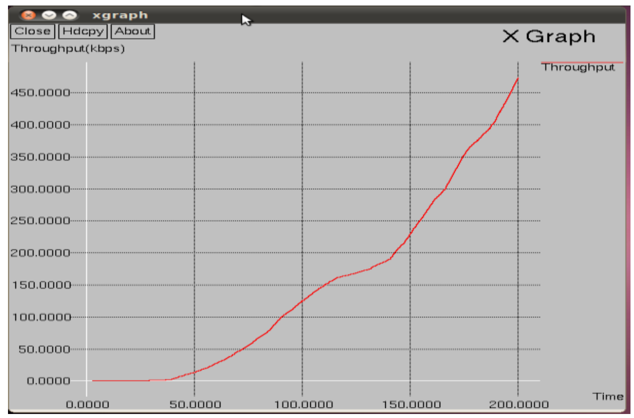

Fig.10. Throughput versus time

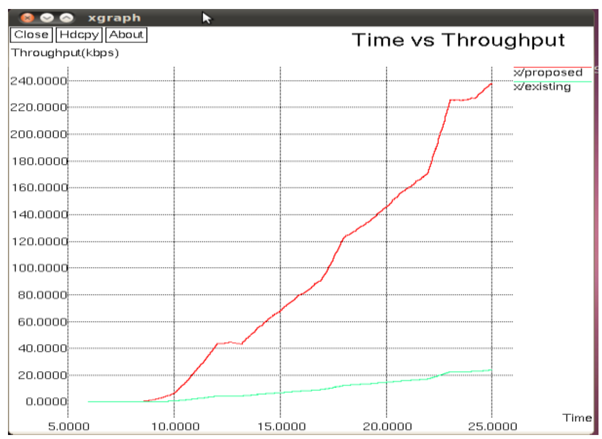

Fig.11. Comparison of throughput

Fig.10 and fig.11 represents the throughput characteristics of UWOC system. By using decision feedback equalization technique, the throughput performance is linearly increased in our system.

VI. CONCLUSION

The experimental verification, UWOC ISI channel capacity, exact relationship between the parameters in double Gamma functions model and link configurations such as water types, source divergence, receiver aperture and FOV, etc. will be future work. In future we decrease the bandwidth and it will reduce the bit error rate and it also increases the performance level. In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors.

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. The bit error probability is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors. The BER may be analyzed using stochastic computer simulations. If a simple transmission channel model and data source model is assumed, the BER may also be calculated analytically.

REFERENCES

[1] Shijian Tang, *Student Member, IEEE*, Yuhan *Dong*, *Member, IEEE, and* Xuedan Zhang, *Member, IEEE, "*Impulse Response Modeling for Underwater Wireless Optical Communication Links" in *IEEE Transactions on Communications*, *VOL.62, NO.1, January 2014., pp. 226-234.*

[2] C. Gabriel, M. Khalighi, S. Bourennane, P. Leon, and V. Rigaud,"Channel modeling for underwater optical communication," in *Proc.2011 IEEE Workshop on Optical Wireless Communications, GlobecomConf., pp. 833–837.*

[3] C. Gabriel, M. Khalighi, S. Bourennane, P. Leon, and V. Rigaud,"Channel modeling for underwater optical communication," in *Proc.2011 IEEE Workshop on Optical Wireless Communications, GlobecomConf., pp. 833–837.*

[4] C. Gabriel, M. Khalighi, S. Bourennane, P. Leon, and V. Rigaud,"Channel modeling for underwater optical communication," in *Proc.2011 IEEE Workshop on Optical Wireless Communications, GlobecomConf., pp. 833–837.*

[5] C. Gabriel, M. Khalighi, S. Bourennane, P. Leon, and V. Rigaud,"Channel modeling for underwater optical communication," in *Proc.2011 IEEE Workshop on Optical Wireless Communications, GlobecomConf., pp. 833–837.*

[6] L. Wang, S. Jacques, and L. Zheng, "MCML, Monte Carlo modeling of light transport in multi-layered tissues," Tech. Rep., Laser Biology Research Laboratory, University of Texas, M.D. Anderson Cancer Center, Nov. 1995.

[7] J. G. Proakis and M. Salehi, *Digital Communications*, 5th ed. McGraw-Hill Inc., 2007.

[8] C. Mobley, *Light and Water: Radiative Transfer in Natural Waters*. Academic Press/Elsevier Science, 1994.

[9] W. Cox, "Simulation, modeling, and design of underwater optical communication systems," Ph.D. dissertation, North Carolina State University, Raleigh, 2012.

[10] S. Tang, X. Zhang, and Y. Dong, "On impulse response for underwater wireless optical communication links," in *Proc. 2013 IEEE/MTS OCEANS Conf.*, pp. 1–4.