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Laser based Optical Wireless Communication using Log Normal Distribution and SIM BPSK Modulation

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Abstract— Laser based Optical Wireless Communication(OWC) is emerging as one of the key advancements for the 5G and beyond technologies. This technology provides high bandwidth, extremely high data rate and high speed communication due to the use of optical waves for data transmission in the field of wireless communication. The system performance is limited due to the presence of turbulence in the atmosphere.We have developed system model using log normal channel distribution in the weak to moderate atmospheric turbulence. Closed form of expression is derived which provides the channel capacity in the presence of weak turbulence using log normal distribution. Subcarrier Internsity Modulation (SIM) BPSK modulation technique is used in OWC system which provides bettter performance in terms of received BER as compared to NRZ – OOK modulation.

Keywords- Log Normal distribution, Optical Wireless Communication (OWC), refractive index structure parameter, SIM BPSK Modulation,

I. INTRODUCTION

Next generation wireless technology should be able to provide high capacity to support various applications like High-definition TV, high bandwidth, high speed internet access and video conferencing for mobile communication. Currently used RF technology has limitations such as expensive license, congested spectrum, low data rate, lower speed. OWC provides the advantages of Optical fibers with wireless data transfer and almost unlimited data rate and unlicensed spectrum.

Optical fibers have enormous capacity about 4THz at 1550nm wavelength. But this requires digging trenching and laying of optical cables. Whereas OWC is wireless communication technology does not require cables and at the same time it provides the same capacity and data rates provided by optical fibres as optical waves are used for the data transmission. So OWC is the last mile access solution to 5G and beyond technologies.

OWC system offers number of advantages as compared to RF wireless communication

- Abundance bandwidth (200THz in 700nm– 1600nm)
- Unlicensed Spectrum
- No multipath fading for intensity modulation and direct detection
- Line of sight communication with high security
- Higher capacity per unit volume
- Small, compact size of components and low-cost installation
- No reuse of frequency as in RF because one frequency covers large number of cells
- No inter channel interference
- No radiation hazards as in RF
- Minimum signal absorption at (800-890nm and 1550nm wavelength)

There are wide range of applications provided by OWC communication such as chip to chip communication (range in mm), outdoor building to building connectivity (Up to few Kilometers), fast connectivity for disaster recovery, Campus Connectivity, Inter Satellite communication (5000km range) etc.

OWC operating at near Infrared region (750-950nm) have almost same property as of visible light, but due to lower part of optical spectrum these waves are invisible. However, eye is sensitive to these wavelengths therefore protected by limiting the intensity. For the wavelengths in the region of 1550nm are less sensitive to eyes and eye safety is ensured.

Earth's Surface absorbs the solar radiation makes the atmospheric temperature warmer as compared to the higher altitudes. The warmer air layer mixes with cooler air turbulently which results in the change of atmospheric temperature. This change of temperature is viewed as turbulent eddies. Interaction between the turbulent addies and optical beam results in signal degradation and fading of received power. Atmospheric turbulence results in fading thus severely degrades the performance of OWC link. Turbulent eddies in the atmosphere is as shown in Fig 1.

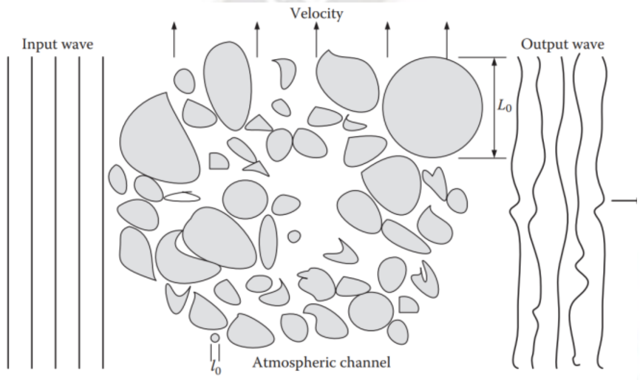

Fig. 1 Turbulent eddies in earth's atmosphere.

The classical modulation scheme used in OWC is OOK due to its simplicity and low-cost installation. But the performance of OOK is limited. The Subcarrier Intensity Modulation BPSK modulation technique is investigated for OWC link in this research work which works better in the presence of atmospheric turbulence.

For next generation 5G and beyond technologies optical wireless communication provides the best solution to back haul links which suffers from low speed and data rate issues [1]. Problems associated with the remote area and sea station distribution is resolved using airship platform based floating base stations. 5G technology needs the data rate to be beyond 1Gbps. Fibre optic cables cannot be implemented for floating base stations and RF technology does not provide required data rate. In this situation OWC provides the promising solution. Thus, OWC can be implemented for 5G and beyond floating base stations [2, 3].

Data transmission rates of 40Gbps could be achieved when distributed feedback laser (DFB) diode is implemented in OWC transmitter section at the optical wavelength of 1550nm. OWC technology is a key element to achieve high bandwidth, and data rate for future technologies [3]. In desert area due to dust storm the performance of the OWC system is limited. Use of QAM modulated optical signal provides the suitable design in the presence of dust storm atmospheric loss [5]. RF signal is not deteriorated with severe dust storm so RF model provides the backup solution. In severe dust storm regions, RF/OWC hybrid model can be used for the better optimization. [6,7].

Fog and smoke attenuate OWC received signal strength. Optical wavelengths in visible – NIR for OWC can be considered to enhance the signal strength during dense fog climatic conditions [9].

OWC provides alternative and complementary solution to optical fibber communication as it does not require digging of optical fibre wires[11, 12]. The performance of the laser based wireless communication is limited in the presence of atmospheric losses such as atmospheric turbulence, rain, haze, dust and fog. With the use of parallel multi bean laser technology the degradation is minimized to a certain extent [12]. Dense fog has the visibility less than 50m which severely affects to performance of the system. Dense fog causes the attenuation up to hundreds of decibels per kilometre. Therefore, the terrestrial OWC is used for short range communication up to few kilometres of link distance can be used in 5G/6G networks [13]. For the dense fog weather when the visibility reduces below 50m charge coupled device (CCD) camera and laser diode at 1550nm wavelength can be used for the better performance [15]. 5G networks need high data rates wireless backhaul links for the link distances up to few kilometres. Degradation of channel capacity can be reduced by using mid – IR optical signals [16]. Fog link attenuation models can be developed based on Kim and Kruse distribution [18]. OWC system performance is affected by atmospheric losses. In severe atmospheric losses, Hybrid RF/ OWC models could be used for the link availability. [19]. The bit error rate can be reduced by using increasing number of detectors [20]. Intensity modulation and direct detection (IM/DD) at 850nm and 1550nm optical signal link can achieve the link distances up to 500m in severe weather conditions [22].

Terrestrial optical wireless communication introduces various losses in the presence of turbulence, rain, fog, haze etc. The attenuation due to atmospheric losses can be overcome using WDM – spatial diversity at the receiver. [12]

In this paper the channel capacity and BER is evaluated for the OWC channel link in the presence of weak to moderate atmospheric turbulence using log normal distribution and SIM BPSK modulation technique.

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II. CHANNEL MODEL FOR WEAK TO MODERATE ATMOSPHERIC TURBULENCE

In this section the atmospheric turbulence channel capacity is evaluated using log normal channel distribution. Log normal distribution is used for weak to moderate atmospheric turbulence levels. Optical channel capacity is evaluated based on the signal amplitude variations, atmospheric turbulence and SNR values.

Earth's atmosphere is complex and dynamic environment that affects the propagation of optical signal results in signal attenuation and turbulent induced amplitude and phase fluctuation. Atmospheric free space channel is random in nature. For weak to moderate levels of atmospheric turbulence log model distribution is used to analyze the nature of atmospheric channel.

Optical signal propagation in free space channel is sensitive to various atmospheric factors such as rain, haze, dust, fog and turbulence. When optical waves are travelling in free space atmosphere photons interact with the molecule constituents of atmospheric mater cause some of the photons to be extinguished while others scatter in the atmosphere. Thus, leads to power transmission loss in the channel.

For a continuous distribution, value of logarithm of a variable is distributed normally using log normal channel model. For a random variable Y, (X) = exp (Y) is a logarithmic- normal distribution. For weak to moderate turbulence in the atmosphere log normal channel model is considered.

A. *Refracrive Index Structure paramater C_n^2*

Due to solar radiation earth's atmosphere is heated up causing temperature and pressure variations in the atmosphere. These variations differ with respect to the height from ground level and wind velocity. The refractive index structure parameter denoted by C_n^2 is dependent on the optical signal wavelength, temperature and pressure of the atmosphere. There are various models proposed which include PAMELA model, Gurvich model, SLC Day model, Hufnagel – Valley model, Greenwood Model etc. Hufnagel – Valley (H-V) model is the popular model used to find the refractive index structure parameter in day. Refractive index structure parameter which indicates the strength of atmospheric turbulence is maximum at the ground level.

The refractive index structure parameter dependent on variations in atmospheric wind speed and height from the ground level. Refractive Index structure parameter during day time is given by H-V model is

$$\mathrm{C_n^2}\,(\mathrm{h}) = \mathrm{C_n^2}\,(0)\exp\left(-\frac{h}{100}\right) + 5.94 \times 10^{-53}\left(\frac{v}{27}\right)^2 \mathrm{h}^{10} \times \exp\left(-\frac{h}{1000}\right) + 2.7 \times 10^{-16}\exp\left(-\frac{h}{1500}\right) \quad (1)$$

where, C_n^2 *(0)* is refractive Index Structure Parameter at the ground level which is 1.7 x $10^{-14}\mathrm{m}^{-2/3}$ during daytime and 8.5 x $10^{-15}\mathrm{m}^{-2/3}$ during night time. 'v' is the value of wind speed given by 21m/s.

The value of refractive index structure parameter at ground level is estimated as follows

$$C_n^2(0) = 1.29 \times 10^{-12} r_0^{-5/3}\lambda^2 - 1.61 \times 10^{-13}\Theta_0^{-5/3}\lambda^2 + 3.89 \times 10^{-15} \quad (2)$$

Where, λ is optical signal wavelength, θ_0 is the isoplanaric angle and r_0 is the atmospheric coherence length.

H-V night model gives the estimates of turbulence conditions during night which is expressed as follows

$$C_n^2\,(h) = 1.95 \times 10^{-15}\exp\left(-\frac{h}{100}\right) + 8.16 \times 10^{-54}\, h^{10} \exp\left(-\frac{h}{1000}\right) + 3.2 \times 10^{-17}\exp\left(-\frac{h}{1500}\right) \quad (3)$$

The strength of atmospheric turbulence decreases as the height from the ground level increases. The decrease in refractive index structure parameter is proportional to $h^{-4/3}$. The strength of atmospheric turbulence which is nothing but refractive index structure parameter varies in the range from "$10^{-17}m^{-2/3}$ *to* $10^{-13}m^{-2/3}$" for weak to strong turbulence regime. For uplink and downlink communication the value of C_n^2 varies widely but for the horizontal free space optical wireless communication C_n^2 is assumed to remain constant.

B. *Average Channel Capacity using log normal distribution*

Earth's atmosphere is random with irregularities in the atmospheric refractive indices values which termed as optical turbulence. This affects the optical signal travelling in the atmosphere resulting in the intensity variations of the signal termed as "scintillation". The changes in the atmospheric temperature and pressure results in varying capacity and refractive indices along the optical signal transmission path results in constructive and destructive interferences. These effects increase the received signal BER.

The optical wireless communication is varying in nature and its instantaneous random SNR value is computed by $\gamma = s^2 / N_0$. The average channel capacity of wireless communication channel is expressed as

$$\langle C \rangle = \int_0^\infty \mathrm{B}\log_2^{(1+\gamma)} \mathrm{P}_\gamma(\gamma) \quad (4)$$

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Scintillations caused by atmosphere is measured in terms of "scintillation index" σ_{I}^2. This is dependent on strength of atmospheric turbulence. The Scintillation index σ^2 is expressed as

$$\sigma_I^2 = \frac{\langle I^2\rangle - \langle I\rangle^2}{\langle I\rangle^2} = \frac{\langle I\rangle^2}{\langle I\rangle^2} - 1 \tag{5}$$

where, 'I' is the 'irradiance value' and ⟨I⟩ represents the value of the 'ensemble'.

$\sigma_{\mathrm{I}}^2<1$ for the weak atmospheric turbulence strength. Log normal distribution is suitable when there is weak turbulence in the atmosphere. $\sigma_{\mathrm{I}}^2 \geq 1$ for the strong atmospheric turbulence.

For the weak atmospheric turbulence, scintillation index in terms of plane and spherical waves is

Plane wave scintillation index

$$\sigma_{\mathrm{I}}^2 = \sigma_{\mathrm{R}}^2 = 1.23 C_n^2\, k^7 L^{11/6} \tag{6}$$

Spherical wave scintillation index

$$\sigma_{\mathrm{I}}^2 = 0.4\sigma_{\mathrm{R}}^2 = 0.5 C_n^2\, k^7 L^{11/6} \tag{7}$$

Where, L is the optical wireless communication link distance, k is optical wave number, $k = \frac{2\pi}{\lambda}$, σ_I^2 is also known as Rytov variance expressed as δ^2.

The scintillation index for weak refractive index structure parameter is given as

$$\sigma^2 = exp\left[\frac{0.49\delta^2}{\left(1+0.18\delta^2+0.56\delta^{\frac{12}{5}}\right)^{\frac{5}{6}}} + \frac{0.51\delta^2}{\left(1+0.9d+0.62d^2\delta^{\frac{12}{5}}\right)^{\frac{5}{6}}}\right] - 1 \tag{8}$$

Where $D = \sqrt{\frac{kD^2}{4L}}$, $k = \frac{2\pi}{\lambda}$ is 'Optical wave number', L is the OWC operating link distance, λ is laser wave optical wavelength of the input signal, D is 'aperture diameter' of the receiver.

Rytov variance δ^2 by considering spherical waves is given as

$$\delta^2 = 1.23 C_n^2\, k^7 L^{11/6}$$

Scintillation causes fluctuations in the irradiation of wireless optical beam and results in significant attenuation of the received signal. The probability density function of log normal distribution is given by

$$P_I(I) = \frac{1}{I\sigma\sqrt{2\pi}} exp\left(-\frac{(ln(I)+\sigma^2)^2}{2\sigma^2}\right) \tag{9}$$

Reforming the Eq. 9 as a function of γ is as follows

$$P_\gamma(\gamma) = \frac{1}{2\gamma\sigma\sqrt{2\pi}} exp\left(-\frac{ln\left(\frac{\gamma}{\Gamma}+\sigma^2\right)^2}{8\sigma^2}\right) \tag{10}$$

where, $\Gamma = \frac{\eta\, E[I]^2}{N_o}$, Average SNR at the receiver end E[.] – Expected value of normalized irradiance I. Substituting Eq. (10) in Eq. (4) results in average channel capacity in the presence of weak atmospheric turbulence using log normal distribution

$$\langle C\rangle = \frac{B}{2\sigma\sqrt{2\pi}\ln(2)}\int_0^\infty \frac{\ln(1+\gamma)}{\gamma} \exp\left(-\frac{\ln\left(\frac{\gamma}{\Gamma}+\sigma^2\right)^2}{8\sigma^2}\right) d\gamma \tag{11}$$

Using $\ln(1+x) = \sum_{k=1}^{\infty}(-1)^{k+1}x^k/k$ for $0 \leq x \leq 1$ and scaled complementary error function which is a built-in function in MATLAB erfcx = $\exp(x^2)\mathrm{erfc}(x)$ the Eq. 11 can be transformed to much simplified version as below

$$\langle C\rangle = B\; C_0 \left\{\sum_{k=1}^{\infty}\frac{(-1)^{k+1}}{k}\left[er\,fcx\left(\sqrt{2}\sigma k + \frac{A}{2\sigma\sqrt{2}}\right) + er\,f\,cx\left((\sigma k\sqrt{2} - \frac{A}{2\sigma\sqrt{2}}\right)\right] + \frac{4\sigma}{\sqrt{2\pi}} + A\,exp\left(\frac{A^2}{8\sigma^2}\right) x\; er\,fc\left(\frac{-A}{2\sigma\sqrt{2}}\right)\right\} \tag{12}$$

where, $A = \ln(\Gamma) - \sigma^2$ and $C_0 = \exp\left(\frac{-A^2}{8\sigma^2}\right)/\,2\ln(2)$ (13)

The function described in Eq. 12 can be further reduced for k values 1 to 8. Because taking infinite samples produces almost the same result as of 8 samples.

$$\langle \hat{C}\rangle = BC_0 \left\{\sum_{k=1}^{8}\frac{(-1)^{k+1}}{k}\left[er\,fcx\left(\sqrt{2}\sigma k + \frac{A}{2\sigma\sqrt{2}}\right) + er\,f\,cx\left((\sigma k\sqrt{2} - \frac{A}{2\sigma\sqrt{2}}\right)\right] + \frac{4\sigma}{\sqrt{2\pi}} + A\,exp\left(\frac{A^2}{8\sigma^2}\right) x\; er\,fc\left(\frac{-A}{2\sigma\sqrt{2}}\right)\right\} \tag{14}$$

The above Eq. 14 describes the closed form solution for average channel capacity in weak atmospheric turbulence using log normal channel distribution for optical wireless communication system.

III. OWC USING SIM BPSK MODULATION TECHNIQUE

In this section BER for Subcarrier intensity modulation BPSK is evaluated in the presence of atmospheric turbulence. Wireless atmospheric channel is random, time varying in nature. Atmospheric channel is constituent of various noise sources, hindrances. Due to the atmospheric turbulence the optical signal gets degraded leading to undesirable mismatch in the received bits. BER is the quality measurements of the erroneous bit received in the stipulated time. '0' can be perceived as '1' and '1' is perceived as '0'.

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BER is expressed as

$$BER = P_0/2 + P_1/2 \quad (15)$$

Where, P_0 represents the probability of receiving '1' instead of '0' and P_1 represents the probability of receiving '0' instead of '1'

On off keying (OOK) is generally used in optical wireless transmission system because of simplicity and ease of implementation. In OOK modulation scheme, the detection of light pulse in on and non-detection of light pulse results in off. But OOK modulation has poor spectral efficiency and low energy density. OOK scheme requires adaptive threshold therefore subcarrier intensity modulation is proposed. SIM BPSK provides optimum capacity in the presence of atmospheric turbulence because different data from different users can be combined on different subcarriers, in turn increases the capacity of optical wireless communication system.

Consider the single BPSK modulated subcarrier $m(t) = g(t)a_c\cos(\omega t + \varphi)$, where $a_c = [-1,1]$ indicates the data '0' and '1'. ω is the carrier frequency of locally generated carrier signal. φ =0.

The output of coherent demodulator is expressed as

$$i_D(t) = \frac{R\xi I a_c g(t)}{2}[1 + \cos(2\omega t)] + n(t)\cos(\omega t) \quad (16)$$

The coherent demodulator output is passed through low pass filter with bandwidth of (1/T). This suppresses the term $\cos(2\omega t)$ without affecting information data bearing signal. This also reduces the noise level to half as compared to the input signal at the coherent demodulator. The resultant signal is expressed as

$$i_D(t) = \frac{R\xi I a_c g(t)}{2} + n_D(t) \quad (17)$$

Where n_D (t) indicates additive noise. Considering equal probability of transmitting the symbols '0' and '1' p(0) = p(1) = ½ , the probability of error conditioned at the receiver will be given by

$$P_{ec} = p(1)p(e/1) + p(0)p(e/0)$$
$$= \frac{1}{2}[p(e/1) + p(e/0)] \quad (18)$$

'0' and '1' bit data transmission with marginal probabilities ,

$$p(e/1) = \int_{-\infty}^{0} \frac{1}{\sqrt{\pi\sigma^2}} \exp\left\{-\frac{(i_D(t)-K)^2}{\sigma^2}\right\} d\, i_D(t) \quad (19)$$

$$p(e/0) = \int_{0}^{\infty} \frac{1}{\sqrt{\pi\sigma^2}} \exp\left\{-\frac{(i_D(t)-K)^2}{\sigma^2}\right\} d\, i_D(t) \quad (20)$$

where $K = \frac{R\xi I}{2}$ and q(t) = 1 for $0 \le t \le T$ and zero otherwise.

Hence BER of the received radiance can be given by

$$P_e = \int_{0}^{\infty} \frac{1}{\sqrt{\pi\sigma^2}} \exp\left\{-\frac{(i_D(t)-K)^2}{\sigma^2}\right\} d\, i_D(t) \quad (21)$$

$$P_e = 1/2\ \mathrm{erfc}\,(K/\sigma) = Q\left(\frac{K2\sqrt{2}}{2\sigma}\right) \quad (22)$$

SNR of the signal received at the input of 'subcarrier coherent demodulator' is

$$\gamma(I) = \frac{(RI\xi)^2}{\sigma^2} P_m \quad (23)$$

where $P_m = \frac{A^2}{2T}\int_0^T g^2(t)dt$ and hence $\sqrt{\gamma(I)} = \sqrt{2}\,(K/\sigma)$.

Thus, the SNR at the input of coherent demodulator is

$$P_e = Q\left(\sqrt{\gamma(I)}\right) \quad (24)$$

Utilizing the normalized log normal irradiance function from Eq. 9, the BER is computed as follows

$$BER = \int_0^{\infty} P_e\, P_I(I)dI \quad (25)$$

$$BER = \int_0^{\infty} Q(\gamma(I)) \frac{1}{I\sqrt{2\pi\sigma^2}} \exp\left\{\frac{-[\ln(I+\sigma^2]^2}{2\sigma^2}\right\} dI \quad (26)$$

Numerical value of the Eq. 26 could be computed using closed form solution of Gauss – Hermite quadrature integration approximation, the received BER is reduced to

$$P_e = \frac{1}{\sqrt{\pi}}\sum_{i=1}^{n} w_i\, Q(\sqrt{K_0}\exp(K_1[\sqrt{2}\sigma x_i - \sigma^2{}_i/2])) \quad (27)$$

The noise levels affect the OWC signal propagation. In the above equation K_1 and K_0 indicate various noise levels. For the computation of OWC signal error rate Gauss – Hermite function of the order of 20 is used.

IV. RESULTS

The capacity of Optical wireless channel is simulated by using the derivation estimated in section II for the weak atmospheric turbulence. The results are obtained using MATLAB 2021 version. Channel capacity is evaluated for different values of rytov variances and refractive index structure parameters. Various numerical computations are carried out to evaluate the performance of OWC system in the presence of turbulent atmosphere. The optical wireless communication system is optimized by choosing appropriate optical wavelength, link distance and receiver's aperture diameter D. The parameters used for simulation are depicted in Table 1.

Table 1: OWC system parameters used in simulation.

Simulation Parameters	Values
Wavelength	1550nm
Rytov Variance	0.0267, 0.1, 0.267
Link diatance	1000 - 4000m
Receiver aperture diameter	0.01m

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Refractive Index Structure Parameter	Weak atmospheric turbulent levels
Modulation Formats used	NRZ OOK, SIM BPSK

It is necessary to use appropriate optical wavelength for the transmitted signal. As Laser is primarily used as optical source for OWC terrestrial communication, we need to consider eye safety standards provided by different optical beams. Near IR range is used in OWC. 1550nm wavelength optical signal is safe to eyes and does not have any health hazards. So, we have considered 1550nm optical wave which provides high data rate and high-speed communication.

The closed form expression derived in section II is used to formulate the channel capacity in the presence of weak atmospheric turbulence. To obtain the results refractive index structure parameter, various link distances and receiver's aperture diameter are considered for the simulation

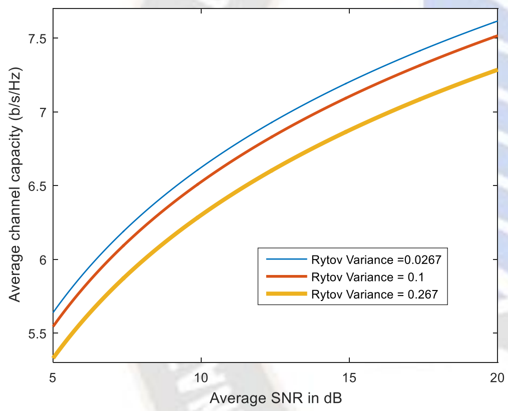

Figure 1: Plot of OWC Channel capacity with respect to average received SNR for different rytov variances.

OWC terrestrial channel is random and time variant due to presence of atmosphere. The average channel capacity is estimated in the presence of atmospheric turbulence using log normal distribution model. Fig 1. Depicts the plot of average channel capacity verses received SNR in the presence of weak atmospheric turbulence. Effect of variation in rytov variance is studied on the OWC channel. To compute the channel capacity the link distance is considered as 1000m, 1550nm optical wavelength and 0.01m receiver's aperture diameter. Rytov variance is the one of the major factor affecting the signal degradation of OWC channel. As the rytov variance is increased which is dependent terrestrial atmosphere OWC the channel capacity decreases.

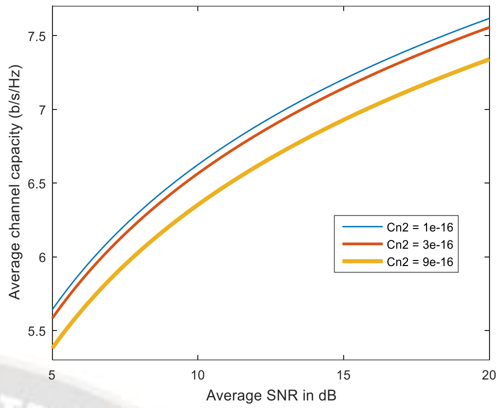

Figure 2: Plot of OWC Channel capacity with respect to average received SNR for different levels of atmospheric turbulence.

Figure 2 indicates "average channel capacity" of OWC channel in different atmospheric turbulence modelled using log normal distribution. The atmospheric turbulence which is nothing but refractive index structure parameter dependent on wind speed, hight of signal propagation from ground level. As the height of propagation from the ground level increases the turbulent strength parameter reduces. In the Figure 2 the effect of variation of atmospheric turbulent strength on the OWC channel is observed. Channel capacity is plotted with respect to received SNR in dB. For the above plot the OWC channel with "log normal distribution" is employed for the link distant of 1000m, Optical signal wavelength of 1550nm and receiver aperture diameter of 0.01m

The average channel capacity obtained for the weak turbulent regime as shown in Figures 1 and 2 is strongly influenced by the turbulent strength. It is observed that, as the value of rytov variance and refractive index structure parameter increases the capacity of OWC channel reduces for the given SNR of 20dB

The channel capacity is also dependent on the OWC link range and receiver's aperture diameter. As the OWC link range is increased the optical signal should travel longer in the atmospheric turbulent condition which affects more degradation of the signal. To increase the distance of communication the SIM BPSK modulation technique is employed.

Figure 3. shows the achieved BER verses SNR in dB for various levels of atmospheric turbulent conditions. SIM BPSK evaluation is estimated in the section III using Gauss Hermite function approximation. For the optical wavelength of 1550nm and receiver aperture diameter of 0.01m the achievable link distance 4000m in the atmospheric turbulence without much degradation of optical signal.

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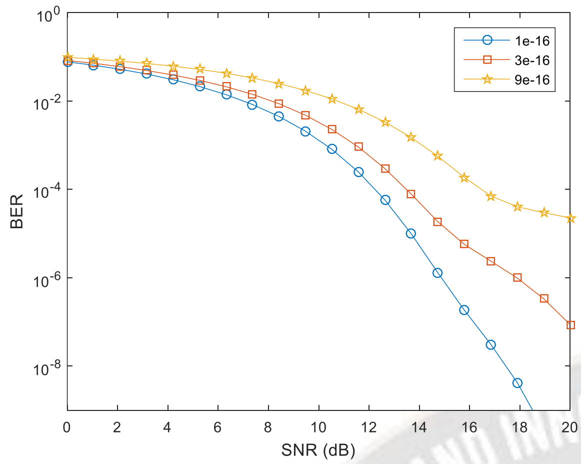

Figure 3: The effect of strength of atmospheric turbulence on OWC SIM BPSK modulation scheme.

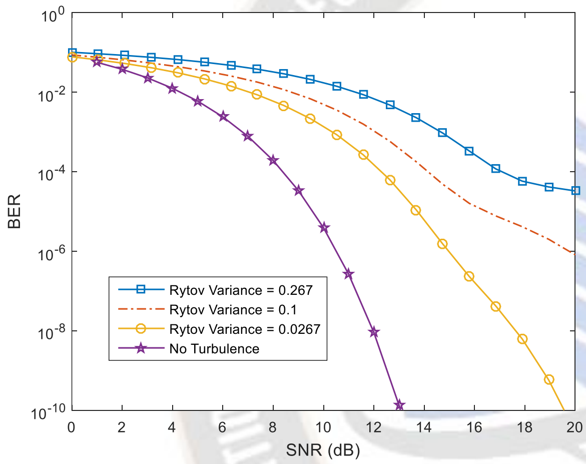

Figure 4: The effect of strength of atmospheric turbulence on OWC SIM BPSK modulation scheme.

Figure 4 depicts the received BER verses different SNR levels by using SIM BPSK modulation scheme for log normal channel distribution. The received signal is evaluated for the different levels of rytov variances. For the simulation optical wavelength of 1550nm and link distance of 4000m is considered. If there is no turbulence in the atmosphere, then it is considered to be ideal case for OWC channel. Ideal case of no turbulence is compared with different level of atmospheric turbulence.

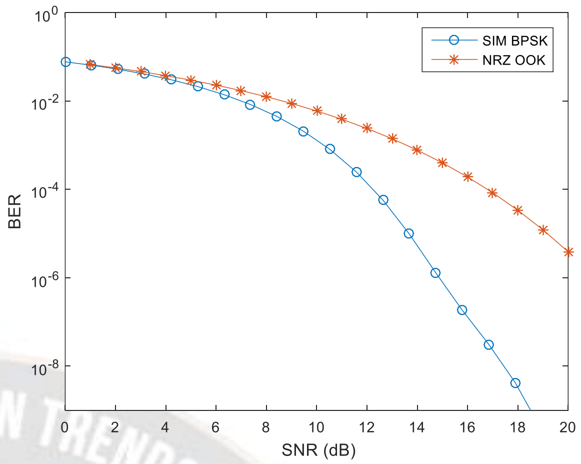

Figure 5: SIM BPSK and OOK modulation comparison for OWC with link distance of 4000m and optical wavelength of 1550nm

Figure 5 depicts BER verses received SNR levels in the presence of atmospheric turbulence using SIM BPSK and NRZ OOK modulation techniques. It is evident from the findings that the SIM BPSK performs better as compared to NRZ OOK using log normal channel distribution. Therefore, from the obtained results it is evident that SIM BPSK modulation is best suited for OWC link as compared to NRZ OOK modulation.

V. CONCLUSION

In this research work, the average channel capacity closed form of equation is estimated in the presence of weak atmospheric turbulence using log normal channel distribution. The average channel capacity of OWC channel is evaluated for different values of rytov variances and refractive index structure parameters. The wavelength, link distance and receiver's aperture diameters have great effect on OWC channel capacity. The link distance can be improved by using SIM BPSK modulation technique. The BER of SIM BPSK modulation methods is evaluated using Gauss Hermite function. Received signal is observed for various levels of atmospheric turbulence by applying SIM BPSK modulation method. It is evident from the obtained results that, OWC system link distance is achieved to be 4000m. SIM BPSK outperforms traditional NRZ OOK scheme in the presence of weak atmospheric turbulence.

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