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Atmospheric Altitude Effects on Optical Channel performance

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***Abstract*:** in this paper, the optical channel performance with respect to varying scintillation index parameters is studied. Where different channel effects are studied and analyzed. In free-space optical (FSO) communication, the major drawback of the optical communication system is the atmospheric turbulence (AT). This effect is nonlinear with optical channel altitude being changed. Therefore, the power margenal (PM) required for such a channel is also inconstant respectively. In this thesis, we analyze AT effect on the optical channel with different altitudes. Such that we found the difference in the range of PM required for such optical link distance. In our result, the Bit Error Rate (BER) VS. PM required is measured. The optical channel model is Log-Normal considered and the BER threshold $BER^{th} = 10^{-10}$ is taken.

Keywords*:* FSO, AT, PM, Optical channel altitude.

1. INTRODUCTION

Free space optical (FSO) communication has been on the rise and broadly used [1] Conceptually, the FSO has infinite bandwidth which is the foremost key benefits versus the RF technologies [2] . The FSO transceiver uses laser-diode and photo-diode to deliver/receive the signals over the channels and this signifies electric-optical (EO) converter devices. The laser avalanche-photodiode (APD) are utilized as transceiver system [3] .

To achieve mitigation for degradation impacts that resulted from AT, some rejoinders are suggested [4], [5]. Which are; error-correcting-codes (ECC), cooperative-systems and optical-adaptation-techniques [6], [7]. In ECC, a low-density parity-check (LDPC)-coding [8] has been suggested and studied by FSO communication system on a channel affected with AT. Systematic-distance (SD-4) codes have been recommended like LDPC-codes with persistent Hamming-distance equivalent to 4 [7]- [8],. As the SD-4 codes have a systematic construction, consequently it offers excessive easiness in process of decoding

2. SYSTEM PERFORMANCE

Our system module based on using unmind aerial vehicle (UAV) [10]to represent the different altitudes of optical points as shown in Figure 1. In this figure, the optical signal transceiver between each i^th^ individual UV's and ground station (GS) with different altitudes (A_1- A_j), where j is the total number of UAVs. The link (L) of is also used as optical channel between any UAVs to send/received the optical signal between them. In our result the maximum L value is set to 5 km distance.

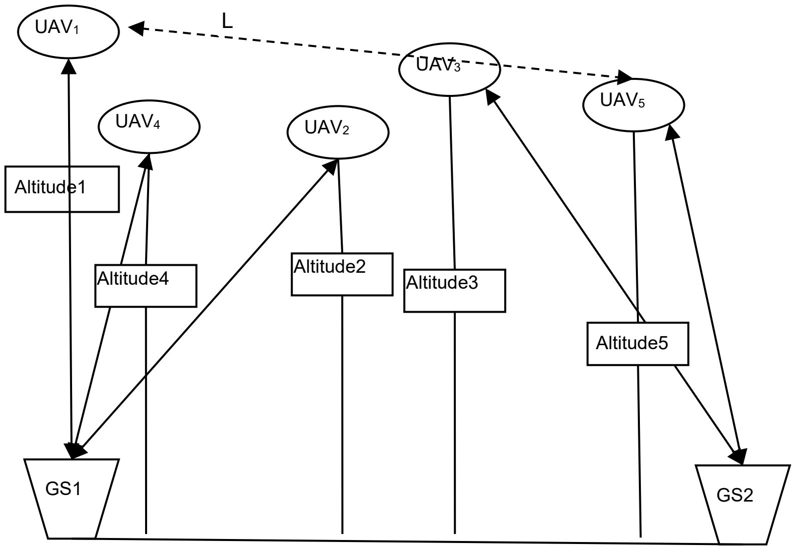

Figure 1: Illustrated difference altitudes of optical points (UAV)

The AT effect on the optical channel by different altitudes (h) is considered as scintillation index parameters (C_n^2) and given for the slant and/or vertical altitude by [11]:

$$c_n^2(h) = 0.00594\left(v/_{27}\right)^2 (10^{-5}\ \mathrm{h})^{10} \exp(\mathrm{h}/1000) + 2.7\times10^{-16} \exp(\mathrm{h}/1500) + c_n^2(0)\times\exp(\mathrm{h}/100) \quad (1)$$

where h is in meters (m), v is the rms (root mean square) of wind-speed in (m/sec) unit, and $C_n^2(0)$ is a scintillation index parameters value at the terrestrial in $m^{-2/3}$ unit. So, the received power from $_i{}^{th}$ optical point out off the optical network can be specified by the transmit power of $_i{}^{th}$ and the transmitted power (P_t) is given by [12]:

$$P_{r(dB)}^{j-1} = p_{t(dB)}^{J} - P_{m(dB)}^{i,i-1} - P_{a(dB)}^{i,i-1} \quad (2)$$

where P_m is the power margin due to the AT effect on the optical link, P_a is the power-loss due to attenuation.

Since our attention is studing the AT altitude on FSO communication system, therefore, the PM value in equation (2) is major key that masuring AT affetc FSO system. Meanwhile $C_n^2(h)$

value has major indigator for h affect on C_n^2 value and intery FSO communication system respectivly. The folowing direc relationship between PM and C_n^2 affect that giving by [13] and will be used in our result :

$$P_M = exp\,(\sqrt{-2\sigma {C_n^2}^2 ln2p_0} + \sigma C_n^2(h)^2/2) \qquad (3)$$

where $\sigma = k\left(\frac{2\pi}{\lambda}\right)^{7/6} L^{11/6}$ is a preselected constant parameter [14] of the optical communication system, k is the optical wave number obtained from wavelength (λ) [11], and L is the optical channel length. (see Table 1 in the Results section)

3. The RESULT & DISCUSSION

We based on Matlab in implementing and analyzing our results. In this paper, the FSO communication system performance with Atmospheric altitude is investigated. In this investigation, the optical channel performance is studied such that the Bit Error Rate (BER) is measured against the Power Margin (PM) required for such system due to the ATeffect on optical channel[15]. Our results intended to show the varied altitude effects on the optical signal according to equation (1). Take into account that the received signal power proportions inversely to the optical channel altitude. Table 1 lists the parameters that used in our simulation:

Table 1: List of parameters used in simulation

Parameter name	Range	Unit
λ	1550	nm
L	1-5	Km
ha	0.2	dB/km
NO. UAV	5	-
$C_n^2(0)$	1×10-14	$m^{-2/3}$

In Figure 2, shows the investigation of 5 UAV's network with different altitudes for each single UAV in such system (network) with 5 km optical channel length. In our investigation, the UAV's altitudes are selected randomly which are respectively; 10 m, 20 m ,50 m , 200 m and 500 m . The total optical channel (Link) distance between each drone in network and the destination is 5 km. Obviously, this network looks like many-one configuration. Since the BER value of the received signal proportioned inversely with the signal strength, accordingly, the Power margin (PM) value is reduced with altitude increasing due to the turbulence reduction with altitude growing [16]. Consequently, the received signal increased in spite of remaining the transmitted signal power values constant, where $R_x = T_x$ - PM, (this issue will be discussed extensively in Figure 4. Where R_x is the received power, T_x is the transmitted power.

At once the flying individual UAV's altitude increased from 10 m to 20 m, the PM for that UAV is reduced from 44 dB at altitude 10 m to be 42 dB at altitude 20 m , such that the net gain in this case (the flying UV's altitude changed from 10 m to 20 m) will be about 2 dB. Wherever this net gain (PM reduced) of flying individual UV's altitude is changed from 10 m to 50 m, 200 m, and 500 m become respectively: 9 dB, 27.7 dB, 38 dB for such optical channel length (i.e. link = 5 km).

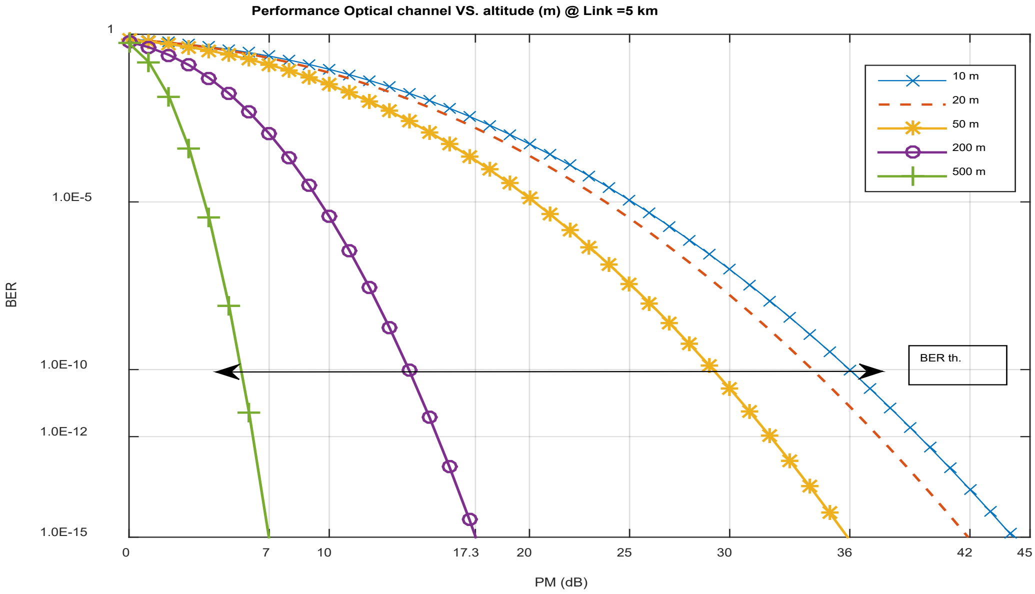

Figure 2: Optical channel performance for 5 km link Vs. Different altitudes

In Figure 3: we investigated the 5 UAV's network with different altitudes for each individual UAV in such system (network) and the optical channel length varied from 5 km to be 1 km. The purposes of this figure are clarifying and comparing the gain of PM reduction due to the optical channel altitude is varied in the same range of different optical channel lengths which changed from 5 km in Figure 3 to be 1 Km link distance. In this configuration, each single drone in UAV network sent an optical signal to the destination independently. As shown in Figure 4.1, the UAV's altitudes are selected randomly which are respectively; 10 m, 20 m, 50 m, 200 m and 500 m. Unlike the investigation of Figure1, the optical channel link distance is chosen at this time equal to 5 km between each drone and the destination in the network. Obviously, this network became like many-one configuration. As mentioned before in Figure 2, the Power margin (PM) value is reduced and the altitude increased, consequently the received signal grew up.

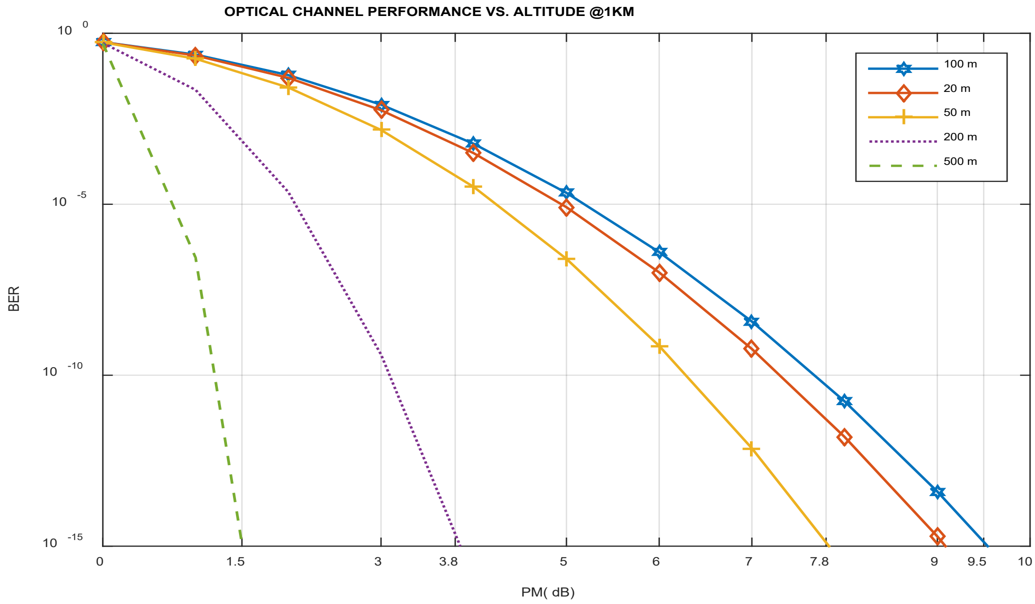

Figure 3: Optical channel performance for 1 km link Vs. Different altitudes

As shown in Figure 3, the individual flying UAV's altitude has been increased from 10 m to 20 m and the PM for that UAV has been reduced from 9.5 dB at altitude 10 m to be only 9 dB at 20 m altitude, in this case , the net gain (the flying UAV's altitude has been changed from 10 m to 20 m) became about 0.5 dB. Where this net gain (PM is reduced) of flying UAV's altitude has been changed from 10 m to 50 m, 200 m, and 500 m and became respectively: 1.7 dB, 5.7 dB, 8 dB for such optical channel length (i.e. link = 1 km).

In Figure 4, we simulated the optical channel length with link source- destination distance equal to 2 km. Nowadays, the FSO communication transceiver equipment's with link distance 2 km is available [17]. By applying the same procedures mentioned in previous simulations in Figures 1 and 2, furthermore, the result of gain in the Power margin with respect to the flying altitudes has been changed from the ground level (terrestrial) and became 0.8 dB, 1.7 dB, 4.1 dB, 11.7 dB, and 16.1 dB respectively for the sequences of the flying altitudes of UAV's : 10 m, 20 m, 50 m, 200 m, and 500 m.

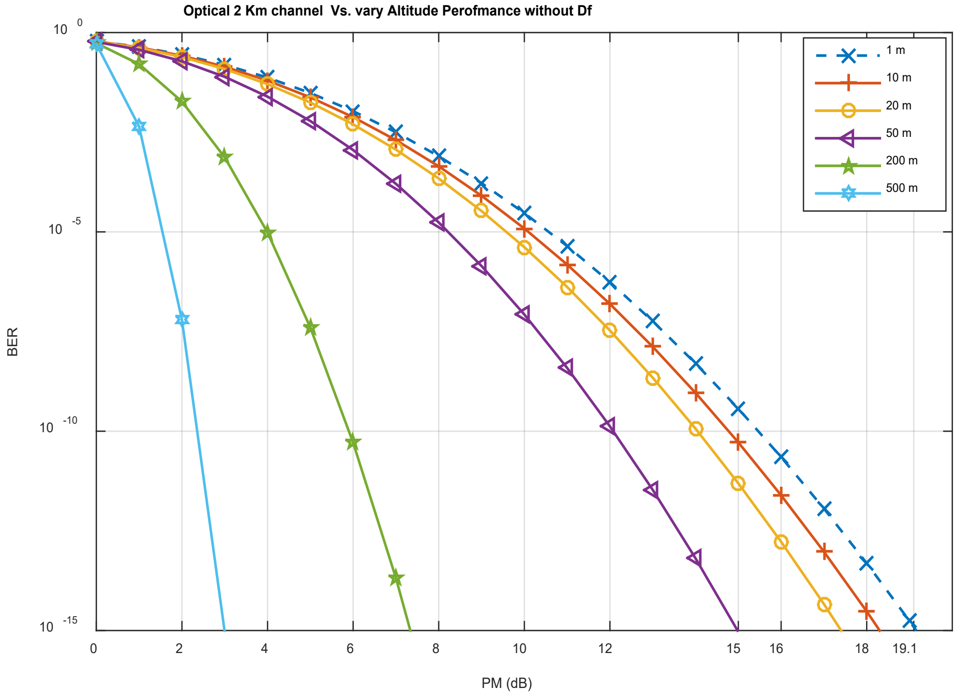

Figure 4: Optical channel performance for 2 km link Vs. Different altitudes

Now, to the best of our knowledge, we summarized the above results in the following table:

Table 2: Summary of required PM for different Link lengths of optical transceiver with two altitudes 1 and 200 m from the ground level.

Link length (km)			1	2	3	4	5
PM (dB)	Altitude (m)	1	8.2	15.3	23.06	30.62	48.12
		200	3.13	6	8.75	11.63	14.25
Gain (dB)			5	9.3	14.31	19	33.87

Another simulation is obtained and clarified in Figure 5, in this figure; we analyzed the power margin (PM) that required for different cases. In first case, the optical system communication is the optical signal transceiver with altitude at 1 m, where in the second scenario (case), the altitude is 200 m. The two scenarios analyzed different optical links that equal to: 1 km, 2 km, 3 km, 4 km, and 5 km respectively. The major reduction in the power margin values are obtained with maximum length link equal to 5 km. Where the required PM for this link is 48.12 dB for 1 m altitude (terrestrial), this PM is reduced for the same link (5 km) and became 14.25 dB at altitude 200 m from the ground level. Therefore the difference in PM values (gain) is became 33.87 dB. The other details for all links lengths with 1 m and 200 m are summarized in

Table 2. As shown in this table the PM reduced and the transceiver should be increased in the altitude (recommended) for UV.

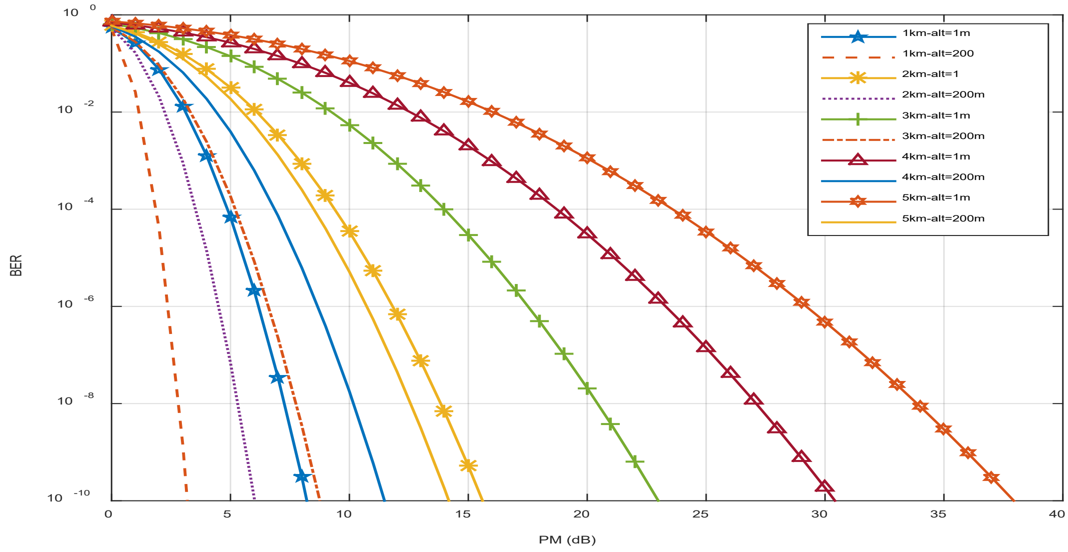

Figure 5: Different Optical channel lengths Vs. (1, 200) m altitude for Different links

4. CONCLUSION

In this study, the optical channel performance with respect to the variation of scintillation index parameters is studied, where different channel effects have been studied and analyzed. As a result, the effect of the nonlinear AT with the optical channel (Link) altitude changes is investigated. Where the PM required for such channel is also varying respectively, the result shows the different cases of the PM required of optical channel altitueds varying.

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