



Transmission of Optical Signals for Wireless Communications under Snow Attenuation Effect

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Abstract : The study focused on optical wireless communications link under snow effect. The snow effect has presented the wet and dry attenuation effect. It is taken into account the study of the receiver signal power, link margin, data rate and the signal to noise ratio. The wavelength 10600nm has more stability and better than the wavelength 630nm. On the other hand the wavelength 630nm suffers more attenuation from the wavelength 10600nm. The dry snow has more attenuation comparing with the wet snow. The comparing between the wavelengths shows that the wavelength 10600nm is the best because it has suffered less attenuation and the data rate 100Mb/s can be reached to distance 450m, 350m for wet and dry snow respectively under the same operating conditions.

Keywords: Free Space Optics, Optical Wireless Communication, signal to noise ratio, Snow Attenuation.

I. Introduction

An optical wireless (OW) of free space optics (FSO) link can be established using Lasers or light emitting diode (LED) between any two line of sight points in free space for a certain link distance, enabling point to point data links at rates exceeding 1 Gbits/s. Laser work in the visible and near infrared spectrum of the electromagnetic radiations. The inherent advantage of using lasers for establishing connection between two geographically separated line of sight points provides a well focused narrow beam that on one hand secured and on the other hand is less scattered as it traverses the free space mostly the earth atmosphere[1]. The propagation channel influences the transmission in any communication system. The propagation channel for FSO is atmosphere. Among various atmospheric attenuation effects on FSO link, snow an important factor. Research studies have shown that attenuation has peak values of 60 dB/km for a snow event in Austria[2]. Optical wireless links are also influenced by atmospheric temperature that varies both in spatial and temporal domains. The variation of temperature in the optical wireless channel is a function of atmospheric pressure and the atmospheric wind speed. This effect is commonly known as optical turbulence or scintillation effect and causes received signal irradiance or power fades in conjunction with the variation of temperature along the propagation path. As a result of this scintillation phenomenon, the optical wireless channel distance and the capacity are reduced. Thereby restricting the regions and times where optical wireless links can be used potentially. In order to take full advantage of the tremendous usefulness of optical wireless technology require a proper characterization of different atmospheric effects influences and a meaningful interpretation of the filed measurements in such adverse conditions [3].

II. The snow attenuation model for FSO

Fog, rain and other precipitations causes the scattering of the light and the laser beam power is attenuated resulting in reduction of received signal strength. Consequently either complete link failure or bit errors occurs when received signal fluctuations are large and received signal level decreases drastically [4]. The amount of light attenuation is proportional to number and size of fog, rain and snow particles [5, 6]. Since snow flakes are generally larger than rain drops, the received signal strength fluctuation will be larger for snow and snow attenuation is not ignorable [7]. The snow flakes as large as 20 mm have been reported [8, 9] and a large snowflake can cause link failure if laser beam is narrow. When a snowflake crosses the laser beam, the receive signal level depends on the diameter of the snowflake and distance from the transmitter, as well as the position of the snowflake relative to the cross section of the beam[7]. The FSO attenuation due to snow has been classified into dry and wet snow attenuations. If S is the snow rate in mm/hr then specific attenuation in dB/km is given by [10]

$$\alpha_{snow} = a.S^b \quad (1)$$

If λ is the wavelength, a and b are as following for dry snow

$$a = 5.42 \times 10^{-5} \times \lambda + 5.4958776, b = 1.38$$

The same parameters for wet snow are given as follows

$$a = 1.023 \times 10^{-4} \times \lambda + 3.7855466, b = 0.72$$

In reference [11] the parameters a & b can be written as:

In dry snow for 10600nm, a=6.07, b=1.4; for 630nm is a=5.53, b=1.38. In wet snow a=4.87, b=0.75 for 10600nm and for 630nm a= 3.85, b=0.72.

III. Communication Link Model

We now consider three types of communication links: the receiver signal power, link margin, and data rate. In addition, we performed a signal to noise ratio calculation.

1. Receiver Signal Power

We shall consider the situation of optical propagation between points underwater. Consider a laser transmitting a total power P_T at the wavelength. The signal power received at the communications detector can be expressed as [12]

$$P_{rec} = P_{trans} \frac{D^2}{\theta_{div}^2 L^2} \cdot 10^{-\gamma \cdot L/10} \tau_{trans} \tau_{rec} \quad (2)$$

Where D is the receiver diameter, θ is the divergence angle, γ is the attenuation factor (dB/m), τ_{trans} , τ_{rec} are the transmitter and receiver optical efficiency respectively.

2. Link Margin

Another important parameter in optical communications link analysis is "Link Margin", which is the ratio of available received power to the receiver power required to achieve a specified BER at a given data rate. Note that the "required" power at the receiver P_{REQ} (watts) to achieve a given data rate, R (bits/sec), we can define the link margin LM as [12]:

$$LM = [P_T \lambda / (N_b R h c)] * [D^2 / (\theta^2 L^2)] * 10^{-\gamma L/10} \tau_{trans} \tau_{rec} \quad (3a)$$

Or can be written as

$$LM = [\lambda / (N_b R h c)] \cdot P_{rec} \quad (3b)$$

Where N_b is the receiver sensitivity (photon/bits) or (dBm), R is a data rate, h is a plank constant and c is the light velocity.

3. Data Rate

Given a laser transmitter power P_{trans} , with transmitter divergence of θ , receiver diameter D, transmit and receive optical efficiency τ_{trans} , τ_{rec} the achievable data rate R can be obtained from [13]

$$R = \frac{P_T \cdot \tau_{trans} \cdot \tau_{rec} \cdot 10^{-\gamma \cdot L/10} D^2}{\pi (\theta/2)^2 L^2 E_p N_b} \quad (4a)$$

Or can be written as

$$R = \frac{4 \cdot P_{rec}}{\pi \cdot E_p N_b} \quad (4b)$$

Where $E_p = hc/\lambda$, is the photon energy at wavelength.

4. Signal to Noise Ratio (SNR)

The electrical power of the received optical signal is proportional to the mean squared avalanche photodiode APD current, which can be written as [14]

$$\langle i_{APD}^2 \rangle = (R_0 P_{rec} M)^2 \quad (5)$$

and

$$R_0 = \frac{\eta q \lambda}{h c} \quad (6)$$

where R_0 denotes the primary sensitivity of the APD, M is the APD gain, η is the quantum efficiency, q is the electron charge. The noise contributions (i.e., the mean-square values of the APD current) are shot noise:

$$\sigma_{sig-noise}^2 = 2q(R_0 P_{rec}) M^{x+2} B \quad (7)$$

Surface leakage current noise:

$$\sigma_{surface}^2 = 2qI_L B \quad (8)$$

multiplied dark current noise:

$$\sigma_{dark,m}^2 = 2q(I_D) M^{x+2} B \quad (9)$$

And Johnson noise:

$$\sigma_{johnson}^2 = \frac{4kT B F_T}{R_{eq}} \quad (10)$$

where I_D is the bulk dark current, I_L is the surface leakage current, $F(M) \approx M^x$ ($0 \leq x \leq 1$) is the excess noise factor, k is the Boltzmann constant, B is the equivalent noise bandwidth, R_{eq} is the equivalent circuit resistance, F_T is the noise figure of the electric circuit, and T is the system temperature. The SNR for the optical communication system is thus given by

$$SNR_{APD} = \frac{(R_0 P_{rec} M)^2}{2q(R_0 P_{rec} + I_D) M^{x+2} B + 2qI_L B + 4kT B F_T / R_{eq}} \quad (11)$$

IV. Simulation Results

The snow attenuation effect of wavelengths 630, 10600 nm has been simulated for wet and dry snow on optical wireless communication link. The investigation of optical wireless communication for different snow rate (S) mm/hr between the transmitter and the receiver to upgrade the receiver signal power, link margin, data rate and the signal to noise ratio for distance about 1000m. The investigating based on the modeling equations analysis and the assumed set of the operating parameters are shown in table (1) [15, 16].

Table (1): Proposed operating parameters for optical communications links

Operating parameter	value
wavelength	630nm, 10600 nm
Transmitter power	50mw
Transmitter divergence angle	1.5mrad
Transmitter efficiency	0.5
Receiver efficiency	0.5
Receiver sensitivity	-20dBm
Receiver diameter	10cm
Bulk dark current, I_D	0.05 nA
The APD gain	100
The excess noise factor, x	0.5
Electrical band, B	25MHz
Surface leakage current, I_L	0.001A
System temperature, T	290K
Noise figure, F_T	3dB
Equivalent resistance, R_{eq}	50k Ω

So the receiver signal power due to the effect of snow (wet, dry) can be evaluated. The receiver signal power is achieved for (630, 10600) nm under wet and dry snow effect as shown in fig. (1), has proved that the receiver signal power decreases with increasing distance link for both wavelengths under both wet and dry snow. It is also observed that the wavelength 630nm has presented high received signal power compared with the wavelength 10600nm. As well as the receiver signal power has high value under wet snow comparing with dry snow for both wavelengths. The receiver signal power decreases with increasing snow rate S mm/hr. The receiver signal power curves have very close behavior for high values under wet snow rate.

The link margin for receiver sensitivity-20dBm is achieved for data rate 100 Mb/s operating under wet and dry snow conditions at distance 1000 m as shown in fig. 2. In figure (2), the conclusion can be got that the 10600nm has better link margin performance that 630nm. The link margin decreases with increasing snow rate S under wet and dry conditions. It also observed that for high snow rate S the wet snow have very close behavior comparing with dry snow. So, high link margin can be achieved to the wavelength 10600nm comparing with the wavelength 630nm

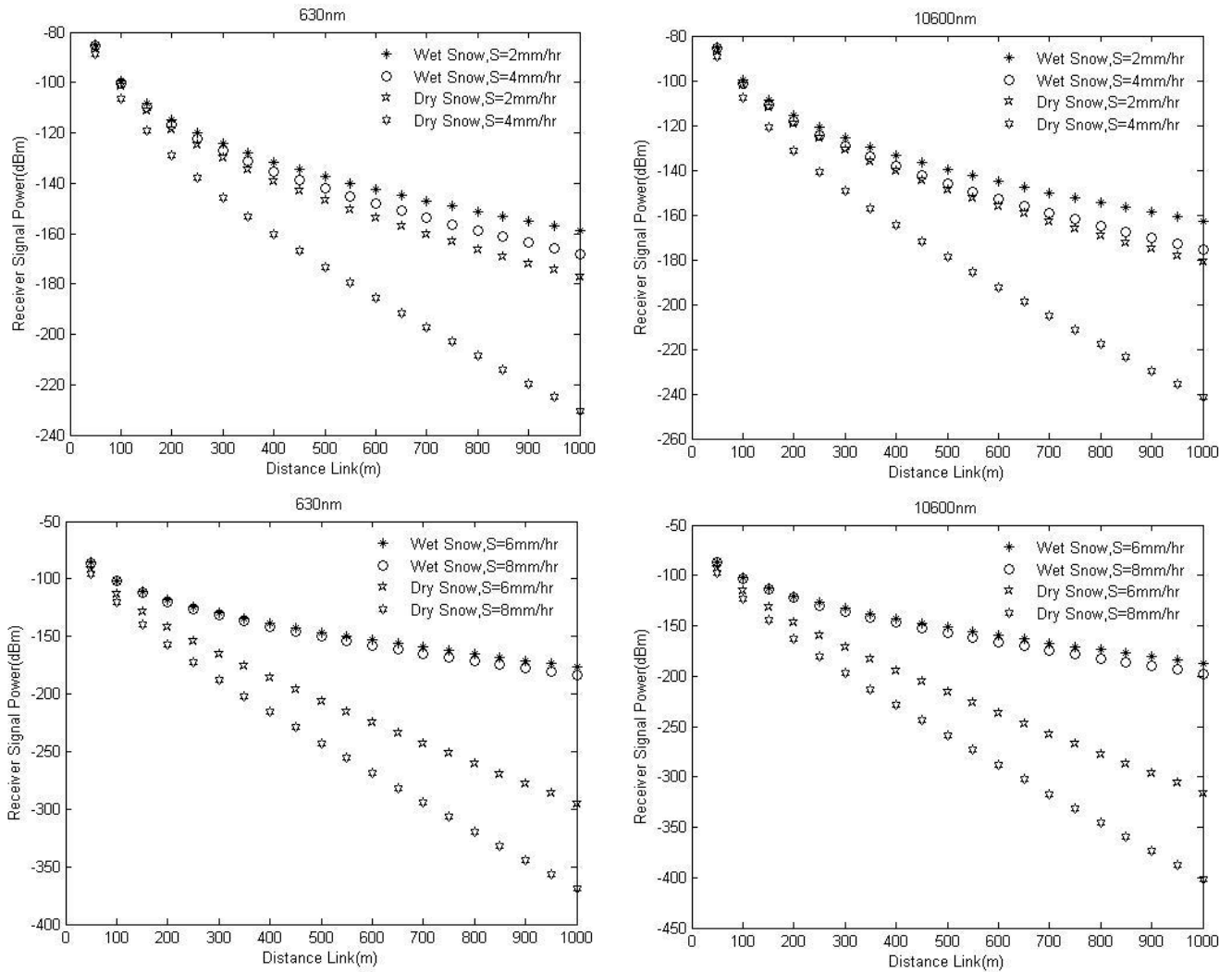
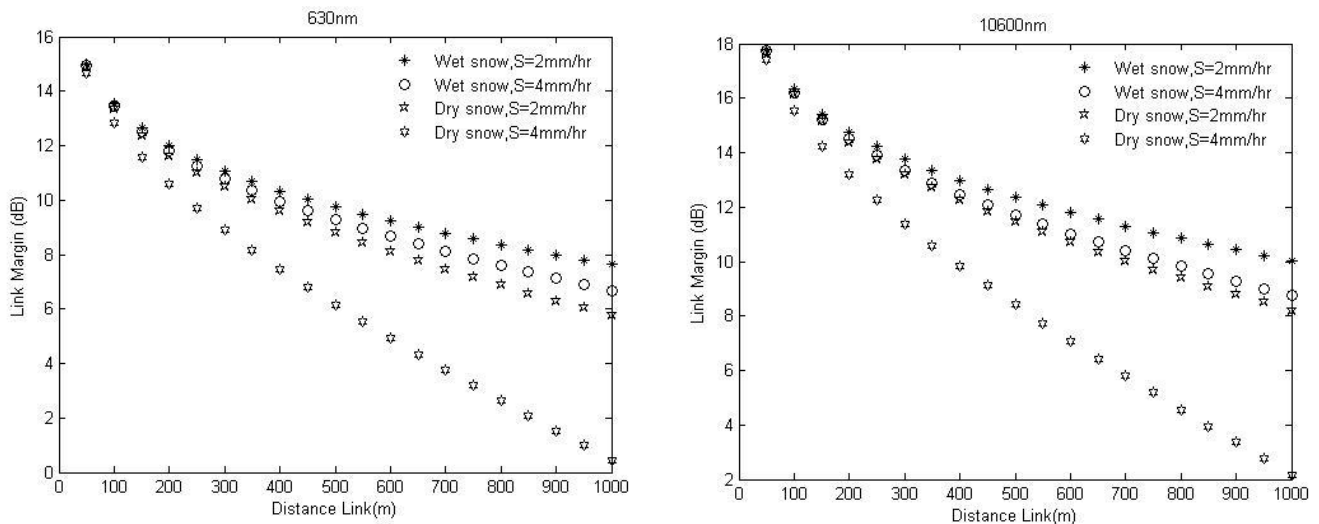


Fig. (1) The receiver signal power vs. distance link for different snow rate



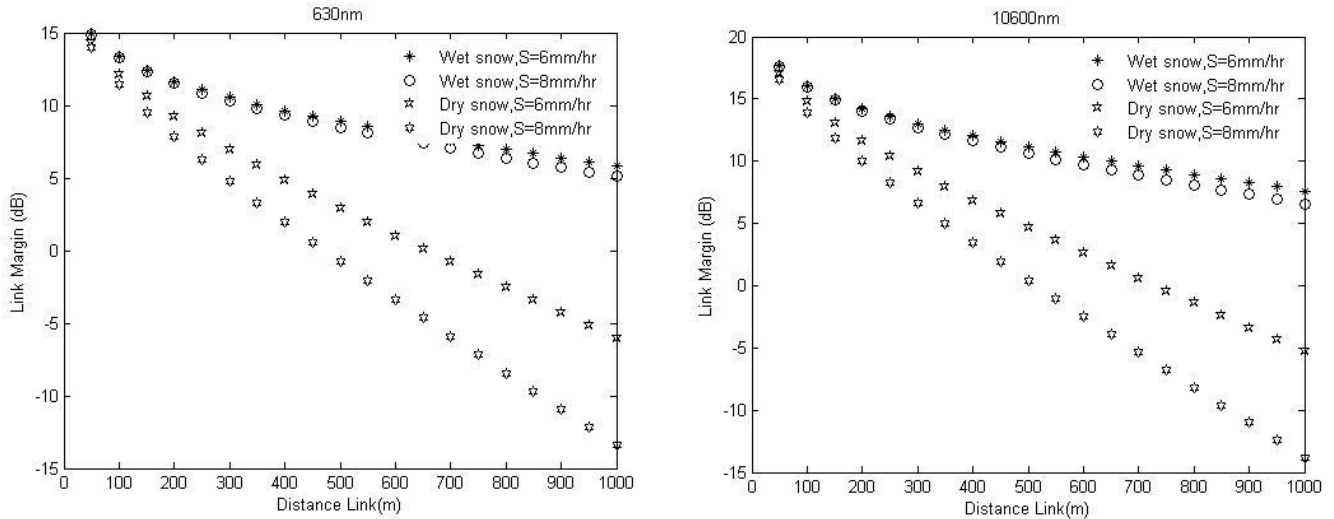
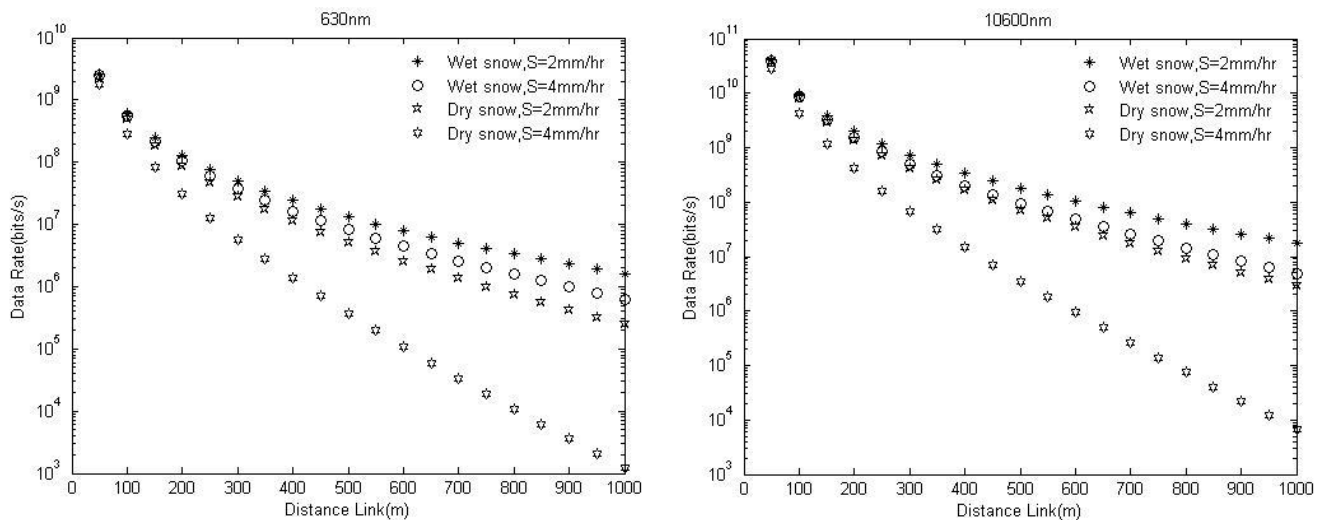


Fig. (2) Link margin vs. distance link for different snow rate

The data rate 100 Mb/s is achieved for wet and dry snow. The data rate of 100 Mb/s is obtained for 630 nm at a about distance 200m while for the wavelength 10600nm this value can be sent to a distance larger than 450 m for low snow rate as shown in fig. (3). While for high snow rate the data rate 100Mb/s can be achieved for the wavelength 630 nm at distance 100m but for the wavelength 10600nm this value reach to distance 350 m for the conditions under study.

To study the signal to noise ratio characteristics of wet and dry snow effect, we analyzed it based on the receiver signal power of the AVD. The simulation result is shown in fig. (4). As can be seen from fig. (4), when the snow rate S increases the signal to noise ratio is decreasing for both wavelengths under study. Also can be seen the wavelength 10600nm is better than the wavelength 630nm for both wet and dry snow effect. So, the dry snow has attenuation effect much greater than wet snow.



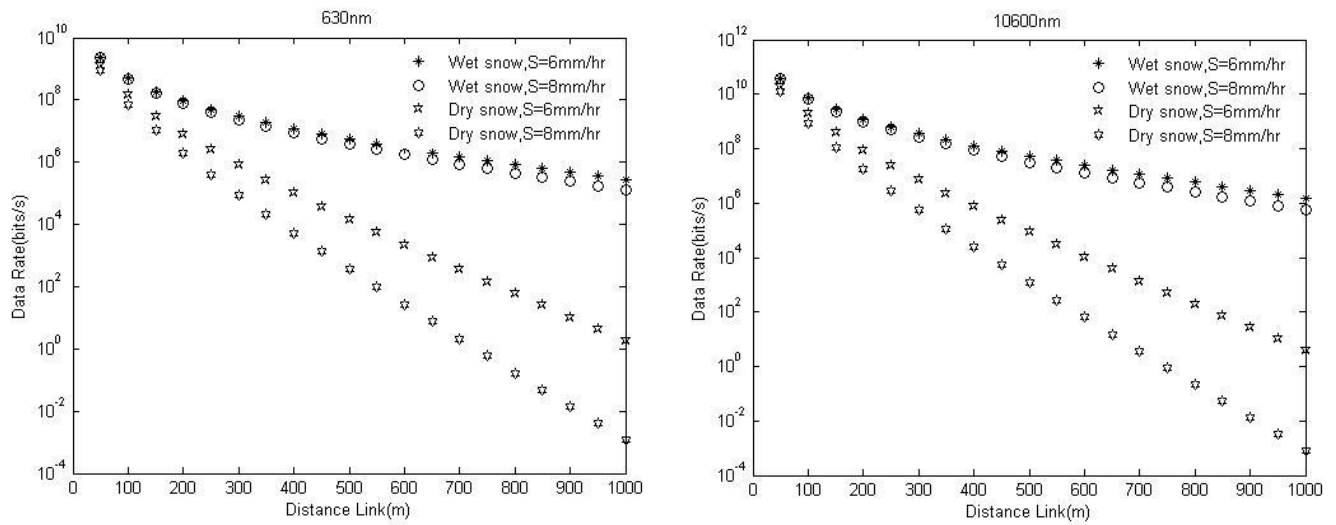


Fig. (3) Data Rate vs. distance link for different snow rate

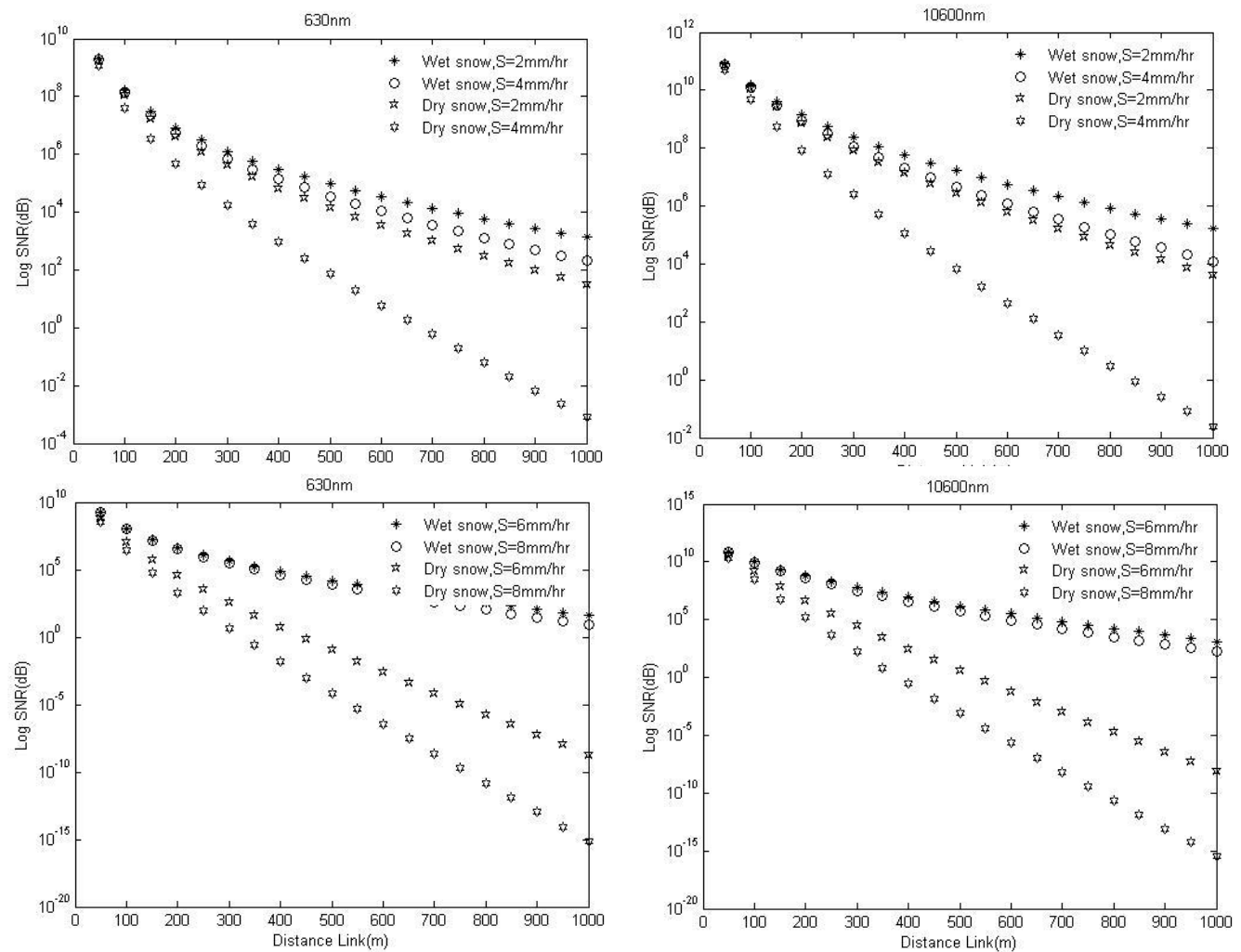


Fig. (4) Signal to noise ratio vs. distance link for different snow rate

V. Conclusion

In this paper, the receiver signal power, link margin, data rate and the signal to noise ratio was analyzed under snow attenuation effect for the wavelengths 630nm, 10600nm. The results show that when the transmission distance increasing the above parameters decreasing for both wavelengths under study. The simulation results observed that the dry snow have higher attenuation on optical communication system comparing with to the wet snow. The wavelength 630nm has better performance than the wavelength 10600nm. On the other hand the wavelength 10600nm more suitable for optical wireless communication system comparing to the wavelength 630nm. The wavelength 10600nm also more stability to used in optical wireless communications system has more link margin, data transfer rate and signal to noise ratio comparing to the wavelength 630nm.

VI. References

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