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Signal Losses and Allowable Optical Received Power Prediction Based on Different Visibilities for Optical Wireless Communication Links

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***Abstract*– Infrared wireless communication possesses two main attractive advantages over its radio frequency counterpart, namely the abundance of unregulated spectrum in 1.3 µm–1.55 µm region and the ease with which the infrared radiation can be confined. Integrating microwave electronics and optics, it is possible to provide wideband communication services but it is well known that the signal level in an optical wireless receiver is weakest at the front end. This paper presented allowable signal losses and optical received power prediction based on different visibilities for optical wireless communication links over wide range of the affecting parameters.**

***Index Terms*– Infrared Wireless Communications, Optics Communications, Signal Losses and Wide band Communication Services**

I. INTRODUCTION

THE Optical Wireless Communications (OWC) is a type of communications system that uses the atmosphere as a communications channel [1]. The OWC systems are attractive to provide broadband services due to their inherent wide bandwidth, easy deployment and no license requirement. The idea to employ the atmosphere as transmission media arises from the invention of the laser. However, the early experiments on this field did not have any baggage of technological development (like the present systems) derived from the fiber optical communications systems, because like this, the interest on them decreased [2] - [4]. At the beginning of the last century, the OWC systems have attracted some interest due to the advantages mentioned above. However, the interaction of the electromagnetic waves with the atmosphere at optical frequencies is stronger than that corresponding at microwave. The intensity of a laser beam propagating through the atmosphere is reduced due to phenomena such as scattering and molecular absorption, among other. The changes in the refractive index of the atmosphere due to optical turbulence affect the quality of laser beam through distortion of its phase front and random modulation of its optical power [5, 6]. Also the presence of fog may completely prevent the passage of the optical beam that leads to a no operational communications link [7].

Figure 1 shows the block diagram of an OWC communications system (also called Free Space optic communications system or FSO). The information signal (analog or digital) is applied to the optical transmitter to be sent through the atmosphere using an optical antenna. At the receiver end the optical beam is concentrated, using an optical antenna, to the photo-detector sensitive area, which output is electrically processed in order to receiver the information signal. The optical wireless communications industry has

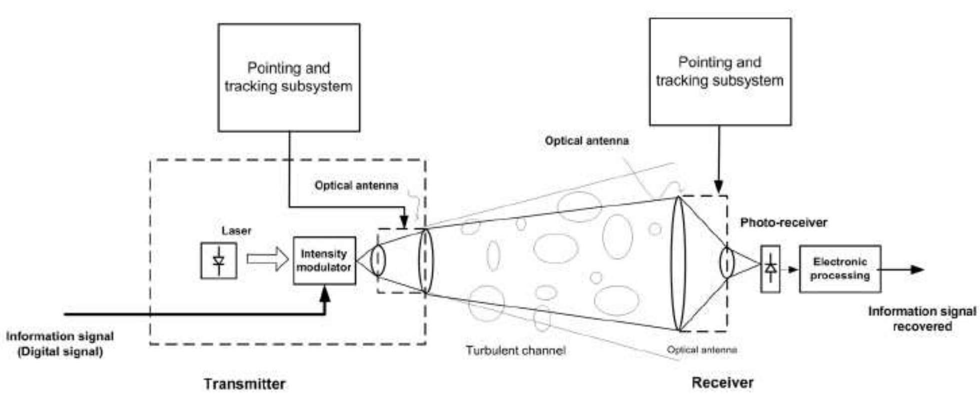

Fig. 1. Model of a typical atmospheric optical communications link [6]

has experienced a healthy growth in the past decade despite the ups and downs of the global economy. This is due to the three main advantages over other competing technologies. First, the wireless optical communications cost is on average about 10% of the cost of an optical fiber system. It also requires only a few hours or weeks to install, similar time to establish a radio link (RF), while installing the fiber optics can take several months. Second, OWC systems have a greater range than systems based on millimeter waves. OWC systems can cover distances greater than a kilometer, in contrast with millimeter-wave systems that require repeaters for the same distance. In addition, millimeter wave systems are affected by rain, but the OWC systems are affected y fog, which makes complementary these transmission technologies [8]. Finally, this type of technology as opposed to radio links, does not require licensing in addition to not cause interference.

In the present study, broadband spectrum of optical wireless communication is available, which can fulfill the requirements of high speed wireless communication. This is the basic advantage of optical wireless communication over conventional wireless communication technologies. Wireless optical communication system has received a great deal of attention lately both in the military and civilian information society due to its potentially high capacity, rapid deployment, portability and high security. Therefore the model has been investigated to predict the allowable signal attenuation and optical received power over wide range of the affecting parameters.

The Optical Wireless Communication is the only elucidation to the next generation wireless communication owing to a quantity of advantages over the existing RF wireless systems are, large information bandwidth (THz range), low transmitted power (mWatt-range), high directionality (beamwidth-mrad.), high speed data transmission (Gb/s), high signal security, free from electromagnetic interference, very less Bit Error Rate (10^{-12}), size and weight of the optical components are very small etc. Fig. 2 and Fig. 3 represent the general block diagram of optical wireless communication system for point to point link for both clear sky and turbulence conditions respectively [9].

In the optical wireless communication systems, the Laser Beam from the source is used as the carrier wave and is transmitted through the free-space (atmosphere) directly. Because of highly directional beam, the transmitted signal is traveling in the straight line with long distance. The transmitter and receiver should be in face-to-face, i.e., line of sight (LOS) condition to be applied for this system. Even though optical wireless communication system has great potential, there are some limitations to overcome the existing optical wireless communication becomes highly efficient one. The major problem in the available optical wireless communication system is multi scattering effect, i.e., in the presence of fog, hail, heavy rain, etc. in the atmosphere causes serious signal degradation in the propagation path [10], [11]. Under clear sky condition, the optical wireless communication system has very less attenuation and scattering effects, but in the fog or snow form condition, the attenuation and scattering effects are very high. This effect limits the maximum system bandwidth and increases bit error rate (BER).

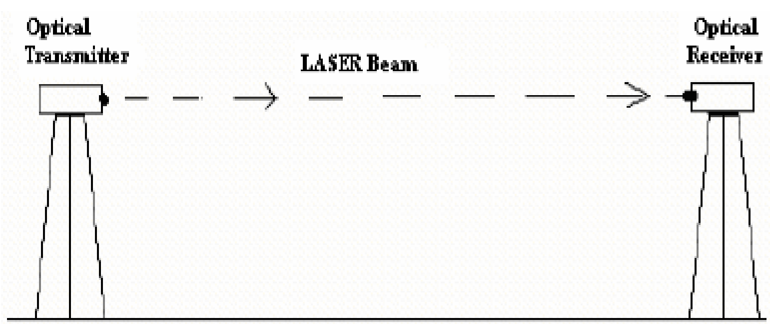

Fig. 2. Optical wireless communication system under clear sky condition

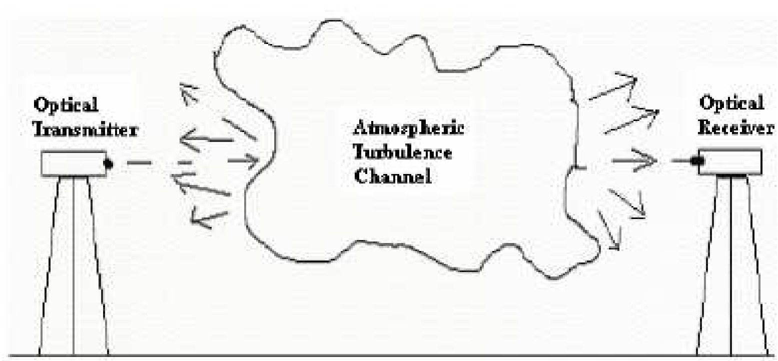

Fig. 3. Optical wireless communication system under clear sky condition

II. SYSTEM MODEL ANALYSIS

The link equation for optical wireless communication system using Beers-Lambert law is given by [12, 13]:

$$P_r = P_t\left(\left(A_r/(D.R)^2\right)\right)\exp(-\sigma R) \quad (1)$$

Where P_r is the received power at the optical receiver in Watts, P_t is the transmitted power at the optical transmitter in Watts, A_r is the receiver aperture area in cm^2 with the radius of r = 30cm, the transmit beam divergence D = 2 mrad, the distance between the optical transmitter and receiver (range) R= 1 km and σ is the atmospheric attenuation coefficient in km^{-1} is given by the following expressions [14], [15]:

$$\sigma = \left(\frac{3.91}{V}\right).\left(\frac{\lambda}{0.55}\right)^{-q} \quad (2)$$

Where V is visibility in the atmosphere in km and q is the size distribution of the scattering particles depends on visibilities, and given by the following formulas [16]:

$$q = 1.6 \ , \ for\ V \geq 50\ km \quad (3)$$

$$q = 1.3 \ , \ for\ 6 \leq V \leq 50\ km \quad (4)$$

$$q = 0.16\ V + 0.34 \ , \ for\ 1 \leq V \leq 6\ km \quad (5)$$

$$q = V - 0.5 \ , \ for\ 0.5 \leq V \leq 1\ km \quad (6)$$

$$q = 0 \ , \ for\ V \leq 0.5\ km \quad (7)$$

III. SIMULATION RESULTS AND DISCUSSIONS

We have investigated the optical received power and allowable signal losses between wireless optical links based on different visibilities over wide range of the affecting parameters. The line of sight between transmitter and receiver is fixed when we can predict total signal losses and allowable optical received power at the receive side for different visibilities ranges.

Based on the modeling equations analysis and the assumed set of the operating system parameters as shown in Table 1, the following facts are assured as shown in the series of Fig. 4 – Fig. 13:

i) As shown in the series of Fig. 4 – Fig. 8 have assured that allowable signal losses decrease with increasing both operating optical signal wavelength and visibilities ranges. While it is observed that the increased visibility range, the decreased signal losses at fixed optical transmission range at 1km range.

ii) Fig. 9 – Fig. 13 have assured that allowable predicted optical received power increase with increasing both operating optical signal wavelength and visibilities ranges. While it is observed that the increased visibility range, the increased predicted optical received power at fixed optical transmission range at 1km range.

Table 1: Proposed operating parameters for wireless optical link design [3, 5, 8, 12].

Operating parameter	Value and units
Transmitting power (P_t)	100 mWatt
Receiver aperture area (A_r)	50 cm^2
Operating signal wavelength (λ)	1.3 μm ≤ λ ≤ 1.55 μm
Optical transmission distance between Tx. and Rx. (R)	1 km
Transmitter beam divergence (D)	2 mrad
Very low visibility (V_{VL})	0.001 ≤ V_{VL}, km ≤ 0.1 μm
Low visibility (V_L)	0.5 ≤ V_L, km ≤ 1 km
Medium visibility (V_M)	1.5 ≤ V_M, km ≤ 6 km
High visibility (V_H)	10 ≤ V_H, km ≤ 50 km
Very high visibility (V_{VH})	60 ≤ V_{VH}, km ≤ 100 km

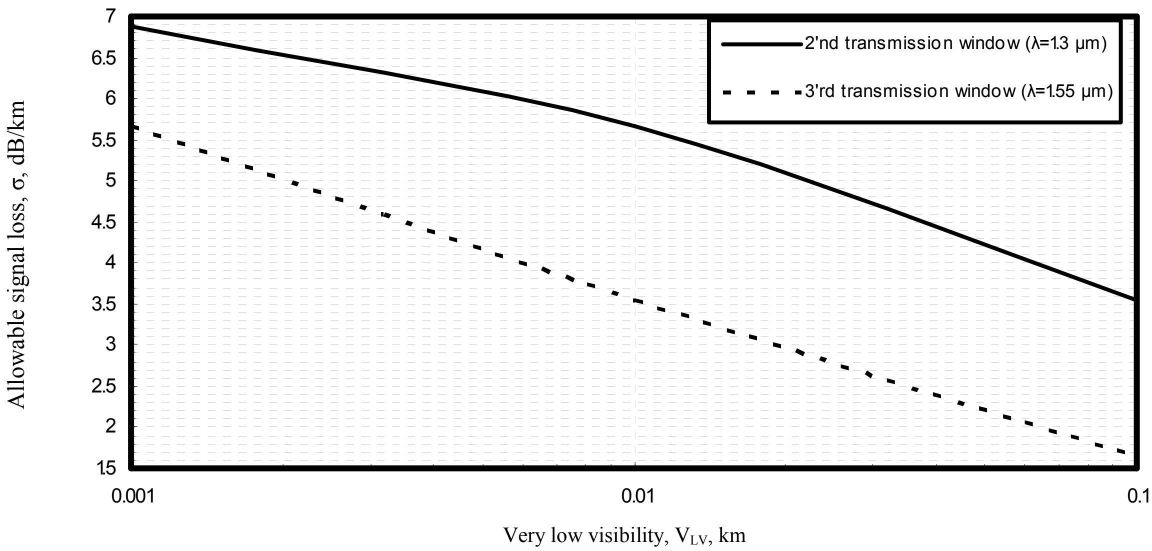

Fig. 4. Allowable signal loss in relation to very low visibility at the assumed set of the operating parameters

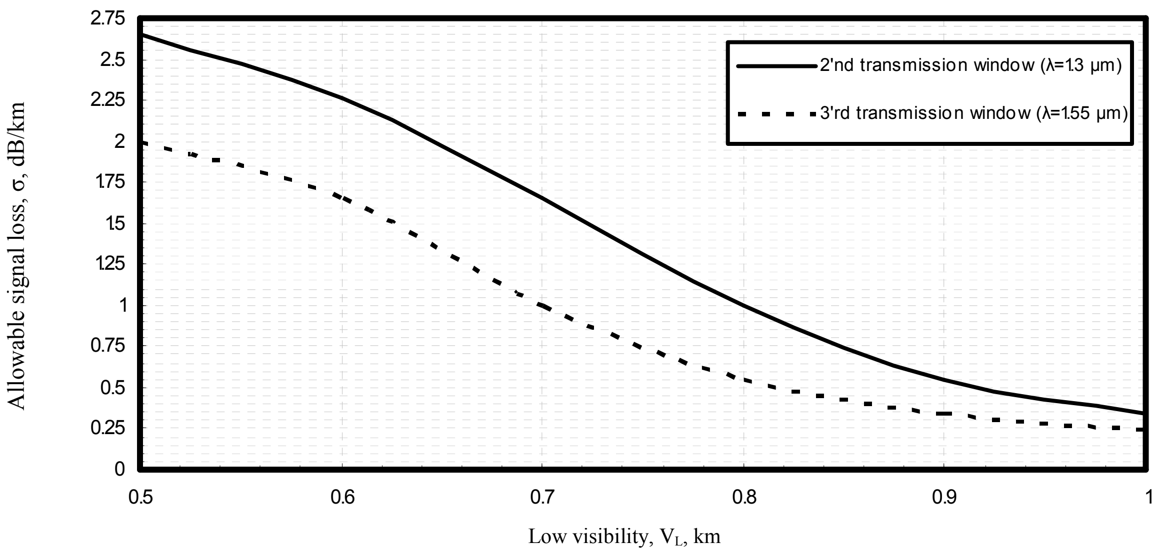

Fig. 5. Allowable signal loss in relation to low visibility at the assumed set of the operating parameters

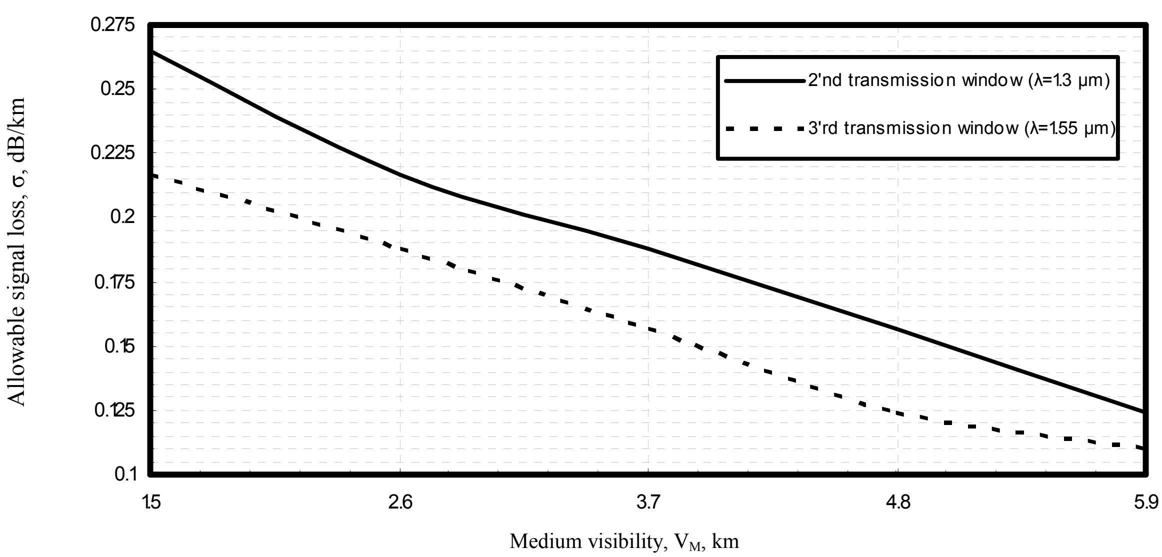

Fig. 6. Allowable signal loss in relation to medium visibility at the assumed set of the operating parameters

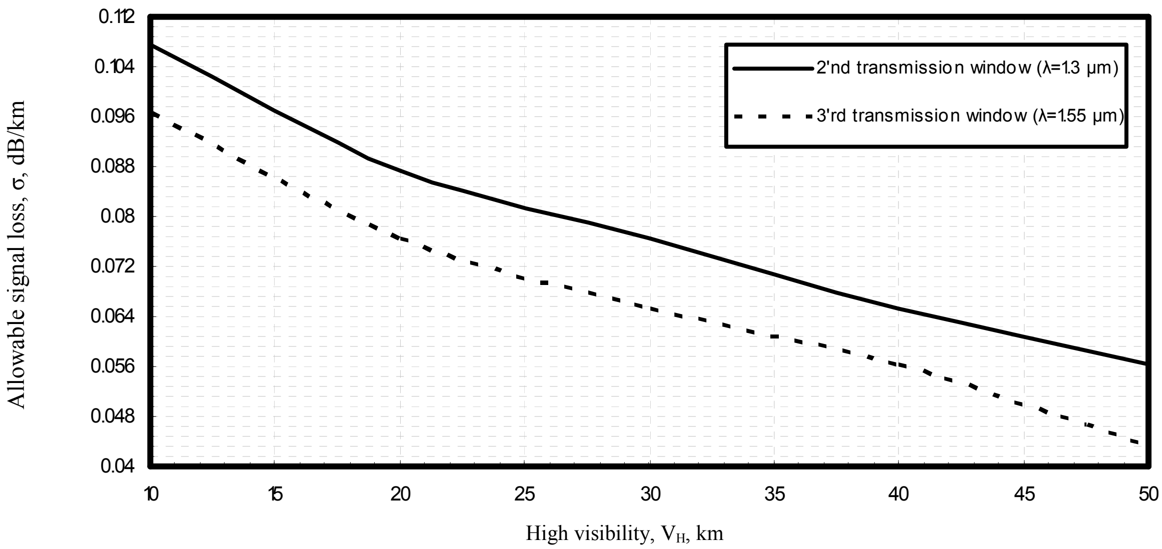

Fig. 7. Allowable signal loss in relation to high visibility at the assumed set of the operating parameters

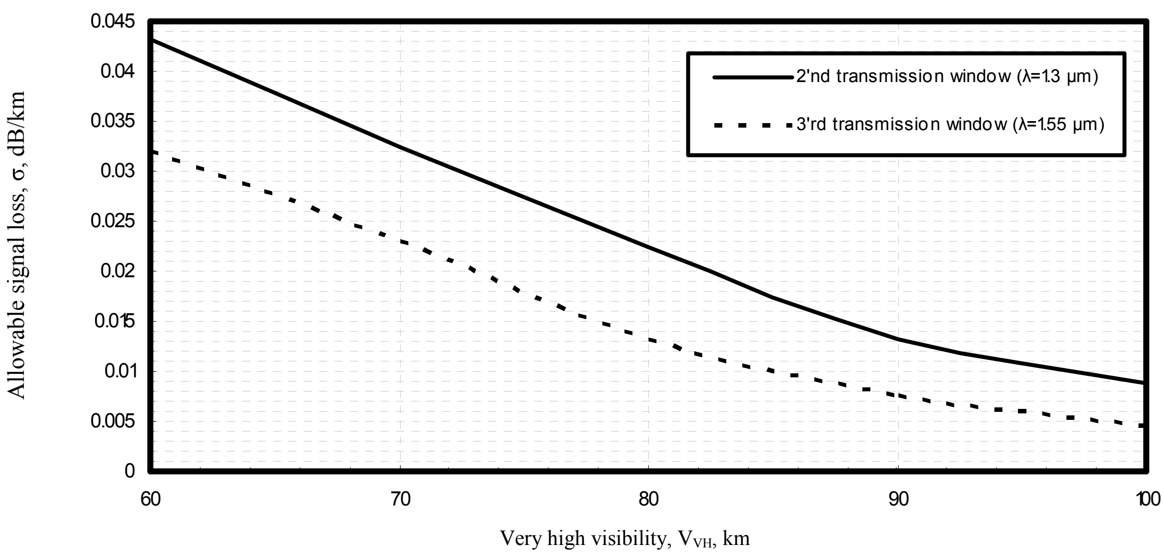

Fig. 8. Allowable signal loss in relation to very high visibility at the assumed set of the operating parameters

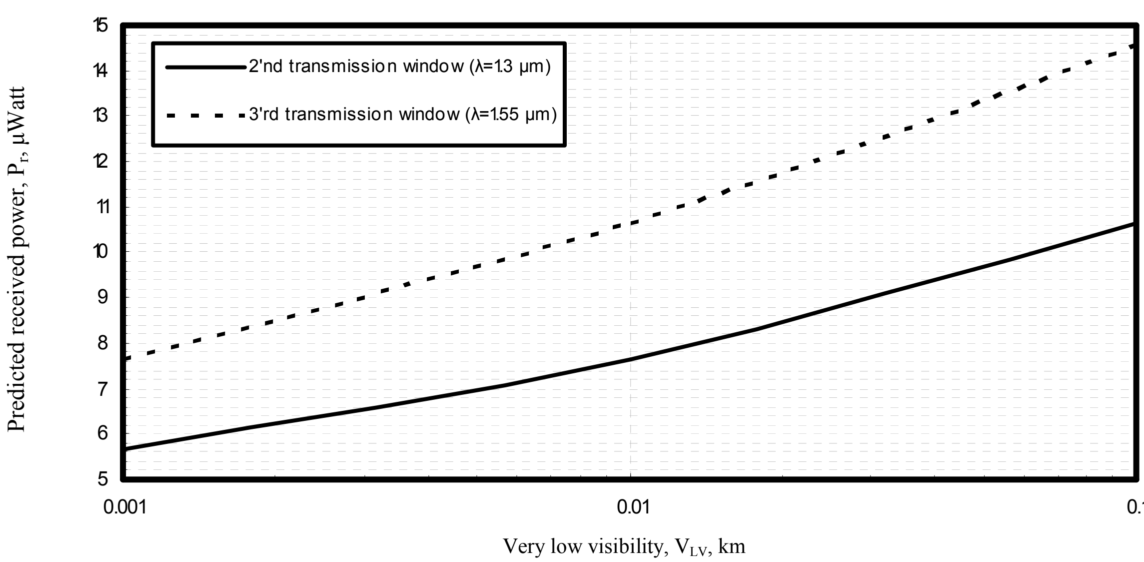

Fig. 9. Predicted optical received power in relation to very low visibility at the assumed set of the operating parameters

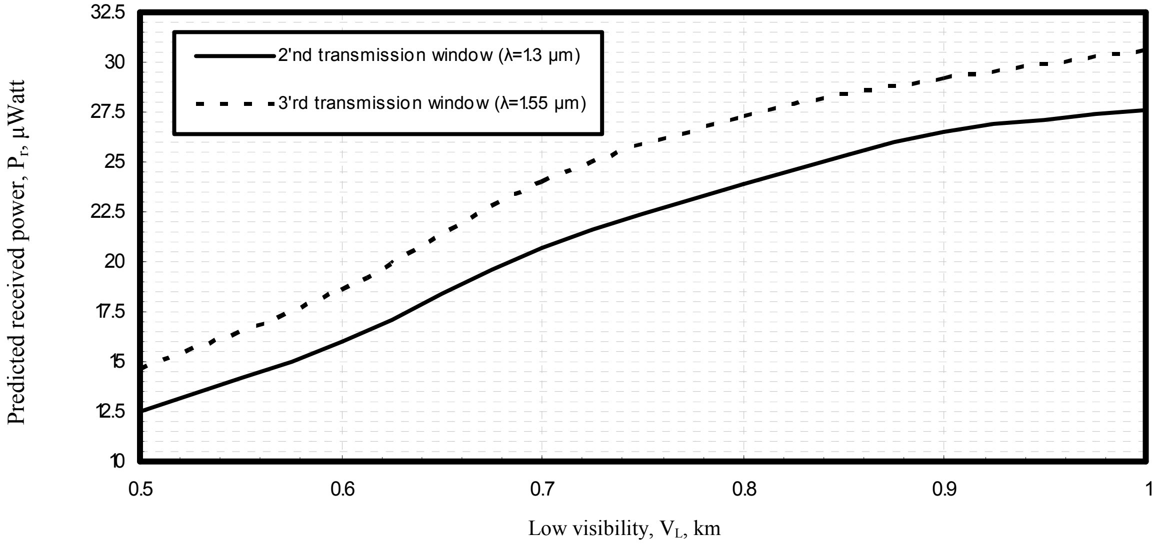

Fig. 10. Predicted optical received power in relation to low visibility at the assumed set of the operating parameters

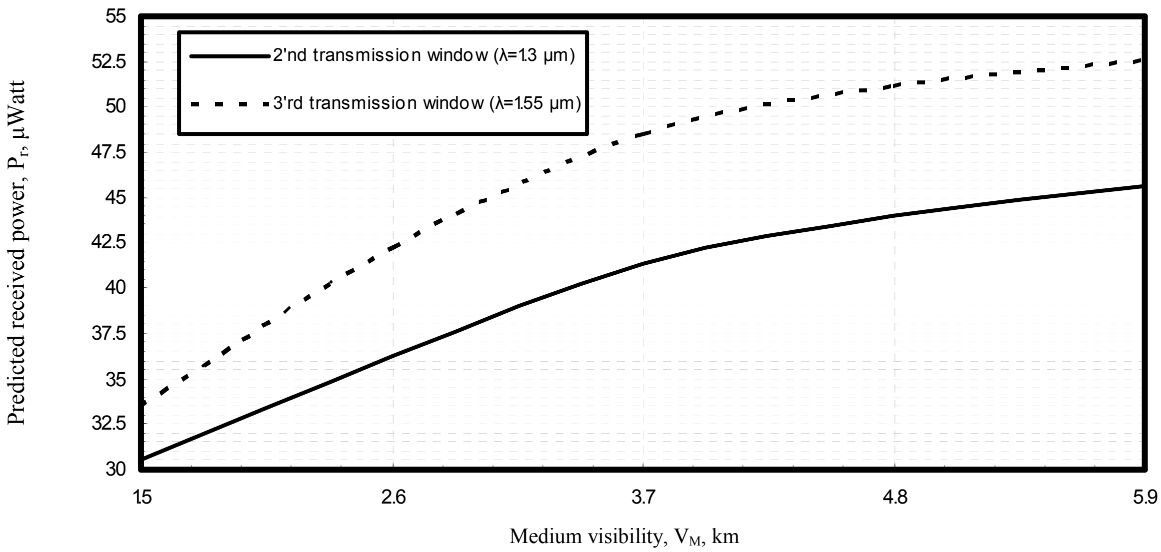

Fig. 11. Predicted optical received power in relation to medium visibility at the assumed set of the operating parameters

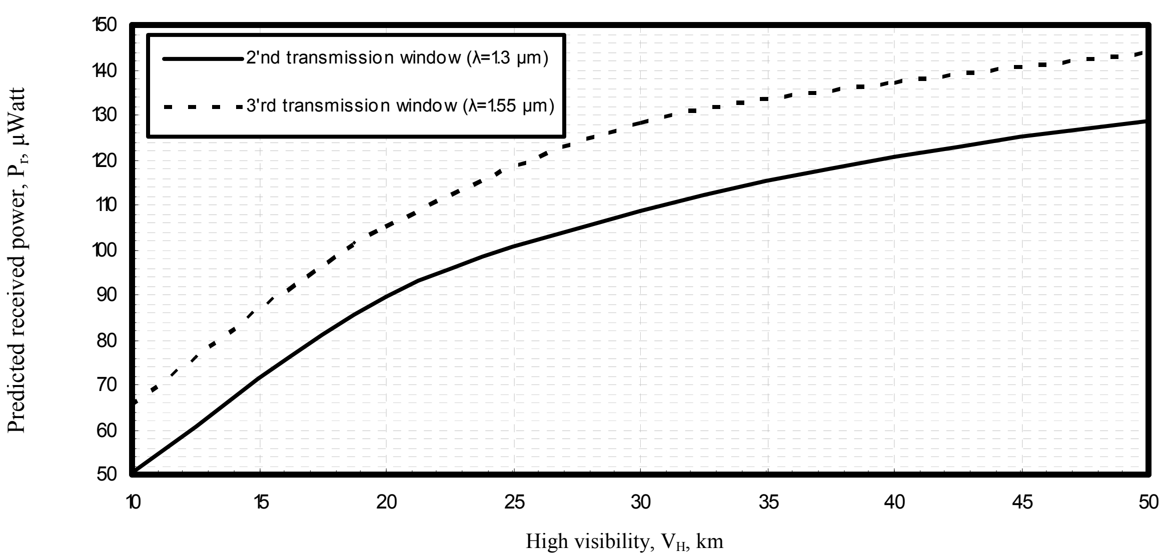

Fig. 12. Predicted optical received power in relation to high visibility at the assumed set of the operating parameters

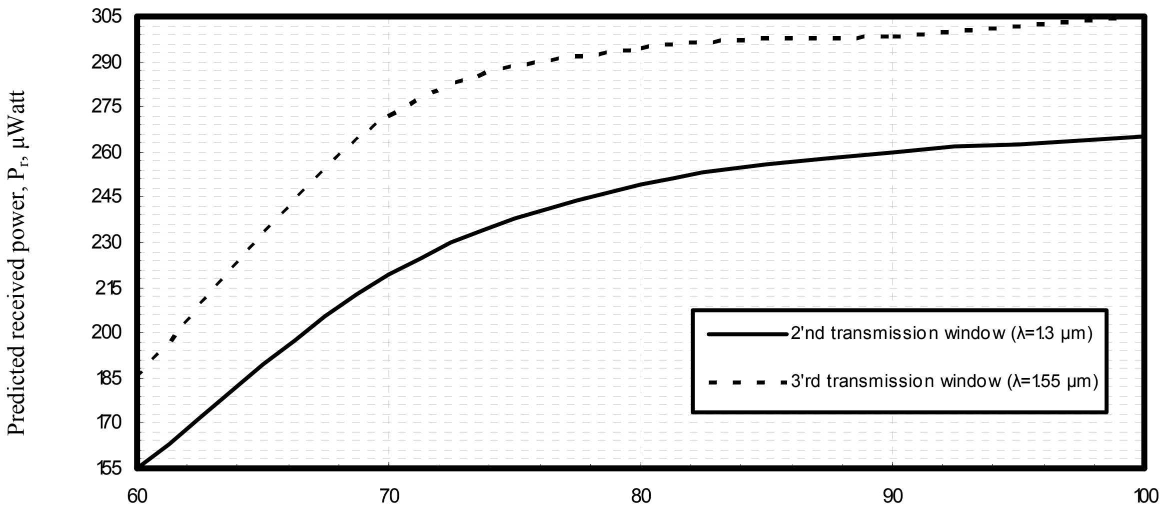

Fig. 13. Predicted optical received power in relation to very high visibility at the assumed set of the operating parameters

IV. CONCLUSIONS

In a summary, the model has been investigated the signal losses and allowable optical predicted signal received power based on different visibilities ranges. It is observed that the increased of both optical signal wavelength and visibility ranges, resulting in the decreased predicted signal losses and the increased predicted optical signal received power at fixed optical transmission line of sight between transmitter and receiver at one kilometer.

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