Characterization Of Signal Loss Due To Dense Fog At 900Mhz Of Optical Wireless Communication System In Ibadan South Western Nigeria

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***Abstract*—The presence of hydrometeors in the atmosphere, for example, fog, mist, clouds, sleet, rain, snow and haze causes very severe challenges to the optical signal propagation; especially fog leads to signal attenuations up to an order of few hundreds of dBm. Attenuation of signal in Fog at different optical window was measured in Ibadan (7^0 22`N, $3^0$ 58`E). In this work, two common peak wavelengths (attenuation windows) were selected. They are: 850nm and 1550nm. The visibility was measured using a Transmissometer. Measurement and theoretical value were compared with the commonly used light attenuation models of Kim and Al-Nabousi, and present some interesting insight. The work clear the air in the confusion and preconceived notions about the true ability of free space laser communication (optical wireless communication) that 1550nm is less affected by any weather conditions than 850nm. Our result revealed that 850nm and 1550nm attenuated the same when visibility is less than 500m.**

Keywords—Attenuation, Fog, Visibility, Transmissometer Optical window.

1. Introduction.

The rising need of wireless broadband communication links has instigated the interest in Free Space Optical Communication technology. Since more than a decade, there is an increasing demand for high bandwidth transmission capabilities which is flexible, low costs and allow quick installation. Among other technologies, this has attracted much attention for wireless optical point -to-point transmission which is also known as free space optics (FSO). As one consequence to this situation, many companies were founded in this time, offering free space optics equipment. Conference sessions dedicated to these topics like free-space laser communications technologies (SPIE photonics west), saw a huge extension, and voices of the different manufacturers present arguments, why their special technology would perform best in typical ambient conditions. It is one deficit of the rapid development, that a major independent research network in this field is still missing, and new measurements are often related to a company's interest.

The transmission of electromagnetic wave through the atmosphere is governed by the attenuation due to both scattering and absorption by all the atmospheric species present in the path of propagation [1]. Attenuation describes the loss of signal energy relative to free space propagation due to materials in the propagation path. Attenuation decreases the received signal power, which in turn decreases the detection range. The atmospheric path is categorized to horizontal path (constant pressure) and slant path (changed pressure) [2], the absorption occurs by water vapour, carbon IV oxide, O_3, NO_2, N_2, and O_2, while the scattering is produced by gas molecules, dust, smoke, fog and rain [3]

There is confusion and many preconceived notions about the true ability of free space Laser communication (optical wireless communication) of signal attenuation in different weather conditions. Due to the published equation and reports [4] that 1550nm is less affected by any weather conditions than 850nm.

This study addresses this misconception for fog where visibility is less than 0.5km. The result obtained gave the modification to the atmospheric attenuation as a function of wavelength

.Attenuation σ, of directed or specula light radiation in the atmosphere was predicted in Kruse formula [1] by:

$$\sigma(\lambda) = \frac{13}{V}\left(\frac{\lambda}{\lambda_0}\right)^{-q} \qquad (1)$$

In equation (1), σ(λ) is the atmosphere attenuation or scattering coefficient as a function of wavelength; V is the visibility (in km); λ is the wavelength (in nm); λ_0 is the visibility reference wavelength, the wavelength corresponding to the maximum intensity of the solar spectrum which is (550nm) and q is the size distribution of the scattering particles. In visible and near infrared up to about 2.5µm, equation (1) relates attenuation to visibility V (km) for a given wavelength (850 and 1550nm) for this work. For Kruse model [1]

$$q=\begin{cases} 1.6 \text{ if } V > 50km \\ 1.3 \text{ if } 6km < V < 50km, \\ 0.585V^{\frac{1}{3}}, \text{ if } V < 6km. \end{cases} \quad (2)$$

Equation (2) implies that for any meteorological condition, there will be attenuation for higher wavelengths. The attenuation of 10µm is expected to be less than attenuation of shorter wavelengths. Kim rejected such wavelength dependent attenuation for low visibility in dense fog. The q variable in equation (1) for Kim model [1] is given by:

$$q=\begin{cases} 1.6 \text{ if } V > 50km \\ 1.3 \text{ if } 6km < V < 50km \\ 0.16V+0.34 \text{ if } 1km < V < 6km \\ V-0.5 \text{ if } 0.5km < V < 1km \\ 0 \text{ if } V < 0.5km \end{cases} \quad (3)$$

The Kruise equation extends the problem of transmission and visibility to other wavelengths (approximately 0.5 to 2.5µm) especially in the infra red [5].

The fog was analyzed as the destructive factor producing huge signal attenuation for considerable amount of time. The models Kruse and Kim predict fog specific attenuation using visibility. The visibility is defined as the distance as the distance where the image distinction drops to 2% of what it would be if the object were nearby instead. Image distinction drop to 5% is also considered for visibility definition. The visibility was measured at 550nm, the wavelength corresponding to the maximum intensity of the solar spectrum.

2. Selection of optical wavelengths

The selection of optical wavelengths for this work is primarily based on the optical transmission windows, eye safety reasons and of course expenses. The wavelength selection is dependent on atmospheric effects (conditions) and laser safety regulations, longer wavelengths are the preferred option. A crucial parameter in the field of FSO is the used wavelength (in terms of optics, wavelength is preferred instead of frequency). The international commission on illumination (CIE) located in Vienna recommends a division of optical into three main bands:
IR-A (700nm-1400nm), IR-B (1400nm – 3000nm) and IR-C (3000nm – 1mm)
Near infrared (NIR): wavelength from 750 nm-1400nm; mainly used in optical fiber (for low attenuation losses).
Short wavelength infrared (SWIR): wavelength from 1400nm – 3000nm; the range from 1530nm – 1560nm in which 1550nm used for this work is embedded are the dominant spectral region for long distance telecommunication.
Mid wavelength infrared (MWIR): wavelengths from 3000nm to 8000nm; are used in military applications for guiding missiles.

3. Measurement

The specific attenuation at 850nm and 1550nm were measured concurrently at the coastal region, Ajibode area in Ibadan metropolis on 22nd day on January, 2014; 10^{th} February, 2014 and 13^{th} March, 2014. The observation site is located at the hill side where there is partial forest and farming. The other site is located at Iroko village along Oyo-Ibadan expressway. Our measurement set up did consist of a Transmissometer to measure visibility at 550nm center wavelength. The optical link for transmission at laser wavelength was able to transmit two optical wavelengths each pulse modulated with individual carrier frequency, Fc 900MHz. Transmitter and receiver were stable mounted in 4.0m height to measure the transmission over a path of free air at about 28m distance. The transmitter sends a laser beam through dense fog toward the receiver. The instrument calculates how much the beam is attenuated by the atmospheric phenomenon (Fog). Laser diode was used because it can output higher power levels of coherent light from a smaller area, allowing for faster modulation and thus higher transport bandwidth designs.

3.1 Specification of instrument used

Light source: SIEMENS CQV 30. 665 LASER DIODE
Light detector: BPYP 07 PHOTODIODE
Path: 0.5m
Maximum sampling frequency: 5Hz
Accuracy: 5% for C > $2m^{-1}$

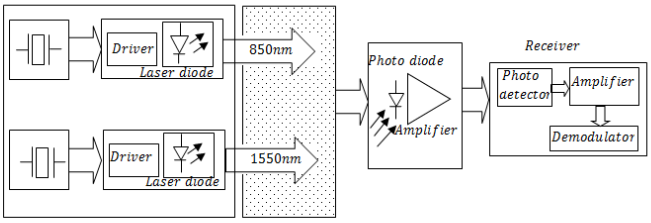

Fig 1 Block diagram of Transmissometer

4. Results and discussion

Result of measurement as well as computations of signal attenuation in 850 and 1550nm optical window for wireless communication is presented in Fig. 4 and 5. The computational values are derived from the attenuation coefficient calculated using equation 1.
Figure 2 shows the variations of liquid-water content as a function of humidity present in each day. The humidity is very high in day 1 and day 3
Figure 3 and 4 shows the normalized optical power as a function of visual range, measured at 850 and 1550 optical window. In our result, the particle distribution is non-uniform. Hence, Infrared links provided superior availability because 10µm light overcome losses in dense fog and maintain link availability whereas shorter wavelength cannot.

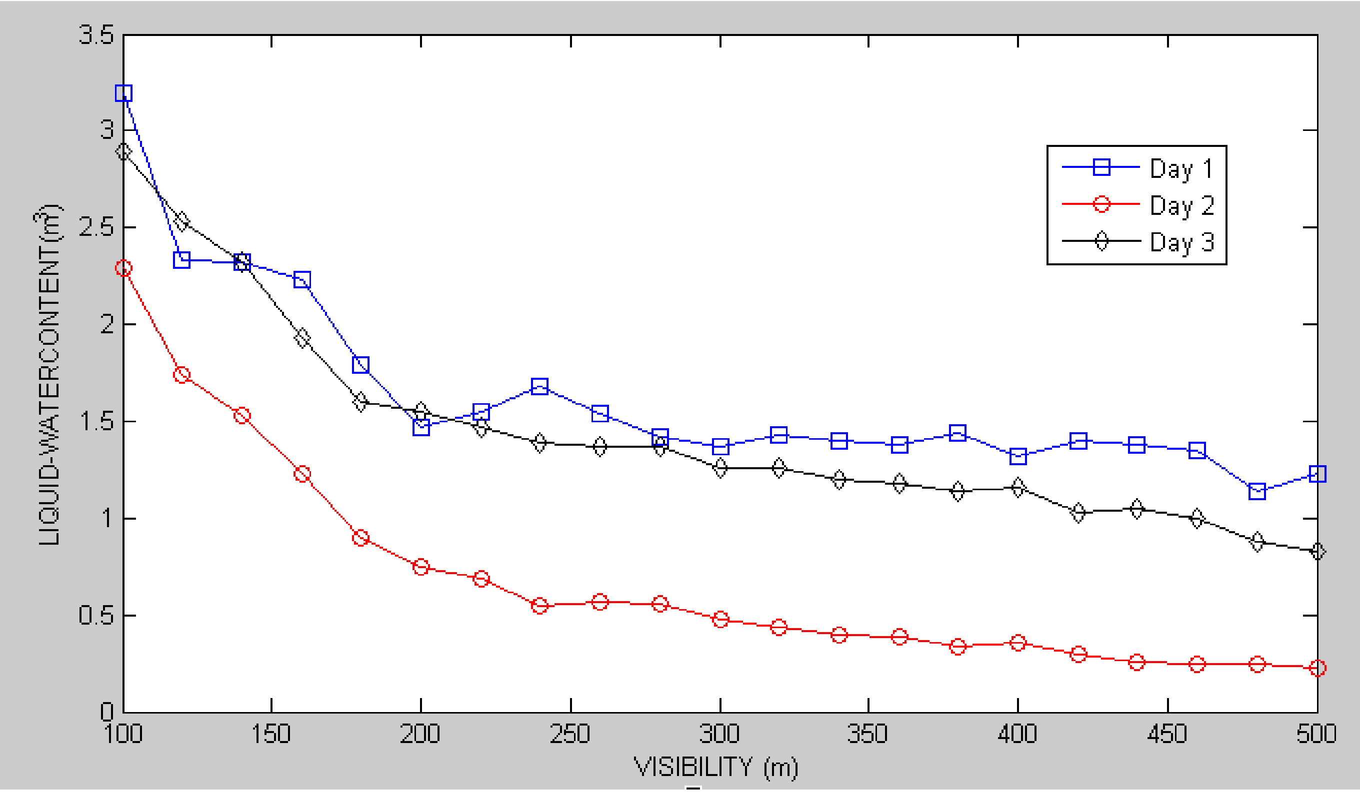

Fig.2 Liquid water content against visibility

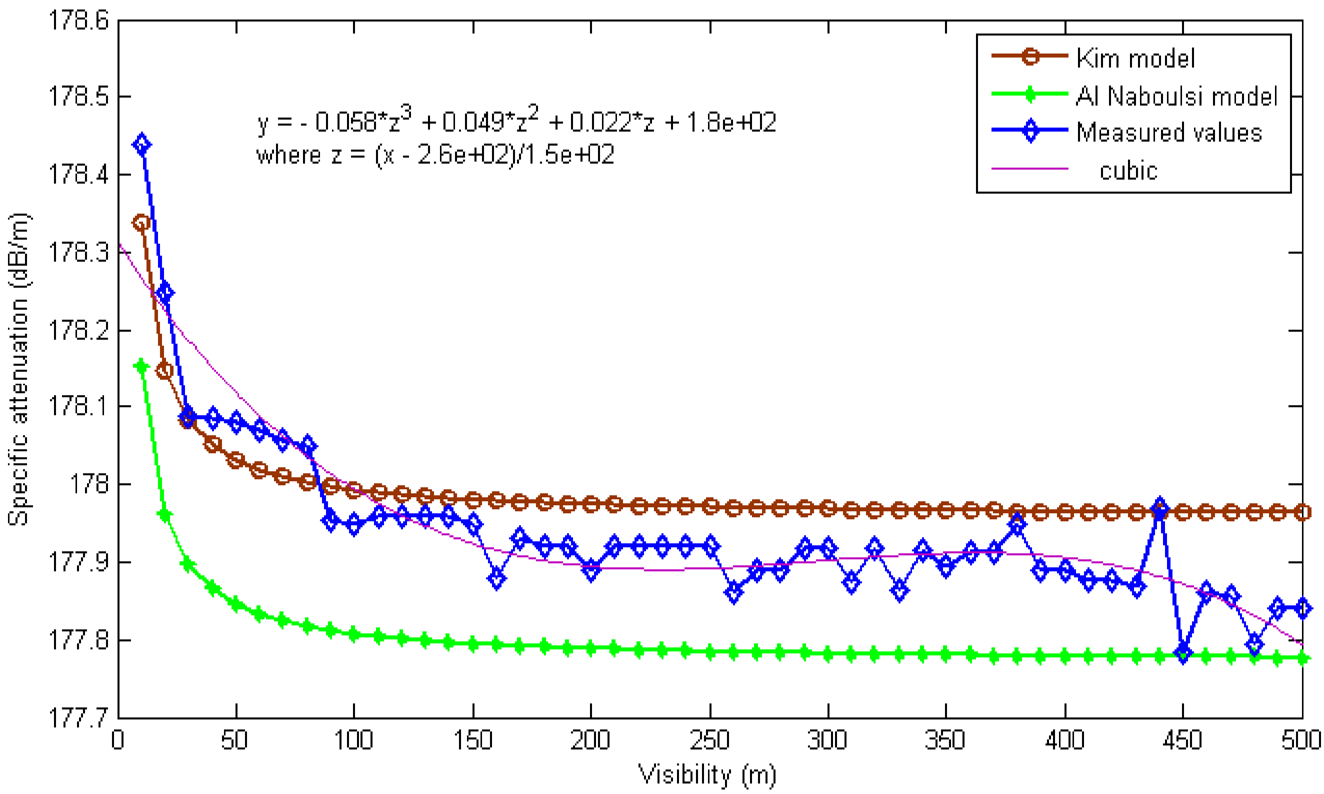

Fig. 3: Atmospheric attenuation as a function of visibility for 850nm

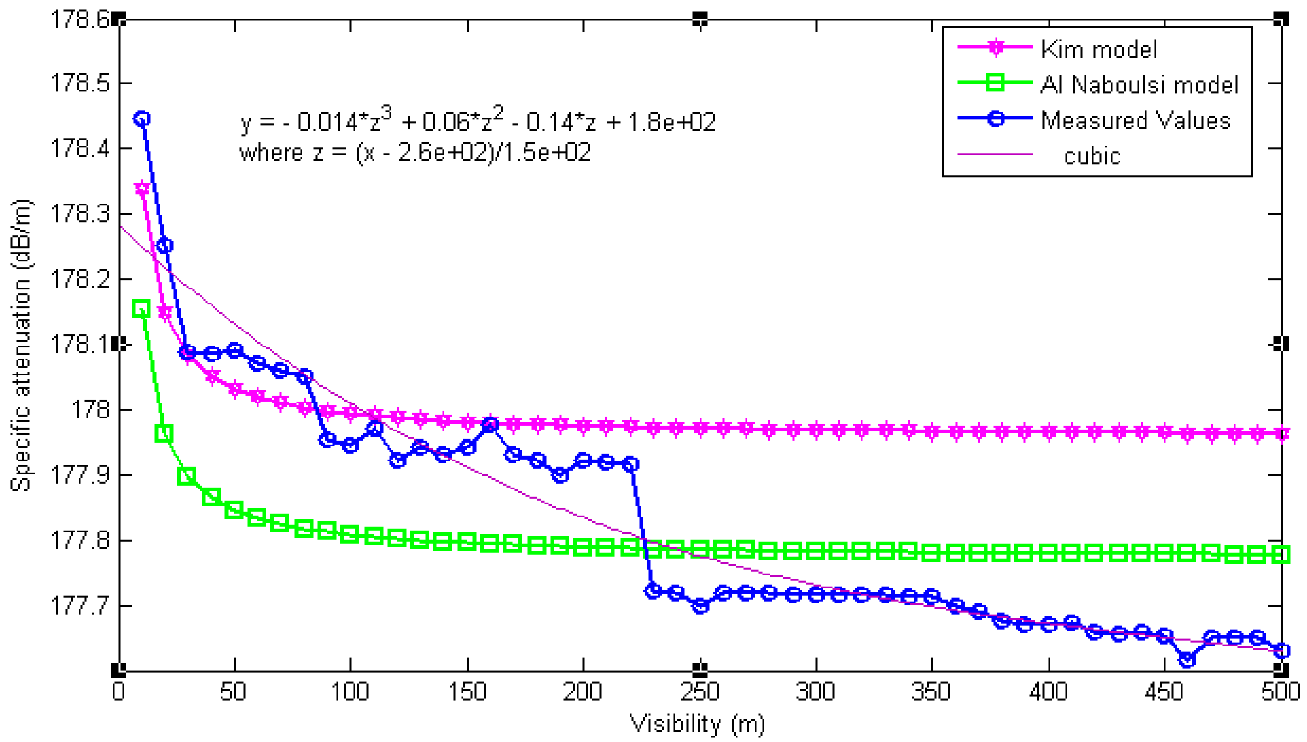

Fig. 4 Atmospheric attenuation as a function of visibility for 1550nm

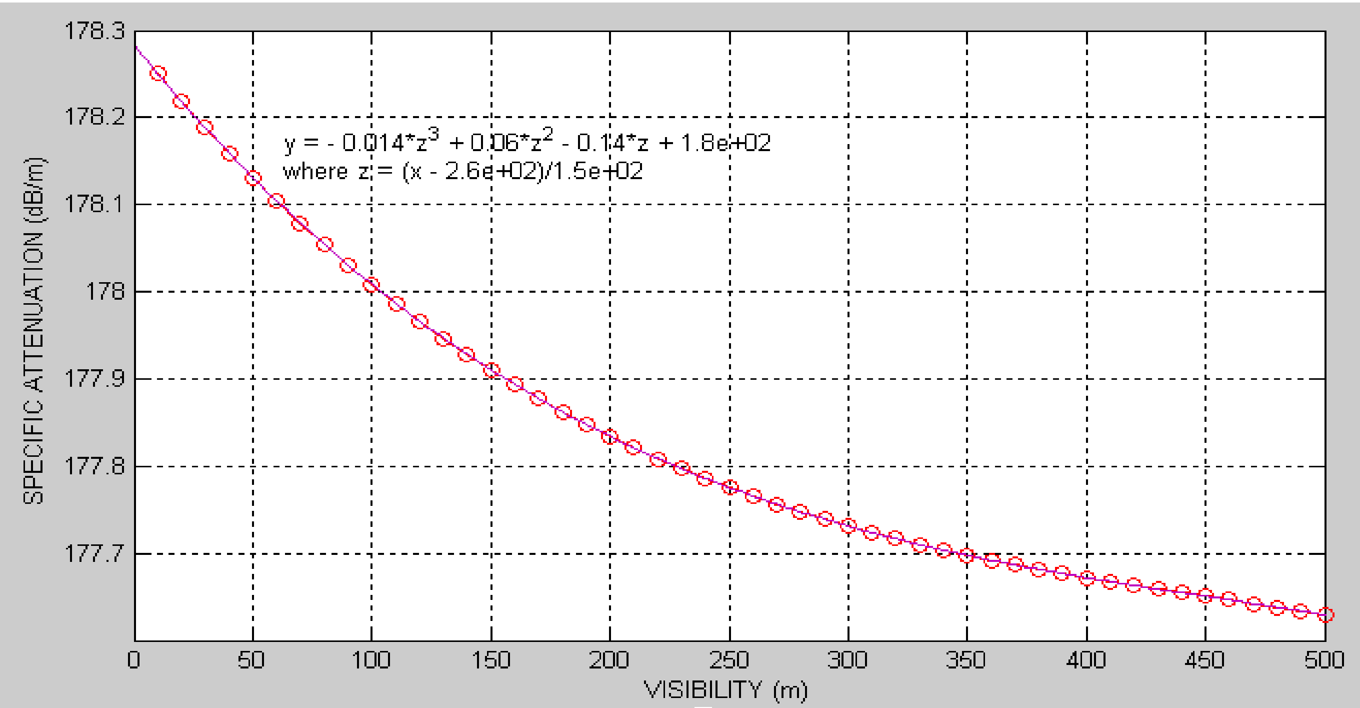

Fig.5 Results of the newly proposed model for specific attenuation against visibility at 900MHz.

It can be noted that the optical signal attenuation and visibility are inversely proportional. When the visibility is high, the attenuation is lower. This is so because when a fog develops, its drops size grows until equilibrium between droplet and its surrounding is achieved, leading to a significant change in the effective cross section of particle radius thereby causing reduction in visibility and increased attenuation.

The most critical impact of the fog is the attenuation of the optical beam by the Mie scattering and absorption. Both phenomena are due to interaction of the particles with the electromagnetic waves propagating through the channel. The interaction depends upon characteristic size of particles, refractive index and the wavelength of the optical beam. From 20 to 220m, the two windows suffers the same attenuation experimentally, but from 230 to

600m the visibility and the optical attenuation are inversely proportional and window 1550nm suffers less attenuation because of lower dispersion.

Comparison between measured and computed values shows a good agreement between theory and experiment for each optical window used. It was discovered that under low visual range conditions, when the visibility is less than 500m, the Kruse equation is inappropriate as it overestimates attenuation by as much as 31% [12]. At higher visibility, the Kruse equation provides acceptable results.

5. Conclusion

Our work shows that in dense Fog condition when the visibility is less than 500m around 230m, the attenuation of signal take the same value for both 850nm and 1550nm window. Therefore, the atmospheric attenuation is independent to the wavelength. But it decrease as the visibility increases when the visibility is above 220m. Hence, the result clears the air in the confusion and preconceived notions about true ability of free space laser communication that 1550nm is less affected by any weather conditions. Our result revealed that 850nm and 1550nm attenuated the same when visibility is less than 500m. Our result also shows that, no wavelength dependency was found for visibilities below a few hundred meters for the investigated wavelengths between 850nm and 1550nm window, indicating that Kim equation fits better to measurement data.

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