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# Temporal characterization of an urban horizontal atmospheric telecom channel

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**Abstract:** Free Space Optics (FSO) are breakable under some climatic conditions. However characterization of the propagation channel by studying wavelength transmittance and data coming from a wavefront experiment could improve FSO's performance. © 2019 The Author(s)

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## 1. Introduction

Many applications are opening to the FSO, therefore this technology is booming because it holds many advantages, like a faster deployment than fiber optics or a lack of spectrum regulation unlike radio frequencies [1]. However the atmospheric telecom channel suffers from weather (fog, haze, rain) and physical phenomena like turbulence and scattering effects (Rayleigh and Mie [2]), which damage the optical link and reduce the communication's performances [3].

## 2. Atmospheric transmittance depending on wavelength

Laser beam transmission through the atmosphere depends on several parameters such as weather, aerosols composition or wavelength. Environmental parameters cannot be controlled but the wavelength can be selected in order to optimize the photometric budget. Thank to a radiative transfer software (MATISSE [4]), three wavelengths of the infrared atmospheric window are compared (1.55  $\mu\text{m}$ , 3.96  $\mu\text{m}$  and 10.05  $\mu\text{m}$ ) with a focus on low visibility situations. Figure 1 shows the transmittance as function of visibility for a 10 km-long horizontal path. For low visibilities, transmittance at 3.96  $\mu\text{m}$  and 10.05  $\mu\text{m}$  is better than 1.55  $\mu\text{m}$ . For instance, transmittance through a 200 m-visibility atmosphere (thick fog) is null for 1.55  $\mu\text{m}$  but at 3.96  $\mu\text{m}$  and 10.05  $\mu\text{m}$  the transmission ratio are -17 dB and -15 dB, respectively. Although transmittance is better at 10.05  $\mu\text{m}$  than at 3.96  $\mu\text{m}$ , the availability, the cost and the user-friendliness of components are more interesting at 3.96  $\mu\text{m}$ .

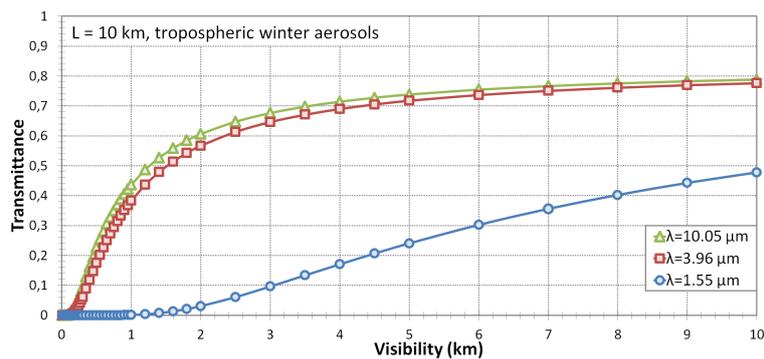


Fig. 1. Transmittance as a function of visibility for three wavelengths.

## 3. Description of the SCINDAR experiment and its available database

The SCINDAR (SCINtillation Detection And Ranging) experiment uses an infrared Shack-Hartmann analyser ( $\lambda = 3.4$  to  $4.2 \mu\text{m}$ ) which aims at two halogen lamps 1 m-apart and that are located at 4.2 km of the receiver. On average the horizontal line of sight is about 40 m above ground [5]. A  $5 \times 5$  array of sub-apertures, 20 of which are effectively operative, samples the wavefront. Thus  $2 \times 20 = 40$  sub-channels, collected by the 20 sub-apertures imaging the 2 sources, are characterized in form of temporal intensity series. Concretely the SCINDAR experiment gathers intensity, phase and  $C_n^2$  profiles series in a big data base for several weather conditions.

#### 4. Coherence time and fading duration

Two time slots that had been recorded during a past SCINDAR experiment are analysed here. The first one corresponds to a 4 hour recording done in the October 19, 2015, when the sky was overcast and the visibilities ranging between 6 km and 12 km. During this period the wind was low, 2.5 m/s in average, and perpendicular to the line of sight. The second period was recorded on the October 30, 2015, during 5 hours, there were sunny spells, better visibilities, from 16 km to 40 km and the wind speed was 3.1 m/s in average, and parallel to the sight line. Then the temporal intensity series are used for computing the intensity sub-channel's coherence time ( $\Delta t$ ), i.e. the full width at half maximum of the normalised autocorrelation of intensity. For each source, we compute the mean of  $\Delta t$  and its standard deviation for the 20 sub-apertures. For the first period, shown on figure 2, the computed  $\Delta t$  varies between 20 ms and 55 ms, and for the second period it varies between 30 ms to 65 ms. The values obtained reveal a coherence time for an horizontal propagation channel slower than in astronomy, a typical value of which is 5 ms and that is derived from an analytical formula using a "one layer" equivalent turbulence profile [6].

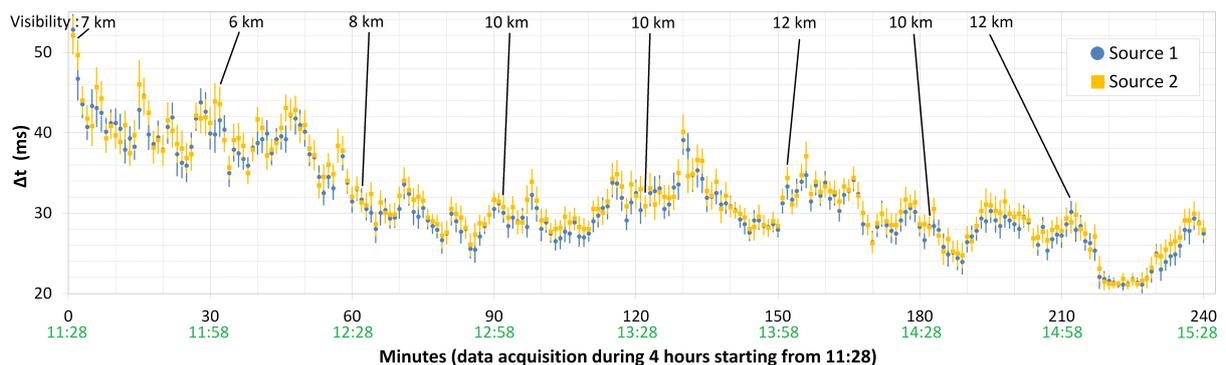


Fig. 2. Temporal evolution of coherence time ( $\Delta t$ ) for each source with its standard deviation.

With the same temporal series, a statistical study of fading duration is performed. By fixing the threshold at 5% of the maximum we compute the cumulative density function (CDF) of the fadings. We derive a mean fade time of 24 ms and of 38 ms respectively for the first and the second period. As expected, these values are ranging in the interval of the coherence time. Notice that [7] simulated median fading durations in an adaptive optics GEO scenario showing comparable values. So our data base could be useful to predict horizontal FSO performance, by using our experimental CDF of fadings, which is necessary to design a time interleaver coupled with error correcting codes.

#### 5. Conclusion and perspectives

This study shows the good transmittance of 3.96  $\mu\text{m}$  communication channel for a 10 km range even in the case of low visibility just below 1 km. The richness of our data base comes from its capability of considering various weather conditions such as rain or strong turbulence. It allows us to link the FSO performance to some temporal characteristics of the propagation channel (as coherence time and CDF of fadings). The next step requires to focus on a physical explanation of the difference of order of magnitude between the coherence time for horizontal and slant path despite comparable fading values. Some specificities of such urban horizontal propagation channel could be involved : we need first to revisit the analytical formula of the coherence time applied to near ground turbulence profiles ( $C_n^2$  and wind), second, envisage a possible interaction between dust and turbulence.

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