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LASER COMMUNICATION AND ATMOSPHERIC IMPAIRMENTS

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ABSTRACT

Varieties of signal-loss components in transmitting a laser signal beam from one point to another over microwave link are usually encountered due to absorption and dispersion by airborne molecules and aerosols and distortion of the wave-front due to atmospheric turbulence resulting from the variation of the refraction index along the direction of the beam. This paper provided information on calculating attenuations generated as a result of these aerosols and hydrometeors effect on laser beams. Effective linking equipment, open-loop power control and feedback loop power control are suggested as mitigation techniques that significantly reduce attenuations when laser signals are transmitted.

INTRODUCTION

Communication technology is continuously progressing to higher transmission frequencies, from a few hundred kilohertz to several hundred terahertz, due to the use of lasers in various complex fibre networks [1] [2]. The laser is an optical device that generates an intense beam of coherent monochromatic light by stimulating radiation emission, its unique characteristics such as coherence, monochromaticity, directionality, and high intensity have, over the years, made it possible for optical fibre communications to transmit information over long distances with low losses, to be used in underwater communication networks and also in space communication, radars, and satellites [3].

Hydrometeors' effects

Lasers were discovered in 1960 and were considered for space communications ever since [4]. However, effect of Hydrometeors in the atmosphere, such as rain, wind, and others on laser beams are closely observed when the cross-link is analysed. Loss of coherence, field attenuation, and loss of transmission are some of the losses caused by the boundaries of the atmosphere [5]. The atmospheric attenuation is wavelength dependent. The spread of the beam caused by atmospheric dispersion results in a weakening of the power the optical receiver receives. In bright days the mixing of warm and cold strata of the atmosphere produces turbulence that may interact with impinging light waves causing the impinging beam to be refocused and reoriented, as seen in Figure 1. This causes the beam to move off-foresight and create problems with the optical pointing [2]. Likewise, these hydrometeors also cause loss of beam front coherence, which means that there will no longer be two points on the beam front in the same process. This affects the optical detection systems for direct and heterodyne [1].

Aerosol, such as fog, mist, dust, possesses molecular scatter and absorption constants. The aerosol scatter, and absorption constant can be added to produce the basic attenuation constant, γ, for the wavelength of the beam that is propagated through the atmosphere. Its attenuation can be estimated using Beer's Law. [6,7].

$$T_R = \frac{I_x}{I_0} = exp(-\gamma)$$

Where T_R is the transmitter,

I_0, the initial beam intensity from the telescope

I_x, the beam intensity at a distance x from the telescope

γ is the specific attenuation expressed as $\alpha_M + \beta_M + \alpha_A + B_A$

α_M is the Molecular absorption constant

β_M, the molecular scattering constant

α_A, the aerosol absorption scattering and

B_A is the aerosol scattering constant

For the molecular absorption constant, when the impinging wavelength is greater than the size of the molecules and when those molecules are primarily composed of water and Carbon dioxide, the most prevalent absorbers, the total molecular absorption can be calculated by adding each of the molecular types and their allowed transitions. Second-order differential equation is used to derive the molecular scattering constant; Hugo Weichel [8] describes the induced dipole under the application of a harmonic field as:

$$\sigma = \frac{f' e^4 \lambda_0^4}{6\pi \varepsilon_0^2 m^2 c^4 \lambda^4}$$

Where f' is the strength of the oscillator which is the effective number of electrons per molecule oscillating at the angular frequency w_0 (natural), e (electron charge), λ (wavelength of the laser beam) and λ_0(wavelength from the natural frequency w_0

Mitigation process

Because hydrometeors and aerosols attenuate laser communications in the atmosphere, attenuations on laser beams can be significantly reduced through the use of effective linking equipment, though they cannot be eliminated completely. The initial approach that is used is to get around the weather problem is by trying to locate optical ground stations in very dry regions.

i. ***Open-loop power control:*** The receiving ground station receives an optical signal from the satellite, which is used to determine the level of downlink attenuation. The ground station's power controller then uses the frequency scaling ratios for cloud, gaseous, and tropospheric scintillation attenuation to estimate the required uplink fade.

ii. ***Feedback loop power control:*** A central station monitors the signal levels of all the received carriers and analyses the power adjustment needed for the affected carriers. This control information and command are subsequently routed to the transmitting ground station to affect the corrective measure(s). Though uplink power control is affordable and simple, it provides marginal benefit as it cannot continuously amplify its margin. Most amplifiers exhibit non-linear behaviour, and the output power will be limited despite an increase in power [9].

Conclusion

For both spatial and temporal variations with regard to dry and wet area, atmospheric impact on laser communication is what should be considered. This paper provided information on the calculation of attenuations and mitigation techniques in order to significantly reduce attenuations when laser signals are transmitted from a ground-based processing station or the weather observing satellites.

References

[1] M. Subramanian.“Atmospheric Limitations for Laser Communications,” EASCON Record, 1968; 125-133
[2] B. D. Van Veen and K. M Buckley, “Beamforming: A versatile approach to spatial filtering”. *IEEE ASSP Magazine1988.*
[3] D. Ruiz, R. Czichy, J. Bara, A. Cameron, A. Belmonte, P. Menendez-Valdes, F. Blanco, and C. Pedreira,“Inter-Mountain Laser Communication Tests,”*Free-Space Laser Comm. Techn. II*, SPIE, 1990; Vol. 1218, pp 419–430.
[4] R. L. Walter. “Space Laser Communications”: Systems, Technologies, and Applications. InstitutfürNachrichtentechnik und Hochfrequenztechnik, Technische Universität Wien, Gusshausstrasse 25/389, A-1040 Wien, Austria. Corpus ID: 11667085
[5] T. A. Milligan, “Modern antenna design”. *Wiley-IEEE Press*. 2005; ISBN 0-471-45776-0. pp. 424-429
[6] T. S.Chu and D. C.Hogg, “Effects of Precipitation on Propagation at 0.53, 3.5, and 10.6 micron, Bell System Technical Journal, May–June 1968; Vol. 47 pp 723–759.
[7] Shaharin AS, Ahmed KA, Ahmed I, Muhammad NF. Scattering Effects in Laser Attenuation System for Measurement of Droplet Number Density, The International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, 2014 TMREES14
[8] Weichel H. Laser Beam Propagation in the Atmosphere, 1990. Volume TT-3, Bellingham, WA: SPIE Optical Engineering Press.
[9] Lee Y, Koh WS, Lee YS. and Michello HX, Obstacle – Understanding Rain Dynamics and Feasible Countermeasures Against Rain Fading in Singapore 2013.