Optical Communications Applications and Regulatory Issues

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1 Executive Summary

Numerous free space optical communications applications are identified to take advantage of the large bandwidth, the efficiency linked to reduced divergence and the miniaturization of the components. After experiments which have proven the feasibility, the business is now emerging to solve radio-frequencies congestion issues. The capacity to transmit through atmosphere (with site diversity to cope with clouds) is opening the door to commercial business and therefore increased usage, in particular thanks to opportunities offered by non-regulation (except eye safety rules) and discretion. This situation shall and can be maintained as the optical systems are deemed insensitive to interferences thanks to very low divergence and field of view associated to very accurate pointing capability.

2 Recall of the Interest for Free Space Laser Communications

Attractiveness of free space laser communications has been identified since the early 80's as linked to high data rate capacity (linked to high frequency domain with large bandwidth) and efficiency (small size & mass/power thanks to low divergence and high antenna gain).
Moreover the laser domain is particularly suitable for use in space of terrestrial solutions developed for commercial applications and therefore at low cost (laser disc or pump sources, camera CCD/APS sensors, fibre components…)
These advantages are compensated by additional constraints linked to high accuracy pointing and transmission limitations, in particular through clouds.
The first applications were therefore focused on inter-satellite links for data relay (LEO-GEO), LEO constellations (were envisaged for Teledesic/Celestri initiative at the end of the 90's).

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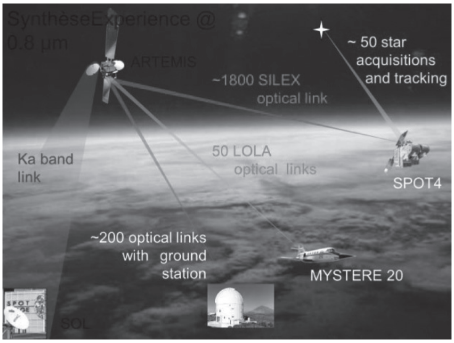
The first worldwide inter-satellite links between LEO and a GEO satellites were performed in 2001 with the ESA programme called SILEX, a 0.8μ system developed by a consortium led by Astrium (50 Mbits/s link between SPOT4 and ARTEMIS). Declared operational after the in orbit validation in October 2003, the optical relay on Artemis is still operational. It has also allowed to obtain 2 major achievements:

1. Interoperability with a Japanese terminal mounted on OICETS, developed independently based on the SILEX Air Interface specification.
2. Geo to ground links with Canarian Island Optical Ground Station

Figure 1 Overview on the Links Performed with SILEX GEO Terminal



More recent developments have also shown the capability to transmit through atmosphere with aircraft. The LOLA programme, sponsored by F MoD, has demonstrated in 2007 in real time at Le Bourget the first optical links at 50 Mbits/s between a GEO satellite and an aircraft at different altitudes and atmospheric conditions (including transmission through Cirrus), to prepare applications for UAVs in particular.

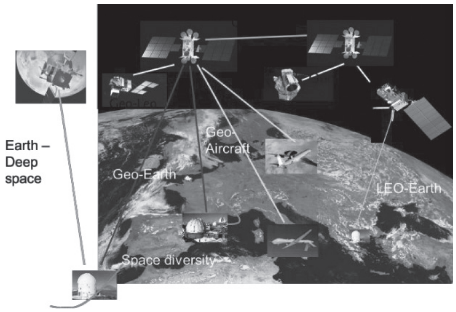
Alternative solutions with different wavelengths have been introduced to exceed 1 Gbits/s communications. The recent decision to develop the European Data Relay System for LEO Sentinel application (based on 1.06μ coherent detection) shows the move towards an operational service. Use of 1,55μ terrestrial components for multiplexing capability and eye safety characteristics is also studied to cope with very high data rate links through atmosphere.

3 Main Envisaged Applications

The main applications for lasercom (with a satellite in the loop) can be classified into 2 categories:

– inter-satellite (ISL) links (Constellations, LEO-GEO).. These systems are generally coupled to RF feeder & TM/TC links. A new concept (LaserLight), a MEO constellation, fully optical for both ISL & links to the ground, was announced at Euroconsult in Sept 2012.

Figure 2 Main Applications Involving One Satellite and Links Through Atmospher



Data rates requirements & acquisition constraints (duration, host stability…) are driving the choice of the technology.

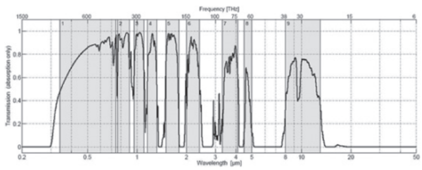
- links through atmosphere, either with aircraft or with the ground

The main applications involving links through atmosphere are summarized in the following figure:
As for the past programmes with RF technology, scientific and governmental applications will take advantage of optical technology evolution to propose efficient transmission (deep space probes) or discrete concepts.

However the main new market for free space optical communications is business oriented, commercial applications using optical solutions being more and more envisaged. The key drivers for this introduction in the commercial business (high data rate telemetry, feeder link and "fibre in the sky" applications) are:
- the congestion of the spectrum in RF band, as the required data rate are exponentially increasing, in particular for backhauling and internet applications. The Ka band shall be kept for users, requiring new bands for the links with the gateways. This opens the door to optical band which allows to limit the number of gateways to the minimum necessary for diversity (the number is not linked to the capacity of the system contrarily to RF gateways)
- The possibility to deploy solutions without filings constraints and associated costs (contrarily to RF)
- The maturity of the technology which allows today to switch to commercial services with limited risks

The impact of atmosphere in terms of transmission or scintillation is today well known and taken into account in the sizing or/and the choice of modulation/coding techniques. Some sub-bands shall be privileged as shown hereunder:

Figure 3 Transmission Performance Through Atmosphere for Various Wavelength



Therefore these applications involving atmosphere are indeed mainly driven by:
- the availability requirements (sizing the number of optical ground stations), Key aspect is the nebulosity and the identification of sites sufficiently uncorrelated to cope with the availability requirement.
- the eye safety constraint (the 1, 55µ technology has a factor > 20 advantage in terms of Maximum Permissible Exposure (MPE)).

Figure 4 Maximum Permissible Exposure for Various Wavelengths (Extract from CNES Presentation June 2012)

EMP depending on Wavelenghts					
	800	980	1060	1550	Unit nm
EMP for 10s exposure time	15,8	36,3	50	1000	W/m2
EMP for 0,1s exposure time	50,6	116	160	100000	W/m2

As an example, an optical feeder link in Europe can be envisaged for future "Terabits/s" satellite at 1,55µ (to take advantage of multiplexing capability and eye safety characteristics) with a 99,9% availability achieved thanks to diversity (through typ. 6 regional sites).

4 Lasercom & Regulatory Issues

Why Optical Band CAN Be "Unregulated"?

The regulatory constraints are generally dictated by the necessity to reduce interferences between systems. It is a protection.

In the case of optical communications, the divergence of the beam is in the range of 10 µrad and the "perturbator" shall be quasi-aligned with both involved terminals. On the ground the spot beam diameter is around 400 m after 40 000 km. In these circumstances, a multitude of systems can work simultaneously without mutual interferences. For fixed terminal, the jammer would be identified immediately (very close) and for mobile terminals, the alignment requirements would limit the potential impact to a few seconds. Moreover the robustness of the optical system with respect to various natural background (like sun reflection on the earth or the clouds) is in general much more demanding. In other words, this protection provided by the regulations is not necessary.

Why Optical Band SHALL Be Maintained "Unregulated"?

As shown here-above, operational services using free space communications are now emerging. This technology has inherent drawbacks to require an accurate pointing system and a diversity management. Introduction of such innovation shall be facilitated. The regulated conditions (except eye safety aspects which are linked to health) would complexify the process, would slow down the introduction through a filing step and would reduce drastically the interest for some applications – e g the discrete ones (see UAV links during flight over countries) - or the number of opportunities – e g decision to embark hosted payloads (no impact on the filing today if optical feeder for instance).