P2-17 Multiple laser transmitter for a ground to OICETS-satellite optical link

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Abstract

A multiple laser transmitter system is proposed to demonstrate a stable optical link with laser beam transmissions from ground to satellite. Gaussian beams propagation is analyzed under various atmospheric environments to provide required number of beams, transmitting optical powers, etc.

Background

The ground-to-satellite laser communication experiments were performed during December 1994 and July 1996 using the ETS-VI satellite to demonstrate basic technologies for space laser communication systems under severe atmospheric scintillation effects [1]. In a future ground system to be built up, mitigation of scintillation effects is strongly required for stable optical links from ground to satellite. Optical ground systems are being developed toward experiments using LEO satellites such as the OICETS satellite in 2002 and the ISS/JEM onboard optical system in 2004.

Analysis

Analysis is based on the theory developed well for a single beam transmission assuming some standard atmospheric turbulence conditions[2], [3]. The theory is applied to multiple laser transmission to derive some statistical quantities such as a probability density function for the received intensity at the satellite.

Suppose the optical link between the CRL ground station and the OICETS satellite flying at an altitude of 590 km, the received intensity variation at the satellite is limited within 10 dB in communication phase. Table 1 shows conditions for numerical calculations. Figure 1 depicts a calculation of the received intensity variation with parameter of number of beams as a function of an elevation angle. In this figure, 1% fade probability and 10 % surge probability are assumed so that the intensity variation range (V [dB]) means 89 % variation range around the mean.

To interface to the OICETS satellite, the variation range should be within 10 dB in communication phase. It is seen from the figure that the interface condition can be fully satisfied in all elevation angles of the satellite with multiple beam transmissions. The transmitter power per one beam is determined taking into account the power capacity and the controllability of lasers available. In this analysis the laser power of 30 mW per one beam is found to be sufficient for four beams transmission case.

Conclusion

Multiple laser transmitters are effective to construct an optical link from ground to a satellite, which can meet the requirements on limitation in the intensity variation at a satellite. Adaptive optics system shall be effective for mitigation of atmospheric turbulence effects and be implemented with a multiple laser uplink beacon system to a ground optical station.

After a demonstration experiments with the OICETS satellite, communication experiments using the ISS/JEM will be conducted for the future extra-high-speed optical link of more than 2.5 Gbps.

References

[1] M. Toyoshima and K. Araki, Applied Optics, Vol.37, No.10, pp. 1720-1730, April 1998.
[2] L. C. Andrews *et al.*, Applied Optics, Vol.34, No.33, pp. 7742-7751, Nov.1995.
[3] L. C. Andrews *et al.*, Applied Optics, Vol.36, No.24, p. 6068, Aug.1997.

Table 1. Conditions for calculation assuming an optical link between the OICETS satellite and a CRL ground station :

Satellite Altitude	Ground Station Altitude	Scintillation Intensity at Ground	Atmospheric Transmissivity
590 km	122 m	$C_n = 5\times10^{-7}\ (m^{-1/3})$	$\tau_a(\zeta) = \tau_a(0)^{\sec\zeta}$, ζ:zenith angle, $\tau_a(0) = 0.8$

	Initial Acquisition Phase	Fine Tracking Phase	Communication Phase
Sensor	CCD	QD	Si-APD
Wavelength	λ =800 nm	λ =820 nm	λ =820 nm
Minimum Intensity	2.25 nWm^{-2}	20 nWm^{-2}	11 nWm^{-2}
Maximum Intensity	7.4 nWm^{-2}	80 nWm^{-2}	110 nWm^{-2}
Permissible Fade Probability	1 %	1 %	1 %
Permissible Surge Probability	10 %	5 %	10 %
Variance reduction ratio	0.1	0.5	1

	Initial Acquisition Phase		Fine Tracking and Communication Phase
	for not Observable Satellite	for Observable Satellite	
Tracking Error (deg)	[0.05(EL-80) +0.2(EL-30)]/50	[0.005(EL-80) +0.02(EL-30)]/50	[0.005(EL-80) +0.02(EL-30)]/50
Beam Width (half angle) (deg) (fixed value)	0.2 - 0.4	0.01 - 0.1	0.01 - 0.1

EL : Elevation angle of a satellite in degrees

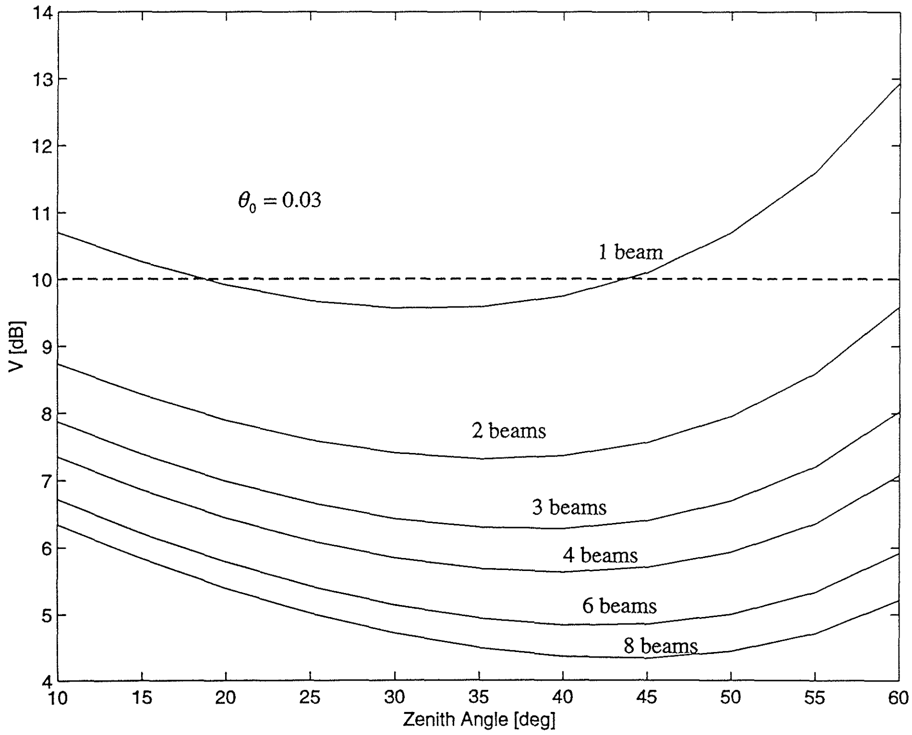

Figure 1. Received level variation at the OICETS satellite as a function of an elevation angle when assuming a fade probability of 1 % and a surge probability of 10 %. Transmitting beam divergence angle is 0.03 degrees (half angle).