A Satellite Tracking Demonstration on Ground Using a 100mm Aperture Optical Antenna for Space Laser Communication

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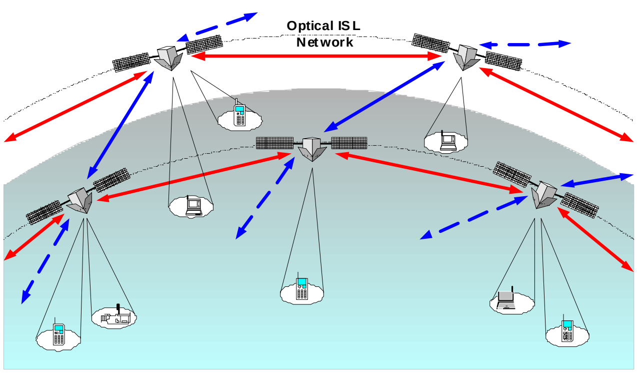
Abstract

The Next Generation LEO System (NeLS) optical terminal was designed for 1.5um wavelength and 2Gbps data rate communication between 500 km – 3000 km inter-satellite link. In the course of ground validation test, using Coarse Pointing Mechanism and Optical Antenna, we demonstrated open tracking capability by ranging to a satellite AJISAI.

Introduction

The Next Generation LEO System Research Center (NeLS) in National Institute of Information and Communications Technology (NICT), of Japan, formed in 1997 for the key technology development of space communication network in future [1,2]. Fig. 1 and Fig. 2 show a concept and development schedule for optical communication part, respectively. Since 2002, it has focusing on the development of optical inter-satellite link technology for the future communication demanding a high data transmission for global multimedia service, as well as requirement of earth observation/ science data communication to ground.

***Figure 1:** Concept of NeLS: Next Generation LEO System*



Optical terminal and key components

Fig. 3 shows block diagram of optical terminal. The optical terminal consists of four units, namely 1) Coarse Pointing Mechanism (CPM) located outside the spacecraft on mission panel, 2) Optical Antenna (OANT) as one of fixed part of optics located on mission panel 3) AT&P unit located outside the spacecraft, and 4) Communication Unit which interface both transmit & receive by optical fibers, located inside the spacecraft.

***Figure 2:** NeLS Optcal Engineering Model Development Schedule*

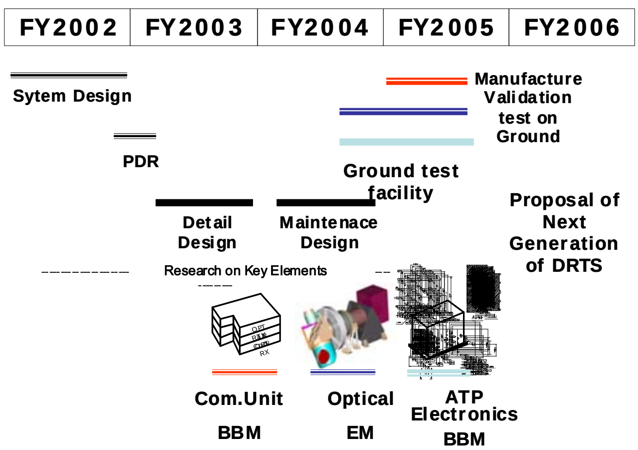


Figure 3: *NeLS Optical Terminal*

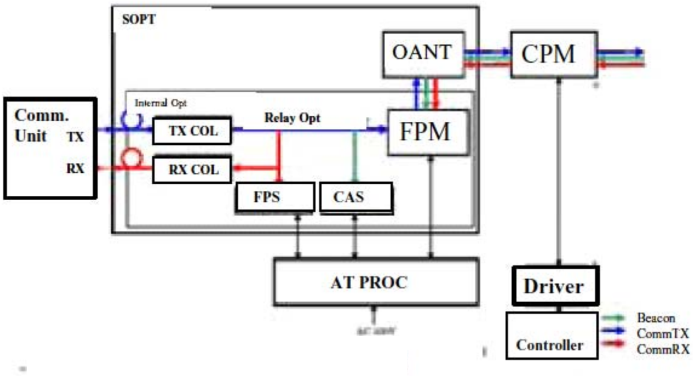


Figure 4: *A 10cm class Coarse Pointing Mechanizm (CPM)*

Item	Specification
Range of drive axis	Az:+/-275deg EL:+/-110deg
Maximum drive speed	3.0deg(slew) 1.0deg(track)
Effective aperture size	85mm
Resolution of encorders	2/10000deg
Weight	16kg

CPM utilizes two-flat mirror type 2-axis gimbals (shown in Fig.4 picture and specification) so-called elbow-type has been adopted to cover all direction in space, where optical antenna fixed to satellite body.

In addition to OANT, as a fixed part of optics, a wide range Fine Pointing Mechanism (FPM), a Coarse Acquisition Sensor (CAS), a Fine Pointing Sensor (FPS), a Transmitting Collimator (TX COL), and a Receiving Collimator (RX COL) are integrated onto an optical bench with relay optics. AT&P UNIT includes terminal control processor circuit and power supply.

The Optical Antenna shown in Fig.5 has type of Cassegrain, where secondary mirror is supported by tripod and main reflector diameter of 125mm diameter, made by material of SiC with gold coating. Total effective focal length is 2600mm and magnification is about 20.

Other key components of internal optics include a fine pointing mirror made by voice coil actuators and GAP sensors, and transmitting and receiving fiber couplers has been tested as space qualification devices(Fig.6).

Utilities for ground test

To perform functional test and validation of optical terminal, we have developed one of utilities an optical tracking simulators utilized in a room spacing several meters between optical terminal and target

Figure5: *Subsystem - OPTICAL ANTENNA*

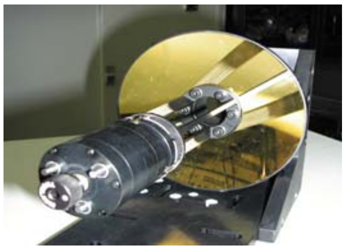
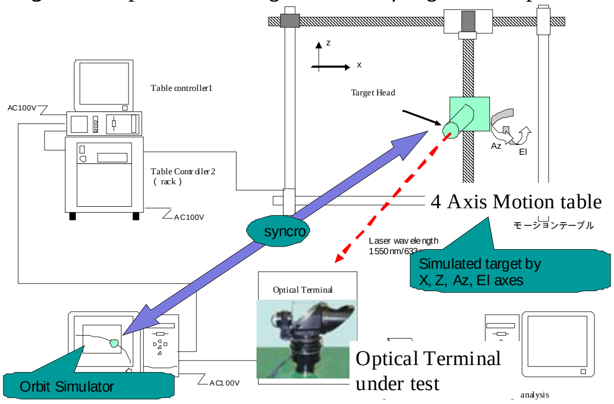


Figure 6: *Key components of internal optics*

Fine Pointing Mirror (FPM)

Transmitting Fiber Coupler (left)
Receiving Fiber Coupler& QD (right)

Figure 7: *Optical Tracking Simulator for ground experiment*



antenna. The target has on 4 axes (X-Z, Tip/Tilt) movement platform and has optical INPUT/OUTPUT capability. Fig.7 shows a schematic configuration of optical tracking simulator. The movement is programmed based on orbit simulation. Although the optical characteristics of terminal is different from that of far field, a basic function of acquisition and tracking during communication has been tested and 2.5Gbps communication BER data acquired and application of HDTV was demonstrated.

Another utility for optical terminal on ground outside, air-conditioned enclosed dome with a 30cm diameter optical window has been developed (Fig.8). The dome has axis of azimuth and rotor on azimuth structure made of stainless steel. The dome is on a box with 2 x 1 x 1 meters dimension, in which there is optical table set as vibration isolated manner, carrying optics and mechanics. Under table there are room and also carrying drivers of dome and electronics and power supply for optical terminal.

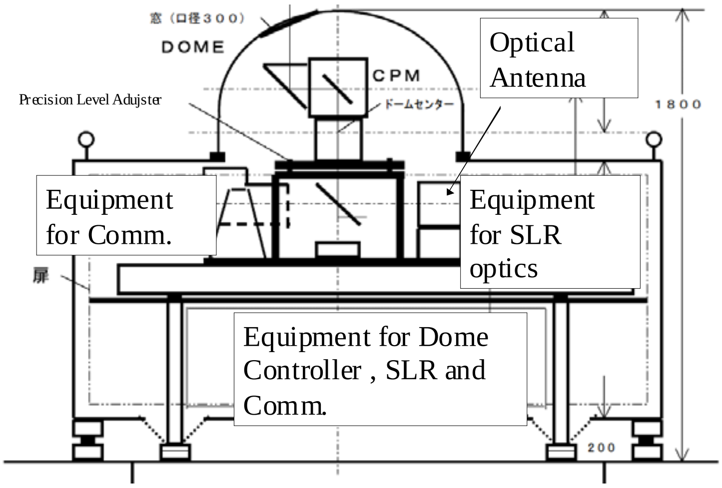
Fig.9 shows a schematic view of arrangement in a dome box called MML (Micro Mobile Laser) utility box. It also has optics for satellite laser ranging set that sharing beam through CPM by 45 degrees flat mirror.

Satellite Pointing capability test

Figure 8: *Utility development for Ground outside experiment*

The CPM was set up on optical bench so that mechanical & optical axis is aligned to gravity field (i.e. leveling) and other principal axis of equipments (laser and receivers). Two axis intersection angle offset orthogonality was measured as 80 ± 5 arcseconds. And star calibration of axis resulted in several arcseconds rms after rigorous alignment work done. Fig.10 shows a follow-on error when CPM tracking a Starlette satellite simulation pass which maximum elevation of 85 degrees. Two passes consecutively run shown. Since keyhole effect exists at zenith on Alt/Az axis gimbals, the performance of Az axis about maximum elevation was degraded to 10 arcseconds, however most of errors except key hole was within one arcsecond. Elevation axis has the same characteristics, but mean following error was larger (2 arcseconds rms) than that of Azimuth. Using standard SLR equipment with a nano second pulse width and 20mJ/pulse Nd:YAG lasers set up on table. We have performed laser ranging to a satellite AJISAI. Return proves the tracking system as open loop (means no use of beacon from satellite) working. Fig.11

Figure 9: *Configuration of Optical comm. and SLR equipments*

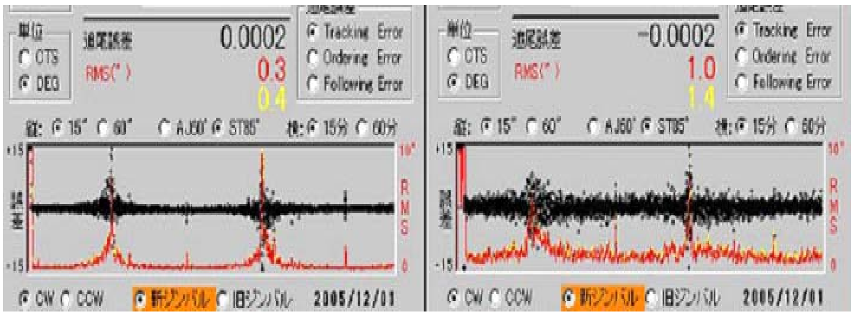


shows range residual vs observation time and there is a series of dots among dark noise and background noises that is from satellite returns. Fig.11 shows range residual vs observation time and there is a series of dots among dark noise and background noises that is from satellite returns.

We have had such four passes acquiring satellite returns during two weeks campaign. During campaign ranging to fix target to a 20meters to 4km distance was used as calibration of range as well as beam divergence and direction. The location of 4km distance is used as fixed distance communication experiment being done almost paralleled.

Figure 10: *LEO Tracking follow-on error evaluation of CPM by Starlette 85 deg elevation pass*

Black dot: Following Error Axis range+- 15arcsec
Red dot error RMS(2sec avarage) Axis range 0-10arcsec



AZ axis:
<1arcsec rms except around zenith about 10arcsec rms

EL axis:
< 2arcsec rms except around zenith about 6 arcsec rms

Summary

The Next Generation Inter-satellite Laser Communication Terminal Optical Part Engineering Model has been developed. By using newly developed utility for ground test validation, such as 4 axis motion table, mobile dome, optical terminal for 1.5um wavelength and 2.4Gbps data rate was evaluated in near-field (5m-5km) including ATP performance with atmospheric existence. Using Coarse Pointing Mechanism (CPM) and 10 cm class Optical antenna and, and associated 532nm pulse laser connection pass, we have demonstrated open-loop satellite tracking capability by ranging to AJISAI. Next Step is now using evaluation of those, we are proposing the next generation of DRTS (Data Relay Technology Satellite) in early 2010's

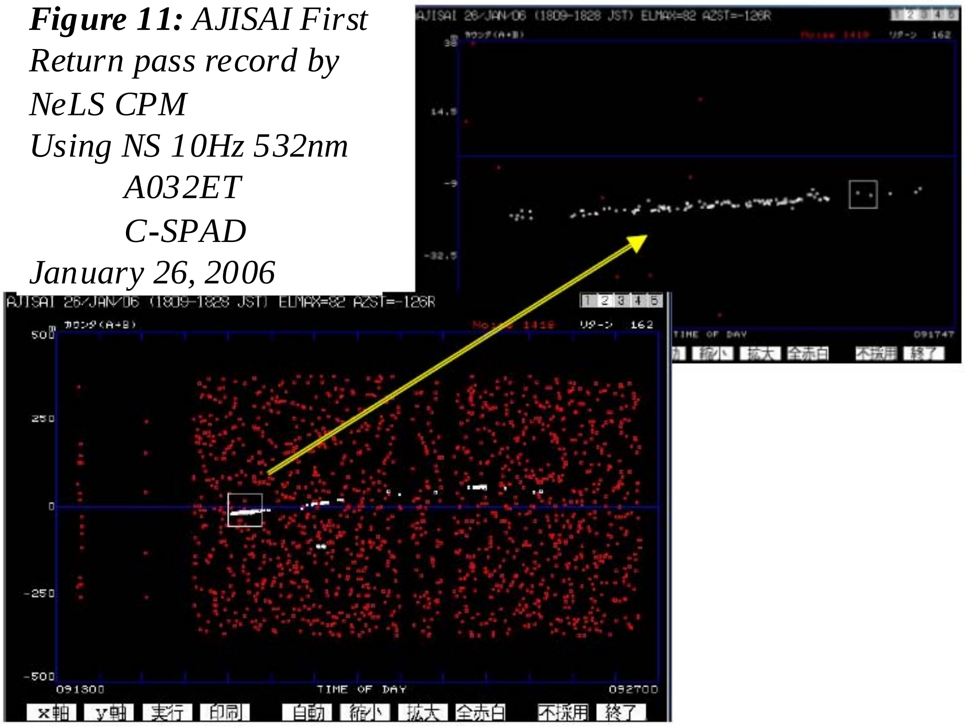


Figure 11: *AJISAI First Return pass record by NeLS CPM*
Using NS 10Hz 532nm
A032ET
C-SPAD
January 26, 2006

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References

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