A-3.1.2 Development of active satellite tracking techniques

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Abstract

Objectives of the project is to develop a new method of tracking satellite shined by the laser radiation, called as active satellite tracking. Results obtained are as follows;

1.Light reflected from the corner cube prisms of a Japanese geodetic satellite "Ajisai" was obtained by a gated CCD camera, which were installed on the optical tracking system with the CRL 1.5m diameter telescope.

2.The optical tracking system was improved to make more accurate satellite tracking by making modification of the software of the telescope model.

According to the results of the research , ADEOS with RIS can be tracked by the active satellite tracking techniques developed by this research.

Key words Satellite tracking, telescope,retroreflector, Laser long path absorption, laser transmission

1.Introduction

Laser long-path absorption method between the ground and a satellite is one of the most sensitive method for measuring the trace gas concentration in the laser path, since we can take the extreme long path. Accuracy of the atmospheric trace gas measurement by the laser long - path absorption method is determined by characteristics of the measurement system. For instance, stability of laser which is absorbed by the atmospheric gas and sensitivity of detector are important for the accurate measurement. When we try to use the long path between the ground and the satellite, tracking accuracy of the satellite also makes a big affect to the accuracy of the measurement of the atmospheric gas.

The satellite shined by the laser radiation from the ground station can be seen with a TV camera and is tracked according to the image of the TV camera in the active tracking method of the satellite. The satellite can be seen and tracked any time since it is shined artificially. The active tracking method is very useful for the laser long-path absorption method between the ground and the satellite to improve the accuracy of the measurement.

2.Research objectives and ways

Lasers are transmitted to the satellite from a tracking telescope at the ground and radiations reflected by retroreflectors of the satellite are received and detected through the same telescope again in long-path absorption method. The concentrations of the atmospheric gas are obtained by the differential absorption of the laser radiation in the optical path between the ground and the satellite. The tracking error becomes fluctuation of the received intensity, which affects the accuracy of the atmospheric gas measurement.

The tracking error is due to the tracking accuracies of the telescope itself and the accuracy of the prediction of the satellite orbit. When the tracking error is so big, it is so difficult to find the satellite and the atmospheric gas measurements cannot be done. The best way to find and track the satellite is to see it directly by using the telescope with wide field of view and the TV camera. The satellite can be seen at a condition of sunlit, which occurs when the satellite is shined by the sun and the site of the tracking telescope at the ground is already dark at a time of sunset or sunrise[1),2)]. We need to track satellite any time to measure the atmospheric gases . The condition of the sunlit does not occur in any time. Orbit of some satellites for observing the earth, which is used to measure the atmosphere, is adopted the sunsynchronous one. The orbit of ADEOS, which is a Japanese earth observing satellite and is planed to launched in 1996, is the sunsynchronous. The sunlit condition for the sunsynchronous satellite satisfies only in a few months in a year. The active tracking technique, in which the satellite is shined by the visible laser radiation transmitted the same tracking telescope at the ground and is seen by the TV camera and tracked by using the image, has been developed by using a 1.5m telescope of Communications Research Laboratory .

A big retro-reflector, called as Retro-reflector In Space (RIS), is installed on the ADEOS to measure various kinds of atmospheric trace gases related to the global atmospheric environment by means of the laser long-path absorption method. The objective of the research is to find the most plausible tracking way for experiments of RIS.

3.Results

3-1 1.5m telescope system of the Communications Research Laboratory

The 1.5m telescope will be used for the experiments of RIS installed ADEOS and is one of the instruments of the Space Optical Communication Ground Center, which is one of the facilities of the Communications Research Laboratory, Ministry of the Post and Telecommunications. Koganei, Tokyo. The telescope have been constructed for the research of the optical communication in space. However, it is multi-purpose telescope since it also can be used the satellite laser ranging, astronomy, lidar and so on[3)]. Fig1. shows a schematic figure of the telescope system. The telescope mount is a type of Azimuth and Elevation and is installed top of a concrete pier. The coude path of the main telescope is located at center of the pier. There are 4 optical tables with a coude optical port attached to the pier, which a big experimental system can be installed. All experimental instruments of RIS including the visible laser for the active tracing will be installed on the one of the optical tables.

A 20cm guide telescope is installed top of the main telescope tube and is used for initial acquisition of the satellite, since the guide telescope could have wide field of view.

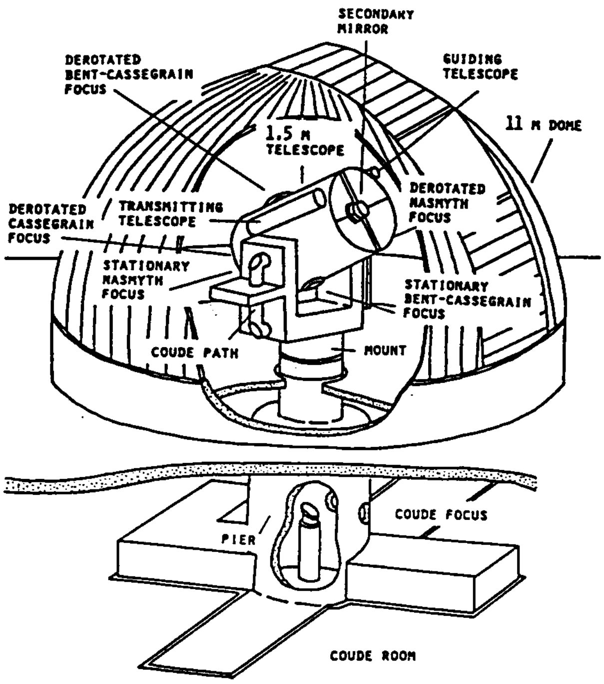

Fig.1 Schematic figure of the telescope system

3-2 Received signal intensity of the active tracking

We estimated the signal intensity received with the guide telescope of the CRL 1.5m telescope system. The received photon number N_r is obtained the following equation[4].

$$Nr = N_0 T^2 \frac{16 S}{\pi^2 \theta_t^2} T_r \left[\frac{\sigma r}{R^4 \theta^2}\right] \quad (1)$$

$$= 7.5 \times 10^{19} \left[\frac{\sigma r}{R^4 \theta^2}\right]$$

where N_0 : transmitting photon number (transmitting energy 100mJ/pulse)

T : atmospheric transmittance

S : receiving area

σ : scattering effective cross section of the retro-reflector

r : reflectivity of the retro-reflector

θ_t : beam divergence of the transmitting laser

θ : diffraction angle of the retro-reflector

R : distance between the telescope and the retro-reflector.

Parameters inside of parentheses in eq.1 are shown in table 1.

Table 1. Optical parameters of RIS, Lageos, Ajisai

	RIS	Lageos	Ajisai
r	0.8	1	1
θ m^2	0.21	0.01	0.05
R km	800	6000[5]	1500
$\sigma_s$rad		1.5×10^{-5}	2.6×10^{-5}
$\left[\frac{\sigma r}{R^4 \theta^2}\right]$	10^{-16} [6]	3×10^{-20}	10^{-17}

The received signal is detected by using a CCD camera with a high speed gate. N_r has to be larger than the noise due to the sky background. Photon number of the sky background N_b within the gate period τ is

$$N_b = \frac{S}{h\nu} \frac{\pi \theta_r^2}{4} \Delta\lambda \; S_b(\lambda) \; \tau \quad (2)$$

and $S_b(\lambda)$ is the sky radiance which is estimated from the reference 6). We take an image constructed from the radiation reflected from the retroreflector. (S/N) 1px is defined as a ratio between signal intensity of only 1 pixel of the image and noise of 1 pixel outside of the image. We assume that the image is made in 4 pixels of 256x256 CCD camera.

$$(S/N)\,1px = \frac{N_r / 4}{(Nb / 256 / 256)^{1/2}} \quad (3)$$

and

$\tau = 3.2 \times 10^{-4} / (S/N)1px^2$ for Ajisai,

$\tau = 1.8 \times 10^{-9} / (S/N)1px^2$ for Lageos.

3-3 Experiment transmitting laser to geodetic satellite.

Laser transmitting experiment was performed by using radiation of SHG of a Nd:YAG laser and 1.5m telescope of CRL. The radiation was transmitted to the Japanese geodetic satellite "Ajisai" from the main telescope. Characteristics of the experiments are shown in table 2.

Table 2. Characteristics of the laser transmitting experiment

Laser

SHG of mode-locked Nd:YAG laser	
wavelength	532nm
repetition	10Hz
output	100mJ/pulse
pulse width	100psec

Detector

II-CCD camera with the high speed gate	
pixels	756x756
sensitivity	35mA/W(550nm)
gate speed	3nsec
quantum efficiency	17%

Telescope system

1.5m telescope Coude path
and
Satellite Laser Ranging Optical system (for both of the transmitter and the receiver)

switching of the transmitter and receiver	a rotating metal mirror
transmitting laser beam divergence	>32arc sec (150μrad)
receiving field of view	32arc sec (150μrad)

The experiment was performed march 4,1994. Fig.2 shows a block diagram of the experiment. The TV video signal was monitored with TV monitor and was recorded to a video tape. The image of the satellite was obtained from the video tape and is shown in fig.3. A bright spot located in the left side of fig.3 is the image obtained from laser reflection of the Ajisai and many tiny spots in fig.3 are due to the dark current of the CCD camera.

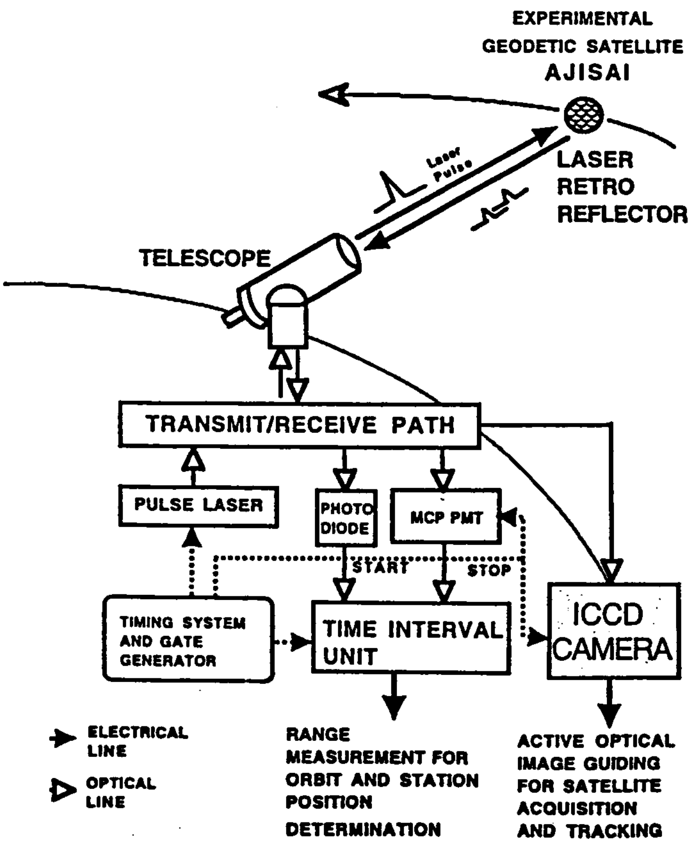

Fig.2 Blockdiagram of the laser transmitting experiment.

Fig.3 A image obtained from laser reflection of the Ajisai.

3-4 Improvement of the CRL telescope system for more precise satellite tracking.

According to the experiment of 3-3, we improved the CRL telescope system for more precise satellite tracking. The items and results of the improvements are as follows.

1.items for improvement of the tracking system

1) automatic star-calibration with cooled CCD camera at each focuses by using an new equipment to detect the center of the star image.
2)addition of function to correct encoder amplitude error.
3)addition of correction term for sag error of the mount model.
4)improvement of the satellite tracking software.
   a.addition of input forms and prediction for NORAD-2line, SAO and IRV format.
   b.addition of function for searching for satellite manually.

2.results of the improvement,

1) accuracy of pointing and tracking.
   a.accuracy of absolute pointing 1.37arc sec(rms) (before 7.2arc sec(rms))
   b.accuracy of tracking 0.58arc sec(rms) (before 1.8arc sec(rms))
   c.accuracy of encoder error correction
      azimuth 0.12arc sec(half amplitude) (before 0.88arc sec(half amplitude)
      elevation 0.43arc sec(half amplitude) (before 1.48arc sec(half amplitude)
2)satellite tracking accuracy

Both geodetic satellites of Ajisai and Lageos were tracked within an 200μ rad (40arc sec) by using orbital predictions produced by all three orbital forms of the NORAD-2line. SAO and IRV format. These orbital data were provided by NASA, NASDA and Texas university.

4. Conclusion

The followings were perform in this research.

1.Light reflected from the corner cube prisms of the Japanese geodetic satellite "Ajisai" was detected easily by a gated CCD camera, which were installed on the optical tracking system with the CRL 1.5m diameter telescope.

2.The optical tracking system was improved to make more accurate tracking by making modification of the software of the telescope model.

According to the results of the research , ADEOS with RIS can be tracked by the active satellite tracking techniques developed by this research.

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