P2-28 Estimation of Brightness of ISS for High Resolution Imaging

Y. Takayama and K. Araki
Communications Research Laboratory, Ministry of Posts and Telecommunications
4-2-1 Nukui-Kitamachi, Koganei, Tokyo 184-8795, JAPAN
Phone: +81 42 327 5450, FAX: +81 42 327 6699, E-mail: takayama@crl.go.jp

1 Introduction

Assembly of the International Space Station (ISS) shown in Fig.1 began with the launches of Zarya in November and Unity in December 1998. The ISS will measure 108m wide and 75m long in the end of the assembly. It orbits 400km above the Earth in 90 minuets a revolution. It is the first time that such a large artificial satellite moves around the Earth at a low altitude like that.

In the development of astronomical observations, it has been aimed to obtain the clear images of further and almost stationary objects. Systems focusing on the near and fast moving targets have seemed to be undeveloped sufficiently, so far. However, missions on the ISS assembly have attracted much attention, and its low orbit altitude and large body size raise the expectation of taking the images with high resolution. Visible information is always important because it assures us the existence of the object directly. Accordingly, we are making a plan for the observation experiment of the ISS. Before actual construction of the experimental setup, the brightness of the ISS and possible spatial resolution of the optical setup need to be calculated. So we estimate them based on several suppositions and present the results in this work.

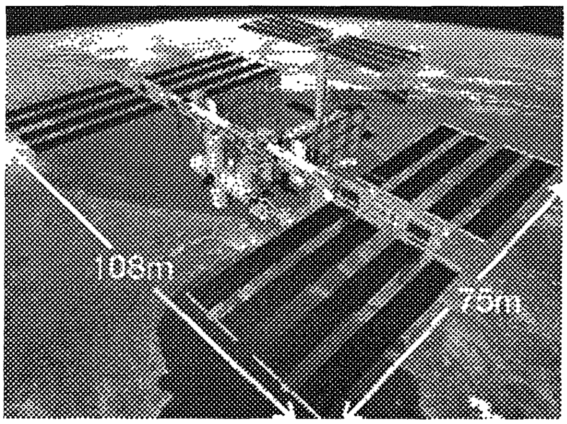

Fig. 1 Illustration of the ISS (Courtesy of NASDA)

2 Estimation

Though the actual ISS will be complicated shape, we use a spatially periodical model shown in Fig. 2 for simplicity. In Fig. 2, an object on the (x_0, y_0) plane is illuminated incoherently and has the periodical intensity distribution of a cosine curve with the spatial frequency N_0 along x_0-axis. The intensity along y_0-axis is constant. If the point-spread function of the optical setup is shift invariant and ideal, the intensity distribution on (x_1, y_1) plane is described with the transfer function $H(N_1)$ as

$$i(x_1) = \bar{a}_0 + \bar{b}_0 |H(N_1)| \cos(2\pi N_1 x_1) \qquad (1)$$

where $N_1 = N_0/M$ and M is the transverse magnification of the optical system. When the optical system has a circular aperture, we have

$$H(N_1) = \frac{2}{\pi}\left[\cos^{-1}\left(\frac{|N_1|}{N_c}\right) - \frac{|N_1|}{N_c}\sqrt{1-\left(\frac{|N_1|}{N_c}\right)^2}\right] \qquad (2)$$

where $N_1 \leq N_c$ should be maintained and N_c is the cut-off spatial frequency.

To observe the periodical distribution of Eq. (1) with a CCD, each of the peak values of the cosine curve has to be detected on the separate pixels. Consequently, several pixels must be included within one period of the distribution as shown in Fig. 3 where k pixels are aligned in one period. In this case, if the observed wavelength is in the visible range, the cut-off spatial frequency is so large that the detectable spatial frequency is restricted by the pixel size.

Now we derive an equation of the radiant flux with consideration of Fig. 4. The area S_o on the surface of the object is illuminated by the sunlight of irradiance E_s with incident angle θ_s. The light is reflected by S_o with reflectivity R. Component of the reflected light of angle θ_d direction propagates distance r and arrives at the area S_a with angle θ_o, where the atmospheric transmittance is T. When the object surface obeys the Lambert's law, the radiant flux arriving at the area S_a is given as

$$P_a = \frac{E_s \cos\theta_s \cos\theta_a \cos\theta_o}{\pi r^2} RTS_o S_a \qquad (3)$$

For instance, we assume that a lens of focal length 50mm is connected to an afocal system of transverse magnification of 300 in which CRL's 1.5m-telescope whose clear aperture is 1.5m and focal length is 27m is placed. The number of pixels within one period of Eq. (2) is 4, and the distance z_0 in Fig. 2 is 500km. If a CCD of 10×10mm with a pixel of $10\times10\mu$m is placed at the focal plane of the optical system, the viewfield of one pixel is 2×10^{-4}rad, that is, one pixel corresponds to an area of 0.1m^2 on (x_0, y_0) plane. Consequently, in Eq. (3), we regard S_a as the cross section of the aperture of 1.5m-telescope and $S_o = 0.1\text{m}^2$. For simplicity, we give $\theta_s=\theta_a=\theta_o=\pi/4$, $r=z_0$, R=0.1 and T=0.4. Most of CCDs detect the wavelength of about 0.3-1μm, so we give E_s 500W/m^2 as total irradiance of the wavelength range.

Under these assumptions, the radiant flux received by one pixel is estimated as 1.8×10^{-12}W. It produces 2.5×10^{6} electrons a second when the quantum efficiency is 0.5. The detectable frequency N_1 is less than 2.5×10^{4}Hz that corresponds to $N_0 \leq 0.75$Hz on (x_0, y_0) plane. Nowadays, such a CCD of 10×10mm with a pixel of $10\times10\mu$m, full well capacity of over 50000 electrons and shutter speed of over 0.01s is available. Therefore, we consider that the estimated radiant flux is enough to be detected, and spatial frequency of under 0.75Hz can be observed when the neighboring peak values of the intensity distribution are sufficiently different to be divided.

3 Conclusion

We have estimated the radiant flux from the ISS, and we have arrived at a conclusion that the observation of the ISS is possible with spatial resolution of ~ 0.75Hz. However, above calculation neglects aberrations of the optical system and seeing effect of atmosphere. Especially, seeing effect affects the resolution, the depletion of this effect is the future study.

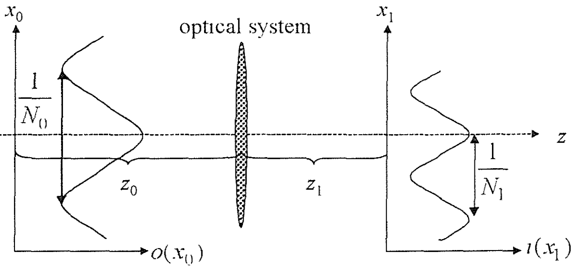

Fig. 2 Diagram of optical setup

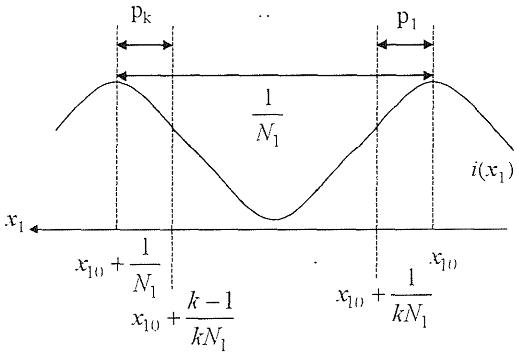

Fig 3 Alignment of CCD pixels

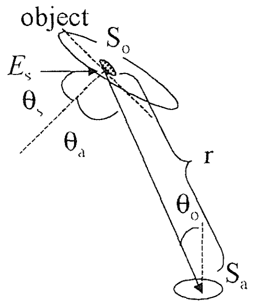

Fig. 4 Diagram for estimation of radiant flux

Reference

Nakajima, A., Kimura, T., Isobe, T., Yamamoto, H., Tsuji, T. (1999). LEO satellite observation by optical telescope. In *15th Space station conference*, Tsukuba space center, Ibaraki, Japan.