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International VLBI Tracking of SELENE

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Abstract

The Japanese lunar explorer SELENE will be launched in 2007. Two sub-satellites, Relay satellite and VLBI satellite, will transmit S and X band carrier signals for precisely measuring the lunar gravity field. It is expected that Wettzell, Shanghai, Urumqi, Hobart and the VERA stations take part in intensive international VLBI observations. The observation period will be 8 hours, 3 days a week in two separate months.

1. Outline of Geodetic Observations in SELENE

The Japanese lunar explorer SELENE will be launched in summer of 2007. SELENE consists of 3 satellites: a main satellite and two sub-satellites, the latter being a VLBI satellite and a relay satellite. They will be entered into different polar orbits of 2,400 km, 800 km and 100 km of apolune, respectively. However, all three satellites have the same perilune of 100 km. Differential VLBI observations will be conducted between the two sub-satellites in order to determine the low degree coefficients of the lunar gravity field. Fig. 1 shows the concept of SELENE.

The Moon is the nearest celestial body from the Earth. However the Moon's origin and evolution remain vague, but are closely related to those of the Earth. We have been trying to extend geodetic measurements to the Moon in order to understand them better, in a similar fashion to studies on the Earth. One of the main problems remaining about the origin and evolution is the existence of a core. The momentum of inertia gives constraints about the size and density of the core, and it can be derived from the dynamical flatness and low degree coefficients of the spherical harmonics of the lunar gravity field. The Moon has been measured by some geodetic methods such as LLR and VLBI observations to radio sources placed on the Moon. The flatness has been precisely determined from LLR. However, the low degree coefficients are not known well enough to determine the momentum of inertia with high accuracy. For this reason, we aim at the precise determination of the low degree coefficients in SELENE project. The key technology to accomplish this purpose is VLBI. We decided to propose an international VLBI observation campaign with an IVS network, with Wettzell playing an important part.

Fig.2 shows the outline of the observations for the geodetic mission of SELENE. Three kinds of observations will be carried out. The first one is a 2-way Doppler measurement. It will be carried out when the satellites make their closest approach. The second is 4-way Doppler: a stable frequency signal is sent to the main orbiter via Rstar and sent back the same way, when the main orbiter is farthest away. This measurement fills the gap in the gravity field at the far-side left by the 2-way Doppler measurements. The last one is a VLBI observation. VLBI observations are essential for the determination of the lunar gravity field around the rim area and for the orbit determination of the relay satellite. The lunar gravity field has been measured by Doppler frequency so far. It is not sensitive to the motion perpendicular to the line of sight, but VLBI is sensitive to this direction. Hence, VLBI observations combined with Doppler frequency observations can greatly improve the lunar gravity field. VLBI observations are frequently carried out when the orbit is in face-on.

Fig.3 shows the estimation error (Matsumoto et al. 2002) of the spherical harmonics as a function of the degree of the expansion, compared with the results of the Lunar Prospector obtained by Doppler frequency measurements. VLBI observations decrease the error to one-tenth for the lower degrees. In addition to this improvement in low degree coefficients, the relay satellite enables us to directly measure the gravity field in the far-side through the variation of orbital motion of the main satellite. It also decreases the error in higher degrees, by one or two orders of magnitude.

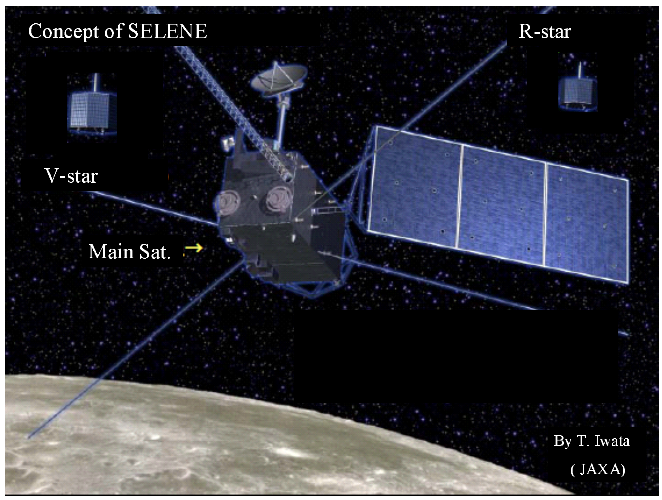

Figure 1. Concept of SELENE.

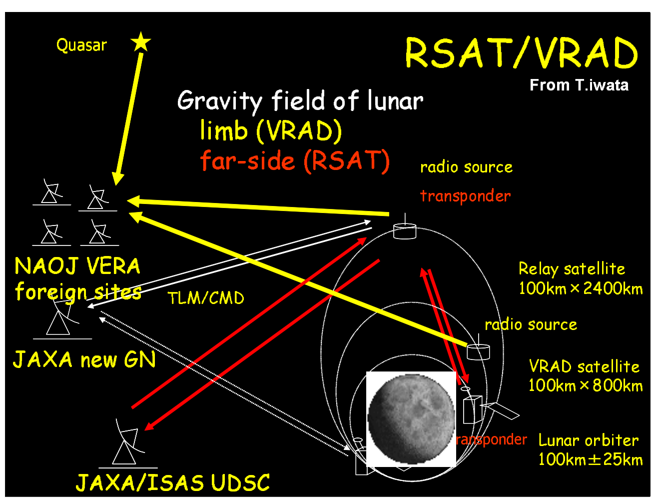

Figure 2. Geodetic observation of SELENE.

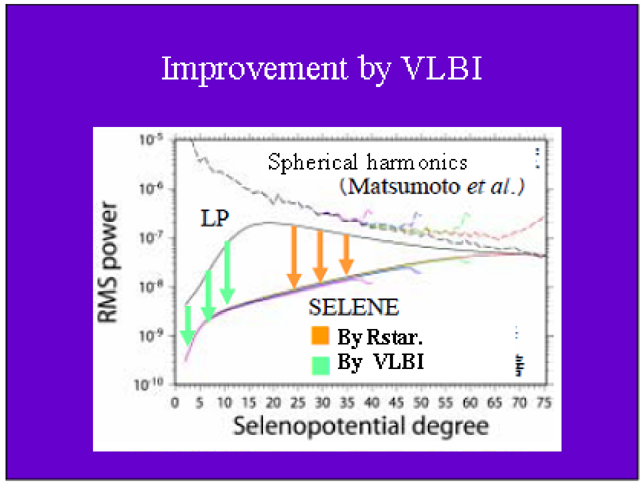

Figure 3. Error estimation of the spherical harmonics for the lunar gravity field.

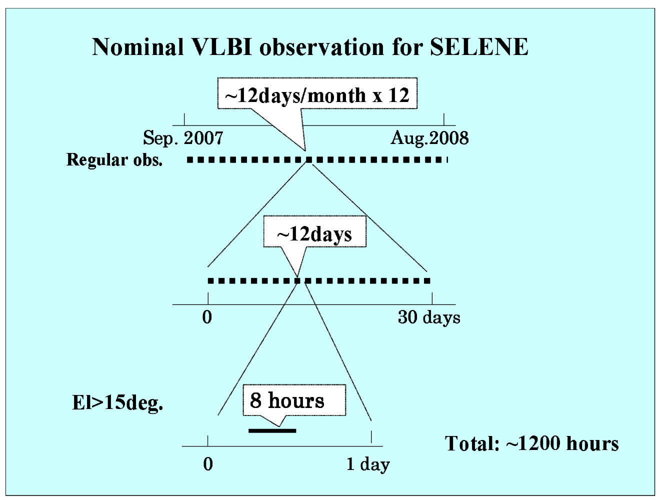

Figure 4. Nominal VLBI observations by VERA.

2. VLBI Observations

VLBI observations are classified in two categories. One consists of regular observations with the VERA network, which is the Japanese domestic VLBI network with about 2000 km baseline lengths. Regular observations will be done 3 days per week over a one year observation window. An observation day requires about 8 hours of observing, when the elevation angle exceeds 15 degrees at all stations. The total observation period amounts to 1,200 hours.

The other important observations are intensive VLBI observations. We propose that three stations (Shanghai and Urumqi, both China and Hobart, Australia) join these observations. Unfortunately, this network has a shape of a long triangle in the North-South direction as shown in Fig. 5. If Wettzell is added, this network broadens both in North-East and East-West direction, creating an optimal configuration. Therefore we submitted a proposal to the IVS Observing Program Committee.

The International VLBI observation campaign will be run twice for a period of 1 month each during the 1 year nominal observation window of SELENE. The campaigns are divided into two parts: a core observation during face-on and an extended observation. The core observation will be held twice a month while the orbit is in face-on, and the face-on continues for four days. Each daily observation session is carried out for four hours which is the duration of the common view. In the extended observation, 4 hours will be shared regularly for a daily observation. The total amount of core observations reaches 64 hours and that of extended observations are about 100 hours.

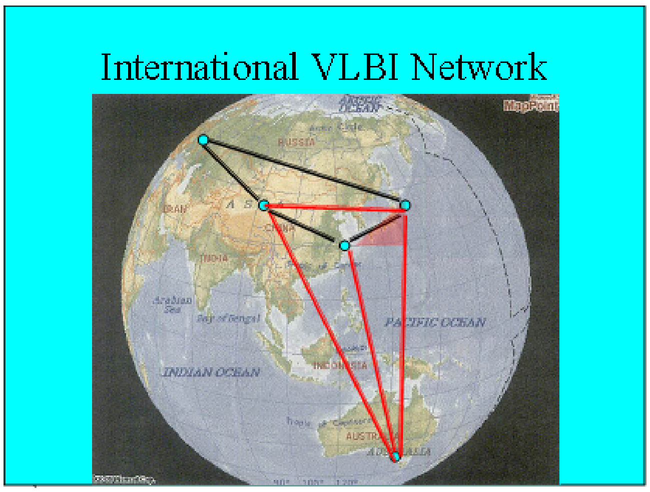

Figure 5. Expected International VLBI network.

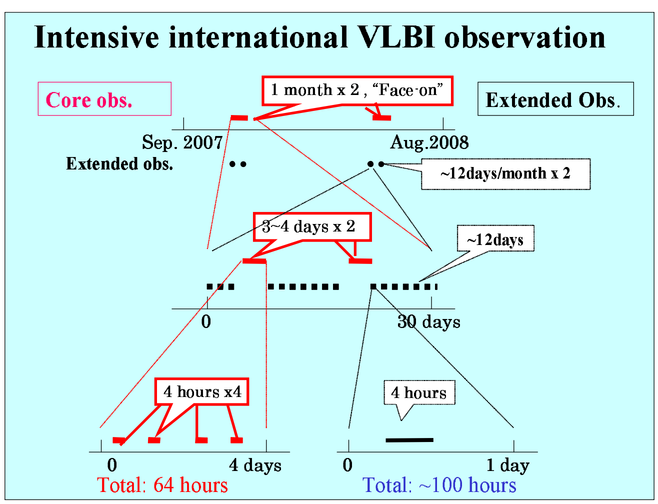

Figure 6. International VLBI Observation.

3. Transmitted Signal and Orbits

Finally the characteristics of the transmitter onboard SELENE are shown in Table 1 and Table 2. Three frequencies are distributed from 2.2 GHz to 2.3 GHz, and one frequency is on X-band. The received signals are sampled with a very narrow VLBI terminal named SRTP. Polarization is RHCP for all signals. Three satellites are brought into different orbits, although the inclination and perilunes are all 90° and 100 km respectively, and they fly in the same orbital plane.

Table 1. Characteristics of the transmitters onboard SELENE.

Center frequency	2212 MHz	2218MHz	2287 MHz	8456 MHz
Band width	CW	CW	CW	CW
Sampling rate	200 ksps	200 ksps	200 ksps	200 ksps
Recording	Hard disc drive			
EIRP	24 mW	24 mW	24 mW	250 mW (Rstar) 38 mW (Vstar)
Polarization	RHCP	RHCP	RHCP	RHCP

Table 2. Orbit characteristics of three spacecraft.

	Perilune	Apolune	Inclination	Period
Main orbiter	100 km	100 km	90°	-120 min.
Vstar	100 km	800 km	90°	-153 min.
Rstar	100 km	2400 km	90°	-240 min.

References

[1] Matsumoto, K., K. Heki, and H. Hanada, Global Lunar Gravity Field Recovery from SELENE, IVS2002 General Meeting Proceedings, 381–385,2002.