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Spacecraft Tracking with the Chinese VLBI Network

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Abstract

VLBI system with highest resolution is used by astronomers to study the most distant objects in detail. e-VLBI has got rapid progress in the past several years. With these characteristics, the VLBI systems are more and more used for spacecraft orbiting application. We briefly introduce the system configuration of the Chinese VLBI network and the orbiting experiment done with the Chinese VLBI network.

1. Introduction

Spacecraft tracking technologies used range and range rate as a basic method for target orbiting. There are some advantages to do spacecraft orbiting with range and range rate system. For example, only one station could complete spacecraft orbiting task. But only using range and range rate systems makes it difficult to determine spacecraft position in deep space. Angle information should be used to make high precision position determination of spacecraft.

VLBI system with highest angle resolution technique (less than 1 mas) is used by astronomers in the radio wave domain; e-VLBI rapidly progressed in recent years; more computing power is available in a single IC chip. With these technique characteristics, the VLBI systems are more and more used for spacecraft orbiting applications. Some events are shown in following:

1. 1980s: VLA as a supersensitive deep space “downlink” station
2. 1980s: NASA DSN stations (Goldstone, Robledo, Tidbinbilla) begin their VLBI duties
3. 1990s: phase-referencing “satellite-3C279” demo (Asaki, Sasao et al.)
4. Activities of spacecraft tracking with VLBI in Japan [1]
5. 2005: Radio Astronomy segment of the Huygens mission [2]

In China, we started spacecraft tracking with the Chinese VLBI network in 2001. Different orbiting spacecraft have been observed with Chinese VLBI network, e.g., GEO, TC-1, TC-2, SMART-1 and the deep space probe. Now we prepare to do the orbit determination of CE-1.

2. Spacecraft Tracking with the Chinese VLBI Network

The spacecraft signal is different from the signal of a radio source. Table 1 shows the differences of the spacecraft and radio source signals.

Some modifications of the VLBI station and VLBI correlator are necessary to adapt for the signal characteristics of a spacecraft. The antenna servo system and the dynamic range of the correlator should be improved for spacecraft tracking and signal correlation. The software correlator and hardware correlator have been used for data correlation. Our hardware correlator is specially designed for spacecraft tracking. There are 16 bits word length processor in hardware correlator to process the spacecraft range and range rate signal, which has more than 40dB dynamic range.

Table 1. Signal characteristic of spacecraft and radio source

	Bandwidth	Signal to noise rate	Spectrum	Signal dynamic range	Range rate
Spacecraft	Narrow	strong	special	large	large
Radio source	Wide	weak	continual	small	small

The automatically fringe finder function is specifically designed for spacecraft signal processing. Normally, the predicted orbit is not accurate enough for the correlator. The real time correlation function is also specially designed for spacecraft tracking. At the station, the Mark 5 system records the data and sends them to the correlation center via network. The data rate is limited to smaller than 10Mbps. The real time interface of the correlator reads the data stream from the Internet and writes to FIFO to smooth the data stream. There is 1 GB DDR RAM in the FIFO. For 10Mbps data rate stream, this FIFO can buffer more than 13 minutes.

2.1. Test Observation and Results

Since 2001 we have done several spacecraft tracking observations using the Chinese VLBI network. The target orbit of these observations were different: they were GEO, ellipse orbit, lunar probe and the deep space probe.

Smart-1 orbiting observation with Chinese VLBI network has been done in last March. Smart-1 is an ESA lunar project. It was launched in 2003. Some information about the observations are shown in the following:

Observing time (UT):	March 20, 2005; 10h30m–16h50m.
Orbit of Smart-1:	polar orbit, 2833 km apolune, 498 km perilune, 4.95-hr period.
Stations:	Seshan (25 m), Nanshan (25 m), Kunming (3 m).
Frequency of carrier wave:	2235.10 MHz.
Observation frequency:	2230.99–2238.99 MHz.
Bandwidth:	8.0 MHz.
Radio sources:	3C84, 4C39.25, 3C279.
Recording system:	Mark 5A, 16 Mbps.
Data processing:	Shanghai VLBI data processing center.
Integration time:	4 s.

Fig. 1 shows the structure of SMART-1 range and range rate signal in wide band mode and narrow band mode.

Fig. 2 shows the comparison results of delay and delay rate between VLBI observation and ESA Smart-1 reconstruction orbit. The best standard error of delay in SH-UR baseline is less than 1ns.

3. Future Plan

The Chinese lunar probe, CE-1, will be launched in 2007. The Chinese VLBI Network will do some tracking observations for orbiting of CE-1. Chinese VLBI network will be extended to 4 stations and will include a data processing center.

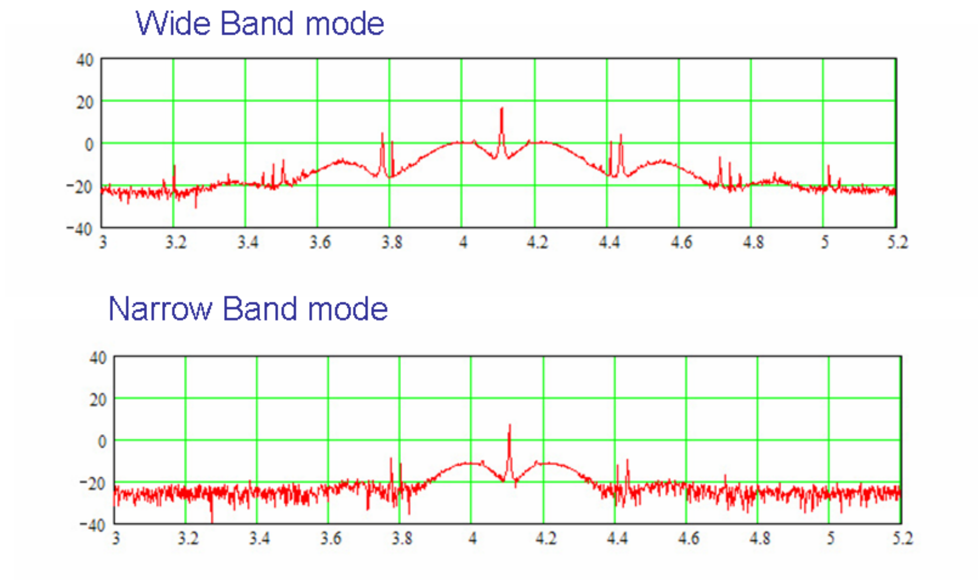

Figure 1. Smart-1 S-Band (2.2GHz) downlink signal.

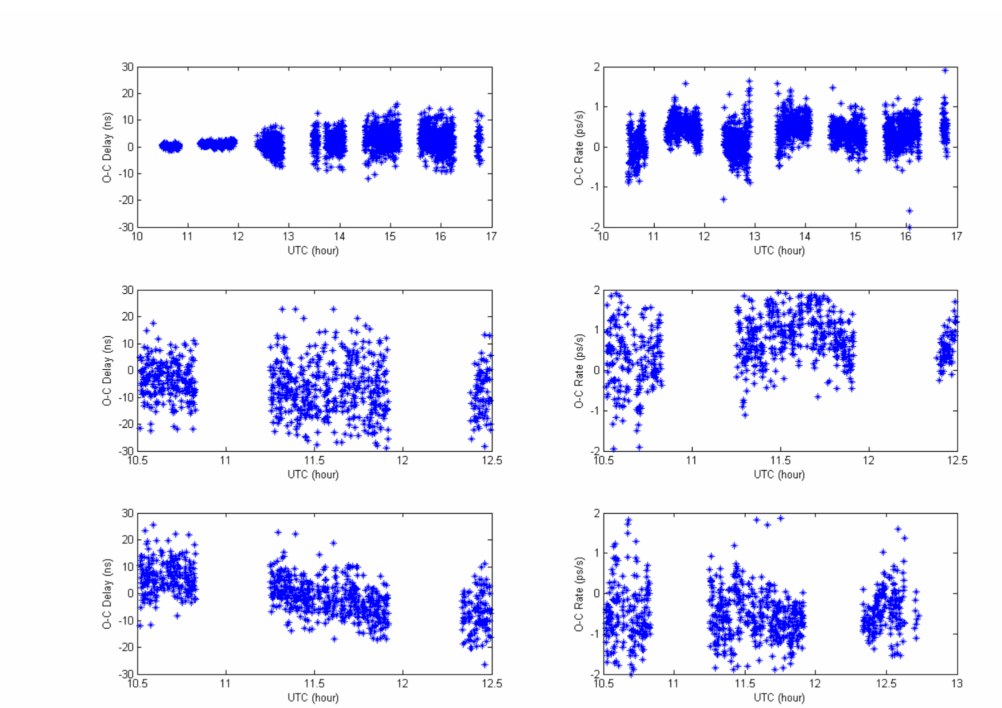

Figure 2. Comparison of VLBI observation and ESA Smart-1 reconstruction orbit delays and delay rates.

References

[1] N.Kawano, H.Hanada and K.Matsumoto , “International VLBI tracking of SELENE”, this volume.

[2] J. Lebreton, O.Witasse, “An overview of the descent and landing of the Huygens probe on Titan”, Nature, Vol. 438/8 December 2005, P.758-764.