Space VLBI Co-Observing Developments in the DSN

Valery I. Altunin, Thomas B. Kuiper, John G. Leflang, George M. Resch
Jet Propulsion Laboratory, California institute of Technology
4800 Oak Grove Dr., Pasadena,
CA, 91109, USA
tel: (818)-354-3358, fax: (818)-393-3299, e-mail: via@dsnra.jpl.nasa.gov

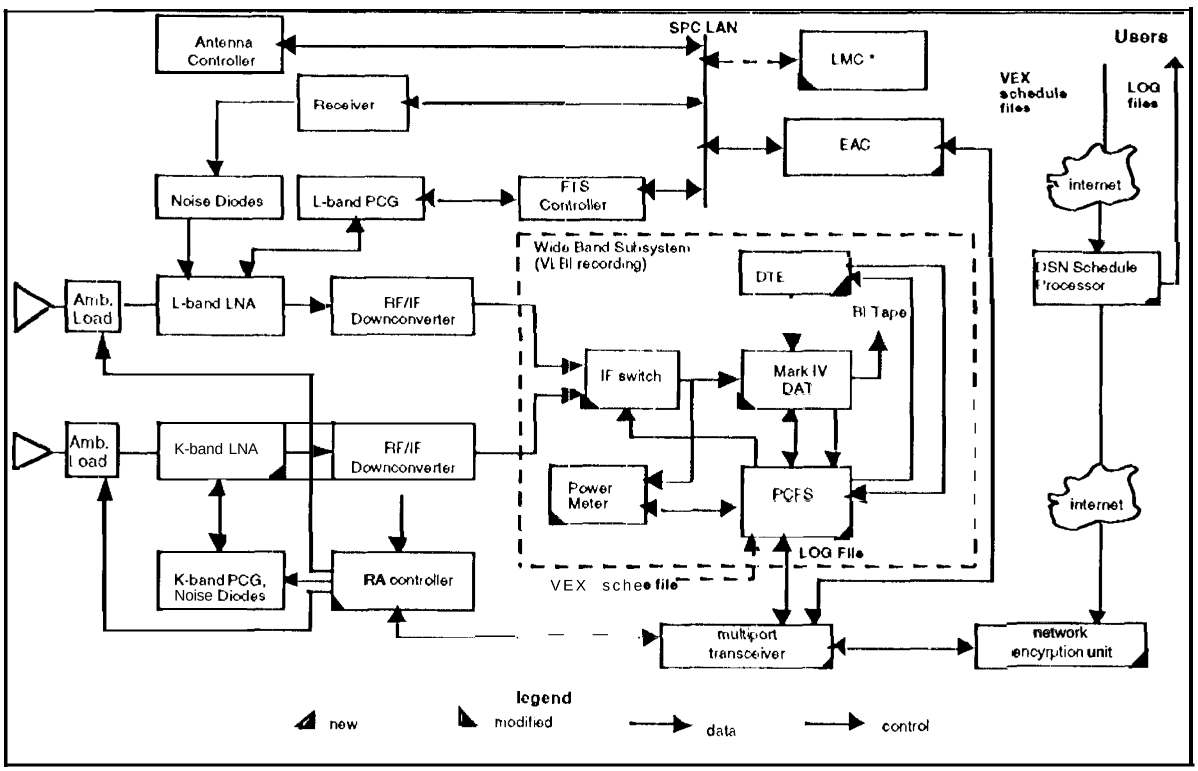
1. Introduction. DSN Space VLBI Co-Observing Upgrade Task

The JPL/NASA Deep Space Network (DSN) plans to participate in the upcoming Space VLBI missions by using its 70m antennas to co-observe with space-based radio telescopes. Almost twenty percent of the DSN's 70m antenna time is committed to providing co-observing support to the VSOP and Radioastron Space VLBI missions for the period January 1997102000. To enhance this support, the DSN is upgrading its radio astronomy equipment at L-and K-band (1 .65 and 22.2 GHz), its VLBI recorders and its computers and software for co-observing operations.

The Space VLBI co-observing upgrade task makes the DSN's VLBI recording compatible with the Space VLBI modes, improves the DSN 70m telescopes receiving characteristics in radio astronomy bands used for SVLBI, improves reliability of the VLBI radio astronomy operations at the DSN, reduces the operations cost and makes the DSN's VLBI radio astronomy operations more "user friendly," This upgrade also will benefit VLBI radio astronomy observations at the DSN which are not connected with Space VLBI.

2. DSN VLBI Radio Astronomy Improvements

The newly-developed radio astronomy equipment configuration to be implemented in the DSN under the Space VLBI co-observing upgrade plan are shown at Figure 1.



The status of the upgrade and parameters of the DSN co-observing system are described below.

2.1 L- and K-band Receiving Capability Upgrades

The DSN 70m antennas are equipped currently with L- and K-band receivers which will be used to support observations at two of the three VSOP wavebands. The DSN does not plan to provide co-observing support at C band (the third VSOP waveband) due to the large cost of implementation of such receiving capability.

The upgraded L-band receivers will have cooled HEMT LNAs to provide a system noise temperature 34K (vs. 45K currently), a wider receiving band, 1600 - 1730 MHz (vs. 1620-1700 currently), in order to accommodate requirements for the VSOP mission. Initially, only single polarization measurements will be possible but, two simultaneous polarization, LCP and RCP, observations will be implemented in order to accommodate the requirements for the RadioAstron mission.

The upgraded K-band receivers have cooled HEMT LNAS with a receiver noise temperature of 20K, and a frequency range of 18 to 26 GHz. The HEMT LNAs replace maser LNAs with little or no penalty in receiver noise temperature but improved cryogenic reliability. Like at L band, simultaneous reception in two polarizations, LCP and RCP, is possible. Additionally, a Dicke-type beam switch is available which provides the capability for K-band radiometric measurement with reduced sensitivity to atmospheric fluctuations.

Both L- and K-band receivers have ambient loads and noise generators controlled by the Radio Astronomy Controller (RAC) to provide automated measurements of the system temperature.

2.2 VLBI recording upgrade

The DSN is upgrading its existing MK III VLBI recording system to a MK IV system that will provide compatible recording with the VSOP and RadioAstron missions, and continued to support a number of activities including the Space Geodesy program, VLBI Radio Astronomy experiments, the JPL's Radio Refrence Frame program, and VLBI for spacecraft navigation and celestial mechanics experiments.

Part of the upgrade to the MK IV system includes the control computer running the PC Field System (PCFS) which can be controlled locally as well as remotely and automatically. the configuration also includes power meters to monitor the wideband if input levels, and dual recorders.

2.3 Interfaces, Control and Monitor of a DSN Radio Telescope

The Deep Space Network has evolved to support the operations of deep space missions. The security required to support these operations with high reliability creates significant differences in the operating environment for the DSN radio telescopes compared to regular radio telescopes. While the PCFS computer provides a high level of compatability with other VLBI installations, it cannot function as a prime DSN station computer. Instead we use two new machines to interface the PCFS computer to other DSN subsystems (see Figure 1.)

Two specialized computers, the Equipment Activity Controller (EAC) and the Radio Astronomy Controller (RAC), will perform interfaces between the PCFS and various DSN equipment. In effect, the EAC and RAC make the rest of the DSN appear like a radio astronomy observatory to the PCFS while providing a high degree of security to the DSN.

The EAC will be a prime interface for the so-called "operational equipment," mainly the antenna It will be used to perform antenna pointing according to a sequence of events provided by a PCFS, and an antenna configuration and calibration performance check. The RAC will be a prime interface to the L- and K-bands radio astronomy receivers which will be used for Space VLBI co-observing. Its functions are to control the receiver LO frequency, noise generator, and tone generator.

It was obvious at the beginning of our upgrade that the existing scheduling process for the VLBI radio astronomy experiments in the DSN could not handle the load anticipated for Space VLBI co-observing. In Order to streamline the scheduling process, make it more reliable, less labor-intensive, and "user friendly", the, DSN is developing an automated VLBI scheduling processor. After a VLBI experimenter has received his antenna time allocation from the Network Operations Engineer (NOPE), this processor will perform as the contact point with the DSN telescopes. The VLBI Schedule Processor will provide a bridge between the Internet and the secure networks internal to the. DSN. Users will be able to get information from this processor but will not be able to put information onto it. The processor will respond to an email message from the experimenter by picking up a schedule file from a machine designated in the message, alert the submitter and the NOPE that the file was received. It will then preprocess the schedule (VEX format), check its validity (including correctness of the scheduled DSN time, format etc.), and respond to the submitter in case the schedule files have problems, It will send the appropriate information (DSN predicts files) to the station operations personnel and to the PCFS for execution during the scheduled time. After the experiment, the machine running the schedule processor will hold the log file for pickup by the experimenter or someone at whatever correlator is to bc used, It should bc noted that this method of schedule processing is a significant departure from current DSN practice. in effect, the experimenter is totally responsible for the content of schedule.

2.4 DSNVLBI Radio Astronomy Operations

Since the configuration of a DSN telescope is often changed to support different projects, it creates the possibility for telescope configuration errors. To make VLBI observations at the 70m DSN telescopes more reliable, especially at K-band, a set of so-called "precalibration" procedures will bc performed before every Observing session. These fully automated sets of procedures will bc pre-pended to the schedule file and will include i) initialization of the antenna and the microwave electronics, and ii) a precalibration procedure that will verify system performance from the microwave through the recorder.

Instead of providing radio astronomy training for a regular DSN operator (which would significantly increase the SVLBI co-observing implementation cost), the DSN Radio Astronomy Office proposed and is implementing remote monitoring and control of the SVLBI co-observing and radio astronomy y operations [1]. According to this concept, the station controllers involved in the SVLBI co-observing operations, PCFS,]:AC, RAC, will provide the monitoring information in a form of X-hosted display s to the designated computers at the DSN sites and at JPL. DSN Friends of the Telescopes in Australia, Madrid and JPL/Goldstone will have access to this information and occasionally, or on-call, will check the status of observations. Another important function of such remote access is to provide the possibility of real-time control of a telescope by VLBI radio astronomy experts in **a case** of telescope **failure or** in order to perform a telescope calibration.

3. DSN VLBI Radio Astronomy System Performance

The aperture efficiency of the DSN 70m antennas at 1, band is about 0.68 and at K band -0.46 (under best weather condition and at elevation angles close to 45 deg). The antenna efficiency at K band decreases to about 0.25 at an elevation angle below 10 deg, and above 80 deg. The system temperature at elevation angles about 45 deg at K-band is about 40K. The L-band system temperature after upgrade will be about 35K at elevation angles about 45 deg. An observing program is currently underway to provide L- and K-bands antenna gain curves and antenna system temperature measurements with an accuracy of a few percent and to improve the antenna pointing models.

The 70m antenna pointing performance at K band is a very critical factor to performing reliable well-calibrated observations. Currently, the accuracy of the. antenna pointing models at DSN antennas is between 3 and S millideg (1 1-18 angular sec). With the antenna beamwidth at this wavelength of about 12 millideg, the estimated error in the signal amplitude may be a few tens of percent. The goal of the DSN is to improve the accuracy of antenna pointing models to 1.2 millideg.

4. Conclusions. Status and Timeline for Implementation

The improvements of receiving capabilities described above will enhance L- and K-band radio astronomy research at the DSN 70m telescopes by providing the capability to observe all four OH maser lines, to measure the Zeeman effect, polarization, etc . Newly-developed MKIV recording capability makes the DSN VLBI compatible with most of the VLBI radio astronomy and geodetic observatories, which will lead to significant scientific return from the VLBI use of the DSN telescopes.

In the first phase of these upgrades - the Goldstone complex will be completed by the cad of 1996, Canberra will be completed in the spring 1997, and Madrid will be ready to co-observe in midsummer 1997. The current status of the DSN VLBI capabilities and 70m antenna performance can bc found at the WWW DSN Radio Astronomy Home page, http://dsnra.jpl.nasa.gov/.

5. References

1. Altunin, V.I., Kuiper, "T'. H. and P.R. Wolken, DSN Co-Observing Operations to Support Space VLBI Missions, in Space Ops. Symposium -94, Maryland, USA/Nov.1994, p.

Acknowledgment

The current VLBI radio astronomy DSN capabilities upgrade is performed under contract with NASA by a team of JPL/DSN engineers and specialists whose high dedication to success made these new developments possible in such a short time. The development described in this paper is carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.