Current activities in the EVN

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Abstract

This report describes the current (February 2000) technical developments in the (astronomical) European VLBI Network (EVN). The EVN has switched over to observing in MkIV and VLBA modes mostly and is currently in the process of upgrading VLBA type terminals to the MkIV standard. The new observing formats, replacing the MkIII modes, have proven to work reliably. Other new developments have been the advent of UHF and 5cm receivers and progress on frequency agility of the telescopes. It is noteworthy that more and more observing programs use phase referencing techniques. The situation with correlators for the EVN is tight. Using the MkIV/VLBA modes initially has been made possible through the VLBA correlator. The EVN MkIV correlator at JIVE is now also operational, albeit for a limited number of observing modes and with limited throughput.

1. Introduction to the EVN

The EVN is a consortium of radio-astronomy institutes operating 16 telescopes (14 sites) in 10 countries, not limited to Europe but also extending to China. The main characteristic of the network is that, although quite inhomogeneous, it is very sensitive, as it contains a number of very large antennas. The sensitivity makes it attractive for a large range of scientific projects. However, the diversity of antenna characteristics poses a challenge when it comes to operations and observing strategies. For instance the receiver capabilities and (polarization) characteristics vary considerably across the network.

The EVN has three deadlines for observing proposals per year and about 40 experiments are scheduled in 3 or 4 observing sessions. This number excludes observations within the VSOP (space VLBI) context. A large fraction of the target sources are of the type familiar to geodetic VLBI: continuum observations of AGN. But also a considerable number of stellar objects can be observed in the same continuum mode. Quite a lot of these experiments employ either parallel or full polarization to obtain additional information on the physical conditions.

2. New capabilities of the EVN

In order to extend these observations to sources that are so weak they cannot be detected in the coherence time, a considerable fraction is done nowadays using phase referencing. This leads to specific requirements for the experiment schedules. For instance, short scans are necessary and therefore fast slewing is beneficial. This is however difficult to establish in the EVN where the dishes are quite large and mostly not built for VLBI applications in the first place. Continuous tape motion, in which tapes are not stopped during source changes, has been implemented to overcome sync up times at the correlator. The technique of phase referencing has become much more accessible now that it can be performed with the residual phases. This has been made possible because the correlators now use very accurate geodetic models. In the EVN there are a number of telescopes for which the positions are still not accurately known, because a few never participate in geodetic campaigns. Further enhancements in the data acquisition terminals to accurately flag the data during slewing would improve the system. Likewise, improvements in the gain calibration are pursued.

Another area of increasing interest are spectral line studies. One category concerns masers, for example interstellar OH and H_2O masers. These observations require narrow bandwidth, 500 or 125 kHz, which in practice is accomplished by oversampling in the MkIV system. Another type of spectral line observations target HI (or OH) absorption in extragalactic sources. These usually require slightly wider (2 – 4 MHz) bandwidths than the Galactic masers. These systems are often cosmologically red-shifted. For galaxies that have their HI shifted outside the traditional L-band, some EVN antennas are equipped with UHF receivers. Another unique frequency band for the EVN is the 5cm system, which enables observations of methanol masers. In these non-standard bands, as well as in the protected astronomy bands, RFI is becoming a severe problem. In some astronomical experiments there is a need for switching receivers during the observation. Several EVN antennas have introduced frequency agility for a selection of receivers. This also makes the switch-over between observing sessions faster and more reliable.

As mentioned earlier, these observations are now predominantly done using MkIV (VLBA) compatible modes, including 2 bit sampling and fan-out recordings. The operational situation for correlating the observations is complicated by the fact that in 1999 and 2000 three correlators are being used for processing EVN projects. Traditionally the Bonn correlator at the MPI Bonn has been used for MkIII experiments. The JIVE correlator (see below) has started operations, focusing on simple MkIV observations. The VLBA correlator in Socorro is also processing a considerable fraction of the EVN data. Besides the “global” experiments, also the more complicated observing modes, such as oversampled spectral line experiments, have been sent to Socorro.

The new MkIV observing modes seem to function reliably; very few problems associated with operating the new formatters have been encountered. The observations are scheduled with Sched, which also schedules NRAO’s VLBA telescopes directly. Currently the recording bit-rates are still limited to 256 Mb/s. The main reason why higher data rate modes have not been tested yet is that only half of the EVN stations have been upgraded to MkIV. Stations which originally had VLBA type equipment are expected to be upgraded to MkIV sometime in 2000. For these systems the VLBA formatter will be replaced with a MkIV formatter and the recorders will be equipped for 320 ips tape speeds and 2 head recording.

Because some telescopes participate in different programs and provide recordings to a number of correlators, stations are forced to switch between thick and thin tapes. This does not seem to be a healthy situation, even for recorders equipped with triple-cap heads. It is certainly a source of recording problems, which affect the reliability of the EVN. Another origin of reliability problems could be the fact that many telescopes in the EVN do not have a permanent setup for VLBI; outside the session they are involved in other, single dish, astronomical programs. The many receiver changes could be another occasion of problems. Clearly, the sites with multiple recorders or dishes are the most complicated in this respect. An EVN project is underway which will allow the stations to make improvements to their equipment leading to higher reliability.

A bright prospect for the EVN is the construction of two more sensitive antennas: a 64m dish at San Basilio, Sardinia, Italy and a 40m at Yebes, Spain.

3. The EVN MkIV Data Processor at JIVE

A central item in the MkIV upgrade of the EVN is the construction of the EVN MkIV data processor at the Joint Institute for VLBI in Europe. JIVE is hosted by NFRA in Dwingeloo, the Netherlands, and funded by science councils in a number of European countries. Special projects have been funded by the EU. Nowadays, a majority of the $\approx$ 20 staff members are involved in further development and operations of the correlator. Other efforts at JIVE include support of the EVN, by carrying out Network Monitor Experiments, as well as maintaining the central information depot (http://www.jive.nl/jive/evn/evn.html). An important aspect of the efforts is user support: assistance to astronomers during all steps in carrying out a VLBI experiment. The facilities include top end computing facilities for visitors.

The construction of the MkIV data processor was completed in October 1998. It was built within the context of an international consortium, in which also the other (geodetic) MkIV correlators were built. The correlator at JIVE differs in several aspects. For one thing, it is a 16 station processor and therefore the total correlator capacity has been quadrupled with respect to the others to yield a total of 262144 lags. A large interconnection switch distributes the data to the 4 correlator crates which contain 1024 special purpose chips. This Data Distributor Unit became operational on February 21 2000. The drives are of a different make (P+G) than those at the other MkIV processors and use tension arms rather than vacuum to control the tape guidance. Finally, the complete control software and the data product have been derived independently and are currently tailored for astronomical use. It uses aips++ data storage for inspection and export of the data, currently in FITS format to classic AIPS.

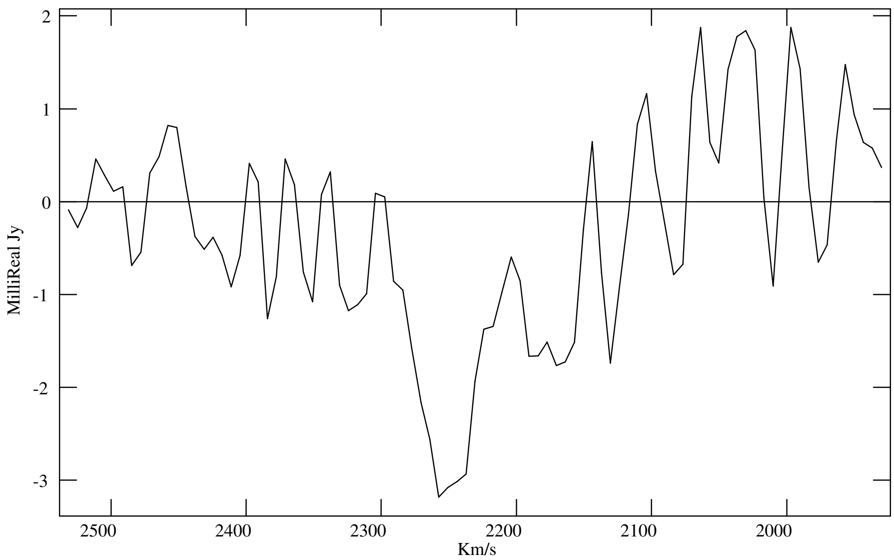

Figure 1. Weak HI absorption towards the nucleus of NGC4261, a good example of what the EVN can achieve.

The first image obtained with the data processor emerged in April 1999. From September 1999 the focus at JIVE was to get user data for a number of astronomical projects completed. These "pilot projects" have exercised the operational procedures at JIVE as well as a number of

MkIV modes. About 10 projects have been completed and delivered to the investigators. The overall data quality has proven to be quite satisfactory, although several subtle problems have been discovered in the process. In addition there are a number of special features which still require considerable development. By February 2000 these included oversampling capabilities, MkIII experiment processing, large output data rates, and modes with more than 256 Mb/s. Some special astronomical capabilities are planned, such as ultra-high spectral resolution, pulsar gating, multiple telescopes per tape, multiple field centers and space VLBI.

The results from a "first science" project have recently appeared in press (Van Langevelde et al., 2000, Astronomy & Astrophysics Letters 354, L45). The paper describes the detection of HI absorption against the counterjet, very close to the AGN in NGC4261 (Fig. 1). The object is a famous radio source associated with an elliptical galaxy. In the inner part of this galaxy the Hubble telescope has found evidence for a massive black hole and an accretion disk of molecular material. The new data shows that close to the nucleus the disk gets heated so much it turns from molecular into atomic form. The very weak detection of 3.5 mJy over a 450 kHz band, highlights what is possible with the "MkIV EVN": very sensitive baselines, even more sensitive with 2 bit sampling, enough bandwidth to span line and continuum, and new correlator capabilities which yield much better spectral resolution.