Part VIII. Telescopes, Observatories & Projects

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The EVN MkIV recording system and the EVN Data Processor at JIVE

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(on behalf of the EVN and JIVE staff involved in the upgrade projects)

Abstract. The European VLBI Network (EVN) is involved in a number of projects to enhance its performance and capabilities. The gradual implementation of the MkIV recording standard has introduced a number of new possibilities. As well as wider bandwidth recording, allowing the detection of ever fainter continuum sources, the system has improved flexibility for doing spectral line VLBI. This is especially true when combined with the very large correlation capacity that the EVN MkIV data processor offers. This correlator, at the Joint Institute for VLBI in Europe (JIVE), Dwingeloo, is now providing the main correlator capacity for the EVN, and its capabilities are still being upgraded.

1. Introduction

The European VLBI Network offers scientific capabilities that attract a widening range of astronomical projects. Nowadays, a large fraction of the proposals request spectral line observing and or phase referencing. Along with the upgrades to allow the recording of more and more bandwidth, mostly to the benefit of continuum observations, the MkIV upgrade has brought more flexibility for spectral line observers too. The most important enhancement for maser VLBI however, is the introduction of the new EVN MkIV data processor at JIVE, Dwingeloo. Its characteristics include the necessary capacity to do high resolution spectral line VLBI.

2. The European VLBI Network

The EVN is a consortium of radio-astronomy institutes operating 16 telescopes at 14 sites in 10 countries. Compared to other VLBI networks, its main characteristic is its great sensitivity, especially at 18 cm, covering the ground state OH transitions. Another unique capability is the combination of the EVN with MERLIN, providing short and sensitive baselines, which have proven to be important, especially in the research of circumstellar OH and OH Megamasers.

Excluding VSOP observations, approximately 40 experiments are conducted using the EVN every year. About half of the observing time is spent on AGN (and stellar) continuum observations. There has been a noticeable increase in spectral line work, including HI and OH absorption studies, as well as maser

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observations. Because of the simultaneous availability of Effelsberg, the phased Westerbork array, and the Lovell telescope, the EVN offers superb sensitivity for L-band OH maser transitions. This is especially true for sources of modest brightness, because of the short baselines and the possible addition of the MERLIN array. The overlap of the Lovell and Cambridge dishes in both the EVN and MERLIN array, enables consistent calibration.

At 5cm the EVN has the special capability to tune to the 6.7 GHz methanol transitions, as well as the excited OH lines. With the recent addition of a receiver for the Cambridge dish, there are now 6 telescopes operating at this frequency. The Cambridge – Jodrell Bank MERLIN baseline also allows astronomers to determine the position of their targets before the main VLBI observations are undertaken. For red-shifted OH (and HI) the EVN has some unique coverage in the UHF band.

To map weaker sources and to determine positions and motions, both continuum and line users now use phase referencing routinely. Although some of the EVN telescopes were never designed for fast switching, the technique has proven to be successful. Using modern correlators, the dominating effect at 18cm has been the ionosphere, and referencing over 1° – 5° has been accomplished. At higher frequencies, the telescope positions still seem to be the most important uncertainty. As not all EVN telescopes are routinely involved in geodesy, special calibration observations have recently been organised to overcome this limitation. In order to accommodate phase referencing, continuous tape motion observing modes have been introduced. Off-source flagging and continuous system temperature measurements will be implemented in the near future.

The above enhancements have come along with the introduction of the MkIV system. Its main goal was to enable 512 Mb/s and 1 Gb/s recording modes, which will become available in 2001. Although the main interest has been to increase the continuum sensitivity, maser astronomers can benefit from some aspects of the upgrade too. For instance, 2-bit recording modes allow increased sensitivity for spectral lines. Other aspects focus on reliability aspects; barrel-rolling and data modulation will be useful for line observers too.

By means of Sched, users can schedule EVN spectral line observations transparently. The program allows one to schedule non-standard narrow filters, using oversampling. Furthermore, it automatically sets the observing frequency by simply supplying the velocity of the target. As is custom in spectral line VLBI, it then calculates the Doppler tracking for the middle of the experiment and uses a fixed frequency throughout the observations.

Other technical developments that spectral line users can benefit from involve new receivers. Of course the new flexible front-ends at WSRT offer both enhanced coverage, as well as flexibility. An increasing number of telescopes have become frequency agile. In addition, new frequencies are made available at some telescopes. For instance, the surface of the Lovell telescope will be upgraded, in order to observe at much higher frequencies up to 15 GHz. The sensitivity and UV-coverage of the EVN will be enhanced further in the future with the addition of a 64m telescope at San Basilio, Sardinia, Italy and a 40m at Yebes, Spain.

The plans for future enhancements include new recorders, using off-the-shelf technology, and optical fiber connected VLBI.

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3. The Joint Institute for VLBI in Europe

The EVN MkIV 16 station data processor was built within an international consortium. It is located at the Joint Institute for VLBI in Europe, in Dwingeloo, and is hosted by ASTRON. JIVE is mainly funded via national research councils/EVN observatories and receives additional EU funding for specific projects via the EVN. The correlator was designed to be able to deal with 1 Gb/s data rates produced by the MkIV data acquisition system (Casse 1999). It can also accept VLBA and MkIII data. The data playback is thus capable of reading 64 tracks per tape at 16 Mb/s/track. Barrel-rolling, data modulation, fan-out, 2 bit and oversampled recordings are all supported.

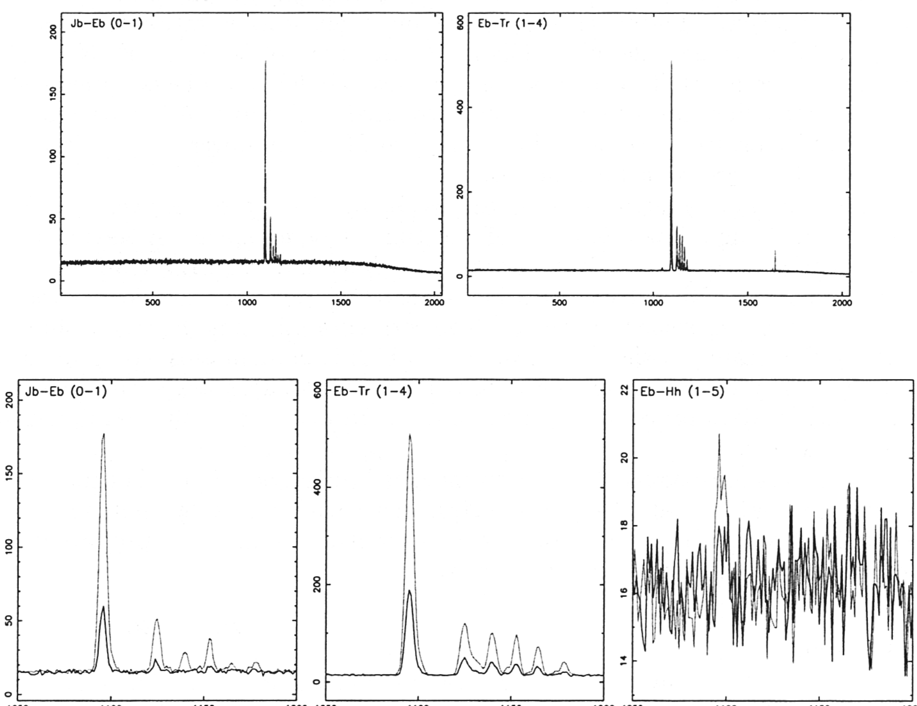

Figure 1. Methanol masers in W75N correlated with 2048 frequency points per product.

The processing of a specific experiment runs from a MkIV VEX file. This file is read in at the correlation stage. Both the decoding of the data streams, as well as the setup of the correlator, including the geometrical model, is derived directly from this. In principle, this information can be obtained from the observing schedule, also in VEX format, but additional information about tapes, earth orientation and clocks is supplied from other sources. The station GPS files, as well as the station logs are used to generate the correlation file.

The processor power for the correlator is delivered by 1024 custom chips, organised in an XF architecture (Whitney 2000). The processor can deliver a

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total of 262144 complex lags. This corresponds, for example, to 512 frequency points on 2 polarizations, 2 frequency bands and 8 telescopes. For such a configuration the data rate is limited to 4 s integration times. There are developments to enhance this data rate in 2001, and eventually, for bandwidths below 16 MHz, recirculation will allow an even higher number of frequency points. In Figure 1 we show an example of how the correlator can be configured to provide 2048 spectral points on a single cross correlation spectrum. The methanol maser in W75N (Phillips et al. 2001) at 6.7 GHz was observed. The 2048 points yield a resolution of 0.98 kHz, equivalent to 42 m/s. Although the data has not been averaged or fringe fitted, a detection on the long baseline Effelsberg – Hartebeesthoek (South Africa), can be seen.

The correlator produced its first fringes in July 21 1997 and started production correlation exactly two years later. The first paper produced from "JIVE data" was a spectral line experiment, albeit on HI absorption, rather than maser emission (Van Langevelde et al. 2000). By the start of 2001 the EVN MkIV data processor at JIVE was processing almost all EVN projects; previously some (spectral line) projects have been correlated at Socorro. A fair fraction of Global VLBI projects are now also coming to JIVE. However, no geodetic or space VLBI processing is possible yet.

The processor is manned for 80 hrs/week, and 1 – 2 projects/week get finished, even though a fair fraction of the time is being spent on testing new capabilities and correlation in support of the Network. The EVN MkIV data processor supports absentee correlation, and work has started to release experiments without consensus from the PI. The correlator staff has the responsibility to verify the quality of the data produced, which is done in aips++. The data is shipped in UVFITS, ready for processing in AIPS. PI's are encouraged to visit JIVE for data processing and calibration. In many cases there is financial support for this.

Future enhancements of the scientific capabilities include further improvements of the output data rate and spectral line capacity. Besides that, software to enable pulsar gating is being developed, as well as the ability to produce data for multiple phase centers simultaneously.

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