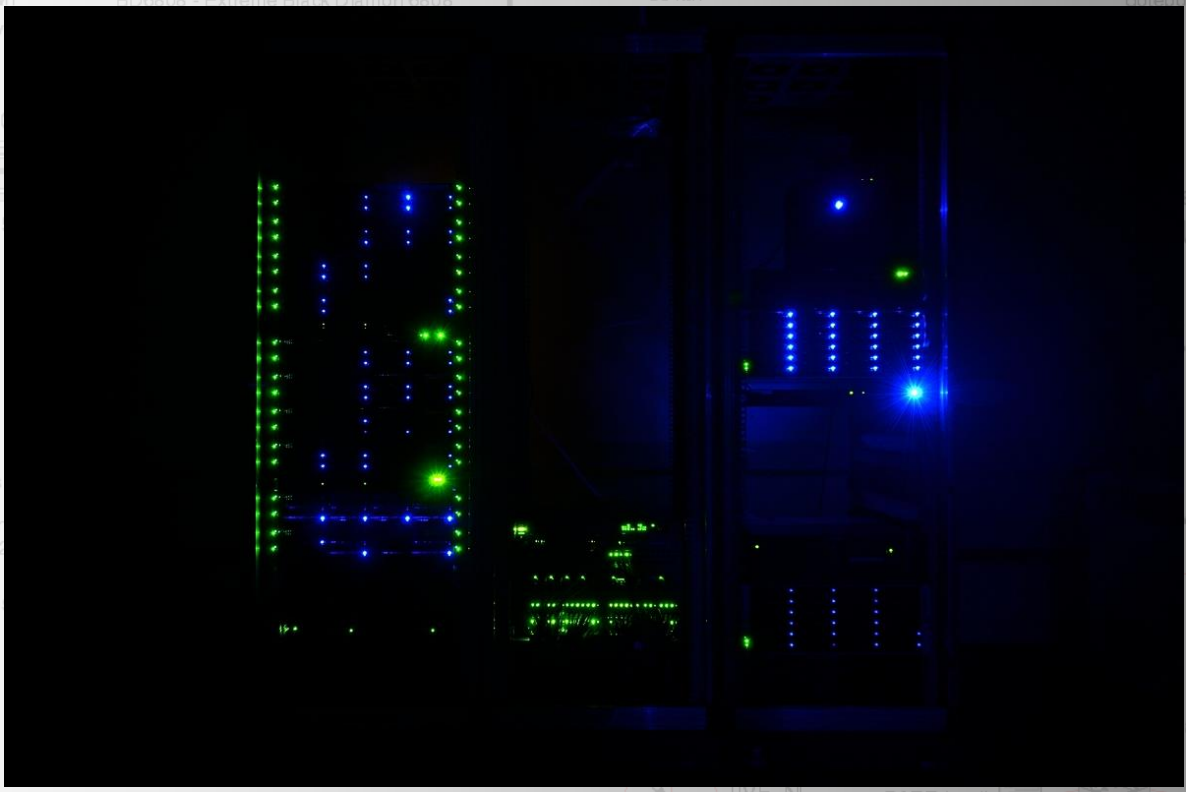
Technological prospects for the EVN for the next decade



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Recommendations in 2007

1. **Extend the IF bandwidth** at the telescopes to at least 1 GHz. Use digital base-band converters (dBBC), with 8-bit sampling (if feasible) and RFI mitigation. Recording systems capable of handling up to 256 Gb/s
2. **Expansion of EVN** below 1 GHz, at 6 GHz, 12-15 GHz, 22 GHz, 30 GHz, 43 GHz and 86 GHz
3. High surface-brightness sensitivity at frequencies below 1 GHz
4. **New broad-band dual-polarization receivers** at cm wavelengths, up to 1 GHz bandwidth in C-band and higher. Frequency agility is required between at least a sub-set of important continuum bands, e.g. L, C/X, and K-band
5. **Additional telescopes** to improve the EVN2015 sensitivity.
6. **Multiple Gb/s connection** of the telescopes to the correlator would allow very high-sensitivity and robust real-time operations for extended times, without disk space limitations at the stations. This is especially required for transient observations, and 24-hour coverage by multi-network VLBI observations
7. **Seamless EVN-MERLIN integration** as the shorter baseline core of EVN operations can be achieved with a 32 Gbps connection from one EVN telescope into the e-MERLIN system and multiple Gbps connections of e-MERLIN telescopes into the current EVN correlator at JIVE
8. **A new generation EVN correlator** at JIVE with a capability of up to 256 Gb/s per radio telescope for routine network operation with 32 station capacity to accommodate all network related stations. The requirements also accommodate very high spectral resolution as well as time resolution experiments

Recommendations in 2007 (continued)

9. Further opportunities need to be explored for **space science** related activities
10. The development of **software tools** for new and improved data products, **advanced data reduction pipelines,** Grid applications, and **Virtual Observatory applications**, leading to improved astrometry, phase-referencing procedures, and high- and low-frequency calibration procedures
11. EVN to continue to **support and enlarge the user community** by means of teaching networks, workshops, symposia, and PR activities. Improved data calibration pipelines and VO capabilities will attract more users from outside of VLBI institutes
12. Maintain a certain fraction of **over-subscription** in order to assure that the best science is done and a wide range of topics is covered. Improved/simplified procedures may be necessary to deal with an increasing number of triggered and Target of Opportunity projects
13. More frequent EVN sessions in support of monitoring programs. The EVN should be more flexible toward projects that require coordinated observations with other instruments, and should **accommodate rapid response science runs with the possibility of immediate feedback**
14. The EVN needs to develop optimal **complementarity for the SKA**. The EVN should serve as a technology test bed for SKA
15. A high priority for spectrum management at all EVN stations and for further development of **RFI mitigation** techniques is essential
16. The EVN2015 should ultimately aim for developing a **real-time VLBI network on global scales**

The future in 2007

Telescopes

- IF bandwidth of the EVN stations to 1 GHz in the L-band, and to 2-4 GHz in the C-band and higher ✗
- Full digital sampling of Ifs (dBBC project) ✓
- Higher bit sampling (up to 8 bits) for RFI mitigation ✗
- Rapid switching time between frequency bands on timescales of few seconds ✗
- Continuous monitoring of telescope performance during the experiments ✗
- Rapid data analysis as well as on-the-fly changes in the observing schedule ✗
- Transfer of calibration data from the telescopes to the correlator in real-time ✗
- Data from co-located WVR radiometers and GPS receivers for the atmospheric and ionospheric phase calibration, respectively ✗
- Installation of dual-feed receivers on the smaller dishes. Even better, focal plane arrays ✗
- New telescopes in strategic places (e.g. North Africa) ✗/✓
- New full EVN members: Latvia (32m), Evpatoria (70m), Simeiz (22m), Miyun (50m), Kunming (40m), Yebes (40m), and the Sardinia telescope (64m). ✗/✓

The future in 2007 (continued)

Correlator

- Correlator capable of processing data from 32 stations in real-time
- 16 Gsamples per second at 8-bit sampling.
  - up to 128 Gbit/s per telescope, or 4 GHz per bandwidth in both polarizations.
- Spectral line experiments with16000 channels per correlation product with floating point accuracy
- mapping of the full primary beam of a 25-m antenna in standard operations

Logistics

- e-VLBI observing with ad-hoc global arrays including telescopes with various backend systems will be straightforward

Post-processing

- Robust and reliable pipeline, providing maps as well as calibrated data.
- Data archive with smart selection for data-mining
- Virtual Observatory tools to help provide data products
  - light curves, spectra, pulsar time series, or overlays of images with results from other instruments.

Questions to ask in 2018

- What happened...?
- And what's next?

- Realism vs blue sky?

- First step, make a list
  - And run it by the usual suspects

Current wish/worry list

Receivers:

- Essential to move to wider bandwidths
  - However, compromises affect Tsys, beam shape, polarisation purity
  - BRAND is a very important development
  - But needs to be made suitable not only for prime focus dishes
- Higher frequencies: Korean receiver system?
  - But not suitable for prime focus

Backends:

- DBBC3: ready for BRAND
  - Direct RF sampling will remove problems with common LO settings in PFB mode (4Gbps)
  - RFI mitigation built in
- Software defined radio, GPU backends
  - useful for pulsar observations
  - much more flexible than current systems
  - No more multiple astronomy backends?

RFI:

- Getting more and more of a problem, should be dealt with
  - Built into wide-band receiver systems
  - Trade in bits for bandwidth?
- Higher bit rates needed

Current wish/worry list

Scheduling:

- Could (should) be far more flexible
  - Optimise use of resources, respond to changing circumstances.
  - Rapid response to transient events, needs further automatisation
  - Transparent global scheduling

Software:

- re-factoring of SCHED
  - Easier scheduling of different hardware, different versions of firmware
- Ongoing worry: Field System
  - Aging, not under our control
  - Depending on the kindness of strangers
- VLBI with CASA
  - Make VLBI data reduction (and science) more accessible to new generation of astronomers
  - Integration into notebooks like Jupyter
  - Bring compute to data

Current wish/worry list

Archive:

- Should be more efficient, accessible, VO compliant
- There may be funding soonish to make the EVN archive more interactive
  - part of a possible upcoming EC project dealing with the EOSC (European Open Science Cloud).

e-VLBI:

- More frequently, at higher bandwidths
- Increase network capacity to correlator dramatically

Magnetic media:

- SSDs: logical next step, but prices!
- The availability of magnetic media in the EVN is still a limiting factor for observing

Current wish/worry list

Correlator:

- Distributed correlation?
  - Upcoming bottleneck for VGOS
- GPU, accelerators

Time and frequency transfer:

- Already in use at Torun and Medicina, between Mopra and ATCA
- Cost saving
  - if H-maser breaks
  - for new VLBI telescopes.
- With a central clock that is part of UTC significant operational improvement of the clock stability
  - no more fringe searches?

SKA

- SKA and precursors: VLBI goes on being something everybody agrees should be done
- However seemingly without any priority whatsoever
- Technically probably not much of a problem, more a political issue
- Financial implications for VLBI once construction starts?