Developments for the Automation and Remote Control of the Radio Telescopes of the Geodetic Observatory Wettzell

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Abstract VGOS is a challenge for all fields of a new radio telescope. For the future software and hardware control mechanisms, it also requires new developments and solutions. More experiments, more data, high-speed data transfers through the Internet, and a real-time monitoring of current system status information must be handled. Additionally, an optimization of the observation shifts is required to reduce work load and costs. Within the framework of the development of the new 13.2-m Twin radio Telescopes Wettzell (TTW) and in combination with upgrades of the 20-m Radio Telescope Wettzell (RTW), some new technical realizations are under development and testing. Besides the activities for the realization of remote control, mainly supported during the project "Novel EXploration Pushing Robust e-VLBI Services (NEXPReS)" of the European VLBI Network (EVN), autonomous, automated, and unattended observations are also planned. A basic infrastructure should enable these, e.g., independent monitoring and security systems or additional, local high-speed transfer networks to ship data directly from a telescope to the main control room.

Keywords Remote control, automation, e-RemoteCtrl

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1 Introduction

The visions for a VLBI Geodetic Observing System (VGOS) call for more than one antenna at one location, which will be operated continuously to derive the IVS products with a higher accuracy [Niell2005]. For a geodetic observatory, such as Wettzell, this is only possible with the same number of personnel staff and while keeping the high reliability and quality if the telescopes can be operated from one control room and if the automation is increased tremendously.

2 Remote Access and Control

The VGOS requires two or more antennas at a site, which share data recording and transmission resources, to increase the observing density [Niell2005]. For a geodetic observatory, such as Wettzell, this means that more than one antenna must be controlled by the operational staff at the same time. In the case of Wettzell, these are the 20-meter Radio Telescope Wettzell (RTW) and the two new 13.2-meter antennas of the Twin Radio Telescope Wettzell (TTW). As it is quite inefficient to have more than one responsible operator for the controlling of the different telescopes, and as it is also impractical to operate each antenna from another control room, the controlling facilities must be shared between the telescopes as well. One operator in one centralized control room must be able to control and monitor all telescopes at the location of the observatory.

Fulfilling this goal means that the operator is not directly in front of the telescope anymore while controlling it. Therefore it is necessary to enable a suitable

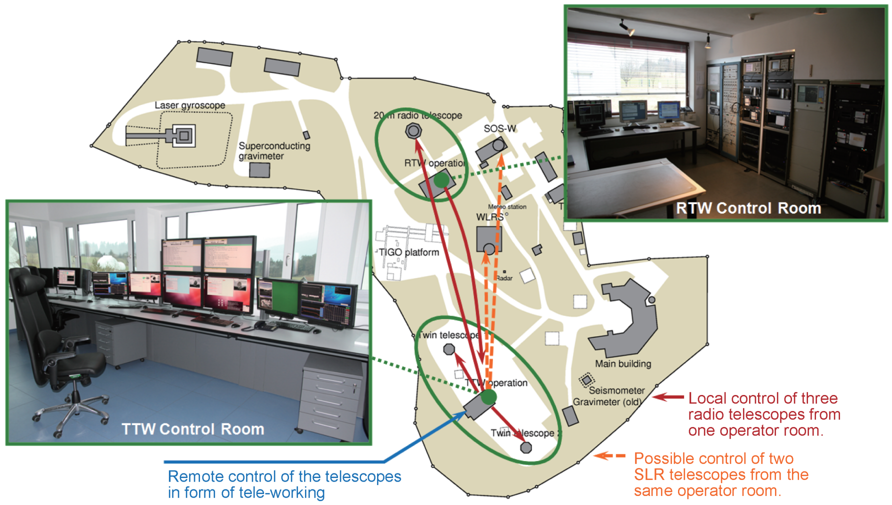

Fig. 1 The idea behind remote control at the observatory Wettzell is the control of three radio telescopes (and maybe in the future of two laser telescopes) from one operator room with an additional access from external.

remote control at the location of the observatory, which will forward the commands from the operator to the antennas and return the feedback again in a reliable way. Remote control then enables the following:

- Running all shifts of the three telescopes with the existing personnel staff will only be made possible by concentrating man power and reducing individual tasks.
- Some cases require remote supervision of student operators.
- Operator times can be shared between the different systems at the observatory.
- VLBI2010 calls for 24/7 operations, perhaps from a few centers across the globe [Lovell2013].
- Remote control can be more efficient and cost effective than local operation: one operator can be used for multiple telescopes [Lovell2013].

To allow such an operating center at Wettzell, a new operations building was constructed during the installation of the new TTW (see Figure 1). In this new building, there is enough space for a control room with at least three operator places and the corresponding facilities for information technology in a special server room. From there, all three telescopes should be controlled. Another possibility for the further future is to run the two laser ranging systems from this room, as well. Dedicated access points additionally allow connections from outside of the observatory for distant remote operators, who are at their homes or at other observatories. This should help to support operators from home during an error situation or to supervise student operators.

The used software is developed by the staff of Wettzell. It consists of two parts: an extension to the NASA Field System (FS), which forwards the monitoring and control of the FS to a remote operator, and a station specific code, supporting the FS in a dedicated way. For the first category of software, realizing remote access, the software extension "e-RemoteCtrl" is used. It is general enough to also be used at other observatories. It is set up on a generated communication middleware on the basis of Remote Procedure Calls. A server realizes the contact to the FS. Several clients can request monitoring data or can send orders in parallel. The middleware implements additional safety mechanisms, such as a process watchdog or semaphore-protected shared variables.

The whole communication is tunneled over a Secure Shell (SSH) connection and is therefore encrypted and quite safe. Additionally, each user must be authenticated and has a dedicated user role with clearly defined and monitored access rights [Neidhardt2013]. After login, each remote user is kept in his own home directory using a special setup of "rbash" as a command shell. The local systems controlling the telescopes are also situated in separate, physical networks. These "network enclaves" are at least protected by a package filter firewall from the rest of the observatory and the external Internet world.

"e-RemoteCtrl" also directly supports "IVS Live", a fully dynamic Web page for the monitoring of IVS sessions. With the injected real-time monitoring data from "e-RemoteCtrl", "IVS Live" can likewise be used to coordinate or check the global network and its current observations [Collioud2013]. Such features must be extended tremendously for the future VGOS network, to simplify the organization and to allow a general overview for coordinators, schedulers, and observatory people.

The secondly mentioned part, the station specific code, is the connection between the general FS programs and the local hardware and software. This software set consists of the antenna control (with the program "antcn"), the station module checking (with the program "cheks"), the interpreter of station-specific commands in the Standard Notation for Astronomical Procedures (SNAP) (with the program "stqkr"), a station error reporting tool (with the program "sterp"), and specific control programs. All of these programs must be developed by the observatory people to support the specific, local conditions [NASA1997]. Having regard to the planned automation, all of these modules follow a dedicated structure, which allows additional monitoring and access possibilities, separate from the FS (see Figure 2 and the following section about automation).

That additional software and equipment is necessary before the FS can be understood, taking a look onto the following points (compare [Lovell2013]):

- Nothing can be touched, moved, or turned directly (e.g., the changing of hard drive modules for the recording of VLBI data).
- Cables cannot be plugged off and on directly.
- Keyboards on location are not immediately accessible.
- Telescopes and their surroundings are not visible without additional equipment.
- Sky conditions are unratable.
- Racks and hardware equipment is not visible (e.g., lights on devices).
- Computer monitors, desktops, and module stores are not directly visible.

This requires amongst others (compare [Lovell2013]):

- Web cams to allow live video streams from the antennas to detect dangerous situations,
- network-based Video, Keyboard and Mouse (KVM) switches to forward monitor screens especially during the booting of the computers,
- network-based power switches to hardly reset hardware equipment,
- remote boot and reboot possibilities (e.g., the new antenna control at Wettzell allows a reset/reboot directly with a SNAP command in the Field System), and
- "cold stand-by" or better "hot stand-by" hardware[1].

At the observatory Wettzell, all of these equipments and possibilities are realized step-by-step and are already productive after the revision of the 20-m RTW. Successively, this equipment is additionally integrated into the system monitoring and control infrastructure, which is an extra, parallel system to detect critical or error states and warning situations [Ettl2010]. It makes its own decisions in substantially shorter time intervals, according to the given situation and parallel to the field system. Because of this, it also supports a higher degree of automation.

3 Automation

Having an additional look into the requirements for the VGOS, it becomes obvious that "continuous measurements for time series of station positions and Earth orientation parameters" [Niell2005] are planned. In principle, this calls for reliable 24/7 operations. This contrasts with the operational costs and required man power at the observatories. Taking the current situation of the VLBI group at Wettzell, currently operating the 20-m RTW, which is one of the most used geodetic radio telescopes, doubles the observation load to 24/7. This increase would require about 20 to 30 percent more man power (according to an internal investigation) if all current duties should be kept as usual. Unfortunately this is unrealistic. Enabling 24/7 while keeping the current state is only possible with an increase of automation.

Fulfilling this goal, this means that the operator is not always available at the telescope anymore. The system is started or starts automatically and processes the

[1] These are spare parts, which can be switched on or replaced quite fast ("cold stand-by") or which run parallel and take over control automatically if a hardware failure appears.

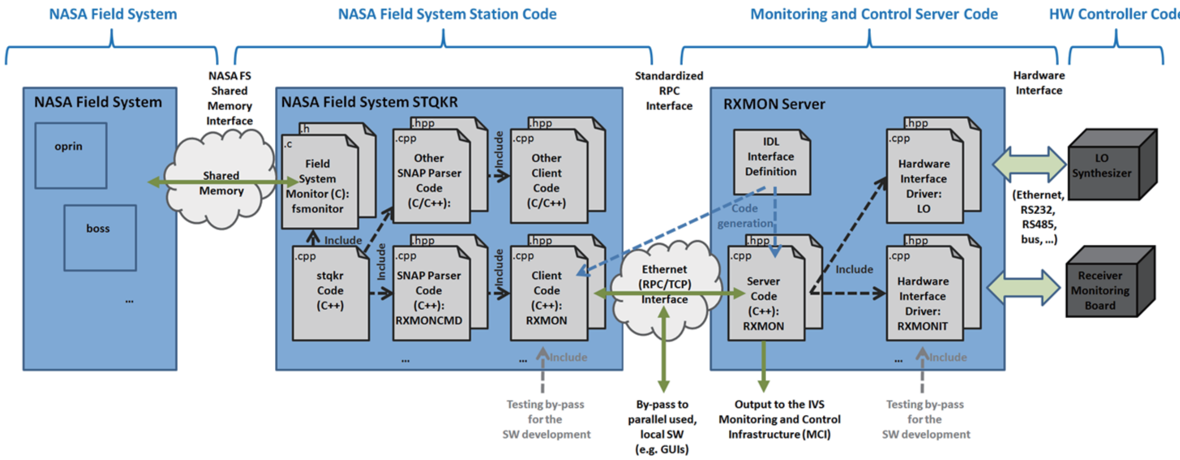

Fig. 2 The structure of local, station-specific programs, supporting a higher degree of automation and an additional system monitoring.

schedules autonomously while checking quality and safety parameters. Then automation enables the following possibilities:

- Surviving connection blackouts if the operator runs operations remotely.
- Simplification of operation workflows.
- Reduction of shifts at weekends and in the night.
- Reduction of monotonous work steps and therefore of error-prone tasks for the operator.
- Improvement of the observation quality because of a clearly defined runtime behavior.

To enable a higher autonomy of the systems at the observatory Wettzell, each hardware device is represented by a special monitoring and control server (see Figure 2), which builds a short feedback loop for the device. The server acts like an intelligent driver, checks the system state regularly, and makes decisions, keeping a stable and reliable state for the device. The local parameters and states are also forwarded to the nodes of the monitoring and control infrastructure, where all data are collected in an archive for real-time and historic data requests. These access points are used for further decisions at the following, higher control layers of monitoring and control nodes. Because the server and all other components of the central nodes are realized with the described RPC middleware, a simple, standardized access from everywhere is possible. This allows by-passes to directly control hardware, to realize Graphical User Interfaces (GUI) for dedicated devices, or to request data by faster checking loops than possible in the regular FS routine. Nevertheless, all data are also regularly available for the FS, realizing the mentioned station specific programs [NASA1997].

Nevertheless, the hierarchical system monitoring and control infrastructure offers a parallel and reliable possibility to check system states and quality parameters. It builds a safe instance to stop operations with interlock mechanisms if there are critical situations. This enables a higher degree of automation, which reduces shifts at unfavorable times, such as on weekends or during the night. It is the only possibility for allowing 24/7 VGOS observations.

4 Conclusion

Wettzell is on its way to realizing a site of the future VGOS. The challenges for doing this require new techniques and realizations to run the different telescopes and to operate the new 24/7 sessions. At the observatory Wettzell, this should be enabled by an increase of automated systems, which can be controlled remotely. First implementations and experiences are promising. The established solutions and the developed software are also interesting for other sites and are freely available. Over the past years, several sites made their own experiments with the software (see Figure 3). The Australian geodetic VLBI telescopes of AuScope can especially be seen as one very sophisticated and well advanced test site for such ideas.

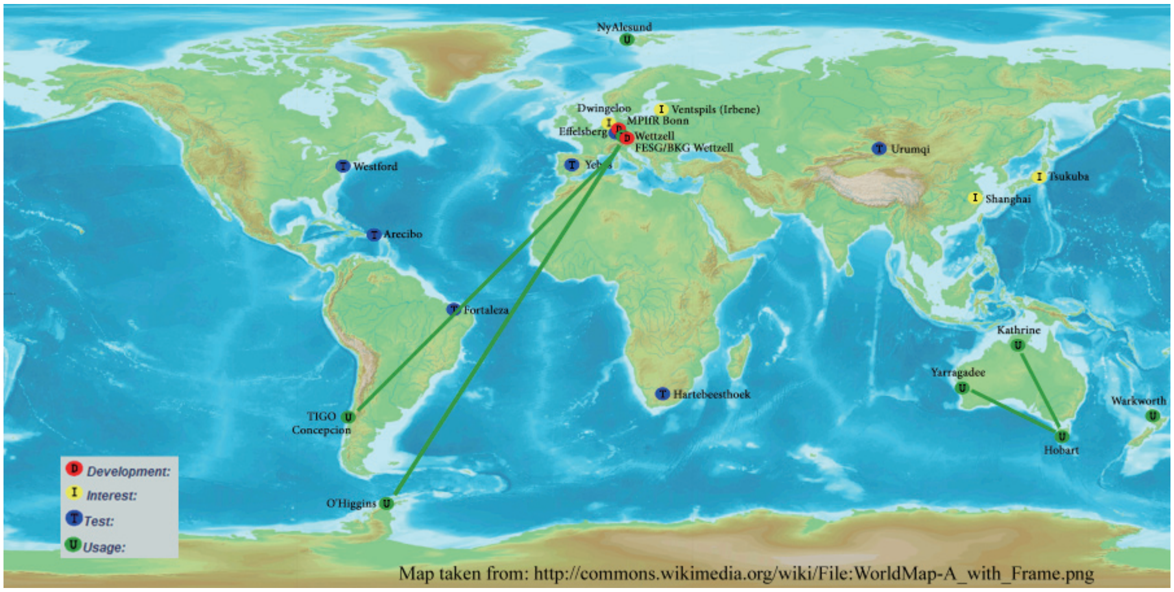

Fig. 3 The distribution of the software "e-RemoteCtrl" (beside several sites, where it was tested, a view observatories run the software regularly).

The three telescopes in Yarragadee, Katherine, and Hobart are controlled from the remote control room at the University of Tasmania, Hobart. Besides its own implementations, "e-RemoteCtrl" is an important pillar for the implementation. It demonstrates impressively that the new techniques are practical and work. Interested sites can register and download the software from: http://www.econtrol-software.de.

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