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Status of the Sardinia Radio Telescope Project

Gianni Tofani*[a], Gianni Alvito[b], Roberto Ambrosini[c], Pietro Bolli[b], Claudio Bortolotti[c],
Loredana Bruca[d], Franco Buffa[b], Alessandro Cattani[b], Gianni Comoretto[a], Andrea Cremonini[b],
Luca Cresci[a], Nichi D'Amico[b], Gian Luigi Deiana[b], Antonietta Fara[b], Luigina Feretti[c],
Franco Fiocchi[c], Enrico Flamini[d], Flavio Fusi Pecci[f], Gavril Grueff[c], Giuseppe Maccaferri[c],
Andrea Maccaferri[c], Franco Mantovani[c], Sergio Mariotti[c], Carlo Migoni[b], Filippo Messina[b],
Jader Monari[c], Marco Morsiani[c], Matteo Murgia[b], José Musmeci[b], Mauro Nanni[c], Vincenzo Natale[e],
Alessandro Navarrini[b], Monia Negusini[c], Renzo Nesti[e], Luca Olmi[e], Alessandro Orfei[c],
Andrea Orlati[c], Francesco Palla[a], Dario Panella[a], Claudio Pernechele[b], Salvatore Pilloni[b],
Tonino Pisanu[b], Antonio Poddighe[b], Marco Poloni[c], Angelo Poma[b], Sergio Poppi[b],
Ignazio Porceddu[b], Isabella Prandoni[c], Juri Roda[c], Mauro Roma[c], Pierguido Sarti[c],
Alessandro Scalambra[c], Francesco Schillirò[c], Andrea Tarchi[b], Gian Paolo Vargiu[b],
Giampaolo Zacchiroli[c]
[a]INAF-Arcetri Astrophysical Observatory, L.go Enrico Fermi 5, Firenze, FI, ITALY 50125;
[b]INAF-Cagliari Astronomy Observatory, L. Poggio dei Pini, S. 54, Capoterra, CA, ITALY 09012;
[c]INAF-Radio Astronomy Institute, Via P. Gobetti 101, Bologna, BO, ITALY, 40129;
[d]ASI (Agenzia Spaziale Italiana), Viale Liegi, 26, Roma, RM, ITALY, 00198;
[e]INAF-Radio Astronomy Institute, L.go Enrico Fermi 5, Firenze, FI, ITALY 50125;
[f]INAF-Bologna Astronomy Observatory, Via Ranzani 1, Bologna, BO, ITALY 40127

ABSTRACT

We present the status of the Sardinia Radio Telescope (SRT) project, a new general purpose, fully steerable 64 m diameter parabolic radiotelescope capable to operate with high efficiency in the 0.3-116 GHz frequency range. The instrument is the result of a scientific and technical collaboration among three Structures of the Italian National Institute for Astrophysics (INAF): the Institute of Radio Astronomy of Bologna, the Cagliari Astronomy Observatory (in Sardinia,) and the Arcetri Astrophysical Observatory in Florence. Funding agencies are the Italian Ministry of Education and Scientific Research, the Sardinia Regional Government, and the Italian Space Agency (ASI,) that has recently rejoined the project. The telescope site is about 35 km North of Cagliari.

The radio telescope has a shaped Gregorian optical configuration with a 7.9 m diameter secondary mirror and supplementary Beam-WaveGuide (BWG) mirrors. With four possible focal positions (primary, Gregorian, and two BWGs), SRT will be able to allocate up to 20 remotely controllable receivers. One of the most advanced technical features of the SRT is the active surface: the primary mirror will be composed by 1008 panels supported by electro-mechanical actuators digitally controlled to compensate for gravitational deformations. With the completion of the foundation on spring 2006 the SRT project entered its final construction phase. This paper reports on the latest advances on the SRT project.

Keywords: Ground-based radio telescopes, receivers, shaped mirrors, active surface, beam waveguide

1. INTRODUCTION

The SRT is a challenging scientific project of the Italian National Institute for Astrophysics (INAF) aiming at constructing and operating in the Sardinia island a new general purpose, fully steerable 64 m diameter radiotelescope capable to operate in the frequency range 0.3-116 GHz. The project is funded by the Italian Ministry of Education and Scientific Research, by the Sardinia Regional Government, and by the Italian Space Agency (ASI).

*tofani@arcetri.astro.it; phone 39 055 2752217; fax 39 055 220039

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In 1991 a feasibility study was funded, and an extensive site testing campaign started. The choice of an optimal site for the SRT radio telescope took many years of investigations. Since 1991, radio interferences and metereologic conditions in Sardinia have been monitored in order to select the best location to operate the SRT. The site that best satisfied these prerequisites is the area named "*Pranu Sanguni*" close to the small town of San Basilio, about 35 km North of Cagliari. The site has a height above the sea level of about 700 m and its geographical coordinates are Lat. 39d 29m 50s N and Long. 9d 14m 40s E.

The SRT will join the existing Italian radiotelescopes operated by the Institute of Radio Astronomy: the 32 m cassegrain twin antennas of Medicina (Bologna) and Noto (Siracusa). The new telescope will be devoted to radioastronomy science, geodynamical studies, and Deep Space Network (DSN) activity. The SRT will be involved in a wide range of scientific projects both as a stand-alone instrument (single-dish) and as part of the Italian and European Very Long Baseline Interferometry (VLBI) networks. Moreover, the geographic position of the SRT itself is fundamental for Geodynamics studies of the Mediterranean region.

A call for bids for the feasibility study of the antenna was issued in 1993 and by the end of the same year a contract was signed with Vertex RSI (Santa Clara, California). In March 1999 ASI assigned to the same company a contract for the production of the executive project. The manufacturing of the SRT mechanical parts was commissioned in 2003 to the MT Aerospace AG (Germany), which is also responsible for the on-site assembly of the telescope.

The telescope is in its final construction phase and will be completed by 2009. A description of the main and unique features of the telescope was presented in 2004 by Grueff et al. [1]. This paper is intended to give an update of the status of advancement of the SRT construction as of May 2008. We refer to [1] for a general presentation of the telescope, and to [2] and [3] (the SRT web site, http://www.srt.inaf.it) for a more detailed description of the whole project.

2. SRT SCIENCE

The unprecedented capabilities of the SRT due to its innovative design, the active surface, and its suite of planned state-of-the-art receivers will be exploited to contribute in a substantial way to the scientific and technological development of the radio astronomy in Italy and in the World.

The SRT is a general-purpose radio telescope, capable of operating with high efficiency from 300 MHz to over 100 GHz. Several challenging scientific topics can be investigated using the SRT, ranging from Galactic Astronomy (e.g. *Spectral line observations*: molecules in comets, studies of H_2O, OH, and SiO masers, surveys for molecular emission from Cloud Cores and the Interstellar Medium, detection of high-density molecular tracers, understanding the early phases of star formation, line measurements with an Italian VLBI array, methanol and water masers; *Continnum observations:* pulsars, studies of radio emission from binary stars, polarized diffuse emission, radio observations of X-ray Binaries, etc…) to Extragalactic Astronomy (e.g. *Spectral line observations*: H_2O megamasers, neutral hydrogen blind searches, cosmological redshifts determination, neutral hydrogen absorption studies; *Continuum observations:* High-frequency mapping of extragalactic sources, studies of Active Galactic Nuclei, rotation measure estimates, the Sunyaev-Zel'dovich effect, millimeter VLBI observations, Wide Field Imaging and Surveys, study of Faint Radio Sources). Furthemore, SRT will be devoted to geodesy and astrometry (geodetic VLBI, VLBI telescopes' co-location in conjunction with the GPS). Last but certainly not least, the SRT has been the subject of a large agreement between INAF and ASI for the use of the instrument for space applications. SRT will be involved in projects of planetary radar astronomy (determination of asteroids orbital parameters, analysis of surface characteristics of asteroids, study and monitoring of the space debris) and space science (planetary atmospheric profiles and ionospheric composition, structure of planetary rings and surfaces, planetary gravitational fields, shapes, masses and ephemerids, solar corona and solar wind). In the period 2012-2020, SRT is expected to operate in connection with the following Space Missions: Cassini, Rosetta, Dawn, Juno, Bepicolombo, Jupiter/Europa or Titan/Enceladus (Cosmic Vision mission), Exomars, Mars Sample return. The performance characteristics of SRT will be crucial in particular for the Radio Science experiments, the high volume of the downlink data rates needed in mission critical phases (for example in orbit insertion, landing, flyby) or special science operations. Typically these observations last few hours but cannot be moved in time, so this type of service requires a very high level of reliability and priority level in scheduling.

Details on all the aforementioned topics and on the projects proposed for the SRT can be found in [2], in the Report "The SRT. Science and Technical Requirements" [4], and on the ASI website (www.asi.it).

3. MECHANICAL STRUCTURE

The main antenna geometry is based on a classical Gregorian configuration. Shaped surfaces do not introduce structural requirements except for more stringent accuracy and stability on geometry. A photo of the site construction works is shown in Fig. 1. The construction of the alidade is almost completed and it is now in the phase of accurate geometrical measurements which would confirm the design goals.

Most of the structure is welded in order to achieve the geometrical stability and, due to the complexity of several elements, require ad hoc welding procedures. The construction details such as welding and assembling phases, which have a strong impact on the operational performances and life time of the instrument, are also carefully controlled. The backup structure is going to be assembled near the instrument foundation in order to be lifted up with cranes, once completed.

A delicate step will be the assembly of the actuators and of the active surface which would respect stringent geometrical requirements to achieve the high frequency operational performance.

Fig. 1: Photo at the SRT site showing the status of the telescope construction work (May 2008).

4. OPTICS

The main antenna geometry, based on a classical Gregorian configuration, consists of a shaped reflector system designed to reduce the stationary wave bouncing between primary and secondary reflector. This kind of shaping increases also the blockage efficiency without limiting too much the Field of View of the antenna. The SRT can operate at several different focal positions: primary focus, secondary or Gregorian focus, and at the foci of the Beam-Waveguide (BWG) system. The latter will be used at intermediate frequencies (1.4 GHz – 35 GHz), and consists of two different beam-waveguide optical systems: BWG layout I and BWG layout II. The two configurations use three mirrors, which are sections of ellipsoids of revolution: M3 is a movable mirror and is shared by both BWG I and BWG II, whereas mirror M4 is used for the first layout and M5 for the second one. The re-imaging optics for BWG I have been designed for maximum focal ratio reduction, from 2.35 at the Gregorian focus, to 1.37 at focus F3 whereas BWG II was designed to position the output focal point F4 beneath the elevation axis of the antenna (at F/D =2.81). Since the two additional mirrors of each BWG system are placed in the vertex room (at an ambient temperature of about 293 K), a high spillover from these mirrors could clearly increase the antenna noise temperature. However, our simulations with GRASP [5] have shown that the spillover from M3 and M4 is actually low, resulting in a spillover efficiency of 99.7% and 98.2%, respectively. The three mirrors of the BWG system were commissioned in December 2005 to the Italian company COSPAL Composites [6], which also manufactured the panels of the primary and secondary mirrors of SRT with an accuracy of respectively, 65 μm and 50 μm (the specification to operate the antenna up to ≈100 GHz sets the total surface accuracy error of the SRT optics to ≈190 μm). The BWG mirrors were cast as a single piece out of an Al alloy and then machined down to a surface accuracy of 227 μm for mirror M3, 108 μm for mirror M4, and 240 μm for mirror M5 (the specification for the surface accuracy of the BWG mirrors was ≤ 300 μm.) The three mirrors have been recently shipped to the SRT site (see Fig. 2) where, given their size, they will be mounted into the vertex room before the walls will be completed.

In preparation for the alignment of the optical system, an accurate analysis of the system's tolerances has been performed using the commercial Physical Optics software, GRASP9.3; as expected, the most critical parameter is the position of the secondary mirror. In fact, we found that in order to minimize the aberrations resulting from misalignments (evaluated at 100 GHz) the secondary mirror will have to be positioned with a decenter accuracy of the order of a millimeter and a tilt less than 0.05°.

Several simulations with a ray-tracing software, ZEMAX [7], and with GRASP9.3 were also performed to show that a simple analytical relationship exists between the Strehl ratio (one of the standard figure-of-merit used in the design of optical system at visible/IR wavelengths) and the aperture efficiency (more often used at microwave frequencies): the Strehl ratio turns out to be equal to the phase efficiency when the apodization factor is taken into account. This result was applied to three different telescope designs including a fully Gregorian version of the SRT [8].

Fig. 2. Photo of the three mirrors of the BWG system (taken from the back) at the SRT site. The 12 m height tower hosting the weather station, the RFI monitoring system, and a webcam is also visible on the right. The SRT construction work site is visible in the background.

5. METROLOGY

The metrology system is organized in a number of different sub-worpakages (SWPs). The goal of the first SWP is to estimate the gravitational and thermal deformations of the antenna using simulation softwares based on the Finite Element Model (FEM). The simulations provide the expected deformations of the structure for a number of different parameters and will be used to control the active optics system in open-loop. A number of temperature sensors will be located at appropriate positions on the antenna structure. The temperature measured by these sensors will be fed into a lookup table from which the *predicted* values of the antenna deformations are extracted; this provides the position of each surface actuator. The FEM model is currently under development.

The second SWP involves the design, realization and test of a close-loop system in which the surface of the telescope is *measured* and corrected in quasi real time. The close-loop system aims at the fine tuning of the surface shape. We discarded the use of the classic range-finder based approach, such as laser radar or laser tracker. Instead, we are investigating different approaches using a web of triangulation sensors (design under development). Other metrology systems under consideration are the microwave holography and on the photogrammetry.

The third SWP regards the alignment and positioning of the sub reflector with respect to the main dish. The sub reflector has six degrees of freedom, five of which will be controlled (the rotation around the optical axis is not considered because of the axisymmetrical shape). Three laser rangefinders placed in the proximity of the primary vertex and pointing toward three corner cubes placed on the sub reflector rim will measure three distances (three degrees of freedom from which the defocus and the tilt of secondary mirror are derived. A prototype of the rangefinders was developed and is currently under test. The subreflector displacement orthogonal to the antenna optical axis can be measured using a high resolution CCD camera located at the antenna vertex. This system, tested in open space using a 8 Mpixels CCD camera, was able to measure a lateral displacement of 100 µm at a distance of ~ 10 m (the primary dish focal length of the 32 m antenna in Medicina).

The goal of the fourth SWP is to design and implement the temperature sensors web which, when used in conjunction with a FEM analysis of the antenna (first SWP), will provide the control of the open-loop. Anemometers (SWP #5) and inclinometers (SWP #6) were acquired and are currently under test.

The seventh SWP concerns the star-tracker, i.e. an optical pointing system consisting of a f/10 18 cm Maksutov-Cassegrain telescope equipped with a CCD camera that yields a resolution of 2.3 arcsec/pixel. Presently, the star-tracker is operating on the Medicina 32 m VLBI radiotelescope (Fig. 3), and allows the fine measure of the optical pointing errors [9] during night-time tracking (RMS errors due to the rail and the alidade are < 2.5 arcsec).The system is being updated with a near infrared sensor (1.1 up to 1.7 µm in wavelengths) that allows operation also under day light condition. The sensor was successfully tested. The new star-tracker will be operational by the summer of 2008.

The goal of the last SWP is to implement the various metrology subsystems in the SRT control software.

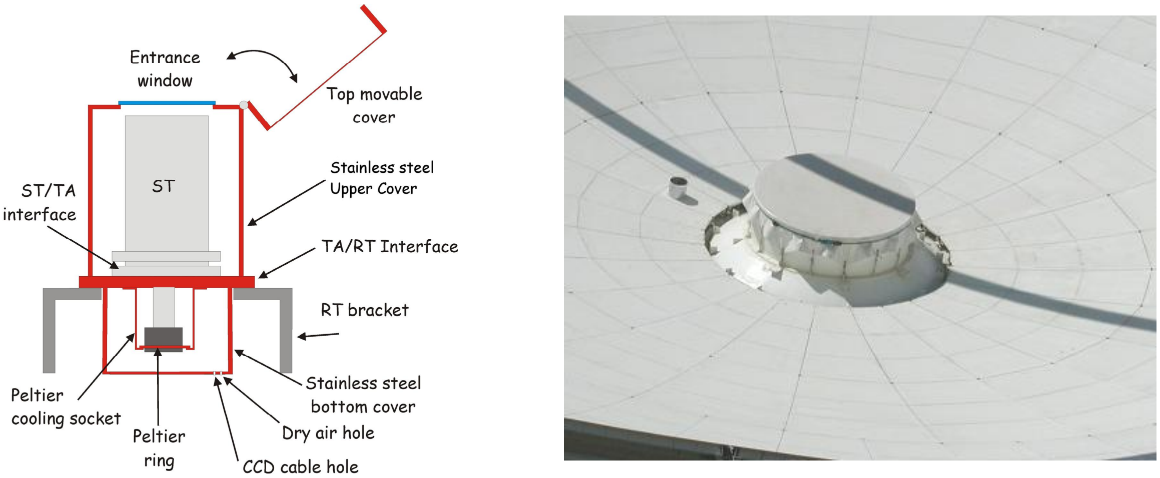

Fig. 3. *Left)*: Sketch of the Star Tracker (ST). *Right):* Photo of the Star Tracker mounted on the 32 m Medicina antenna (on the left of the primary mirror vertex).

6. RECEIVERS

Four receivers are planned for the commissioning of the SRT [10]. The first of such receivers has been recently installed in the secondary focus cabin of the 32 m Medicina antenna in order to test its performance. It was partially funded by EU in the framework project FARADAY (Focal-plane Arrays for Radio Astronomy, Design, Access and Yield) referred to produce multifeed systems and related technology. Principal characteristics are as the following:

- 7 horn arranged in hexagonal form with a central horn;
- RF band from 18 to 26GHz;
- 14 IF outputs right and left polarization;
- IF bandwidths selectable up to 2GHz, tunable everywhere in the RF band;
- All the 7 feed systems plus Low Noise Amplifiers (LNA) are cooled at 20 K;
- Measured receiver noise temperatures = 20-30K from 18 to 24 GHz, 30-50K from 24 to 26 GHz;
- Equipped with a mechanical de-rotator to maintain the field of view;

The receiver [11] [12], shown in Fig. 4, has 14 cooled LNAs [13] and 14 not cooled post amplifiers made in MMIC InP technology (Fig. 5). The antenna illumination design was done for the Sardinia Radio Telescope but the tapering is also suitable to use the receiver on the Medicina 32 m dish. Although devoted to continuum and spectroscopy single-dish observations, the central horn will also be used for VLBI. First tests on the antenna show a system temperature of about 75K at El=58 with an atmosphere transparency at the zenith = 0.1. The right panel of Fig. 4 shows the multifeed mounted in the central location of the secondary cabin.

At the same time is in progress the production of the 5.7-7.7 GHz receiver to be mounted on the Beam Waveguide (BWG) focus of the SRT antenna. It will also be tested on the Medicina 32m dish. Fig. 6 shows photos of the horn [14] and of the polarizer/omt (OrthoMode Transducer) [15]. The dewar construction is in progress and it will be a replica of that already in use in the Medicina 4.3-5.8 GHz receiver (it can be seen on the left of Fig. 4, right panel).

A dual linear polarization coaxial receiver that covers two frequency bands, the L band (1.3-1.8 GHz) and the P band (305-425 MHz) is in an advanced design phase. The receiver will be located at the SRT primary focus and consists of room temperature coaxial feeds with an inner circular waveguide for the high frequency (L-band) and of an external coaxial feed with external corrugations for the low frequency (P-band). A compact dewar allows to cool down to 20 K, among other components, the L-band omt, the two L-band and two P-band LNAs. The L-band omt is based on a turnstile junction design and has already been fabricated and tested [16].

Fig. 4. *Left):* Internal view of the 18-26 GHz multifeed receiver during assembly. *Right):* Photo of the multifeed mounted on the secondary focus (central location) of the Medicina antenna.

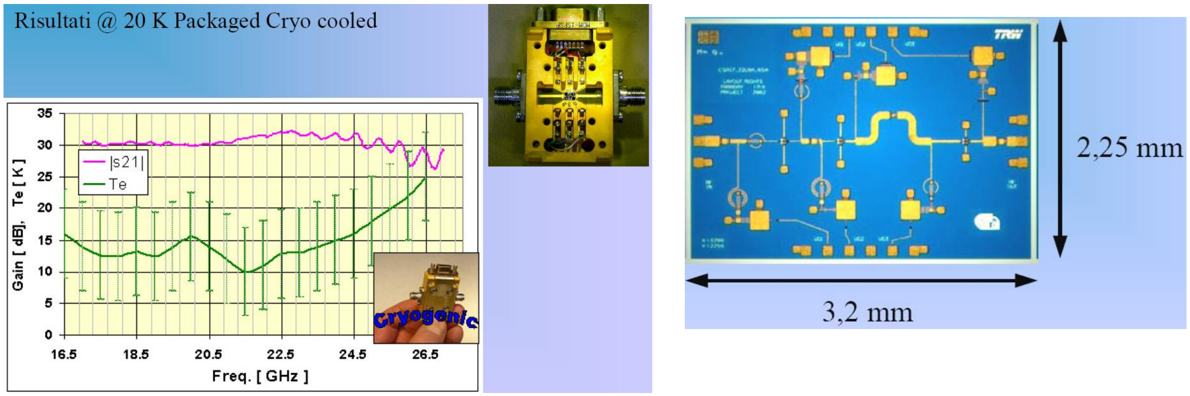

Fig. 5. *Left):* Measured gain and noise of a typical 18-26 GHz coaxial amplifier module (upper inset) of the multifeed system. *Right):* Photo of the InP MMIC chip developed by the IRA (Italian Radio Astronomy Institute).

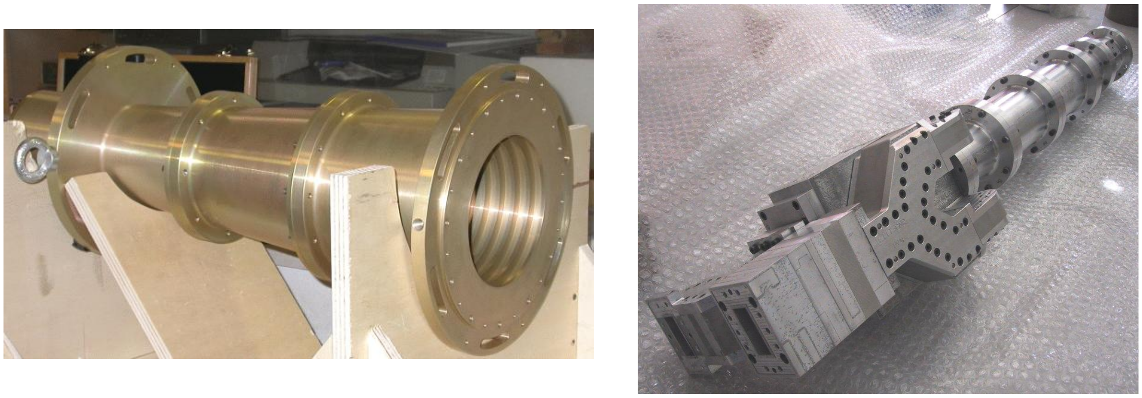

Fig. 6. The horn (left) and the chain of marker injector-polarizer-omt (right) for the 5.7-7.7 GHz receiver.

7. RECEIVERS CONTROL AND BACKENDS

7.1 Control system of multibeam receiver

A multiprocessor RX control system was design to provide the observers the control of the main parameters of each receiver. Low cost Ethernet twisted pair cable and fiber optics media will be available at each focal position. Ethernet and TCP/IP protocol will be used to connect the receiver control system to the main control computer located in the observer control room.

The RX control system of the 18-26GHz multibeam receiver allows to control the following parameters and devices: 1) Low Noise Amplifier power on/off and Bias control; 2) Dewar vacuum pump; 3) Dewar vacuum gauge; 4) Dewar vacum valve; 5) Dewar cryogenics temperature sensors; 6) Dewar heater resistors; 7) Noise cal source on/off; 8) IF Bandwith selection; 9) Power level indicator to easily detect RF amplifiers failures.

A single microcontroller board together with 7 "ALISRT" boards (one for each feed) enables to control LNA bias parameters, V-gate, V-drain, and I-drain for all 70 LNA stage used in the 18-26 GHz receiver.

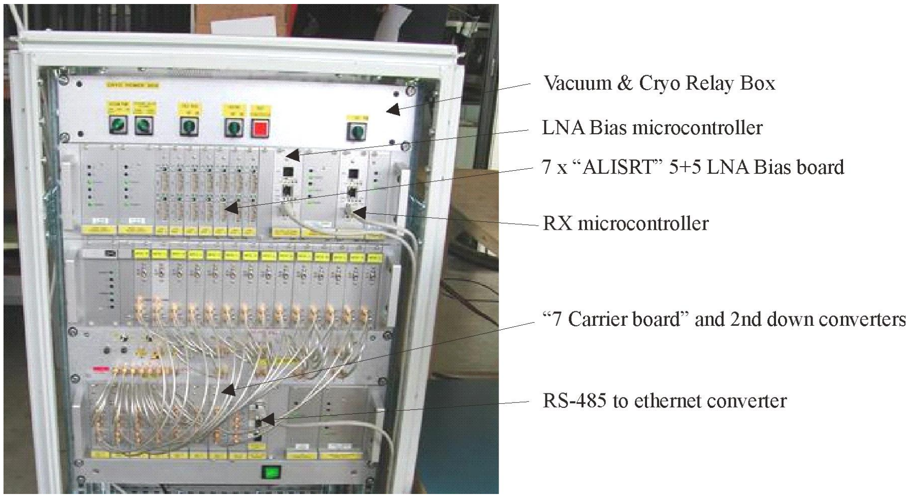

Fig. 7. Photo of the SRT K-band seven-beam receiver control system

A second microcontroller board located into the same sub-rack, is dedicated to control the other main physical parameters of the receiver (vacuum, cryogenics, temperature, etc..). High power relay circuits that control the vacuum pump, the heaters etc.., are located in an external box.

A third microcontroller board, called "carrier board" was designed to enable the remote control of the RF circuits used in the second downconverters. The carrier board hosts an aluminium box containing the RF circuits. Seven boards controlled by a RS485 local bus act as a second downconverter for the dual polarization multibeam receiver. A RS485-to-ethernet interface connects this set of microcontroller to the LAN.

7.2 Backends

A three-way focus selector box with 14 channels integrated with a total power backend was developed for SRT. The main task of the focus selector box is to select the IF signals coming from the receivers located at the three focal positions (primary, Gregorian, and BWG). The system was designed to be modular in order to be easily upgraded. Each focus selector module process one single IF for each focal position. One rack with 14 modules and one controller can manage up to seven dual polarization feeds. A programmable filter bank allows to select among four output bandwiths (100-250MHz, 100-650MHz, 100-1200MHz or 100-2100 MHz). Two outputs are available for external backends (analog or digital) to be developed. An internal detector can be used for continuum observation. The detected signals are digitally converted by a voltage to frequency converter and accumulated into 14 counters each having 24 bit length; they are located inside the controller FPGA. A fast synchronous switching of the cal noise source overcomes RF gain variation from data acquired. The sampling rate of the system is programmable from 1 msec to 1 sec. The nominal resolution changes with sample rate, at 1 sec is 21 bit, while decreases to 11 bit at 1 msec. A single board computer running Linux OS configures the different parameters of the system and send the acquired data to a host computer by the local area network. The backend will soon be installed to operate with the K-band dual polarization seven-beam SRT receiver which is currently under test at the Medicina station.

Analog and digital pulsar backends are also under development together with a spectral line facility.

Fig. 8. Photo of the total power backend.

8. CONTROL SOFTWARE

The SRT control software, named NURAGHE, is based on the Advanced Control Software (ACS), developed by ESO for the ALMA project [17]: ACS provides the communication channel between the distributed objects, gives a centralized logging system, an error and alarm system and a central configuration database as well. The NURAGHE software is written in C++ with Trolltech QT libraries for the graphical user interface, and is organized in subsystem (see Fig. 9), following the ACS component/container model.

The antenna pointing system is almost finished and first tests are started on Medicina telescope. It will provide the pointing and tracking of three kind of objects (stars, planets and moving bodies). The coordinate can be typically provided by users in horizontal, equatorial and galactic coordinates, or as orbital parameters for the moving bodies.

Some graphical interface are planned to make the telescope interactions and observation configuration easiest as possible. In the same way users can plan a schedule composed of many observations and test it off line without waste telescope time. Other interfaces are planned to control and monitor the telescope activity and the flowing of schedule as well.

Data acquisition and archiving are already planned following the MBFits standard protocol [18] and implementation of many different scan and mapping modes for typical single dish activity are undergoing.

It is also under development the active surface control software, a system for control and monitor of the 1116 primary reflector actuators [19], deployed in a private network and moved together on elevation basis.

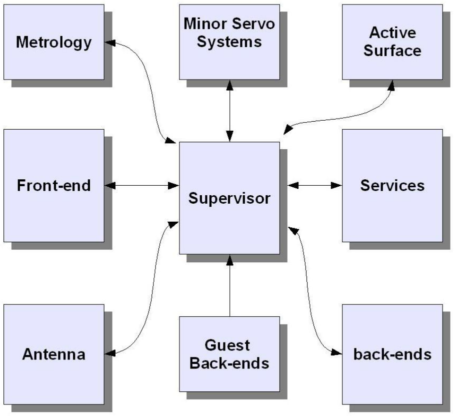

Fig 9. NURAGHE system

9. SITE FACILITIES AND FORTHCOMING DEVELOPMENT

A shared (general) view of a radio astronomical observing facility must address two main operational blocks: the telescope itself and its supporting infrastructures. We therefore refer to a "telescope" as a whole, including structural mechanic frame (and related servo systems), receivers, cryogenic facilities and so on. Infrastructural elements do include both buildings and services, which range from electric power supply (network and uninterruptible) up to computing services and ancillary technical infrastructures. So it is the Sardinia Radio Telescope project organization, where six internal teams are carrying out specific activities in order to provide a fully operational radio astronomical station for the time being: a short description of the six work packages will follow.

9.1 SRT Local Area Network

SRT local area network (LAN) topology has been designed to provide robust and redundant links between antenna facilities and central computing area, where backends, digital correlator, VLBI station etc. will be located. Further two subnets will connect local personal computing facilities (laboratories and/or offices), as well as ancillary or delocalized computing / data acquisition facilities. SRT LAN network topology, which does not follow a specific "canonical" approach for interconnecting all these nodes, will rely on a fiber based MM 10GbE backbone. This fiber link will interconnect the antenna with the Station main routing facilities, where the Wide Area Network fiber cable will be positioned. From here, distribution inside station buildings will be a mix of SM 1GbE fiber – connecting the main switching facilities with the peripheral ones - and Cat. 6a copper. Extimated number of end user nodes is relatively low, about 150.

9.2 SRT supercomputing facility

Quite recently, the INAF – Cagliari Astronomical Observatory, as a member of the Cosmolab consortium, did get approved and funded for the realization of a High Performance distributed computing infrastructure, interconnected with a dedicated multimode fiber optic network. Once completed, the Cybersar project will have six computing sites: the high bandwidth between them, the reliability of distributed parallel network filesystems and of the grid middleware software will allow to configure all sites as part of single cluster distributed on each site, a so called "OptiPuter". INAF owns two of these computing clusters, and one of this will be installed at the SRT site. This cluster is made with 60 rack mount servers IBM x3455, each one hosting two quad-core CPUs, 32 GB RAM, interconnected by an InfiniBand link.The cluster provides also a 12TB safe storage area. The high speed connection between sites and with the GEANT network makes SRT ready to be included into the EVN network. The ATNF DiFX [20] and NRAO-DiFX [21] software correlators are under testing at the INAF-OAC cyberSAR cluster. Both correlators work in HPC environment and ATNF-DiFX is ready to work also in a grid environment, once completed the high bandwith network across the CyberSAR sites.

9.3 VLBI terminal

Since its first light, the Sardinia Radio Telescope will be ready to join the Very Long Baseline Interferometry (VLBI) international community. In order to fulfil this goal, a DBBC (Digital Base Band Converter) and Mar5C recording facilities will be available on site; correlation step of the Mark V data will still be done at JIVE, the European Institute for VLBI.

But the operational phase of SRT will be also the kick-off time for the Italian VLBI network, where the three INAF antennas (Medicina, Noto and San Basilio) will define a subnet of the whole European VLBI Network (EVN). Since then, two further activities are currently being carried out, as part of the High Performance Computing: the development of a software correlator (see section on Supercomputing on this paper) and the set up of an infrastructure ready for running the forthcoming correlation methodology, the electronic VLBI, or shortly "eVLBI". Instead of physically sending the MarkV hard discs, this rather new technology - the first eVLBI experiment dates back to 2004 – allows for a realtime transfer of the observational data which are being acquired at each radiotelescope. This methodology dramatically improves the observational techniques, provided that large broadband link (from 512Mb/s up) between the observing site are available. In order to perform eVLBI runs, SRT will make use of the Cybersar infrastructure, currently under construction, where such a broadband will be actually available.

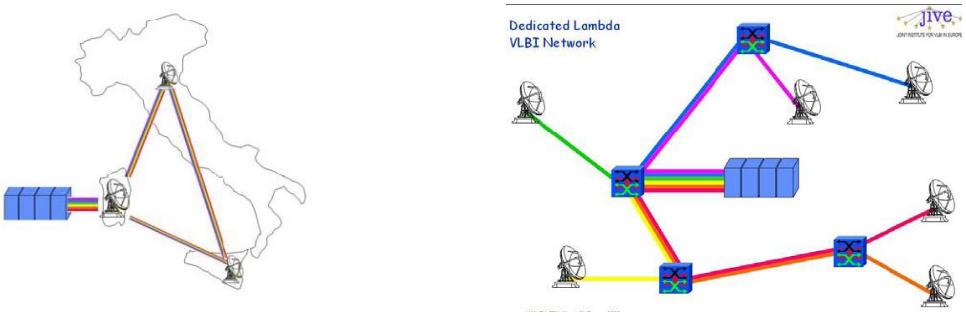

Fig. 10. Schematic of VLBI networks.

9.4 Atmospheric Site Monitoring

The tropospheric water vapour in the atmosphere is one of the main causes for the astronomical signal attenuation at millimetre wavelengths. Single-dish observations in the 3 mm atmospheric window can be efficiently performed only under appropriate atmospheric conditions with low water vapour content, typically during the winter season. Because of the high variability of the water vapour that introduces a delay in the phase of the received signal, mm-VLBI observations may be prevented, unless its contribution is properly taken into account. Therefore, an accurate measurement of the atmospheric integrated water vapour (IWV) is required. The measure of the IWV allows also to efficiently plan the high frequency observations through a flexible or "dynamic scheduling".

The atmosphere at the SRT site has been characterized using a 50-year long radiosounding time-series measured at a launch site located near the telescope (at about ~35 km). A radiative transfer model for the millimetre spectral range [22] was used to derive the atmospheric properties.

The SRT will be equipped with a real-time atmospheric monitoring system. A new microwave radiometer (MWR) will be soon available at the site. The MWR measures the water vapour and the liquid water microwave emissions in the atmosphere and provides a real-time estimate of sky opacity and IWV. The IWV will be measured with an accuracy of at least 1 mm.

A geodetic GPS is operated at the site since 2006 as ancillary sensor. The aim is to retrieve the zenithal path delay in quasi real-time. Both hydrostatic and wet path-delay are routinely estimated from GPS using automatic procedures.

A weather station located at the SRT site (see Fig. 2) provides the ground meteo data that will be used for the observations as well as for the radio telescope safety (extreme adverse weather conditions will require to stop the observations). In order to determine the geological stability of the site on a local scale, a very precise geodetic network will be defined and measured. The network is being defined by taking into account of the conformation and the geological nature of the site.

9.5 Radio Spectrum Protection Activity

An important aspect for the radio astronomical station is the Radio Frequency Interference (RFI) monitoring system. The amplitude of artificial man-made signals are typically orders of magnitudes larger than the astronomical signals to be detected; then RFI can reduce the observing sensitivity or even totally hide the natural radiation coming from the sky. The primary goal of the spectrum protection activity will be to continuously monitor the frequency bands allocated to the Radio Astronomy Service (RAS) by the International Telecommunication Union and promptly react to any new non-legitimate occurrence of RFI. Secondly, it will be used to verify the statistical occupancy of other frequency bands non reserved to RAS, as the starting information to predict how any new developed mitigation technique will be able to open new fruitful observing bandwidths to the radioastronomy research. Finally, since SRT will also be used for Space Science and Deep Space Network activity, the RFI monitoring system will also cover the frequency bands allocated to the deep space communications: Space-Earth-Space down/uplinks (up to Ka band).

All of these activities are undertaken by almost the same persons who follow, at the Italian (and by now also European) level, the regulatory aspects of the Spectrum Management. We have experienced that only a tight collaboration between these to fields of actions, experimental and regulatory, can give the best confidence in achieving, at the time of the planned observations, the theoretical sensitivities that can be expected from the present National band plan frequency band assignments to the radioastronomy service.

In the last years, many RFI campaigns were performed around the SRT area using the 0.1-12 GHz mobile unit of the Radio Astronomy Institute (Bologna, Italy). At the present time a preliminary RFI monitoring system, operating up to 3 GHz, has been installed on the top of a 12 m height tower located within the SRT site (see Fig. 2). It consists of a commercial single linear polarization Log-Periodic Dipole-Antenna with flat gain (5 - 7 dBi) operating in the frequency band: 0.3-5 GHz. The antenna is supported by a two-axis rotor allowing full azimuth pointing as well as the polarization orientation. The antenna is connected to a receiver box where three microwave pass-band filters (295-425, 1250-1740 and 2105-3355 MHz,) remotely switched, feed a microwave amplifier, providing typically 35 dB gain over the full bandwidth. The output signal is sent to the laboratory through a 55 m long coaxial cable where a 2.9 GHz HP spectrum analyser analyse the Spectrum.

In order to monitor the RFI across the L-band (1.3 - 1.8 GHz) of the dual frequency coaxial receiver (for more details about the receiver see section 6) a specific Log-Periodic Dipole-Antenna was designed, manufactured and finally tested in an anechoic chamber. This antenna has gain larger than 11 dBi (peaks up to 13 dBi) and good impedance match in the whole band [23].

The current activities on the RFI issues are:

- Bidding call for a mobile unit dedicated to the RFI monitoring. Together with the fixed station, this is the only strategy suitable to collect as many triangulations as needed for the precise determination of the location, emitting the interfering signal.

- Evaluation about the necessity to install a Faraday room at the SRT station to shield electromagnetic emission from the computational facilities.

- Upgrade of the receiver box to extend its maximum operational frequency (up to 40 GHz) and to reduce its noise figure.

- Participation to meetings with public and private bodies (police force, forest ranger) which use portions of the EM spectrum in the proximity of SRT in order to harmonize as much as possible the different services.

9.6 Time and frequency references

A Time&Frequency laboratory has been operating at the Cagliari Astronomy Observatory since the seventies. The laboratory participates in the calculation of the international time scales by sending its clock data to the BIPM (Bureau International des Poids et Mesures,) whose goal is to realize and disseminate the universal time. The current uncertainty of the local time scale is about 7.1 nanosecond. The laboratory is currently equipped with two commercial cesium clocks (HP-5071A) characterized by excellent long-term stability; the clocks provide the definition of the PPS (pulse per second) sufficiently accurate for most applications. The laboratory is also equipped with a Time Interval Counter having a resolution of 20 ps, and of a multichannel GPS receiver for the timing.

The Time&Frequency laboratory, which will be moved to the SRT site, will provide a precise time reference during the astronomical observations and will be used by the geodetic GPS receivers. Two H-masers with very high short-term stability will be added to the present configuration in order to lock the local oscillators of the SRT receivers during VLBI observations and the most challenging space science experiments. This new Time&Frequency laboratory will offer unique top performance in support of all metrology activity planned for SRT. This site will become soon one of the very few location in the world where a cross comparison (or co-location) of different techniques like VLBI, GPS, local surveys and extremely precise time transfers will be available.

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