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SRT: design and technical specifications

L. Olmi[1], G. Grueff[2]

[1] INAF–Istituto di Radioastronomia, Sez. di Firenze, Largo E. Fermi 5, I-50125 Firenze
[2] INAF–Istituto di Radioastronomia, Via P. Gobetti 101, I-40129 Bologna

Abstract. The Sardinia Radio Telescope (SRT) is a general purpose, fully steerable radio telescope currently being built in Sardinia, that will be operated by the National Institute for Astrophysics (INAF). The SRT will be a large-aperture antenna (64-m diameter) with a classical Gregorian configuration and the possibility to use three different focal positions. The primary and secondary reflectors are shaped to minimize spillover and the standing waves between the feed and the subreflector. The primary active surface will give the SRT the possibility to operate in the 3-mm band, and will thus contribute significantly to many science areas. At present, the foundation of the antenna is almost complete, and the components of the alidade and of the track are under construction.

1. Introduction

The SRT project has been proposed and managed by the Istituto di Radioastronomia, formerly a scientific structure of the National Research Council (CNR) and now belonging to INAF. The project is funded by the Italian Ministry of University and of Scientific and Technological Research (MURST) and by the Sardinian Regional Government. The SRT project aims to construct a general purpose, fully steerable, 64-m diameter "shaped" radio telescope capable of operating with high efficiency from 300 MHz to over 100 GHz. When the active surface will become fully operational, the expected antenna efficiency will range from the maximum value of about 63% (at 10 GHz) to about 35% (at 100 GHz).

The selected site (Lat 39° 29′ 50″ N, Lon 09° 14′ 40″ E) is the area named "Pranu Sanguni" close to the town of San Basilio, about 35 km North of Cagliari, and is at about 700 meters above sea level. This site is characterized by low radio frequency interference, it is reasonably dry during the winter season and, finally, it is located in an orographic depression that acts as a natural wind-screen (the recorded average wind speed is about 4 m/s).

The SRT will be used as single-dish and also as a fundamental component of the enhanced VLBI network. The combination of multiple focal positions and a wide frequency range will offer the users of the SRT a great flexibility. The main antenna geometry is a shaped reflector system pair, based on the classical Gregorian configuration. The shaped surfaces eliminate the multiple reflections between the secondary and the feed, while optimizing field-of-view and antenna efficiency.

2. Mechanical structure

The antenna design is based on the classical wheel-and-track configuration (Fig. 1). The main reflector consists of a backstructure which, through several actuators, supports the surface composed of rings of reflecting panels. The primary reflector surface consists of 1008

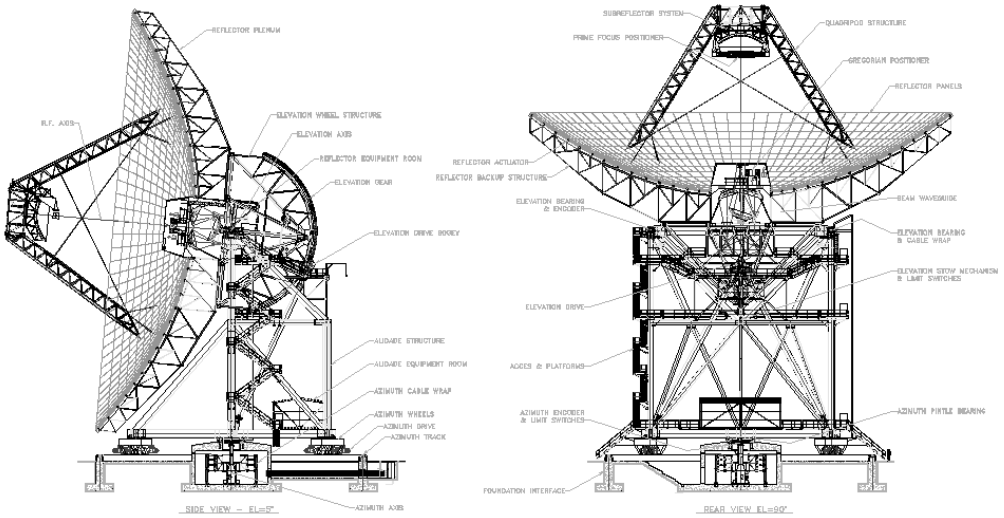

Fig. 1. Schematic view of the SRT.

individual aluminum panels (with a panel manufacturing RMS $< 70\,\mu$m), with a surface area between 2.4 m^2 and 5.3 m^2, which are divided into 14 concentric rings. The actuators system is composed of 1120 precision actuators (maximum error 15 μm) under computer control, to compensate gravitational and thermal distortions of the backstructure. The subreflector surface consists of 49 individual aluminum panels (with a panel manufacturing RMS $< 50\mu$m), having an average area of about 1 m^2, with one central panel and the other 48 panels assembled into 3 rings. The position of the subreflector relative to the primary mirror is constantly controlled in real time by means of six large precision actuators and an elaborate metrology system.

A quadrupod connected to the backstructure supports the subrefector, the prime focus positioner and instrumentation. The SRT alidade is a welded steel structure on a large concrete tower that forms the bulk of the antenna foundation. A pintle-bearing at the top of the tower provides support against lateral loads. The mechanical design provides a nearly uniform loading condition on the reflector in order to maintain symmetry (homology) in the surface deflections. The reflector backstructure is attached to the elevation wheel through a massive pyramidal structure. This design allows the construction of a large room within the alidade for installing instrumentation at the Gregorian and Beam Wave Guide (BWG) focal positions.

One advantage of the Gregorian configuration is its capability to have prime focus instruments that can be positioned and moved away when necessary for observations from the Gregorian or BWG focal positions. To access the prime focus on the SRT a rotating arm is eccentrically mounted near the secondary mirror. It may house several feed horns and associated cryogenic receiving systems for operating over a range of radio frequencies from 300 MHz to 20 GHz. A drive system can rotate the arm and then two servo-motors can move the selected feed assembly into the position of the prime focus.

3. Optics

As mentioned earlier, the SRT optical design is based on the classical symmetrical Gregorian configuration (Fig. 2); however, the primary and secondary surfaces are "shaped", i.e. they cannot be described with a classical conical or

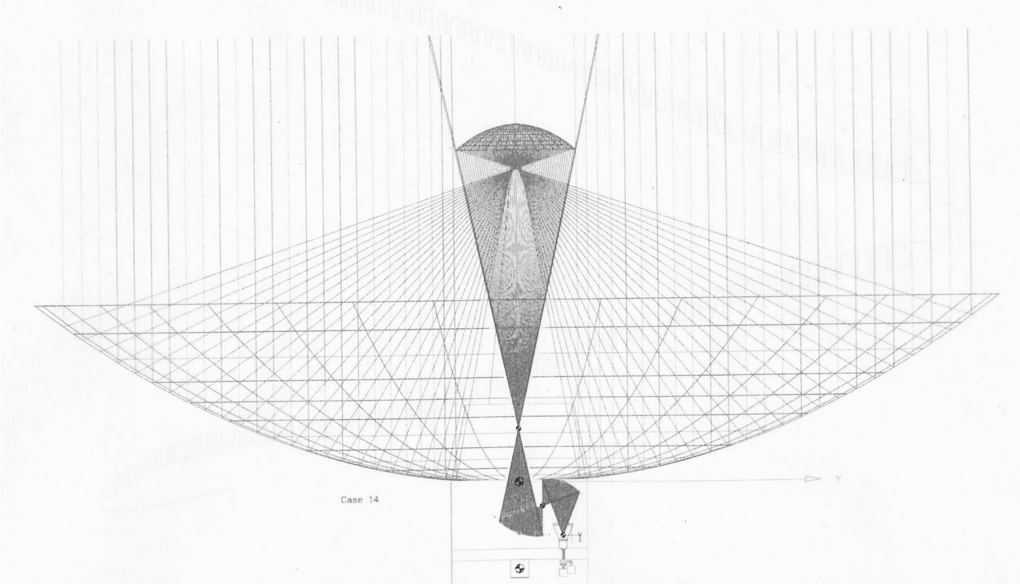

Fig. 2. Optical configuration and ray tracing of the SRT.

aspherical surface and are given in terms of a table of sags, with rotational symmetry, as a function of the radial coordinate. In the past, the introduction of shaped surfaces in antenna design had the purpose to provide the maximum antenna efficiency for tracking or observing point sources. The condition of maximum antenna efficiency naturally leads to having uniform illumination over the antenna aperture, which cannot be achieved with any standard feed-horn. As a consequence, design techniques have been developed where special surfaces, which can be calculated numerically, accept the non-uniform illumination of the feed and redistribute it uniformly over the antenna aperture (Galindo 1964; Collins 1973). The conservation of energy flow along the ray trajectories, the condition of uniform illumination over the antenna aperture and the application of Snell's law are sufficient to completely specify the antenna surfaces.

However, antenna systems shaped for optimal axial performance fail to meet the basic criteria required for reasonable off-axis performance, because they violate the Abbe sine condition (Hudson 1989). The predominant off-axis aberrations are severe coma and field curvature. For this reason, the SRT optics were designed to increase the field-of-view (FOV) for off-axis imaging scanning, by using reflector shapes close to the classical Gregorian system, but with reduced center illumination of the subreflector (Cortes-Medellin 2002) to minimize multiple reflections between the feed and the secondary mirror, which have adverse effects on spectroscopic observations. In addition, the SRT shaping design also reduces the main reflector edge illumination resulting in low sidelobes and low antenna noise temperatures (Fig. 3). Thus, the SRT shaping achieves a trade-off between antenna efficiency and extent of the FOV, which will not prevent the use of heterodyne focal plane arrays (Olmi, these Proceedings). The resulting FOV at the Gregorian focus is, e.g., more than $4'$ at 22 GHz and about $1'$ at 100 GHz.

4. Active surface

At high frequencies, and particularly in the 3-mm band, the SRT becomes electrically very large ($D/\lambda > 2\times10^4$) and thus an actively controlled surface (ACS) is required to adjust the surface sections in (quasi-) real time to main-

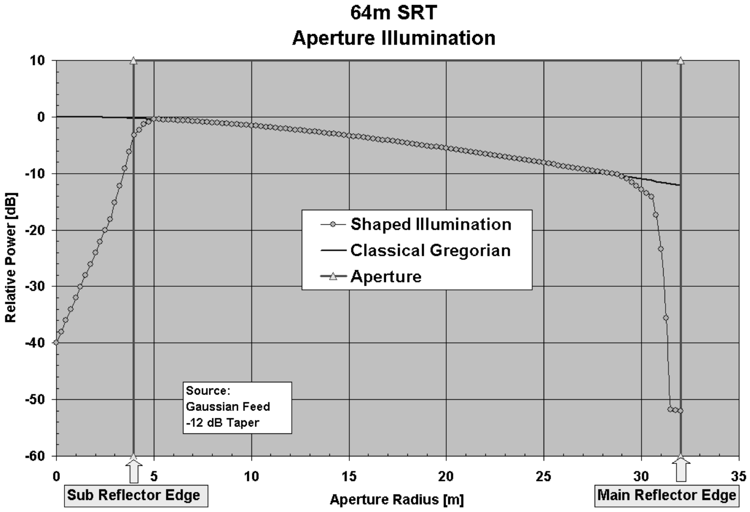

Fig. 3. SRT aperture illumination.

Table 1. Focal positions and frequency ranges of the SRT

Focal position	Frequency range (GHz)	F/D ratio
Prime	$0.3< \nu <20$	0.33
Gregorian	$7.5< \nu \lesssim 100$	2.35
BWG	$1.4< \nu <35$	1.37 & 2.84

tain the nominal shape of the primary reflector. The ACS mainly consists of a series of sensors and an active control system to compensate repeatable gravitational deformations, thermal deformations with long ($\gtrsim$ 0.5 hr) time-scales, and possibly quasi-static wind loads. In the SRT the ACS will also be used to convert the shaped primary reflector into a paraboloid for operations at the prime focus.

The development of the ACS and metrology system for the SRT is still ongoing, but it is likely to be very similar to the Flexible Body Compensation (FBC) system proposed for the Large Millimeter Telescope (LMT). This technique uses panel actuators, thermal sensors, inclinometers and a focus-center device for correcting the subreflector position. Therefore, this method relies on a correct understanding and modeling of the telescope structure, which is different from, e.g., the Green Bank Telescope (GBT) approach, where the geometrical shape of the deformed surface is measured directly, with a huge sensing effort (Olmi 2003 for a review).

5. Receivers and focal positions

One of the special characteristics of the SRT is the availability of three different focal positions, summarized in Table 1, to operate in different frequency ranges. The use of the prime focus position is possible also at relatively high frequencies, thanks to the ability of the active surface to convert the shaped primary reflector into a paraboloid, and can be accessed through the Prime Focus positioner assembly described above. It will be used mainly for P- and L-band receivers. The Gregorian focal position is located on the upper level of the tilting receiver cabin, and can be accessed by up to eight receivers, for operations from 7.5 GHz to the 3-mm band, housed on a rotating turret 3.7 m in diameter (Gregorian positioner assembly; see Fig. 4). The turret is also provided with a circular hole to illuminate the BWG optics located on the lower level of the receiver cabin.

The BWG optical system consists of an axial rotating tertiary mirror and fixed relay mirrors to provide up to four additional focal

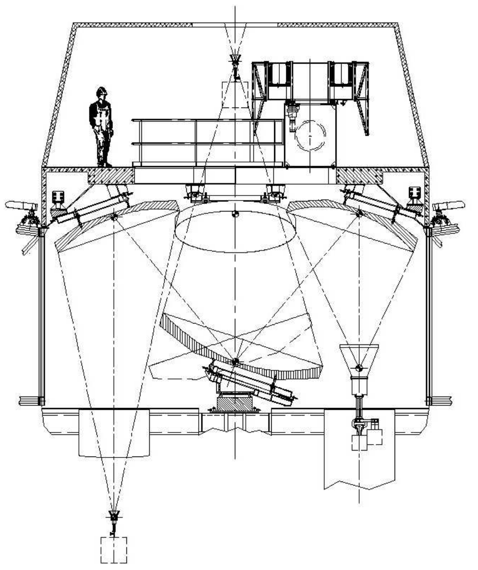

Fig. 4. Receiver cabin of the SRT with the Gregorian positioner assembly and the BWG system.

points. The two BWG layouts currently designed provide two different focal ratio transformations: the BWG-I layout converts the Gregorian focal ratio, from $F = 2.35$ to $F = 1.37$, whereas the BWG-II layout converts from $F = 2.35$ to $F = 2.84$ and was designed such that the output focal point lies beneath the elevation axis of the antenna. The BWG focal positions will be used at frequencies between about 1.4 and 35 GHz. The BWG focus can also host transmitting equipment, suitable for Space Radio Science and the active tracking of spacecraft.

6. Current status of work

The foundation of the telescope is a circular ring of reinforced concrete with a diameter of about 40 m. Its design is based on an octagonal structure, consisting of concrete arms that connect the central room to the perimeter wall that will support the antenna track: this structure is almost completed (Fig. 5). The contract for engineering and fabrication of the mechanical structure has been awarded to MAN Technologie AG (Mainz, Germany), and the beams and nodes components of the alidade are currently under construction (Figs. 6 and 7). Shipping to Sardinia and installation on site should be completed by the end of 2006. The contracts for the fabrication of the primary and secondary reflector panels have been awarded to Cospal (Bergamo, Italy). The contract for the fabrication of the panel actuators system has been awarded to Vitrociset (Rome, Italy). All the mechanical parts (AZ track and wheels, EL-gears, bearings, etc.) have already been fabricated at several factories in Germany and Italy (e.g., Fig 8).

Fig. 5. Aerial view of the current status of the SRT foundation.

Fig. 6. A series of alidade beams already completed.

Fig. 7. One of the structural nodes of the alidade.

Fig. 8. One of the wheels that will allow the AZ movement of the SRT.

7. Conclusions

The SRT is one of the next-generation cm- and mm-wave single-dish telescopes currently under construction and will constitute a highly flexible, sensitive antenna that will also significantly contribute to the Italian, European and international VLBI networks. Its novel, shaped design will allow high-sensitivity spectral observations and will also have a field-of-view large enough for populating the Gregorian focal plane with arrays of receivers. The SRT will be capable of operating with high efficiency in a wide frequency range, and particularly in the astronomically important 3-mm wavelength band. Commissioning of the telescope and “early science” observations are expected to take place during the year 2008.

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