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How to improve the High Frequency capabilities of SRT

T. Pisanu[1], M. Morsiani[1], C. Pernechele[2], F. Buffa[2] and G. Vargiu[1]

[1] Institue of Radio Astronomy (CNR), via P. Gobetti 101, 40129 BO, Italy
[2] Astronomical Observatory of Cagliari, loc. Poggio dei Pini strada 54, 09012 Capoterra(CA), Italy

Abstract. The SRT (Sardinia Radio Telescope) is a general purpose, fully steerable, active surface equipped, 64 meters antenna, which is in an advanced construction state near Cagliari (Sardinia - Italy). It will be an antenna which could improve a lot the performances of the EVN network, particularly at frequencies higher than 22 GHz.

The main antenna geometry consist of a shaped reflector system pair, based on the classical parabola-ellipse Gregorian configuration. It is designed to be able to operate with a good efficiency in a frequency range from 300 MHz up to 100 GHz. This frequency range, is divided in two parts which define also two antenna operational modes, one up to 22 GHz with a minimal amount of accessory instrumentation, and the other up to 100 GHz with a full complement of instrumentation.

The goal is to make it possible to build a telescope operable up to 22 GHz, and then upgrade it at a future date to operate at frequencies up to 100 GHz.

In order to get these goals, the SRT Metrology group is studying and developing different types of strategies, instrumentation, and techniques for measuring and reducing the various components of pointing and efficiency errors, taking advantage also from experiences developed in other radio telescopes, like GBT (Green Bank Telescope, USA), LMT (Large Millimiter Telescope, MEX), and IRAM (Institut de Radio Astronomie Millimetrique, Fr).

Many of those system will be installed and tested at the 32 meters radio-telescope in Medicina (Bologna), before of their implementation on SRT.

1. Introduction

The causes which mainly contribute to a degradation in pointing and gain efficiency of a Radio Telescope, can be divided in two main classes: repeatable errors (for example mechanical errors during initial alignment, gravity deformations) and more critical, non-repeatable errors (thermal gradients and wind effects).

The performances of the antenna in pointing and surface accuracy, clearly depends on environmental conditions, better with benign conditions, and degraded when the environment is severe.

SRT weights more than 3000 ton and has a diameter of 64 meters. According to von Hoerner (1) the maximum rms surface value for a millimeter-wavelength telescope of 64 meters, is $\sim 2mm$, which means a λ_{min} of $\sim 9GHz$ using the empirical rule of $\lambda_{min} \sim 16\sigma$.

To have a good efficiency at 100 GHz, the root-mean-square accuracy of the reflector surfaces, should be of $\epsilon \sim \lambda/20 \sim 190\mu m$, and the precision for non-repeatable pointing at 100 GHz, should be a tenth of the beam width, i.e., 1 arcsec in good environmental conditions, which means without solar radiation, no precipitation, air temperature between -10^o C and 40^oC, a temperature drift $< 10^oC/h$ and an humidity $< 90\%$.

To compensate those errors, we are testing different subsystems for measuring and compensating the causes.

The sub-systems that we are studying are: a **laser with a PSD** (Position Sensing Device) system for measuring the subreflector position, a **temperature probes** network for measuring and predicting thermal deformations on the supporting structure, a **star tracker** system for assisting pointing model upgrade and source tracking, **anemometers** and pressure probes for measuring wind effects, a **FEM model** of the antenna for assisting the metrology development and for predicting wind and thermal deformations, **two inclinometers** for measuring aliadade and rail track deformations and a **laser ranging** system for measuring structural dimensions.

2. Sub-reflector alignment

To achieve the required pointing accuracy for the SRT 64-meter telescope, the position of the subreflector must be accurately known relative to the vertex of the main reflecting surface.

A laser metrology system with five degrees of freedom is the ideal technical solution.

The system shall consist of a stationary laser and a 20 meters far away head sensor, able to measure its more important degrees of freedom.

A system which could satisfy our requirements, is that produced by Apisensor (www.apisensor.com), the API 6D Laser Measuring System, with a linear range up to 25 meters, a linear accuracy of 1 p.p.m, a straightness accuracy of $1\mu m$ and an angular accuracy of 1.0 arc-second.

We are also testing a less expensive system, using a solid state laser, with a PSD from Duma Optronics (www.duma.co.il), the model AlignMeter PC. In this case, the head sensor has two $10 \times 10mm$ dual axis silicon Lateral Effect PSD, one for measuring the translations perpendicular to the laser beam direction and the other one, which is in the focal plane of a lens, measure the angular deviations.

The position resolution is better than $\pm 1\mu m$, and the angle resolution is $\pm 2arcsec$, the operational spectral range goes from 300 to 1100 nm.

3. Temperature monitoring

A network of temperature probes distributed on the whole structure, (alidade, backstructure of the primary mirror, primary panels, quadrupod and secondary mirror) has been also foreseen.

Because we have abandoned the originally planned thermal insulation and forced ventilation of the reflector surface, as is at the 30 m IRAM telescope(2), this network of temperature sensors is very crucial.

The optimal position of each probe will be set through a FEM analysis software which, according to the measured temperatures, will drive the active surface actuators in a open loop fashion.

The sensors which we acquired and tested in the laboratory, are Negative Thermistors NTC from YSI, model GEM 55036 with a Resistance Ω at 25^oC of $10k\Omega$ and a tolerance interchangeability of $\pm 0.1^oC$ from 0 to 70^oC.

We performed few laboratory test, introducing our sensors in a cooler and measuring their responses from -20 up to 70^oC. The results are in a very good accordance with predictions.

4. Optical Star Tracker

The pointing model and the tracking, will be supported by an optical star tracker (OST), which we are planning to develop and to use also in daylight situations.

In order to have enough sky coverage it will be realized by using a commercial Maksutov-Cassegrain optical telescope with a primary diameter of 180 mm and an aperture of f/10. The CCD will be a peltier cooled 512x512 pixels with 20 micron of pixel size. The covered field of view results of 19 x 19 arcminutes, while the plate scale is of 2.3 arcsec/px. The latter seems to be well compatible with the typical atmospheric conditions of the site.

Initially we are planning to use the OST only for monitoring purposes, of the pointing model and of the antenna servo system. The last step will be one of realize the auto-guide during day time, using a IR filter able to cut off the visible wavelenghts.

5. Pressure probes

The wind pressure sensor system hardware is required for good pointing accuracy whenever the wind is in excess of ”precision” wind conditions.

The accuracy of this hardware will greatly impact the pointing, focus, and surface accuracies of the telescope.

The wind pressure sensor hardware shall operate at full accuracy when subjected to ”Normal” operating conditions, i.e., an ambient temperature range of -10 C to +40 C, with humidity 90%. When operating in ”Extreme” conditions, i.e., -15 to +50 ^oC, degraded accuracy is permitted. All components shall survive (non-operating) in temperatures down to 30 ^oC.

From the FEM model, we have found that for having a good are necessary a total of 152 sensors are used. This number of sensors gives significant redundancy and hence high availability to system

6. The Finite Element Model

The improvement in the predictions from FEM software simulations, involved us to use it as a diagnostic tool for knowing the more critical points in the antenna structure and for knowing the thermal and wind effects on it.

There are many studies related to the use of FEM simulations for predicting and correcting non-systematic errors in radio-telescopes.

We already have at home the FEM model of the antenna, developed for us by BCV consulting with the ANSYS software, for evaluating the compatibility between the preliminary project and the executive project.

Once that the structural critical point have been selected, we can use the FEM together with the measured temperature and wind pressures, for predicting and correcting the pointing and efficiency errors.

7. Inclinometers

The tilt meter subsystem will consist of two bi-axial tilt meters, with one tilt meter located near each of the elevation bearings.

The purpose of the tilt meters is to measure changes (due to wind and temperature) in the orientation of the elevation axle relative to the encoders. Once these rotations are measured, a portion of the pedestals pointing error can be calculated and then removed.

A described before, the metrology system, uses wind pressure sensors, thermal sensors, and subreflector laser metrology to compute and correct for pointing errors.

The information from the tilt meters will be used mainly as a sanity check and redundant back-up system.

8. Laser RangeFinders

Finally, the possibility to install laser rangefinders for monitoring the primary reflector surface deformation, and if necessary the pointing with the help of triangulation algorithm, as foreseen also for the GBT, is under study.

9. Conclusions

The possibility to use SRT up to 100 GHz, will depend from the performances of the metrology system mounted on it.

We are involved into the study of different sub-systems, for measuring and correcting the structural deformations produced by gravity, temperature gradients and wind.

Few of those sub-systems are redundant, because of their unknown performances and so we are experimenting more than one in such a way that we could use the more performing.

References

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