INTERNAL REPORT

Perspectives for the Sardinia Radio Telescope as a SETI facility

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ABSTRACT

The Sardinia Radio Telescope (SRT) is a new 64-meter radio telescope operating in the 0.3-115 GHz frequency range, and is designed for both single-dish and interferometric observations. It is equipped with programmable digital backends that allow for a wide variety of scientific studies. This includes effective SETI-mode observations. In this paper, we present an overview of the SRT hardware/software digital processing platforms, with particular emphasis on those which will soon be available.

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1. INTRODUCTION

The Sardinia Radio Telescope (SRT) is the largest radio telescope in Italy and was recently inaugurated in Sardinia, 35 km north of Cagliari. It is a general-purpose, fully-steerable radio telescope designed to operate in the 300 MHz – 115 GHz frequency range. Thanks to these features, a wide variety of scientific studies are possible, including Search for Extra Terrestrial Intelligence programs. The advanced electronic digital platforms that are installed at SRT play a key role in this, in particular those based on FPGAs (Field Programmable Gate Array), both because of their processing capability and their reconfigurability. In this paper, we present an overview of SRT, then focus on the digital backends that we will use for SETI-mode observations. Finally, we mention all of the mathematical methods that will be applied to the acquired signals.

2. AN OVERVIEW OF THE SARDINIA RADIO TELESCOPE

SRT is a new Italian radio telescope with a diameter of 64 meters that is situated in a locality called Pranu Sanguni, near Cagliari. Despite not being one of the top largest radio telescopes, its active surface makes SRT the second-largest radio telescope in the world with this technical feature.

The 1008 panels that compose the main dish are controlled and moved by 1116 electro-mechanical actuators, to maintain the highest efficiency at every elevation position. We are studying several metrology systems, [1] to correct gravitational, thermal and wind effect that modify the ideal optical configuration of the antenna. The two main operational measuring methods used for obtaining proper surface accuracy are: microwave holography and photogrammetry. We are also developing and testing other independent measurements systems like inclinometers, position-sensing devices, optoelectronic linear sensors, thermal sensors and FEM analysis.

Three receivers are currently available and operational at L-P bands [2] (305 – 410 MHz, 1.3 – 1.8 GHz), C-high band (5.7 – 7.7 GHz) and K-band (18 – 26.5 GHz, with 7-feeds) [3]. The dual-frequency L-P receiver is installed at the primary focus; the monofeed C-high band receiver is in the beam wave-guide focus, and the 7-feed K-band receiver is in the Gregorian focus. A few other receivers (a mono-feed for the lower C-low band, a 7-feed for S-band, and a 19-feed for the Q-band) are under development.

All provided intermediate frequency signals (IFs) go through a focus selector and signal conditioning system; inside the latter, an FPGA-based board performs total power calculations for each IF.

The antenna control software [4] is based on the ACS (ALMA Common Software) framework; even though it was not designed for single-dish stations, the ACS's versatility allows a very efficient use for a single-dish antenna like SRT.

SRT is equipped with different digital backends [5]: Total Power, XARCOS, Digital Base Band Converter (DBBC), Digital Filter Bank (DFB) and a ROACH board (Reconfigurable Open Architecture and Computing Hardware).

The Total Power backend, developed by the Institute of RadioAstronomy (IRA) Medicina, Italy, acts both as a focus selector and as a continuum backend. The selected signal can be attenuated (range: 0-15 dB) and then filtered selecting one of the low-pass filters (with cutoff frequency of 350, 830, 1300 MHz, respectively, or 2.1 GHz (all band)). An Actel FPGA-based controller contains 14 digital counters that count the pulses generated by the corresponding voltage-to-frequency converter; the integration time is programmable by the user from 1 ms to 0.5 sec.

XARCOS [6] is a spectro-polarimeter developed by the electronic group of the Astrophysical Observatory of Arcetri, Florence, Italy. The system is capable of acquiring and processing up to 16 IF signals, each with a bandwidth of 125 MHz, and provides full-Stokes spectra with 2048x4 channels. Several variable-decimating filters are available in order to select different values for the input bandwidth for each IF, starting from a bandwidth of 125 MHz down to a bandwidth of 0.488 MHz. Up to four sub-bands can be studied simultaneously.

The DBBC [7], developed by the IRA Noto, is the digital backend chosen by the EVN (European VLBI Network) to replace the old analog VLBI terminals. When not used for VLBI, this backend is used as an RFI-monitoring system [8] exploiting a two-stage polyphase filterbank [9], [10]; such a configuration has an excellent dynamic range, even when a spurious signal produces saturation in one of the first stage channels.

The DFB [11] is a digital platform developed by the ATNF (Australia Telescope National Facility). It is mostly used for pulsar observations (in particular folding, search and baseband modes); however, its FPGAs can be reconfigured in wideband spectro-polarimetric mode (with a bandwidth of up to 1 GHz), providing up to 8192 spectral channels.

Finally, a ROACH [12] board is used mainly for the LEAP (Large European Array for Pulsars) [13] project. However, as for the DFB, the board can be used for other purposes, in particular single-dish pulsar and spectroscopic observations.

3. A GENERAL PURPOSE WIDEBAND DIGITAL PLATFORM FOR SRT

As mentioned above, SRT is equipped with a variety of digital platforms that are applicable to a significant amount of scientific studies. However, they present both pros and cons: the Total Power backend is the only backend capable of processing the entire bandwidth (2.1 GHz) and all (up to) 14 IFs, but can be used solely for continuum studies; XARCOS can act as a full-Stokes spectrometer, but 125 MHz is the widest available bandwidth; the DFB can be used as a spectro-polarimeter as well and with a greater instantaneous bandwidth (1 GHz) than XARCOS, but only 4 IFs are available.

What is lacking is an infrastructure that can combine the aforementioned characteristics; in particular, the ideal system for SRT should be able to meet the following requirements:

- Up to 14 IFs simultaneously
- Up to 2.1 GHz of bandwidth for each IF
- Full reconfigurability and adaptability for all scientific requirements, in particular for wide-band spectro-polarimetry, wide & narrow band spectroscopy, pulsar science and Search for ExtraTerrestrial Intelligence

To accomplish these goals, we chose to use the new ROACH2 [14] boards developed by the CASPER [15] consortium (Collaboration for Astronomy Signal Processing and Electronic Research). A Xilinx Virtex6 is the centerpiece of the boards, and the available ADCs, with a sampling time of 5GSample/s, allow us to obtain a bandwidth as large as 2.5 GHz. This fits the requirements listed above perfectly. Moreover, by exploiting the two SFP+ mezzanine cards of the board, up to 80 Gbit/sec can be sent out to recording or post-processing systems. The whole system consists of eight ROACH2 boards (one of them is a spare), each board being equipped with two 5GSample/s ADCs [16]. The eight outputs of the mezzanine cards are used (via optical fibers) to connect each ROACH2 board to the other boards and to a GPU-based PC, in which a dual-port SFP+ 10 Gbe is installed. A 24-port SFP (Small Form-factor Pluggable)+ 10 Gbe is also used to interface the PCs with a 96 TB data storage unit. Figure 1 shows a block diagram of the entire system.

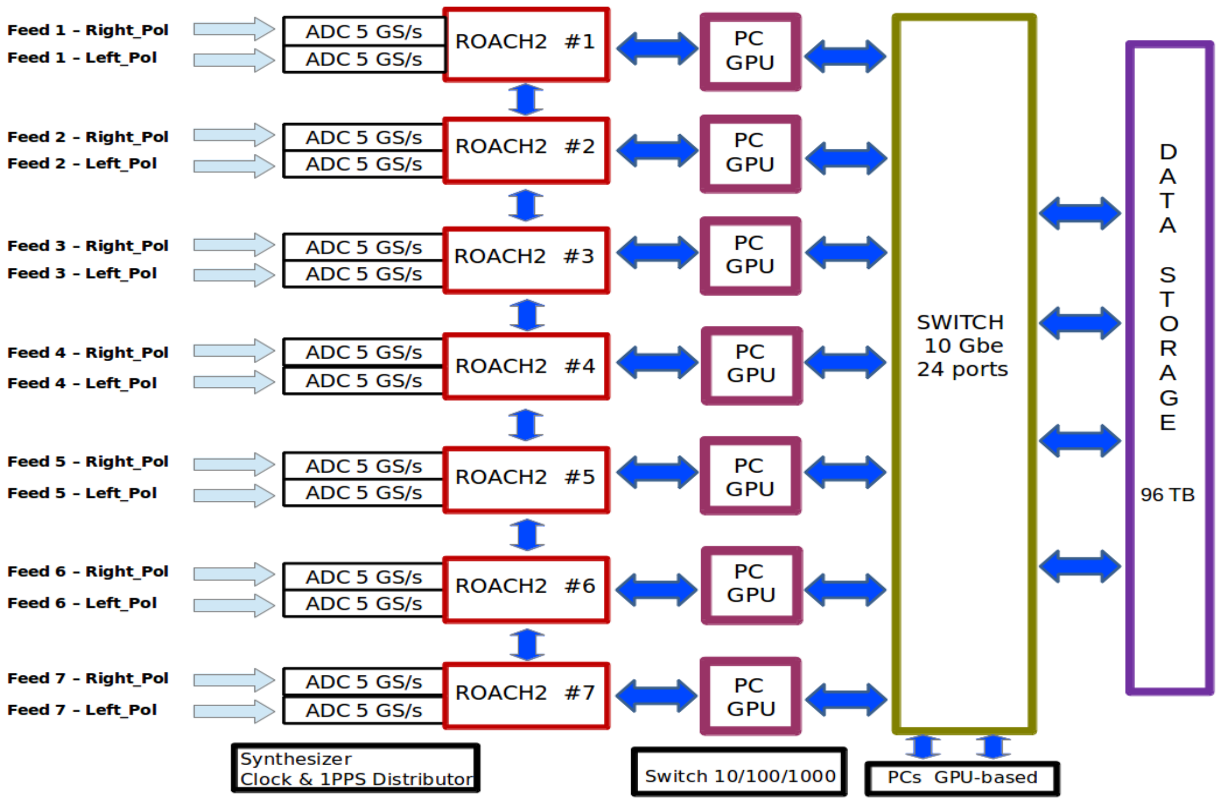

Figure 1: Wideband multi-feed digital backend suitable for SETI

Such a versatile infrastructure will be able to satisfy a large range of radio-astronomical requests, and the interconnection between all of the nodes makes it possible to optimize the available hardware and software. For instance, if a mono-feed or dual-feed receiver is being used, six ROACH2 board and corresponding PCs can be used to distribute the processing among them. The first ROACH2 board can split up the bandwidth in eight sub-bands, and the other ROACH2-PC pairs can each process one of these sub-bands; such a solution could for instance be used to operate in spectrometer modality with a very high frequency resolution. Every PC will be equipped with two powerful Nvidia GPUs GTX980 Ti. Almost 3000 units will be available for each of these GPUs, making it possible to do several post-processing analyses; in particular, more than one single mathematical treatment can be applied to the signal.
We describe in the next chapter how we wish to take advantage of these opportunities in the field of possible SETI research. Once the whole system is tested and functional at SRT, it would be desirable that all Italian telescopes (the 64 m diameter SRT, as well as the two 32 m at Medicina and Noto) be equipped with the same digital infrastructure, so as to carry out fully-coordinated SETI campaigns in Italy.

4. POSSIBLE SETI RESEARCH AT SRT

The infrastructure described in the previous section was designed mainly for radio astronomy. SETI research is considered to be a different kind of science; it is therefore difficult to obtain dedicated time and instrumentation to hold SETI campaigns, especially because of the extremely slim probabilities of obtaining positive results. This is why the most widely-used way to do SETI observations is in piggyback mode: while the astronomer points the telescope in the sky area of scientific interest, a copy of the observed signal is simultaneously analyzed by a dedicated SETI machine.

The search for extraterrestrial intelligence is traditionally Fast Fourier Transform (FFT)-based. One of the most famous projects in this area is SERENDIP [17], which is led by the University of California, Berkeley, USA. It was installed in piggyback mode in version IV at Medicina in 1998 and was operative for about ten years (see [18]). The latest version (SERENDIP VI, which is also ROACH2-based) consists of a very powerful spectrometer that is able to divide a bandwidth of up to 2.4 GHz into very narrow channels of the order of Hz.
In the near future, we will set one of the ROACH2-backend configuration according to the FFT-based approach described above, in collaboration with Dan Werthimer, Andrew Siemion, David MacMahon and Jeff Cobb. In addition, we will enhance the signal analysis capabilities of our machine by exploring and applying all kinds of solutions that have been proposed so far in the literature on SETI data processing. In particular, the same signal will be converted into digital format, and three other transform-algorithms will be applied: the Karhunen–Loève Transform (KLT) [19], the Hilbert–Huang Transform (HHT) [20] and the Wavelet [21], but without excluding any additional ideas that could be worth investigating. This will require a combination of new software and new computational capabilities (making large use of GPU-based processing units), and new firmware coding for the ROACH2's FPGA.

The first step will be to investigate how these algorithms work when a pure software implementation is done. After that, the hardware option will also be tackled and explored, in particular the KLT because it could be a better choice in case signals are unintentionally transmitted; in order to do that, the edging of the autocorrelation matrix [22] is essential due to the low sensibility of the KLT's standard approach.
This exercise will provide us with a machine with highly innovative capabilities in the international context, and which will be immediately usable at SRT, while teaching us the best approach for designing a system able to simultaneously deal with all of the “interesting” algorithms for data processing mentioned above. In particular, for the case of the KLT, we will work in close collaboration with Claudio Maccone, Pierpaolo Pari and Stelio Montebugnoli. Some interesting references are the following: [23], [24], [25].
Clearly, the development of a powerful analysis tool will be essential, and we will take advantage of the expertise already gained in this field [26] by Jader Monari and Stelio Montebugnoli. Finally, we will investigate whether the use of the aforementioned alternative algorithms can produce significant improvements in ordinary radio astronomy applications like spectroscopy, polarimetry, imaging, pulsar and so on.

In addition, in parallel with the development of the technological and scientific research, we are producing a dedicated communication plan towards media and general public. The importance of the argument and the implicit difficulties of this kind of research deserve to be properly exposed to people, without sensationalisms and trying to avoid easy misunderstandings, but simply "translating" them in an every-day language. Information about the SETI project will be given during all the guided tours at SRT. Our plan will also provide adequate material for media and press releases.

5. CONCLUSIONS

In this paper, we provided an overview of the properties of the Sardinia Radio Telescope, focusing on the perspectives of possible SETI research from a technical viewpoint. In particular, we described a general purpose multi-feed wideband digital backend consisting of ROACH2 boards and GPU-based PCs, which can be set up in piggyback mode for SETI studies; several different mathematical transforms can then be applied to the signal of interest. Thanks to the large effort of many people who worked on SRT's technical [27] and scientific validations [28], the SRT's scientific commissioning will be completed before the end of this year, and the first call for early science shared-risk proposals should be out in a few months.

Meanwhile, the development of the infrastructure described in section 3 is being pursued and should also be ready by the end of this year. Thus, technically speaking, the Sardinia Radio Telescope will be able to join SETI programs at the same time. As for the allocation of observing time, specific proposals will be submitted although observations will be done in piggyback mode, and the amount of time for SETI observations at SRT will be decided by the TAC on the basis of scientific merit.

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