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Radio Frequency Interference Monitoring at Sardinia Radio Telescope

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Abstract

Radio frequency interference monitoring is a crucial task to protect the radio astronomical observations from artificial signals. This task started at the Sardinia Radio Telescope in the early 2000s and still successfully continues by monitoring the frequency bands of the current and future telescope receivers. Since 2009 this monitoring has been routinely performed by means mainly of a state-of-the-art technology mobile laboratory up to 40 GHz. In addition, more recently a new software tool has been installed in the telescope control room to monitor in real-time the intermediate frequency baseband of the operating telescope receiver into the background of an astronomical observation.

We present a summary of the results of the radio interference monitoring performed around the telescope by the SRT mobile laboratory in the last years. Furthermore, we describe the main features of the new software tool and show some preliminary results obtained during a recent monitoring of the C-high receiver baseband. The final discussion presents what we are doing to define a radio protect zone around the telescope site.

Figure 1. The mountain valley where SRT (in foreground) rises.

1. Introduction

The Sardinia Radio Telescope (from here on SRT, Figure 1) rises on a mountain valley at 600 m above the sea level in the territory of S. Basilio, a village about 40 km North of Cagliari, the administrative capital of Sardinia.

SRT is a general-purpose, 64-m fully steerable, quasi-Gregorian reflector antenna operated by National Institute for Astrophysics (INAF) and Italian Space Agency (ASI) [1]-[2]. Currently, SRT observes in the frequency range between 0.3-26.5 GHz with four dual-polarization cryogenic receivers for astrophysics research and space debris monitoring: an L-P band coaxial feed in primary focus; a K-band 7-feed-planar-array installed in one of the 7 positions of a rotating turret in charge of placing the receiver in the secondary (or Gregorian) focus; a C-high band feed in one of the four beam waveguide (BWG) focal positions (two for INAF receivers and two for the ASI ones). INAF is currently constructing two new dual-polarization cryogenic receivers to increase the coverage of the current operation frequency range: a 7-feed S-band for the primary focus observations and a C-low band to be installed in one of the remaining six positions in the Gregorian rotating turret. In addition, ASI has recently installed a cryogenic X-band receiver in one of its two BWG focus, allocated for probes tracking and space science observations. Furthermore, thanks to its innovative active optics, the SRT will be able to observe efficiently in the range 26.5-116 GHz, when, in a full operational mode, it will be equipped with new astronomical receivers at higher frequency. To this purpose, a Q-band 19-feed dual-polarization cryogenic receiver for the Gregorian focus is under construction by INAF.

A high antenna gain and a wide-band cryogenic receivers make the SRT very sensitive to detect the weak radio astronomical signals far beyond the frequency bands the International Telecommunication Union (ITU) and, then, the Italian government have allocated to the radio astronomy service (RAS) and to the space science service in the national frequency allocation plan [3]. It is also true that such performances make the SRT vulnerable to the strong radio frequency interferences (RFI) due to the artificial signals which might pollute the frequency band of its receivers. Although ITU has defined the interference threshold level over which an RFI is considered harmful for a radio astronomy experiment in each allocated frequency band [4], the continue evolution of the RFI environment and the lack of a radio quiet zone around the telescope site put the SRT scientific experiments at the risk of receiver saturation and data loss. For this reason, the RFI monitoring at the SRT has been always considered a crucial task to take the more suitable actions to protect the scientific experiments from harmful signals polluting its receiver bands.

Here we report a summary of the RFI activity up to now performed to monitor the band of the SRT receivers. In particular, in Section 2 we describe the results of the routinely RFI measurement campaigns carried out by means of the SRT mobile laboratory in last years. Then, in Section 3, we present a new software tool able to monitor the intermediate frequency (IF) baseband of the SRT receivers and some results obtained during a recent RFI monitoring in the C-high receiver baseband. Finally, the first steps toward a definition of a radio respect zone around the SRT are discussed.

2. RFI Monitoring at SRT

The RFI activity at SRT site started in the early 2000s, when the telescope was not constructed yet. Between 2002-2007 six RFI monitoring campaigns were performed at SRT thanks to RFI team of the Medicina Radio Astronomical Station and its mobile laboratory [5]. In particular, the sixth campaign [6], aimed to monitor the bands of the first receivers under development, was conducted together with local representatives and the mobile laboratory of the Ministry of Economic Development [7]. Then, in 2009 SRT was equipped with a new dedicated mobile laboratory for RFI measurement [8], see Figure 2. Since then the RFI occupancy of the SRT frequency bands has been routinely monitored, and in particular much more frequently after the telescope started scientific observations in 2016. In the last years, many measurement campaigns were carried out by using mainly the mobile laboratory which, thanks to periodic maintenance and hardware/software upgrading, still keeps a state-of-the-art technology from 50 MHz to 40 GHz with a measurement sensitivity up to -125 dBm.

Such RFI measurements around the telescope have allowed to characterise the frequency bands of the SRT working receivers and the under construction ones, as soon as their bands have been defined (see Table 1). This characterisation has turned out to be very useful for different reasons. First of all, it has allowed to extend the astronomical experiments to the frequencies beyond the RAS bands and to keep these latter clean, even reporting harmful RFI signals to the local authority when it was necessary. Then, it has provided astronomers with a case

Figure 2. RFI mobile laboratory during an RFI monitoring at a measuring station close to SRT (in background).

Table 2. Band of the SRT receivers, their status and RFI occupancy percentage up to 2017.

Receiver (focus)	Frequency Band [GHz]	Status	RFI occupancy [%]
P-L (primary)	.305-.41	Under maintenance	52
	1.3-1.8	Under maintenance	57
C-high (BWG-I)	5.7-7.7	Working	10
K (Gregorian)	18-26.5	Working	7
S (primary)	3-4.5	Under Construction	6
C-low (Gregorian)	4.2-5.6	Under Construction	10
X- (BWG-II)	8.2-8.6	Working	1
Q (Gregorian)	33-50	Under Construction	Clean (at least up to 40 GHz)

series of RFI signals, which helped to develop and test a spectrometer and a software dedicated to real-time RFI monitoring and post-processing clipping/mitigation in the astronomical data [9]. The fourth column of Table 1 summarizes the results of the analysis of the RFI case series gathered in the last years and still polluting the SRT frequency bands. These results express the percentage of the band of each SRT receiver occupied by the RFI signals, with respect to the whole receiver bandwidth. It means, for instance, that the X-receiver band (about 400 MHz) is polluted by artificial signals whose bands added together occupy a portion equal to 1% of the whole receiver bandwidth (about 4 MHz). Following in Table 3, it can be seen that the most polluted frequency bands turn out to be those of the coaxial P-, L- receiver with an RFI occupancy percentage of 52% and 57% respectively for the two frequency bands. These receivers are affected by different kinds of RFI signals such as sporadic RF emissions from power lines, aeronautical digital links and other services in P- band, and radar, satellite downlinks and cell phone networks in L-band. Currently, the P-, L-band receiver is in our laboratory for maintenance and RFI measurements are ongoing to investigate and, possibly, remove unwanted and spurious signals emitted by some devices inside the on-board control system of the same receiver. Furthermore, the frequency band of the other receivers appear to be essentially clean except for some RFI arising from HiperLan (C-high and C-low bands) and WLAN services (C-low band), some digital links (C-high, K-, S-, C-low and X-bands). In the worst case (C-high and C-low bands), the occupancy percentage is approximately 10% and in the other cases it is equal or less than 7%. Finally, Q-band appears to be completely clean, at least up to 40 GHz, i.e. the maximum monitoring frequency of the RFI mobile laboratory.

It is worth noting that these results provide a good estimation of the RFI band occupancy, but it is still not a complete representation of the RFI signals polluting the SRT receivers. In fact, they have been obtained by setting the mobile laboratory spectrum analyser in max-hold, broad and narrow resolution bandwidth (RBW) acquisition, while the antenna on the top of the telescopic mast was performing a 360° azimuth scan, each one taking about 1 minute, for both the linear (vertical and horizontal) polarizations. Therefore, for each polarization the weaker power signals were detected with a narrow resolution bandwidth (RBW = 100 KHz) and the broad band and impulsive ones by setting a wider resolution bandwidth (RBW = 3 MHz), but with a resulting reduction of the system sensitivity. However, only a real–time continuous monitoring of the telescope IF baseband during astronomical observations will give a complete and up-to-date description of the RFI scenario in the band of the receivers.

Finally, we report that in these last years other RFI signals self-generated by electronic devices installed at the SRT site have been detected mainly in P-, L- and C-high bands. Most of them have already been switched off or strongly attenuated ever since all the telescope backend receivers and network apparatus have been moved in the new buildings and put inside a shielded room [10]. However, a self-generated RFI signals due to a local oscillator located inside the telescope are still present in the C-high receiver band (see Section 3) and therefore considered in Table 1.

3. A New Tool for RFI Monitoring

Up to now, the SRT mobile laboratory has been the main tool to perform RFI monitoring at the telescope site. Recently, after moving in the new site buildings, a new tool

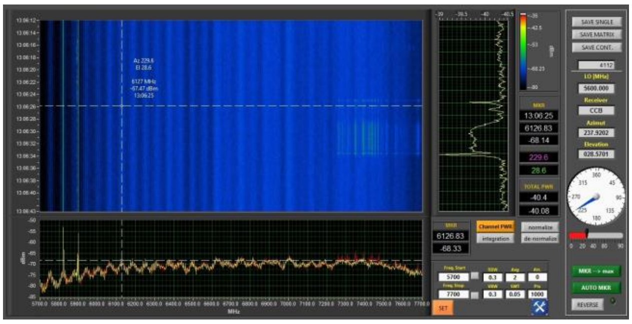

Figure 3. Graphycal user interface of the software for the SRT IF baseband real-time monitoring. Receiver and its setting in use (last right panel), spectrum analyzer control (right bottom panel), spectrogram (left up panel), power spectrum (left bottom panel) and total power plot (90 deg-rotated right up panel) are shown.

is available in the antenna control room (CR) for a real-time RFI monitoring of the SRT receiver bands. The new RFI station is able to perform continuous monitoring of the SRT IF baseband, extending from 100 to 2100 MHz and including both the circular (left and right) polarizations of the receiver operating in that moment. Basically, the two IF baseband signals can be acquired into the background mode (without interfering with the telescope schedule), by using a spectrum analyser, and processed in real-time thanks to a dedicated LabVIEW software, see Figure 3. Figure 3 shows all the panels composing the software graphical user interface. The vertical panel on the right side recognises the receiver in use and its settings (local oscillator frequency and receiver) and shows the antenna pointing coordinates. In addition, the panel on the right bottom side is in charge of the spectrum analyser control and its settings. Then, the plot panels with a power spectrogram versus time-frequency, power versus frequency and a total-power show in real-time the evolution of the RFI scenario in the baseband during the telescope data acquisition. Furthermore, the system can acquire spectra (at least 50 per second) and save them in a data-log file, together with the corresponding antenna pointing position and a time-stamp.

Finally, this tool has been successfully tested and is now operative in the SRT CR even though in a preliminary configuration. The results of a recent RFI monitoring, consisting in measuring the combined right- and left-circular polarizations of the C-high receiver baseband, while the telescope was performing a 360° azimuthal scan at different elevations (each one about 5 minutes long), are shown in Figure 4. Two narrow band RFI signals were detected at 5900 and 5822 MHz and both turned out to be inside the telescope, because invariant during the antenna azimuthal scan. The first one, already known by a previous RFI monitoring, is due to the local oscillator used for the K-band receiver frequency down conversion. The second one, never detected before, is still under investigation. In addition, a broad band RFI signal was received in the frequency range 7250-7690 MHz and its peak level was

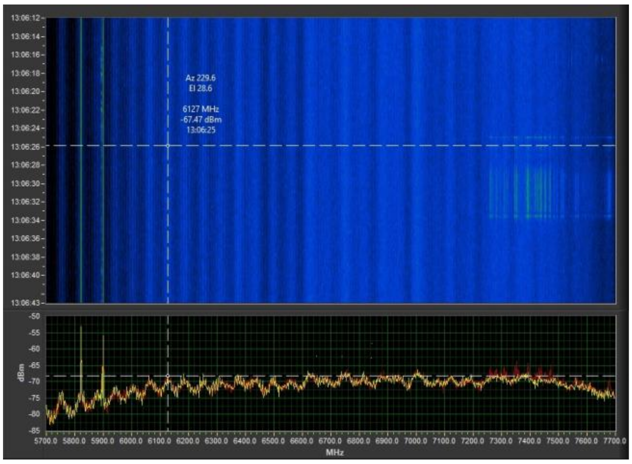

Figure 4. Power spectrogram versus time-frequency (top) and power spectrum (bottom) of the C-high receiver baseband. The frequency axis shows the receiver sky frequency. Only 31 seconds of the spectrogram acquired at the elevation 28.6 degree, lasting about 5 minutes, is shown in order to highlight when telescope received the broad band signal (at 1 h : 06 m : 32 s p.m. in the frequency range 7250-7690 MHz) and at which azimuthal direction (229.6 deg). Power spectrum shows the active trace (yellow line) and the trace acquired when the maximum of the broad band signal was detected (red line). The other two permanent narrow band signals, invariant with the telescope moving, are detected at 5822 and 5900 MHz.

maximized in a narrow solid angle around 229.6 deg and 28.6 deg, respectively the azimuthal and elevation coordinates of the antenna pointing. This signal (not included in Table 1), due probably to a geosynchronous satellite transmission, would hardly have been detected by the mobile laboratory, because this latter can perform azimuthal scans only at one elevation close to the horizon and, of course, with a sensitivity worse than the telescope's one.

4. Conclusion

Many efforts have been addressed to the RFI monitoring at SRT since the telescope was under construction. This activity has been very useful to characterize the frequency band of the SRT receivers and keep the RAS and space science bands clean from RFI. Moreover, it leads us to deep the knowledge of the territory around the radio telescope station and establish good relationship with the local municipalities. All of this has contributed to increase local people and authority awareness about the SRT sensitivity and, therefore, how the artificial radio signals can be harmful for the radio astronomical experiments.

Thanks to that, since 2017 the union of the local municipalities [11], located around the SRT site, has started informing the SRT administrative office whenever a request for a new radio transmitter installations (or an upgrading of existing installation) within its territory is submitted. When it happens, the SRT administrative office can express a negative opinion about the request adding binding technical prescriptions, if the power emission of the proposed installation turns to be harmful for the SRT operations, after an accurate electromagnetic simulation. This represents the first step toward a definition of a radio respect zone around the SRT which, however, have to be still formally approved.

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