Mem. S.A.It. Vol. 75, 282

Memorie della

The SRT receiving system and the receivers for the commissioning phase

A. Orfei[1], P. Bolli[1], L. Carbonaro[2], A. Cremonini[1], L. Cresci[2], T. Idda[3], S. Mariotti[1], J. Monari[1], V. Natale[4], R. Nesti[2], G. Nicotra[5], L. Olmi[4], D. Panella[2], T. Pisanu[6], M. Poloni[1], J. Roda[1], A. Scalambra[1], F. Schillirò[5]

[1] INAF - Istituto di Radioastronomia, Via P. Gobetti 101, I-40129 Bologna
[2] INAF - Osservatorio Astronomico di Arcetri, Largo E. Fermi 5, I-50125 Firenze
[3] INAF - Osservatorio Astronomico di Cagliari, Loc. Poggio dei Pini, Strada 54, I-09012 Capoterra (CA)
[4] INAF - Istituto di Radioastronomia, Sez. di Firenze, Largo E. Fermi 5, I-50125 Firenze
[5] INAF - Istituto di Radioastronomia, Sez. di Noto, C.da Renna Bassa, I-96017 Noto (SR)
[6] INAF - Istituto di Radioastronomia, Sez. di Cagliari, Loc. Poggio dei Pini, Strada 54, I-09012 Capoterra (CA)

Abstract. In this paper we describe the receiving system planned for the Sardinia Radio Telescope for a frequency range between 300 MHz and 100 GHz. The predicted performance and the structure of the overall receiving system are shown in order to give an overview of what can be available for science. A description of the current designs for the first four commissioned frequency bands completes the presentation.

1. Introduction

Organizing a complete receiving system implies that many constraints have to be faced simultaneously in order to allow a gradually (receiver-by-receiver) growing system. The receivers for the SRT will mainly have the classical heterodyne configuration, whose fundamental blocks are reported in Fig. 1 together with the related design parameters.

To minimize the overall noise, both the LNA (Low Noise Amplifier) and most of the feed system will be cooled at 20 K. A fiber optic link is already included in the receiver chain, stating that it may affect the overall performance in terms of noise and robustness with respect to the interferences.

2. Designing the SRT receiving architecture

Many constraints affect the receiving system of the SRT, one of them being the number of locations available for placing receivers. In Fig. 2 the four focal positions of the SRT are shown. In the primary focus F1 about 8 RX locations can be used (placed inside a maximum of 4 “small” boxes or 3 “large” boxes); also in the Gregorian focus F2, 8 locations can be chosen on the rotating drum. Finally, the Beam Wave Guide (BWG) foci F3 and F4 allow two RX locations each. A total of about 20 receiver locations are available.

Other constraints to be taken into account are:
- frequency coverage: the SRT aims to observe

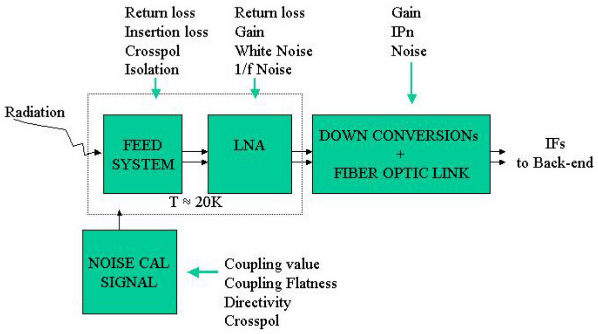

Fig. 1. Key elements of a classical receiver.

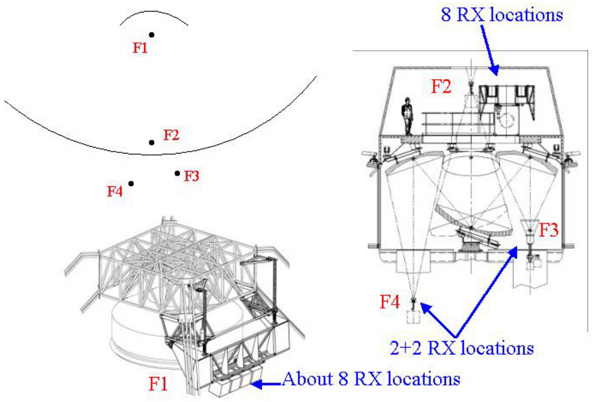

Fig. 2. Available locations for placing receivers.

from 300 MHz to 100 GHz with a continuous coverage. Some exceptions to this aim will be at the lowest frequencies, due to the expected presence of interferences (the last RFI monitoring made at the SRT site showed this to be a problem for $\nu < 3$ GHz).
- feed organization: various feed assemblies are requested, mono-, dual-, multi-feed as well as dual-frequency (two bands at the same time).
- frequency agility: the switching among all receivers must be fast (a few minutes at the most) and automatic.
- robust receiver w.r.t. interference: this implies a careful design in terms of intermodulation products.
- performance: the SRT aims to be a new generation antenna, so the receivers must be state-of-the-art in order to best exploit the large collecting area and the very low total surface rms. For the same reason it is worth to predispose the highest-frequency receivers to the adding of a "full band" detection scheme.

The sum of the frequency coverage, agility and restricted number of locations force us to design receivers with a bandwidth of about 35% of the central frequencies, a challenging task compared to our previous experience of no more than 20%. Moreover, the performance has to be provided in this wide band, together with sending a larger intermediate frequency (IF-) band to the back-end in order to enhance the instantaneous sensitivity: a value of 2 GHz

Table 1. Left: SRT receivers; **Right:** RF vs IF Bandwidth Comparison

λ (cm)	FLow sky (GHz)	FHigh sky (GHz)	BW (GHz)	BW (%)	Note	Focus Position	
90	**0.31**	**0.42**	**0.11**	**30**	**Dual frequency**	Primary	Boxes choice: a) 4 x 0.8m b) 3 x 1.4m c) intermediate
18-21	**1.3**	**1.8**	**0.5**	**32**			
50	0.58	0.62	0.04	7			
30	0.7	1.3	0.6	60			
13	2.2	2.36	0.16	7	Dual frequency		
3.6	8.18	8.98	0.8	9			
10	2.36	3.22	0.86	27			
7.5	3.22	4.3	1.08	32			
6	4.3	5.8	1.5	32		BWG	Down to 1.4GHz Up to 32GHz
5	**5.7**	**7.7**	**2**	**30**	**Monofeed**		
3.3	7.5	10.4	2.9	32		Gregorian	
2.3	10.3	14.4	4.1	33			
1.8	14.4	19.8	5.4	32			
1.3	**19**	**26.5**	**7.5**	**33**	**Multifeed**		
0.9	26	36	10	32			
0.7	35	50	15	35			
0.4	70	90	20	25			
0.3	90	115	25	25			

λ (cm)	FLow sky (GHz)	FHigh sky (GHz)	RF BW (MHz)	IF BW (MHz)
90	**0.31**	**0.42**	110	110
18-21	**1.3**	**1.8**	500	500
50	0.58	0.62	40	40
30	0.7	1.3	600	600
13	2.2	2.36	160	160
3.6	8.18	8.98	800	800
10	2.36	3.22	860	860
7.5	3.22	4.3	1080	1080
6	4.3	5.8	1500	1500
5	**5.7**	**7.7**	2000	2000
3.3	7.5	10.4	2900	2000
2.3	10.3	14.4	4100	2000
1.8	14.4	19.8	5500	2000
1.3	**19**	**26.5**	7500	2000
0.9	26	36	10000	2000
0.7	35	50	15000	2000
0.4	70	90	20000	2000
0.3	90	115	25000	2000

is compatible with overall performances but, again, it is five times larger than what we managed to do in the past.

Finally, the beginning of the multi-feed "era" implies the managing and routing of tens of wide channels from movable boxes. In fact, most of the multi-feed systems will be placed on the rotating drum and equipped with a mechanical de-rotator in order to compensate the systematic field-of-view rotations affecting the off-axis beams.

A list of receiving bands is reported in Table 1 (left). As can be seen, most of the receivers show around 30–35% bandwidth. Two dual-frequency receivers are planned at the moment (the S/X-band for geodetic observations and the commissioned P/L-band for pulsar research), and only two of the four BWG receivers are planned (the BWG foci allow frequencies from 1.4 GHz to 32 GHz). In spite of this, a continuous coverage is obtained, although some of the requested receivers are not shown in the Table (for example a multifeed L-band system for the primary focus). The primary focus location is somewhat crowded with respect to the permitted three or four boxes, also considering that the re-configurable mirror properties of the SRT should allow one to place in this location multi-feed systems which it not possible to locate in the other foci (for example for bands ranging from 2 GHz to 10 GHz).
We note that generally the output of the receivers will be left and right circular polarization.

In Table 1 (right) the instantaneous bandwidth sent to the back-end (the so-called Intermediate Frequency bandwidth, IF-BW, tunable everywhere inside the Radio Frequency bandwidth, RF-BW) is compared with the total RF band (or sky band) available. Up to about 10 GHz there is no difference, whereas RF-BW strongly increases with respect to IF-BW for the highest frequencies, and this should be exploited. Managing these large amounts of bandwidth from the IF point of view is not feasible, but the problem can be circumvented by making available an additional receiver upon request: a direct detection receiver scheme can use all of the RF-BW, for example for total power surveys. The schematic block diagram is shown in Fig. 3.

Referring to Fig. 1, the aimed performance for the Feed System, the LNA and the overall receiver are reported in Table 2. As a Feed

Table 2. Goal performances

	Insertion loss(dB)	Return loss(dB)	Crosspol.(dB)	Noise(@20K)	Gain(dB)	OIP3(dBm)
Feed System	0.2-0.3	< -26	< -35			
LNA		< -10		1 K/GHz	30-35	
Receiver		< -26	< -35	Best effort		>30

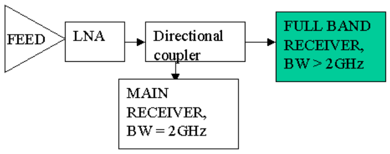

Fig. 3. Dual scheme receiving system.

System we refer to an assembly of passive devices consisting at most of a horn, an injection system, a vacuum window, a polarizer and an Orthomode Transducer (OMT). The LNA has to be intended as a complete active device, ready to be connected in the receiver chain while the overall receiver is the full system depicted in Fig. 1.

Some explanations of the terms appearing in the Table are necessary. The insertion loss of the overall feed system should in principle be as low as possible because it affects the total receiver noise: this value may be relaxed if the components can be cooled (at a physical temperature of 20 K), and this depends on their dimensions. As a rule of thumb it can be said that as the frequency increases the loss is higher but the dimensions of the passive device decrease and therefore it can be cooled. This is also the meaning of the label "Best effort", i.e. as many components as possible are cooled.
The value of the crosspolarization has to be verified both on-axis and off-axis of the antenna. The OIP3 (Output Intermodulation Product of the 3rd order) is directly related to the robustness of the receiver with respect to the presence of the interferences. Details on the overall architecture of the SRT receiving system are reported by Monari et al. (these Proceedings).

3. The receivers for the commissioning phase

Four frequency bands are planned to be available for the "first light" of the antenna. General criteria for choosing which frequencies to start with could be:
- Testing all types of antenna foci; this means providing receivers for F1, F2 and F3
- The SRT should be able to work up to 22 GHz without any metrological system or other particular facility; this means that the chosen bands should span the range from 300 MHz to 22 GHz. Note that the highest frequency is also high enough for testing of the active surface system.
- Exploiting the K-band multi-feed system already under construction, in order to begin the "multi-feed era" at the Institute, by combining the best performing antenna with the best performing receiver.
- Last but not least, selecting bands which allow one to undertake valuable scientific projects immediately after the antenna commissioning.

Therefore, the commissioned bands are shown in boldface in Table 1:
- A dual low-frequency system for F1 in the bands 310–420 MHz (P-band) together with 1.3–1.8 GHz (L-band).
- A mono-feed mid-frequency system for F3 in the band 5.7–7.7 GHz (C-band).
- A high-frequency multi-feed system for F2 in the band 19–26.5 GHz (K-band; the system will work down to 18 GHz).

The first system is mainly requested for pulsar research, but the two bands are also VLBI standards. The second and third systems were primarily chosen for spectroscopy

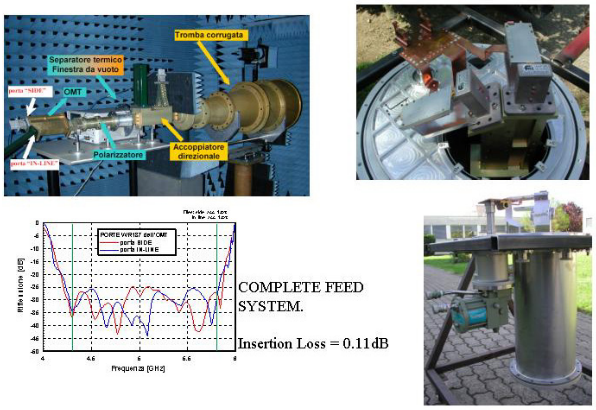

Fig. 4. The monofeed 4.3-5.8 GHz for the Medicina antenna and the dewar.

(methanol, water and ammonia lines), but they are VLBI standards as well.

The multi-feed system will have the following characteristics:
- A 7-horn dual circular polarization feed system.
- All feed systems and 14 Monolithic Microwave Integrated Circuit (MMIC) LNAs cooled at 20 K followed by 14 MMIC warm LNAs.
- 14 IF 2 GHz-wide output channels (so issuing a total of 28 GHz to the back-end)
- Mechanical de-rotator under evaluation

For the performance of the LNAs and the feed system see Cresci et al. (these Proceedings).

The monofeed system will be very similar to the 4.3 – 5.8 GHz system designed for the Medicina parabolic antenna (Fig. 4), whose performance satisfies that which is reported in Table 2. We are therefore confident that the same or even better results can be achieved in the contiguous band.

A feasibility study is currently ongoing for the dual frequency system. The constraint to observe simultaneously at two frequencies imposes some compromises in terms of performance compared to having two separate systems, so the goal of the feasibility study is to achieve the best in terms of sensitivity (i.e. G/T or System Equivalent Flux Density, SEFD) for both bands. At the moment two options are under comparison: an L-band corrugated horn plus a P-band dipole array, or coaxial corrugated horns for both bands. The first solution is schematically shown in Fig. 5 (left). The central cylinder represents the L-band horn while the four dipoles, two for each linear polarization together with the circular metal sheet acting as a reflector, are necessary in order to point to the same direction with a convenient directivity.

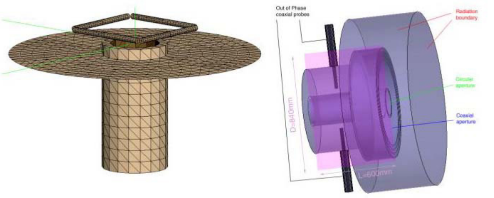

Fig. 5. Two options for the dual frequency feed system.

In the second option (Fig. 5, right), the inner circular horn works in the L-band, the outer coaxial one operates in the P-band. Four dipole launchers give proper excitation of symmetrical field configurations thus reducing cross-coupling. Since the inner waveguide

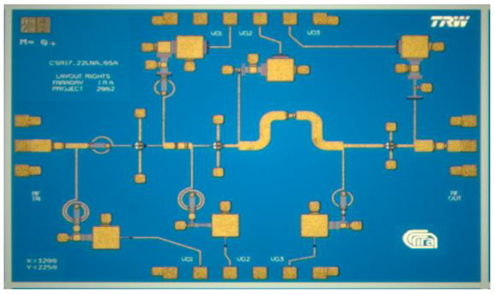

Fig. 6. An IRA 18-26 GHz InP MMIC LNA, 3.2 x 2.25 mm.

acts as a reactive load for the coaxial horn, great attention has been payed to having good input matching, low cross-polarization, high efficiency and wide band. In order to manage the two incoming linear polarizations, a power combiner is required for every couple of launchers. A number of choke rings are placed around the illuminator in order to improve radiation features and to reduce surface currents and backscattering.

A second step of the study will regard the best way for cooling as many devices as possible, but this will be driven by the mechanical constraints arising from the dual configuration assembly.

4. Components for next receivers

As can be seen from Table 1 a lot of work remains to be done after the commissioning phase is completed. The demand for new receivers to equip the antenna in a convenient time will be pressing (Brand et al. 2005). On the other hand, constructing a receiver is a long task, particularly for multi-feed schemes. It implies many different fields of knowledge to be integrated harmonically in the whole receiving antenna system: passive devices, LNAs, cryogenics, dewar, IF electronics, control & switching, cable managing on movable equipment, etc.

The only way we see for speeding up the work is by relaying as much as possible the manufacturing process for the different bands, exploiting what has been made previously. That means the same process for dewars, LNAs, feed systems and so on.
In this respect, many LNAs are under construction following the successful results obtained in the 18–26 GHz product (Fig. 6). The same design rules and manufacturing process will provide us with LNAs in the following bands: 4–8 GHz, 8–12 GHz, 26–40 GHz, 33–50 GHz, 70–90 GHz, and 90–115 GHz.

All of these will be in monolithic technology using InP material. From the same wafer run we shall get HEMT transistors as well, for those cases not needing monolithic solution.
Besides this a 4.3–5.8 GHz GaAs LNA is under construction for a new receiver at Medicina, so it will be ready also for the SRT.
Looking at Table 1 this means that six more bands can be served together with the commissioned ones.
The same process could be used for dewars for multi-feed (re-use K-band) and for mono-feed (re-use new Medicina C-band solution), at least for those receivers placed in the same focus.

References

Brand, J., Caselli, P., Felli, M., Mack, K.-H., Poppi, S., Possenti, A., Prandoni, I., & Tarchi, A. (Eds.) 2005, “The Sardinia Radio Telescope (SRT). Science and technical requirements”, IRA Internal Report 371/05