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The Sardinia Radio Telescope conversion, distribution, and receiver control system

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Abstract. The recent upgrade of the 32-m radio telescope located in Medicina (Bologna - Italy) has allowed us to gain a lot of know-how about "frequency agility" management. In this parabolic dish antenna the receiver change is now completely performed only using software controls and avoiding, in this way, human intervention. The acquired experience on this topic has been used to define the framework for the conversion/distribution system design for the SRT (Sardinia Radio Telescope), the new "64-meter class" Italian radio telescope. The suitably designed architectures for Local Oscillators (LOs), Intermediate Frequencies (IFs), Ground Unit (GU), Reference (REF) distribution systems and control system will be described in this paper.

1. Main specifications

The main system peculiarities, needed by the observers for observing and for performing experiments, is briefly introduced:

- Continuous Frequency Coverage (300 MHz−115 GHz)
- Single Feeds and Multi-Feeds (MFs). The MFs are only located in the Gregorian focus.
- Frequency agility in a multi-focus architecture (Primary, Gregorian and Beam Wave Guide, BWG, focus)
- Double 2nd IF outputs.
- Double polarization for each frequency.
- Minimizing spurious signals, harmonic and intermodulation products (IPn) generated in the system.
- High gain and phase stability related to environmental parameters.
- Possibility to receive two different frequencies for the two polarizations of a single receiver.

From the technical point of view, the design has been studied in order to get both cost reduction and an open/replicable system for future upgrade. This means that a new and more compact receiving system concept has been developed based on grouping more frequency conversion systems. The new system can basically be summarized by:

1. Minimizing the number of second conversions.
2. Spare parts reduction.
3. Maintenance simplification.
4. High system compactness/replicability.
5. Open system for future upgrade.
6. Distributed control system infrastructure

Table 1.

Fo [GHz]	No RX	FL sky [GHz]	FH sky [GHz]	B	Conversione	FImm [GHz]	Rej Imm	x N OL1	OL1 F low [GHz]	OL1 F high [GHz]	IF1 F low [GHz]	IF1 F high [GHz]	OL2 [GHz]	IF2 F low [GHz]	IF2 F high [GHz]
0.3	1P	**0.31**	**0.35**	12%	DIRETTA									0.31	0.35
0.6	1P	**0.58**	**0.62**	7%	DIRETTA									0.58	0.62
1	1P	**0.70**	**1.30**	60%	DOPPIA LSB	2.5	2.5	1	1.90		0.6	1.2	1.30	0.1	0.7
1.5	2P	**1.30**	**1.80**	32%	SINGOLA USB	1.1	0.9	1	1.20					0.1	0.6
3	3P	**2.36**	**3.22**	31%	SINGOLA USB	2.16	0.73	1	2.26					0.1	0.96
4	3P	**3.22**	**4.30**	29%	SINGOLA USB	3.02	0.68	1	3.12					0.1	1.18
2	2P	**2.20**	**2.36**	7%	SINGOLA USB	1.9	1.27	1	2.02					0.18	0.34
8	2P	**8.18**	**8.98**	9%	SINGOLA USB	7.98	0.75	4	2.02					0.1	0.9
5	1B	**4.30**	**5.80**	30%	DOPPIA LSB	10.8	3.8	1	8.30		2.00	3.50	4.10	0.1	1.6
7	2B	**5.70**	**7.70**	30%	DOPPIA LSB	11.7	2.5	1	9.70		2.00	4.00	4.10	0.1	2.1
9	1G	**7.50**	**10.40**	32%	DOPPIA LSB	13.5	1.57	1	11.5	12.4	2.00	4.00	4.10	0.1	2.1
13	2G	**10.30**	**14.40**	33%	DOPPIA LSB	16.3	0.96	1	14.3	16.4	2.00	4.00	4.10	0.1	2.1
17	3G	**14.40**	**19.80**	32%	DOPPIA LSB	24.4	1.35	1	20.4	23.8	4.00	6.00	6.10	0.1	2.1
23	4G	**19.00**	**26.50**	33%	DOPPIA USB	11.0	1.3	1	12.0	17.5	6.00	8.00	5.90	0.1	2.1
32	5G	**26.00**	**36.00**	32%	DOPPIA USB	22.0	0.9	2	10.0	14.0	6.00	8.00	5.90	0.1	2.1
43	6G	**35.00**	**50.00**	35%	DOPPIA USB	16.0	1.76	2	9.50	16.0	16.00	18.0	15.9	0.1	2.1
80	7G	**70.00**	**90.00**	25%	DOPPIA USB	56.0	1.2	4	13.5	18.0	16.00	18.0	15.9	0.1	2.1
100	8G	**90.00**	**115.00**	25%	DOPPIA USB	81.0	0.8	4	18.5	24.25	16.00	18.0	15.9	0.1	2.1

Table 2.

Optical Links' Parameters	Gain Full Band [dB]	NF @ 408MHz [dB]	IP3Out @ 408MHz [dBm]	NF @ 2100MHz [dB]	IP3Out @ 2100MHz [dBm]
	4±0.5	37±1	36.0±1	40.5±1	33.5±1

2. General description of the receiving system

The whole system architecture design has brought the following results: for primary focus receivers the system is based on direct amplification and/or single/double conversion while, for Gregorian and BWG focus only on a double conversion. The situation is summarized in Table 1.

In this new concept, the whole architecture can be considered as a distributed receiving system where the first conversion is located close to the dewars, in order to minimize the first IF transmission losses. A possible second conversion and all general distribution systems (IF-, LO-, GU-, and REF-distributor) are placed in the same Gregorian/BWG room or in an *ad hoc* box (PRIM).

3. IF distribution

The focus and its related receivers can be selected with a particular switch called focus selector, FS, located in the control room. Because of the distance from the control room to the antenna (more than 600 m), in order to minimize the insertion losses and the in-band disequalizations, and in order to electrically isolate both sides, each IF signal coming from one of the three foci is converted into an optical signal and transmitted by fiber. The optical fiber link (loose- buffered), compared to a coaxial cable, allows to get higher gain and phase stability tightly related to the environmental parameters and to the cable bending due to the antenna movement.

The TX/RX analog link has been designed by Tekmar Sistemi S.r.l., an Andrew Company, in collaboration with our laboratories at the Medicina Radio Astronomical Station, following the same guiding principle of the optical

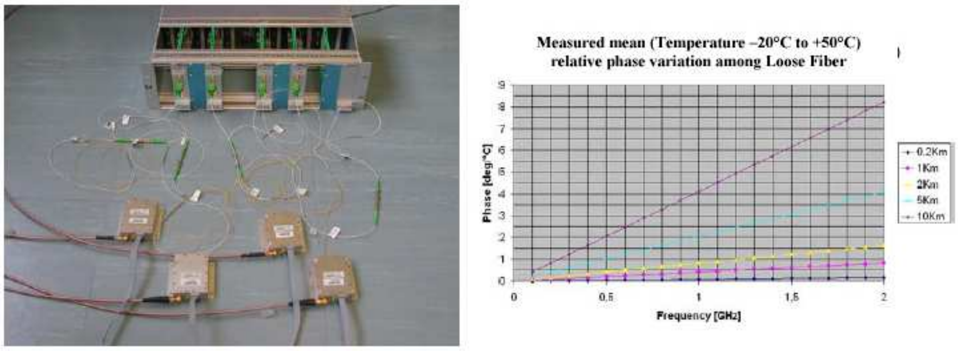

Fig. 1. Optical link test bench (to the left) and relative phase vs. frequency diagram (to the right).

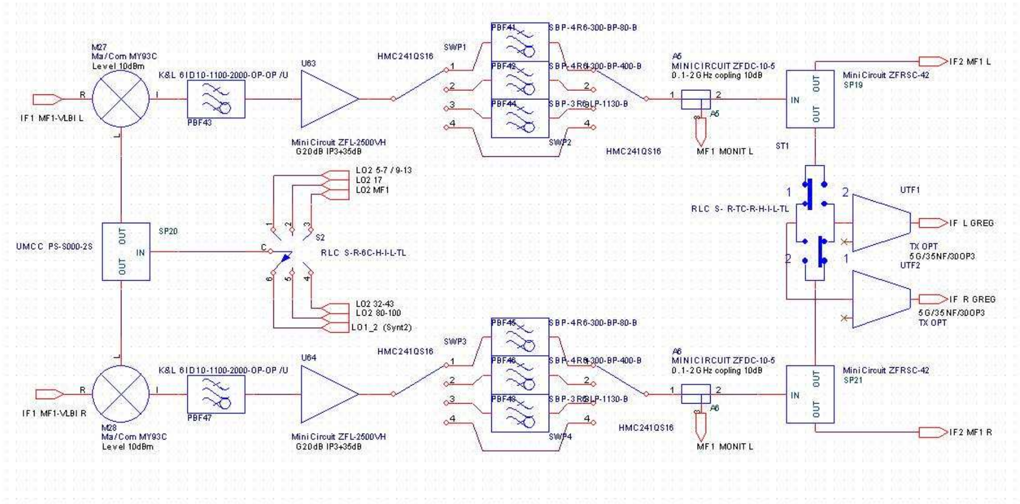

Fig. 2. The "in common" second conversion for all the Gregorian/BWG receivers.

link already realized within the Medicina SKA Demonstrator. A suitable design has been studied in order to get appropriate matching parameters for the SRT main specifications (Fig. 1). Table 2 shows the performance of the optical analog link considering the entire bandwidth of 2nd IF (100 MHz−2100 MHz).

As mentioned above, the second conversion for the Gregorian/BWG focus is in common for all the receivers. This is because of the selected mixer characteristics. Furthermore, the second conversion system will be implemented inside a separate box allowing, in this way, a cost reduction and a high efficiency during maintenance operations. In Fig. 2 the electrical scheme is displayed. As shown in Fig. 3, a 1st IF switch located in the Gregorian focus room allows one to select the appropriate receiver. Moreover, a particular position is dedicated to select the receivers in the BWG focus room.

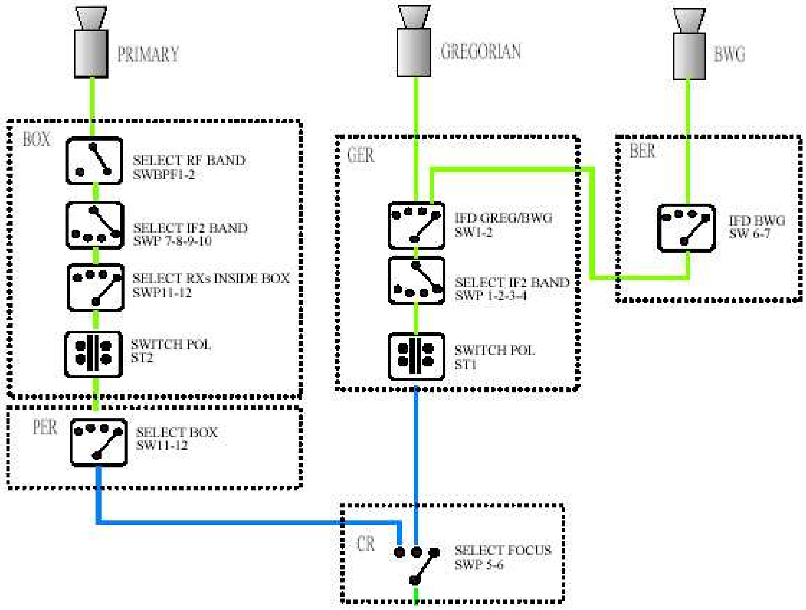

Fig. 3. Block diagram for IF switches.

At the present status of the project, all multi-feed receivers are located in the Gregorian room. The IF outputs will be directly connected to the backend (IF processor) by coaxial cable, if it is located in the same Gregorian/BWG room, or by optical fiber if its location is far away from the MF system. The MF receivers are endowed with N equal 1st IF conversions and N-1 equal 2nd IF conversions since the central feed will use the "in common" second conversion previously described.

In order to minimize the number of cables coming out from the various primary focus receivers, an auxiliary expansion box has been designed (see Fig. 4). Within this additional box all the common parts of the various receiving systems and all the components necessary for signal distribution will be placed. Note that, as shown in Table 1, the primary focus receiving system is realized inside three boxes.

Within the auxiliary box, a selector will allow the selection of the proper box. Moreover, inside each box, a further switch will enable one to select the right receiver (if more than one receiver is present). The receiving system provides an output bandwidth starting from 100 MHz up to 2.1 GHz. Depending on the backend type, a switching filter bank is able to select a number of different output bandwidths: 100-250 MHz, 100-500 MHz, 100-1100 MHz, 100-2100 MHz (Fig. 2).

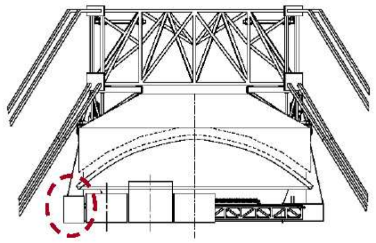

Fig. 4. The auxiliary box in primary focus (circled).

4. LOs distribution

Each conversion system for the three SRT foci is served by two synthesizers (Agilent

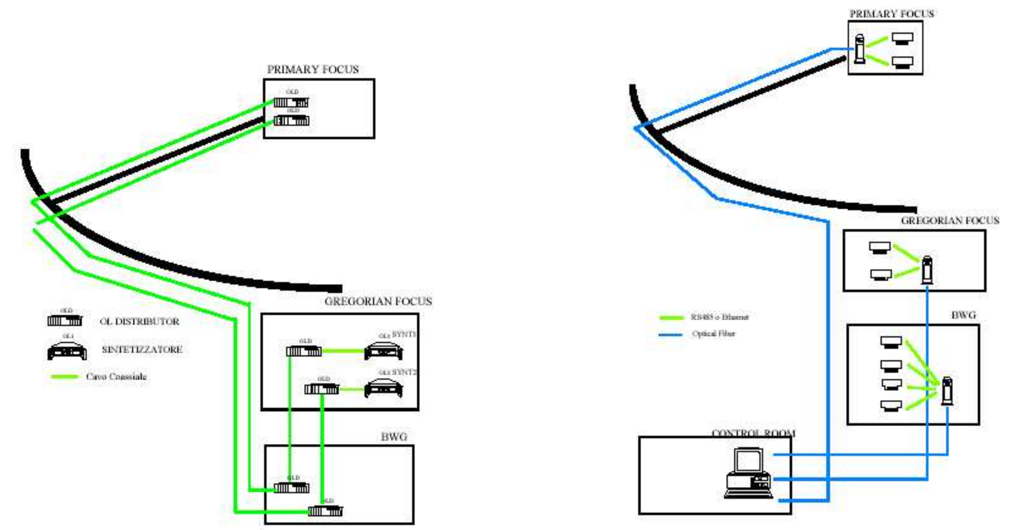

Fig. 5. Conceptual scheme for LOs distribution for each focus and control system.

E8257C-520) located within the Gregorian focus room (because in this room all the higher-frequency receivers will be placed). The synthesizer outputs are opportunely distributed to other foci by a suitable switching system (Fig. 5).

In order to observe with two different sky frequencies in the two polarizations a further switching level in the second conversion allows the selection of a fixed LO.

5. GUs and REF distribution

The GU output signal used for the VLBI Mark IV/V acquisition system is transmitted towards the BWG focus room where it is subsequently switched to the primary and Gregorian foci (Fig. 6). The REF signal is generated with a 10-MHz H-Maser. Its output is distributed with a non-passive system with a "100 dB minimum" isolation between output ports (Fig. 5).

6. Control and monitoring

To support the frequency agility requirement all the receiving and distribution systems inside the three foci of the SRT need to be remotely controlled. The main communication system was studied taking into account the 600 m distance between the control room, where the main control computer should be located, and the devices to be controlled on the 3 foci area; we also consider the electronics needed all around the structure of the antenna for the active surface system.

Ethernet and TCP/IP protocol over-fiber for the long distance backbones has been chosen as the main communication channel, after considering the low cost, the high diffusion of network solutions, and also the low RFI emissions.

In each focus area a mix of low-cost and easily expandable Ethernet over copper network and RS485 serial bus will be used as a local communication system. A high-speed communication channel as Ethernet over fiber is useful considering that most of the back-end (especially for multi-feeds) will be located directly over the antenna inside the Gregorian room or BWG room.

For the network architecture, used to control the receivers, it is possible to choose between two philosophies:

1. All tasks are concentrated in the PCs located inside the control room;
2. The tasks are distributed to local embedded

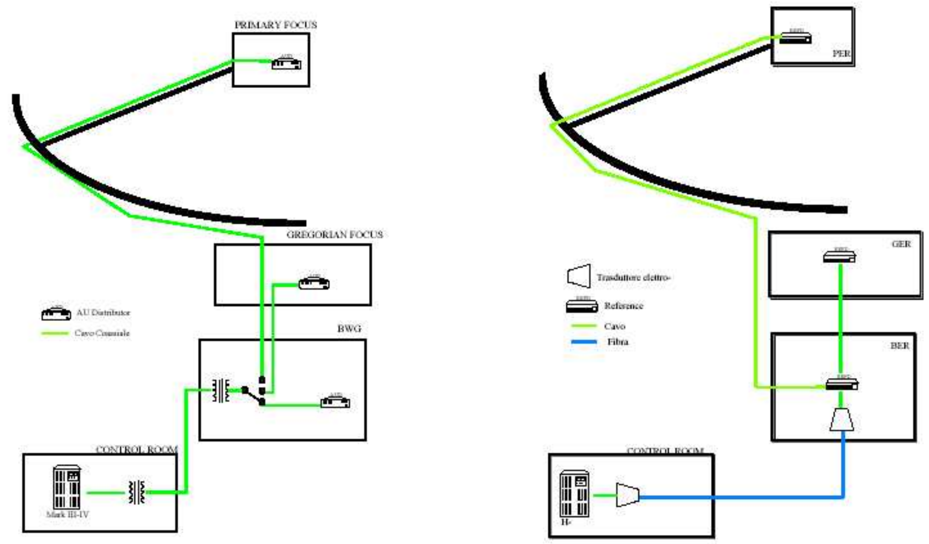

Fig. 6. Distribution systems: GU distribution (to the left) and REF distribution (to the right).

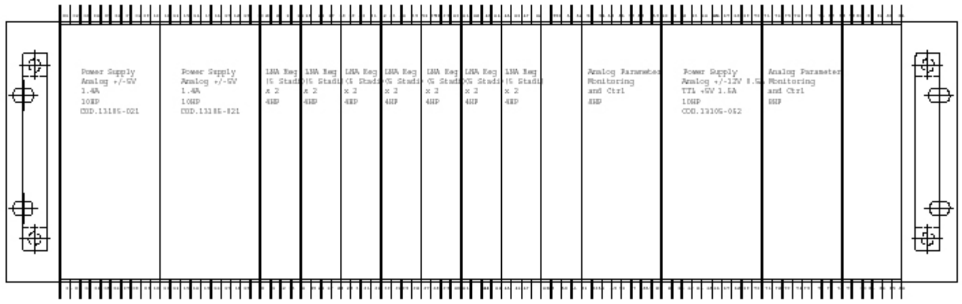

Fig. 7. 7+7 LNA (35+35 Stage L+R) + DEWAR parameters monitoring for K-band multifeed receiver.

computers inside each focus.

Each receiver will be controlled by 2 microprocessor control boards (MCB); one is necessary to remote the monitoring of the LNA bias settings (VD, VG and ID) and the second one to control the dewar and to acquire all the receiver parameters.

An upgraded version is under development with an integrated Ethernet port of the microprocessor control boards already tested on the Medicina Radio Telescope.

The main board features are listed below:

- 8 analog differential inputs.
- 8 analog single ended inputs.
- 2 10-bit analog outputs.
- 16 digital I/O opto-isolated.
- 1 serial port RS485/RS232.
- Ethernet interface.
- 1 serial bus interface (I2C or SPI).

- 1 10-μA constant current generator (for cryogenic temperature sensors).
- 1 temperature sensor.

Next we give a list of the more important receiver parameters that these boards can manage:
- Monitoring LNA FETs biasing (VD, ID,VG);
- Monitoring Total Power level at strategic points in the chain;
- Monitoring of dewar parameters: cryo temperature and vacuum pressure;
- Vacuum pump and valve control;
- Monitoring LO levels;
- Calibration noise source control;
- Selecting IF bandwidth and to control other useful switches.

A new board (ALISRT) is under development, based on the SPORT project and designed to monitor and to control the LNA bias settings. This new schematic integrates a test FET to adjust VD and ID before supplying the real LNA, and it requires less power. This is very important to minimize the cost of multi-feed receivers and the size of power supplies (Fig. 7). One of these boards can control 5 stages for polarization.

To control all the switches for IF, LO, and GU, a distributed digital I/O system is required. To implement this function some low cost commercial-off-the-shelf Ethernet ready devices will be tested. Using these devices the main computer may have direct control of the entire switching configuration. In case of RF interferences due to Ethernet communication close to the receiver, an *ad hoc* board will be developed based on a low cost microprocessor system and an RS485 serial bus.

7. Summary

A new control system design has been studied in order to get a complete software control of the SRT. In order to get a continuous frequency coverage starting from 300 MHz up to 115 GHz, a number of receivers distributed in three focal positions (Primary, Gregorian and Beam Wave Guide foci) will be built in the near future. Therefore, optimized conversion and distribution systems will be necessary to avoid a redundancy of devices and a significant increment of costs. Based on the experience in the upgrade of the Medicina Radio Telescope, the complete control, monitoring and signal distribution in the SRT will be implemented with a dedicated LAN and optical fiber link system. The system has already been designed, and the simulation, purchasing and prototyping phases are now under way.