

Medicina User Manual

32-m Antenna

Version 1

Elena Cenacchi

Alessandro Orfei, Karl-Heinz Mack, Giuseppe Maccaferri

e.cenacchi@ira.inaf.it

THE RADIOTELESCOPE

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1. Introduction

The Medicina 32 m antenna is a Cassegrain radiotelescope operating since 1983, managed by the Istituto di Radioastronomia, until 2004 part of the CNR (Consiglio Nazionale delle Ricerche) and now part the INAF (Istituto Nazionale di AstroFisica).



Fig. 1.1 : The Medicina antenna

The main features of this instrument are the following :

- Frequency agility (the observing frequency can be changed very quickly), $t_{max} \leq 4$ min
- Secondary reflector wobbling (shifting time ≤ 1 sec (at $\nu \geq 20$ GHz))
- Complete automation and remote control of the observing settings

Position	Medicina (BO), Italy
Coordinates	Lat. 44°31'15" N - Long. 11°38'49" E - Alt. 25 m f.s.l.
Optics	Cassegrain
Frequency coverage	1.4 ÷ 22 GHz
Primary reflector diameter	32 m
Secondary reflector diameter	3.2 m
Available foci	Primario f/D = 0.32 Cassegrain f/D = 3.04
Elevation range	0° ÷ 90°
Azimuth range	± 270°
Slew rates (wind speed < 60 km/h)	48°/min Azimuth 30°/min Elevation
Surface accuracy (<i>rms</i> specified)	0.6 mm*
Pointing accuracy (<i>rms</i> specified)	8 arcsec
FWHM Beamwidth	38.7 arcmin/f (GHz)
Gain	0.10 ÷ 0.16 K/Jy
First secondary lobes	≈ 20 dB under the main lobe
Receivers mounts	Primary focus : movable positioner (3 receiver bays) Cassegrain focus : fixed (9 receiver bays)

Tab. 1.1 : Characteristics of Medicina's antenna

* 60° Elevation

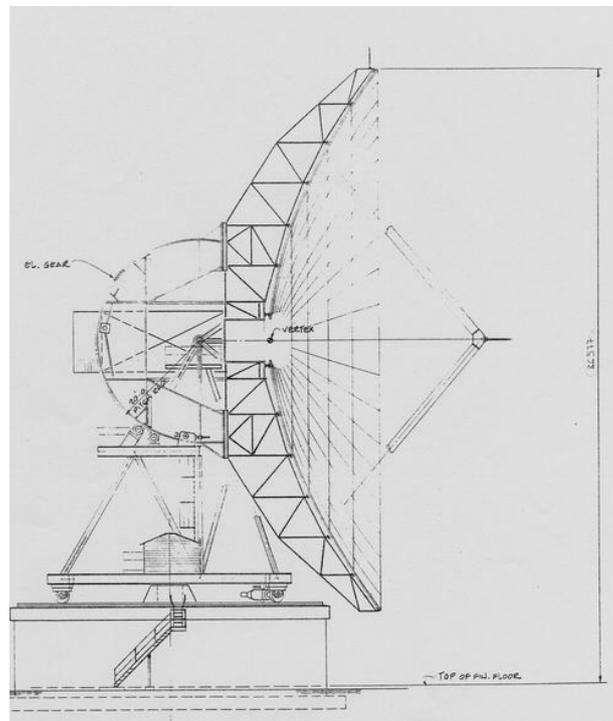


Fig. 1.2 : Medicina's antenna, side

2. Antenna Structure

2.1 Azimuth Rail

The whole antenna leans upon the azimuth rail, which has a 18.3 m diameter and has recently (2001) been renewed. Until 2000 the rail was directly substained by the grout basement (see fig. 2.1)

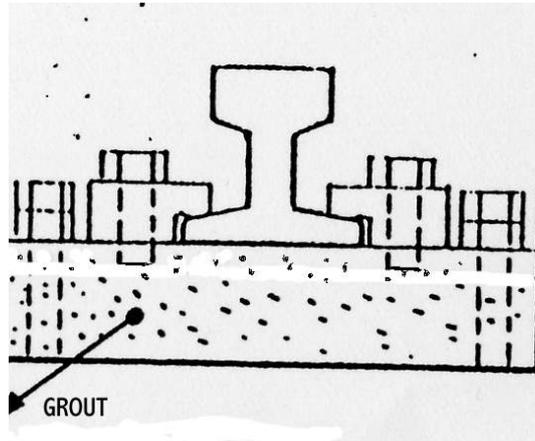


Fig. 2.1 : First solution

Then a more efficient solution, in terms of endurance, was proposed, and a metal plate was interposed between the rail and the grout basement. Moreover, a new kind of grout, a reinforced grout, was



Fig. 2.2 : Installation of the metal plate (antenna lifted) and finished work (the plate and the basement are both white painted)

2.2 Primary Reflector

The primary reflector, diameter 32 m, is made of 240 aluminium panels (RMS = 0.4 mm) substained by a backup reticular truss. The housing of the Cassegrain focus feeds is at the mirror vertex.

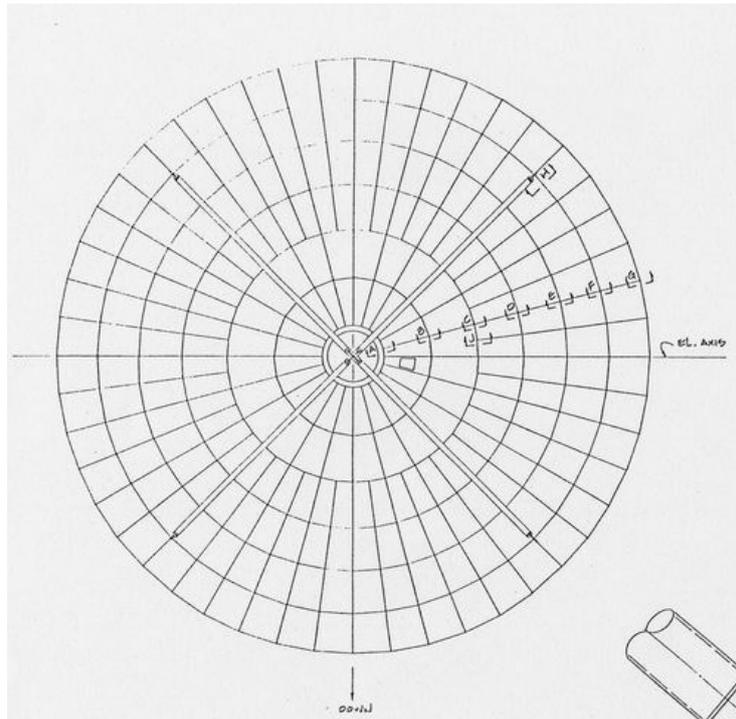
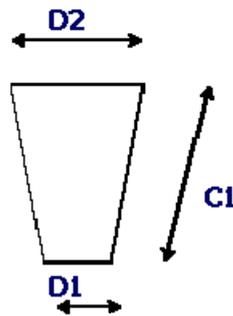


Fig. 2.3 : Primary reflector, front



	C1 (mm)	D1 (mm)	D2 (mm)
Raw B	2617.8	437.62	1113.96
Raw C	2604.15	1113.96	1770.4
Raw D	2617.24	887.1	1206.06
Raw E	2648.38	1206	1515
Raw F	2659.33	1515.04	1810.74
Raw G	2718	1810.74	2098.14

Tab 2.1 : Geometry of the panels

2.3 Quadrapod and Secondary Reflector

The primary reflector backup structure sustains the secondary mirror, placed at a distance of 9 m, through 4x45° inclined beams (quadrapod).

2.3.1 Wobbling

The system that rotates the secondary mirror has been optimized in order to enhance the number of receivers that can be installed at the Cassegrain focus.

Anyway, for the receivers installed in the [external circumference](#), the same movement can be used for the [Wobbling](#) technique. Typical shifting times, quite more [advantageous](#) if compared with the [Position Switching](#) technique, are listed in the following table.

Frequency (GHz)	Beam HPBW (")	Mirror rotation 2.5 beam (°)	Required time (sec)	Mirror rotation 5 beam (°)	Required time (sec)
5	450	2.56	1.16	5.12	2.12
6	390	2.22	1.03	4.44	1.86
22	120	0.68	0.45	1.37	0.71

Tab. 2.3 : Wobbling time for 2.5 beam and 5 beam

2.4 Pointing Errors

The accuracy of the pointing correction increases with the observing frequency, i.e. as the antenna beam width decreases.

It is commonly assumed the following :

$$\delta_p = \frac{HPBW}{10}$$

δ_p = pointing accuracy

HPBW = -3 dB beam width (main lobe)

For the Medicina antenna the values are listed in the following :

Frequency (GHz)	HPBW (')	Error (')
1.5	29	≤ 2.9
22	2	≤ 0.2

Tab. 2.4 : Beam and pointing errors

The systematic errors are usually quite high (some arcminute). Anyway they have been determined according to the antenna position (Az/EI) after apposite astronomical observations (reference radio sources) and a correction model has been derived.

Once the model has been applied, the residual error is 0.13' (both in azimuth and elevation), exactly as required.

2.5 Specification Summary

2.5.1 Observation conditions

	Parameters	Specifications
Precision	Wind, continuous	< 25 km/h
	Wind, gusts	20 ÷ 30 km/h
	Sun	Absent
	Precipitation	Absent
	Temperature	-25 ÷ 30 °C
Normal	Humidity	< 90 %
	Wind, continuous	< 65 km/h
	Wind, gusts	50 ÷ 80 km/h
	Precipitation	Absent
Survival	Temperature	-30 ÷ 50 °C
	Humidity	< 100%
	Wind	200 km/h
	Precipitation	< 5 cm/h snow
	Seismic	0.3 g horizontal

Tab. 2.5 : Observation conditions

In survival conditions, and when not in use, the antenna must be settled at 90° elevation and 180° azimuth (stow position).

2.5.2 Surface Accuracy

Structural Elements	(RSS mm) 90° EI	(RSS mm) 60° EI
Primary reflector panels	0.4	0.4
Secondary reflector panels	0.35	0.35
Gravitational deformation	0.58	0.19
Total surface accuracy	0.8	0.6

Tab. 2.6 : Surface accuracy at 90° and 60° elevation

To estimate the phase error from the surface accuracy, the following can be used :

$$\varepsilon = \frac{4\pi\delta}{\lambda} [\text{rad}]$$

δ = surface accuracy

λ = observation wavelength

Usually a maximum tolerable phase error is assumed as $\varepsilon \approx 36^\circ \approx 0.63 \text{ rad}$, so that the minimum observable wavelength is

$$\lambda_{\min} \approx 20\delta_{\max}$$

For the Medicina antenna :

$$\lambda_{\min} \approx 16 \div 12 \text{ mm} \rightarrow \nu_{\max} \approx 19 \div 25 \text{ GHz}$$

2.5.3 Pointing accuracy

E' IN ITALIANO!!

Condizione di osservazione	Precisione di puntamento (rms arcmin)
Normale/Precisione	0.13

Tab. 2.6 : Precisione di puntamento

3. Optics

The Medicina antenna has 2 focal positions :

- Primary focus : F1
- Cassegrain focus : F2

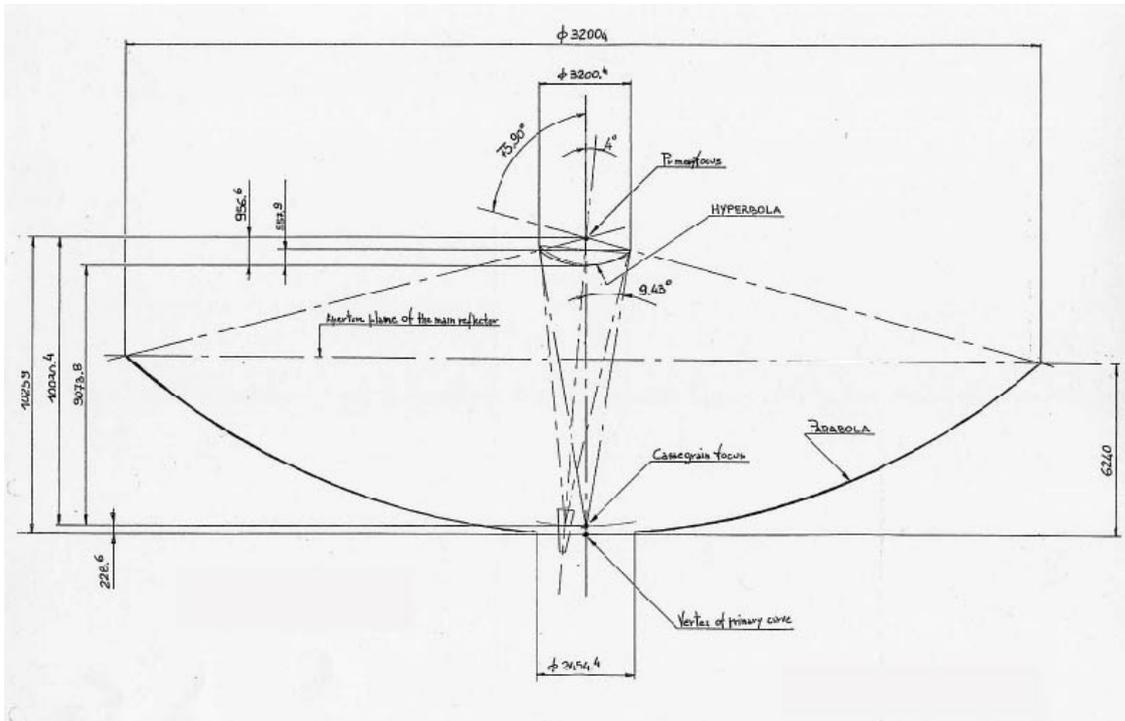


Fig. 3.1 : Optics of Medicina antenna [dimensions : mm]

3.1 Primary Focus

With the Cassegrain optic the primary reflector focus is usable only if the secondary reflector is completely retracted. Behind the mirror a movable positioner is installed, equipped with 3 receiver bays.



Fig. 3.2 : Primary focus feed positioner

The primary mirror focal length is nearly 10.3 m, therefore the focal ratio is $F_1/D \approx 0.32$.

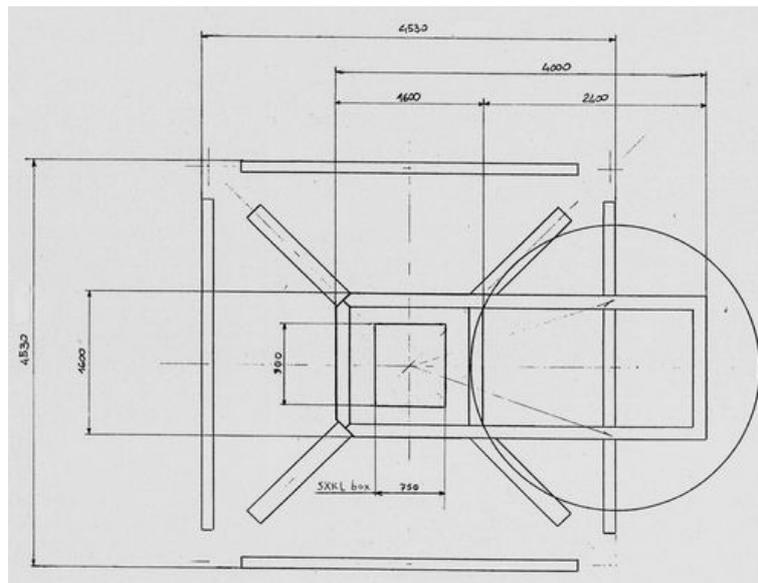


Fig. 3.3 : Primary focus (dimensions : mm)

3.2 Cassegrain Focus

The secondary mirror (9 m from the primary mirror) allows the usage of the Cassegrain focus (at nearly 20 cm above the reflector's vertex)

This focus has been studied to offer more adjacent focal positions, which can be obtained through the angular movement of the secondary mirror (see fig. 3.4).

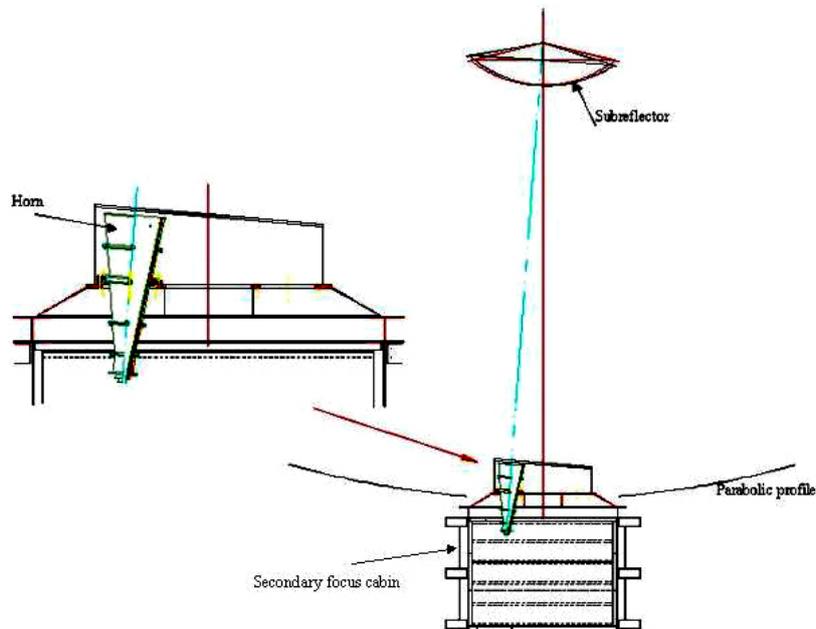


Fig. 3.4 : Cassegrain focal plane

At this focus, 9 receivers can be mounted (a central one plus eight around).



Fig. 3.5 : Cassegrain receiver bays

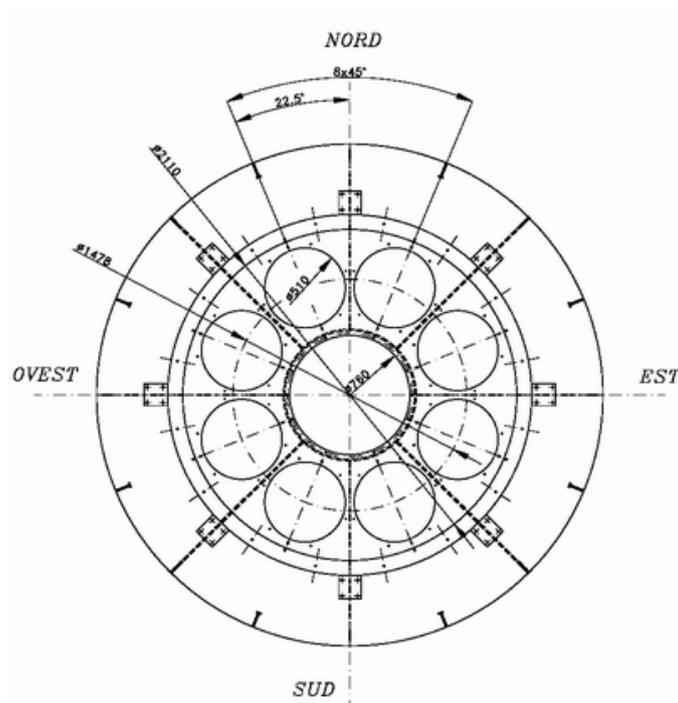


Fig. 3.6 : Cassegrain focus (dimensions : mm)

The secondary hyperbolic reflector operates a magnification i_2 which depends on the ratio between the focal length and the distance from the prime focus (nearly 20 m and 3 m, respectively).

The total focal length can be estimated as follows :

$$i_2 = \frac{9.074}{0.956} \approx 9.49$$

$$F_2 = i_2 \cdot F_1 \approx 97.36 \text{ [m]}$$

The focal ratio is therefore: $F_2 / D \approx 3.04$

By now at this focus the 5 GHz and 6 GHz receivers are installed.

3.3 Servosystems Specifications

Azimuth drive		Unity	Value
Kinematics	Angular travel	(°)	540
	Angular velocity	(°/sec)	0.8
	Angular acceleration	(°/sec ²)	0.82
Configuration	Number of wheels	(-)	4
	Driving wheels	(-)	2
	Drives per wheel	(-)	1
Track	Diameter	(m)	18.3

Tab. 3.1 : Azimuth drive

Elevation drive		Unity	Value
Kinematics	Angular travel	(°)	90
	Angular velocity	(°/sec)	0.5
	Angular acceleration	(°/sec ²)	0.31

Tab. 3.2 : Elevation Drive

Primary focus feed positioner		Unity	Value
Kinematics	Linear travel	(mm)	420
	Linear velocity	(mm/sec)	7.2
	Linear acceleration	(mm/sec ²)	24

Tab. 3.3 : Primary focus feed positioner, transverse axis

Primary focus feed positioner z axis		Unity	Value
Kinematics	Linear travel	(mm)	350
	Linear velocity	(mm/sec)	7.2
	Linear acceleration	(mm/sec ²)	24

Tab. 3.4 : Primary focus feed positioner, z axis

Sub-reflector		Unity	Value
Kinematics	Linear travel x axis	(mm)	160
	Linear travel y axis	(mm)	160
	Linear travel y axis out of focus	(mm)	2240
	Linear travel z axis	(mm)	250
	Angular travel x axis	(°)	±4.2*
	Angular travel y axis	(°)	±4.2*
	Linear velocity x axis	(mm/sec)	55.5
	Linear velocity y axis	(mm/sec)	17.1
	Linear velocity z axis	(mm/sec)	48.3
	Angular velocity	(°/sec)	1.9

Tab. 3.5 : Sub-reflector kinematics

4. Front End

The Medicina antenna covers the range 1.35÷24.1 GHz. As shown in the following scheme, the receivers installed in the primary focus (1.4/1.6, 2.3-8.3, 22 GHz) share some electronic parts (the single [sections](#) dedicated to the receivers show the connection lines for each frequency).

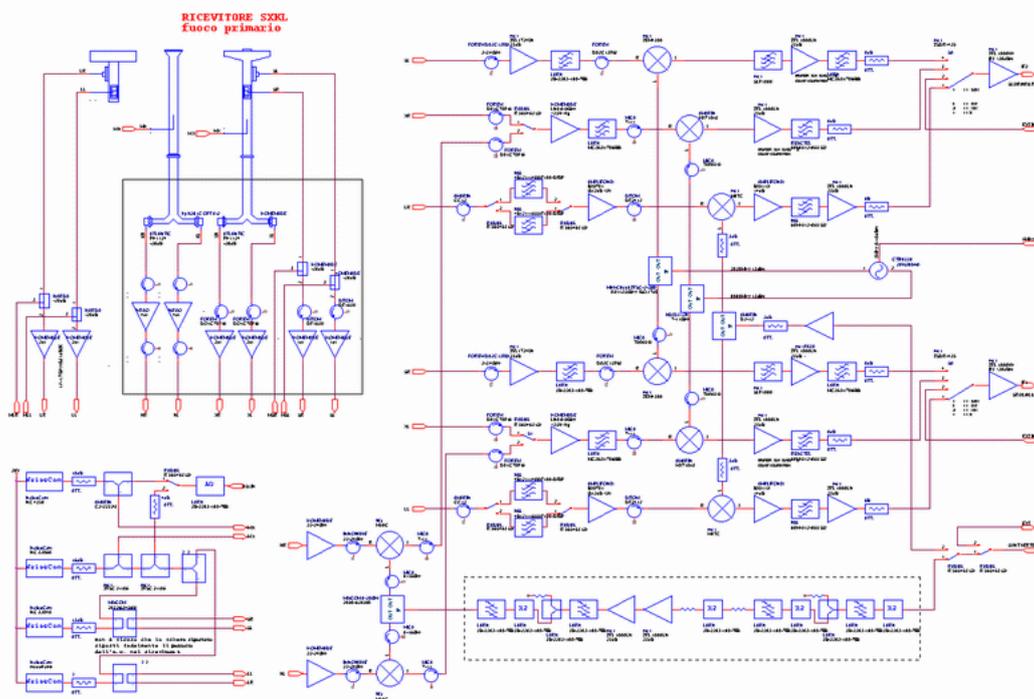


Fig. 4.1: Primary focus receivers scheme

The Cassegrain focus receivers are currently being updated and will soon be substituted with the wider band system developed for the Sardinia Radio Telescope (the 6 GHz receiver will be included in the new 7 GHz system).

The taper levels are the following :

Frequency (GHz)	Taper (dB)
<u>1.4/1.6</u>	-17
2.3	-16
5	-10
6	-14
8.3	-16
22	-15

Tab. 4.1 : Taper levels

4.1 Feeds and Receivers

The following receivers are available (click on frequencies for details) :

Band (Name)	ν_0 (GHz)	λ (cm)	Receiver N°	Beam (°)		ν_{Lsky} (GHz)	ν_{Hsky} (GHz)	Receivers band (MHz)	Noise temperature (K)	Configuration	Calibration Info
				N/S	E/W						
L	1.4	21	lhp	31.0	31.3	1.35	1.45	2x80	50		LH
L	1.6	18	llp	27.5	27.6	1.595	1.715	2x80	60		LL
S	2.3	13	ssp or sxp*	18.6	17.3	2.20	2.36	2x160	40	Coaxial 8.3 GHz	SS
C	5	6	ccc	7.50	7.40	4.65	5.15	2x350	44		CC
C	6	5	chc	7.00	6.50	5.90	7.10	2x400	57		CH
X	8.3	3.6	xsp or sxp*	4.80	5.00	8.18	8.98	2x800	25	Coaxial 2.3 GHz	XX
K	22	1.3	kkp	2.00	2.00	21.86	24.14	2x800	80		KK

Tab. 4.2 : Receivers parameters

*Name related to the coaxial use

Primary Focus
Cassegrain Focus

$\nu_{Lsky} \div \nu_{Hsky}$: receiver maximum bandwidth

The receivers label has been assigned only for identification (purpose) (the p and c letters stands for (primary) and Cassegrain focus respectively).

[HOW TO READ THE CALIBRATION TEXT FILES](#) (See Appendix)

At 1.4, 1.6, 2.3 GHz available bandwidths may be considered less than what reported because of interferences.

Multifrequencies observations can be conducted by quick receiver changes (frequency agility):

	LL/LH	SX/SS/XX	CC	CH	KK
LL/LH		46 sec	3 min 20 sec	3 min 20 sec	22 sec
SX/SS/XX	46 sec		3 min 25 sec	3 min 25 sec	26 sec
CC	3 min 20 sec	3 min 25 sec		3 sec	3 min 21 sec
CH	3 min 20 sec	3 min 25 sec	3 sec		3 min 21 sec
KK	22 sec	26 sec	3 min 21 sec	3 min 21 sec	

Tab. 4.3 : Switching times between receivers (COLORI DIVERSI?)

1.4/1.6 GHz

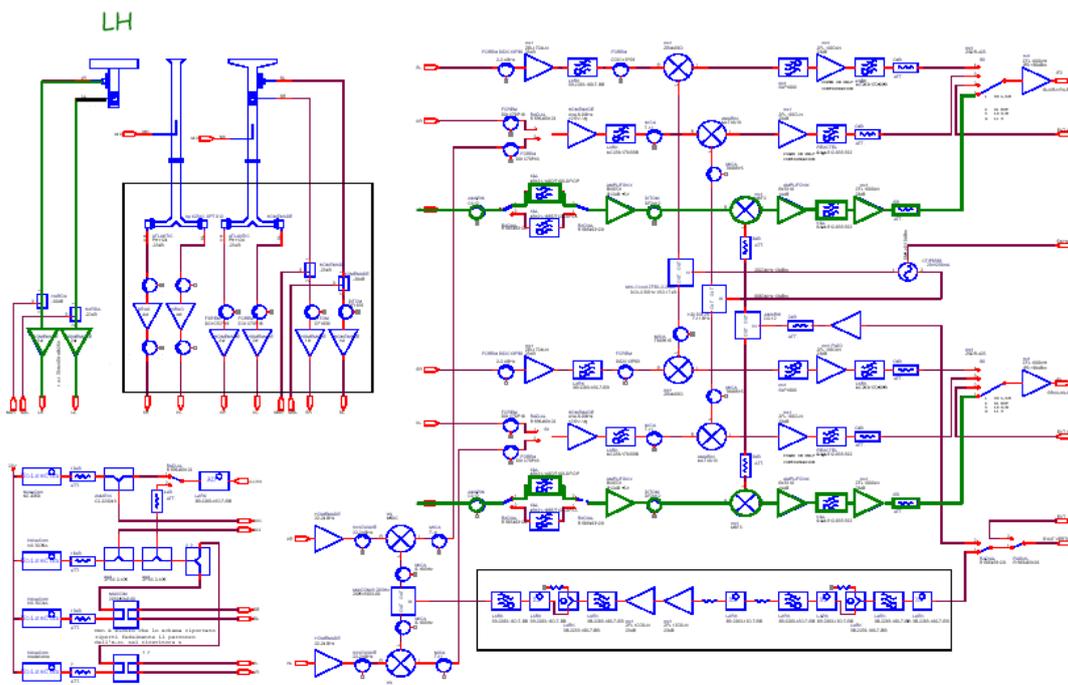
Type	Hot	
Channels	2	
Polarization	LHC-RHC	
Central frequency (GHz)	1.406	1.665
Noise temperature	50 K	60 K
Useful RF band (GHz)	1.35÷1.45	1.595÷1.715
RF filter width (MHz)	100	120
IF filter width (MHz)	80	80
Istantaneous RF band (GHz)	1.366÷1.446	1.625÷1.705
OL frequency (GHz)	1.036	1.295
OL range (GHz)	1.020÷1.040	1.265÷1.305
Conversion (GHz)	Single USB 0.33÷0.41	

Standard parameters of the 1.5 GHz parameters

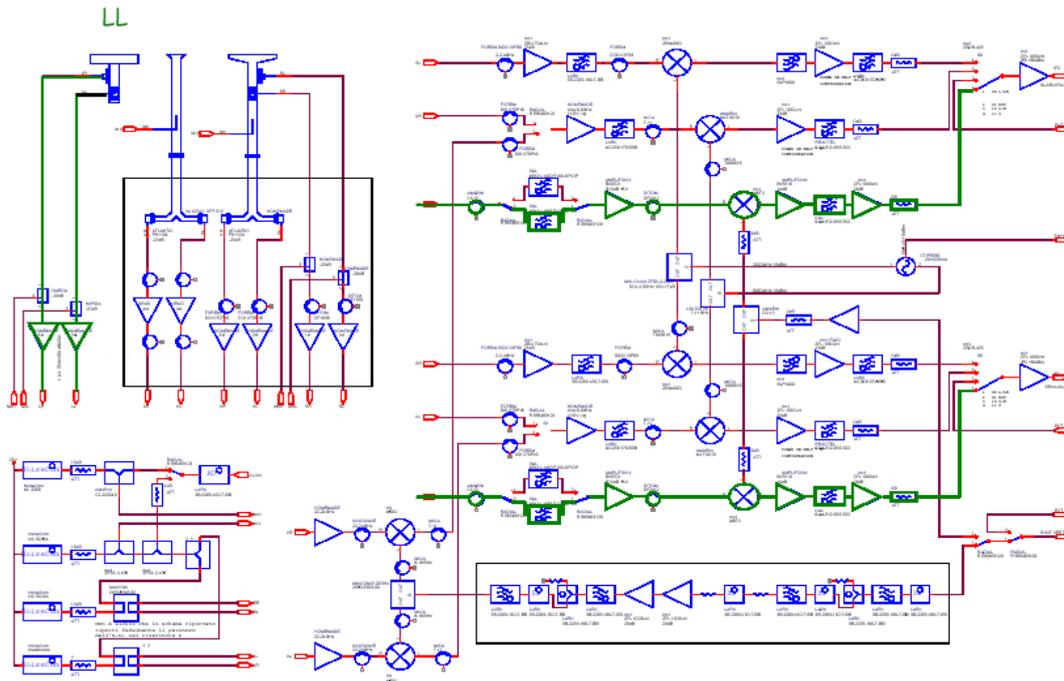
The maximum bandwidth is 80 MHz, tunable only within the two RF ranges listed in the above table. To shift the IF standard band inside the RF band of $\Delta\nu$, the OL frequency must be changed (within the range listed in the table) according to the following :

$$RF = 1.350 \div 1.450 \rightarrow v_{OL} = 1.036 \pm \Delta\nu$$

$$RF = 1.595 \div 1.715 \rightarrow v_{OL} = 1.295 \pm \Delta\nu$$



1.4 GHz receiver scheme (green lines)



1.6 GHz receiver scheme (green lines)

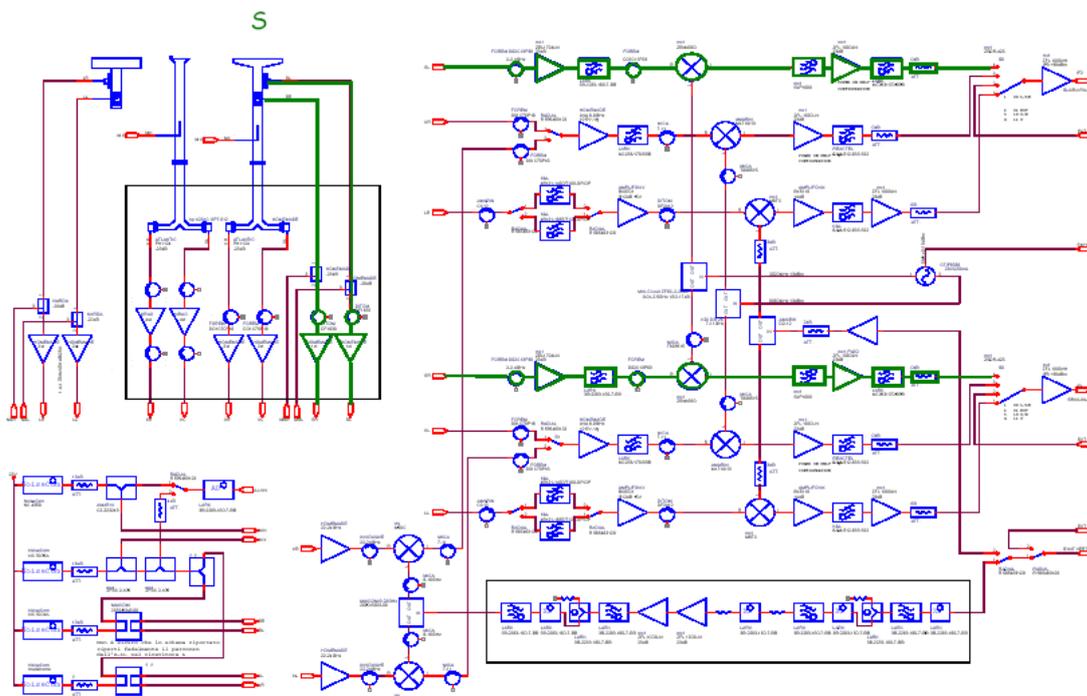
At 1.4, 1.6 GHz available bandwidths may be considered less than what reported because of interferences.

2.3-8.3 GHz

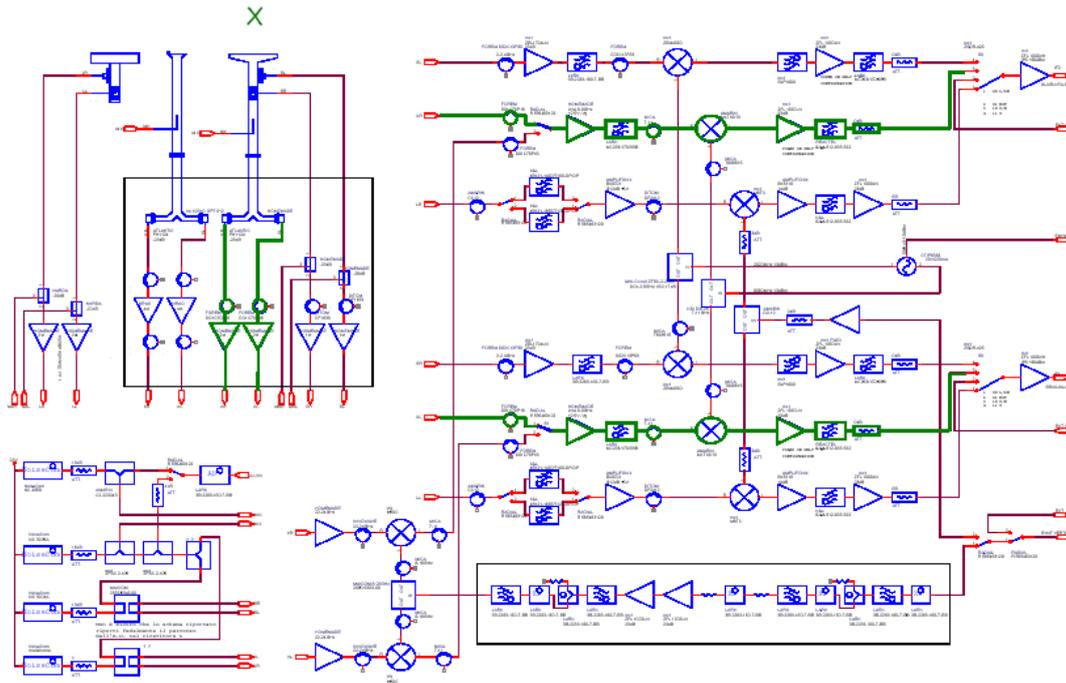
Type	Cooled Coaxial	
Canali	2	
Polarization	LHC-RHC	LHC-RHC
Central frequency (GHz)	2.28	8.58
Noise temperature	40	25
Useful RF band (GHz)	2.20÷2.36	8.18÷8.98
RF filter width (MHz)	160	800
IF filter width (MHz)	160	800
Istantaneous RF band (GHz)	2.20÷2.36	8.18÷8.98
OL frequency (GHz)	2.020	8.080
OL range (GHz)	0	0
Conversion (GHz)	Single USB 0.18÷0.34	Single USB 0.1÷0.9

Standard parameters of the 2.3-8.3 GHz coaxial receiver

It is possible to use the receivers both together (coaxial, 2 IF outputs, one per each frequency) and separately (2 IF outputs). For the VLBI coaxial observation one channel only for each receiver is used, typically the right polarization one (this because the Mark IV can handle only 2 IF inputs).



2.3 GHz receiver scheme (green lines)



8.3 GHz receiver scheme (green lines)

At 2.3 GHz available bandwidths may be considered less than what reported because of interferences.

5 GHz

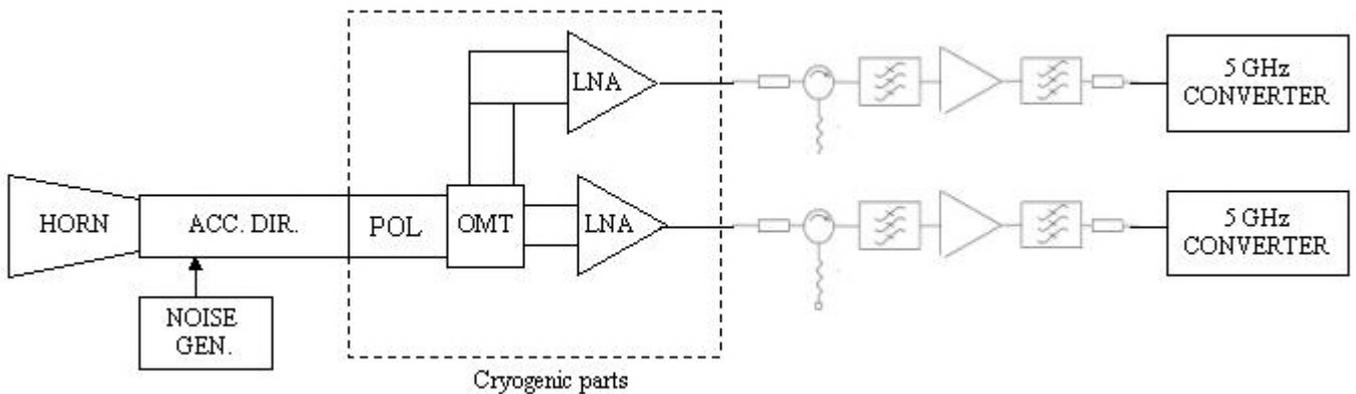
Type	Cooled
Channels	2
Polarization	LHC-RHC
Central frequency (GHz)	4.875
Noise temperature	44
Useful RF band (GHz)	4.65÷5.15
RF filter width (MHz)	500
IF filter width (MHz)	350
Istantaneous RF band (GHz)	4.700÷5.050
OL frequency (GHz)	1.150x4
OL range (GHz)	1.138÷1.175
Conversion (GHz)	Single USB 0.1÷0.45

Standard parameters of the 5 GHz receiver

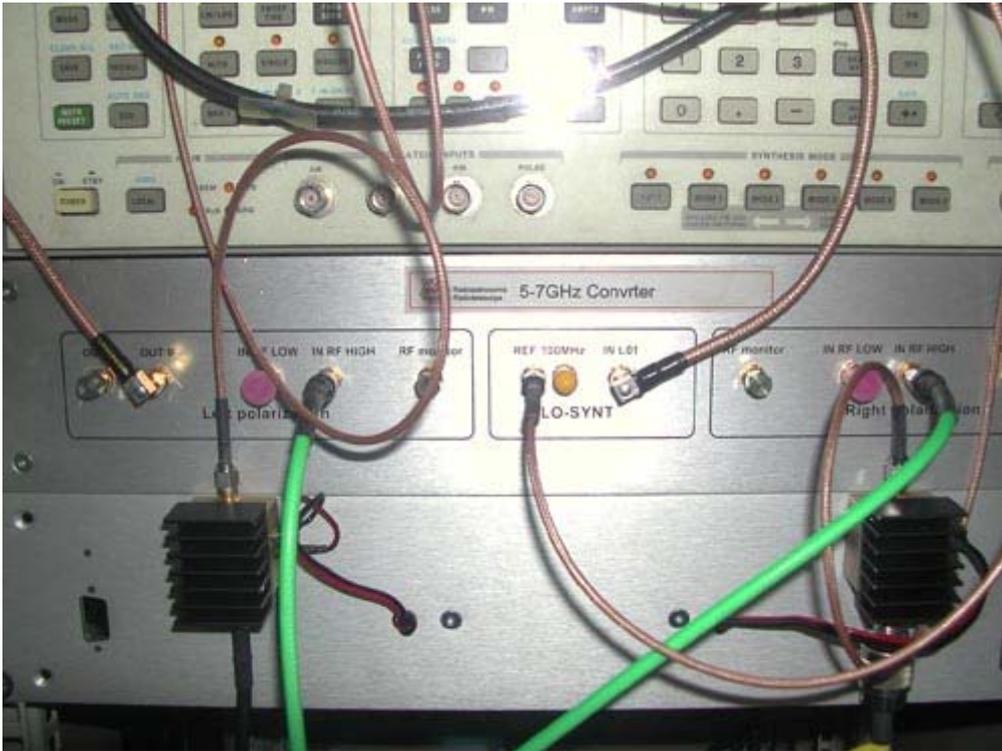
To shift the IF standard band inside the RF band of $\Delta\nu$, the OL frequency must be changed (within the range listed in the table) according to the following :

$$v_{OL} = \frac{4.600 \pm \Delta\nu}{4}$$

This receiver will be soon updated (the band will become wider). The following conversion scheme is related to the new receiving system.



5 GHz receiver scheme



5-7 GHz converter

6 GHz

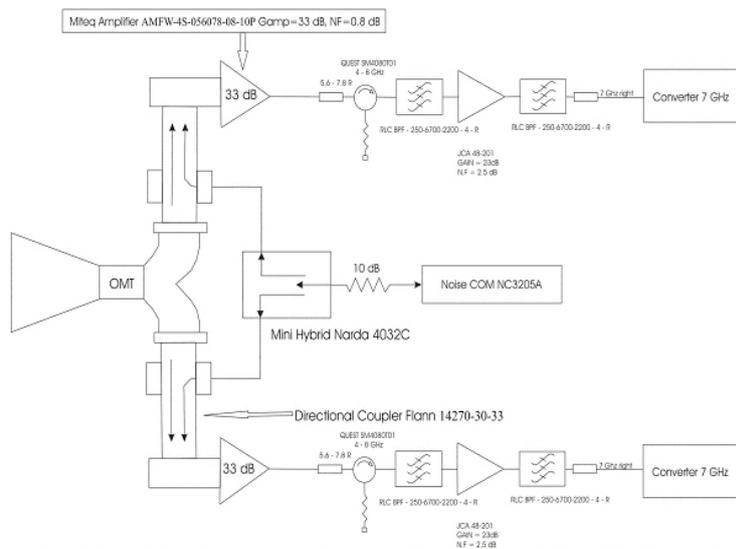
Type	Hot	
Channels	2	
Polarization	LHC-RHC	
Central frequency (GHz)	6.1	6.7
Noise temperature	57	
Useful RF band (GHz)	5.90÷7.10	
RF filter width (MHz)	1200	
IF filter width (MHz)	400	
Istantaneous RF band (GHz)	5.90÷6.30	6.50÷6.90
OL1 frequency (GHz)	8.10	8.70
OL2 frequency (GHz)	2.30	2.30
OL1 range (GHz)	8.10÷9.30	
Conversion (GHz)	Double LSB 1.80÷2.20 0.1÷0.5	

Standard parameters of the 6 GHz receiver

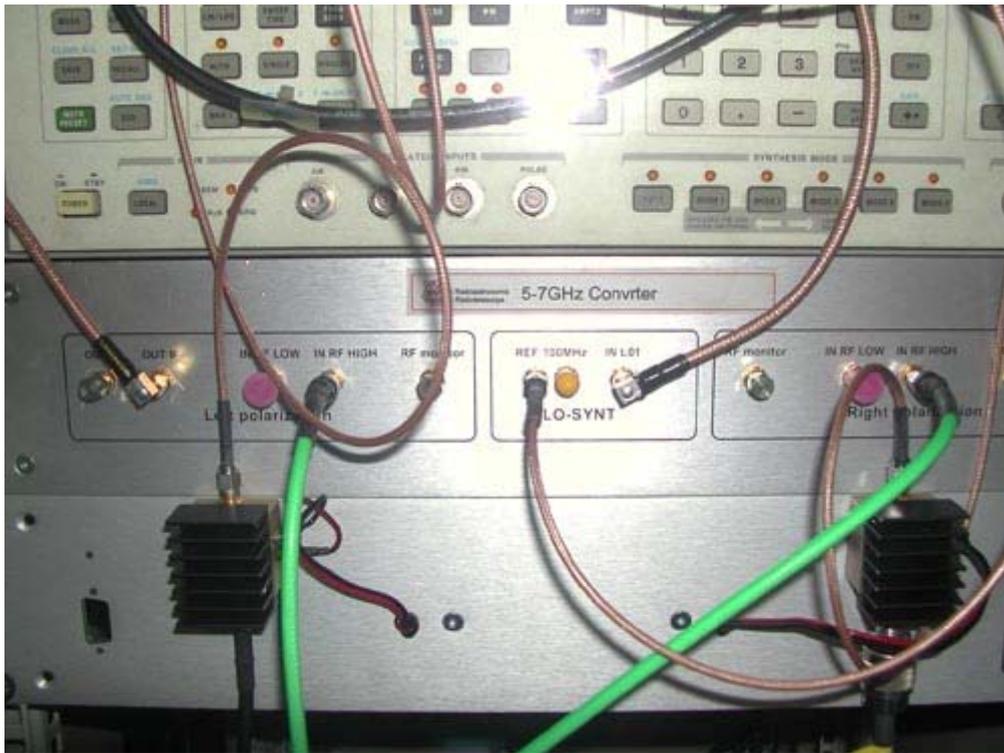
To shift the IF standard band inside the RF band of $\Delta\nu$, the OL frequency must be changed (within the range listed in the table) according to the following :

$$\nu_{OL} = 8.10 \pm \Delta\nu$$

This receiver will be soon updated(?) (the band will become wider and the central frequency will be 7 GHz). The following conversion's scheme is related to the new receiving system.



7 GHz receiver scheme



5-7 GHz converter

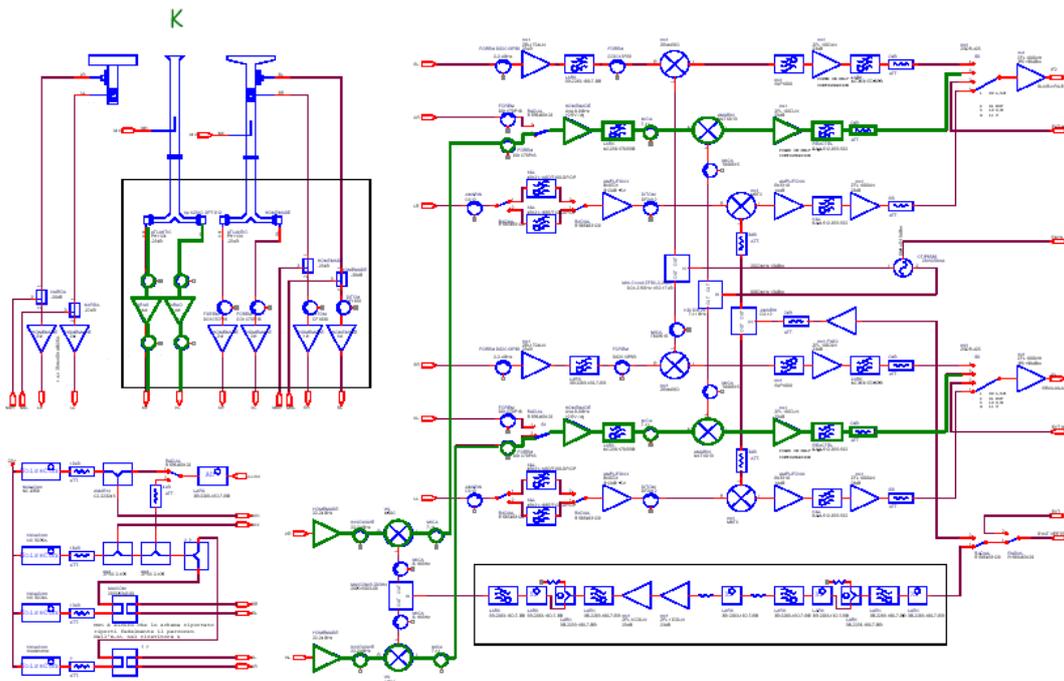
22 GHz

Type	Cooled
Channels	2
Polarization	LHC-RHC
Central frequency (GHz)	22.464
Noise temperature (K)	80
Useful RF band (GHz)	21.86÷24.14
RF filter width (MHz)	2300
IF filter width (MHz)	800
Istantaneous RF band (GHz)	22.064÷22.864
OL1 frequency (GHz)	1.7355 (x8)
OL2 frequency (GHz)	8.080
OL1 range (GHz)	1.710÷1.945
Conversion (GHz)	Double USB 8.18÷8.98 0.1÷0.9

Standard parameters of the 22 GHz receiver

To shift the IF standard band inside the RF band of $\Delta\nu$, the OL frequency must be changed (within the range listed in the table) according to the following :

$$v_{OL} = \frac{(21.964 \pm \Delta\nu) - 8.080}{8}$$

Schema del ricevitore a 22 GHz (evidenziato in verde) **E' IN ITALIANO**

4.2 Distribution

The connections between the radiotelescope's foci involve three different kinds of signal :

- . Local Oscillator : in order to cut down the expenses related to the construction of an high number of independent superheterodyne receivers, a very common solution is to share some local oscillators (at least for one conversion). A single local oscillator therefore can serve more receivers through a signal distribution system.
- . IF : the RF signals, once received and converted by the Front End, are sent to the Back End installed in the Control Room, at the antenna's base.
- . Reference : 5 MHz H-maser signal, necessary for the local oscillator stability.

All the signals are distributed via coaxial cable.

The distribution scheme is simplified by the fact that there are only two double conversion receivers (6 GHz at the Cassegrain focus and 22 GHz at the primary focus) and both use the same local oscillator for the second conversion. Besides the two receivers' channels can't be placed in different position inside the RF bandwidth.

The OL signal is distributed by and OL distributor (OLD).

The reference distributor (REFD) and the IF distributor (IFD) are also installed at the Cassegrain focus. From the control room it is possible to choose the receiver through the selector.

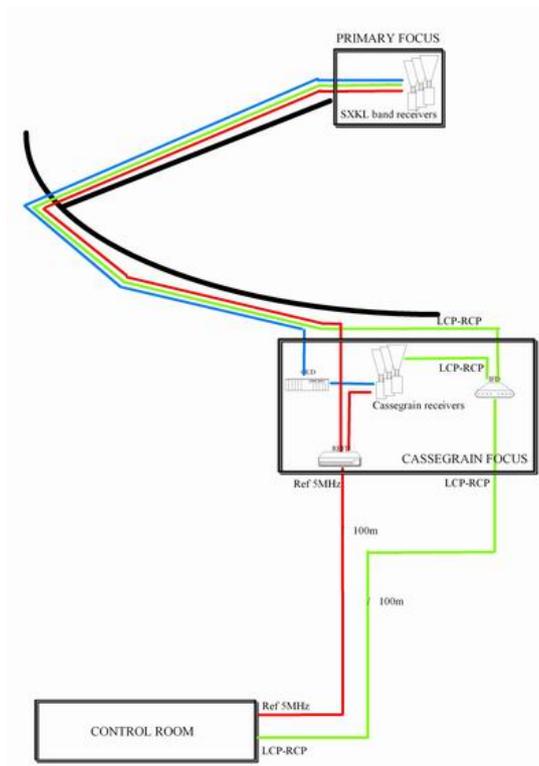


Fig. 4.2 : Signal distribution between the foci

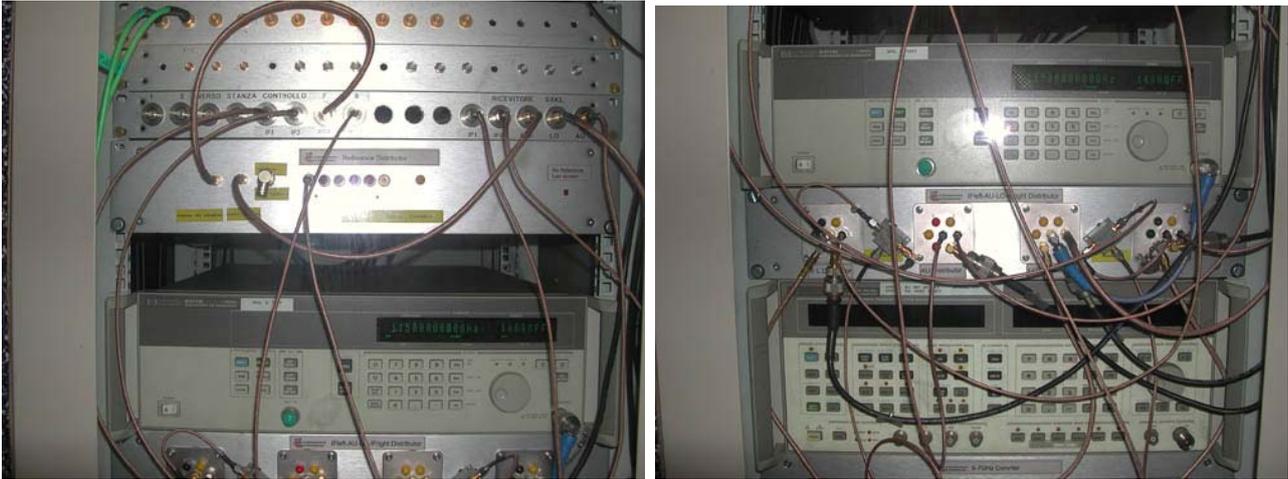


Fig. 4.3 : Distributors : reference signal (on the left) and local oscillator (on the right)

4.3 Control Room

The backend systems are installed in the control room, located at the antenna's base. It is connected to the foci through the links shown in the following (red line and green line are fiber optic links) :

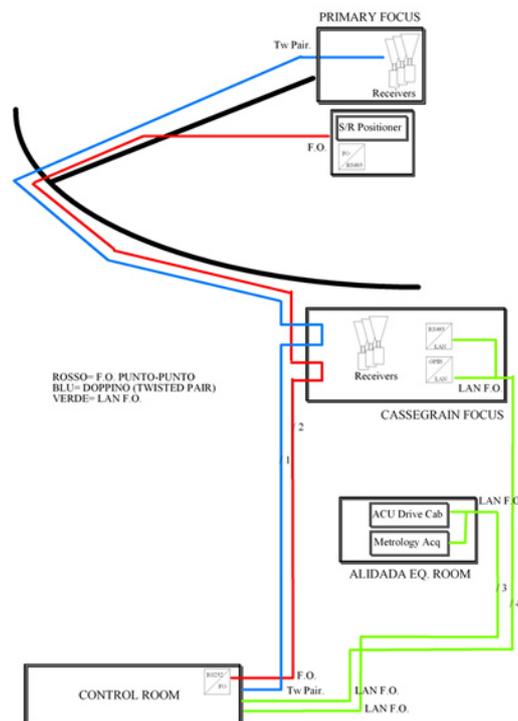


Fig. 4.3 : Control links

From the control room it is possible to act on receivers, antenna's movement and sub-reflector's movement. Besides it will be possible to interact with the new metrology system (temperature sensors and a little optical telescope installed at the Cassegrain focus) projected for SRT and that will be tested on the Medicina's antenna

The control room is part of the Observatory LAN (at nearly 500 meters from the antenna).

5. Efficiency and System Temperature

The antenna gain is defined as :

$$G = 10^{-26} \frac{m \eta_A A_g}{k_B} \left[\frac{\text{K}}{\text{Jy}} \right]$$

$m = 0.5$ (non polarized radiation)

A_g = geometric area

k_B = Boltzmann's constant

η_A = antenna efficiency

For the Medicina antenna, the constants are :

$$10^{-26} \frac{A_g}{2 \cdot k_B} \approx 0.292$$

η_A is the overall efficiency, estimated assembling all the signal degradation factors.

The antenna gain varies according to the elevation and it reaches a maximum at 45°. A good interpolation is obtained with a second degree curve, such as :

$$ax^2 + bx + c$$

The coefficients of the normalized polynomials, at each frequency, are listed in the following :

Frequency (GHz)	a	b	c
1.4	$-6.8310687 \cdot 10^{-5}$	$7.285044 \cdot 10^{-3}$	$8.0577027 \cdot 10^{-1}$
1.6	$-2.6828893 \cdot 10^{-5}$	$3.4836402 \cdot 10^{-3}$	$8.869153 \cdot 10^{-1}$
2.3	$-1.3256035 \cdot 10^{-4}$	$1.7229174 \cdot 10^{-2}$	$4.4017117 \cdot 10^{-1}$
5	$-5.3473118 \cdot 10^{-5}$	$6.0312044 \cdot 10^{-3}$	$8.2993592 \cdot 10^{-1}$
6	$-5.8197959 \cdot 10^{-5}$	$9.4270958 \cdot 10^{-3}$	$6.1824204 \cdot 10^{-1}$
8.3	$-7.2457279 \cdot 10^{-5}$	$1.0623634 \cdot 10^{-2}$	$6.1059261 \cdot 10^{-1}$
22	$-2.4658337 \cdot 10^{-4}$	$2.0935913 \cdot 10^{-2}$	$4.4252013 \cdot 10^{-1}$

Tab. 5.1 : Normalized gain curves, coefficients

[FROM THIS PAGE IT IS POSSIBLE THE DOWNLOAD OF THE UPDATED CALIBRATION FILES](#)

The sensitivity can be estimated as follows :

$$\Delta S = \frac{\alpha T_{sys}}{G \sqrt{\Delta \nu \tau n N_{IF}}}$$

α = receiver constant (=1)

T_{sys} = system temperature

G = gain (K/Jy)

$\Delta \nu$ = bandwidth

τ = integration time

n = integration number

N_{IF} = available channels (= 1,2)

In the following table the system temperatures and the sensitivities of the Medicina antenna are listed :

ν_0 (GHz)	T receiver (K)	Tsys (K)	η_A (%)	G (K/Jy)	SEFD (Jy)	Band (MHz)	ΔS ($mJy\sqrt{s}$)
1.4	50	58	41	0.120	483	2x80*	38.2
1.6	60	64	36	0.106	604	2x80*	47.8
2.3	40	58	43	0.125	464	2x160*	26.0
5	44	50	58	0.169	296	2x350	11.2
6	57	65	50	0.145	676	2x400	23.9
8.3	25	40	48	0.141	284	2x800	7.1
22	80	145	38	0.110	1318	2x800	33.0

Tab. 5.2 : Sensitivity of the antenna, assuming $\tau = 1$ sec, $n=1$, $N_{IF} = 2$

Primary Focus

Cassegrain Focus

*Usually at this frequencies the band used is narrower than the maximum allowed by the receivers, because of the interferences.

6. VLBI

Regarding the VLBI observations, the Medicina antenna is part of the EVN ([European VLBI Network](#)) since 1984.

Some observations are conducted using only the two Italian antennas (Noto and Medicina) and the Bonn correlator. Once SRT will be operating there will be the possibility of using an all Italian VLBI network (I-VLBI).

7. Observing Modes

7.1 ON-OFF Techniques

In order to reduce as much as possible the atmospheric contribution during an observation, it is possible to apply some techniques based on at least a couple of exposures, one on source and one on an adjacent area ("OFF source" reference position), sufficiently free from emission.

At high frequencies short-scale and strong atmospheric fluctuations affect the observation, hence the need of quick antenna shifts between the two positions (which have to be reasonably next to each other) or the usage of other techniques which do not involve the movement of the entire structure.

The Medicina antenna offers the following ON-OFF techniques :

. Position Switching

The antenna shifts between two different positions. The time needed to cover some beams is nearly 5 seconds at all frequencies.

. Wobbling

The shifting of the beam is obtained moving the secondary mirror only. This technique requires always a shorter time than the Position Switching but it can be used only with the [external circumference receivers](#). As the maximum angular travel of the secondary reflector is limited, a single OFF position, inside the circumference, can be setted.

In both cases the algorithm used is of the type ON-OFF-ON-OFF.

7.2 Mapping Techniques

If the radio emission is extended over an area larger than the antenna beam, several pointings might be necessary in order to cover the entire area of interest.

The Nyquist theorem states that the correct source sampling along a direction requires an angular distance between the pointings of :

$$\Delta\theta = \frac{1\lambda}{2D}$$

The Nyquist sampling is commonly expressed as beam's fraction :

$$\Delta\theta = \frac{1\lambda}{2D} \approx 0.43HPBW$$

The Medicina antenna mainly offers two mapping techniques :

. Raster Scan

The map is obtained through discrete adjacent pointings ("point and shoot" mode). At every step the antenna stops and acquires data for the exposure time required.

The time necessary to cover an area A , considering the on-source time only, with a monofeed system, can be roughly estimated with the following :

$$t_{ON} \approx N_p \cdot t_{esp}$$

$$N_p = \frac{A}{(HPBW/2)^2}$$

N_p = number of pointings

t_{esp} = single exposure time (depending on the sensitivity required).

The Nyquist sampling is approximated with a $1/2$ beam shift in both directions (vertical and horizontal).

Usually this mapping technique is associated with an ON-OFF technique, therefore the total time necessary to complete a survey is given by :

$$t_{TOT} = t_{ON} + t_{OFF} + t_{sh}$$

$$t_{OFF} = N_p \cdot t_{esp} = t_{ON}$$

t_{sh} = antenna shifting time (Position Switching) or secondary mirror shifting time (Wobbling)

The scan can be conducted in several user-defined ways, the most common is along two perpendicular directions ("cross scan").

. On-The-Fly

In the "On-The-Fly" mode the antenna is moved along one direction, usually with a "raws-and-columns" path, at constant speed. The data are continuously acquired and downloaded by the backend every few seconds ("OTF dumps"), corresponding to angular excursions of few arcseconds (depending on the antenna speed).

To reach the required sensitivity it is necessary to scan the same area several times, preferably along different directions.

The ON-source time is :

$$t_{ON} = N_d \cdot t_d$$

t_d = acquisition time

N_d = number of dumps (depending on the required sensitivity).

The Nyquist sampling is obtained if the acquisition time, for each dump, corresponds to an angular antenna shift equal or shorter than the ideal Nyquist distance.

Also the distance between raws and columns must be coherent with the Nyquist sampling.

The On-The-Fly technique is characterized by very short scanning times, so it is the best one in order to reduce the atmospheric contribution (anyway it is necessary to use an ON-OFF technique). For a squared spectroscopic map the total observing time is estimable with the following :

$$t_{ON} = t_{ON} + t_{OFF}$$

$$t_{OFF} = \sqrt{N_d} \cdot t_{ON}$$

The Medicina antenna offers the On-The-Fly Mapping on a user defined RA/Dec map, with a maximum scan's speed of 200 "/s.

By now this technique has been tested and used only for polarimetric observations.

7.3 Pulsar

The radio pulses observed from pulsar sources meet with a delay which is also function of the frequency.

If the total delay is comparable to the pulses period the impulsive peculiarity of the signal can be cancelled. Hence the need of many narrow adjacent channels that must be revealed and summed with the right respective delay. This technique is named "coherent dedispersion".

8. Back End

The Medicina antenna is equipped with the following processing systems :

- [ARCOS Autocorrelator](#)

Input	2
Maximum bandwidth per input	16 MHz
Minimum bandwidth per input	0.125 MHz*
Channels	2048
A/D Conversion	2 bit
Available software	ADLB4

Tab. 8.1

*Can be further reduced on request

- [Mspec0 Spectrometer](#)

Input	1
Maximum bandwidth per input	16 MHz
Minimum bandwidth per input	0.5 MHz
Channels (by choice)	512÷131000
A/D Conversion	10 bit
Available software	SPETT

Tab. 8.2

- [Total Power](#)

Input	3
Maximum bandwidth per input	400 MHz
A/D Conversion	16 bit
Available software	ON-OFF

Tab. 8.3

- [Polarimeter](#)

Input	2 LHC - RHC
Maximum bandwidth per input	400 MHz
Stokes output	Digital Q - U
Available software	POLSCHE POLMED

Tab. 8.4

- [Pulsar](#) (SPEX)

Input	2
Maximum bandwidth per input	64 MHz
Filters	4 x 32 x 1 MHz
A/D	16 x 8 ch x 1 bit
Data acquisition	3 ÷ 15 µs
Timing precision	< 1 µs

Tab. 8.5

- [VLBI](#) (Mark IV / Mark V)

Input	2
Maximum bandwidth per input	400 MHz
Output (by chance)	28 x 0.125 ÷ 16 MHz
A/D Conversion (by chance)	1 ÷ 2 bit
Data transfer	1 Gbit/s
Hard Disk	2 x 8 x 400 Gbyte

Tab. 8.6

At 1.4, 1.6, 2.3 GHz available bandwidths may be considered less than what reported because of interferences.

8.1 Spectrometers

8.1.1 Arcos

Arcos (ARcetri COrrrelation Spectrometer) is a digital spectrometer developed by the Osservatorio di Arcetri. It is connected to the Mark IV and receives 2x16 MHz input from the videoconverters of the terminal.

The system could handle 2x20 MHz bands, anyway the Mark IV imposes 2x0.125 ÷ 16 MHz bands (2ⁿ steps)*

The main constituents are :

- . 2 correlation boards (2048 channels in total)
- . 2 A/D sampler (4 channel sampler boards, 2 bit, 4 levels)

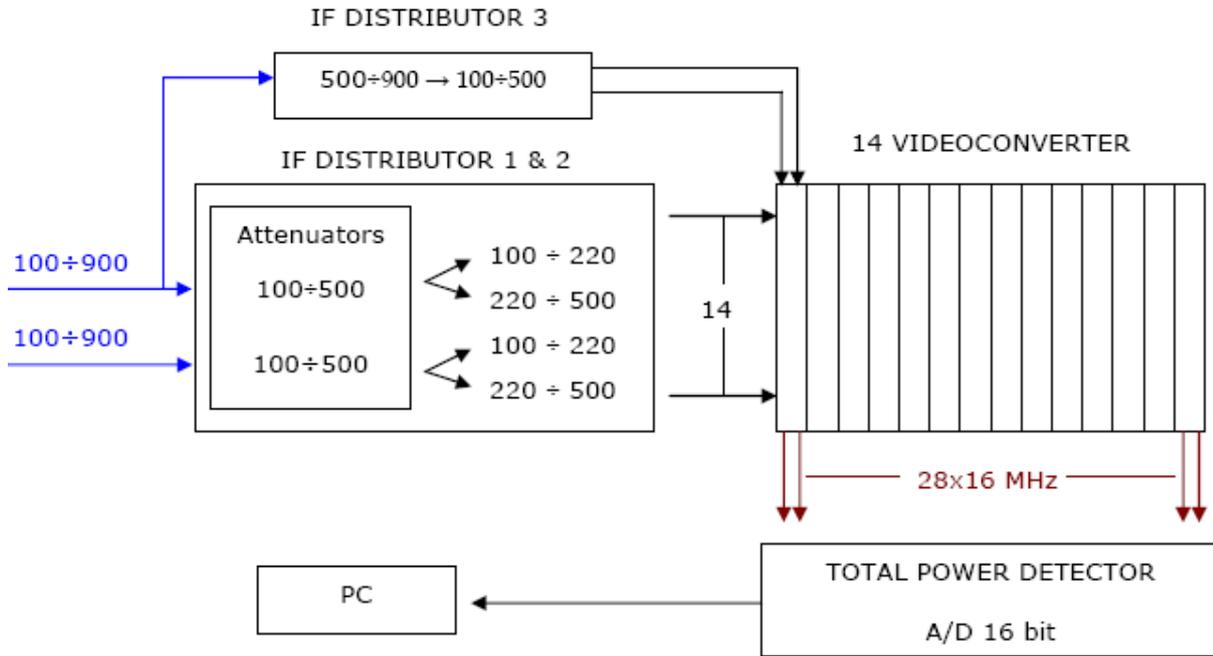


Fig. 8.1 : ARCOS correlator scheme, example at 22 GHz (bands in MHz)

8.1.2 Mspec0

[Mspec0 WEB SITE](#) (Italian only)

This high resolution digital spectrometer, installed in 1994, offers from 512 to 131072 channels (2^n steps)* on a maximum bandwidth from 125 kHz to 16 MHz. Inside those ranges the resolution is user-defined. In the following table there are some examples :

Band	Channels	Resolution
0.125 kHz	512	0.24 Hz
1 MHz	4096	244 Hz
16 MHz	131072	122 Hz

Tab. 8.7 : Resolutions that can be obtained with Mspec0

The spectrometer receives 1 analog band from the Mark IV, digitizes it and applies an high efficiency FFT algorithm.

The main components are :

- . 1 Ultra ADC A/D board
- . 1 VT-524 board
- . 2 UltraDSP/1128 board equipped with 2 LH9124 processors (VME environment)

The processors run in parallel and operate the 24 bit, 256000 spectral points, Fourier transforms. The resulting spectra are integrated on the VT-524 board.

The DSP boards are completely programmable through the VME bus. The VT-524 board also allows the results to be shown in real time, as they are processed (the time required for the processing of a single spectrum is nearly 1 ms).

The spectrometer is TCP/IP connected to an external PC equipped with the "Spett" software, which supplies the user interface, in order to set the control system (channels number, sampling frequency, number of spectra to be averaged, number of On-Off cycles), and which is integrated in the "Field System" software for the antenna set up (pointing, observing frequencies, etc...).

The same PC is used to see the results during the observation.

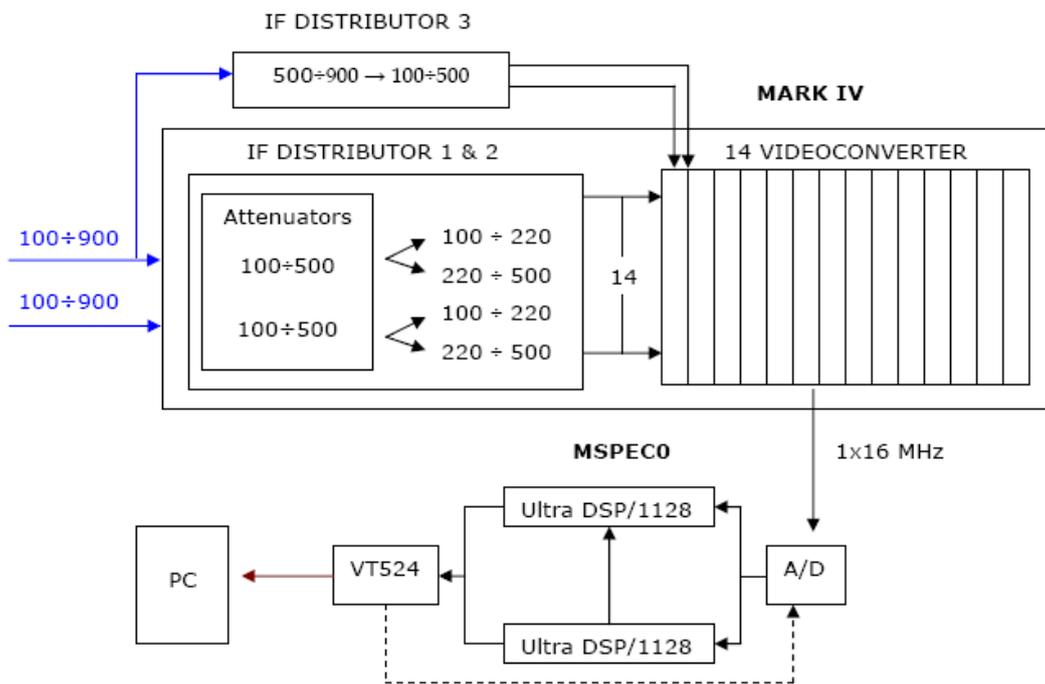


Fig. 8.2 : Mspec0 scheme example at 22 GHz (bands in MHz)

* 0.125 MHz and 1 MHz band are available only with external filter, please ask if available at the site.

8.2 Continuum

8.2.1 Mark IV

The Total Power observations use the Mark IV terminal and the "Field System" software.

The terminal is made of two parts: IF distributor (receives the input from the Front End and splits them in sub-bands), Videoconverters (14 unities that operate the base-band conversion and the integration). It is possible to choose between two outputs :

A) 28 narrow bands : minimum width 0.125 MHz, maximum 16 MHz*, central frequency user-defined (maximum total bandwidth 400 MHz).

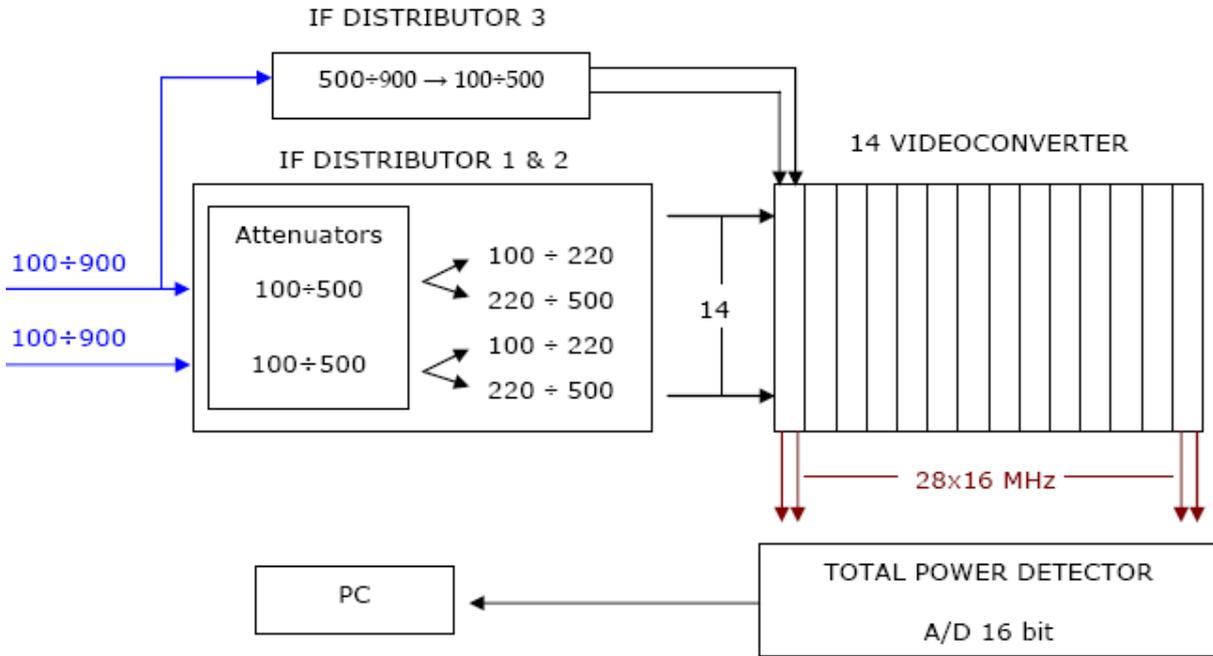


Fig. 8.3 : Maximum bandwidths (MHz) processed by the Mark IV, example at 22 GHz

* 0.125 MHz and 1 MHz band are available only with external filter, please ask if available at the site.

B) Processing of the whole inputs: 2×400 MHz centered at 300 MHz and 1×400 MHz centered at 700 MHz

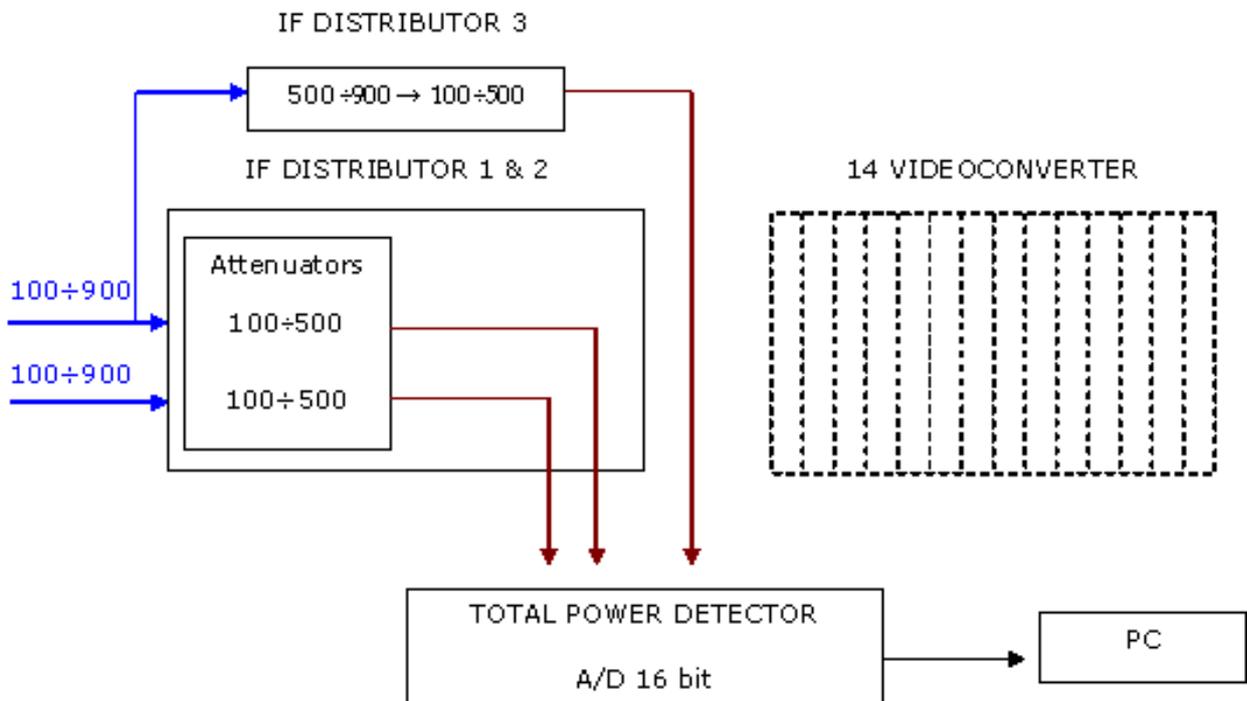


Fig. 8.4 : Maximum total bandwidths (MHz), example at 22 GHz

At 1.4, 1.6, 2.3 GHz available bandwidths may be considered less than what reported because of interferences.

8.3 Polarimeter

The polarimeter can be connected to any receiver and receives directly 2 analog inputs from the Front End corresponding to the circular polarizations. It supplies 4 outputs on 2x400 MHz sub-bands :

- Total power measurement on the two channels :Stokes I_1, I_2
- Linear polarizations measurements : Stokes Q, U

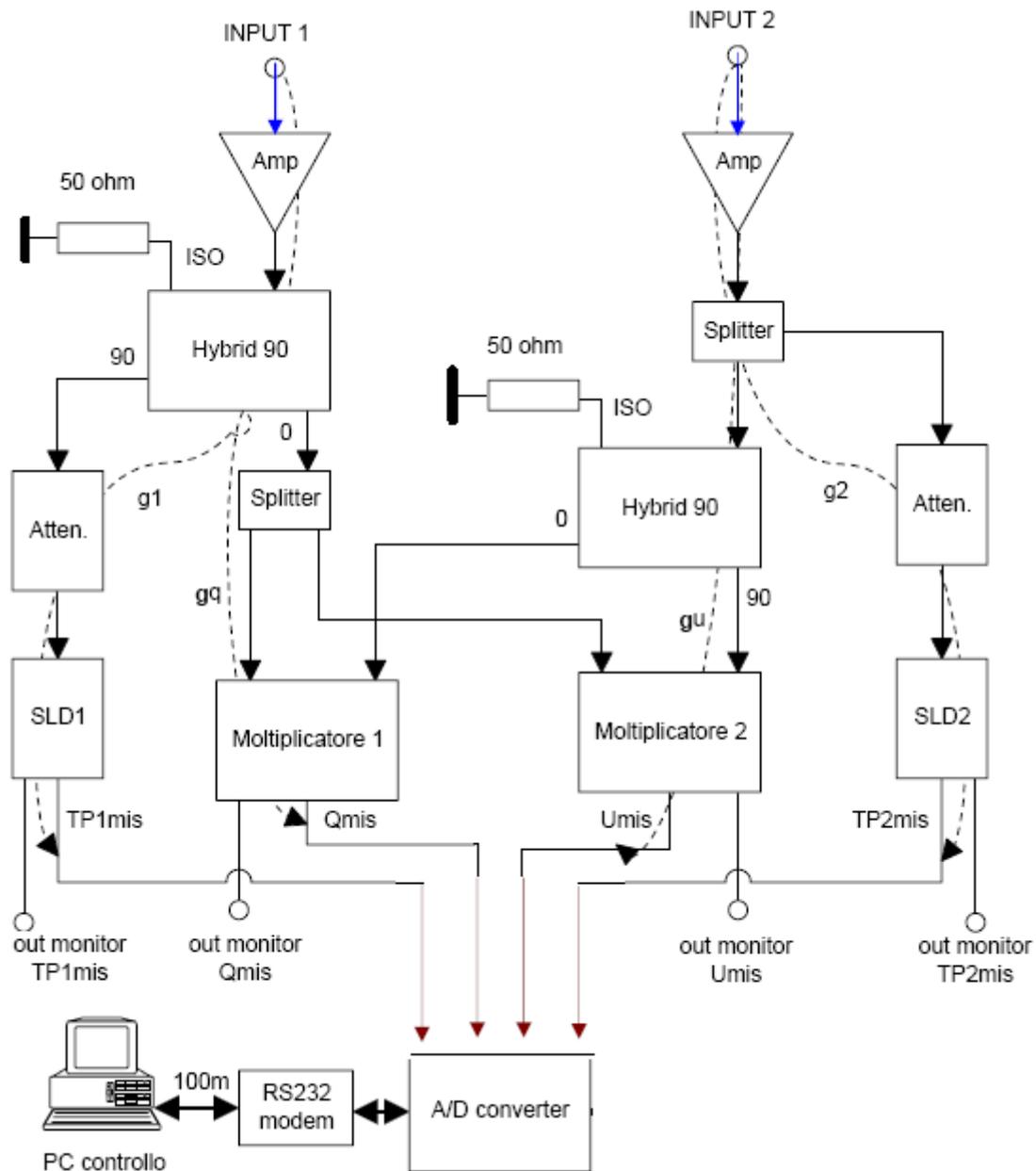


Fig. 8.5 : Polarimeter, sketch

At 1.4, 1.6, 2.3 GHz available bandwidths may be considered less than what reported because of interferences.

8.4 Pulsar

8.4.1 SPEX

The pulsar system has been developed as part of the SRT radiotelescope research (Srt Pulsar Experiment - SPEX).

SPEX is connected with the Mark IV IF distributor and with a further interface (MARK IV Interface for Single dish Antenna - MARISA), these are the main characteristics of the whole system :

- . 4x32 MHz inputs, divided in 1 MHz channels through 2 filterbanks (64 channels for each polarization) realized by the Jodrell Bank Observatory.
- . 1x128 channels filterbank with 2 poles active filters, central frequency programmable (0.9 kHz, 1 kHz, 5 kHz, 10 kHz) and anti-aliasing function.
- . Interference monitoring system, 128 channels (0.4 Hz anti-aliasing filters), 12 bit acquisition.
- . A/D converter, 128 channels, 1 bit per channel.
- . Reference time signal generator, for the programmable sampling, synchronized with the hydrogen maser and the 1 PPS signal inside the observatory. The time allocation of the signal with respect of UTC has a precision of less than 1 microsecond.
- . Interface board (FEMB) between the A/D and the link (Slink CERN) to the user's pc.
- . Link Slink (transmitter and receiver), transfer's rate 133 Mb/s
- . User's pc, Pentium III-500 MHz with RAM 128 Mb, system Linux Red Hat 6.1 with the necessary software for the data processing (coherent dedispersion).
- . Tape recorder DLT (single tape storage 20 Gb)
- . GPS receiver Motorola Oncore UT+ for the synchronization of the user's pc internal clock.

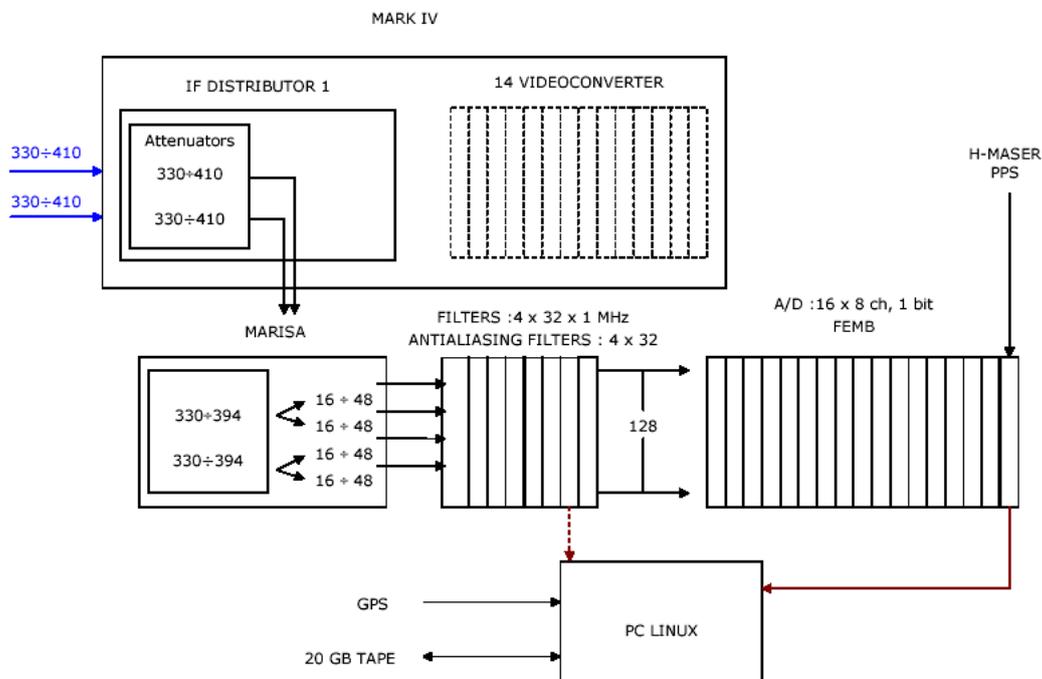


Fig. 8.6 : SPEX scheme, example at 1.4 GHz (band in MHz)

8.5 VLBI

8.5.1 Mark V

The VLBI observations are handled with the [Mark IV](#) (base conversion, bands splitting, A/D conversion) and the Mark V (data storage) terminals.

The Mark V is made of 2 blocks of 8x400 Gbyte hard disks. Once the VLBI session is terminated the hard disks are sent to the EVN JIVE correlator (Dwingeloo, Holland)

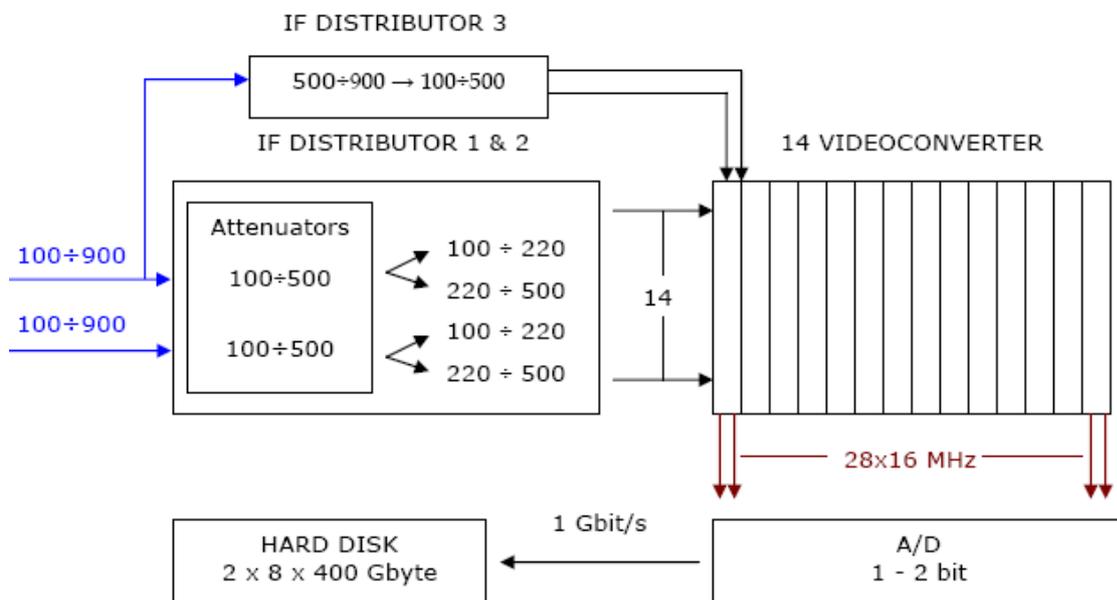


Fig. 8.7 : Mark IV/V scheme, example at 22 GHz (bands in MHz)

8.5.2 e-VLBI

In order to optimize the data collection time at the correlator, it is important to [develop](#) a solution for a real time data transfer. The telephone network used for internet is not able to handle the huge amount of data resulting from a VLBI session and now is used only during the initial check phase.

Recently it is wide spread in Europe the installation of fiber optic networks for commercial uses and this new technology has all the characteristics to be used for a real time connection to the JIVE correlator. Recently the connection between the Medicina station and the GARR network has been completed. It's still not the final solution on the shorter section (40 km), by now the backup ring (120 km via Faenza city) is used, anyway the available transfer rate is already of 1 Gbit/sec and it allows to join completely the e-VLBI observing sessions.

By now the antenna has been involved in two experiments : one on January 23rd, 2006 and one on March 9th, 2006, in this second occasion, for the first time, we obtained the fringes in real time. To view a picture of the results obtained from the correlation click [HERE](#).

The test phase will be made on a 16 MHz band, than an interface will be developed which will send to the electro-optical transducer the whole 28x16 MHz bands.

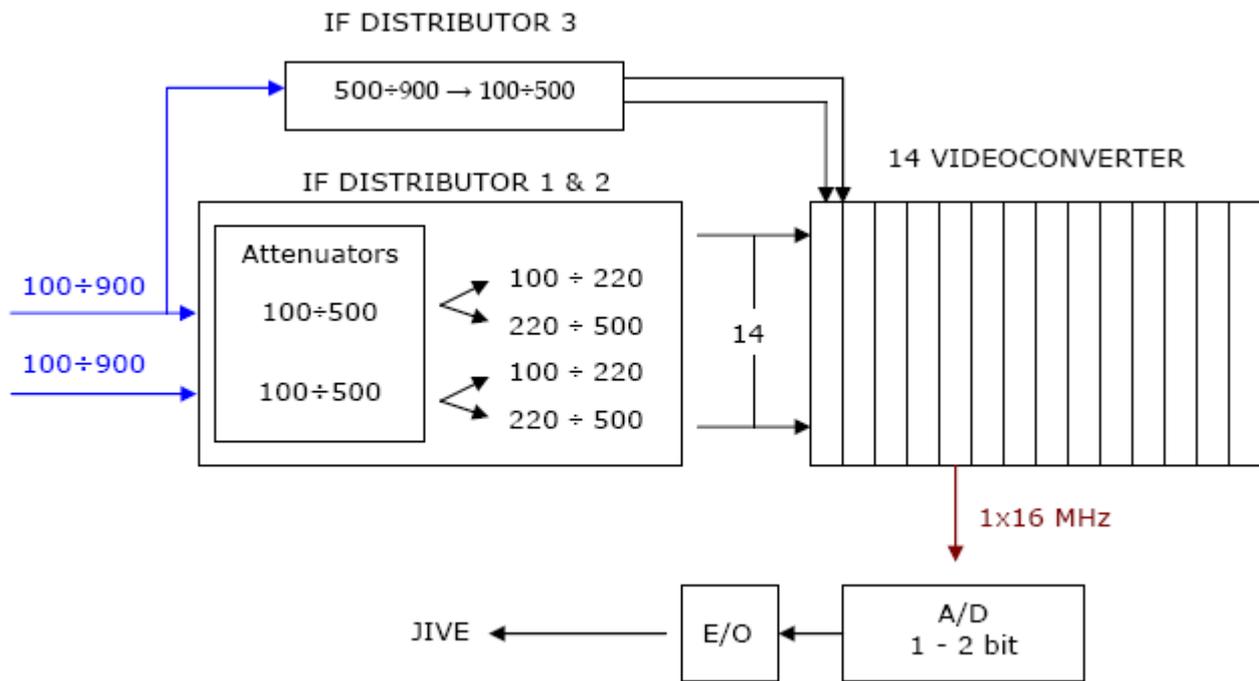


Fig. 8.8 : Mark IV scheme, fiber optic link

9. Remote Control

The Medicina antenna can be used remotely at the following locations :

- . Istituto di Radioastronomia, Bologna section
- . Osservatorio Astronomico di Arretri
- . Istituto di Radioastronomia, Noto section
- . Osservatorio Astronomico di Cagliari

It is possible to ask for the remote use of the antenna and to do astronomical campaigns* even from one of the above mentioned institutes.

The personnel who already have experience with the Observatory devices can ask the authorization to access the internal net also from other locations, through a static IP addressed pc.

Anyway, the availability of this observing mode must be discussed on a case-by-case basis.

*The ARCOS autocorrelator is still on updating and by now doesn't offer the remote control mode.

Appendix : How to read the calibration files

The calibration files are text file with the .rxg extension and are computer generated after the calibration operations.

For each receiver they contains mainly the FWHM, the gain curves and the calibrations temperature as function of the frequency. The calibrations temperature are given for fixed frequency values, in order to cover the whole receiver's band. The calibrations values for not listed frequencies must be interpolated from the nearest values.

The following table shows how to read the data :

Line	Label	Description
1		Receiver name
2	Fixed	LO values (MHz)
	Range	LO range of values (MHz)
3		Creation's date (yyyy/mm/dd)
4	Constant	FWHM (rad)
	Frequency	FWHM constant ($FWHM = 1.22 \cdot value \cdot \lambda/D$ [rad])
5		Available polarizations
6		Maximum gain (DPFU) for each polarization as listed above (K/Jy)
7	Elev Poly	G(el) Normalized gain curve's polynomial coefficient (increasing powers)
	Altaz	G(z) Normalized gain curve's polynomial coefficient (increasing powers)
8 and following		Polarization, Frequency (MHz), Calibration temperature (K)

D = diameter of the antenna
 DPFU = Degrees Per Flux Unit
 el = elevation
 z = zenith distance