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26.5-40 and 76.5-90 GHz

ECE Radiometer

Technical Description and User Manual

November 2008

Contents

1. Introduction

The multichannel 26.5-40 GHz and 76.5-90 GHz Radiometer has been designed for plasma electron temperature measurements in TOKAMAKs.

The Radiometer is a super heterodyne receiver with double frequency conversion. The fact is taken as a basis of the device that the intensity of the ECE 2-nd harmonic is proportional to the electron plasma temperature in situations when the plasma can be considered as the black body for its own cyclotron radiation.

The Radiometer picks up the plasma electromagnetic emission and produces 0…+10V analogue output signal proportional to the plasma emission power. The measurements are performed simultaneously in 16 frequency channels covering 26.5-40 GHz or 76.5-90 GHz band.

2. Parameters and specifications

▪ Principle of functioning:	super heterodyne receiver with double frequency conversion
▪ Input frequency band (Ka-band Front-End)	26.5-40 GHz
▪ Input frequency band (E-band Front-End)	76.5-90 GHz
▪ Intermediate Frequency (IF) bandwidth	1.5-15 GHz
▪ Number of output frequency channels	16
▪ Bandwidth of an individual channel	850 MHz
▪ Maximum output voltage	+10 V
▪ Input waveguide (Ka-band Front-End)	WR-28
▪ Waveguide flange (Ka-band Front-End)	UG-599/U
▪ Input waveguide (E-band Front-End)	WR-12
▪ Waveguide flange (E-band Front-End)	UG-387/U
▪ Output connectors	BNC
▪ Operating temperature	+10°C…+40°C
▪ Power supply	220 V, 50 Hz

3. Design and principles of operation

The Radiometer consists of 7 separate units:

- Ka-Band Gauss optic lens antenna with two outputs with cross polarization
- E-band Gauss optic lens antenna
- Ka-Band Front-End (down converter)
- E-Band Front-End (down converter)
- 16 channel IF receiver

- two Power Supply Units for Front-Ends

Block-scheme of the Radiometer is presented below:

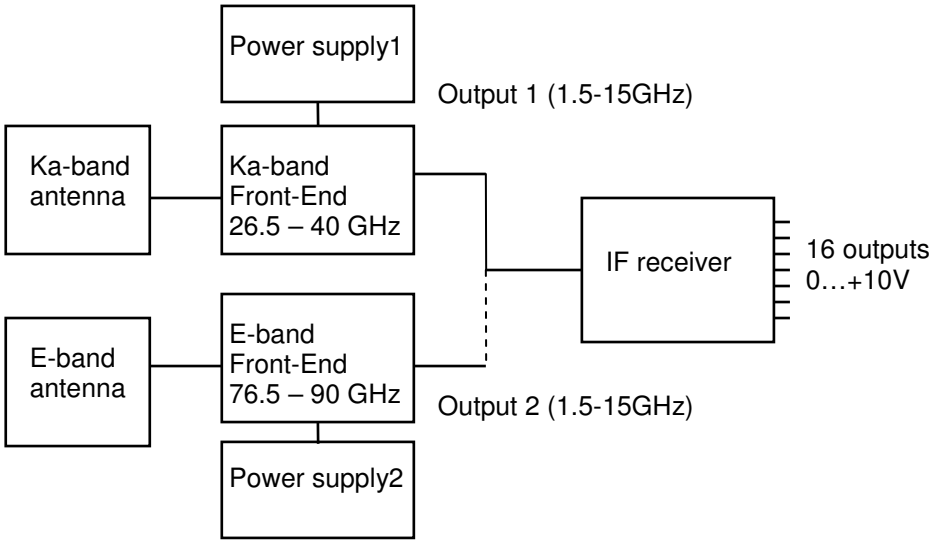

Fig. 1. Block-scheme of the Radiometer

3.1 Front-Ends of the Radiometer

Front Ends make first frequency conversion of the input 26.5-40 GHz or 76.5-90 GHz ECE signal. The conversion is done with Down Converter (DC); output frequency band is 1.5-15 GHz for the both Front-Ends. Front-End block scheme is presented in Fig. 2. Inside and outside views of the Front-Ends are presented in Fig. 3 – Fig.8.

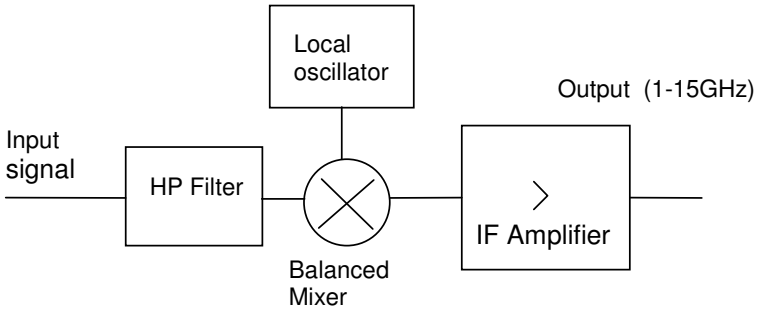

Fig. 2. Block-scheme of a Front-End

High pass waveguide filters (HP Filter in Fig.2) are used to cut off low frequency band of received signal: below 25 GHz for Ka-band channel and below 75 GHz for E-band channel. Local oscillators of the down converters operate at fixed frequency. It is 25 GHz for Ka-band down converter and 75 GHz for E-band one.

Balanced mixers have conversion losses from -7 dB to -10 dB within operating frequency range. Gain of a low noise IF amplifiers is approximately 40 dB within frequency range 1.5 - 15 GHz.

Total gain of the Front-Ends is presented in Fig. 9 and 10.

Fig. 3. E-band Front-End. Outside view 1.

Fig. 4. E-band Front-End. Outside view 2.

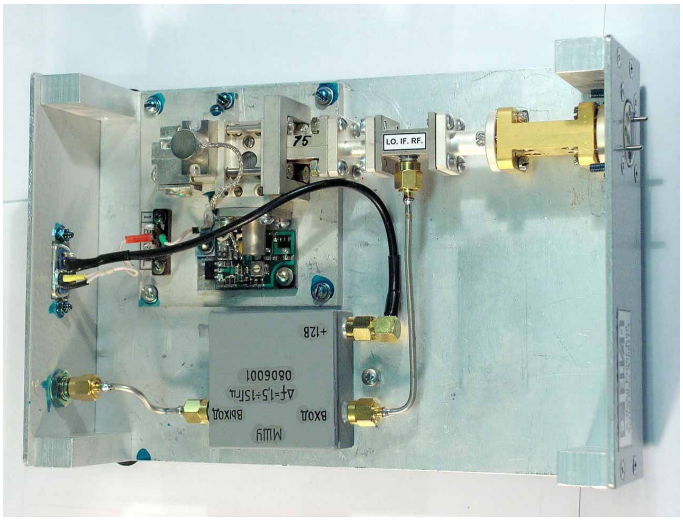

Fig. 5. E-band Front-End. Inside view

Fig. 6. Ka-band Front-End. Outside view 1.

Fig. 7. Ka-band Front-End. Outside view 2.

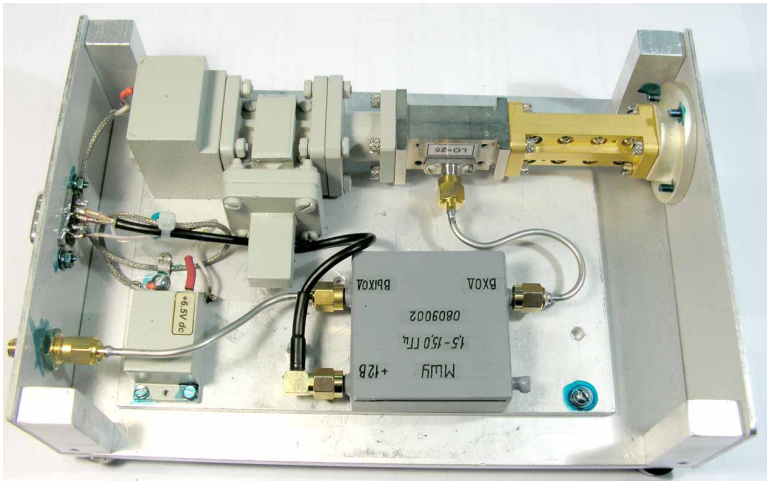

Fig. 8. Ka-band Front-End. Inside view

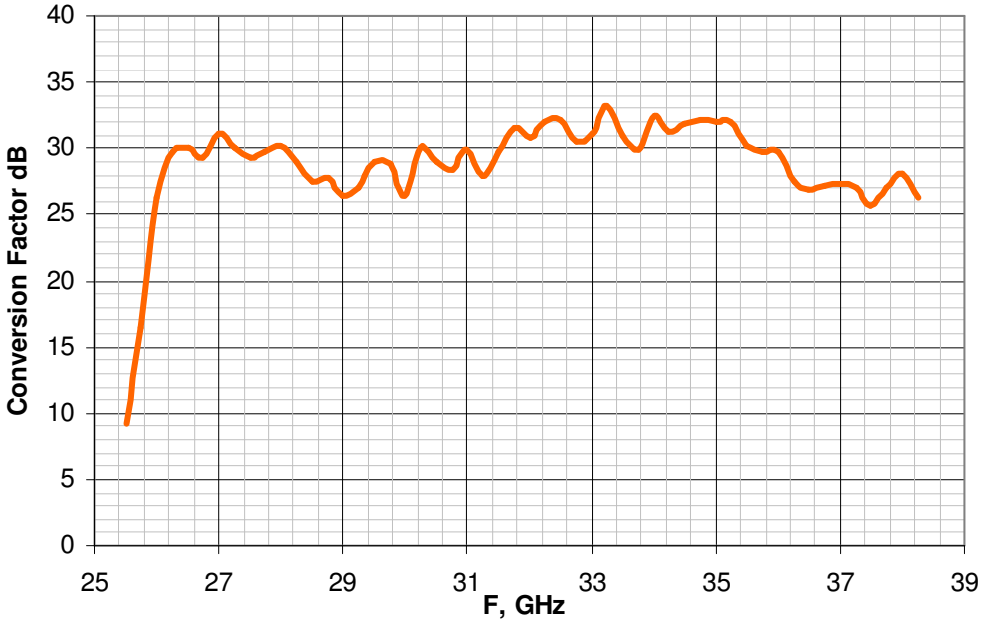

Fig. 9. Total gain of the 26.5-40 GHz Down Converter vs frequency

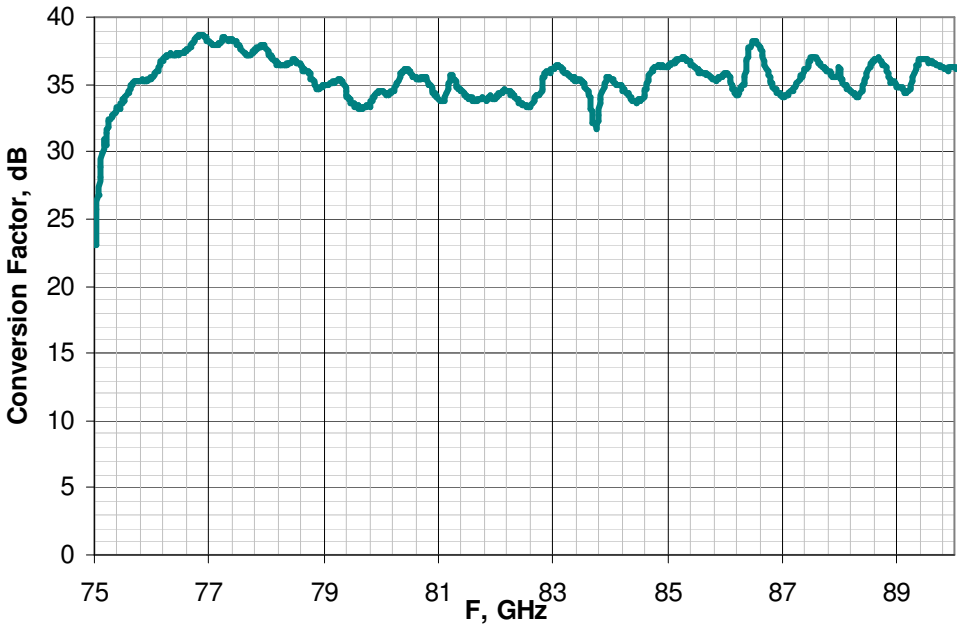

Fig. 10. Total gain of the 76.5-90 GHz Down Converter vs frequency

3.2 Front-End Power Supply blocks

Two power supply blocks are based on switching power supplies made by "Sunpower" and "MeanWeal". Input voltage of these AC-DC converters is 100-240V, input frequency – 47-63Hz. Fuses used in power supplies are for 2A current. Output 12V is used for IF amplifiers, 6.5V or 27V is used for local oscillator power supplying.

Two cables connecting power supply and Front-End are included in the Radiometer set. The cables are equal for E-band and Ka-band Front-Ends.

Note: Be attentive. Each power supply block has matched Front-End.

Connection of a Front-End to wrong Power Supply block (not intended for the Front-End) does **NOT** cause damage of the Front-End or Power Supply block only if **original cables** are used.

Fig. 11. Power Supply block. Front Panel.

Fig. 12. Power Supply block for Ka-band Front-End. Rear Panel

Fig. 13. Power Supply block for E-band Front-End. Rear Panel

3.3 Antennas.

Radiometer has two Gauss optic lens antennas:

- GOLA-12 for E-Band channel
- GOLA-28 for Ka-band channel. The antenna has two outputs with cross polarisation.

Fig. 14. E-band Antenna

Fig. 15. Ka-band Antenna (Assembled)

3.4 IF Receiver

The 16-channel 1.5-15.0 GHz IF Receiver (below referred to as Receiver) is intended to be used with wideband RF front-Ends (down converters).

3.4.1 Parameters and specifications of IF receiver

- Principle of functioning: heterodyne receiver
- Input frequency band 1.5 ÷ 15.0 GHz
- Output frequency band DC ÷ 1 MHz
- Number of output frequency channels 16
- Total gain 20-25 dB
- Built-in attenuation of each channel 0- 30.5 dB
- Attenuation step 0.5 dB
- Bandwidth of a channel 850 MHz
- Maximum output voltage +10 V
- Input connector SMA, female
- Output connectors BNC, female
- Operating temperature +10°C…+40°C
- Power supply 220 V, 50 Hz

3.4.2 Design and principles of functioning

The Receiver has 16 channels and consists of an input power divider and 16 separated heterodyne receivers. Block-scheme of the Radiometer is presented below:

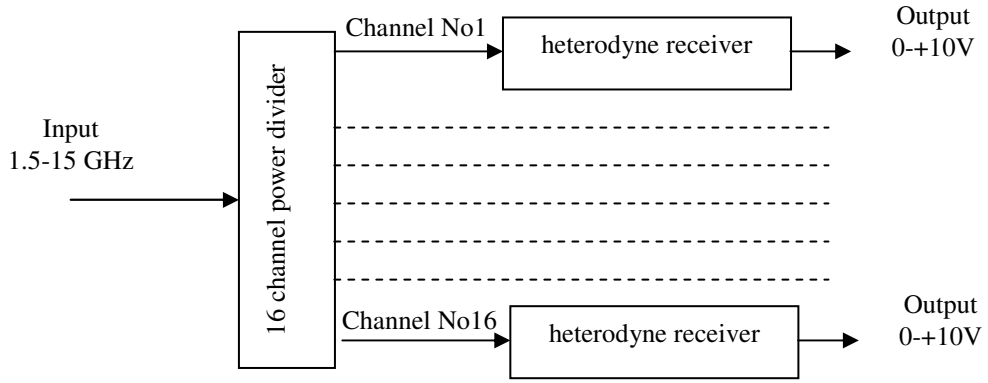

Fig. 16 Block-scheme of the Receiver.

3.4.3 Block scheme of heterodyne receivers.

All the receivers have equal block-scheme, which is depicted in Fig. 17.

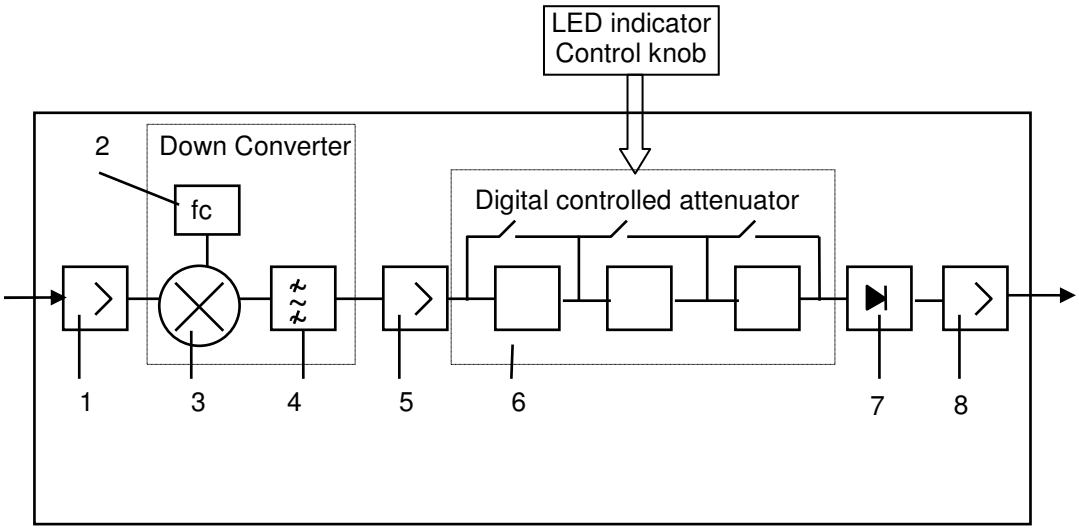

Fig. 17 Super heterodyne receiver.

Just at the entrance of the Module the signal is amplified with a bandpass amplifier (1, Fig. 17). Then the second frequency conversion is occurred that transforms the input signals with the frequency band 1.5÷15 GHz into output signals with frequencies within a range from 0 … 425 MHz. Balanced mixer (3, Fig. 17), local oscillator (2, Fig. 17) and low frequency bandpass filter (4, Fig. 17) are assembled into a double side band Down Converter unit. The amplifier (5, Fig. 17) has gain approx. 25 dB.

Detectors (7, Fig. 17) rectify the entering signals transforming them into output video signals. Conversion factor of the detectors varies around 100 mV/mW in different channels being linear vs the input power if the power does not exceed 1 mW. Upper frequency limit of the detectors is not less 10 MHz.

Digital controlled attenuator (6, Fig. 17) is installed in each channel to extend dynamic range of the measurements. It allows keeping the power entering into the detector below 1 mW. This ensures the detector linearity. The attenuator is controlled with external microcontroller and allows getting 0.5 dB step. Every 2 sec microcontroller stories current setting of the attenuator and after switch receiver off/on sets last set value.

The output Video amplifiers (8, Fig. 17) have about 100 times amplification factor and provide 0…+10V output in linear mode of the detector.

The IF receiver channels operate at different frequencies. They also have different gain value of conversion of input IF signal to output voltage. So if built-in attenuators are set at “0dB” the Radiometer has the highest sensitivity but channels have different total gain. One can equalize gain of all channels but it can be done with suppression of sensitivity of some channels. The operation can be done during the radiometer calibration with a reference noise source of mm-wave signal.

Central frequency f_c and the bandwidth Δf of individual channels of the IF receiver are presented in Table below:

Channel number	Central frequency, f_c, GHz	Frequency bandwidth at level –20dB, Δf, GHz
16	14,675	14,25 - 15,1
15	13,825	13,4 - 14,25
14	12,975	12,55 - 13,4
13	12,125	11,7 - 12,55
12	11,275	10,85 - 11,7
11	10,425	10 - 10,85
10	9,575	9,15 – 10
9	8,725	8,3 - 9,15
8	7,875	7,45 - 8,3
7	7,025	6,6 - 7,45
6	6,175	5,75 - 6,6
5	5,325	4,9 - 5,75
4	4,475	4,05 - 4,9
3	3,625	3,2 - 4,05
2	2,775	2,35 - 3,2
1	1,925	1,5 - 2,35

3.4.4 Front panel and controls.

Front panel with control knobs is shown in Fig.18.

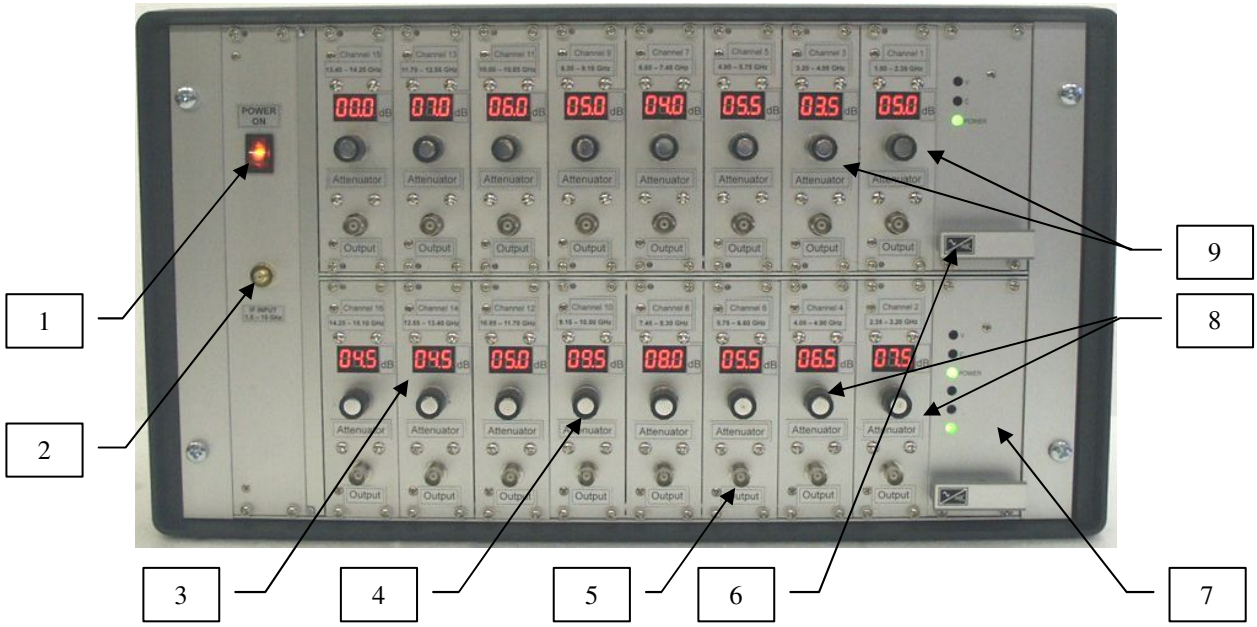

Fig. 18 Front panel and control knobs.

1. Power switch with indicator
2. Input 1.5-15 GHz, SMA connector
3. LED Indicator of built-in attenuator
4. Control knob of built-in attenuator
5. Receiver output, BNC connector
6. Power supply module +5 DCV
7. Power supply module +/-12 DCV
8. Line Channels No. 2, 4, 6,…16
9. Line Channels No. 1, 3, 5….15

3.4.5 Outward view

Outward view and rear panel of the receiver are shown in Fig.19 and 20.

Fig. 19 Outward view

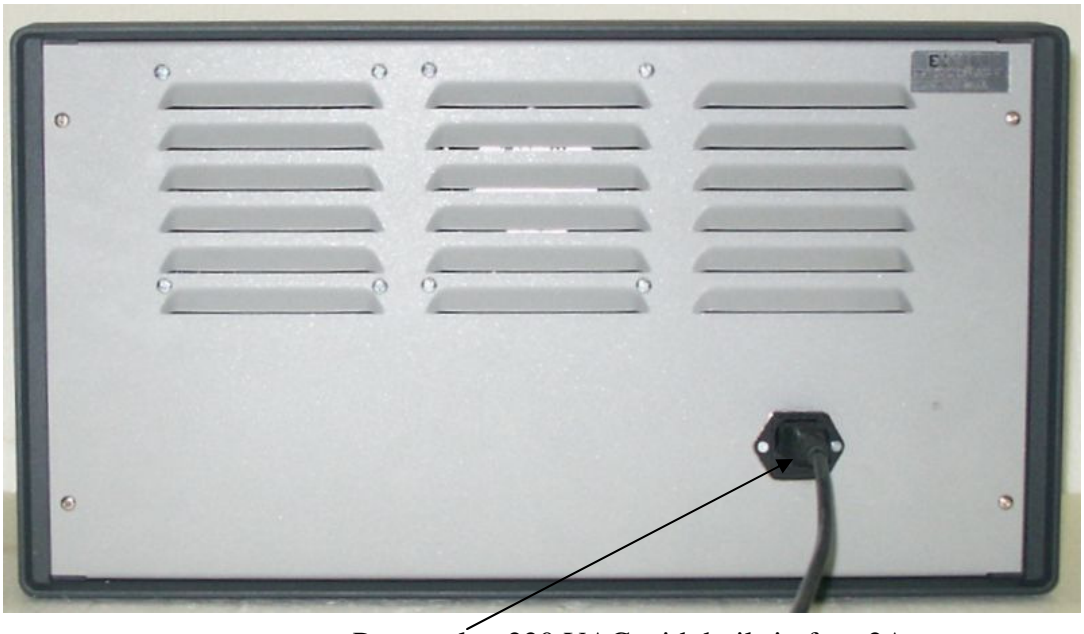

Fig. 20 Rear panel

4. Operational Manual

4.1 Preoperational preparation.

- Assemble Ka-band antenna.

Marker on the horn part (gold plated) of the antenna (see Fig.21) is to be fixed at position shown in Fig. 22. It must be fitted to the edge of black case of the antenna. Next screw shown in Fig. 21 and Fig.22 must be turned in.

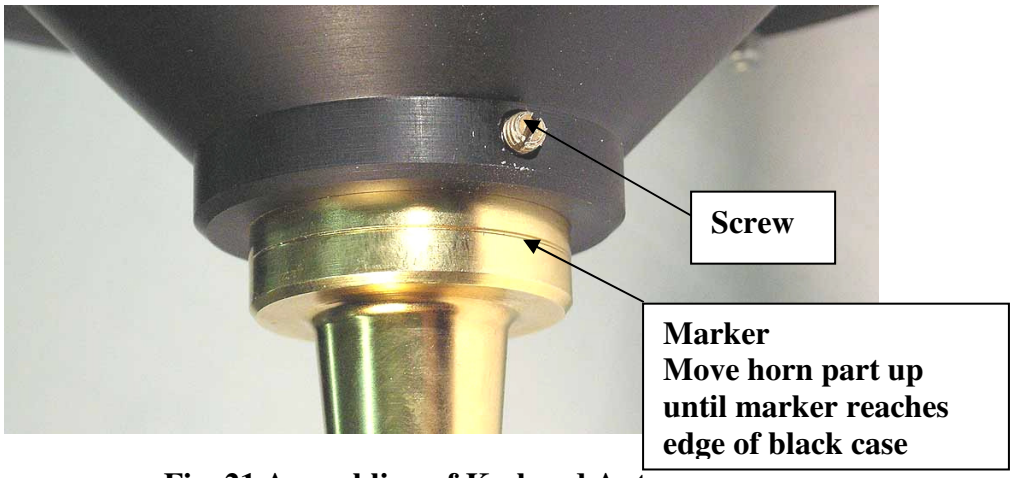

Fig. 21 Assembling of Ka-band Antenna.

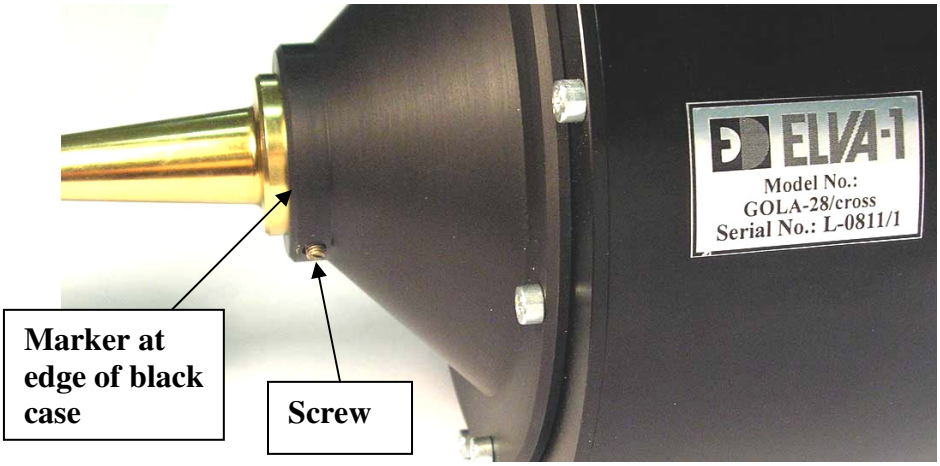

Fig. 22. Assembling of Ka-band Antenna. Final Position

- Connect input flange of a Front End to an antenna. GOLA-28 antenna has two output ports with cross polarization.
- Connect Front-End output to IF receiver input with coaxial cable supplied with the Radiometer or with another coaxial cable having low losses at frequencies up to 15GHz.
- Connect 16 BNC connectors of IF receiver to data acquisition system.
- Connect Front end to matched Power Supply block.

4.2 Switching the Radiometer on

- Turn a power supply connected to a Front-End “ON”.
- Turn IF receiver “ON”.
- The Radiometer is ready for the measurements approximately in 15 minutes of warming-up.

4.3 Switching the Radiometer off

- To switch off the Radiometer, all the operations above have to be done in the inverse sequence.