K band interference measurement campaign with the 40m radiotelescope

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Revision history

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Contents

1 Introduction

This report presents the measurements made during the second week of june of 2016 with the 40 meter diameter radiotelescope at Yebes Observatory, in search of radio frequency interference (RFI) in the K frequency band. The maximum allowed level of RFI in this band is regulated in the *Orden CTE / 1444/2003*, which sets a power flux intensity limit of -148 dB(w/m^2) for the 22,21-22,5 GHz band and -147 dB(w/m^2) for the 23,6-24 GHz band **(Figure 1)**.

Banda de frecuencias	Densidad de flujo de potencia (db(w/m^2))	Intensidad de campo eléctrico equivalente (dB(µV/m))
1400-1427 MHz	-180	-34,2
1610,6-1613,8 MHz	-181	-35,2
1660-1670 MHz	-181	-35,2
2690-2700 MHz	-177	-31,2
4990-5000 MHz	-171	-25,2
10,6-10,7 GHz	-160	-14,2
15,35-15,4 GHz	-156	-10,2
22,21-22,5 GHz	-148	- 2,2
23,6-24 GHz	-147	- 1,2
31,3-31,8 GHz	-141	4,8
42,5-43,5 GHz	-137	8,8
86-92 GHz	-125	20,8

Figure 1. Radio astronomy protected bands at Yebes observatory

To detect the interferences, the K band receiver of the 40m radiotelescope was used. Specifically, the measurements were made in the frequency ranges from 21.75 to 22.575 GHz and 23.6 to 24GHz. The analysis of a given interference was performed using the Fast Fourier Transform Spectrometer, which provides 16384 channels and an instant bandwidth anaylsis of 500 MHz, with a channel width or spectral resolution of 30.5 KHz. The radiotelescope was turned from 0° to 360° in 1° steps, with an elevation of 5°.

This report consists of two parts: the first presents the self-interference radio signals ie, those interferences signals generated by the electronic equipment of the radiotelescope itself.

In the second, they are shown in detail the external interferences detected in the K band along with the calculation of their power.

2 Internal interferences

The internal RFI in the K band was measured closing the vertex of the radiotelescope, so no radiation was coming from the primary reflector. The signal measured consequently comes from radiation of the internal equipment of the radiotelescope. The spectrum of this radiation is depicted in **Figure 2.** Examining the spectrum, the main contribution to the RFI is at 22.250GHz and is caused by the frequency of the 3^{rd} local oscillator of the K band receiver which is being radiated away and enters back again in the receiver via its feed horn. Several attempts were made to increase the insulation of the oscillator but were unsuccefull, so the OL module will be moved away to the control room where it will not affect the receiver. The other big contribution to the RFI is at 22.400GHz and is due to an intermodulation product caused by the undesired re- entering in the receiver's frontend of the 22.250GHz frequency.

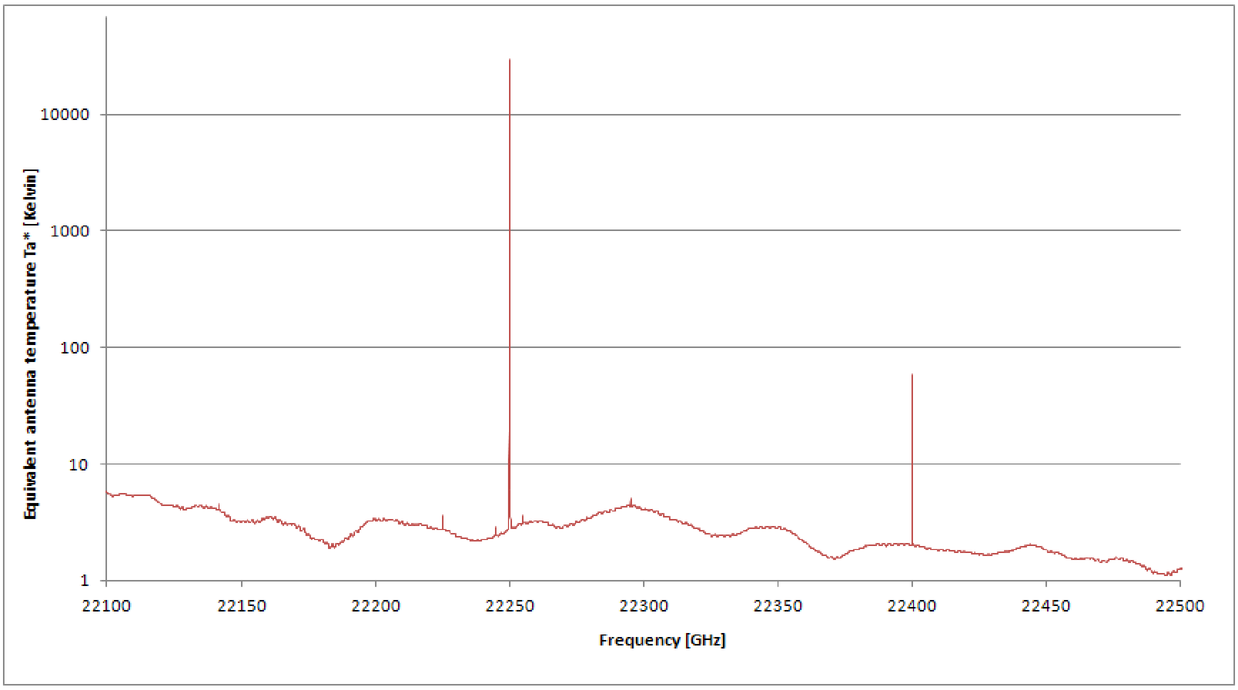

Figure 2: RFI spectrum measured with the vertex of the radiotelescope closed.

3 External interferences

The observation procedure used for the detection of the interferences has been accomplished with azimuth sweeps in 1° steps at an elevation of 5°. Once a RFI signal was detected, *on-off* measurements with an integration time of 5 seconds were made. The *on* was done pointing to the direction of the source with an elevation of 5°, and the *off* was done pointing to an elevation of 15°. We assume that the RFI is coming from an elevation of 0°, and since the radiotelescope can't go below 5° due to structural reasons, all the RFI is not coming through the main radiation lobe, but from side lobes.

The spectra depicted in the following figures is the result of taking the RMS values of the two circular polarizations (clockwise and counterclockwise) that the K band receiver is able to detect.

3.1 Interferences detected

3.1.1 22.0915GHz

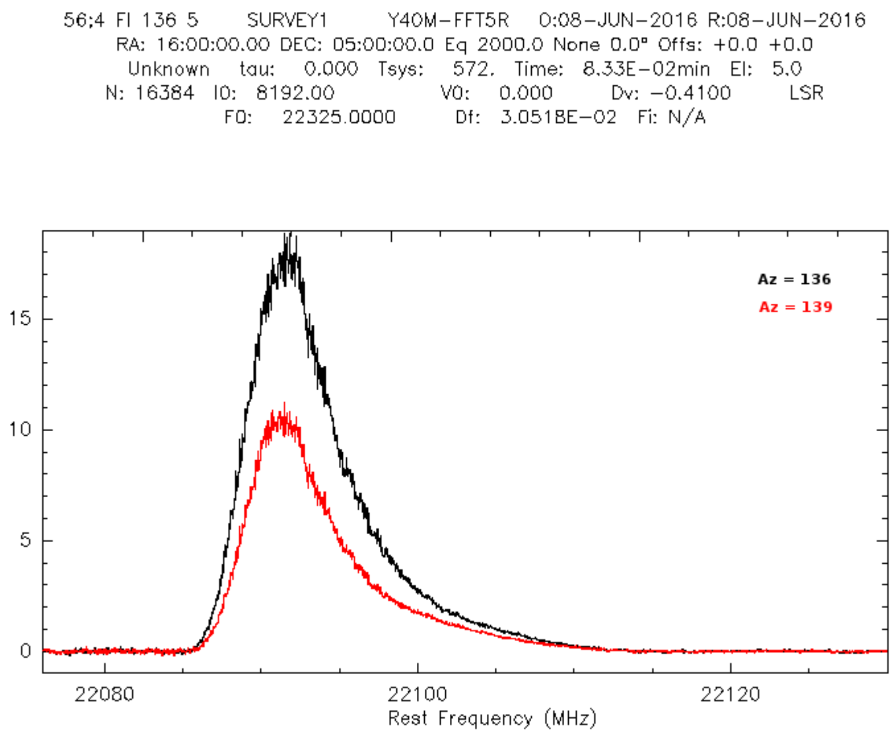

Figure 3: Interference detected at 22.0915GHz. The same signal was detected coming from different azimuths, probably due to reflections in the observatory site. Vertical scale is the equivalent antenna temperature in Kelvin degrees.

3.1.2 22.325GHz

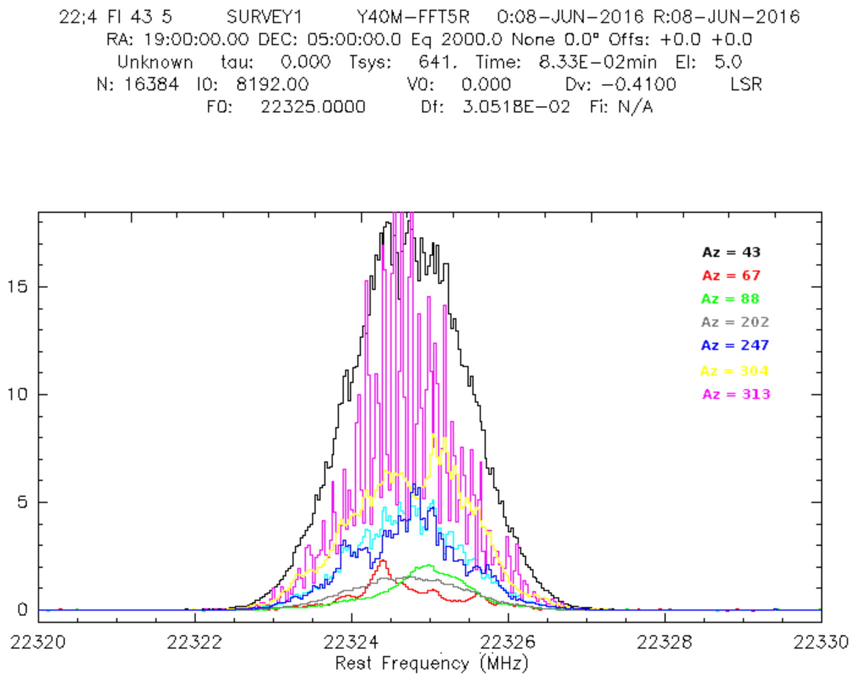

Figure 4: Interference detected at 22.325GHz. The same signal was detected coming from different azimuths, probably due to reflections in the observatory site. Vertical scale is the equivalent antenna temperature in Kelvin degrees.

3.1.3 22.326GHz

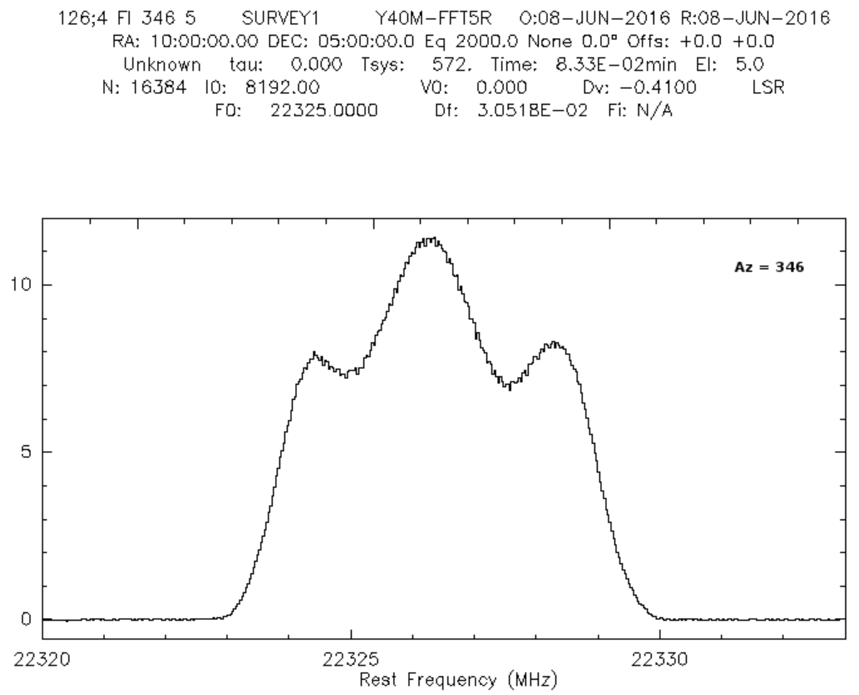

Figure 5: Interference detected at 22.326GHz. The same signal was detected coming from different azimuths, probably due to reflections in the observatory site. Vertical scale is the equivalent antenna temperature in Kelvin degrees.

3.1.4 22.472GHz

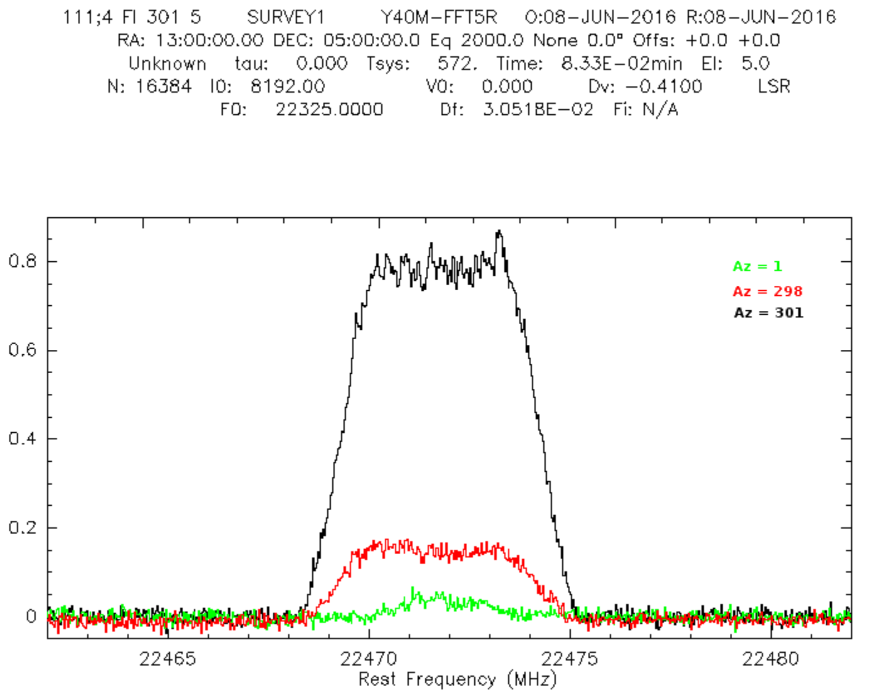

Figure 6: Interference detected at 22.472GHz. The same signal was detected coming from different azimuths, probably due to reflections in the observatory site. Vertical scale is the equivalent antenna temperature in Kelvin degrees.

3.1.5 22.475GHz

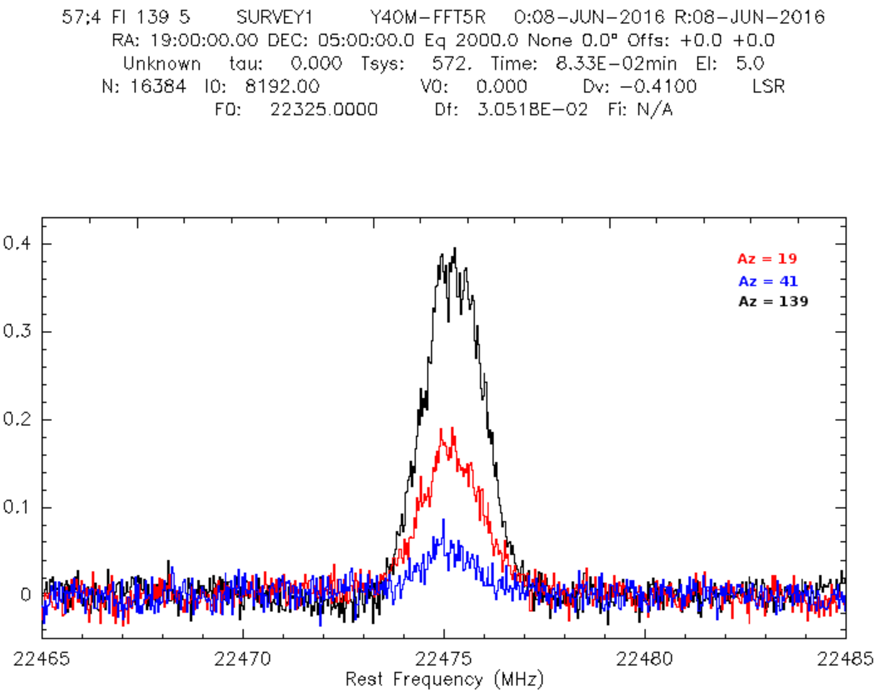

Figure 7: Interference detected at 22.475GHz. The same signal was detected coming from different azimuths, probably due to reflections in the observatory site. Vertical scale is the equivalent antenna temperature in Kelvin degrees.

3.1.6 24.080GHz

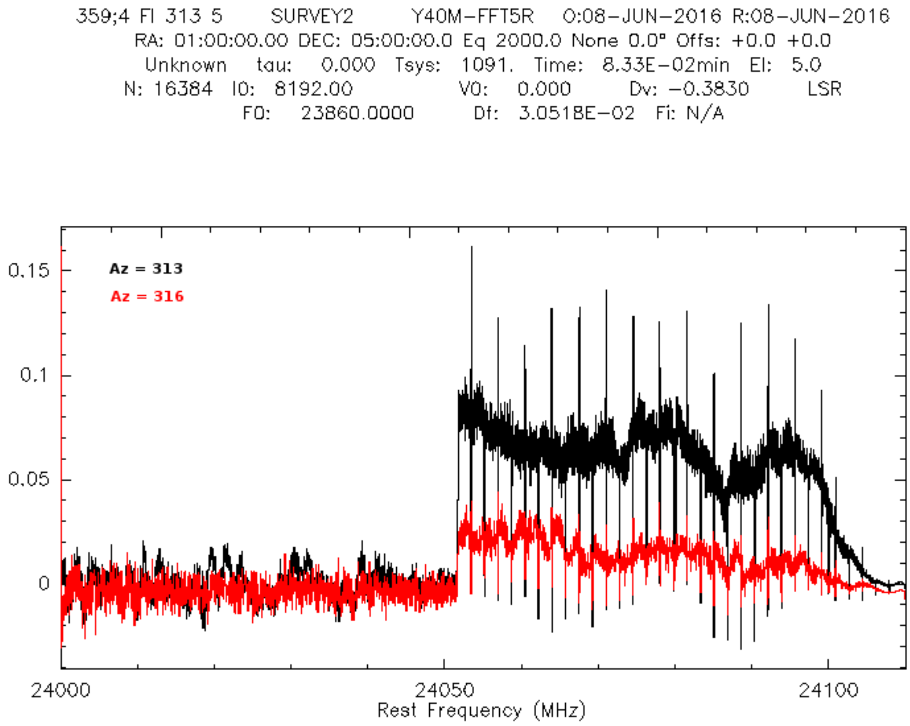

Figure 8: Interference detected at 24.080GHz. The same signal was detected coming from different azimuths, probably due to reflections in the observatory site. Vertical scale is the equivalent antenna temperature in Kelvin degrees.

3.2 Calculation of the flux density

In this section the calculated flux density of each of the detected interference in its maximum radiation azimuth is presented. It's important to note that the RFI comes from the side lobes of the radiotelescope, as the radiotelescope was not pointing directly to the radiolink sources. The method to compute the flux density is the following:

- First, we get the flux density peak value *S(°K)* of each of the interference line spectrum shown in the previous figures. The final value is the RMS of the two polarizations that the receiver detects.

- Using the efficiency curve of the radiotelescope at K band (see Apendix), we can transform the flux density in °K to flux in Jy, multipliying it by the conversion factor of 5.7 (see section 4).

$$S(\mathrm{Jy}) = 5.7 \cdot S(°\mathrm{K}) \qquad [1]$$

- Janskys are defined as $1\,Jy = 10^{-26}\frac{W}{Hz\cdot m^2}$, so we can compute the flux peak density that reaches the side lobe as:

$$S_{SL}\left(dB\left(\frac{w}{Hz\cdot m^2}\right)\right) = 10\log(S(Jy)\cdot\ 10^{-26}) \qquad [2]$$

and

$$S_{SL}\left(dB\left(\frac{w}{m^2}\right)\right) = S_{SL}\left(dB\left(\frac{w}{Hz\cdot m^2}\right)\right) + 10\log(B) \qquad [3]$$

where *B* is the bandwith in Hz of the RFI signal.

- As the RFI is coming from a sidelobe, the total flux density that the main lobe would receive is:

$$S_{ML} = S_{SL} + G_{ML} - G_{SL}(\varphi) \qquad [4]$$

$$G_{ML} = \eta_{AP}\left(\frac{\pi\cdot D}{\lambda}\right)^2 \qquad [5]$$

where G_{ML} is the main lobe antenna gain, η_{AP} the antenna aperture efficiency, D the radiotelescope diameter, λ the wavelength of the radiation and G_{SL} *(φ)* is the antenna gain at an angle φ displaced from the main beam axis. In our case, the antenna was pointing to an elevation of *5°*, and assuming that the RFI is coming from an elevation of 0°, we get φ=*5°*.

According to the ITU-R RA.769-2 recommendation:

$$G_{SL}(\varphi) = 32 - 25LOG(\varphi),\ \text{for } 1 < \varphi < 48 \qquad [6]$$

η_{AP} and G_{ML} have been measured and for the 40m radiotelescope at Yebes they have the values 0.4 and 75.4dBi, respectively. Now we have all the data and we can calculate S_{ML} .

The results are presented in **Table 1.**

Frequency [GHz]	Azimuth [deg]	$S_{SL}\left(dB\left(\frac{w}{m^2}\right)\right)$	$S_{ML}\left(dB\left(\frac{w}{m^2}\right)\right)$	Orden CTE 1444/2003 $S\left(dB\left(\frac{w}{m^2}\right)\right)$	Difference (dB)
22.0915	136°	-167	-110	-148	38
22.325	43°	-169	-117.9	-148	30.1
22.326	346°	-170.7	-114.4	-148	33.6
22.472	301°	-181.7	-125.3	-148	22.7
22.475	139°	-184.1	-132.7	-148	15.3
24.080	313°	-189.3	-123.3	-147	23.7

Table 1. Calculated RFI flux in main lobe and comparison with the regulation's limits at Yebes

4 K-band efficiency curve of the 40m radiotelescope

With the purpose of converting the units used in radio astronomy to others in the universal metric system, removing the dependency on factors such as the diameter of the radiotelescope, a K-band gain calibration observation was carried out to obtain the Jy / °K conversion factor. The results are shown in **Figure 9** and **10**. As the detection of the interferences has been done at 5 degrees of elevation, we have assumed a conversion factor of 5.7 Jy / °K, that has been used in equation [1].

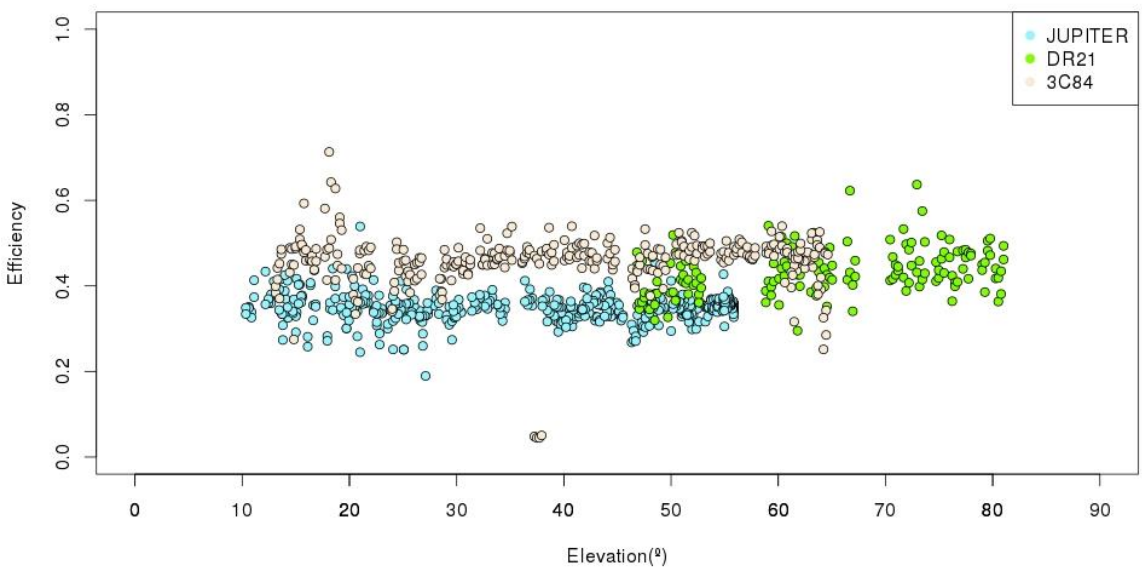

Figure 9: Efficiency of the 40m radiotelescope at K band

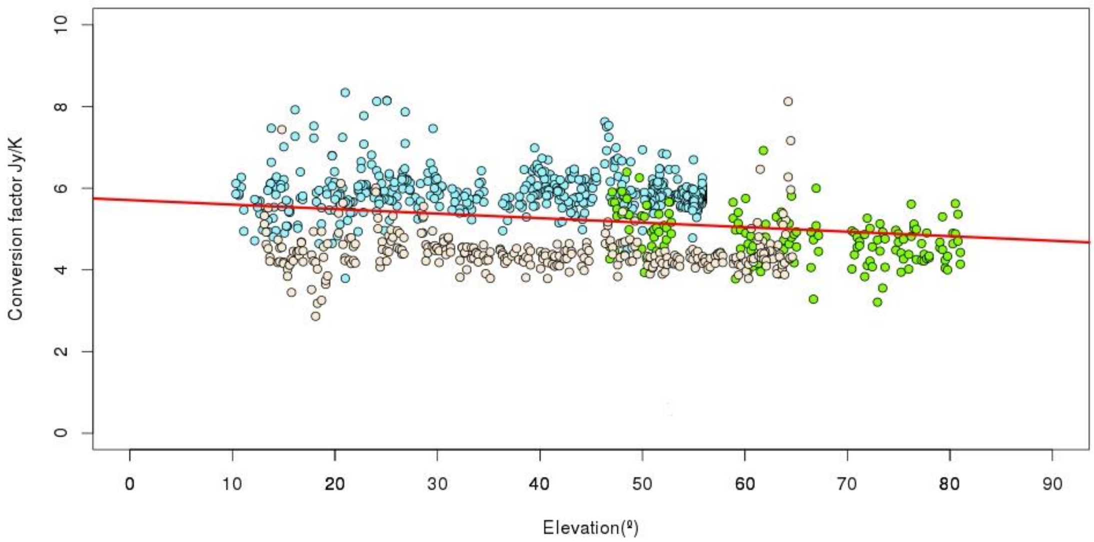

Figure 10: Jy/°K conversion factor of the 40m radiotelescope at K band

5 Conclusions

In this report, there have been shown some unwanted signals that appear in the K band of the 40m radio telescope. One of them is caused by the internal electronic equipment of the receiver's cabin and will be fixed in the short term. The others are coming from the outside, probably from fixed service radio links, and measures to be taken will be discussed with the local radioelectric service' authorities.

Appendix

45GHz-band efficiency curve of the 40m radiotelescope