Second radio-frequency interference measurement campaign at Yebes Observatory

D. Cordobés, José A. López-Pérez

IT CDT 2016 - 8

Observatorio de Yebes
Apartado 148, 19080 Guadalajara, SPAIN

Revision history

Version	Date	Author	Comments
1.0	09.05.2016	D. Cordobés	First version
1.1	18.05.2016	J. A. López-Pérez	Some comments added

Contents

1 Introduction

During the first week of May, 2016, several measurements have been carried out to check the radio frequency interference (RFI) signals that are reaching the *Centro Astronómico de Yebes* (CAY), in order to compare them with those measured by José A. López-Pérez in 2010 [1].

The instrumentation used is the same that was described in [1], being the following:

- Wideband 0.9m parabolic antenna Rohde-Schwarz AC008.
- Wideband 0.85-26.5GHz log-periodic antenna Rohde-Schwarz HL050, working as the feed for the parabola.
- Wideband 0.5-26.5GHz microwave amplifier from Agilent Technologies, model 83017A.
- DC - 40GHz HP8564E spectrum analyzer.
- Low loss coaxial cables.

The measurements were performed on the roof of the CAY building, WGS84 coordinates 40°N31’28.73” / 03°W05’18.98”.

Firstly, the calculations used to obtain the electric field intensity from the analyzer power measurements are introduced. Then, the results of these measurements are shown.

2 Obtaining the electric field intensity

It can be shown that the electric field intensity in the surroundings of an antenna is given by:

$$E[dB(uV/m)] = AF[dB(1/m)]+V[dB(uV)] \quad (1)$$

where *E* is the electric field, *AF* is the antenna factor and *V* is the voltage measured at the output terminals of the antenna. Assuming a 50 ohm load at the antenna port, the voltage *V* and the antenna factor *AF* can be expressed as:

$$V[dB(uV)] = 107dB + P\,[dBm] = P_m\,[dBm] - G_{amp}[dB] + 107dB \quad (2)$$

$$AF[dB(1/m)] = 20 \log F[MHz] - G_{ant}\,[dBi] -29.77 \quad (3)$$

where F is the frequency, P_m is the power measured by the analyzer, G_{amp} is the gain of the antenna amplifier plus the losses of the coaxial cables from the antenna to the analyzer and G_{ant} is the gain of the antenna.

Substituting (2) and (3) into (1) we get:

$$E[dB(uV/m)] = P_m\,[dBm] + 20 \log F[MHz] - G_{ant}\,[dBi] - G_{amp}[dB] + 77.23 \qquad (4)$$

where G_{amp} was measured in the lab with the help of a vector network analyzer and was fitted to a 7th degree polynomial, so it can be expressed as $G_{amp} = a_0+a_1f+a_2f^2+a_3f^3+a_4f^4+a_5f^5+a_6f^6+a_7f^7$, being f the frequency and $a_{0...7}$ the fitting coefficients. The fitting was done with Gnuplot program and the results are shown in **figure 1**.

G_{ant} was obtained from the datasheet of the antenna, provided by the manufacturer, and was likewise also fitted to a 6th degree polynomial. The measurement and the fit are shown in **figure 2**.

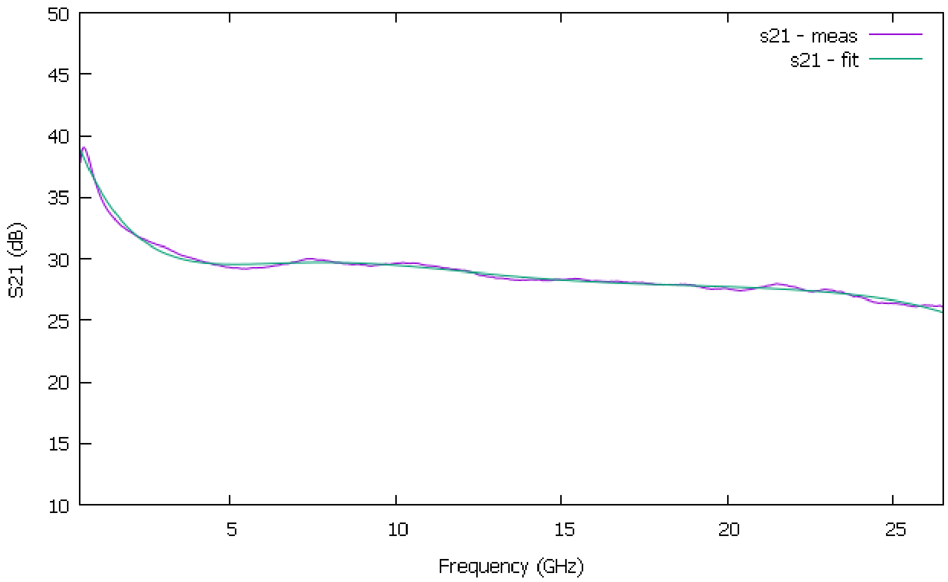

Figure 1: Measured and fitted gain of the amplifier plus the cables from the antenna to the spectrum analyzer

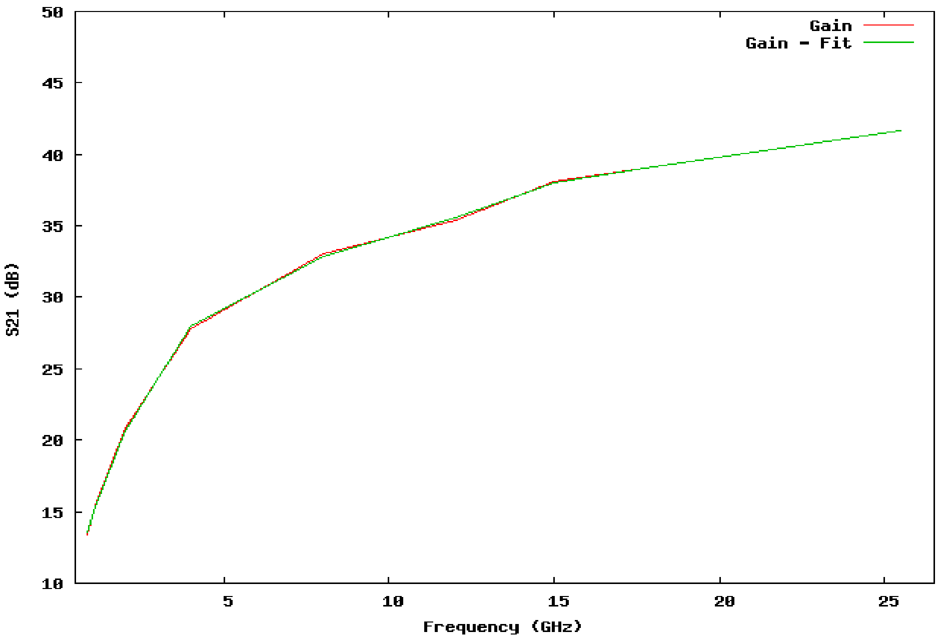

Figure 2: Fitted gain of the AC008 antenna and HL050 feed.

According to (3) the antenna factor, *AF[dB(1/m)],* can be computed too (**Figure 3**).

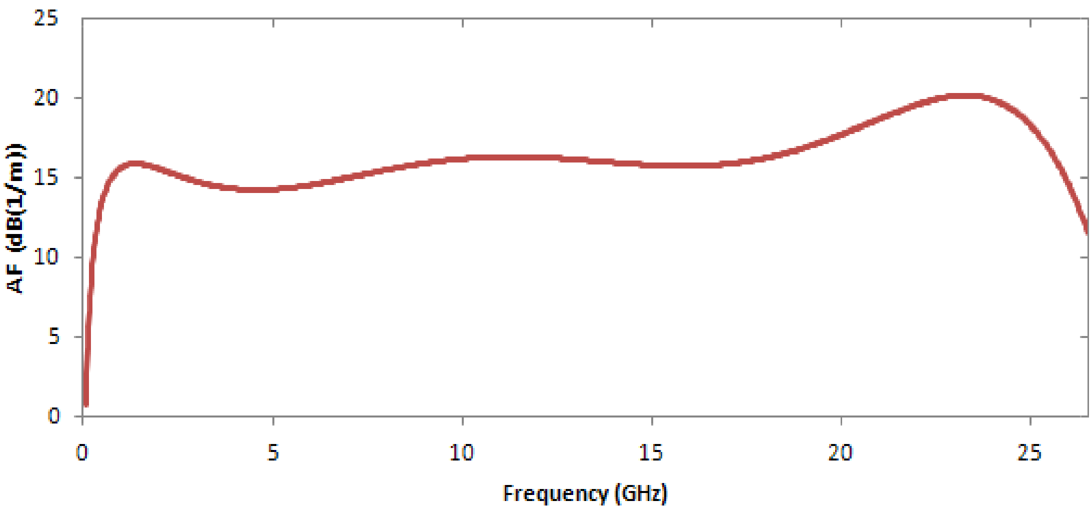

Figure 3: Computed antenna factor

Now all the parameters involved in equation (4) are known and, once the RFI power is measured with the spectrum analyzer, the electric field intensity can be derived.

3 Results

A set of spectra graphs is presented to show the RFI received at the observatory. Each spectrum has been taken with the analyzer in *MaxHold* mode during one complete turn in azimuth of the antenna, which was pointing to the horizon with vertical and horizontal polarization. Other measurements at different elevations angles have also been made and are presented.

First, a full panorama from 0.5 GHz to 26.5 GHz in vertical polarization is shown in **figure 4**, comparing it with the one measured by José A. López-Pérez in March 2010. The limit of +88dB(uV/m) established in the Spanish regulation (*Orden CTE/1444/2003, BOE 04/06/2003*) is depicted in the graph. As it can be seen, the RFI level is lower, for instance, in the 23 GHz band, as some radio links have been substituted by optic fiber, after discussions and meetings with the Spanish regulator and the telecom operator. Unfortunately, there are still important RFI levels in the 0.9-4GHz frequency band, mainly due to GSM, UMTS and other cellular frequency bands.

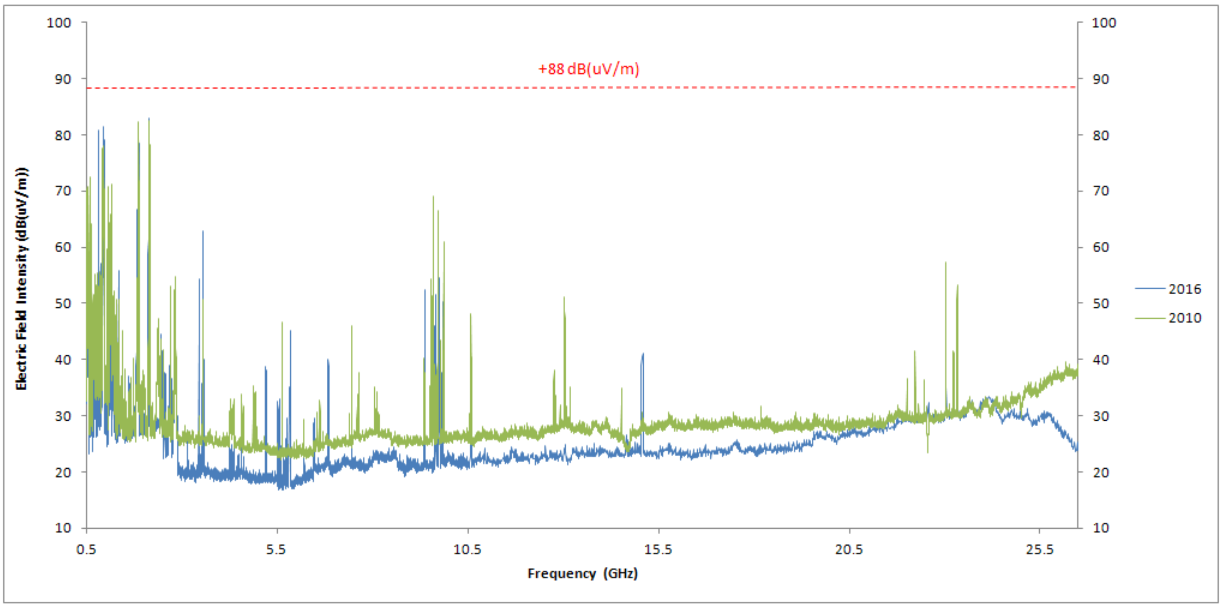

Figure 4: Comparison between the RFI measurements performed in 2010 with the ones in 2016. Vertical polarization with elevation pointing to the local horizon.

In the following pages, several slices of this spectrum will be plotted for better zooming into the details. The frequency bands of the different communication services are represented with red segments while some radio astronomy interest frequencies and the 40m radiotelescope receiver bands are depicted in green.

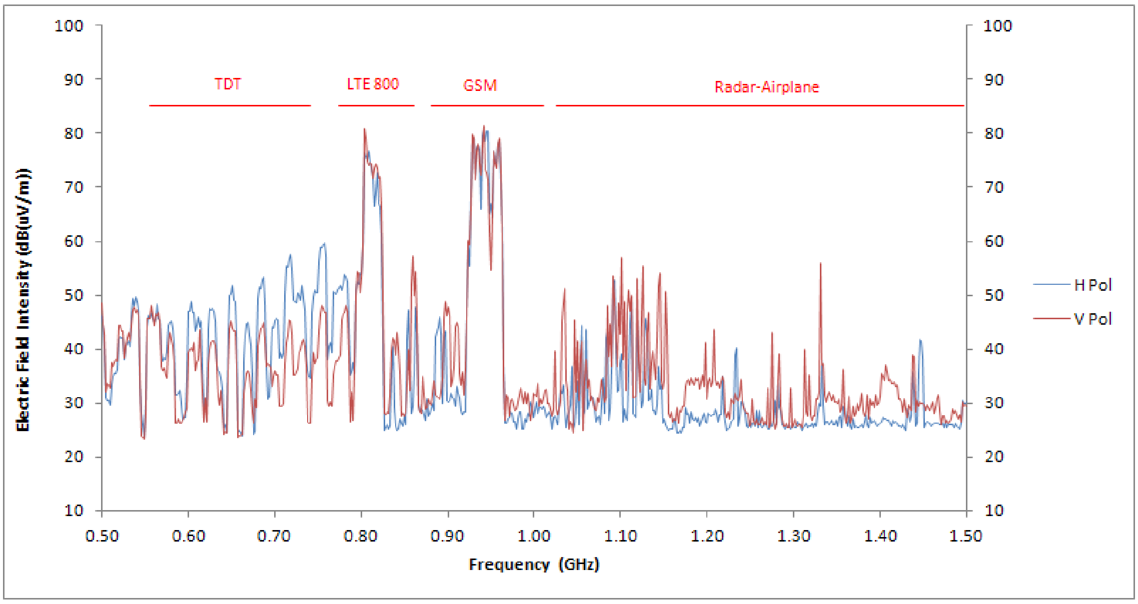

Figure 5: 0.5GHz to 1.5GHz RFI spectrum. GSM band detected from azimuths 25° and 300°.

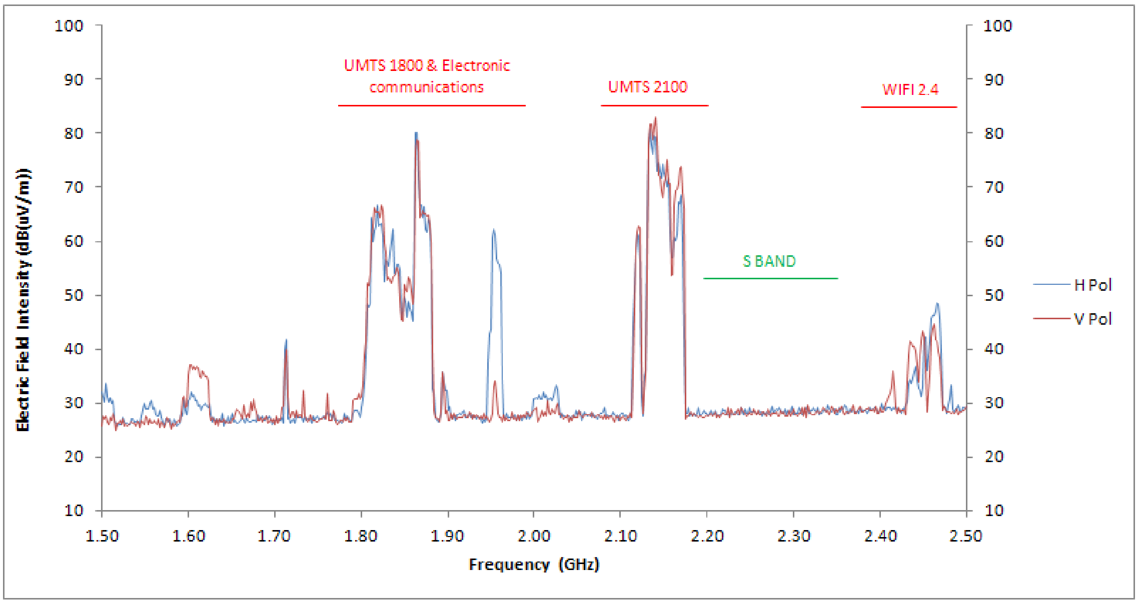

Figure 6: 1.5GHz to 2.5GHz RFI spectrum. UMTS bands detected from azimuths 25° and 300°.

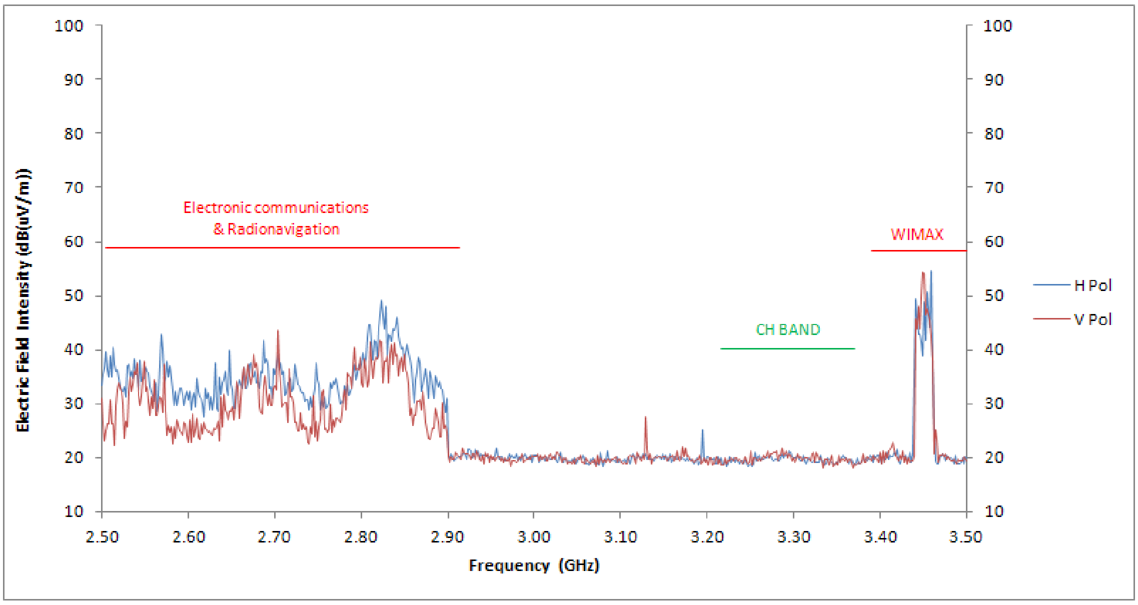

Figure 7: 2.5GHz to 3.5GHz RFI spectrum. Wimax detected from azimuths 225° and 135° and 345°. Electronic communications detected from azimuth 300°.

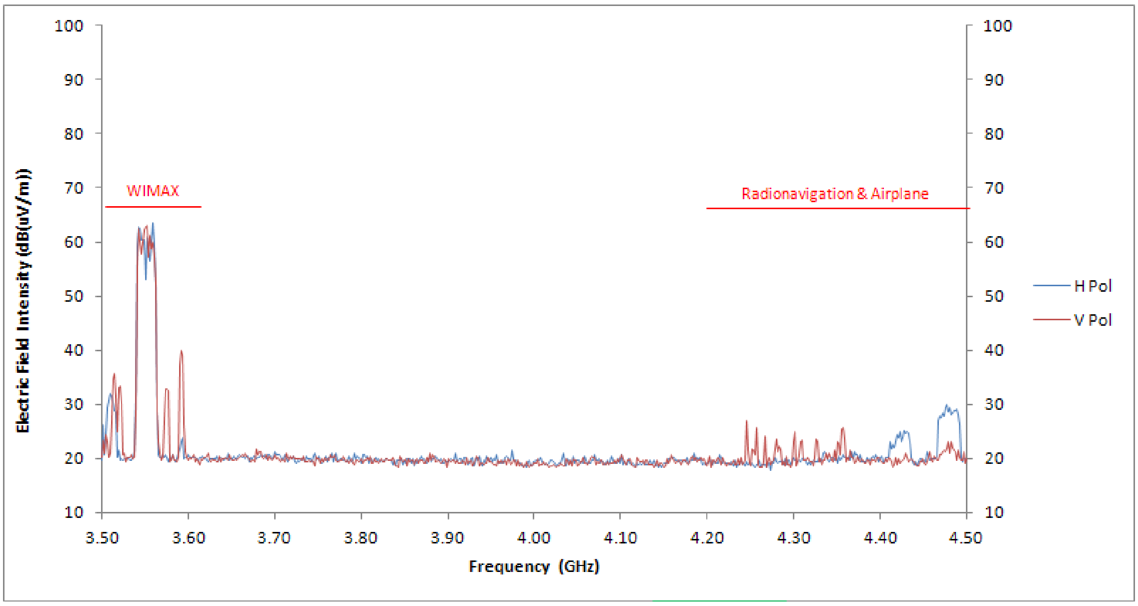

Figure 8: 3.5GHz to 4.5GHz RFI spectrum. Wimax detected from azimuths 225° and 135° and 345°.

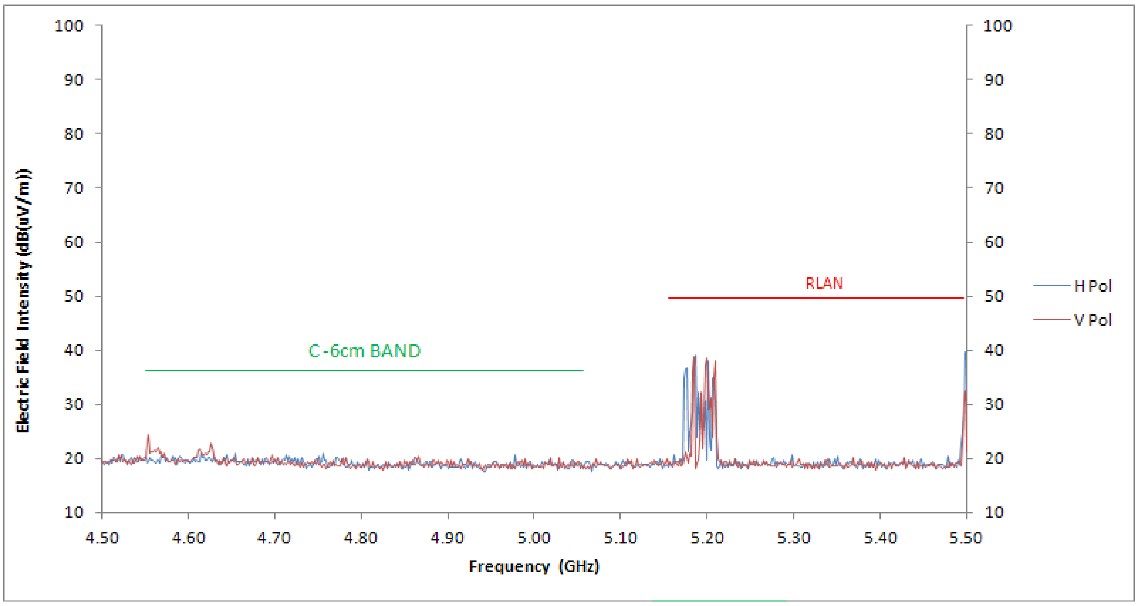

Figure 9: 4.5GHz to 5.5GHz RFI spectrum. RFI detected coming from different azimuths.

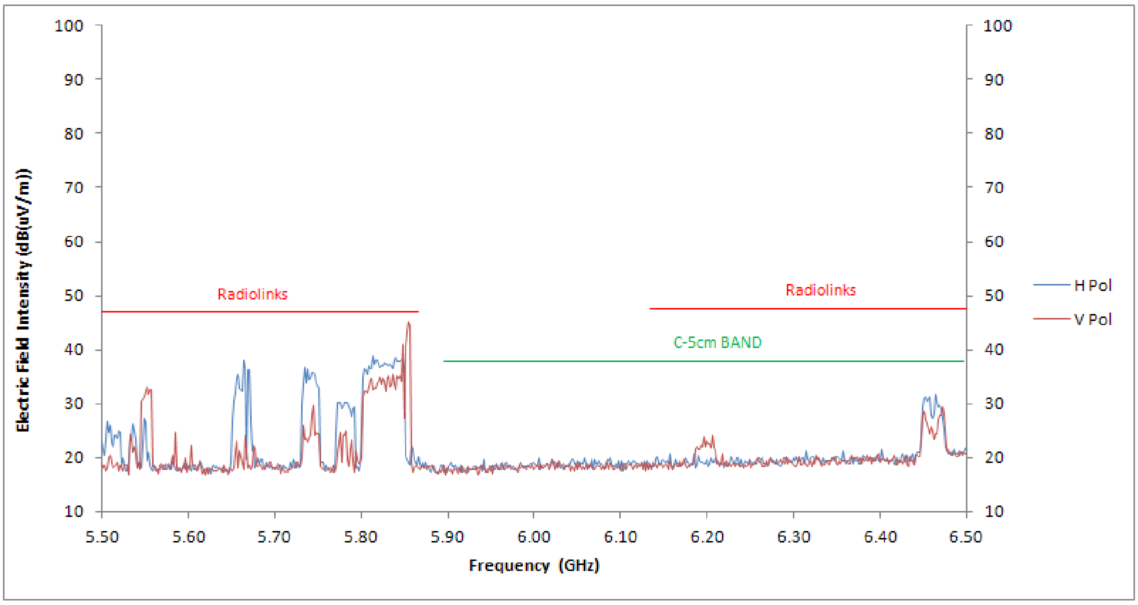

Figure 10: 5.5GHz to 6.5GHz RFI spectrum. Radio links detected from azimuths 310° and 195° and 345°.

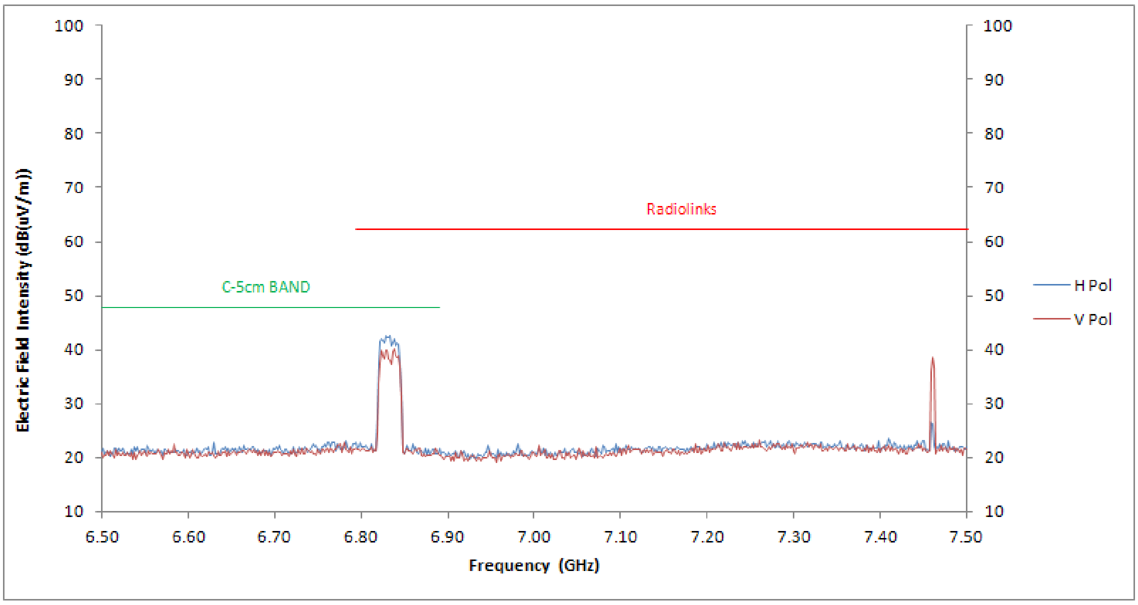

Figure 11: 6.5GHz to 7.5GHz RFI spectrum. Radio links detected from azimuth 0°.

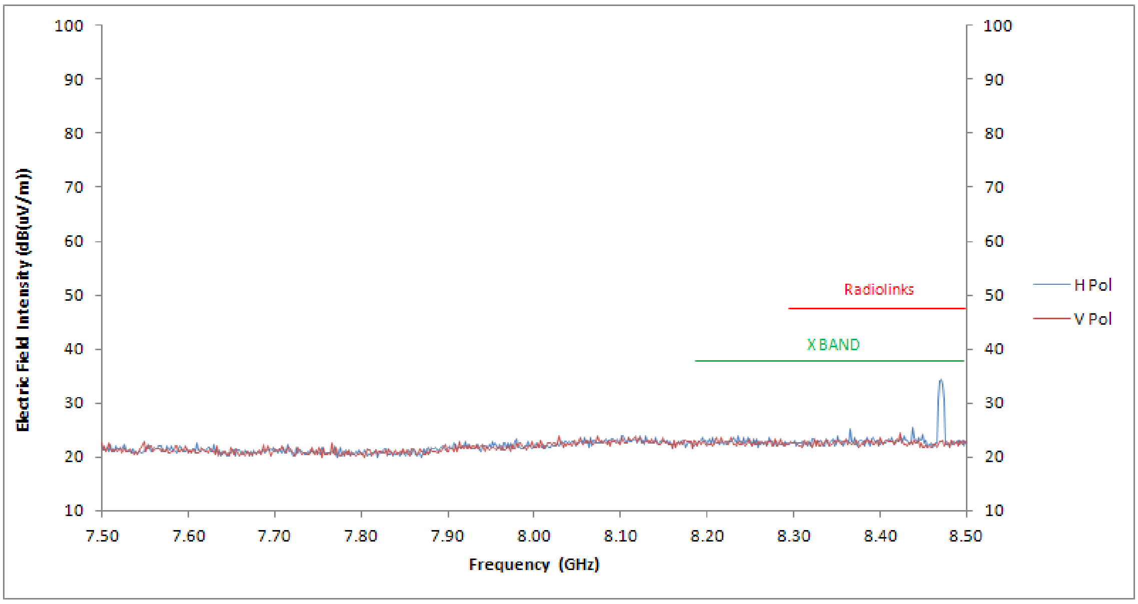

Figure 12: 7.5GHz to 8.5GHz RFI spectrum. Radio links detected from azimuth 12°.

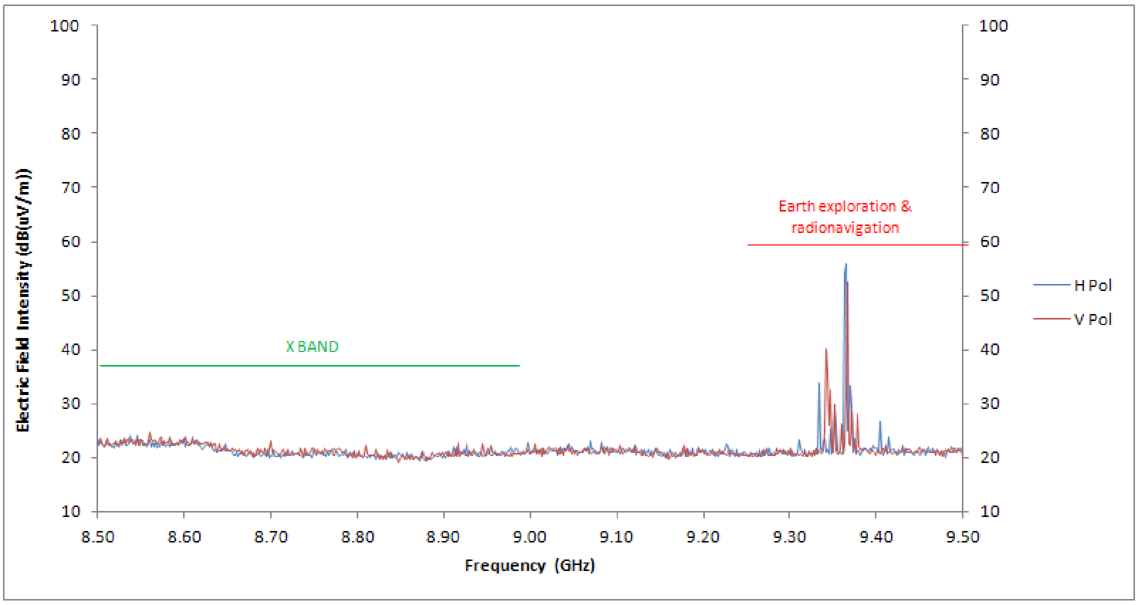

Figure 13: 8.5GHz to 9.5GHz RFI spectrum. RFI detected from azimuth 260°.

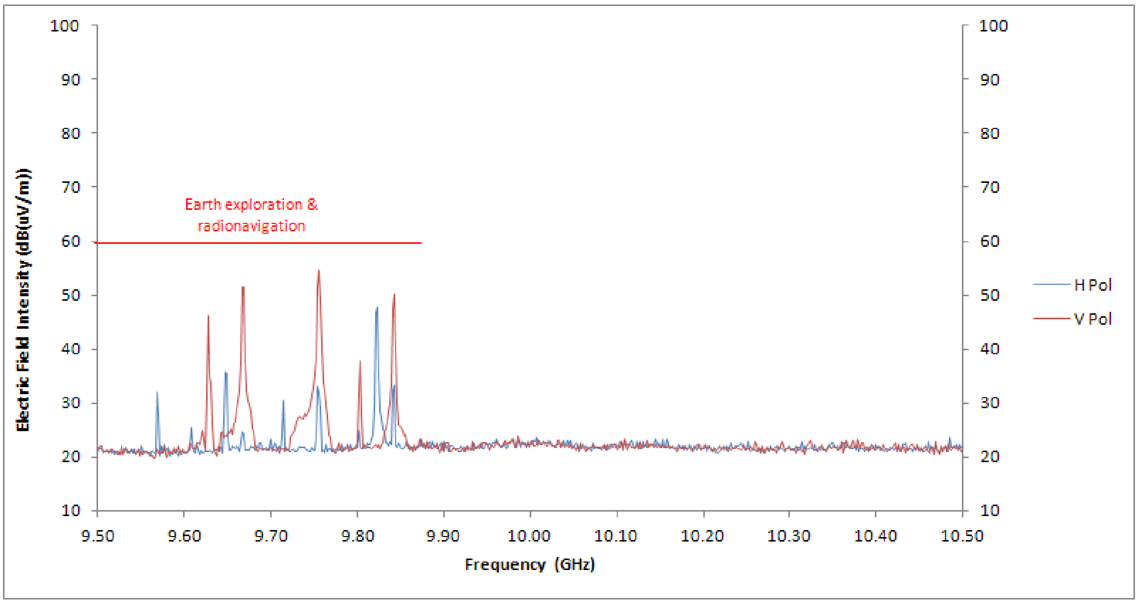

Figure 14: 9.5GHz to 10.5GHz RFI spectrum. RFI detected coming from different azimuths.

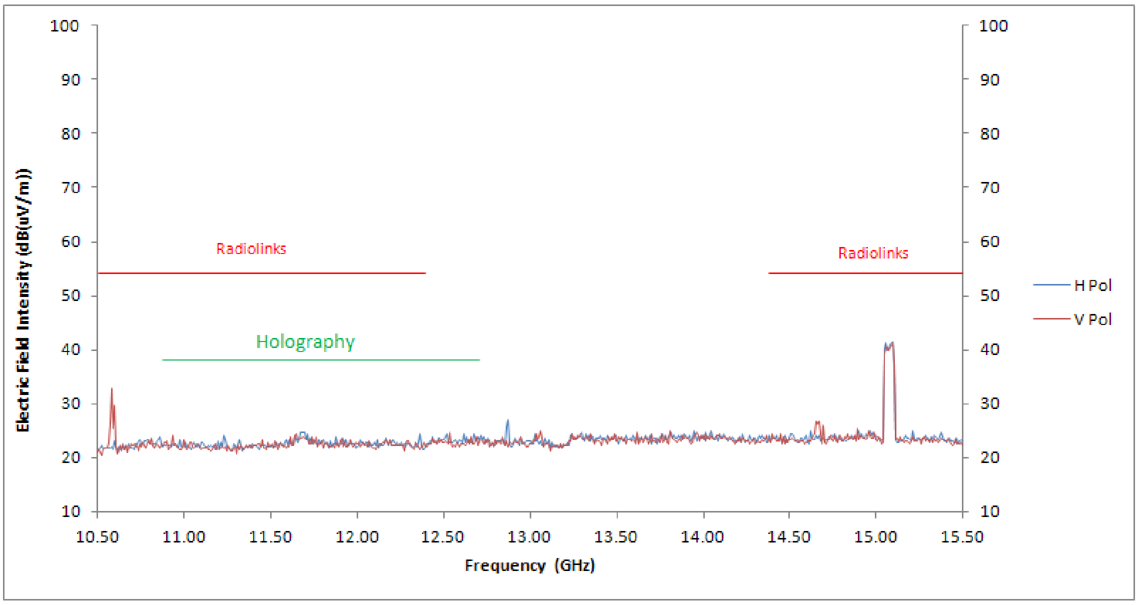

Figure 15: 10.5GHz to 15.5GHz RFI spectrum. Radio links detected from azimuth 310°.

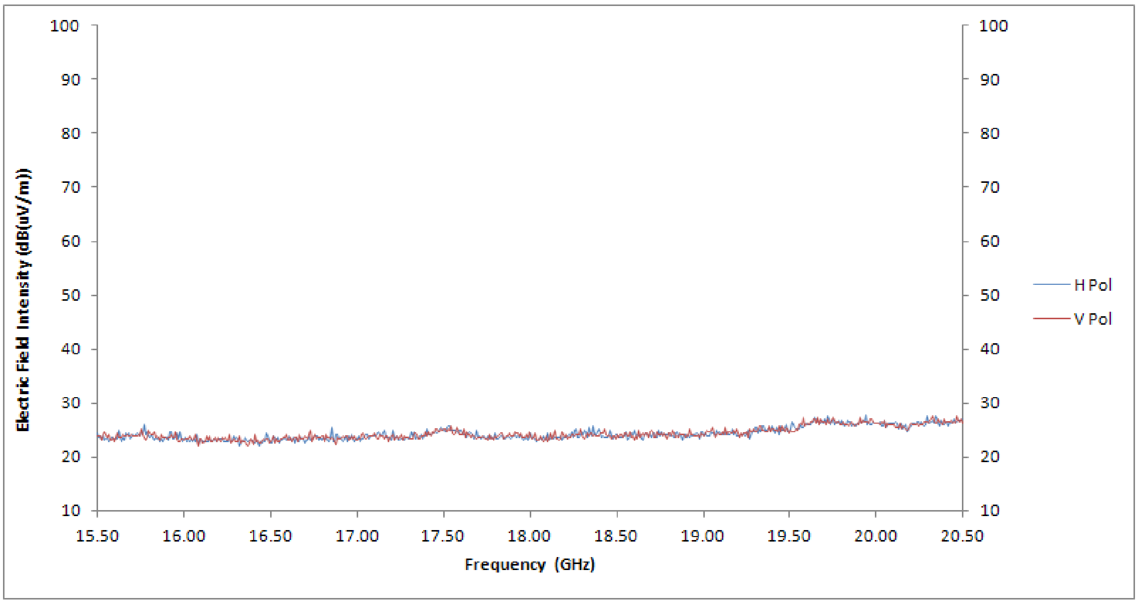

Figure 16: 15.5GHz to 20.5GHz RFI spectrum.

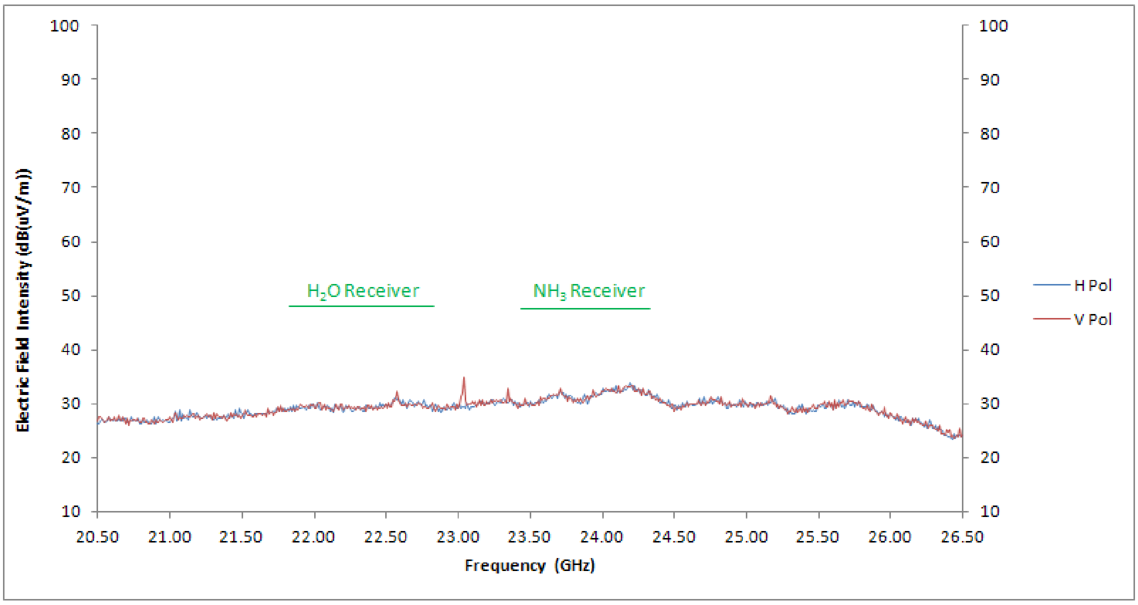

Figure 17: 20.5GHz to 26.5GHz RFI spectrum.

It can be seen from these measurements that the main RFI signal levels are in the cellular frequency bands from stations that are in the vicinity of Yebes and Horche cities. The remaining RFI comes from fixed service radio link stations that go through the observatory site, mainly. A map that shows the relative position of the Yebes Observatory and the main RFI sources is shown in **Fig 18**.

Figure 18: Major RFI sources detected.

Measurements at different elevation angles were performed too (**Figs. 19, 20**), concluding that the RFI signal levels are reduced, in general terms, when elevation is increased.

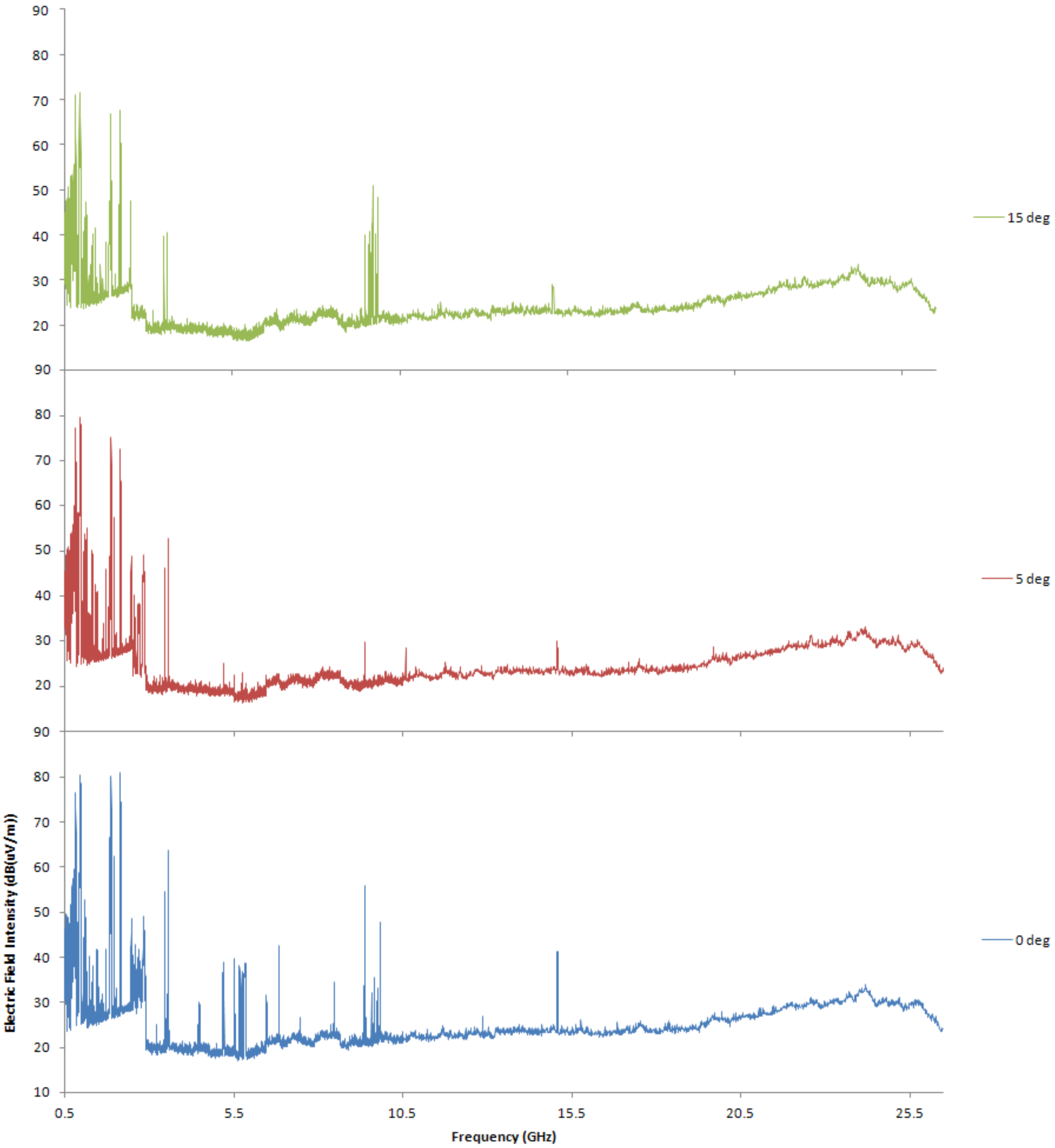

Figure 19: 0.5GHz to 26.5GHz RFI spectrum (H polarization) at different elevation angles.

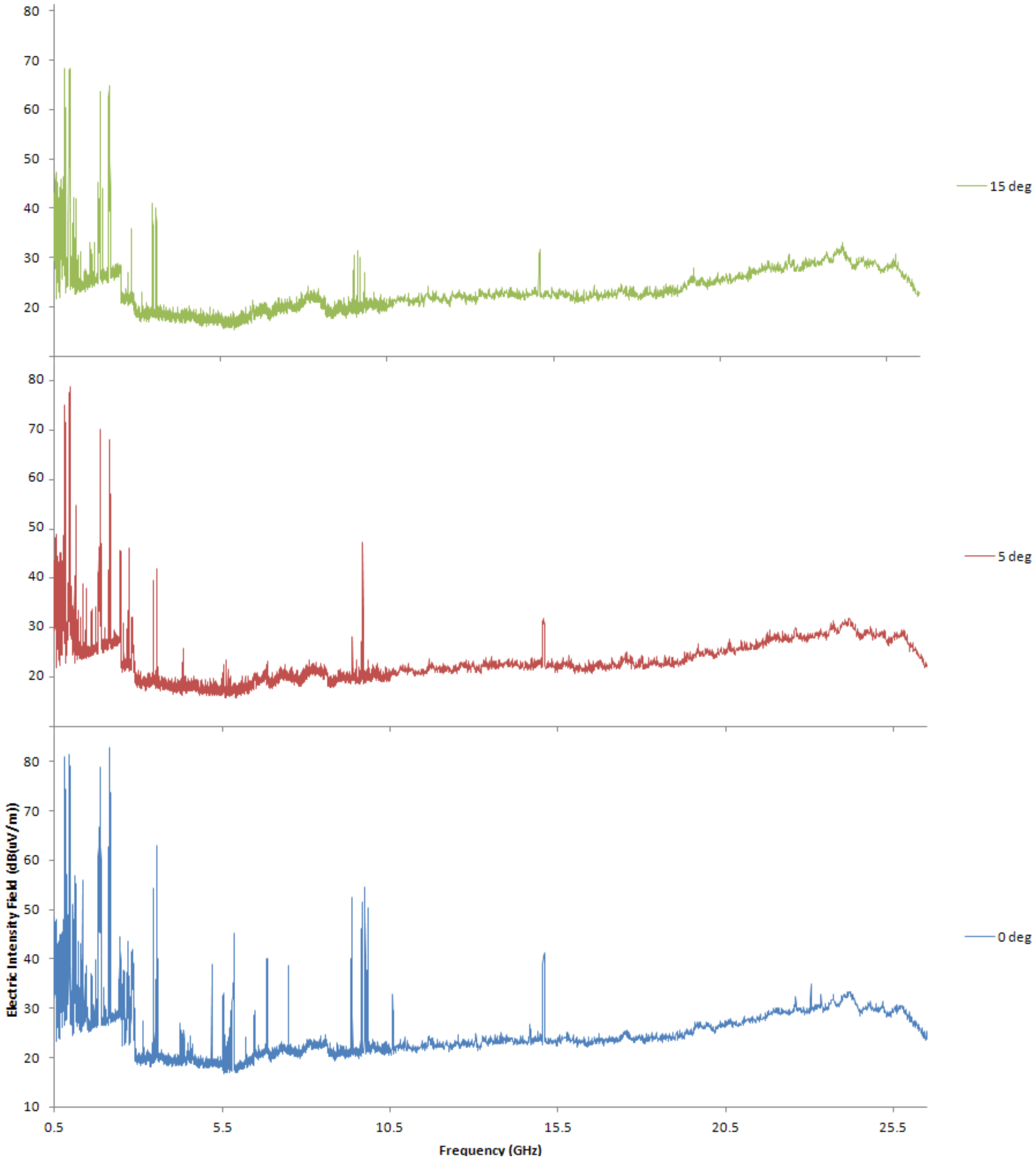

Figure 20: 0.5GHz to 26.5GHz RFI spectrum (V polarization) at different elevation angles.

4 Estimation of the power received by an isotropic antenna

Once we have measured the electric field intensity at the observatory site, the received power by an isotropic antenna (0 dBi) can be estimated. This estimation allows a quick computation of the received power by any other antenna, just adding its gain.

It can be derived that, the received power is given by:

$$P_{rx}\,[dBm] = E[dB(uV/m)] - 20 \log F[MHz] + G_{rx}\,[dB] - 77.23$$

where G_{rx} represents the gain of the receiving antenna. In **Figure 21** it has been plotted the power P_{rx} when the receiver antenna gain is 0dBi. The electric field intensity considered for these plots is the one measured at zero degrees elevation.

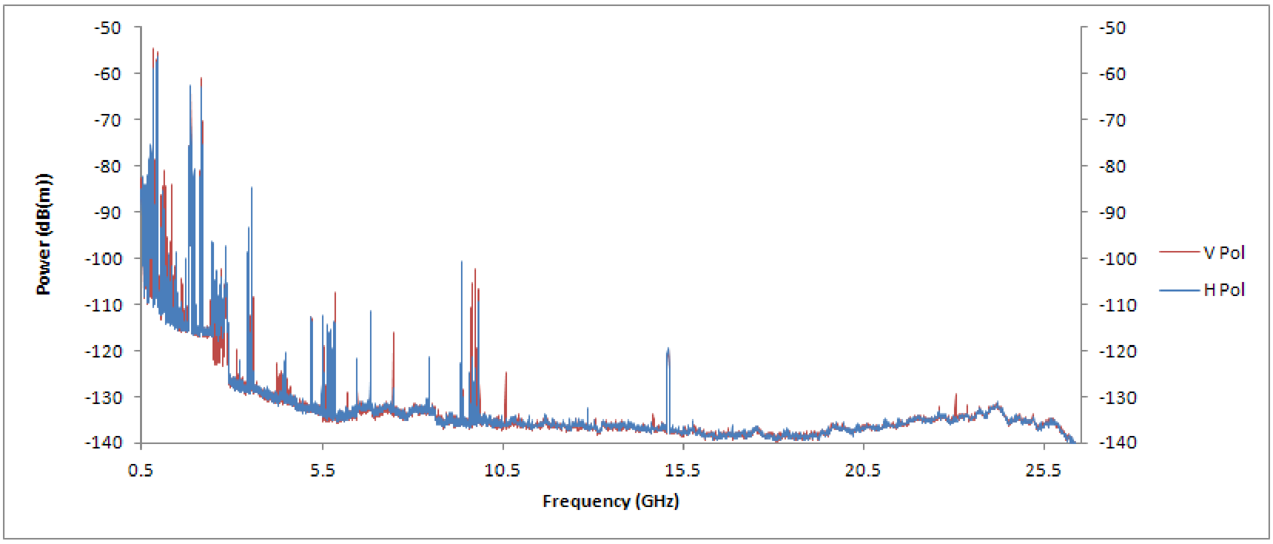

Figure 21: Power received by an individual element with G_{rx} =0 dB in the vertical and horizontal polarization plane.

Received power in the low frequency part of the spectrum can be as high as **-55dBm** for a 0dBi gain antenna. If these signals are received through a radio telescope side lobe, they could saturate the receiver's low noise amplifiers (LNA), depending on the side lobe level.

5 Conclusions

- The 2-14 GHz band for the VLBI2010 geodetic receiver is very polluted at 0° elevation, specially the 2-4 GHz part, but improves at higher elevation angles.
- S-band (2.2-2.37 GHz) is strongly polluted in the lower end of the band.
- CH-band (3.22-3.39 GHz) and C - 6cm band (4.56 – 5.06 GHz) are reasonably clean.
- C - 5cm band (5.9 – 6.9 GHz) is polluted, as can be seen in figures 10 and 11.
- X band (8.18- 8.98 GHz) is reasonably clean with just one radio link in 8.47 GHz with horizontal polarization.
- The holography receiver band (10.9 – 12.75 GHz) is quite clean.
- K-band (21.75-22.85 GHz and 23.35-24.45 GHz) is reasonably clean.

References

[1] José A. López-Pérez, J.A. López-Fernández. *First Radio-Frequency Interference Measurement Campaign at Yebes Observatory*. Informe Técnico IT-OAN-2010-5.