Radio Frequency Interference Observations at IAR La Plata

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Abstract The Wettzell RFI-Monitoring system was developed to monitor radio frequency interference at existing and potential VLBI sites. It was used at the Instituto Argentino de Radioastronomía (IAR) in La Plata, Argentina, to evaluate a future site for the Transportable Integrated Geodetic Observatory (TIGO). A 24h/7d survey was conducted during September and October 2012. This huge data set required the development of a specific analysis strategy and data representation. The results of this survey revealed, that IAR is a suitable site for geodetic VLBI observations: most of the present RFI signals occure sporadically and may take away less than 5% of the observation time; moreover VLBI receivers will not be saturated.

Keywords RFI monitoring, VLBI sites, TIGO

1 Motivation

The existing global VLBI network infrastructure is lacking radio telescope installations especially in the Southern hemisphere. The German Transportable Integrated Geodetic Observatory (TIGO) of the Bundesamt für Kartographie und Geodäsie (BKG) is one initiative to improve the global distribution of geodetic observatories. Since 2002, TIGO has been operating in Concepción, Chile, within the context of technical and scientific cooperation. After Chilean partner universities have withdrawn from the TIGO project, BKG needs to find a new project partner. A proposed site for the future operation of TIGO is the Instituto Argentino de Radioastronomía near the city of La Plata. Prior to the decision about the proposal the suitability of this site for VLBI and SLR observations has to be evaluated. As far as VLBI is concerned it is essential to know the use of the electromagnetic spectrum in the vicinity of the urban region of La Plata and Buenos Aires. Therefore BKG and IAR conducted a measuring campaign with their radio frequency interference (RFI)-monitoring equipments during the period June to October 2012.

2 Equipments

Radio frequency interference monitoring requires a radiometer capable to measure the amplitudes and frequencies of signals above noise floor within a given spectral range. The ideal equipment to realize this monitoring would be radio telescopes with cryogenic cooled receivers, but previous to the costly installation of a radio telescope, mobile RFI monitoring systems are used for a site evaluation, although their technical performance is minor compared to a fully equipped VLBI-radio telescope. The RFI monitoring system permits quantitative measurements about the presence or absence of man made noise. A qualitative analysis can be done, if the measuring system includes a noise calibration system. With a careful selection of low noise components, such as amplifiers, cables and spectrum analyzer, the thermal noise of the

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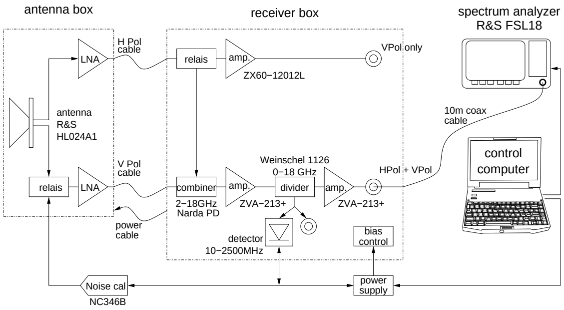

Fig. 1 Block diagram of the Wettzell RFI monitoring system.

measuring system must be minimized. Two systems were available for the evaluation: (a.) BKG Wettzell RFI Measurement System, (b.) IAR La Plata RFI Measurement System.

2.1 BKG Wettzell RFI Measurement System

This system was developed for VLBI2010 site investigations and is described in (1). Fig. 1 shows a block diagram of the components. It uses a Rohde& Schwarz HL024A1 antenna covering the frequency range from 1-18 GHz in a beam of approximately 40 degree, hosting two low noise amplifiers supplying two output signals of horizontal and vertical polarisation. The antenna box contains also an input signal for the noise calibration diode NC346B. The receiver box contains a relais with a combiner in order to produce a mixed output of both vertical and horizontal polarisation as an alternative to the individual polarizations. Later on the signals are finally registered and displayed with a spectrum analyzer Rohde& Schwarz FSL18. A control computer is used to setup the spectrum analyzer, to record its images and to switch on/off the noise diode. Once the antenna is pointed manually to one direction at the horizon, the data acquisition runs automatically.

2.2 IAR La Plata RFI Measurement System

This system was developed for SKA site investigations in Argentina (2). Therefore its frequency range is limited to 2-8 GHz. (With the exchange of two low noise amplifiers and cables it covers an extended range to higher frequencies up to 18 GHz.) The antenna is a dual ridge horn type, Emco 3115, supporting the range of 1-18 GHz. It delivers one linear polarization. Rotating the antenna by 90 degree enables the measurement of horizontal and vertical polarization. The antenna is mounted on a pedestal with two perpendicular axes: one rotates along the antenna axis (polarisation) and the other rotates the antenna azimuthal by computer controlled motor drives. The pedestal is a fixed installation at La Plata. The noise calibrator is realized by a 50 Ohm reference load. The signals are registered with a spectrum analyzer HP9583E. The system is fully automated and secured by an uninterruptable power supply.

3 Measurements

3.1 Flux density

Among many ways of expressing energy received by a receiving system, we chose the flux density with the unit $dBWm^{-2}Hz^{-1}$. This unit can be easily related to the radio source flux density of VLBI observations which is expressed in Jansky $1Jy = 10^{-26}Wm^{-2}Hz^{-1} = 260dBWm^{-2}Hz^{-1} = 230dBmm^{-2}Hz^{-1}$. The flux density of the electromagnetic spectrum can be written after (4) as

$$
\begin{aligned}
S_{dB} &= P_{SA_{dBm}} - 10\log(B_S) - G_{R_{dB}} + k_{A_{dB}} - 35.77 \\
&\text{with} \\
S_{dB} &\text{ in } \left[\frac{dBW}{m^2Hz}\right] \qquad (1) \\
P_{SA_{dBm}} &= \text{power in dBm read at spectrum analyzer} \\
B_S &= \text{resolution bandwidth} = setto30kHz \\
G_{R_{dB}} &= \text{receiver system gain} \\
&= \text{median from calibration measurement} \\
k_{A_{dB}} &= 20log(f_{MHz}) - G_{_{dBi}} - 29.79 \qquad (2) \\
&\text{with} \\
f_{MHz} &= \text{ant. frequency} = 2000\ldots14000MHz \\
G_{_{dBi}} &= \sim 7dBi \qquad \text{(data sheet)}
\end{aligned}
$$

From equation 1 follows, that for the determination of the flux density only two measures have to be taken: the amplitude per frequency from the spectrum analyzer of the targeted direction $P_{SA_{dBm}}$ and the calibrated gain of the system $G_{R_{dB}}$. The other parameters are settings or conversion factors.

The RFI measurement systems used in the evaluation have uncooled wide beamwidth antennas. Pointing to the horizon at least half of the beam pattern intersects with the ground and raises the system temperature to higher levels than those that are typical for the VLBI radio telescope. Moreover without a reflector the antenna gain is low and the RFI signals may not stand out far enough above the noise floor (which is composed by ground pickup and amplifier noise). However, with the collected data it is possible to conclude, whether the detected signals above noise floor will saturate the LNA used in VLBI radio telescopes or not.

3.2 Setup and yield of RFI measurements

Once the Wettzell RFI measurement system had arrived at IAR in La Plata a comparison between both systems was carried out. It was confirmed that both systems detected the same signals in the overlapping frequency range. The advantage of the Argentinean system was its computer controlled pedestal which enabled 24h/7d measurements, while the German system had the advantage of covering the full spectral range of interest from 2-14 GHz. Therefore, it was decided to temporarily mount the Wettzell equipment on the La Plata pedestal in order to carry out an almost continuous measurement for one month (s. fig. 2). The spectrum analyzer was set to 30 kHz resolution bandwidth in order to pick up any possible narrow band signal. The spectrum 2-14 GHz was subdivided into 1 GHz wide bands. Each subband required 2.5 seconds sweepttime; hence 12 subbands needed 30 seconds. The antenna beamsize of about 40 degree suggested to used eight pointing directions (N, NE, E, SE, S, SW, W, NW). Together with the calibration an entire azimuth scan registring the spectrum 2-14 GHz needed 15 minutes. The yield was 96 azimuth scans per day respectively 768 spectrum analyzer images each with 9600 amplitude data points (spaced by 1.25 MHz). Thus, within 30 days of measurements (September 14 to October 14, 2012), a total of 21776 images of the spectrum analyzer respectively 209 million data points had been registered.

Fig. 2 Foto of pedestal mounted on the roof of the operation house with the broadband antenna from the Wettzell RFI monitoring system. This configuration was used almost continuously from September 14 until October 14, 2012.

4 Analysis and results

The analysis of the huge amount of collected data took several steps. Firstly the calibration data was applied to the spectrum analyzer readings according to equation 1. Secondly, a statistical method was applied to all the monitoring data regardless of the antenna pointing direction. The measured signal amplitude data was superimposed and five parameters were identified: maximum, 90-percentile, median, 10-percentile and minimum. (The maximum and minimum are equivalent to the max hold and min hold button at the spectrum analyzer throughout the measured period.) This quantitative approach revealed, that radio interference is present almost throughout the entire spectrum during the period of 30 days. The maximum level was up to 50dB significantly above the minimum noise level. However, the 90-percentile line shows where 90% of the amplitude measurements are equal or less. Thus, it is an indicator for the temporary or continuous nature of a signal. The median value shows the value which is in the middle of measured samples. It means that half of measured signals are found above that line and half below.

Fig. 3 shows fluctuation of the noise floor with some signals peaking out of it. A filter of $+6dB > median$ was applied as a criteria to discriminate noise from an interference signal . The result of this process applied to all measurements is shown in fig. 4. Fig. 4 shows strong peaks at 5.16 and 5.8 GHz which are re-

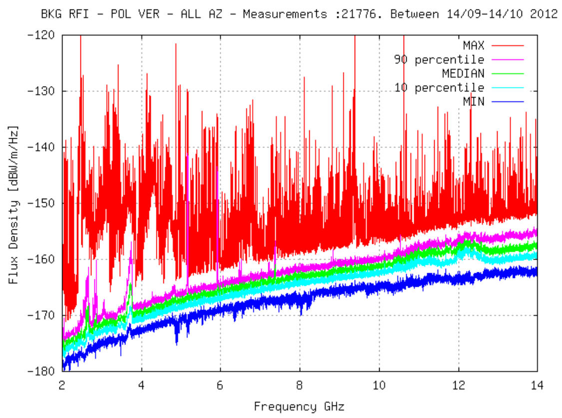

Fig. 3 Flux density vs. frequency from 21776 measurements at IAR La Plata during September 14 - October 14, 2012.

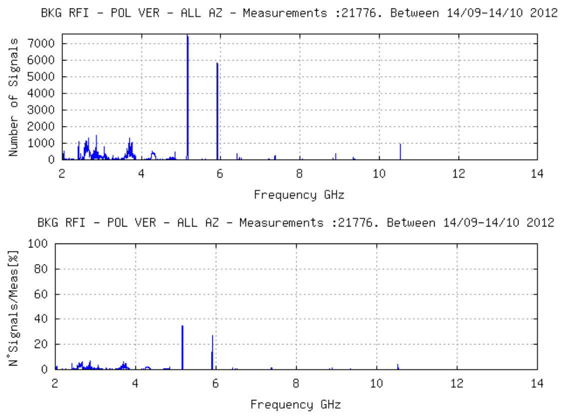

Fig. 4 RFI detections based on a filter $+6dB > median$. The upper plot shows the absolute number of detected RFI events during one month, the lower plot shows the percentage of the overall measurements in all directions.

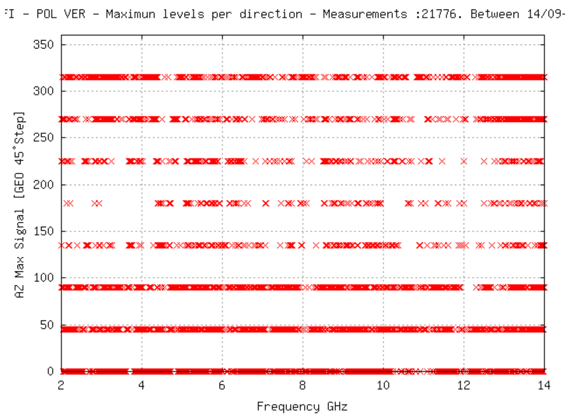

Fig. 5 Azimuth direction vs. observed spectrum. The amount of detected events is correlated with the directions in which urbanized areas are located. The Southern direction points to a rural area and less events have shown up.

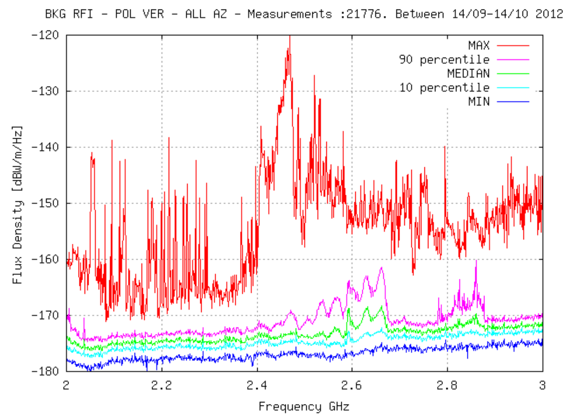

Fig. 6 S-band 2.0-3.0 GHz. Some intereference is present at 2.4-2.7 GHz and 2.8-2.9 GHz. The VLBI band 2.2-2.35 GHz does not contain any continuous interference signal.

lated to a local internet link from IAR to the National University of La Plata. Below that frequency the other interfering signals are related to wireless lan above 2.4 GHz, Wimax above 2.5 GHz, mobile telephone frequencies (LTE) above 2.6 GHz and air radar systems between 2.7 and 2.9 GHz. Interference signals are also visible at 3.7-3.9 GHz, 8.80-8.85 GHz.

How is the relation between the eight observed directions and the detected radiation? To answer this question the azimuth direction was plotted versus the observed spectrum. Fig. 5 shows the observed directions. The city of Buenos Aires is located in the North-West of the monitoring site at IAR, the city of La Plata lays in the East and in the South direction we find rural areas. As indicated in fig. 5 the presence of detected signals is correlated with urbanized areas. This result can be considered typical for sites near urban regions.

Fig. 6 and fig. 8 give a closer look to the S-band and X-band. The colour-coded directions in fig. 7 and fig. 9 show, that those signals are directional and may possibly limit the applied elevation mask in VLBI-observations. However, the observed S-band spectrum and observed X-band spectrum tend to be free of interference signals in the corresponding spectrum.

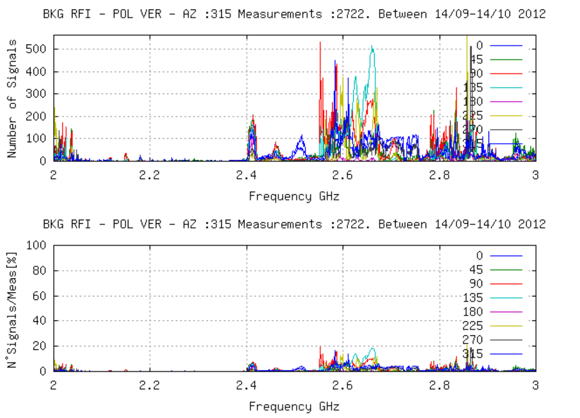

Fig. 7 S-band 2.0-3.0 GHz. The colour coded antenna directions show, that most of the interfering signals are directional. The wifi signal at 2.4 GHz is omnidirectional and locally generated. The VLBI-frequencies at 2.2-2.35 GHz are not disturbed.

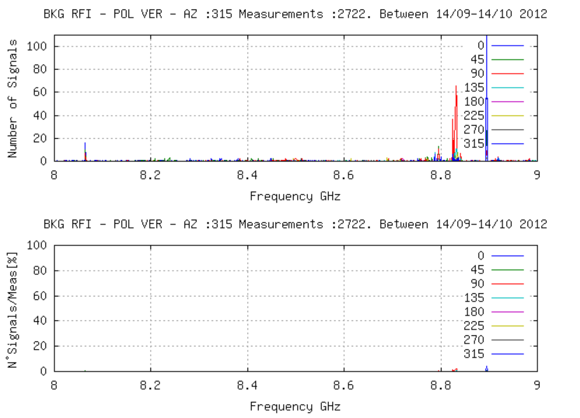

Fig. 9 X-band 8.0-9.0 GHz. The colour coded antenna directions indicate, that the signal at 8.82 and 8.85 GHz are directional and can be filtered out by an adjustment of the elevation mask in those directions if necessary.

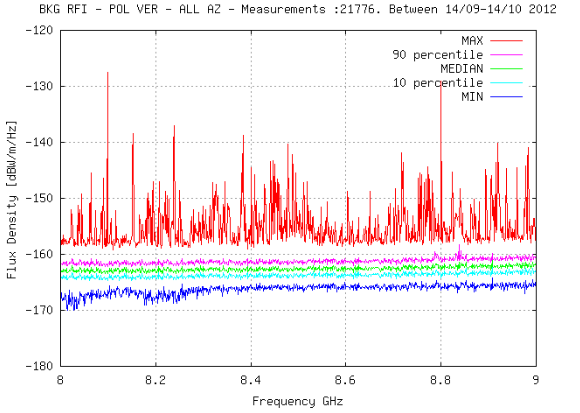

Fig. 8 X-band 8.0-9.0 GHz. Some intereference is present in the VLBI band 8.1-8.9 GHz at 8.80-8.85 GHz.

5 Conclusions

A RFI-monitoring system for 1-18 GHz was devel-loped at the Geodetic Observatory Wettzell and was used in an automated measuring campaign at IAR La Plata for 30 days. In the frequency range of 2-14 GHz 21776 radiation images were taken and processed. The most important findings are: The largest interference signal was caused by a local internet radio link at the IAR site. This is not a problem because this signal will be switched off as soon as a cable connection will have been intalled. Interference signals exist in the range of 2.4-2.9 GHz and around 8.81 GHz. As for the rest of the signals most of them appear sporadically. Directional continuous interference signals will determine the elevation mask for future VLBI-observations. RFI monitoring should be a permanent task. The presented results have been further analyzed by the IVS RFI-group and confirmed that the present RFI noise levels will not saturate the LNA of a VLBI radio telescope (5). This analysis confirms, that the IAR La Plata is a suitable site for geodetic VLBI measurements using S-band and X-band.

References

1. Kronschnabl, G. Projekt RFI-Meßsystem, Beschreibung: Empfangssystem zur Überprüfung des jeweiligen Standortes auf hochfrequente Störsignale im Bezug auf die Empfangseigenschaften von VLBI Radioteleskopen *(internal document)*, 18.08.2012
2. Gancio, G. Equipamiento para monitoreo RFI disponible en IAR, Descripción general OBS-RFI-00110-DG, Instituto Argentino de Radioastronomía, *(internal report)* 04.04.2012
3. Gancio, G., Perilli, D., Hase, H., Larrarte, J.J. BKG RFI Month Report. OBS-RFI-00126-RP, Instituto Argentino de Radioastronoma, *(internal report)*, 22.10.2012
4. R.P. Millenaar. SSSM System Design Considerations. ASTRON-RP-013 Document, *10.1.1.103.3528.pdf*, 21.02.2006
5. Petrachenko, B., Corey, B., Beaudoin, C. VGOS RFI Survey Proceedings of the EVGA-Meeting 2013, Espoo, Finland