INTERNAL REPORT

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1 Abstract

We present the results of radio frequency interferences (RFI) measurements in the frequency band 50 to 500 MHz conducted at the site of the Sardinia Radio Telescope (SRT). The measurements have been performed on December 11th, 2012 and partially repeated on January 9th and 15th, 2013 with the INAF mobile laboratory for RFI searches on service at the SRT site. Data were collected for both the horizontal and vertical polarization at two different locations within the SRT site. We compare our results with that of a similar study conducted at the Medicina station on December 7th, 2011.

2 Introduction

This investigation is conducted in the context of a project[1] aimed to the study of new technologies for the observation of the sky at low radio frequencies. The goal of the project is the realization of an aperture phased array demonstrator at the site of the SRT. The array will be constituted by prototypical low-frequency antennas designed to operate in the range 70 - 450 MHz. The antennas will be grouped in stations whose size will be limited if measured in terms of wavelengths (ranging from about 4 to 1 meters). As a consequence the station main beam will be wide and the side-lobes level high. Indeed, the knowledge of the strong man-made signals in the station side lobes it is important in the receivers design.

Here we report the results of RFI measurements in the frequency band 50 to 500 MHz conducted at the site of the SRT. This frequency band encloses the working frequency range – 70 to 450 MHz – of the prototype Vivaldi antenna developed by INAF - Istituto di Radioastronomia in the context of the Aperture Array Design Consortium & Construction in the pathway to the Square Kilometer Array. A similar low-frequency RFI investigation was performed at the INAF Medicina station. We compare the two measurement sets with the aim to possibly evaluate the RFI conditions for broadband low-frequency observations at the two sites. The figures-of-merit to compare the two sites from an RFI point of view are represented by: (i) the spectral occupancy (*id est* the frequency portions of the spectrum occupied by artificial signals)

[1]L.R. 7 Agosto 2007, N.7 : "Promozione della Ricerca Scientifica e dell'innovazione Tecnologica in Sardegna", Progetti di ricerca fondamentale o di base annualitá 2012; CRP-60151, PI M.Murgia.

and (ii) the power level of the more powerful signals (basically the FM radio broadcast). The first key-element limits the radio-window where scientific observations can be performed, the second one limits the amplitude dynamic range of the receiving system.

Figure 1: The Log periodic LPA 360-6 antenna is prepared to be mounted at the mobile laboratory.

3 Equipment

The measurements have been collected using the equipment on board the INAF mobile laboratory for RFI searches on service at the SRT site, see Bolli et al. (2012) for a detailed description of this facility. The frequency range of interest was 50 MHz - 500 MHz and we adopted the following receiving RF chain: antenna - coaxial cable - spectrum analyzer;

Antenna: Log periodic LPA 360-6 characterized by a gain of 6.8 dBi at 200 MHz. At this frequency the beam widths are 65° in the *E*-plane and 110° in the *H*-plane. In Figure 1 we show the mounting of the antenna at the mobile laboratory;

Coaxial cable: RG214 (lenght=50 cm) + GORE 0K (lenght=7 m).

Spectrum analyzer: Spectrum Master MS2724B Anritsu. The analyzer was used both with the internal pre-amplifier OFF and ON. In Fig. 2 we show the spectrum analyzer noise levels for both configurations of the pre-amplifier. With the pre-amplifier OFF the sensitivity of the instrument is clearly degraded but in this way the noise floor turns out -103 dBm which is comparable to the noise floor of ≃-100 dBm of the measurements collected at the Medicina station.

4 Data

Data were collected for both the horizontal and the vertical polarizations. For each of the two polarizations, we produced max hold spectra over 360° for six different angular positions evenly spaced by 60° of the Log periodic antenna. Data have been acquired for 26 seconds in each of the six pointings and then the max hold spectra were saved into a file with 550 points per spectrum. For these measurements, the spectrum analyzer resolution bandwidth and video bandwidth were both set to 10 kHz, the attenuation factor was set to 0 dB, and finally the sweep time was 13 seconds.

The measurements were taken at two different locations within the perimeter of the SRT site. The first location was in front of the radio telescope while the second one was close to the apparati box near the site entrance, see Figure 3.

The coordinates of the first position are: *Lat.*=+39° 29′ 31″ *Lon.*=09° 14′ 40″. In this location we collected 4 different spectra, for each polarization. Both the status of the pre-amplifier (ON and OFF) and the height above the ground of the antenna (8 meters and 4.7 meters) have been changed. With the antenna height fixed at 8 meters we obtained a standard RFI characterization. However, since the Vivaldi antenna are designed to be mounted on the ground (where the RFI may

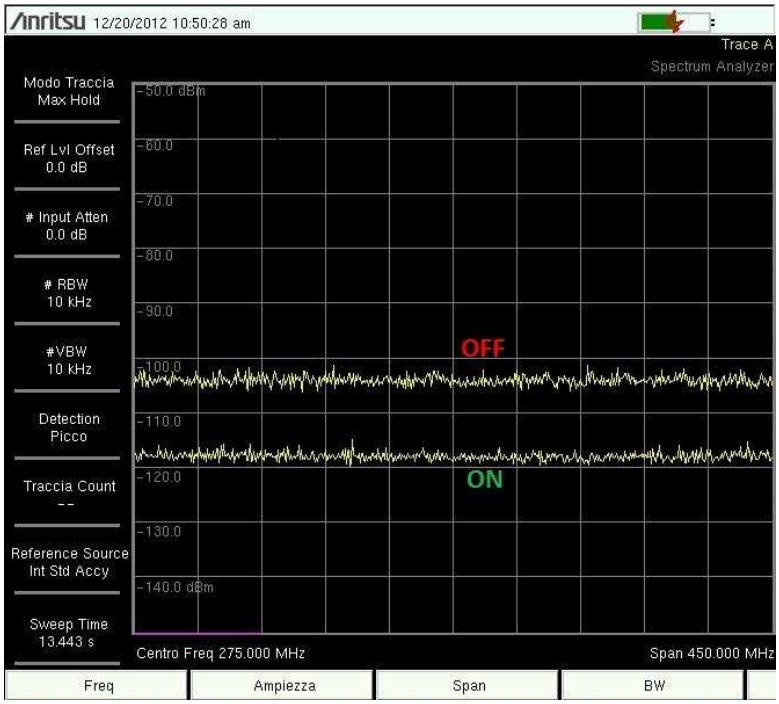

Figure 2: Spectrum analyzer noise levels for the pre-amplifier ON and OFF are shown with a 50 Ωhm matched load at input connector. For both configurations the video and resolution bandwidth are set to 10 kHz and the attenuator factor is set to 0 dB.

be slightly different), we also tried to characterize the RFI with a lower height for the Log periodic antenna.

The coordinates of the second position are: *Lat.*=+39° 29′ 24″ *Lon.*=09° 14′ 43″. In this location only a spectrum with the pre-amplifier ON and with the antenna at a height of 8 meters have been obtained. The RFI investigation here has been performed for a comparison with the first position. In fact, at this location is positioned a radiometer which is known to be a source of noise.

In Table 1 we summarize the different set-up of our RFI measurements. In Figure 4 we report the spectra resulting from the RFI measurements at the location 1. The spectra shown in top-panels of Figure 4 correspond to the measures with the pre-amplifier OFF, while the remaining spectra correspond to the pre-amplifier ON. On the-left panels we present the horizontal (red) and the vertical (blue) polarizations with the antenna at a height of 8 meters. On the right panels we present the spectra obtained with the antenna at a height of 4.7 meters. Note that the spectra at 8 meters height with the pre-amplifier ON collected on Dec-11-2012 have been erroneously recorded at the same (unknown) polarization. Indeed, the measure was repeated on Jan-8-2013 (bottom-left panel).

The highest RFI levels are measured around 100 MHz (FM radio broadcast) and, especially for the vertical polarization, between 450 - 500 MHz. Also the spectral region between 100 - 250 MHz is deeply contaminated by several RFI

Table 1: Data sets and measurement set-up.

File name	Location 1= near SRT 2= entrance	Antenna's height meters	Polarization H=Horizontal V=Vertical	Pre-amplifier	Date
r1	1	8	H	OFF	Dec-11-2012
r2	1	8	V	OFF	Dec-11-2012
r3	1	8	?, H	ON	Dec-11-2012, Jan-8-2013
r4	1	8	?, V	ON	Dec-11-2012, Jan-8-2013
r5	1	4.7	H	OFF	Dec-11-2012
r6	1	4.7	V	OFF	Dec-11-2012
r7	1	4.7	H	ON	Dec-11-2012
r8	1	4.7	V	ON	Dec-11-2012
r9	2	8	H	ON	Jan-15-2013
r10	2	8	V	ON	Jan-15-2013

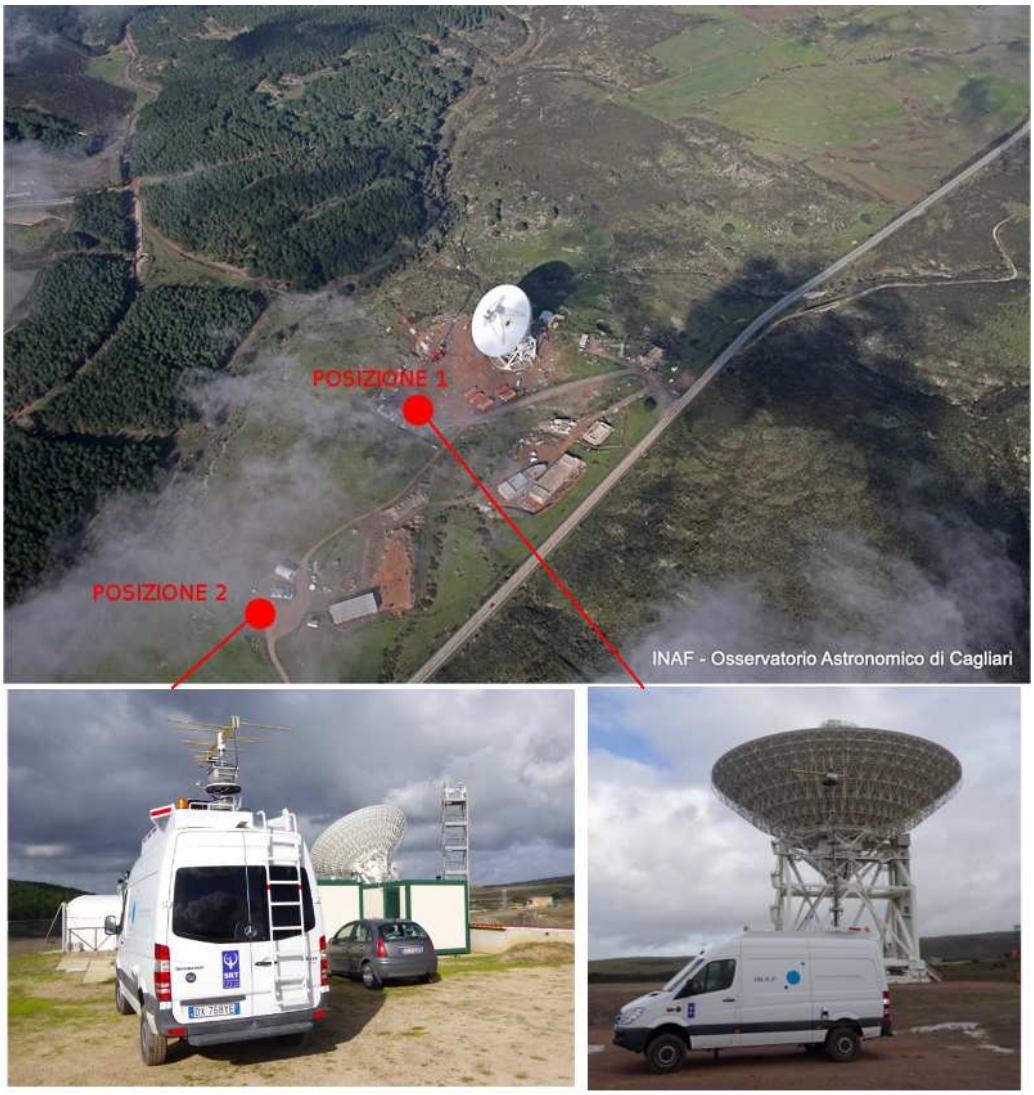

Figure 3: The two locations considered in this investigation: “posizione 1” (close to the SRT) and “posizione 2” (close to the apparati box).

signals characterized by different amplitudes. In general, the Horizontal polarization seems to be slightly worse than the Vertical polarization.

With the pre-amplifier OFF, the spectral region in between 275 - 425 MHz appear to be relatively free of RFI, at least at the sensitivity threshold of the noise floor (see Figure 4 top-panels).
By switching the pre-amplifier ON, the noise floor is lowered and more low-level RFI signals become visible. Still the spectral regions in between 300 - 325 MHz and in between 375 - 400 MHz are by far the less contaminated.

In Figure 5 we report the results of the RFI monitoring at the location 2 (near site entrance), with the pre-amplifier ON and the antenna at a height of 8 meters. As expected, a stronger RFI contamination is generally present all over the frequency band at this location due to the proximity to the radiometer installed on top the apparati box.

5 Comparison between the SRT site and the Medicina station

The low-frequency RFI investigation at the SRT site was motivated by a comparison with a similar study conducted at the Medicina station, with the aim to possibly evaluate if one of the two could offer better conditions over the other for broad-band low-frequency observations. The low-frequency RFI investigation at the Medicina station was performed by C. Bortolotti and M. Roma at the Medicina station on December 7, 2011 (Perini et al 2012).

To compare the two data sets we have taken into account the different antenna gains and the different losses of the coaxial cables. In particular, in correcting the SRT measurements we subtracted from the spectral data a total of 5 dB

(7 dB corresponding to the antenna gain and -2 dB for the estimated coaxial cable losses assumed to be constant over the frequency range). For the correction of the Medicina measurements, we considered 11 dB for the antenna gain while the coaxial cable attenuation has been estimated to vary in the range from -0.5 dB at 50 MHz and -2 dB at 500 MHz (intermediate values have been linearly interpolated). Thus, an average of $\simeq$ 9.75 dB has been subtracted from the spectral data.

Figure 6 shows the RFI spectra on the frequency band 50 - 500 MHz collected at the Medicina station (magenta lines) and at the SRT site (green lines) with the pre-amplifier ON (top-panels) and OFF (bottom-panels). The SRT measurements all correspond to the data taken with the log periodic antenna at a height of 4.7 m since this set-up is more similar to that adopted in Medicina where the measures have been taken at about 1 meter above the ground.

By comparing the spectra taken at the two observatories we can draw the following considerations:

For what concerns the strongly contaminated spectral regions around 100 MHz (FM radio broadcast) and in between 450 - 500 MHz the RFI situation at the SRT site is quite similar to that measured at the Medicina station. Nevertheless, it is worth mention that in general the intensity of the RFI at the SRT site is sensibly lower than that at the Medicina station, mainly in the FM frequency range.

In between 50 - 80 MHz the RFI level seems to be slightly higher at the SRT site. The Medicina spectra shows higher RFI around 125 MHz, 240 MHz, 330 MHz, and in between 400 - 450 MHz. Finally, at the SRT site we observe a few strong narrow band RFI above 425 MHz for the vertical polarization.

6 Concluding remarks

A dependence of the RFI intensity as a function of the height above the ground could be expected. The RFI measurements at Medicina station have been taken at height of about 1 meter above the ground and thus they could be considered appropriate to characterize the situation for the antennas of the aperture array (e.g. the Vivaldi prototypes). At the SRT site we do not had the possibility to sample RFI at the ground level, however we tried to compensate for this by lowering the height above the ground of the log periodic antenna. Effectively we noted a hint that the lower the height the lower the RFI intensity: generally the FM signals decreases of about 5 dB by lowering the height of the log periodic antenna from 8 to 4.7 meters.

Therefore, the RFI measurements at the SRT site taken at a height of 4.7 meters could be safely considered as a *pessimistic* estimate of the true situation at the ground level. Future measurements with the Vivaldi antenna at the SRT site will be used for a more precise characterization of the RFI at the ground level.

7 References

P. Bolli, F. Gaudiomonte, R. Ambrosini, C. Bortolotti, & M. Roma, 2012, “The receiving system of the mobile laboratory for RFI measurements”, OAC Internal report n.20

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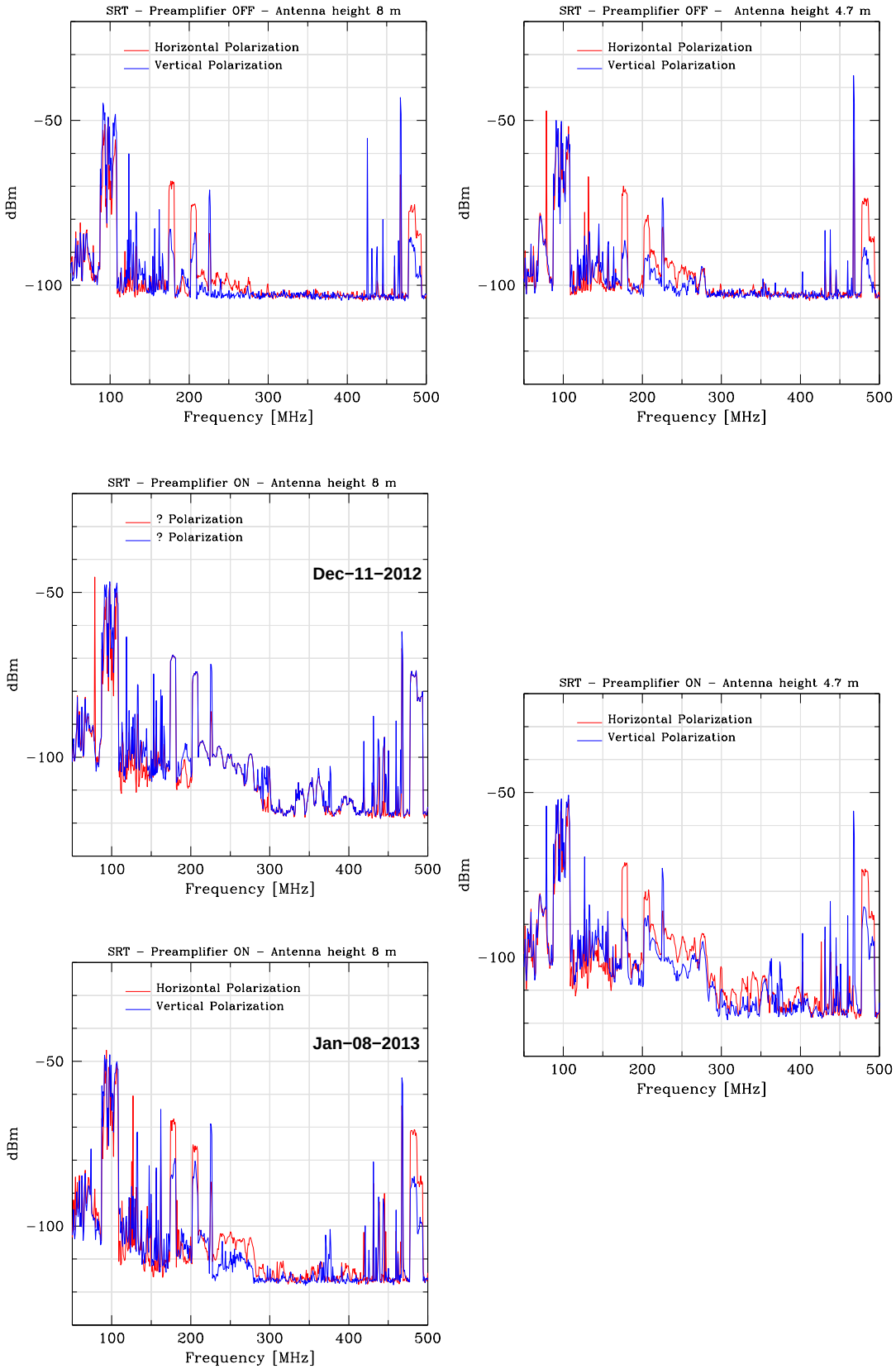

Figure 4: Results of the RFI measurements in the location 1. The spectra shown in top-panels correspond to the measures with the pre-amplifier OFF, while the remaining spectra correspond to the pre-amplifier ON. On the-left panels we present the horizontal (red) and the vertical (blue) polarizations with the antenna at a height of 8 meters. On the right panels we present the spectra obtained with the antenna at a height of 4.7 meters. Note that the spectra at 8 meters height with the pre-amplifier ON collected on Dec-11-2012 have been erroneously recorded at the same (unknown) polarization. Indeed, the measure was repeated on Jan-8-2013 (bottom-left panel).

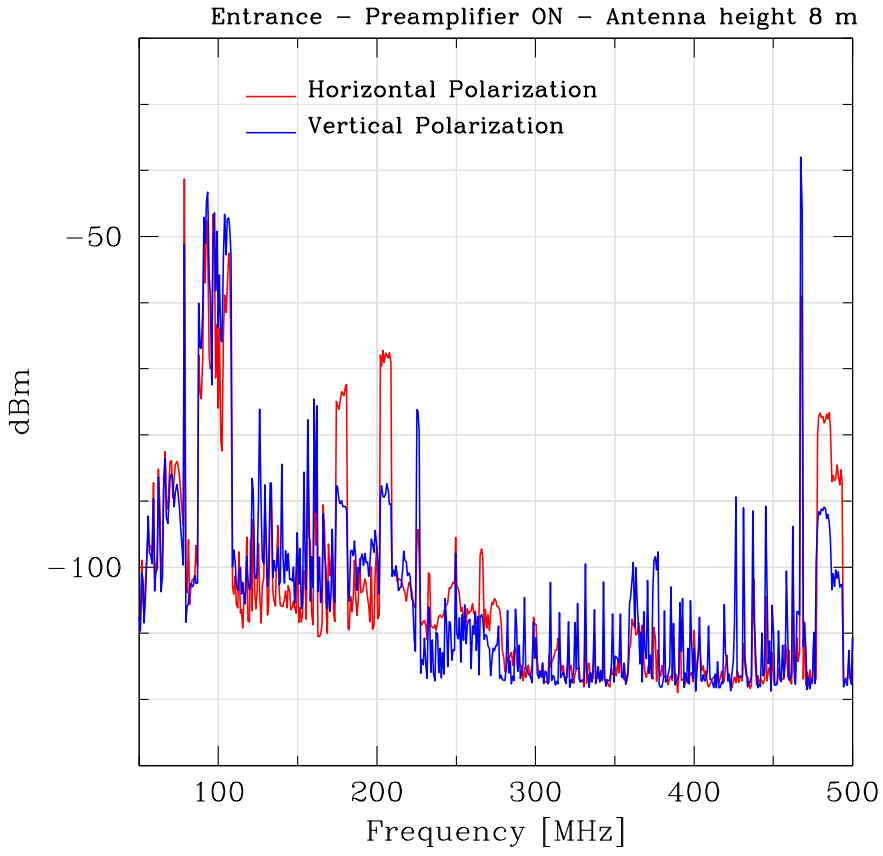

Figure 5: Results of the RFI measurements in the location 2. Horizontal (red) and the vertical (blue) polarization obtained with the pre-amplifier ON and the antenna at a height of 8 meters. A strong RFI contamination is generally present all over the frequency band at this location due to the proximity to the radiometer installed on top the apparati box.

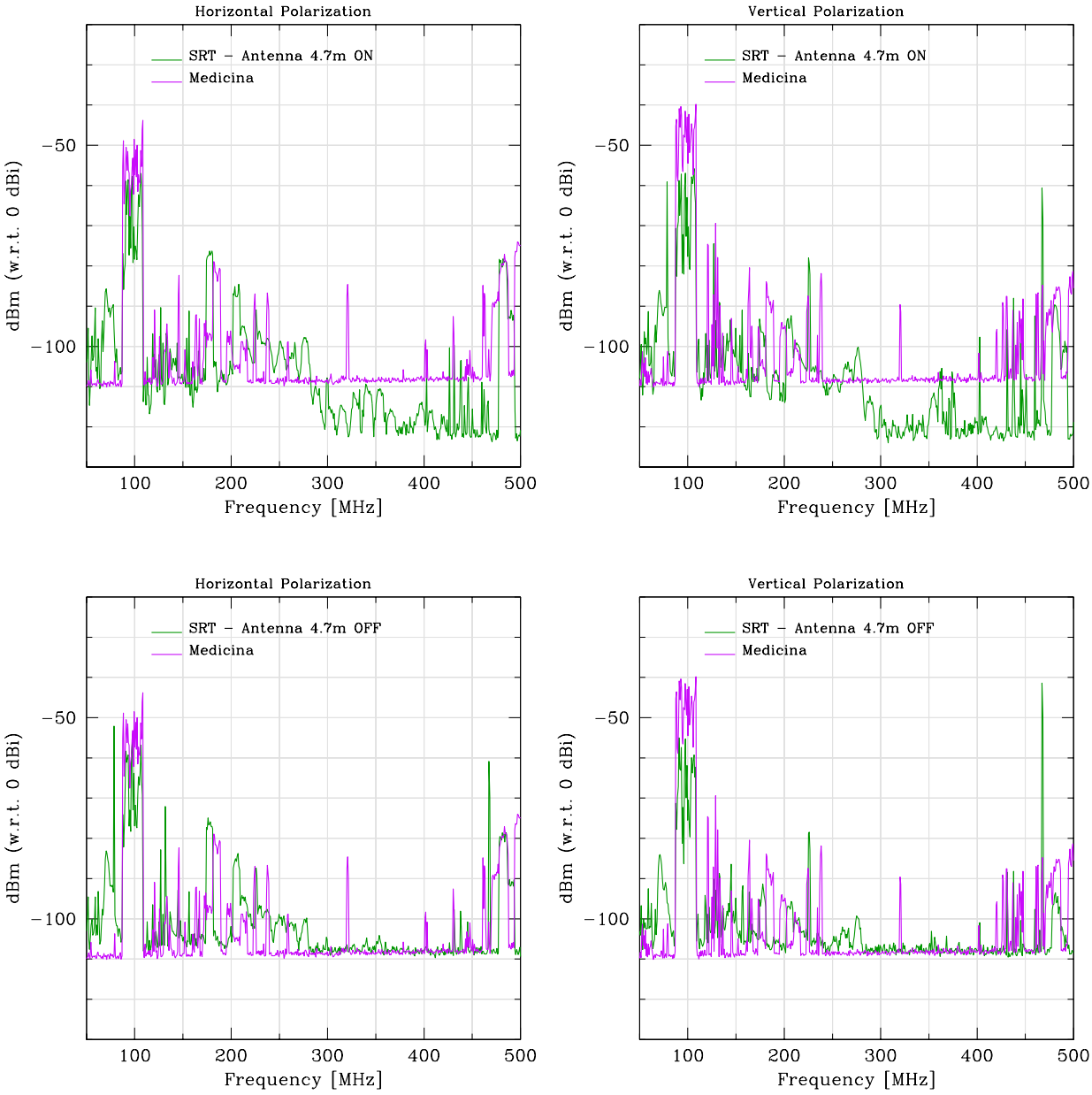

Figure 6: RFI spectra on the frequency band 50 - 500 MHz collected at the Medicina station (magenta lines) and at the SRT site (green lines). Note that, for a proper comparison, both measurements sets have been rescaled to take into account of the different gains/losses of the two receiving chains (see text). The SRT measurements all correspond to the data taken with the log periodic antenna at a height of 4.7m with the pre-amplifier ON (top-panels) and OFF (bottom-panels).