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) on 19th of April 2013 by using a prototype Vivaldi antenna developed by INAF in the framework of the exploration of new technologies for the next generation of aperture arrays. A similar study was conducted by Govoni et al. (2013; hereafter IR24) on the same site on December 2012 and January 2013 with the instrumentation on board the INAF mobile laboratory for RFI searches, but the results presented here should be more representative of the RFI environment at the ground level where these array of low-frequency antennas are designed to operate.

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 (hereafter Sardinia Array Demonstrator; SAD). The array will be constituted by prototypical low-frequency antennas designed to operate at frequencies below 500MHz. The power pattern of the single antenna element is maximum at the zenith but the beam is extremely wide. Furthermore, even if the antennas will be grouped in stations forming an antenna array, the side-lobes level of the station beam will be high. Indeed, the knowledge of the strong man-made signals in the surrounding electromagnetic environment it is important in the receivers design. In particular, we are interested in (i) the spectral occupancy (id est the frequency portions of the spectrum occupied by artificial signals) and (ii) in 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. For this purpose, we performed RFI measurements in the frequency band 50 to 500 MHz at the

[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 annualità 2012; CRP-60151, PI M.Murgia.

SRT site with the prototype Vivaldi v2.0 antenna developed by INAF - Istituto di Radioastronomia in the framework of the Aperture Array Design Consortium & Construction in the pathway to the Square Kilometer Array. A similar low-frequency RFI investigation (IR24) was performed four months earlier using a Log periodic antenna and the equipment on board the INAF mobile laboratory for RFI searches[2] on service at the SRT site. However, the data presented here should be more representative of the RFI environment as it will be seen by SAD since the data have been collected at the ground level with the Vivaldi v2.0 prototype, which is one of the possible antenna element we are considering for the array. Note that in the previous RFI investigation presented in IR24 only narrow-band measurements were collected while here we acquired also broad band resolution data.

Figure 1: The cross marks the location of the measurements.

3 Data

The measurements were taken on the morning of 19th of April 2013 at the position shown in Fig. 1. This is the approximated point proposed for the center of the core of SAD (Lat: 39º29′28″ N, Lon: 9º14′41″ E). The Vivaldi antenna was deployed on the ground and aligned to the vertical axis. The wings of the Vivaldi were oriented toward North-South and

[2]See Bolli et al. (2012) for a detailed description of this facility.

Figure 2: The Vivaldi antenna with SRT in background.

Table 1: Data sets and measurement set-up.

Configuration	Frequency range (MHz)	Polarization	Resolution bandwidth (MHz)	Video bandwidth (MHz)
BROAD	50 - 500	NS, EW, BOTH	3	1
NARROW	50 - 500	NS, EW, BOTH	0.01	0.01
NARROW (Sub-Band)	250 - 450	NS, EW	0.01	0.01

East-West directions (see Fig. 2).

We made use of the following equipment:

- *Antenna*: Vivaldi 2.0, gain -3 dB at El=90^o (horizon), beam FWHM $\sim$ 70^o at 300 MHz;
- *Coaxial Cable*: HUBER+SUHNER MULTIFLEX_141, length$\simeq$2m, total attenuation factor varies from 0.2 to 0.5 dB for frequencies between 50 and 500 MHz;
- *Coaxial Power Combiner*: MINI CIRCUITS ZAPD-30+, total loss (insertion Loss + 3dB splitter loss) $\simeq$ 4.1 dB in the frequency range 50$-$500 MHz;
- *Spectrum Analyzer*: SPECTRUM MASTER MS2724B ANRITSU.

The Vivaldi antenna was connected by the coaxial cable to the power combiner attached to the spectrum analyzer.

We acquired measurements in broad band configuration (resolution bandwidth RBW=3MHz and video bandwidth VBW=1MHz) and narrow band configuration (with both RBW and VBW set to 10 kHz). We collected data in the spectral window 50 - 500 MHz and in the sub band 250 - 450 MHz.

Data have been acquired for about 1.5 minutes and then the max hold spectra were saved into a file with 550 points per spectrum. The attenuation factor was set to 5 dB, and finally the sweep times were about 0.092 and 13.4 seconds for the broad and narrow band configurations, respectively. Data were collected for each of the two antenna polarizations separately and in this case the unused port of the power combiner was connected to a 50 Ωhm matched load. In addition,

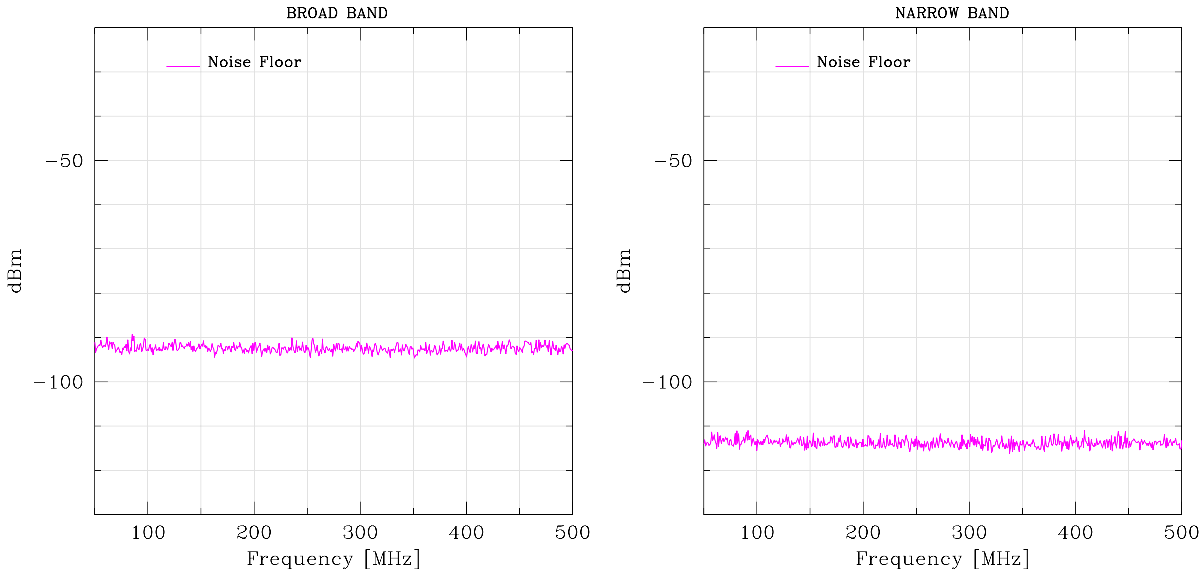

Figure 3: Spectrum analyzer noise floor levels. The spectrum analyzer pre-amplifier was ON and the attenuator factor was set to 5 dB. For the wide band configuration (left) the video and resolution bandwidth were set to RBW=3 and VBW=1MHz, respectively. For the narrow band configuration (right) both RBW and VBW were set to 10 kHz.

for the frequency range 50 - 500MHz, we repeated the measures adding the signals from the two polarizations all together with the power combiner. A summary of the data set is presented in Table 1. During all measurements the pre-amplifier of the spectrum analyzer was ON while the Vivaldi antenna was passive. The sensitivity threshold of the noise floors are shown in Fig. 3 for the broad and narrow band configurations [3].

4 Results

Fig. 4 shows the RFI spectra in the frequency band 50 - 500 MHz collected at the SRT site with the Vivaldi v2.0 antenna in broad band configuration (top-panels) and narrow band configuration (bottom-panels). The overall picture emerging from the new measurement confirms what observed in IR24 using the Log periodic antenna: the strongest RFI signals are around 100 MHz (FM radio broadcast) and between 450 - 500 MHz (a strong narrow band signal is seen at 470 MHz), while, in terms of spectral occupancy, the less contaminated spectral region is found in between 250 to 450 MHz.

The comparison between the Log Periodic and Vivaldi data is shown in Fig. 5. There is a hint that the Vivaldi spectra appear to be slightly better in terms of RFI contamination (see e.g. amplitude of RFI between 50 - 100 MHz and between 150 - 250 MHz). This is mainly due to two factors: i) the smaller gain of the Vivaldi antenna towards the horizon (i.e. the presumed incoming direction of most RFI) and ii) the fact that Vivaldi sits on the ground where the RFI terrain shielding is stronger.

Since in this investigation we are primarily interested in the RFI power level as detected by the Vivaldi antenna, the data in Fig. 5 have not been compensated for the different antenna gains and attenuation factors of the two receiving chains.

We do not show any plot for the corrected data. However, we have taken into account of the different antenna gains and the different losses of the coaxial cables and we compared the RFI power level referred to 0 dBi. In particular, in correcting the Log Periodic 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 Vivaldi data, we considered -3 dB for the antenna gain at El=90^{o} (horizon) while the coaxial cable plus the power combiner attenuation losses have been estimated -4.4 dB in total. Thus, a -7.4 dB has been subtracted from the Vivaldi data. We then checked that the corrected RFI power level in Vivaldi data resulted in line with the previous measurements performed with the Log periodic antenna.

Broad band spectra are most indicated to detect very short impulsive signals (like those associated to electric sparks or radar emissions). Along the last years, the RFI monitoring group has verified that this phenomenon is often present at

[3] Note that the narrow band noise floor is 5 dB worse than that presented in Fig. 2 of IR24 (pre-amplifier ON) due to the different attenuation factors used.

the site especially in the low-frequency bands of SRT (specifically in P-band, see Ambrosini et al. 2013). However, from the broad band here plotted, we can state that during the measurements these signals were not present.

Looking carefully at narrow band spectra, where a better sensitivity is reached, we have an idea of the spectral occupancy and the power level of the RFI received by the Vivaldi antenna. In Fig. 6 we present the measurement set in narrow band configuration for the frequency window 250 - 450 MHz. Our data confirm that, at least at the sensitivity level of these measurements, this frequency range appears to be relatively free from RFI and thus it results the most promising one for scientific observations with SAD.

5 Conclusions

Measurements with the Vivaldi v2.0 prototype antenna at the SRT site have been used for a more precise characterization of the RFI at the ground level. Spectra in the frequency window 50 to 500 MHz have been acquired for both antenna polarizations. Our results confirm that in terms of spectral occupancy, the less contaminated spectral region is found in between 250 to 450 MHz. There is a hint that Vivaldi spectra appear to be slightly better in terms of RFI contamination with respect to those acquired with the Log periodic antenna in IR24. This is expected since the Vivaldi antenna operates on the ground and it is less sensitive toward the horizon, however further repeated measurements with enhanced sensitivity and are needed to confirm this finding.

6 Acknowledgments

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7 References

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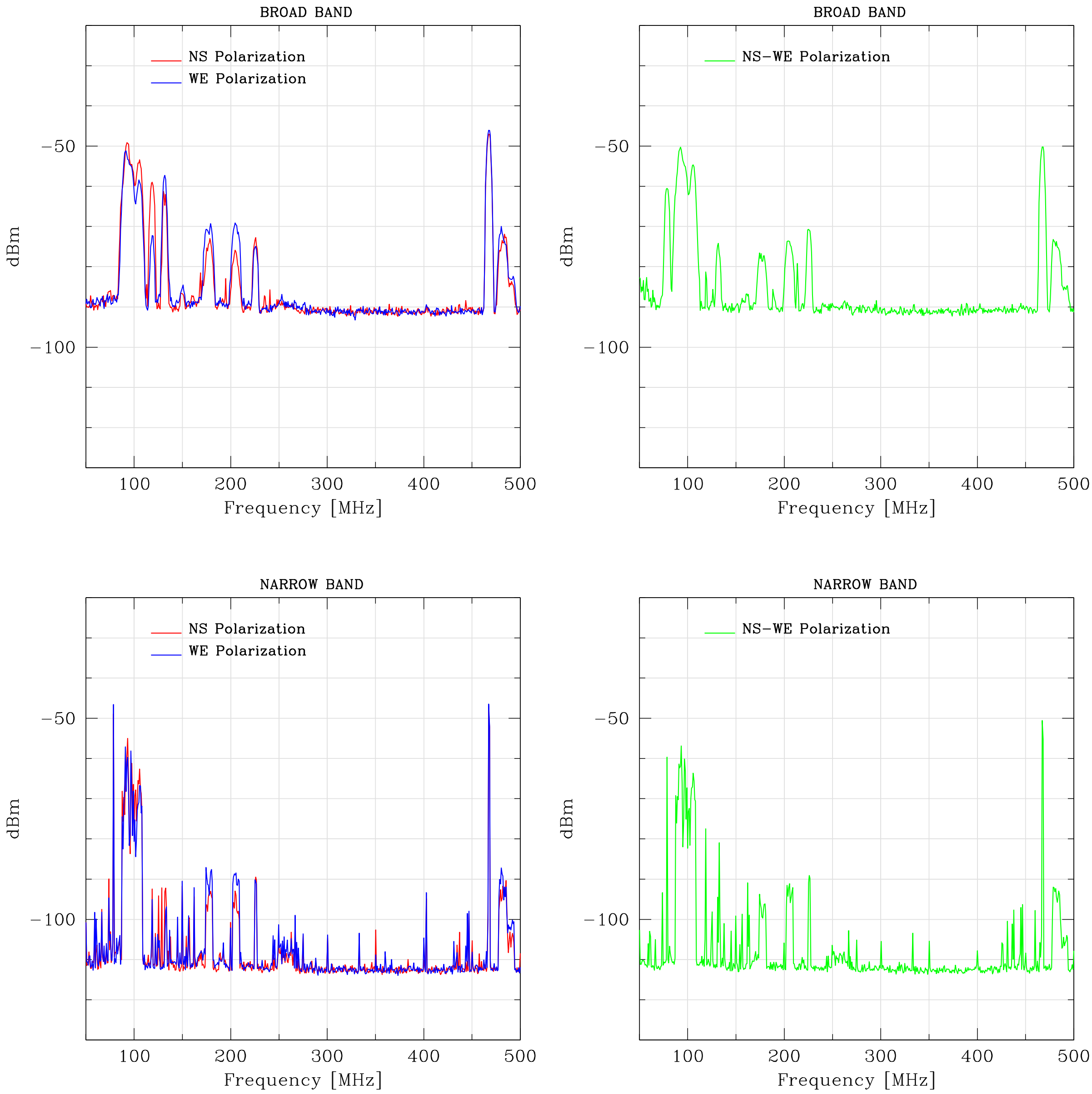

Figure 4: Measurements set acquired in the frequency band 50 - 500 MHz in broad (top) and narrow (bottom) configurations. In the left we show spectra collected separately for the two antenna polarizations. Plots on the right refer to data acquired simultaneously for the two polarizations.

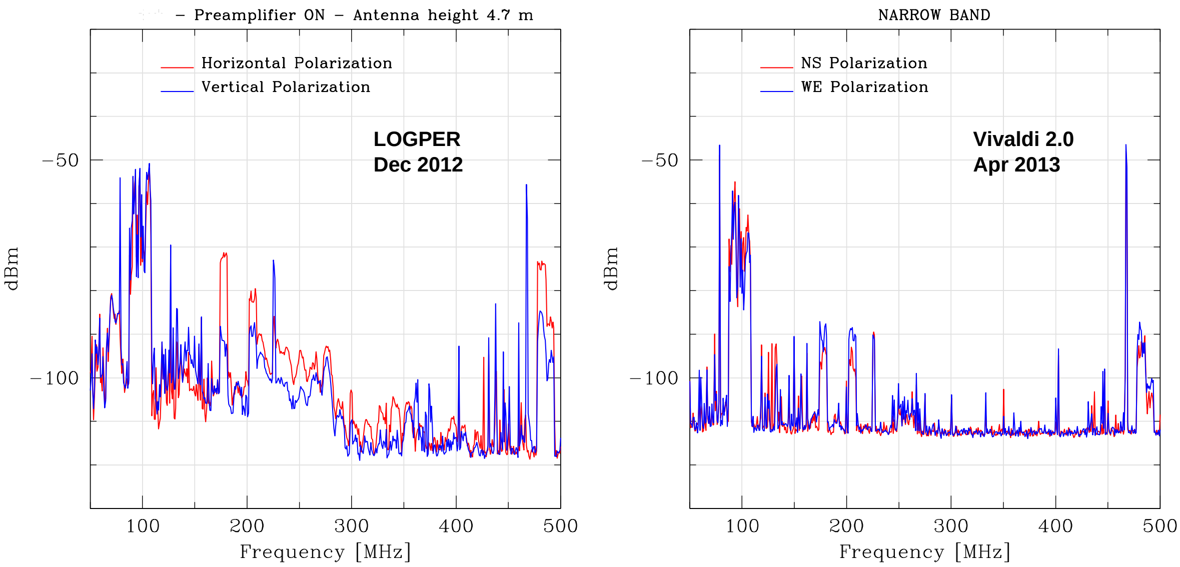

Figure 5: Comparison between Log periodic (IR24; left panel) and Vivaldi data (this work; right panel), see text.

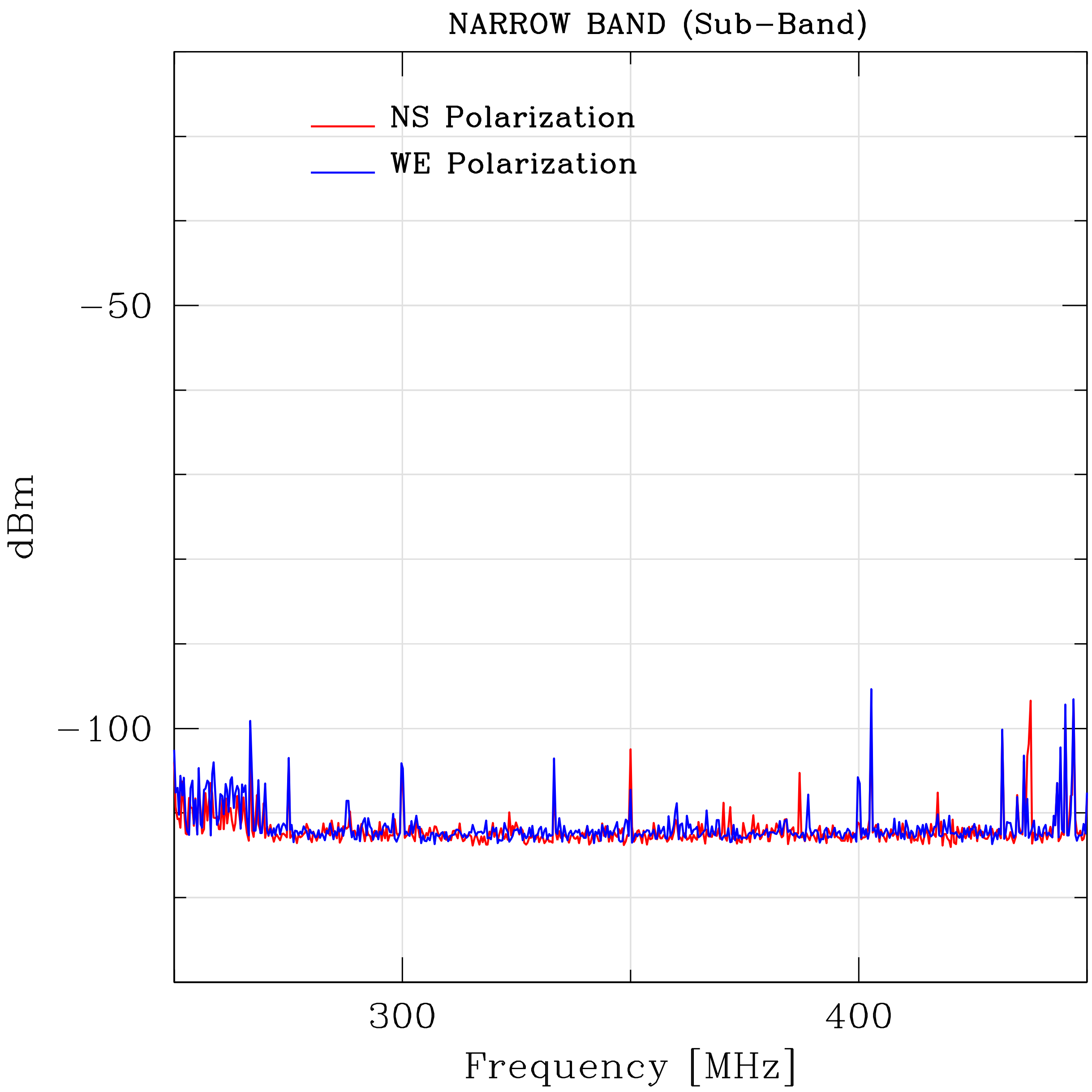

Figure 6: Measurements set for the spectral window from 250 to 450 MHz acquired in narrow band configuration.