THE ELECTROMAGNETIC ENVIRONMENT SURVEY AT THE BRAZILIAN SOUTHERN SPACE OBSERVATORY FOR THE INSTALLATION OF LOFAR STATIONS

ROSA, G. S. [1]; SCHUCH. N. J. [1]; GOMES, N. R. [1]; ECHER, E. [2]; JASKULSKI, T. [1]; FAGUNDES, I. F. [1]; STEKEL, T. R. C. [1]; ANTUNES, C. E. [1].

[1] Southern Regional Space Research Center - CRS/INPE - MCT, in collaboration with the Santa Maria Space Science Laboratory - LACESM/CT- UFSM, Santa Maria, RS, Brazil.
[2] National Institute for Space Research - DGE/CEA/INPE - MCT, São José dos Campos, SP, Brazil.

This paper was prepared for presentation during the 11th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, August 24-28, 2009.

Abstract

The radio interference survey at the Site of the Southern Space Observatory - SSO/CRS/INPE-MCT, (29.4°S, 53.8°W, 480 m a.s.l.), São Martinho da Serra, Rio Grande do Sul (RS), in South of Brazil, aims to gather spectral data to qualify the Observatory's Site as a radio quite site for installation of sensitive radio astronomy instrumentation, as a radio noise free site. The determination of the radio interference level is being conducted by using a spectrum analyzer and Omni directional antennas remotely controlled through a GPIB interface, via IEEE 488.2 bus. Some programs and routines were developed to control equipments, allowing the scanning of the Electromagnetic Spectrum power over the examined frequency range from 10 to 240 MHz. The adopted methodology starts by amplifying the radio signal from the antenna. Subsequently, the received signals are evaluated by a spectrum analyzer. A dedicated PC computer is used for the control and data acquisition. The data are stored in digital format and remotely transferred via TCP/IP (Internet) by VNC software from the SSO Site to the Radio Frequency and Telecommunication Laboratory at the Southern Regional Space Research Center - CRS/INPE - MCT, in Santa Maria, RS, for analysis and storage on the long period radio interference data base. It is compared the Electromagnetic Spectrum data for the SSO obtained at the beginning of the 1990's, before the Site constructions, with the new information obtained during the years: 2003, 2006 and 2009. From the observations of the radio interference systematic monitoring at SSO one may say that in South of Brazil there is a good radio-quite site, which is potential for installation of sophisticated and sensible data acquisition passive radio instrumentation for radio astronomy and space science research, similar to the European LOFAR stations, that is, at the INPE's Southern Space Observatory, in São Martinho da Serra, RS, Brazil.

Introduction

The Southern Regional Space Research Center - CRS/INPE-MCT in collaboration with the Santa Maria Space Science Laboratory - LACESM/CT-UFSM, in Santa Maria, RS, South of Brazil, are interested in developing low frequencies radio telescopes and radio interferometers systems based on the concept of phased array interferometric stations.

Some studies have been performed to analyze the real possibility to install Low Frequency Array (LOFAR) stations at the site of the SSO, in São Martinho da Serra, RS, Brazil, which is approximately 54 Km distant far from the city of Santa Maria, in Rio Grande do Sul state.

The motivation for the monitoring of the Electromagnetic Spectrum at the site of SSO, in the low frequencies ranges, initially aimed to demonstrate which frequency spectral bands were free of artificial radio noise interference, and to verify the potential existence of nature radio interference in the site. Currently, this motivation added on it the possibility to install at the SSO modern LOFAR stations.

This monitoring has been conducted periodically since 1992, before the construction of the SSO. The spectrum monitoring results for 1992 showed that the SSO site area was free from artificial and natural radio interference, which was important for choosing the Observatory location and for its construction, since the SSO principal project was to implement on it the installation of a interferometric phased array, a radio telescope, similar to the Cambridge 150 MHz Radio Interferometer Telescope, which was named The Brazilian Synthesis Telescope – TSB, from the Radio Astronomy Project. However, because of several problems such as: political, the very difficult Brazilian financial instability during the 1980's - 1990's and heavy bureaucracy, the TSB radio interferometer was not yet constructed. But, the site is good for implementation of a modern version of a radio interferometric phased array such as employed in the construction of the Low Frequency Array (LOFAR), following the European way of implementation.

The Low Frequency Array (LOFAR) is a next generation digital aperture synthesis radio interferometer based on the concept of phased array interferometric stations, operating between 10 and 240 MHz.

The LOFAR network is under construction by ASTRON - Institute of the Netherlands Organization for Scientific Research – in the Netherlands, operating between 10 and 240 MHz. As a predecessor to the Square Kilometer Array (SKA) planned to be constructed after 2015, it has a broad impact on the future of Radio Astronomy and Astrophysics, which goes well beyond the current project (Bregman, 2000).

LOFAR is an emerging European sensor network of continental dimensions for space and earth observations. There are currently discussions with research institutions from Germany, UK, Italy, France, Poland and Sweden, aiming the installation of some LOFAR stations in these countries. These partnerships will extend the “Wide Area Sensor Network” and the resolution and sensitivity of the LOFAR system in Europe.

According to Brüggen et al. (2005) LOFAR will be the dominant telescope over the next decade in this largely unexplored frequency range. LOFAR is the first telescope of this new sort, using an array of simple omni-directional antennas instead of mechanical signal processing with a dish antenna, since half the cost of these telescopes lies in the steel and moving structure.

At the low frequencies range, between 20 MHz and 80 MHz, on which LOFAR works, each LOFAR antenna observes cosmic radio waves from the full sky, as mentioned in the Official Site of the LOFAR Project (2009). The viewing direction and field of view of a LOFAR station are electronically steered when combining signals from the 96 single antennas of a station and from the different stations. LOFAR will also have antennas operating at radio frequencies between 120 MHz and 240 MHz. A central supercomputer receives and correlates all digital signals together. The first LOFAR station is CS1 which is in operation at Exloo (NL), since 2006.

LOFAR's science objectives include:

(1) Study of planetary and solar radio emission processes;

(2) Constraining the three-dimensional distribution of the Galactic cosmic ray gas and studying Galactic supernova remnants and pulsars; and

(3) Imaging the high-redshift Universe, including high-redshift radio galaxies and galaxy clusters and possibly the first structures formed near the epoch of reionization. LOFAR may also serve as the receiving instrument for imaging bi-static solar radar experiments (Lazio et al., 1999).

According to Lazio et al. (1999), LOFAR will open a new window on the spectrum, allowing the possibility of discovering new classes of sources or physical phenomena is also likely.

Method

The methodology of data acquisition for power levels of the Electromagnetic Spectrum used in the SSO has received upgrades over the long period of monitoring. Basically, since the first monitoring, it has been used a monopole antenna optimized for the range of frequencies from 25 to 1300 MHz. The antenna signals are sent to a spectrum analyzer, after passing through a block amplifier. The spectrum analyzer, in turn, analyzes the radio signals, and the results are printed or transmitted and stored in a computer.

For the spectral data acquisition the spectrum analyzer employs a data acquisition card, which makes the link between a computer and the spectrum analyzer.

The spectrum analyzer used for monitoring the radio interference level is a Tektronix model 2754P, where one can define a frequency range of observation and power. The equipment is controlled by a computer through a GPIB bus. The receiver antenna is a monopole, optimezed for omnidirectional radiation, model D130 Super Discone Antenna. Some amplifiers were developed specifically for this monitoring in SSO.

Some softwares were developed for acquisition, communication and processing of data from the spectrum analyzer. The controlling of the software was developed in structured C programming language, which communicates the hardware with the equipment used. The software part dedicated to analysis was developed in high-level programming languages, using GUI (Graphical User Interface). It is also used the remote access via the VNC protocol for communication, which allows the communication of equipment located at SSO to be controlled from the Radio Frequency and Telecommunication Laboratory at the Southern Regional Space Research Center - CRS/INPE - MCT, Santa Maria, RS.

The software makes possible to compare the Electromagnetic Spectra at SSO obtained in the early 1990's, before the construction of its current "site" with information from recent surveying observations. In addition, you can perform a check of the frequency bands regulated in Brazil by ANATEL (the Brazilian National Telecommunications Agency) to detect abnormalities, such as, possible noise in the frequency bands not regulated in the instant of the data acquisition.

Results

The oldest Electromagnetic Spectrum characterization record of SSO was obtained in 1992, illustrated in Figure 1. It is remarkable the presence of radio interference intense levels of radio interference in the frequency range 90 to 110 MHz and the presence of noise in AM radio broadcasting at the beginning of the spectrum, around 20 to 30 MHz. Channels are also found in radio broadcasting of sound and images in the range of 54 to 72 MHz and 174 to 200 MHz.

The monitoring conducted in the SSO during 2003 characterizes the spectral graph on Figure 2. Again it is evident the presence of radio signals on the same frequency ranges of events observed in 1992, without major changes. The power levels in Figure 2 are not absolute values, serving only to highlight the presence of radio signals in the Electromagnetic Spectrum over the frequency. The magnitude of the power is for comparative purposes only.

The Electromagnetic Spectrum obtained in the SSO in 2006 is shown in Figure 3. Data were monitored with more accuracy, using a horizontal resolution about 21 times larger than used in previous monitoring. Figure 3 is in a relative scale of intensity values of power, but even so, it is quite clear an increase in power levels around 42 MHz. This modification found around 42 MHz is due to the increasing of radio transmitter power that uses the frequency band.

The Electromagnetic Spectrum obtained in the SSO in March, 2009, is shown in Figure 4. Just as the 2006 surveying, the data were monitored using more accurate techniques. Again, the Electromagnetic Spectrum characterizations do not diverge from those observed during the previous years of surveying. However, the presence of the power levels at 157.8 MHz and around 173 MHZ were detected in 2009. Such as Figure 3, the Figure 4 data is in a relative scale of intensity for the power values.

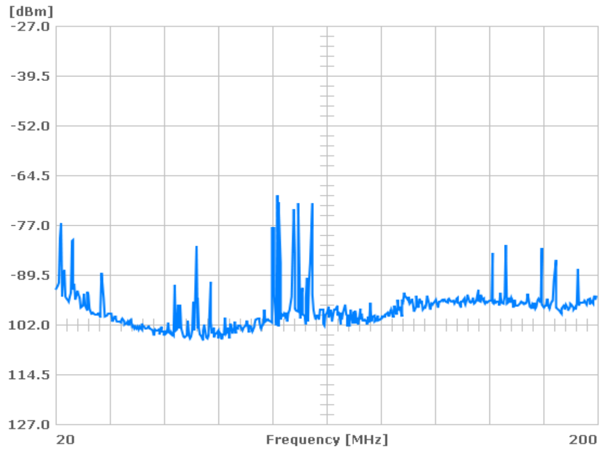

Figure 1: RF Spectrum surveying in the frequency range of 20 to 200 MHz observed at SSO/CRS/INPE-MCT, in 1992.

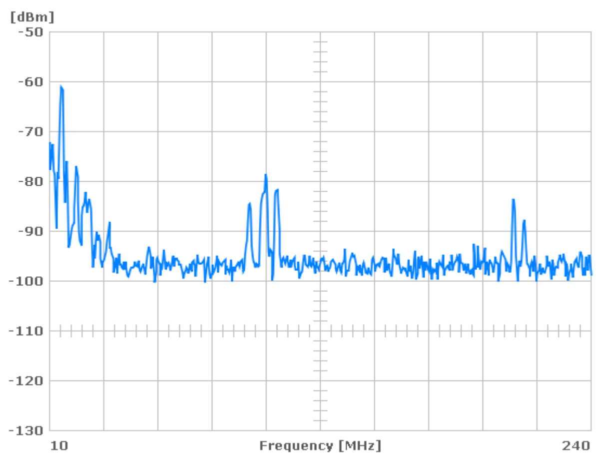

Figure 2: RF Spectrum surveying in the frequency range of 10 to 240 MHz observed at SSO/CRS/INPE-MCT, in 2003.

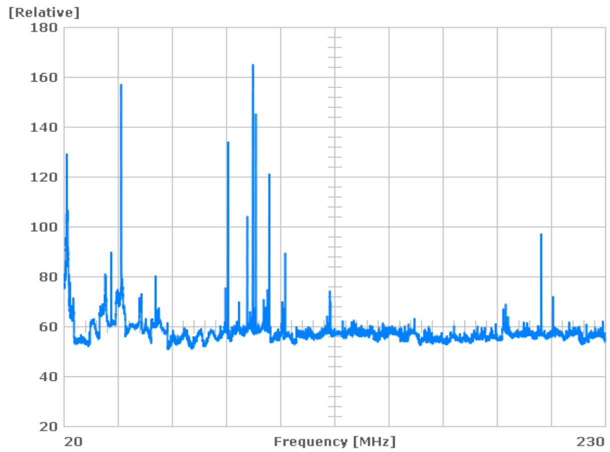

Figure 3: RF Spectrum surveying in the frequency range of 20 to 230 MHz observed at SSO/CRS/INPE-MCT, in 2006. The magnitude of the signals is not an absolute value.

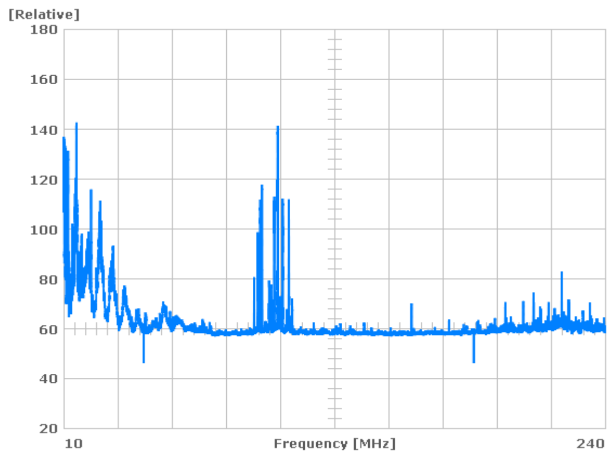

Figure 4: RF Spectrum surveying in the frequency range of 10 to 240 MHz observed at SSO/CRS/INPE-MCT, in March 2009. The magnitude of the signals is not an absolute value.

Results Analysis

The data analysis of the Electromagnetic Spectrum collected for different periods of data acquisition at the SSO site shows a feature that keeps the RFI constant.

The RF Spectrum in the frequency range of 20 to 230 MHz observed at SSO, in 2006 is presented in Figure 5, which is the composition of all the Electromagnetic Spectrum collected data for that specific day of acquisition.

Analyzing Figure 5, one can observe that the Electromagnetic Spectrum power level is dependent on frequency and time of observations. The signals occurrence is mostly continuous, without significant changes in the power levels over time. Except for the occurrence of some transmitting radio broadcast on AM, FM and VHF, it is clear that most of the Electromagnetic Spectrum at the SSO is free of intense RFI. Moreover, the radios interferences found are basically artificial signals and are recognized and regulated by Anatel, which characterizes the SSO Site as free of radio interference.

The correlation between the SSO Electromagnetic Spectrum with the data of the European LOFAR sites, obtained from Boonstra et al. (2000), shows that the Spectral characteristic and power levels found are consistent, as shown in Figure 6. The spectral feature found for the European LOFAR stations, ploted in yellow in Figure 6, is also present in the SSO/CRS/INPE-MCT.

The basic RFI site specifications for the International LOFAR stations sites requirements are attended by the surveying results made at the SSO, therefore, attending the RFI parameters for the construction on it of LOFAR stations.

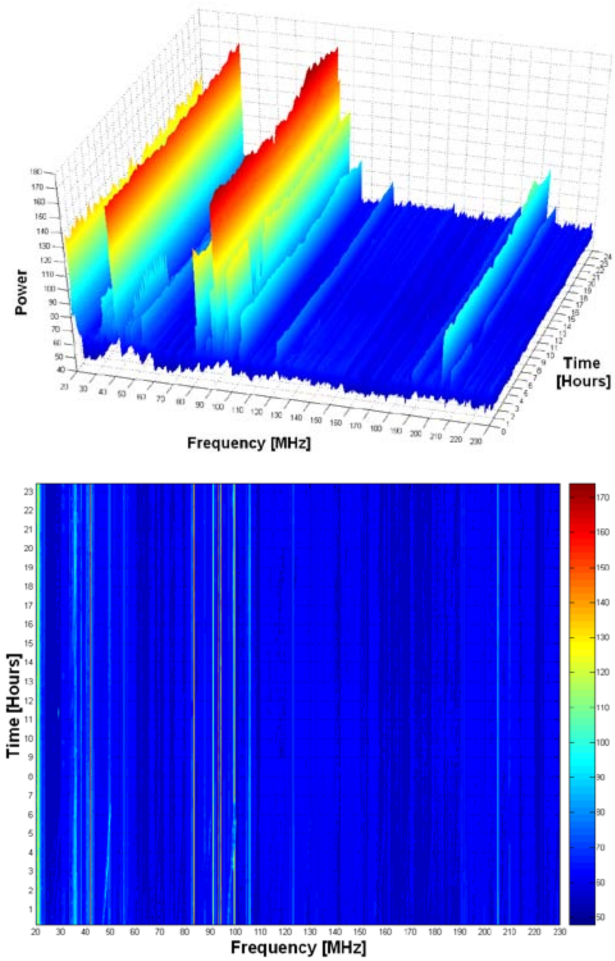

Figure 5: Top: composition between all the resulting surveying observations for one day of data acquisition, February 4-5, 2006 at SSO/CRS/INPE-MCT; Bottom: different diagram presenting the same results as presented in top. The magnitude of the signals is not in absolute values.

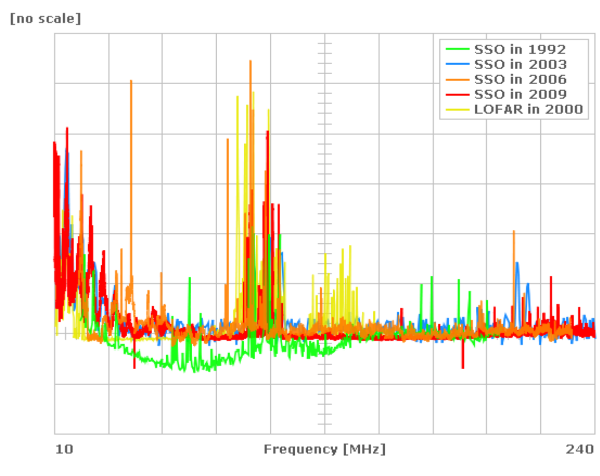

Figure 6: Composition of the characteristic of the Electromagnetic Spectrum surveying for all observations in SSO/CRS/INPE-MCT with the data Spectrum measured on a European LOFAR station proposed by Boonstra et al. (2000). This chart serves for comparison of the horizontal (frequency) of Spectrum. The magnitude of the signals is not in scale.

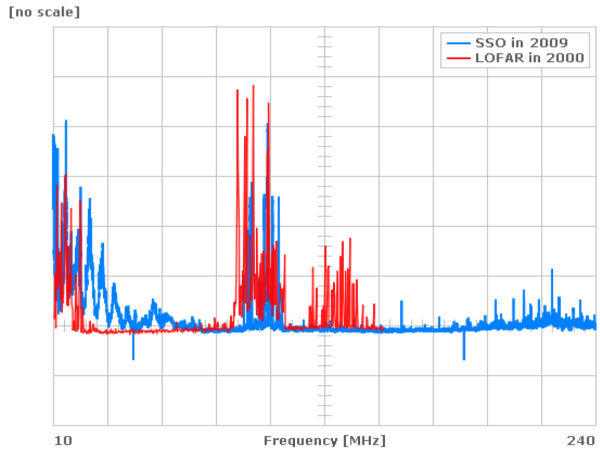

Figure 7: The characteristic of the Electromagnetic Spectrum surveying for observations at the SSO/CRS/INPE-MCT in 2009 (10 to 240 MHz), in comparison with the data Spectrum measured at a European LOFAR station, 10 to 150 MHz, published by Boonstra et al. (2000). The magnitude of the signals is not in scale. This is a simplification of Figure 6.

Conclusions

Analyzing the surveying results it is possible to conclude that the stability of the Electromagnetic Spectrum at the of the SSO/CRS/INPE-MCT, São Martinho da Serra, RS, Brazil. This is an important factor, which can be used for decision making for the possibility of installation of equipment such as LOFAR stations in the Site, since the same spectral feature is found in the SSO and in the European LOFAR stations. Through these data analysis it is evident the remarkable quality of the SSO Site to install sensitive radio interferometers based on the concept of phased array, such as LOFAR.

Acknowledgments

The authors acknowledge the Program PIBIC/INPE – CNPq/MCT for fellowship.

References

Bregman, J. D., 2000, Concept design for a low-frequency array. In: Harvey R. Butcher (Ed.), Proceedings of SPIE, vol. 4015, Radio Telescopes, pp. 19–32.

Boonstra, A. J.; Bregman, J.D.; Mohamoud, A.A., 2000, LOFAR spectrum monitoring: dynamic range and spectral occupancy issues, SKA workshop, Jodrell Bank, UK.

H. Kollen, Y.; Koopman, M.J. Bentum, A.; Huigen, P. Maat, 2008, LOFAR International Site preparation document, available electronically at *www.lofar.org*

Brüggen, M., Falcke, H., Beck, R., et al., 2005, German LOFAR white paper, available electronically at http://lofar.mpa-garching.mpg.de/glow.html

Official Site of the LOFAR Project, 2009, available electronically at http://www.lofar.org

T.J.W. Lazio, N.E. Kassim, K. Weiler and C.A. Gross, The Low Frequency Array (LOFAR). Bull, Am. Astron. Soc. 31 (1999), p. 1498.