v. 2, n. 16, 2022

Journal of
Engineering
Research

MEASUREMENTS OF NON-IONIZING ENVIRONMENTAL RADIATION FROM 1HZ TO 9400 MHZ IN SÃO JOSÉ DOS CAMPOS, SP, BRAZIL

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Abstract: The electromagnetic spectrum of environmental energy between **(1 Hz - 9,4 GHz)** was measured in the region of São José dos Campos, SP, with a sensitivity of up to **-170 dB_m** (unidade de potência) In addition to the typical environmental radiation, the main human sources polluting this environmental radiation in these places were also identified in the measurements of the electromagnetic spectra. In the range (1 Hz to 1 kHz) the average value of the electric field strength measured in this frequency range was 50 V/m, with peaks that reached up to 730 V/m at a time. Between 1 kHz to 1 MHz, the average value of the electric field of these radiations was 1 V/m, with some peaks reaching up to 12 V/m. In the frequency range (1 MHz to 9400 MHz) there are radiations with a minimum intensity of up to -90 dBm. Several peaks above this power identify the main emission sources existing in this frequency range in the region between the years 2011 to 2022. The sensors used in these measurements were the **SpectranNF e SpectranHF.**
Keywords: Environmental Electromagnetic Energy, Electric Field, Non-Ionizing Radiation, Magnetic Field, Electromagnetic Spectra, Electromagnetic Sensors.

INTRODUCTION

Environmental non-ionizing radiation from a region has its intensity measured in power (dBm, where, 0 dBm = 1 mW, regardless of which resistance is measured) and in V/m for the local electric field strength. These values always vary with frequency (Elbern, 2011). Spectrum analyzers in general can observe the radiation present in a certain frequency range, this with continuous monitoring or intervals of previously determined frequency values. In general, analyzers that cover the frequency range from 10 kHz to 26 GHz available in the international market, in addition to presenting high costs, are used for measurements in laboratories, as they are not portable, and cannot measure intensity values lower than -80 dBm. (Zell, 2011). They also need several sets of antennas to cover the entire frequency range, which makes measurements in any chosen spectral range very difficult.

Non-ionizing radiations are those that do not produce ionizations, that is, they do not have enough energy to rip electrons from atoms (~ 12 eV) from the medium through which they travel, but they have the power to dissociate molecules, that is, to break chemical bonds. Non-ionizing radiation is always around us (Gusev, 2005). Electromagnetic radiation consists of waves that propagate through space. These waves are formed by the sum of an electric field (E) and a magnetic field (B), which oscillate perpendicularly to each other in the simplest case and the direction of propagation corresponds to the energy displacement (Poynting vector). These radiations include ultraviolet (near visible), visible light, infrared, ELF (Extremely Low Frequency), LF (Low Frequency), VHF (Very High Frequency) and microwaves. For example, radio and television signals operate in radio frequency (RF) and VHF bands, which range up to 300 MHz (Megahertz). Alternating electric current also produces electromagnetic fields around conductors and various equipment, in Brazil, for example, the frequency of oscillation of alternating current is 60 Hz. The microwave band ranges from 300 MHz to 300 GHz, which is the threshold of the light spectrum; the beginning of the infrared, which later evolves into the visible and ultraviolet A spectrum (Viegas, 2006).

Since the beginning of its use, cell phones operate in the microwave band, starting at 900 MHz for analog cell phones, passing through 1800 to 1900 MHz for GSM (Groupe Special Mobile), 2450 MHz for 3G, and more. recently around 3500 MHz for Wimax (Worldwide Interoperability for Microwave Access). The

C band (6000 MHz) and KU band 14000 MHz are used in special situations such as truck tracking and satellite communications. The frequency of approximately 8000 MHz is used to transmit data from the Earth's surface to satellites (Freitas, 2006; Guimarães, 2011). Between 8000 and 12000 MHz, weather radars on board aircraft and search, rescue and location operation radars operate. Ultrasound at 20MHz is also widely used in medical laboratories and hospitals. Some industrial equipment operating at frequencies from 20 to 40 MHz are also responsible for the presence of non-ionizing radiation in the environment.

MATEIALS AND METHODS

To measure the ionizing radiation between 1 Hz to 9400 MHz, two state-of-the-art equipment acquired from the company Aaronia AG, from Germany, were used. Two Spectran NF (1 Hz to 1kHz, 1 kHz to 1 MHz) and Spectran HF (1 MHz to 9400MHz) sensors cover the frequency range described above. A compact, omnidirectional antenna is employed on both sensors. For the Spectran HF there is also a compact and a directional antenna. The sampling time in measurements can be chosen from 5 ms to 3000 ms. The resolution bandwidth (RBW) can range from 0.1 Hz to 300 MHz. The sensors are fully portable with their own batteries for 8 hours of continuous operation. Specific software writes the data to files and generates graphics on the computer screen that can be saved as images. All details of the spectrum analyzer settings and operation parameters can be consulted on the manufacturer's website: Aaronia AG (Aaronia, 2011) at http://www.spectran.com. A laptop PC (Dell Vostro i5) was used to acquire and determine the frequency spectra measured with data files. As the system is compact and portable, it is possible to carry out surveys of the non-ionizing radiation field at any remote location.

RESULT AND DISCUSSIONS

Measurements in São José dos Campos were made at points to the north, south, east and west and from the ITA (Instituto Tecnológico de Aeronáutica) campus, always at the city/field boundary. All measurements were taken on December 21, 2021. As a first result, it was found that the spectrum between 1 MHz and 9400 MHz is repetitive and constant in this region. Only in the range above 8000 MHz, intense weather radar emissions from aircraft traveling over the region were occasionally observed.

Figure 1 shows the spectrum of the electric field strength in the environment. The average value between 1 Hz to 1 kHz is 40 V/m, and they show important emission peaks corresponding mainly to high-voltage electricity transmission lines at 60 Hz with a maximum peak of 730 V/m and at 120 Hz with maximum peak of 500 V/m.

Figure 2 shows measurements performed between 1 kHz to 1 MHz, the average signal amplitude value was approximately 1 V/m, other radiation peaks whose amplitudes are between 4 mV to 12 V/m are observed. Note that this frequency range has few emission peaks. The few peaks observed are certainly caused by RF emissions in the region.

Figure 3 shows the spectrum observed as a function of frequency between 1 MHz and 9400 MHz. The minimum measured signal strength is -90 dBm with emission peaks reaching -5 dBm., corresponding to aircraft weather radar.

In Figure 3, in the frequency band from 1 MHz to 2000 MHz are the cellular and VHF emissions, and this band is quite congested with several emission peaks. Between 2000 MHz to 5000 MHz, WI-FI emissions are very evident and predominant in the city. Between

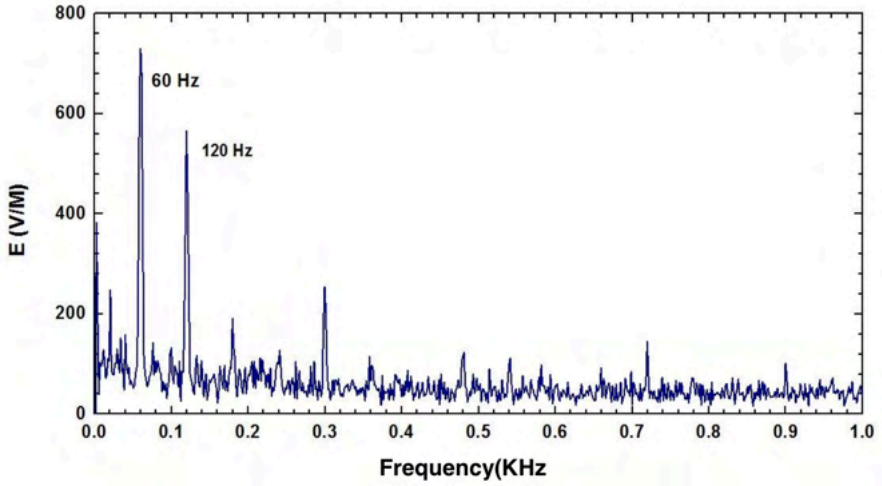

Figure 1- Energy spectrum (electric field strength versus frequency) of electromagnetic radiation in the range of 1 Hz to 1k Hz. This spectrum is representative of the city of São José dos Campos, SP, obtained on December 21, 2021, (author).

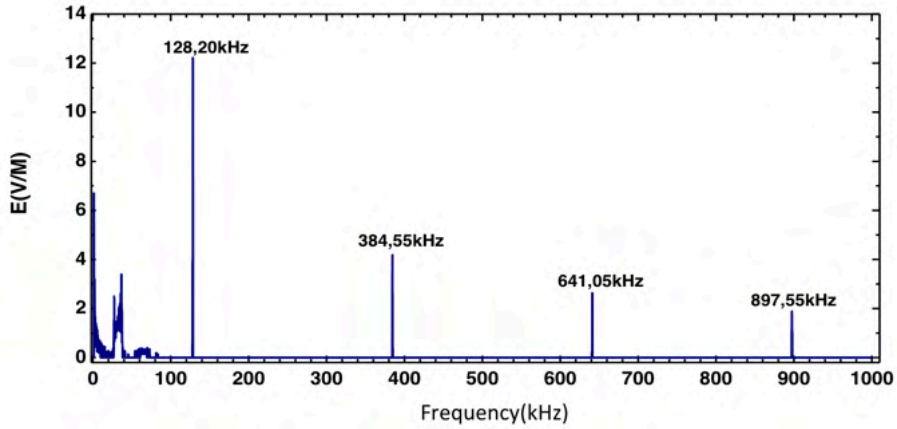

Figure 2 – Spectrum as a function of frequency in the range of 1 kHz to 1 MHz. This spectrum is representative of the city of São José dos Campos, SP, obtained on December 21, 2021, (author).

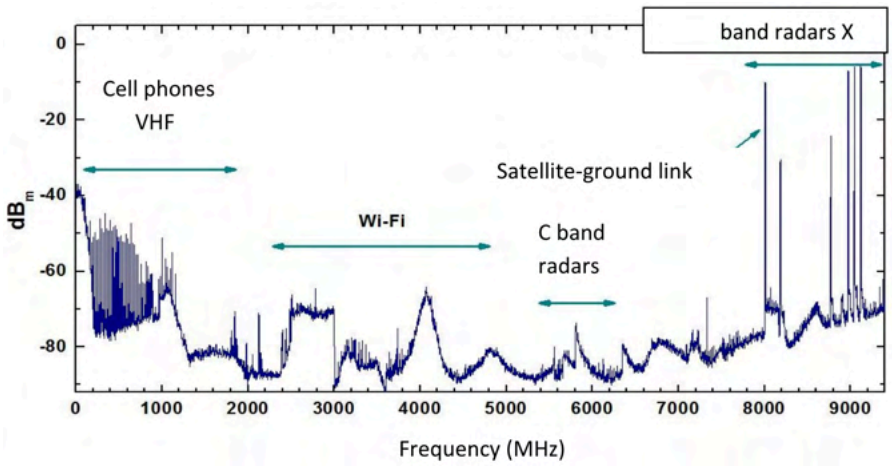

Figure 3 – Frequency spectrum of signals measured in the region of São José dos Campos SP, between 1 MHz to 9400 MHz, and with a minimum signal strength of -90 dBm obtained on December 21, 2021 (author).

5000 MHz and 8000 MHz, only the peak of ground-to-satellite data transmission at 8000 MHz is visible. On some occasions, intense signals around 6000 MHz were detected, related to C-band radar emissions at the local airport. Between 8000 MHz and 9400 MHz, emissions from aircraft on flights operating on-board weather radars (band X, 8000 MHz to 12000 MHz) are observed. These emissions are highly variable in time and signal strength. Figures 1, 2 and 3 show the observed environmental radiation signal strength as a function of a wide frequency variation (1 Hz to 9400 MHz). However, with the compact and portable measurement sensors used in this study, it is possible to easily measure in greater detail a small desired frequency range within the wide range shown in this work.

Figure 4 below was copied directly from the SpectranHF sensor graph on December 10, 2021. The peak at 5800 MHz comes from the C-band radar at São José dos Campos airport and the others correspond to the same as in Figure 3.

CONCLUSION

This work presents, for the first time, the spectrum in frequency between 1 Hz to 9400 MHz, in the region of São José dos Campos, SP. In the range from 1Hz to 1000Hz, two important peaks were detected at 60 and 120 Hz; the energy corresponding to these two frequencies constituting the biggest polluter in the band. Between (1 kHz to 1000 kHz) the peak of 12 V/m was the highest observed, probably being pollution from RF transmitters. In the range (1 MHz to 9400 MHz), several peaks of emissions from cell phones and VHF as well as (WI-FI), radars in the C and X band and ground-to-satellite data transmission were identified. Cellular and VHF emissions are the most polluting sources of this frequency band in the measurement region. A compact and fully portable system

Figure 4 - Measurement of environmental and man-made radiation in the region of São Jose dos Campos, SP on December 10, 2021, (author).

was assembled with sensors sensitive to non-ionizing radiation between (1 Hz to 9400 MHz), with different possible scan times and RBW. This system is essential for checking the electromagnetic field of a specific region or place where the power (W) or electric and/or magnetic field of the place is to be measured.

ACKNOWLEDGMENTS

To Fortunato Rezende Guimarães for funding the instruments, to CNPq projects processes 480407/2011-8 and 305145/2009-6, to INCT-FNA-ITA and ITA Department of Physics for supporting the measurement missions.

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