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RADIO DIRECTION FINDING, A NEW METHOD FOR THE INVESTIGATION OF PRESISMIC PHENOMENA. THE CASE OF JAPAN

Valentino Straser*[1], Daniele Cataldi[2] & Gabriele Cataldi[3]
*1Department of Science and Environment UPKL, Brussels, Belgium;
[2]Radio Emissions Project, Lariano, Rome, Italy;
[3]Radio Emissions Project, Albano Laziale, Rome, Italy

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ABSTRACT

This study the LTPA Emission Project Team presents a new method of detecting electromagnetic signals that is a candidate for the analysis of seismic precursors and for a crustal diagnosis in real time. Earthquakes are an expression of the Earth System and is therefore clear that the anlysis of data must be evaluated in a holistic context, supported by advanced technologies and by the constant and rapid synergy with the scientific community thanks to the web. The RDF experimentation proposed in this paper is based on some precursor candidates, such as a magnetic anomalies and particular frequency bands, activated by the minerals of the rocks under tectonic stress. The monitoring station, localted in Rome and Pisa (Italy), used two types of radio receivers to continuosly monitor the electromagnetic spectrum located between the lower limit of the SELF band (Super Extremely Low Frequency) and upper limit of the VLF band (Very Low Frequency). In this study, as a demonstrative example, the seismicity in Japan is analyzed, as detected by the Italian monitoring stations.

KEYWORDS: Keywords are your own designated keywords which can be used for easy location of the manuscript using any search engines.

1. INTRODUCTION

The data from this innovative research on Electromagnetic Seismic Precursors (ESP) provided important indications that found acceptance even within the international scientific community [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30]. A new phase of research opened in 2019: the authors began a project to monitor electromagnetic anomalies that had azimuth compatible with the seismic district of Japan: a geographical area approximately 9,800 km from the RDF station of Lariano (Rome, Italy) (**Fig. 1**).

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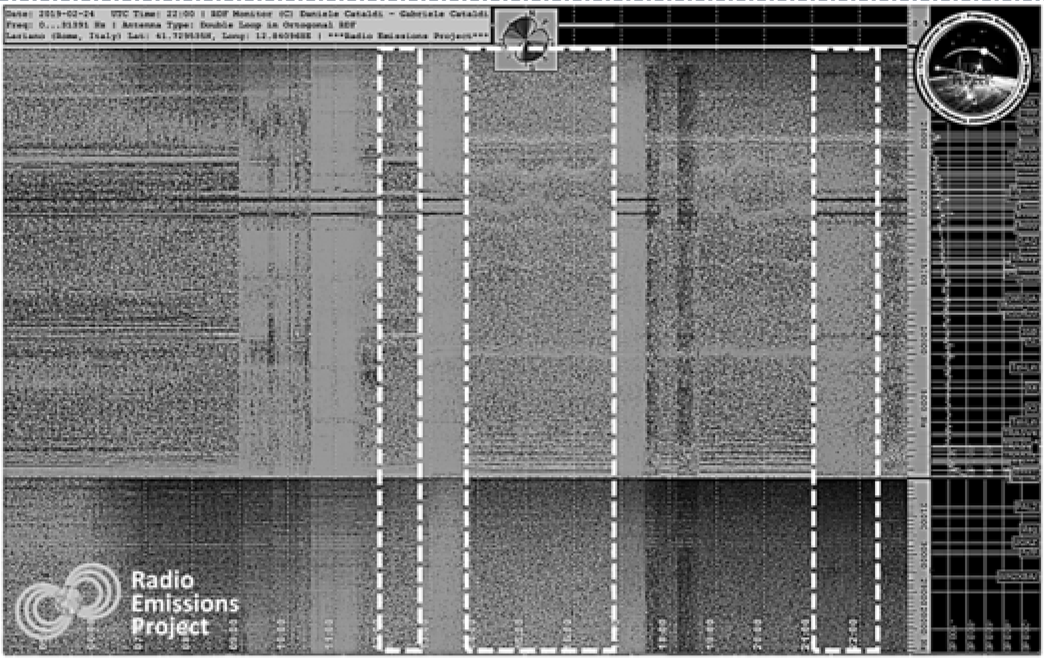

Fig. 2 – RDF spectrogram.

The graph shows a Fourier transform (spectrogram) of the natural electromagnetic background, generated by the RDF detection system used by the Radio Emissions Project. On the ordinate axis we can observe the electromagnetic frequency of the radio signals received by the monitoring station, on the abscissa axis we can observe instead the timeline (UTC time); on the right side the list of anthropic emitters, arranged according to their electromagnetic emission frequency, and at the center the colorimetric variation of electromagnetic emissions, both natural and anthropic. In evidence with the discontinuous lines, we observe the emission areas having as origin azimuth the Japanese seismic district. At the top, instead, the amplitude bar is visible, which indicates the intensity of the received signals, with a range that goes from 0% to 100% saturation. Credits: Radio Emissions Project.

In this case the electromagnetic signals coming from the Japanese seismic district (perimeter = 5.862 km; area = 1.983.373.034 km^2), considering the effects of the Earth's curvature, must come in the NE–NNE direction maintaining an angular width of about 10°. The RDF electromagnetic monitoring system has made it possible to filter all electromagnetic emissions with azimuth not compatible with the seismic district of Japan thanks to the colorimetric scale associated with the azimuth of the captured radio signals. The preliminary data obtained indicated the presence of some electromagnetic signals coming from the Japanese seismic district (**Fig. 2**) that appeared before the occurrence of earthquakes with magnitude M4.5+.

These pre-seismic radio signals had characteristics similar to those found in the past for other seismic districts [8]: pre-seismic electromagnetic emissions were distributed in the >0-32kHz band and had a wide bandwidth; the magnitude was directly proportional to their frequency; electromagnetic anomalies preceded earthquakes (**Fig. 3** and **4**).

Looking at the graphs we understand how the curve associated with the magnitude of earthquakes recorded in the Japanese seismic district, follow the trend of the variation in frequency of radio-anomalies recorded with azimuth NE–NNE. Another important fact observed also in the previous studies carried out with the RDF system is represented by the time of appearance of the electromagnetic signals: the number of radio-anomalies with azimuth NE-NNE is greater in the periods in which the ionospheric layers increase above the monitoring station, due to the direct effect of ionospheric radiation by the Sun [8].

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With regard to Japan, the peaks were distributed mainly at dawn, during the hours when the sun was high in the sky (noon local geographical Italian) and just before sunset, after which the percentages decreased rapidly [8].

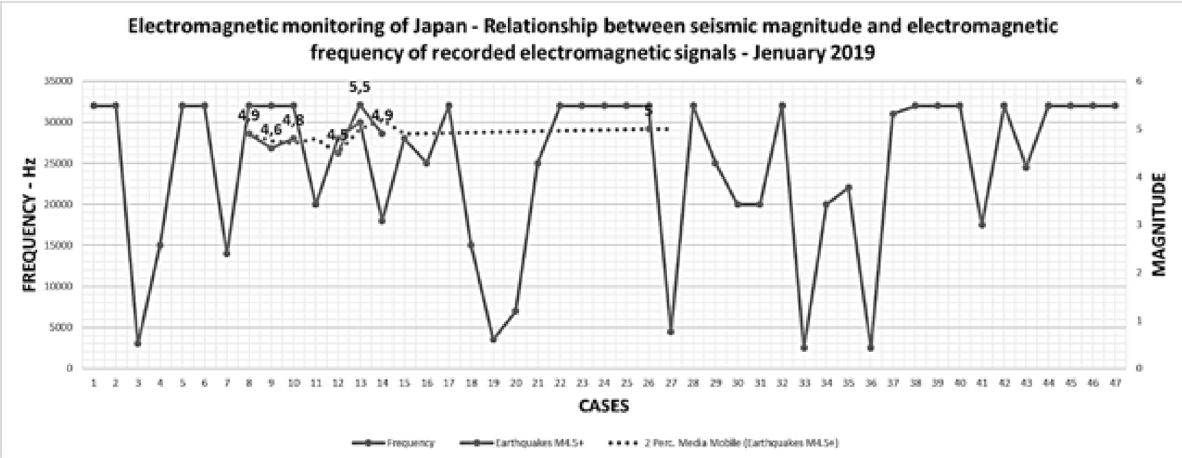

Fig. 3 – Relationship between frequency and magnitude of the earthquake (January 2019).

The graph above shows the relationship between frequency (continuous line, round indicator) of the detected electromagnetic signals and magnitude (dotted line, square indicator) of the earthquakes that occurred in the Japanese seismic district. The dotted line shows the moving average of the magnitude (trend line), which follows the trend of the electromagnetic frequency of the recorded signals. January 2019. Credits: Radio Emissions Project.

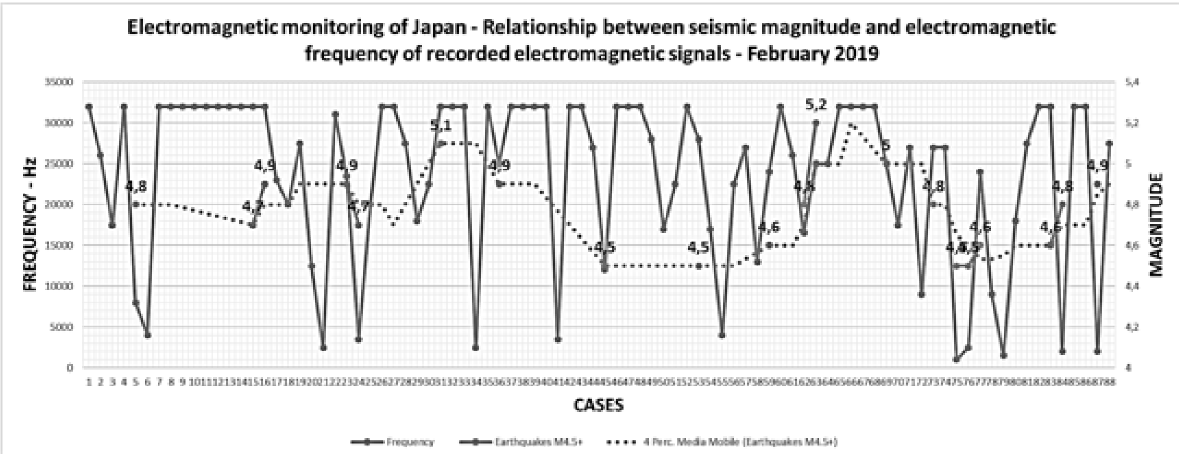

Fig. 4 – Relationship between frequency and magnitude of the earthquake (February 2019).

The graph above shows the relationship between frequency (continuous line, round indicator) of the detected electromagnetic signals and magnitude (dotted line, square indicator) of the earthquakes that occurred in the Japanese seismic district. The dotted line shows the moving average of the magnitude (trend line), which follows the trend of the electromagnetic frequency of the recorded signals. February 2019. Credits: Radio Emissions Project.

2. TOOLS

The electromagnetic monitoring station of the Radio Emissions Project is equipped with radio receivers that have the characteristic of being all powered via USB; this was possible by reducing the energy consumption of the electronics contained in the amplification devices, rationalizing the components preferring low voltage supply solutions. The total current consumption of the amplification devices does not exceed 500mA. Each receiver has an amplification stage that is potentially able to work on a bandwidth of at least 8 MHz (8 MHz for the OP27 chip, 65 MHz for the OP37 chip) while maintaining an electronic noise density that is among the lowest (3.5-8nV√Hz at 10 Hz) of those present on most operational amplifiers available on the market [31]. These solutions make the monitoring system developed by the Radio Emissions Project one of the best in the world both in terms of reliability and efficiency, also considering recent implementations with the Radio Direction Finder (RDF) system whose hardware technology has been entirely designed and built by Gabriele Cataldi and Daniele Cataldi for monitoring "local" electromagnetic seismic precursors. In addition to the use of ad-hoc electronic technologies, the Radio Emissions Project's monitoring stations use free software to fully manage 24-bit analog-to-digital conversion (with 192 kHz sampling) and recording on disk fixed data from radio receivers (**Fig. 5**).

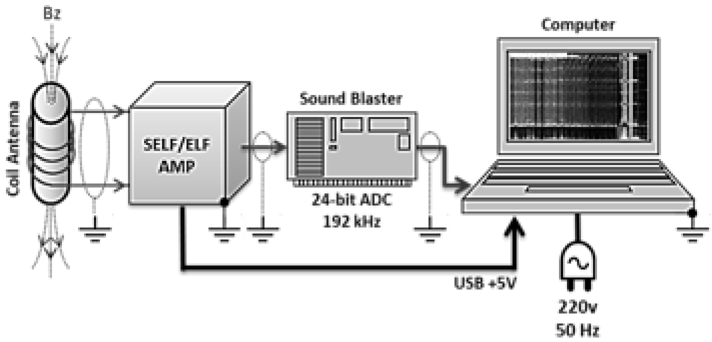

Fig. 5 – "Continuous" electromagnetic monitoring system dedicated to the SELF-ELF band.

The figure above shows a simplified diagram of the computerized radio receiver used by the Radio Emissions Project for the "continuous" electromagnetic monitoring of the SELF-ELF band (>0-30Hz). The amplification system (SELF-ELF AMP) is powered directly through the USB port of the notebook computer. This solution makes it possible to take advantage of the computer's battery power supply if the 220V/50Hz electrical network has a fault. In this case the monitoring system will continue to work with maximum efficiency continuously for a few hours. Credits: Radio Emissions Project.

The SELF-ELF receiver consists of an amplification unit and a magnetic induction sensor represented by a coil antenna with a ferromagnetic core containing tens of thousands of turns while maintaining a low impedance.

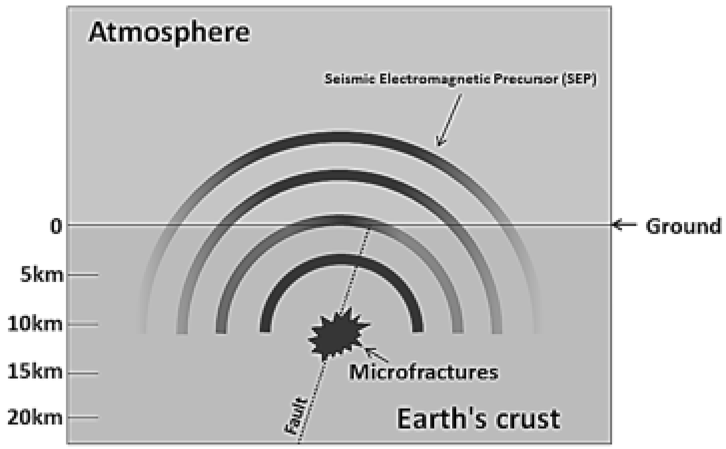

Fig. 6 – Attenuation of pre-seismic radio signals.

In the representation at the top it was very synthetically reconstructed the attenuation phenomenon that undergoes a Electromagnetic Seismic Precursors when it passes through the means of propagation (Earth's crust, atmosphere). The degree of attenuation to which an electromagnetic wave is subjected is greater when it propagates inside the Earth's crust than when it reaches the atmosphere. For this reason as we move away from the source of electromagnetic emission (focal area of the earthquake, micro-cracks) the pre-seismic radio signals gradually lose intensity, also depending on their frequency: the attenuation, in fact, turns out to be directly proportional to the frequency of the electromagnetic signal. Credits: Radio Emissions Project.

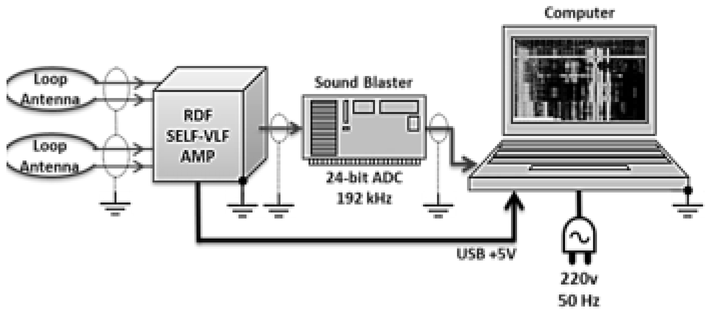

Fig. 7 – Radio Direction Finder (RDF) electromagnetic monitoring system.

In the upper representation is visible a simplified diagram of the ULF-VLF monitoring system implemented with RDF technology or Radio Direction Finder. This monitoring station uses two loop antennas aligned orthogonally to calculate, through dedicated software, the azimuth of the electromagnetic signals picked up. This is the most recent technological innovation introduced in the field of seismic forecasting by the Radio Emissions Project. Currently in Italy two RDF monitoring stations of this type are active: the first is located in Lariano (RM), the second at Pontedera (PI). Credits: Radio Emissions Project.

Through a software, the data output from the amplification system are converted into 24-bit digital signals and sampled at 192 kHz. Through the analog-digital conversion (ADC) the software manages to obtain the frequency response of the signals starting from the impulse response (Fourier Transform), generating dynamic spectrograms with a resolution of a few milliHz (mHz, 1mHz = 0.001Hz) over a bandwidth of some tens of Hz. The only limit of the system is represented by the presence of DC decouplers (capacitors) located in the ADC input stage that determine an attenuation of the input signal directly proportional to its wavelength (capacitive reactance). Since the attenuation is inversely proportional to the capacity of the DC decouplers, it is essential to use computers equipped with high quality sound cards, designed to work even at subsonic frequencies. Generally, using a quality sound card, the capacitive reactance is negligible and the monitoring system can work without major problems even at a frequency of 0.01Hz. The best hardware alternative, however, is represented by the use of external analog-to-digital converters (ADC) not equipped with DC decouplers, powered via USB and which have a resolution of at least 16-bit. In addition to monitoring the SELF-ELF band, the Radio Emissions Project is also dedicated to monitoring the ULF-VLF band (0.3-30kHz) thus covering a total bandwidth of at least 30kHz. The "continuous" electromagnetic monitoring of the ULF-VLF band is indispensable for detecting "local" pre-seismic radio signals placed a few hundred km away from the emission source. The available literature has shown that emissions in the VLF band have been observed near important seismic epicenters even through satellite detection systems [32] [33]. These radio emissions, as happens for the SELF-ELF emissions, are generated following the creation of micro-fractures in the focal area of the earthquake but undergo a greater attenuation compared to the first as they have a higher frequency (**Fig. 6**), or at least this is what emerged from the studies conducted on the VLF band. Recently, the experimentation of RDF technology (**Fig. 7**) has allowed to identify a second type of Electromagnetic Seismic Precursor that appears in the VLF band: background noise increases which, according to the data, have the same azimuth as the seismic districts affected by potentially destructive earthquakes (M6+), even tens of thousands of km from the monitoring station [27] [28] [29].

3. DISCUSSION

The electromagnetic signals having azimut of arrival the Japanese area have been identified by the RDF network developed by the Radio Emissions Project. The data indicate how the increase in the seismic magnitude, has been preceded and accompanied by an increase in the electromagnetic frequency of the recorded signals (Fig. 2 and 3). This indicates how electromagnetic emissions are closely related to seismic events. The most likely hypothesis is

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that these signals are issued at the crusta level, when the tectonic stress tends to increase, generating radio emissions for the piezoelectric effect which generates flowing electric charges, at the point where this stress accumulates. The particles flow, freed from the rupture of the crystalline rocks of the rocks, generating an electromagnetic field. This issue propagates in the earth-ionosphere cavity, along long distances, then picked up, recorded and processed by the RDF monitoring system.

The study therefore indicates how these emissions behave, compared to the characteristics of the earthquakes recorded during the period in which the Japanese area monitoring has continued.

Fig. 3 and Fig. 4 indicate the data derived from the monitoring of the months of January and February 2019, they indicate to us as the trend of the seismic magnitude, is directly proportional to the increase in the electromagnetic frequency of the signals.

4. CONCLUSIONS

The state of the art of the seismic precursor candidates presented in this research, currently in progress, highlights the role of the hypothesis "and its necessary verification, also in the field of seismology. A study that combines the knowledge of the various scientific fields and underlines the need to reinterpret Geology today as a "forecast" science at the expense of the "historical" one. The monitoring of the RDF and SGP Systems of the Radio Emissions Project has shown that:

1) by monitoring the natural background electromagnetic noise in the ELF-VLF band ($3 \leq f \lesssim 30$kHz) with a network of electromagnetic monitoring stations implemented with the Radio Direction Finding (RDF) system it was possible to detect broadband radio emissions from surface areas terrestrial where seismic events of medium and strong intensity were recorded;
2) by monitoring solar activity and the geomagnetic field through a network of electromagnetic monitoring stations tuned in the SELF-VLF band (>0-30kHz) it's possible to detect and follow the evolution of some natural electromagnetic phenomena correlated to M6+ global seismic activity, with an average advance of a few days (**Fig. 8**).
3) The encouraging results, obtained by superimposing Geology, Physics and Cosmology in a synergistic and holistic way, are currently provisional, still far from being considered definitive.

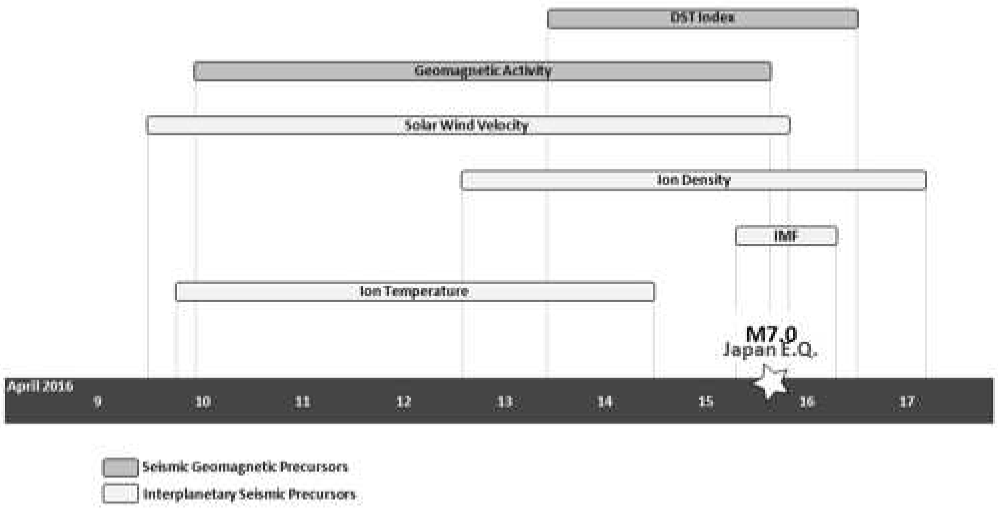

Fig. 8 – Electromagnetic Precursors correlated to Japan M7.0 Earthquake.

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