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SELF and VLF electromagnetic signal variations that preceded the Central Italy earthquake on August 24, 2016

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Abstract: The strong earthquake hit Central Italy on August 24, 2016 with the loss of human lives and extensive damages to buildings and the historic and architectural heritage. It reopens the delicate theme of seismic precursors candidates and their future application. The main shock of magnitude (Mw) 6.2 occurred at 01:36:32 (UTC), with geographical coordinates (lat. and long.) 42.7, 13.23 at a depth of 8 km, and in the next ten days was followed by more than 5,500 events, in which 159 earthquakes of magnitude between 3.0 and 4.0, and 15 with magnitude in the range between 4.0 and 5.0. The observation of signals and radio anomalies detected by the LTPA Observer Project, Observatory of Rome, showed the appearance of unusual signals in the VLF band, appeared on August 18, 2016 and a radio anomaly recorded at 9:00 UTC on August 23, 2016. The natural change (variation) of electromagnetic emissions, in particular the anomaly observed in VLF band in 5 days before the main earthquake and the clear interference by SELF registered roughly 18 hours before the quake, bring us to suppose that these two elements could be pre-seismic signals of the strong earthquake and the following seismic swarm.

Keywords*: seismic precursors, SELF-VLF frequency band, radio anomalies.*

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Introduction

The relative proximity of the survey station LTPA Observer Project di Roma to the epicentral zone of the earthquake with magnitude Mw6.2 (see: USGS) of Central Italy on August 24, 2016 (**Fig. 1**), gives us an opportunity to verify the potential variation of the electromagnetic emissions occurred on a global scale before a quake of more than magnitude 6.0 (Molchanov and Hayakawa, 2008; Straser, 2011; Cataldi et al., 2014; Hayakawa, 2015). At the beginning of 1988 some hypotheses on possible correlation among the earthquake, variation of electromagnetic background and vertical and horizontal atmospheric flows were born. These studies were possible for the historic data of Black Sea. The link between the local variation of geomagnetic background and terrestrial electric flows was ascertained in the 2001 during a seminar organized by Institute for Nuclear Researcher and Nuclear Energy – INRNE in Sofia, Bulgaria (Mavrodiev et al., 2001). Anomalies of electromagnetic background on VLF band were observed 16 days before the earthquake with magnitude M6.8 occurred in Chamoli (India) on March 29 1999 (Singh et al., 2001). The satellite "Intercosmos-24" was launched into the Space on September 29 1989, in order to study the pre-seismic radio emission. The satellite during its journey through the 180 orbits from November 16 1989 to December 31 1989, analyzed 28 seismic event with medium-high intensity, between M5.2 and 6.1. This process of survey was possible thanks to a series of radio receptacle that are able to monitor ELF, ULF and VLF bands. The results of electromagnetic monitoring highlighted the presence of pre-seismic radio emission on ELF-ULF bands (f< 1000 Hz) and VLF band. The pre-seismic radio emissions achieve the highest intensity in the 12-24 hours before the seismic event. The pre-seismic radio emissions were observed on the ELF-ULF band roughly over the epicenter zone, while the VLF emission was observed far from the epicenter point (Molchanov et al., 1993). Anomalies of VLF propagation are revealed in the time between 22 and 31 in the month of December. In this period of time a train of strong earthquakes (M6+) was registered; they predated the earthquake M9.1 that hit the northern Sumatra on December 26, 2004 (Chakrabarti et al., 2005).

Radio anomalies are interferences that usually appear from 16 hours to a few minutes before an earthquake

of magnitude equal or greater than 6.0. Similarly, other authors (Hayakawa et al., 2010; Molchanov and Hayakawa, 1998; Pulinets, 1998) believe that changes in the ELF-VLF frequency band may be associated to the seismic precursors, as reported by studies directly conducted on the field. Data presented in this report show the analysis of electromagnetic waves generated by tectonic stress in the preparatory stages of an earthquake (Freund et al., 2006).

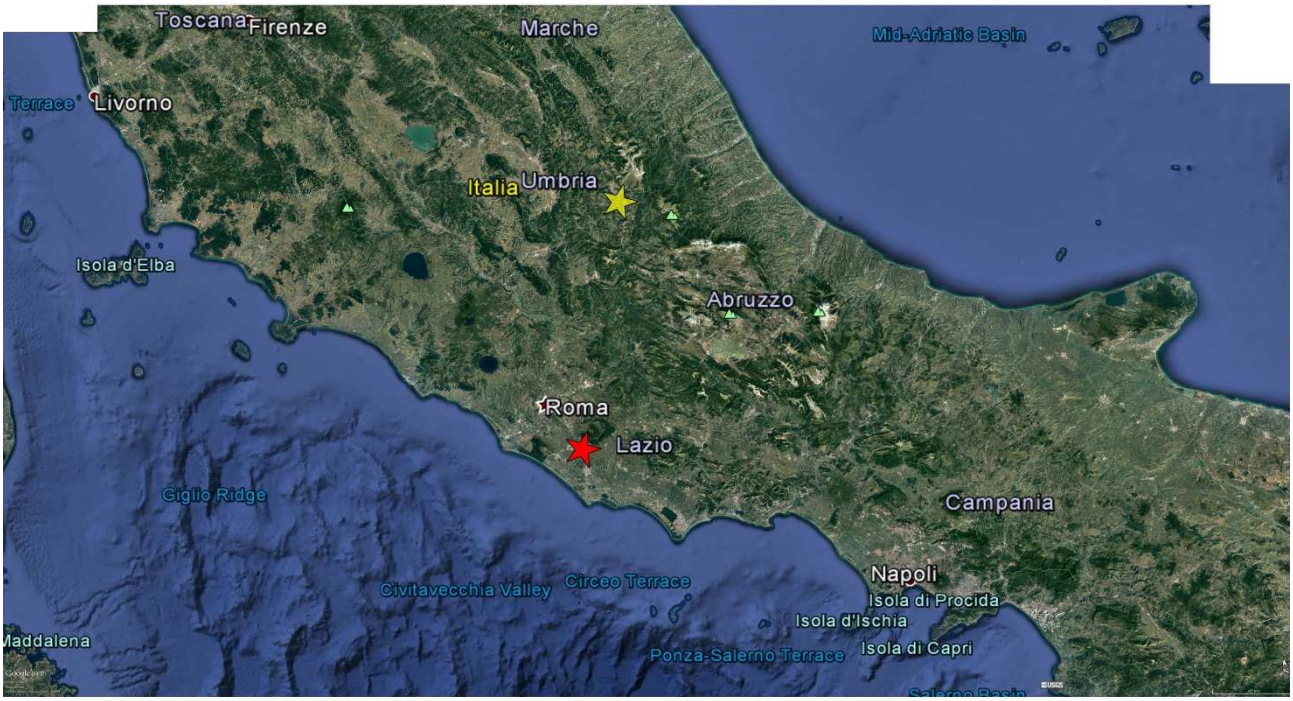

Fig. 1. Index Map.

Anomalies detected in VLF band

The VLF electromagnetic (EM) signal monitoring is available 24/7. The spectrogram (**Fig. 2**) has been realized through a radio receiver prototype developed by Gabriele Cataldi, designed to work efficiently in the VLF band. The core of the receiver is represented by the LM386 chip, a very common operational amplifier in electronics, capable of working with a bandwidth of 300kHz and provide an amplification included between 20 and 74 dB. This is the same chip found in the famous receiver "INSPIRE VLF-3", but unlike this, the prototype developed by Gabriele Cataldi has a single amplification stage (always represented by the LM386 chip) that provides a gain of 44.95dB (177x). This receiver is connected to a loop antenna of square shape of dimensions of 60 x 60cm, containing 50 turns of enameled copper wire of 0.18mm diameter. The antenna is aligned in the direction of 310°NW and maintains a high directivity in this direction and in the opposite direction, ie. at 130°SE. Instead, it is "blind" to the electromagnetic radiation in the direction of 40°NE and 220°SW corresponding to the two null points **(Fig. 2**).

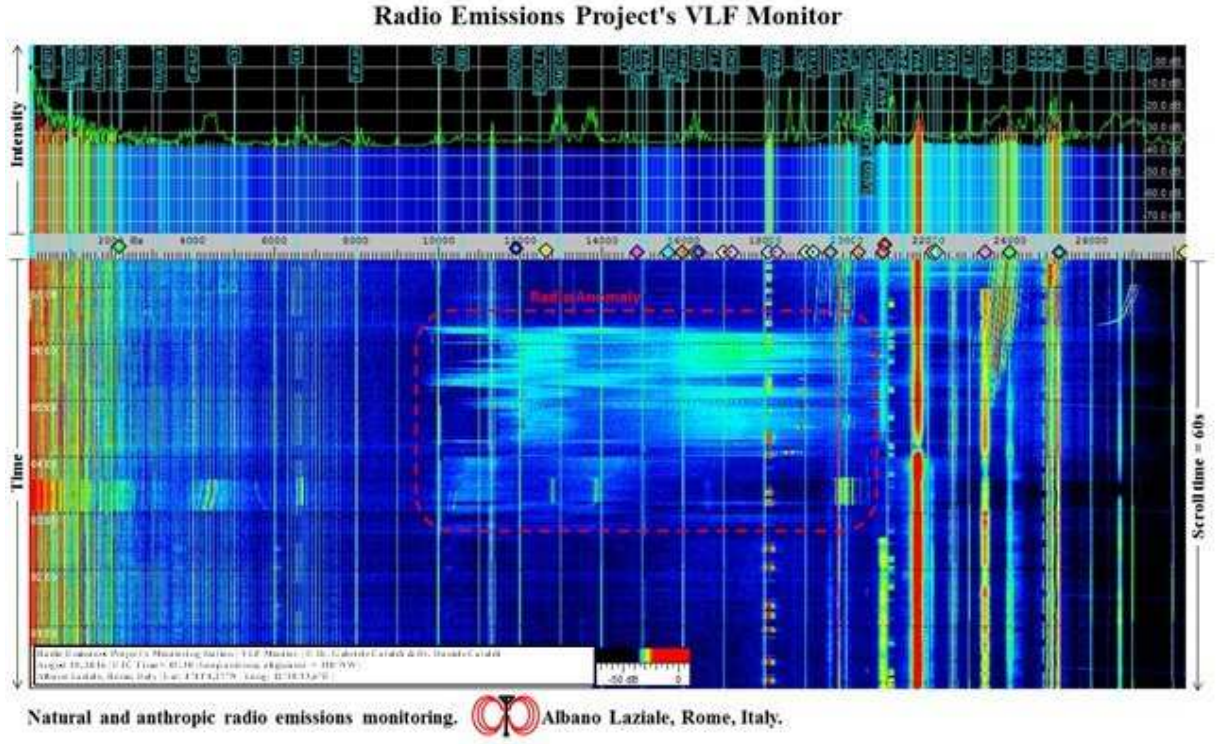

Fig. 2. VLF Monitor: The image represents the dynamic spectrogram of the Earth's electromagnetic field registered on August 18, 2016 between the 24:00 UTC and 07:30 UTC from the electromagnetic environment monitoring station of Radio Emissions Project, located at Albano Laziale (RM), Italy. In the middle of the picture, inside the red dotted line, a radio anomaly was recorded which predates the M6.2 Italian earthquake. The strange radio emission appeared at 02:47 UTC and disappeared at 06:21 UTC. The labels at the top of the spectrogram (in light blue) indicate known radio stations, mainly anthropogenic. The spectrogram recording speed is 1 line/minute.

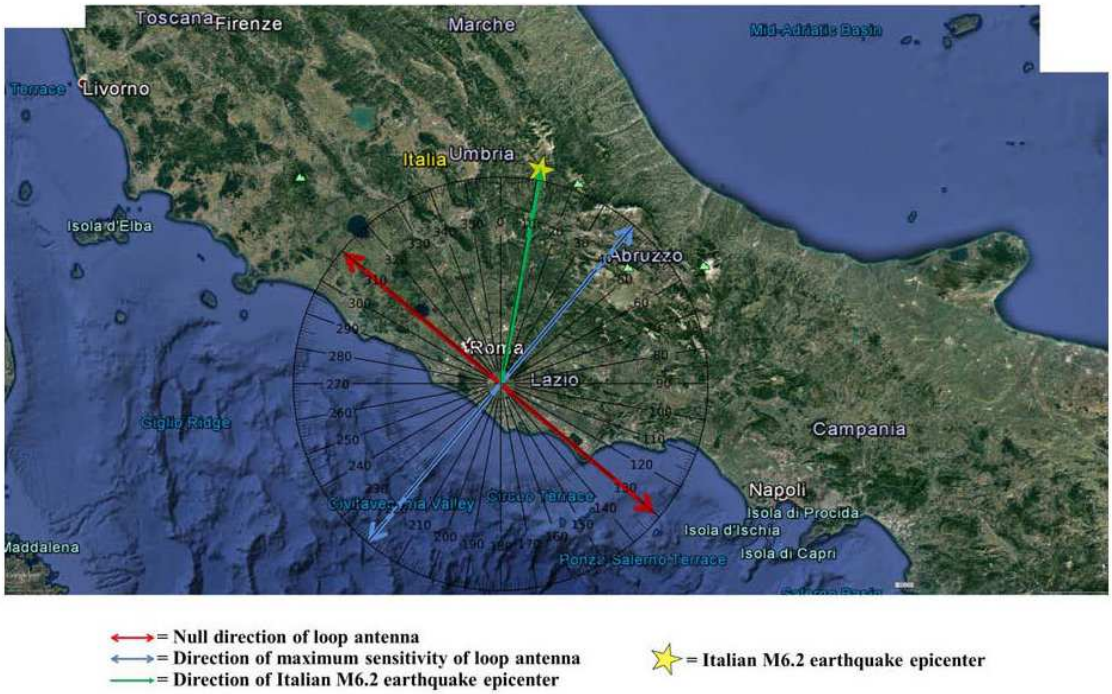

Fig. 3. Alignment of the loop antenna in respect to the “F” geomagnetic component: The image shows the alignment of the loop antenna which is equipped with the Radio Emissions Project’s VLF monitoring station compared to the “F” geomagnetic component. The red line provided with arrows at the end represents the direction in which the loop antenna retains its maximum sensitivity (210°NW-130°SE) to the magnetic component. The blue line provided with arrows at the ends represents the direction in which the loop completely loses its sensitivity (40°NE-220°SW) and is "blind" to the magnetic radiation.

Anomalies detected in the SELF band

In general the pre-seismic radio emissions reach their maximum intensity 12-24 hours before the earthquake. Pre-seismic radio emissions that have been observed in the ELF-ULF band are observed almost above the epicenter, while VLF emissions are observed far away from the epicenter (Molchanov et al., 1993). Anomalies in VLF radiowave propagation were observed from 22 to 31 December 2004, the period in which a seismic train of strong earthquakes (M6+) was registered preceding the M9.1 Sumatra Island quake that occurred on December 26, 2004 (Chakrabarti et al., 2005).

The spectrogram, **Fig. 4**, shows an increase of the natural electromagnetic background mainly between 0 and 0.7Hz that predated the Italian M6.2 earthquake of about 2 hours (magnitude of the main earthquake is indicated by the red square and the vertical yellow line represents the temporal marker). This increase (indicated by the large red arrow) predated the M6.2 earthquake occurred on August 24, 2016 at 01:36 UTC, by approximately 70 minutes. It was characterized by strongest impulsive changes that predate the three big earthquakes after the main one (M6.2), whose magnitude is indicated in yellow. The emission peak identified by the acronym "SGP" is an intense emission which lasted about 40 minutes and that preceded the M6.2 earthquake for 17 hours. The similar ELF impulsive emissions (f=1~10Hz) have been observed by Ohta et al. (2013) prior the 2011 Tohoku EQ and to other seismic events (Shekotov et al., 2013).

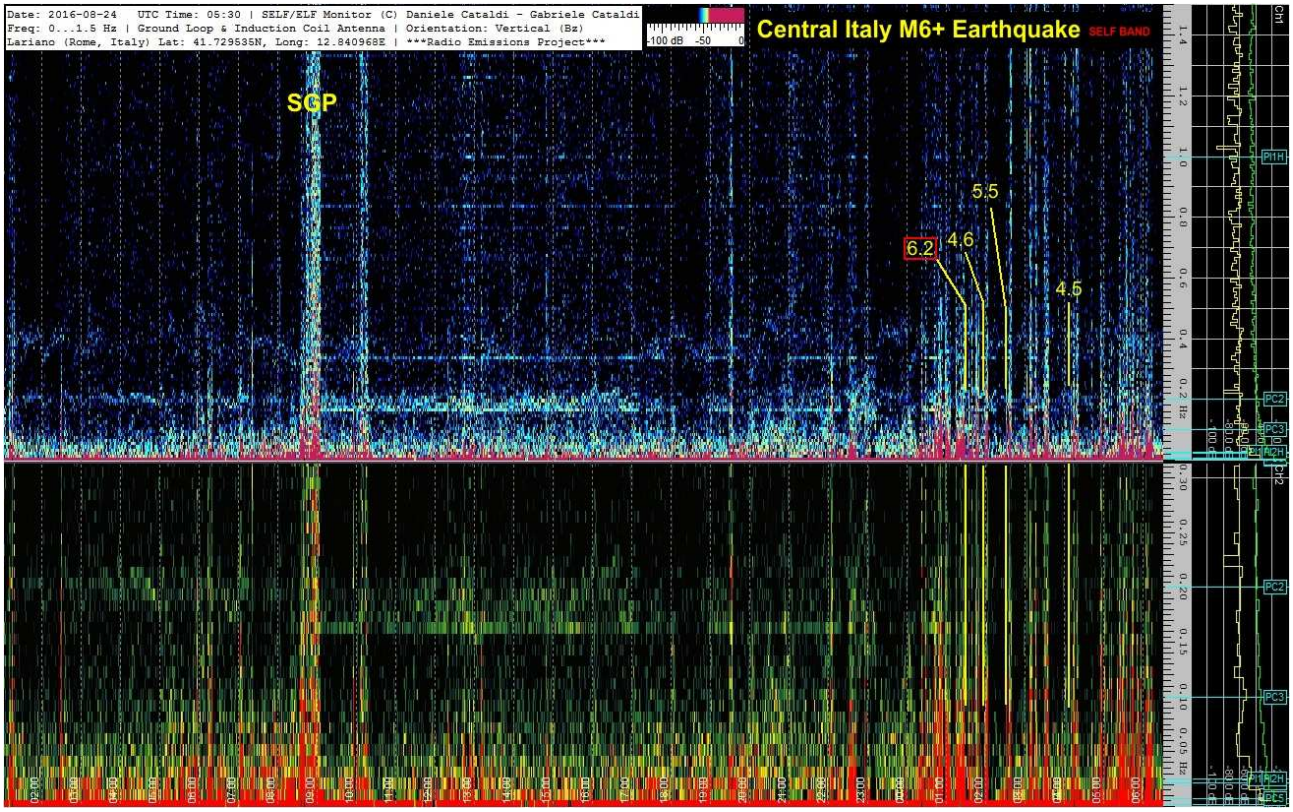

Fig. 4. SELF-ELF Monitor. The image represents the dynamic spectrogram of the Earth's electromagnetic field registered between 02:00 UTC, August 23, 2016 and 06:30 UTC, August 24, 2016 by environmental electromagnetic monitoring station of Radio Emissions Project, located in Lariano (RM), Italy; it monitors the band SELF and ELF with a resolution of 10.1mHz. The upper portion of the spectrogram is centered in the SELF band between 0 and 1.5Hz, while the lower portion is centered in the SELF band between 0 and 0.31Hz. The spectrogram is acquired through a radio receiver prototype developed by Gabriele Cataldi designed to work efficiently between the SELF band (<3 Hz) and the ELF band (3-30Hz). The used antenna is a coil antenna aligned vertically. The word "SGP" is an acronym coined by the authors that identifies the radio emission of electromagnetic nature that was observed to precede large earthquakes (seismic geomagnetic precursor).

Conclusions

The seismic events potentially destructive are rare. For this reason a statistical analysis of the data is currently unreliable. This paper is preliminary, so that further detailed analysis is highly required. However, elements of coincidence between the appearance of radio anomalies in the SELF-VLF band before strong earthquakes, suggests that the search address can be developed waiting for a data modeling, finalized to the seismic prediction. The data collected before the Italian M6.2 earthquake occurred on August 24, 2016, is a new element to complement the complex mosaic of the seismic prediction.

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