# Comparison of Electromagnetic Signals Before an Earthquake Using the Radio Direction Finding Method. The Case of Po Plain Valley (Italy)

Valentino Straser, Daniele Cataldi, and Gabriele Cataldi

**Abstract**

In this study, we present the outcome of a trial of the Radio Direction Finding detection system, aimed at verifying the link between electromagnetic signals detected in Italian monitoring centers from those emitted in tectonically stressed areas. The area studied is in the Po Valley, in Northern Italy, in an area historically affected by seismicity with earthquakes rarely exceeding magnitude 6. The Radio Direction Finding system, designed to detect the direction of electromagnetic signals, confirmed the applicability of this method for areas subjected to crustal stresses that can evolve into seismic shocks. In the case of this experiment, the signals preceded the seismic events by about 24 h, and the intersection of the colorimetric lines, which appeared in the dynamic spectrograms, coincided with the future epicenter zone of the earthquakes. The seismic occurrence fell within a time window of three days, confirming a well-established trend, that overlapping with previously studied cases.

**Keywords**

RDF systems • Earthquake • Electromagnetic signals • Crustal diagnosis • Elf frequency

## 1 Introduction

After a pioneering phase and initial skepticism about the study of seismic precursors, expressed by the scientific community, today more and more research centers are taking up this area of seismology. Among the methods tested by various research teams on an international scale, this study presents the Radio Direction Finding (RDF) method, designed and tested in Italy since 2017 (Straser et al., 2017) by Radio Emissions Project (Rome, Italy), and discusses a successful application for two earthquakes, which occurred in Italy on February 9, 2022, with magnitudes between 4.0 and 4.3. Three RDF monitoring stations are set up in Italy: Lariano in Rome; Ripa-Fagnano in L'Aquila; and in Pontedera, near Pisa. The 24-h monitoring is based on the identification of different electromagnetic frequency bands, distinguishing natural-type signals that are emitted from the Earth's crust. The instrumentation is currently designed to identify the intensity, electromagnetic frequency, duration, and most importantly, the direction of arrival of the signals (azimuth) with respect to the geographical position of the station itself. The data, analyzed daily, have made it possible to ascertain that the electromagnetic signals come from areas under tectonic stress and historical seismicity (Cataldi et al., 2019; Straser et al., 2019). The archive of data extracted from the Italian RDF network shows common features regarding the occurrence of radio anomalies, associated with the azimuth of seismic epicenters. The detection of the anomalies occurs, instrumentally, 3 to 7 days before the seismic event, in which the signals decrease and then reappear a day before the earthquake. This repeated variation of discontinuous electromagnetic increments can be interpreted as increased tectonic stresses that usually occur in pre-earthquake phases.

## 2 Methods or Materials

The monitoring stations of the Italian RDF network are equipped with antennas connected to a radio receiver and interfaced with a computer, which is active 24 h a day. The device is equipped with two antennas aligned with each other orthogonally to the geographical poles. The variation of radio anomalies is detected in the VLF band in the range from 0.3-a to 96 kHz. The innovative aspect of the method is

V. Straser (✉)
UPKL, Rue de La Presse 4, Brussels, Belgium
e-mail: valentino.straser@gmail.com

D. Cataldi
Radio Emission Project, Lariano, Rome, Italy

G. Cataldi
Radio Emission Project, Albano Laziale, Rome, Italy



M. Bezzeghoud et al. (eds.), *Recent Research on Geotechnical Engineering, Remote Sensing, Geophysics and Earthquake Seismology*, Advances in Science, Technology & Innovation,
https://doi.org/10.1007/978-3-031-48715-6_60

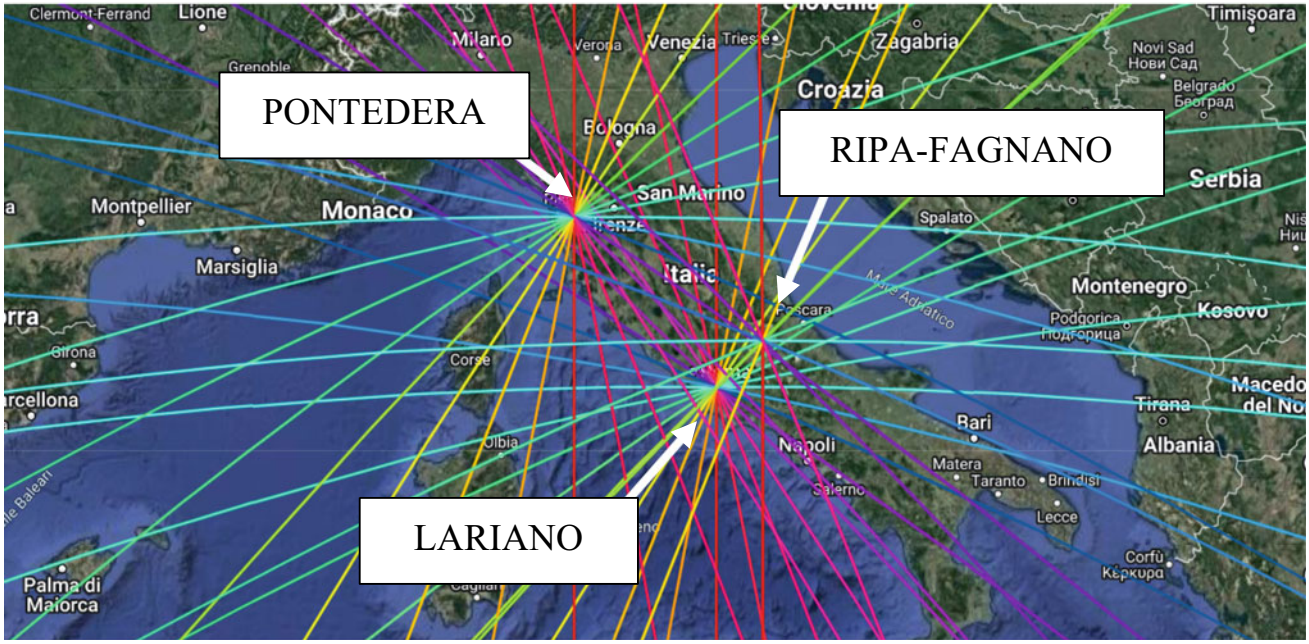


**Fig. 1** RDF mapping of the three Italian stations. It shows the position of the RDF stations of Pontedera, Pisa, Italy; Lariano, Rome, Italy; and Ripa-Fagnano, L'Aquila, Italy. The colored lines identify the different azimuths of origin of the radio signals, recorded by each survey station. *Credits* Radio Emissions Project; Google My Maps

to associate the colors of the magnetic anomalies in the spectrogram (Fig. 1) with a map indicating the direction of the signals (azimuth).

The RDF stations are three and located at:

(1) Lariano, Rome, Italy (GPS: Lat. 41.728799 N, Long. 12.843205 E).
(2) Pontedera, Pisa, Italy (GPS: Lat. 43.672445 N, Long. 10.640100 E).
(3) Ripa-Fagnano, L'Aquila, Italy (GPS. Lat: 42.265709 N, Long. 13.583850 E).

RDF survey stations record electromagnetic monitoring, generating an archive of spectrograms that can be analyzed to understand the characteristics and evolution of natural-type radio signals. The data collected by the RDF monitoring stations are compared with earthquakes published on the website of the National Institute of Geophysics and Volcanology. The method used is the analysis, comparison, and interpretation of electromagnetic data compared with the azimuth of the signals and compared with known situations of previous earthquake events.

## 3 Results

The two earthquakes, which occurred on February 9, 2022, and were located at Bagnolo in Piano in the Po Valley in northern Italy (Figs. 2 and 3), were inferred from the website of the National Institute of Geophysics and Volcanology in Rome. The two seismic events had the same epicentral zone, spaced at the time level by a little more than an hour.

1. Ml 4.0 on 09-02-2022 at 18:55:12 (UTC), 44.7800, 10.7250, depth 6 km.
2. Ml 4.3 on 09-02-2022 at 20:00:57 (UTC) 44.7860, 10.7240, depth 7 km.

## 4 Discussion

The monitored area was chosen randomly and fell in the Po Valley in Northern Italy, identified based on historical and recent seismicity, to test the RDF method. The duration of monitoring was six months. The traces of radio anomaly signals to be considered in the experimentation are two: the color purple for the Lariano-Rome station and red for the Pontedera station. The frequency band considered for the study of these seismic precursor candidates is between 0.01 and 7 Hz. The colored lines appearing in the spectrogram represent the azimuth within which the natural electromagnetic signals are identified and detected by the RDF stations of Pontedera-Pisa and that of Lariano-Roma. On the day before the two seismic events, February 8, 2022, from 1:00 p.m. to 5:00 p.m., the Lariano-Rome station recorded violet signals from, therefore, the investigation area of the Po Valley (Fig. 4). Similarly, the RDF station in Pontedera, too,

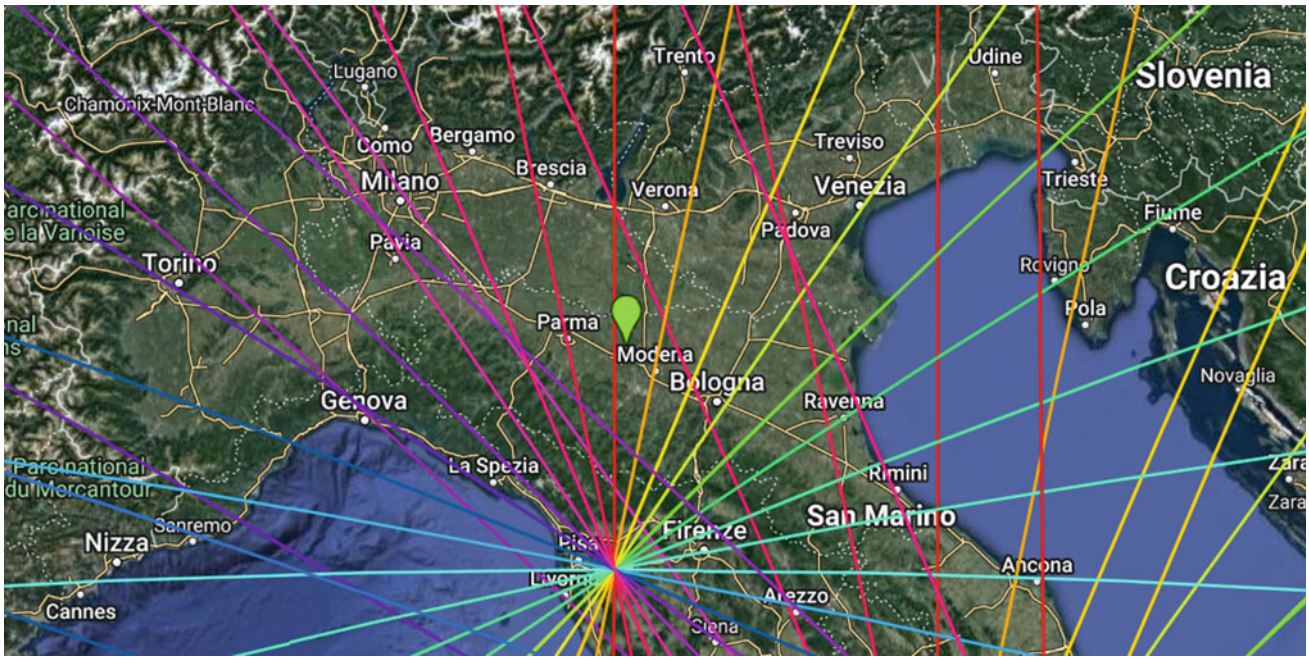


**Fig. 2** Spatial position of the seismic epicenter with respect to the Italian territory which occurred in northern Italy on February 9, 2022, and of magnitude Ml 4.0. *Credits* Radio Emissions Project; Google My Maps

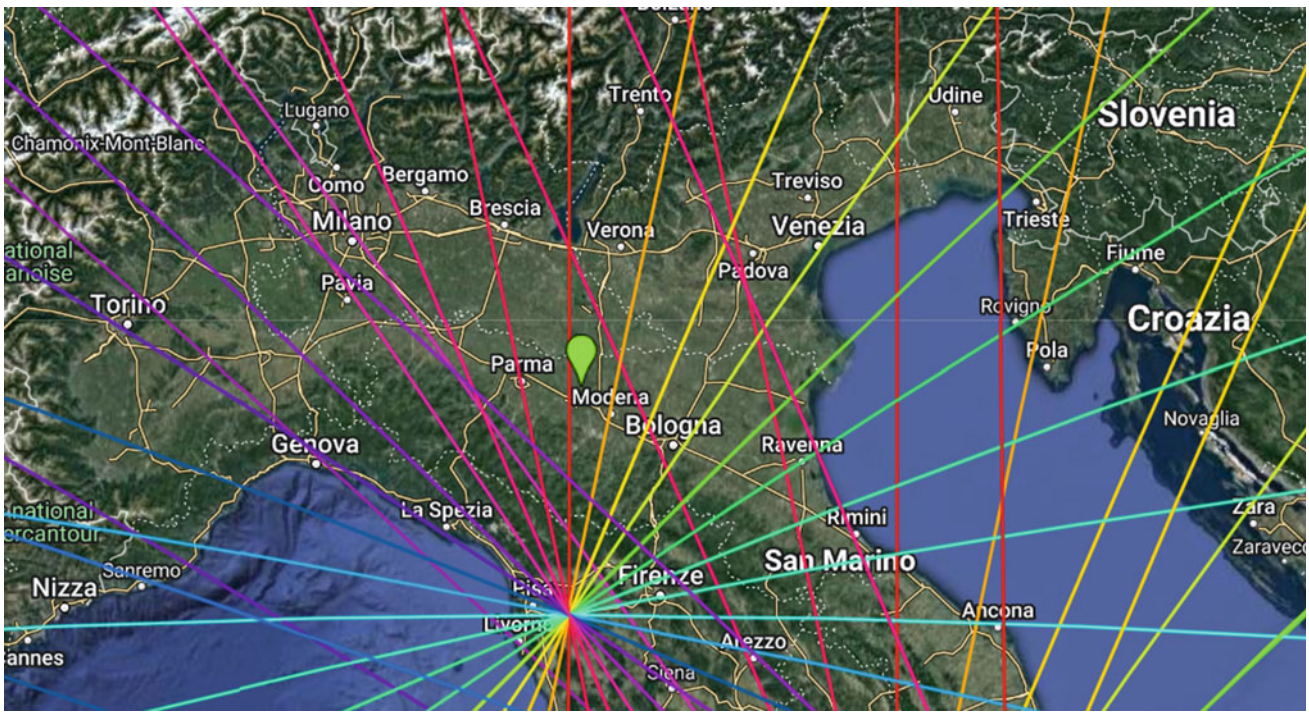


**Fig. 3** Spatial position of the seismic epicenter with respect to the Italian territory which occurred in northern Italy on February 9, 2022, and of magnitude Ml 4.3. *Credits* Radio Emissions Project; Google My Maps

showed the appearance of a series of electromagnetic signals, which appeared suddenly and disappeared after a few hours. These signals presented a precise red-colored azimuth, indicating the geographical area of study. These emissions, clearly distinguishable from the natural geomagnetic background, identified a circumscribed geographical area, the location of future epicenters. By intersecting the directions of the two monitoring stations (purple and red),

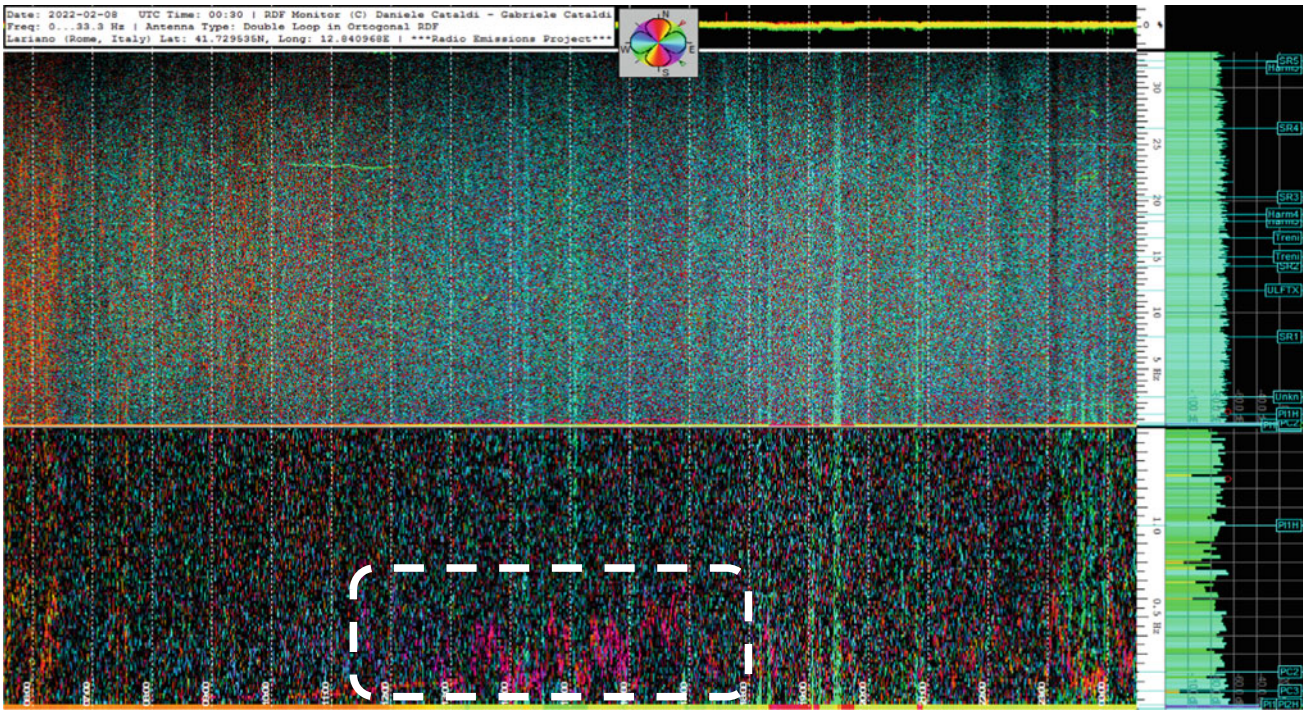


**Fig. 4** Spectrogram produced by the RDF station in Lariano, Rome, Italy on February 8, 2022. The spectrogram shows the sudden appearance of a signal having as azimuth (purplish) the study area of the Po Valley. *Credits* Radio Emissions Project

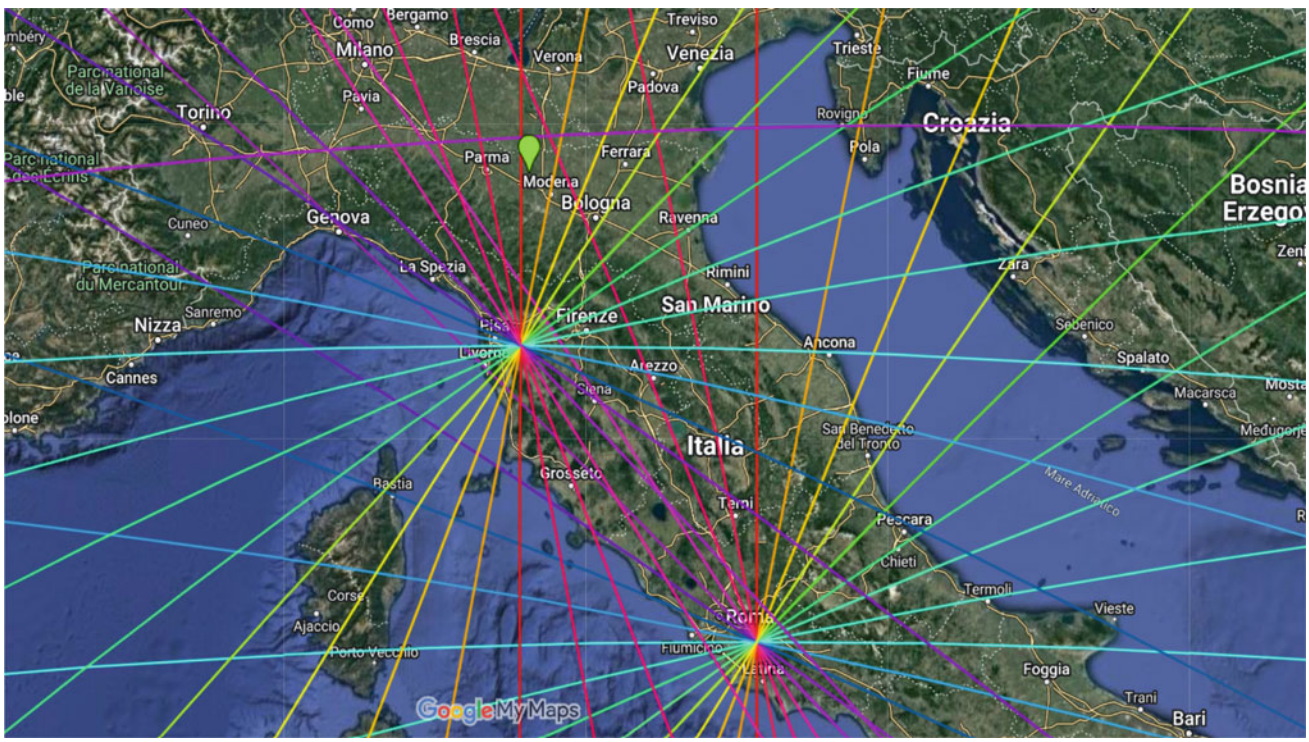


**Fig. 5** Colorimetric map of the Italian RDF network showing the location of the epicenters of the earthquakes that occurred in northern Italy on February 9, 2022, of magnitude Ml 4.0 and Ml 4.3. The colored lines represent the azimuth within which natural electromagnetic signals are identified and depart from RDF stations. The purple line (RDF) at the top of the graph that crosses the word "Croazia" refers to the University of Malaya station, and does not refer to the Italian RDF stations, used in this study. *Credits* Radio Emissions Project; Google MY Maps

the area under crustal stress and the possibility of occurrence of a seismic event of magnitude 4 or greater was assumed. The colorimetric signals, associated with the map to identify the direction of the tectonic disturbance, usually appear within a three-day time window. In this case, however, the earthquakes occurred about 24 h after the appearance of the radio anomalies (Figs. 4 and 5).

## 5 Conclusions

We conclude that the occurrence of the radio anomalies, detected by the RDF Method, can be associated with instrumentally detectable tectonic stress conditions for a given seismic zone by comparison with the color scale and azimuth of the signals. The method of triangulation of electromagnetic signals carried out through the three Italian stations (Fig. 1), at low and very low frequencies, also made it possible to establish an element of coincidence between the intersection of the signals and the future epicentral zone, in the three-day time window. Such signals, for all cases studied in Italy, vary from three days to a few hours before the seismic event. Further steps of experimentation and an interdisciplinary comparison will confirm or not the reliability of the method.

## References

Cataldi, D., Cataldi, G., & Straser, V. (2019). Radio Direction Finding (RDF)—Pre-seismic signals recorded before the earthquake in central Italy on 1/1/2019 west of Collelongo (AQ). *Geophysical Research Abstracts*, Vol. 21, EGU2019–3124, EGU General Assembly.

Straser, V., Cataldi, D., & Cataldi, G. (2017). Radio direction finding system, a new perspective for global crust diagnosis. *New Concepts in Global Tectonics Journal, 6*(2), 202–210.

Straser, V., Cataldi, D., & Cataldi, G. (2019). Radio Direction Finding (RDF)—Geomagnetic monitoring study of the Himalaya area in search of pre-seismic electromagnetic signals, *Asian Review of Environmental and Earth Sciences, 6*(1), 16–27.