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SEISMICITY AND MEASUREMENTS OF ELECTROMAGNETIC FORERUNNERS IN THE KRESNA'S EARTHQUAKE ZONE

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***Abstract** The earthquake zone of the Kresna-Krupnik region (Bulgaria) is the most dangerous one found in the Balkan peninsula. In 1904 two earthquakes of magnitudes 7.2 and 7.8 have been occurred within 20 minutes interval. The second one was considered as the strongest that struck in the last 200-300 years the continental part of Europe. This earthquake zone is the most active in released seismic energy for the last 15 years, as well. Due to these characteristics the Kresna-Krupnik earthquake zone is an object of active investigations, including electromagnetic ULF continuous measurements of possible forerunners. A specialized measuring system is designed, installed, and set up that works in the seismic station "Krupnik" for more that 2 years.*

The system is aimed toward measurements of geoelectric potentials and ultra-low-frequency electric and magnetic fields, induced by processes both in the magnetosphere-ionosphere and in the lithosphere. The primary goals of these measurements are a study and monitoring of both the natural electromagnetic field variations and the geoelectric potential anomalous changes associated with seimic activity.

Data for the local seismic activity provided by NOTSSI, GPhI are collected. The seismic information for all registered local earthquakes is processed statistically in several parameters – spatial distribution, magnitude, depth and earthquake moments. The information of electromagnetic field measurements is included in order to look for possible relationships between the seismic events and the dynamical variations in the electromagnetic field characteristics – frequency spectrum, amplitude, etc. The goal is to answer to the main question: is there an earthquake electromagnetic forerunners and how we can register them.

Introduction

Earthquake events occurred in the Kresna-Krupnik area (South_West Bulgaria) and their characteristics are under study in this paper. The time interval under consideration is from the beginning of 2004, when the first regular measurements of the ultra low frequency (ULF) electro-magnetic variations have been put. Among earthquakes in this region of 1 by 1 geographical degrees, the strongest ones, with M=7.2 and 7.8 within interval of only 20 min have been occurred on April 4, 1904. Those events have been caused macro seismic effects in the epicentral area, reaching X-th degree on the MSK. The quakes have been followed by the whole spectrum of secondary events, that is typical for earthquakes of that magnitude [1]. The second earthquake (of M7.8) appears as the strongest tremor in the continental Europe in the last 200-300 years. The same region, known as Kresna-Krupnik area even today releases the highest level of seismic energy in Bulgaria [2]. These are the main factors that have directed us in our selection for the investigation of possible electro-magnetic precursors. Over 700 week earthquakes have occurred in last few months and they are presented on Fig 1. The registration is done on the NOTSSI network and earthquakes within magnitude interval M < 1.0 up to M > 3.5 – Fig. 2 are selected. The weak seismicity distribution in time is illustrated in Figure 3, where the occurrence number of seismic events is by month. As it is seen a clearly defined maximum in October 2004 is visible. The relevant magnitude distribution (Fig.2) demonstrates a dominant maximum for the weak events. It is obvious that the relative stronger earthquake events (of M > 3.0) are relatively small number (less than 10 or in average 1 in a month), which is an indicator for more careful investigation when searching for electro-magnetic precursors. Obviously, the occurrence number of small earthquake events is not informative enough for discovering anomalies in the electro-magnetic field, and most probably creates and/or includes background disturbances. The decrease in the number of seismic events in the last few months is quite usual and is not a peculiar feature.

Fig. 1.

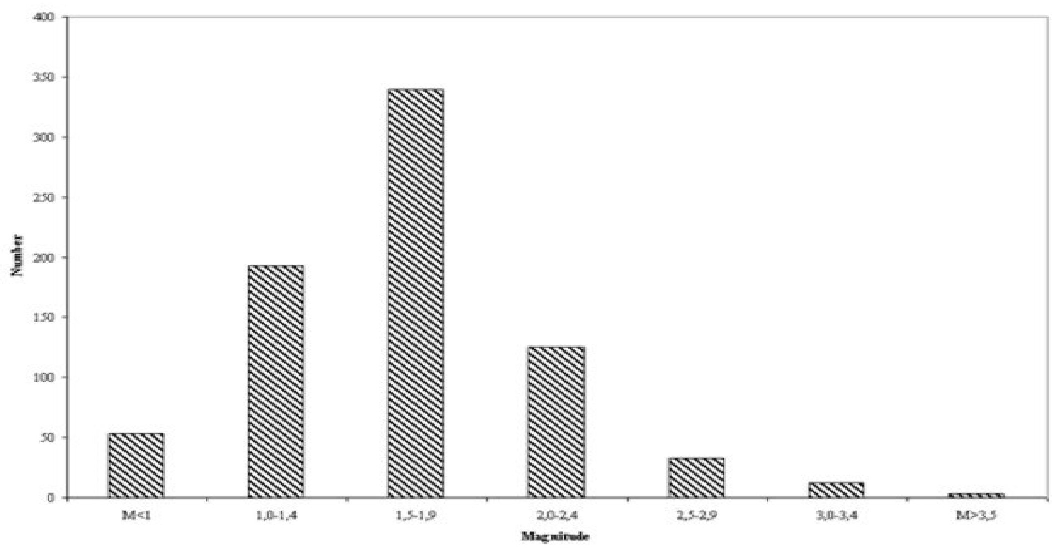

Fig. 2.

Description of the equipment and a functional block diagram

We are presenting an instrument designed for selective measurements of electric and magnetic components of ULF signals of lithospheric and magnetospheric origin at the Earth's surface. The electric pulsations are measured in DC – 1 Hz frequency range. Frequency selection criteria have been adapted for a successive discrimination of both sorts of signal [3,4,5]. Due to the large amplitude variations of signals, the whole DC - 1 Hz frequency range is divided into 2 sub-bands: DC - 0.02 Hz (BW1) and 0.002 - 1 Hz (BW2). This allows for parallel processing of the signals from both sub-bands. Magnetic components are measured in BW2 sub-band only. Both magnetic and electric signals are measured in East-West and North-South direction. The instrument consists of sensors, analogue module, digital interface block, IBM compatible PC and a modem. The instrument allows for:

1. Stand-alone operation at remote sites.
2. Multi-point synchronized observations and centralized data acquisition.

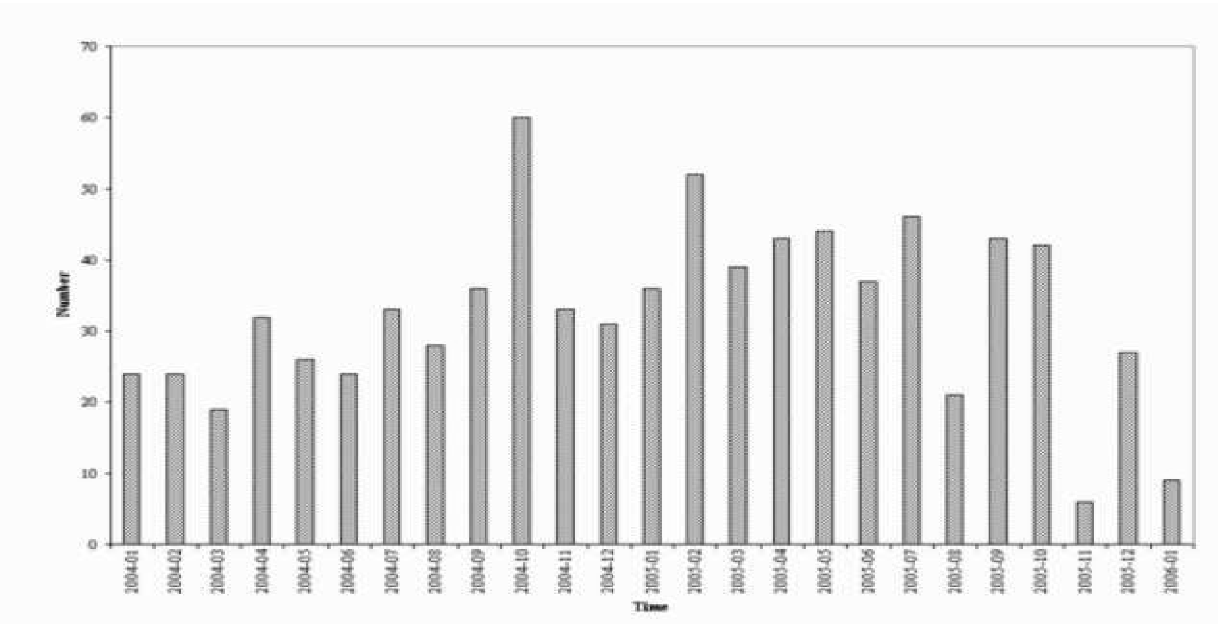

Fig. 3.

Sensors

The electrical sensors are corrosion-resistant metal bodies, buried in the ground. Depending on the soil composite and the level of moisture saturation, the contact sensor-ground resistance varies in the range 50 Ω - 50 kΩ. The sensors are placed at distance of several hundreds meters from each other and from the instrument. The magnetic sensors are separate units with their own power supply.

Analogue Module

The analogue module is galvanically decoupled from the digital module and the PC through optocouplers, with a separate power supply. The entire block diagram is shown in Figure 1. The analogue module deals with the correct reception, amplification and subsequent discrimination of the signals derived from the electric and magnetic sensors. The signals are divided into 2 sub-bands and converted into digital pulses with varying frequencies. The input resistance (Rin) of the electric sensors is greater than 10^{12} Ω. The filter (F) suppress parasite signals outside the active DC-1 Hz bandwidth, especially those from industrial power lines 50 Hz/60 Hz and their respective harmonics. The Instrumentation Amplifier (IA) provides the signal difference between each pair of electric sensors for further processing. The Low Pass Filters (LPF), High Pass Filters (HPF) and the Amplifier (A) divide the signals from each pair of electric sensors in two sub-bands.

The same procedure is followed for the signals from the magnetic sensors in BW2 band. Each of the analogue signals is then converted into pulse sequences with varying frequencies by using Voltage-Frequency Converter (VFC) and then fed into the digital module via optocouplers (O).

Digital module

The digital module works as a frequency meter. The number of pulses of each pulse sequence, counted in a time frame of 0.1s, defines the instant frequency of the respective channel. The digital module converts the instant frequencies into 12 bit words and save them in the PC. The sampling rate of BW1 range is 1/60 Hz, while that of BW2 range is 5 Hz. The digital module is designed in a way to be directly integrated in the IBM AT PC. The digital module also generates commands controlling the calibration of the analogue module. On Figure 4, the digital module is marked as INTERFACE.

A supporting software package is developed to assure to proper functioning of the instrument. It consists of a software, supporting the measurements (MS) and a software, supporting the data acquisition (DAS). MS performs the real-time astronomic synchronization and re-scaling of the measured signals and their storage in the local PC. MS provides a visualization of the measured signals from BW2 bands in the last 90 seconds and the signals from BW1 bands in last 9 hours. DAS is responsible for acquisition and collection of the data from all measurement sites. DAS supports an operational database. The software package supports the transfer of data from the measurement sites and acquisition center through modems.

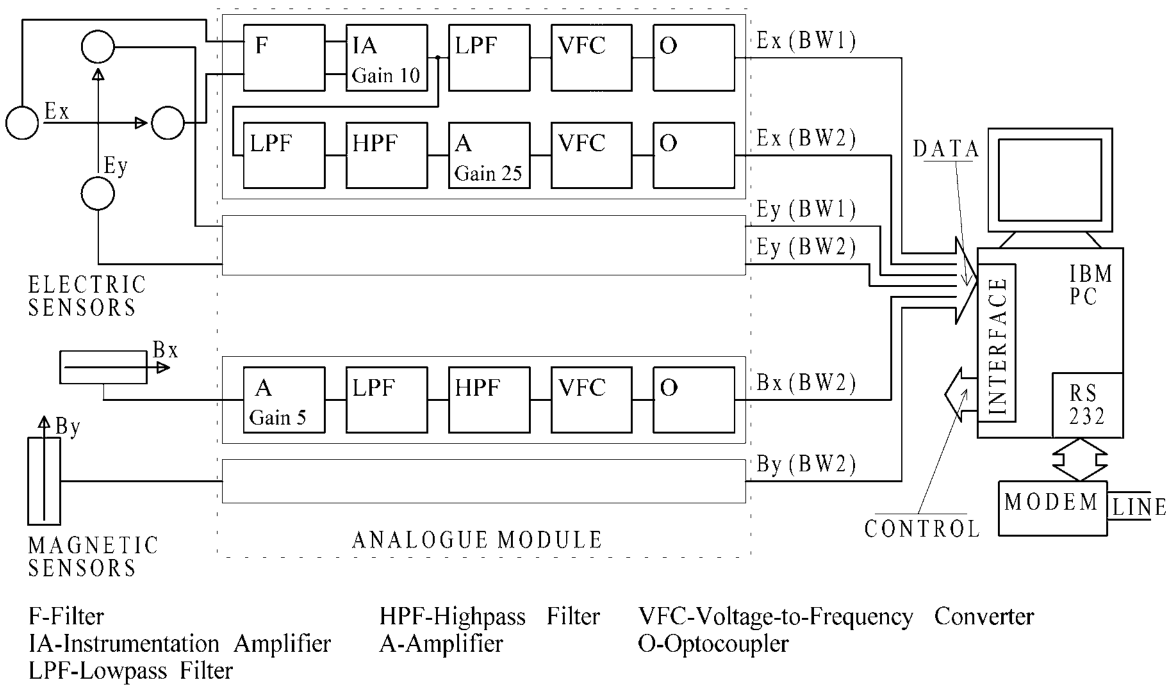

Fig. 4. Functional block diagram of instrument.

Summary of the technical characteristics of the instrument

1. The input electric signals are differential voltage between two sensors placed in the ground at a distance of 100 – 500 m. The electric sensors are connected to the instrument by isolated non-shielded wires. The magnetic sensors, placed at a distance of 25 m from the instrument, are connected by shielded cables.

2. Dynamic range and frequency range: Dynamic range of quasi-static electric signals and those in frequency band DC ÷ 0,02 Hz is -0,5 V ÷ +0,5 V. Dynamic range of electric

signals and in frequency band 0.002 Hz ÷ 1 Hz is -0,02 V ÷ +0,02 V. Dynamic range of the magnetic field signals in the frequency band 0.002 Hz ÷ 1 Hz is -2.10^{-6} T ÷ $+2.10^{-6}$ T with resolution: ± 1.10^{-9} T.

3. Filtering and electromagnetic compatibility: The input filter (F) consists of two parts with a buffer repeater between them. The entire damping for disturbances in sin-phase with a power-line frequency 50 Hz exceeds 100 dB.

Analysis of electro-magnetic ULF data

In this paper an analysis of electro-magnetic ULF data were performed. To avoid any anthropogenic factors we used data set gathered only in night hours. Hence, both the ionospheric influence effects and anthropogenic effects were minimized. Two data intervals of length ~1 month were chosen for our analysis. The first month interval was 25 July – 21 August 2003 and the second one – September 2004. In the first interval the geomagnetic activity was low to moderate with one exception – a recurrent geomagnetic storm occurred at 17–21 August 2003. In the second one, 01-30 September 2004 no geomagnetic storm was registered, the Kp index was low to moderate – less than 4 ÷ 4.5.

Local weak earthquakes of magnitude of ~ 3–3.5 have been registered during these monthly intervals. Most of them struck at distances ~ 50 and more km from Krupnik. For the chosen interval only one earthquake of magnitude greater 3, i.e. of M3.2, occurred at a distance as close as 10 km from the Krupnik station on 15 August 2003. In August 2003 a great earthquake (of Mw 6.3) however struck the Balkan peninsula (Lefkada island, Greece). The epicenter of this earthquake was at ~ four hundreds km away from Krupnik. Having in mind previous investigations our expectation was that any ULF field signatures possibly connected to the 2003 Lefkada earthquake cannot be registered at the Krupnik station. The September 2004 interval was without strong earthquakes both in Bulgaria and the Balkan peninsula.

A data set from September 2004 was used and a dispersion analysis of this data set was performed (Fig. 5). In this period we did not find long periods (more than 2 days) with stable low geomagnetic activity ($Kp < 3$). On Fig. 5 all local earthquakes with magnitude $M > 2.5$ and corresponding increases in the dispersion value are marked. As we see, no visible correlation between the local weak earthquakes and the dispersion peaks could be observed. Such a conclusion could be viable unless the geomagnetic activity level is very low. In September 2004 the mean Kp index was around 3, i.e. the geomagnetic activity was close to moderate (Fig. 6). Reminder that all year 2004 was characterized with such moderate geomagnetic activity.

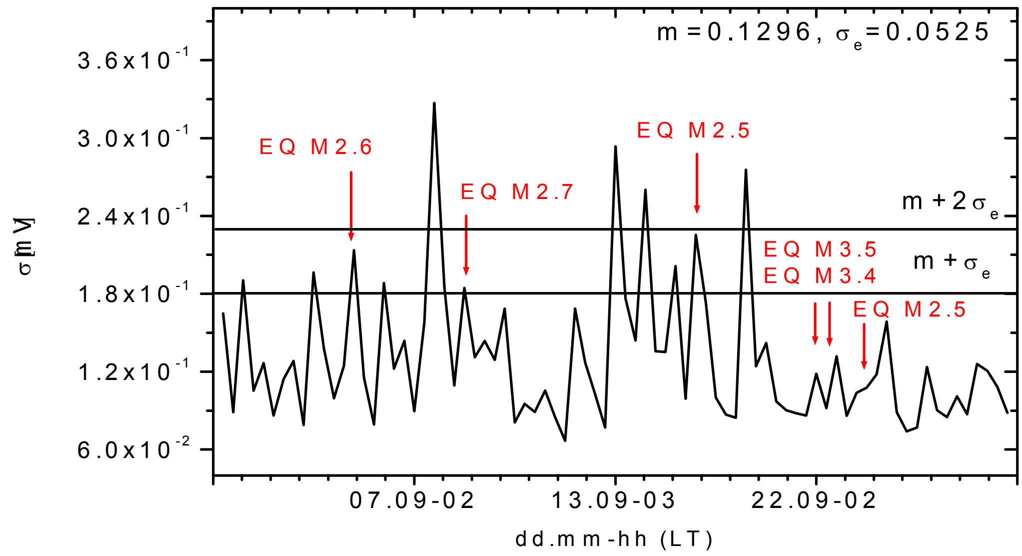

Fig. 5.

Figure 7 reveals the data dispersion dynamics in August 2003. Besides the geomagnetic activity-related ULF noise enhancements, the data also reveal a number of pulse-rate peaks, which could not be correlated with the ULF magnetospheric, ionospheric and atmospheric events. Such a period was 08-17 August 2003. Under quiet geomagnetic activity conditions that last more than 5 days, the dispersion analysis indicates that the ULF noise activity possesses anomalous peaks in his day interval. The greatest one emerges on 13. August 2003. This day precedes the great Lefkada earthquake (on 14 august 2003) and the local one (on 15 August 2003) [6]. In all night hours, just before the time Lefkada earthquake occurred (05:14:55 UT), the dispersion is stable above the mean dispersion. This unusual day is preceded by very low dispersion trend visible on 11-th and 12-th August 2003. The dispersion sharply increases steeply again at the beginning of 17th August 2003 when the recurrent geomagnetic storm took place.

Our results on the data dispersion were based on August-September season only. First, we did not obtain any evidence for possible correlation between the local weak earthquakes and the data dispersion. The outcome is explainable by the fact that when the geomagnetic activity is moderate and/or high, any ULF signals possibly connected with the pre-seismic processes could not be discriminated. Instead, other methods, e.g. polarization ones or Z/H ratio of the ULF magnetic field, are also needed.

Fig. 6

In this study we showed initial results on the ULF electrotelluric field dynamics registered at Krupnik (South-West Bulgaria, Balkan peninsula). We observed various ULF spectra and identified the sources of some of them. Nevertheless, there was anomalous ULF events unexplained so far.

The investigation presented here suggests that this seismic zone remains one of the most active zones in Bulgaria and any search for electromagnetic precursors there has a future.

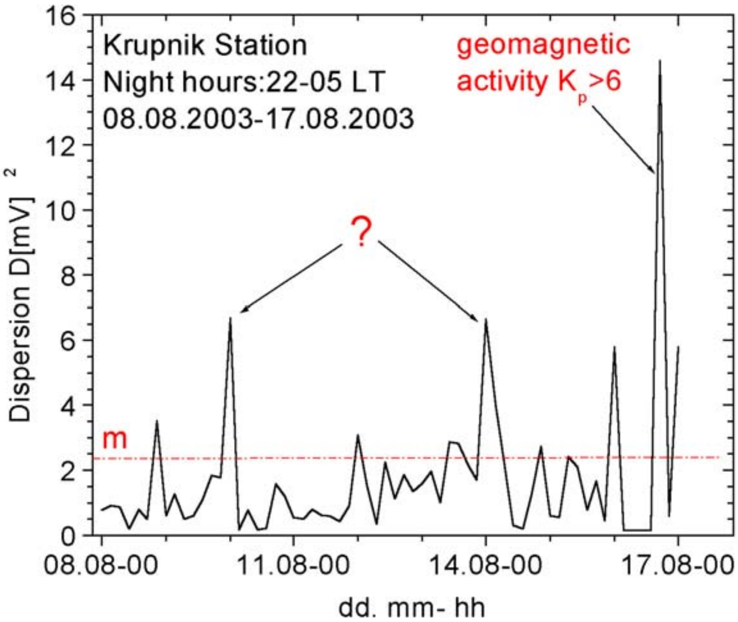

Fig. 7.

For extensive search of electro-magnetic precursors the need for expanding the network at the other NOTSSI stations is quite obvious also.

Acknowledgement

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