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ELECTROMAGNETIC VARIATIONS ASSOCIATED WITH THE SEISMICITY OF THE FRONTAL HELLENIC ARC

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Abstract: In the present paper we report the results of almost three years of measurements of the electromagnetic variations in 3 and 10 kHz, 41 and 53 MHz. The data are collected using a telemetric network installed along the island of Crete, i.e. in the central segment of the South Hellenic arc. The experiment indicates that electromagnetic perturbations occur prior to seismic activity and supports previous observations that the time sequence of the variations appears in an invariant pattern.

Key words: seismoelectromagnetism, Greece, Hellenic arc.

Introduction

A number of electromagnetic phenomena associated with earthquakes have been reported in recent time in different frequency ranges. There are slow magnetic field variations which are claimed as a useful tool for earthquake prediction (Shapiro et al. 1994). Ultra low frequency (ULF) electromagnetic emissions (0.01–10 Hz) (Fraser-Smith et al. 1990), ELF-VLF electromagnetic radiation (0.1–100 kHz), (Gokhberg et al. 1982; Fujinawa & Takahashi 1990; Nomikos et al. 1994) and HF emission (f>1 MHz) (Nomikos et al. 1997) are also associated with earthquakes.

In order to study the aforementioned preseismic electromagnetic phenomena, a telemetric system has been installed on the island of Crete (South Aegean, Greece). Structurally, our test area is linked with the frontal part of the central segment of the Hellenic arc. The south Aegean is an appropriate place for our experimentation, because in this area the existence of shallow and intermediate depth seismicity has long been recognized (Hatzfeld & Martin 1992).

The latter multipoint network records the earth's electromagnetic field variations in four field stations installed along the island of Crete. In each field station, we measure, using tuned loop antennas, the two horizontal components of the electromagnetic field variations, in low frequencies (LF), i.e. in 3 and 10 kHz. Using half-wavelength dipoles we measure high frequencies (HF), i.e. in 41 and 53 MHz. The central station communicates with a datalogger in the field station and collects the data through a standard telephone line (Fig. 1). In this work we present data recorded from the telemetric network during the time period from October 1992 to December 1995.

Instrumentation and data selection

For the observation of electromagnetic variation in each field station, the following instruments are used:

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a) Four receivers appropriate for measuring the electromagnetic field variations at 3 and 10 kHz into EW and NS directions. These receivers are constructed using wide band and low noise amplifiers and switching band-pass filters tuned by crystal oscillators. The final stage of the receiver is an RMS to DC converter. Thus, the output V_{out} of the receiver is a DC voltage proportional to the power spectrum density Φ_H of the magnetic field which excites the antenna and is given by the expression

$$V_{out} = \omega\mu_o N\alpha^2 Q_{\mathbf{A}}\, G(\Phi_H\, \Delta f_{\mathbf{F}})^{1/2}$$

where N, α and $Q_{\mathbf{A}}$ are the number of turns, the radius and the quality factor of the antenna, respectively. Δf_F is the bandwidth of the filter, G is the total gain of the system, $\mu_o = 4\pi.10^{-7}$ H/m the magnetic permeabilitty of free space and ω the angular frequency of the electromagnetic wave.

b) Two receivers for measuring the electric field variations at 41 MHz and 53 MHz. The receivers are constructed using double supper heterodyne technology and the output in each of them is a DC voltage which is proportional to the

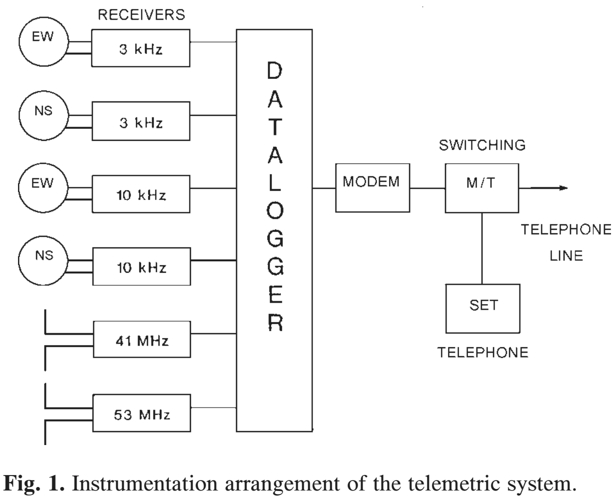

Fig. 1. Instrumentation arrangement of the telemetric system.

electric field which appears on the antenna. The antennas used for these very high frequencies are horizontal half-wavelength dipoles tuned at the above frequencies.

c) a datalogger that is the main instrument for reading the analog information from the electromagnetic receivers. The sampling rate was taken on a channel basis every second, and the average value of 60 samples for each channel saved in the final memory. The signal from the field station was transmitted through a telephone line to the Central one (Fig. 1).

We would like to point out that the most crucial point in our experiment was to determine noise free observation frequencies. A number of transmitting stations radiate electromagnetic signals at almost all frequencies over and around the island of Crete. To make sure that the observation frequencies were silent, they were checked using a radio receiver, for several months. We emphasize that a criterion for the selection of an electromagnetic variation as a preseismic signal, associated with an event of magnitude Ms approximatly grater than 5.0, should be its existence in both components simultaneously, otherwise they could be artificial interference. Any interference from mobile transmitters at these two frequencies obviously will produce spikes on the recordings for at most a few minutes and in the specific frequency of the transmitter and not simultaneously in both of them. Furthermore, in order to localize the anomalous pattern, artificial intelligence techniques have recently applied (Yalouris et al. 1996). Among other criteria the latter technique is checking the change with time of the mean level and the sampling variance of the background noise.

Observational results

Recording of the electromagnetic variations started in October 1992.

We proceed now to the presentation of the recordings obtained from October 1992 to December 1995. Table 1 shows

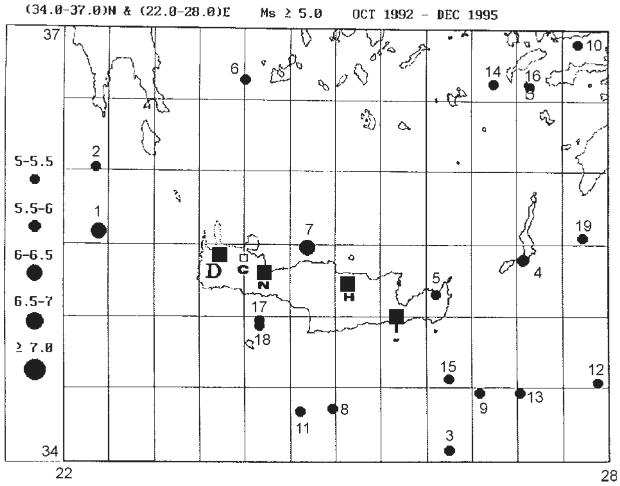

Fig. 2. Map showing the sites of the stations of the telemetric network and the distribution of epicentres of earthquakes with Ms>5 in the vicinity of Crete, from October, 1992 to December, 1995 (see Table 1).

all the earthquakes with Ms magnitude greater than 5 in the vicinity of Crete (latitude: 34–37, longitude: 22–28) during the above time window. The stations of our network and the frequencies in which electromagnetic emissions were observed prior to earthquakes are shown in Table 1. Fig. 2 shows the earthquakes during the aforementioned period. Furthermore, the field stations of the telemetric network indicated by their initial (i.e. N = Nipos, I = Ierapetra, H = Heraklion and D = Drapanias).

Figures 3 and 4 show typical recordings of an electromagnetic variation prior an earthquake.

In a recent paper the time sequence of seismoelectromagnetic events studied constructed time charts (Nomikos et al. 1997). The conclusion was that a sequence of electromagnetic events which precede an earthquake exists. In all the examined cases the LF variations (i.e. in 3 and 10 kHz)

Table 1: List of the earthquakes with electromagnetic variations collected at the stations of the network. The position of the observation station inticated by its initial i.e. N = Nipos, I = Ierapetra, H = Heraklion and D = Drapania.

No	Date		Time	Lat.	Long.	Ms	H	3	10	41	53	REM
							km	kHz		MHz		
								Stations				
1	1992	NOV 21	05:07:19.4	35.58	22.39	6.0	70	NDH	NDH	NDH	NDH	
2	1993	JAN 27	23:41: 1.0	36.02	22.36	5.4	120	N	N	ND	ND	
3	1993	JUN 1	09:45:25.2	34.07	26.25	5.2	1	—	—	—	—	
4	1993	JUN 29	04:37:12.5	35.39	27.07	5.5	1	I	I	ND	ND	
5	1993	AUG 18	12:09:26.1	35.15	26.11	5.2	72	NDI	NDI	NDH	NDH	
6	1993	OCT 1	03:59:34.3	36.64	24.01	5.4	109	NHI	NHI	NDI	NDI	
7	1994	MAY 23	06:46:17.3	35.48	24.70	6.0	66	NDI	NDI	ND	ND	
8	1995	FEB 3	22:29:14.1	34.35	24.97	5.0	38	HN	HN	-	-	
9	1995	FEB 16	13:02:22.5	34.46	26.59	5.0	28	N	N	-	-	H,D,I=NOP
10	1995	MAR 7	03:58:11.9	36.90	27.67	5.0	5	HN	HN	HN	HN	D,N=NOP
11	1995	MAR 30	18:17:17.1	34.33	24.61	5.1	1	HI	HI	HI	HI	D,N=NOP
12	1995	APR 5	07:52:13.8	34.53	27.88	5.0	35	HI	HI	-	-	
13	1995	JUL 29	07:59:35.9	34.46	27.03	5.0	1	DNH	DNH	DNI	DNI	
14	1995	AUG 22	05:34:17.7	36.62	26.74	5.4	179	N	N	N	N	
15	1995	SEP19	01:48:10.1	34.56	26.25	5.0	1	DNHI	DNHI	I	I	
16	1995	NOV 30	11:49:35.4	36.60	27.14	5.3	136	HNI	HNI	-	-	
17	1995	DEC 7	18:00:58.3	34.97	24.17	5.1	22	N	N	NHI	NHI	D=NOP
18	1995	DEC 10	03:27:53.0	34.93	24.17	5.4	24	N	N	NHI	NHI	D=NOP
19	1995	DEC 18	19:28:11.9	35.54	27.73	5.1	1	NI	NI	I	I	

NOP= Station not in operation during this period

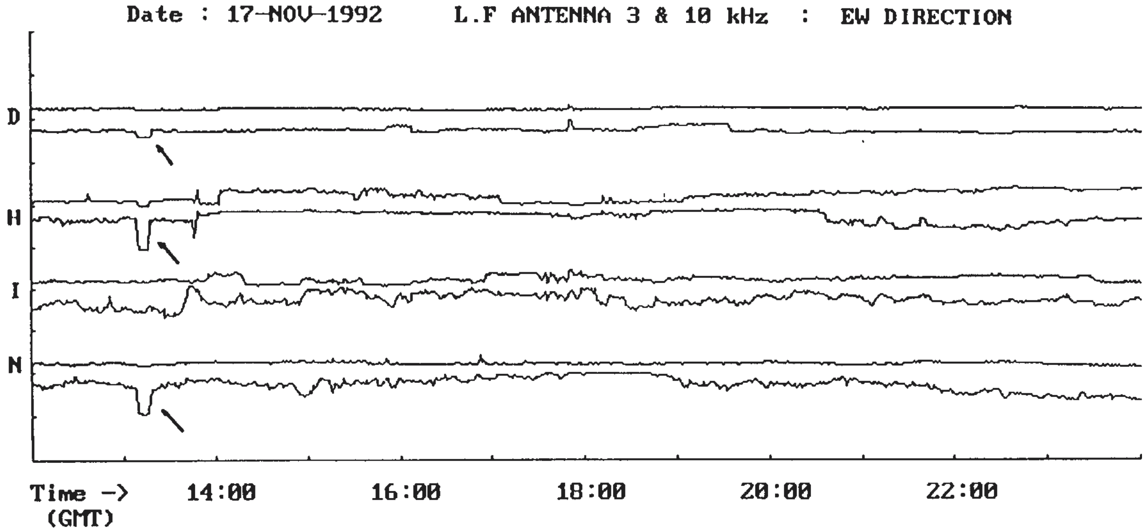

Fig. 3. Electromagnetic variation at 3 and 10 KHz in EW direction, recorded prior to November 21st 1992 earthquake.

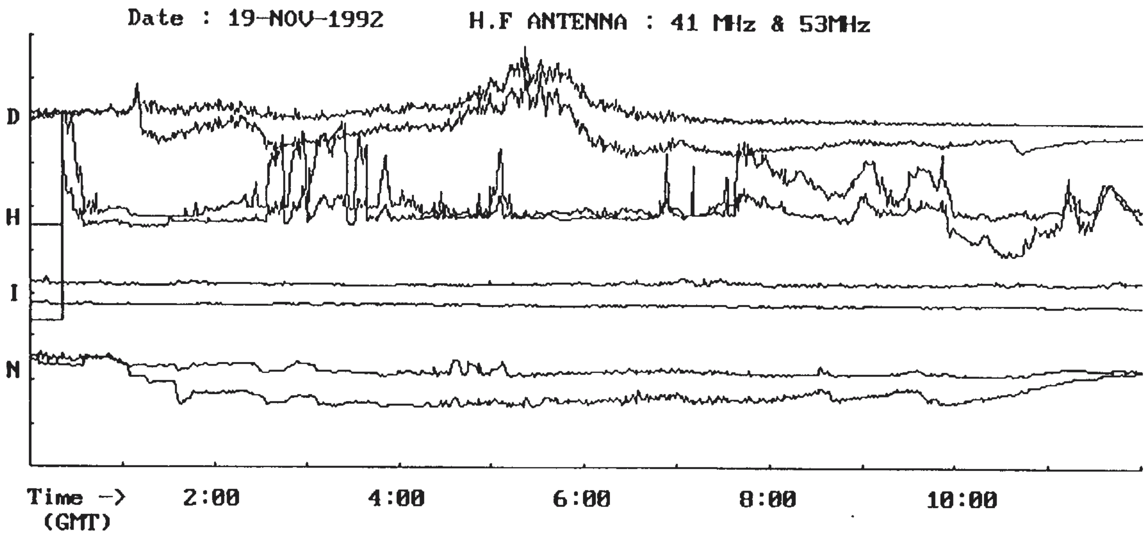

Fig. 4. Electromagnetic variation at 41 and 53 MHz, recorded prior to November 21st 1992 earthquake.

always precede the HF variations (i.e. in 41 and 53 MHz).

In the present paper we will discuss more specificly the electromagnetic variations which preceded the November 21st 1992 and May 23rd 1994 intermediate depth earthquakes which were the strongest in magnitude events in the study territory.

The first one on November 21st 1992 with Ms 6, epicenter at (35.9° N, 22.5° E) and focal depth 70 km belongs to the seismogenic source zone 1A, as identified by Papazachos (1990); this source region lies under the eastern part of Peloponnese but extends to the north up to 39° latitude and to the south up to the western corner of the island of Crete. The second earthquake, on May 23st 1994 with magnitude Ms = 6, epicenter at (35.48° N, 24.70° E) and focal depth 66 km belongs to source volume 1B, which lies under the island of Crete (see Fig. 1 of Kiratzi & Papazachos 1995).

a) Electromagnetic variations prior to the November 21st 1992 earthquake

(i) At the low frequencies, 3 and 10 kHz, on November 17th 1992 and at 13:15 GMT, for a time period of 15 minutes a simultaneous electromagnetic variation was recorded, at Drapania, Nipos and Heraklion and in both measuring directions. The strongest signal appeared in Heraklion and the weakest in Drapania. Ierapetra being the furthest from the epicenter, did not record any signal.

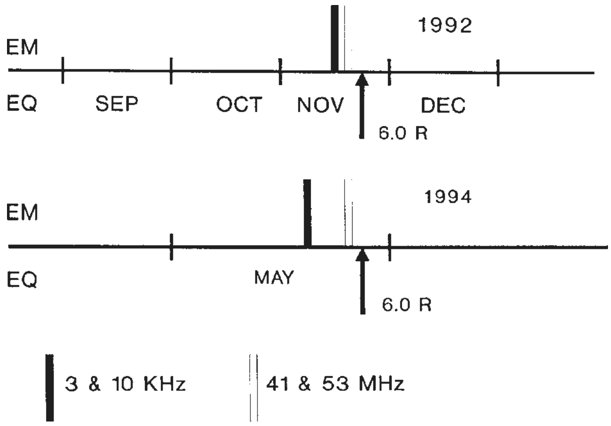

Fig. 5. Time chart depicting the electromagnetic variations in association to the Ms = 6 earthquakes of November 21st 1992 and May 23rd 1994 to December 1995. Both of them have epicenters in the vicinity of Crete (see Fig. 1). The arrows indicate the earthquake events.

(ii) At high frequencies the electromagnetic variations started mainly from 1:00 GMT of November 19th 1992 and continued until 22:00 GMT of the same day, even though slight variations did continue through the following day. It can be seen that the strongest signals were recorded at the nearest (to the epicenter) station of Drapania.

b) Electromagnetic variations prior to the May 23rd 1994 earthquake

(i) At the low frequencies, 3 and 10 kHz, on May 17th 1994 and at 6:00 to 16:00 GMT a simultaneous electromagnetic variations was recorded, at Drapania, Nipos and Ierapetra and in both measuring directions. The strongest signal appeared in Drapania and the weakest in Ierapetra. The strange thing is that station Heraklion being quite close to the epicenter, did not record any signal, either at low or high frequencies.

(ii) At high frequencies the electromagnetic variations were detected at 14:00 to 18:00 GMT of May 22nd 1994 at Drapanias and Nipos stations.

In Fig. 4 we see the time charts describing the sequence of electromagnetic events. We observe the already reported time pattern, i.e. LF variations - HF variations - Earthquake event.

Conclusion

In the present contribution recordings of the electromagnetic anomalies that precede to earthquakes in the time window October 1992–December 1995 are presented.

The experimental results indicate the presence of electromagnetic variations in the frequencies of 3 and 10 kHz, 41 and 53 MHz, associated with shallow and intermediate depth earthquakes in the vicinity of Crete Island (South Aegean—Greece).

The study of the time sequence of seismoelectromagnetic events the constructed time charts shows that a sequence of electromagnetic events that precede the earthquakes exists. The recently collected data strengthen the conclusion that the electromagnetic variations appears to follow an invariant time pattern (i.e. LF variations - HF variations - Earthquake event). The latter pattern suggests that the appearance of HF variations as follows of an LF anomaly observation is a strong indicator that an earthquake process is in the final stage of preparation.

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