
بسم الله الرحمن الرحيم

Periodic Seminar of Civil Aviation Technology of College

New Earthquake Prediction Methods Based on ULF-ELF Signals

Presented by

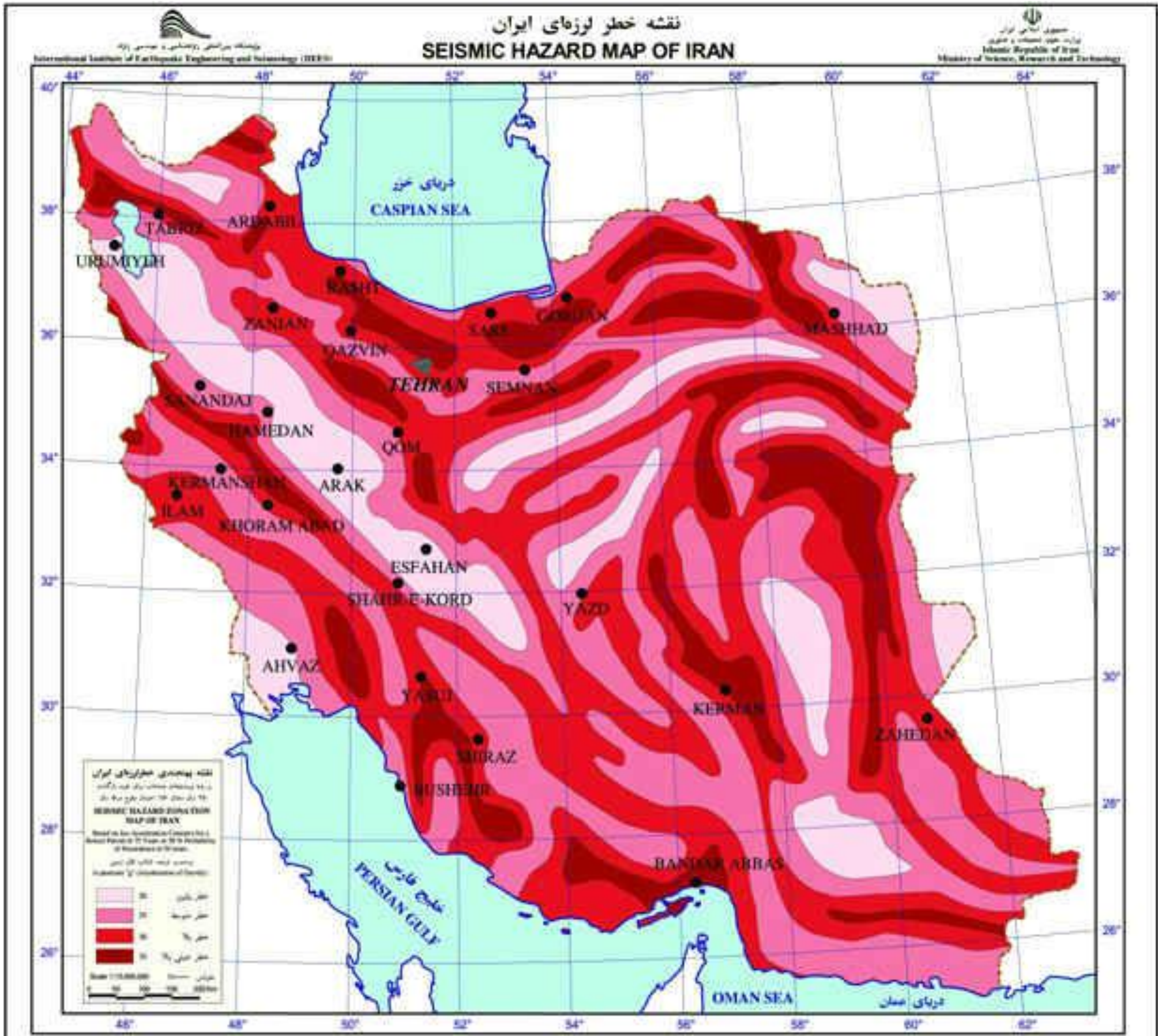
Mohammad Rashtian

7 March 2012

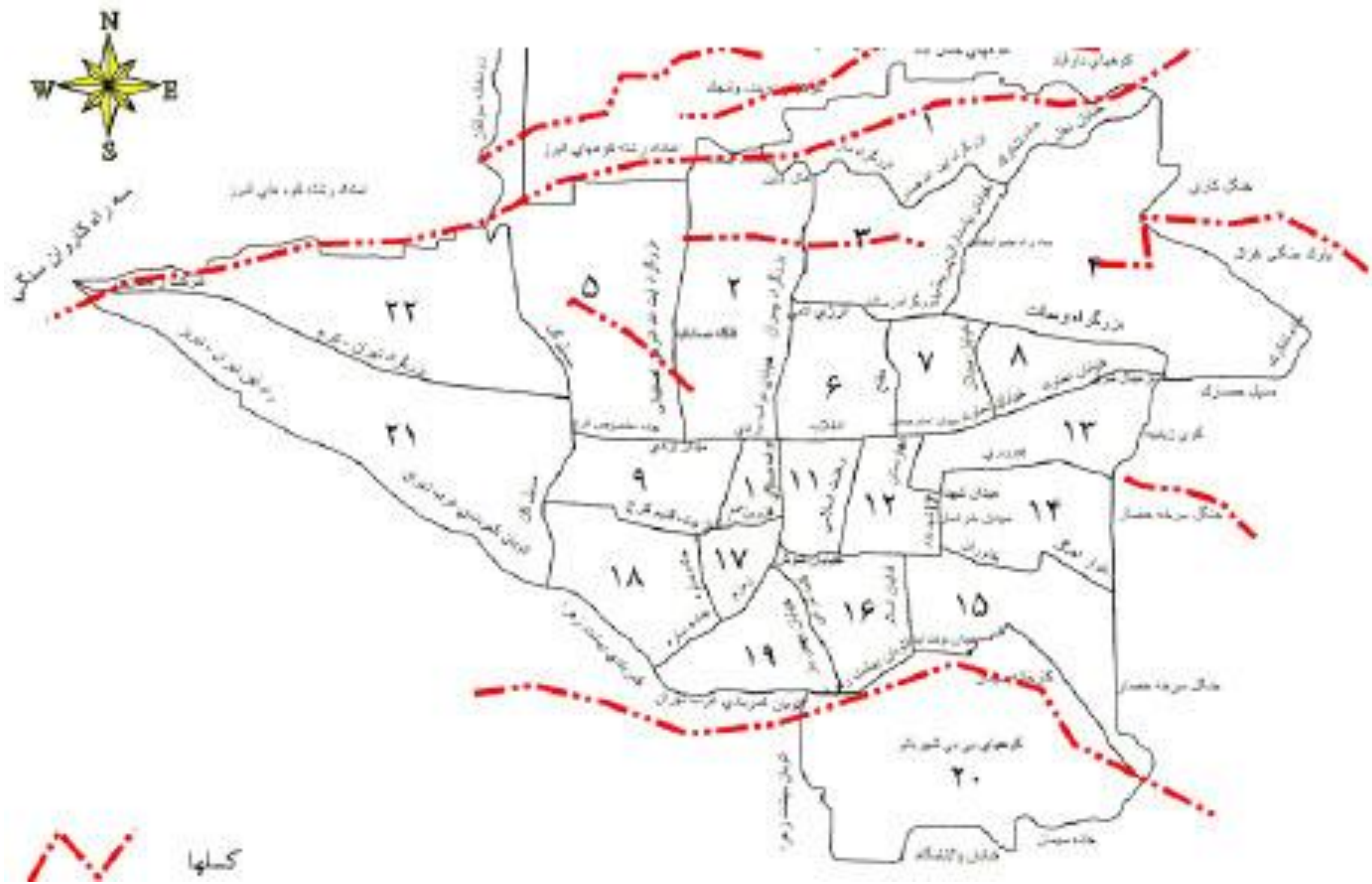
Outline

- Iran and Earthquake
- Different Methods of Prediction
- Extremely Low Frequency Electromagnetic Wave
- Sources of ELF
- First reports of Using ELF for Prediction of The Earthquake
- Review of Some Reports
- ELF Receiver Block Diagram

Seismic Hazard Map of Iran



Tehran & Earthquake



Different Methods

- Ground Water Level
- Chemical Changes in Ground Water
- Radon Gas in The Ground Water Wells
- Tilt
- Thermal Anomaly
- Animals & Earthquake Prediction
- ***ULF-ELF Electromagnetic Waves***

Electromagnetic Wave Categories

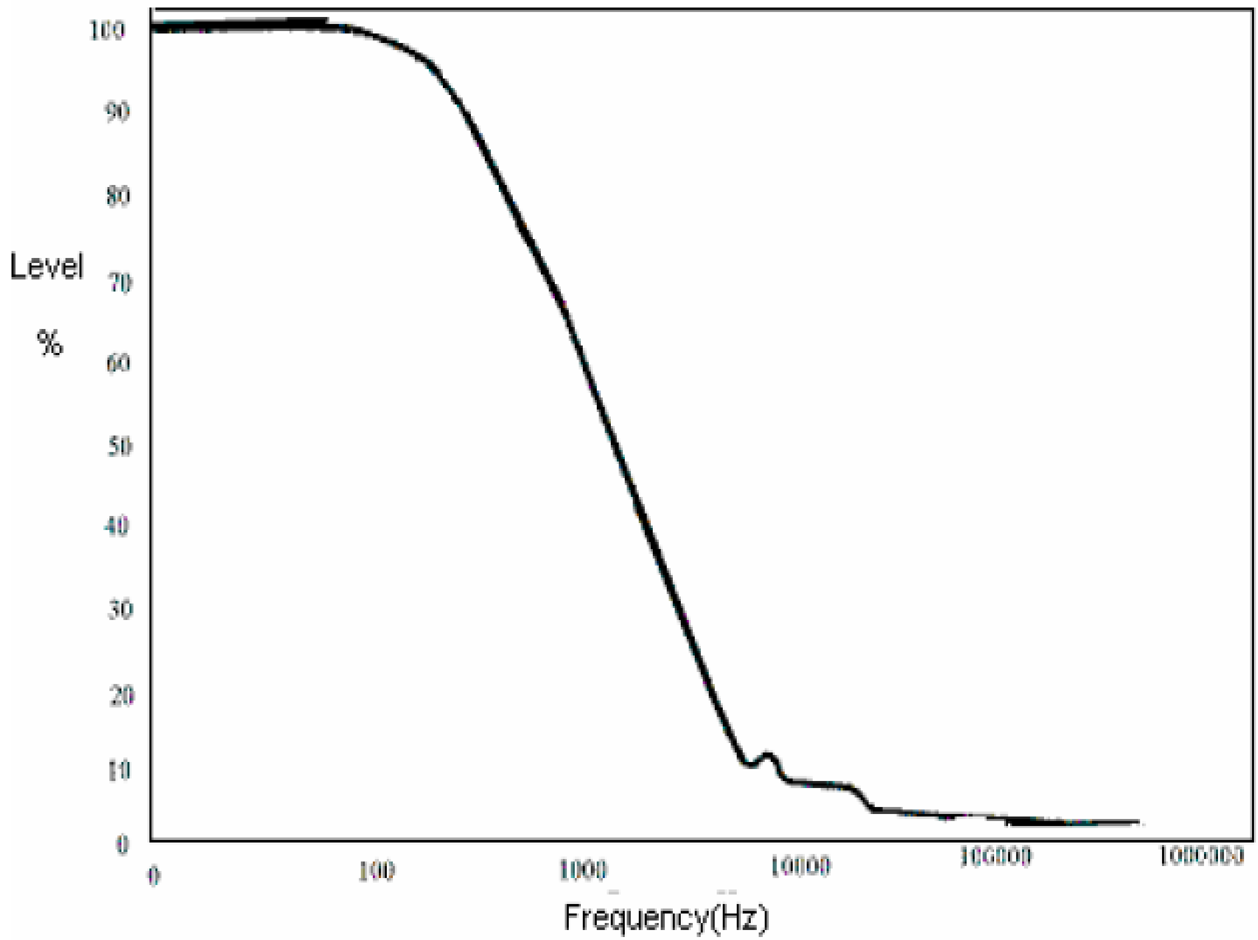
Different Frequency Categories according to IEEE Standard

	Designation	Frequency	Wavelength
ULF	Ultra Low Frequency	< 3Hz	> 100'000km
ELF	Extremely Low Frequency	3Hz to 3kHz	100'000km to 100km
VLF	Very Low Frequency	3kHz to 30kHz	100km to 10km
LF	Low Frequency	30kHz to 300kHz	10km to 1km
MF	Medium Frequency	300kHz to 3000kHz	1km to 100m
HF	High Frequency	3MHz to 30MHz	100m to 10m
VHF	Very High Frequency	30MHz to 300MHz	10m to 1m
UHF	Ultra High Frequency	300MHz to 3000MHz	1m to 10cm
SHF	Super High Frequency	3GHz to 30GHz	10cm to 1cm
EHF	Extremely High Frequency	30GHz to 300GHz	1cm to 1mm

ELF Sources(1)

- **1. Natural Sources.**
- lightning discharges
- volcanic eruptions
- dust storms
- charged particles in polar region

ELF Sources(2)



Power Spectrum Desity of a Lightening

ELF Sources(3)

- **2. Man Made Sources.**
- **Ionosphere Heaters**
- **Special Communications With Submarines**
- **Public Electricity Network**
- **nuclear explosions**

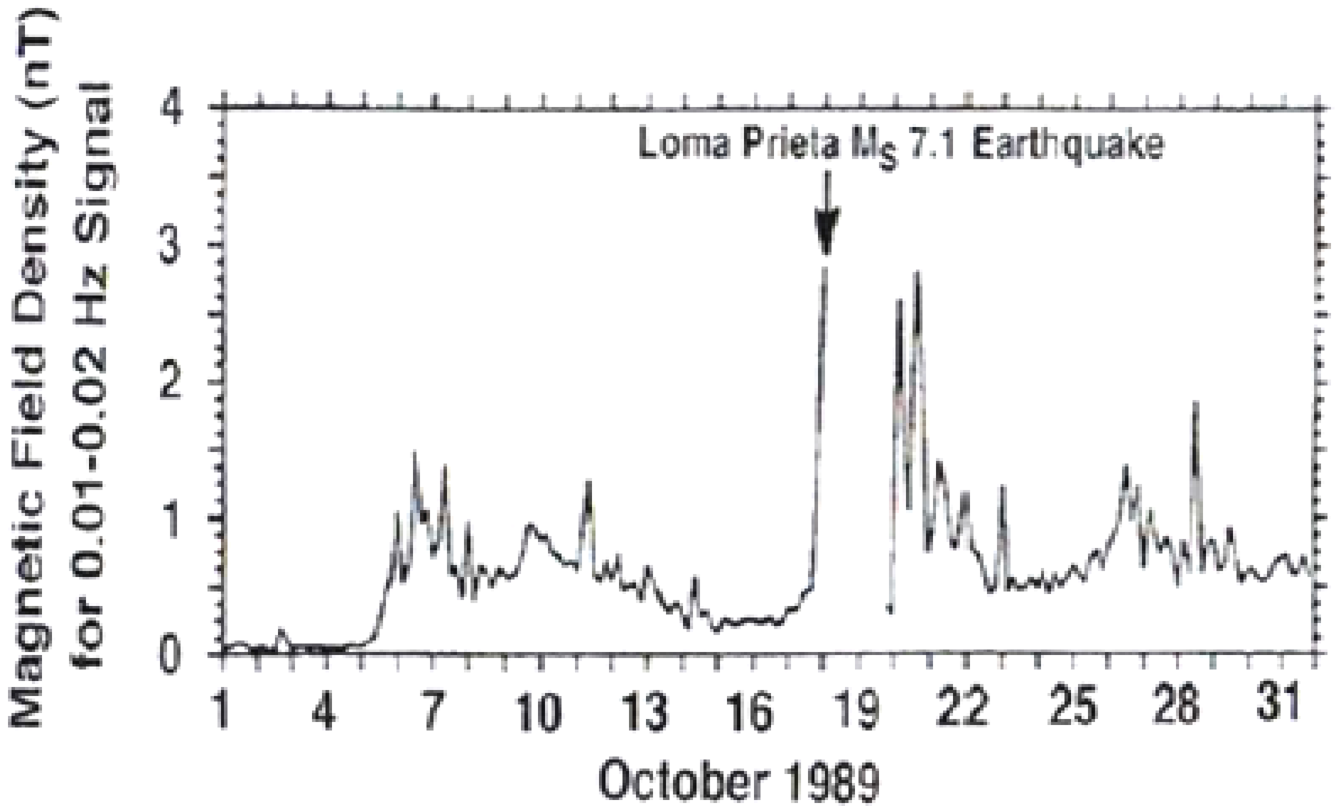
First Reports(1)

- **Gokhberg, M.B., and Morgounov, V.A. (1982)**
  The recorded noise level at 81 kHz is comparatively quiet throughout the day and night. However, about one-half hour before the main shock of a magnitude 7 earthquake at 07:33 UT on March 31, 1980, the instrument recorded an anomalous amplitude increase to 15 dB higher than the normal level. VLF data recorded synoptically at Sugadaira suggest that unusual impulsive radiation at frequencies below 1.5 kHz also occurred shortly before the earthquake. Similar 81-kHz emissions were observed prior to magnitude 5 and 6 earthquakes on September 25, 1980, and January 28, 1981.

First Reports(2)

- Fraser-Smith, A.C. ; *et Al.*(Stanford Univ), 1990 Aug, 7.1 Loma Prieta Earthquake, (17 October 1989), San Francisco
- Using of 25 narrow frequency bands (0.01 Hz-32 kHz) with two Independent Receivers(7&52Km from epicenter)
- On 3 October, two weeks before the quake, Fraser-Smith's sensors registered a huge jump in the ULF magnetic field at the 0.01-Hz frequency—about 20 times that of normal background noise at that frequency. Three hours before the quake, the 0.01-Hz signal jumped to 60 times normal. Elevated ULF signals continued for several months after the quake, a period rife with aftershocks, and then they disappeared.

First Reports(3)



How the current is generated?

- **Piezoelectricity**

- **ionized groundwater move into the cracks.**

Case Study(1)

- CHI-CHI Earthquake in Taiwan
  - Chi-Chi earthquake in Taiwan at 02:27 Japanese Standard Time on 21 September 1999 (M = 7.6; depth 11 km).
  - The equipment consists of three-orthogonal magnetic sensors (induction coils). The frequency range of observation is from 0.001 Hz to 50Hz.

Case Study(2)

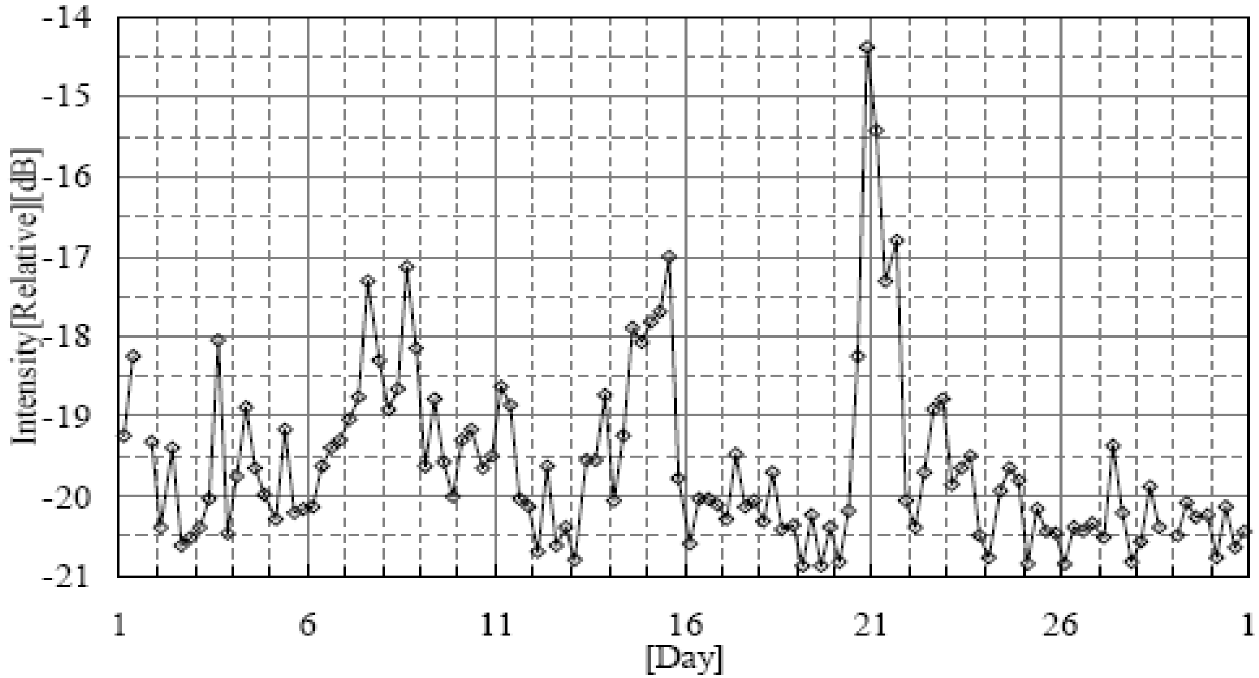


Fig. 3. Temporal evolution of the magnetic field $\left(\sqrt{B_X^2 + B_Y^2}\right)$ at a frequency of 10 Hz during 1 to 30 September 1999. Each square indicates the magnetic field intensity averaged over 6 h.

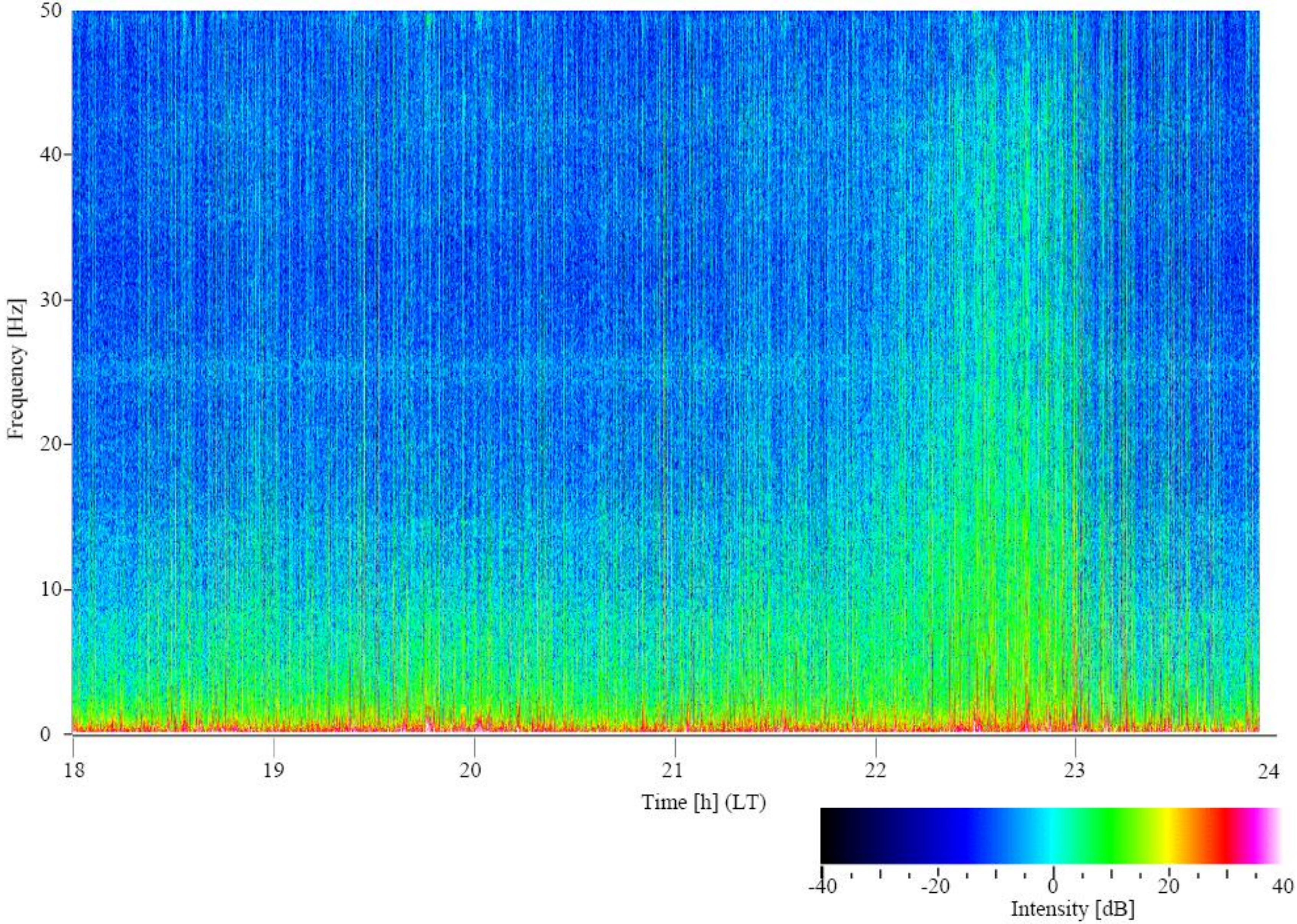


Fig. 6. Dynamic spectrogram during 18 h to 24 h on 20 September (in colour format).

Case Study(3)

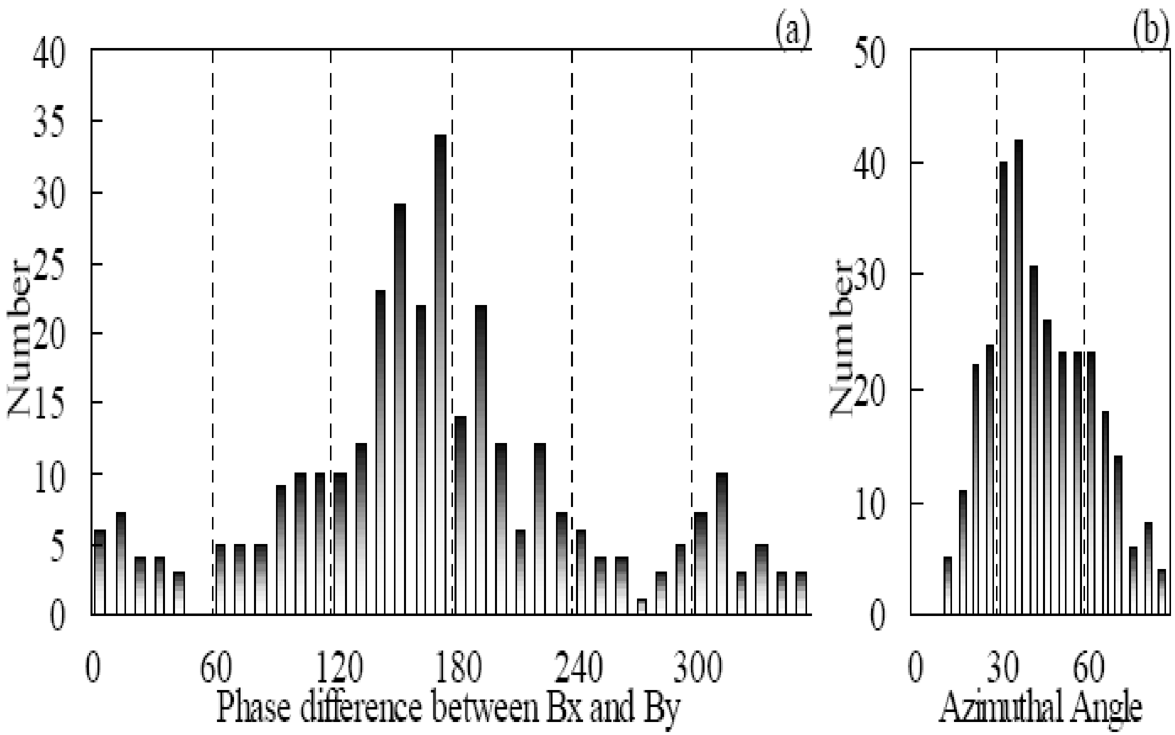


Fig. 7. (**a**) Phase difference between B_X and B_Y for the ELF background emission and (**b**) the corresponding azimuth angle determined by the goniometric method.

Case Study(4)

- Gujarat earthquake in March 2006
  - 7 March 2006, of magnitude 5.5 on the Richter scale.
  - The epicentre of this activity was in the remote Rann of Kutch area near the border with Pakistan.
  - Strong electromagnetic emissions have been observed with the help of the DEMETER satellite in the ELF (extremely low frequency) electric and magnetic components pertaining to the seismic activity. Complementarily, we have also studied the ground based data of ULF (ultra low frequency) magnetic field and found significant enhancement of polarization ratio employing the LEMI-30i search coil magnetometer at the Department of Physics, Barkatullah University, Bhopal.

Case Study(5)

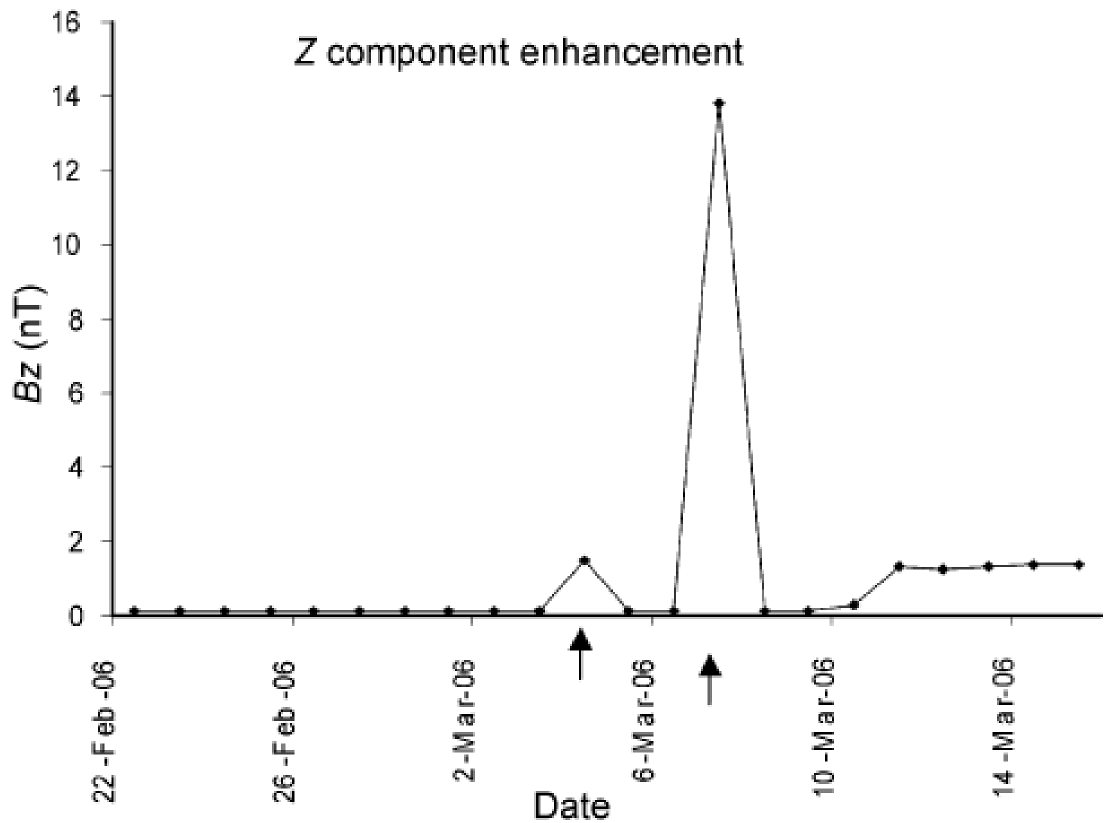


Figure 5. Vertical magnetic field variation recorded by LEMI-30i magnetometer between February and March 2006.

Earthquakes with Reported Electomagnetic Precursors

earthquake	mag.	date	type of emmission	before/during/after?	freq. range(Hz)	signal level	background level	SNR	distance from epicenter	instrumentation	reference
Armenia, Spitak	6.9 Ms	12/7/1988	ULF magnetic	b (4hours), a	0.01 - 1	0.2 nT	0.02 nT	10	128 km	3-axis high-sensitivity magnetometers	3
Armenia, Spitak	6.9 Ms	12/7/1988	ULF magnetic	b (4 hours), a	0.005 - 1	0.1 - 0.2 nT	0.03 nT	6.67	120 km and 200 km	-	6
Guam	7.1 Ms	8/8/1993	ULF magnetic	b (1 month)	0.02 - 0.05	0.1 nT	not reported	-	65 km	3-axis ring-core-type fluxgate magnetometer	4
Loma Prieta, CA	7.1 Ms	11/19/1989	ELF/VLF EM	b (3 hours), d	0.01	5 - 60 nT Hz-1/2	~1 nT Hz-1/2	-	52 km	ground-based magnetometers	8
Loma Prieta, CA	7.1 Ms	11/18/1989	ULF magnetic	b (3 hours), a	0.01	4-5 nT	not reported	-	7 km	-	3
Loma Prieta, CA	7.1 Ms	11/18/1989	ULF magnetic	a	0.01 - 10	1 nT	not reported	-	7.3 km	proton magnetometers	5
Armenia region	-	1989	ELF/VLF EM	b (3 hours)	140 Hz	10 mγ	not reported	-	6 deg. in long, 2 - 4 in latitude	COSMOS-1809 satellite	7

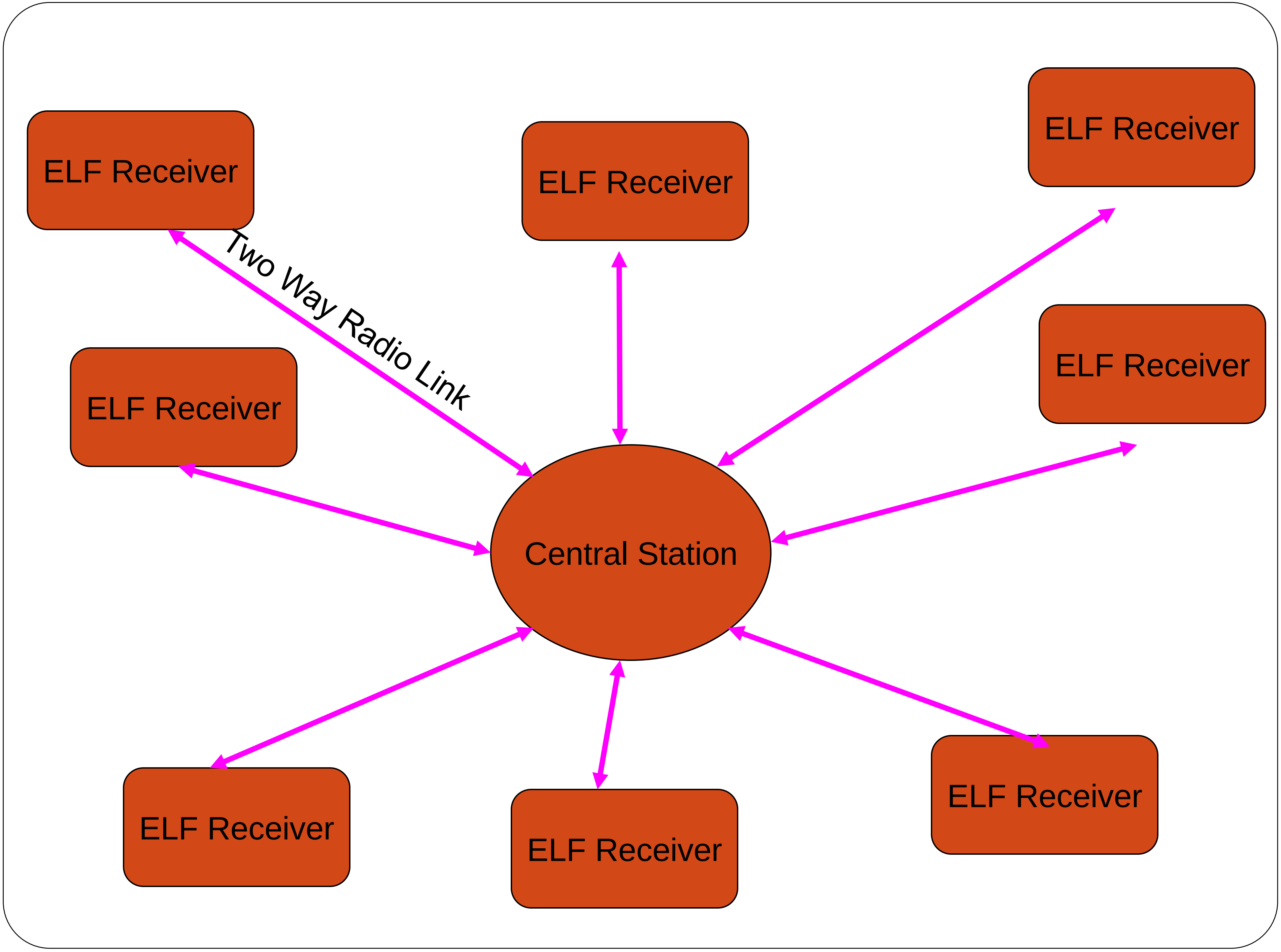
Earthquakes with Reported Electomagnetic Precursors

earthquake	mag.	date	type of emmission	before/during/after?	freq. range(Hz)	signal level	background level	SNR	distance from epicenter	instrumentation	reference
Armenia region	-	1990	ELF/VLF EM	b (3 hours)	450 Hz	3 mγ	not reported	-	6 deg. in long, 2 - 4 in latitude	COSMOS-1809 satellite	7
worldwide (325 eq's)	Ms > 5	-	ELF/VLF EM	b (0-4 hours)	140 Hz	3.28E-5 γ Hz-1/2	1.53E-5 γ Hz-1/2	2.14	Δ long < 10 deg.	ARCAD 3 aboard AUREOL 3 satellite	2
worldwide (325 eq's)	Ms > 5	-	ELF/VLF EM	b (0-4 hours)	800 Hz	9.08E-5 γ Hz-1/2	1.57E-5 γ Hz-1/2	5.78	Δ long < 10 deg.	ARCAD 3 aboard AUREOL 3 satellite	2
-	Ms > 5.5	-	LF radiowave	-	-	102-103 V m-1	-	-	60 deg. in long, 2 in latitude	Intercosmos 19 satellite	2
Upland, CA	4.7	4/17/1990	ULF magnetic	b (1 day)	3.0 - 4.0	- 40 dB	- 46.8 dB	-	160 km	vertical magnetic sensor	1
Watsonville, CA	4.3	3/23/1991	ULF magnetic	b (data averaged over 2 days)	3.0 - 4.0	- 43 dB	- 47.6 dB	-	600 km	north-south magnetic sensor	1
Watsonville, CA	4.3	3/23/1991	ULF Magnetic	b (data averaged over two days)	3.0 - 4.0	- 44 dB	- 46.8 dB	-	600 km	vertical magnetic sensor	1

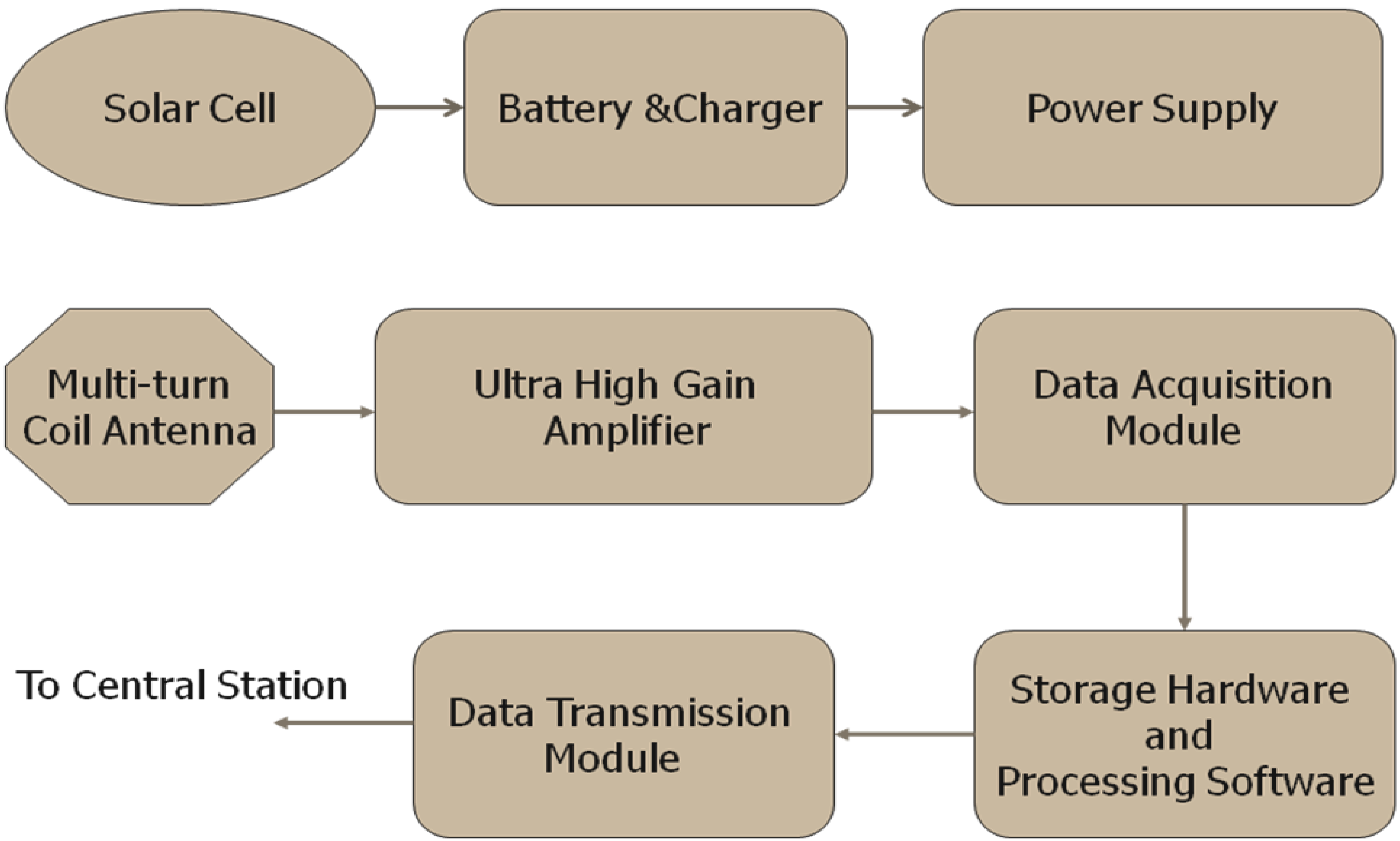
References of this page

ELF Receiver(1)

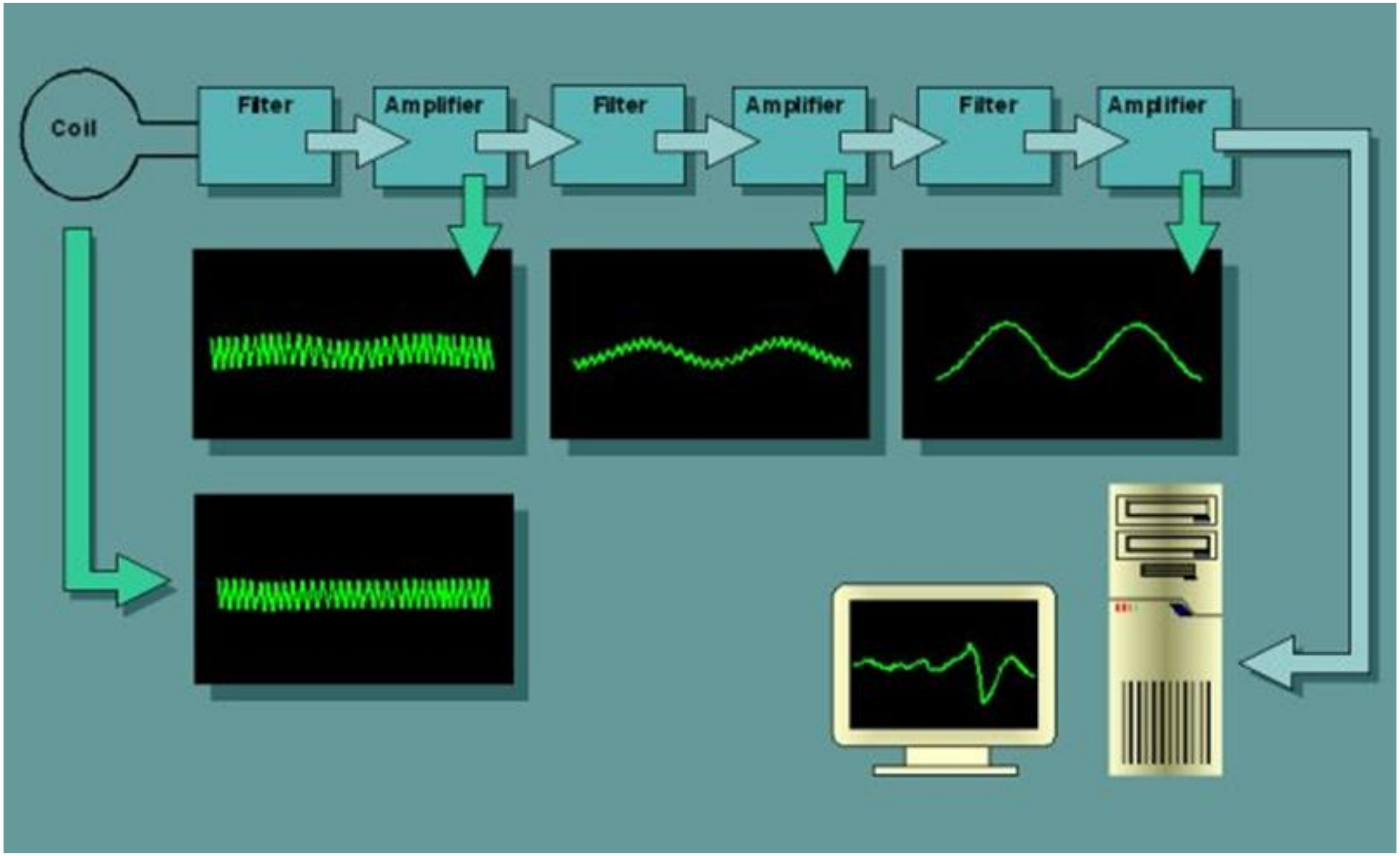
- Extremely Large Typical Antenna
- Extremely High Gain Amplifier
- Very Complicated Configuration Due to the Effect of 50Hz Power Distribution Line
- Distance of Receivers ?
- Elf Receiver should be work with A VLF Receiver simultaneously.
- An Ion Detector might be helpful.


ELF Receiver
ELF Receiver
ELF Receiver
Two Way Radio Link
ELF Receiver
ELF Receiver
Central Station
ELF Receiver
ELF Receiver
ELF Receiver

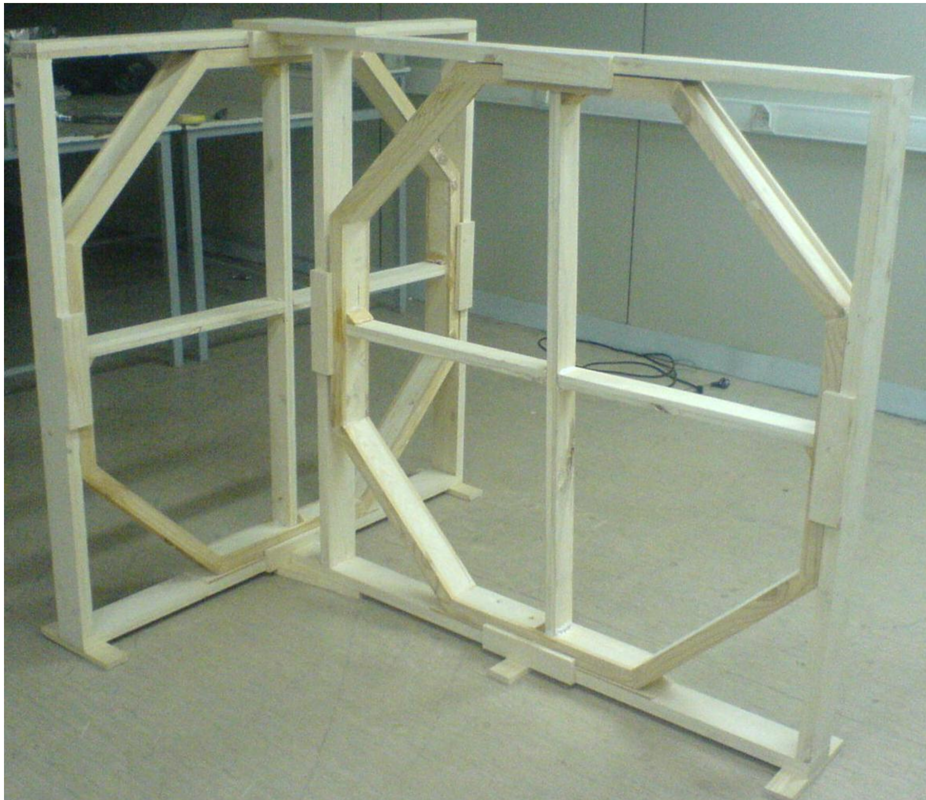
ELF Block Diagram



Different Type of Filters and Amplifiers



Antenna (NS and EW)



Thermal Noise& Equivalent Inductance of Antenna

Faraday's Law:

$$V = N\frac{d}{dt}(\varphi) = NA.B(2\pi f)\cos(\omega t),\ B = 4\pi 10^{-7}\mu_r H$$

$$L \cong N^2 r\mu_0\mu_r[Ln(\frac{8r}{a} - 2)]$$

$$R = \rho\frac{\ell}{A} \quad \text{and} \quad f_{3dB} = \frac{R}{2\pi L}$$

$$V_n = \sqrt{\frac{R(K\Omega)}{1(K\Omega)}} \times 4.069 \quad (nv/\sqrt{Hz})$$

Quake Finder System

- Quake Finder was formed in 1999 with the specific purpose of conducting simultaneous space and ground observations at ELF frequencies in California to collect more ELF data.
- Quake Sat's single-axis search coil magnetometer and ELF receiver had a frequency response of 1-1000 Hz in 4 bands.
- The overall data gathering strategy also included a ground component, namely a network of 35 three-axis magnetometer sensors.

Quake Finder

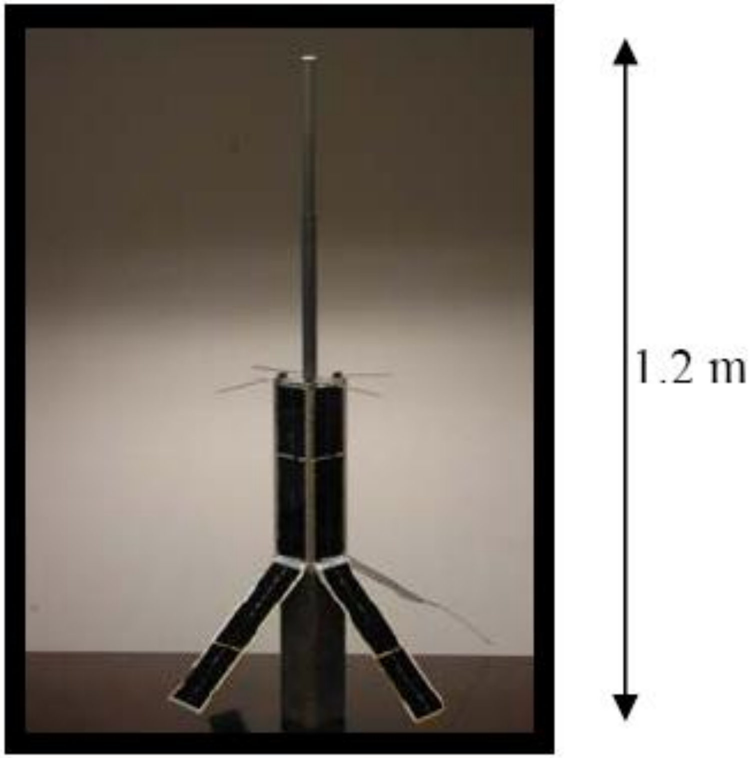
Quake Finder Ground Network

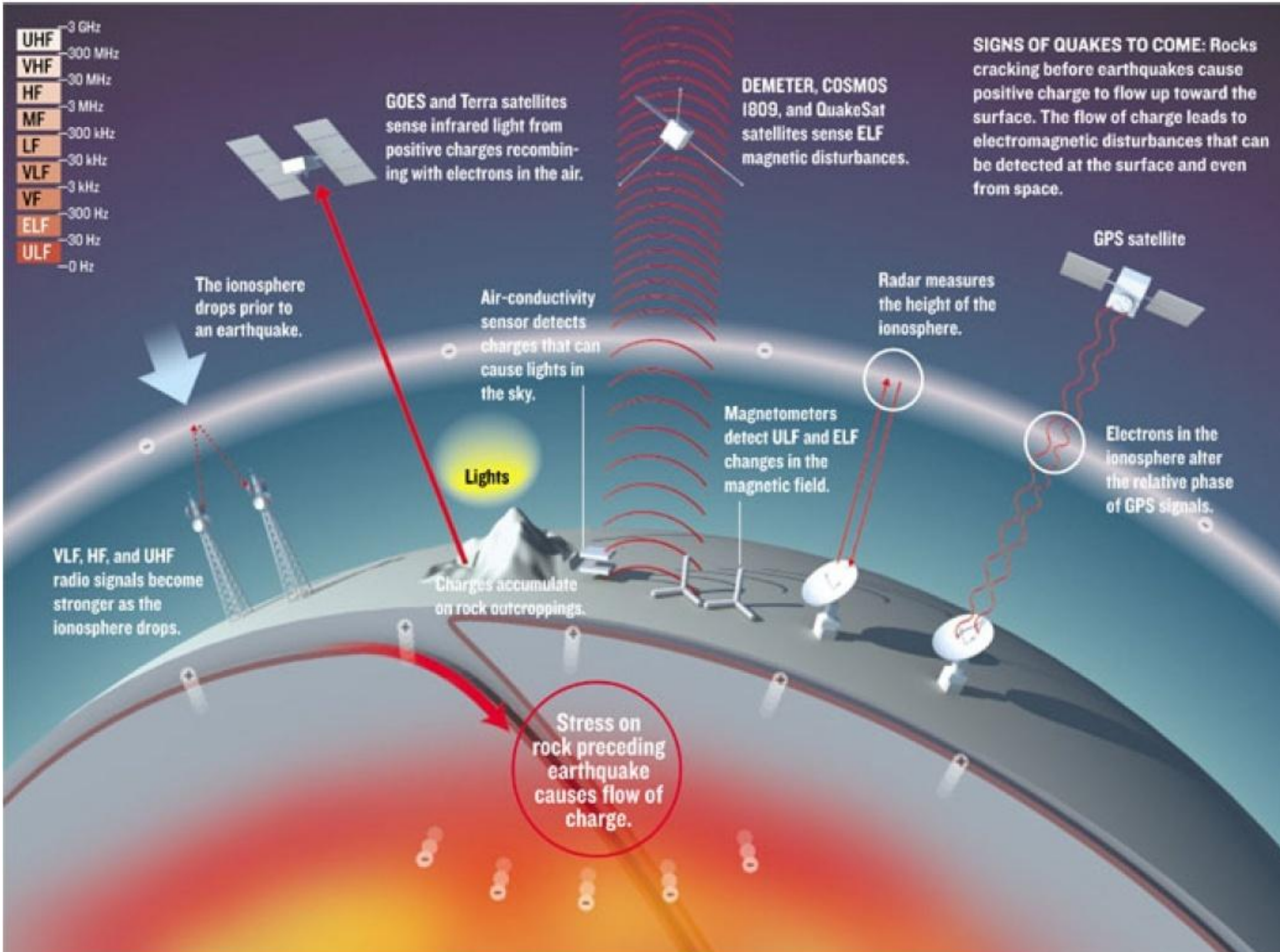
Fig. 3 QF Ground Network (9/04)

Quake Sat

- Quake finder LLC, in collaboration with Stanford University, launched a 4.5 kg nanosatellite called Quake Sat (Fig 1) into an 840 km circular sun-synchronous orbit on June 30 2003.

Wide Area Warning
Expensive




UHF
VHF
HF
MF
LF
VLF
VF
ELF
ULF
3 GHz
300 MHz
30 MHz
3 MHz
300 kHz
30 kHz
3 kHz
300 Hz
30 Hz
0 Hz
GOES and Terra satellites sense infrared light from positive charges recombining with electrons in the air.
DEMETER, COSMOS 1809, and QuakeSat satellites sense ELF magnetic disturbances.
SIGNS OF QUAKES TO COME: Rocks cracking before earthquakes cause positive charge to flow up toward the surface. The flow of charge leads to electromagnetic disturbances that can be detected at the surface and even from space.
GPS satellite
The ionosphere drops prior to an earthquake.
Air-conductivity sensor detects charges that can cause lights in the sky.
Radar measures the height of the ionosphere.
Magnetometers detect ULF and ELF changes in the magnetic field.
Electrons in the ionosphere alter the relative phase of GPS signals.
Lights
VLF, HF, and UHF radio signals become stronger as the ionosphere drops.
Charges accumulate on rock outcroppings.
Stress on rock preceding earthquake causes flow of charge.

Thanks for your attention!