The new Italian Geomagnetic Observatory of Duronia: experimental setup and first results

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Abstract

Since the end of 2007 a new geomagnetic observatory is in operation in Central Italy in the area of the village of Duronia (41°39'N, 14°28'E, 910m a.s.l.). The observatory has been created in the framework of the MEM (Magnetic and Electric fields Monitoring) Project. The main target of the MEM Project is to create in Central Italy a network of observatories to monitoring the environmental electromagnetic signals in the frequency band from 0.001Hz to 100kHz (ULF-ELF-VLF). Actually the network consists of two observatories, L'Aquila (42°23'N, 13°19'E, 682m a.s.l.) and Duronia. Next year a third observatory will be activated in Central Italy. Moreover, in the future we plan to widen the network in the Adriatic area, creating two new observatories in the other countries of the MEM partners. The peculiarity of the Duronia's Observatory is the low electromagnetic background noise of the site and the low noise instrumentation used for the measurements. These characteristics allow us to plan new research activities in the field of the geomagnetic sciences. Here we show the experimental setup of the observatory with a brief discussion of the installed instrumentation. Moreover, some examples of the scientific results obtained in the first months of operation are shown. The new research activity is mainly focused on the analysis of the spectral resonance structure, and its evolution in time, of the Schumann Resonance in the range of

frequencies [5.0-35.0]Hz, and the Ionospheric Alfvén Resonator in the range of frequencies [0.1-7.0]Hz. Another research activity of the observatory concerns the long term monitoring of local magnetic field anomalies, to underline their possible correlation with the geodynamical processes.

1. Introduction

The evolution of the measurement techniques and the continuous research activity have a considerable importance for a better understanding of the environmental electromagnetic fields (Bianchi and Meloni, 2008). The main objectives of these studies are both the deepening of the knowledge on the natural electromagnetic fields, and the study of the electromagnetic anomalies associated to anthropogenic sources, the well known man–made fields. The knowledge of how these anomalies are distributed in space and time can be useful to a life improvement in our planet. On the other hand, the study of the non ionizing radiation effects on the biological tissues is an actual theme that needs an answer. The MEM Project was activated in the INGV (Italian Istituto Nazionale di Geofisica e Vulcanologia) Observatory of L'Aquila in order to study the electromagnetic fields, both natural and due to artificial sources. The project started in 2005 and ended in 2007. The leader partner of the project is the Italian Abruzzo Region. The other partners are the Geomagnetic Observatory of L'Aquila, the Regional Environmental Agency of Molise Region, Italy, the University of Ferrara, Italy, the University of Tirana, Albania and the Geomagnetic Institute of Grocka, Beograd, Serbia. The principal purpose of the project was the development in Central Italy of a network of observatories to monitoring the electromagnetic signals in the frequency band [0.001Hz-100kHz]. Actually the network consists of two observatories, L'Aquila and Duronia. In the next year the network will be widen by the activation in Central Italy of a third observatory. Moreover, our future target is to widen the network to the Adriatic countries of Serbia and Albany to create a triangular interferometric array with a side about 500 km long. Figure 1 shows the location in Central Italy of the two MEM observatories of L'Aquila and Duronia, and the possible position in the Adriatic area of the future interferometer. The technological objective of the MEM Project was the development of new low noise instrumentation (Palangio et al., 2008a, 2008b, 2008c) and the know-how transfer to the industry. These instruments are designed for automatic long term recording of the electromagnetic fields in a wide band of frequency. The developed instruments have been installed in the first two MEM observatories. Concerning the data elaboration, the data set of each site can be used individually in a single station approach of the data analysis, or all the data of the network can be analyzed by a multi-station approach using techniques like the wide band interferometry (Palangio, 2008c). The network configuration is needed to separate the natural electromagnetic fields from the artificial ones, and to separate the electromagnetic fields originated in the Earth's interior from those having an external source. Another target is the long term monitoring of the geodynamical processes, such as the earthquakes. In the next years, through the analysis of the magnetic transfer functions and the evaluation of the impedance tensor, we will be able to study the possible correlation between the geodynamical processes and the local magnetic field anomalies (Palangio et al., 2008b). For this purpose the Observatory of Duronia will be added to the INGV tectonomagnetic network already existing in Central Italy (Masci et al., 2006, 2007, 2008).

2. The Geomagnetic Observatory of Duronia

The Observatory of Duronia was created at the middle of 2007 in an area characterized by low electromagnetic noise. The observatory started its operations at the end of the same year. Figures 1, 2 and 3 show respectively the location in Central Italy, the map and a view of the observatory. The observatory covers an area of about 7500 m^2 far away 2 km from the village of Duronia and is completely plunged inside a wood of pine trees. Actually the observatory consists of four wooden non-magnetic chalets (3x2 m) and is enclosed with a fence made of wood and plastic. One of the chalets contains the acquisition systems, whereas the other three chalets contain the instrumentation. Each chalet is located far from the fence at least 30m and placed in the observatory with a configuration that avoids that the instruments affected each other. The peculiarity of the Observatory of Duronia is the low electromagnetic background noise of the site and the low noise instrumentation used for the measurements. For example, in the frequency band from 0.1Hz to 40Hz the background magnetic noise level is particularly low, less than $20\mathrm{fT}/\sqrt{\mathrm{Hz}}$. These characteristics allow us to plan new activities in the field of geomagnetic research. In the next two sessions we show a brief description of the instrumentation installed in the observatory, and some examples of the results obtained in the first months of operation.

2.1. Experimental setup

As previously reported the instrumentation is located in three of the four chalets of the observatory (see Fig. 2). All the instruments of the observatory have been developed in the frame of the MEM project, except the total field magnetometer. The instrumentation setup was carried out during the last months of 2007, and the full operation of the observatory started at the beginning of 2008. Actually five instruments are installed in the observatory. On end, we report a brief description of these instruments.

1) *Triaxial magnetic variometer*

Orientation: HDZ; linear frequency response [DC-1Hz]; dynamic range: ±2000nT; resolution: 0.03 nT; sampling rate: 1s with a time resolution of 1ms; filter type: 8 poles elliptic low pass filter.

2) *Triaxial high frequency search-coil magnetometer*

Orientation: HDZ. Each of the three search coil sensors has a linear frequency response in the range [10Hz - 100kHz]. Each sensor is equipped with a low pass antialiasing filter with a 40 kHz cut-off frequency. The output signals of each search coil are sampled simultaneously at 100 kHz and are digitized using a 24-bit A/D converter. The dynamical range is between ±10fT and ±100nT. The magnetic noise level of the sensors is about $1\,\mathrm{fT}/\sqrt{\mathrm{Hz}}$.

3) *Triaxial low frequency search-coil magnetometer*

Orientation: HDZ. This magnetometer is used to measure geomagnetic field variations in the frequency range [0.001 - 40]Hz. The sensitivity of the magnetometer is better than $10\,\mathrm{pT}/\sqrt{\mathrm{Hz}}$ at a frequency of 0.01Hz, and $20\,\mathrm{fT}/\sqrt{\mathrm{Hz}}$ above 10Hz. The sampling rate per channel is 100Hz, with a sampling resolution of 24 bit. The accuracy between the timing channels is better than 0.1ms, because we use three independent A/D circuit, one for each channel H, D and Z.

4) *Proton precession magnetometer*

The scalar magnetometer is an Overhauser magnetometer and it is the only industrial instrument installed in the observatory. The magnetometer, model Pos1, is produced by the Quantum Magnetometry Laboratory, Russia. The instrument measures the total magnetic field F with a sampling rate of 1s.

5) *Telluric electric potential measurement system*

This instrument is a typical system used to measure the telluric electric field. The instrument consists of two orthogonal line NS and EW and four electrodes of coal coke distant about 80m. The electrodes are located outside the fence of the observatory. The frequency band is [DC-1Hz], and the sensitivity is 1μv/m. The sampling rate is 1Hz, with a sampling resolution of 24 bit. Some photos of the instrumentation installed in the Observatory of Duronia can be found in Palangio et al. (2008a, 2008b, 2008c). In the future, a fifth chalet will be built near the gate of the observatory (see Fig. 2), as new location of the acquisition system. In this way, the chalet 1 will be used as housing of a DIM (Declination Inclination Magnetometer) for absolute magnetic field measurements.

2.2. First results

Due to the very low background noise, in the Observatory of Duronia can be performed detailed observation of the spectral resonance structures of the Schumann Resonance (SR) and the Ionospheric Alfvén Resonator (IAR). In literature, the study of SR and IAR will be used to infer ionospheric parameters, to monitoring the large-scale ionospheric modulation by gravity and planetary waves, the ionosphere-magnetosphere coupling, and the planetary temperature (Williams, 1992). Moreover, some authors have found very anomalous effect in SR, probably associated with large earthquakes with magnitude greater than 6 (Hayakawa, 2005; Nickolaenko, 2006; Ohta, 2006). SR is the resonance of electromagnetic waves in the Earth-ionosphere cavity with a fundamental frequency of about 8 Hz and higher order harmonics separated about 6 Hz (Schumann, 1952; Schumann and König, 1954). The Earth-ionosphere cavity is bounded by the Earth's surface and the lower region of the ionosphere, the so called D-layer. This cavity can support, as quasi-waveguide, electromagnetic standing waves which wavelengths are comparable to the planetary dimension. The fundamental mode of SR is a quasi-standing wave in the Earth-ionosphere cavity with a wavelength of about the Earth's circumference. Changes of the D region ionization can modify the SR parameters. It is well assumed that lightning dischargers due to thunderstorm activity are the main excitation source of the SR (Sentman, 1995). The low frequency components of these electromagnetic transients can circle the globe several times and therefore produce resonant spectrum lines. Figure 4 shows an example about the spectral resonance structure of SR, for the three components X, Y, and Z, obtained from the data of the Observatory of Duronia collected on February, 14 2008 between 20:00 UT and 21:00 UT. The power spectral densities shown in Fig. 4, and later in Figs. 5 and 6, are estimated via the maximum entropy method in order to improve the spectral resolution between the SR peaks (Marple, 1987). In Fig. 4, the presence of the first 4 SR harmonics is clearly evident in all the tree components. The Z component also shows two peaks at frequencies ≈ 16.7Hz and ≈ 26.2Hz due to artificial signals; the first one is certainly due to the German railway network. This artificial magnetic field is produced by the uncoupled current component which flows deeper in the Earth's crust and depends on the resistivity of the soil and on the linear extension of the railway network (Palangio et al., 1991). These artificial signals are evident in the vertical component, whereas do not appear in the horizontal components, because the spectral amplitude of the natural signals on the horizontal components is larger than thirty times respect to the vertical component. Figure 5 shows the SR fundamental mode, for the three components, obtained from the data of Duronia on January, 1st 2008 between 15:00 UT and 16:00 UT. The frequencies of the peaks are f_x=7.6 Hz, f_y=7.6 Hz and f_z=8.0 Hz. In this case $f_x \equiv f_y$, but generally, the frequencies f_i of the three components are different (Nickolaenko and M. Hayakawa, 2002). At frequencies that are below the SR there is another kind of resonance, named IAR. The Ionospheric Alfvén Resonator is the definition of the vertical structure of the plasma density decay from the ionosphere to the magnetosphere. The existence of this resonator was proposed for the first time by Polyakov (1976). Alfvén waves propagating along the geomagnetic field lines are partially reflected from regions of large Alfvén velocity gradient. The lover boundary of the resonator coincides with the ionospheric E-layer. The upper boundary of the resonator is located at an altitude of about 3000km where the Alfvén waves are partially reflected from region of large Alfvén velocity gradient due to the rapid decrease of the plasma density (Surkov et al, 2004). IAR resonance spectrum shows daily and latitude dependence and it is regularly observed, especially at night time, at middle latitudes. Usually the resonance frequencies ranges in the interval [0.5 - 7.0]Hz, while the frequency interval Δf between the peaks ranges in the interval [0.5 - 3.0]Hz at mid latitudes (Belayaev et al., 2000; Hayakawa et al., 2004). As for the SR, it is supposed that the electromagnetic emissions due to the global thunderstorm activity and the vertical neutral wind are the main excitation source of IAR (Belayaev et al., 1989). Figure 6 shows an example about the spectral resonance structure of IAR for the three components X, Y, and Z calculated from the data collected in Duronia on December, 29 2007 between 19:00 UT and 20:00 UT. In this case, the IAR resonance structure shows five peaks at frequencies below 8Hz with a frequency interval between the peaks about 1Hz. As previously reported, one of the targets of the MEM Project is the study in

Central Italy of the electromagnetic anomalies associated with the geodynamical processes. Actually a different approach in the data analysis is tested taking into account the inductive effects by the evaluation of the magnetic Inter Station Transfer Function (ISTF) calculated between the components of the magnetic field simultaneously measured in the two MEM observatories. Monitoring the variation of the nine parameters obtained by the ISTF evaluation, we could obtain some information concerning the geodynamical processes observed in Central Italy (Palangio et al., 2007, 2008c).

3. Conclusions

Here we have presented the new Italian Geomagnetic Observatory of Duronia. The peculiarity of this observatory is the low electromagnetic background noise of the site that allows us to plan new research activities in the field of the geomagnetic sciences. The background magnetic noise level of the site is less than $20\mathrm{fT}/\sqrt{\mathrm{Hz}}$ in the frequency band from 0.1Hz to 40Hz. We briefly described the experimental setup of the observatory emphasizing the low noise of the installed instrumentation. Some preliminary results are shown concerning the study of the spectral resonance structure of the Schumann Resonance (SR), in the Earth-ionospere cavity, and the Ionospheric Alfvén Resonator (IAR). When a great deal of data will be available, we will be able to plan a systematic study about the changes of SR and IAR parameters. Moreover, another target is the study in Central Italy of the electromagnetic anomalies associated with the geodynamical processes by the magnetic Inter Station Transfer Function evaluation.

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Figure captions

Fig. 1. Yellow circles show the location in Central Italy of the first two MEM observatories of L'Aquila (AQU) and Duronia (DUR). The red triangle shows the pattern of the future interferometer in the Adriatic area.

Fig. 2. Map of the Duronia's Observatory. The chalet 1 contains the acquisition systems. The chalets 2, 3 and 4, contain the instrumentation.

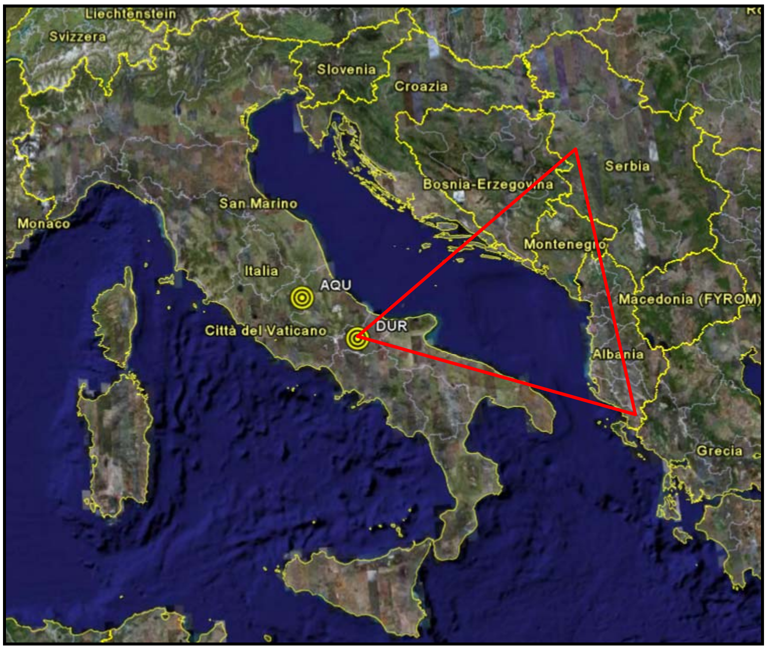
Fig. 3. A view of the Observatory of Duronia.

Fig. 4. An example of the SR spectral resonance structures (February 14, 2008 20:00-21:00 UT). The first four harmonics are evident in all the three components. The Z component shows also two peaks at frequencies ≈ 16.7Hz and ≈ 26.2Hz due to artificial signals. For clarity the values of the Z component are multiplied by 30.

Fig. 5. An example of the SR fundamental mode (January 1st, 2008 25:00-26:00 UT). Note that the peak frequency f_x = 7.6Hz is equal to f_y, whereas f_z = 8.2Hz. For clarity the values of the Z component are multiplied by 100.

Fig. 6. An example of the spectral resonance structures of IAR (December 12, 2007 19:00-20:00 UT). The frequency interval between the peaks is about 1Hz. For clarity the values of the Z component are multiplied by 100.

Fig. 1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Svizzera
Slovenia
Croazia
Serbia
Bosnia-Erzegovina
San Marino
Monaco
Montenegro
Italia
AQU
Macedonia (FYROM)
DUR
Città del Vaticano
Albania
Grecia

Fig. 2

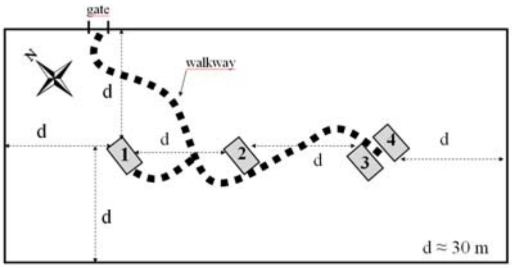


Fig. 3

Fig. 4

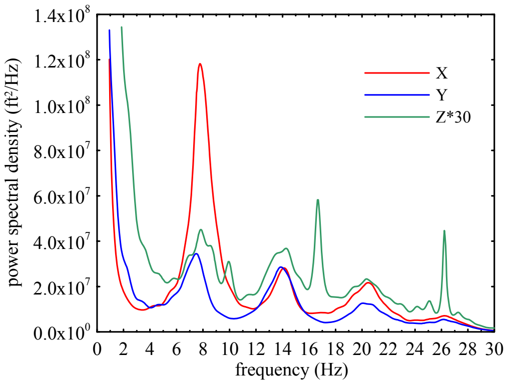
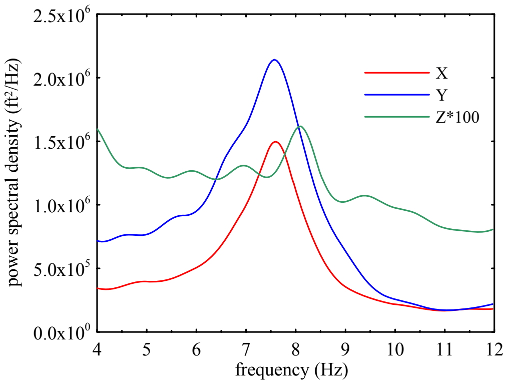
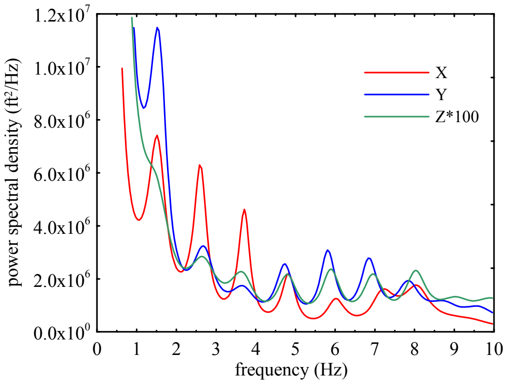

1.4x10^8
1.2x10^8
1.0x10^8
8.0x10^7
6.0x10^7
4.0x10^7
2.0x10^7
0.0x10^0
power spectral density (ft²/Hz)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
frequency (Hz)
X
Y
Z*30

Fig. 5



power spectral density (ft²/Hz)
frequency (Hz)
X
Y
Z*100
2.5x10^6
2.0x10^6
1.5x10^6
1.0x10^6
5.0x10^5
0.0x10^0
4
5
6
7
8
9
10
11
12

Fig. 6



1.2x10^7
1.0x10^7
8.0x10^6
6.0x10^6
4.0x10^6
2.0x10^6
0.0x10^0
power spectral density (ft²/Hz)
0 1 2 3 4 5 6 7 8 9 10
frequency (Hz)
X
Y
Z*100