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A NEW STANDARD FOR SEISMIC STATION INSTALLATION OF THE OSSERVATORIO VESUVIANO SURVEILLANCE NETWORK (INGV, NAPOLI)

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Abstract

Seismic networks are worldwide diffuse to monitor both volcanic and tectonic seismogenetic areas. Some differences, such the basement on which the seismometer is located and the environmental conditions, characterize the installation of seismic stations in volcanic and tectonic areas. Nevertheless, some basic principles are common. To obtain good quality seismic data is very important to realize a high grade installation of all the instruments equipping a seismic station. Several procedure must be taken into account to optimize the instrument setting up. Electronic noise may be minimize using proper connecting line and adequate grounding. Effective lightning protections are essential to save instruments from both surges and strikes. Good seismometer ground coupling improves the signal quality and the signal-to-noise ratio. These procedures have been carried out at the Osservatorio Vesuviano to improve the existing seismic network as well as the installation of the new stations. As a result of this action an improvement of both the signal-to-noise ratio and the network reliability has been obtained.

1. Introduction

Seismic monitoring is one of the most important and worldwide diffuse methods for volcano surveillance. The gathered data are analyzed to determine location, energy and source parameters of the local seismicity. Seismic signals occurring in active volcanoes can be characterized by low frequency content and require both specific instruments and techniques for their analysis and interpretation [Chouet, 1996].

Some aspects make more complex to realize a reliable seismic network in volcanic areas with respect to seismic networks in tectonic areas. The main difference regards the basement on which the seismometer will be located. On volcanic areas is very difficult to find solid bedrock owing to the presence of pyroclastic deposits (ash, pumice, etc.) or lava reefs alternating with unconsolidated soil or ash. Moreover, an effective network geometry requires that some stations must be installed as close as possible to the volcanic area [Wassermann, 2001]. In these cases, the harsh environment (fumarolic gases, acid soil) undergoes the instruments to corrosion and alteration requiring protective materials and special care for station installation. Despite these difficulties, volcano-seismology holds a very important role for volcano monitoring [e.g. Scarpa and Tilling, 1996] and seismic networks on active volcanoes have been developed using both techniques and instruments of the modern seismology [McNutt, 1996, 2000].

The Osservatorio Vesuviano (INGV-Napoli) deployed modern seismic networks (electro-magnetic seismometers, frequency modulation, radio and phone links) for monitoring the active volcanoes of the Campania Region (Vesuvio, Campi Flegrei, Ischia Island; figure 1) since '70s. Since February 2000 began a project for the unification and standardization of the networks [Buonocunto et al., 2001]. The project provided the modernization of all the instruments and the improvement of the seismic installations [Buonocunto, 2000; Castellano et al., 2002].

In this paper the procedures adopted to improve the site conditioning, the equipment specifications and the systems designed to a remote control of the instrument effectiveness are described to give a short but detailed report of the technological upgrade.

2. Geological framework

The active volcanoes of the Neapolitan area (Vesuvio, Campi Flegrei and Ischia Island) are located in the Campania Plain (Southern

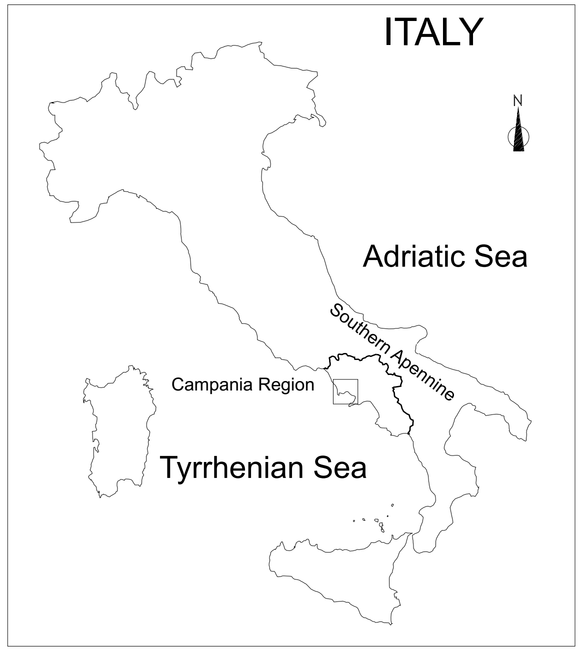

Figure 1. Sketch map of Italy. The location of Campania Region is shown. Square indicates the Neapolitan volcanic area (Vesuvio, Campi Flegrei and Ischia Island).

Italy) which is a Plio-Quaternary depression filled by sedimentary deposits between the Southern Apenninic chain and the Tyrrhenian sea (figure 1). The plain is bordered by Mesozoic carbonates. During Pliocene and Pleistocene, the area has been characterized by deformations linked to NE-SW and NW-SE extensions along lineaments with Apenninic and anti-Apenninic directions (NW-SE/NE-SW) [Patacca and Scandone, 1989].

During the Quaternary, volcanic activity took place along the western margin of the plain [Rosi and Sbrana, 1987] with explosive and effusive eruptions. The Neapolitan volcanic area is characterized by different types of volcanic structures. Vesuvio is a polygenic volcano with eruptive activity occurred mainly from the central conduit [Scandone et al., 1993]. Campi Flegrei is a complex monogenic volcanic area, where activity occurred rarely more than once from the same vent [Orsi et al., 1999]. Ischia Island is a volcanic zone characterized by a central shearing block-resurgent area with small eruptive centers located along the border fractures [Orsi et al., 1991].

Last eruptions occurred at Vesuvio in 1944 [Scandone et al., 1993], Campi Flegrei in 1958 [Dvorak and Gasparini, 1991] and Ischia Island in 1302 [Vezzoli, 1988].

Because of this geological evolution, the monitored area is characterized by strong heterogeneity in the soil typology, showing outcropped hard-rock in the external Apenninic zones and both unconsolidated volcanic deposits and lava flows in the inner part.

3. The Seismic Network

The Osservatorio Vesuviano Seismic Network (OVSN) is a regional scale network composed, at present, by 28 analog short period (1 Hz) and 3 digital broad band stations (figure 2). The station distribution covers the seismogenetic areas with two configuration: a large scale network (mean distance among the stations D ª 30-50 km) external to the volcanic areas, and a short scale network (D ª 1-3 km) with the stations concentrated on the volcanic structures.

All the stations record seismic signals from several sources: volcanic activity, local earthquakes, regional earthquakes and teleseisms [Iannaccone et al., 2001]. The 7 large scale stations located in the Campania region (figure 2) are useful to discriminate between the external (regional) seismicity and the local (volcanic areas) one. Moreover they give an important contribution for the location of deeper earthquakes occurring in the volcanic areas. The higher density network deployed on the volcanic areas (12 stations at Vesuvio, 9 stations at Campi Flegrei and 3 stations at Ischia Island; figure 2) allows to obtain constrained hypocentral location for the shallow, low energy, seismic activity occurring in these areas [Bianco et al., 1999; Saccorotti et al., 2001].

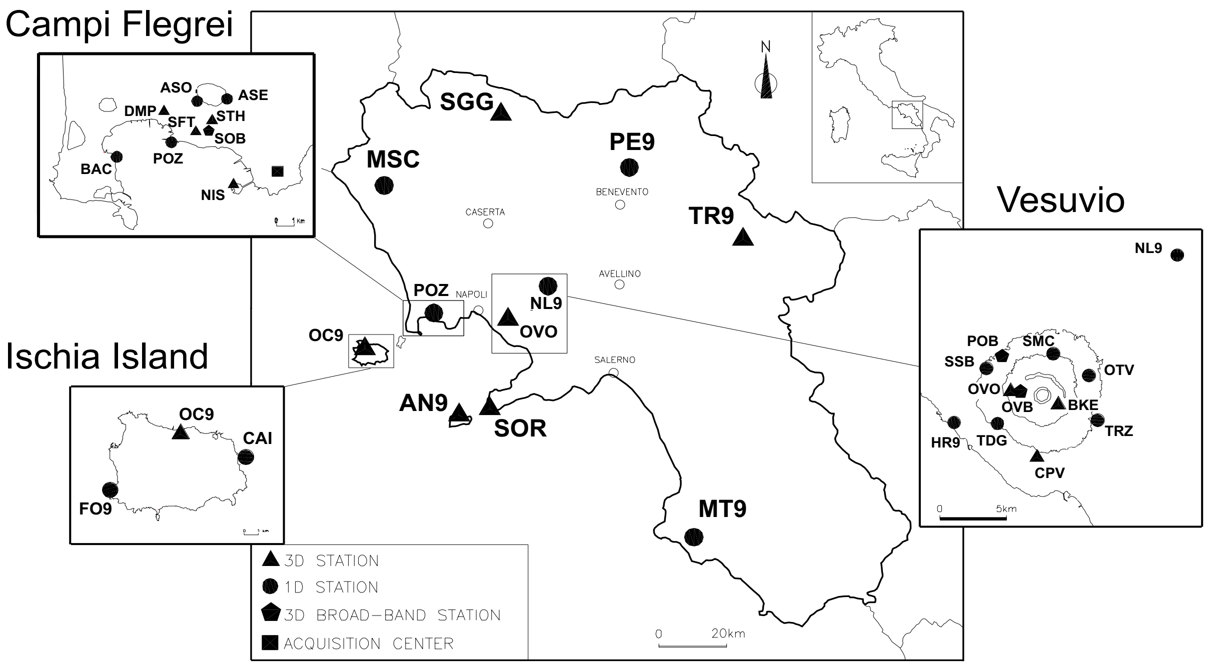

Figure 2. Location map of the Osservatorio Vesuviano Seismic Network. Both short period (triangles and circles) and broad band (pentagons) stations are reported. The Acquisition Center (square) is also shown.

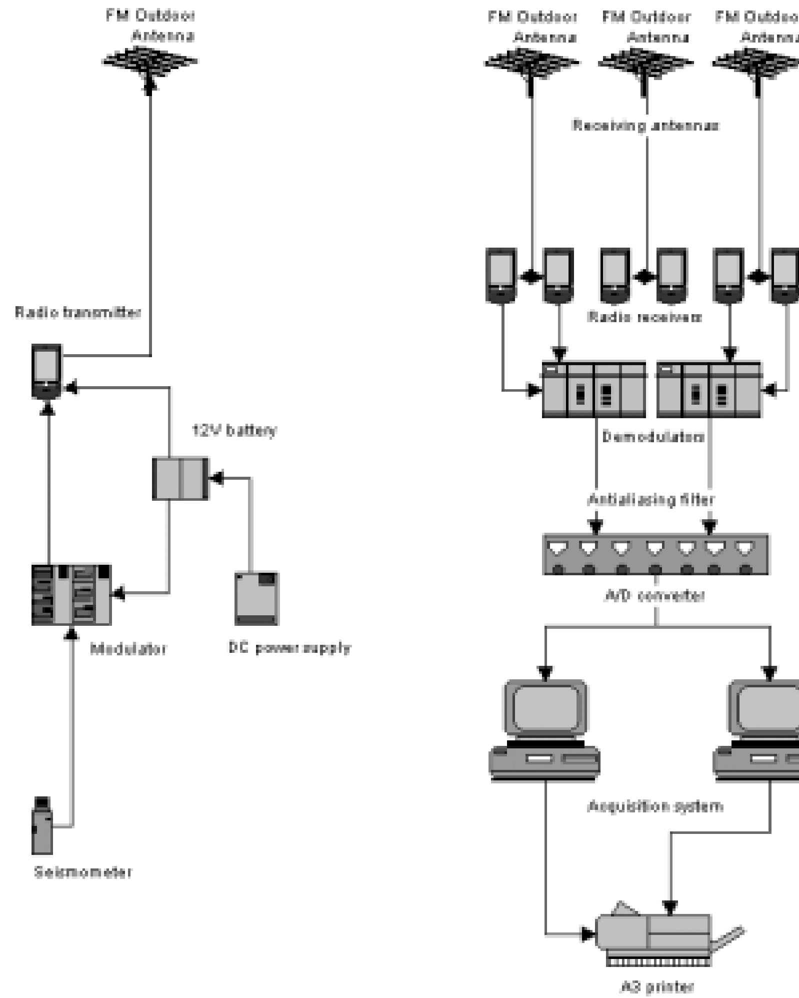

Figure 3. Block diagram of a typical telemetered analog short period seismic station and the Acquisition system.

The short period vertical component stations (16 stations; figure 2) are equipped with Mark L4-C or Geotech S13 sensors, whereas the three component stations (12 stations; figure 2) are equipped with Mark L4-3D or terns of Geotech S13 sensors. All the signals are FM modulated by means of an Amplifer/VCO (Voltage-Controlled Oscillator) apparatus designed and realized by the Electronic Laboratory of the OVSN [Capello, 1996]. The signals are telemetered to the Acquisition Center via UHF radio links (430-450 MHz frequency band) by means of directive antennas (figure 3); six stations transmit data via leased phone lines.

The broad band stations are composed by three-axial Guralp CMG-40T seismometer with Kinemetrics K2 datalogger and real-time broadcasting of data to the Acquisition Center by UHF-FSK (Frequency Shift Keying) module radio [Castellano et al., 2002]. The Acquisition system is based on continuous data storage on personal computer and visualization of the seismic signals on 19” monitors [Giudicepietro et al., 2000; Giudicepietro, 2001].

4. Site selection and general improvement

For the planning of a new seismic station it is very important an accurate field study of the site characteristics in terms of local geology, topography, natural and cultural noise, visibility for RF telemetry, power facilities and so on. The choice of a station site is often a compromise between accessibility and general noise considerations. Detailed information about site selection criteria and noise considerations are reported in Trnkoczy et al. [2001].

Since ’70s the OVSN has been developed according to geometrical considerations on the spatial coverage of the volcanic areas.

Vesuvio, Campi Flegrei and Ischia Island are densely urbanized areas with a wide diffusion of road and railway traffic, industry and agricultural activity. The high cultural noise produced by these activities represents a very serious problem which affects the OVSN (figure 4). Moreover, every station suffers of the low frequency noise caused by the sea oscillations. Another disturbance element is related to elec-

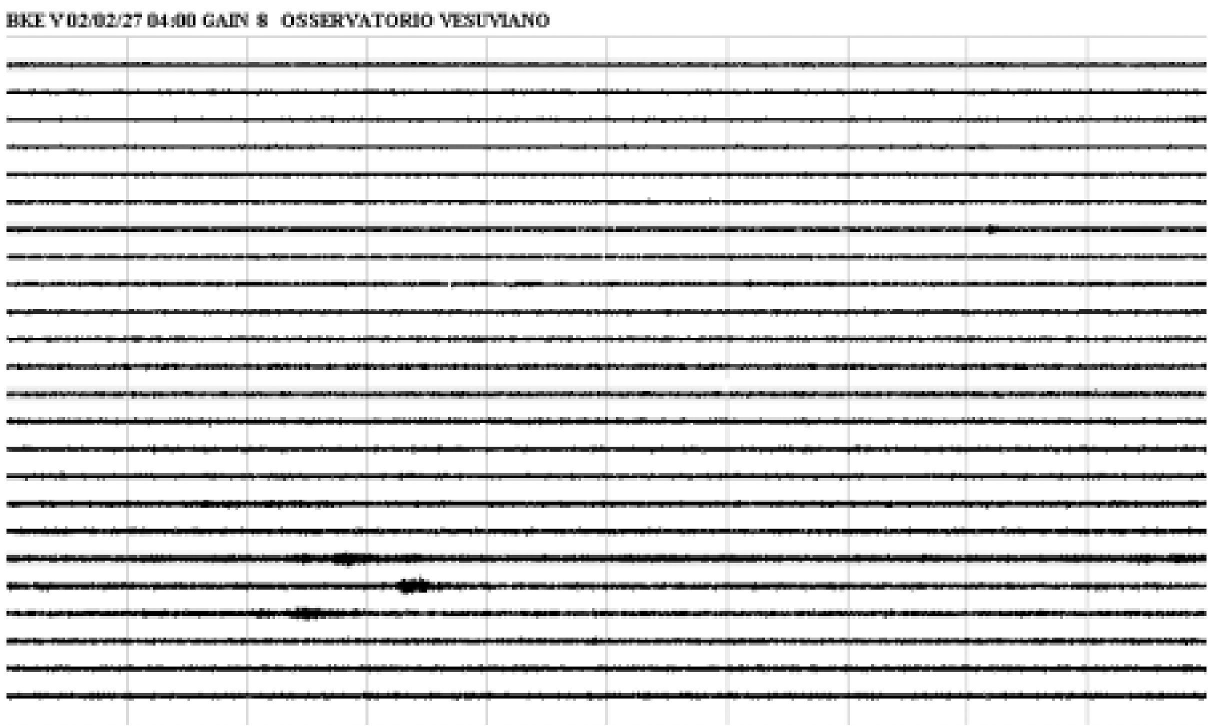

Figure 4. Seismic signal of BKE station (vertical component) starting at 04:00 to 08:00 U.T. (each line is ten minutes). Can be noted the increase of the noise amplitude due to cultural activity in the early hours of the morning.

tromagnetic pollution that causes radio interference with transmissions and receptions which result affected by noise and spikes. Finally, volcanic unconsolidated deposits are a poor basement for an optimum signal features. All these characteristics make very difficult the choice of adequate sites for low-noise seismic stations.

With these environmental conditions we have preferred not to change the existing station locations but to improve the electronics (according to both seismometer and amplifier characteristics; e.g. Rodgers, 1993) and in particular the site conditioning. The site selection for the new stations installed after February 2000 has been checked to minimize the local noise according to the following criteria.

To improve the overall instrumental setup and the signal-to-noise ratio, taking into account the aforesaid problems, a new standard installation procedure was designed. All the existing stations have been subjected to a restructuring according to the new criteria. After the standardization of all the instruments (DC power supply, modulator and UHF transmitter; for details on the equipment improvement see Castellano et al., 2002), this procedure allows to optimize the instrument setting as well as to improve the sensor ground coupling.

5. Cables and connections

Special care has been taken to conform the cables of the connecting lines to the specific use. The choice of the appropriate cable allows to obtain high quality transfer between the instruments. Moreover, it allows to reduce or avoid amplitude and current drops as well as induction for both signals and supply lines respectively.

For the seismometer signal, double shielded cables are used (four couples for three component sensors and two couples for vertical ones; one couple is linked to the calibration coil). Connectors from seismometer to modulator or datalogger respond to military standard insuring optimal contact and watertight protection. Coaxial RG-58 cable with standard BNC connectors is adopted for the modulator output and 50 ohm coaxial RG-213 cable with waterproof type N connectors is adopted from UHF radio to directive antenna. DC power lines are provided by 1 mm cross-section two poles flat cable.

If solar panels are used for power supply, it has been necessary to use cables as short as possible to minimize the stray loss. Moreover, for the same reason, the cable cross-section is of 5-6 mm at least.

6. Seismometer installation

Once a new site has been selected, or a station is going to be restructured, special care has been taken in sensor positioning. Under the same environmental conditions an effective sensor installation with good ground coupling and mitigation of weathering noise (rain, wind) has given a sensible improvement of the signal-to-noise ratio. Several reports and manuals give complete information about the correct procedure for both short period and broad band sensor installation [e.g. Uhrhammer et al., 1998; Trnkoczy et al. 2001]. In order to make a reliable sensor installation for the OVSN a simple, but useful, procedure has been designed (figure 5).

The exact orientation of the three component sensors is common to both short period and broad band seismometers. The north-south alignment has been checked using a precision compass (taking into account the interference by ferrous materials and the presence of high voltage lines that can modified the local magnetic field) or a detailed topographic maps (1:10.000 o better). A mistake of 3-5 degrees is generally accepted.

6.1. Short period seismometer

To install a short period seismometer, both vertical and three component, a seismic vault about 0.5-1 m deep has been dug in the soil down to the bedrock. The dimension of the hole depends on the seismometer type. In particular, if a three component station equipped with a tern of Geotech S13 sensors is going to be installed, the horizontal dimension of the vault can not be less than 80x80 cm owing to the possible cross-coupling effects due to induced magnetic fields of these sensors [IRIS, 2001].

Inside the vault a bottomless heavy plastic case of adequate dimension is positioned in

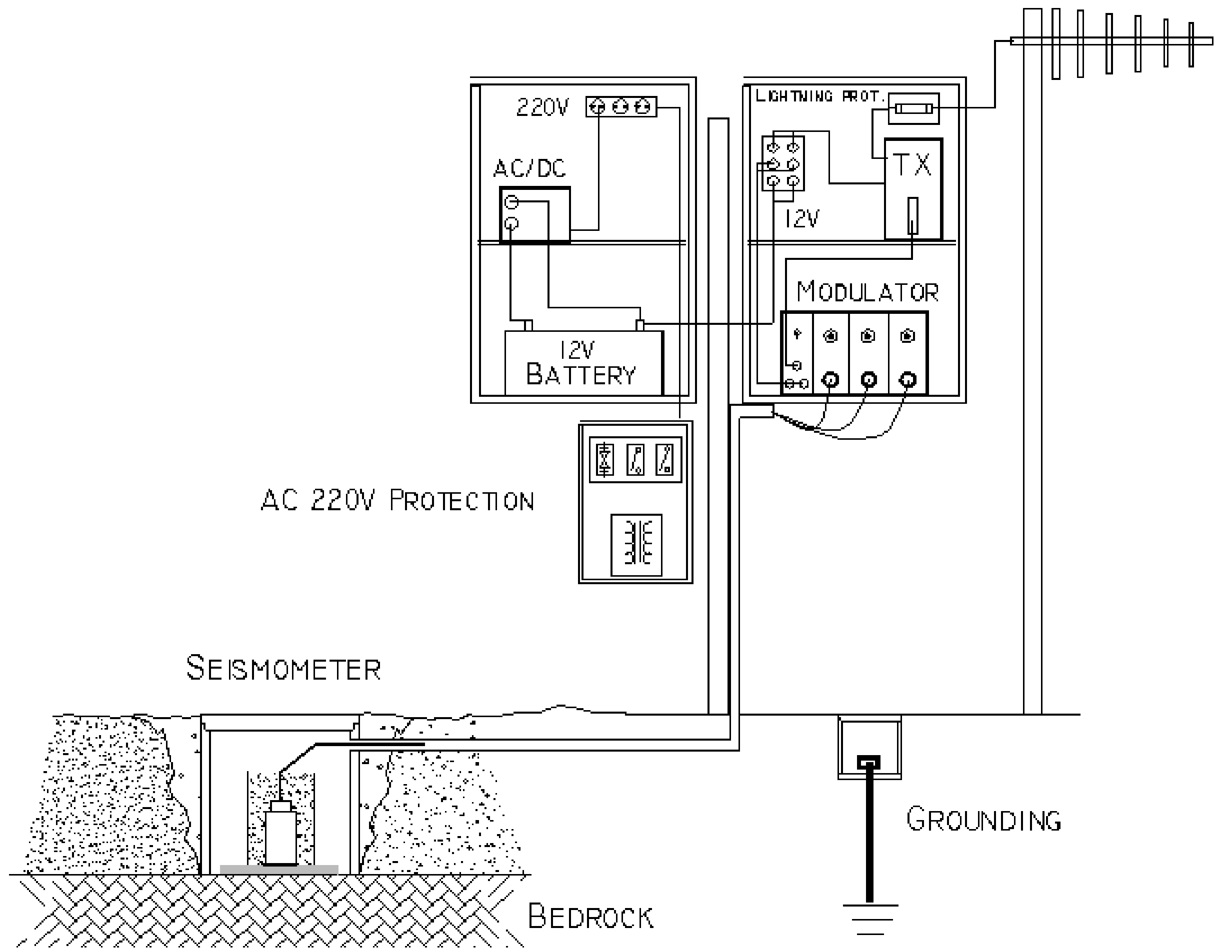

Figure 5. Scheme of a free field installation. Seismometer installation in a vault on bedrock is shown. The datalogger (modulator in this case) installation is also shown as described in chapter 6. AC protections comprise an insulating 220V AC line transformer, a lightning protector and circuit breakers for both magnetothermal and differential protection. Dimension of the single elements (seismic vault, equipment, AC protection, grounding, antenna) are not in scale.

order to isolate the hole by the soil walls. A concrete pad is realized at the bottom of the vault. To prevent induced vibrations and to allow the water discharge, the pad is not in contact with the case walls, leaving a gap of about 5 cm between the concrete basement and the shell walls. In the central part of the basement, a leveled glass plate is cemented. This glass plate allows to isolate the sensor from stray currents and, moreover, it is a good horizontal surface for the seismometer.

The sensor is placed on the concrete pad inside a thin plastic bag that rolls up the sensor and part of the cable. A PVC cylinder is placed over the seismometer and glued or cemented on the basement. In order to improve the sensor ground coupling and the insulation, the cylinder is filled with fine sand (figure 5).

The sensor cable is linked to the datalogger cabinet through an underground plastic tube. Finally, the plastic case is closed with a watertight lid. In some locations the vault (and the plastic case) is further roofed with a plastic sheet covered with soil.

6.2. Broad band seismometer

Broad band sensors are very sensible to many parameters that can influence their response [Holcomb and Hutt, 1992; Uhrhammer et al., 1998]. In particular, temperature variations influence the mass position requiring periodic mass centering.

Generally, the construction of the seismic vault and the connecting lines for a broad band seismometer follows the same procedure as short period seismometer. Nevertheless some differences characterize broad band installation (figure 6). The vault is deeper than short period sensor vault (1-2 m) and special care is taken in the basement choice. The bedrock is essential to avoid tilt and deformation caused by unconsolidated soil [Uhrhammer et al., 1998].

An effective thermal stability is obtained by means of several levels of insulation (figure 6). Fine sand covers the seismometer to improve insulation and ground coupling. Granular polystyrene fills the space around the PVC tube up to the heavy plastic case walls. Finally about total 20 cm thick polystyrene slices make the top insulation. In a building installation, as galleries (e.g. OVB station; figure 2), cellars (e.g. POB station; figure 2) or tunnels, in which the broad band seismometer is placed on reinforced concrete basement, the external sides of the plastic case may be further insulate with polystyrene slices faced with aluminum foil.

7. Datalogger installation

Being the monitored areas densely urbanized, most of the stations are located in proximity or inside existing buildings, so no particular constructions are necessary for station housing. Nevertheless, a good equipment setting is very important to optimize the different sections of the instruments and the connecting lines.

Two types of settings are designed according to indoor or outdoor installations for both short period and broad band stations. In a free field installation (e.g. SFT, TRZ, OTV stations; figure 2) electronics is put in two watertight cabinets. In the first one, the frequency modulator or datalogger, the control systems and the UHF transmitter are installed, while in the second one DC power supply and the sealed lead battery are set. PVC cable pipes are used for connections between the cabinets and toward both the antenna and the local AC power line (figure 5). In a building location (e.g. BAC, ASO, SOB stations; figure 2) a single large PVC cabinet is adopted. The equipment is arranged in order to keep apart power section from datalogger. Both settings allow a good positioning of all the instruments and guarantee easy maintenance operations.

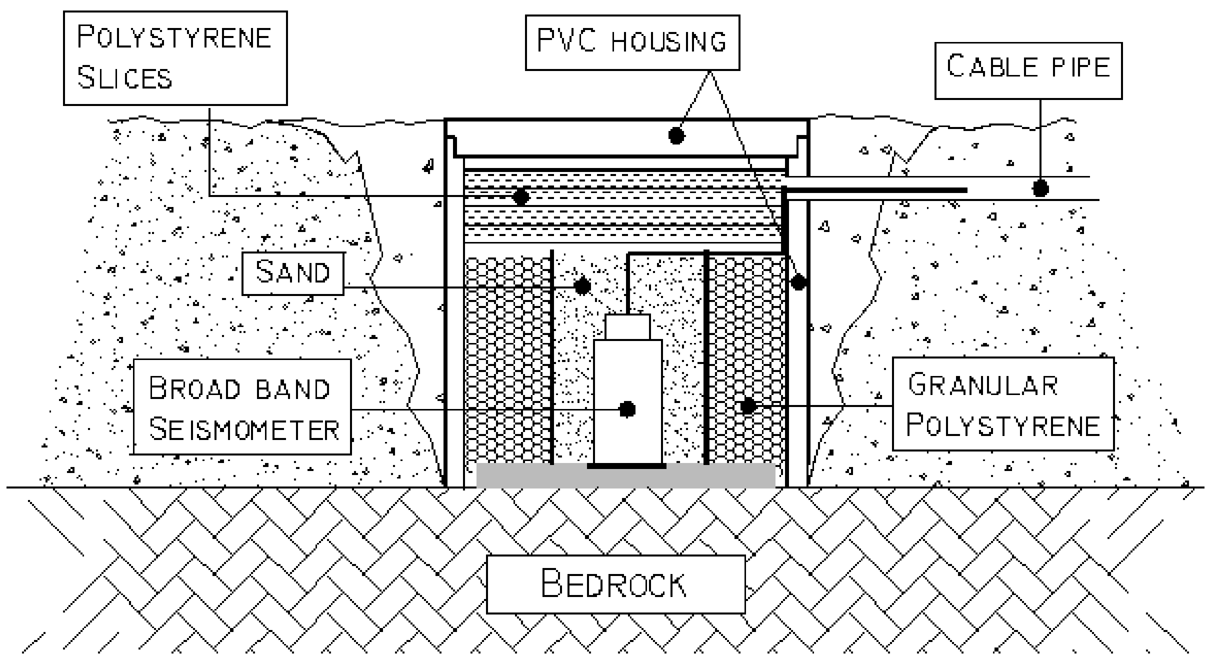

Figure 6. Detail of a broad band seismometer installation. Several level of insulation are used to keep stable the temperature.

8. Telemetry systems

The OVSN signals are transmitted to the Acquisition Center by means of both radio links and leased phone lines. Radio links are the most used (25 stations). They guarantee real time, continuous and low cost data transmission. Data are broadcast using UHF frequency band (430-450 MHz) by means of programmable radio and directive antennas. For short period data we use synthetized transmitters with 12.5 kHz canalization and power emission less than 2 watt. This power is enough for point-to-point connection of about 100 km with low consumption (£ 0.5 A). The operative frequency is set up by a RS-232 port and dedicated software. Broad band data are transmitted via UHF-FSK (Frequency Shift Keying) module radio. The frequency is programmable by means of two banks of internal dip-switches. Power emission is up to 2.5 watt with consumption of 0.65 A max.

The directive antennas are 6 or 12 element Yagi type; gain is 10 or 13 dB respectively. All the antennas are installed with vertical polarization to improve the radiation pattern. The antennas are manufactured to minimize environmental corrosion.

At present six stations (STH, NIS, DMP, SFT, TR9 and PE9; figure 2) broadcast data via leased phone lines. This type of data transmission allows inexpensive establishment but high operation cost. It is used for sites that are not in direct connection between the seismic station and the Acquisition Center, and for which is not useful to use radio repeaters.

9. Power supply

All the equipment is powered at 12V DC. Main power is provided by 220V AC line with local 12V AC/DC converter. Each station is provided with one or two 75 A/h sealed lead batteries that are able to supply instruments for about 3-4 days. When installation is far from AC source, the power is supplied by solar panels. For sizing the solar array, both the total station current draw and the local climatic conditions have been taken into account. The panel output current changes during the day. To dimension the solar panels, the output current averaged over 24 hours as a fraction of the daily peak current has been taken into account (table 1) [McChesney, 2000].

Hours of daylight	6	8	10	12	14	16
Fraction of peak	0.15	0.20	0.25	0.30	0.35	0.40

Table 1. Daily mean current as a fraction of peak solar panel current vs the hours of sunlight amount [from McChesney, 2000].

This means that with about 10 hours of daylight a panel with a peak current of 3A supplies 18 A/h per day:

$$3\text{ A} \times 0.25 = 0.75\text{A}$$

$$\Downarrow$$

$$0.75\text{ A} \times 24\text{ h} = 18\text{ A/h}$$

These considerations are true if the panels have correct orientation and tilt. To maximize the output the panel must be oriented to south with tilt according to table 2.

At the OVSN, 2x50 watt panels are

Latitude	Angle from horizontal
0 – 4°	10°
5 – 20°	Latitude + 5°
21 – 45°	Latitude + 10°
45 – 65°	Latitude + 15°
65 – 75°	80°

Table 2. Tilt of solar panel according to site latitude for maximum output [from Solarex, 1988].

enough for analog short period stations, whereas to assure the right current for digital broad band stations 2x75 watt panels are necessary. Tilt is about 50°.

10. Lightning protection and control systems

Most of the seismic station failures around the world are caused by both voltage and current surges, and lightning. Good surge and lightning protections can preserve seismic equipment from damage and failure.

The seismic stations of the OVSN are equipped with several levels of lightning and electrical protection according to general approach for low voltage facilities [Edwards and Wherrett, 1998]. The UHF radio transmitters are protected by coaxial grounded gas arresters. With this type of protection the voltage is maintained at a safe level regardless of the increase in current or duration of the power surge. A watertight electrical panel furnishes adequate surge protection on the 220V AC power supply. This panel comprises an insulating 220V AC line transformer, a grounded self-restored lightning protector, circuit breakers for both magnetothermal and differential protection (figure 5).

The stations that transmit data by means of leased phone lines are connected to the phone line with overvoltage suppressors to avoid failure due to strikes induced on the line [Engdahl, 1998]. The suppressors are ground connected to assure effective protection for both differential and common mode surges.

All the instruments are properly grounded and shielded. The grounding system is realized with 1.5 m metal bar made of copper or zinc plated iron buried in the soil, with the head protected by a little (20x20 cm) PVC box (figure 5). The grounding cable is a heavy 6 mm cross-section copper wire. Such level of protection has improved the network effectiveness reducing the emergency maintenance.

Together with the improvement of the network, some control systems have been designed and installed to realize both an instrumental calibration and a remote check of the instrument function. All the stations are periodically calibrated to determine the transfer function of the entire instrumental chain [La Rocca, 2000]. Standard 70% of critical damping is regulated on site by means of a mobile acquisition system based on a notebook and a 12-bit PCMCIA DAQCard. Each station is equipped with a circuit that provides a daily calibration with two pulses (up and down) to check the polarity and the overall status of the instruments (figure 7) [Capello, 2001]. An additional circuit checks the battery voltage; if this falls under 12.2V no daily calibration will be made. In this way, in case of

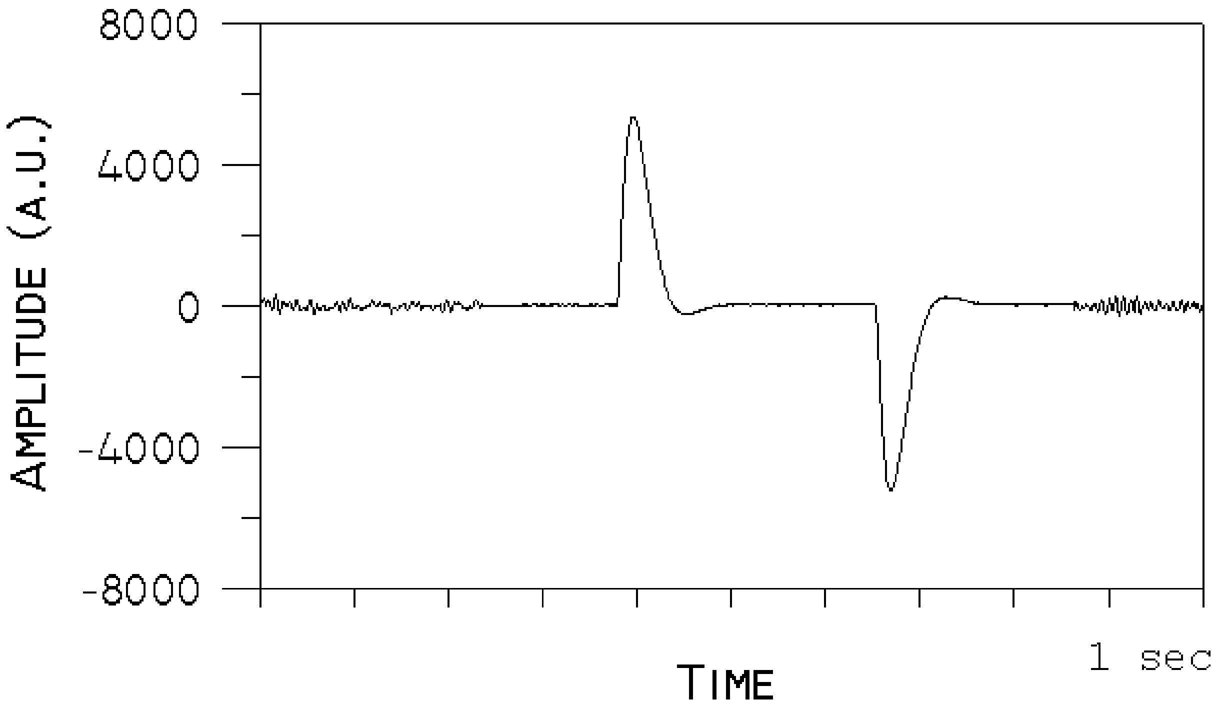

Figure 7. Daily calibration pulse at the CPV station. Calibration signal is short as possible to minimize the seismic signal interruption. The circuit provides to change the amplification to unitary value before the pulse, and it restores the operative amplification after the pulse.

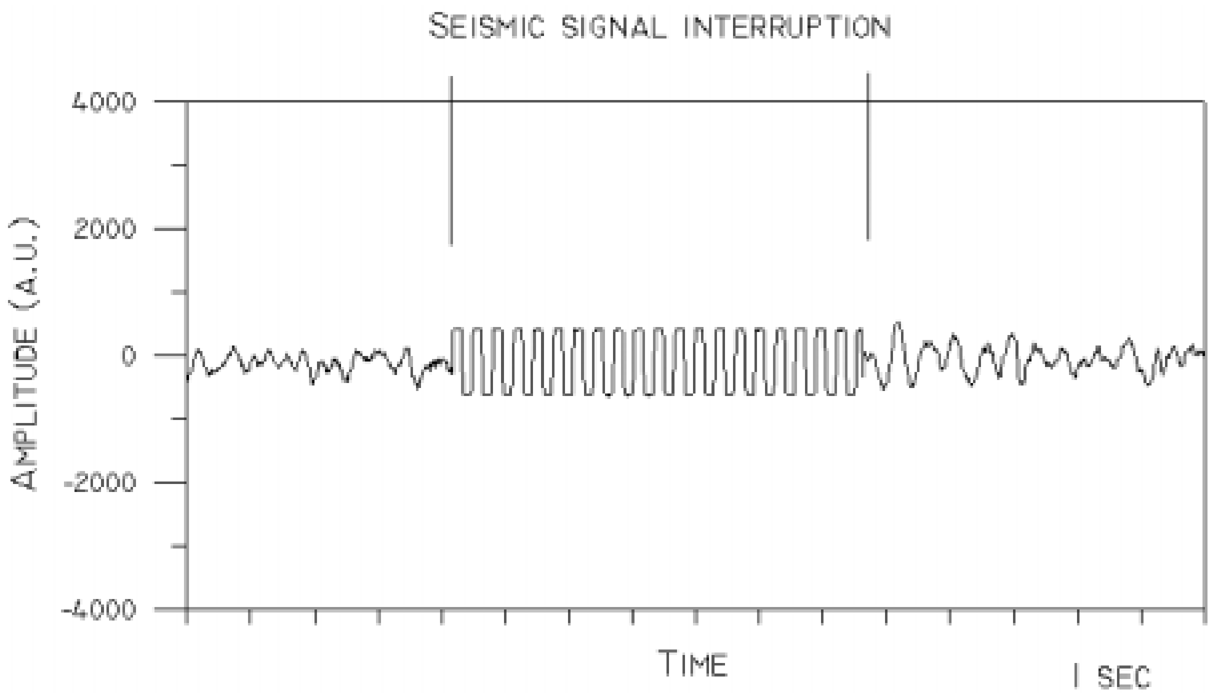

Figure 8. a) Block diagram of the circuit that carry out the control on the modulated seismic signal presence.

AC or DC power failure or activation of surge protections, it is possible to restore in time the DC power supply before battery exhausting. Moreover, a system provides the cutoff of the DC output voltage if it falls below 11.5 V to avoid damage to batteries.

The acquisition of data transmitted by phone line can be affected by a diagnostic problem. The lack of the seismic signal at the Acquisition Center can be due either to the seismic modulator failure or to the phone line failure. To understand which type of failure is occurred, a simple self-powered apparatus equips the seismic station [Buonocunto, 2002].

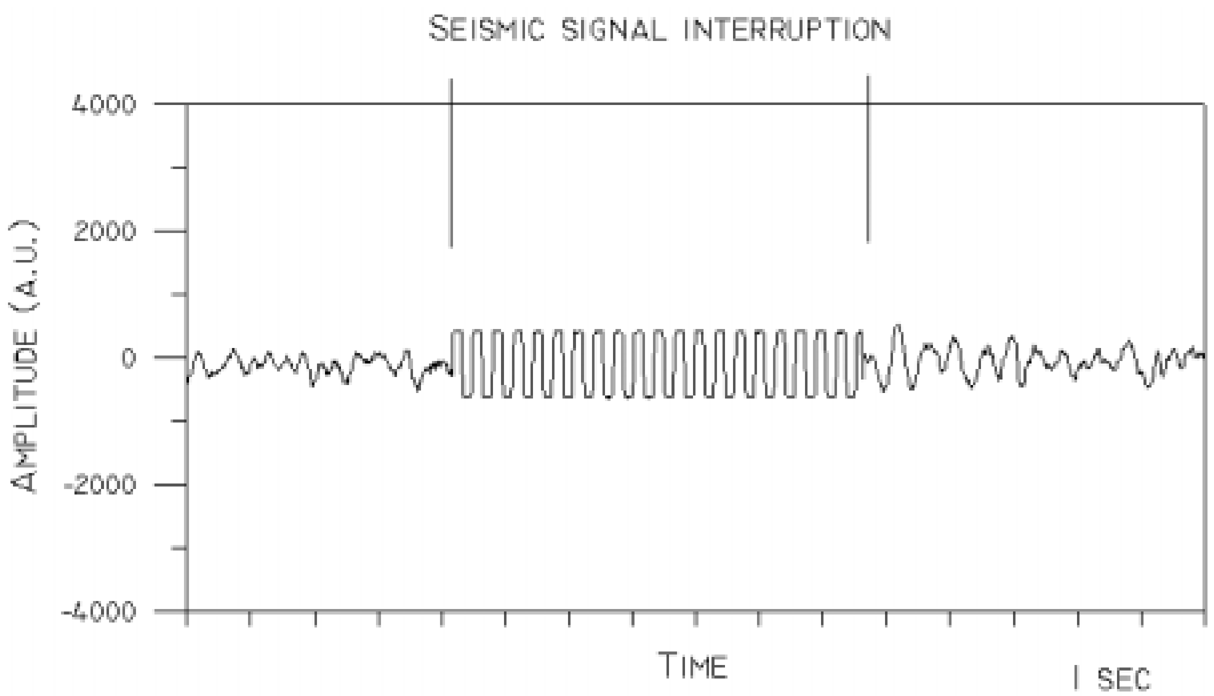

Figure 8. b) Example of control signal on phone line in case of seismic modulator failure. A 3 Hz square wave is broadcast with the same carrier frequency of the seismic signal [from Buonocunto 2002, modified].

This apparatus provides a 3 Hz square wave signal modulated at the same carrier frequency of the station (figure 8 a, b) that is broadcast only in the case of seismic modulator failure. In this way, the presence of the 3 Hz signal indicates the good functionality of the phone line and, otherwise, the modulator failure allowing fast emergency operations.

11. Conclusion

A good seismic network, both in terms of geometry and signal-to-noise ratio, allows to obtain high quality data. The first step to obtain this quality is to realize a high grade installation of all the instruments of a seismic station to minimize the electronic noise and improve the signal-to-noise ratio. In this construction the seismometer ground coupling plays the most important role on the signal quality.

The Osservatorio Vesuviano Seismic Network is installed in a highly urbanized area characterized by a high level cultural noise. Electromagnetic interference cause noise too. The new standard adopted for seismic station installation assures a good level of the signal-to-noise ratio as wall as an effective surge and lightning protection. These improvements provide both better quality data and the reduction of the seismic station emergency maintenance.

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References

Bianco, F., Castellano M., Milano G., Vilardo G., Ferrucci F. and Gresta S., (1999). *The seismic crises at Mt.Vesuvius during 1995 and 1996*. Phys. Chem. Earth, 24, 11-12, 977-983.

Buonocunto, C., (2000). *Rete Sismica Permanente: Analisi e taratura dei sistemi modulatore-demodulatore in esercizio.* Osservatorio Vesuviano Open File Report, 7-2000, 10 pp. (in Italian).

Buonocunto, C., (2002). *Sistema di controllo per segnali sismici trasmessi via linea telefonica.* Osservatorio Vesuviano Open-File Report, 2-2002, 9 pp. (in Italian).

Buonocunto, C., Capello M., Castellano M. and La Rocca M., (2001). *La Rete Sismica Permanente dell'Osservatorio Vesuviano,* Osservatorio Vesuviano Open-File Report, 1-2001, 55 pp. (in Italian).

Capello, M., (1996). *Progetto di stazione sismica analogica a tre componenti: manuale operativo, schede, componentistica,* Osservatorio Vesuviano Internal Report, 26 pp. (in Italian).

Capello, M. (2001): *Calibrazione automatica di stazioni sismiche dotate di sensori a corto periodo.* Osservatorio Vesuviano Open-File Report, 3-2001, 10 pp. (in Italian).

Castellano, M., Buonocunto C., Capello M. and La Rocca M., (2002). *Seismic Surveillance of Active Volcanoes: The Osservatorio Vesuviano Seismic Network (OVSN – Southern Italy).* Seismol. Res. Letters, 73, 2, 168-175.

Chouet, B.A., (1996). *New methods and future trends in seismological volcano monitoring.* In: Monitoring and Mitigation of Volcano Hazards (R. Scarpa and R. Tilling eds.), pp. 23-97. Springer-Verlag, Berlin Heidelberg.

Dvorak J.J. and Gasparini P., (1991). *History of earthquakes and vertical movement in Campi Flegrei caldera, Southern Italy: comparison of precursory events to the A.D. 1538 eruption of Monte Nuovo and activity since 1968.* Jour. Volcanol. Geoth. Res., 48, 77-92.

Edward, D.W. and Wherrett P.M., (1998). *A six point protection approach for lightning protection, surge protection and single point grounding for low voltage facilities.* ERICO Technical Note, Solon (US), 6 pp.

Engdahl, T., (1998). *Telephone line surge protection.* ELH Communications Ltd., http://www.epanorama.net;, 7 pp.

Giudicepietro F., De Cesare W., Martini M. and Meglio V., (2000). *Il Sistema Sismometrico Modulare Integrato (SISMI).* Ext. abs. 19° GNGTS-CNR Meeting, Rome 7-9 November 2000, pp. 31-33 (in Italian).

Giudicepietro F., (2001). *WINDRUM: a program for the continuous seismic monitoring. New version.* Osservatorio Vesuviano Open-File Report, 2-2001, 14 pp.

Holcomb, L.G. and Hutt C.R., (1992). *An evaluation of installation methods for STS-1 seismometers.* USGS Open-File Report, 92-302, 37 pp.

Iannaccone G., Alessio G., Borriello G., Cusano P., Petrosino S., Ricciolino P., Talarico G. and Torello V., (2001). *Characteristics of the seismicity of Vesuvius and Campi Flegrei occurred during the year 2000.* Annali di Geofisica, Vol. 44, n. 5/6 (in press).

IRIS Consortium, (2001). *Summary sheet for PASSCAL sensor: Appendix B.* PASSCAL Sensor Information, Socorro (NM), http://www.passcal.nmt.edu, 1 p.

La Rocca, M., (2000). *Circuito per la calibrazione dei sismometri.* Osservatorio Vesuviano Open-File Report, 8-2001, 8 pp. (in Italian).

McChesney, P. J., (2000). *Solar electric power for instruments at remote sites.* USGS Open-File Report, 00-128, 71 pp.

McNutt S.R., (1996). *Seismic monitoring and eruption forecasting of volcanoes: a review of the state-of-the-art and case histories.* In: Monitoring and Mitigation of Volcano Hazards (R. Scarpa and R. Tilling, eds.), pp. 99-146, Springer-Verlag, Berlin Heidelberg.

McNutt S.R., (2000). *Seismic monitoring.* In: Encyclopedia of Volcanoes (H. Sigurdsson, ed.), pp. 1095-1119, Academic Press San Diego.

Orsi, G., Gallo G. and Zanchi G., (1991). *Simple shearing block-resurgence in caldera depression. A model from Pantelleria and Ischia.* Jour. Volcanol. Geoth. Res., 47, 1-11.

Orsi G., Civetta L., Del Gaudio C., de Vita S., Di Vito M.A., Isaia R., Petrazzuoli S.M., Ricciardi G.P. and Ricco C., (1999). *Short-term ground deformations and seismicity in the resurgent Campi Flegrei caldera (Italy): an example of active block-resurgence in a densely populated area.* Jour. Volcanol. Geoth. Res., 91, 415-451.

Patacca E. and Scandone P., (1989). *Post-Tortonian mountain building in the Apennines. The role of the passive sinking of a relic lithospheric slab.* In: The Lithosphere in Italy (A. Boriani, M. Bonafede, G.P. Piccardo and G.B. Vai, eds.), pp. 157-176, Adv. Earth Sci. Res., Acc. Naz. Lincei, Roma.

Rodgers, P.W., (1993). *Maximizing the signal-to-noise ratio of the electromagnetic seismometer: the optimum coil resistance, amplifier characteristics and circuit.* Bull. Seism. Soc. Am., 83, 561-582.

Rosi M. and Sbrana A., (1987). *Phlegraean Fields.* CNR, Quaderni de "La Ricerca Scientifica". 114-8, 251 pp.

Saccorotti, G., Bianco F., Castellano M. and Del Pezzo E., (2001). *The July-August 2000 seismic swarms at Campi Flegrei volcanic complex, Italy.* Geophys. Res. Lett., 28, 13, 2525-2528.

Scandone R., Giacomelli L. and Gasparini P., (1993). *Mount Vesuvius: 2000 years of volcanological observations.* Jour. Volcanol. Geoth. Res., 58, 5-25.

Scarpa, R. and Tilling R., (1996). *Monitoring and Mitigation of Volcano Hazards.* Springer-Verlag, Berlin Heidelberg.

Solarex Corporation, (1988). MSX-Lite 5, 10 and 18. Rockville, Md., 4 pp.

Trnkoczy, A., Bormann P., Hanka W., Halcomb L.G. and Nigbor R.L., (2001). *Site Selection, Preparation, and Installation of Seismic Stations.* In: New Manual of Seismological Observatory Practice (P. Borman and E. Bergmann, eds.). Global Seismological Service, http://www.seismo.com/.

Urhammer, R.A., Karavas W. and Romanovicz B., (1998). *Broadband seismic station installation guidelines.* Seismol. Res. Letters, 69, 15-26.

Vezzoli L., (Ed), (1988). *Island of Ischia.* CNR, Quaderni de "La Ricerca Scientifica". 114-10, 122 pp.

Wassermann, J., (2001): *Volcano Seismology.* In: New Manual of Seismological Observatory Practice (P. Borman and E. Bergmann, eds.). Global Seismological Service, http://www.seismo.com/.

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