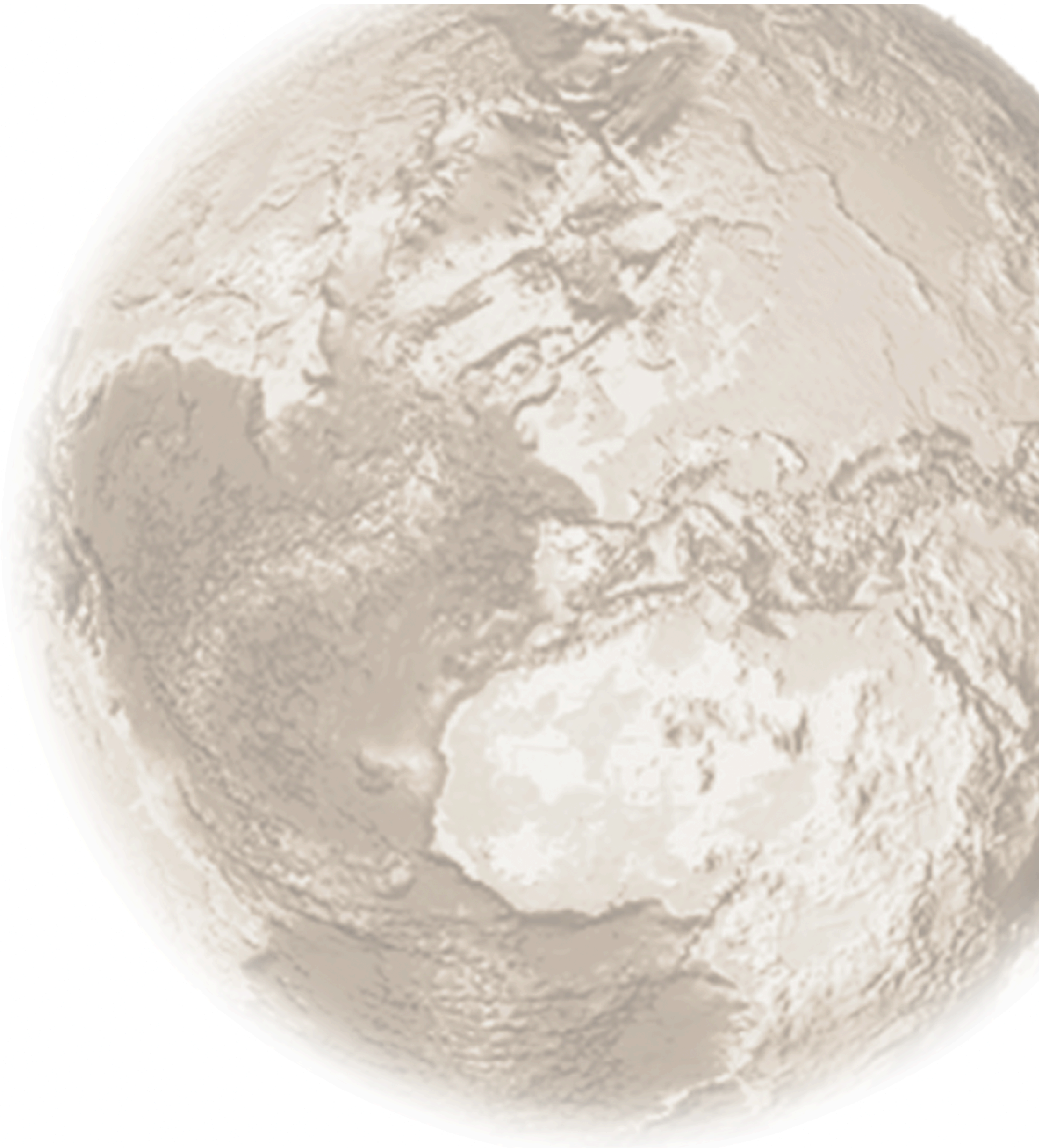
Rapporti Tecnici INGV



2002

Technical characteristics of a very broadband seismographic station at Valguarnera (Sicily, Italy)

D. Reitano, A. Ursino, H. Langer

n.4

Istituto Nazionale di Geofisica e Vulcanologia
Via di Vigna Murata 605 - 00143 Roma
tel 06518601 • fax 065041181
www.ingv.it

Technical characteristics of a very broadband seismographic station at Valguarnera (Sicily, Italy)

D. Reitano[(1)], A. Ursino[(1)], H. Langer[(1)]

[(1)]Istituto Nazionale di Geofisica e Vulcanologia – Sezione di Catania, Piazza Roma, 2- 95123 Catania (Italy).

Abstract

Goal of this report is to give some information about the data acquisition system and sensors of a very broadband seismographic station at Valguarnera in Sicily. The actual configuration, and also a few details about technical improvements, will be described.

Introduction

This paper describes the main features of the very broadband seismographic station in Valguarnera (VAE) located in central part of Sicily. This station was installed in 1994 and was set up originally in the framework of the POSEIDON project. It is now operated inside the seismic network of the *Istituto Nazionale di Geofisica e Vulcanologia (INGV) - Sezione di Catania.* The seismic station is a remotely-controlled unmanned acquisition system, which allows continuous and triggered recording of very broadband and short-period data. The importance of VAE derives, above all, from the good site conditions and its advanced instrumental characteristics. In fact the site has been selected by the CTBTO (**C**omprehensive Nuclear-**T**est-**B**an **T**reaty **O**rganization) to be integrated to the IMS (**I**nternational **M**onitoring **S**ystem) which is dedicated to the surveillance and detection of nuclear explosions. Actually the station VAE is integrated in the MEDNET very broadband seismic network, deployed in various countries around the Mediterranean Sea (Boschi et al., 1994; Mazza et al., 1998). On a local scale the data are used for microearthquake studies and the routine determination of the local magnitudes.

1. Characteristics of the station

The seismic station of Valguarnera (AS050, VAE) is located in the central part of Sicily (Fig 1 and Tab I) close to the city of Enna and is installed in a 150 m long former railway tunnel (Fig. 2).

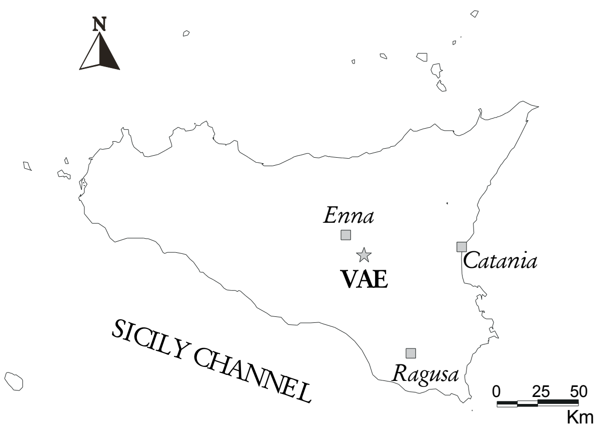


Fig 1. Map of the station

Tab. I

Station code	Lat. deg N	Lon. deg E	Elev. (m)	Geology
AS050 VAE	37.469	14.353	690	Limestone

Fig. 2 - View of tunnel entrance

Inside the tunnel there are two shelters, one containing the sensors, the other the Quanterra acquisition system. Both shelters are made up of isolating material, in order to guarantee a good thermal isolation of the instruments (Fig. 3).

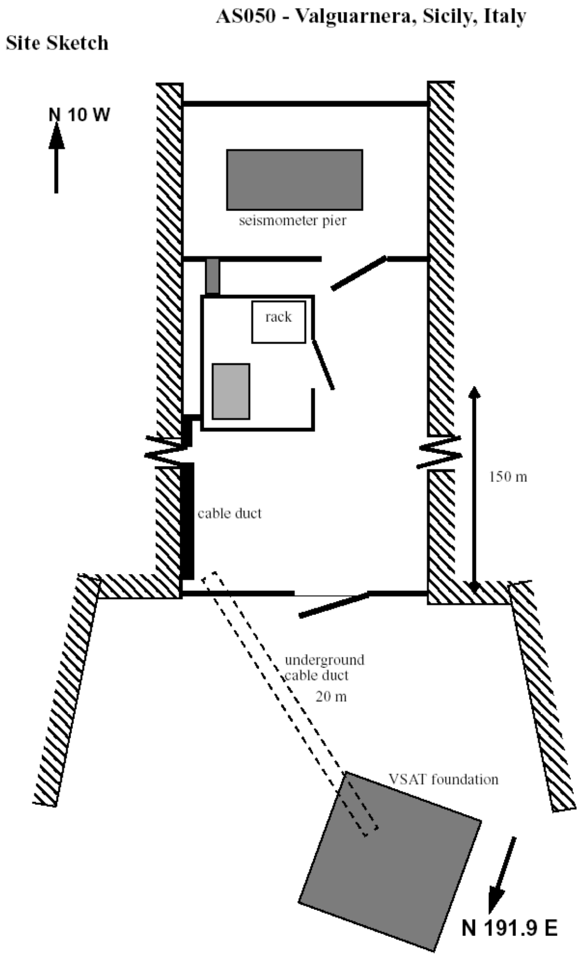


Fig. 3 – Plant of the site.

After an interruption of several years the station became operational again in March 2001 when a number of technical problems could be fixed. The infrastructure in the tunnel (power supply, cable ducts, seismometer vault and equipment container) were upgraded in order to provide a stable operation of the system (Pesaresi, 1996-97; 1998). The GPS antenna and receiver installation is temporary at the moment and needs improvement. There are no severe problems with the power supply infrastructure,

besides rare power outages of limited duration (no more than several hours). Actually the power supply system is buffered by a lead-acid battery, the installation of a UPS back up is foreseen.
Previously a satellite link was installed in this site, but the antenna was removed about five years ago (Fig. 4). The concrete pad from this installation is still there and is used for the installation of a VSAT antenna which will transfer the data to the data center of the CTBTO in Vienna.

Fig. 4 - VSAT foundation seen from above.

Even though lightning is not felt to pose a great danger in this region, basic lightning protection for the power supply and the VSAT should be included in the future upgrade.
The Quanterra data acquisition system Q680 has a six-channel high resolution 24-bit digitizer with a dynamic range as high as 140 dB and a wide frequency range. Actually various data streams are recorded with sampling frequencies of 80, 20, 1, 0.1 and 0.01 Hz. This configuration provides a good compromise and an optimum acquisition system for a very broadband triaxial seismograph like the STS-1.
The mass data storage consists of an internal 200 MByte SCSI disk drive with continuos and trigger data and a 2 GByte streamer tape drive for continuos archiving of all data streams (Fig. 5). The data on the disk-drive can be accessed to via a dial-up modem connection.

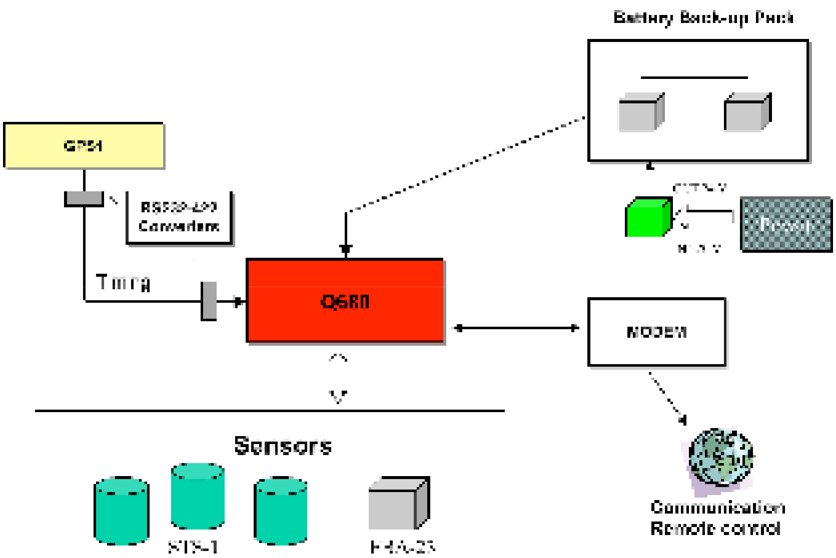


Fig. 5 – Block diagram of acquiring data system.

1.1 Time accuracy

High-quality time information is critical to the operation of a seismic network. Although each Quanterra datalogger contains an internal clock, the accuracy of the external clocks are much higher. The Quanterra uses the external clock as an absolute time base. If the external clock fails, the internal Quanterra clock is used until the external clock is replaced.
In particular the time signal is compared against an external one, the 1 PPS signal derived from a GPS receiver's output. From the difference in time, a control signal is derived and the internal clock is adjusted accordingly. Normally this is done by a phase locked loop in combination with a voltage controlled oscillator. If the difference is bigger than a selectable amount of time, the adjustment is done instantly.
During normal operation the time base advance and retard control provides the capability to adjust the internal oscillator without disturbing data acquisition. Adjustments in the order of µseconds per millisecond of the time base are allowed to smoothly synchronize the internal timing clocks with an external source or to simply adjust the internal clocks for known drift rates.
Quanterra uses a GPS clock (Quanterra GPS1). This device, connected with the datalogger, transmits the PPM signal, while a RS232 output transmits the correct position and the complete time string. Because of the long distance (ca 150 m) it was recommendable to use two different RS232 – RS422 converters and connect the devices with a RS485 line wire.

1.2 Communications

The ring buffer data (stored on the RAM and the hard-disk) are accessible by dial-up via public phone line. Automated dial-up data retrieval is used at VAE for receiving selected event data in near-real-time from the **U**nified **A**cquiring **D**ata **C**enter (CUAD) of INGV, Sezione di Catania.

1.3 Sensors

The station is equipped with three Streckeisen STS-1 and with a Kinemetrics FBA-23.

Streckeisen STS-1

The STS-1 was designed in 1976 and is a Very Broadband (VBB) seismometer mainly dedicated to the registration teleseismic earthquakes in the framework of global seismological studies.
Its sensitivity is 2400 Vs/m with a dynamic range better than 140 dB in the frequency range of 0.0001 Hz to 10 relative to 1 [m^2/s^3]. Special thermal enclosures (styrofoam), pressure (glass bell, vacuum-packed) and EMI shielding; glass plate installation must be used to take full advantage of the low frequency characteristics of the STS-1. Maximum 5 °C operational temperature changes are allowed, requiring very stable temperature control in seismic vaults (Trnkoczy, 1997)
The Streckeisen STS-1 is a leaf-spring seismometer which employs a force-feedback system to extend the bandwidth and linearity of the seismometer (Fig. 7).
The bell jars provide thermal stability and protect the seismometer from hostile environmental conditions. In fact, the three sensors are put in an evacuated glass bell, to reduce the noise introduced by different variations (atmospheric, tilt and thermal) which change the buoyancy of the seismometer's mass.
The bell is closed hermetically at its base by a glass plate, which itself is fixed on marble surface covering a concrete cement block (Fig. 6).
Furthermore the seismometers are located inside a protected room with robust walls that repair sensors from environmental conditions (Wielandt and Streckeisen., 1982; Wielandt and Steim., 1986).

Fig. 6 – Basement of instrumentation: on the left the accelerometer FBA-23, on the right the three sensors STS-1.

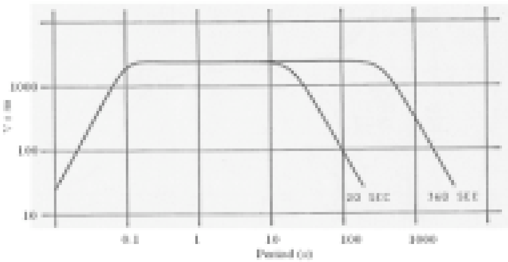


Fig. 7 – STS1: curve response

Kinematrics FBA-23

The FBA-23 is a spring-mass device using variable capacitance transduction and electromagnetic feedback. The output is fed back to the torquer coil, which is an integral part of the mass. From the coil, the feedback loop is completed through resistors Rh and Rs. This stiffens the system, thereby increasing the natural frequency to 50 Hz. Resistor Ro and capacitor Co control the damping, normally adjusted to 70% critical. The acceleration sensitivity is controlled by the gain Kp of the post-amplifier. Aluminum pivot support blocks are used to maintain long-term drift-free stability of the accelerometer mass. The FBA-23 has three accelerometers orthogonally mounted on an internal deck plate. Each of these units, housed in cast aluminum base and cover, is sealed to prevent the entrance of moisture and dirt. The instruments have full scale of ± 3.2 V and a noise level of ca 0.001 V peak to peak. In Fig. 8 the response curve of the sensor is shown.

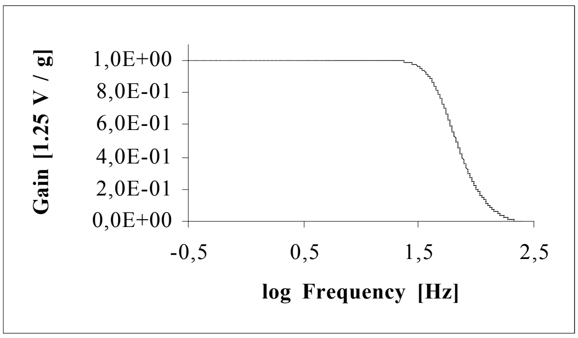


Fig. 8 – FBA-23: curve response

1.4 The Quanterra Acquisition System

The Quanterra Q680-family Very Broadband data acquisition systems comprise a 3 to 12 channel high resolution digitizer package with internal sampling timebase, and a data processing and recorder using an industry-standard VMEbus 68030 computer and real-time operating system, OS9/68000.
Quanterra VBB systems are deployed in almost every major program for broadband seismology in the world. The Quanterra system acquires data both in trigger mode and in continuous buffers, as well. The details of the buffer organization, e.g., the size of the various event and continuous buffers depends on the technical characteristics of the system, such as the size of the RAM and the hard-disk.
The Quanterra uses three devices for data storage: the RAM of the computer (the /r0 directory in the OS9 operation system), the hard-disk (/h0 in OS9) and the tape drive. In the actual configuration the storage capacities are of 8 MB RAM, 200 MB (hard-disk) and 2 GB (tape).
The data acquisition itself is controlled by the software package called Multi-Shear. Multi-Shear is a suite of separate processes that execute under the control of the OS9 operating system. MultiShear is automatically loaded when the Quanterra is booted.
The software handles the data from many different types of physical data sources uniformly. All data are compressed to the so called SEED format (see below) and analyzed by automatic signal detectors. The raw data channels from each physical data source is processed by *aqsample* to create a logical channel. The acquisition configuration file *acqcfg*, which is created by Multi-Shear describes the connection between a physical and logical channel. Other important information which can be found in the *acqcfg* file is the configuration and size of continuous and event buffers. It is a good idea not to edit the *acqcfg* file in order not to confuse the configuration of data acquisition.
One significant improvement of Multi-Shear, compared to the older versions like Shear and Ultra-Shear is the correction of a systematic timing error of the decimated channels from software in the Quanterra datalogger.
Fundamental client processes of MultiShear are:

- **Aqsample:** receives data from the server (a process that operates in background without input/output) and performs the essential data recording and processing tasks such as:
- data compression and blocking into records
- event detection
- filtering and decimation

- **Aqshell:** is the user-interface during station operation. It allows an on-site or dial-up monitoring and to controlling of the aqsample program.

The data are collected in a proprietary format SEED, which stands for ***S****tandard for the* ***E****xchange of* ***E****arthquake* ***D****ata*. It is a data packaging protocol that was developed as a standard format for exchanging seismic data. The flat file format consists of compressed waveforms and headers containing relevant station and sensor parameters.
The coding of the data stream can be interpreted in the following way:

- first letter: specifies the general sampling rate and the response band of the instruments
- second letter: specifies the family to which the sensors belongs
- third letter: specifies the physical configuration of the main axis

For example, typical seednames are:

Name	**Stream**	**Frequency**
HHZ, HHN, HHE	Hires-Broadband	80 Hz
BHZ, BHN, BHE	Broadband	20 Hz
LHZ, LHN, LHE	Long Period	1 Hz
VHZ, VHN, VHE	Very Long Period	0.1 Hz
UHZ, UHN, UHE	Ultra Long Period	0.01 Hz

In general data of all channels are stored on the hard disk and the tape. The size of event and continuous buffers, however, depend on the actual configuration of the Quanterra data logger. For instance, on a 200 MB hard disk the Quanterra will store about 3 days of the BHZ, BHN, BHE- channels in continuous mode, and about 12 hours of continuous data of the HHZ, HHN, HHE channels. These data are available via dial-up connection. The tape has to be changed about every two months.
Data are recorded locally to the Q680 hard disk and about 15 Gbytes have been actually collected on DAT. The software for reading Quanterra's tape is available from the ORFEUS website http://orfeus.kmni.nl, search "rdseed.v4.16" or "Seedstuff". This software runs under SUN's Solaris or under LINUX systems. Important programs are "extr_tape", "extr_qic" and "extr_file". They offer options to convert the data to various output formats (e.g., PITSA ASCII), to select start and end of desired data and other. The options are selected using C (UNIX) type command-line arguments.
In Fig. 9 an example of a seismic event (05/26/01 06:02 GMT, M_L= 3.8) located in Ionian Sea is shown; the event occurred at a distance of about 150 km from the station. With a 20 Hz sample rate it is possible to notice the good signal to noise ratio.

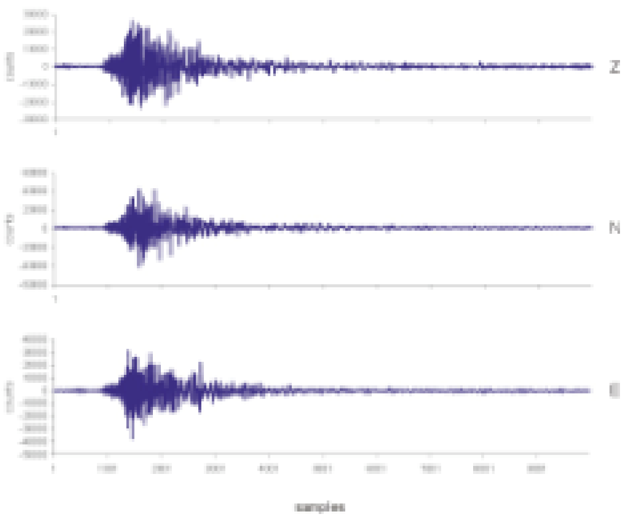


Fig. 9 – Example of a seismic event recorded by Q680 with a 20 Hz sample rate. From top to bottom: vertical (Z), north-south (N) and east-west (E) components.

1.5 Controlling the Quanterra Acquisition System

The operational configuration of the Quanterra is controlled by a series of *key* macros. The Quanterra reads the so called *key file* , and executes the macros listed there. Other items are configured, for instance in the "userinfo.pos" file.

An example for a typical key file is shown below:

FILE "key"

```
grp 1
SI SRVB
SN "SRVB"
Installed  13/05/00
LA 00.000
LN 00.000
EV 0000
MODEM_PORT /s1b          # The modem port
PERCENT_DATA 10
MODEM_BAUD 9600
```

```
level 2
MODEM_TYPE usr56k   # The modem type
netdir /h0/MSHEAR/CFG/NETWORKS/MASTER
$8MEGRAM                        # RAM storage capacity
$NO_NETWORKING
$NO_WEB


$NO_ETHER
$det_lev5  1
$include  /h0/mshear/cfg/networks/userinfo/userinfo.pos
$DEST_SX
$TAPE_HP_DAT    # The tape drive
$SENSOR STS_1;B   # Sensor type
$STYLE_VBB B;U   # Sensor style
$1GBDISK              # Storage capacity of the hard-disk
$Q680 DV
```

FILE "userinfo.pos"

```
net_banner "Istituto Nazionale Geofisica"
NETID MN                    Sets MSEED Network ID in AQCFG
License 14525419469046943176    Sets customer license code in AQCFG
supassword [password]
p1 35004
p2 37004
p3 39004
dss_port 36004
VC 1800
ip-host 1
ip-domain int.ingrm.it              Datalogger domain
ip-net 10.60.4              Datalogger ethernet ip network
ip-broadcast 10.0.0.255
ip-defaultrouter 10.0.0.253
ip-bcast 255
ip-subnet 0xffffff00
ip-defroute 253
sl1-net 192.168.1              Datalogger slip ip network on sl1
sl2-net 192.168.2              Datalogger slip ip network on sl2
sl3-net 192.168.3              Datalogger slip ip network on sl3
i1-net 193.206.122           comlink pri destination ip address is i1-net.i1-host
i1-host 24
i2-net 193.206.122            comlink sec destination ip address is i2-net.i2-host
i2-host 100
i3-net 193.206.122            comlink aux destination ip address is i3-net.i3-host
i3-host 100
$EVENT_BUFFER
$DIAL_MODEM
$ETHER
$WEB
$NETWORKING
```

2. Technical improvements and perspectives

In order to be compliant to the requirements of CTBTO new civil works and technical upgrades of instrumentations are needed to the station.
In particular the INGV is planning a series of improvements regarding:

- electrical and power supply of the whole site.
- new rack shelters for the instruments
- satellite transmission of acquired data to the Data Communication Center of ZAMNG (Central Institute of Meteorology and Geodynamics) in Vienna
- state of health remote control and alarms

3. Conclusions

This work illustrates the main characteristics of the AS050 VAE seismic station, and also gives the first grade of information regarding this acquiring system.
This site has been selected by the CTBTO to be a part of the IMS which is dedicated to the surveillance and detection of nuclear explosions for good site conditions and its high quality instrumental characteristics.
Data recorded (very broadband and short period data) by this station are embedded in research projects devoted to global and regional seismology (see e.g., MEDNET). The data are going to be exploited also on a local scale for microearthquake studies, such as the estimation of true WOOD-ANDERSON magnitudes and seismic moments, as well as long period signals radiated from Mt. Etna volcano.

4. Acknowledgements

We are grateful to Prof. Stefano Gresta (University of Catania) for his useful suggestions to the paper. We also thank an anonymous reviewer for his comments which helped to improve the quality of the original manuscript.

Bibliography

Berkeley Seismological Laboratory (1999-2000): Annual Report – Data Acquisition and Network Enhancements

Boschi E. and Morelli A. (1994). *The MEDNET Program,* Annali di Geofisica, **XXXVII**, 5, 1066-1070

Kinemetrics Inc. Web Site, URL http://www.kinemetrics.com/

Mazza S.,. Morelli A. and. Boschi E. (1998). *Near real-time data collection and processing at MEDNET*, EOS Trans., Am. Geophys. Union, **79**, 569.

Mednet (Mediterranean Very Broadband Seismographic Network) Web Site, http://www.ingv.it/~roma/

Orfeus **(O**bservatories and **R**esearch **F**acilities for **EU**ropean **S**eismology) Web Site, http://orfeus.knmi.nl

Pesaresi D. (1996-97): Seismic Observatory in Terra Nova: the 1996-97 Field Report.

Pesaresi D. (1998). Installation and Maintenance of Very-Broad-Band Stations, ORFEUS workshop on "Installation and operation of broad-band seismograph stations", Praga, 1998.

Quanterra Inc. (1999) : Quanterra Multi-Shear, Software Configuration Guide

Quanterra Inc. (1993) : Q680/SXS-G Operation

Trnkoczy A. (1997): STS-1 and STS-2 Sensors in National Seismic Networks – Application Note #40, Kinemetrics S.A.

Wielandt E. and Streckeisen G. (1982): The leaf spring seismometer: design and performance, *Bull. Seis. Soc. Am.*, **72**, Part A, 2349-2367.

Wielandt E. and Steim J. (1986): A digital very broadband seismograph, *Ann. Geophys.*, **4b**, 227.