Proposal of an environmental monitoring station isolated from the interferometer environment

Advanced Virgo scientific and technical note

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Abstract:

It is proposed the realization of one set of continuously running environmental sensors, hereafter called "External Environmental Monitoring Station - EEMS", to be placed in a fixed suitable location external to the experimental buildings in order to be maximally isolated from the interferometer noise environment and maximally sensitive to external noise sources. The EEMS is complementary to the designed AdV environmental monitoring probes network. The EEMS is aimed to serve mainly as: (1) efficient monitor of variations of acoustic, seismic and Electro-Magnetic noise from present and future anthropogenic sources in the detector site surrounding territory; (2) assure continuity of monitoring also during the AdV construction phase; (3) during AdV operation, allow correlating noise from external sources to the noise sensed close to the ITF, and specifically to the ITF signals themselves. It is proposed here the realization of a basic version of EEMS, which leaves the opportunity of future useful upgrades.

Introduction

Noise from the environment surrounding EGO can have significant effect on the sensitivity of our interferometer. We have evidenced that electromagnetic, seismic and acoustic noise coupled significantly with the Virgo signals. Studied noise paths are: scattered light from seismically and acoustically excited surfaces, magnetic coupling to mirror magnets, Radio-Frequency disturbances (see [1]).

Powerful sources of seismic, acoustic or electro-magnetic noise are present in the territory, known examples are: roads and bridges [2], wind power plants [3], radio transmitters [4], electro-ducts [5], and aircrafts [6]. Studies have evidenced that noise from these sources reach the interferometer and we can expect significant noise at the site from sources located as far as 10-20km away.

The territory around EGO is in evolution. Significant changes have been implemented during the 10-year Virgo lifetime, and we can expect similar changes to be operated during the AdV lifetime. For examples, since Virgo started operation we noted the construction of the "il Faldo" large car-storage park (2005, 1km West of WE building), one wind-turbine farm (2009, 5km East of Virgo NE building), two photovoltaic plants at less than 1km from Virgo arms. In addition, new potentially harmful installations have been proposed in the vicinity of EGO: the extension of the present Pontedera wind park; one large wind farm (50 turbines) along the cost (15km from us); and one car raceway at 5km East of Virgo NE [7]. Medium-term plans of the "Regione Toscana" foresee: (1) one additional landing path of the Pisa Airport towards Cascina; (2) one railway line connecting the Livorno harbor to Pisa passing through Collesalvetti; (3) one new exit of the FI-PI-LI large communication road at S.Frediano (1km from NE); (4) one amusement park resort between Pontedera and Cascina.

Being concerned in preserving the "noise climate" of the EGO site, in 2006 EGO signed with the local authorities (Provincia di Pisa) one agreement which had been included in the current plan for the regulation of the "Provincia di Pisa" territory (PTC [8]). In this document EGO set limits for the immission level of seismic, acoustic, and electro-magnetic noise into our site, and define verification procedures. With this document the Provincia commits to notify EGO about potential noise sources in the territory and to invite EGO to take part in the project approval procedure ("procedura di Valutazione Impatto Ambientale"). A revised version of the document has been communicated to the Provincia di Pisa in March 2011.

1. Scientific motivation

A continuous and efficient monitoring of the noise coming from the EGO site environment is crucial to the Advanced Virgo experiment, in order to: (1) correlate noise from external sources with the noise sensed close to the detector and the interferometer signal, (2) characterize and eventually localize external noise sources, (3) sense variations of the noise levels due to new activities or changes in existing activities in the EGO site surrounding territory, (4) verification of compliance of the external noise levels with the noise immission limits agreed with the local authorities.

The existing Virgo environmental monitoring sensor network [9] cannot efficiently fulfill this role since: (1) it is overwhelmed by noise from local infrastructure sources, thus the sensitivity to external sources is extremely reduced, (2) it is entirely confined inside experimental buildings, and thus alone it cannot help disentangling noises coming from the outside, (3) it cannot guarantee continuity and efficiency in the monitoring of the EGO site during the about two-year long period of AdV construction.

We thus propose, as part of the Advanced Virgo project, the realization of one "External Environmental Monitoring Station" (***EEMS***) which shall fulfill the above tasks.

We judge particularly important that a site monitoring is guaranteed during the AdV construction phase. For this, we urge for the realization of the EEMS, at least in its "reduced cost" version described in **Section 6**, in a reasonably short time, of the order of six month from now.

Subsequently, during the running phase of the AdV interferometer, this Environmental Station will be a useful reference and eventually provide a trigger for external environmental transients (e.g. airplanes, helicopters, vehicles, EM pulses) that are potential sources of noise for the interferometer. To this end, the EEMS shall for example eventually include one system for airplane identification (see **Section 5**).

We propose the construction of a basic version of EEMS, which contains a minimal set of sensors, but which yet allows to be expanded hosting subsequent upgrades which we describe in a dedicated section. We also propose an initial version of EEMS which temporarily re-uses some existing sensors, thus allowing delaying some of the costs.

Here below we describe EEMS general requirements (**Section 2**), its technical characteristics (**Section 3**) and the proposed location (**Section 4**). In **Section 5** we list possible future upgrades. In **Section 6** we give an estimate of costs for the basic version, specifying also costs which could be delayed. In **Section 7** we give an estimate of construction time.

2. General requirements

The External Environmental Monitoring Station should fulfill the following requirements:

- It shall contain appropriate sensors to measure seismic, acoustic and magnetic noise in an useful (see **Table 1** below) bandwidth;
- It shall be located outside of buildings and the far as possible from local noise generated by Virgo site infrastructures, however its location has to be within EGO site;
- Sensors shall be operated continuously;
- Data shall be GPS tagged and made available to the Virgo Data Stream;

- Being the interesting noises potentially influenced by weather conditions (e.g. noise from electric plant windmills, but also transmission of acoustic noise), we consider useful include in the same location also the current weather station (wind, rain, pressure, humidity and a temperature sensors) and the lightning detector.
- Be operational in a reasonably short time (summer 2012) in order to guarantee continuity in the environmental monitoring also during the AdV construction phase.

3. Technical details

The environmental monitoring station we propose is sketched in **Figure 1**, while **Table 1** lists its basic electronic components. The station consists of the following elements:

- Shelter house (in **Section 3.1**);
- Environmental sensors (in **Section 3.2**);
- Power supply (in **Section 3.3**);
- Data acquisition, transfer and storage (in **Section 3.4**).

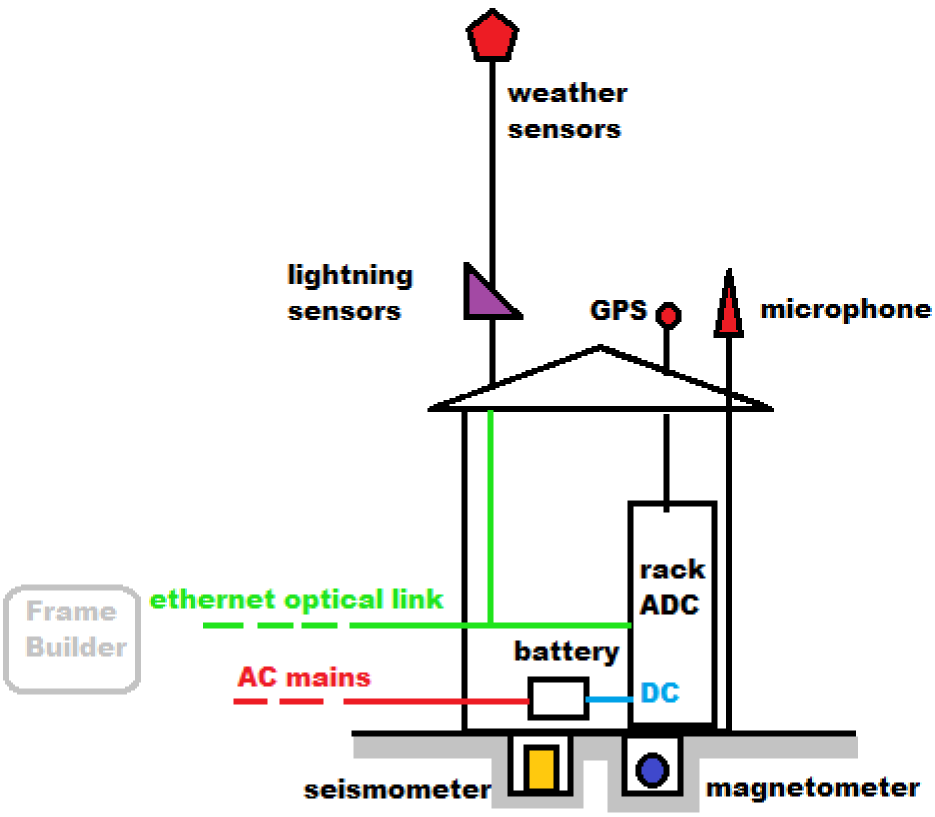

Figure 1: Sketch view of the EEMS.

Type	Number of channels	Sampling Freq. (Hz)	ADC resolution (bits)	data rate (bit/s)
Acoustic	1	5000	24	120000
Magnetic	1	5000	24	120000
Seismic	3	500	24	36000
Battery Monitor	3	1	8	24

Table 1.a: List of sensors with analogue output.

Type	Number of channels	Sampling Freq. (Hz)	SMS typical length (byte)	data rate (bit/s)
Lightning Detector	3	1	40	320
Weather Station	7	1	80	640

Table 1.b: List of sensors with digital output.

3.1 Shelter house

A container box is necessary to host and shelter the sensors, power supplies and data acquisition devices. The container walls and roof shall be of electric and magnetic-inert material. We propose one wooden box. This box should sit on rigid basement in contact with the ground. The basement possibly should be not armed with metallic parts (in order to avoid local distortion of the magnetic field). The basement should include water-proof pits for hosting the seismometer and the magnetometer (see **Figures 2** and **3**). The normal protection against lightings and electric shocks must be granted and a good grounding shall be supplied, to connect all the devices hosted within. The container should be screened from direct solar radiation and have a natural insulation and aeration in such a way to obtain a passive internal temperature control.

3.2 Sensors

- *One tri-axial low frequency seismometer*. The Guralp-40T velocimeter [12], the same model installed at Virgo Central Building floor seems well suited (sensitive range 0.03Hz to 50Hz). The seismometer is required to be installed in a pit, as sketched in **Figure 2.**
- *One low noise magnetometer.* The model used in Virgo (Metronix MFS-06, [13]) is optimally suited, being recommended also for magneto-telluric applications. It has very low noise (below typical magnetic field variations in a quiet day) and a wide sensitive frequency range extending from 0.0001Hz to 10 kHz. This instrument shall allow

efficiently detecting both magnetic pulses/noise from HF sources (High Voltage ducts, lightning …) and magnetic noise phenomena in the atmosphere (e.g. Shuman's resonances [10]). The magnetometer shall be installed in a pit as shown in **Figure 3**.

- *One microphone* (optimal range should be 1Hz-10kHz). The microphone shall be placed outside the container, on a few meter high pole to avoid sound wave distortions from the container itself, as illustrated in **Figure 4.** It is also important that the microphone has as much has possible free horizon view (see **Sec. On Future Upgrades**). The microphone shall be of pre-polarized type and capable of surviving any external weather conditions. The setup shall include protections against wind, rain and perching birds. Some models (i.e. LD) also include desiccant cartridges [14].
- *One weather station*. The Virgo weather station [15] currently installed atop the control building shall be moved here. The station will be placed on a few meter high pole, and care must be taken it is not shadowed by buildings. A 20m long cable allows placing it, if necessary, at some distance from the shelter house to avoid sound interference with the microphone.
- *One lightning detector*. The current Virgo lightning sensor is installed atop the control building. Indeed its current position is not well suited since it is close to switching water chillers which can mimic false lighting signals. The proposed sensor by *BlitzOrtung* [16] permits us to become part of a network of similar sensor covering large part of Italy and Europe, we would get accurate lightning localization resulting from the Time of Arrival correlation with all sensors in the network.
- *Voltage and Current Probes* for monitoring status of: Battery voltage, Battery current, and Battery charge current.

3.3 Power supply

No galvanic link should exist between the monitoring station and Virgo infrastructures. The power supply will be preferably given by CC solar panel system (12 – 24 V) with backup batteries. Since this option is expensive (see **Section 6**) in the following we consider the alternative option that is: ENEL mains supply charging local DC batteries. The power supply needs are:

- DC batteries for backup (two units);
- Power supplies (about 10 units); these are DC/DC voltage regulators needed to convert the battery power to instruments needs. Sensor probes (including the pre-polarized microphone) necessitate of +-12V or +-24V DC power supply.

3.4 Data acquisition, data transfer and data storage

The basic EEMS version foresees the acquisition of 8 analogue signals (**Table 1.a**: magnetometer, microphone, seismometer and battery status monitor). The weather station and the lightning detector have instead a digital output (**Table 1.b**). However, we foresee the data acquisition system could be expanded to satisfy future needs (see **Section Future**

Upgrades). Thus a 12-channel ADC seems a reasonable request. A 24-bit ADC is needed in order to fully exploit the instruments extremely good sensitivity, low intrinsic noise and full dynamic range.

One option is the commercial system of reference [17]. This system requires of one GPS antenna for time stamping.

The signals sampling rate is chosen in order not to overload the data flux, yet allowing enough signal bandwidth for the aimed noise studies. Table 1 lists the planned sampling rates. The total data flux would be ≤300 kb/s. The data will be transferred into the Virgo Frame Builder through an optical link.

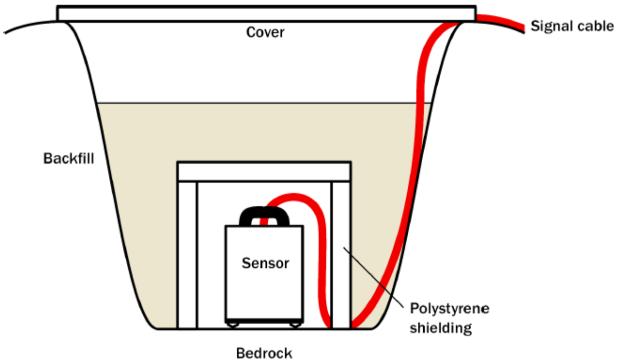

Figure 2: Seismometer pit installation, suggested by Guralp.

Figure 3: Example of temporary installation of a magnetometer to use in magneto-telluric measurements. The MFS-06 magnetometer user guide explains that to preserve the performance of the magnetometer in the very low frequency range, it is important that the magnetometer is protected against low frequency vibrations. Thus, in outdoor installation the magnetometer has to be protected against wind. The user guide suggests to bury the magnetometer in ground and to firmly fix its cables in a way they cannot move in the wind. For long term measurements it seems important using a water proof pit. A concrete pit underneath the shelter hut should do a good job.

Figure 4: Example of one outdoor microphone installation

4 Proposed location

The station should be located on the EGO site property, but as far as possible from known noise sources of any kind, like: underground electric cables, high voltage electric lines above, air conditioning devices, roads, etc. On the other hand, it shall be not too far from infrastructure services as Ethernet and 220V power line (in order to reduce link costs). It is also important for the acoustic and weather sensors to have a free-horizon view and not to be shadowed by presence of close buildings. We identified three possible locations, illustrated in **Figure 5**.

The most convenient location seems to be in the proximity of 1500W, about 150m North of the building (position named “A” in **Figure 5**). This location is far from intense local noise sources, but yet not too far from Ethernet and AC power connections which are available in the Building. A concrete basement is already present, which would reduce infrastructure costs.

The second alternative (named “B” in **Figure 5**) is about 100m North of the Central Building. The disadvantage of this location is in proximity (less than 25m) of one 15kV underground cable. Another disadvantage is that in this location the EEMS would be partially shadowed by the tall Building and also be more sensitive to noise from the CB infrastructures.

The third considered location is in the South-most corner of the EGO site property (position named “C” in **Figure 5**). This location has the disadvantage of requiring longer cabling paths, thus would require longer infrastructure works and higher costs. As well, this location would be exposed to the noise from EGO site access roads.

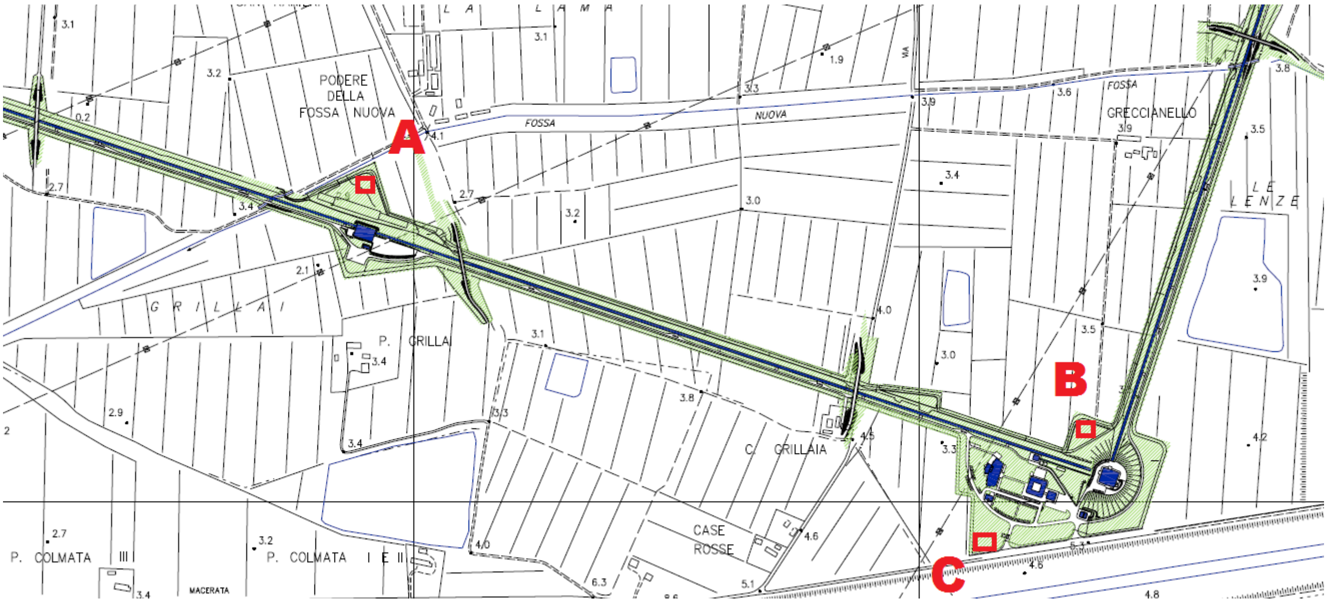

Figure 5: Aerial view of Virgo. Rectangles indicate candidate locations of the EEMS.

5 Possible Future Upgrades

The implementation of a system for aircraft noise identification and tracking seems a feasible application. It would provide clean aircraft triggers vetoes to GW data quality pipelines. Commercial systems do exist [11] and colleagues at University of Pisa have experience on a prototype device.

A radio frequency antenna could be eventually added to monitor daily/seasonal variations of the EM field. Eventually the RF antenna could be "tuned" to monitor external EM field RMS in the 10kHz bandwidth around AdV modulation frequencies.

6 Costs estimate

Table 2 lists the costs estimate for the EEMS basic version assuming it located in position "A". The total cost is 48 k€+IVA. As described below, we foresee possible saving or delaying of some costs. As well, we have investigated of possible additional costs depending on the choice of the site location and the type of power supply.

Reduced cost option:

During the AdV construction time some of the Virgo sensors can be moved to the EEMS, thus delaying their purchase by 2 years or so, these are:

- One magnetometer (6.1k€);
- The Guralp seismometer of the Central Building (10k€);

- The spare weather station (1k€).

Meaning that about 17k€ expenses could be delayed, and the prompt budget request is approximately 30k€+IVA.

Optionally additional costs:

- If the power supply will be entirely given by CC solar panel system (12 – 24 V) with backup batteries (indicatively: 10 square meters effective surface with a fixed orientation can produce an average minimum guaranteed power of 100W/h) a tentative cost estimation is around 10 k€ comprehensive of installation.
- If the chosen location is too far from network facilities, a “HyperLAN” radio system could be used; a tentative cost estimation is around 5 k€ comprehensive of installation

7 Construction time estimate

Construction civil works are estimated to last about three months, including the time needed to ask permissions to the local authorities. One additional month is needed for sensors installation.

We consider crucial to have the station operational in a reasonably short time in order to guarantee continuity in environmental monitor also during the AdV construction phase.

Item	#	Cost x1 (euro)	Total cost (euro)	Note
Seismic tri-axial [12]	1	10000	10000	Guralp (Virgo like)
Magnetic [13]	1	6100	6100	Metronix (Virgo like)
Acoustic [14]	1	5000	5000	Outdoor microphone
Weather station [15]	1	1000	1000	Davis (Virgo like)
Lightning [16]	1	500	500	Blitzortung
Data logger [17]	12 chs	625	7500	Dymas24 (24 bit, 10kHz configurable)
DC batteries	2	100	200	Power supply and backup
Battery status probes	3	33	100	
Power supplies	10	100	1000	DC regulators, if needed
GPS timing antenna	1	1000	1000	PPS clock
Net stuff, opt fiber ...	1	4000 (*)	4000	By A.Bozzi
Shelter & infra. works	1	11600 (*)	11600	By P.Popolizio
Grand total cost =			**48000 + VAT (21%) (58080 euro)**	

Table 2. Cost estimate list. (*) costs are given assuming a position in the area at North side of 1500-West building. This area looks the “cleanest” in terms of acoustic, seismic and magnetic noise generated by local infrastructure sources. Other areas could have different infrastructure and network costs.

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[10] http://en.wikipedia.org/wiki/Schumann_resonances. Also: http://www.hese-project.org/hese-uk/en/papers/schlegel_schumann.pdf

[11] Example of a commercial product for aircraft noise identification and measurement of arrival direction: http://www.rion.co.jp/dbcon/pdf/NA-37-E.pdf

[12] Seismometer: http://www.guralp.com/products/40T/

[13] Magnetometer: http://178.63.62.205/mtxgeo/index.php/sensors/mfs-06e

[14] Microphone outdoor kit:

http://www.larsondavis.com/Downloads/426A12_0808_LoRes.pdf

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