Site Characterization/Preparation Board

WD1 - M1.2 Report

Measurements standards and procedures for the characterization of the ET candidate sites

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L. Naticchioni[1], S. Shani-Kadmiel[2], C. Giunchi[3], R. Devoti[4], R. Hanssen[5], R. De Rosa[6], T. Bulik[7]

1 *INFN, Sezione di Roma, 00185, Roma, Italy*

2 *R&D Department of Seismology and Acoustics, Royal Netherlands Meteorological Institute (KNMI), 3731 GA De Bilt, The Netherlands*

3 *INGV, Sezione di Pisa, Via Cesare Battisti 53, 56125, Pisa, Italy*

4 *INGV, Sezione di Roma, Via di Vigna Murata 605, 00143 Roma, Italy*

5 *Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands*

6 *Università degli studi Federico II Napoli and INFN, Sezione di Napoli, 80126, Napoli, Italy*

7 *Astronomical Observatory Warsaw University, 00-478 Warsaw, Poland*

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1 Introduction

In this document we describe the measurement standards and procedures that must be carried out in the characterization of the Einstein Telescope candidate site. The physical variables and measurements required for the characterization are reported in the document WD1 - M1.1. This document is divided into four sections reflecting the work package organization of division 1 within the Site Preparation Board.

2 WP1.1: seismic measurements

2.1 long-duration measurements

Broadband three-components high-class seismometers are required for the evaluation of the seismic levels measured at the candidate site area. They should be placed in vault and borehole installation ensuring a good contact with the surrounding rock and the best thermal insulation possible.
In particular, for the proper evaluation of the seismic background level, the 10^{th}, 50^{th} and 90^{th} percentile of the acceleration proper spectral density (PSD) has to be assessed in the 10^{-2} - 20 Hz band. The PSD should be calculated following the McNamara & Buland method with a 1800 s window and 50% (900 s) overlap.
Broadband measurements should last at least two years. Host teams should assess the microseismic amplitude and its seasonal variations.
Borehole seismometer installations are required at the proposed corners of the ET infrastructure.
Underground borehole installation should be always paired with a surface-level installation, while where possible (e.g. former mines, underground laboratories) vault installation are recommended at different depths, in order to calculate the cross-correlation and amplitude-depth function. All the stations have to be synchronized in time with a common timing reference (e.g. GPS timing).
Three-component measurements are required for the calculation of the H/V (horizontal to vertical) spectral ratio, providing information about the source mechanism of the noise as well as information about the local geological setup.
The stationarity of the background noise should be assessed by the measurements, evaluating the occurrence of transient noises (glitches lasting tens to few hundred of seconds) and their amplitude. In particular, significant transient events (either of natural or anthropic origin) should be collected in a catalogue for the observation time. The host teams should also provide a historical log of seismic events in the candidate area.

2.2 short-duration measurements

Short-duration measurements can be achieved using arrays of broadband and/or short-period seismometers (tens to hundreds). These measurements should provide information about the body to surface wave content of the seismic noise and the propagation characteristics like the surface-wave dispersion and its propagation direction. It is required that host teams provide array measurements at least in the areas surrounding the proposed corners of the ET infrastructure. Ideally, PSD should be measured by an array covering a larger extent than just the corner point. This would allow the generation of spectral noise distribution maps in four frequency bands: [0.5-2 Hz], [2-4 Hz], [4-10 Hz], [10-20 Hz].
Seismometers have to be chosen according to the ambient seismic-noise spectrum and should achieve a signal-to-noise ratio better than 10 between 3 and 10 Hz. This requirement could be not achievable in underground installations and in general when the local natural background noise approaches the Peterson's low noise model (NLNM). In this case, the requirement could be relaxed to a factor 7 profiting from the higher level of stationarity of the seismic field [1]. Minimum and maximum aperture of the array should be chosen according to the Rayleigh-wave speeds in the considered frequency band [1].
Performing array measurements the host teams should provide an estimation of the surface wave dispersion curve, the characterization of seismic sources (e.g. unravelling the anisotropy of the seismic field), and the

estimation of the modal content of the seismic noise. If there is evidence of local sources of noise (e.g. wind farms, railways, operating quarries, etc), they should be studied evaluating the properties of the associated spectral lines (e.g. amplitude with respect to the mean background, percentiles, stationarity, etc) in the band of interest. Short-duration measurements with seismic arrays should last a period of several weeks for a better understanding of the diurnal and the weekly variations in the seismic noise background.
Active seismic surveys based on reflection/refraction seismology should be performed in the areas covered by the seismic arrays, possibly complementing the seismometer array with lines of geophones (tens to hundreds of sensors), providing information about subsurface structures. Active seismic surveys should be performed in collaboration with the WD2 activities to maximize the scientific output of these measurements.

3 WP1.2: gravimetry & geodynamics studies

A gravimetric survey is worthy to gain a better understanding of the subsurface geology at the proposed ET sites. The availability of continuous gravimetric measurements at the ET site will also enable it to detect time-varying mass distributions. A complete annual cycle could be used for the detection of groundwater mass variations.
The regional surface deformations can be monitored by means of GNSS and InSAR techniques, possibly combining the two data sets. The regional differential deformation could be inferred using the existing GNSS stations within a radius of at least 80 km from the proposed site and covering a time span of at least 4 years. Time series of daily GNSS positions are well suited to infer the actual active tectonic motions (i.e. secular drifts) and consequently the strain-rate map of the region (the rate of change of the deformation). GNSS stations located in proximity of the ET site will provide useful data to study the response to groundwater cycle. For this particular study, at least one year of daily observations should be available. Long time series of ground deformation determinations, based on ascending and descending In SAR acquisitions, will be useful in characterising the expected deformation in the full area of the proposed ET site. The available GNSS data should also be used as ground control points in the time series analysis to mitigate possible atmospheric artifacts.

4 WP1.3: magnetic noise

A set of at least 2 magnetometers are required for the characterization of the locations corresponding to the vertices of ET. The probes have to be installed horizontally to increase the sensitivity to the Schumann Resonances (SR); the probe orientation should be north-south and east-west to help comparison with similar far stations. Eventually a third probe can be installed vertically to have a complete magnetic characterization of the selected location. The probes located in the surface should be buried at least for 20 cm underground to avoid possible distortion, at low frequency, produced by mechanical vibrations [4.1]. In case of installation in underground caverns or tunnels it is enough to firmly fix the sensor on the ground. If possible, the probes should be far enough from power lines or strongly emitting electric equipment, like pumps, air treatment units and so on. This is important to avoid possible probe saturation due to very intense electromagnetic (EM) emission occurring at selected frequencies, like 50 Hz.

Suitable data logger, having input dynamic range compatible with the magnetometer output, at least 24 bits resolution, GPS disciplined timing and fully remotely configurable should be used. The sampling frequency to obtain a good monitoring of the SR should be at least 150 Hz since for a very quiet environment it is possible to detect up to the 9^{th} SR at about 60 Hz [4.2, 4.3].

For a complete characterization of the site, data should be collected for a period of at least one year; this will allow more detailed indication about the daily/seasonal variations of the natural and artificial magnetic noise intensity, the spectral characteristic, and the typical time evolution. When possible, to get information about

the characteristics of the underground environment, it is suggested to install at least a couple of probes with the same orientation, one in surface and one underground at one of the vertices. In this way a direct comparison between surface and underground magnetic noise would be possible.

Before the installation, especially for sensors placed at different levels, the recommendation is to perform a parallel sensor test, placing all the sensors horizontally and parallel, separated by a distance of about 2 meters and far enough from local electromagnetic noise sources. In this way the calibration of each probe can be verified, and defective sensors can be eventually individuated.

5 WP1.4: other environmental noises

The other environmental variables to be measured are: infrasonic noise, micro marymetric noise, and weather: temperature, humidity, wind, precipitation.

- Infrasonic noise

The measurements will be done using the Gras (or similar microphones). The microphones on the ground should be shielded from the wind and precipitation by tents/covers. The measurements should be done with the sampling frequency of at least 250Hz. The duration of the measurements should cover one year - although the measurements can be restricted to short - one week campaigns covering different seasons.

- Weather data:

The weather information should be collected either from dedicated stations at the locations close to the planned locations of ET end stations, or from public weather stations in these locations if they exist. Temperature, humidity, precipitation rate should be sampled with the frequency of 1 per minute, while the wind speed should be measured with the frequency of 1Hz. The measurements of temperature, humidity should be done at the height of 1.5 above the ground. Ideally the wind measurement should be done at the height 2 metres, at least 15 metres from buildings or trees.

6 References

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