

RAPPORTI TECNICI INGV

Using obsinfo to organize and format
OBS-B metadata



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

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Abstract

The larger amount of data made available today is one of the most important factors driving innovation but not the only one. In particular, standardization of data and metadata formats is widely considered an essential goal for the scientific community to pursue. This report presents how a new publicly available tool for organizing and formatting metadata for Ocean Bottom Seismometers (OBS), *obsinfo*, has been used to organize and format metadata for INGV OBS Lab OBS-B (<https://www.ct.ingv.it/index.php/risorse-e-servizi/laboratori/325-laboratorio-obs>) The OBS & Earth Lab, located at the Gibilmanna Geophysical Observatory near Cefalù (Palermo - ITALY), has as its main mission the design, construction and management of a fleet of underwater seismic instruments. The software, developed by RESIF (<https://gitlab.com/resif/smm/obsinfo>) breaking down the metadata into smaller and reusable pieces of information, speeds up the process of creating StationXML files for OBS and other kinds of geophysical instruments. Besides assembling a useful StationXML file for the OBS-B, the work done has confirmed that *obsinfo* can be a valuable tool for managing station metadata.

Keywords OBS; StationXML; Obsinfo

Introduction

Data and metadata formats for seismology

Today, scientific research requires an ever increasing amount of data and the scientific community puts great effort into producing new data and ensuring that established data quality standards are met. The larger amount of data made available is one of the most important factors driving innovation but not the only one. In particular, standardization of data and metadata formats is widely considered an essential goal for the scientific community to pursue.

Concerning seismic and geophysical data, the Standard for the Exchange of Earthquake Data (SEED) [FDSN, 2009] helped research institutions across the world share seismic data. The format, maintained by the International Federation of Digital Seismograph Networks (FDSN), has been enhanced and refined a number of times and remains in widespread use (<https://ds.iris.edu/ds/nodes/dmc/data/formats/seed/>).

Within the SEED standard, an organized set of data and metadata, containing all the information needed for processing and analysis, is referred to as a logical volume. Logical volumes contain control headers and time series. Control headers are sequences of smaller objects, called blockettes: data structures that contain a type identifier, a length field and specific metadata fields. Blockettes can be either binary or ASCII. The widespread file type named miniSEED, is a sequence of SEED data records (no information about channel response is included), whereas its counterpart, that is a file containing a series of blockettes (just metadata and no data records), is called a dataless SEED file. Among the file types descending directly from the SEED, there is the RESP type, used to describe the transfer function of a data acquisition channel. One of the disadvantages of RESP files is that each line must start with an alphanumeric code, identifying a blockette number and a field number within the blockette. Today the scientific community is moving away from RESP files and their use is deprecated.

The StationXML format has been gaining popularity and represents today a de-facto standard for sharing metadata. Just like SEED, StationXML is maintained by FDSN. StationXML was developed as a replacement and extension of the SEED standard. The purpose of the FDSN StationXML

schema (fdsn-station.xsd) is to define an XML representation of the most important and commonly used structures of SEED 2.4 metadata with enhancements.

However, StationXML does not solve certain problems with seismic metadata. For example, StationXML files contain repeated sections, in particular those needed to describe Finite Impulse Response (FIR) digital filter stages, which are usually identical across the channels of a definite data acquisition system. In addition, a complete StationXML file can be remarkably big, because it stores all the information pertaining to a certain station, from starting time and location to channel response. The software tool *obsinfo* (<https://obsinfo.readthedocs.io/en/latest/overview.html>), which will be described below, was specifically created by the seismological community to overcome the problems mentioned above.

This report presents the work done in order to create StationXML files for a specific kind of Ocean Bottom Seismometer (OBS), among the various versions built at Istituto Nazionale di Geofisica e Vulcanologia (INGV) OBS Lab. The next section will provide key information about this kind of marine instrument, followed by a description of the *obsinfo* tool.

1. The OBS-B instrument

The broadband (indicated with acronym prefix BB) Ocean Bottom Seismometer (OBS) version-A was the first instrument developed by INGV OBS Lab, aiming to extend the seismic monitoring to offshore areas. The OBS is a complex instrument composed by different parts, such as: a frame, seismic sensors, data acquisition systems, batteries, ballast, thrust buoys, acoustic modem and systems to geolocate instruments (the acronym BB-OBS/H is used to designate the same instrument, when equipped with a low-frequency hydrophone in addition to the seismometer) [D'Anna, 2009]. Over the time, the design has been revised and improved. Both BB-OBS/H A and B versions called for short OBS-B, can reach 15 months of battery life and 6000 meters of depth and can be equipped with a three-component broad-band seismometer (for example Trillium Compact OBS 120s-100Hz or Guralp OBS 6TC 60s-100Hz). In addition to seismometer, it's possible to choose between: a low-frequency hydrophone or a Cox-Webb Differential Pressure Gauge (DPG). Version B is much more compact and it guarantees sensor seismic protection reducing submarine environmental noise and risk of collisions. A fleet of 8 OBS-B was used in the Seismofaults experiment to gather seismic data from active tectonic structures in the Ionian Sea [SgROI et al., 2021].

Like its predecessor, the OBS-B is a stand-alone seismic station, deployed by free-fall, which means by letting the instrument fall gently toward the seabed. For the duration of the experiment, a ballast anchors the OBS to the seabed. At the end of the experiment, the user prompts the instrument to release the ballast. This is accomplished by sending a specific command, over an acoustic link, from a marine vessel. In a few hours, depending on the original depth, the OBS surfaces. At this point, the crew on the marine vessel locates the instrument and recovers it.

Figure 1 shows a picture of the OBS-B instrument. The seismometer (not visible) is at the bottom, inside a telescopic tube in the middle of the OBS (the tube in black is partially visible). The large yellow blocks held by the metal frame (see Figure 1), are made of syntactic foam and are used to provide enough buoyancy for the instrument to float up after the ballast has been released. At the top, the picture shows an acoustic modem and various positioning systems: a flash beacon, a satellite beacon with GPS receiver and a radio beacon; however, the three positioning systems are rarely used at the same time. The positioning systems are designed to stay powered-off and save power while the instrument is submerged.

In the past, metadata for B-version OBSs were created by manually writing RESP files. The RESP files were merged to form a dataless SEED with the PDCC software (<https://ds.iris.edu/ds/nodes/dmc/software/downloads/pdcc/>), while the frequency responses were verified with the JPlotResp tool (<https://ds.iris.edu/ds/nodes/dmc/software/downloads/jplotresp/>).



Figure 1 Picture of an OBS-B.

2. Using obsinfo

2.1 Introduction to obsinfo

StationXML is a FDSN-standard format file not easy to write and maintain so Obsinfo, a Python (<https://www.python.org/>, <https://obsinfo.readthedocs.io/en/latest/overview.html>) standalone application, helps to create data and metadata for ocean bottom seismometers using standardized, easy-to-read information files in YAML (<https://yaml.org/spec/1.2/spec.html>) or JSON (<https://www.json.org/json-en.html>) formats. The advantages of obsinfo, instead of writing a RESP files and assembling a SEED dataless file with PDCC, are the following: it has an easier input user format, because YAML and JSON syntax is simpler than XML; it avoids redundancy; it is flexible because it allows changing configurations avoiding rewriting or modifying a new StationXML file each time; it does not use external web services, it is text-based; it adapts StationXML to OBS-specific functionality; it has a simple interface to other systems, such as Yasmine (<https://github.com/iris-edu/yasmine-stationxml-editor>).

In order to start using obsinfo the user first installs a software environment for python (conda in our case), installs obsinfo and finally creates the folder-tree needed to work with obsinfo, by using the obsinfo-setup command. All the steps above are well documented in the support pages for obsinfo, (<https://obsinfo.readthedocs.io/en/latest/>). The newly created folder-tree will not be empty, in fact, obsinfo populates it with example files in YAML format during setup.

Obsinfo has a command line interface, featuring numerous commands, but the most frequently used are

- obsinfo-validate;
- obsinfo-print;
- obsinfo-makeStationXML.

By using the commands above, the user can respectively validate the YAML or JSON syntax within the metadata files, print their content and create StationXML files. While it is recommended to refer to the official documentation for further details, the key point here is that even though the software does not feature a graphical interface, the essential commands to be learnt are just a few and the interface is easy to use.

The folder-tree contains folders and subfolders that help the user to organize and maintain metadata for specific parts of an OBS. *Obsinfo* lets break down metadata into small files that are easy to write, verify and reuse. Files are divided into different categories or types, and each category goes in a specific folder with a self-explanatory name. A set of instruments that could

be used in an experiment can be conveniently described by a subnetwork file, stored in the "subnetworks" folder. The subnetwork file does not contain all the metadata pertaining to the instruments, but it contains references to other files in the "instrumentation_base" folders. Files of type `instrumentation_base`, describe sets of channels. Each channel can be composed of up to three parts: a sensor, a preamplifier and a datalogger. For each of those parts, there is a specific file type and folder (`sensor_base`, `preamplifier_base` and `datalogger_base`).

If a real-world instrument uses the same datalogger to acquire certain channels, those channels will have references to the same `datalogger_base` file inside the folder tree. This is just an example of how `obsinfo` allows reusing existing metadata in an efficient way.

Even though the ability to reuse existing files to assemble larger metadata files is a convenient feature, some kinds of metadata, like instrument sensitivity, can vary across instruments of the same type. Therefore, a method to handle this case the user must be provided. Within `obsinfo` environment, instruments, sensors, preamplifiers and dataloggers are described by base files. Each base file contains a set of default characteristics and a list of configurations, each one with slightly different characteristics. This is why the suffix "_base" is appended to file names for the same types. When base files are referenced, the user can add the "configuration" key in order to recall one of the configurations in the base files. The "configuration" key allows handling customization and calibration data. The reader is encouraged to refer to the official documentation for in-depth information about configurations. Please, note that the work presented in this report does not use configurations. Therefore, the resulting metadata file is generic and will have to be edited to represent a specific instrument, with a given serial number and defined calibration data.

2.2 Preparing the metadata files for creating the StationXML file

OBS-Bs can be equipped with different sensors, but this work focuses on a specific configuration, featuring a three-axial seismometer produced by Guralp, Model CMG-6TC and a hydrophone produced by HITECH, model HTI-04-PCA-ULF, paired with a preamplifier LOWN-32 produced by SEND. The three seismometer's channels and the single hydrophone's channel are digitized by a GURALP Datalogger model CD24 at 100 sps.

Figure 2 shows how the information about OBS-B is organized within the `obsinfo` environment. Each block represents an object, which is stored in a separate file, describing devices network hardware or software characteristics coded using `yaml` language.

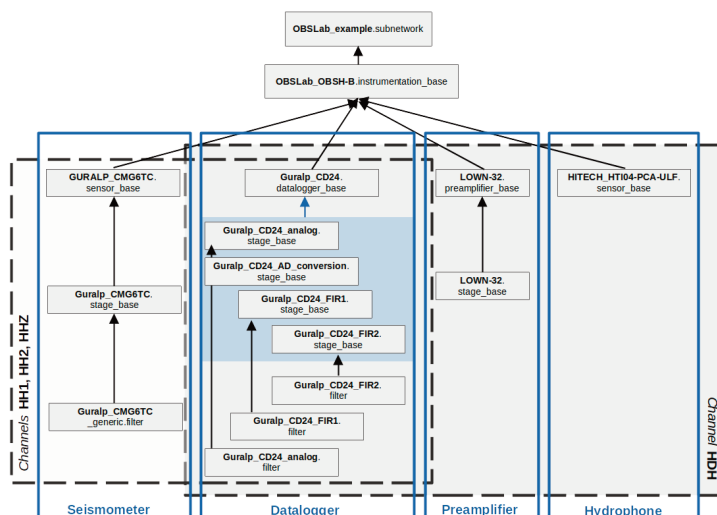


Figure 2 OBS-B metadata organization and mutual dependencies within the `obsinfo` environment.

Our scheme starts with a subnetwork file. Normally this file lists several OBSs forming a cluster of nodes used for a single experiment and for each node it contains coordinates, depth, time frame and details about the station clock. In our case there is just one station with fictitious coordinates and time frame.

The OBS, considered in our paper, is composed by an instrumentation set explained on the instrumentation_base file, which gives information on channel composition.

Using YAML language and obsinfo coding protocol, as seen on the code snippet of OBSLab_OBSH-B.instrumentation_base.yaml file shown below, it is possible to determine channels hardware configuration.

All 4 channels use Guralp CD24 datalogger to store signals coming from three CMG6TC seismometer sensors, oriented along three orthogonal axes. The fourth channel uses a hydrophone model HighTech HTI04 with a Send Lown-32 preamplifier.

OBSLab_OBSH-B.instrumentation_base.yaml

instrumentation_base:

```
channels:
  default:
    datalogger: {base: {$ref: "dataloggers/Guralp_CD24.datalogger_base.yaml#datalogger_base"}}
    sensor: {base: {$ref: "sensors/GURALP_CMG6TC.sensor_base.yaml#sensor_base"}}
  "1":
    orientation: {"2": {azimuth.deg: {value: 90, uncertainty: 180}}}
  "2":
    orientation: {"1": {azimuth.deg: {value: 90, uncertainty: 180}}}
  "3":
    orientation: {"Z": {azimuth.deg: {value: 0}, dip.deg: {value: -90}}}
  "4":
    orientation : {"H": {azimuth.deg: {value: 0}, dip.deg: {value: 90}}
preamplifier: {base: {$ref: "preamplifiers/LOWN- 32.preamplifier_base.yaml#preamplifier_base"}}
^sensor: {base: {$ref: "sensors/HITECH-HTI04-PCA-ULF.sensor_base.yaml#sensor_base"}}
```

Obsinfo automatically forms channel names based on sensor type, sampling frequency and orientation. The same channel names are written to the stationXML file and, in our case, the resulting channel names are HH1, HH2 and HHZ for the seismometer; HDH for the hydrophone. Note that HH1 and HH2 replace the usual HHE and HHZ, because orientation is unknown on the horizontal plane, which is a common assumption when working with OBSs.

Seismometer sensor information is split in three files as shown and explained later.

The datalogger that is common to all sensor channels has a dalogger_base file which references 4 different stages: analog, AD_conversion, FIR1 and FIR2. Any of these stages is coded in a separate file and bound to its filter. Stages are intended like a series of processing components comprising an analog filter, an Analog-Digital Converter (ADC) and two digital filters.

Hydrophone analog hardware info is coded on HiTech-HTI-04-PCA-ULF.stage_base.yaml. In it are described input and output units, gain values and info to build transfer LaPlace transfer function.

Hydrophone has been connected to a preamplifier in which the configuration has been split into two files.

Horizontally, wrapped by a blue line, all files are organized for any specific device: seismometer, datalogger, preamplifier and hydrophone.

In the following, we present a simplified version of how Guralp CMG-6TC sensor metadata is coded in a yaml file.

GURALP_CMG6TC.sensor_base.yaml (1)

```
format_version: "0.111"
revision:
  date: "2023-05-04"
  authors:
    - {$ref: "persons/Gioacchino_Fertitta.person.yaml#person"}
    - {$ref: "persons/Antonio_Costanza.person.yaml#person"}
sensor_base:
  equipment:
    model: "CMG-6TC"
    type: "broadband seismometer"
    description: "Guralp CMG-6TC OBS seismometer"
    manufacturer: "Guralp"
    vendor: "Guralp"
  seed_codes:
    band_base: "B"
    instrument: "H"
  stages:
    - {base: {$ref: "sensors/stages/Guralp_CMG6TC.stage_base.yaml#stage_base"}}
```

Guralp_CMG6TC.stage_base.yaml (2)

```
format_version: "0.111"
stage_base:
  description: "SENSOR - GURALP CMG6TC"
  input_units: {name: "m/s", description: "VELOCITY"}
  output_units: {name: "V", description: "VOLTS"}
  gain:
    value: 2000
    frequency: 1.
  filter:
    $ref: "sensors/stages/filters/Guralp_CMG6TC_generic.filter.yaml#filter"
  configuration_default: "differential"
  configurations:
    "differential":
      configuration_description: "differential"
    "single-sided":
      configuration_description: "single-sided"
      gain: {value: 1000}
```

Guralp_CMG6TC_generic.filter.yaml (3)

```

format_version: "0.111"
filter:
  type: "PolesZeros"
  transfer_function_type: "LAPLACE (RADIANS/SECOND)"
  normalization_factor : 409858294.3550555
  normalization_frequency : 1
  zeros :
    - '0.0 + 0.0j'
    - '0.0 + 0.0j'
    - '-62.8 + 0.0j'
  poles :
    - '-74.047e-3 + 74.047e-3j'
    - '-74.047e-3 - 74.047e-3j'
    - '-75.04 + 0j'
    - '-942 + 0j'
    - '-427 + 427j'
    - '-427 - 427j'

```

“Sensor base” file describes sensor high level information like: model and brand. The file references a stage_base file (Guralp_CMG6TC.stage_base.yaml) which specifies input and output units and frequency response.

Stage_base file refers to further filter details linking file **Guralp_CMG6TC_generic.filter.yaml** which contains the normalized transfer function.

The analog frequency response is represented in this case as a Laplace function defined by zeros and poles.

The normalization factor is calculated so that the frequency response is 1 at the normalization frequency of 1 Hz.

The following folder-tree structure shows object file system organization of yaml metadata files.

```

|—— dataloggers
| |—— Guralp_CD24.datalogger_base.yaml
| |—— stages
| | |—— filters
| | | |—— Guralp_CD24_analog.filter.yaml
| | | |—— Guralp_CD24_FIR1.filter.yaml
| | | |—— Guralp_CD24_FIR2.filter.yaml
| | |—— Guralp_CD24_AD_conversion.stage_base.yaml
| | |—— Guralp_CD24_analog.stage_base.yaml
| | |—— Guralp_CD24_FIR1.stage_base.yaml
| | |—— Guralp_CD24_FIR2.stage_base.yaml
|—— instrumentation_bases
| |—— OBSLab_OBSH-B.instrumentation_base.yaml
|—— preamplifiers
| |—— LOWN-32.preamplifier_base.yaml
| |—— stages
| | |—— LOWN-32.stage_base.yaml
|—— sensors
| |—— GURALP_CMG6TC.sensor_base.yaml

```

```

|   |   |   | HITECH_HTI04-PCA-ULF.sensor_base.yaml
|   |   |   | stages
|   |   |   | |   | filters
|   |   |   | |   | |   | Guralp_CMG6TC_generic.filter.yaml
|   |   |   | |   | |   | HiTech_HTI-04-PLC-ULF_voltage-mode_theoretical.filter.yaml
|   |   |   | |   |   | Guralp_CMG6TC.stage_base.yaml
|   |   |   | |   |   | HiTech_HTI-04-PCA-ULF.stage_base.yaml
|   |   |   | subnetworks
|   |   |   | |   | OBSLab_example.subnetwork.yaml
|   |   |   | timing_bases
|   |   |   | |   | Guralp_CD24_integrated_RTC.timing_base.yaml

```

2.3 Verifying the frequency response

Once obsinfo creates a StationXML file for the OBS-B, it is possible to visually verify the frequency responses by plotting the curves. The python script, written to perform the task, is shown below.

The current version of obsinfo does not handle the decimation-offset property for decimation stages, but the ObsPy libraries strictly require it. This little known (and often neglected) property permits the accurate calculation of the delay introduced by decimation filters. It is widely known that an N-tap linear phase filter introduces a delay equal to $(N-1)/2$ input samples. This value, times the input sampling period, expresses the filter delay measured in seconds. However, a decimation filter with decimation ratio DR keeps one output sample for every group of DR input samples and discards the remaining DR-1 output samples.

The input sample series can be represented as a series of consecutive groups of DR samples. The decimation-offset tells which sample is kept, in every group. Its value ranges therefore from 0 to DR-1, with 0 indicating that the first sample is kept. The following example could help to further explain this concept. At a generic point in time, a data acquisition system starts to process a group of M samples. The time of the first sample is stored in memory and will be referred to as t_0 . The M samples will go through an N-tap decimation stage with $DR=3$. The memory within the decimation stage contains N-2 samples from the previous group of M samples, which means that the filter is ready to output a sample as soon as 2 more samples are fed to it. The data acquisition system feeds sample 0 then 1, hence the decimation stage produces one output sample. Now, the data acquisition system has to timestamp this sample. To do so, the data acquisition system will take t_0 then subtract $T_i(N-1)/2$ (where T_i is the input sampling period) in order to compensate for the delay arising from the coefficients. However, this value would only be accurate if the decimation stage had calculated the first sample after processing sample 0 alone, but it needed one sample more (sample 1). Therefore, the data acquisition system will have to add T_i to calculate the correct sample time. Whereas the delay from the coefficients is subtracted by t_0 , the term resulting from the decimation offset (equal to the decimation offset times the sampling period T_i) adds to t_0 .

As a result, the StationXML file output by obsinfo does not contain such property, which is required by the python libraries used to plot the transfer functions. In order to make the python code work, the offset property was added manually to every decimation stage in the StationXML file. During the obsinfo training course held in Paris from 2nd to 5th May 2023, the problem was included in the list of issues to be fixed.

- `import obspy`
- `from obspy.clients.nrl import NRL`
- `from obspy.core.inventory import Inventory, Network, Station, Channel, Site`

- `from obspy.core import UTCDateTime`
- `from obspy.io.stationxml.core import _read_stationxml`
- `inv = _read_stationxml("OBSLab_ver_1.station.xml", level='response')`
- `inv.networks[0].stations[0].channels[0].response.plot(min_freq=.001, outfile="/OBS_report/channel1.png")`
- `inv.networks[0].stations[0].channels[3].response.plot(min_freq=.001, outfile="/OBS_report/channel2.png")`

The script reads the StationXML file, calculates the frequency responses for each channel, and creates two plots, one for the seismic channels and one for the hydrophone channel. As previously noted, the presented work does not take into account calibration data. As a result, the frequency responses for the three seismic channels are identical. Figueres 3 and 4 show the curves produced by the script.

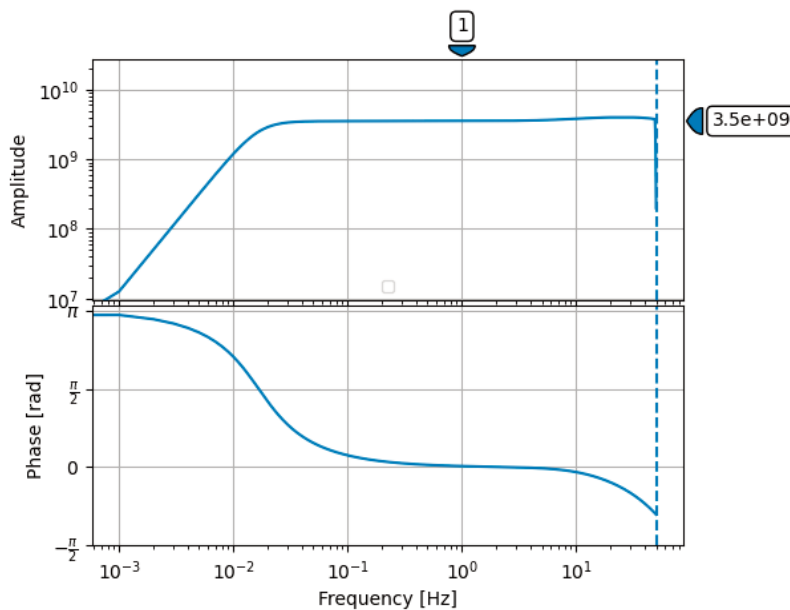


Figure 3 Frequency response plot for seismic channels HH1, HH2, HHZ.

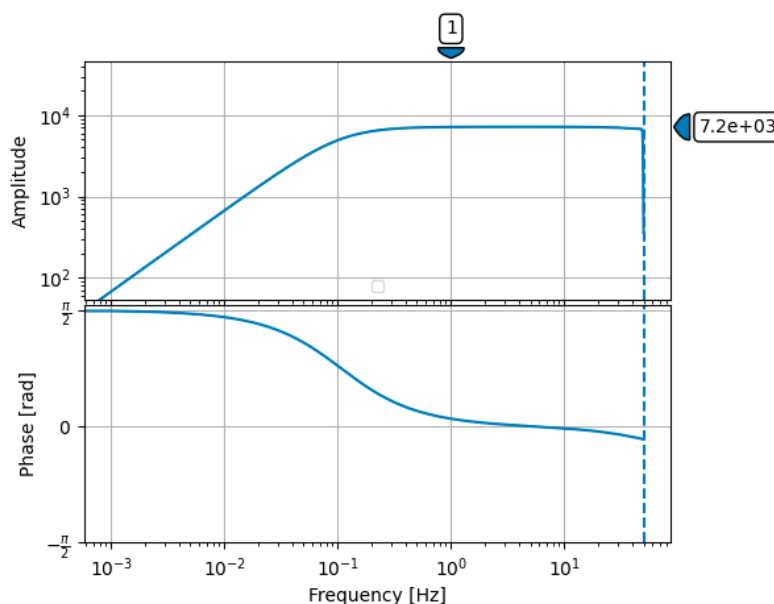


Figure 4 Frequency response plot for hydrophone channel HDH.

3. Conclusions and future steps

OBS B metadata were originally created by manually writing RESP files and assembling a SEED dataless file with PDCC.

Recently, obsinfo developed by RESIF (<https://gitlab.com/resif/smm/obsinfo>), has been used to create metadata for the same instrument, this time in StationXML format, the successor of SEED. Obsinfo allows breaking down the information into smaller and more manageable files, compared to StationXML. In addition, the YAML (or JASON) format is easier to write and read compared to XML. In conclusion, obsinfo proved to be a valuable tool for maintaining, organizing and preparing metadata.

In the next future, the authors plan to create StationXML files for all the instruments currently used at the OBS Lab, thus aligning the stations metadata with the format internationally adopted. This will allow the data collected by the OBS INGV instrument pool to be publicly available on the European Integrated Data Archive (EIDA). In addition, in the framework of the project InSEA [De Santis et al. 2022], 5 new OBSs will be deployed by our Lab, each one close to an oil platform in the Mediterranean Sea. The new stations will become part of the Italian seismic monitoring network and the data from these stations together with their metadata will be publicly available on the EIDA archive (<https://eida.ingv.it/it/>). Therefore, it is essential to prepare detailed and standardized StationXML files for the new stations.

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