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# The Calibration of IMS Seismic and Hydroacoustic T-Phase Stations

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## ABSTRACT

The purpose of the Seismic and Hydroacoustic T-Phase Stations calibration activity is the verification of the stability of calibration parameters and instrument responses over time against reference values established at the certification/revalidation time. The calibration process implements the workflow and associated reporting of the calibration activity at each particular station. Regardless of the type of equipment, the relative calibration process has to be the same and should rely on the comparison of an on-site measured system response against a reference established at the time when the station has been certified or when revalidation has been completed. However, technical implementation of calibration procedures, parameters of the calibration signals and the methodology used to evaluate the results are different and depend on the equipment characteristics, available calibration software and any other arrangements. We present the results of the calibration activities performed at IMS Seismic and Hydroacoustic T-phase stations in 2016. Calibration activities were initiated at 149 seismic stations of the International Monitoring System (IMS) (42 primary stations and 107 auxiliary stations). Of these 121 stations (39 primary stations and 82 auxiliary stations) were calibrated. The second scheduled calibration of all 5 certified IMS Hydroacoustic T-phase stations was successfully conducted in 2016.

## INTRODUCTION

The station calibration programme aims to implement the calibration requirements defined in the International Monitoring System (IMS) Operational Manual (OM) [CTBT/WGB/TL-11, 17/15/Rev.5] for all IMS primary and auxiliary seismic stations and Hydroacoustic T-phase stations.

The IMS OM document states that IMS seismological stations "…are provided with the means to carry out calibrations whose result can be compared against a reference that was established at the time the station was certified or when a revalidation was completed at the station". In addition, the IMS OM states that calibrations shall be full frequency for all types of sensors. The PTS was requested to implement calibration of non-feedback seismometers once a year [WGB-40 report].

The calibration schedule for 2016 was compiled so that IMS primary seismic stations calibrated during the same time window were at least 60 degrees apart and that auxiliary seismic stations were at least 40 degrees from a simultaneously calibrated primary seismic station. Each week was divided into two windows of three days each. Every station was assigned a main time slot during the period January to June along with a backup time slot during the period July to December.

A message describing the calibration activities at the IMS primary and auxiliary seismic stations was broadcast to the Station Operator (SO) on 7 December 2015, together with supporting material and the calibration schedule for 2016. The SOs were requested to review the schedule and to report on their ability to proceed with the calibration.

All available IMS primary and auxiliary seismic stations were requested to implement a full frequency response calibration. NCALIB values from the ***static.instrument*** table of the IDC operational database were used as a reference against which the measured values were compared.

The calibration task is the responsibility of the SOs and the PTS. The PTS compiles the calibration schedule, initiates the calibration, advises on the calibration scenario, assists the SOs with technical issues, analyses and reports on calibration results and implements follow-up maintenance actions when needed. The SOs is expected to submit agreed documents, including the calibration results, to the PTS.

The main goal of the 2016 calibration activities was to verify whether IMS seismic stations conform to the required 5% tolerance amplitude level compared to the known nominal calibration values at the calibration periods.

# SUMMARY OF RESULTS in 2016

## CALIBRATION RESULTS FROM SEISMIC STATIONS

In 2016, 42 IMS primary and 107 IMS auxiliary certified seismic stations were in operation. After distributing the calibration schedule, some SOs of auxiliary seismic stations informed the PTS of their inability to perform the calibration due to a lack of funding.

Calibrations were not attempted for stations which were down, or where the SOs identified technical or non-technical constraints affecting their ability to conduct the calibration. Calibration activities were initiated at 126 stations (39 IMS primary stations and 87 IMS auxiliary stations). Of those stations 121 (39 primary and 82 auxiliary seismic stations) were successfully calibrated (See Table 1).

| Type of Seismic Station | Calibrations Scheduled for 2016 | Calibrations Attempted | Attempts as a Share of Scheduled | Stations Calibrated | Calibrations as a Share of Scheduled |
|---|---|---|---|---|---|
| **All types** | 149 | 126 | 85% | 121 | 81% |
| **Primary** | 42 | 39 | 93% | 39 | 93% |
| **Auxiliary** | 107 | 87 | 81% | 82 | 77% |
| **Array** | 31 | 28 | 90% | 28 | 90% |
| **Three component** | 118 | 98 | 83% | 93 | 80% |

*Table 1. Summary of Seismic Station Calibration Activities in 2016*

Out of eighty five (85) stations where calibrations were attempted during the main time slots, eighty four (84) were calibrated successfully;
Of eighteen (18) stations where calibrations were attempted during the backup time slots, sixteen (16) were calibrated successfully;
Of twenty three (23) stations where calibrations were attempted in a time window agreed between PTS and SO, twenty one (21) were calibrated successfully (See Table 2).



*Table 2. Examples of planning and communication between the PTS and the SO*

1097 channels were scheduled for calibration in 2016 and calibration was attempted at 999 of these. Calibration results were obtained for 935 channels (85.2% of the total scheduled). Calibration results were not obtained for 15 channels, because the calibration failed due to technical reasons (neither a CALIB value nor a full frequency response was obtained).

112 channels were found to have a CALIB value deviating by more than 5% from its nominal (NCALIB) value.

Comparisons between the measured CALIB values reported in CALIBRATE_RESULT messages and the nominal calibration values NCALIB in the PTS databases as well as full-frequency measured responses in amplitude and phase were reviewed against nominal responses from the PTS database when possible.

The difference between the measured calibration factor and the nominal calibration factor stored in the PTS databases was well and those channels reported as ***out of spec*** (see Figure 1).are less than 11 % of total channels. Some outlier values are still under investigation.

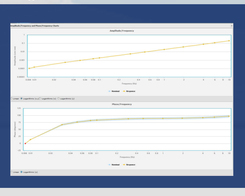


**Figure 2. An example of Calibration results**

- **VRAC**
- **STS-2 + Q330**
- **White noise - 120 min**

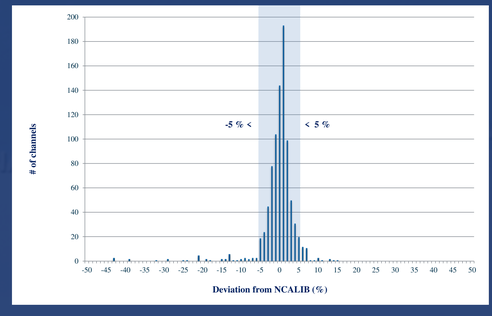



*Figure 1. Distribution of deviations in % between reported CALIB value and NCALIB value*

## METHODOLOGY

The IMS Operational Manual stipulates that an initial calibration be performed to verify that the measured system response is within tolerances of the manufacturer supplied data. The result of the initial calibration forms the baseline for certification and future calibrations.

Calibration is based on the response of the system to a known input signal, where multiple frequencies are excited. Test signals differ considerably in the accuracy that can be obtained in a given time. In practice the input signal (ie. Random Binary, Pulse, or Sine Wave) is often chosen for practical rather than theoretical considerations eg. availability of hardware or software. The diversity of the sensing and data acquisition systems in the IMS seismic network increases the complexity of defining standard approaches to calibration.

- ❑ Random Binary calibration (RNB) provides reliable results regardless of the noise level at the station. Currently this method requires an outage time of around 9000 seconds for broadband sensors. It is not supported by older models of digitizers used in the IMS seismic network.
- ❑ Pulse calibration is quick (~30 minutes for broadband channels) and efficient at stations having low noise level. Unfortunately, it does not provide output for precise response estimation at noisy stations. It is not supported by older models of digitizers used in the IMS seismic network.
- ❑ Sine wave calibration is supported by any type of digitizers available in the IMS seismic network. However, it is time-consuming for the long period signals as at least 30 periods of the signal are required. In particular, calibration of large arrays having only sine wave calibration capability can require more than the allocated time slot.

When PTS support is requested to define the calibration scenario for a particular station, a customized solution is proposed to the SO, favouring the combination of a full-frequency sequence (such as RNB, pulse or white noise for the estimation of the relative amplitude and phase response shapes over the whole passband of the channel) and a sine wave at the nominal calibration period (NCALPER) for the estimation of the calibration factor (CALIB).

## CALIBRATION RESULTS FROM HYDROACOUSTIC T-PHASE STATIONS

In 2016, the second scheduled calibration of all 5 operating IMS Hydroacoustic T-phase certified stations was planned: HA02, HA05, HA06, HA07 and HA09. Two stations (HA06 and HA07) could not be calibrated due to planning issues. The scheduled calibration of the three remaining stations (HA02, HA05 and HA09) was attempted, and conducted successfully. Calibration results were therefore obtained for 15 channels (50% of the total scheduled from all 5 IMS Hydroacoustic T-phase stations).

