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Test Definitions for the Evaluation of Infrasound Sensors

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Test Definitions For the Evaluation of Infrasound Sensors

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Abstract

Most test methodologies referenced in this Test Definition and Test Procedures were designed by Sandia specifically for geophysical instrumentation evaluation. When appropriate, test instrumentation calibration is traceable to the National Institute for Standards Technology (NIST).

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INTRODUCTION

Scope

This Test Definition and Test Procedures for the Evaluation of infrasound sensors define the process that can be performed as part of the evaluation and testing of geophysical sensors, digitizers, sensor sub-systems and geophysical station/array systems.

Background

An infrasound sensor can be an absolute pressure micro-barometer, a differential pressure sensor or low frequency microphone. Infrasound sensors are usually manufactured to be installed in an infrasound vault or deployed in a borehole. The interface to the atmosphere is usually through hose or pipe array connection. The infrasound element converts air pressure changes to analog signals. The analog signals are sent to a Digitizing Waveform Recorder (DWR) to be either stored on local recording media or sent to a central recording facility for storage and/or analysis. The infrasound sensor seldom provides a mechanism for external calibration of the sensor or an indication of operational capability. The sensor output is a voltage representation of units of pressure in Pascal.

Objectives

The objectives are to evaluate the overall technical performance of the infrasound sensor.

The results of these evaluations can be compared to the manufacturer's specifications and any relevant application requirements or specifications.

TEST AND EVALUATION PROGRAM

Test and Evaluation Background

Sandia National Laboratories (SNL) Ground-based Monitoring R&E Department has the capability of evaluating the performance of infrasound sensors for geophysical applications.

Infrasound Sensor Tests

The following set of tests has been developed or is under development to evaluate infrasound sensor performance.

General Infrasound Sensor Tests

- Infrasound Sensor Characterization
  - Response Model Determination - Infrasound Sensor Frequency Response
    - Infrasound Sensor Frequency Response Verification (IS-FRV)
  - Response Model Determination - Infrasound Sensor Amplitude Response
    - Infrasound Sensor Amplitude Response Verification (IS-ARV)
  - Response Model Determination - Alternative Frequency/Amplitude Response
    - Infrasound Sensor Frequency/Amplitude Response Verification (IS-FAR)
  - Response Model Determination - Alternative Frequency/Amplitude/Phase Response
    - Infrasound Sensor Frequency/Amplitude/Phase Response Verification (IS-FAPR)
- Infrasound Sensor Performance Tests
    - Infrasound Sensor Piston-phone Linearity Verification (IS-PLV)
    - Infrasound Sensor Self-Noise (IS-SN)
    - Infrasound Sensor Calibration Response (IS-CR)

Temperature Tests

Infrasound sensors with sub-milliPascal resolution can be affected by small temperature changes. A sensor may be required to operate over a range of environments from arctic to desert. Also, depending on the type of installation, the seasonal and diurnal variation can be significant. Tests can be performed at SNL to determine the sensor's sensitivity to temperature over a range from -65° C to +125° C.

Temperature testing can be performed at the high and low end of the manufacturer's temperature specifications or over the range for the application requirements. Unless otherwise specified, the temperature is changed slowly and the sensors internal temperature is allowed to stabilize before testing.

INFRASOUND SENSOR TEST DEFINITIONS

Infrasound Sensor Tests

Infrasound Sensor Characterization

The infrasound sensor can be characterized using manufacturer supplied data to determine sensor gain, sensor bandwidth, self-noise and output impedance. Factory data should lead to a mathematical response model.

If the manufacturer has not provided adequate sensor information, the actual response can be determined through various tests.

Response Model Determination - Infrasound Sensor Frequency Response

Infrasound Sensor Frequency Response Verification (IS-FRV)
Purpose: The purpose of the infrasound sensor frequency response verification test is to determine or verify the infrasound sensor frequency response using an acoustic step function.

Configuration: The infrasound sensors are installed in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor output(s) are connected to a data acquisition system. A step function is programmed into a variable amplitude, variable frequency piston-phone acoustic signal generator.

Evaluation: The sensor frequency response is determined from the recorded data. A mathematical fit of the step response data determines the poles and zeros of the sensor(s). The poles and zeros define the frequency and phase response of the sensor.

Response Model Determination - Infrasound Sensor Amplitude Response

Infrasound Sensor Amplitude Response Verification (IS-ARV)
Purpose: The purpose of the infrasound sensor amplitude response verification test is to determine or verify the infrasound sensor amplitude response at one frequency using a variable amplitude, variable frequency piston-phone acoustic signal generator.

Configuration: Infrasound sensors, (1) a characterized reference infrasound sensor and (2) the infrasound sensors under test, are installed side-by-side in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor output(s) are connected to a data acquisition system. A sine-wave of known amplitude and frequency is programmed into a variable amplitude, variable frequency piston-phone acoustic signal generator. A co-located, characterized infrasound sensor is used as a reference.

Evaluation: The sensor amplitude response is determined from the recorded data. A mathematical fit of the sine data determines the amplitude response of the sensor(s) at the test frequency.

The poles and zeros derived from the step response and the amplitude response at one frequency define the total frequency, amplitude and phase response of the sensor.

Response Model Determination - Alternative Frequency/Amplitude Response

Infrasound Sensor Frequency/Amplitude Response Verification (IS-FAR)
Purpose: The purpose of the infrasound sensor frequency/amplitude response verification test is to determine or verify the infrasound sensor amplitude response at multiple frequencies using a variable amplitude, variable frequency piston-phone acoustic signal generator.

Configuration: Infrasound sensors, (1) a characterized reference infrasound sensor and (2) the infrasound sensors under test, are installed side-by-side in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor output(s) are connected to a data acquisition system. A multiple sine-waves of known amplitude and frequency is programmed into a variable amplitude, variable frequency piston-phone acoustic signal generator. A co-located, characterized infrasound sensor is used as a reference.

Evaluation: The sensor amplitude response is determined from the recorded data. A mathematical fit of the sine data determines the amplitude response of the sensor(s) at the multiple test frequencies. A plot of frequency vs. amplitude indicates overall frequency/amplitude response.

Response Model Determination - Alternative Frequency/Amplitude/Phase Response

Infrasound Sensor Frequency/Amplitude/Phase Response Verification (IS-FAPR)
Purpose: The purpose of the infrasound sensor frequency/amplitude/phase response verification test is to determine or verify the infrasound sensor frequency/amplitude/phase response at all frequencies using a variable amplitude, variable frequency piston-phone acoustic signal generator and a characterized reference infrasound sensor.

Configuration: Infrasound sensors, (1) a characterized reference infrasound sensor and (2) the infrasound sensors under test, are installed side-by-side in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor output(s) are connected to a data acquisition system. A bandwidth-limited white noise function is programmed into a variable amplitude, variable frequency piston-phone acoustic signal generator. A co-located, characterized infrasound sensor is used as a reference.

Evaluation: The sensor frequency/amplitude/phase response is determined from the recorded data. Coherence analysis indicates the relative gain and phase for the infrasound sensors under test with respect to the reference infrasound sensor. The frequency, amplitude and phase response of the sensor under test can be determined by mathematically correcting for the response of the characterized reference infrasound sensor.

Infrasound Sensor Performance Tests
Piston-phone generated signals are used as test stimuli to measure sensor performance.

Infrasound Sensor Piston-phone Linearity Verification (IS-PLV)
Purpose: The purpose of the infrasound sensor piston-phone linearity verification test is to determine or verify the infrasound sensor linearity at one frequency using a variable amplitude, variable frequency piston-phone acoustic signal generator.

Configuration: Infrasound sensors, (1) a characterized reference infrasound sensor and (2) the infrasound sensors under test, are installed side-by-side in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor output(s) are connected to a data acquisition system. A sine-wave of different amplitudes at a known frequency are programmed into a variable amplitude, variable frequency piston-phone acoustic signal generator. A co-located, characterized infrasound sensor is used as a reference.

Evaluation: The sensor amplitudes are determined from the recorded data. A mathematical fit of the amplitude data determines the linearity of the sensor(s) at the test frequency.

Infrasound Sensor Self- Noise (IS-SN)
Purpose: The purpose of the infrasound sensor self-noise test is to determine the infrasound sensor self-noise in the absence of infrasound background signals.

Configuration: The infrasound sensors are installed in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor outputs are connected to a data acquisition system that samples the data synchronously.

Evaluation: The sensor self-noise is determined from the recorded data. Convert the data from each infrasound sensor to pressure units using the sensor response mathematical model for each sensor.

Coherence analysis should indicate that there is no coherence between the sensors. If some coherence is present from conditions such as local barometric pressure changes over the test period, the coherence noise-power computation provides the noise-floor of the infrasound sensor with the coherent signal removed.

Infrasound Sensor Calibration Response (IS-CR)
Purpose: The purpose of the infrasound calibration response verification test is to verify the sensor calibration response using an internally generated electronics step calibration signal, or from an external acoustic signal generator.

Configuration: The infrasound sensors are installed in a specially designed infrasonic test chamber. The chamber is sealed and isolated from external acoustic signals. Sensor outputs are connected to a data acquisition system that samples the data synchronously. Use sensor appropriate method for initiating electronics step calibration signal.

Evaluation: Visual inspection or measurement of the sensor’s output response amplitudes are determined from the recorded data. These measured values can be used to check for changes in microphone, or electronics sensitivity.

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