southdowns
environmental consultants

QINETIQ LTD

MOD UK NOISE AND VIBRATION SURVEYS

MOD PENDINE RANGE

JUNE 2016

VOLUME 2: TECHNICAL APPENDICES – DETAILED METHODOLOGY

1897M-SEC-00168-05

www.southdowns.eu.com

southdowns
environmental consultants

QINETIQ LTD
MOD UK NOISE AND VIBRATION SURVEYS
MOD PENDINE RANGE
VOLUME 2: TECHNICAL APPENDICES – DETAILED METHODOLOGY

DOCUMENT REFERENCE: 1897M-SEC-00168-05

REVIEW AND AUTHORISATION			
Authored By Ian Arthurs BSc (Hons), MSc, MIOA James Glen BEng, AMIOA	**Position** Senior Consultant Consultant	**Signature**	**Date** 21/06/2016
Reviewed By Rick Methold BEng (Hons), CEng, FIOA	**Position** Director	**Signature**	**Date** 21/06/2016
Checked By Matthew Tomes BSc (Hons), MSc, MIOA	**Position** Senior Consultant	**Signature**	**Date** 21/06/2016
Approved By Rick Methold BEng (Hons), Ceng, FIOA	**Position** Director	**Signature**	**Date** 21/06/2016

AMENDMENT HISTORY			
Issue	**Status**	**Description**	**Date**
01	Final Draft	Draft Report issued to QinetiQ for comment	29/09/2015
02	Final	Final Report issued	21/12/2015
03	Final	Final Report Updated and Issued	15/03/2016
04	Final	Final Report	03/06/2016
05	Final	Final Report	22/06/2016

This is Volume 2 of 3 of the MOD Pendine Range Final Report. This volume should be read in conjunction with Volumes 1 and 3.

HEAD OFFICE: 16 Station Street, Lewes, East Sussex, BN7 2DB, UK Tel: +44 (0)1273 488186
LONDON OFFICE: 10 Greycoat Place, London, SW1P 1SB, UK Tel: +44 (0)207 9606255
enquiries@southdowns.eu.com www.southdowns.eu.com

REG. IN ENGLAND NO: 3150111

CONTENTS	PAGE NO.

VOLUME 2: TECHNICAL APPENDICES – DETAILED METHODOLOGY
CHAPTER 1: SITE SELECTION PROCESS

1 SITE SELECTION PROCESS

1.1 Introduction

1.1.1. Figure 1.1 below sets out a simplified depiction of the site selection process to highlight the various stages involved in finalising the preferred monitoring locations. Each stage is described in the following subsections in more detail.

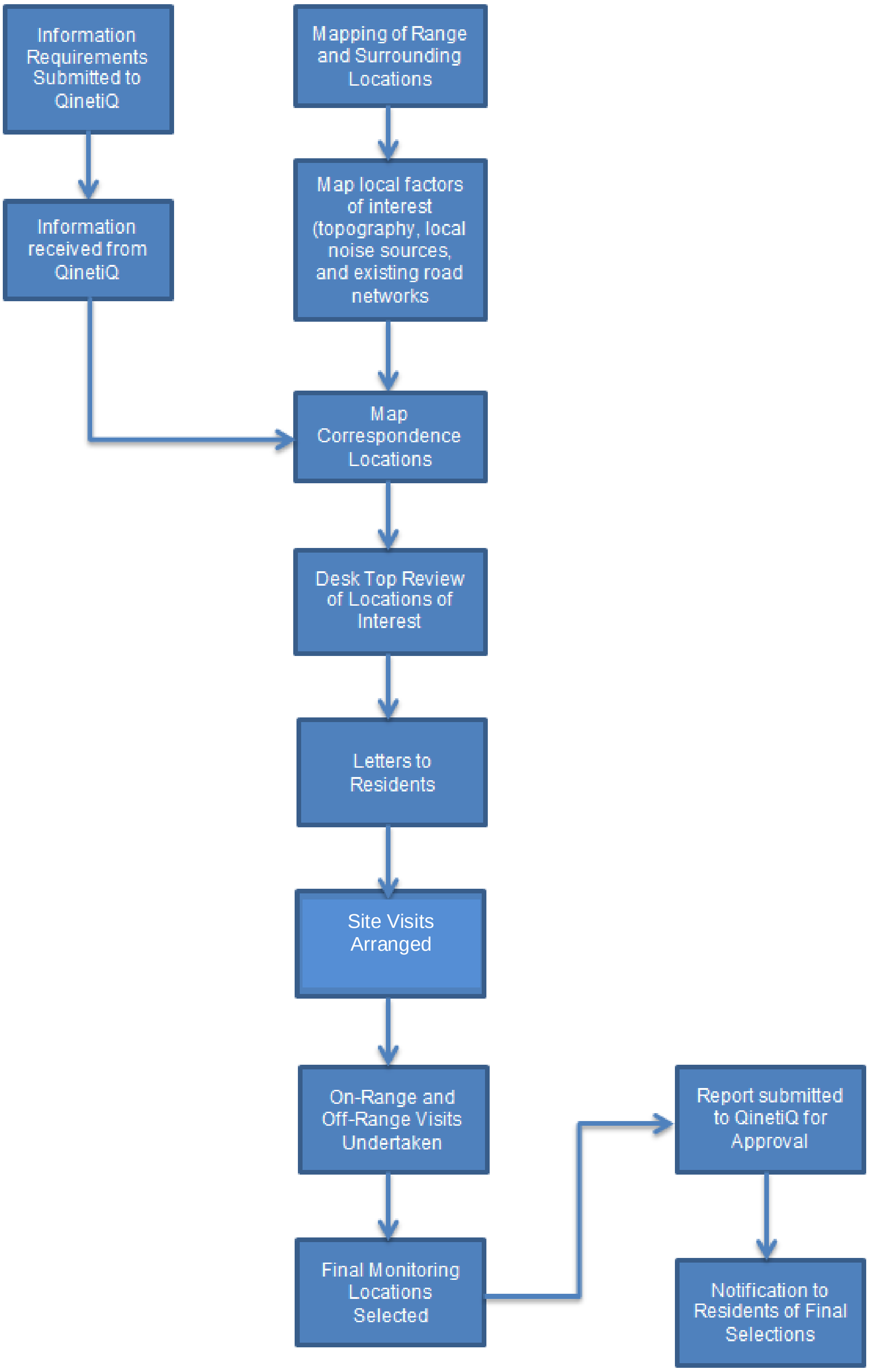


FIGURE 1.1: SITE SELECTION PROCESS

1.2 Acoustic Considerations

1.2.1. The key acoustic considerations when selecting appropriate monitoring locations are summarised below:

- land topography and type (including the effects of ground absorption, reflections, and presence of major intervening landforms);
- prevailing wind direction;
- unobstructed line of sight to Range;
- existence of other extraneous local noise sources;
- distance to Range; and
- other physical obstructions (e.g. buildings, dense vegetation / foliage, etc).

1.2.2. The preferences applied to provide a consistent approach to the siting of monitoring equipment included, where practicable:

- free-field positioning of the microphone (e.g. > 3.5m from any reflecting structure other than the ground) on the elevation of the structure nearest, and facing, the Range;
- use of enhanced windshields to reduce wind effects over the microphone;
- avoidance of shielding of microphone by nearby buildings; and
- vibration transducer sensor placement (e.g. geophone / seismometer / accelerometer array) required on the side of the building nearest to, and facing, the Range.

1.3 Non-Acoustic Considerations

1.3.1. Non-acoustic factors considered when selecting a suitable monitoring location include:

- the availability of continuous, uninterrupted 240v AC mains power supply;
- the availability of a stable internet connection, with suitable minimum bandwidth, and suitable upload and download speeds;
- the siting of equipment to avoid electrical interference from other electrical equipment;
- minimum space available for the installation of the equipment housing and microphone mounting poles;
- obtaining permission from the property owners to install associated equipment mounting accessories;
- provision of safe cable runs between the sound pressure and vibration monitoring equipment, the mains power and internet connection point;
- ensuring the sound pressure and vibration monitoring equipment can be located in a secure location to avoid tampering;

- specific preferences of the occupants of the buildings;
- any potential access restriction a site may have; and
- health and safety hazard which may affect installing and accessing the equipment for maintenance purposes.

1.3.2. Having regard for the considerations set out above, a detailed site selection process was undertaken, to identify suitable monitoring locations for the study. The process included the following stages:

- Review of received information from QinetiQ;
- Desktop study;
- Letters to residents;
- Site suitability walkovers; and
- Selection of monitoring locations.

1.4 Information from Range Operators

1.4.1. Potential locations of interest were presented in 'Pendine Noise and Vibration Monitoring Study (NVMS) - System Requirements Document (SRD) [1] produced on behalf of the MOD by QinetiQ.Identified as Category A locations, these provided an early indication of the candidate properties in the vicinity of the Range.

1.5 Desktop Study

1.5.1. An initial detailed desktop study was undertaken to identify potential locations of interest. The area was mapped electronically using a series of relevant overlays which enabled an accurate overview of the Range and surrounding areas. The mapping allowed for consideration of important information including topographical features, community areas, building density and major and minor road networks.

1.5.2. The Category A locations of interest were then overlaid, along with the specific properties taken from the correspondence register.

1.5.3. A map showing the physical topography of the Pendine area, along with the community areas and other locations of interest is presented in Figure 1.2..

1.5.4. The mapping, in conjunction with satellite photography available from internet resources, was used to consider each location of interest and identify, where possible, the following information:

- property type;
- existence of garage/outbuildings;
- indication of likely building construction;
- proximity to the Range;
- description of the immediate area; and
- initial identification of likely local ambient noise sources.

1.5.5. Figure 1.3 presents mapping showing the local road network and other likely local ambient noise sources.

1.5.6. The desktop study was used to generate an initial sifted list of residential properties for further consideration.

1.6 Letter to Residents

1.6.1. Following the desk top study, personalised letters were sent to residents whose properties represented potential monitoring locations of interest. The letter included a registration form to enable residents to register their interest in participating in the study ahead of a planned site walkover visit.

1.6.2. A list of Frequently Asked Questions (FAQ's) was compiled and was included with the letters to provide residents with further information on the study and the terms of their potential involvement.

1.6.3. A copy of the letter template, the registration form and the FAQ sheet are presented in Figures 1.4, 1.5 and 1.6 respectively.

1.6.4. Twenty-nine letters were submitted, with thirteen responses received (two of which arrived after the site walkover had been completed). These responses were collated and contact was made with residents to arrange suitable times to visit during the site walkover.

1.6.5. A map highlighting the locations of the residents who responded to the letters is presented in Figure 1.7.

1.7 Site Suitability Walkovers – Pendine Range (On-Range)

1.7.1. A full on-Range walkover of the Pendine Range was undertaken on Wednesday 19th March 2014. Following a site induction and introduction to the main staff areas, including Range control, visits were made to individual test sites set out across the Range.

1.7.2. The purpose of the Range walkover was to determine suitable locations for the on-Range monitoring equipment. Monitoring equipment installed on-Range was to be configured to operate as control monitors, to be used both to confirm on-Range activity and send triggering commands to the off-Range monitors to ensure Range events were captured off-Range, in the far-field.

1.7.3. Siting a monitor at the western end of the Range was not considered a priority, due to the nature of the tests undertaken. It was understood that the repetitive noise from the gun shots could be heard in Pendine and the surrounding locale, however it was considered unlikely that activities taking place on this area of the range would be the cause of the perceived effects on buildings at residential locations in the far-field.

1.7.4. A monitor was however required to measure activities in the central section of the Range, specifically at the test track at C9 Range and at the eastern end of the Range. Locations for these monitors were selected at Brill Gate, which is located approximately 900m from C9 and at Building 214, which is the control building approximately 30 metres from the test site E8

1.8 Site Suitability Walkovers – Off-Range Surveys

1.8.1. A total of 16 off-Range properties were visited by Southdowns on 19th, 20th and 21st March 2014. The properties visited included those from the 13 letter responses received, and additional properties identified by Southdowns during the site suitability walkovers. The locations are presented in Figure 1.8 and summarised in Table 1.2.

Southdowns Mapping ID	Property Area	Property Type
CR02	Kidwelly	Residential detached bungalow
CR07	Ferryside	Residential terraced house
CR10	Ferryside	Residential detached house
CR17	Llanstephan	Residential detached house with outbuildings
CR21	Ferryside	Residential detached bungalow
CR22	Ferryside	Residential detached house
CR25	Laugharne	Residential detached house
CR27	Laugharne	Residential detached house
CR28	Laugharne	Residential detached house
CR29	Laugharne	Residential detached bungalow
CR30	Kidwelly	Commercial car showroom
CR32	Ferryside	Residential detached house
CR34	Laugharne Church	Church
CR35	Laugharne	Residential detached house
CR36	Plashett	Residential bungalow
CR37	Pendine	Residential detached property

TABLE 1.1: OFF-RANGE PROPERTIES VISITED BY SOUTHDOWNS

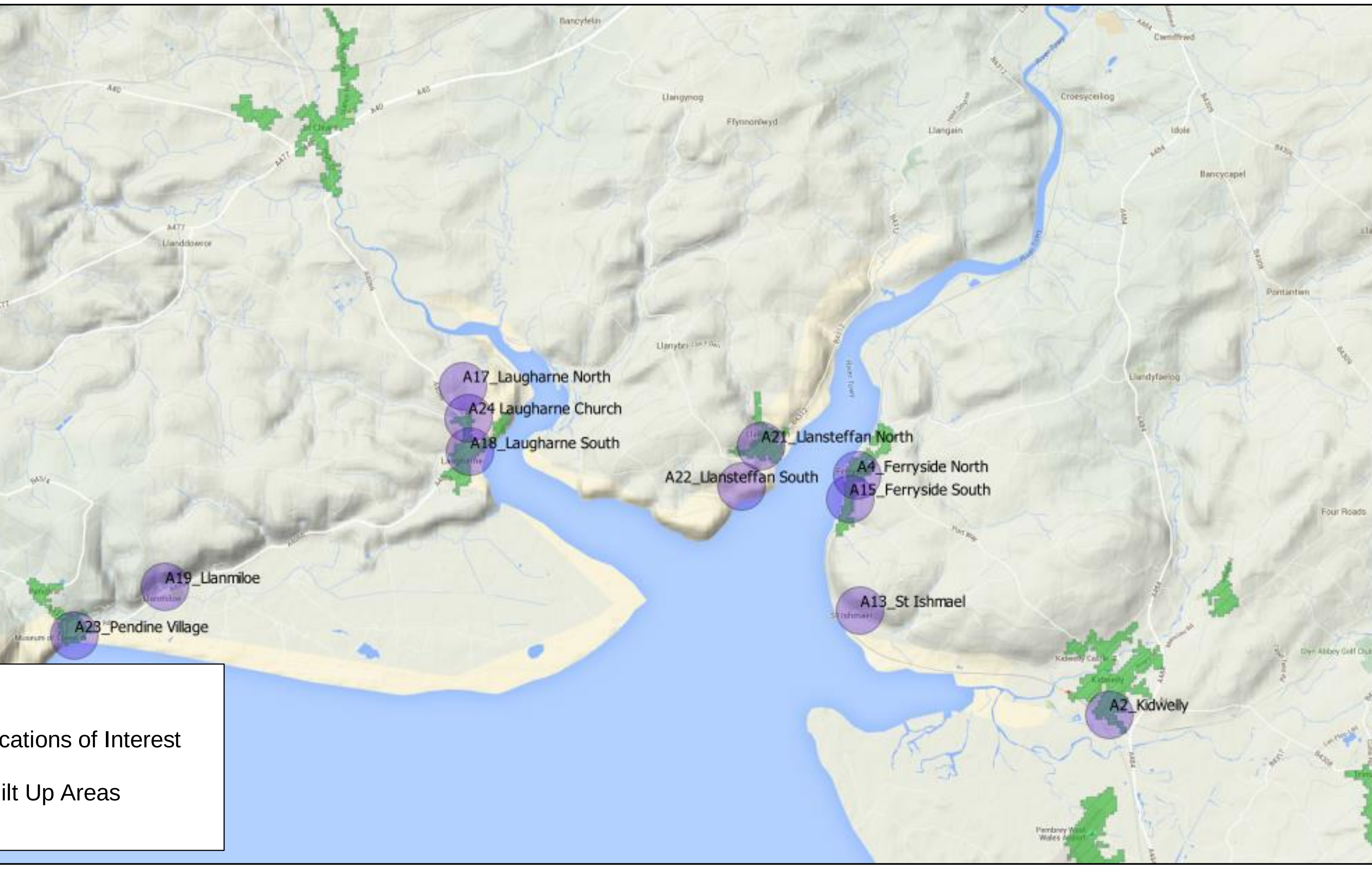
1.8.2. For each location, a detailed site suitability survey sheet was completed.. The survey sheets were used to collate both the acoustic and non-acoustic information. This information was entered into a site suitability selection matrix and used to make the final location selections.

1.9 Selected Monitoring Locations

1.9.1. The final selected monitoring locations are presented in Table 1.2 and presented in Figure 1.9.

Mapping Ref. (Southdowns)	Monitoring Station ID	Area /Region
PR1	PEN_R1	On-Range
PR2	PEN_R2	On-Range
CR34	PEN_OS1	Laugharne
CR29	PEN_OS2	Laugharne
CR28	PEN_OS3	Laugharne
CR35	PEN_OS4	Laugharne
CR17	PEN_OS5	Llanstephan
CR22	PEN_OS6	Ferryside
CR2	PEN_OS7	Kidwelly
CR21	PEN_OS8	Ferryside
CR36	PEN_OS9	Plashett
CR37	PEN_OS10	Pendine

TABLE 1.2: MONITORING LOCATIONS



IAPPING SHOWING TOPOGRAPHY, LOCATIONS OF INTEREST AND COMMUNITY AREAS IN THE VICINITY OF PENDINE RAN

3: LOCAL ROAD NETWORK AND POTENTIAL LOCAL NOISE SOURCES IN THE VICINITY OF PENDINE RANGE

By Letter

PRIVATE AND CONFIDENTIAL

Mr/Mrs xxx
Address Line 1
Address Line 2
Postcode

Date XXXX 2014 Our Reference: 1897m-SEC-00027-0x

Dear xxx

Subject: Noise and Vibration Monitoring Study
MOD Pendine Range

Southdowns Environmental Consultants Ltd (Southdowns) has been appointed to undertake a noise and vibration monitoring study around the Ministry of Defence (MOD) Range at Pendine.

QinetiQ Ltd, which operates the Range at Pendine on behalf of the UK Ministry of Defence (MOD), has commissioned an independent study to determine the noise and vibration effects of Test, Evaluation, Demilitarisation and Training Support activities which are carried out on the Range.

Southdowns is an independent noise and vibration consultancy, established in January 1996. As a corporate member of the Association of Noise Consultants, our experts are affiliated with professional bodies including the Institute of Acoustics and the Chartered Institute of Environmental Health. For further information about our company, please visit our website www.southdowns.eu.com.

The Noise and Vibration study will require continuous monitoring of noise and vibration at multiple locations of interest in the vicinity of the Range. Following the completion of a desktop study, we have identified your property as a potential location of interest for the study and would like to discuss with you the possibility of installing a monitoring system at your property.

Typically, such a system would be installed externally. The monitoring duration would be between six and nine months, commencing this summer (2014). You would not be required to operate or maintain the equipment, although access to an electricity supply and internet connection would be required, for which you would receive financial compensation to cover usage costs.

Should you wish to assist with the study and are willing to allow a monitoring system to be installed at your property, please complete the enclosed form and return it in the pre-paid reply envelope by Monday 17th March 2014. The preferred sites will then be shortlisted and we will contact you to discuss further. We enclose a Frequently Asked Questions (FAQ) sheet which I hope you will find useful.

I look forward to hearing from you.

Yours sincerely

For Southdowns Environmental Consultants Ltd

Richard Fenton BSc (Hons), MSc, MCIEH, MIOA
Senior Consultant
Telephone: 01273 488186/ Email: rjf@southdowns.eu.com

FIGURE 1.4: SAMPLE LETTER TO RESIDENTS

Noise and Vibration Monitoring Study – Pendine

Registration Form for Participants

Name:		Contact telephone number:	
Address:			

Contact email address:		Tenancy status (e.g. owner, rented):	
Alternative contact name & details:		Landlord contact details (if applicable):	

Property type (bungalow, terraced, detached):		No. of floors:	
Garage/Outbuildings with power supply:	Yes / No	Secure garden area:	Yes / No

Internet provider (if known):		Type: (if known)	Fibre / ADSL
Router type (if known):		Location of router in property:	

FIGURE 1.5: SAMPLE REGISTRATION FORM

MOD Pendine Noise & Vibration Study

Frequently Asked Questions

1. Why is this Study being carried out?

There is a public perception that some activities at the Ministry of Defence (MOD) Pendine (the Range) produce noise and vibration that may be damaging to property. The Study is being carried out to address concerns raised by communities surrounding the Range.

2. Why has the Study taken so long to get underway?

As a Defence contractor, QinetiQ has to abide by Government contracting policies that ensure value for money for the taxpayer when inviting bids and placing a contract.

3. Who has arranged this Study and who is paying for it?

QinetiQ, as operator and manager of the site, has contracted Southdowns Environmental Consultants Ltd (Southdowns) but the Study itself is being paid for by the MOD.

4. If I have a noise and / or vibration complaint during the study, whom should I contact?

Any concerns or complaints regarding range activity should continue to be directed to QinetiQ who operate the range on behalf of the MOD on the Freephone Careline 0800 092 1345 or by email at pendineinfo@qinetiq.com.

5. What is the Study measuring?

The Study will measure what, if any, effect noise and vibration emanating from the Range has on property and whether this has the potential to cause damage.

6. When will the Study start?

The Study is scheduled to start this summer (2014).

7. How long will the Study last?

The Study will last for approximately six months, to cover a representative selection of the work undertaken on the Range, across a representative selection of meteorological (and therefore acoustic) conditions.

8. Will the monitors be switched on all the time?

Yes. The monitors require a continuous 240v power supply and will remain switched on at all times during the Study.

Ctd.

Ctd.

9. Will the monitors record my conversations?

The monitors will be configured to continuously collect numerical noise level and vibration data. However, in the event of a central trigger signal being generated by activity on the Range, the monitors will also capture the measured sound and vibration waveforms for a short duration (up to approximately 10 seconds). This information is needed to allow further technical analysis after the Range event has finished. If the waveforms contain any extraneous contribution as a result of domestic activity in the vicinity of the microphone they will automatically be discarded from further consideration in any case.

10. Why have you chosen my property?

Following a desktop study of data supplied by QinetiQ and examination of local conditions, your property has been identified as a potential monitoring location.

11. Will I get paid for my help?

Access to an electricity supply and internet connection will be required, for which Southdowns will make a small payment to cover the direct costs as a goodwill gesture.

12. When will the findings of the Study be made available to the Public?

Following the Study, there will be a period of data analysis. It is too early to say how long this will take, but the findings will be made available as soon as practicably possible after the end of the Study.

13. What will happen if the Study proves that the noise and vibration is damaging property?

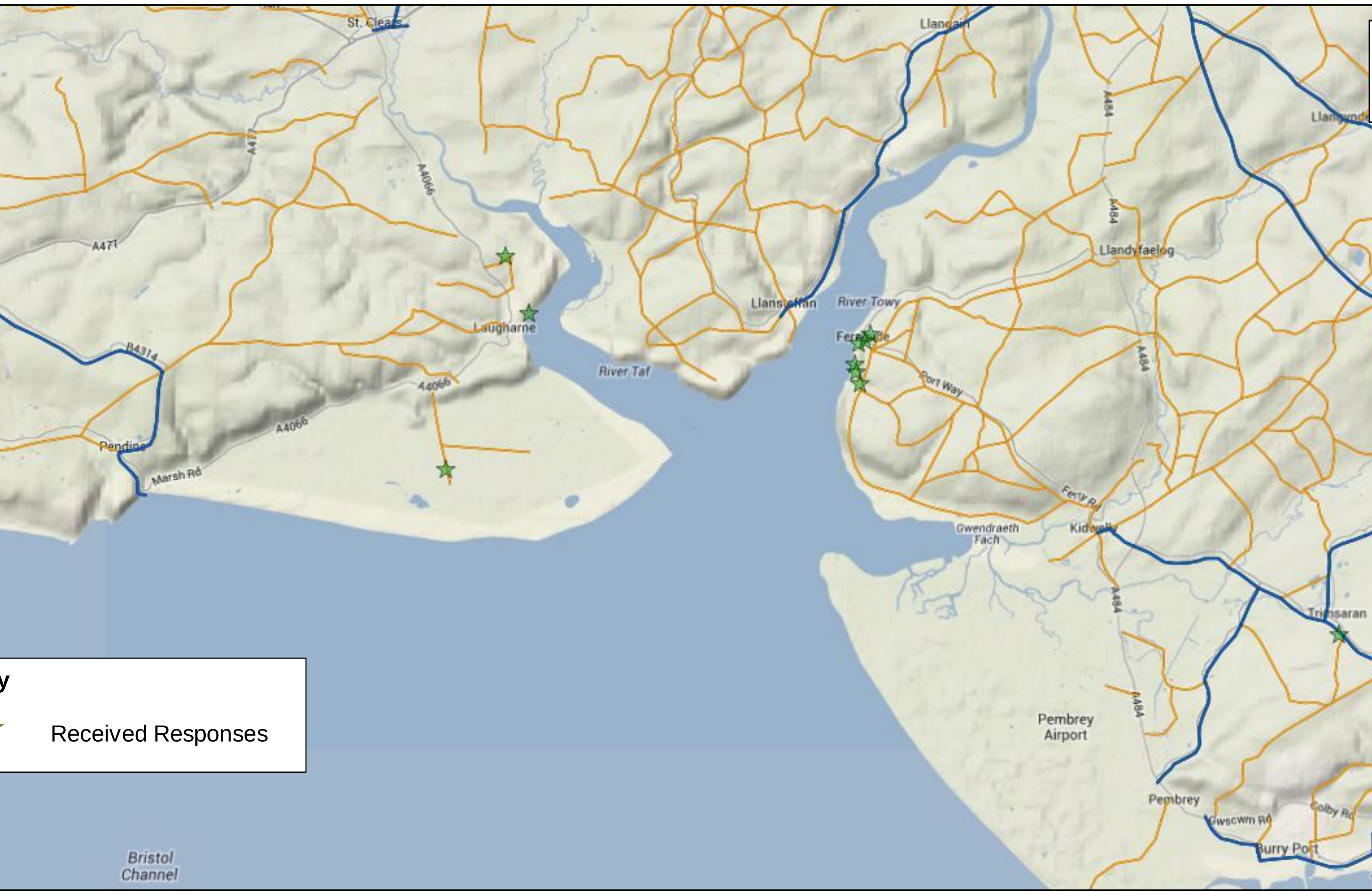
The MOD, as owner of the site, will be responsible for any subsequent action if the Study concludes that damage is being caused to property as a result of Range activity.

14. If I agree to help, what is the next step?

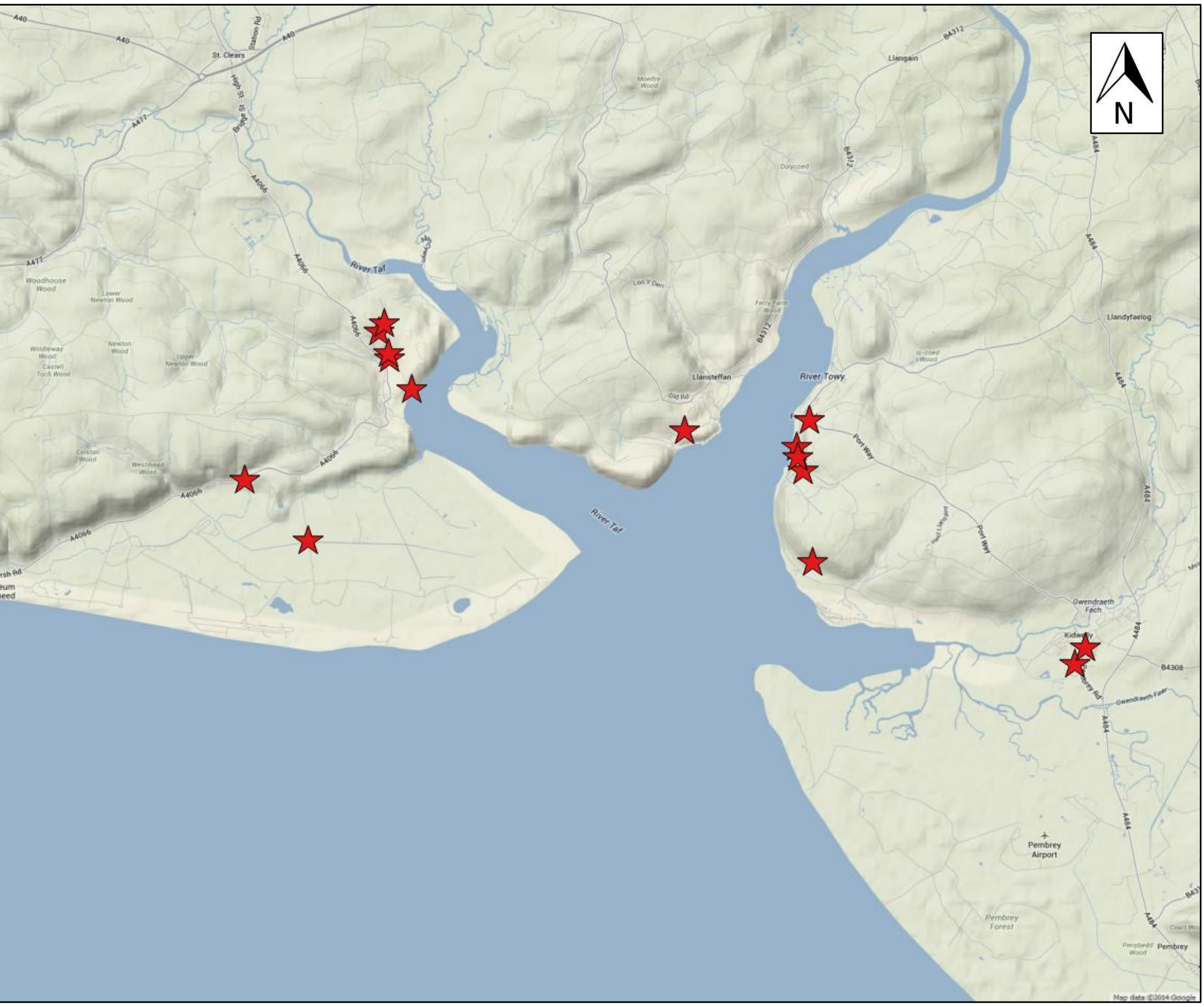
If you are agreeable to a monitor being placed on your property, please contact Southdowns on 01273 488186 or by email at rjf@southdowns.eu.com to discuss further. Preferred candidate locations will then be shortlisted and contact will be made to arrange a suitable date to visit those properties and undertake a more detailed survey. Only after completion of this exercise can a decision on final monitoring locations be made. This site visit will also provide an opportunity to discuss in more detail any other queries or concerns which may arise.

- END –

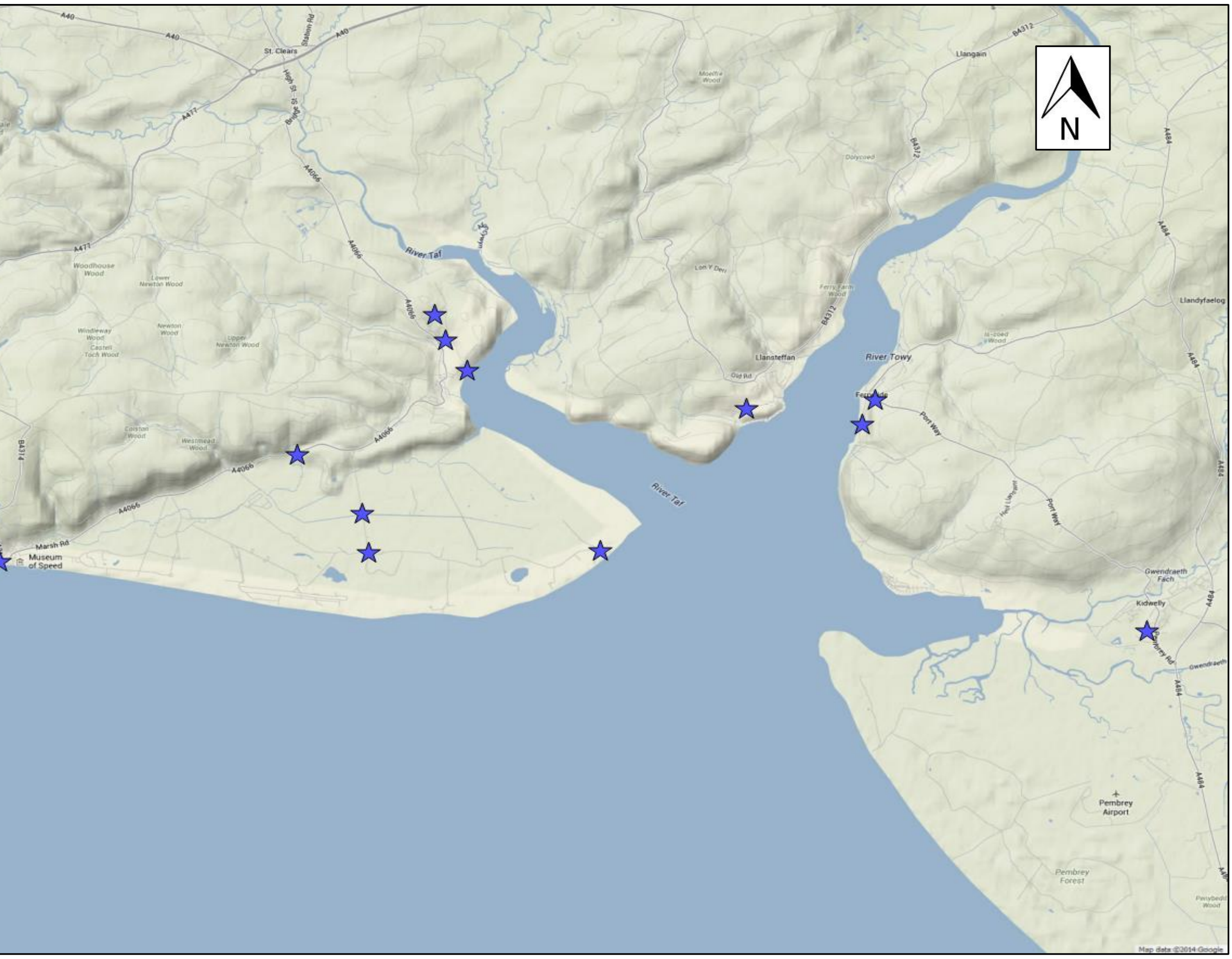
FIGURE 1.6: FREQUENTLY ASKED QUESTIONS



7: LOCATIONS OF RESIDENT RESPONSES



3: VISITED PROPERTIES



9: MONITORING LOCATIONS

VOLUME 2: TECHNICAL APPENDICES – DETAILED METHODOLOGY
CHAPTER 2: MONITORING METHODOLOGY

2 MONITORING METHODOLOGY

2.1 Samurai Noise and Vibration Monitoring System

2.1.1. Each monitoring station comprised of:

- SINUS Swing 4-channel noise and vibration monitoring station; and
- Uninterruptible Power Supply (UPS) system (up to 48 hours of power backup).

2.1.2. Instrumentation connected to the SINUS noise and vibration monitoring station include:

- G.R.A.S. 41CN Outdoor Microphone System;
- SINUS tri-axial geophone;
- Garmin Global Positioning System (GPS) receiver; and
- Thies Clima Sensor (selected monitoring locations).

2.1.3. Services requirements for each monitoring station comprised of a 220 – 240 AC continuous power supply and hardwired broadband internet connection, including Fixed Internet Protocol (Fixed I.P.).

2.1.4. Dedicated third party desktop control software was installed on each monitoring station which allowed remote connection to each of the monitoring stations to change system settings and monitoring parameters as required.

2.2 Measurement Parameters - Sound / Air Overpressure

2.2.1. The monitoring systems were configured to measure:

- uncompressed instantaneous time and frequency weighted levels, at 125 msec sampling intervals, in the frequency range 0.5 Hz to 20 kHz;
- maximum microphone input sound pressure level of 156 dB re. 20 µPa (on-Range monitors);
- simultaneous measurement of A, C and Z frequency weighted levels;
- simultaneous measurement of Fast, Slow and Impulse time weighted levels;
- simultaneous L_{max}, L_{eq}, L_{peak} measurements for all frequency weightings;
- user defined measurement intervals;
- third-octave band measurements (in accordance with IEC 61260 Class 0);
- third-octave band middle frequencies from 0.04 Hz to 20 kHz;
- uncompressed raw waveform capture (event triggered or continuous) for subsequent analysis of stored signals. Sample rate 51200 Hz, 32bit and effective 21 kHz bandwidth.

2.2.2. Field calibration checks of each sound / air overpressure measurement system installed (including extension cables and adaptors) were undertaken at the start (during installation), at 3 months, and at the end (during decommissioning) of the monitoring study. Field calibration checks were undertaken using a Rion NC-74, Class 1 (IEC 60942) Acoustic Calibrator fitted with a G.R.A.S RA0041 Sound Calibrator adaptor to generate a calibration level of 92.6 dB at 1 kHz.

2.2.3. In addition, the G.R.A.S 41CN outdoor microphone system is equipped with a built-in electrostatic actuator and test oscillator to enable precise in-situ calibration checks at 1000 Hz.

2.2.4. Each monitoring station was configured to perform in-situ electrostatic calibration checks via the built-in electrostatic actuator at 12 hour intervals throughout the monitoring study.

2.3 Measurement Parameters - Vibration

2.3.1. The monitoring systems were configured to measure:

- continuous maximum component Peak Particle Velocity (PPV);
- frequency range 0.5 Hz to 315 Hz (PPV), and 0.2 Hz to 700 Hz (acceleration);
- third-octave band measurements; and
- uncompressed raw waveform capture (event triggered or continuous) for subsequent analysis of stored signals). Sample rate 6400 Hz, 32bit.

2.4 Meteorological Stations

2.4.1. Wind strength and direction can have a dramatic effect on sound pressure levels received at receptors over longer distances. Temperature inversions also need consideration as sound can travel over greater distances when ground temperatures cool relative to atmospheric temperatures leading to the refraction of sound waves back towards the ground.

2.4.2. Meteorological data were acquired using Thies Clima Sensor US (Ultrasonic) sensors. Monitoring stations with meteorological sensors attached are shown on Figure 2.1. Where installed, the meteorological stations were configured to measure the following parameters:

- wind velocity;
- wind direction;
- air temperature;
- relative air humidity;
- barometric pressure;
- precipitation; and
- precipitation intensity.

2.4.3. Monitoring locations were grouped into five zones allowing a single meteorological station to provide representative data for the zone.

2.4.4. The zones are presented in Figure 2.1 below, and further details presented in Table 2.1.

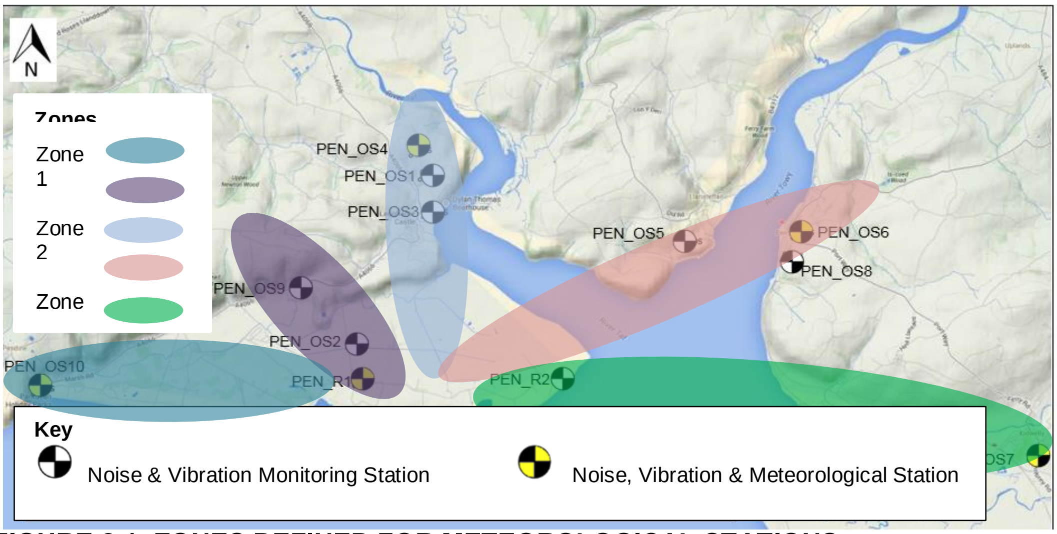


FIGURE 2.1: ZONES DEFINED FOR METEOROLOGICAL STATIONS

Monitoring Station I.D.	Zone	Expected Worse Case Wind Direction [1]	Approx. Distance to Range (km)	Representative Meteorological Station
PEN_OS1	Zone 3	S	4.0	PEN_OS4
PEN_OS2	Zone 2	SE	<1	PEN_R1
PEN_OS3	Zone 3	S	3.5	PEN_OS4
PEN_OS4	Zone 3	S	4.5	PEN_OS4
PEN_OS5	Zone 4	SW	6.0	PEN_OS6
PEN_OS6	Zone 4	SW	7.0	PEN_OS6
PEN_OS7	Zone 5	W	10.5	PEN_OS7
PEN_OS8	Zone 4	SW	6.0	PEN_OS6
PEN_OS9	Zone 2	SE	3.0	PEN_R1
PEN_OS10	Zone 1	E	6.5	PEN_OS10

TABLE 2.1: OFF-RANGE MONITORING LOCATION ZONING CATEGORIES

Note:
[1] Represents wind direction which would result in positive wind vector at each off-Range monitoring location.

2.5 Equipment Installations

2.5.1. Prior to the equipment installations, successful commissioning of each monitoring station was undertaken.

2.5.2. During the installations, on-site acceptance testing of various system component functions were tested, including:

- acoustic calibration check of measurement system;
- built in electrostatic check of measurement system;
- UPS operation and mains failure notification;
- triggering functions; and
- sensor failure.

2.5.3. For each equipment installation location, an Equipment Installation Record (EIR) was completed, detailing:

- equipment serial numbers;
- installation date;
- monitoring start date;
- location of equipment (including co-ordinates);
- estimated straight-line distance to Pendine Range;
- field calibration check details (performed at the start, during and end of monitoring period);
- on-site acceptance testing results; and
- photographic evidence of installation.

2.5.4. Full copies of the installation records are presented in section 2.6.

2.5.5. Before any equipment installation works started, detailed Risk Assessment Method Statements (RAMS) were prepared by Southdowns and submitted to the QinetiQ project team for approval.

2.5.6. Throughout the monitoring study, daily checks for each monitoring station and central data management systems were performed, including:

- ensuring station(s) were on-line;
- ensuring off-Range monitors were receiving trigger commands from the Range monitors;
- successful built-in electrostatic calibration checks complete;
- successful data transfer from monitoring station(s) to central data server; and
- successful back up of central data server (physical and cloud backups).

2.6 Installation Records

2.6.1. Installation records are presented in full in Tables 2.2 – 2.13 below.

INSTALLATION RECORD: PEN_R1, PENDINE RANGE, BRILL GATE					
SWING Serial No:	#0010024	**Microphone Type & Serial No:**	G.R.A.S 41CN 177434	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 503949
Installation Date:	28/09/2014	**Last Microphone Field Calibration:**	14/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic	**Fitted With UPS backup:**	Yes	**Weather Station:**	Clima Sensor US s/n 8140254
Location of Equipment Cabinet:	Internal. Within Brill Gate Operations Room	**Location of Microphone:**	Fixed to external brickwork or Brill Gate Building. Microphone elevated. 4 m above local ground, Free-Field.	**Location of Transducer:**	Fixed to slab of buildings concrete foundations (externally) Southern façade.
Estimated Distance from Range (Central) [km]	0.91	**Estimated Distance from Range (East) [km]**	3.52	**Co-ordinates**	51°44'39.36"N, 4°28'47.48"W
Master / Slave Monitor	Master	**Trigger Threshold:**	75.0 dB(A)	**Installation Undertaken by:**	IJA & ASW
Notes	None				

Field Calibration Check Details – Study Start			
Time : Date:	08:28 14/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.00537007 V/Pa	0.00537064 V/Pa	0.00536879 V/Pa
Used Sensitivity:	0.00485355 V/Pa	0.00537007 V/Pa	0.00537064 V/Pa
New Calibration Level:	93.48 dB	92.60 dB	92.60 dB

On-Site Acceptance Testing			
Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval			
Time : Date:	2015.01.29 14:21:10	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.00499865 V/Pa	0.00498285 V/Pa	0.00498669 V/Pa
Used Sensitivity:	0.00536879 V/Pa	0.00499865 V/Pa	0.00498285 V/Pa
New Calibration Level:	91.98dB	92.57dB	92.61dB

Field Calibration Check Details – Study End				
Time : Date:	2015.05.07 18:03:10	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.00500179 V/Pa	0.00498669 V/Pa	92.63 dB

TABLE 2.2: PEN_R1 PENDINE RANGE, BRILL GATE

INSTALLATION RECORD: PEN_R2, PENDINE RANGE, BUILDING 214, E8 TEST SITE					
SWING Serial No:	#0010025	**Microphone Type & Serial No:**	G.R.A.S 41CN 177432	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 503950
Installation Date:	28/09/2014	**Last Microphone Field Calibration:**	14/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic	**Fitted With UPS backup:**	Yes	**Weather Station:**	None
Location of Equipment Cabinet:	Internal. Within Building 214	**Location of Microphone:**	Fixed to external brickwork of 214 Building. Microphone elevated c. 4.5m above local ground, Free-Field.	**Location of Transducer:**	Fixed to concrete foundation slab of Building 214 (western façade) using Epoxy Resin
Estimated Distance from Range (Central) [km]	4.05	**Estimated Distance from Range (East) [km]**	0.11	**Co-ordinates**	51°44'38.44"N, 4°25'43.78"W
Master / Slave Monitor	Master	**Trigger Threshold:**	75.0 dB(A)	**Installation Undertaken by:**	IJA & ASW
Notes:	None				
Field Calibration Check Details – Study Start					
Time : Date:	09:03 14/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)		
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**		
Reference Value:	92.60 dB	92.60 dB	92.60 dB		
New Sensitivity:	0.00519817 V/Pa	0.00519817 V/Pa	0.0051944 V/Pa		
Used Sensitivity:	0.00531111 V/Pa	0.00519808 V/Pa	0.00519817 V/Pa		
New Calibration Level:	92.41 dB	92.60 dB	92.59 dB		
On-Site Acceptance Testing					
Acoustic Calibration:		PASS	**Triggering From Master(s):**	PASS	
Electrostatic Calibration:		PASS	**Sensor Failure Notification:**	PASS	
Main Failure Notification:		PASS	**UPS:**	PASS	
GPS Sync:		PASS	**Local Trigger:**	PASS	
Notes:		None			
Field Calibration Check Details – 3 Month Interval					
Time : Date:	2015.02.19 11:58	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)		
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**		
Reference Value:	92.60 dB	92.60 dB	92.60 dB		
New Sensitivity:	0.00519289 V/Pa	0.00531473 V/Pa	0.00539578 V/Pa		
Used Sensitivity:	0.00498669 V/Pa	0.00519289 V/Pa	0.00531473 V/Pa		
New Calibration Level:	92.95	92.80	92.73 dB		
Field Calibration Check Details – Study End					
Time : Date:	2015.05.07 16:53:17	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)		
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**	
	92.60 dB	0.00527305	0.00539578	92.40	

TABLE 2.3: PEN_R2: PENDINE RANGE, BUILDING 214, E8 TEST SITE

<table>
<tr><th colspan="6">INSTALLATION RECORD: PEN_OS1, LAUGHARNE, SA33</th></tr>
<tr><td>SWING Serial No:</td><td>#0010027</td><td>Microphone Type & Serial No:</td><td>G.R.A.S 41CN 218137</td><td>Transducer Type & Serial No:</td><td>SINUS tri-axial velocity sensor 504083</td></tr>
<tr><td>Installation Date:</td><td>15/10/2014</td><td>Last Microphone Field Calibration:</td><td>15/10/2014</td><td>Monitoring Start Date:</td><td>20/10/2014</td></tr>
<tr><td>Unit Powered:</td><td>240v domestic (outdoor socket)</td><td>Fitted With UPS backup:</td><td>Yes</td><td>Weather Station:</td><td>None</td></tr>
<tr><td>Location of Equipment Cabinet:</td><td>Outside in rear garden</td><td>Location of Microphone:</td><td>Rear Garden (Southern façade) free-field location. Microphone elevated c. 3m above local ground.</td><td rowspan="2">Location of Transducer:</td><td rowspan="2">Fixed to Plaster of Paris Patch using Epoxy Resin. Free-field monitoring location. X-axis perpendicular with southern façade.</td></tr>
<tr><td>Estimated Distance from Range (Central) [km]</td><td>4.62</td><td>Estimated Distance from Range (East) [km]</td><td>4.36</td></tr>
<tr><td>Master / Slave Monitor</td><td>Slave</td><td>Trigger Threshold:</td><td>85.0 dB(A)</td><td>Installation Undertaken by:</td><td>IJA & ASW</td></tr>
<tr><td>Notes:</td><td colspan="5">Microphone elevated to minimise screening effects. Not possible to locate Seismometer at building point of entry.</td></tr>
</table>

<table>
<tr><th colspan="4">Field Calibration Check Details – Study Start</th></tr>
<tr><td>Time : Date:</td><td>12:28 31/10/2014</td><td>Calibrator Make:</td><td>Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)</td></tr>
<tr><td>Cal no.</td><td>Cal #1</td><td>Cal #2</td><td>Cal #3</td></tr>
<tr><td>Reference Value:</td><td>92.60 dB</td><td>92.60 dB</td><td>92.60 dB</td></tr>
<tr><td>New Sensitivity:</td><td>0.0532047 V/Pa</td><td>0.053267 V/Pa</td><td>0.053245 V/Pa</td></tr>
<tr><td>Used Sensitivity:</td><td>0.0521483 V/Pa</td><td>0.0532047 V/Pa</td><td>0.053267 V/Pa</td></tr>
<tr><td>New Calibration Level:</td><td>92.77 dB</td><td>92.61 dB</td><td>92.60 dB</td></tr>
</table>

<table>
<tr><th colspan="4">On-Site Acceptance Testing</th></tr>
<tr><td>Acoustic Calibration:</td><td>PASS</td><td>Triggering From Master(s):</td><td>PASS</td></tr>
<tr><td>Electrostatic Calibration:</td><td>PASS</td><td>Sensor Failure Notification:</td><td>PASS</td></tr>
<tr><td>Main Failure Notification:</td><td>PASS</td><td>UPS:</td><td>PASS</td></tr>
<tr><td>GPS Sync:</td><td>PASS</td><td>Local Trigger:</td><td>PASS</td></tr>
<tr><td>Notes:</td><td colspan="3">Equipment installed 15/10/2014. Microphone & Transducer relocated on 31/10/2014. Calibration undertaken.</td></tr>
</table>

<table>
<tr><th colspan="4">Field Calibration Check Details – 3 Month Interval</th></tr>
<tr><td>Time : Date:</td><td>2015.01.29 09:25:24</td><td>Calibrator Make:</td><td>Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)</td></tr>
<tr><td>Cal no.</td><td>Cal #1</td><td>Cal #2</td><td>Cal #3</td></tr>
<tr><td>Reference Value:</td><td>92.60 dB</td><td>92.60 dB</td><td>92.60 dB</td></tr>
<tr><td>New Sensitivity:</td><td>0.0533556 V/Pa</td><td>0.0533158 V/Pa</td><td>0.0531872 V/Pa</td></tr>
<tr><td>Used Sensitivity:</td><td>0.0534027 V/Pa</td><td>0.0533556 V/Pa</td><td>0.0533158 V/Pa</td></tr>
<tr><td>New Calibration Level:</td><td>92.59 dB</td><td>92.59 dB</td><td>92.58 dB</td></tr>
</table>

<table>
<tr><th colspan="5">Field Calibration Check Details – Study End</th></tr>
<tr><td>Time : Date:</td><td>2015.05.07 14:38:43</td><td>Calibrator Make:</td><td colspan="2">Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)</td></tr>
<tr><td rowspan="2">Cal #1</td><td>Reference Value:</td><td>New Sensitivity:</td><td>Used Sensitivity:</td><td>New Calibration Level:</td></tr>
<tr><td>92.60 dB</td><td>0.0384829 V/Pa</td><td>0.0381003 V/Pa</td><td>92.69 dB</td></tr>
</table>

TABLE 2.4: PEN_OS1: LAUGHARNE, SA33

INSTALLATION RECORD: PEN_OS2, LAUGHARNE, SA33					
SWING Serial No:	#0010023	**Microphone Type & Serial No:**	G.R.A.S 41CN 218136	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504070
Installation Date:	12/10/2014	**Last Microphone Field Calibration:**	15/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic (garage)	**Fitted With UPS backup:**	Yes	**Weather Station:**	None
Location of Equipment Cabinet:	Within garage	**Location of Microphone:**	Rear garden. Free-Field location c. 1.5 m above local ground.	**Location of Transducer:**	Fixed to concrete slab using Epoxy Resin at property foundations with X-axis perpendicular to eastern façade
Estimated Distance from Range (Central) [km]	1.47	**Estimated Distance from Range (East) [km]**	3.64		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken by:**	IJA & ASW
Notes:	None				

Field Calibration Check Details – Study Start			
Time : Date:	14:41 16/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0542706 V/Pa	0.0542389 V/Pa	0.0542446 V/Pa
Used Sensitivity:	0.0492399 V/Pa	0.0542706 V/Pa	0.0542389 V/Pa
New Calibration Level:	93.44 dB	92.60 dB	92.59 dB

On-Site Acceptance Testing			
Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval			
Time : Date:	29/01/2015 12:13	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0515302 V/Pa	0.0514771 V/Pa	0.0515281 V/Pa
Used Sensitivity:	0.0515302 V/Pa	0.0515281 V/Pa	0.0515302 V/Pa
New Calibration Level:	92.15dB	92.59dB	92.60dB

Field Calibration Check Details – Study End				
Time : Date:	08/05/2015 08:44	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.0507823V/Pa	0.0514771V/Pa	92.48 dB

TABLE 2.5: PEN_OS2: LAUGHARNE, SA33

INSTALLATION RECORD: PEN_OS3, LAUGHARNE, SA33

SWING Serial No:	#0010030	**Microphone Type & Serial No:**	G.R.A.S 41CN 218142	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504077
Installation Date:	12/10/2014	**Last Microphone Field Calibration:**	12/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic (outdoor socket)	**Fitted With UPS backup:**	Yes	**Weather Station:**	None
Location of Equipment Cabinet:	Outdoor Balcony	**Location of Microphone:**	Fixed to vertical of 1st floor balcony hand-rail, representative of 1st floor height of façade looking towards Range, within 2m of reflective surface.	**Location of Transducer:**	Fixed to Plaster of Paris Patch using Epoxy Resin at foundations of façade looking towards Range. X-axis perpendicular properties south façade.
Estimated Distance from Range (Central) [km	4.05	**Estimated Distance from Range (East) [km]**	3.73		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken by:**	IJA
Notes:	None				

Acoustic Calibration

Time : Date:	11:49 12/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0493353 V/Pa	0.0493122 V/Pa	0.0493135 V/Pa
Used Sensitivity:	0.0460416 V/Pa	0.0493353 V/Pa	0.0493122 V/Pa
New Calibration Level:	93.20 dB	92.60 dB	92.60 dB

Field Calibration Check Details – Study Start

Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval

Time : Date:	29/01/2015 15:53	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0497466 V/Pa	0.049465 V/Pa	0.0498409 V/Pa
Used Sensitivity:	0.0493135 V/Pa	0.0497466 V/Pa	0.049465 V/Pa
New Calibration Level:	92.68dB	92.55dB	92.67dB

Field Calibration Check Details – Study End

Time : Date:		**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.0507111 V/Pa	0.0517222 V/Pa	92.43 dB

TABLE 2.6: PEN_OS3: LAUGHARNE, SA33

INSTALLATION RECORD: PEN_OS4, LAUGHARNE, SA33					
SWING Serial No:	#0010026	**Microphone Type & Serial No:**	G.R.A.S 41CN 214167	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504078
Installation Date:	27/11/2014	**Last Microphone Field Calibration:**	27/11/2014	**Monitoring Start Date:**	28/11/2014
Unit Powered:	240v domestic	**Fitted With UPS backup:**	Yes	**Weather Station:**	Clima Sensor US s/n 8140257
Location of Equipment Cabinet:	Property Basement	**Location of Microphone:**	Rear garden (south facing) free-field location. Microphone elevated c.2m above local ground.	**Location of Transducer:**	Fixed to concrete slab with Epoxy Resin at property foundation with X-axis perpendicular to southern façade.
Estimated Distance from Range (Central) [km	4.8	**Estimated Distance from Range (East) [km]**	4.5		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken by:**	ASW
Notes:	None				

Field Calibration Check Details – Study Start				
Time : Date:	15:39 27/11/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal no.	Cal #1	**Cal #2**	**Cal #3**	
Reference Value:	92.60 dB	92.60 dB	92.60 dB	
New Sensitivity:	0.0513943 V/Pa	0.0513155 V/Pa	0.051386 V/Pa	
Used Sensitivity:	0.0514799 V/Pa	0.0513943 V/Pa	0.0513155 V/Pa	
New Calibration Level:	92.59 dB	92.59 dB	92.61 dB	

On-Site Acceptance Testing			
Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval			
Time : Date:	29/01/2015 11:12	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0511146 V/Pa	0.0511887 V/Pa	0.0512267 V/Pa
Used Sensitivity:	0.0500183 V/Pa	0.0511146 V/Pa	0.0511887 V/Pa
New Calibration Level:	92.79dB	92.61dB	92.61dB

Field Calibration Check Details – Study End				
Time : Date:	2015.05.08 10:21:55	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.0504334 V/Pa	0.0512267 V/Pa	92.46

TABLE 2.7: PEN_OS4: LAUGHARNE, SA33

INSTALLATION RECORD: PEN_OS5, LLANSTEPHAN, SA33

SWING Serial No:	#0010029	**Microphone Type & Serial No:**	G.R.A.S 41CN 214166	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504076
Installation Date:	12/10/2014	**Last Microphone Field Calibration:**	15/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic (garage)	**Fitted With UPS backup:**	Yes	**Weather Station:**	None
Location of Equipment Cabinet:	Within garage	**Location of Microphone:**	Rear garden. Free-Field location c. 1.5 m above local ground.	**Location of Transducer:**	Fixed to concrete slab using Epoxy Resin at property foundations with X-axis perpendicular to eastern façade
Estimated Distance from Range (Central) [km]	1.47	**Estimated Distance from Range (East) [km]**	3.64		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken by:**	IJA & ASW
Notes:	None.				

On-Site Acceptance Testing

Time : Date:	14:41 16/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0542706 V/Pa	0.0542389 V/Pa	0.0542446 V/Pa
Used Sensitivity:	0.0492399 V/Pa	0.0542706 V/Pa	0.0542389 V/Pa
New Calibration Level:	93.44 dB	92.60 dB	92.59 dB

On-Site Acceptance Testing

Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval

Time : Date:	28/01/2015 16:25	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0517699 V/Pa	0.0517222 V/Pa	0.0517997 V/Pa
Used Sensitivity:	0.05005 V/Pa	0.0517997 V/Pa	0.0517699 V/Pa
New Calibration Level:	92.89dB	92.59dB	92.60dB

Field Calibration Check Details – Study End

Time : Date:	2015.05.07 13:10:13	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.0507111 V/Pa	0.0517222 V/Pa	92.43 dB
Notes				

TABLE 2.8: PEN_OS5: LLANSTEPHAN, SA33

INSTALLATION RECORD: PEN_OS6, FERRYSIDE, SA17					
SWING Serial No:	#0010033	**Microphone Type & Serial No:**	G.R.A.S 41CN 214165	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504081
Installation Date:	13/10/2014	**Last Microphone Field Calibration:**	13/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic (garage)	**Fitted With UPS backup:**	Yes	**Weather Station:**	Clima Sensor US s/n 8140260
Location of Equipment Cabinet:	Inside garage	**Location of Microphone:**	Elevated c. 3.2m above local ground to first floor height, representative of properties western façade looking towards Range. Free-Field monitoring location.	**Location of Transducer:**	Fixed to Foundation of Garage (directly coupled with property foundations) using Epoxy Resin X-axis perpendicular with properties western façade
Estimated Distance from Range (Central) [km	8.77	**Estimated Distance from Range (East) [km]**	4.92		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken by:**	IJA & ASW
Notes:	None				

Field Calibration Check Details – Study Start			
Time : Date:	11:58 13/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60dB
New Sensitivity:	0.0501976 V/Pa	0.0505122 V/Pa	0.0503753 V/Pa
Used Sensitivity:	0.0458496 V/Pa	0.0501976 V/Pa	0.0505122 V/Pa
New Calibration Level:	93.39 dB	92.65 dB	92.61 dB

On-Site Acceptance Testing			
Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval			
Time : Date:	30/01/2015 13:29	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0502454 V/Pa	0.050204 V/Pa	0.0502677 V/Pa
Used Sensitivity:	0.0504503 V/Pa	0.0502677 V/Pa	0.0502454 V/Pa
New Calibration Level:	92.56dB	92.59dB	92.60dB

Field Calibration Check Details – Study End				
Time : Date:	2015.05.07 13:10:13	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB		0.0507111 V/Pa	0.0517222 V/Pa
Notes:	Calibration on decommission date was not possible due to adverse weather. Calibration was undertaken in house on 13/05/2015			

TABLE 2.9: PEN_OS6: FERRYSIDE, SA17

INSTALLATION RECORD: PEN_OS7, KIDWELLY					
SWING Serial No:	#0010035	**Microphone Type & Serial No:**	G.R.A.S 41CN 218141	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504072
Installation Date:	14/10/2014	**Last Microphone Field Calibration:**	14/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic (garage)	**Fitted With UPS backup:**	Yes	**Weather Station:**	Clima Sensor US s/n 8140255
Location of Equipment Cabinet:	Inside garage	**Location of Microphone:**	Rear Garden (western façade) free-field location. Microphone elevated c. 1.5m.	**Location of Transducer:**	Fixed to Plaster of Paris Patch using Epoxy Resin. Free-field monitoring location. X-axis perpendicular with western façade.
Estimated Distance from Range (Central) [km	12.22	**Estimated Distance from Range (East) [km]**	8.33		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken by:**	IJA & ASW
Notes:	Seismometer installed in free-field location on patch. Not possible to install on building foundation due to trip hazard it would pose on property patio.				

Field Calibration Check Details – Study Start			
Time / Date:	16:01 30/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
New Sensitivity:	0.0521718 V/Pa	0.0519744 V/Pa	0.0521759 V/Pa
Used Sensitivity:	0.0501887 V/Pa	0.0521718 V/Pa	0.0519744 V/Pa
New Calibration Level:	92.94 dB	92.57 dB	92.63 dB
On-Site Acceptance Testing			

On-Site Acceptance Testing			
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	Equipment installed 16/10/2014. Microphone & Transducer relocated on 31/10/2014. Calibration Undertaken.		

Field Calibration Check Details – 3 Month Interval			
Time : Date:	28/01/2015 14:08	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0500003V/Pa	0.0500449 V/Pa	0.0499696 V/Pa
Used Sensitivity:	0.0521759V/Pa	0.0500003 V/Pa	0.0500449 V/Pa
New Calibration Level:	92.23dB	92.61dB	92.59dB

Field Calibration Check Details – Study End				
Time : Date:	2015.05.13 09:25:49	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.6 dB	0.0527876 dB	0.0499696 dB	93.08 dB
Notes:	Calibration on decommission date was not possible due to adverse weather. Calibration was undertaken in house on 13/05/2015			

TABLE 2.10: PEN_OS7: KIDWELLY

INSTALLATION RECORD: PEN_OS8, FERRYSIDE					
SWING Serial No:	#0010032	**Microphone Type & Serial No:**	G.R.A.S 41CN 218139	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504075
Installation Date:	28/10/2014	**Last Microphone Field Calibration:**	28/10/2014	**Monitoring Start Date:**	28/10/2014
Unit Powered:	240v domestic (garage)	**Fitted With UPS backup:**	Yes	**Weather Station:**	None
Location of Equipment Cabinet:	First floor balcony	**Location of Microphone:**	Fixed to upright of handrail. Microphone elevated to first floor height. Façade monitoring location to rear of property (western façade)	**Location of Transducer:**	Fixed to concrete slab with Epoxy Resin at property foundations with X-axis perpendicular to western façade
Estimated Distance from Range (Central) [km	8.53	**Estimated Distance from Range (East) [km]**	4.66		
Master / Slave Monitor	Slave	**Trigger Threshold:**	95.0 dB(A)	**Installation Undertaken by:**	ASW
Notes:	Property bounded with railway line to south.				

Field Calibration Check Details – Study Start				
Time : Date:	16:22 2810/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal no.	**Cal #1**	**Cal #2**		**Cal #3**
Reference Value:	92.60 dB	92.60 dB		92.60 dB
New Sensitivity:	0.0509414 V/Pa	0.0510484 V/Pa		0.0510253 V/Pa
Used Sensitivity:	0.0433084 V/Pa	0.0509414 V/Pa		0.0510484 V/Pa
New Calibration Level:	94.01 dB	92.62 dB		92.60 dB

On-Site Acceptance Testing			
Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – 3 Month Interval				
Time : Date:	30/01/2015 13:42	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal no.	**Cal #1**	**Cal #2**		**Cal #3**
Reference Value:	92.60 dB	92.60 dB		92.60 dB
New Sensitivity:	0.0508037V/Pa	0.050555 V/Pa		0.0505489 V/Pa
Used Sensitivity:	0.0510253V/Pa	0.0508037 V/Pa		0.0505549 V/Pa
New Calibration Level:	92.56dB	92.56dB		92.60dB

Field Calibration Check Details – Study End				
Time : Date:		**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.0503138 V/Pa	0.0505489 V/Pa	92.56 dB
Notes:				

TABLE 2.11: PEN_OS8: FERRYSIDE

<table>
<tr><th colspan="6">INSTALLATION RECORD: PEN_OS9, PLASHETT, SA33</th></tr>
<tr><td>SWING Serial No:</td><td>#0010036</td><td>Microphone Type & Serial No:</td><td>G.R.A.S 41CN 218135</td><td>Transducer Type & Serial No:</td><td>SINUS tri-axial velocity sensor 504073</td></tr>
<tr><td>Installation Date:</td><td>26/11/2014</td><td>Last Microphone Field Calibration:</td><td>26/11/2014</td><td>Monitoring Start Date:</td><td>27/11/2014</td></tr>
<tr><td>Unit Powered:</td><td>240v domestic (garage)</td><td>Fitted With UPS backup:</td><td>Yes</td><td>Weather Station:</td><td>None</td></tr>
<tr><td>Location of Equipment Cabinet:</td><td>Outside (front garden)</td><td>Location of Microphone:</td><td>Front garden (south west facing) free-field location. Microphone elevated c. 2m above local ground.</td><td rowspan="2">Location of Transducer:</td><td rowspan="2">Fixed to Plaster of Paris Patch using Epoxy Resin. Free-field monitoring location with X-axis perpendicular with western façade</td></tr>
<tr><td>Estimated Distance from Range (Central) [km</td><td>2.44</td><td>Estimated Distance from Range (East) [km]</td><td>4.95</td></tr>
<tr><td>Master / Slave Monitor</td><td>Slave</td><td>Trigger Threshold:</td><td>85.0 dB(A)</td><td>Installation Undertaken by:</td><td>ASW</td></tr>
<tr><td>Notes:</td><td colspan="5">Unable to install seismometer at property foundations, due to the trip risk cable runs would create.</td></tr>
</table>

<table>
<tr><th colspan="5">Field Calibration Check Details – Study Start</th></tr>
<tr><td>Time : Date:</td><td>17:38 26/11/2014</td><td>Calibrator Make:</td><td colspan="2">Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)</td></tr>
<tr><td>Cal no.</td><td>Cal #1</td><td colspan="2">Cal #2</td><td>Cal #3</td></tr>
<tr><td>Reference Value:</td><td>92.60 dB</td><td colspan="2">92.60 dB</td><td>92.60 dB</td></tr>
<tr><td>New Sensitivity:</td><td>0.0458675 V/Pa</td><td colspan="2">0.0458749 V/Pa</td><td>0.0491637 V/Pa</td></tr>
<tr><td>Used Sensitivity:</td><td>0.05 V/Pa</td><td colspan="2">0.0458675 V/Pa</td><td>0.0458749 V/Pa</td></tr>
<tr><td>New Calibration Level:</td><td>91.85 dB</td><td colspan="2">92.60 dB</td><td>92.60 dB</td></tr>
</table>

<table>
<tr><th colspan="4">On-Site Acceptance Testing</th></tr>
<tr><td>Acoustic Calibration:</td><td>PASS</td><td>Triggering From Master(s):</td><td>PASS</td></tr>
<tr><td>Electrostatic Calibration:</td><td>PASS</td><td>Sensor Failure Notification:</td><td>PASS</td></tr>
<tr><td>Main Failure Notification:</td><td>PASS</td><td>UPS:</td><td>PASS</td></tr>
<tr><td>GPS Sync:</td><td>PASS</td><td>Local Trigger:</td><td>PASS</td></tr>
<tr><td>Notes:</td><td colspan="3"></td></tr>
</table>

<table>
<tr><th colspan="4">Field Calibration Check Details – 3 Month Interval</th></tr>
<tr><td>Time : Date:</td><td>30/01/2015 12:28</td><td>Calibrator Make:</td><td>Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)</td></tr>
<tr><td>Cal no.</td><td>Cal #1</td><td>Cal #2</td><td>Cal #3</td></tr>
<tr><td>Reference Value:</td><td>92.60 dB</td><td>92.60 dB</td><td>92.60 dB</td></tr>
<tr><td>New Sensitivity:</td><td>0.0497084V/Pa</td><td>0.0496115 V/Pa</td><td>0.0495921 V/Pa</td></tr>
<tr><td>Used Sensitivity:</td><td>0.0491637V/Pa</td><td>0.0497084 V/Pa</td><td>0.0496115 V/Pa</td></tr>
<tr><td>New Calibration Level:</td><td>92.70dB</td><td>92.58dB</td><td>92.60 dB</td></tr>
</table>

<table>
<tr><th colspan="5">Field Calibration Check Details – Study End</th></tr>
<tr><td>Time : Date:</td><td>2015.05.08 10:55:40</td><td>Calibrator Make:</td><td colspan="2">Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)</td></tr>
<tr><td rowspan="2">Cal #1</td><td>Reference Value:</td><td>New Sensitivity:</td><td>Used Sensitivity:</td><td>New Calibration Level:</td></tr>
<tr><td>92.60 dB</td><td>0.0461986 V/Pa</td><td>0.0495921 V/Pa</td><td>91.98</td></tr>
<tr><td>Notes</td><td colspan="4"></td></tr>
</table>

TABLE 2.12: PEN_OS9: PLASHETT, SA33

INSTALLATION RECORD: PEN_OS10, PENDINE, SA33					
SWING Serial No:	#0010031	**Microphone Type & Serial No:**	G.R.A.S 41CN 218138	**Transducer Type & Serial No:**	SINUS tri-axial velocity sensor 504070
Installation Date:	15/10/2014	**Last Microphone Field Calibration:**	15/10/2014	**Monitoring Start Date:**	20/10/2014
Unit Powered:	240v domestic (garage)	**Fitted With UPS backup:**	Yes	**Weather Station:**	Clima Sensor US s/n 8140256
Location of Equipment Cabinet:	tbc	**Location of Microphone:**	Fixed to vertical of handrail. Microphone elevated to upper ground floor level, within 3m of reflective surfaces. Eastern façade, looking towards Range.	**Location of Transducer:**	Fixed to Plaster of Paris Patch using Epoxy Resin X-axis perpendicular with properties eastern façade. Plaster of Patch located within properties garden area looking towards Range.
Estimated Distance from Range (Central) [km	5.17	**Estimated Distance from Range (East) [km]**	9.10		
Master / Slave Monitor	Slave	**Trigger Threshold:**	85.0 dB(A)	**Installation Undertaken By:**	IJA & ASW
Notes:	None				

Field Calibration Check Details – Study Start			
Time : Date:	15:34 15/10/2014	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0500176 V/Pa	0.0500714 V/Pa	0.0500416 V/Pa
Used Sensitivity:	0.0568684 V/Pa	0.0500176 V/Pa	0.0500714 V/Pa
New Calibration Level:	91.49 dB	92.59 dB	92.59 dB

Field Calibration Check Details – 3 Month Interval			
Acoustic Calibration:	PASS	**Triggering From Master(s):**	PASS
Electrostatic Calibration:	PASS	**Sensor Failure Notification:**	PASS
Main Failure Notification:	PASS	**UPS:**	PASS
GPS Sync:	PASS	**Local Trigger:**	PASS
Notes:	None		

Field Calibration Check Details – Study End			
Time : Date:		**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)
Cal no.	**Cal #1**	**Cal #2**	**Cal #3**
Reference Value:	92.60 dB	92.60 dB	92.60 dB
New Sensitivity:	0.0489596V/Pa	0.0489404 V/Pa	0.0489927 V/Pa
Used Sensitivity:	0.0505279V/Pa	0.0489596 V/Pa	0.0489404 V/Pa
New Calibration Level:	92.33dB	92.60dB	92.61dB

Field Calibration Check Details – Study End				
Time : Date:	2015.05.14 12:42:06	**Calibrator Make:**	Rion NC-74 s/n 00830791 (fitted with G.R.A.S. RA0041 Adaptor)	
Cal #1	**Reference Value:**	**New Sensitivity:**	**Used Sensitivity:**	**New Calibration Level:**
	92.60 dB	0.0517319 V/Pa	0.0489927 V/Pa	93.07 dB
Notes	Calibration on decommission date was not possible due to adverse weather. Calibration was undertaken in house on 14/05/2015			

TABLE 2.13: PEN_OS10: PENDINE, SA33

2.7 Calibration Certification

2.7.1. The calibration certificates for each of the monitoring stations are presented in the subsequent pages.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10024

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 177434

G.R.A.S.
Sound & Vibration

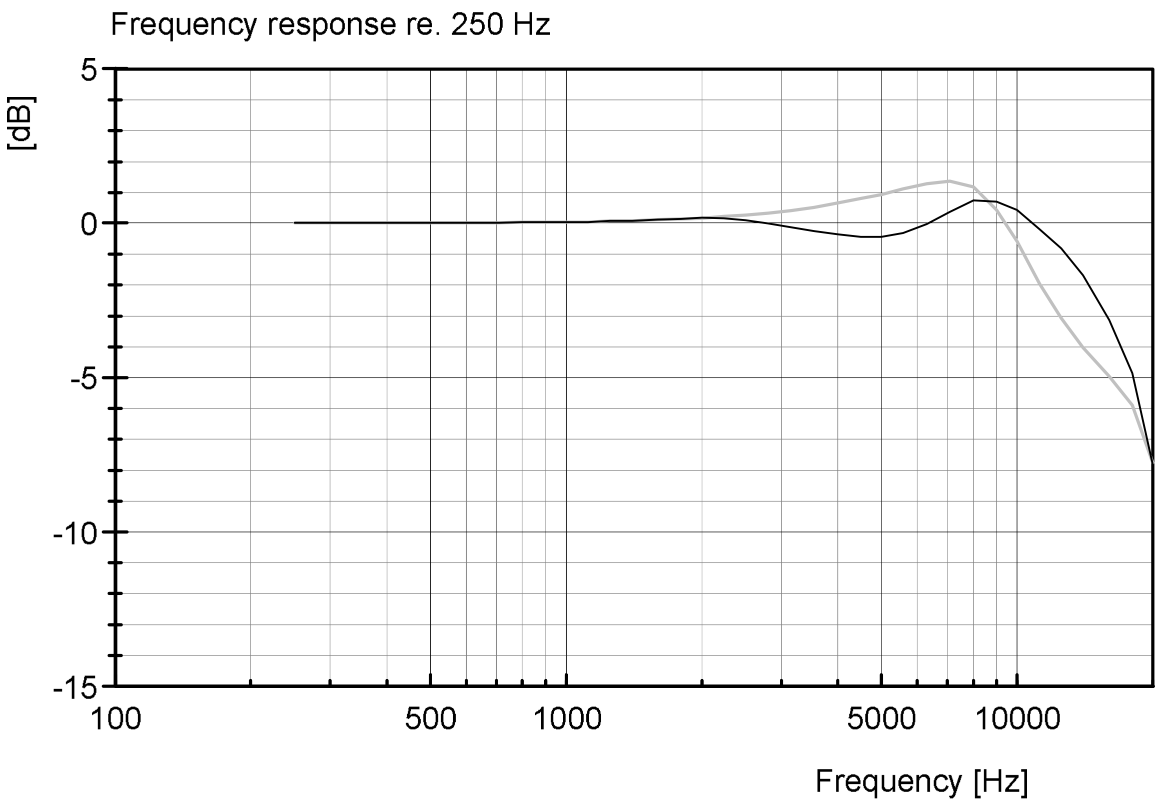
System Sensitivity:	50.02 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.65 mV
Preamplifier type:	26AX
Preamplifier serial no:	192401
Microphone type:	40AS
Microphone Serial No:	138460
Operator:	DN
Date:	28. jan 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

1912
D-K-15183-01-00
2014-09

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0503949**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**16/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
17/09/2014	Mario Chares	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0503949**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(23.8 ± 1) °C**
Relative humidity:	**(55 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(23.8 ± 2) °C**

Attachment of test object to vibration exciter:

z-axis:	**screwed SAM-018**
x- and y-axis:	**screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)

Manufacturer:	**SINUS Messtechnik GmbH**
Type:	**902246**
Length:	**2 m**

Specification of excitation
for determination of the transfer coefficient

Frequency:	**16 Hz**
Velocity (peak)	**10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:

- for determination of the transfer coefficient at 16 Hz			1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range			
	0.5 Hz bis	< 1 Hz	2.0% / 2.0°
	1 Hz bis	80 Hz	1.5% / 1.5°
	> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**28.986 mV/(mm/s)**	**0.004 %**	**0.0012 mV/(mm/s)**
y-axis:	**29.162 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**
z-axis:	**30.024 mV/(mm/s)**	**0.025 %**	**0.0075 mV/(mm/s)**

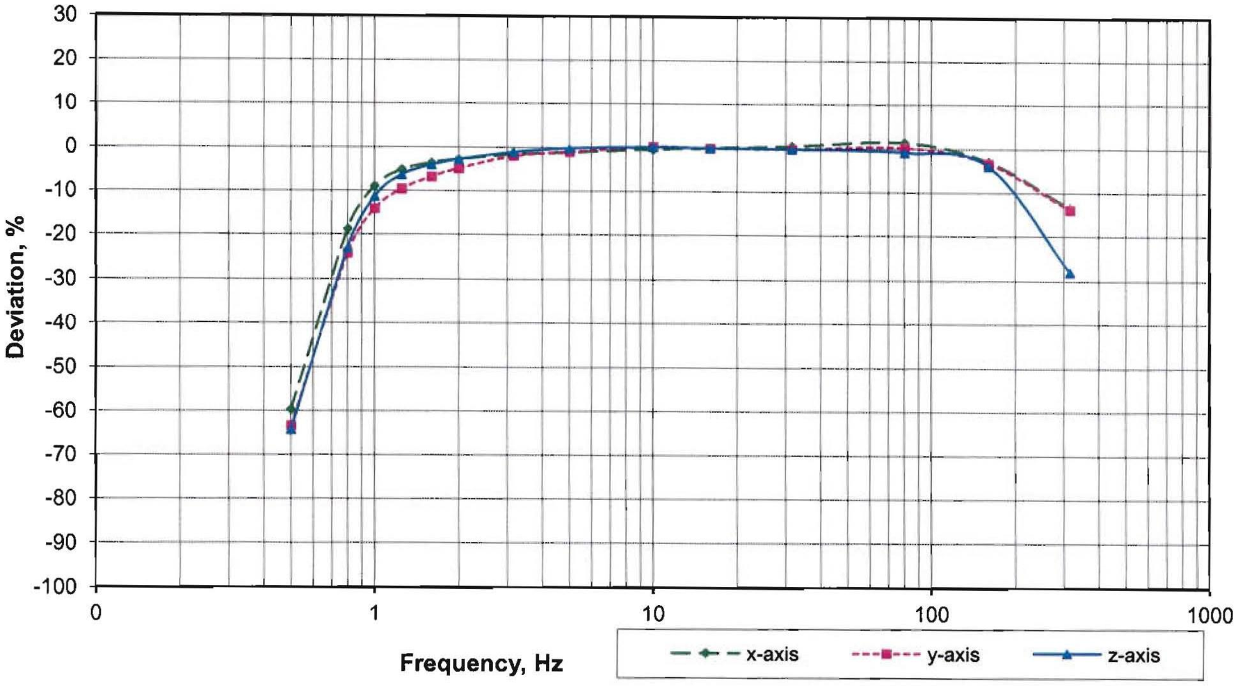
(acceleration due to gravity 1 g_n = 9.80665 m/s²)

7.2 Amplitude frequency response (relative to 16 Hz)

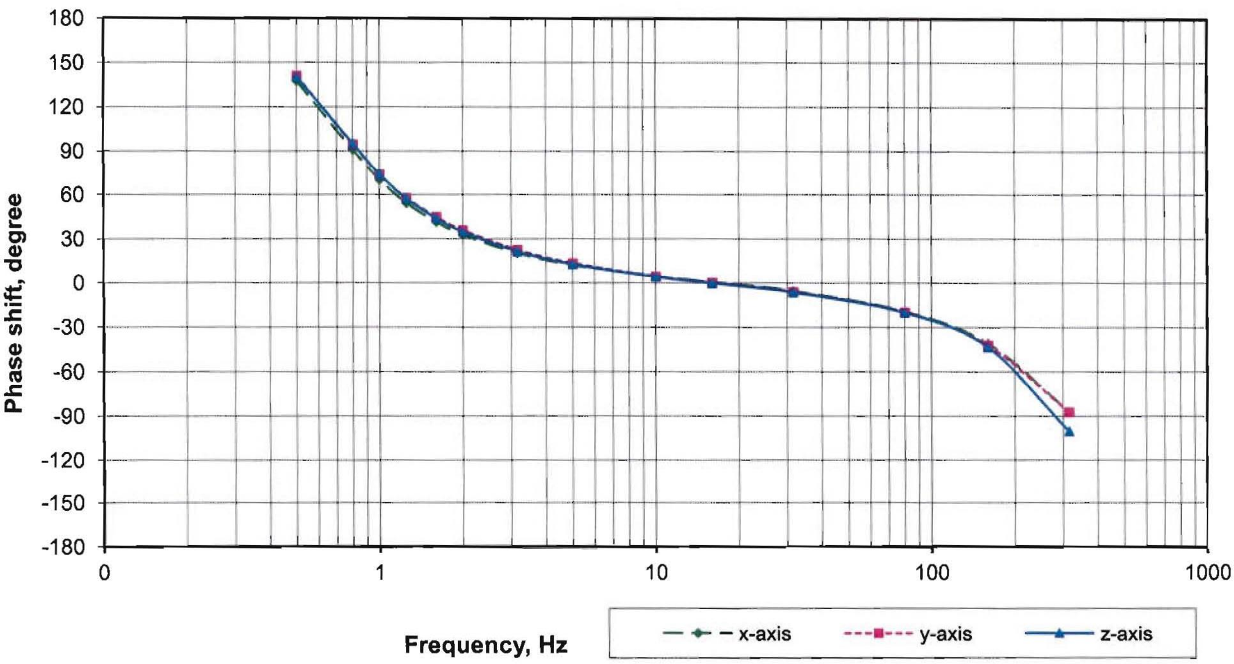
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.68	-59.69	137.8	10.68	-63.38	141.2	10.72	-64.29	140.6
0.8	23.56	-18.74	91.2	22.14	-24.07	94.7	23.16	-22.88	95.5
1	26.39	-8.96	70.3	25.05	-14.09	73.7	26.65	-11.25	74.1
1.25	27.49	-5.16	54.4	26.39	-9.52	57.9	28.13	-6.29	57.4
1.6	27.97	-3.51	41.6	27.21	-6.70	44.9	28.83	-3.97	44.0
2	28.20	-2.70	32.9	27.76	-4.80	36.0	29.21	-2.73	34.8
3.15	28.52	-1.60	20.5	28.59	-1.98	22.7	29.70	-1.09	21.6
5	28.67	-1.10	12.3	28.88	-0.98	13.6	29.97	-0.17	12.8
10	28.89	-0.32	4.5	29.25	0.29	4.7	30.08	0.18	4.2
16	**28.99**	**0.0**	**0.6**	**29.16**	**0.0**	**0.4**	**30.02**	**0.0**	**-0.1**
31.5	29.13	0.49	-5.5	29.12	-0.16	-5.8	29.97	-0.18	-6.3
80	29.39	1.38	-19.4	29.24	0.27	-19.6	29.77	-0.83	-20.1
160	28.15	-2.88	-40.9	28.22	-3.22	-41.9	28.86	-3.89	-43.3
315	25.09	-13.44	-86.8	25.15	-13.75	-87.0	21.64	-27.92	-100.2

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)

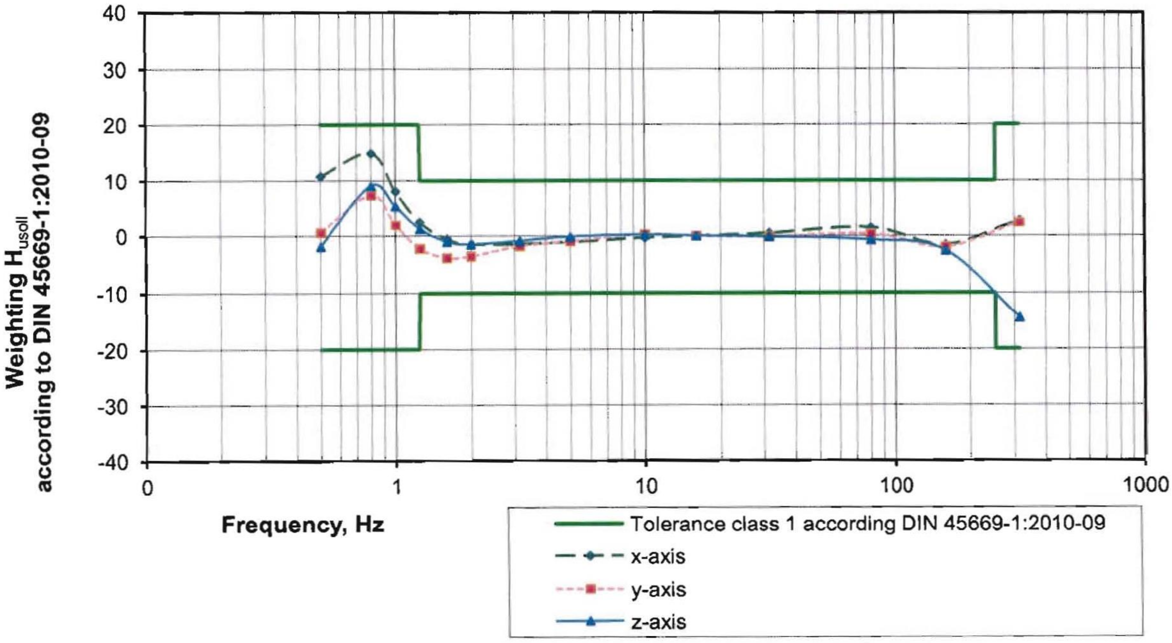


Phase frequency response



7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis: Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	x-axis: Weighting factor, (measured value)	x-axis: Deviation to H_{uSOLL}	y-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	y-axis: Weighting factor, (measured value)	y-axis: Deviation to H_{uSOLL}	z-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	z-axis: Weighting factor, (measured value)	z-axis: Deviation to H_{uSOLL}
0.5	0.364	0.403	10.8	0.364	0.366	0.6	0.364	0.357	-1.9
0.8	0.707	0.813	14.9	0.707	0.759	7.4	0.707	0.771	9.1
1	0.842	0.910	8.1	0.842	0.859	2.0	0.842	0.887	5.4
1.25	0.925	0.948	2.5	0.925	0.905	-2.2	0.925	0.937	1.3
1.6	0.970	0.965	-0.5	0.970	0.933	-3.8	0.970	0.960	-1.0
2	0.987	0.973	-1.5	0.987	0.952	-3.6	0.987	0.973	-1.5
3.15	0.998	0.984	-1.4	0.998	0.980	-1.8	0.998	0.989	-0.9
5	1.000	0.989	-1.1	1.000	0.990	-1.0	1.000	0.998	-0.1
10	1.000	0.997	-0.3	1.000	1.003	0.3	1.000	1.002	0.2
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	1.005	0.5	1.000	0.998	-0.2	1.000	0.998	-0.2
80	0.999	1.014	1.5	0.999	1.003	0.4	0.999	0.992	-0.7
160	0.987	0.971	-1.6	0.987	0.968	-1.9	0.987	0.961	-2.6
315	0.842	0.866	2.8	0.842	0.863	2.4	0.842	0.721	-14.4



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10025

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 177432

G.R.A.S.
Sound & Vibration

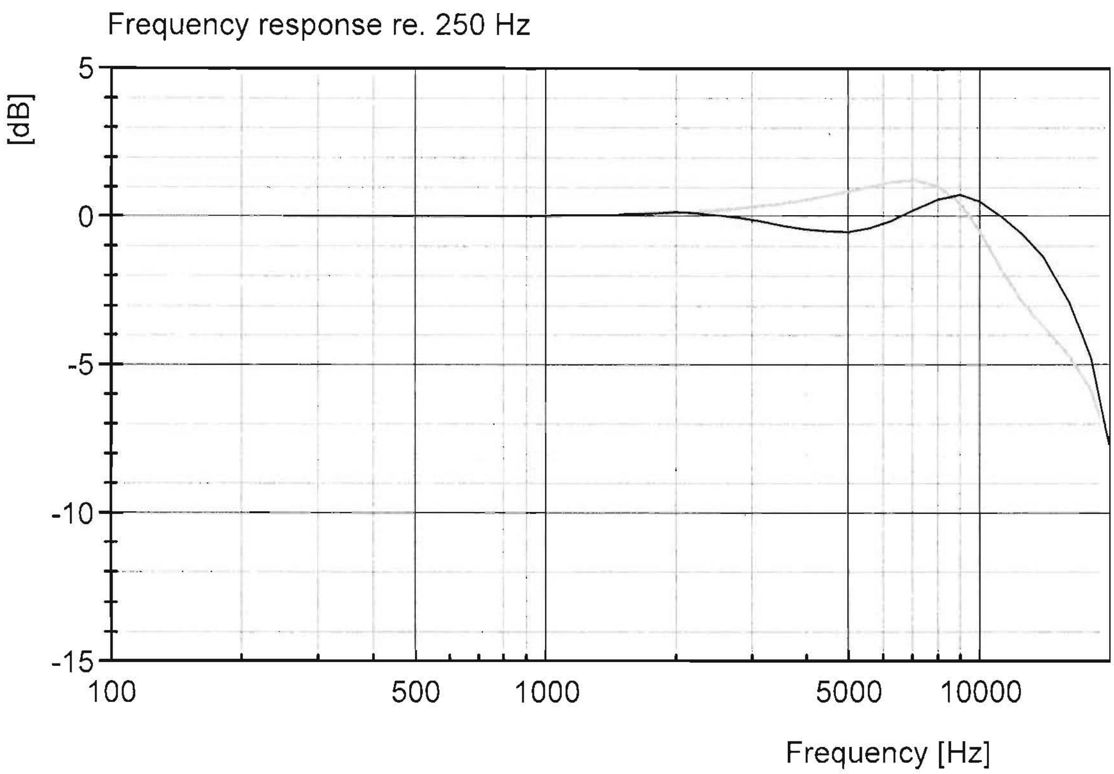
System Sensitivity:	50.00 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.65 mV
Preamplifier type:	26AX
Preamplifier serial no:	163450
Microphone type:	40AS
Microphone Serial No:	138453
Operator:	DN
Date:	28. jan 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1913
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0503950**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH** **DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**12/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
15/09/2014	Mario Chares	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0503950**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(24.1 ± 1) °C**
Relative humidity:	**(50 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(24.1 ± 2) °C**

Attachment of test object to vibration exciter:
z-axis: **screwed SAM-018**
x- and y-axis: **screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)
Manufacturer: **SINUS Messtechnik GmbH**
Type: **902246**
Length: **2 m**

Specification of excitation
for determination of the transfer coefficient
Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:

- for determination of the transfer coefficient at 16 Hz		1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range		
0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.596 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**
y-axis:	**30.248 mV/(mm/s)**	**0.007 %**	**0.0021 mV/(mm/s)**
z-axis:	**29.668 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**

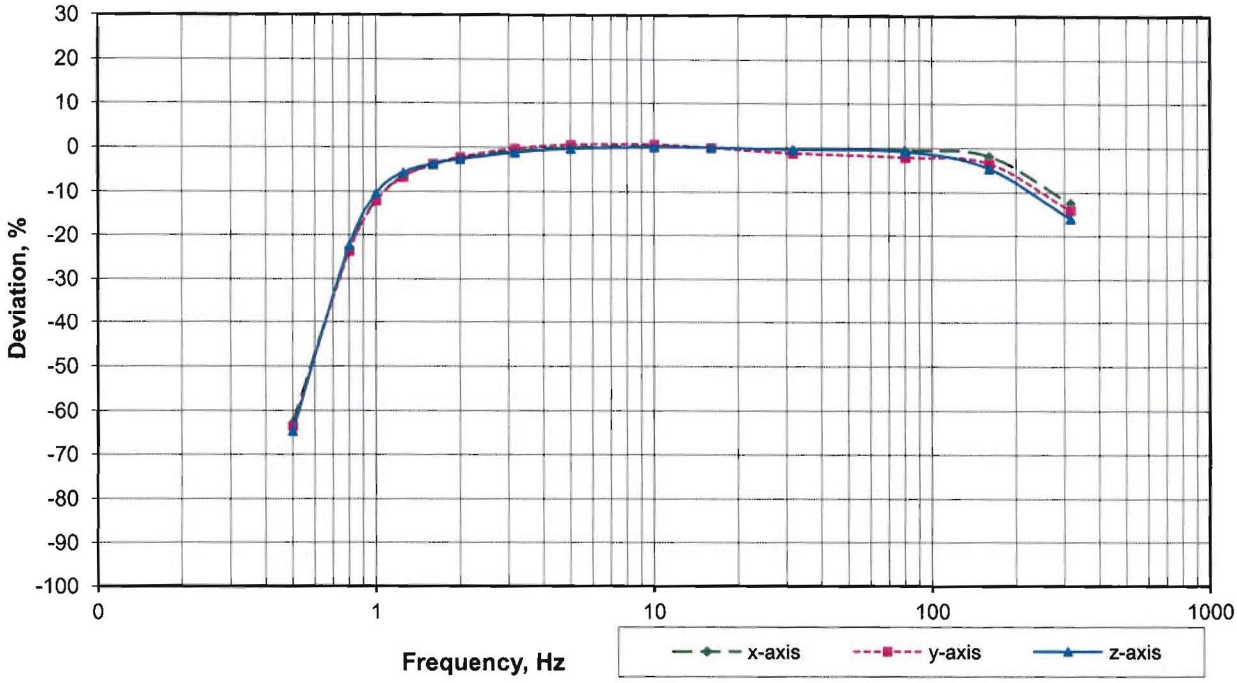
(acceleration due to gravity 1 g_n = 9.80665 m/s²)

7.2 Amplitude frequency response (relative to 16 Hz)

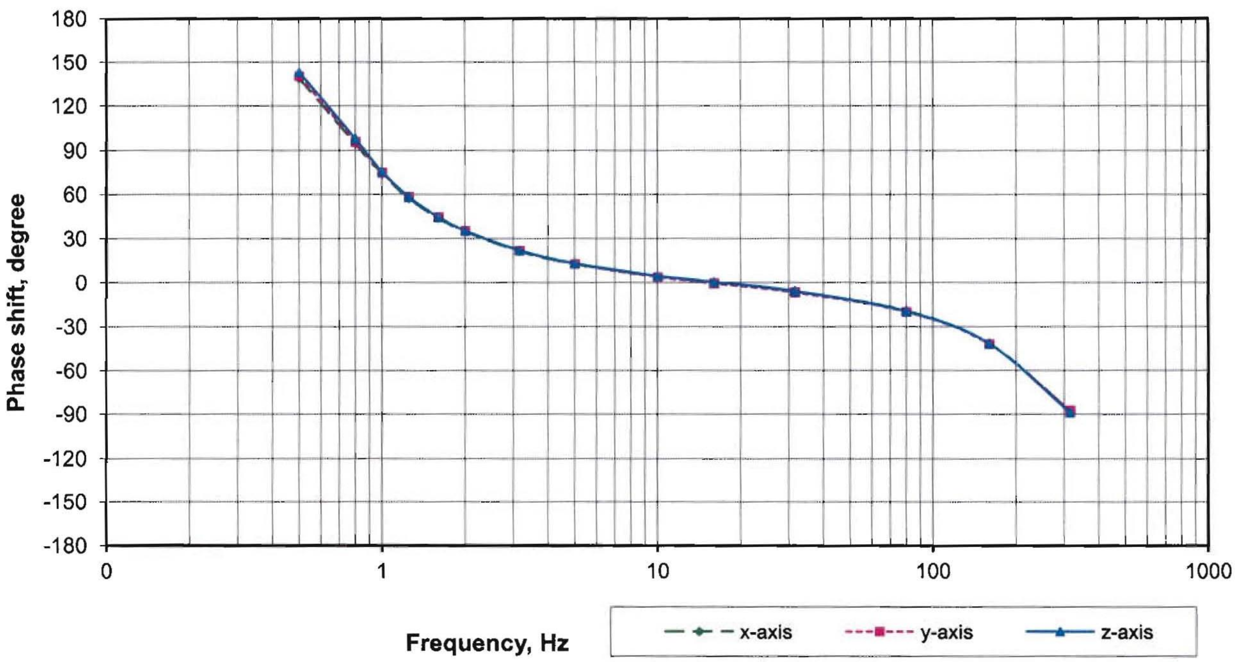
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.00	-62.85	139.0	11.00	-63.62	140.4	10.44	-64.82	143.2
0.8	22.67	-23.42	94.8	23.09	-23.66	95.9	23.04	-22.36	97.9
1	26.04	-12.02	74.0	26.59	-12.11	74.8	26.59	-10.38	75.5
1.25	27.63	-6.64	57.7	28.23	-6.67	58.3	27.98	-5.70	58.3
1.6	28.44	-3.91	44.1	29.11	-3.78	44.7	28.57	-3.71	44.6
2	28.85	-2.52	34.9	29.58	-2.21	35.4	28.88	-2.67	35.3
3.15	29.32	-0.95	21.6	30.17	-0.25	21.9	29.32	-1.17	21.9
5	29.55	-0.14	12.7	30.44	0.63	12.8	29.58	-0.29	13.0
10	29.66	0.23	4.3	30.47	0.74	3.9	29.69	0.07	4.4
16	**29.60**	**0.0**	**0.1**	**30.25**	**0.0**	**-0.6**	**29.67**	**0.0**	**0.1**
31.5	29.48	-0.39	-6.0	29.89	-1.17	-6.7	29.55	-0.39	-6.1
80	29.43	-0.55	-19.5	29.64	-2.03	-20.0	29.42	-0.83	-19.7
160	29.06	-1.80	-41.6	29.23	-3.36	-42.0	28.31	-4.57	-41.8
315	25.92	-12.43	-87.5	26.01	-14.00	-87.3	24.92	-16.02	-88.8

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)

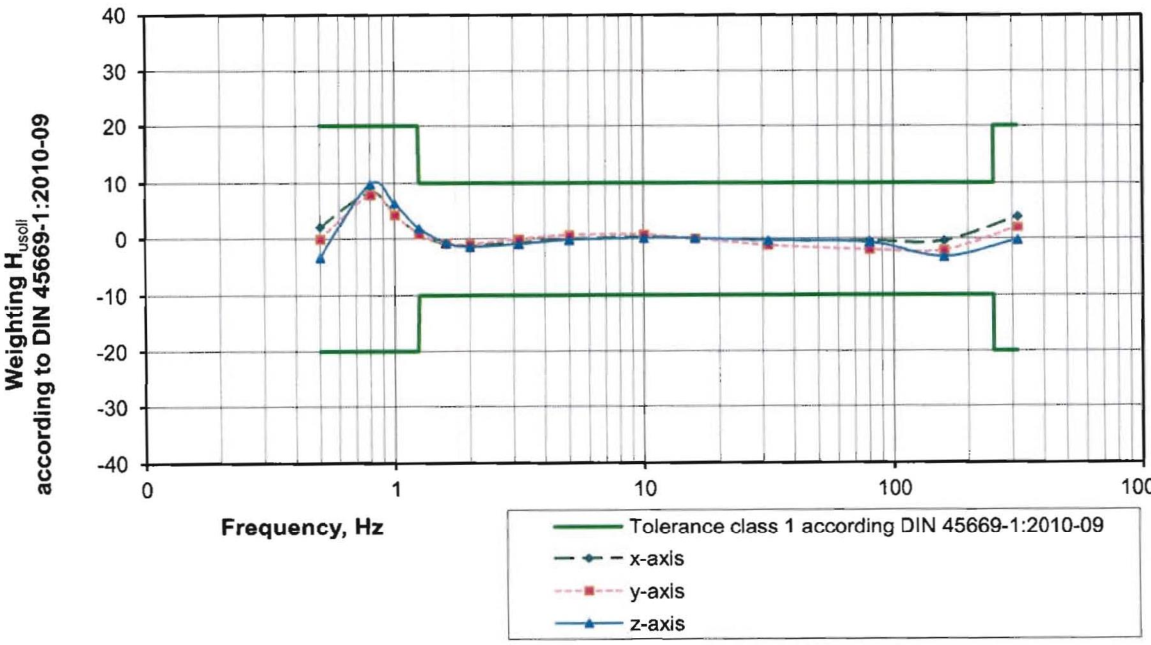


Phase frequency response



7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.372	2.1	0.364	0.364	0.0	0.364	0.352	-3.3
0.8	0.707	0.766	8.3	0.707	0.763	8.0	0.707	0.776	9.8
1	0.842	0.880	4.5	0.842	0.879	4.4	0.842	0.896	6.4
1.25	0.925	0.934	0.9	0.925	0.933	0.9	0.925	0.943	1.9
1.6	0.970	0.961	-0.9	0.970	0.962	-0.8	0.970	0.963	-0.7
2	0.987	0.975	-1.3	0.987	0.978	-1.0	0.987	0.973	-1.4
3.15	0.998	0.991	-0.7	0.998	0.997	0.0	0.998	0.988	-1.0
5	1.000	0.999	-0.1	1.000	1.006	0.7	1.000	0.997	-0.3
10	1.000	1.002	0.2	1.000	1.007	0.7	1.000	1.001	0.1
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.996	-0.4	1.000	0.988	-1.2	1.000	0.996	-0.4
80	0.999	0.994	-0.5	0.999	0.980	-1.9	0.999	0.992	-0.7
160	0.987	0.982	-0.5	0.987	0.966	-2.0	0.987	0.954	-3.3
315	0.842	0.876	4.0	0.842	0.860	2.1	0.842	0.840	-0.3



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10027

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218137

G.R.A.S.
Sound & Vibration

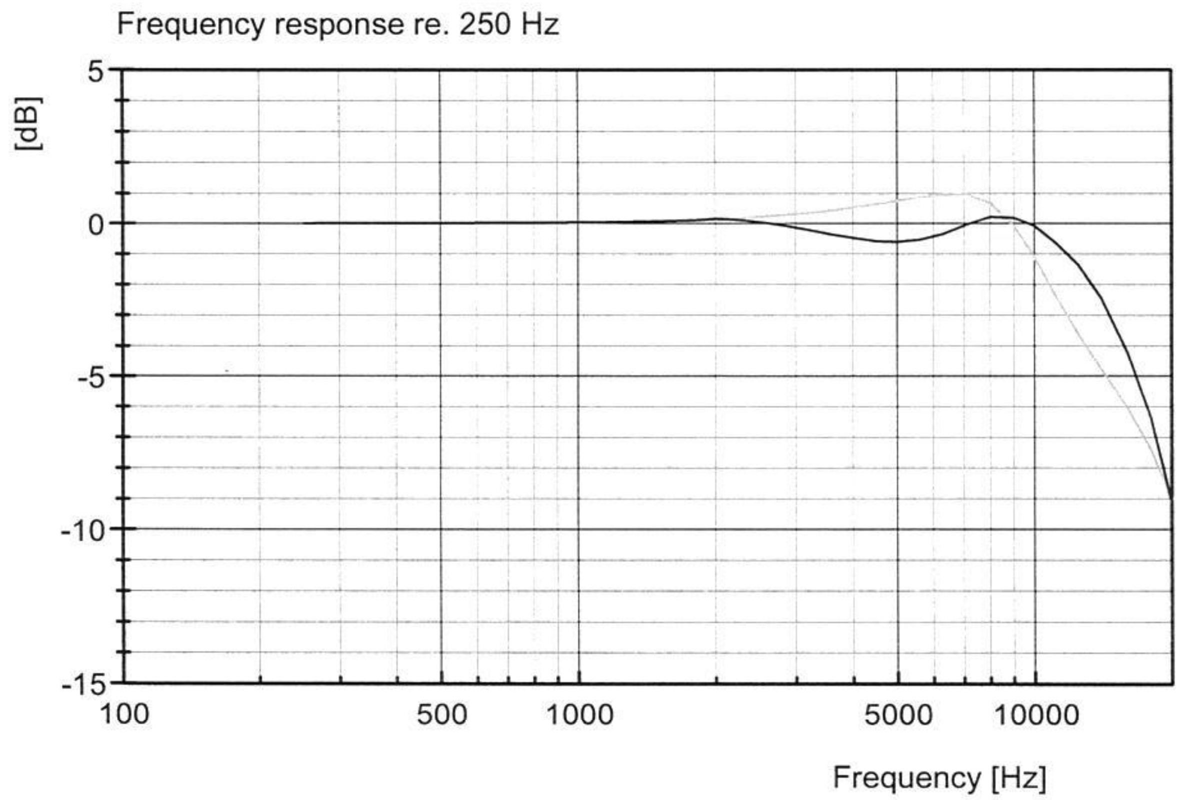
System Sensitivity:	50.06 mV/Pa
	-26.01 dB re. 1V/Pa
Actuator output:	31.68 mV
Preamplifier type:	26AX
Preamplifier serial no:	214112
Microphone type:	40AS
Microphone Serial No:	178531
Operator:	FBL
Date:	21. aug 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1977
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504083**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141335**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**24/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
24/09/2014	Philipp Begoff	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504083**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(22.8 ± 1) °C**
Relative humidity:	**(38 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity:	**horizontal (x- and y-axis)** **vertical (z-axis)**	
Temperature of test object:	**(22.8 ± 2) °C**	
Attachment of test object to vibration exciter:		
z-axis:	**screwed SAM-018**	
x- and y-axis:	**screwed SAM-025**	
Technical data of the connecting cable (cable of the laboratory)		
Manufacturer:	**SINUS Messtechnik GmbH**	
Type:	**902246**	
Length:	**2 m**	
Specification of excitation for determination of the transfer coefficient		
Frequency:	**16 Hz**	
Velocity (peak)	**10 mm/s**	
for determination of the amplitude-frequency response		
Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:

- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.815 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
y-axis:	**29.517 mV/(mm/s)**	**0.008 %**	**0.0024 mV/(mm/s)**
z-axis:	**30.128 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**

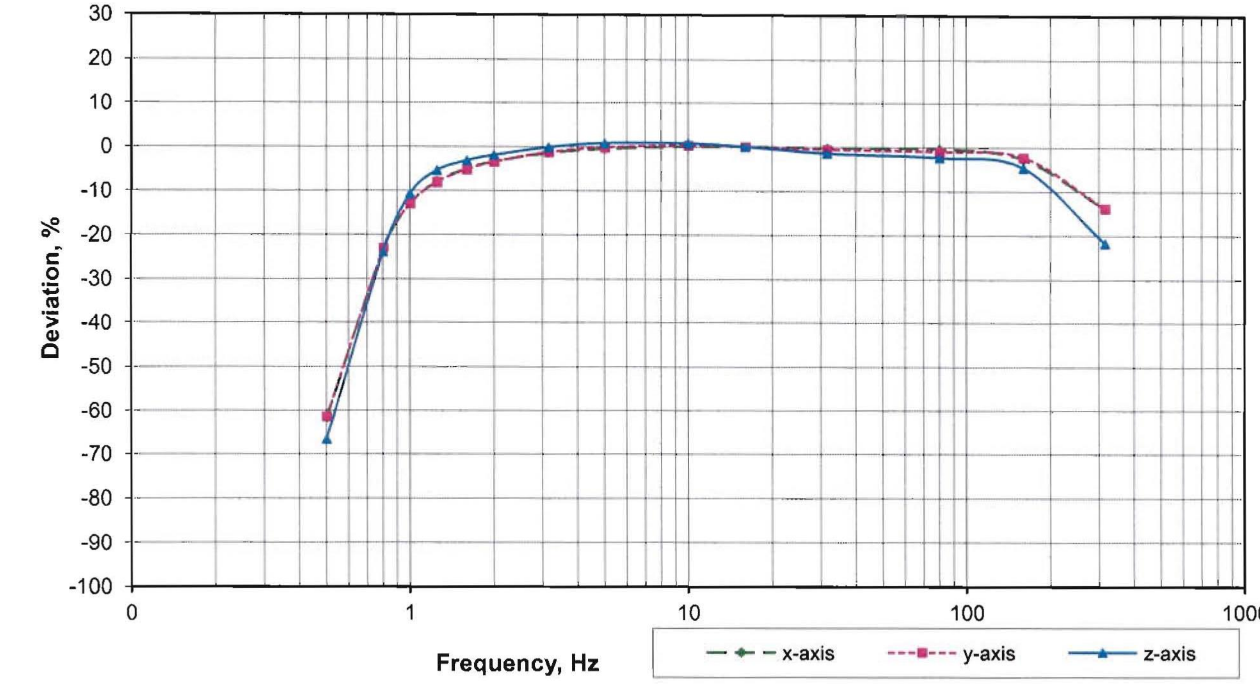
(acceleration due to gravity 1 g_n = 9.80665 m/s²)

7.2 Amplitude frequency response (relative to 16 Hz)

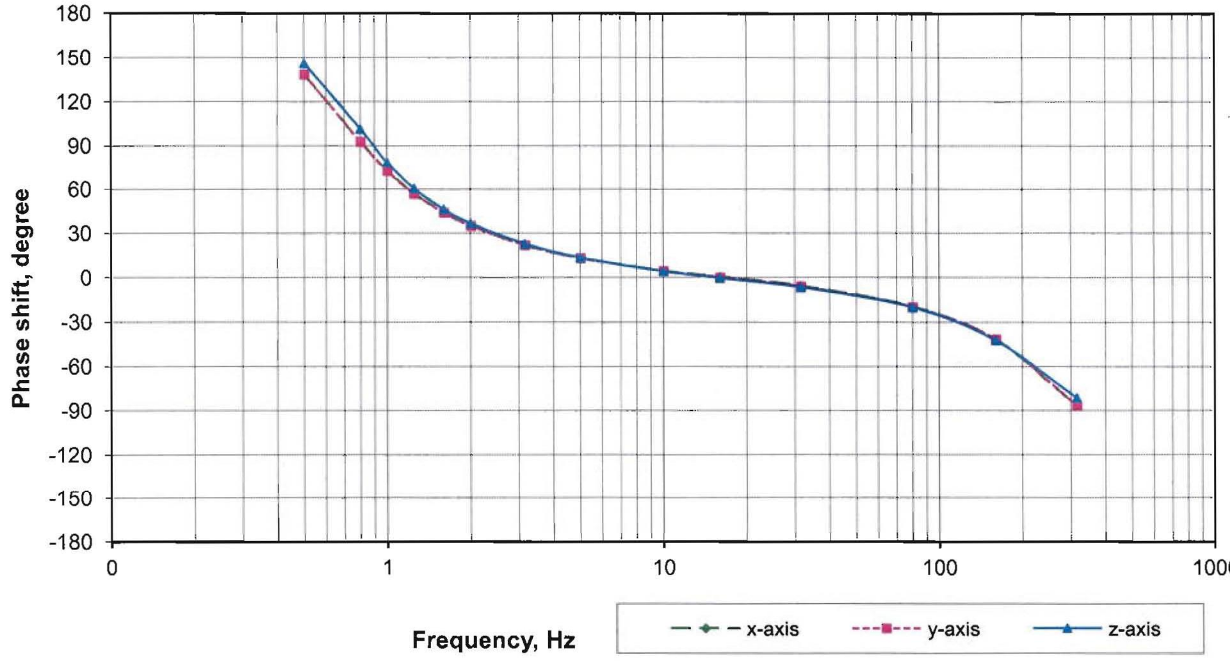
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.40	-61.75	138.2	11.39	-61.42	138.2	10.04	-66.68	146.0
0.8	22.83	-23.43	93.0	22.73	-23.00	92.5	22.93	-23.91	101.2
1	25.92	-13.06	72.7	25.68	-12.99	72.3	26.88	-10.78	78.2
1.25	27.43	-8.00	57.0	27.12	-8.14	56.7	28.47	-5.50	60.3
1.6	28.29	-5.11	43.9	27.97	-5.23	43.8	29.15	-3.24	46.0
2	28.78	-3.47	34.9	28.47	-3.53	34.9	29.52	-2.01	36.4
3.15	29.38	-1.47	21.7	29.12	-1.33	21.8	30.06	-0.22	22.6
5	29.66	-0.51	12.9	29.45	-0.22	12.9	30.35	0.75	13.2
10	29.83	0.04	4.5	29.60	0.28	4.3	30.34	0.72	4.0
16	**29.82**	**0.0**	**0.3**	**29.52**	**0.0**	**0.0**	**30.13**	**0.0**	**-0.7**
31.5	29.74	-0.24	-5.8	29.35	-0.58	-6.1	29.68	-1.49	-6.9
80	29.68	-0.45	-19.9	29.21	-1.03	-20.0	29.39	-2.45	-20.4
160	29.01	-2.71	-41.7	28.85	-2.27	-41.5	28.70	-4.73	-42.5
315	25.69	-13.85	-86.8	25.46	-13.73	-86.3	23.57	-21.78	-81.5

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)

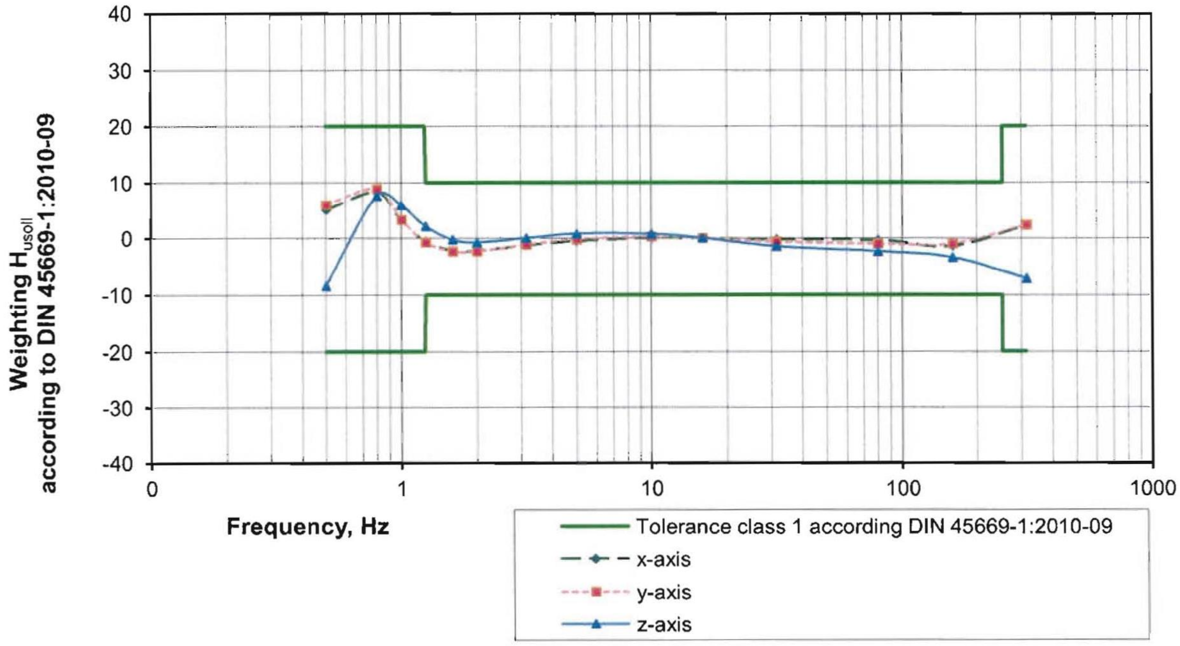


Phase frequency response



7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis: Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	x-axis: Weighting factor, (measured value)	x-axis: Deviation to H_{uSOLL}	y-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	y-axis: Weighting factor, (measured value)	y-axis: Deviation to H_{uSOLL}	z-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	z-axis: Weighting factor, (measured value)	z-axis: Deviation to H_{uSOLL}
0.5	0.364	0.382	5.1	0.364	0.386	6.0	0.364	0.333	-8.4
0.8	0.707	0.766	8.3	0.707	0.770	8.9	0.707	0.761	7.6
1	0.842	0.869	3.2	0.842	0.870	3.3	0.842	0.892	5.9
1.25	0.925	0.920	-0.6	0.925	0.919	-0.7	0.925	0.945	2.1
1.6	0.970	0.949	-2.2	0.970	0.948	-2.3	0.970	0.968	-0.3
2	0.987	0.965	-2.2	0.987	0.965	-2.3	0.987	0.980	-0.8
3.15	0.998	0.985	-1.3	0.998	0.987	-1.1	0.998	0.998	0.0
5	1.000	0.995	-0.5	1.000	0.998	-0.2	1.000	1.007	0.8
10	1.000	1.000	0.0	1.000	1.003	0.3	1.000	1.007	0.7
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.998	-0.2	1.000	0.994	-0.6	1.000	0.985	-1.5
80	0.999	0.996	-0.4	0.999	0.990	-0.9	0.999	0.976	-2.4
160	0.987	0.973	-1.4	0.987	0.977	-0.9	0.987	0.953	-3.4
315	0.842	0.862	2.3	0.842	0.863	2.4	0.842	0.782	-7.1



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10023

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

G. Papsdorf

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218136

G.R.A.S.
Sound & Vibration

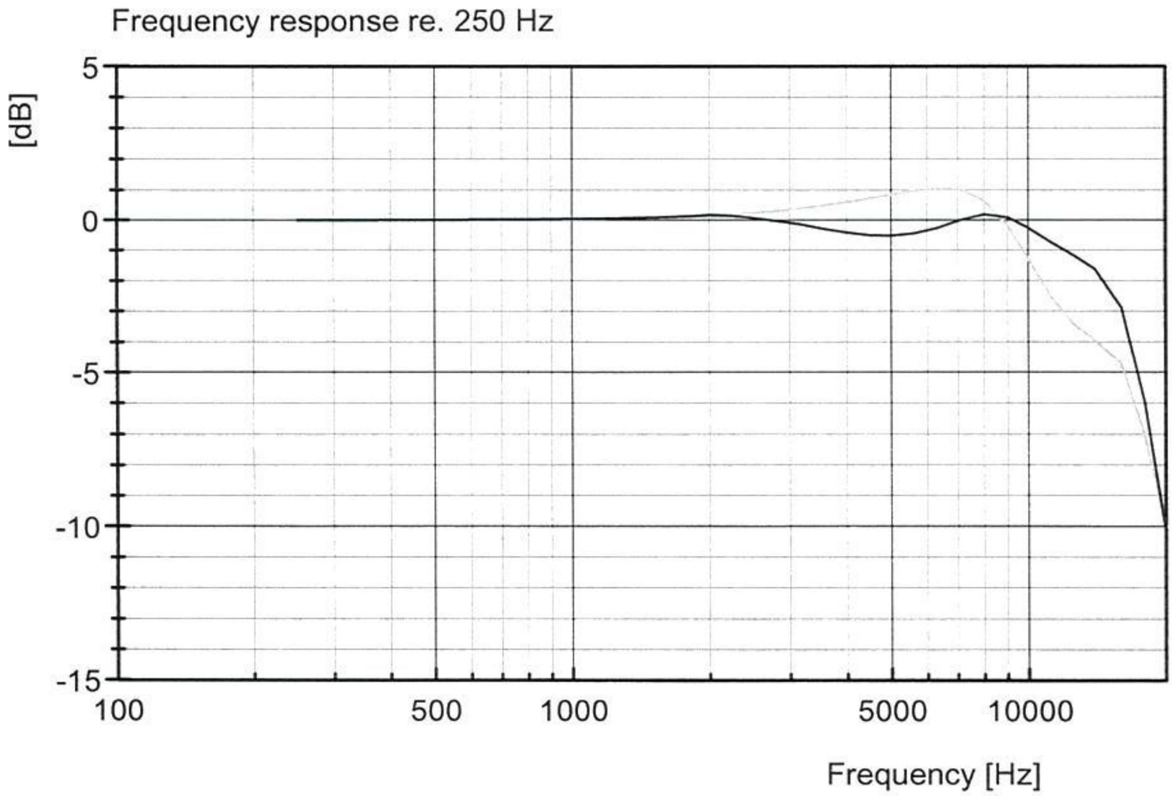
System Sensitivity:	49.99 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.70 mV
Preamplifier type:	26AX
Preamplifier serial no:	214104
Microphone type:	40AS
Microphone Serial No:	138456
Operator:	FBL
Date:	19. aug 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

ilac-MRA · DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

1914
D-K-15183-01-00
2014-09

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504070**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**17/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
18/09/2014	Heiko Deierlein	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504070**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(23.6 ± 1) °C**
Relative humidity:	**(46 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(23.6 ± 2) °C**

Attachment of test object to vibration exciter:

z-axis:	**screwed SAM-018**
x- and y-axis:	**screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)

Manufacturer:	**SINUS Messtechnik GmbH**
Type:	**902246**
Length:	**2 m**

Specification of excitation
for determination of the transfer coefficient

Frequency:	**16 Hz**
Velocity (peak)	**10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:
- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.569 mV/(mm/s)**	**0.004 %**	**0.0012 mV/(mm/s)**
y-axis:	**31.294 mV/(mm/s)**	**0.006 %**	**0.0019 mV/(mm/s)**
z-axis:	**29.448 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

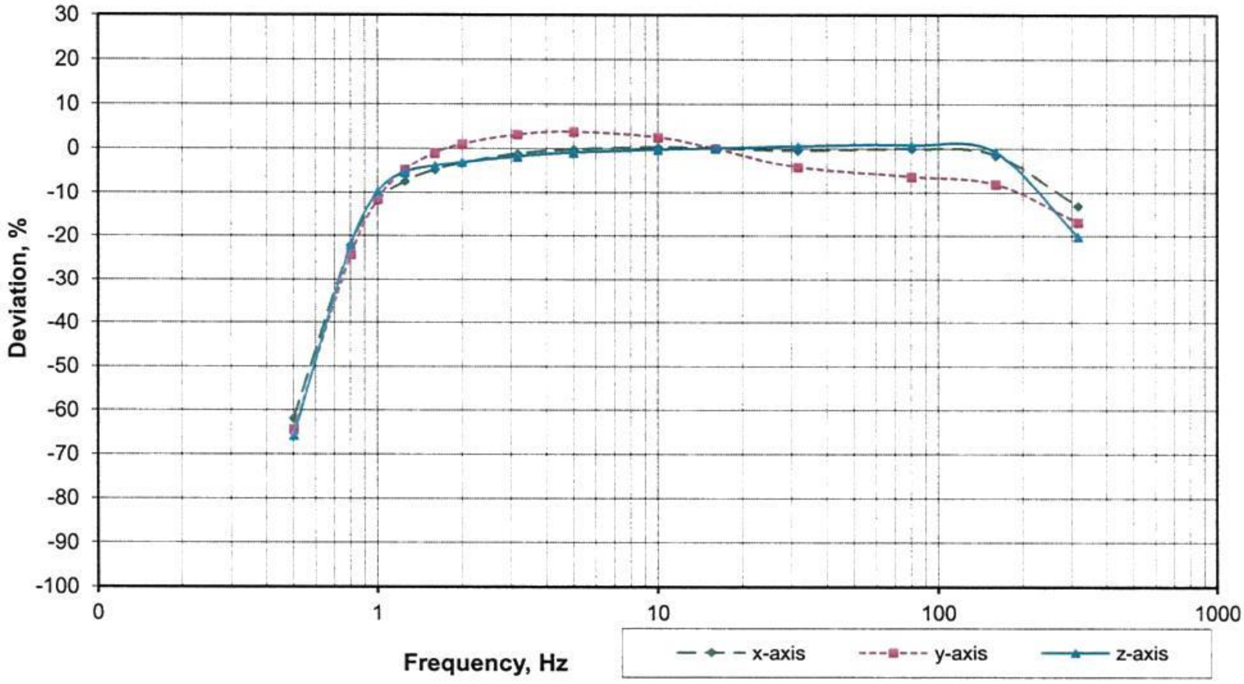
7.2 Amplitude frequency response (relative to 16 Hz)

Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.31	-61.77	139.7	11.19	-64.25	141.1	10.16	-65.48	145.1
0.8	23.01	-22.17	93.5	23.68	-24.32	97.9	22.95	-22.06	99.4
1	26.02	-12.00	72.7	27.73	-11.40	77.0	26.58	-9.74	76.3
1.25	27.38	-7.39	56.8	29.83	-4.67	60.2	27.87	-5.38	58.6
1.6	28.15	-4.80	43.8	30.99	-0.96	46.1	28.31	-3.86	44.6
2	28.60	-3.27	34.8	31.61	1.01	36.2	28.53	-3.11	35.3
3.15	29.21	-1.21	21.7	32.28	3.16	21.9	28.90	-1.85	22.1
5	29.50	-0.25	12.9	32.48	3.79	12.0	29.16	-0.99	13.3
10	29.65	0.28	4.3	32.09	2.55	2.0	29.36	-0.31	4.9
16	**29.57**	**0.0**	**0.0**	**31.29**	**0.0**	**-3.0**	**29.45**	**0.0**	**0.7**
31.5	29.42	-0.49	-6.1	30.03	-4.05	-8.9	29.60	0.50	-5.7
80	29.54	-0.09	-19.6	29.36	-6.19	-21.0	29.67	0.77	-19.9
160	29.13	-1.47	-41.8	28.81	-7.92	-42.3	29.20	-0.85	-42.4
315	25.71	-13.05	-87.4	26.05	-16.76	-87.1	23.52	-20.14	-98.4

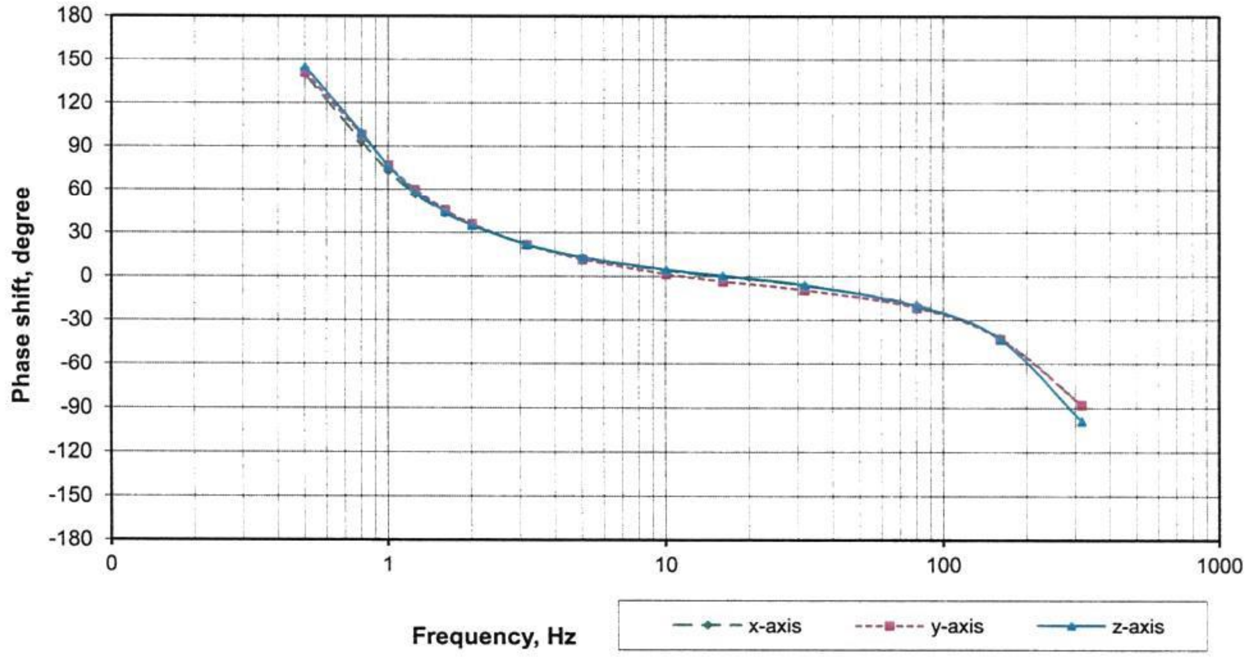
Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

Amplitude frequency response (relative to 16 Hz)



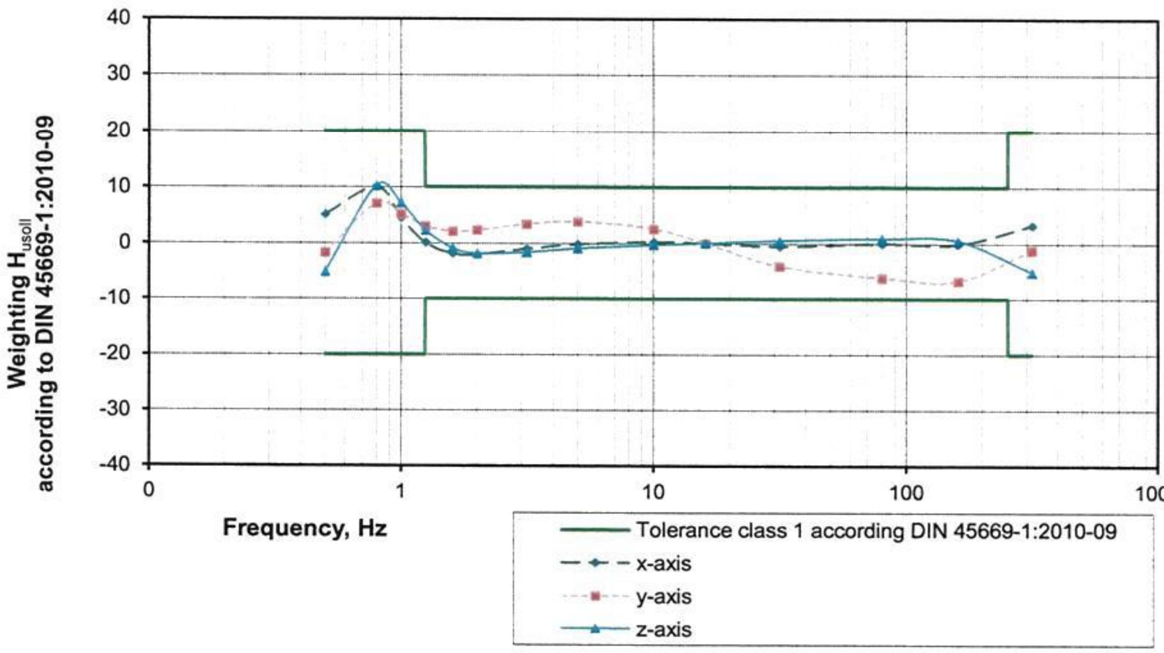
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.382	5.1	0.364	0.357	-1.8	0.364	0.345	-5.1
0.8	0.707	0.778	10.1	0.707	0.757	7.0	0.707	0.779	10.2
1	0.842	0.880	4.5	0.842	0.886	5.2	0.842	0.903	7.2
1.25	0.925	0.926	0.1	0.925	0.953	3.0	0.925	0.946	2.3
1.6	0.970	0.952	-1.9	0.970	0.990	2.1	0.970	0.961	-0.9
2	0.987	0.967	-2.0	0.987	1.010	2.3	0.987	0.969	-1.9
3.15	0.998	0.988	-1.0	0.998	1.032	3.4	0.998	0.981	-1.7
5	1.000	0.997	-0.2	1.000	1.038	3.8	1.000	0.990	-1.0
10	1.000	1.003	0.3	1.000	1.026	2.6	1.000	0.997	-0.3
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.995	-0.5	1.000	0.959	-4.0	1.000	1.005	0.5
80	0.999	0.999	0.0	0.999	0.938	-6.1	0.999	1.008	0.9
160	0.987	0.985	-0.1	0.987	0.921	-6.7	0.987	0.992	0.5
315	0.842	0.869	3.2	0.842	0.832	-1.2	0.842	0.799	-5.2



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10030

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218142

G.R.A.S.
Sound & Vibration

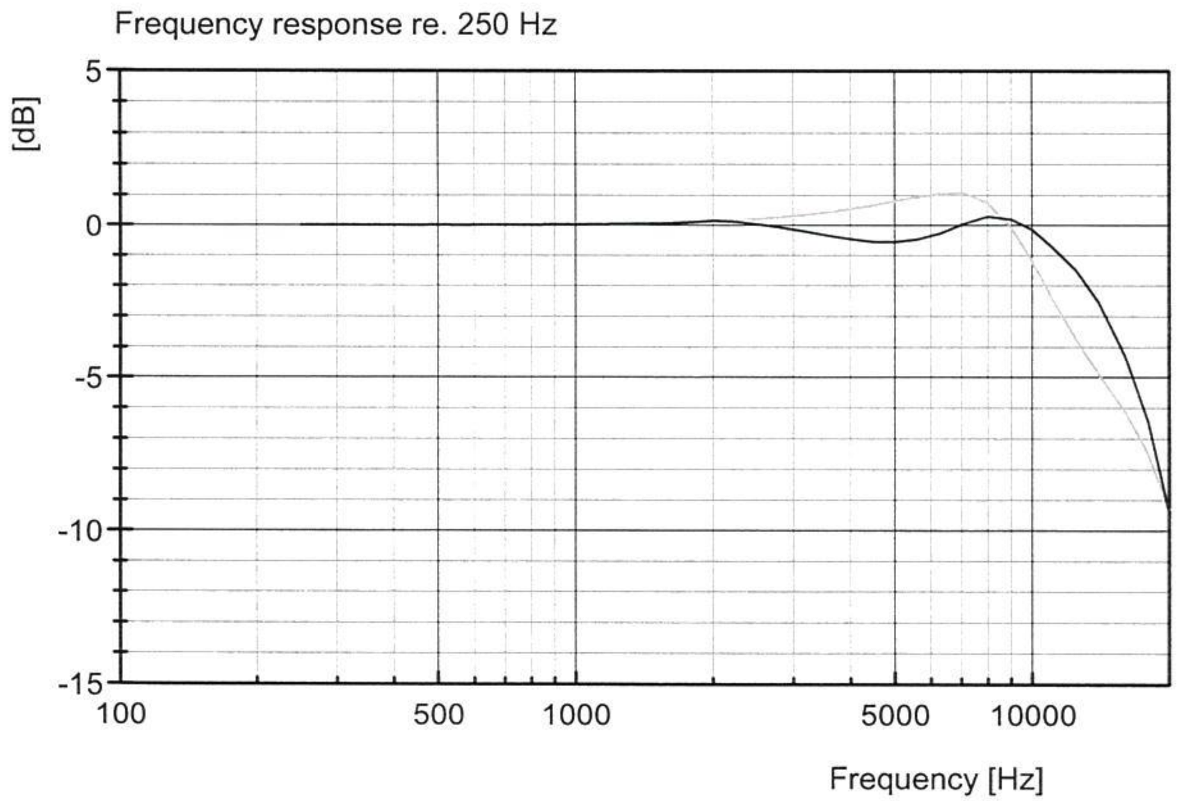
System Sensitivity:	50.02 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.68 mV
Preamplifier type:	26AX
Preamplifier serial no:	214113
Microphone type:	40AS
Microphone Serial No:	178567
Operator:	FBL
Date:	22. aug 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

Kalibrierschein
Calibration Certificate

Kalibrierzeichen *Calibration mark*

1921
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504077**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**12/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
15/09/2014	Mario Chares	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504077**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(24.2 ± 1) °C**
Relative humidity:	**(50 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity:	**horizontal (x- and y-axis)** **vertical (z-axis)**
Temperature of test object:	**(24.2 ± 2) °C**
Attachment of test object to vibration exciter:	
z-axis:	**screwed SAM-018**
x- and y-axis:	**screwed SAM-025**
Technical data of the connecting cable (cable of the laboratory)	
Manufacturer:	**SINUS Messtechnik GmbH**
Type:	**902246**
Length:	**2 m**
Specification of excitation for determination of the transfer coefficient	
Frequency:	**16 Hz**
Velocity (peak)	**10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:
- for determination of the transfer coefficient at 16 Hz — 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**28.912 mV/(mm/s)**	**0.007 %**	**0.0020 mV/(mm/s)**
y-axis:	**29.380 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
z-axis:	**29.623 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

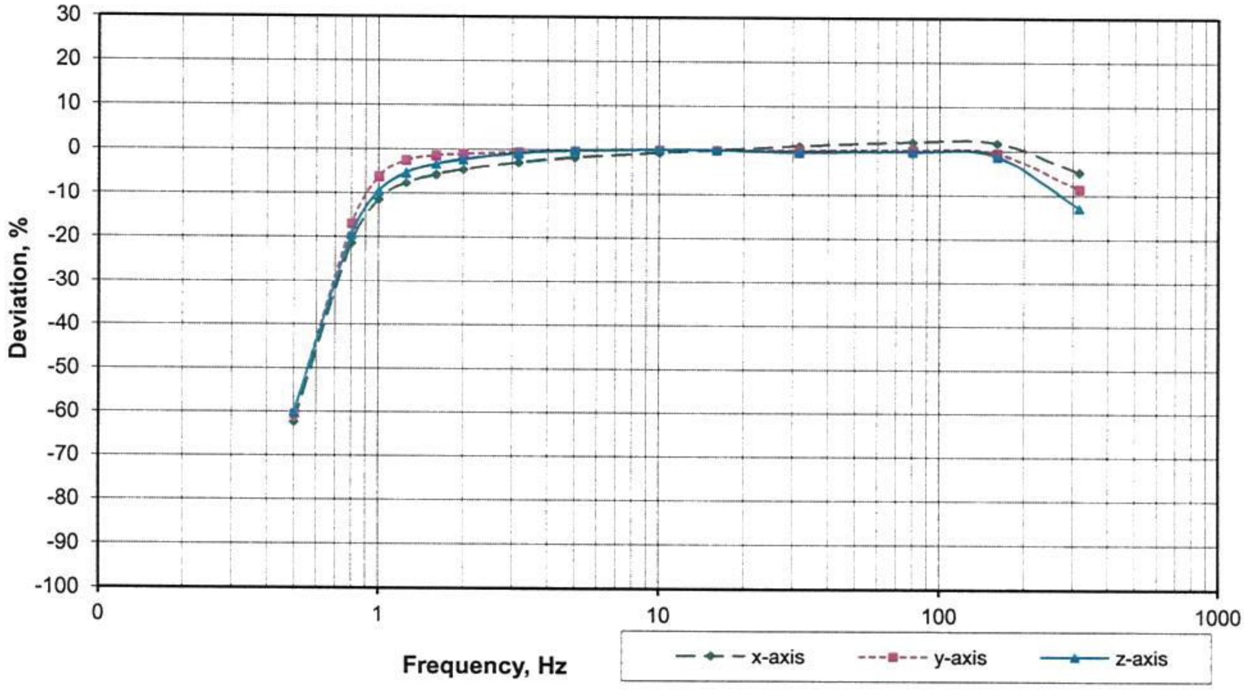
7.2 Amplitude frequency response (relative to 16 Hz)

Frequency, Hz	x-axis Transfer coefficient, mV/(mm/s)	x-axis Deviation, %	x-axis Phase shift, degree	y-axis Transfer coefficient, mV/(mm/s)	y-axis Deviation, %	y-axis Phase shift, degree	z-axis Transfer coefficient, mV/(mm/s)	z-axis Deviation, %	z-axis Phase shift, degree
0.5	10.92	-62.22	140.8	11.63	-60.42	139.9	11.90	-59.82	137.7
0.8	22.72	-21.41	93.7	24.37	-17.06	93.4	23.85	-19.48	91.4
1	25.58	-11.53	72.3	27.55	-6.24	71.5	26.79	-9.57	70.7
1.25	26.70	-7.65	56.2	28.64	-2.52	54.8	28.02	-5.40	55.0
1.6	27.24	-5.78	43.2	28.96	-1.43	41.5	28.62	-3.37	42.1
2	27.58	-4.62	34.5	29.06	-1.08	32.6	28.94	-2.30	33.3
3.15	28.07	-2.91	21.7	29.20	-0.63	20.1	29.34	-0.96	20.6
5	28.39	-1.81	13.3	29.29	-0.31	11.9	29.55	-0.26	12.2
10	28.72	-0.66	5.3	29.39	0.04	4.0	29.63	0.04	4.0
16	**28.91**	**0.0**	**1.2**	**29.38**	**0.0**	**0.1**	**29.62**	**0.0**	**-0.1**
31.5	29.20	0.99	-5.0	29.40	0.05	-6.0	29.49	-0.44	-6.2
80	29.49	2.00	-19.1	29.44	0.20	-19.7	29.55	-0.24	-19.9
160	29.43	1.80	-41.1	29.25	-0.46	-42.2	29.27	-1.21	-42.1
315	27.53	-4.79	-87.2	26.87	-8.55	-87.3	25.81	-12.86	-87.5

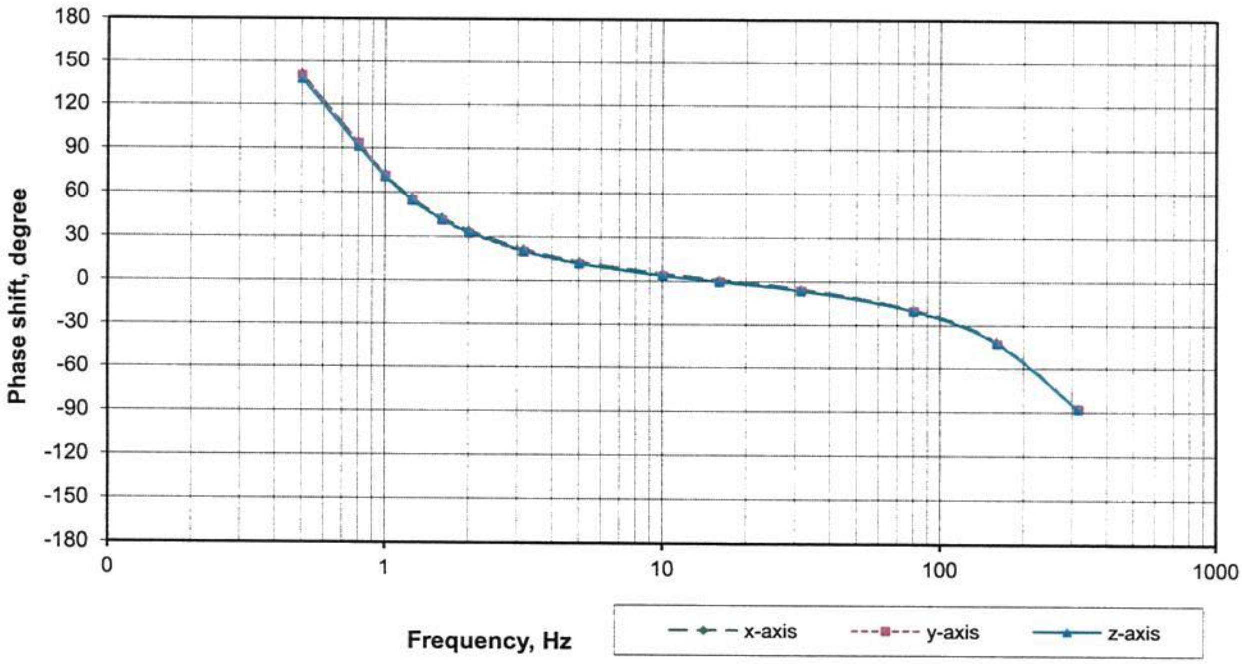
Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

1921
D-K-15183-01-00
2014-09

Amplitude frequency response (relative to 16 Hz)



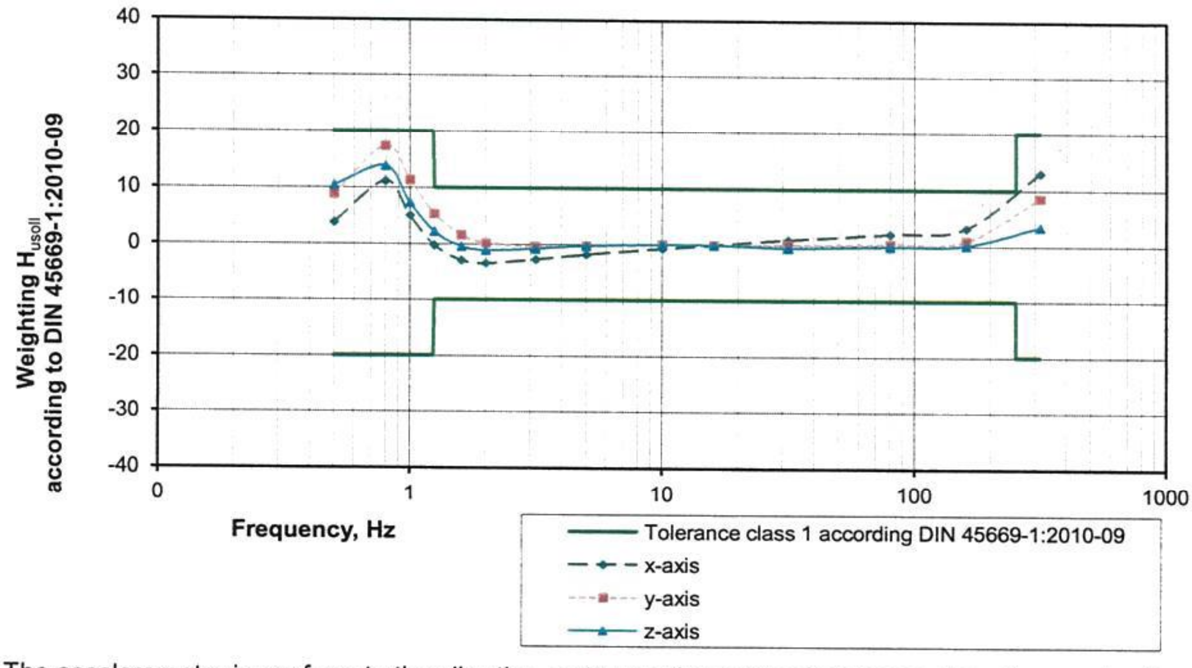
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.378	3.8	0.364	0.396	8.8	0.364	0.402	10.4
0.8	0.707	0.786	11.1	0.707	0.829	17.3	0.707	0.805	13.9
1	0.842	0.885	5.0	0.842	0.938	11.3	0.842	0.904	7.4
1.25	0.925	0.923	-0.2	0.925	0.975	5.3	0.925	0.946	2.2
1.6	0.970	0.942	-2.9	0.970	0.986	1.6	0.970	0.966	-0.4
2	0.987	0.954	-3.4	0.987	0.989	0.2	0.987	0.977	-1.1
3.15	0.998	0.971	-2.7	0.998	0.994	-0.4	0.998	0.990	-0.8
5	1.000	0.982	-1.8	1.000	0.997	-0.3	1.000	0.997	-0.2
10	1.000	0.993	-0.7	1.000	1.000	0.0	1.000	1.000	0.0
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	1.010	1.0	1.000	1.001	0.1	1.000	0.996	-0.4
80	0.999	1.020	2.1	0.999	1.002	0.3	0.999	0.998	-0.2
160	0.987	1.018	3.2	0.987	0.995	0.9	0.987	0.988	0.1
315	0.842	0.952	13.0	0.842	0.914	8.6	0.842	0.871	3.5



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10026

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 214167

G.R.A.S.
Sound & Vibration

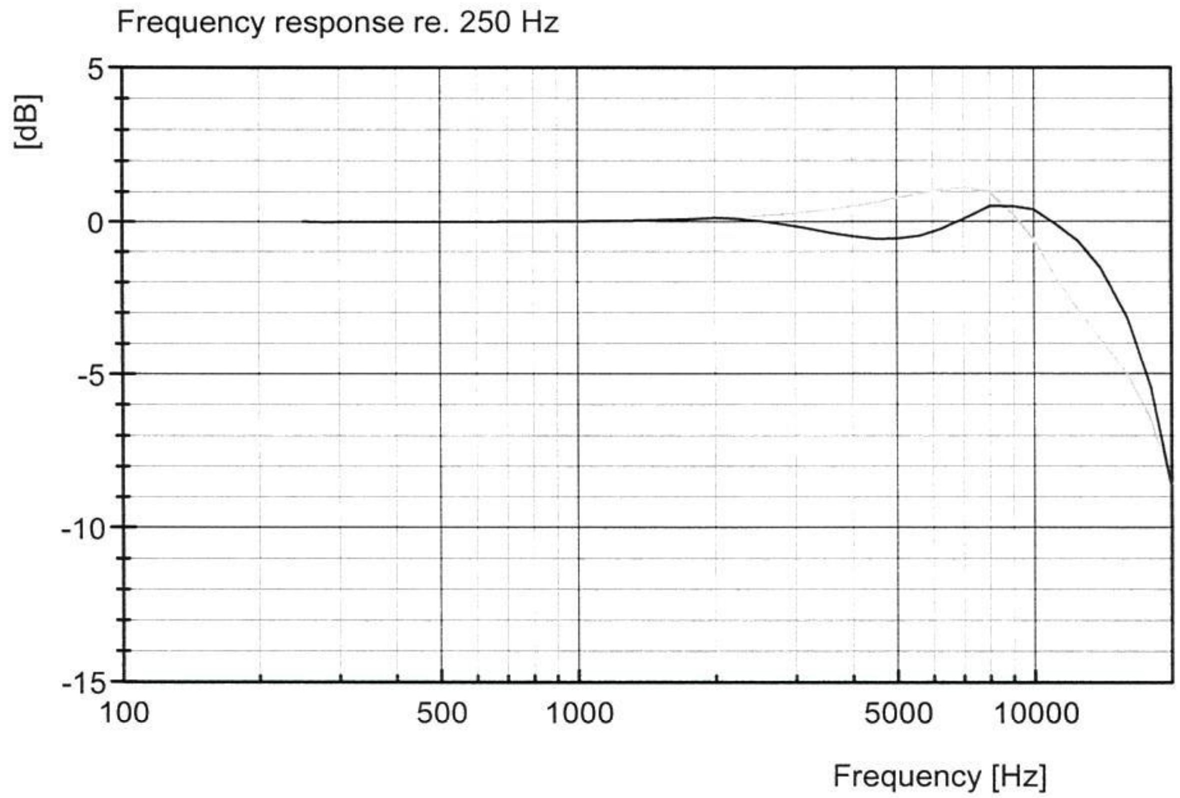
System Sensitivity:	50.01 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.85 mV
Preamplifier type:	26AX
Preamplifier serial no:	210483
Microphone type:	40AS
Microphone Serial No:	178519
Operator:	FBL
Date:	17. jul 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst **DKD**

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1922
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504078**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**15/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
15/09/2014	Mario Chares	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504078**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(24.1 ± 1) °C**
Relative humidity:	**(57 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(24.1 ± 2) °C**

Attachment of test object to vibration exciter:
- z-axis: **screwed SAM-018**
- x- and y-axis: **screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)
- Manufacturer: **SINUS Messtechnik GmbH**
- Type: **902246**
- Length: **2 m**

Specification of excitation
for determination of the transfer coefficient
- Frequency: **16 Hz**
- Velocity (peak) **10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:
- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.647 mV/(mm/s)**	**0.004 %**	**0.0012 mV/(mm/s)**
y-axis:	**30.733 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
z-axis:	**30.125 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

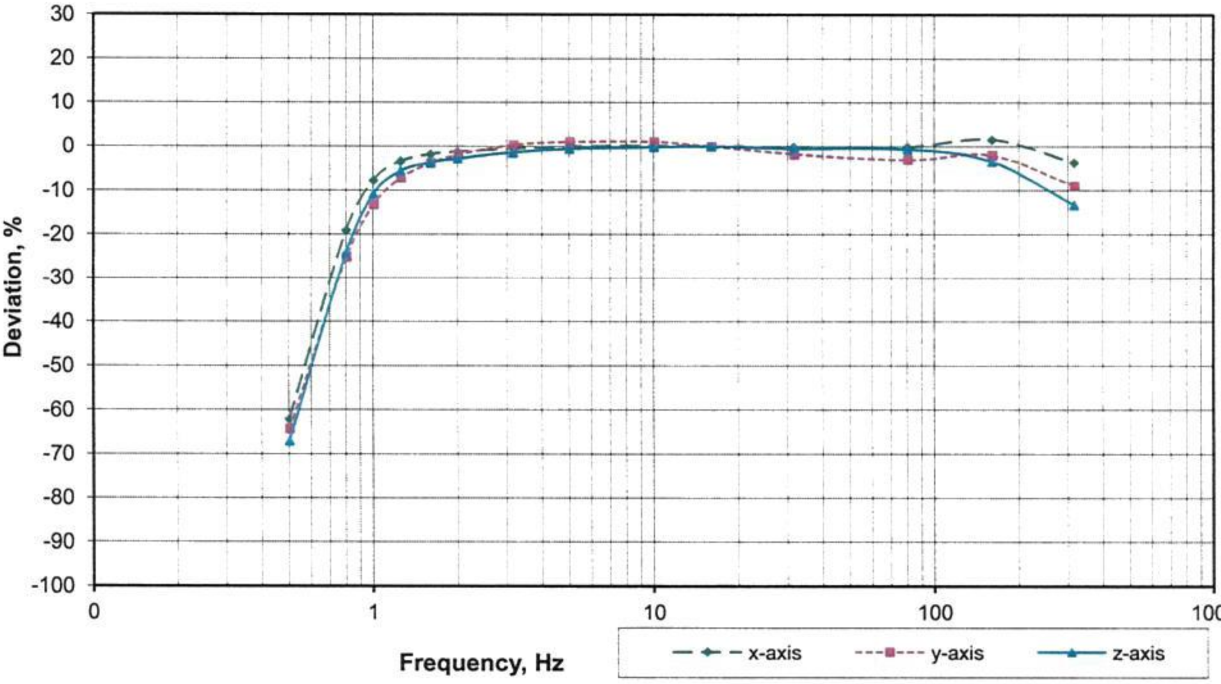
7.2 Amplitude frequency response (relative to 16 Hz)

Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.27	-62.00	140.8	11.01	-64.17	140.1	10.00	-66.80	145.2
0.8	24.00	-19.06	95.0	23.02	-25.09	96.4	22.88	-24.06	101.0
1	27.37	-7.67	73.1	26.70	-13.11	75.7	26.90	-10.72	77.9
1.25	28.64	-3.40	56.1	28.56	-7.07	59.2	28.47	-5.51	59.8
1.6	29.09	-1.87	42.6	29.60	-3.70	45.5	29.05	-3.58	45.5
2	29.26	-1.29	33.5	30.16	-1.86	36.0	29.31	-2.69	35.9
3.15	29.48	-0.56	20.6	30.83	0.32	22.2	29.70	-1.40	22.3
5	29.62	-0.10	12.2	31.05	1.02	12.8	29.95	-0.58	13.3
10	29.70	0.19	4.0	31.06	1.08	3.6	30.08	-0.14	4.7
16	**29.65**	**0.0**	**0.0**	**30.73**	**0.0**	**-0.9**	**30.13**	**0.0**	**0.3**
31.5	29.59	-0.19	-6.1	30.22	-1.68	-7.0	29.97	-0.51	-5.9
80	29.60	-0.17	-19.9	29.83	-2.93	-20.2	29.93	-0.63	-19.9
160	30.11	1.55	-42.4	30.14	-1.94	-42.0	29.11	-3.36	-42.1
315	28.57	-3.63	-88.0	28.00	-8.89	-87.5	26.16	-13.18	-89.6

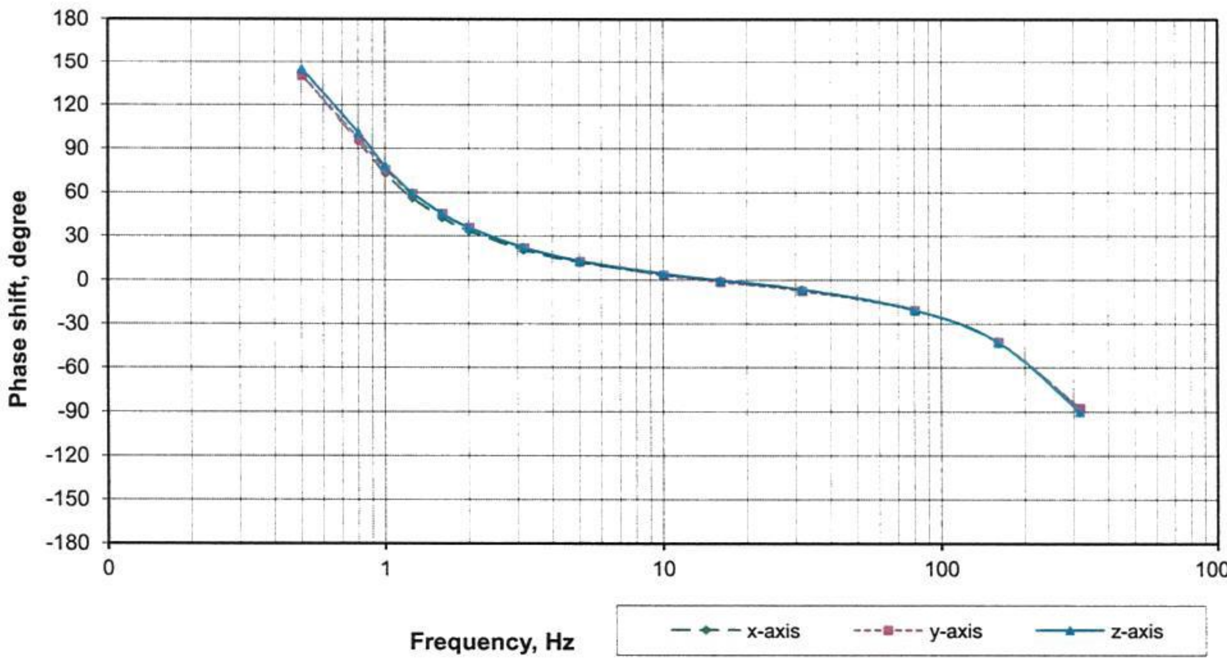
Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

1922
D-K- 15183-01-00
2014-09

Amplitude frequency response (relative to 16 Hz)



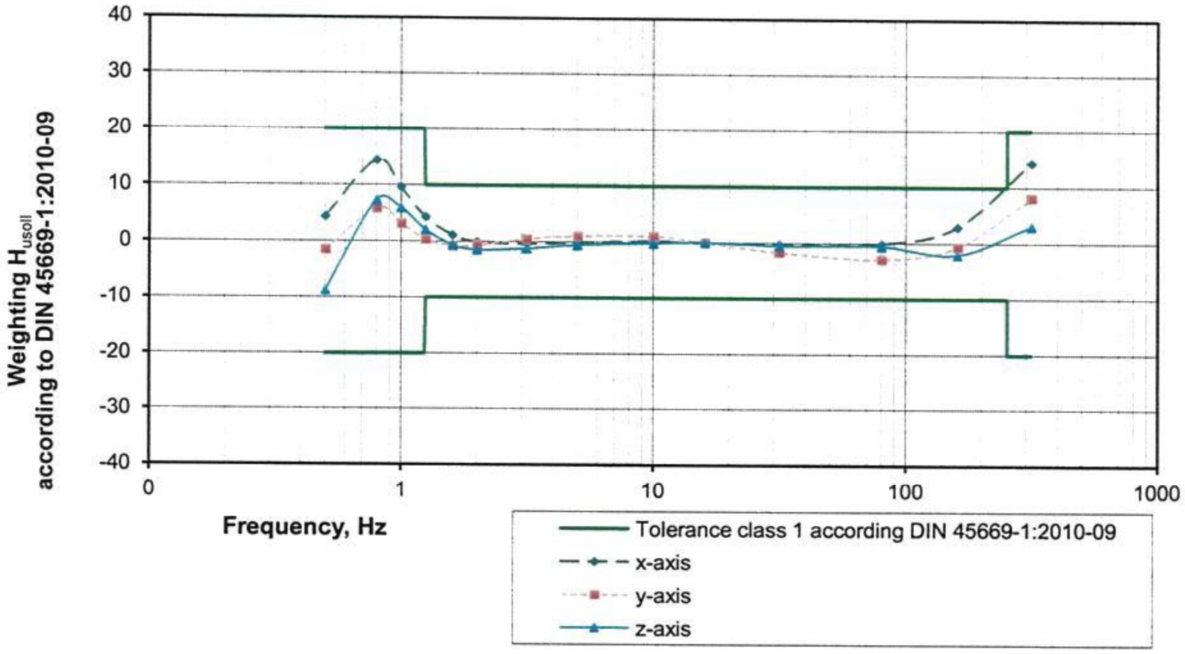
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.380	4.4	0.364	0.358	-1.5	0.364	0.332	-8.7
0.8	0.707	0.809	14.5	0.707	0.749	5.9	0.707	0.759	7.4
1	0.842	0.923	9.6	0.842	0.869	3.2	0.842	0.893	6.0
1.25	0.925	0.966	4.4	0.925	0.929	0.4	0.925	0.945	2.1
1.6	0.970	0.981	1.2	0.970	0.963	-0.7	0.970	0.964	-0.6
2	0.987	0.987	0.0	0.987	0.981	-0.6	0.987	0.973	-1.5
3.15	0.998	0.994	-0.4	0.998	1.003	0.5	0.998	0.986	-1.2
5	1.000	0.999	-0.1	1.000	1.010	1.1	1.000	0.994	-0.5
10	1.000	1.002	0.2	1.000	1.011	1.1	1.000	0.999	-0.1
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.998	-0.2	1.000	0.983	-1.7	1.000	0.995	-0.5
80	0.999	0.998	-0.1	0.999	0.971	-2.9	0.999	0.994	-0.5
160	0.987	1.015	2.9	0.987	0.981	-0.6	0.987	0.966	-2.0
315	0.842	0.964	14.4	0.842	0.911	8.2	0.842	0.868	3.1



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10029

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 214166

G.R.A.S.
Sound & Vibration

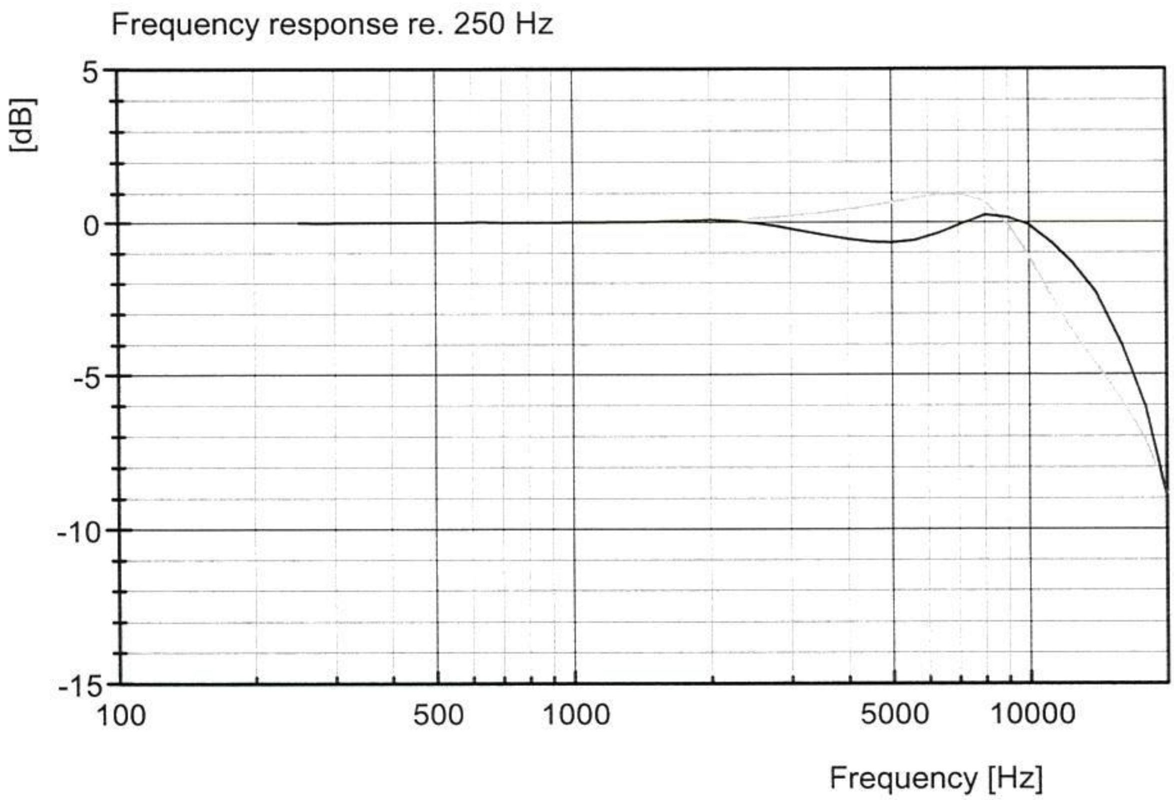
System Sensitivity:	49.99 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.74 mV
Preamplifier type:	26AX
Preamplifier serial no:	210482
Microphone type:	40AS
Microphone Serial No:	178510
Operator:	FBL
Date:	17. jul 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

ilac-MRA · DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst **DKD**

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1920
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504076**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH** **DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**18/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
18/09/2014	Heiko Deierlein	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504076**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(22.4 ± 1) °C**
Relative humidity:	**(52 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(22.4 ± 2) °C**

Attachment of test object to vibration exciter:
- z-axis: **screwed SAM-018**
- x- and y-axis: **screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)
- Manufacturer: **SINUS Messtechnik GmbH**
- Type: **902246**
- Length: **2 m**

Specification of excitation
for determination of the transfer coefficient
- Frequency: **16 Hz**
- Velocity (peak) **10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:

- for determination of the transfer coefficient at 16 Hz — 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.836 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
y-axis:	**30.114 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
z-axis:	**29.843 mV/(mm/s)**	**0.004 %**	**0.0012 mV/(mm/s)**

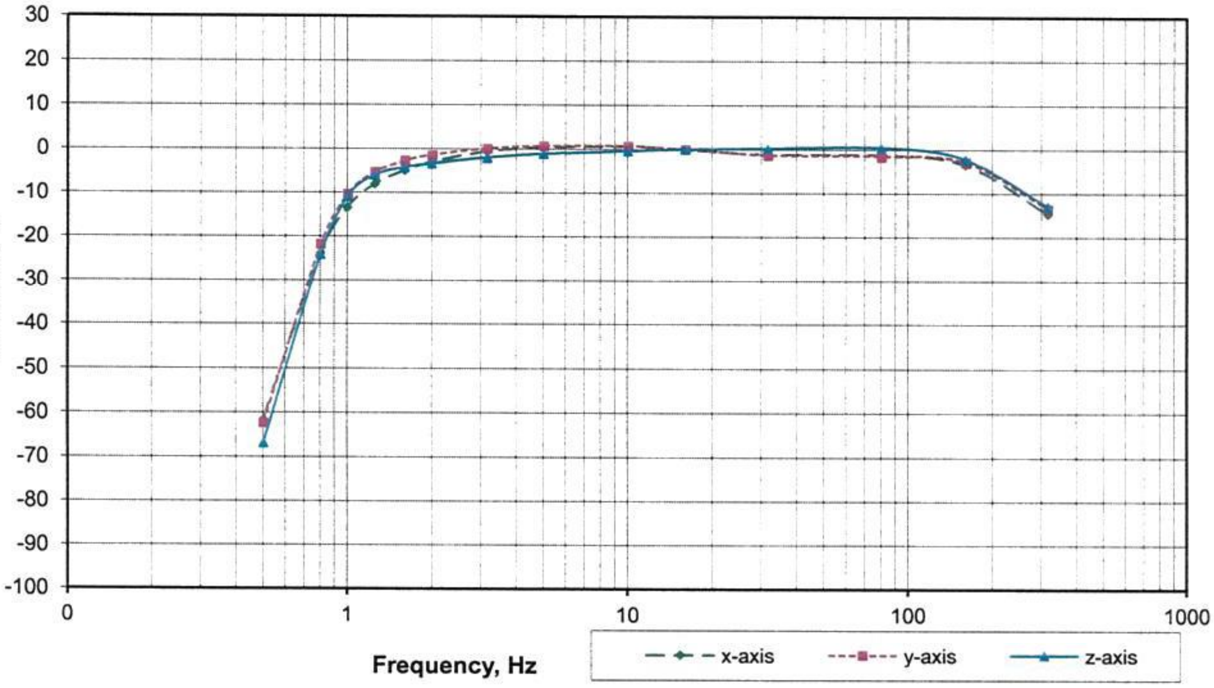
(acceleration due to gravity 1 g_n = 9.80665 m/s²)

7.2 Amplitude frequency response (relative to 16 Hz)

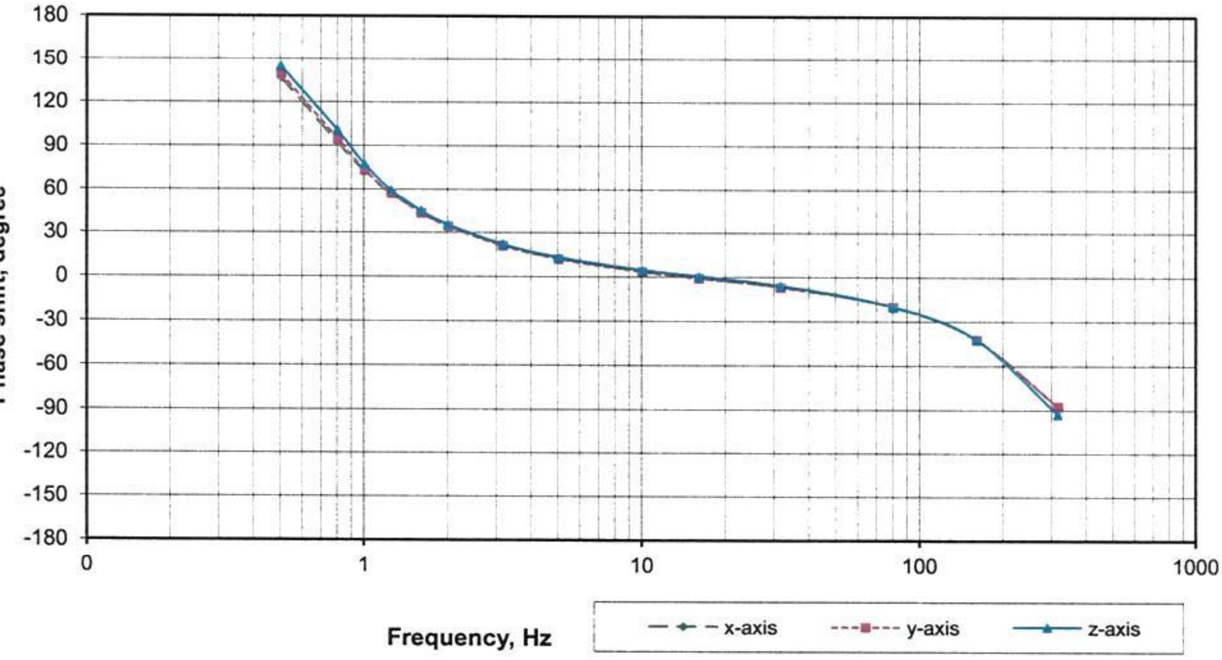
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.43	-61.69	137.3	11.33	-62.37	139.4	9.89	-66.87	145.5
0.8	22.76	-23.73	92.5	23.57	-21.74	94.6	22.67	-24.04	101.0
1	25.86	-13.33	72.6	27.01	-10.32	73.6	26.60	-10.88	77.8
1.25	27.44	-8.03	57.1	28.55	-5.19	57.1	28.08	-5.90	59.7
1.6	28.40	-4.81	44.1	29.31	-2.67	43.7	28.62	-4.10	45.4
2	28.97	-2.91	35.0	29.70	-1.38	34.5	28.87	-3.26	35.9
3.15	29.67	-0.57	21.7	30.15	0.13	21.2	29.26	-1.96	22.4
5	29.95	0.40	12.7	30.34	0.74	12.3	29.52	-1.08	13.5
10	30.04	0.67	3.9	30.35	0.77	3.6	29.73	-0.39	5.1
16	**29.84**	**0.0**	**-0.5**	**30.11**	**0.0**	**-0.7**	**29.84**	**0.0**	**0.8**
31.5	29.50	-1.12	-6.6	29.74	-1.23	-6.8	29.92	0.25	-5.5
80	29.48	-1.21	-19.9	29.68	-1.46	-20.0	29.99	0.49	-19.7
160	28.84	-3.33	-42.1	29.28	-2.77	-42.2	29.21	-2.13	-42.2
315	25.50	-14.53	-87.6	26.10	-13.33	-87.5	26.02	-12.80	-92.9

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)

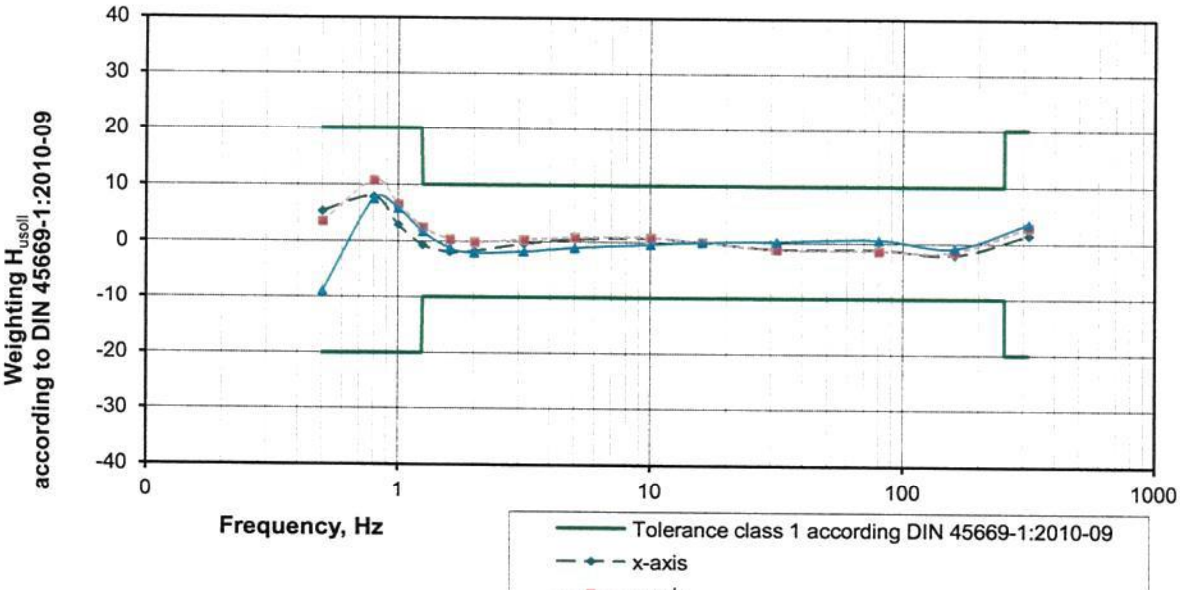


Phase frequency response



7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis: Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	x-axis: Weighting factor, (measured value)	x-axis: Deviation to H_{uSOLL}	y-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	y-axis: Weighting factor, (measured value)	y-axis: Deviation to H_{uSOLL}	z-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	z-axis: Weighting factor, (measured value)	z-axis: Deviation to H_{uSOLL}
0.5	0.364	0.383	5.3	0.364	0.376	3.4	0.364	0.331	-8.9
0.8	0.707	0.763	7.9	0.707	0.783	10.7	0.707	0.760	7.4
1	0.842	0.867	2.9	0.842	0.897	6.5	0.842	0.891	5.8
1.25	0.925	0.920	-0.6	0.925	0.948	2.5	0.925	0.941	1.7
1.6	0.970	0.952	-1.9	0.970	0.973	0.3	0.970	0.959	-1.2
2	0.987	0.971	-1.7	0.987	0.986	-0.1	0.987	0.967	-2.0
3.15	0.998	0.994	-0.4	0.998	1.001	0.3	0.998	0.980	-1.8
5	1.000	1.004	0.4	1.000	1.007	0.8	1.000	0.989	-1.0
10	1.000	1.007	0.7	1.000	1.008	0.8	1.000	0.996	-0.4
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.989	-1.1	1.000	0.988	-1.2	1.000	1.003	0.3
80	0.999	0.988	-1.1	0.999	0.985	-1.4	0.999	1.005	0.6
160	0.987	0.967	-2.0	0.987	0.972	-1.4	0.987	0.979	-0.8
315	0.842	0.855	1.5	0.842	0.867	2.9	0.842	0.872	3.5



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10033

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 214165

G.R.A.S.
Sound & Vibration

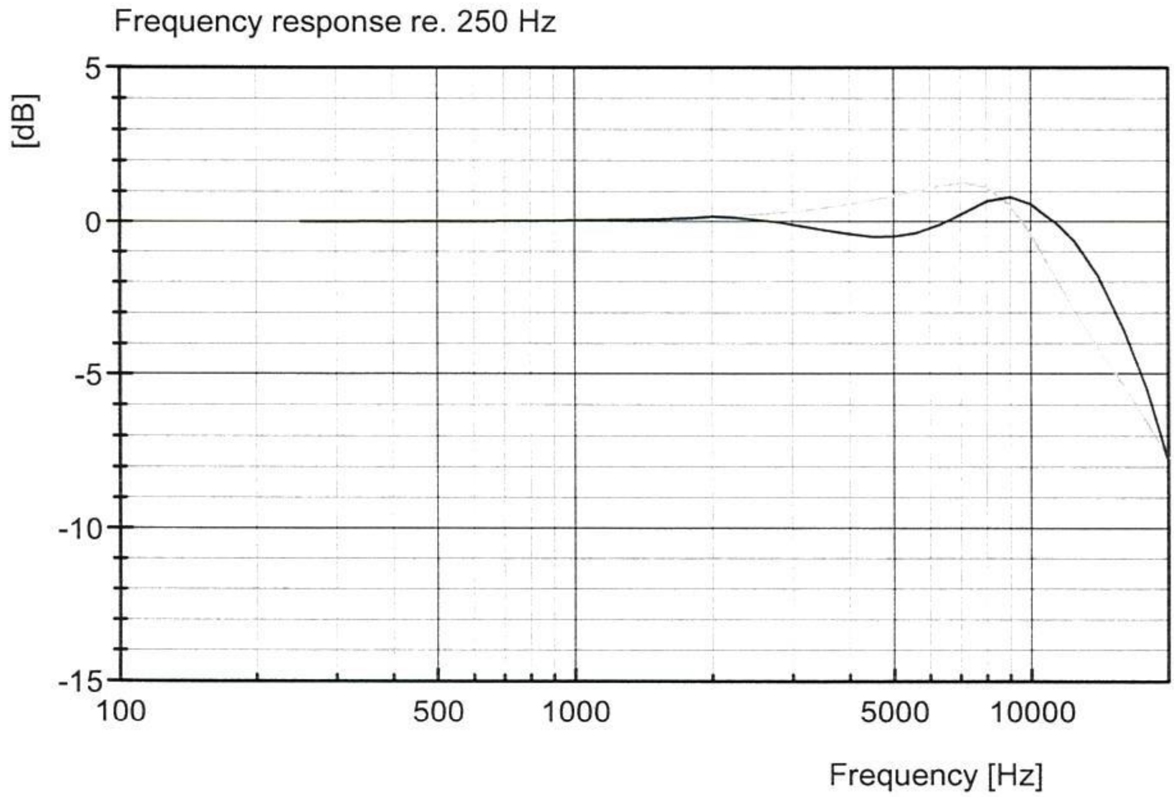
System Sensitivity:	50.04 mV/Pa
	-26.01 dB re. 1V/Pa
Actuator output:	31.72 mV
Preamplifier type:	26AX
Preamplifier serial no:	210477
Microphone type:	40AS
Microphone Serial No:	138457
Operator:	FBL
Date:	16. jul 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst **DKD**

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1925
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504081**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH** **DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**17/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
17/09/2014	Mario Chares	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504081**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(23.1 ± 1) °C**
Relative humidity:	**(55 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(23.1 ± 2) °C**

Attachment of test object to vibration exciter:

z-axis:	**screwed SAM-018**
x- and y-axis:	**screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)

Manufacturer:	**SINUS Messtechnik GmbH**
Type:	**902246**
Length:	**2 m**

Specification of excitation
for determination of the transfer coefficient

Frequency:	**16 Hz**
Velocity (peak)	**10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:
- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	**Mean value**	**Standard deviation**	
x-axis:	**29.734 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**
y-axis:	**30.034 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**
z-axis:	**29.650 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

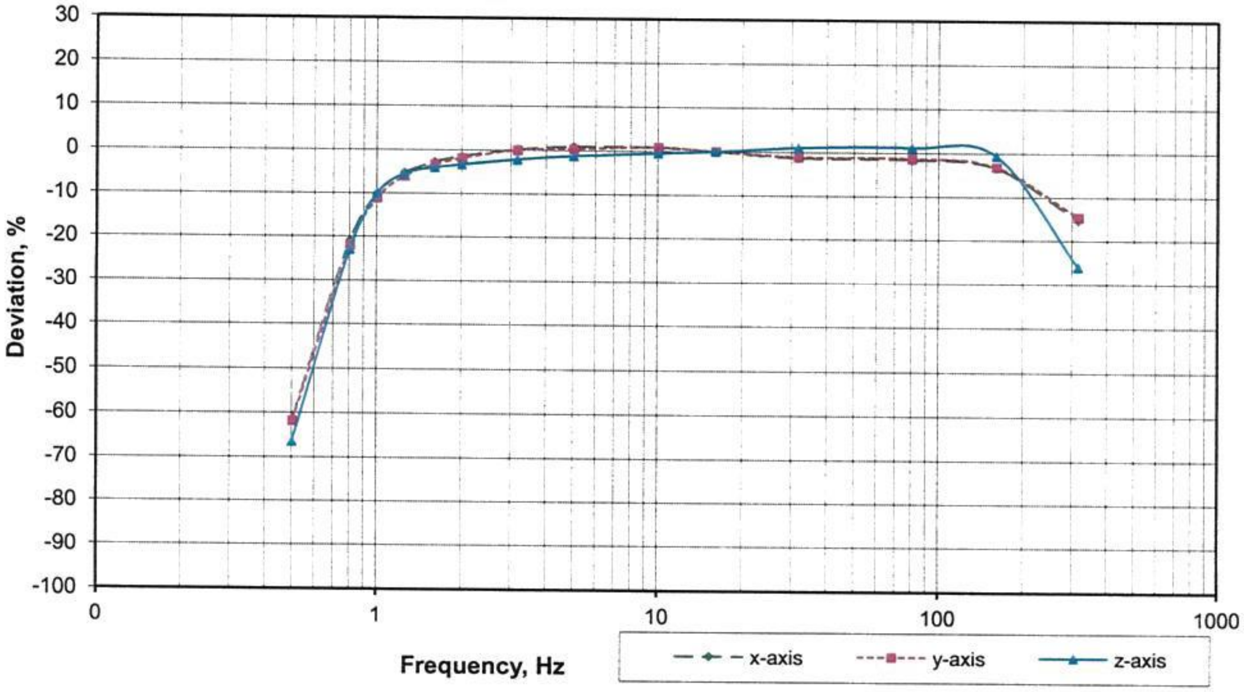
7.2 Amplitude frequency response (relative to 16 Hz)

Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.37	-61.76	140.0	11.48	-61.78	138.9	9.96	-66.40	145.9
0.8	23.48	-21.03	94.3	23.44	-21.95	93.7	22.86	-22.89	100.7
1	26.74	-10.08	73.2	26.72	-11.05	73.1	26.68	-10.03	77.3
1.25	28.17	-5.26	56.9	28.24	-5.99	57.0	28.03	-5.47	59.2
1.6	28.90	-2.80	43.6	29.04	-3.31	43.7	28.47	-3.99	45.0
2	29.30	-1.48	34.5	29.48	-1.84	34.6	28.67	-3.30	35.6
3.15	29.78	0.15	21.3	30.04	0.02	21.4	29.02	-2.12	22.3
5	29.99	0.84	12.3	30.14	0.36	12.4	29.28	-1.26	13.5
10	29.98	0.82	3.6	30.30	0.89	3.6	29.51	-0.47	5.2
16	**29.73**	**0.0**	**-0.8**	**30.03**	**0.0**	**-0.6**	**29.65**	**0.0**	**1.0**
31.5	29.36	-1.26	-6.8	29.72	-1.06	-6.6	29.95	1.02	-5.2
80	29.29	-1.50	-19.9	29.65	-1.27	-19.9	30.01	1.20	-19.1
160	28.74	-3.34	-41.8	29.11	-3.07	-41.7	29.47	-0.59	-41.6
315	25.19	-15.28	-86.9	25.67	-14.54	-86.6	21.99	-25.84	-92.3

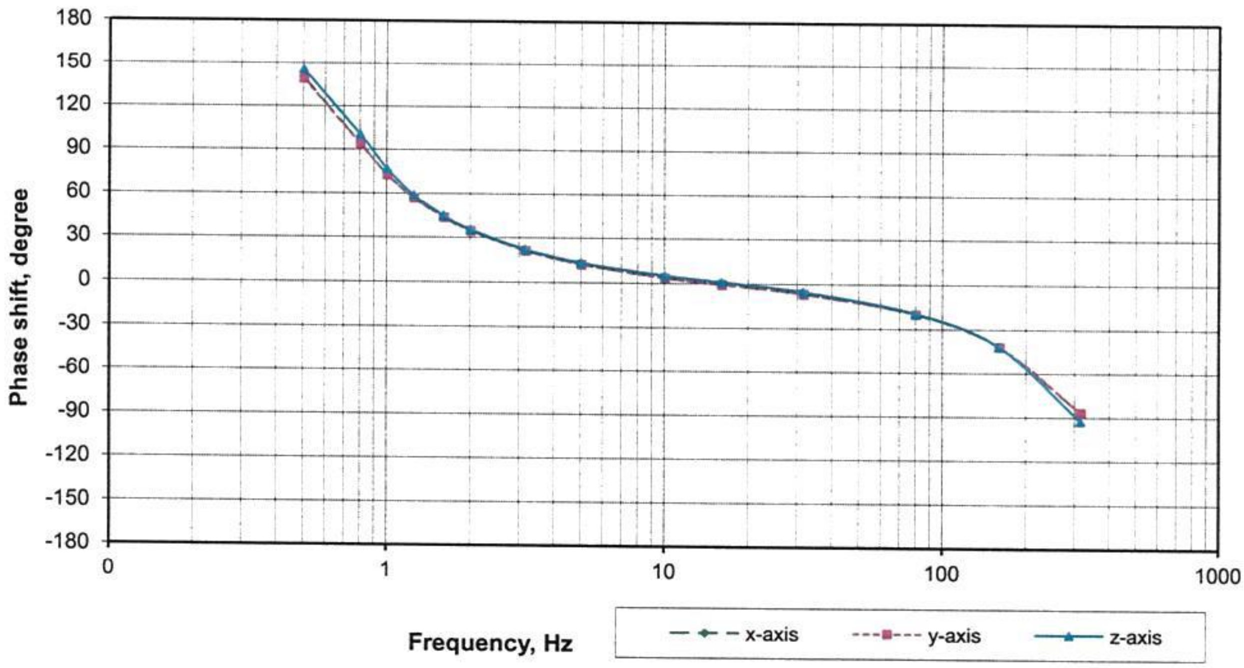
Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

1925
D-K-15183-01-00
2014-09

Amplitude frequency response (relative to 16 Hz)



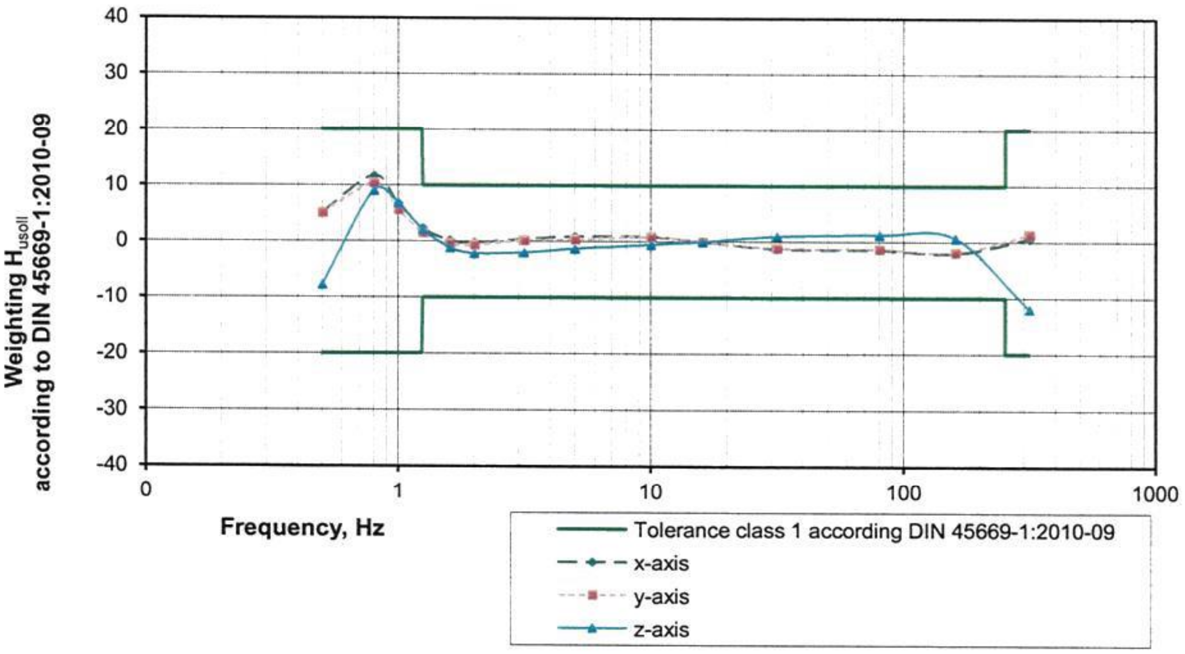
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis: Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	x-axis: Weighting factor, (measured value)	x-axis: Deviation to H_{uSOLL}	y-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	y-axis: Weighting factor, (measured value)	y-axis: Deviation to H_{uSOLL}	z-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	z-axis: Weighting factor, (measured value)	z-axis: Deviation to H_{uSOLL}
0.5	0.364	0.382	5.1	0.364	0.382	5.1	0.364	0.336	-7.6
0.8	0.707	0.790	11.7	0.707	0.780	10.4	0.707	0.771	9.0
1	0.842	0.899	6.8	0.842	0.890	5.6	0.842	0.900	6.8
1.25	0.925	0.947	2.4	0.925	0.940	1.6	0.925	0.945	2.2
1.6	0.970	0.972	0.2	0.970	0.967	-0.3	0.970	0.960	-1.0
2	0.987	0.985	-0.2	0.987	0.982	-0.6	0.987	0.967	-2.1
3.15	0.998	1.002	0.4	0.998	1.000	0.2	0.998	0.979	-1.9
5	1.000	1.008	0.9	1.000	1.004	0.4	1.000	0.987	-1.2
10	1.000	1.008	0.8	1.000	1.009	0.9	1.000	0.995	-0.5
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.987	-1.3	1.000	0.989	-1.1	1.000	1.010	1.0
80	0.999	0.985	-1.4	0.999	0.987	-1.2	0.999	1.012	1.3
160	0.987	0.967	-2.0	0.987	0.969	-1.8	0.987	0.994	0.8
315	0.842	0.847	0.6	0.842	0.855	1.5	0.842	0.742	-12.0



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10035

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218141

G.R.A.S.
Sound & Vibration

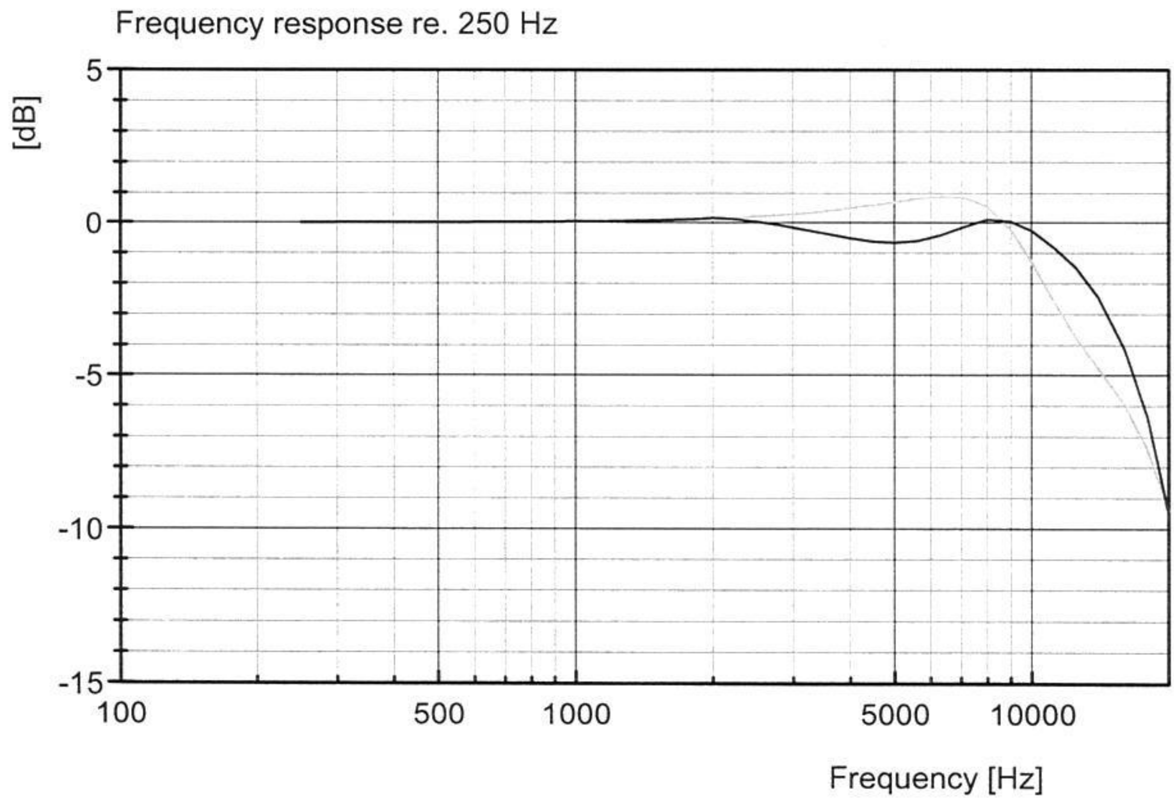
System Sensitivity:	49.99 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.67 mV
Preamplifier type:	26AX
Preamplifier serial no:	214111
Microphone type:	40AS
Microphone Serial No:	178541
Operator:	FBL
Date:	22. aug 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

SPEKTRA Vibration and Acoustics Systems Engineering

Calibration Systems · Special Equipment · DAkkS Laboratory · Environmental Simulation

SPEKTRA

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

Kalibrierschein
Calibration Certificate

Kalibrierzeichen / *Calibration mark*: 1916 D-K-15183-01-00 2014-09

Gegenstand / *Object*	**Velocity transducer**
Hersteller / *Manufacturer*	**SINUS Messtechnik**
Typ / *Type*	**902219.7**
Fabrikat/Serien-Nr. / *Serial number*	**#0504072**
Auftraggeber / *Customer*	**SINUS Messtechnik GmbH DE-04347 Leipzig**
Auftragsnummer / *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines / *Number of pages of the certificate*	**6**
Datum der Kalibrierung / *Date of calibration*	**15/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum / *Date*	Stellv. Leiter des Kalibrierlaboratoriums / *Deputy head of the calibration laboratory*	Bearbeiter / *Person in charge*
15/09/2014	Mario Chares	René Zimmermann

"DK14-1916/6"

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504072**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(24.1 ± 1) °C**
Relative humidity:	**(56 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity: **horizontal (x- and y-axis)**
vertical (z-axis)

Temperature of test object: **(24.1 ± 2) °C**

Attachment of test object to vibration exciter:

z-axis:	**screwed SAM-018**
x- and y-axis:	**screwed SAM-025**

Technical data of the connecting cable (cable of the laboratory)

Manufacturer:	**SINUS Messtechnik GmbH**
Type:	**902246**
Length:	**2 m**

Specification of excitation
for determination of the transfer coefficient

Frequency:	**16 Hz**
Velocity (peak)	**10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:

- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**28.819 mV/(mm/s)**	**0.005 %**	**0.0014 mV/(mm/s)**
y-axis:	**29.607 mV/(mm/s)**	**0.010 %**	**0.0030 mV/(mm/s)**
z-axis:	**29.466 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

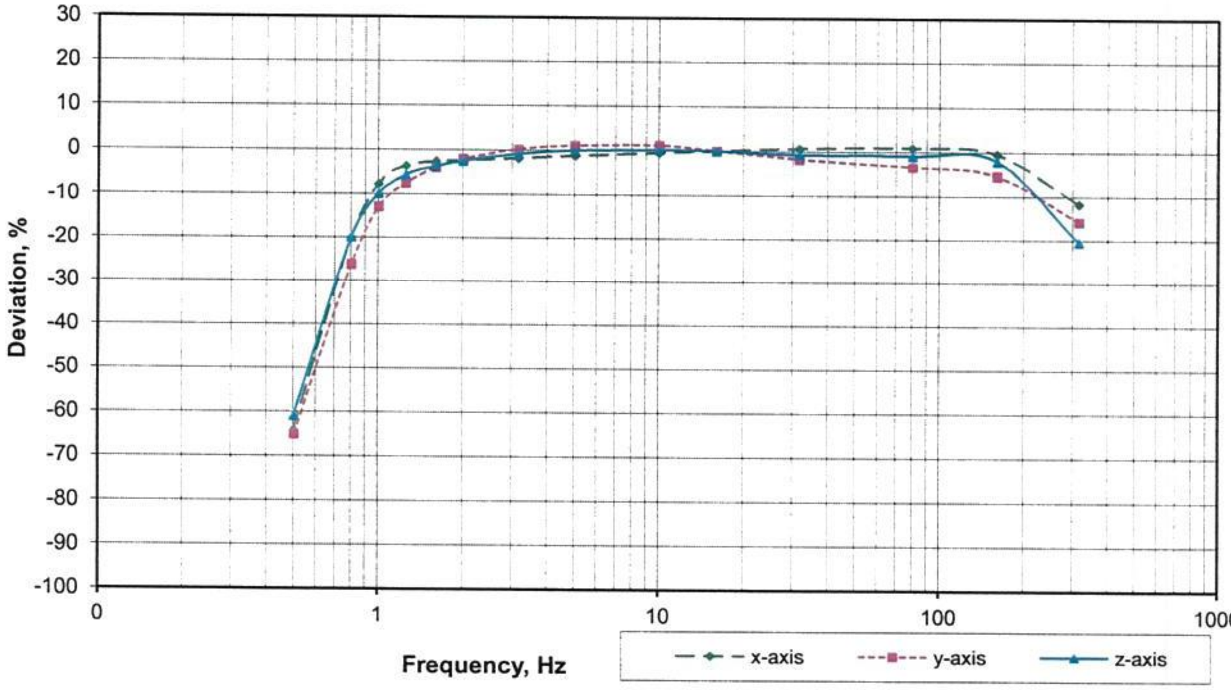
SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.2 Amplitude frequency response (relative to 16 Hz)

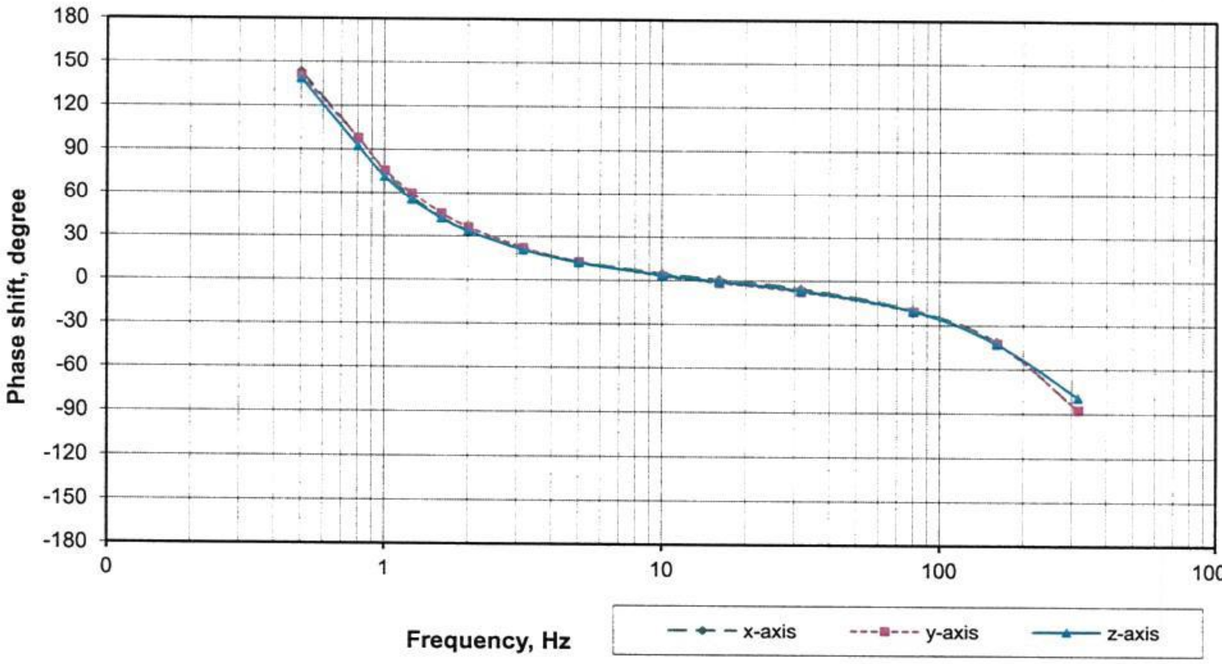
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	10.31	-64.23	143.5	10.37	-64.99	140.6	11.57	-60.73	138.7
0.8	23.03	-20.09	98.2	21.83	-26.27	97.6	23.59	-19.96	92.3
1	26.59	-7.75	75.2	25.78	-12.94	75.7	26.55	-9.89	71.4
1.25	27.78	-3.62	57.4	27.37	-7.57	60.0	27.79	-5.70	55.5
1.6	28.06	-2.62	43.4	28.42	-4.01	46.1	28.40	-3.62	42.6
2	28.14	-2.35	34.1	28.99	-2.10	36.4	28.74	-2.45	33.7
3.15	28.29	-1.82	21.2	29.65	0.14	22.4	29.21	-0.88	20.9
5	28.46	-1.26	12.8	29.91	1.04	12.8	29.45	-0.06	12.3
10	28.68	-0.47	4.9	29.96	1.18	3.5	29.52	0.18	4.0
16	**28.82**	**0.0**	**1.0**	**29.61**	**0.0**	**-1.0**	**29.47**	**0.0**	**-0.3**
31.5	29.00	0.64	-5.2	29.10	-1.70	-7.0	29.25	-0.72	-6.4
80	29.07	0.87	-19.4	28.61	-3.36	-20.2	29.21	-0.87	-19.9
160	28.69	-0.44	-40.8	28.03	-5.33	-41.7	28.89	-1.96	-42.0
315	25.45	-11.68	-87.4	24.94	-15.75	-86.9	23.44	-20.44	-78.8

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)



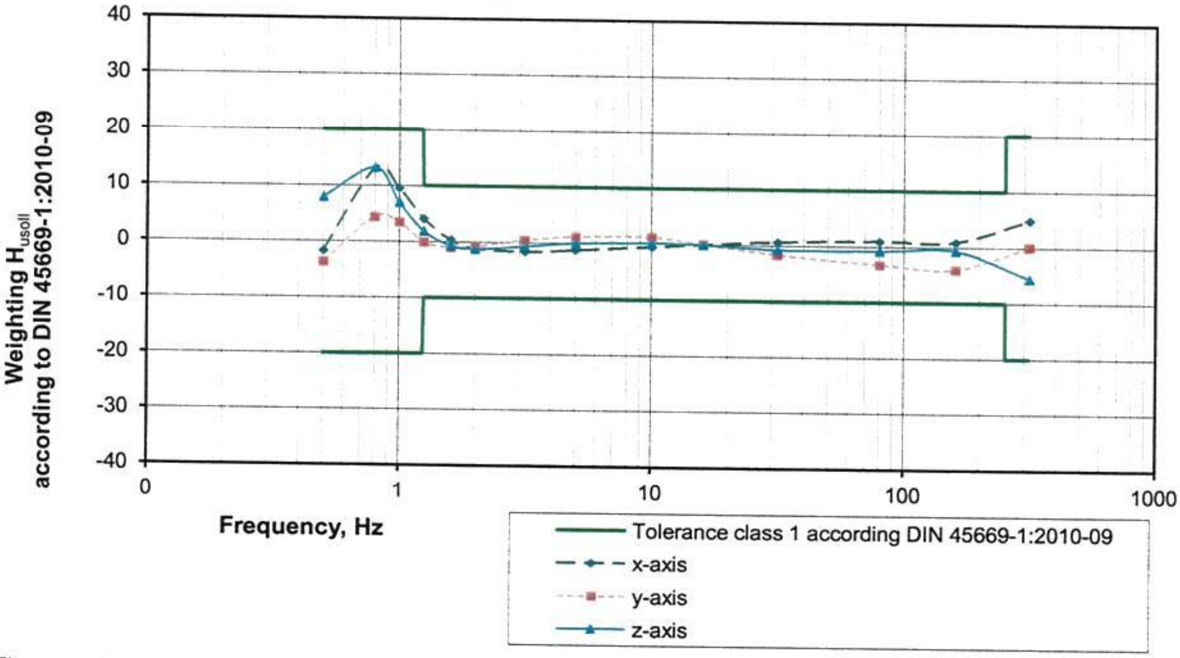
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis: Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	x-axis: Weighting factor, (measured value)	x-axis: Deviation to H_{uSOLL}	y-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	y-axis: Weighting factor, (measured value)	y-axis: Deviation to H_{uSOLL}	z-axis: Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	z-axis: Weighting factor, (measured value)	z-axis: Deviation to H_{uSOLL}
0.5	0.364	0.358	-1.7	0.364	0.350	-3.8	0.364	0.393	7.9
0.8	0.707	0.799	13.0	0.707	0.737	4.3	0.707	0.800	13.2
1	0.842	0.922	9.5	0.842	0.871	3.4	0.842	0.901	7.0
1.25	0.925	0.964	4.2	0.925	0.924	-0.1	0.925	0.943	1.9
1.6	0.970	0.974	0.4	0.970	0.960	-1.1	0.970	0.964	-0.7
2	0.987	0.976	-1.1	0.987	0.979	-0.9	0.987	0.975	-1.2
3.15	0.998	0.982	-1.6	0.998	1.001	0.3	0.998	0.991	-0.7
5	1.000	0.987	-1.2	1.000	1.010	1.1	1.000	0.999	0.0
10	1.000	0.995	-0.5	1.000	1.012	1.2	1.000	1.002	0.2
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	1.006	0.6	1.000	0.983	-1.7	1.000	0.993	-0.7
80	0.999	1.009	1.0	0.999	0.966	-3.3	0.999	0.991	-0.8
160	0.987	0.996	0.9	0.987	0.947	-4.0	0.987	0.980	-0.6
315	0.842	0.883	4.9	0.842	0.842	0.0	0.842	0.796	-5.5



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10032

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218139

G.R.A.S.
Sound & Vibration

System Sensitivity:	49.99 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.72 mV
Preamplifier type:	26AX
Preamplifier serial no:	214109
Microphone type:	40AS
Microphone Serial No:	178539
Operator:	FBL
Date:	21. aug 2014

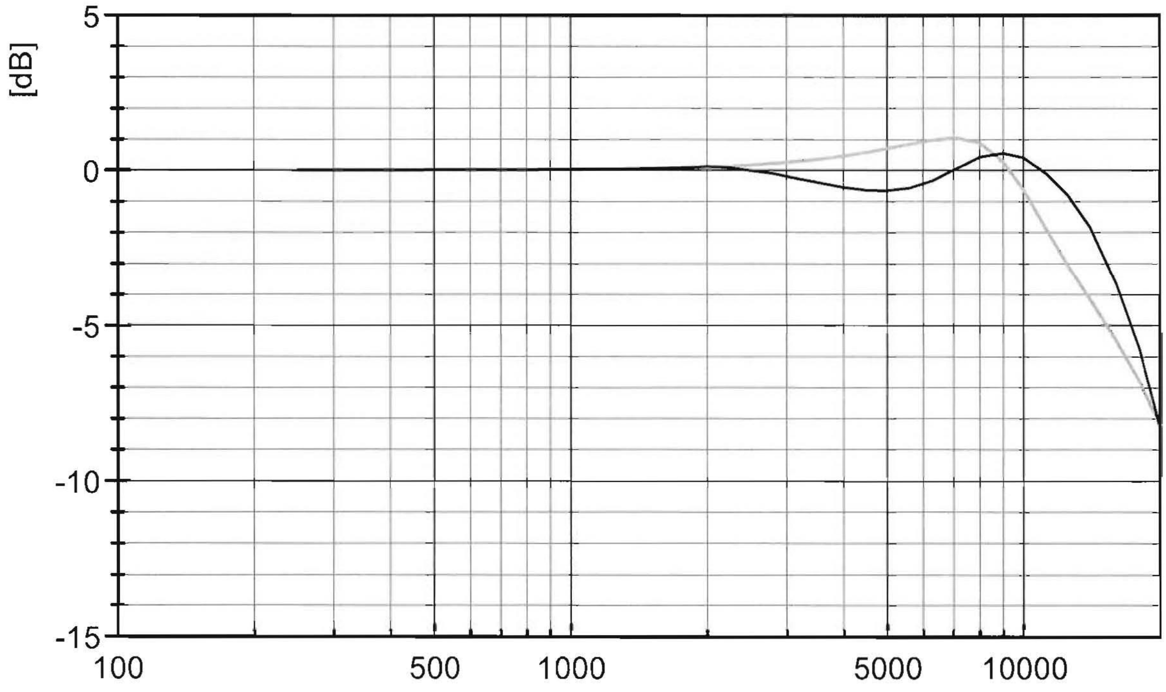
The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa

Frequency response re. 250 Hz



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst DKD

1919
D-K-15183-01-00
2014-09

Kalibrierzeichen
Calibration mark

Kalibrierschein
Calibration Certificate

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504075**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH** **DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**16/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
16/09/2014	Mario Chares	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504075**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(23.3 ± 1) °C**
Relative humidity:	**(58 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity:	**horizontal (x- and y-axis)** **vertical (z-axis)**	
Temperature of test object:	**(23.3 ± 2) °C**	
Attachment of test object to vibration exciter:		
z-axis:	**screwed SAM-018**	
x- and y-axis:	**screwed SAM-025**	
Technical data of the connecting cable (cable of the laboratory)		
Manufacturer:	**SINUS Messtechnik GmbH**	
Type:	**902246**	
Length:	**2 m**	
Specification of excitation for determination of the transfer coefficient		
Frequency:	**16 Hz**	
Velocity (peak)	**10 mm/s**	
for determination of the amplitude-frequency response		
Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:
- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.623 mV/(mm/s)**	**0.004 %**	**0.0012 mV/(mm/s)**
y-axis:	**29.199 mV/(mm/s)**	**0.003 %**	**0.0009 mV/(mm/s)**
z-axis:	**29.083 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

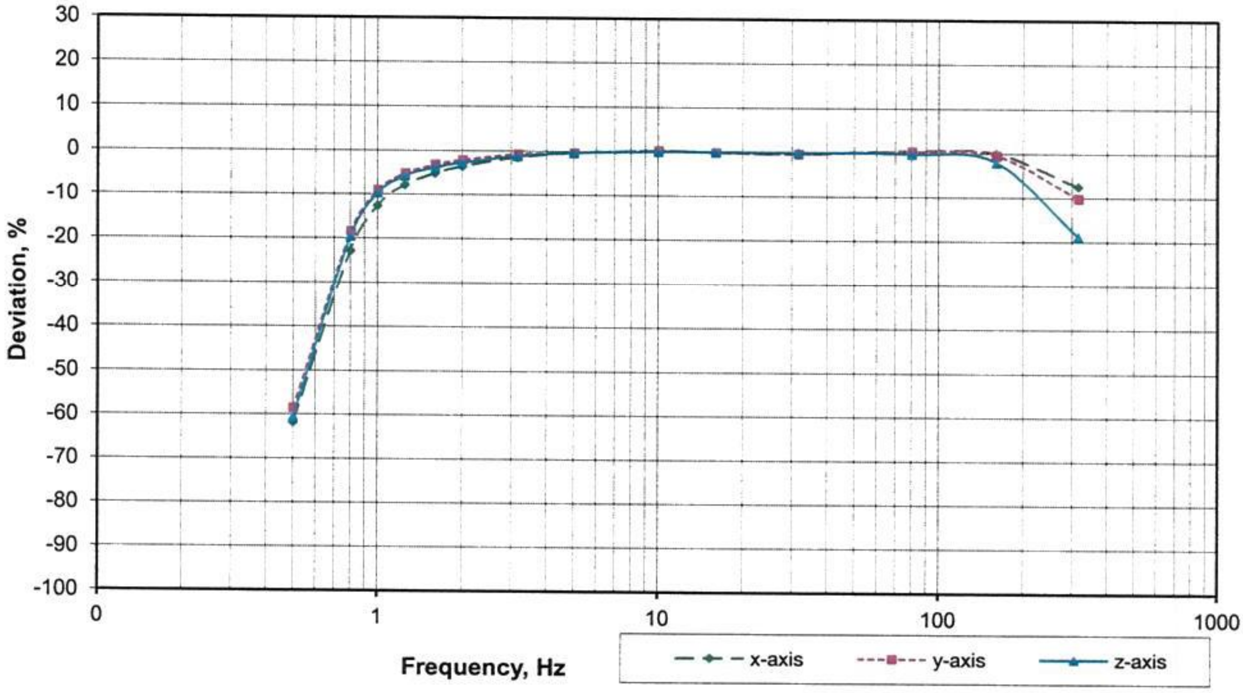
SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.2 Amplitude frequency response (relative to 16 Hz)

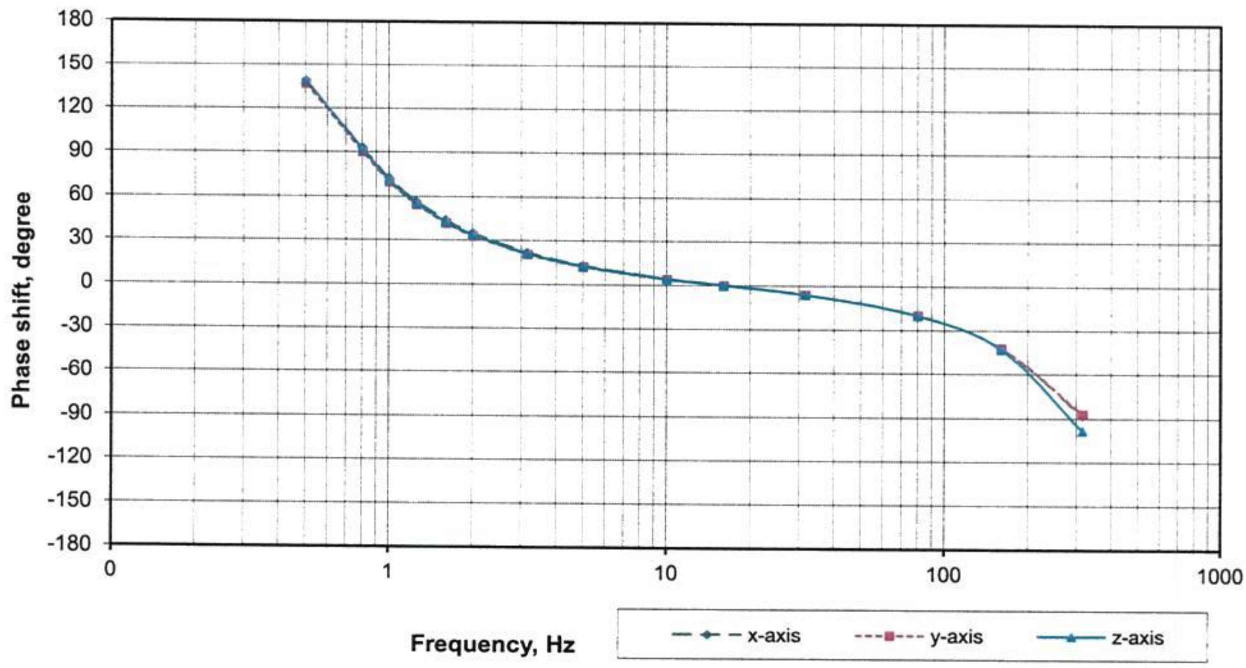
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.32	-61.79	138.9	12.09	-58.58	136.8	11.48	-60.54	139.3
0.8	22.88	-22.76	93.0	23.81	-18.45	90.1	23.41	-19.50	92.4
1	25.90	-12.58	72.5	26.57	-9.01	69.7	26.28	-9.64	71.3
1.25	27.31	-7.83	56.8	27.72	-5.07	54.2	27.43	-5.68	55.4
1.6	28.10	-5.13	43.8	28.29	-3.12	41.6	27.99	-3.78	42.5
2	28.59	-3.50	34.8	28.60	-2.07	32.9	28.30	-2.70	33.7
3.15	29.20	-1.42	21.7	29.00	-0.67	20.4	28.74	-1.19	21.0
5	29.52	-0.34	12.9	29.10	-0.33	12.0	28.98	-0.36	12.5
10	29.68	0.20	4.3	29.30	0.33	3.8	29.10	0.04	4.2
16	**29.62**	**0.0**	**0.1**	**29.20**	**0.0**	**-0.1**	**29.08**	**0.0**	**0.0**
31.5	29.53	-0.31	-6.1	29.13	-0.23	-6.1	29.09	0.02	-6.2
80	29.78	0.51	-19.9	29.33	0.45	-19.9	29.03	-0.19	-20.0
160	29.64	0.06	-41.9	29.10	-0.35	-42.0	28.53	-1.92	-42.8
315	27.44	-7.37	-87.8	26.27	-10.02	-87.0	23.62	-18.77	-98.3

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)



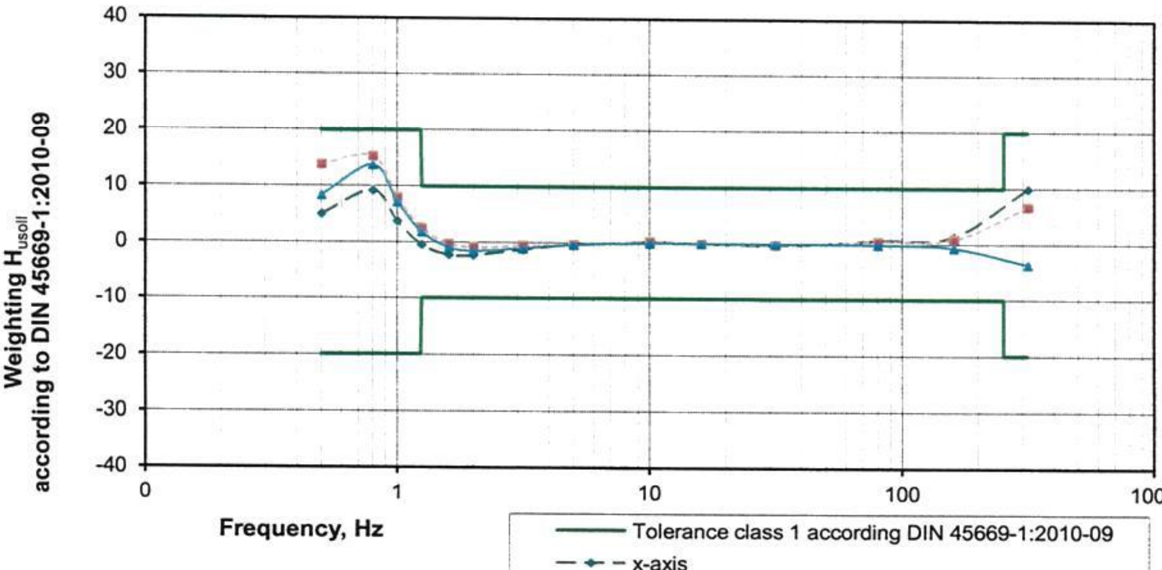
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.382	5.0	0.364	0.414	13.8	0.364	0.395	8.4
0.8	0.707	0.772	9.2	0.707	0.815	15.3	0.707	0.805	13.8
1	0.842	0.874	3.8	0.842	0.910	8.0	0.842	0.904	7.3
1.25	0.925	0.922	-0.4	0.925	0.949	2.6	0.925	0.943	1.9
1.6	0.970	0.949	-2.2	0.970	0.969	-0.1	0.970	0.962	-0.8
2	0.987	0.965	-2.3	0.987	0.979	-0.8	0.987	0.973	-1.5
3.15	0.998	0.986	-1.2	0.998	0.993	-0.5	0.998	0.988	-1.0
5	1.000	0.997	-0.3	1.000	0.997	-0.3	1.000	0.996	-0.3
10	1.000	1.002	0.2	1.000	1.003	0.3	1.000	1.000	0.0
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.997	-0.3	1.000	0.998	-0.2	1.000	1.000	0.0
80	0.999	1.005	0.6	0.999	1.004	0.5	0.999	0.998	-0.1
160	0.987	1.001	1.4	0.987	0.996	1.0	0.987	0.981	-0.6
315	0.842	0.926	10.0	0.842	0.900	6.8	0.842	0.812	-3.6



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station
SN: #10036

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218135

G.R.A.S.
Sound & Vibration

System Sensitivity:	50.00 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.71 mV
Preamplifier type:	26AX
Preamplifier serial no:	214103
Microphone type:	40AS
Microphone Serial No:	138462
Operator:	FBL
Date:	18. aug 2014

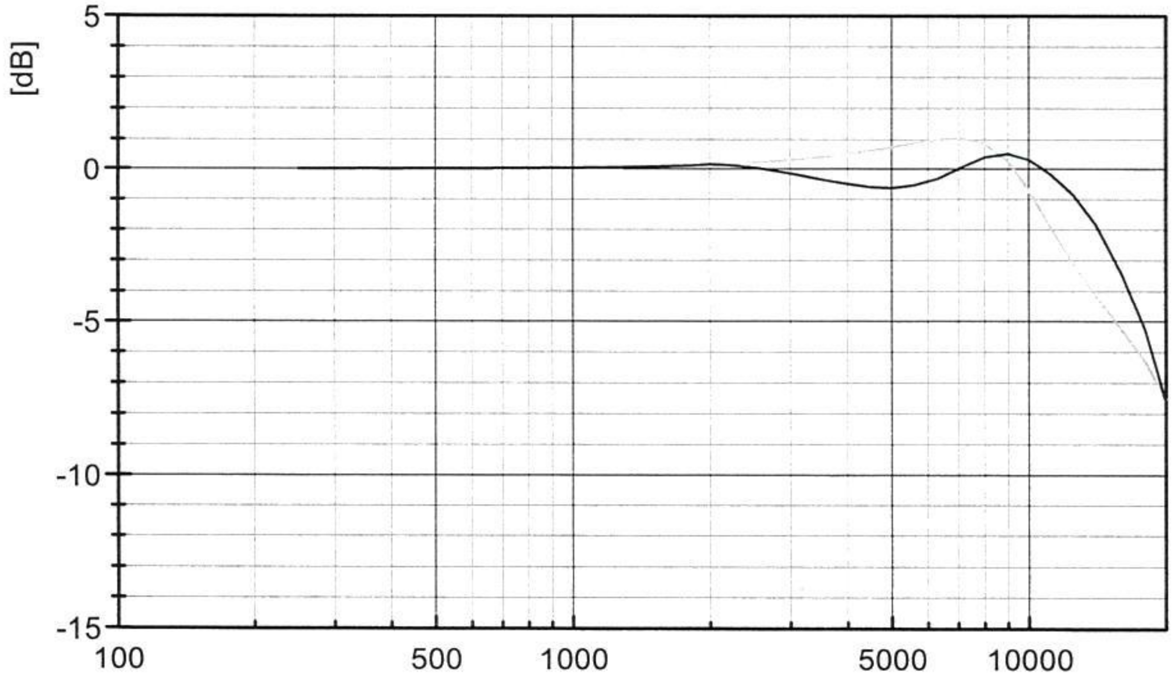
The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa

Frequency response re. 250 Hz



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst **DKD**

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1974
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504073**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH** **DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141335**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**23/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
24/09/2014	Philipp Begoff	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504073**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(22.3 ± 1) °C**
Relative humidity:	**(41 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity:	**horizontal (x- and y-axis)** **vertical (z-axis)**
Temperature of test object:	**(22.3 ± 2) °C**
Attachment of test object to vibration exciter:	
z-axis:	**screwed SAM-018**
x- and y-axis:	**screwed SAM-025**
Technical data of the connecting cable (cable of the laboratory)	
Manufacturer:	**SINUS Messtechnik GmbH**
Type:	**902246**
Length:	**2 m**

Specification of excitation
for determination of the transfer coefficient

Frequency:	**16 Hz**
Velocity (peak)	**10 mm/s**

for determination of the amplitude-frequency response

Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**15**	

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:

- for determination of the transfer coefficient at 16 Hz 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	**Mean value**	**Standard deviation**	
x-axis:	**29.183 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
y-axis:	**29.183 mV/(mm/s)**	**0.005 %**	**0.0015 mV/(mm/s)**
z-axis:	**29.710 mV/(mm/s)**	**0.001 %**	**0.0003 mV/(mm/s)**

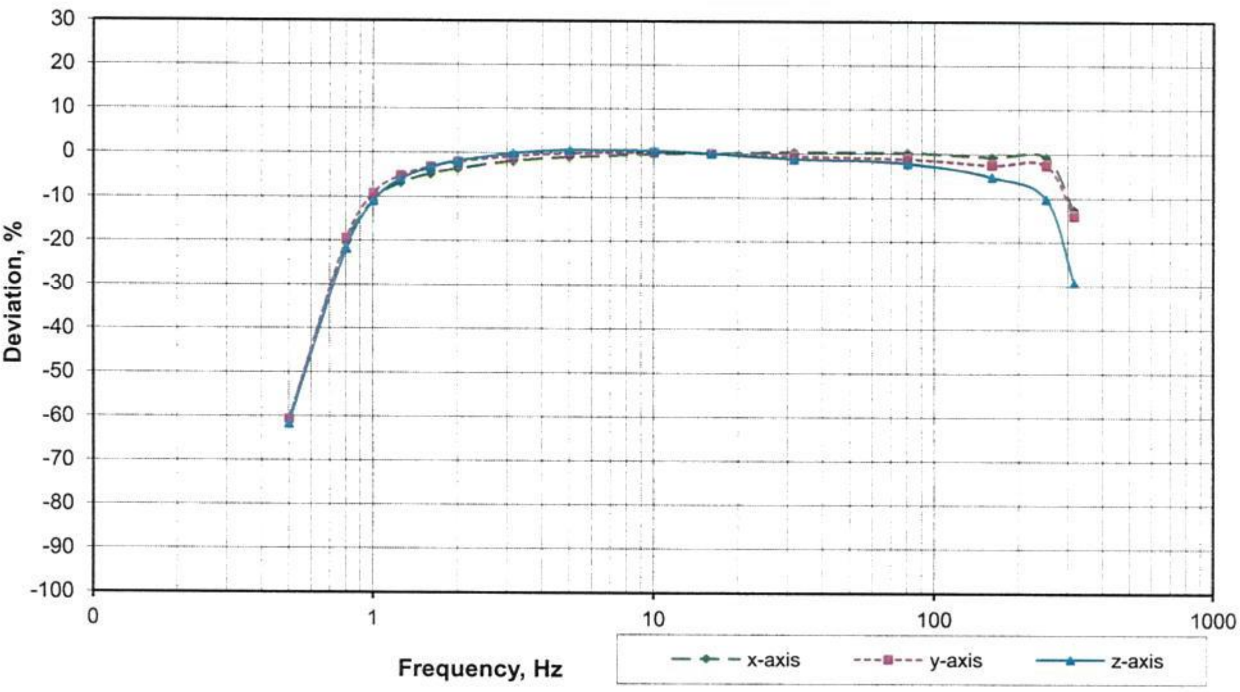
(acceleration due to gravity 1 g_n = 9.80665 m/s²)

7.2 Amplitude frequency response (relative to 16 Hz)

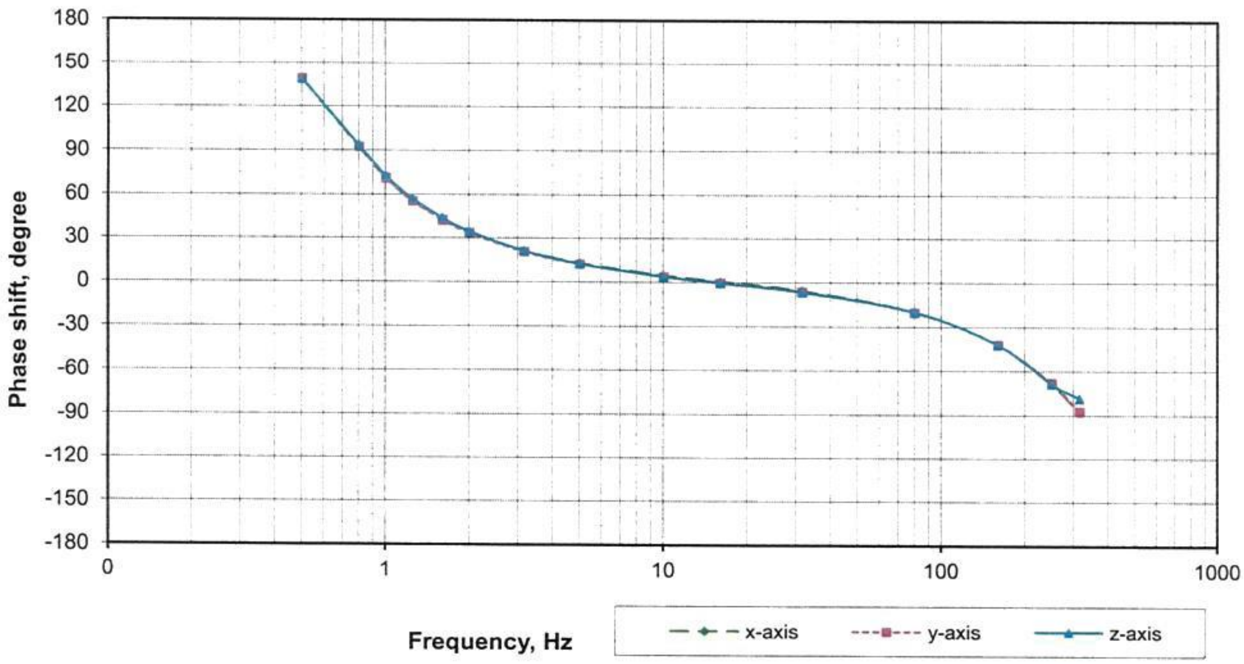
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.42	-60.85	139.1	11.48	-60.66	139.4	11.39	-61.68	139.1
0.8	23.19	-20.53	92.3	23.55	-19.31	92.8	23.27	-21.68	93.7
1	26.03	-10.80	71.4	26.53	-9.08	71.6	26.48	-10.86	73.0
1.25	27.21	-6.76	55.6	27.73	-4.97	55.5	27.96	-5.88	56.9
1.6	27.81	-4.71	42.7	28.29	-3.06	42.5	28.74	-3.25	43.6
2	28.16	-3.51	34.0	28.59	-2.04	33.6	29.17	-1.82	34.5
3.15	28.64	-1.85	21.2	28.98	-0.71	20.8	29.69	-0.08	21.3
5	28.91	-0.94	12.8	29.18	-0.02	12.3	29.92	0.69	12.4
10	29.14	-0.16	4.6	29.27	0.28	4.0	29.90	0.63	3.7
16	**29.18**	**0.0**	**0.5**	**29.18**	**0.0**	**-0.2**	**29.71**	**0.0**	**-0.7**
31.5	29.28	0.34	-5.7	29.04	-0.51	-6.2	29.36	-1.16	-6.7
80	29.26	0.26	-20.0	28.87	-1.08	-20.1	29.11	-2.03	-20.0
160	28.99	-0.67	-41.9	28.52	-2.27	-41.7	28.20	-5.10	-42.0
250	29.01	-0.61	-68.7	28.49	-2.37	-67.9	26.73	-10.03	-68.6
315	25.51	-12.60	-87.8	25.14	-13.87	-86.9	21.05	-29.16	-78.5

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)



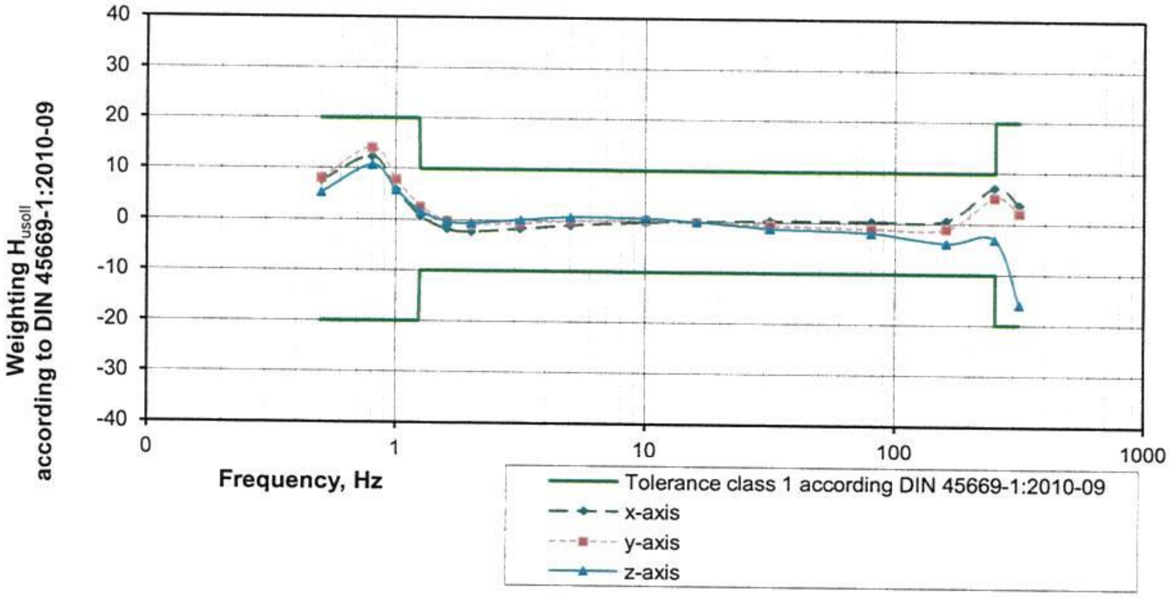
Phase frequency response



SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.391	7.6	0.364	0.393	8.1	0.364	0.383	5.3
0.8	0.707	0.795	12.4	0.707	0.807	14.1	0.707	0.783	10.8
1	0.842	0.892	5.9	0.842	0.909	7.9	0.842	0.891	5.8
1.25	0.925	0.932	0.8	0.925	0.950	2.7	0.925	0.941	1.7
1.6	0.970	0.953	-1.8	0.970	0.969	-0.1	0.970	0.967	-0.3
2	0.987	0.965	-2.3	0.987	0.980	-0.8	0.987	0.982	-0.6
3.15	0.998	0.981	-1.6	0.998	0.993	-0.5	0.998	0.999	0.1
5	1.000	0.991	-0.9	1.000	1.000	0.0	1.000	1.007	0.7
10	1.000	0.998	-0.2	1.000	1.003	0.3	1.000	1.006	0.6
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	1.003	0.3	1.000	0.995	-0.5	1.000	0.988	-1.2
80	0.999	1.003	0.3	0.999	0.989	-1.0	0.999	0.980	-1.9
160	0.987	0.993	0.7	0.987	0.977	-0.9	0.987	0.949	-3.8
250	0.927	0.994	7.2	0.927	0.976	5.3	0.927	0.900	-3.0
315	0.842	0.874	3.8	0.842	0.861	2.3	0.842	0.708	-15.9



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SINUS Messtechnik GmbH
Foepplstrasse 13
D-04347 Leipzig
Tel: +49-341-244290
Fax: +49-341-2442999

Declaration of Conformity

We, SINUS Messtechnik GmbH, Foepplstrasse 13, 04347 Leipzig, GERMANY, declare under our sole responsibility that our product

SWING_4ch Monitor Station

SN: #10031

to which this declaration relates, is in conformity with the following standards or other normative documents:

Performance compliant with:	IEC 61672 type 1 IEC 60651/60804 IEC 60260 type 1
EMC:	EN 50081-1 EN 50082-1

The measuring system is for use with outdoor measuring microphones GRAS 41CN.

This product has been manufactured in compliance with the provisions of the relevant internal SINUS Messtechnik GmbH documentation for production including quality management documentation.

Test documentation:	- SINUS QS-Handbuch ISO 9001	
	- Prüfvorschrift FBG DT-Apollo	908351.2/12
	- Prüfvorschrift FBG AT-Apollo	908357.8/12
	- Prüfvorschrift Apollo_PCIe	908035.8/12
	- Prüfvorschrift SWING	901301.8/12
	- FAT SWING	901301.8/12

This product has been tested individually and found to fulfill all specifications.

Leipzig, September 2014

Gunther Papsdorf
General Manager

Calibration Chart for
41CN Outdoor Microphone
Serial No. 218138

G.R.A.S.
Sound & Vibration

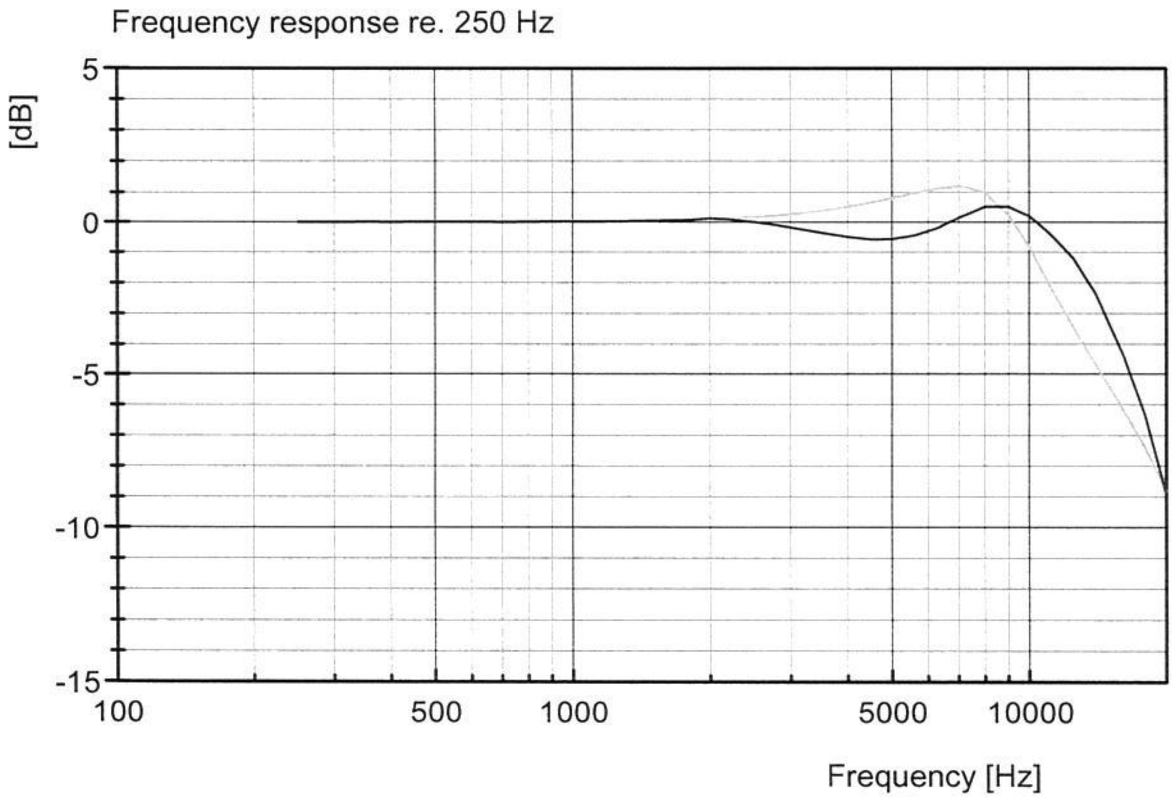
System Sensitivity:	49.98 mV/Pa
	-26.02 dB re. 1V/Pa
Actuator output:	31.71 mV
Preamplifier type:	26AX
Preamplifier serial no:	214106
Microphone type:	40AS
Microphone Serial No:	178538
Operator:	FBL
Date:	20. aug 2014

The stated sensitivity is the sensitivity for the complete microphone unit including preamplifier for 0 dB Gain setting and without A-weighting filter, with an uncertainty of ± 0.1 dB. The calibration is performed with a 42AA Pistonphone and is traceable to National Physical Laboratory, UK. The stated actuator calibration output is for 1kHz and with an uncertainty of ± 0.4 dB.

The frequency response is recorded with electrostatic actuator. The grey curve is the pressure response and the black curve is the free field response for 90 deg. incidence with the raincap and windscreen mounted on the microphone.

Environmental Calibration Conditions:

Temperature:	23 ± 3 C°
Relative humidity:	60 ± 20 %
Barometric pressure:	101.3 ± 3 kPa



G.R.A.S. Sound & Vibration A/S
Skovlytoften 33
DK-2840 Holte, Denmark

Tel.: +45 45 66 40 46
Fax : +45 45 66 40 47
e-mail : gras@gras.dk

akkreditiert durch die / *accredited by the*

Deutsche Akkreditierungsstelle GmbH

als Kalibrierlaboratorium im / *as calibration laboratory in the*

Deutschen Kalibrierdienst **DKD**

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-K-15183-01-00

Kalibrierschein
Calibration Certificate

Kalibrierzeichen
Calibration mark

1914
D-K-15183-01-00
2014-09

Gegenstand *Object*	**Velocity transducer**
Hersteller *Manufacturer*	**SINUS Messtechnik**
Typ *Type*	**902219.7**
Fabrikat/Serien-Nr. *Serial number*	**#0504070**
Auftraggeber *Customer*	**SINUS Messtechnik GmbH** **DE-04347 Leipzig**
Auftragsnummer *Order No.*	**141290**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**6**
Datum der Kalibrierung *Date of calibration*	**17/09/2014**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
18/09/2014	Heiko Deierlein	René Zimmermann

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

1. Object of Calibration

Object:	**Velocity transducer**
Manufacturer:	**SINUS Messtechnik**
Type:	**902219.7**
Serial number:	**#0504070**

2. Calibration Method

Calibration was performed by using the method of primary calibration according to the Directive ISO 16063-11. The transducer was exposed to sinusoidal acceleration which was applied by means of an electrodynamic vibration exciter. The transducer was calibrated by comparing the display of the transducer under test with the measured velocity.

3. Environmental Conditions

Environmental temperature of the test object:	**(23.6 ± 1) °C**
Relative humidity:	**(46 ± 5) %**

4. Test Conditions

Position of exciting axis (axes) relative to the earth gravity:	**horizontal (x- and y-axis)** **vertical (z-axis)**	
Temperature of test object:	**(23.6 ± 2) °C**	
Attachment of test object to vibration exciter:		
z-axis:	**screwed SAM-018**	
x- and y-axis:	**screwed SAM-025**	
Technical data of the connecting cable (cable of the laboratory)		
Manufacturer:	**SINUS Messtechnik GmbH**	
Type:	**902246**	
Length:	**2 m**	
Specification of excitation for determination of the transfer coefficient		
Frequency:	**16 Hz**	
Velocity (peak)	**10 mm/s**	
for determination of the amplitude-frequency response		
Frequency range:	**0.5 Hz to 16 Hz**	**>16 Hz to 315 Hz**
Velocity (peak):	**10 mm/s**	
Acceleration (peak)		**1 m/s²**
Number of frequency points on log scale:	**14**	

5. Measurement Uncertainty

These are the total relative measurement uncertainties at selected values:
- for determination of the transfer coefficient at 16 Hz — 1.5% / 1.5°
- for determination of the amplitude-frequency response in the frequency range

0.5 Hz bis	< 1 Hz	2.0% / 2.0°
1 Hz bis	80 Hz	1.5% / 1.5°
> 80 Hz bis	315 Hz	2.0% / 2.0°

The specified values are the extended measurement uncertainties obtained by multiplying the standard measurement uncertainties by extension factor k = 2. They were ascertained in line with DAkkS-DKD-3. The values of the measuring quantity fall into the assigned intervals with a probability of 95 %.

6. Components of the Reference Measuring Equipment

	Manufacturer	Type	Serial number
Vibration exciter	APS DYNAMICS INC.	113AB	836
Vibration exciter	APS DYNAMICS INC.	129	165
Laservibrometer	Polytec	CLV-1000	1 00 0633 0005
Calibration system	SPEKTRA	CS18 STF HF	200112

7. Results

7.1 Determination of the Transfer Coefficient

Frequency: **16 Hz**
Velocity (peak) **10 mm/s**

Axis	Mean value	Standard deviation	
x-axis:	**29.569 mV/(mm/s)**	**0.004 %**	**0.0012 mV/(mm/s)**
y-axis:	**31.294 mV/(mm/s)**	**0.006 %**	**0.0019 mV/(mm/s)**
z-axis:	**29.448 mV/(mm/s)**	**0.002 %**	**0.0006 mV/(mm/s)**

(acceleration due to gravity 1 g_n = 9.80665 m/s²)

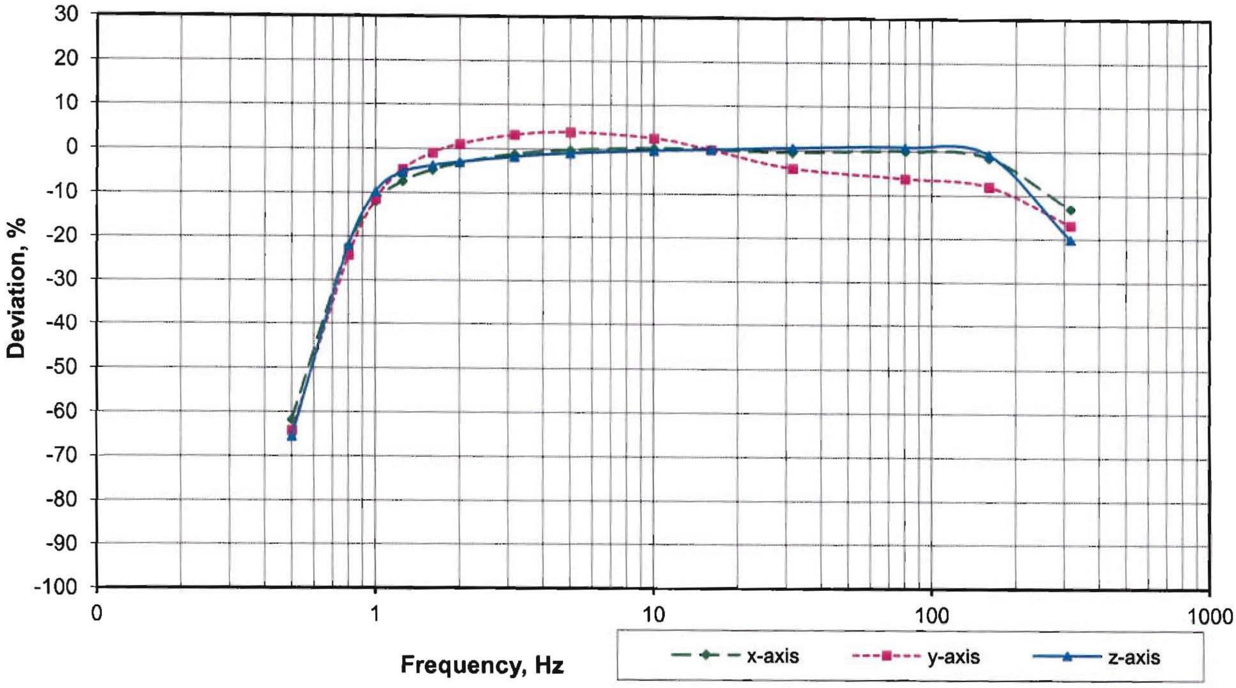
SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

7.2 Amplitude frequency response (relative to 16 Hz)

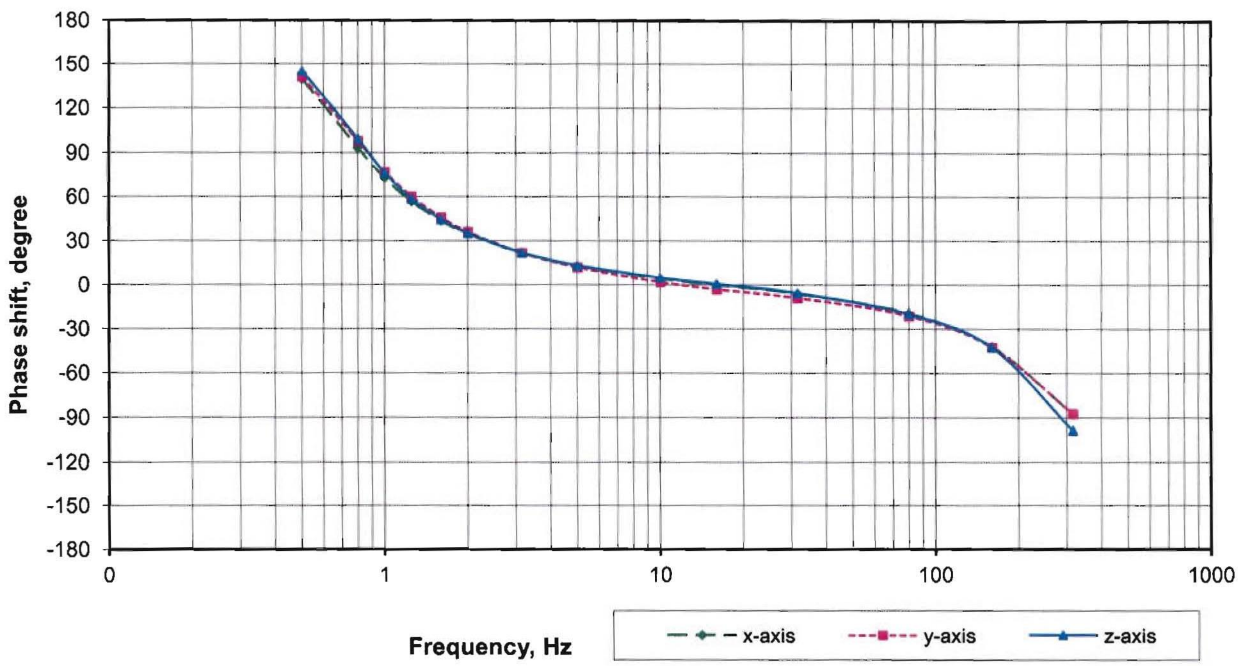
Frequency, Hz	x-axis			y-axis			z-axis		
	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree	Transfer coefficient, mV/(mm/s)	Deviation, %	Phase shift, degree
0.5	11.31	-61.77	139.7	11.19	-64.25	141.1	10.16	-65.48	145.1
0.8	23.01	-22.17	93.5	23.68	-24.32	97.9	22.95	-22.06	99.4
1	26.02	-12.00	72.7	27.73	-11.40	77.0	26.58	-9.74	76.3
1.25	27.38	-7.39	56.8	29.83	-4.67	60.2	27.87	-5.38	58.6
1.6	28.15	-4.80	43.8	30.99	-0.96	46.1	28.31	-3.86	44.6
2	28.60	-3.27	34.8	31.61	1.01	36.2	28.53	-3.11	35.3
3.15	29.21	-1.21	21.7	32.28	3.16	21.9	28.90	-1.85	22.1
5	29.50	-0.25	12.9	32.48	3.79	12.0	29.16	-0.99	13.3
10	29.65	0.28	4.3	32.09	2.55	2.0	29.36	-0.31	4.9
16	**29.57**	**0.0**	**0.0**	**31.29**	**0.0**	**-3.0**	**29.45**	**0.0**	**0.7**
31.5	29.42	-0.49	-6.1	30.03	-4.05	-8.9	29.60	0.50	-5.7
80	29.54	-0.09	-19.6	29.36	-6.19	-21.0	29.67	0.77	-19.9
160	29.13	-1.47	-41.8	28.81	-7.92	-42.3	29.20	-0.85	-42.4
315	25.71	-13.05	-87.4	26.05	-16.76	-87.1	23.52	-20.14	-98.4

Factory calibration:
Values higher than 80 Hz (color marked) are outside of the accredited range of the calibration laboratory. Those result have the state of a factory calibration.

Amplitude frequency response (relative to 16 Hz)

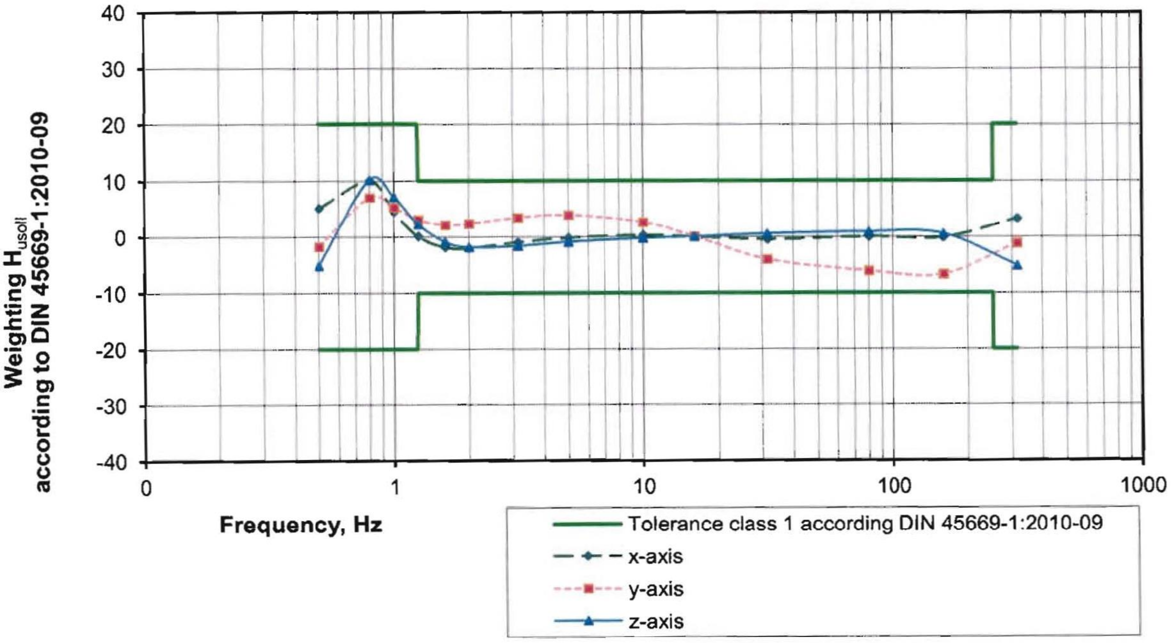


Phase frequency response



7.3 According to DIN 45669-1:2010-09

Frequency, Hz	x-axis			y-axis			z-axis		
	Weighting factor H_{uSOLL} according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}	Weighting factor HuSOLL according DIN 45669-1:2010-09 (nominal value)	Weighting factor, (measured value)	Deviation to H_{uSOLL}
0.5	0.364	0.382	5.1	0.364	0.357	-1.8	0.364	0.345	-5.1
0.8	0.707	0.778	10.1	0.707	0.757	7.0	0.707	0.779	10.2
1	0.842	0.880	4.5	0.842	0.886	5.2	0.842	0.903	7.2
1.25	0.925	0.926	0.1	0.925	0.953	3.0	0.925	0.946	2.3
1.6	0.970	0.952	-1.9	0.970	0.990	2.1	0.970	0.961	-0.9
2	0.987	0.967	-2.0	0.987	1.010	2.3	0.987	0.969	-1.9
3.15	0.998	0.988	-1.0	0.998	1.032	3.4	0.998	0.981	-1.7
5	1.000	0.997	-0.2	1.000	1.038	3.8	1.000	0.990	-1.0
10	1.000	1.003	0.3	1.000	1.026	2.6	1.000	0.997	-0.3
16	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**0.0**
31.5	1.000	0.995	-0.5	1.000	0.959	-4.0	1.000	1.005	0.5
80	0.999	0.999	0.0	0.999	0.938	-6.1	0.999	1.008	0.9
160	0.987	0.985	-0.1	0.987	0.921	-6.7	0.987	0.992	0.5
315	0.842	0.869	3.2	0.842	0.832	-1.2	0.842	0.799	-5.2



The accelerometer is conform to the vibration meter requirements of tolerance class 1 according to DIN 45669-1:2010-09.

SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
Heidelberger Str. 12, DE-01189 Dresden - Tel. (0351) 4 00 24 31

VOLUME 2 – TECHNICAL APPENDICES – DETAILED METHODOLOGY

CHAPTER 3: EQUIPMENT OUTAGES AND SCHEDULED MAINTENANCE

SCHEDULED EQUIPMENT / TELECOMS / DATA MANAGEMENT MAINTENANCE						
Date	**Time**	**Maintenance Description**	**Affected Stations (Monitoring Locations)**	**On-Site Trigger During Outage**	**Trigger Captured**	**Notes**
Sat 1/11/14 to Sun 30/11/14	08:30	Daily Trigger Check (Manual trigger command) to test / check trigger function	All stations	N/A	-	
Sat 1/11/14 to Sun 30/11/14	07:30	Daily Electrostatic calibration check	All stations	N/A	-	
Mon 3/11/14	08:30	Measurement time for all off-site station changed from 120secs to 60secs	All off-site stations	-	-	
Fri 21/11/14	08:30	Local Trigger Level changed from 85 dB(A) to 90 dB(A)	PEN_OS3	-	-	
Fri 21/11/14	08:30	Local Trigger Level changed from 85 dB(A) to 90 dB(A)	PEN_OS7	-	-	
Fri 21/11/14	08:30	Local Trigger Level (local) changed from 85 dB(A) to 90 dB(A)	PEN_OS8	-	-	Local trigger level increased due to proximity to railway
Wed 26/11/14	-	Installation of PEN_OS9	PEN_OS9	-	-	Installation of PEN_OS9 completed. Equipment installation delay due to Openreach works not being completed.
Thur 27/11/14	-	Installation of PEN_OS4	PEN_OS4	-	-	Installation of PEN_OS4 completed. Equipment installation delayed due to previous resident wishing not to participate in study.
Sat 13/12/14	-	Rollout of new server software	All stations	No	N/A	Roll-out of new server software updated to include weather data in summary files, real-time display of metrological sensor data via controller software. Restricted FTP bandwidth to improve system stability.
Wed 28/01/15	14:08	Routine Field calibration check of all monitoring stations	PEN_OS7	-	-	-
Wed 28/01/15	15:48		PEN_OS5	-	-	-
Thur 29/01/15	09:26		PEN_OS1	-	-	-
Thur 29/01/15	11:14		PEN_OS4	-	-	-
Thur 29/01/15	12:14		PEN_OS2	-	-	-
Thur 29/01/15	12:34		PEN_OS10	-	-	-
Thur 29/01/15	13:38		PEN_R2	-	-	-
Thur 29/01/15	14:21		PEN_R1	-	-	-
Thur 29/01/15	15:52		PEN_OS3	-	-	-
Fri 30/01/15	13:29		PEN_OS6	-	-	-
Fri 30/01/15	13:41		PEN_OS8	-	-	-
Fri 30/01/15	12:28		PEN_OS9	-	-	-
Tue 31/03/2015	-	Early retrieval of monitoring station installed at PEN_OS10. Resident no longer wants to participate in study.	PEN_OS10	-	-	-

TABLE 3.1: SUMMARY OF SCHEDULED EQUIPMENT / TELECOMS / DATA MANAGEMENT MAINTENANCE FOR MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

RANGE EQUIPMENT / TELECOMS OUTAGES DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
14/11/2014	10:33	Station Crash	1.5hr	Yes	No. Static 4M005 Missed.	Multiple remote connections to station attempted between 09:00 and 10:15 but connection could not be established. Remote connection successful at 10:20hrs.
13/01/2015	Intermittent throughout day	Intermittent Range network problems	09:00 – 19:00	S2-97 S2-99 S2-100	Yes	Intermittent Range network problems prevented trigger commands being sent to all or some off-Range stations.
14/01/2014	Intermittent throughout day	Intermittent Range network problems	09:00 – 19:00	S2-122 S2-123 S2-125 S2-126	Yes	Intermittent Range network problems prevented trigger commands being sent to all or some off-Range stations.
Fri 13/02/2015 to Mon 16/02/2015	c.13:00 13/02/2015 – c. 09:00 16/02/2015	Rage Network Outage. Both Range monitors unable to send trigger commands	c.70hrs	No	n/a	Range network outage.
Mon 16/02/2015 to Thur 19/02/2015	c. 09:00 16/02/2015 19/02/2015 c. 12:00	Unable to establish remote connection to station SAM02(E7)	c. 72hrs c. 72hrs	No No	n/a n/a	Approx.09:00hrs Mon 16/02/15. SAM02 failed to restart following Range network outage. Approx. 09:10hrs Mon 16/02/15. Remote connection to SAM02 could not be established. Approx. 09:50hrs Tue 17/02/15. Further network checks undertaken by QinetiQ firewalls team which confirmed SAM02 (E7) not responding on QinetiQ network. Approx. 10:00hrs Tue 17/02/15. Southdowns mobilise for complete system swap out Wed 18/02/15. Southdowns attend SAM02 and confirm station in non-responsive state. Approx. 11:00hrs Thur 19/02/15. SAM02 back on-line and functioning following complete system swap out Fri 20/02/15 Station returned to equipment manufacturer for repair.

TABLE 3.2: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-R1 & PEN R2 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS1 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
14/11/2014	14:55	Station Crashed. Server Remotely Re-started.	approx 20 mins	Yes	No. Trigger S1-66 Missed	Equipment manufacturer advised slow FTP transfer (a combination of poor ADSL server and large number of local trigger events) limiting bandwidth. New server software deployed to restrict data transfer bandwidth.
18/11/2014	16:55	Station Crashed. Remote Connection Lost. Server Remotely Re-started.	approx 2 hrs	Yes	No. Trigger S1-165 Missed	
01/12/2014	08:03	Connection to meter could not be established	10 hours	Yes S1-2	No	Remote connection could not be established. Identified at c. 08:03 following daily checks. Remote connection to associated modem OK. Issued raised with equipment supplier at c. 08:10 hrs. Station back on-line at 18:00hrs. Cause of crash related to FTP bandwidth.
Thur 15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	No	

TABLE 3.3: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS1 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS2 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223 S2-244	No	

TABLE 3.4: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS2 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS3 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
10/11/2014	08:00 – 17:00	Connection to meter could not be established	c. 9 hours	S1-35 S2-69 S1-36 S2-70	No	Station crash detected during routine checks, remote access to meter was unavailable. Local agent instructed to perform a manual restart which resolved the issued.
01/12/2014	08:03 - 15.21	Connection to meter could not be established	10 hours	Yes S1-2	No	Remote connection could not be established. Identified at c. 08:03 following daily checks. Remote connection to associated modem OK. Issued raised with equipment supplier at c. 08:10 hrs. Station back on-line at 18:00hrs. Cause of crash due to FTP bandwidth.
12/01/2015	08:00 – 16:00	System crash	c.12 hours	S2-80 S2-84 S2-89	No	Crash picked up late Sunday 11/01/15 during routine checks, remote access to meter was unavailable. Local agent instructed to perform a manual restart resolved the issued.
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	No	

TABLE 3.5: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS3 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS4 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
26th December 2014 (advised)	Unknown	BT/Openreach equipment struck by lighting	12 days	No	n/a	Remote connection to PEN-OS4 lost. Identified during daily checks undertaken on 29th December 2014. Southdowns raised the fault with internet provider on 29/12/14 who confirmed a fault on the line. BT/Openreach confirmed the fault was due to damaged equipment caused by lightning with at least 4 other properties affected. Internet provider confirmed following replacement of underground cabling BT/Openreach had repaired the problem with tests showing the line operating correctly. 02/01/2015 Southdowns still unable to remotely connect to PEN-OS4. Internet provider carried out additional testing on line and suggested it was possible the router associated with PEN-SO4 was also damaged by lighting. Replacement router dispatched and replaced by Southdowns on 07/01/2015. Remote connection to PEN-OS4 restored on 07/01/2015.
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	Yes	

TABLE 3.6: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS4 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS5 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	Yes	

TABLE 3.7: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS5 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS6 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
14/11/2014	14:39 - 14:59	Station crashed and stopped receiving trigger commands. Server Re-started.	Approx. 11mins	Yes	No. Trigger S1-66 Missed.	
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	Yes	Equipment manufacturer advised slow FTP transfer (a combination of poor ADSL server and large number of local trigger events) limiting bandwidth. New server software deployed to restrict data transfer bandwidth.

TABLE 3.8: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS6 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS7 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
12/01/2015	c. 08:00	Hardware failure of Apollo Card.	c.3.5 days	S2-80 S2-84 S2-89	No. S2-80; S2-84; S2-89 Missed.	Hardware failure observed at c. 08:00hrs during daily system checks. Southdowns attended site 15/01/215 with replacement failed hardware component.
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	No	

TABLE 3.9: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS7 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS8 DURING MONITORING STUDY						
Date	**Time**	**Fault Description**	**Downtime**	**Range Trigger Occurred During Outage**	**Range Trigger Captured**	**Notes**
12/11/14	14:08 – 15.37	Station crashed and stopped receiving trigger commands. Server remotely restarted.	2.5min	Yes	No. Triggers S2-108 and S2-11 Missed	Equipment manufacturer advised slow FTP transfer (a combination of poor ADSL server and large number of local trigger events) limiting bandwidth. New server software deployed to restrict data transfer bandwidth.
15/01/15	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	Yes	

TABLE 3.10: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS8 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS9 DURING MONITORING STUDY

Date	Time	Fault Description	Downtime	Range Trigger Occurred During Outage	Range Trigger Captured	Notes
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	Yes	
16/01/2015	c.08:00 – 18:00	Router offline subsequent to internet outage.	10 hours	S1-124 S2-242 S2-243 S2-244 S2-246 S2-249 S2-251	Yes	Required manual restart by local agent.

TABLE 3.11: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS9 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

EQUIPMENT / TELECOMS OUTAGES AT PEN-OS10 DURING MONITORING STUDY

Date	Time	Fault Description	Downtime	Range Trigger Occurred During Outage	Range Trigger Captured	Notes
12/11/2014	14:08	Station crashed and stopped receiving trigger commands. Server remotely re-started.	10mins	Y	No Trigger S2-104 Missed	Equipment manufacturer advised slow FTP transfer (a combination of poor ADSL server and large number of local trigger events) limiting bandwidth. New server software deployed to restrict data transfer bandwidth.
14/11/2014	10:33 - 14:39.	Station crashed and stopped receiving trigger commands. Server remotely re-started.	10min	Y	No. Trigger S1-66 Missed	
15/01/2015	c.08:00 – 15:00	Authentication failure preventing off site meter services connecting to Open Reach's authentication servers. Affected a large number of users across the UK.	c.7 hours	S2-214 S2-223	Yes	

TABLE 3.12: SUMMARY OF EQUIPMENT / TELECOMS OUTAGES AT PEN-OS10 DURING MONITORING PERIOD 3RD NOVEMBER 2014 TO 3RD MAY 2015

VOLUME 2: TECHNICAL APPENDICES – DETAILED METHODOLOGY

CHAPTER 4: DATA PROCESSING METHODS

4. DATA PROCESSING METHODS

4.1 Introduction

4.1.1 One of the key strengths of this study is the ability to analyse the recorded signals after they have been captured.

4.1.2 Digital signal processing methods have been applied to ensure: a consistent treatment of the large data-set; minimisation of any potential skew to the assessment due to subjective approaches; and to provide a robust scientific approach to the determination of a causal link.

4.1.3 The processing and analysis of the collated dataset has been separated into two stages, namely:

- determining the probability of causal link using signal processing techniques; and
- calculation of sound / air overpressure and vibration magnitudes for events with a confirmed causal link.

4.1.4 An overview of the methodologies and signal statistical techniques used and subsequent calculation and presentation of sound / air overpressure and vibration magnitudes is presented in the following subsections and includes detailed, annotated examples of a selection of Range Activities captured during the monitoring study along with some locally triggered events not associated with Range Activity. These were undertaken and documented as part of an assurance study to verify the application of the analytical methods prior to their wider application on the main study data.

4.1.5 The full results of the processing for all Range Activities are presented graphically in Volume 03 – Technical Appendices – Results.

4.1.6 An overview of the approach is presented schematically in Figure 4.1.

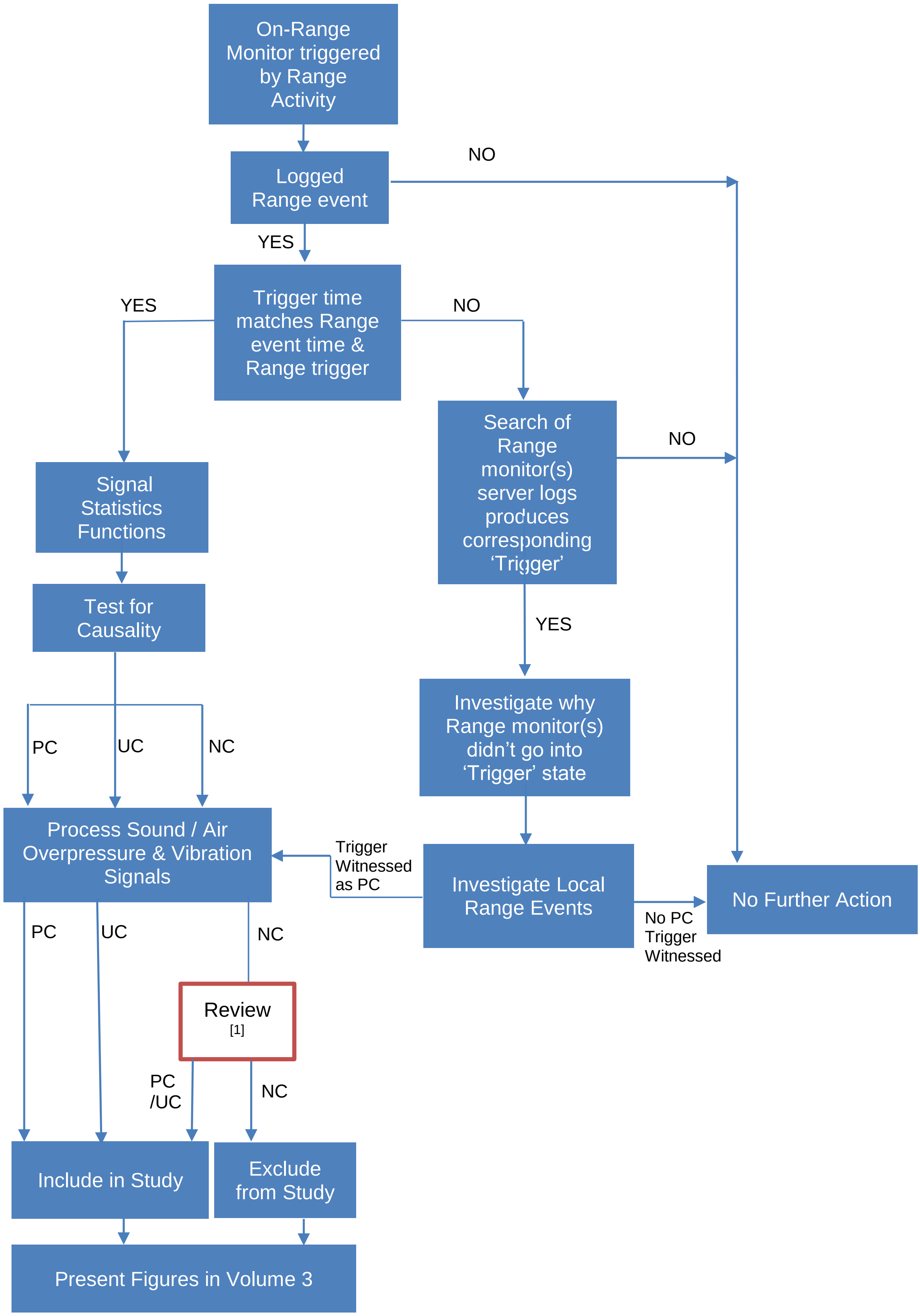


FIGURE 4.1: OVERVIEW OF DATASET PROCESSING

Notes

[1] manual analysis of dataset undertaken and review where levels are likely to have a tangible effect on the outcome of the study

[2] where PC = positive causality; UC = uncertain causality; NC = non-causal

4.2 Test for Causal Link

4.2.1 The Range Activity logs provided by QinetiQ (as presented in Vol 3 – Chapter 1) provided an approximation of when an on-Range triggered Activity might be expected to occur at an off-Range monitoring location. With each monitoring station synchronised with a GPS clock, this approach provides a first pass assumption that a confirmed Range Activity would need to exist within a predefined time window following the event itself.

4.2.2 A test for causal link was developed to assess the likelihood of an off-Range measured event occurring from a Range Activity. A number of individual analytical and statistical functions have been developed using MATLAB, a proprietary software package which allows mathematical calculations, plotting of functions and data, and the implementation of digital signal processing algorithms. Functions have been developed using MATLAB to collectively enable the testing of captured signals. A description of these individual functions is described in more detail below.

4.3 Statistical Function - Signal Cross-Correlation

4.3.1 Cross-correlation is a signal statistic used to assess the similarity between two signals. It is a measure of the similarity as a function of time, specifically the time lag. It is a useful function for the calculation of a time separation or a delay between two signals.

4.3.2 The function shifts one signal in time and compares the summation of the two signals. When two signals are summed, a maximum will occur at the point at which the signals are most similar.

4.3.3 Figure 4.2 shows a simplified example of cross-correlation using two signals 'Range' and 'Off-Range' and the cross-correlation depicted by the function name 'Range * Off-Range'. It can be seen from the graphical representation that Off-Range moves across Range and they are summed at every iteration producing 'Range * Off-Range'.

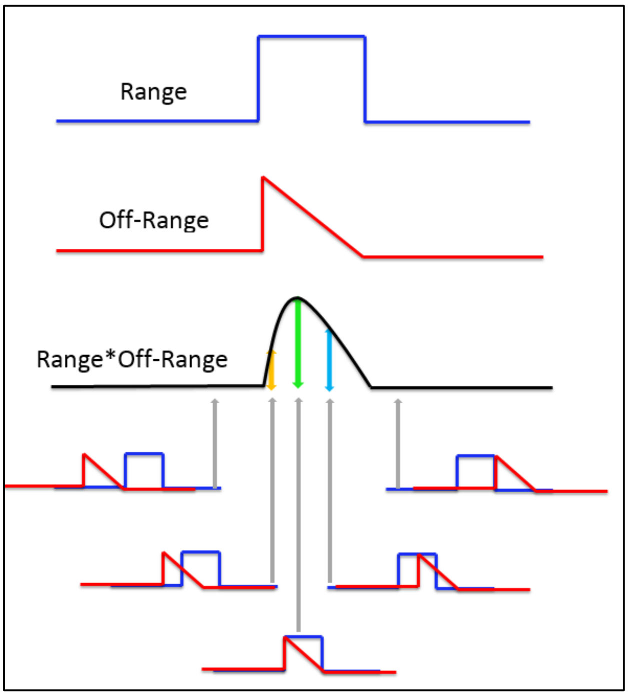


FIGURE 4.2: GRAPHICAL REPRESENTATION OF CROSS-CORRELATION

4.3.4 The peak occurs when the signals are most similar, even though they may not be exactly the same.

4.3.5 An example of a typical cross-correlation plot produced using this technique is presented in Figure 4.3 overleaf.

4.4 Statistical Function – Signal Coherence

4.4.1 The coherence is a statistical quantity that is used to examine relationships between two digital signals and estimate the similarity of the two signals.

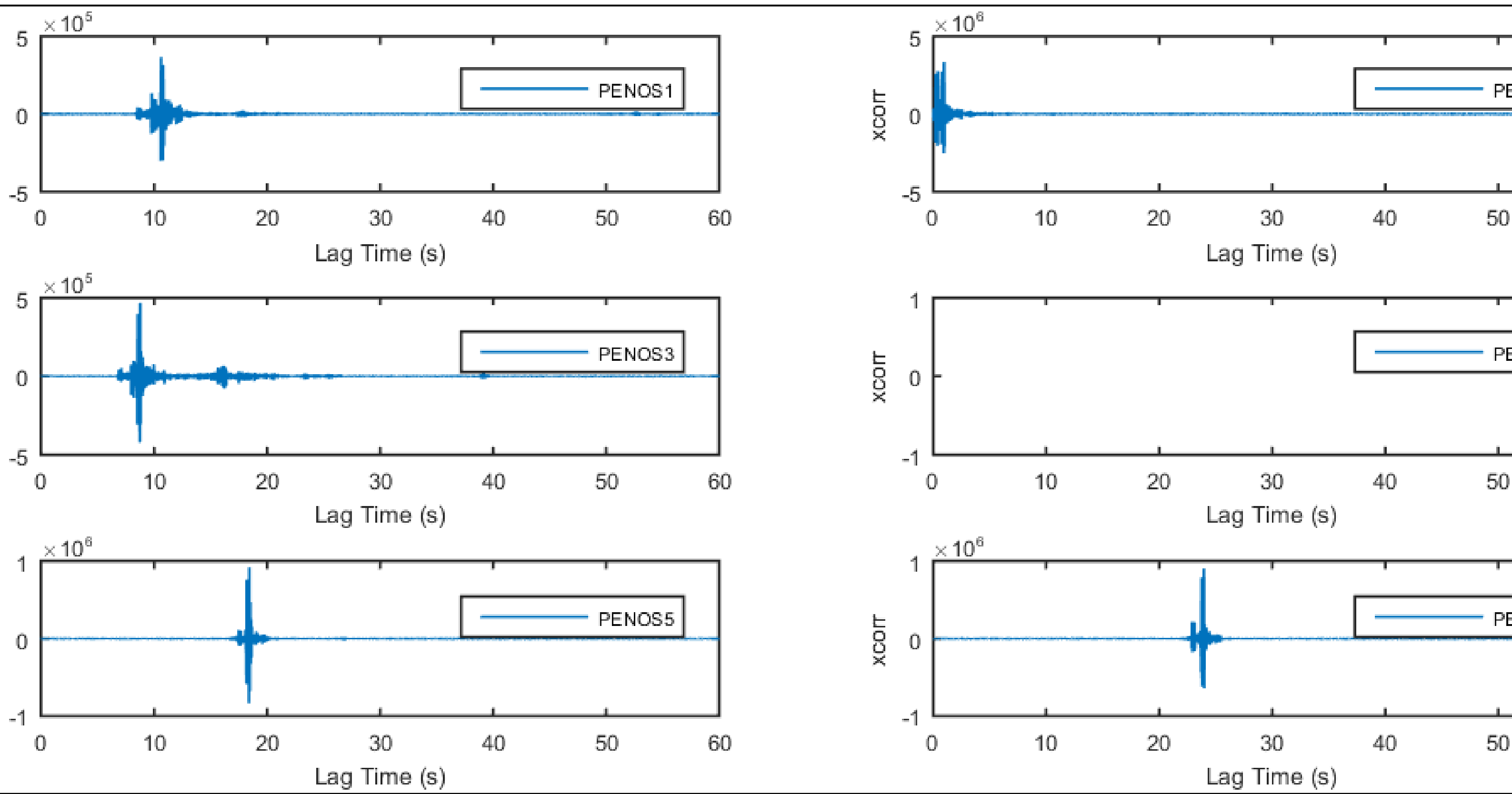
4.4.2 The coherence function produces a series of measures between 0 and 1 across the frequency spectrum. If the coherence is zero, this is an indication that the signals are not similar.

4.4.3 If the coherence between two signals is greater than zero but less than one, there is some similarity evident with a greater level of confidence the higher the numerical value.

4.4.4 For the purposes of establishing a causal link from Range activities, the coherence function uses the signal from an identified Range Activity and compares it against waveforms captured at off-Range locations.

4.4.5 Owing to the expected low frequency component of Range activities, and the higher degree of sound energy decay due to distance in the mid to high frequencies, the coherence of the signals focussed primarily on the frequency range of 1 to 500Hz.

4.4.6 An example of a typical coherence plot produced is presented in Figure 4.4 overleaf.



URE 4.3: EXAMPLE OF A TYPICAL CROSS-CORRELATION ACOUSTIC PLOT

:

Cross correlation peak presented in plots identifies the time when the off-Range signal is most similar to the Range signal. This technique is also useful for determining the acoustic waveform arrives at the monitor point..

lo dataset for PEN_OS4 (station not installed at this point in this example)

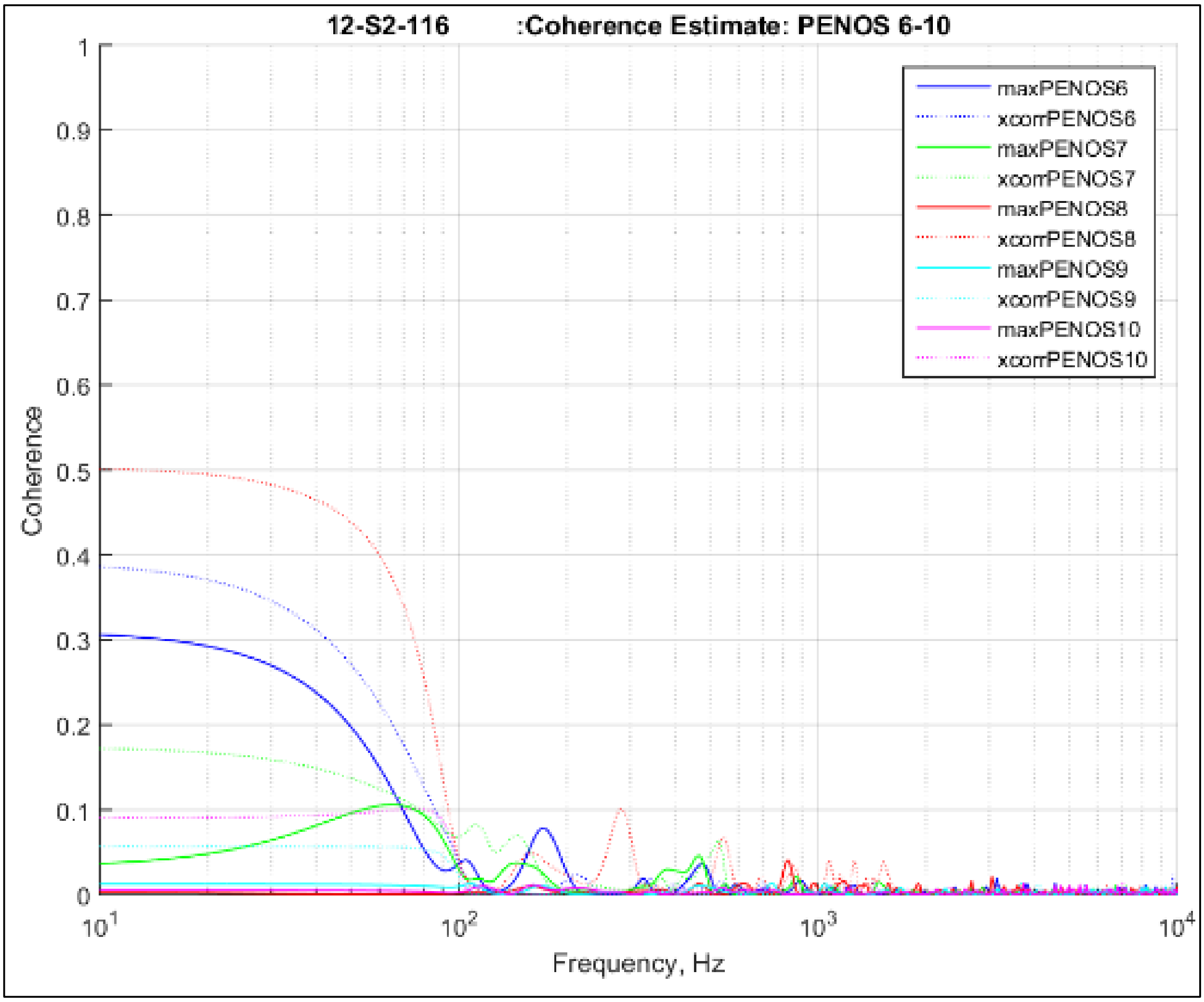


FIGURE 4.4: EXAMPLE OF A TYPICAL COHERENCE CALCULATION

Notes:

[1] 'max' presents the coherence of the maximum value in the audio signal; and

[2] 'xcorr' presents the coherence of event found by cross correlation.

4.5 Derivation of Threshold Values for Causality Categories

4.5.1 These signal processing techniques have been used to determine causality at all monitoring locations for all captured Range activities. The magnitude of causality has been categorised as follows:

- positive causality (PC) – reasonable likelihood that an Range Activity has caused an off-Range effect (i.e. probable causality);
- uncertain causality (UC) – insufficient statistical evidence to confirm that the Range Activity caused an off-Range effect (i.e. possible causality);
- non-causal (NC) – little or no evidence to suggest that the Range Activity has caused an off-Range effect (i.e. unlikely causality).

4.5.2 A number of tests were performed on a sample of the collated dataset, to enable a threshold value to be calculated for each causality category.

4.5.3 The sample dataset used to derive the threshold values for causality categories included a sample of measurements that were confirmed as being causal from audio playback and analysis of Range firing logs. In addition, the sample dataset also included a number of null tests carried out on data known not to be causal (non-causal), which included:

- unrelated Range activities of the same type;
- unrelated Range activities of different types; and
- events not related to Range activities.

4.5.4 A maximum value of coherence from the selected frequency range, (between 1 and 500Hz due to the low frequency nature of the events) was chosen for the three causality categories.

<u>Positive Causality (PC)</u>

4.5.5 From the test performed (as presented in Section 4.4) it was observed that Coherence values of above 0.15 provided positive causality across the frequency range of interest.

4.5.6 Results which fall into the Positive Causality category will include off-Range captured events which exhibit similar characteristics to that of the measured Range events, such as event rise time; and that occur at an off-Range monitoring location at or around the time that a Range generated signal could be expected to arrive.

4.5.7 It is very unlikely that a small or significant event which is not related to the Range signal will fall into this category. Typical events which fall into this category are Range events which are not heavily affected by ambient noise contributions at the off-Range monitor.

<u>Uncertain Causality (UC)</u>

4.5.8 From the tests performed (as presented in Section 4.4) it was observed that Coherence values between 0.05 and 0.15 introduced a level of ‘uncertain causality’.

4.5.9 The uncertain causality category may contain events that are similar to the Range event in some respects but may differ in others, for example a low level, low frequency event which is not related to Range Activity such as wind noise. Also events which share all of the same features but are low level in comparison to the existing ambient are likely to be rated within this category.

4.5.10 It is unlikely that a significant event which is not related to Range Activity will fall into this category.

Non-causal (NC).

4.5.11 From the tests performed (as presented in Section 4.4) it was observed that Coherence values below 0.05 indicated no causality.

4.5.12 Results which fall into the 'no causality' category will include large events which are not related to Range Activity. It is very unlikely that a Range Activity will fall into this category, unless it has been heavily affected by ambient sound.

4.5.13 Typical events which will fall into this category are events which are unrelated to Range Activity.

4.6 Testing and Effectiveness

4.6.1 Testing was undertaken to validate the causality categories using a selection of 15 no. triggered events which via audio play back were identified as non-causal and uncertain causality. Details of the sample dataset used for this purpose are presented in Table 4.1.

Southdowns Generated Trigger ID	No. of Monitoring Station Events in Causal Category			Analyst Comment
	NC[1]	UC[2]	PC[3]	
11-S2-111	6	0	0	No Range Event
11-S2-104	1	5	0	Factors (wind) affecting Range Measurement, Events observed off-Range Change to UC where appropriate
12-S2-82	1	7	2	Wind Affects Measurement Categories Stand
12-S2-61*	6	4	0	Factors (wind) affecting Range Measurement, Events observed off-Range Change to UC
01-S2-80	2	4	2	Wind Affecting Measurement Categories Stand
01-S2-100	2	5	2	Wind Affecting Measurement Categories Stand
01-S2-244	1	5	3	Event (Low Level at offsite locations) (PENOS8 train pass by in measurement adjusts to best match which is still heavily affected by ambient).
01-S1-124	6	2	0	Aircraft
02-S1-13 & S2-22	10	0	0	Aircraft
03-S2-142	7	3	0	Alarm
03-S1-134*	10	0	0	Factors (wind) affecting Range Measurement, Events observed off-Range Change to UC
03-S1-213	9	1	0	No event OS6 large amount of background
03-S1-237	8	2	0	Aircraft
04-S2-30	6	3	0	Alarm

TABLE 4.1: EVENT BY EVENT INVESTIGATION

Notes:
[1] where NC = non-casual
[2] where UC = Uncertain Causality
[3] where PC = Positive Causality
*[4] * indicates where categories have been manually altered to UC following review of firings events.*

4.6.2 Table 4.1 shows that none of the triggered events which were not related to Range Activity were classified as having positive causality.

4.6.3 Table 4.1 also shows that triggered events which are adversely affected by wind or other factors are largely classified into Uncertain Causality. In the example of 12-S2-61 a number of events were not picked up at off Range locations due to the comparative low level of the event.

4.7 Manual Identification of Causality

4.7.1 Following the application of the automated digital signal process, activities which fall into the uncertain causality (UC) category have been included in the data set for assessing magnitudes of sound / air overpressure and vibration at off-Range locations, as it is accepted that the measured effect could be due to Range activities.

4.7.2 For activities where the test showed no causality (NC) following the initial application of the signal processing techniques, manual analysis of the data set was applied to determine whether causal link could be established by other techniques.

4.7.3 This included visual inspection of the spectrograms to identify 'typical' Range Activity signals and review of the audio wave file for Range Activity confirmation.

4.7.4 Where causality could be established, the individual activities were included in the assessment of sound / air overpressure magnitudes from Range activities.

4.8 Calculation of Sound / Air Overpressure and Vibration Magnitudes for Events

4.8.1 Functions have been developed using MATLAB to collectively enable the calculation of sound / air overpressure and vibration magnitudes of captured signals. A description of these individual functions is described in more detail below.

Time History

4.8.2 The L_{Zpeak}, L_{Cpeak} and $L_{Amax,F}$ levels, along with the time histories of the raw sound pressure signals captured during a Range Activity at all Range and off-Range monitoring locations have been produced. Elevated levels or other distinguishing features can be used to assist in the positive recognition and quantification of Range activities.

4.8.3 An example of a typical time history plot produced is presented in Figure 4.5 below.

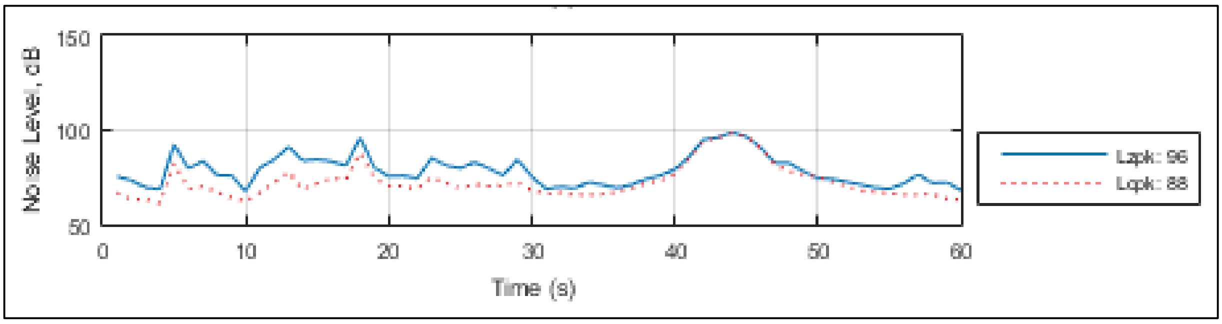


FIGURE 4.5: EXAMPLE OF A TYPICAL TIME HISTORY

4.8.4 The time histories produced using MATLAB coded functions have been verified against those produced in a proprietary software package SINUS SAMURAI 2.6 to ensure correct functionality.

Sound Spectrogram

4.8.5 A sound spectrogram (or sonogram) was used to enable visual analysis of the frequency and amplitude components of a signal in the time domain. Frequency is represented in the vertical axis, time in the horizontal axis, and the amplitude of the signal is represented by a colour scale. Spectrograms have been produced for the raw sound pressure signals collated, enabling analyses and comparison of the acoustic signatures of Range Activities captured by on-Range and off-Range monitors. An example of a sound spectrogram, produced by a typical Range Activity is presented in Figure 4.6.

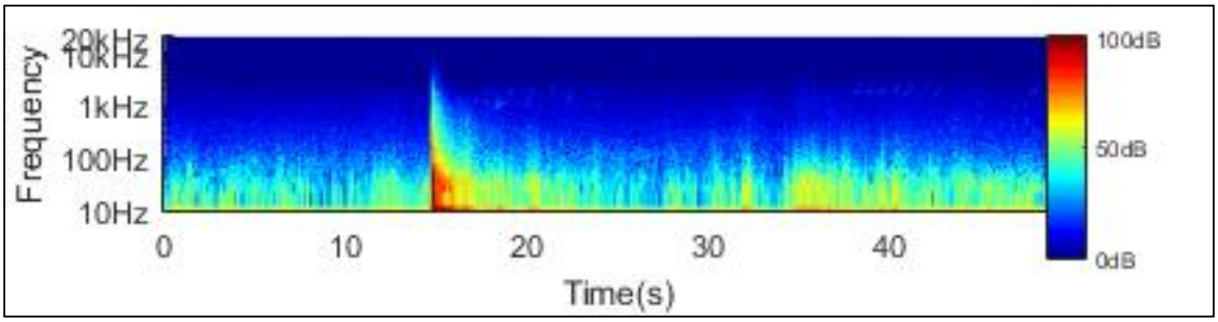


FIGURE 4.6: EXAMPLE OF A TYPICAL SOUND SPECTROGRAM PRODUCED

4.8.6 The time resolution was based on a compromise between peak approximation and dynamic range.

4.8.7 The methodology applied for the spectrogram production using MATLAB coded functions were verified against those produced using the proprietary software SINUS SAMURAI 2.6 and against a computer generated 1kHz sine-wave test signal.

Vibration

Peak Particle Velocity

4.8.8 In addition to sound pressure signals, the raw measured vibration signals have been considered. As discussed in the main body of the report, seismometers have been used to measure ground vibration in this study, with velocity being the physical units measured (expressed as mms^{-1}).

4.8.9 The uncompressed .wav files measured by each monitor will display physical units (mms^{-1}). These units can be directly imported into MATLAB for presentation and results. Cross correlation has been used for event time identification.

4.8.10 Seismic signals can travel through the earth much faster than the speed of sound through air (in materials such as clay it can be up to 5 times faster). To ensure that the seismic signals, would be captured at off Range locations, the off-Range monitors were configured with a 5 second pre-trigger. This would allow for the delay in the off-Range monitor receiving its trigger command, while still ensuring any seismic signal was captured.

4.8.11 For the assessment against the criteria presented in the Section 2.2 of Volume 1, max component peak particle velocities have been presented.

4.8.12 However, the analysis of the data set indicates that the detectable vibration signals captured during Range Activity arrive at a similar time to the air pressure signal. This would indicate that the vibration captured during the activity is likely to have been caused by a coupling effect with the ground, from the air pressure wave, rather than from direct ground-borne propagation of vibration from the site of the activity.

Displacement

4.8.13 The transient vibration thresholds for the on-set of cosmetic damage as previously presented in Chapter 3 of main report, considers Maximum Displacement for frequency components below 4 Hz. Using integration, displacement values have been derived from the raw velocity signals.

4.9 Effectiveness of Signal Processing Techniques

4.9.1 The information set out in this sub-section provides an example of how the signal processing techniques can be used to identify an event and determine the causality and measure the magnitude of the sound pressure and vibration magnitudes.

4.9.2 Figure 4.7 presents the spectrogram relating to a 0.68 kg static Range Activity captured on 17th December 2014, assigned trigger ID S2-116, processed for Range monitor PEN_R2. Figure 4.8 and Figure 4.9 present the spectrogram and time history with the L_{Cpeak} and L_{Zpeak} traces for the same event, captured at off-Range monitor PEN_OS8.

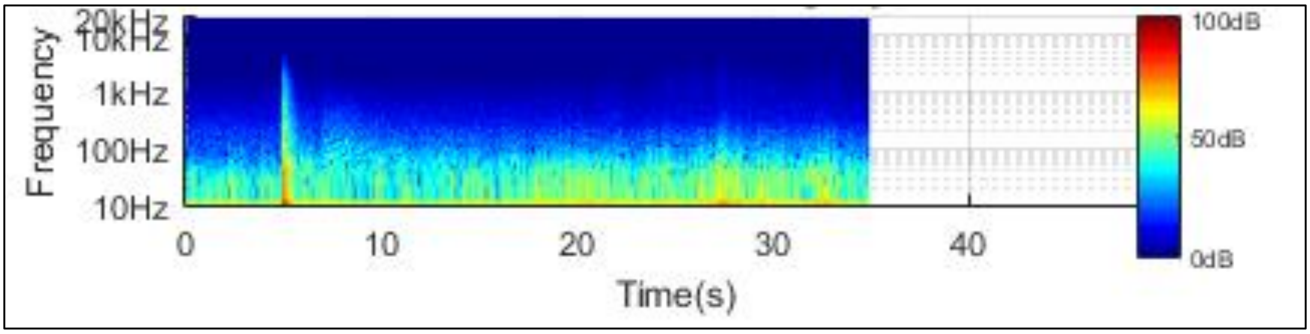


FIGURE 4.7: SPECTROGRAM – 0.68KG STATIC EVENT, 17TH DECEMBER 2014 – (PEN_R2)

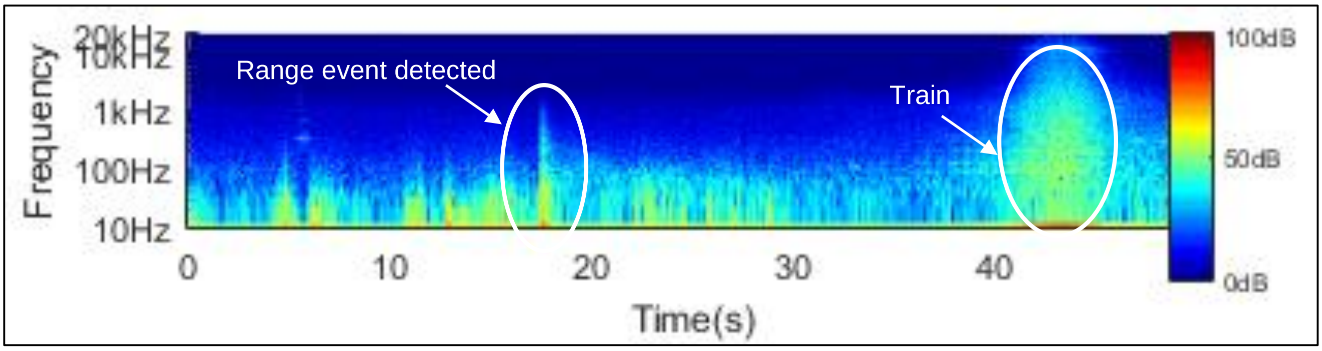


FIGURE 4.8: SPECTROGRAM – 0.68KG STATIC EVENT, 17TH DECEMBER 2014 – PEN_OS8

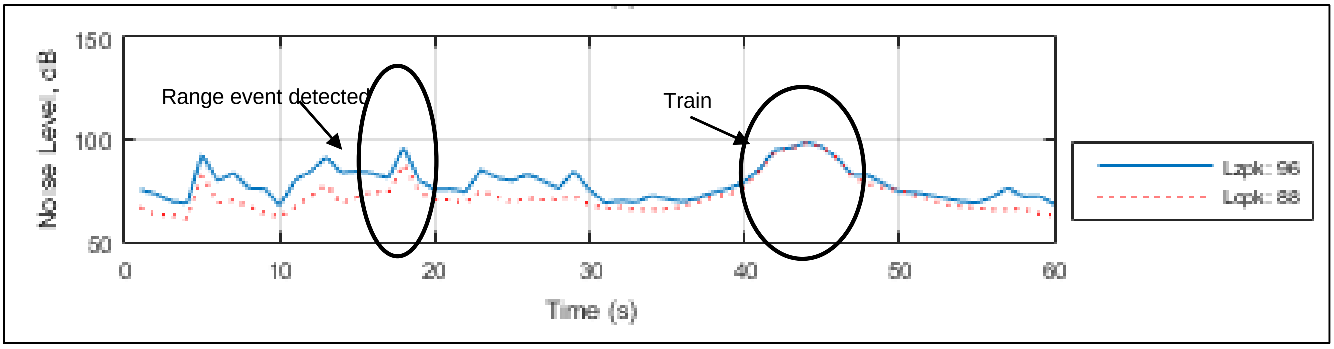


FIGURE 4.9: TIME HISTORIES – 0.68KG STATIC EVENT, 17TH DECEMBER 2014 – (PEN_R2)

4.9.3 Figure 4.7 above clearly shows the static Range Activity at a point 5 seconds into the captured signal at the on-Range monitor PEN_R2. The unique acoustic signature is evident in the spectrogram produced for off-Range monitor PEN_OS8 at approximately 17 seconds into the signal trace, as presented in Figure 4.8.

4.9.4 Apparent from the time histories presented in Figure 4.9, the graph also shows a second local event (with the characteristics of a train pass-by) occurring at approximately 40 seconds into the signal trace with an apparently greater magnitude of sound than the Range event.

4.9.5 Inspection of the cross correlation shown in Figure 4.10 confirms the on-Range event at 17 seconds (12 seconds when adjusted for the 5 second pre-trigger) whilst the coherence shown in Figure 4.11 validates the time correction from the cross correlation. This allows for the calculation of the L_{Cpeak} and L_{Zpeak} of the Range Activity, not the louder local train noise event captured within the waveform.

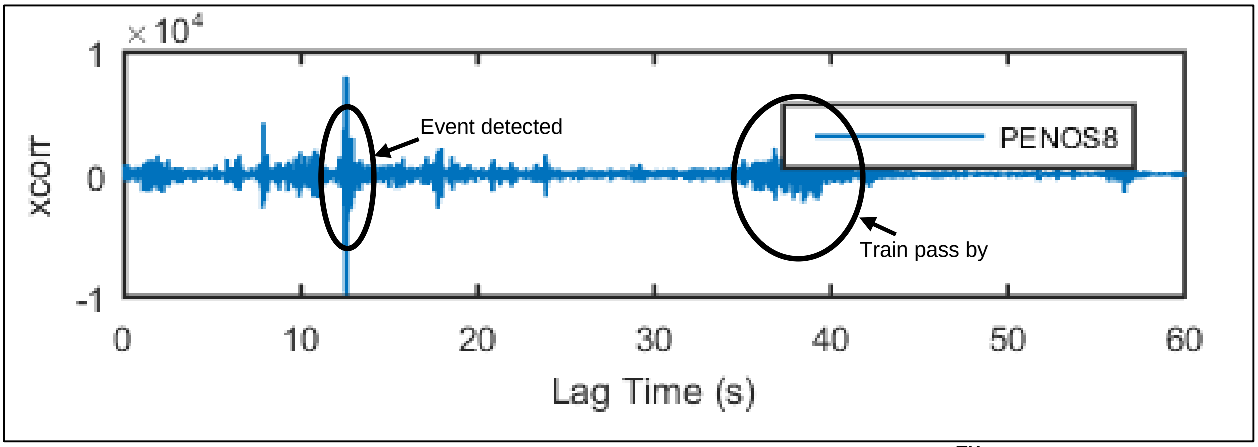


FIGURE 4.10: CROSS CORRELATION – 0.68KG STATIC ACTIVITY, 17TH DECEMBER 2014 –PEN_OS8

Notes:

[1] where cross-correlation is a measure of the similarity as a function of time, specifically the time lag

4.9.6 It should be noted that the cross correlation plots do not share a common time zero with the noise and vibration plots. The cross correlation results present a time difference between Range and off Range signals or '*Lag Time'* in this context.

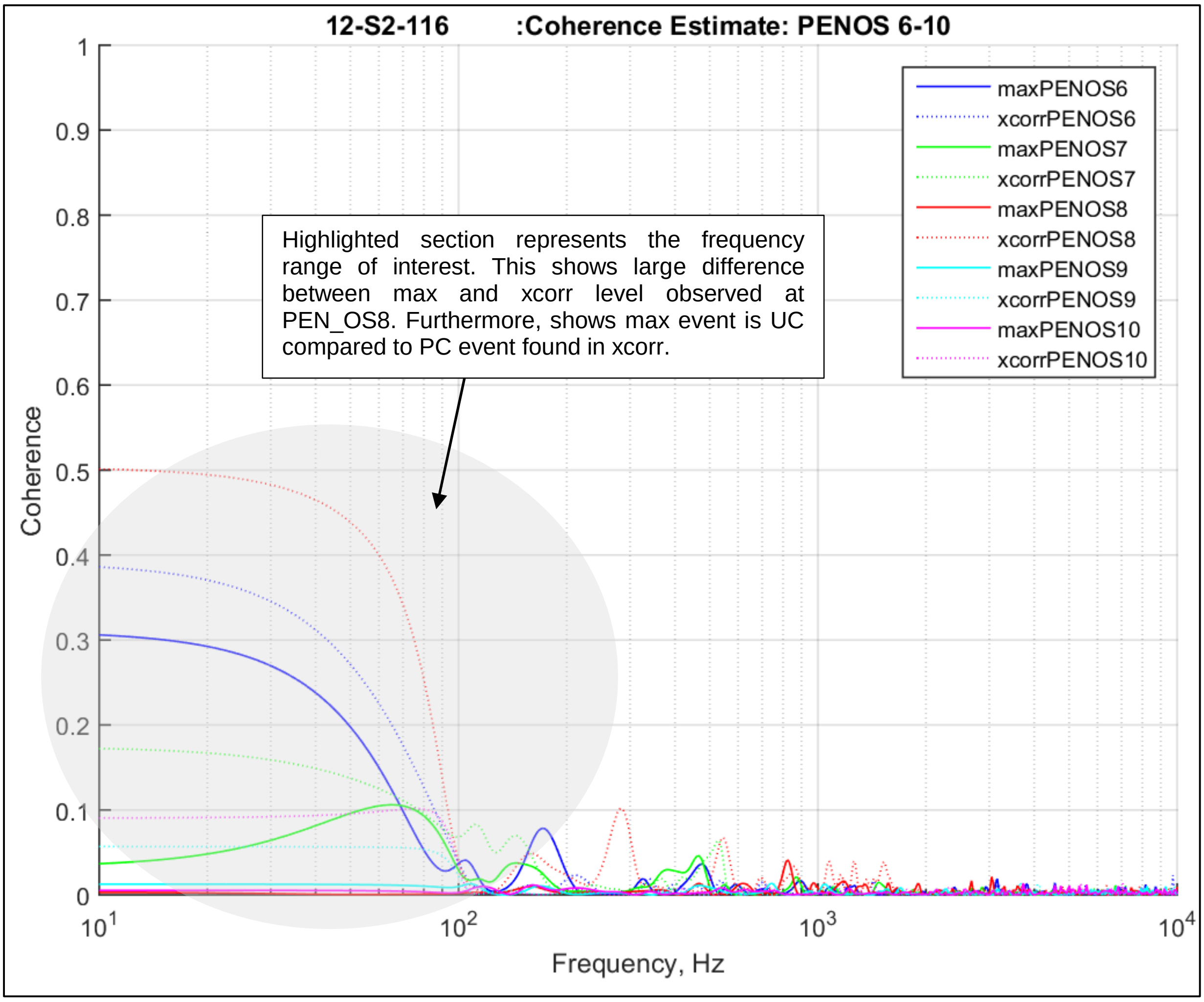


FIGURE 4.11: COHERENCE– 0.68KG STATIC EVENT, 17TH DECEMBER 2014 –PEN_OS6 – PEN_OS10

Notes:
[1] 'max' presents the coherence of the maximum value in the audio signal; and
[2] 'xcorr' presents the coherence of event found by cross correlation.

4.9.7 The above coherence plot presented in Figure 4.11, shows two important roles of the techniques applied. Namely, that the localised train noise activity is shown to be in the NC category, whereas the actual Range Activity was classified as being in the PC category according to the cross correlation analysis.

4.9.8 Once the on-Range event has been identified as having positive causality, the time history data can be used to identify the L_{Cpeak} and L_{Zpeak} sound pressure levels. In this case, the event was measured at 96 dB L_{Zpeak}.

4.10 Detailed Examples

4.10.1 A selection of events captured during the monitoring study between 3rd November 2014 and 3rd May 2015 are presented in the following sub-section to demonstrate the analytical and statistical methods described above, and how they have been applied to the obtained data for determining causal link and assessing the potential effects.

4.10.2 The examples include dynamic and static Range activities from the Pendine Range along with some examples of locally triggered events known not to be associated with Range Activity for comparative purposes.

Detailed Example – 13kg Dynamic Events, 14:48 24th November 2014

Sound Pressure

4.10.3 The spectrograms associated with trigger S1-187 relating to a 13 kg dynamic Range Activity at 14:48 on 24th November 2014, are presented in Figures 4.12 – 4.20.

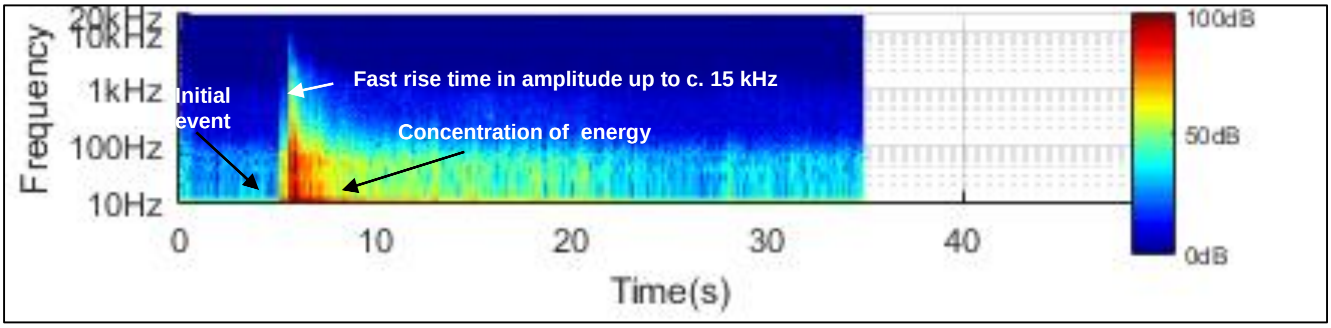


FIGURE 4.12: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – BRILL GATE (PEN_R1)

4.10.4 Figure 4.12 above shows the spectrogram processed from the raw data signal captured by the on-Range monitor installed at Brill Gate (PEN_R1). The spectrogram clearly shows the dynamic Range Activity at approximately 5.6 seconds (n.b. total signal includes 5 second pre-trigger).

4.10.5 The very fast rise time in amplitude across the frequency spectrum up to approximately 10 kHz, along with a concentration of energy of approximately 100 - 140 dB in the 10 – 100 Hz zone is apparent (represented by red, orange and yellow).

4.10.6

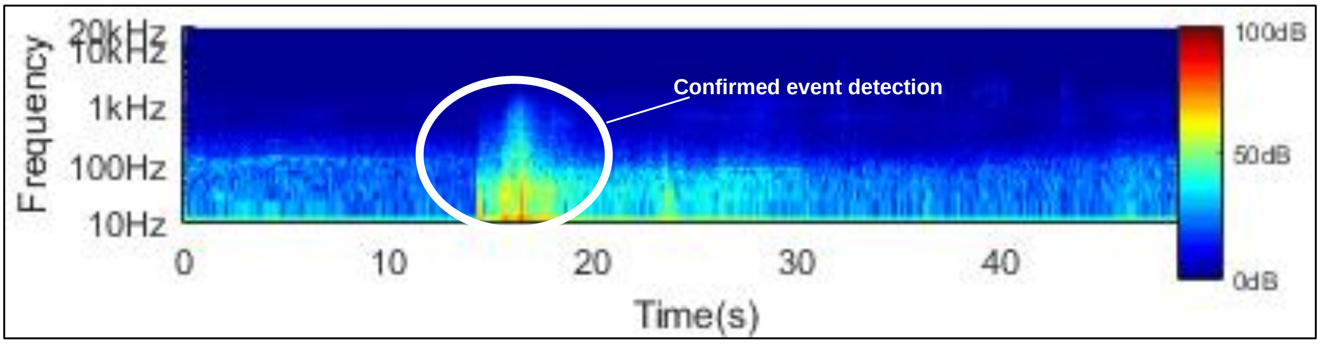


FIGURE 4.13: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS1

4.10.7 Figure 4.13 above shows the spectrogram processed from the raw data signal captured at a distance of approximately 4 km north east of the Brill Gate monitor (PEN_R1) at PEN_OS1 during the same 13 kg dynamic Range Activity. Detection of the dynamic Range Activity is evident at approximately 16.5 seconds (which includes the 5 second pre-trigger) with the concentration of energy in the 10 – 50 Hz zone also apparent (represented by red and yellow). The staggered arrival times of the 10 – 50 Hz frequencies combined with the attenuation of frequencies above 50 Hz is also noticeable.

4.10.8 The spectrograms processed from the raw signals captured at the remaining off-Range monitoring locations during the same 13 kg dynamic Range Activity are presented in Figures 4.14 – 4.20 below with detection of the dynamic Range Activity evident at all off-Range monitors. At PEN_OS10 (Figure 4.20) an event, assumed to be associated with the initial launch of a rocket along the main test track (along the axis of, and behind, the rocket motors) is shown, followed by the impact event.

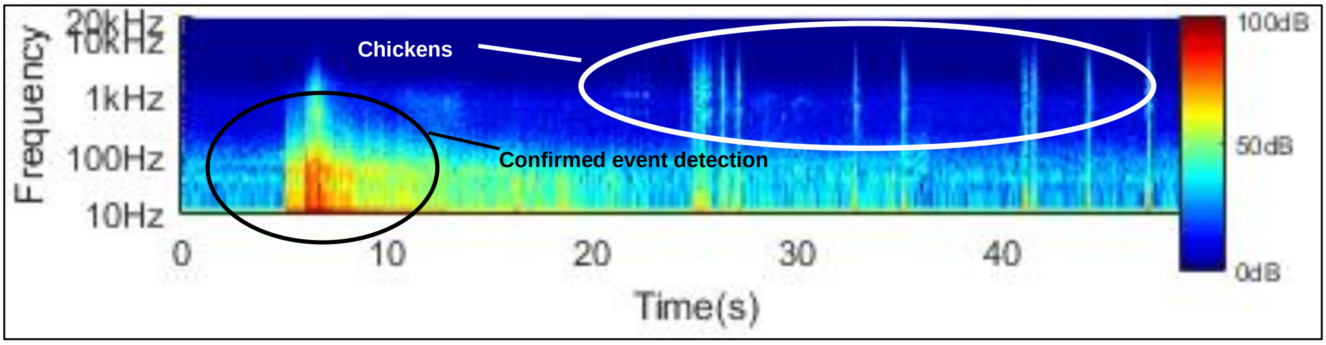


FIGURE 4.14: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS2

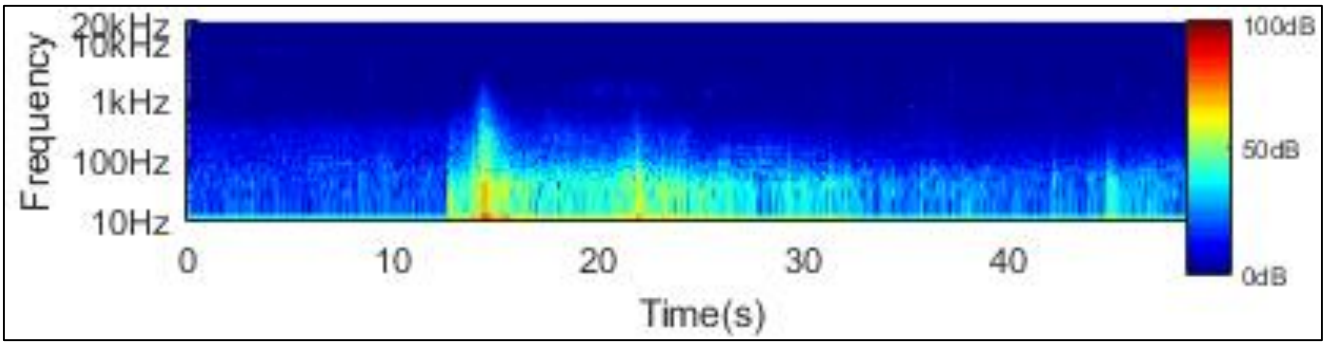


FIGURE 4.15: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS3

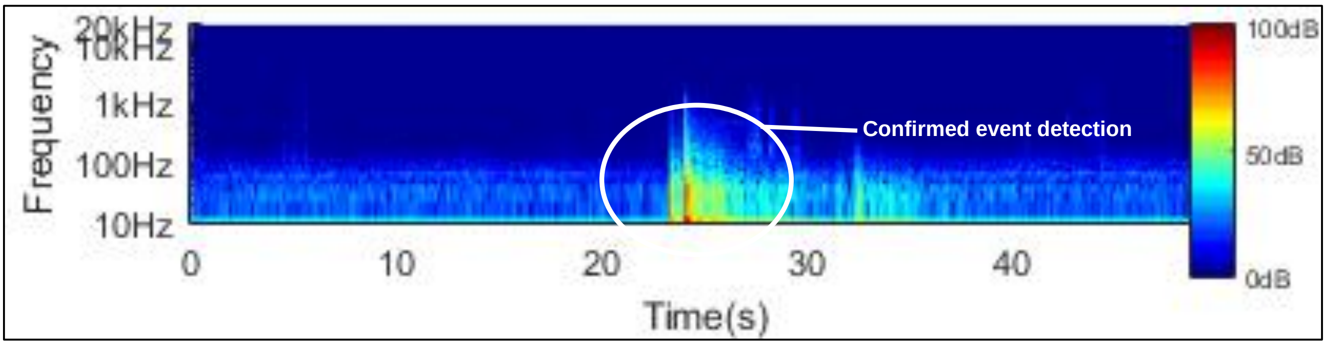


FIGURE 4.16: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS5

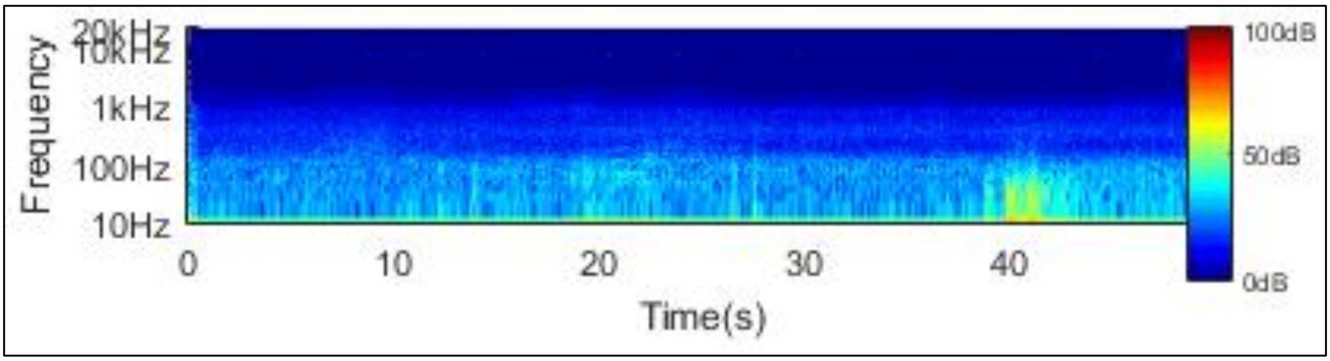


FIGURE 4.17: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS6

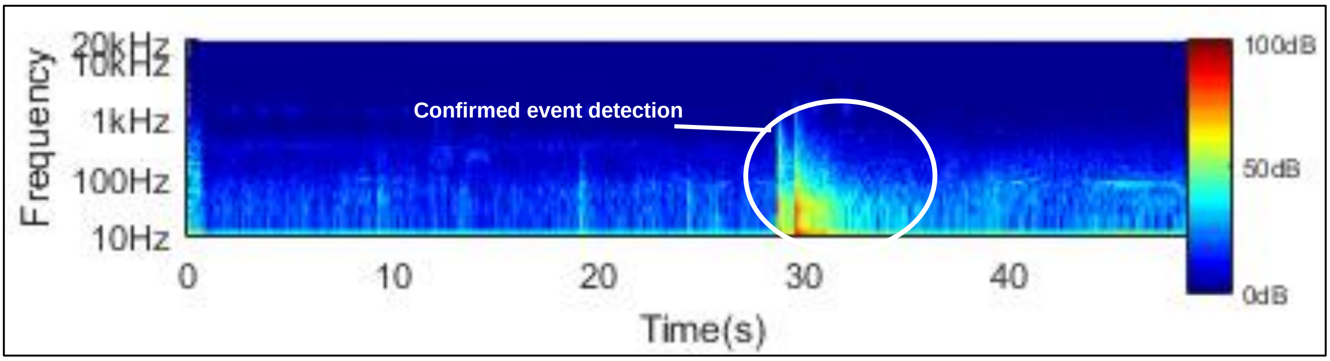


FIGURE 4.18: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS7

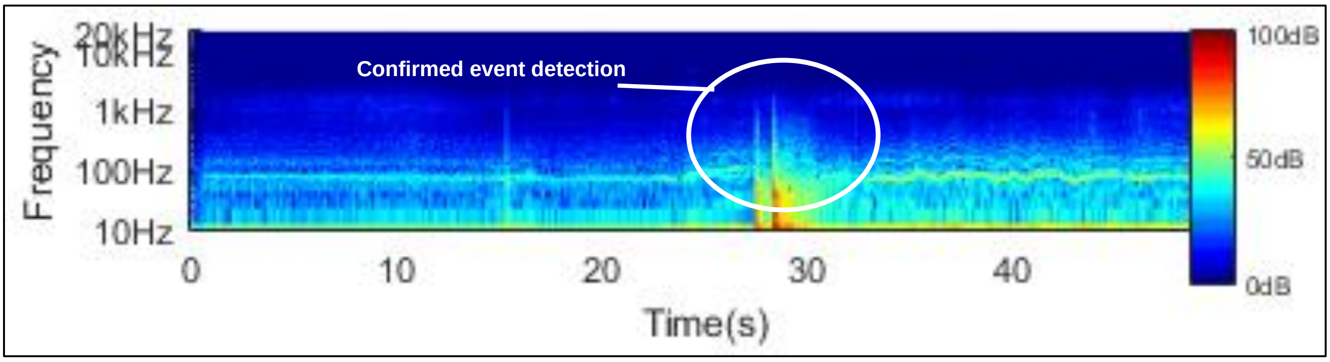


FIGURE 4.19: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS8

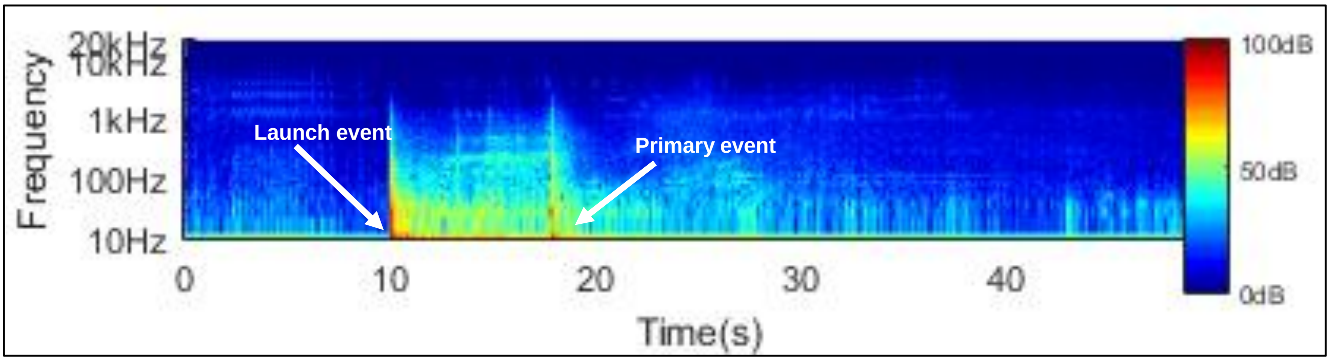


FIGURE 4.20: SPECTROGRAM – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014 – PEN_OS10

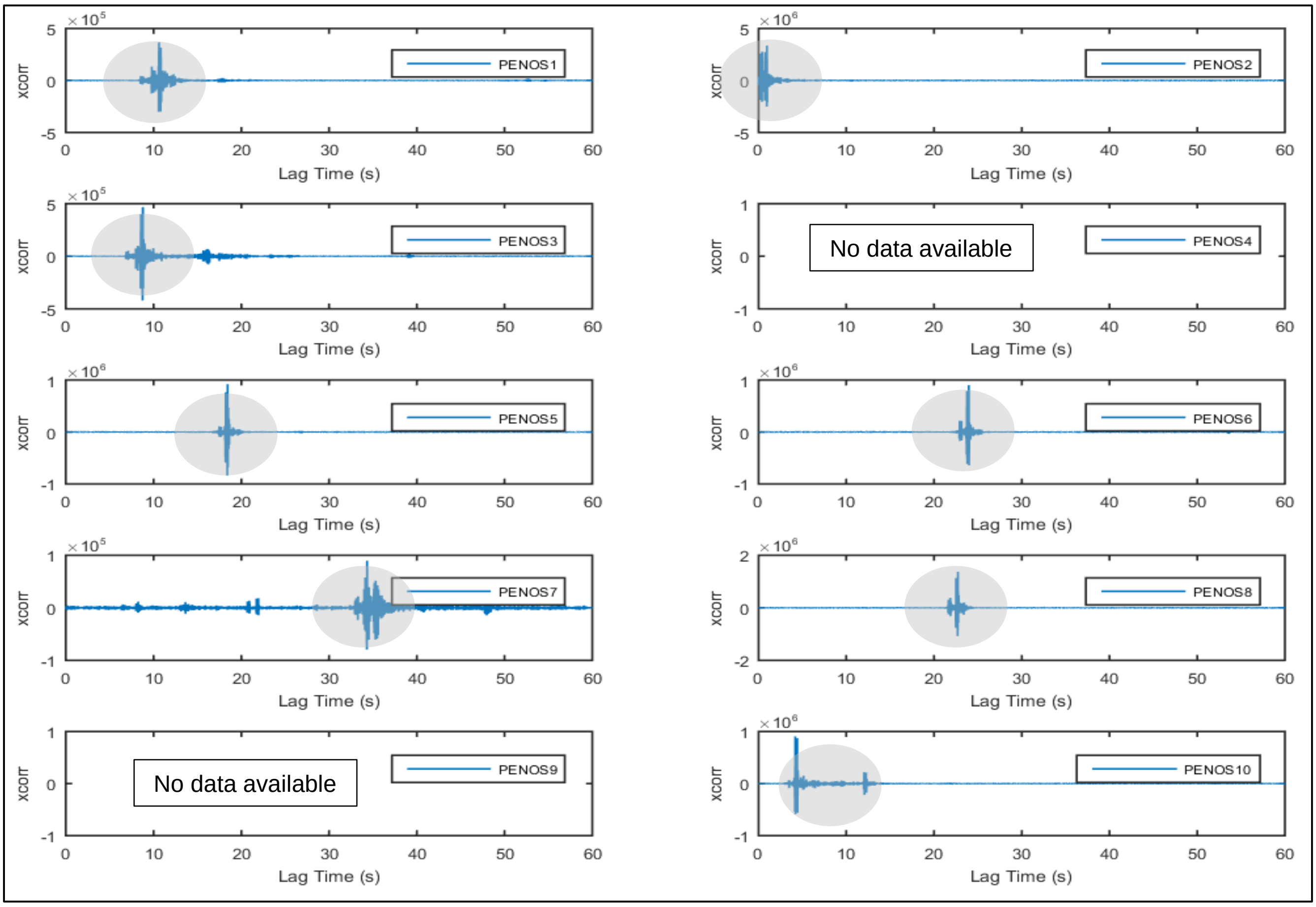


FIGURE 4.21: CROSS-CORRELATION – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014

Notes:
[1] highlighted area indicates Range Activity detection
[2] no data for PEN_OS4 and PEN_OS9 (equipment not installed for selected example event)
[3] where cross-correlation is a measure of the similarity as a function of time, specifically the time lag

4.10.9 The results presented in Figure 4.21 show the time lag between a Range Activity captured at on-Range and off-Range locations. At PEN_OS2 it can be seen that a very short delay time is observed between the on-Range and off-Range monitor. The spectrogram of this event is presented in Figure 4.14 and it can be seen that the event occurs at c.6 seconds, around one second after it is measured on the on-Range monitor.

4.10.10 This is most likely due to the Range event occurring at a similar distance between the on-Range monitor (PEN_R1) and off-Range monitor (PEN_OS2). The event occurred at Central 7 which is equidistant between the two monitoring locations.

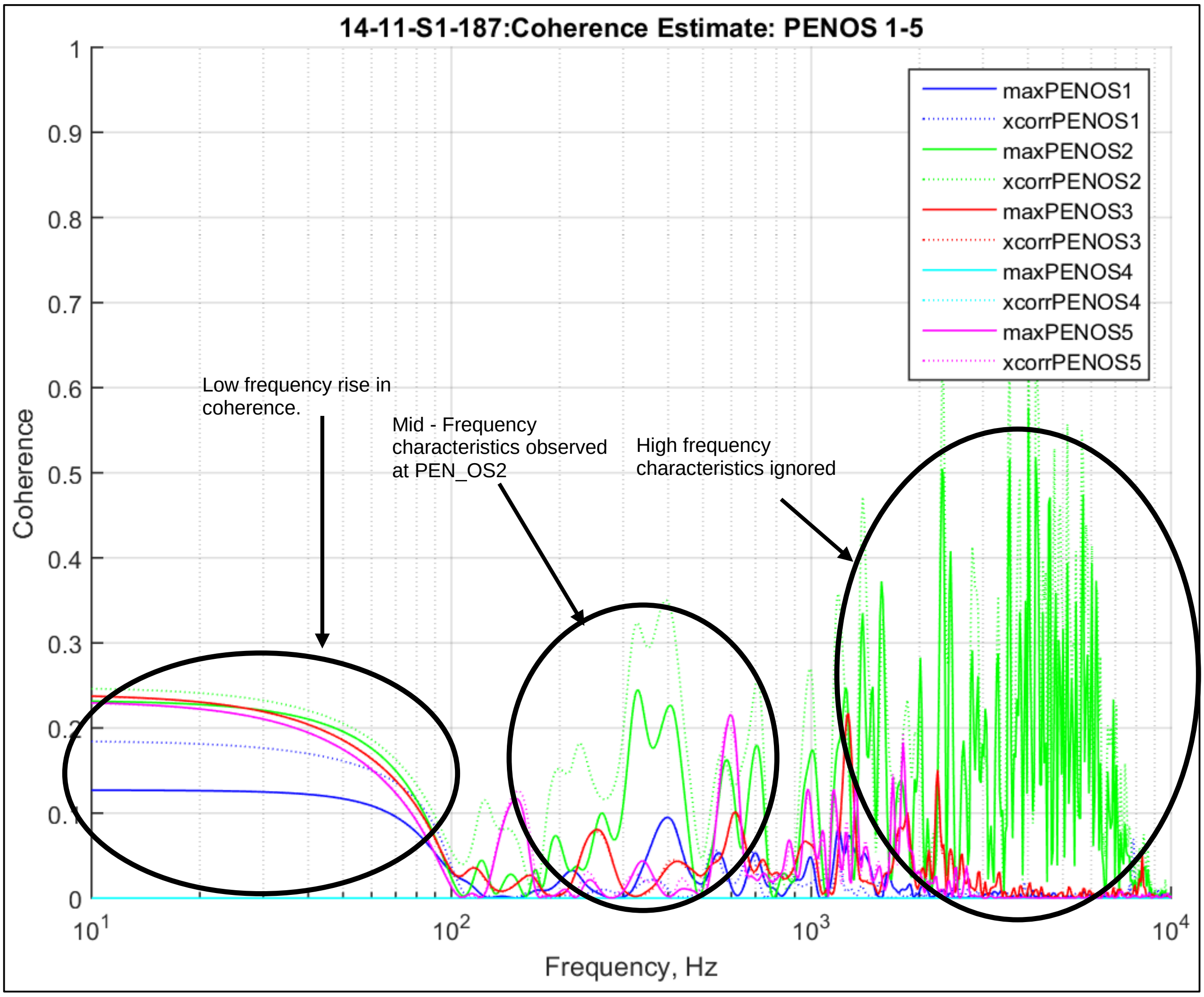


FIGURE 4.22: COHERENCE – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014, PEN_OS1 – PEN_OS5

Notes:
[1] 'max' presents the coherence of the maximum value in the audio signal; and
[2] 'xcorr' presents the coherence of event found by cross correlation.

4.10.11 The coherence traces for PEN_OS1 – PEN_OS5 presented in Figure 4.22 during a 13kg dynamic event show decreasing coherence with increasing frequency in the lower frequency range. Evident, is the steady coherence below approximately 60 Hz which is considered a typical signature for activities from the Range.

4.10.12 At PEN_OS2 it can be seen that there is erratic high frequency coherence, but as this falls outside of the frequency range of interest no further consideration is required. Explosive detonations cause pressure impulses which are broadband in nature at source, and any local environmental noise sources at the off-Range monitors containing similar frequency content have the propensity to give rise to such coherence patterns even though they are totally unrelated in terms of causal link.

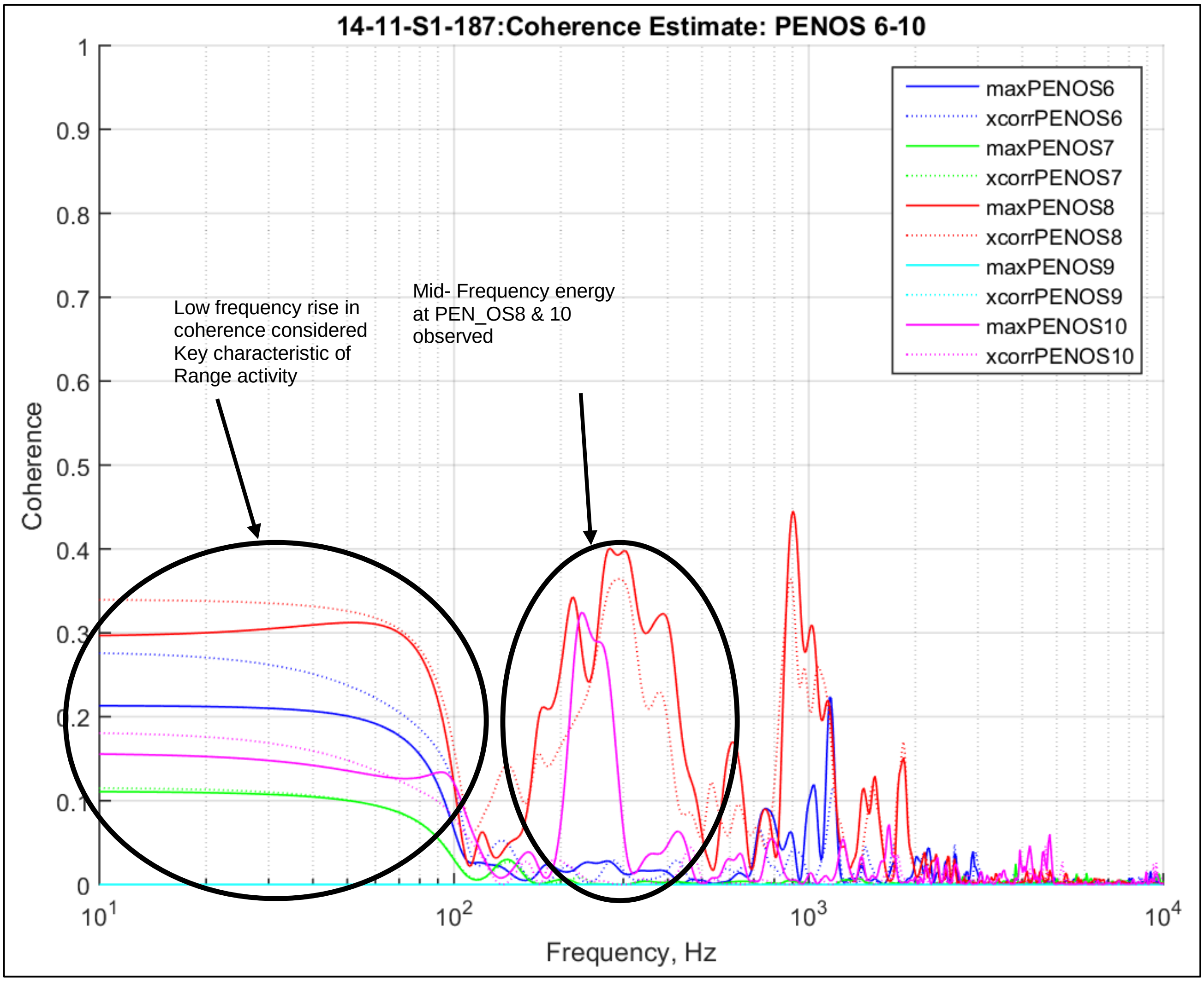


FIGURE 4.23: COHERENCE – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014, PEN_OS6 – PEN_OS10

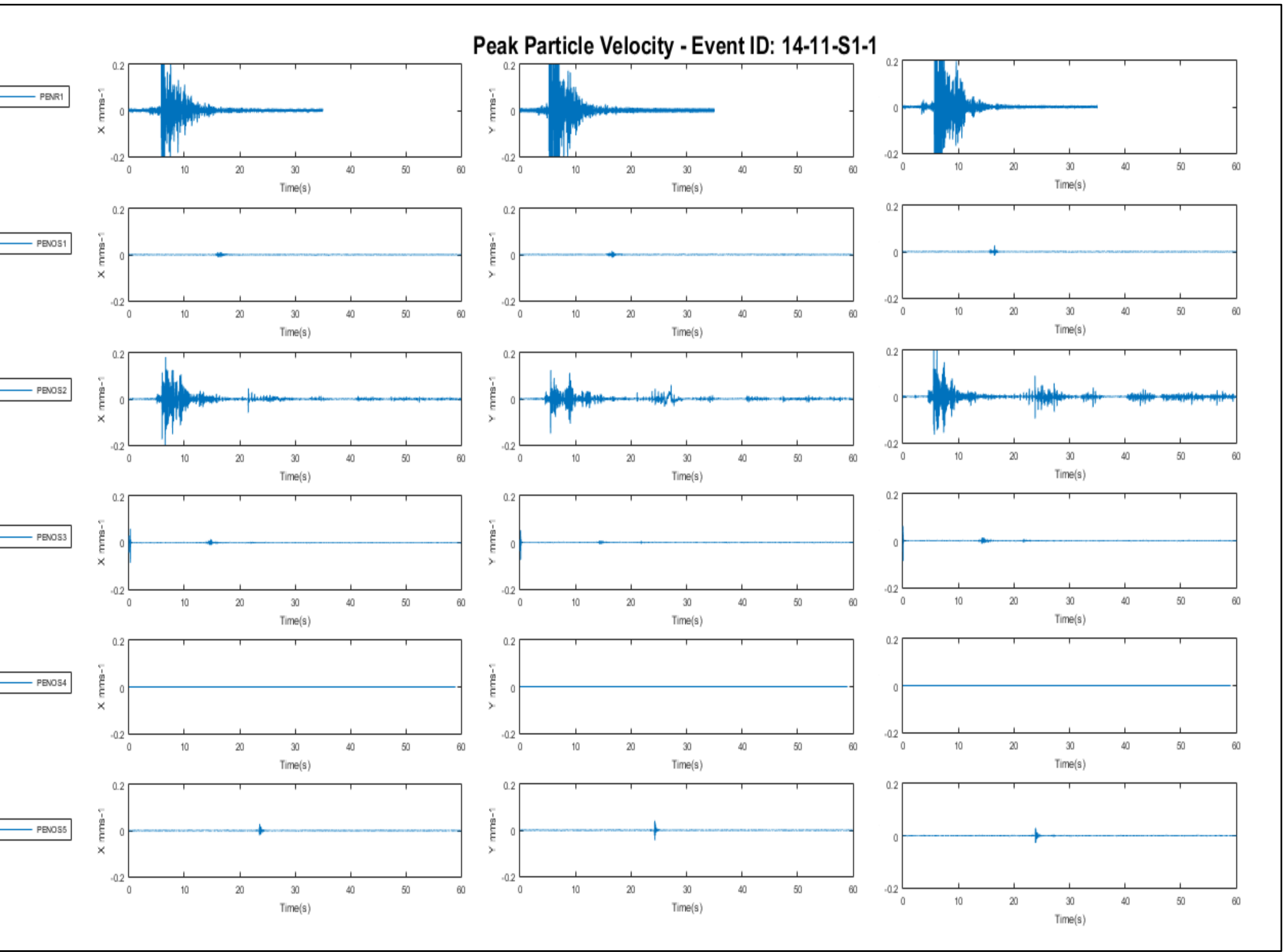
Notes:
[1] 'max' presents the coherence of the maximum value in the audio signal; and
[2] 'xcorr' presents the coherence of event found by cross correlation.

4.10.13 A similar spectral shape of coherence can be seen for PEN_OS8 and PEN_OS10 between 100 and 400 Hz in Figure 4.23 above. Elevated levels of coherence within this range are considered to be a key characteristic of any Range event at these two locations.

Vibration

4.10.14 The velocity traces processed from the raw data signals captured at PEN_OS1 to PEN_0S5 are presented in Figure 4.24, with the applied cross-correlation function presented in Figure 4.25.

4.10.15 While vibration is evident at all locations where equipment was installed, Figure 4.24 highlights the very low magnitudes measured at some locations. Having looked in detail at the event times, and compared them to the sound pressure graphs, there is an indication that the vibration captured during the event is likely to have been caused by a coupling effect with the ground, from the air pressure wave, rather than from direct ground vibration from the site ofthe event.



URE 4.24: VELOCITY SIGNALS – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014, PEN_OS1 – PEN_OS5

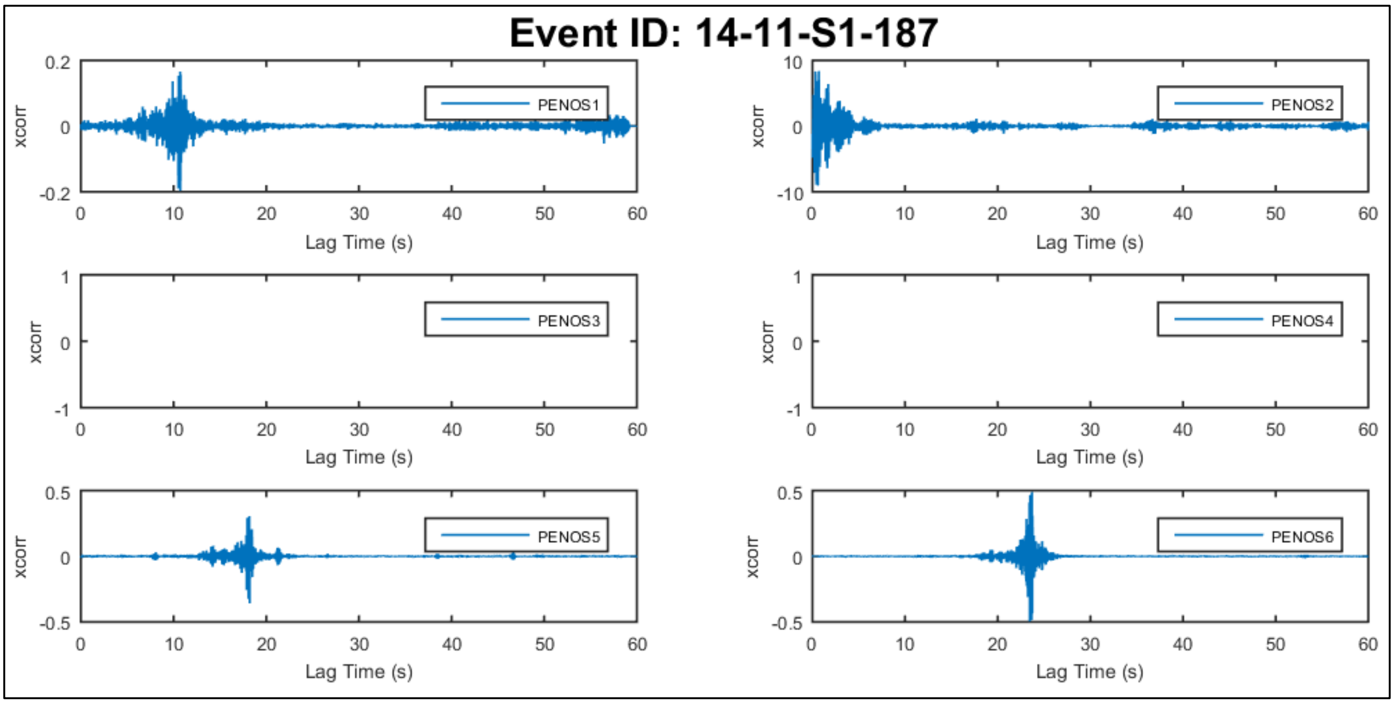


FIGURE 4.25: VELOCITY CROSS-CORRELATION FOR PEN_OS1 TO PEN_OS6 – 13KG DYNAMIC EVENT 14:48 24TH NOVEMBER 2014

Notes:

[1] where cross-correlation is a measure of the similarity as a function of time, specifically the time lag

Detailed Example – 20Kg Static Event, 11:26 on 13th November 2014

4.10.17 Triggered event S1-50 relating to a 20kg static event at 11:26 on 13th November 2014 is presented in Figures 4.26 – 4.36

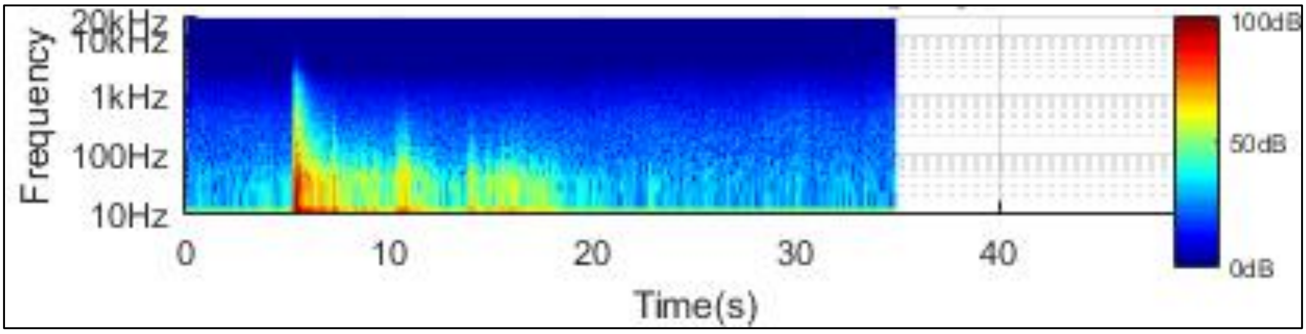


FIGURE 4.26: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – BRILL GATE (PEN_R1)

4.10.18 Figure 4.26 above shows the spectrogram processed from the raw data signal captured by the Range monitor installed at Brill Gate (PEN_R1). As with the previous dynamic event presented in 4.12, the static Range Activity can be seen at approximately 5.6 seconds. The fast rise time in amplitude in frequencies up to 5 kHz is evident along with the concentration of energy up to approximately 500 Hz (represented by red and yellow).

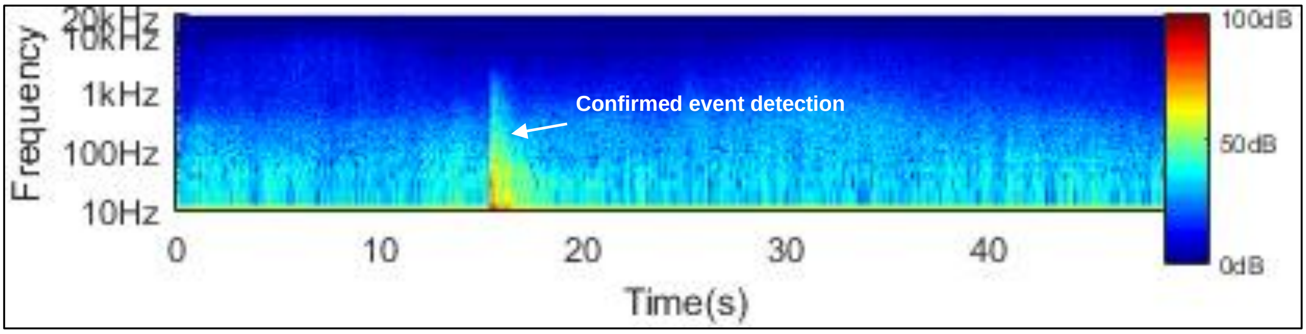


FIGURE 4.27: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS5

4.10.19 Figure 4.27 above show the spectrogram processed from the raw data signal captured at PEN_OS5 during the same 20kg static Range Activity. Unlike the dynamic event, fast rise times are noticeable in the far-field monitoring locations. The spectrograms from the raw signals captured at the other off-Range monitoring locations are presented in Figure 4.28 to 4.33. The low frequency energy observed within the ambient noise levels, especially at PEN_OS3 is attributable to wind noise.

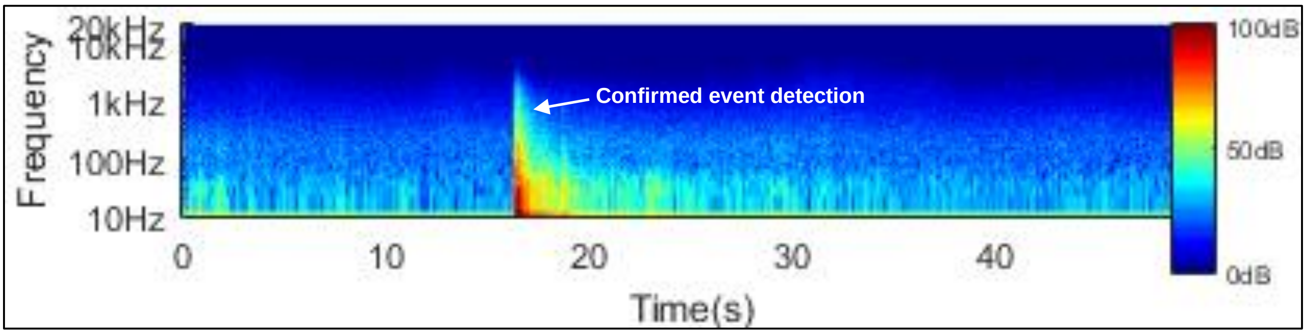


FIGURE 4.28: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS1

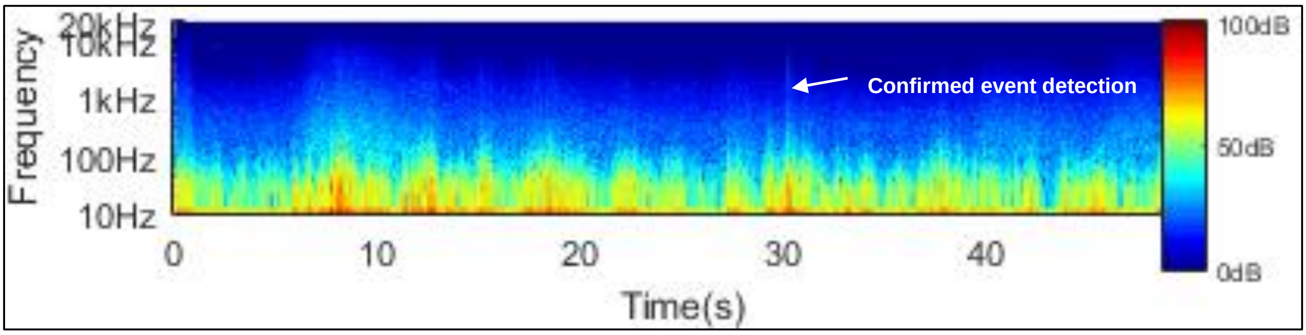


FIGURE 4.29: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS2

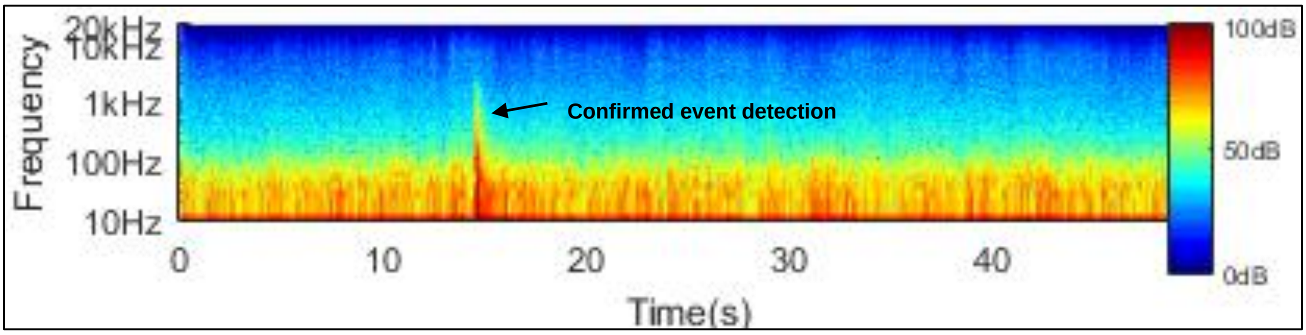


FIGURE 4.30: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS3

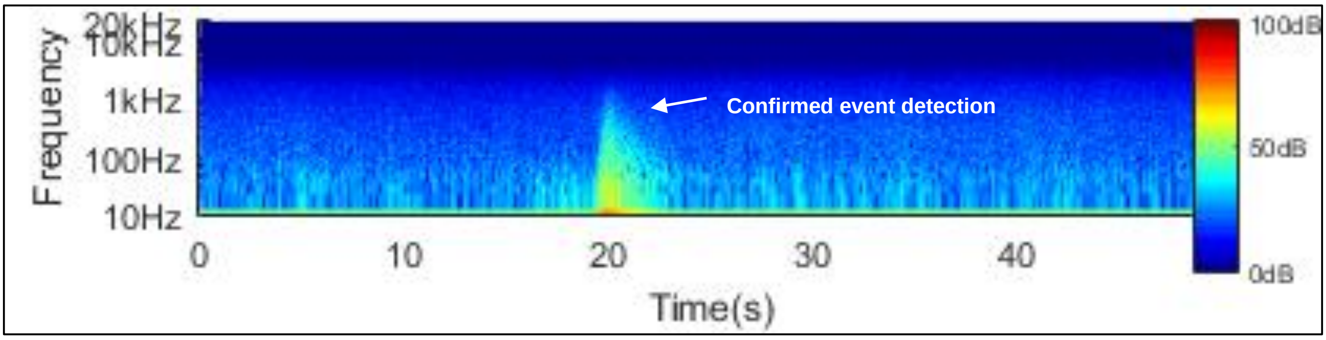


FIGURE 4.31: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS6

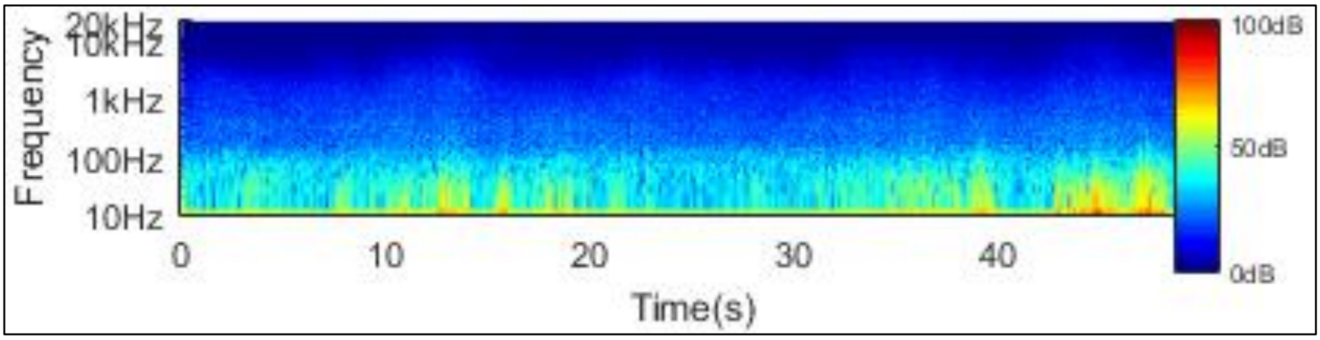


FIGURE 4.32: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS7

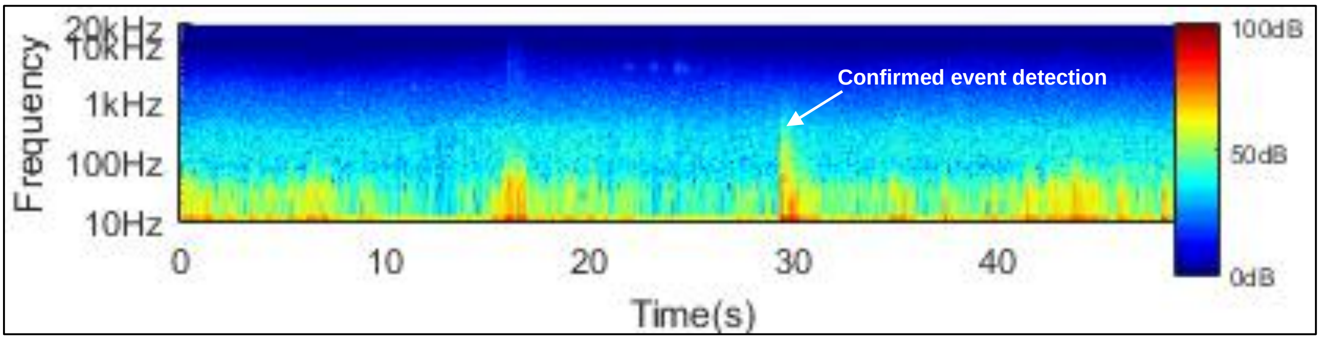


FIGURE 4.33: SPECTROGRAM – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014 – PEN_OS10

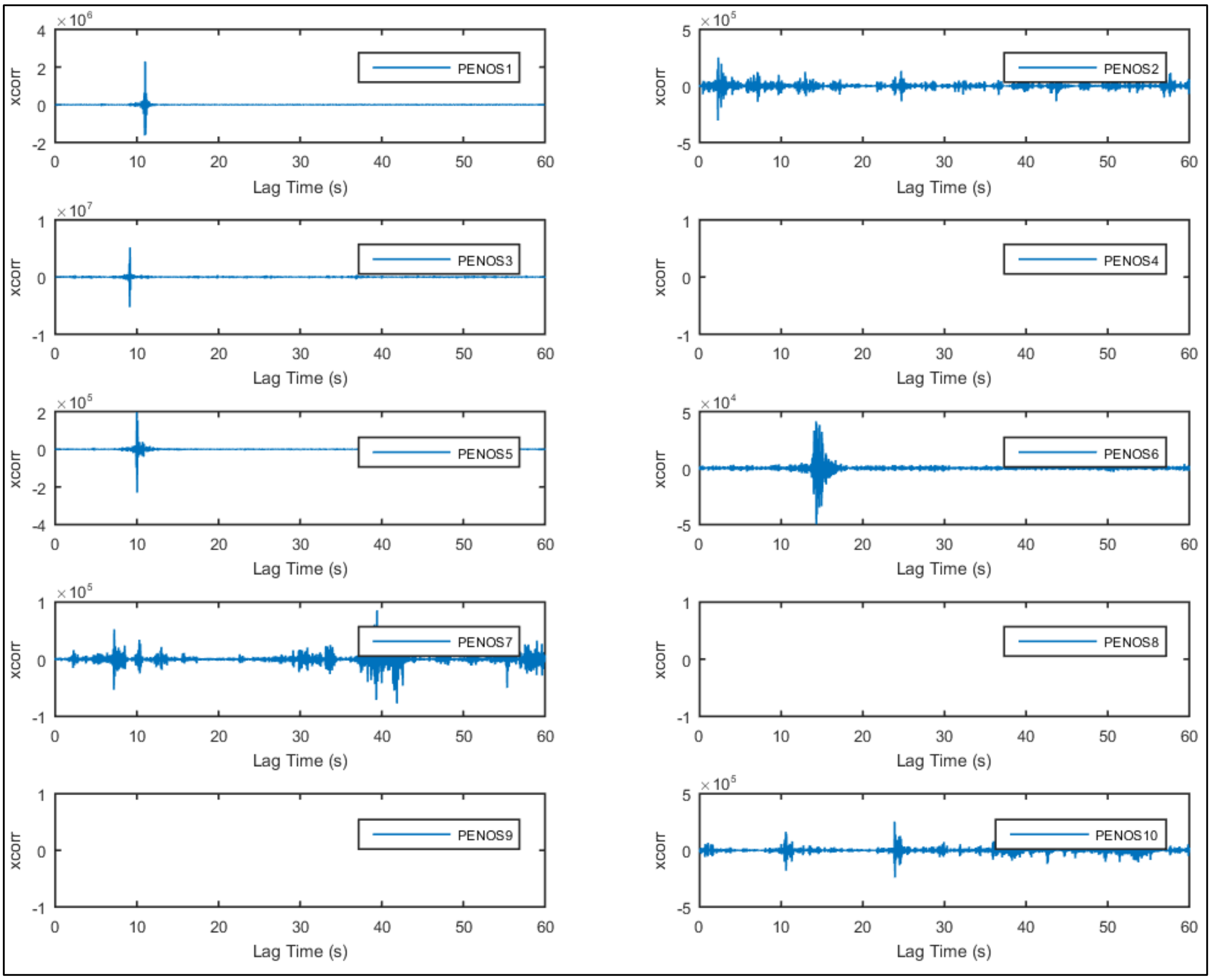


FIGURE 4.34: CROSS-CORRELATION – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014

Notes:
[1] where cross-correlation is a measure of the similarity as a function of time, specifically the time lag.

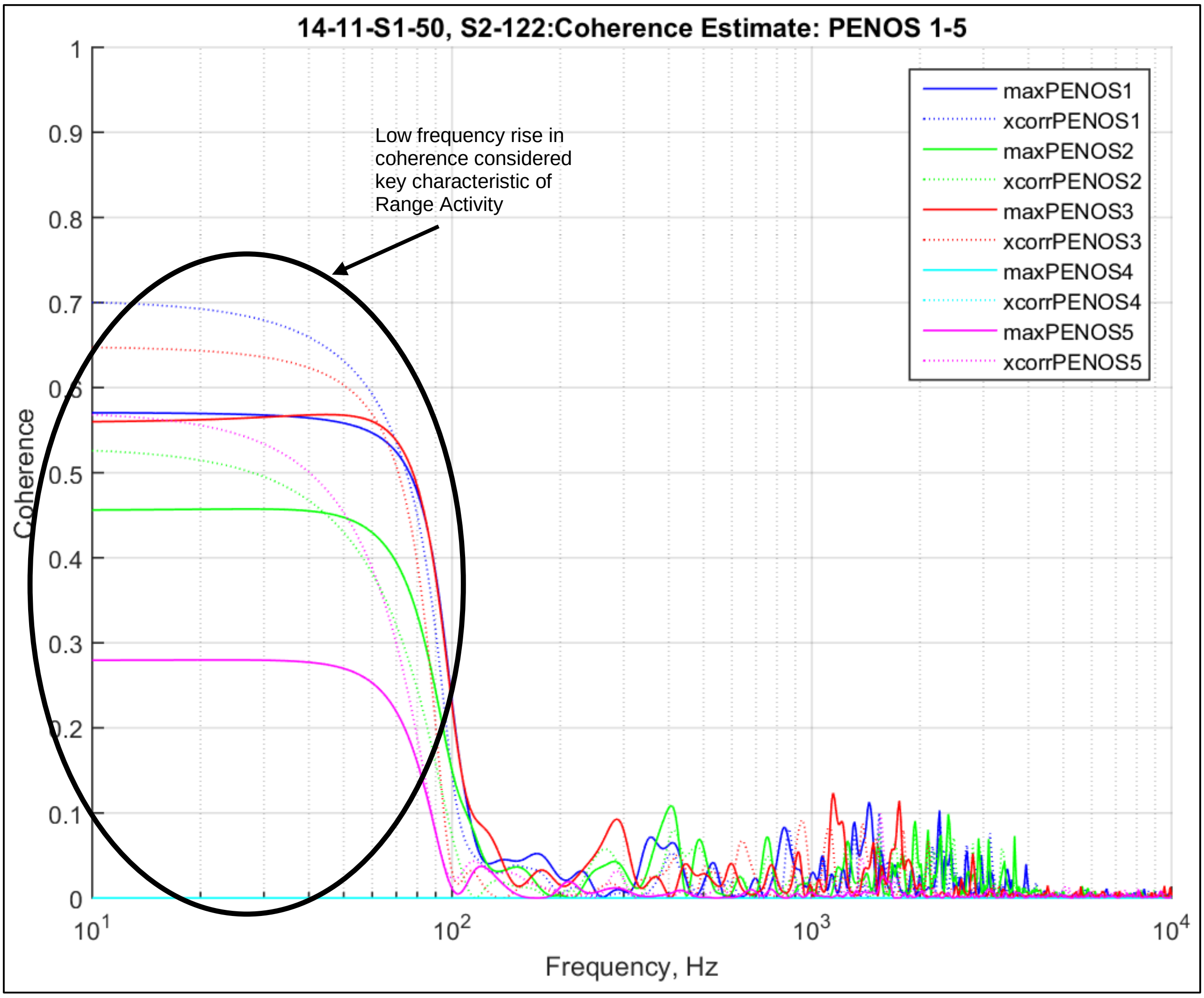


FIGURE 4.35: COHERENCE – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014, PEN_OS1 – PEN_OS5

Notes:
[1] 'max' presents the coherence of the maximum value in the audio signal; and
[2] 'xcorr' presents the coherence of event found by cross correlation.

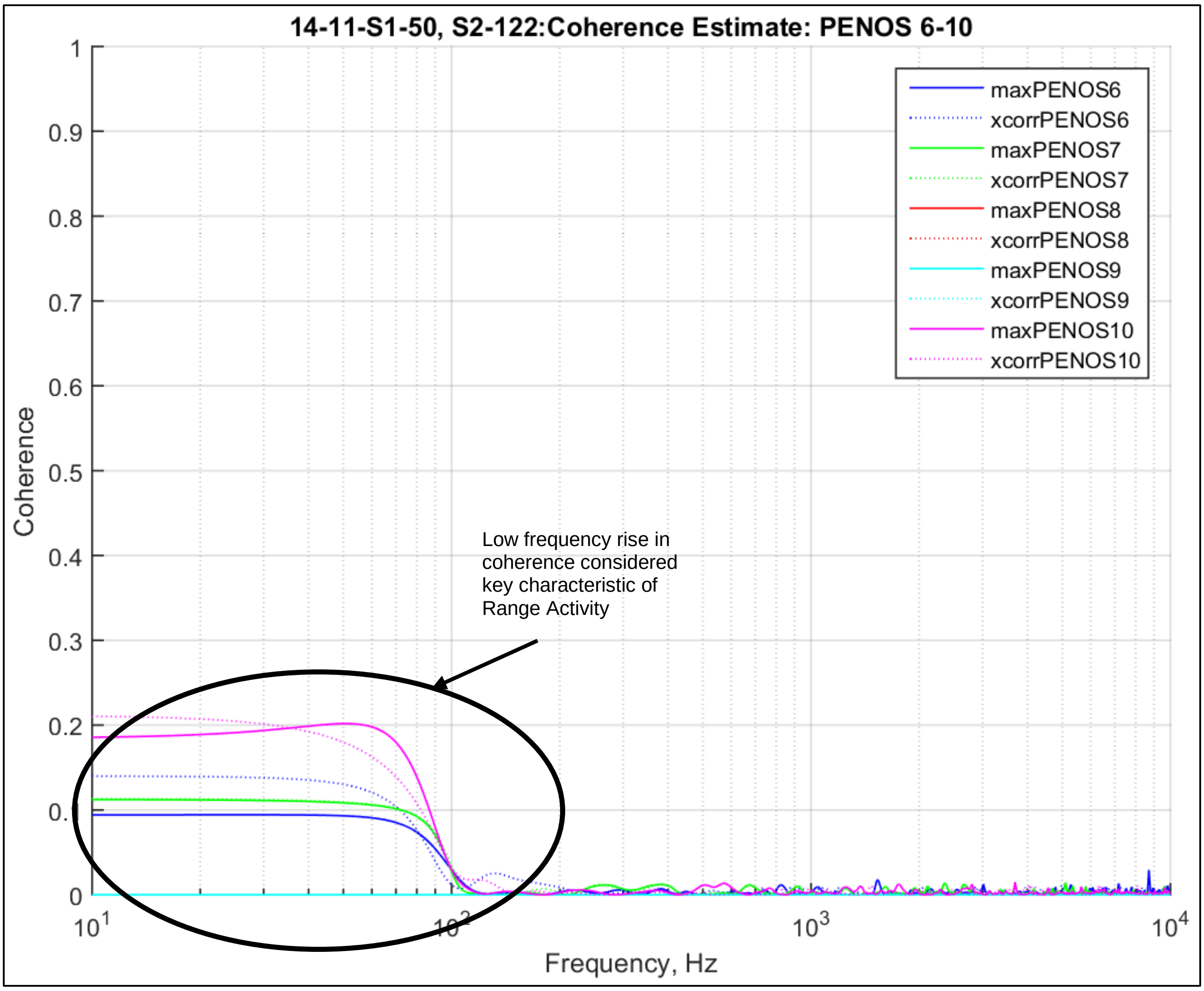


FIGURE 4.36: COHERENCE – 20KG STATIC EVENT 11:26 13TH NOVEMBER 2014, PEN_OS5 – PEN_OS10

Notes:
[1] 'max' presents the coherence of the maximum value in the audio signal; and
[2] 'xcorr' presents the coherence of event found by cross correlation.

Detailed Example – Locally Triggered Non-Range Event (Train Pass-by) PEN_OS8

4.10.20 Figure 4.37 presents the spectrogram of a train pass-by at Ferryside (PEN_OS8) and has been processed to show the differences in acoustic signatures between Range Activities and non-Range Activities contributing to the local noise environment. The example presented in Figure 4.37 can be considered to be typical of a train pass-by. When compared to the dynamic and static events, the absence of particularly low frequency energy is evident.

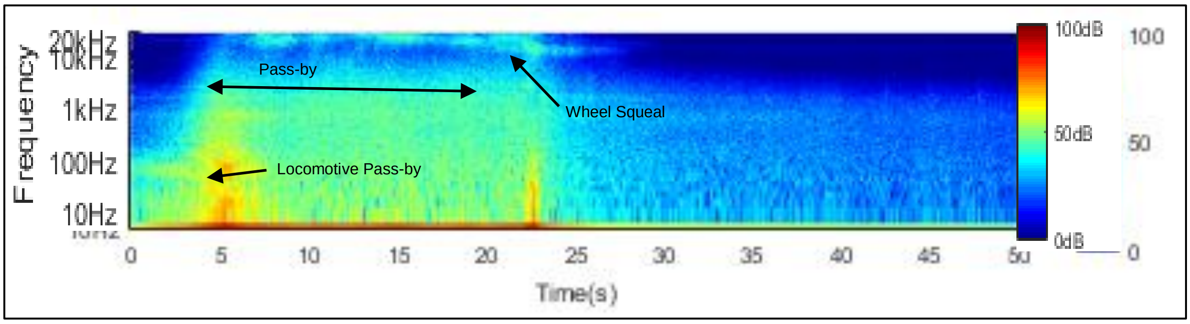


FIGURE 4.37: SPECTROGRAM – LOCALLY TRIGGERED EVENT (TRAIN PASS-BY) – FERRYSIDE PEN_OS8

<u>Detailed Example – Local Trigger Event (Dog Barking), PEN_OS3</u>

4.10.21 In addition to train pass-by presented in above, a local event captured at The Coach House (PEN_OS3) triggered by a dog barking has also been processed and is presented in Figure 4.38 below. As with the train pass-by at Ferryside, when comparing the acoustic signature of Range Range Activities, the absence of low frequency energy is evident, and other characteristics are revealed by the spectrogram enabling a clear visual checking process for all triggered events at off-Range monitors, thus improving the quality of assessment and conclusions presented in this report.

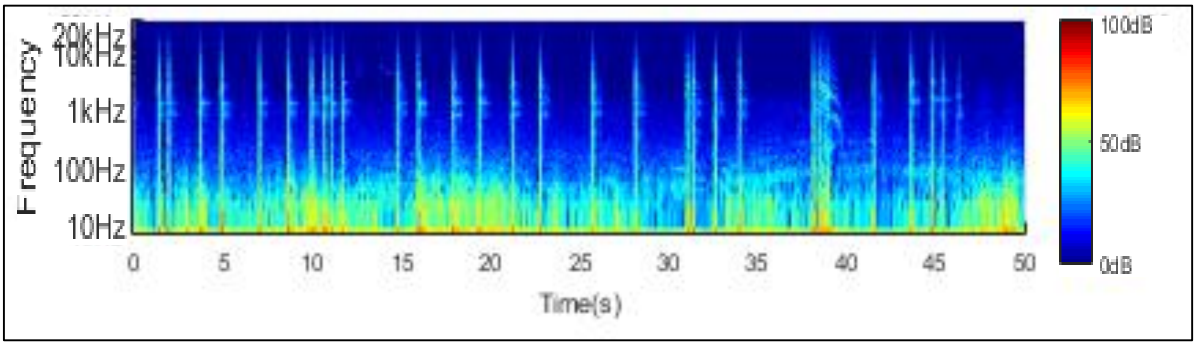


FIGURE 4.38: SPECTROGRAM – LOCALLY TRIGGERED EVENT (DOG BARKING) – PEN_OS3