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6.4 Responses of the Infrasound Channels of ARCES and NORES

6.4.1 ARCES infrasound station instrument response

ARCES has been complemented with an experimental infrasound array. Three sites, ARA1, ARA2, ARB2, were installed in 2008 (Roth et al., 2008) and one additional site ARB3 was installed in 2010. The infrasound sensors and digitizers share the same pit as the seismic sensors and the acquisition system consists of a Güralp CMG-DM24 digitizer and a Martec MB2005 microbarometer.

Fig. 6.4.1 ARCES seismic and infrasound instrumentation, as installed in the field.

Fig. 6.4.1 above shows one ARCES pit with seismic and infrasound acquisition system. Clockwise from top we see the short-period GS13 seismometer (red casing), the pit tamper switch, the power/communication box, the Nanometrics digitizer for the seismic sensor, the MB2005 microbarometer , the Güralp CMG-DM24 digitizer (black Pelicase) and an inlet for the hose and GPS cable. Outside of the pit we are using four twelve meter long porous hoses laid out in a cross pattern acting as air inlet and wind noise reduction system. The infrasound data from the four pits are recorded on a laptop in the ARCES central recording facility for local backup and are immediately forwarded to the NORSAR data center at Kjeller.

Fig. 6.4.2 Picture of an opened MB2005 sensor (left: electronic card, right: barometric aneroid bellows and displacement transducer).

The response characteristics (poles/zeros, sensitivity values and digital filters) of the ARCES (ARCI) infrasound stations, equipped with MB2005 microbarometers and Güralp CMG-DM24 digitizers, are listed below.

	Real part	Imaginary part
Poles (2)		
Real pole	-0.03141593	0
Real pole	-99.9968941	0
Zeros (1)		
Zero	0	0

Table 6.4.1. Poles and zeros in rad/s for the MB2005 microbarometer (MARTEC, 2007).

The sensitivity of the MB2005 is equal to 20 mV/Pa.

The sensitivity values for the digitizers installed at ARCI are shown in Table 6.4.2.

Channel	Digitizer serial number	sensitivity
ARA1 BDF	A087	3.185 μV/count
ARA2 BDF	A222	3.189 μV/count
ARB2 BDF	A093	3.170 μV/count
ARB3 BDF	A216	3.178 μV/count

Table 6.4.2. Digitizer sensitivity values for the ARCES infrasound channels.

ARCES infrasound channels output data at 80 sps. The digital filters of the DM24 used to output this sampling rate are listed in Table 6.4.3. They correspond to a TTL value of 79 in the Güralp Systems tabulated, decimation cascade look-up system.

Input sampling rate	Digital filter name	Decimation	Symmetry	N coeff.
512000 sps	CS5376 stage 1, sinc-1	8	symmetric even	36
64000 sps	CS5376 stage 3, sinc-2	2	symmetric even	6
32000 sps	CS5376 stage 4, sinc-2	2	symmetric odd	7
16000 sps	CS5376 stage 5, FIR 1	4	symmetric even	48
4000 sps	CS5376 stage 6, FIR 2	2	symmetric even	126
2000 sps	DM24 FIR stage 1, SWA-D24-3D08	5	symmetric odd	501
400 sps	DM24 FIR stage 2, SWA-D24-3D08	5	symmetric odd	501

Table 6.4.3. Digital FIR filter cascade TTL = 79 and corresponding filter characteristics, used to output the selected sampling rate for the ARCES infrasound data.

The ARCES infrasound (ARCI) configuration described above and corresponding *Respid* flags (Pirli, 2010) are listed in Table 6.4.4.

Time	Channel	Installation name Respid(s)	System components	Calib [Pa/count]	Calper [s]
2008/05/13 – …	ARA1 BDF ARA2 BDF ARB2 BDF	ARCIBD1	MB2005 microbarometer CMG-DM24 digitizer	0.00015925 0.00015945 0.00015850	1
2010/10/08 – …	ARB3 BDF	ARCIBD1	MB2005 microbarometer CMG-DM24 digitizer	0.00015890	1

Table 6.4.4. Instrument configuration for the ARCES infrasound stations.

The amplitude and phase response of the ARCI configuration described above is shown in Fig. 6.4.5 (blue curve), at the end of section 6.4.2.

6.4.2 NORES infrasound station instrument response

In 2013, we started with the installation of infrasound sensors at the NORES array, with the intention to establish a 9-site infrasound array using the inner sites (ring A and B) of the seismic array. Three sites, NRA1, NRA2, NRA3, were completed in February and five more, NRA0, NRB2, NRB3, NRB4, NRB5, on April 19. At site NRB1 the infrasound sensor was installed on May 6, 2013. The infrasound acquisition system consists of Hyperion IFS-3000 sensors and Güralp CMG-DM24 digitizers. Infrasound and seismic sensors are co-located in the same pit and they are connected to the same digitizer. The seismic sensor is connected to the conventional Z, N, E channels of the digitizer and the infrasound sensor to the so-called X channel (the X-channels have similar sensitivities to the

conventional data channels and can be used amongst others as calibration signal monitor). Data are recorded in the NORES central recording facility and forwarded to the NORSAR data centre at Kjeller. Fig. 6.4.3 below shows the geometry of the NORES array. The sites marked with magenta symbols have seismic and infrasound sensors. The outer sites marked in red are currently not used, but will be equipped with seismic sensors at a later time.

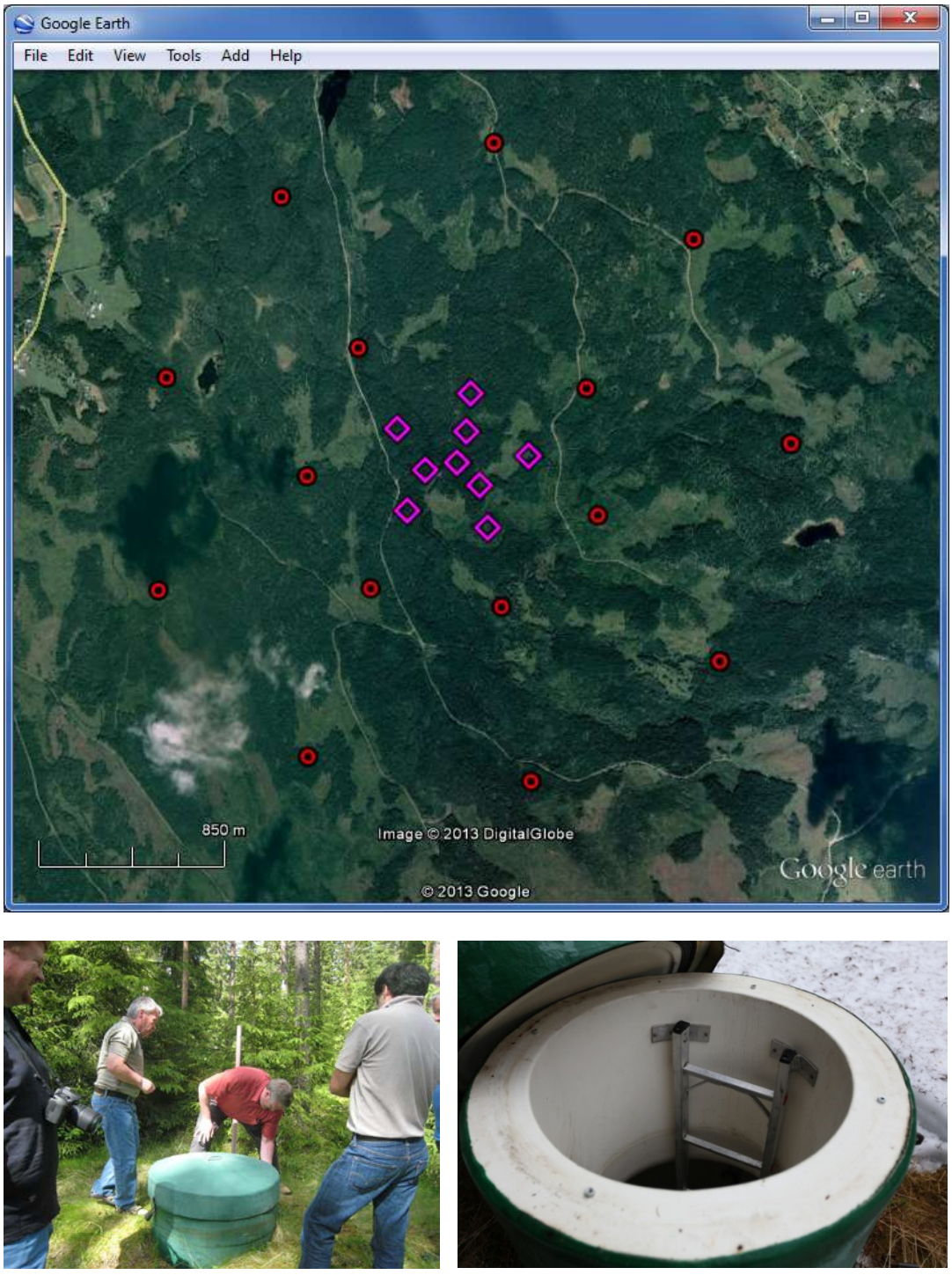

Fig. 6.4.3 Map of NORES array location and geometry. Circles note future sites with seismic channels, while rhombuses note currently sites with both seismic and infrasound channels (top). Cover (left) and entrance (right) to one of the NORES sites (bottom).

For the time being, we do not have a wind noise reduction system for the infrasound sensors. The sensor is simply placed at the floor of the pit and air pressure variations can access the pit through the gap between the lid and the rim of the pit. We are using screw nuts and washers placed on the rim of the entrance (see Fig. 6.4.3, photo at bottom right) to create a small gap/inlet to the pit.

Fig. 6.4.4 NORES seismic and infrasound instrumentation, as installed in the field.

Fig. 6.4.4 above shows clockwise from the top left corner one of the two horizontal short-period seismic sensors (red casing), the seismometer pre-amplifiers, a coupling box, the Hyperion infrasound sensor (white casing) and the Güralp CMG-DM24 digitizer. The inlet of the IFS-3000 is protected by a piece of sponge rubber.

The response characteristics (poles/zeros, sensitivity values and digital filters) of the NORES infrasound stations, equipped with Hyperion IFS-3000 infrasound sensors and Güralp CMG-DM24 digitizers are listed below.

	Real part	Imaginary part
Poles (3)		
Real pole	-0.00931796379	0
Real pole	-0.0212811486	0
Real pole	-0.185291134	0
Zeros (3)		
Zero	0	0
Zero	0	0
Zero	0	0

Table 6.4.5. Poles and zeros in rad/s for the IFS-3000 infrasound sensor (Hyperion Technology Group, 2012).

The sensitivity of the IFS-3000 is equal to 150 mV/Pa at 1 Hz.

The sensitivity values for the digitizers installed at NORES are shown in Table 6.4.6. As mentioned earlier, the Calibration Signal Monitoring channel of the digitizer is being used for the infrasound channels.

Channel	Digitizer serial number	sensitivity
NRA0 BDF	A203 (A203X2)	3.185 μV/count
NRA1 BDF	A098 (A098X2)	3.177 μV/count
NRA2 BDF	A085 (A085X2)	3.171 μV/count
NRA3 BDF	A253 (A253X2)	3.180 μV/count
NRB1 BDF	A309 (A309X2)	3.173 μV/count
NRB2 BDF	A247 (A247X2)	3.173 μV/count
NRB3 BDF	A287 (A287X2)	3.184 μV/count
NRB4 BDF	A217 (A217X2)	3.182 μV/count
NRB5 BDF	A313 (A313X2)	3.162 μV/count

Table 6.4.6. Digitizer sensitivity values for the NORES infrasound channels.

NORES infrasound channels output data at 80 sps. The digital filters of the CMG-DM24 used to output this sampling rate are listed in Table 6.4.7. They correspond to a TTL value of 91.

Input sampling rate	Digital filter name	Decimation	Symmetry	N coeff.
512000 sps	CS5376 stage 1, sinc-1	8	symmetric even	36
64000 sps	CS5376 stage 3, sinc-2	2	symmetric even	6
32000 sps	CS5376 stage 4, sinc-2	2	symmetric odd	7
16000 sps	CS5376 stage 5, FIR 1	4	symmetric even	48
4000 sps	CS5376 stage 6, FIR 2	2	symmetric even	126
2000 sps	DM24 FIR stage 1, SWA-D24-3D08	5	symmetric odd	501
400 sps	DM24 FIR stage 2, SWA-D24-3D08	5	symmetric odd	501

Table 6.4.7. Digital FIR filter cascade TTL = 91 and corresponding filter characteristics, used to output the selected sampling rate for the NORES infrasound data.

The NORES infrasound configuration described above and corresponding *Respid* flags (Pirli, 2010) are listed in Table 6.4.8.

Time	Channel	Installation name Respid(s)	System components	Calib [Pa/count]	Calper [s]
2013/02/06 – …	NRA1 BDF NRA2 BDF NRA3 BDF	NORESBD1	IFS-3000 infrasound sensor CMG-DM24 digitizer	0.00002118 0.00002114 0.00002120	1
2013/04/19 – …	NRA0 BDF NRB2 BDF NRB3 BDF NRB4 BDF NRB5 BDF	NORESBD1	IFS-3000 infrasound sensor CMG-DM24 digitizer	0.00002123 0.00002115 0.00002123 0.00002121 0.00002108	1
2013/05/06 – …	NRB1 BDF	NORESBD1	IFS-3000 infrasound sensor CMG-DM24 digitizer	0.00002115	1

Table 6.4.8. Instrument configuration for the NORES infrasound stations.

The amplitude and phase response for the NORES infrasound configuration described above is shown in Fig. 6.4.5 (red curve). The shaded area marks the frequency range beyond the Nyquist frequency.

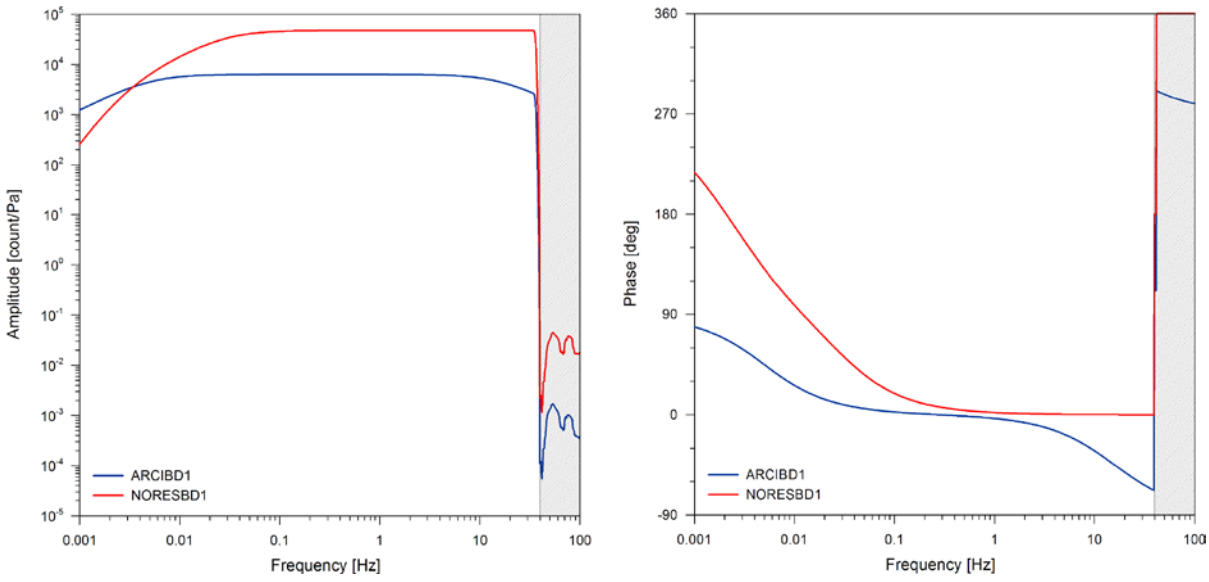

Fig. 6.4.5 Amplitude and phase response for the infrasound stations of ARCES (blue) and NORES (red). Shading marks the frequency range beyond the Nyquist (= 40 Hz).

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