



ANALISI PRELIMINARI RELATIVE ALLA CARATTERIZZAZIONE DEL COMPORTAMENTO DINAMICO DI STRUTTURE E TERRENI RICADENTI NELLE AREE INTERESSATE DAL SISMA DEL 24/08/2016 (TERREMOTO CENTRO ITALIA 2016)

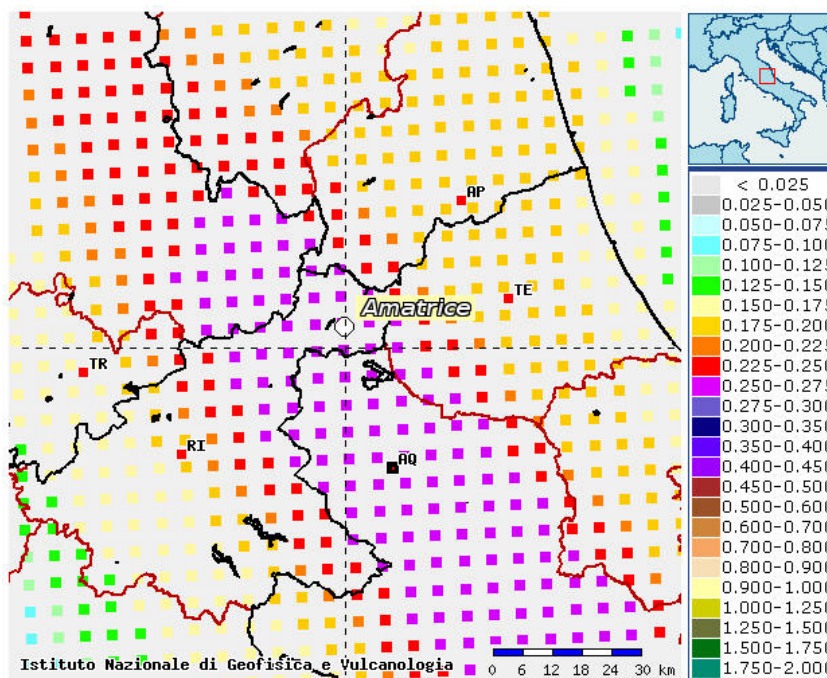
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Dipartimento della Protezione Civile, Presidenza del Consiglio dei Ministri



Mappa di Pericolosità Sismica del Territorio (Accelerazione in frazione di g, probabilità di superamento del 10% in 50 anni)

* Le attività svolte sono state focalizzate sul monitoraggio degli edifici

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PREMESSA

A valle dell'evento sismico avvenuto il 24 agosto 2016 alle 3.36 (ora locale), con epicentro ubicato nella Valle del Tronto tra i comuni di Accumoli, Amatrice (Provincia di Rieti) e Arquata del Tronto (Provincia di Ascoli Piceno), è stata avviata una serie di attività di monitoraggio del comportamento dinamico di alcune strutture di interesse strategico per la Protezione Civile, ubicate nelle zone prossime all'epicentro, e di valutazione degli effetti di amplificazione locale del terreno (sia in fase strong motion che in rumore ambientale) nelle zone colpite dal sisma (con particolare riferimento al Comune di Amatrice).

I dati sperimentali sono stati acquisiti mediante due stazioni velocimetriche tridirezionali opportunamente sincronizzate, con frequenza propria pari a 0.5Hz e risoluzione pari a 24bit.

Il presente rapporto fornisce in via preliminare ed in maniera sintetica i risultati della campagna sperimentale per la caratterizzazione dinamica di siti e strutture effettuata nei giorni 13 e 14 settembre 2016 nei comuni di Amatrice, Antrodoto e Norcia (Figura 1) e le prime interpretazioni dei dati acquisiti. Le attività di analisi e di acquisizione dei dati sono tuttora in corso.



Figura 1: Immagine Satellitare dei Siti Investigati

Analisi preliminari del MainShock acquisito alla stazione AMT della Rete Accelerometrica Nazionale

Le risultanze preliminari di seguito riportate sono riferite all'evento sismico principale (mainshock) acquisito dalla stazione accelerometrica AMT (ubicata nel comune di Amatrice su sottosuolo di Tipo B*) della Rete Accelerometrica Nazionale (RAN). La risposta in vibrazione ambientale del sito ospitante la stazione AMT è quasi piatta, così come mostrato dalla Figura 2.

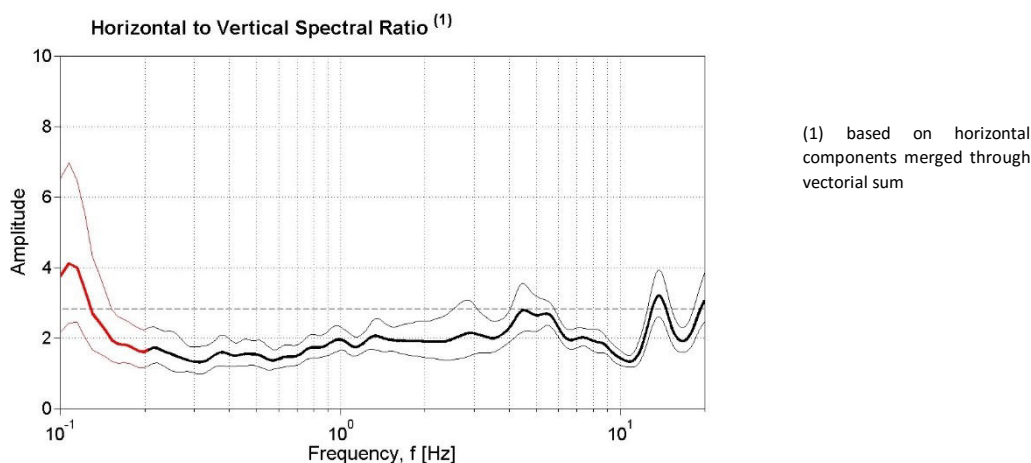


Figura 2: HVSr del sito ospitante la stazione AMT della Rete RAN (fonte INGV)

L'evento sismico principale è stato acquisito con una frequenza di campionamento pari a 200Hz (dati ITACA INGV) ed è caratterizzato da una PGA pari a 0.43g (come rappresentato in Figura 3).

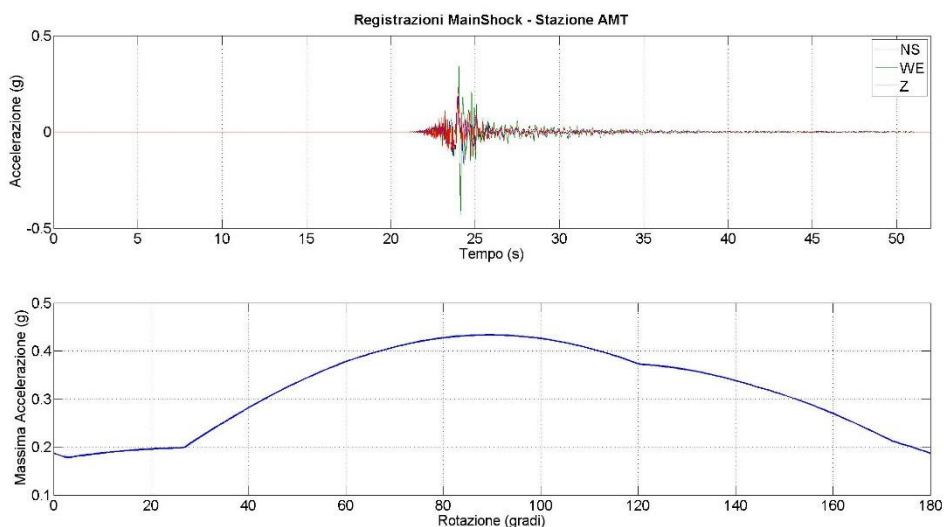


Figura 3: Analisi Rotazionale dell'evento sismico principale

È interessante notare la forte direttività che caratterizza l'evento sismico: lungo la direzione NS l'accelerazione massima risulta inferiore a 0.2g e raggiunge il suo valore massimo a circa 90° dalla stessa, dunque, in corrispondenza della direzione WE. Al fine di comprendere le azioni trasmesse alle strutture, sono stati calcolati gli spettri di risposta in accelerazione lungo le direzioni comprese tra 0° e 180° (la parte restante sarebbe simmetrica). Le risultanze sono state rappresentate in Figura 4.

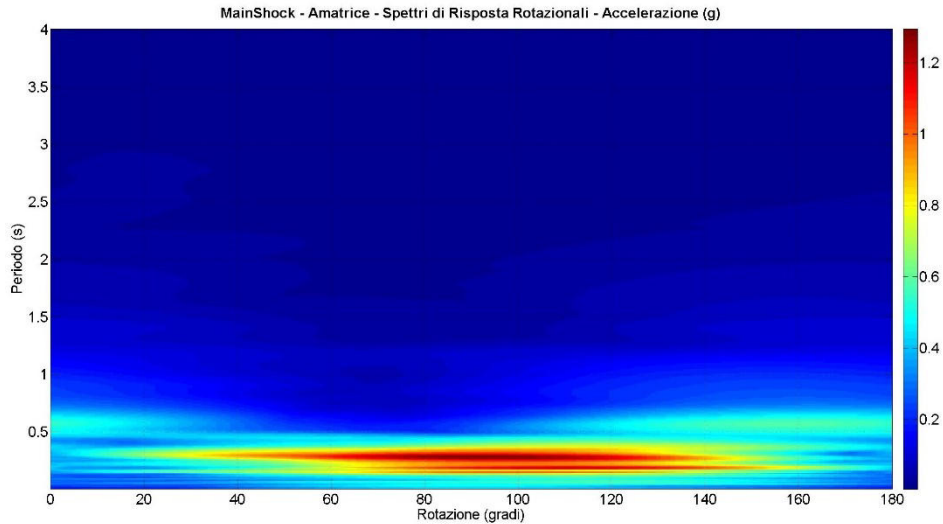


Figura 4: Spettri di Risposta in Accelerazione valutati lungo le direzioni comprese tra 0° e 180°

L'analisi rotazionale consente di visualizzare meglio la distribuzione dell'energia del terremoto ai diversi periodi e lungo le diverse direzioni. Le analisi preliminari condotte sui dati hanno messo in evidenza che la massima accelerazione spettrale si è manifestata lungo una direzione posta a 93° dalla direzione NS con un valore pari a 1.295g, in corrispondenza di un periodo pari a 0.28s.

Si riportano di seguito i risultati delle analisi tempo-frequenza effettuate sulla registrazione del mainshock (stazione AMT) e rappresentate in Figura 5.

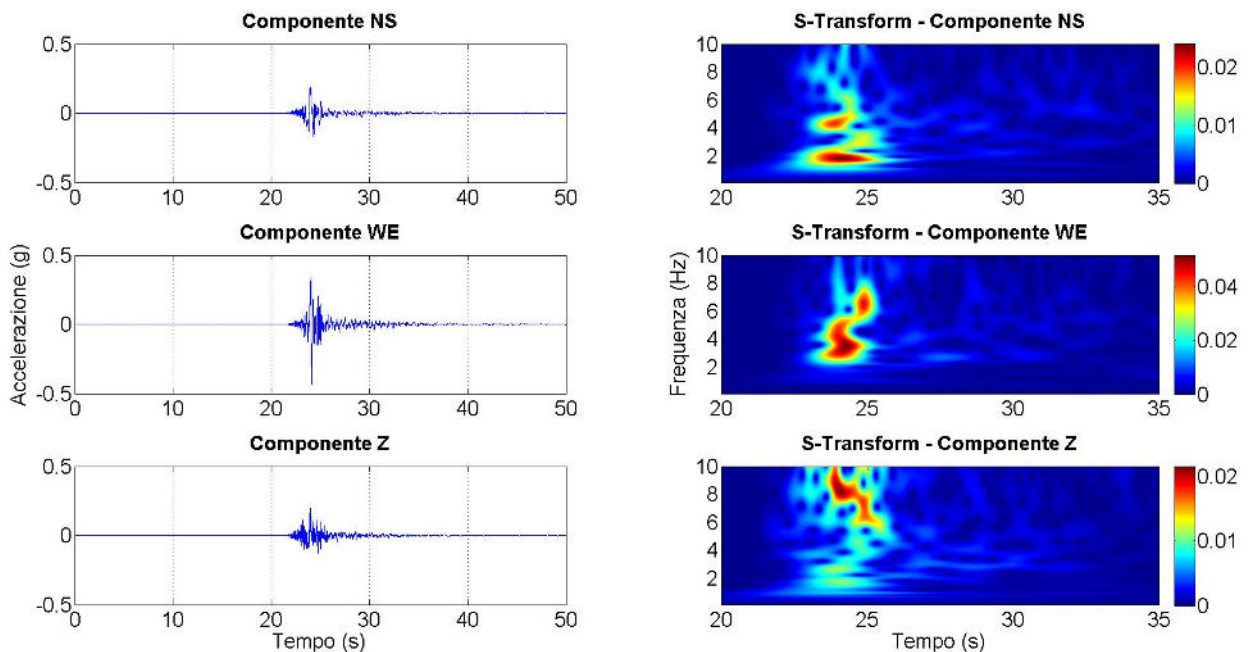


Figura 5: Trasformata di Stockwell del Mainshock

Le analisi effettuate mediante la trasformata di Stockwell evidenziano un contributo energetico della componente WE circa doppio rispetto a quello della componente NS. Inoltre, in direzione NS la massima energia è stata rilasciata in un intervallo di tempo pari a circa 2s e in un intervallo di frequenze prossimo a 2Hz. Al contrario, lungo la direzione WE la massima energia è stata rilasciata in un intervallo di tempo pari a

circa 2s e in un intervallo di frequenze compreso tra 2Hz e 6Hz. La componente verticale esibisce un picco di energia nell'intervallo di frequenze compreso tra 7.5Hz e 9Hz.

Analisi delle registrazioni in rumore ambientale effettuate nell'abitato di Amatrice

Al fine di caratterizzare il comportamento dinamico del sottosuolo in corrispondenza della zona più danneggiata dell'abitato di Amatrice, il giorno 14 settembre 2016 sono state effettuate diverse acquisizioni in rumore ambientale sui siti rappresentati in Figura 6 e Figura 7.

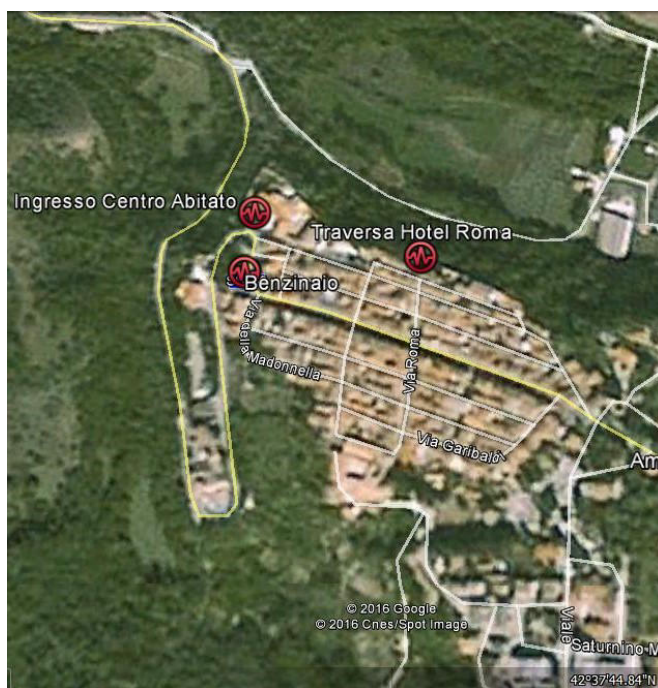


Figura 6: Mappa dei siti delle Indagini Vibrazionali effettuate nell'abitato di Amatrice



Figura 7: Coordinate GPS dei siti delle Indagini Vibrazionali effettuate nell'abitato di Amatrice

I risultati preliminari delle indagini vibrazionali sono di seguito riportati in termini di HVSR e di HVSR rotazionali:

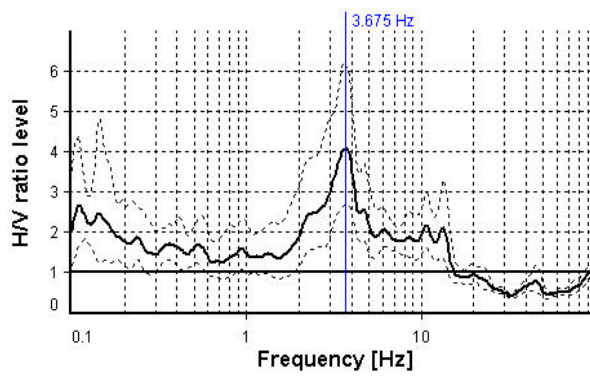


Figura 8: Analisi HVSR - Ingresso Centro Abitato

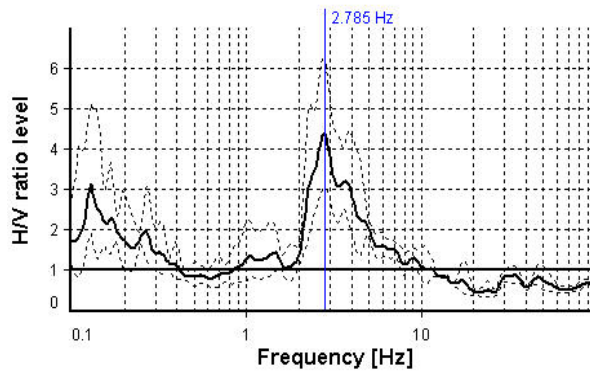


Figura 9: Analisi HVSR – Benzinaio

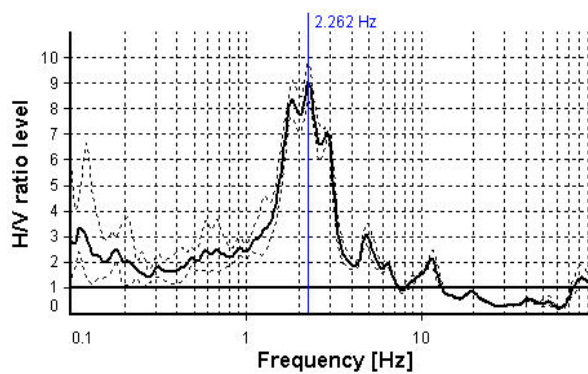


Figura 10: Analisi HVSR - Traversa Hotel Roma

È interessante notare come tutti i siti investigati presentino un picco di amplificazione significativo in un intervallo di frequenze potenzialmente di interesse per le strutture ubicate nel centro abitato. Inoltre, le frequenze di risonanza evidenziate sono tutte prossime alla frequenza in corrispondenza della quale il terremoto ha esibito il massimo valore di accelerazione spettrale ($T=0.28s \Rightarrow f=3.57Hz$) (Vedi Figura 4). Tali considerazioni sembrerebbero avvalorate dal fatto che le strutture più alte (per esempio, la torre campanaria), caratterizzate da periodi fondamentali di oscillazione più elevati, hanno risentito meno dell'azione del terremoto.

Caratterizzazione Dinamica delle Strutture e dei Terreni di Fondazione - Norcia (PG)

Al fine di caratterizzare il comportamento dinamico delle strutture (e dei terreni di fondazione) di interesse strategico per il Dipartimento Nazionale di Protezione Civile, nell'area del comune di Norcia (PG), il giorno 13 settembre 2016, sono state effettuate diverse acquisizioni in rumore ambientale sui siti rappresentati in Figura 11.

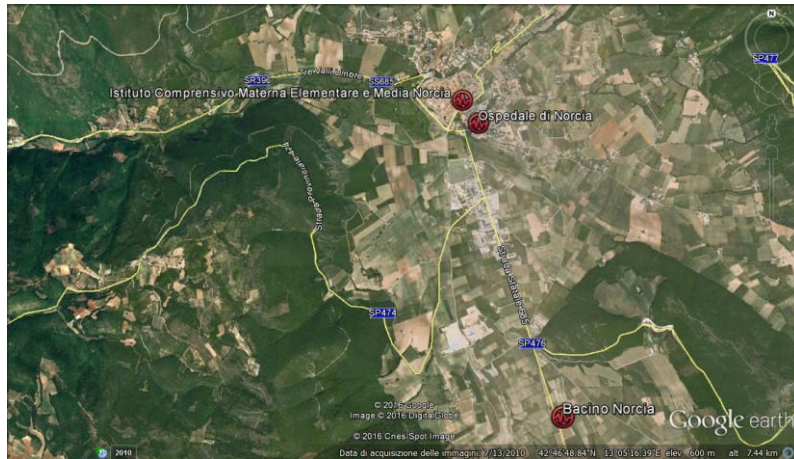


Figura 11: Mappa delle Indagini Vibrazionali effettuate a Norcia

In particolare, sono state caratterizzate le frequenze fondamentali di oscillazione dell'Istituto Comprensivo (Materna, Elementari e Medie), dell'Ospedale e dei relativi terreni di fondazione al fine di verificare la possibilità di fenomeni di risonanza terreno-struttura. I risultati preliminari delle indagini vibrazionali sono di seguito riportati (Figura 12 e Figura 13):

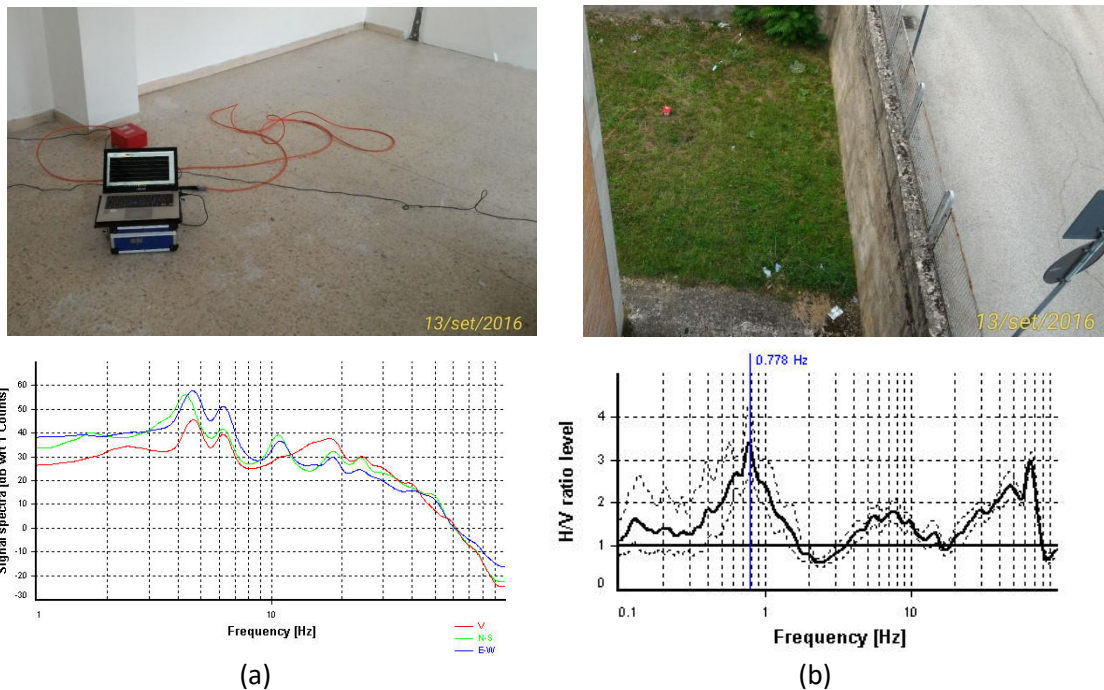


Figura 12: (a) Spettri di Fourier valutati in Testa alla struttura (b) Analisi HVSR Terreno – Istituto Comprensivo Materna, Elementare e Media (Norcia) - Coordinate 42.79170N - 13.09654E

La frequenza di risonanza della struttura che ospita la scuola risulta avere un valore prossimo a 4.03 Hz (Figura 12a) ed è associata ad un modo di tipo roto-traslazionale. La frequenza fondamentale del terreno di fondazione è pari a circa 0.78Hz (Figura 12b) e nell'intervallo di interesse strutturale il terreno ha una risposta sostanzialmente piatta, dunque si possono escludere problemi di risonanza terreno-edificio.

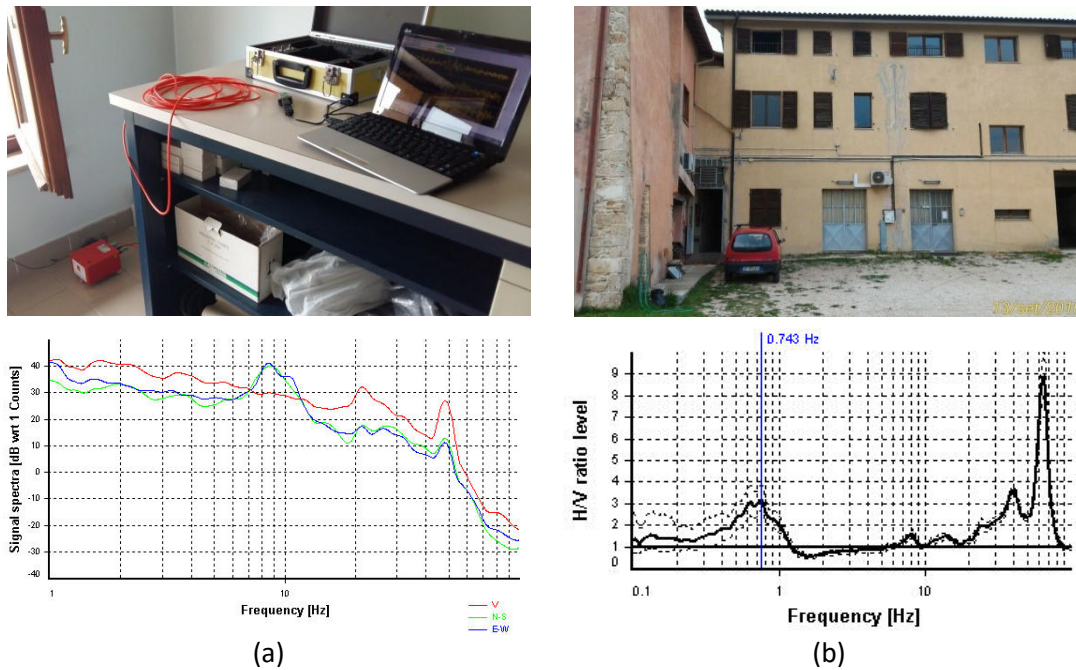


Figura 13: (a) Spettri di Fourier valutati in Testa alla struttura (b) Analisi HVSR Terreno – Ospedale di Norcia - Coordinate 42.78920N - 13.097388E

Per quanto riguarda l'ospedale, la frequenza fondamentale di oscillazione risulta essere pari a circa 8.55Hz (Figura 13a) ed è associata a un modo di tipo prevalentemente rotazionale. La frequenza fondamentale del terreno di fondazione è pari a circa 0.74Hz (Figura 13b) e nell'intervallo di interesse strutturale il terreno ha una risposta sostanzialmente piatta, dunque si possono escludere problemi di risonanza terreno-edificio.

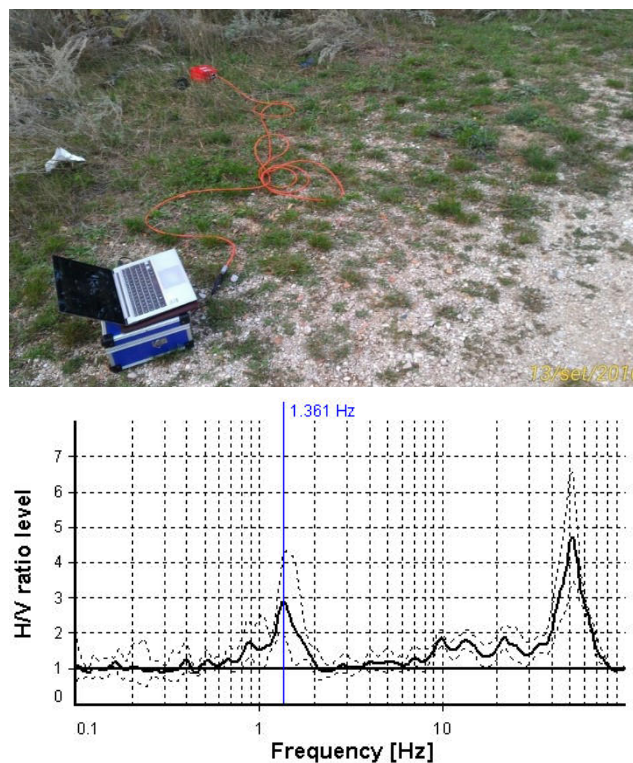


Figura 14: - Analisi HVSR – Bacino Norcia - Coordinate 42.76341N - 13.10604E

Per quanto riguarda l'area del bacino, la frequenza fondamentale di oscillazione risulta essere pari a circa 1.36Hz (Figura 14). Eventuali problemi di amplificazione sismica potrebbero manifestarsi nell'intervallo 1-2Hz (si esclude che il picco a 50Hz possa essere di interesse strutturale).

Caratterizzazione Dinamica delle Strutture e dei Terreni di Fondazione - Antrodoco (RI)

Al fine di caratterizzare il comportamento dinamico della struttura (e del terreno di fondazione) ospitante il Comando Stazione del Corpo Forestale dello Stato ubicato nel comune di Antrodoco (RI), di interesse strategico per il Dipartimento Nazionale di Protezione Civile, il giorno 14 settembre 2016, sono state effettuate due acquisizioni in rumore ambientale sul sito rappresentato in Figura 15.

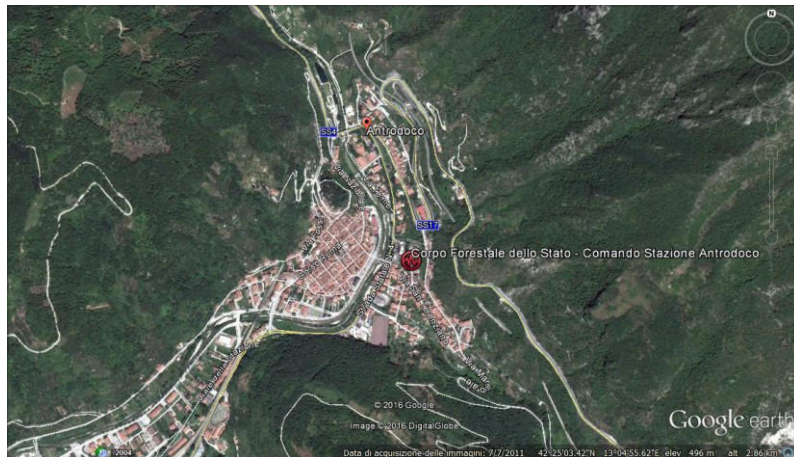


Figura 15: Mappa delle Indagini Vibrazionali effettuate ad Antrodoco

I risultati preliminari delle indagini vibrazionali eseguite ad Antrodoco sono di seguito riportati (Figura 16):

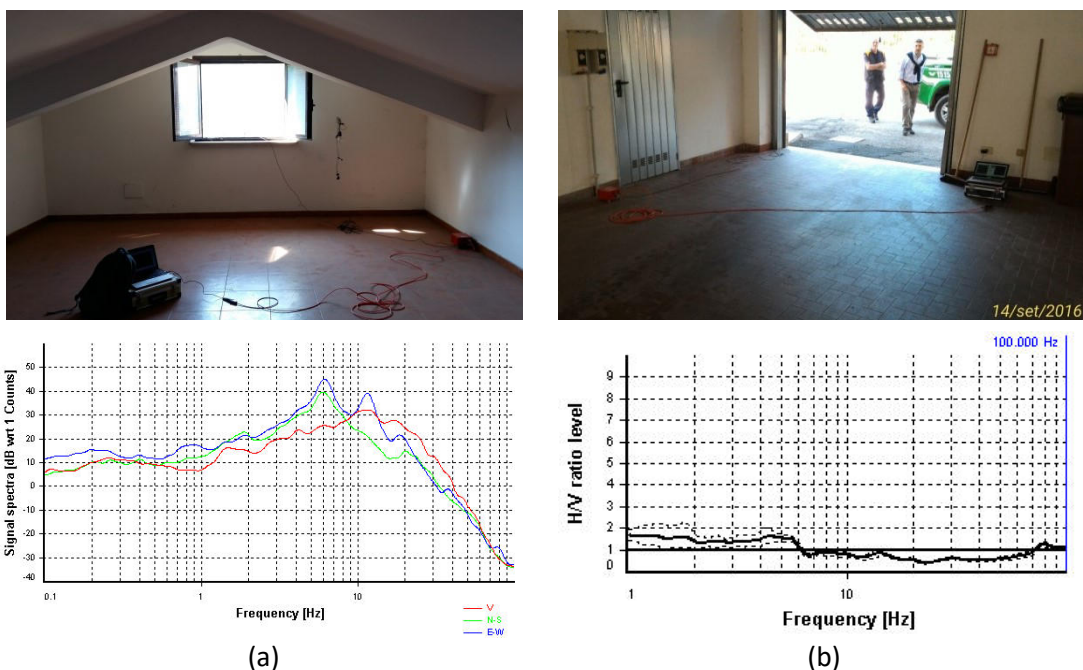


Figura 16: (a) Spettri di Fourier valutati in Testa alla struttura (b) Analisi HVSr Terreno – Caserma Corpo Forestale dello Stato - Comando Stazione di Antrodoco - Coordinate 42.41664N - 13.08229E

La frequenza di risonanza della struttura che ospita la caserma risulta avere un valore prossimo a 6.1 Hz (Figura 16a) ed è associata ad un modo di tipo roto-traslazionale. Il terreno esibisce una risposta sostanzialmente piatta nell'intervallo 1-100Hz (Figura 16b), dunque si possono escludere problemi di risonanza terreno-edificio.

ARTICOLI CORRELATI

[F.C. Ponzo, R. Ditommaso, G. Auletta, A. Mossucca \(2010\). A Fast Method for Structural Health Monitoring of Italian Strategic Reinforced Concrete Buildings. *Bulletin of Earthquake Engineering*; **8**, Number 6, 1421-1434, DOI: 10.1007/s10518-010-9194-6.](#)

[Ditommaso R, Ponzo FC, Auletta G. \(2015\). Damage detection on framed structures: modal curvature evaluation using Stockwell Transform under seismic excitation. *Earthquake Engineering and Engineering Vibration*,**14**, 265-274.](#)

[Ditommaso R, Mucciarelli M, Ponzo FC \(2012\). Analysis of non-stationary structural systems by using a band-variable filter. *Bulletin of Earthquake Engineering*, DOI: 10.1007/s10518-012-9338-y.](#)

[R. Ditommaso, F.C. Ponzo \(2015\). Automatic evaluation of the fundamental frequency variations and related damping factor of reinforced concrete framed structures using the Short Time Impulse Response Function \(STIRF\). *Engineering Structures*; **82**: 104–112.](#)

[R. Ditommaso, M. Mucciarelli, M. R. Gallipoli, F. C. Ponzo \(2010\). Effect of a single vibrating building on free-field ground motion: numerical and experimental evidences. *Bull. Earthquake Eng.* \(2010\) 8:693–703. DOI 10.1007/s10518-009-9134-5.](#)

APPENDICE

STATION INFORMATION

Station code: -

Model: -

Sensor: -

Notes: -

PLACE INFORMATION

Place ID: Amatrice - Benzinaio

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

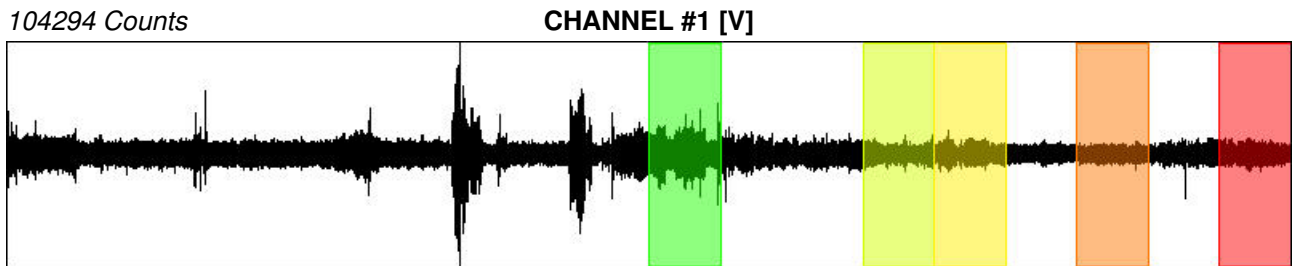
Recording start time: 2016/09/14 15:10:32

Recording length: 30 min

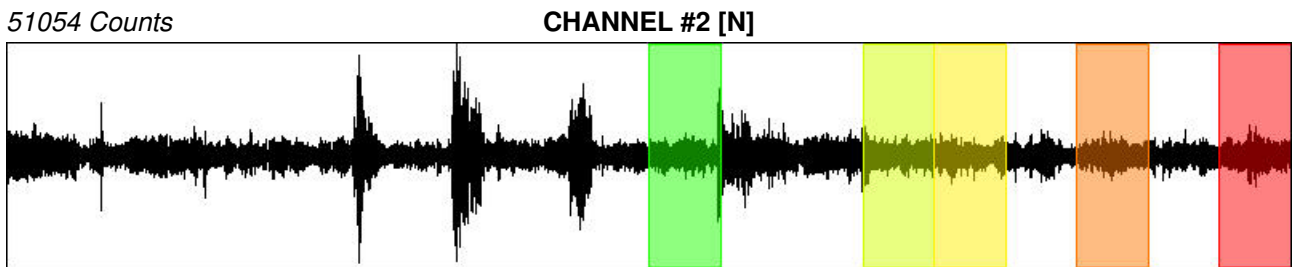
Windows count: 5

Average windows length: 100

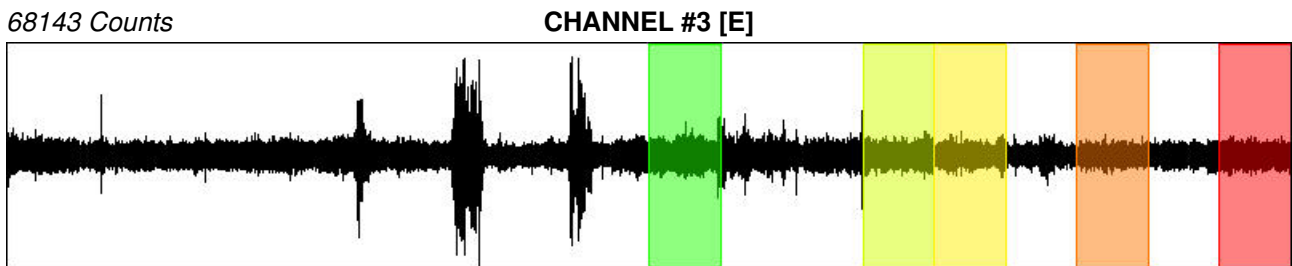
Signal coverage: 27.78%



-104899 Counts



-49102 Counts



-77043 Counts

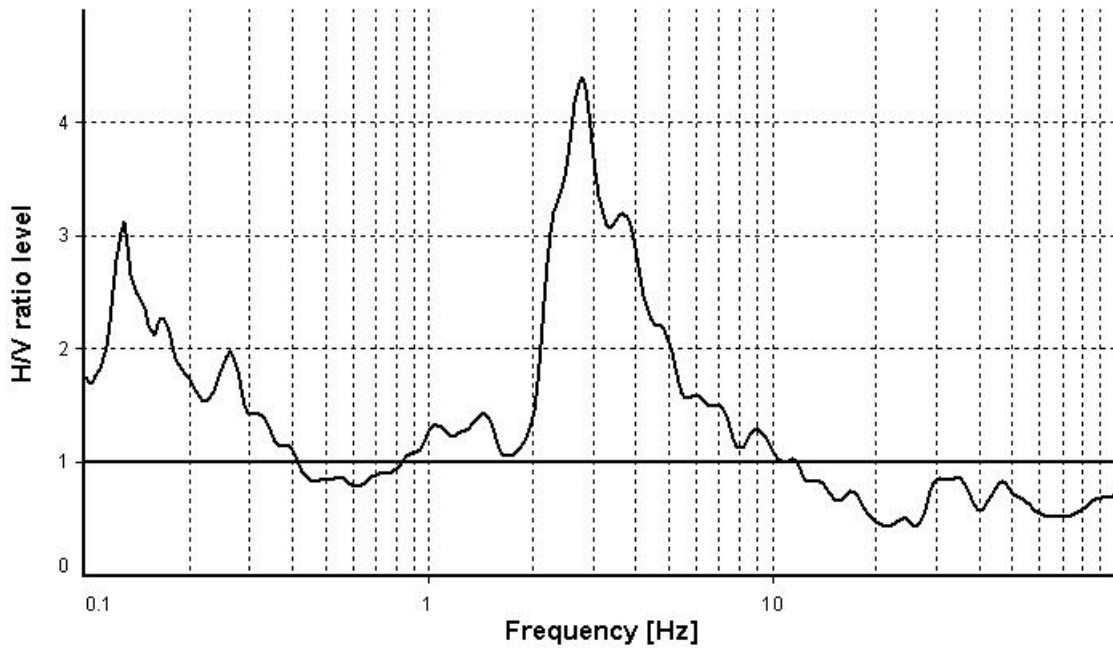
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

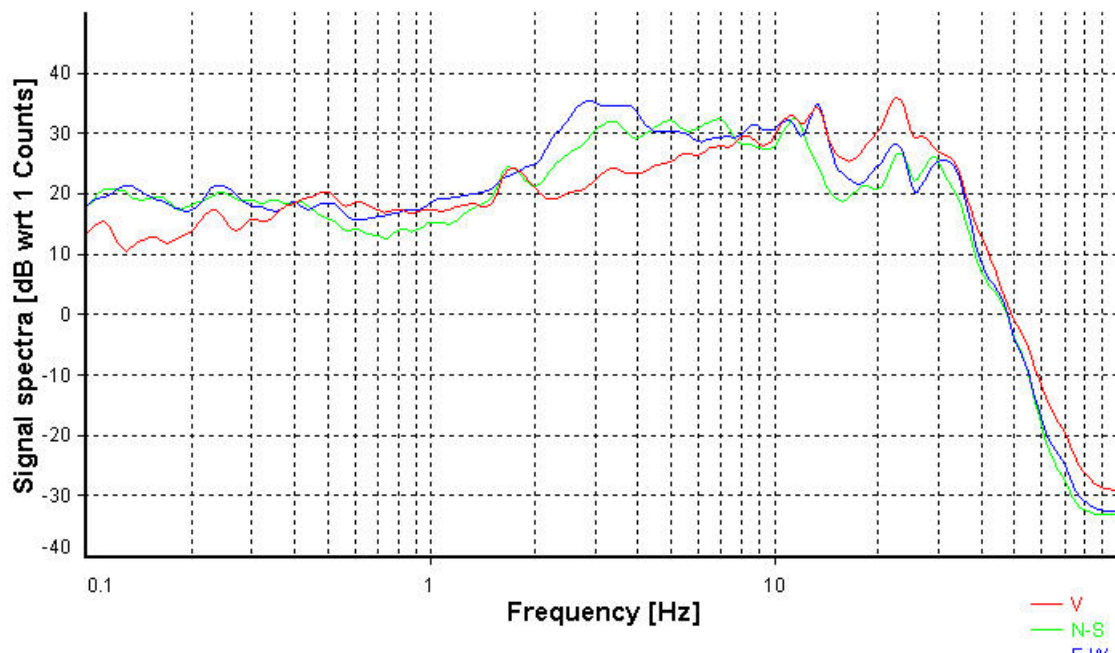
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

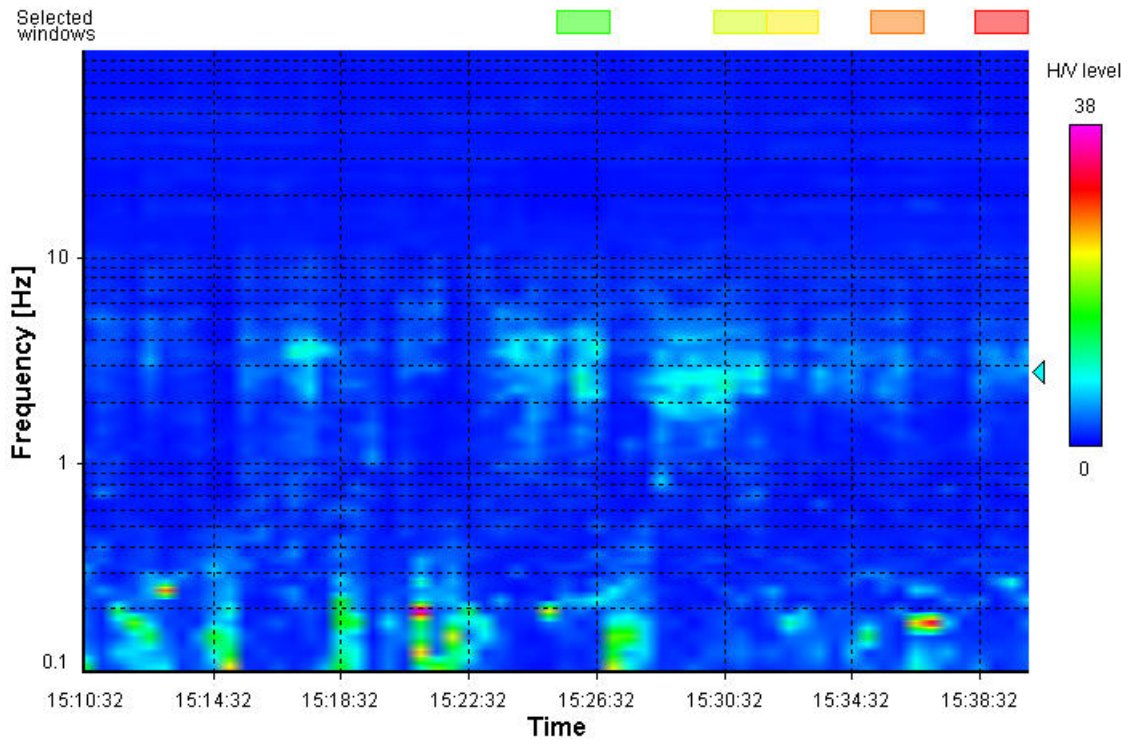
HVSR average



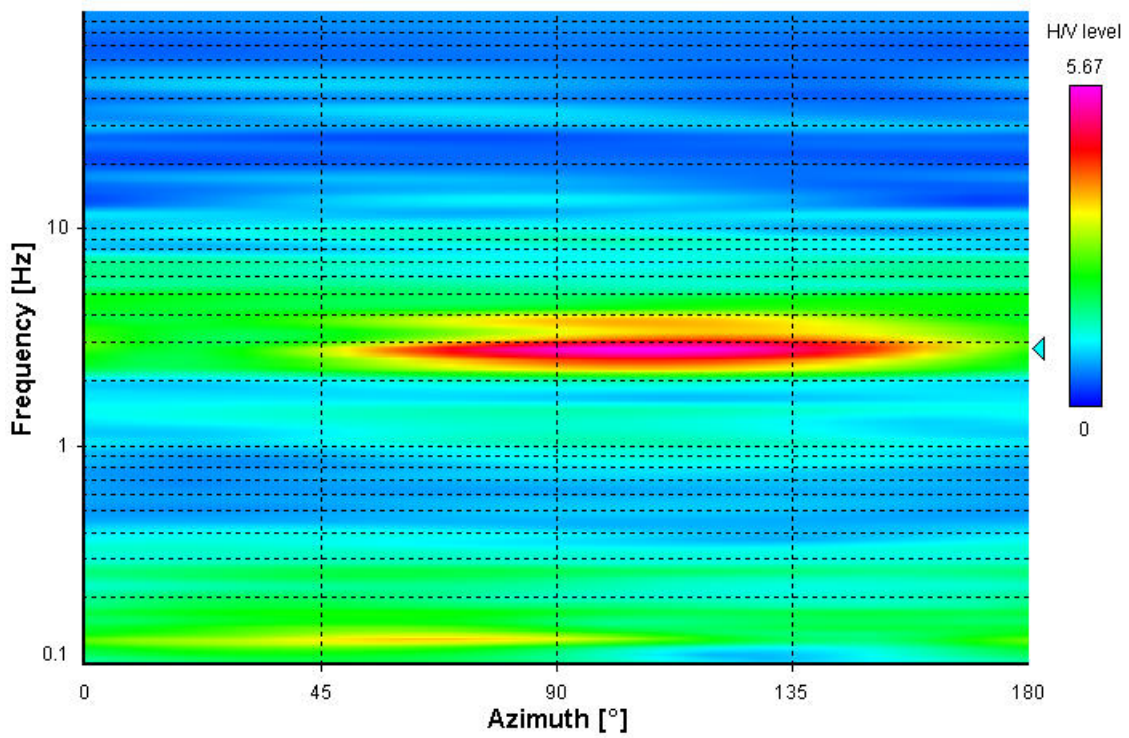
Signal spectra average



HVSR time-frequency analysis (30 seconds windows)



HVSR directional analysis



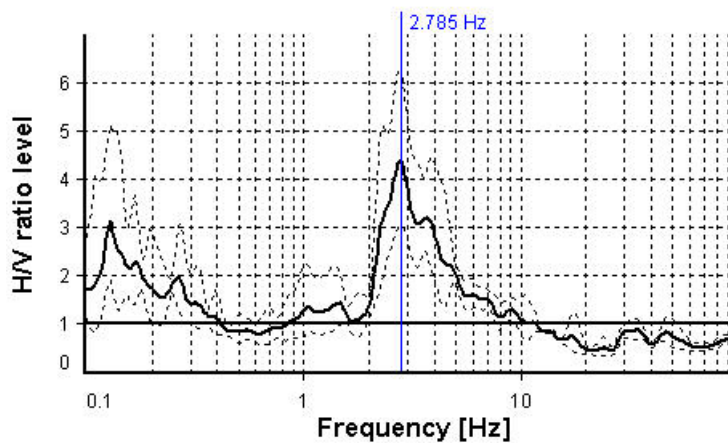
SESAME CRITERIA

Selected f_0 frequency

2.785 Hz

A_0 amplitude = 4.399

Average $f_0 = 2.786 \pm 0.090$



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	5 valid windows (length > 3.59 s) out of 5	OK
$n_c(f_0) > 200$	1392.47 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 61	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{HV}(f) < A_0/2$	2.11064 Hz	OK
$\exists f'$ in $[f_0, 4f_0] \mid A_{HV}(f') < A_0/2$	4.73789 Hz	OK
$A_0 > 2$	4.4 > 2	OK
$f_{\text{peak}}[A_{HV}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.09022 < 0.13925	OK
$\sigma_A(f_0) < \theta(f_0)$	1.4355 < 1.58	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: -

Model: -

Sensor: -

Notes: -

PLACE INFORMATION

Place ID: Amatrice - Hotel Roma

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

Recording start time: 2016/09/14 15:57:52

Recording length: 20 min

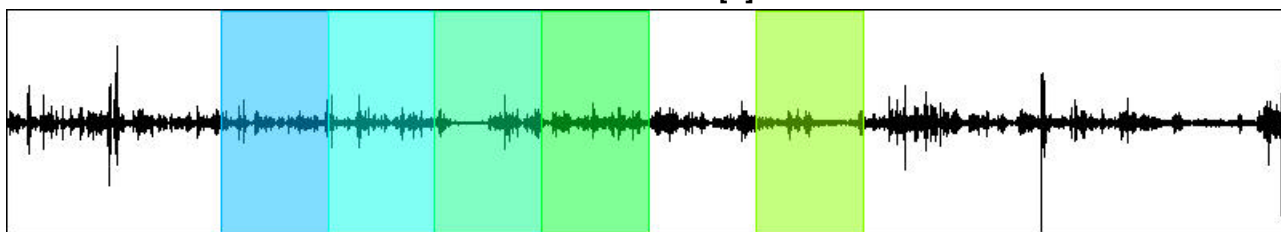
Windows count: 5

Average windows length: 100

Signal coverage: 41.67%

184587 Counts

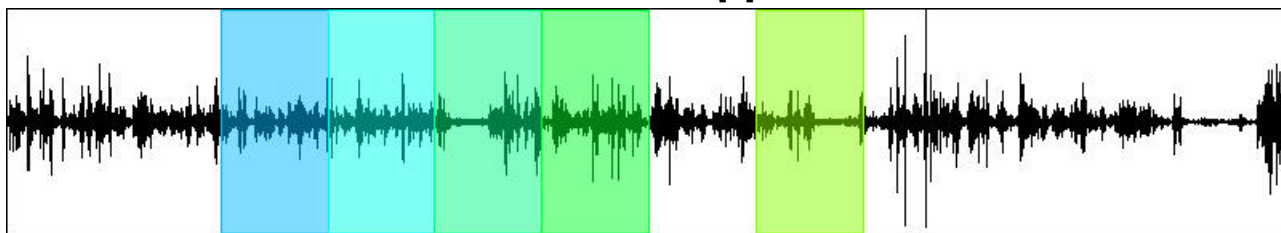
CHANNEL #1 [V]



-268801 Counts

207602 Counts

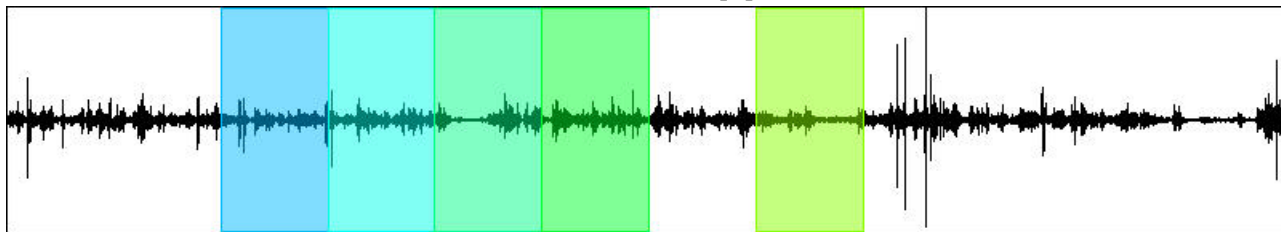
CHANNEL #2 [N]



-196569 Counts

221901 Counts

CHANNEL #3 [E]



-211614 Counts

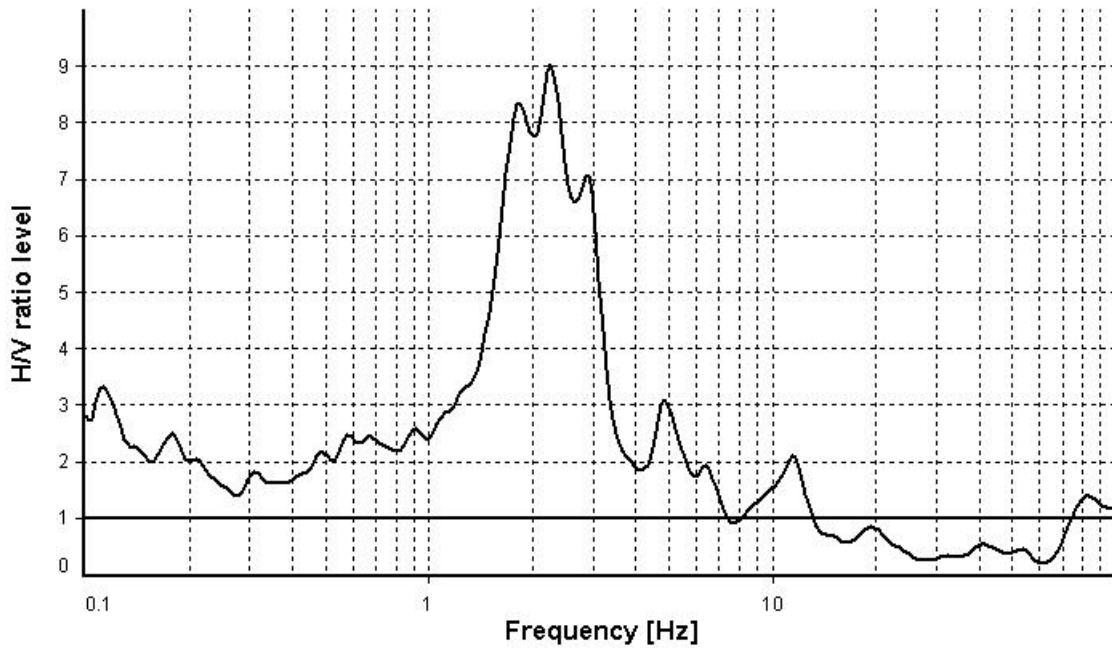
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

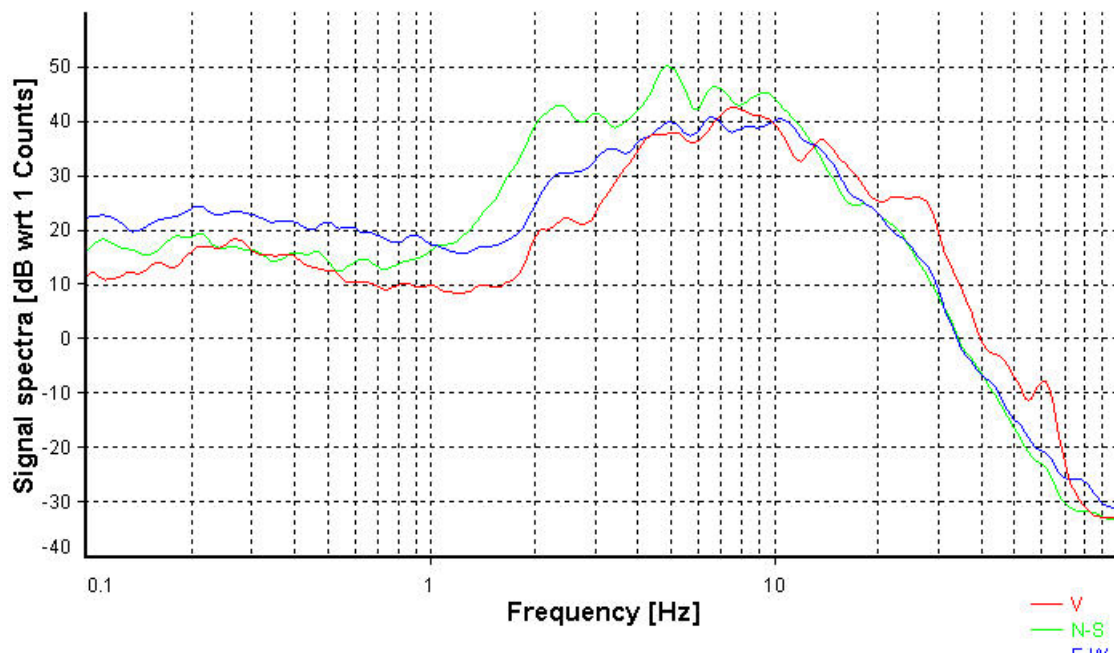
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

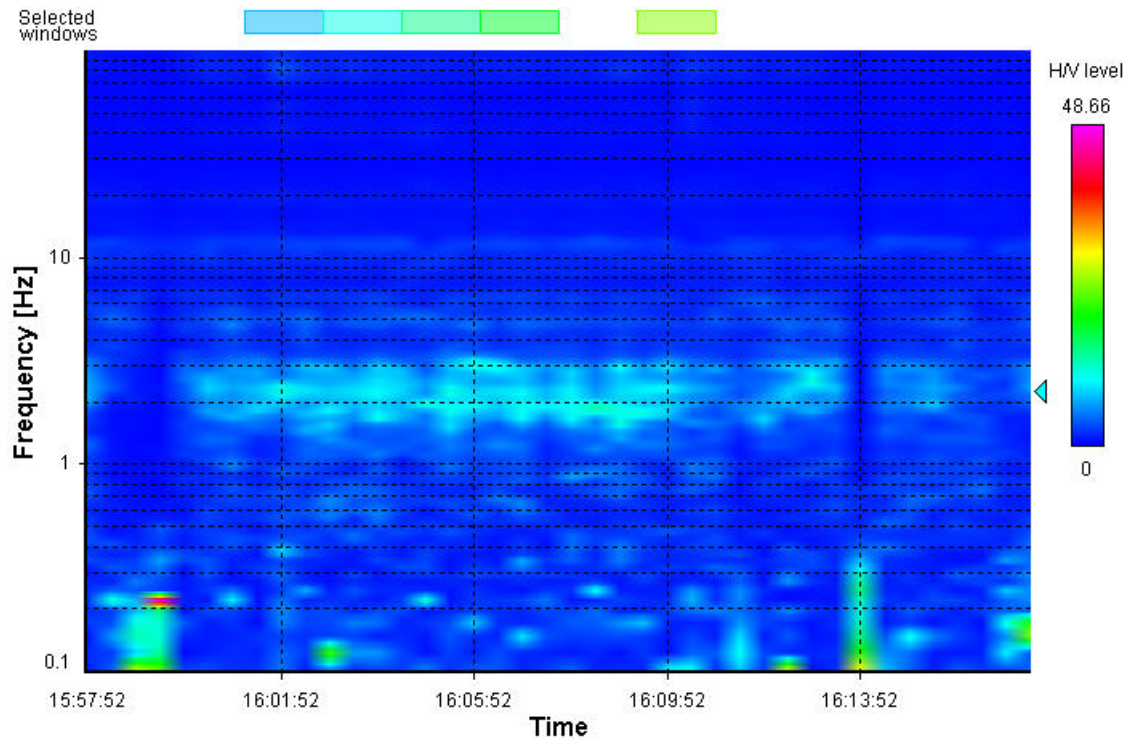
HVSR average



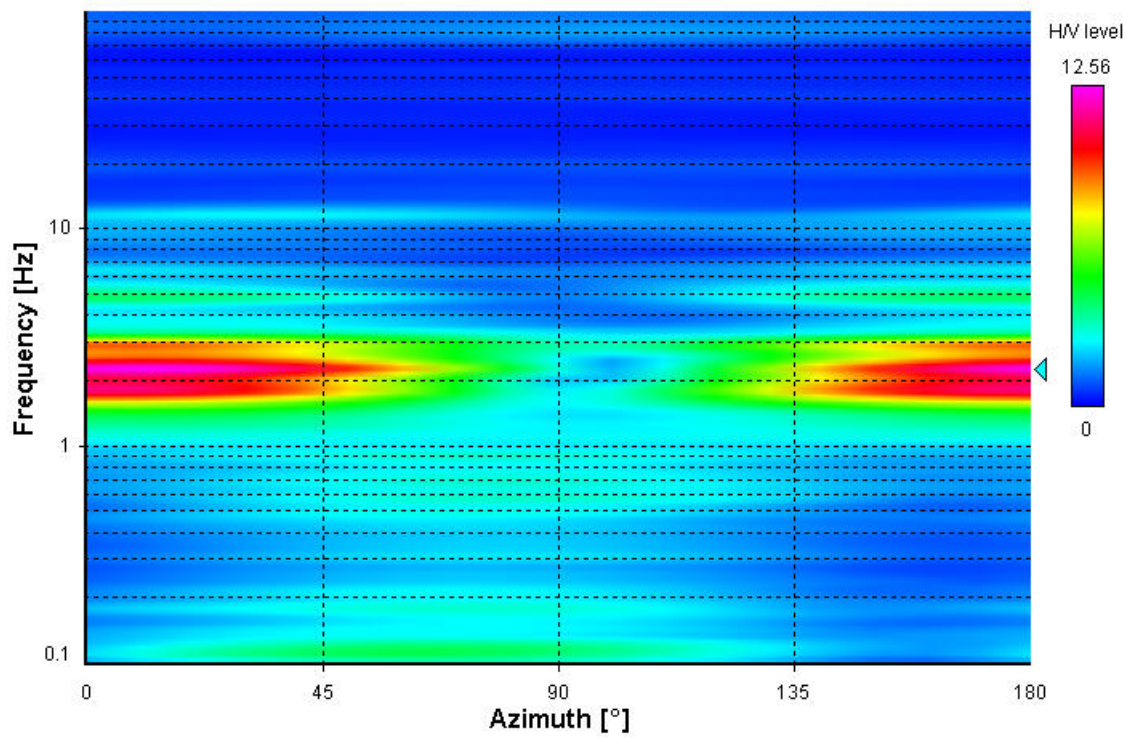
Signal spectra average



HVSR time-frequency analysis (30 seconds windows)



HVSR directional analysis



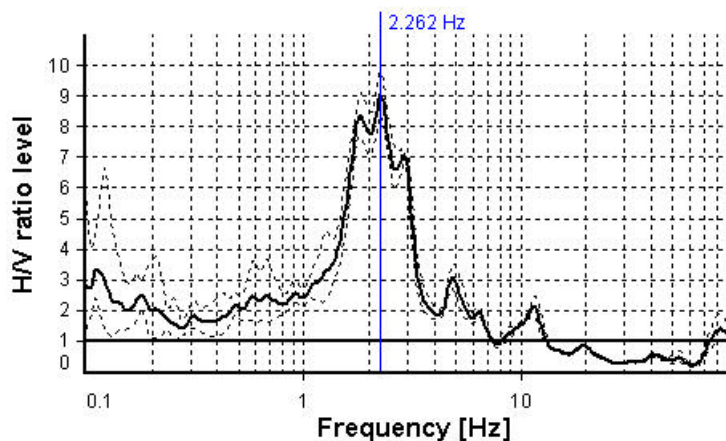
SESAME CRITERIA

Selected f_0 frequency

2.262 Hz

A_0 amplitude = 9.041

Average f_0 = 2.252 ± 0.044



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	5 valid windows (length > 4.42 s) out of 5	OK
$n_c(f_0) > 200$	1131.06 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 61	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{HV}(f) < A_0/2$	1.45841 Hz	OK
$\exists f'$ in $[f_0, 4f_0] \mid A_{HV}(f') < A_0/2$	3.19902 Hz	OK
$A_0 > 2$	9.04 > 2	OK
$f_{\text{peak}}[A_{HV}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.04366 < 0.11311	OK
$\sigma_A(f_0) < \theta(f_0)$	1.08181 < 1.58	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: -

Model: -

Sensor: -

Notes: -

PLACE INFORMATION

Place ID: Amatrice - Terreno - Ingresso Città

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

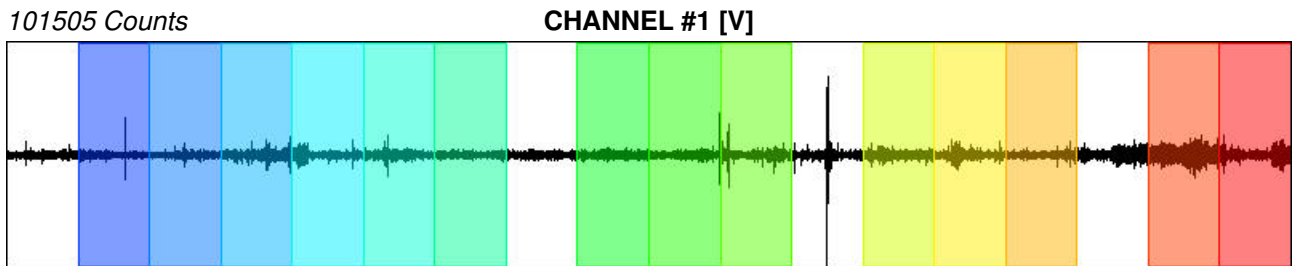
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Recording length: 30 min

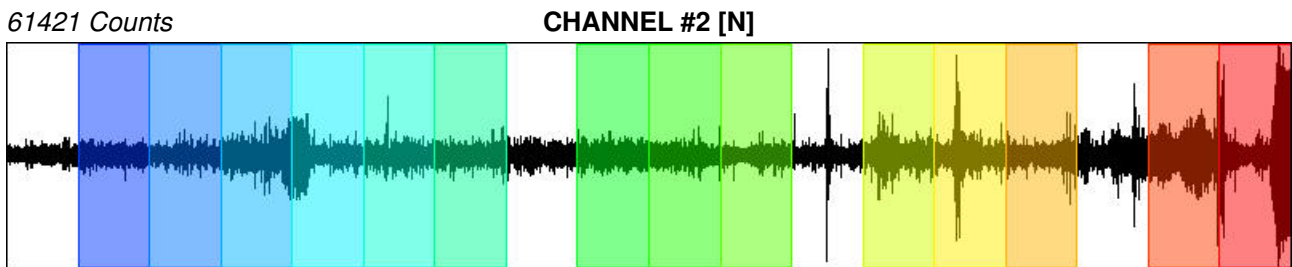
Windows count: 14

Average windows length: 100

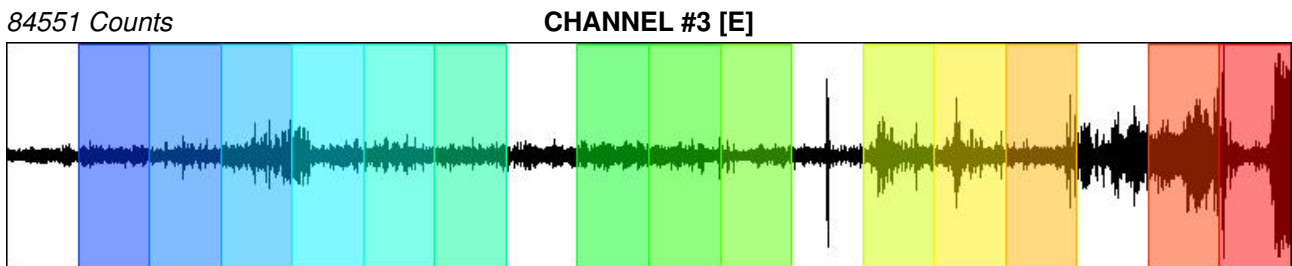
Signal coverage: 77.78%



-145617 Counts



-61799 Counts



-76844 Counts

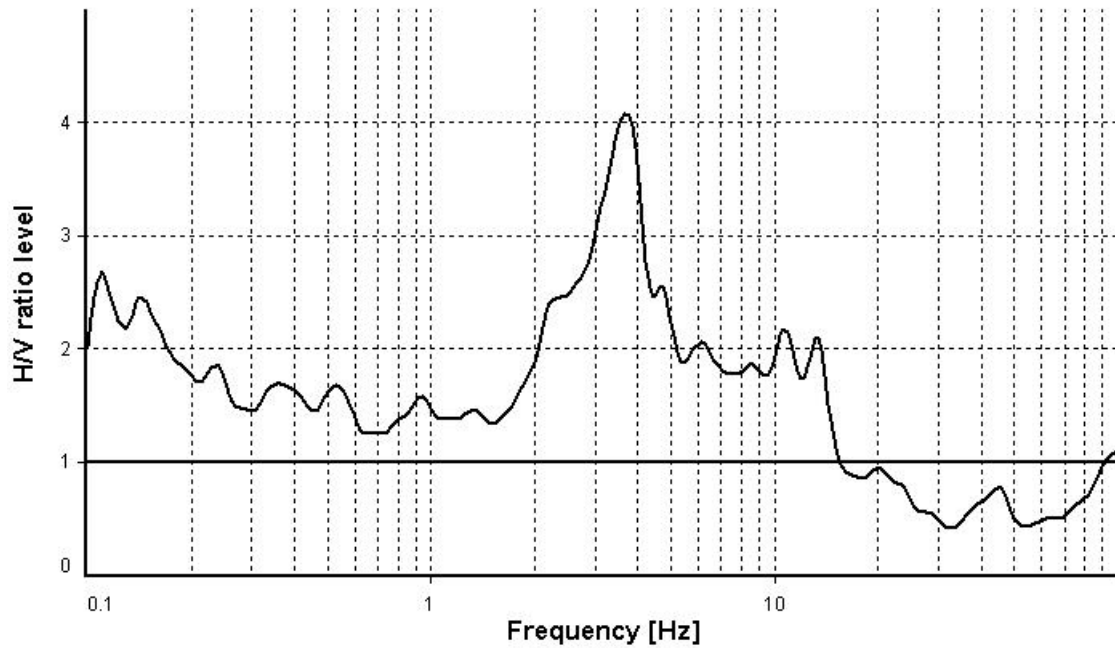
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

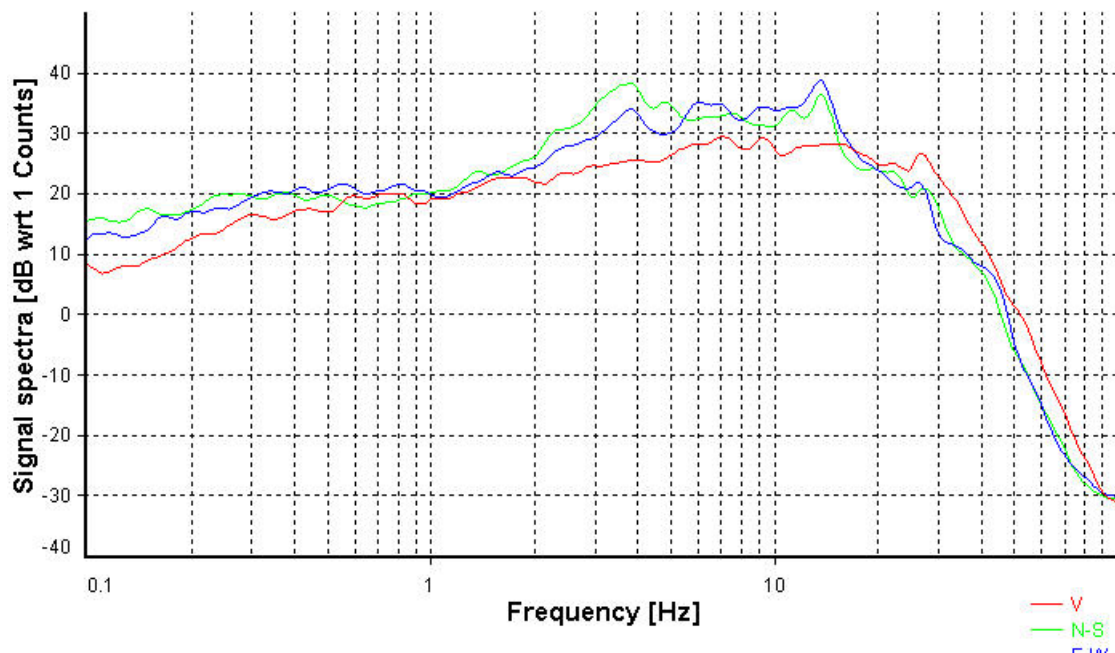
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

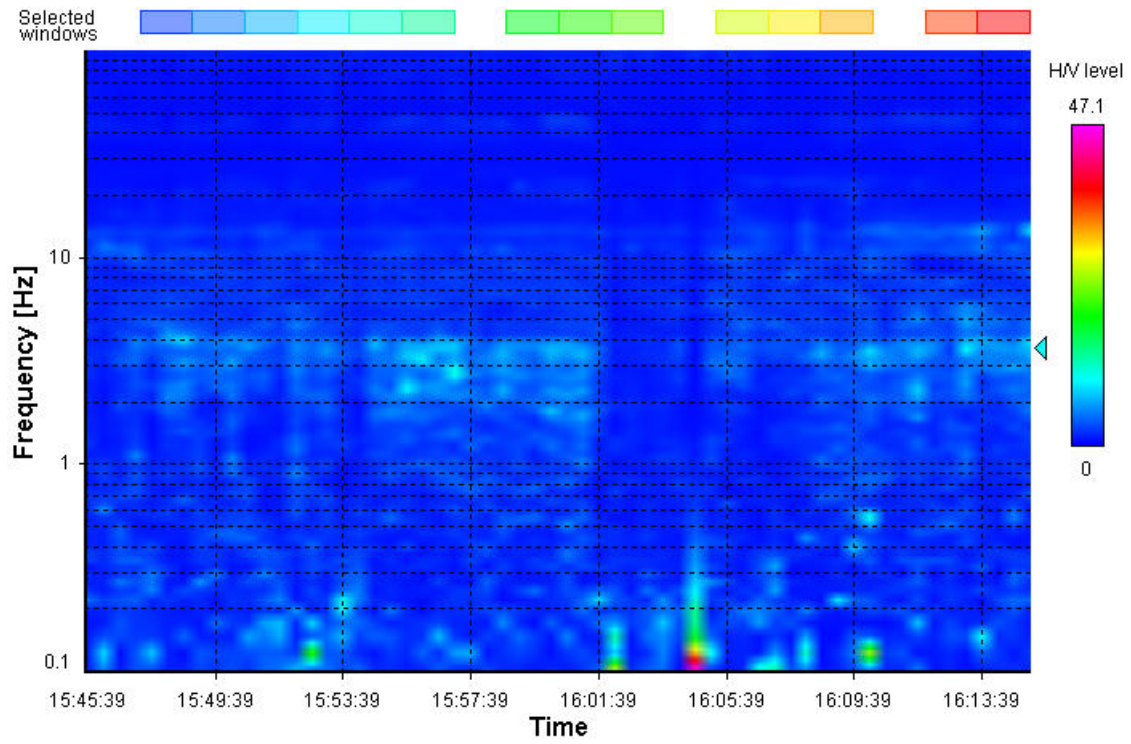
HVSR average



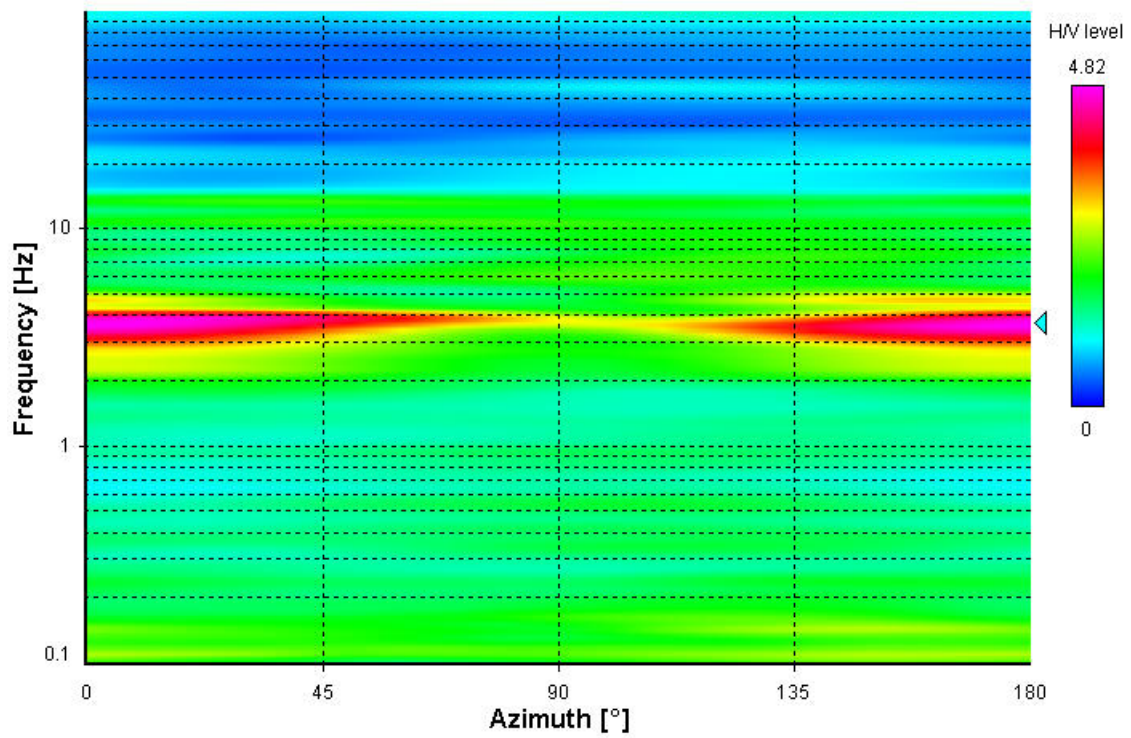
Signal spectra average



HVSR time-frequency analysis (30 seconds windows)



HVSR directional analysis



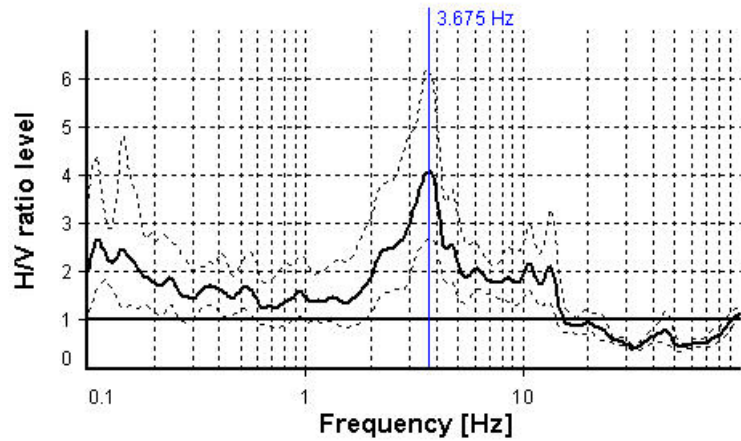
SESAME CRITERIA

Selected f_0 frequency

3.675 Hz

A_0 amplitude = 4.073

Average f_0 = 3.726 ± 0.151



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	14 valid windows (length > 2.72 s) out of 14	OK
$n_c(f_0) > 200$	5144.53 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 61	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{HV}(f) < A_0/2$	2.01534 Hz	OK
$\exists f'$ in $[f_0, 4f_0] \mid A_{HV}(f') < A_0/2$	5.1966 Hz	OK
$A_0 > 2$	4.07 > 2	OK
$f_{\text{peak}}[A_{HV}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	2.34% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.15058 < 0.18373	OK
$\sigma_A(f_0) < \theta(f_0)$	1.51956 < 1.58	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Antrodoco - Caserma CFS - Base

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

Recording start time: 2016/09/14 08:31:42

Recording length: 30 min

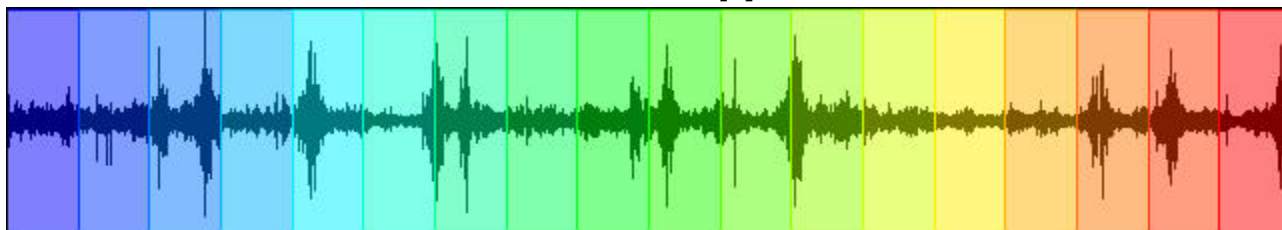
Windows count: 18

Average windows length: 100

Signal coverage: 100%

24682 Counts

CHANNEL #1 [V]



-20984 Counts

9388 Counts

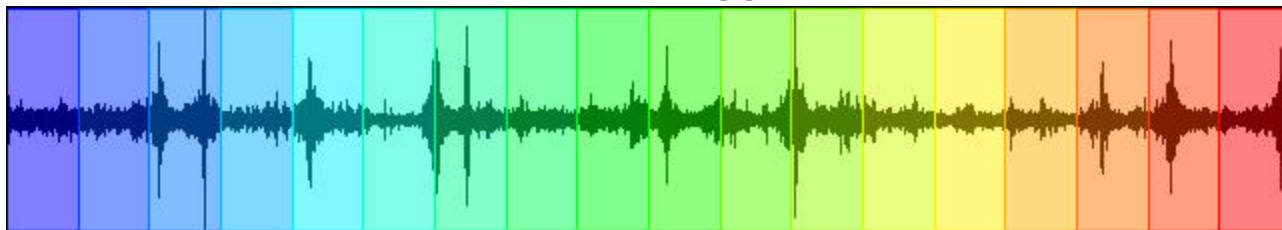
CHANNEL #2 [N]



-9908 Counts

22482 Counts

CHANNEL #3 [E]



-22226 Counts

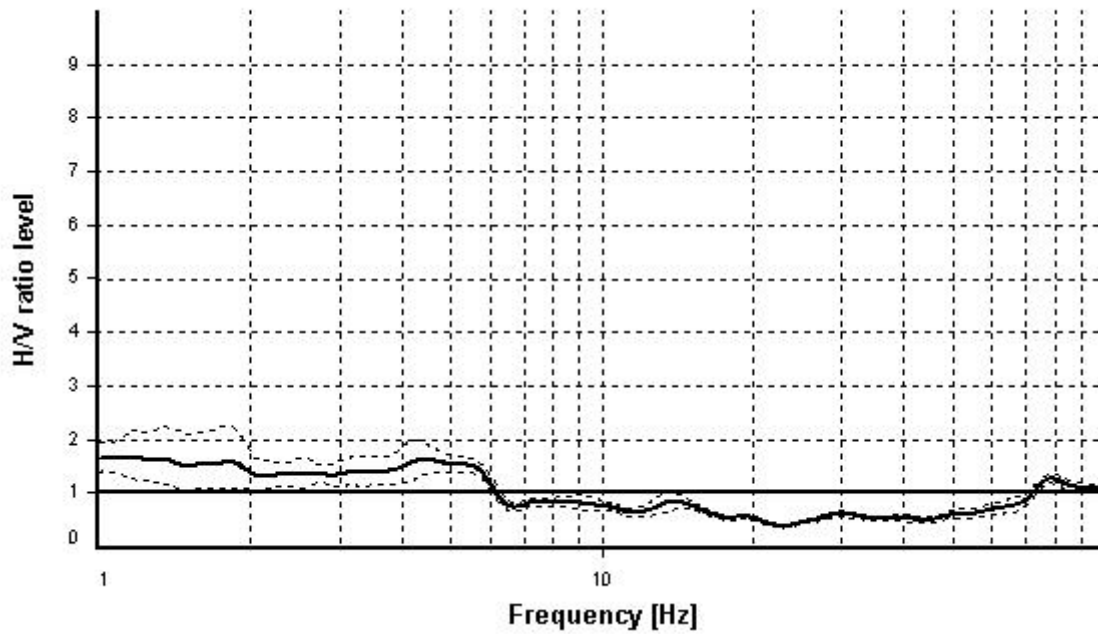
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

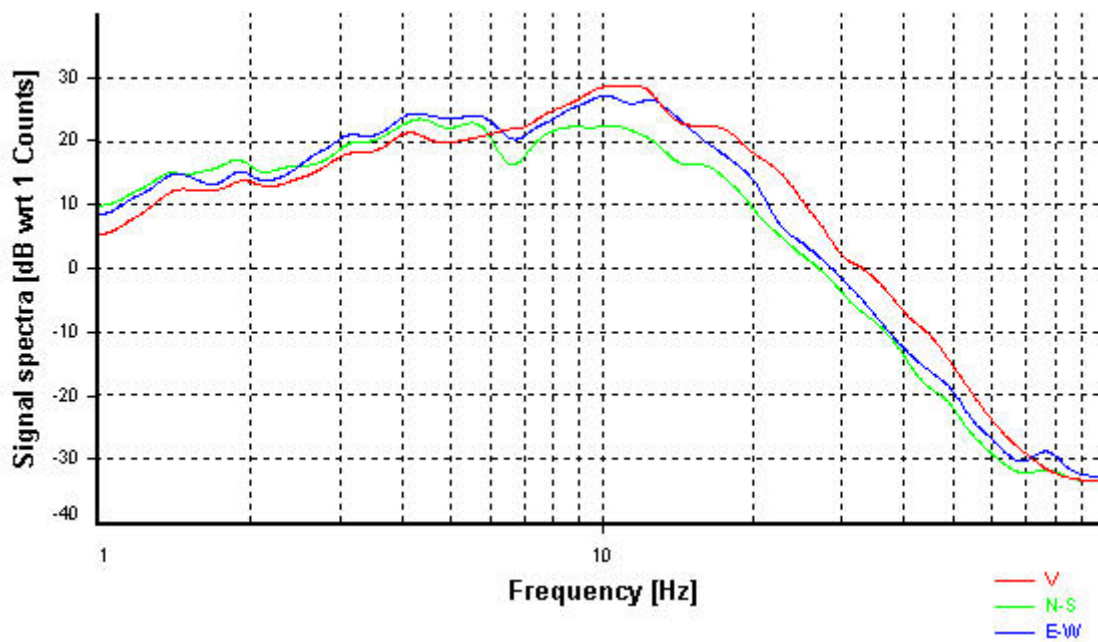
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

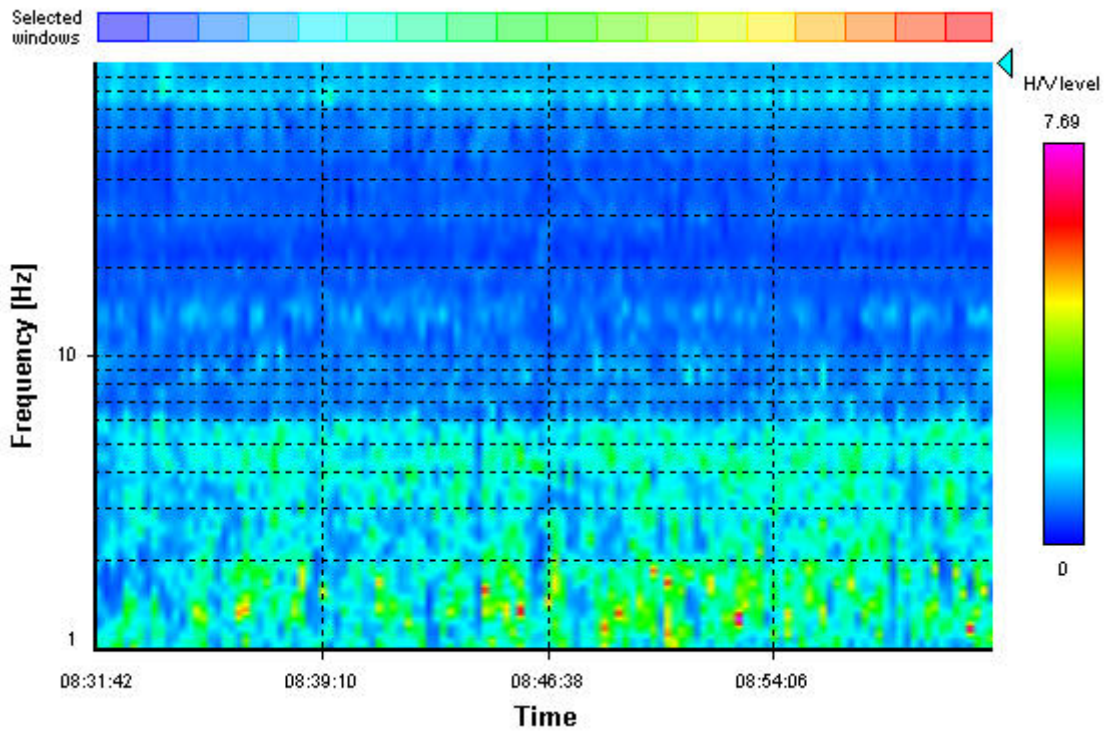
HVSR average



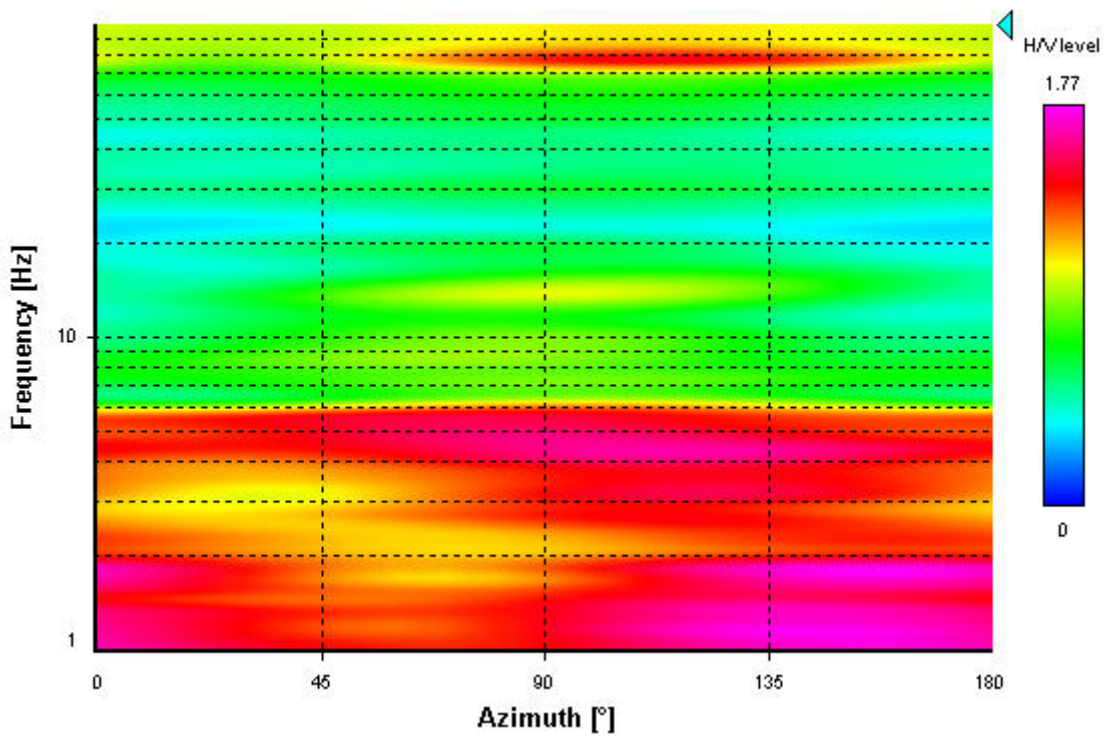
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



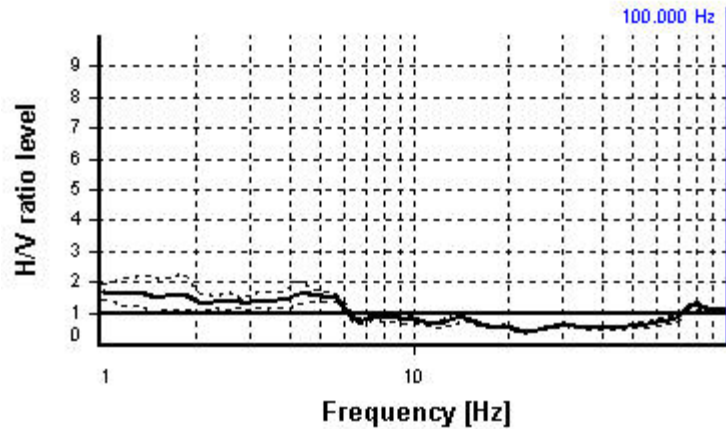
SESAME CRITERIA

Selected f_0 frequency

100.000 Hz

A_0 amplitude = 1.100

Average $f_0 = 80.323 \pm 0.391$



HVSr curve reliability criteria		
$f_0 > 10 / L_w$	18 valid windows (length > 0.1 s) out of 18	OK
$n_c(f_0) > 200$	180000 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 136	OK
HVSr peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	47.57944 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	0 Hz	NO
$A_0 > 2$	1.1 <= 2	NO
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	19.77% > 5%	NO
$\sigma_f < \varepsilon(f_0)$	0.39148 < 5	OK
$\sigma_A(f_0) < \theta(f_0)$	1.07705 < 1.58	OK
Overall criteria fulfillment		NO

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Antrodoco - Edificio Caserma CFS - Testa

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

Recording start time: 2016/09/14 08:31:42

Recording length: 30 min

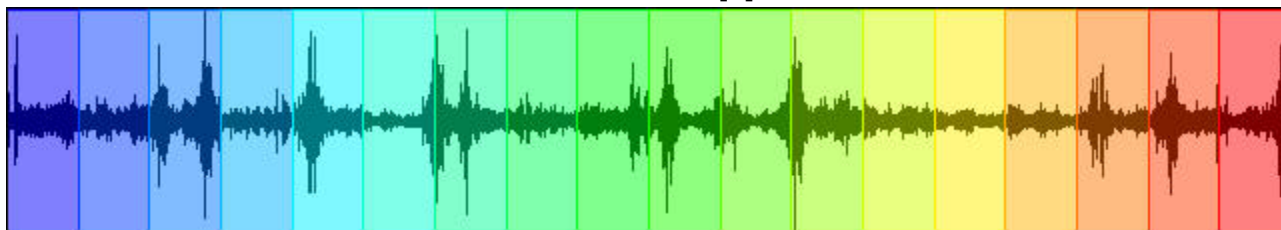
Windows count: 18

Average windows length: 100

Signal coverage: 100%

37096 Counts

CHANNEL #1 [V]



-37912 Counts

32279 Counts

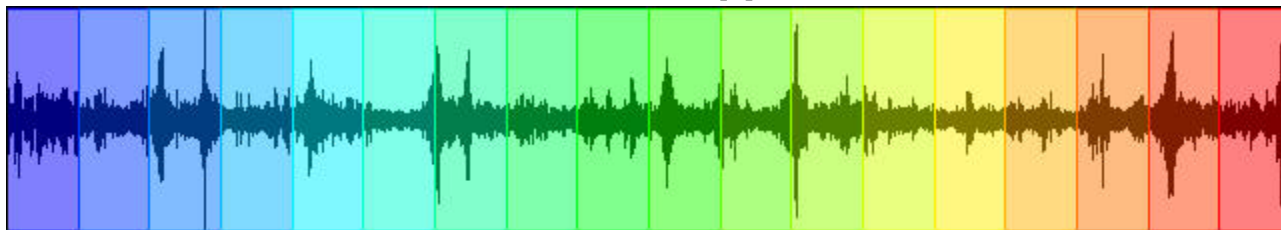
CHANNEL #2 [N]



-33333 Counts

67097 Counts

CHANNEL #3 [E]



-66725 Counts

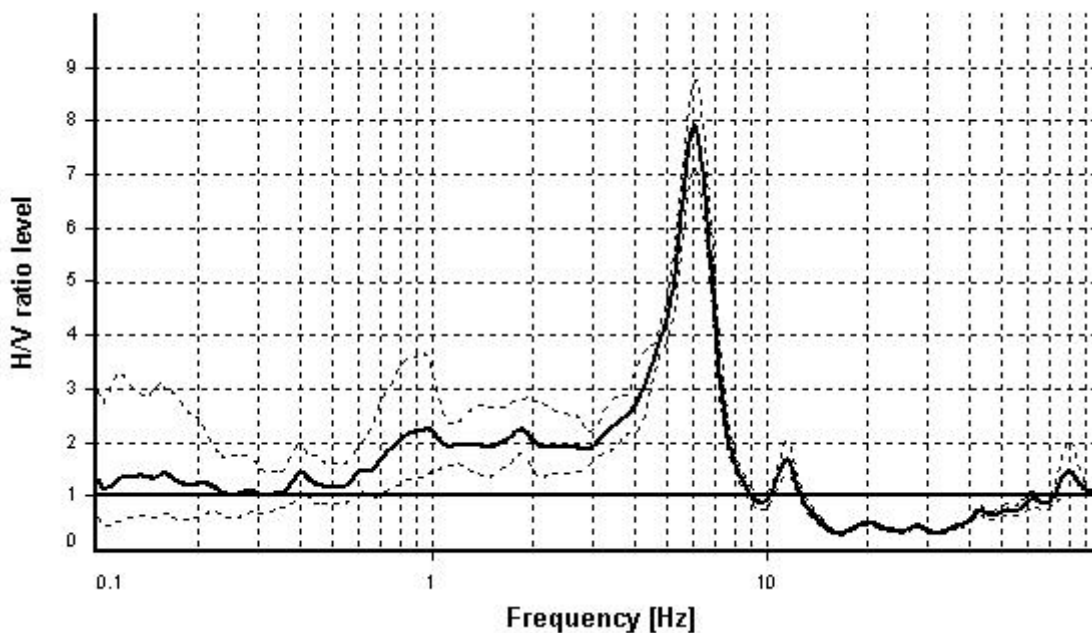
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

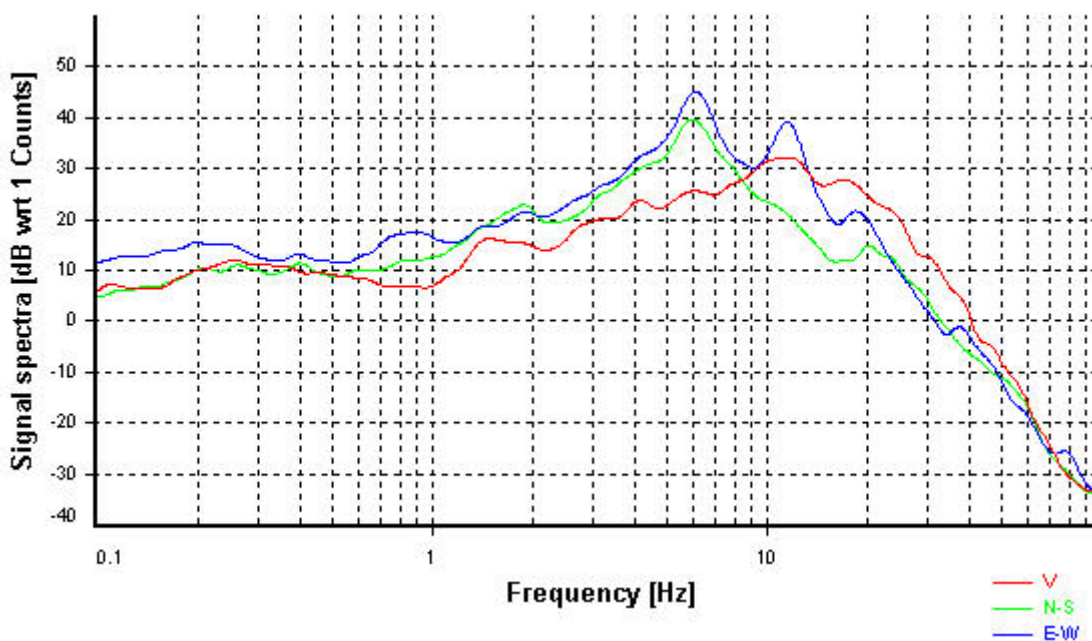
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

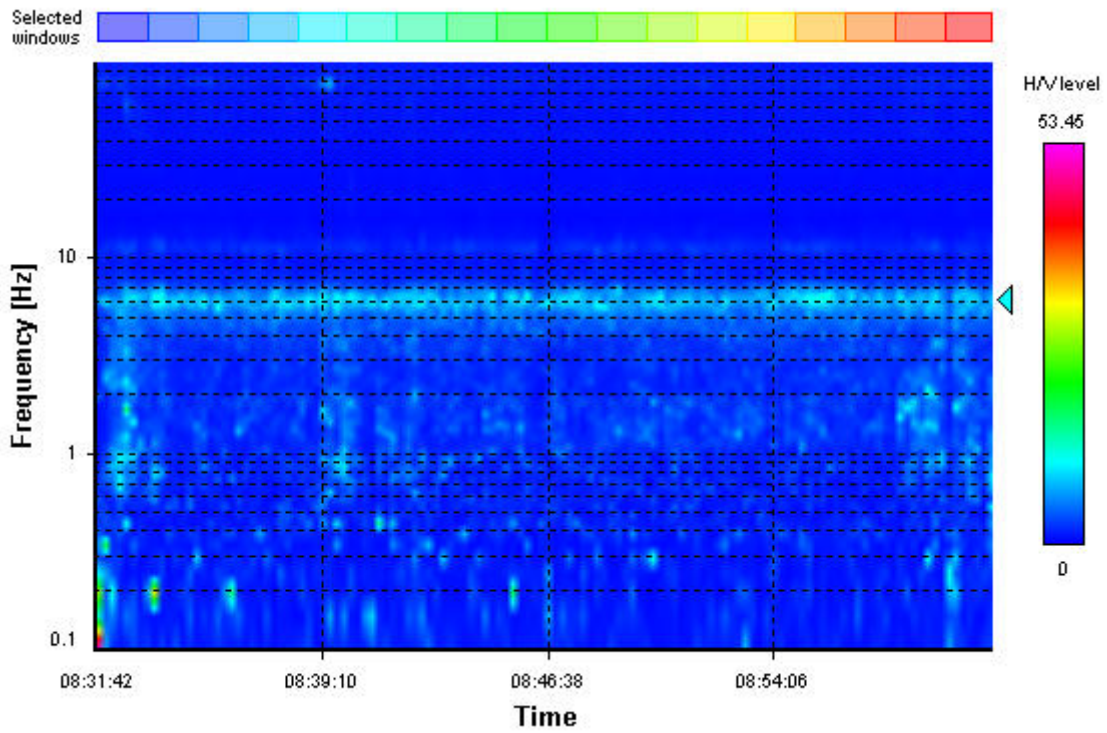
HVSR average



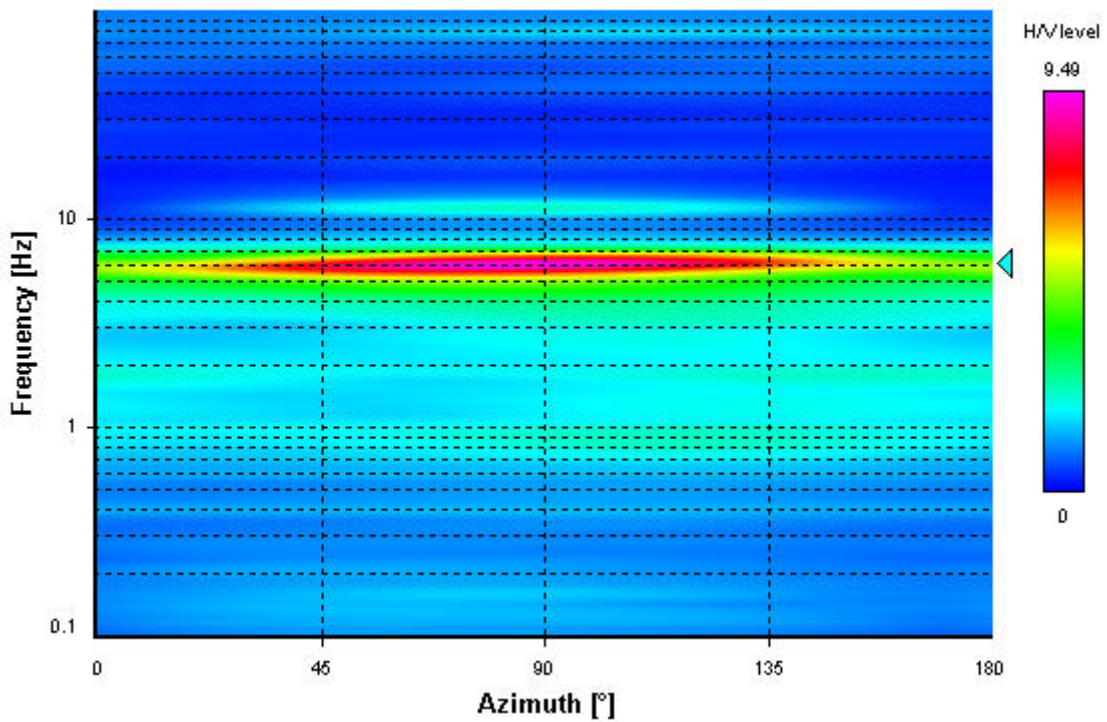
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



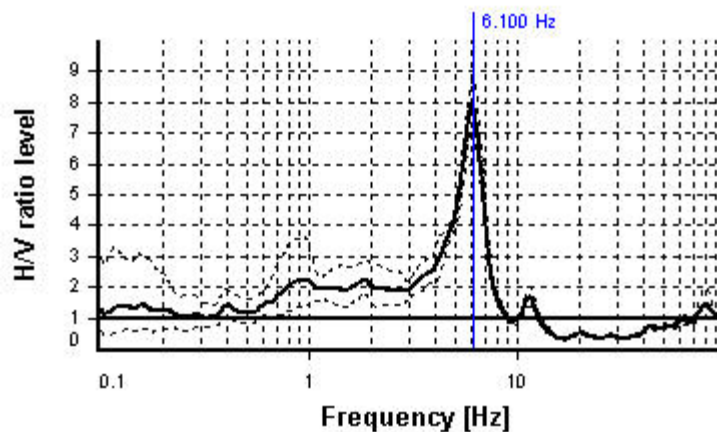
SESAME CRITERIA

Selected f_0 frequency

6.100 Hz

A_0 amplitude = 7.893

Average $f_0 = 6.075 \pm 0.096$



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	18 valid windows (length > 1.64 s) out of 18	OK
$n_c(f_0) > 200$	10979.68 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 181	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	4.80694 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	7.11308 Hz	OK
$A_0 > 2$	7.89 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0.77% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.096 < 0.30499	OK
$\sigma_A(f_0) < \theta(f_0)$	1.11129 < 1.58	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Norcia - Ospedale - Terreno

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

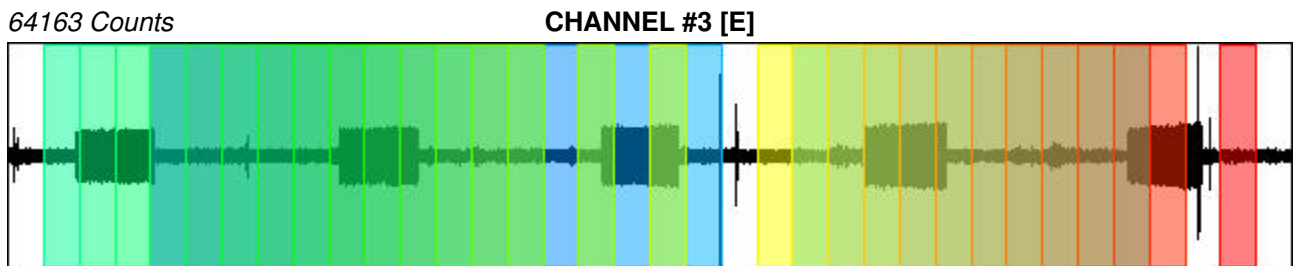
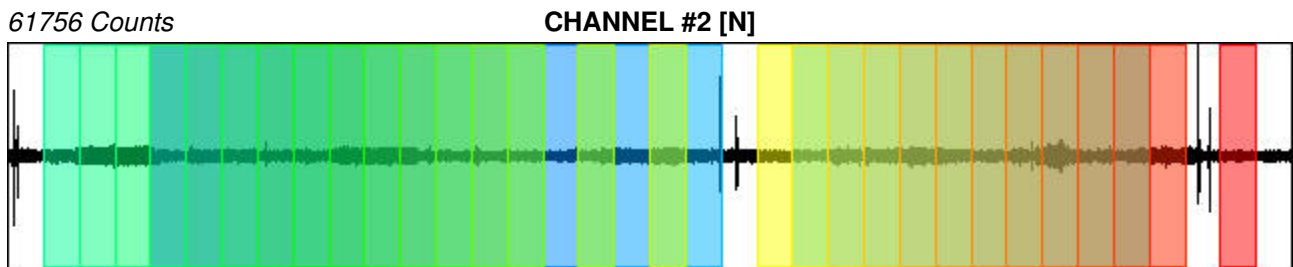
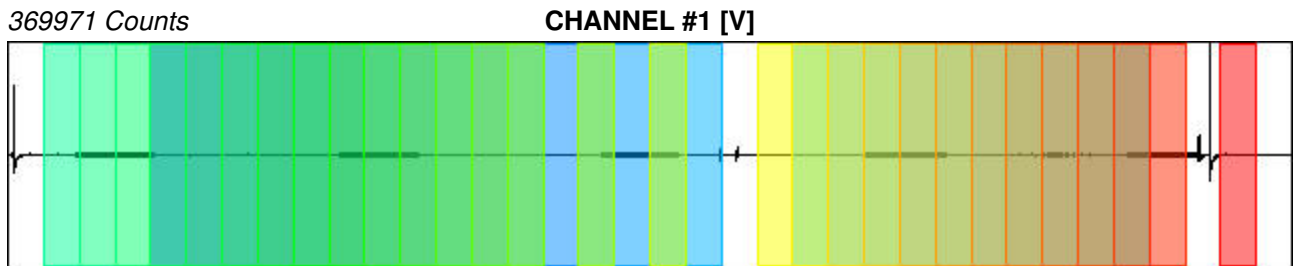
Recording start time: 2016/09/13 15:55:26

Recording length: 30 min

Windows count: 42

Average windows length: 65.48

Signal coverage: 152.78%



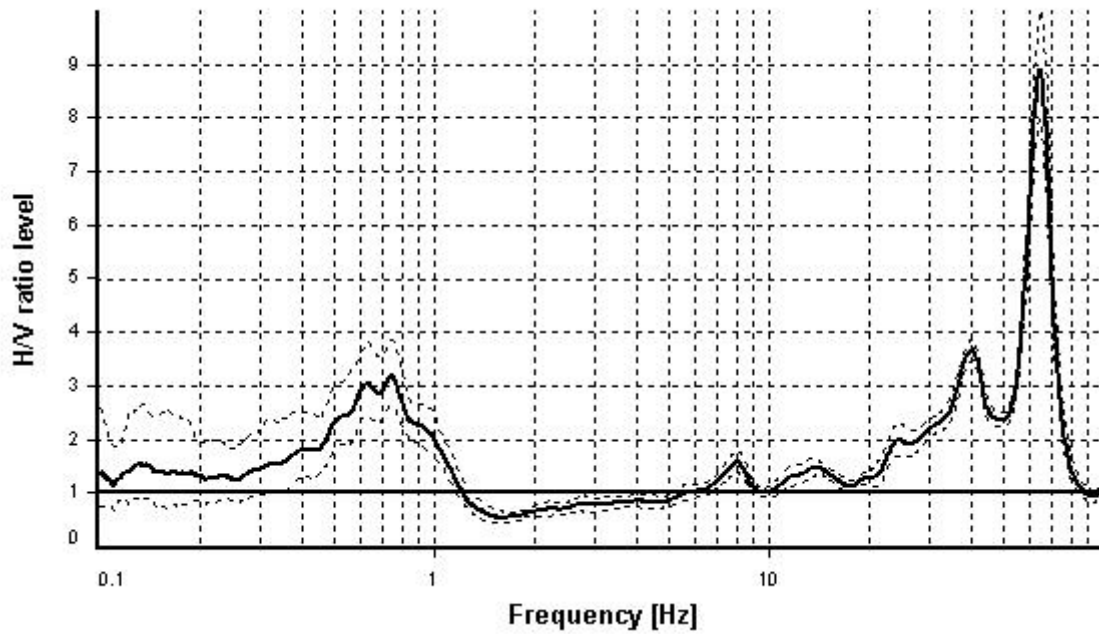
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

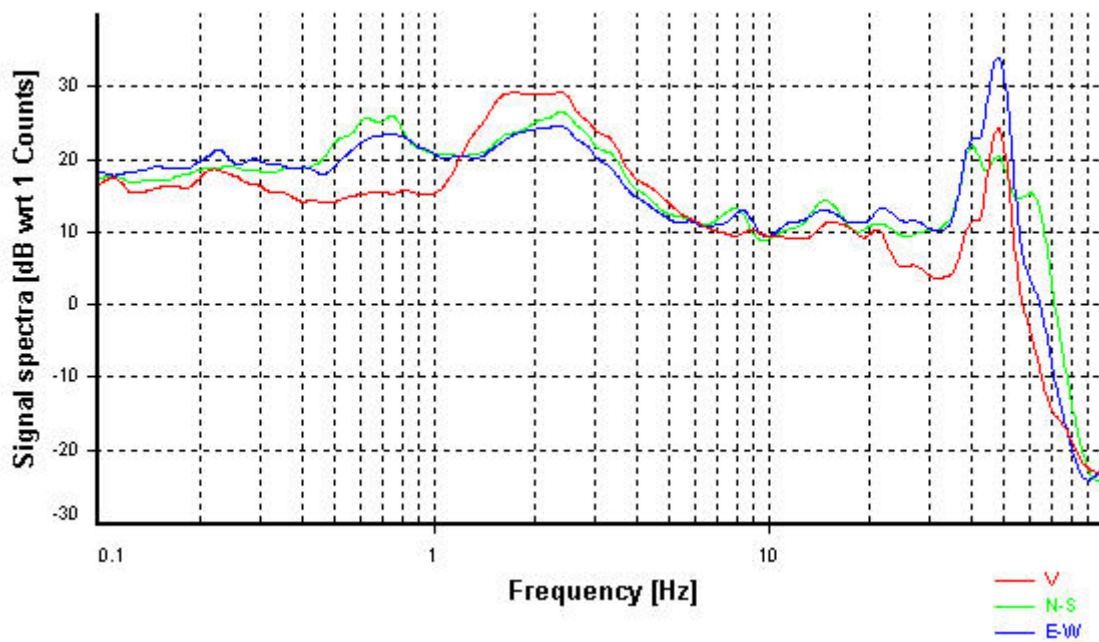
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

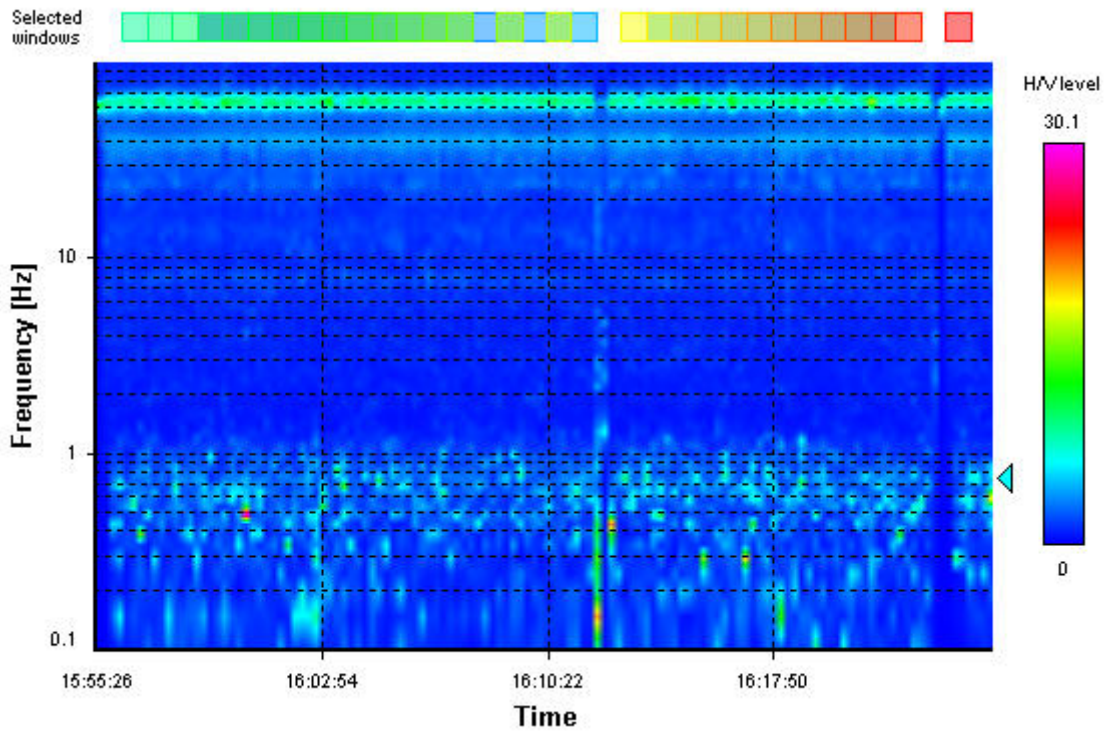
HVSR average



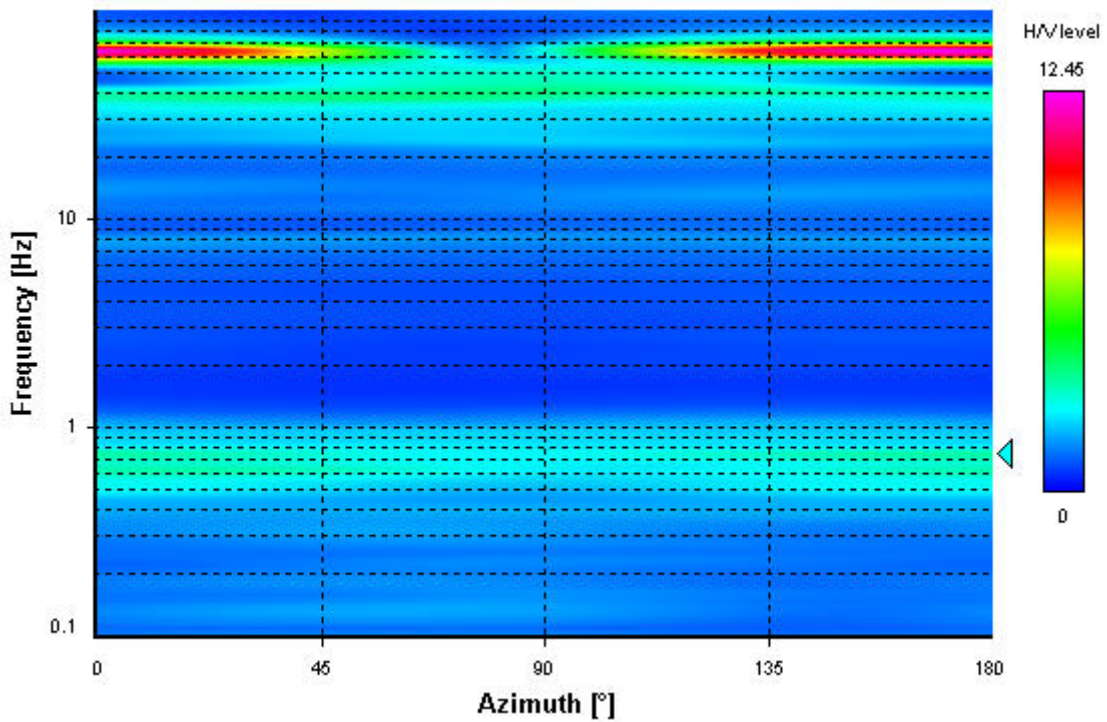
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



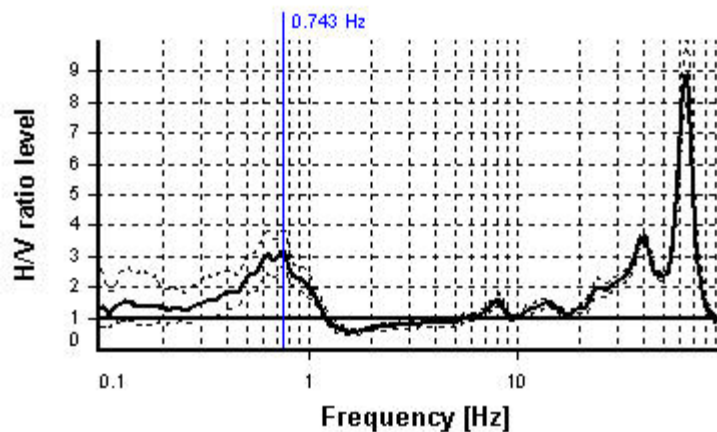
SESAME CRITERIA

Selected f_0 frequency

0.743 Hz

A_0 amplitude = 3.180

Average $f_0 = 0.675 \pm 0.080$



HVSR curve reliability criteria

$f_0 > 10 / L_w$	42 valid windows (length > 13.46 s) out of 42	OK
$n_c(f_0) > 200$	2043.15 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 181	OK

HVSR peak clarity criteria

$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	0.35805 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	1.09099 Hz	OK
$A_0 > 2$	3.18 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0.77% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.0797 < 0.11144	OK
$\sigma_A(f_0) < \theta(f_0)$	1.20859 < 2	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Norcia - Ospedale - Testa

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

Recording start time: 2016/09/13 15:55:21

Recording length: 15 min

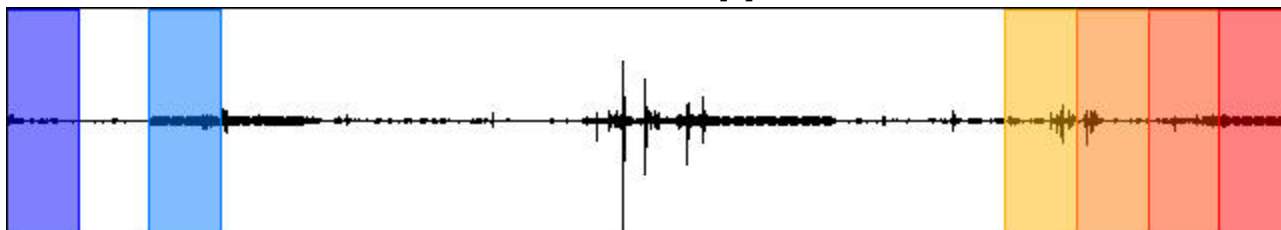
Windows count: 6

Average windows length: 50

Signal coverage: 33.33%

182947 Counts

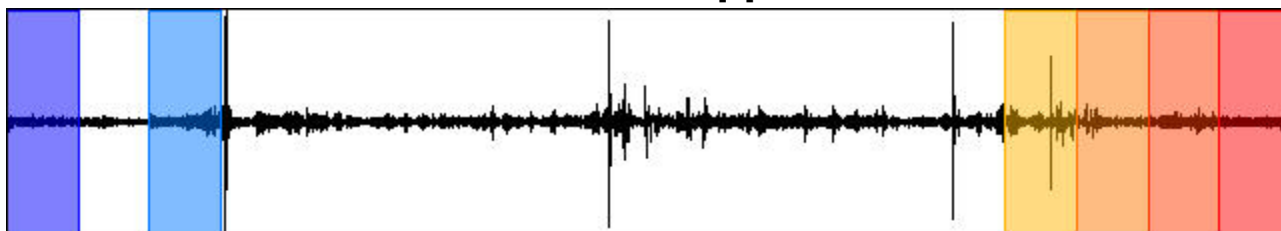
CHANNEL #1 [V]



-337027 Counts

107309 Counts

CHANNEL #2 [N]



-105138 Counts

68006 Counts

CHANNEL #3 [E]



-54604 Counts

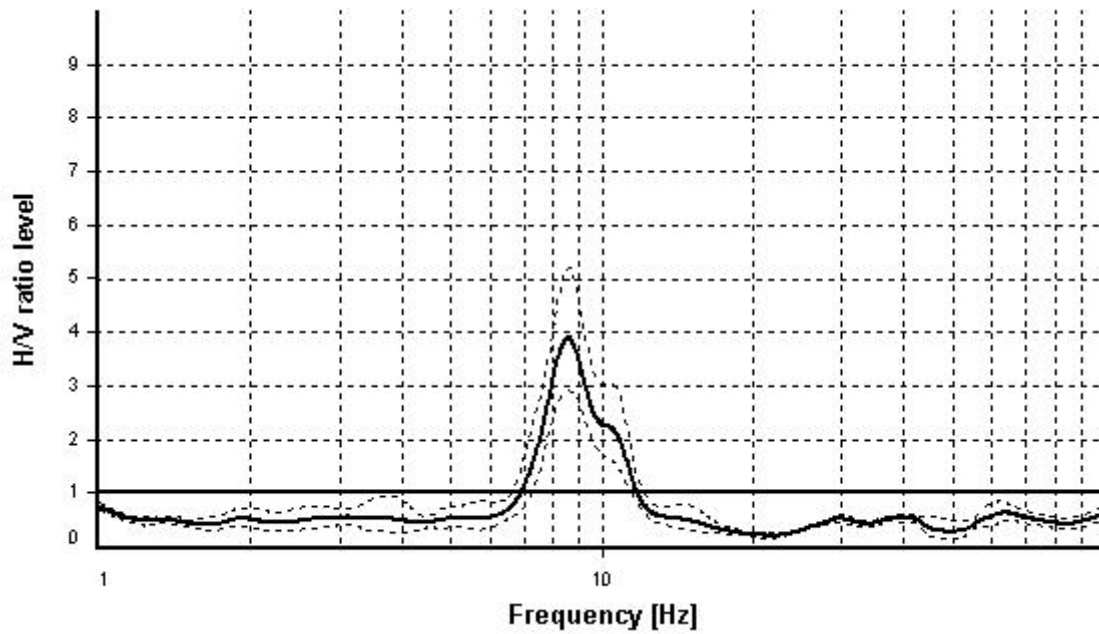
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

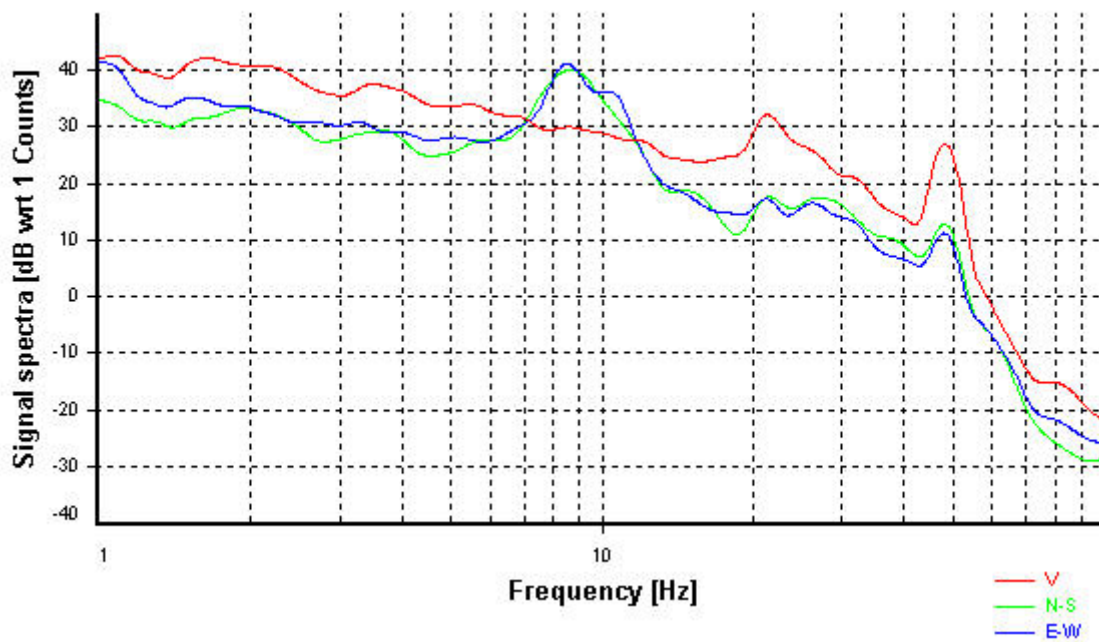
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

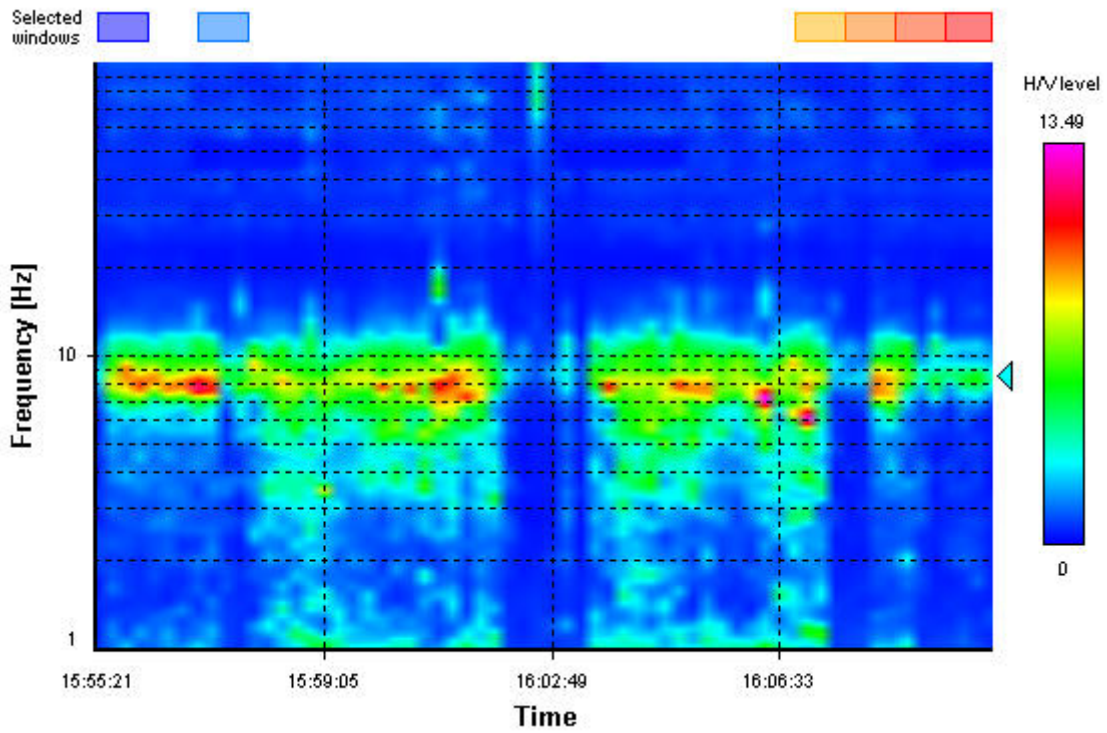
HVSR average



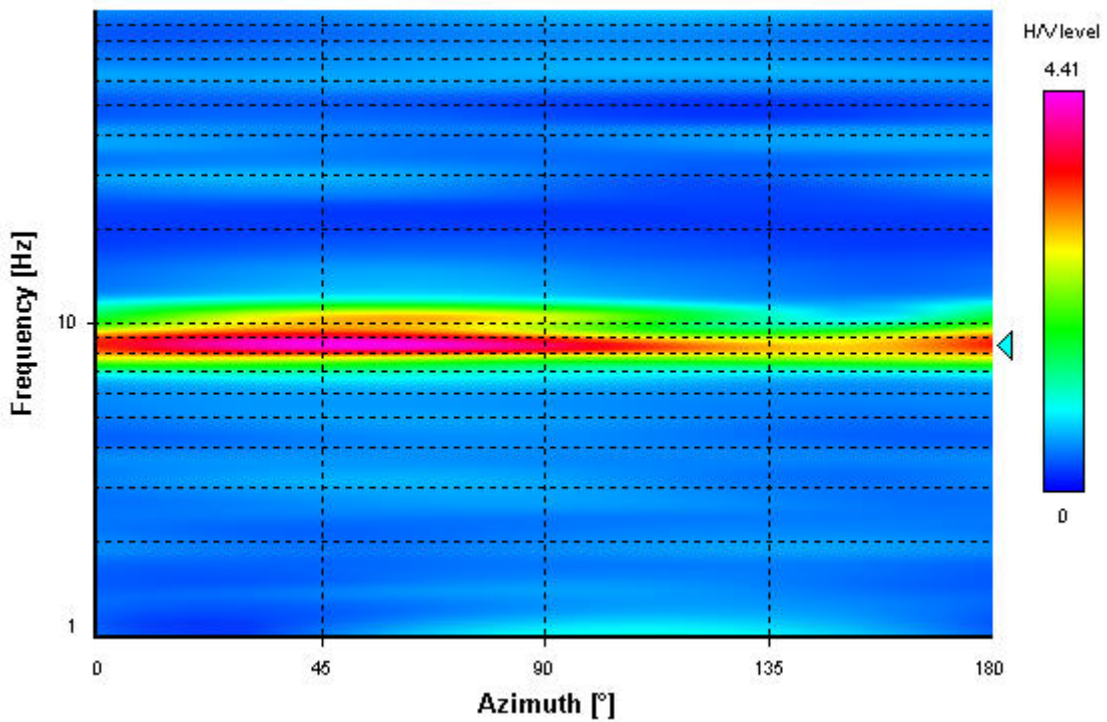
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



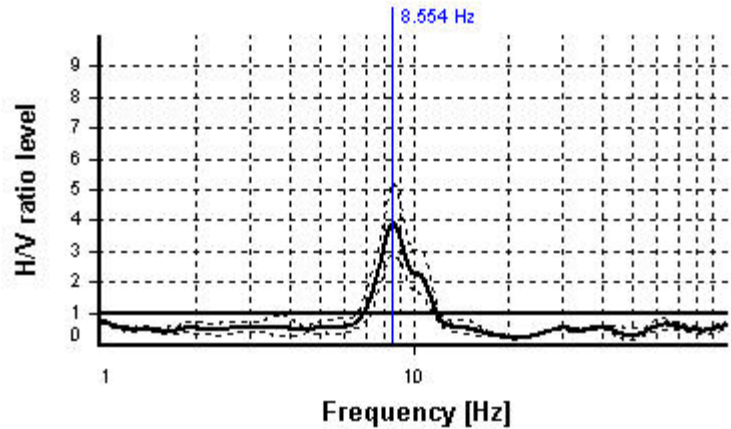
SESAME CRITERIA

Selected f_0 frequency

8.554 Hz

A_0 amplitude = 3.890

Average $f_0 = 8.652 \pm 0.242$



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	6 valid windows (length > 1.17 s) out of 6	OK
$n_c(f_0) > 200$	2566.07 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 271	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	7.48695 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	10.93785 Hz	OK
$A_0 > 2$	3.89 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0.51% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.24183 < 0.42768	OK
$\sigma_A(f_0) < \theta(f_0)$	1.33781 < 1.58	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Norcia - Scuola Media - Base

Address: -

Latitude: 42.79170N

Longitude: 013.09654E

Coordinate system: WGS84

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

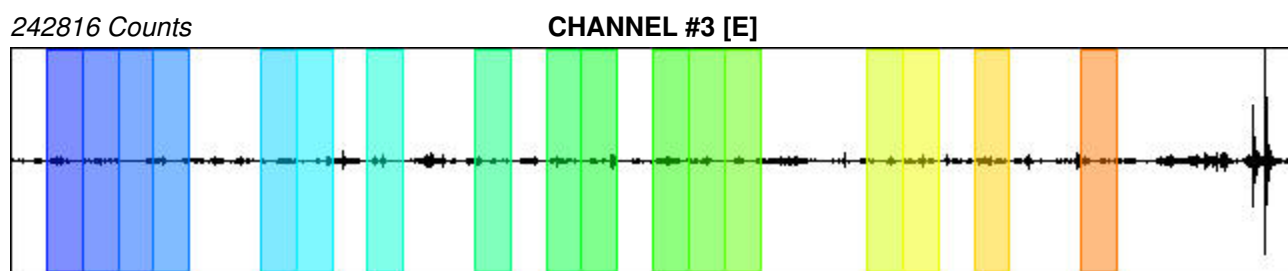
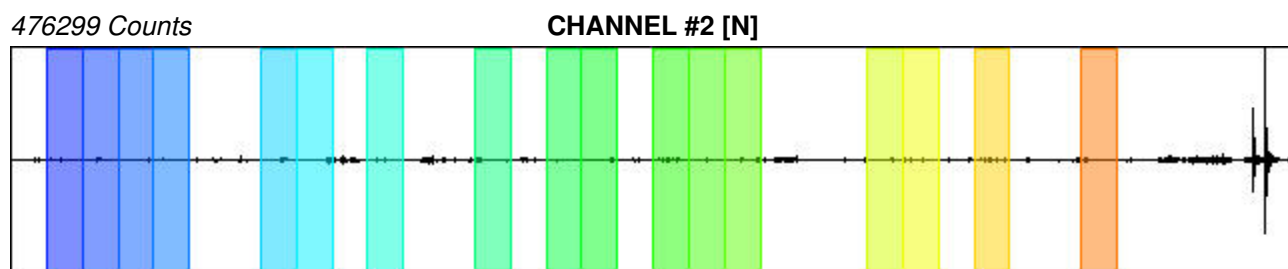
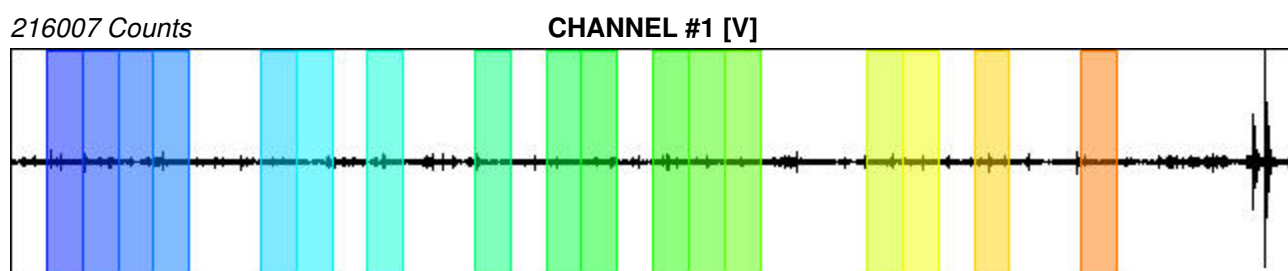
Recording start time: 2016/09/13 13:17:27

Recording length: 60 min

Windows count: 17

Average windows length: 100

Signal coverage: 47.22%



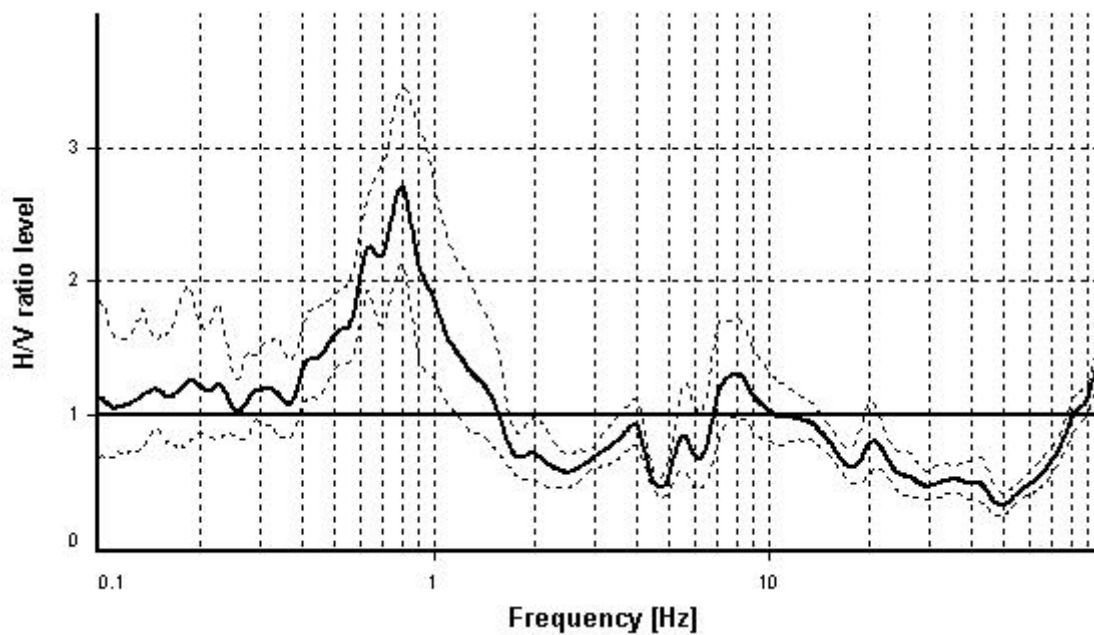
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

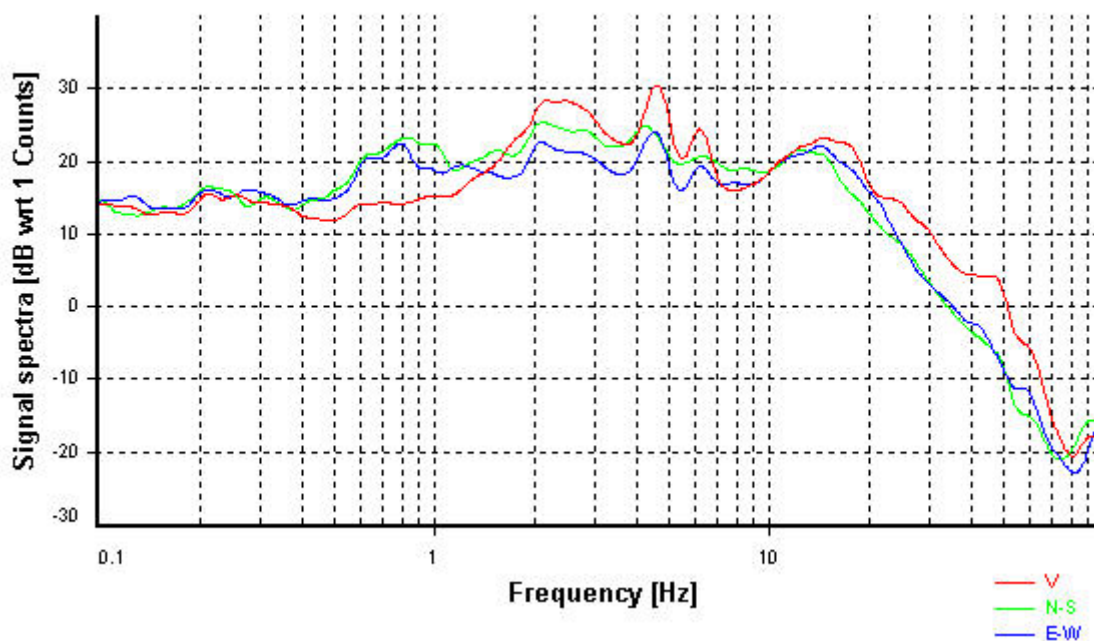
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

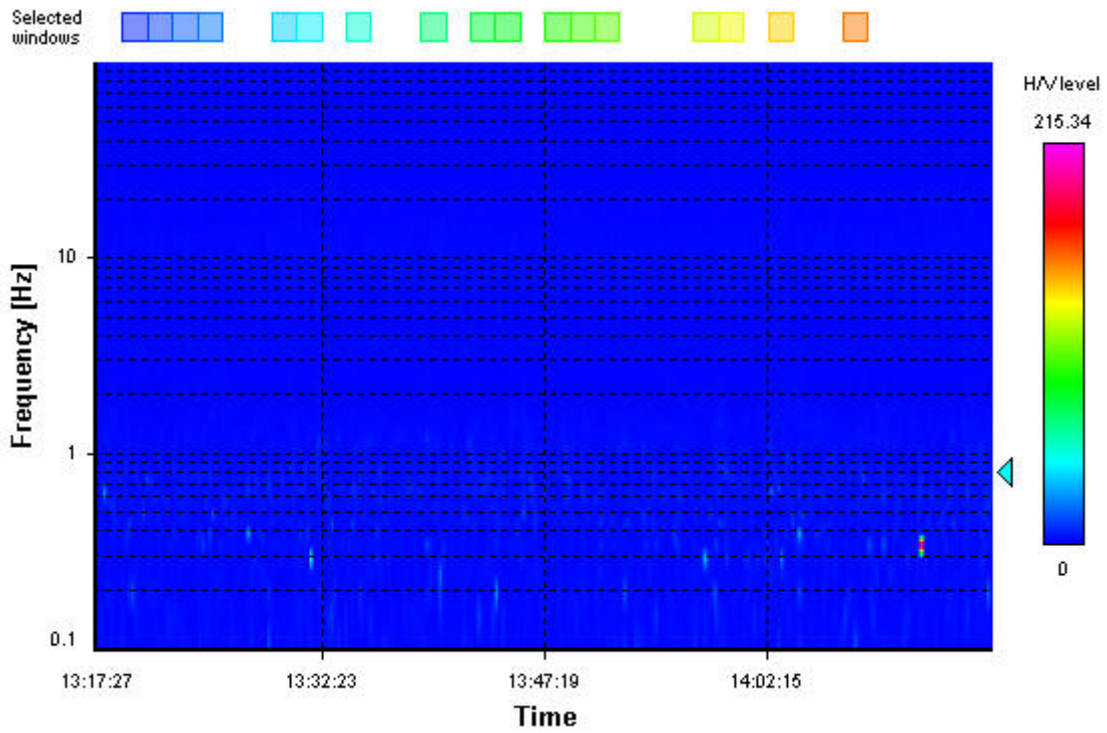
HVSR average



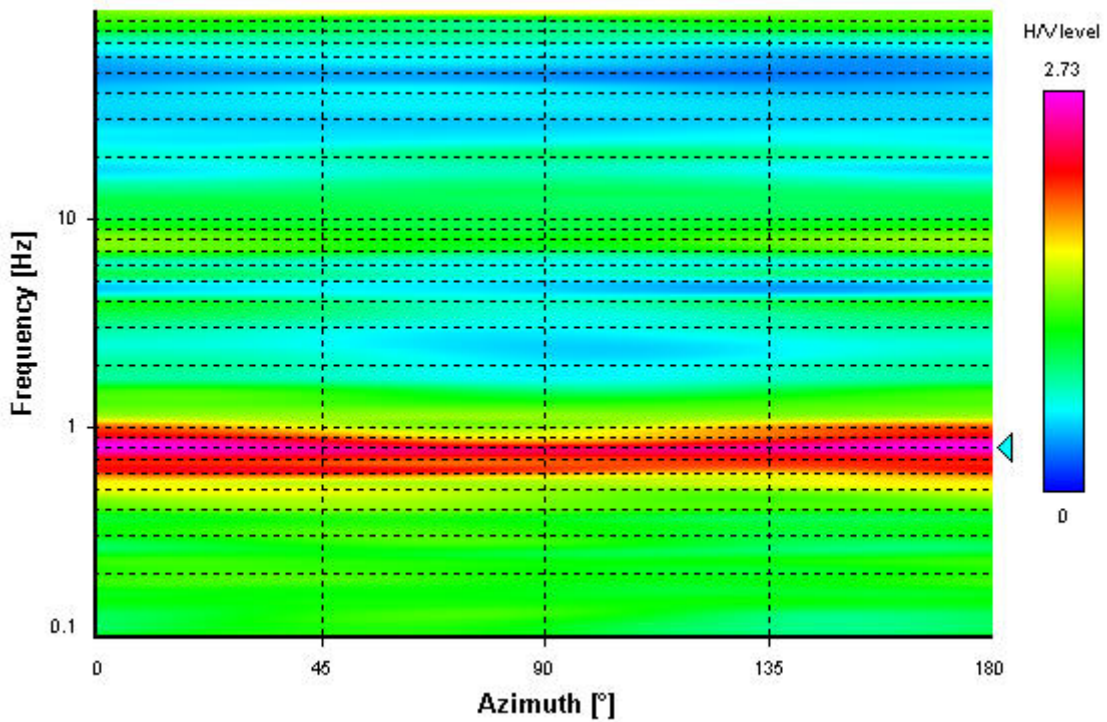
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



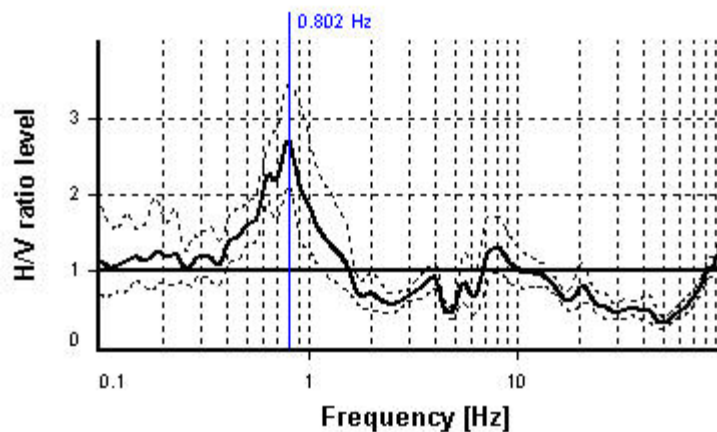
SESAME CRITERIA

Selected f_0 frequency

0.802 Hz

A_0 amplitude = 2.701

Average $f_0 = 0.813 \pm 0.085$



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	17 valid windows (length > 12.46 s) out of 17	OK
$n_c(f_0) > 200$	1363.91 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 181	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	0.40489 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	1.27222 Hz	OK
$A_0 > 2$	2.7 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0.77% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.08481 < 0.12035	OK
$\sigma_A(f_0) < \theta(f_0)$	1.27321 < 2	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Norcia - Scuola Media - Terreno

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

Recording start time: 2016/09/13 14:54:18

Recording length: 30 min

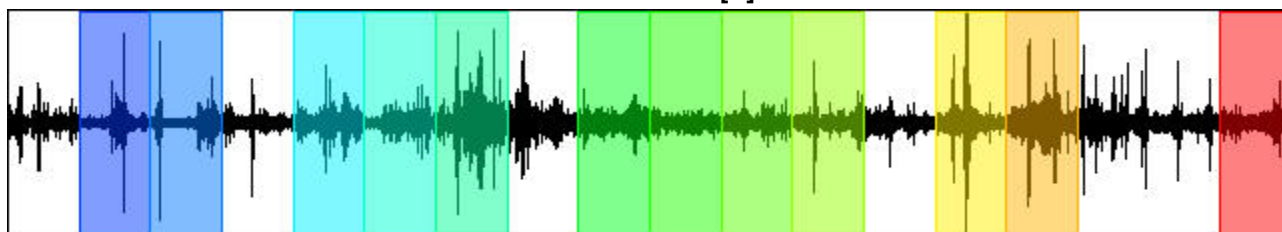
Windows count: 12

Average windows length: 100

Signal coverage: 66.67%

33361 Counts

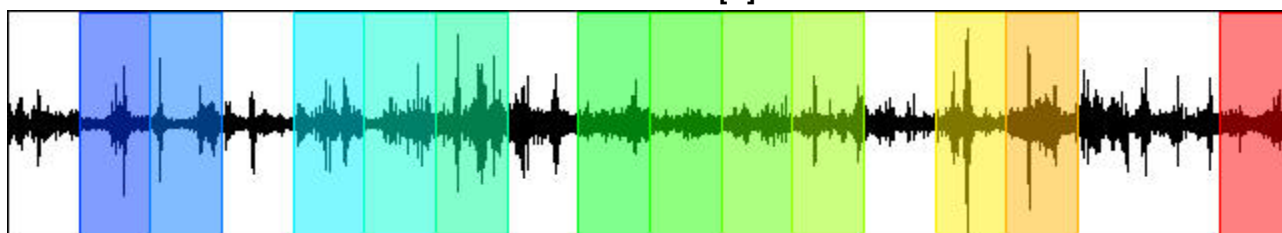
CHANNEL #1 [V]



-32983 Counts

29926 Counts

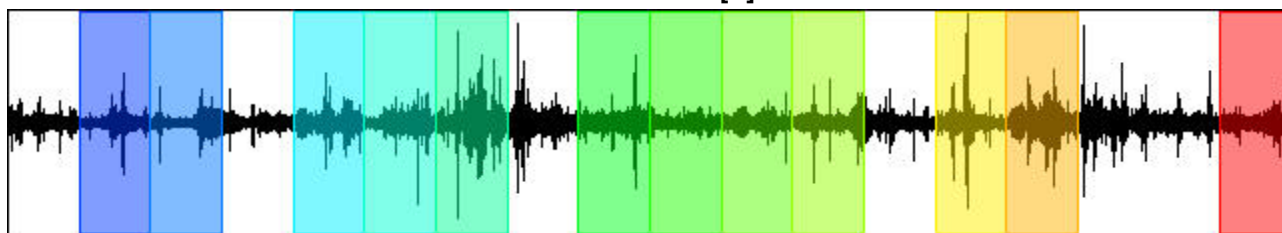
CHANNEL #2 [N]



-35028 Counts

48484 Counts

CHANNEL #3 [E]



-41136 Counts

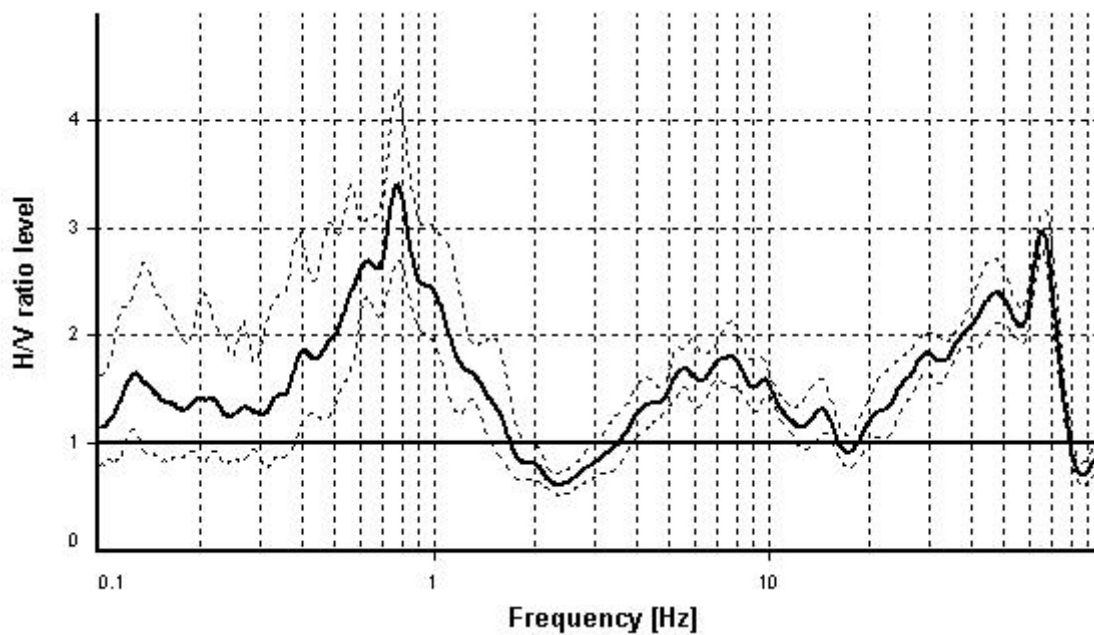
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

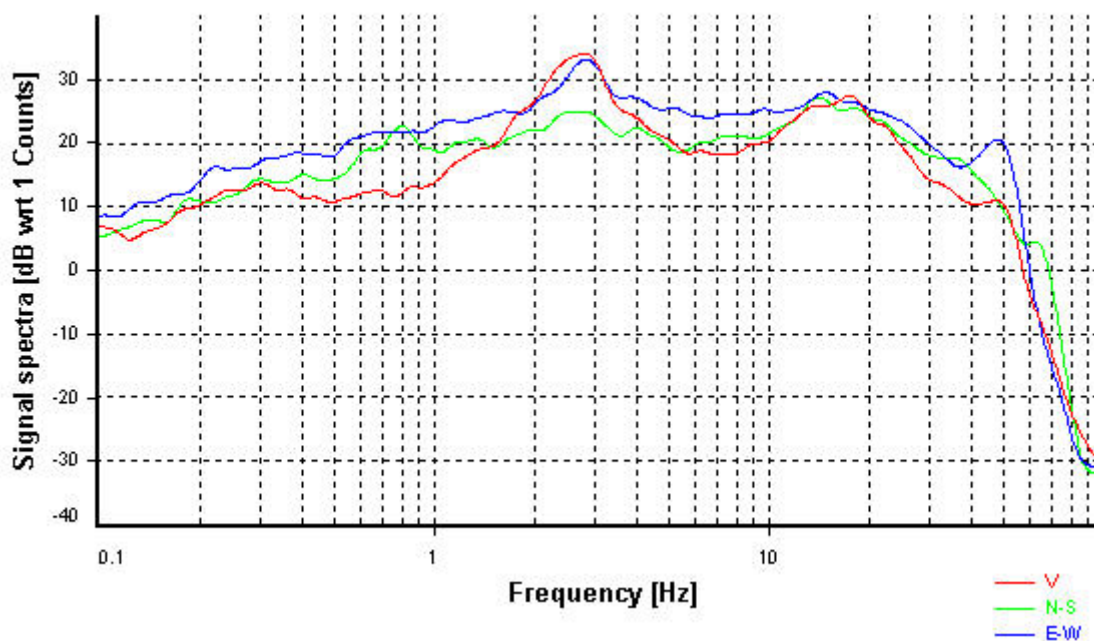
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

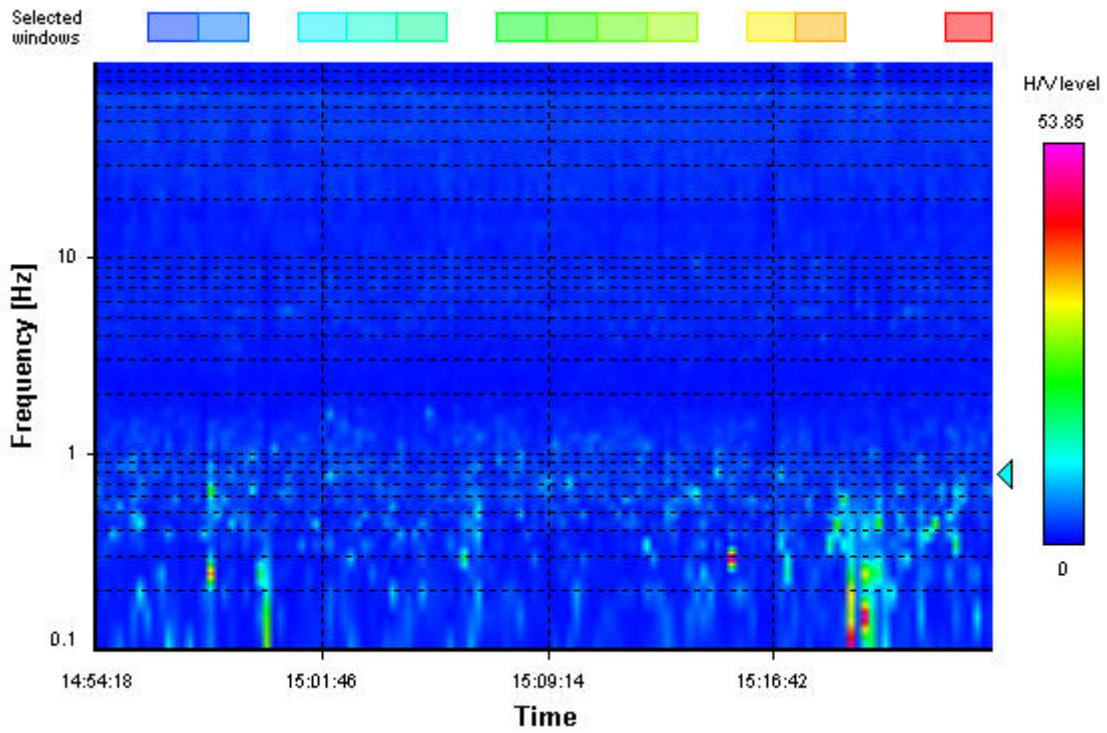
HVSR average



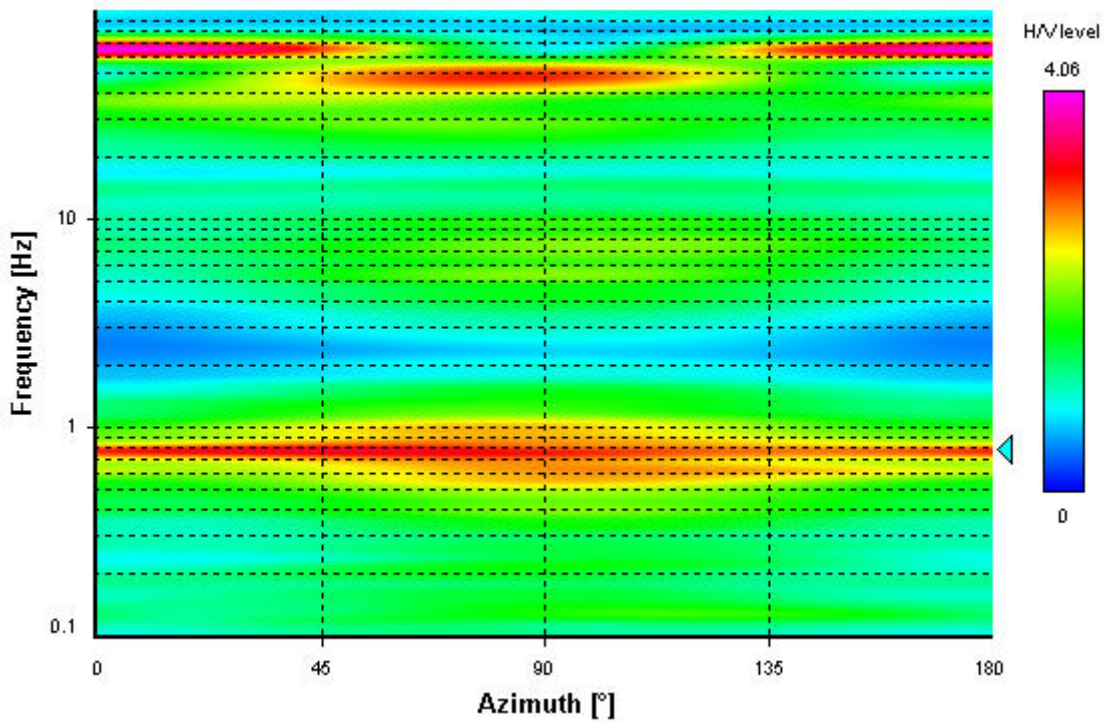
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



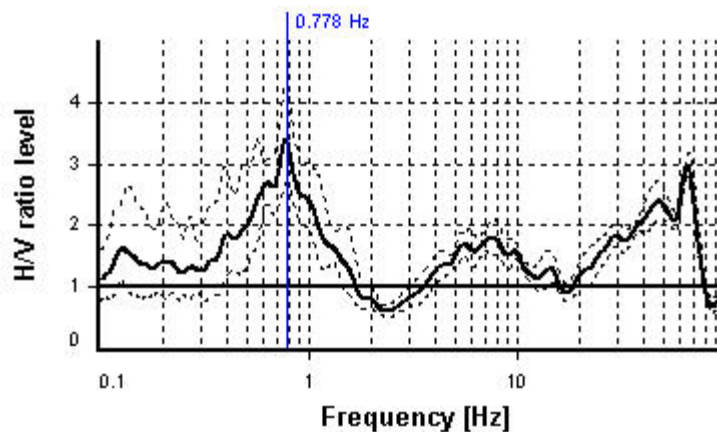
SESAME CRITERIA

Selected f_0 frequency

0.778 Hz

A_0 amplitude = 3.406

Average $f_0 = 0.729 \pm 0.114$



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	12 valid windows (length > 12.85 s) out of 12	OK
$n_c(f_0) > 200$	933.62 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 181	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	0.38075 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	1.22426 Hz	OK
$A_0 > 2$	3.41 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	0.77% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.11419 < 0.1167	OK
$\sigma_A(f_0) < \theta(f_0)$	1.26171 < 2	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Norcia - Scuola Media - Testa

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

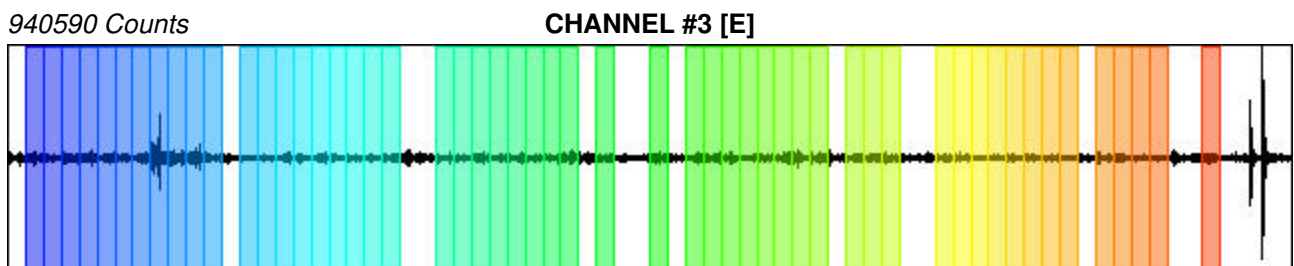
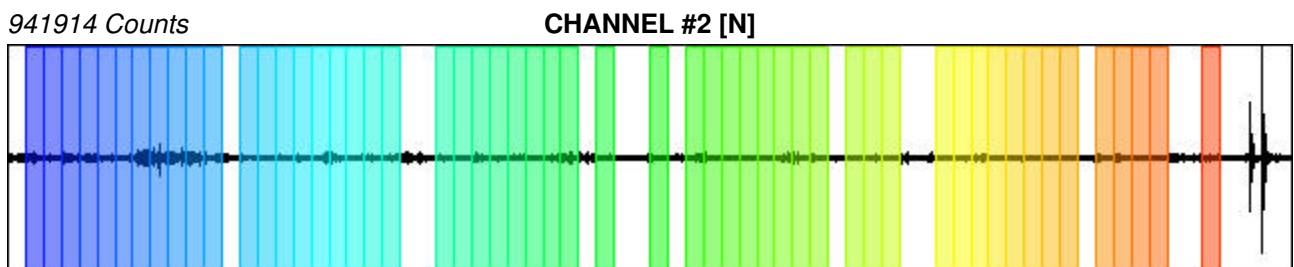
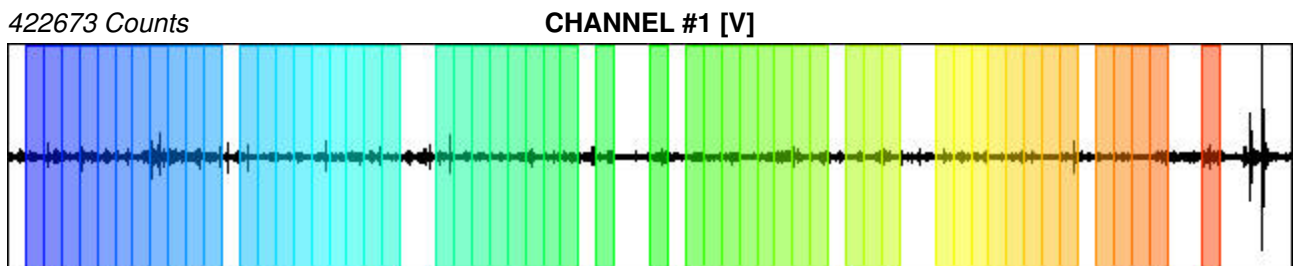
Recording start time: 2016/09/13 13:17:28

Recording length: 60 min

Windows count: 54

Average windows length: 50

Signal coverage: 75%



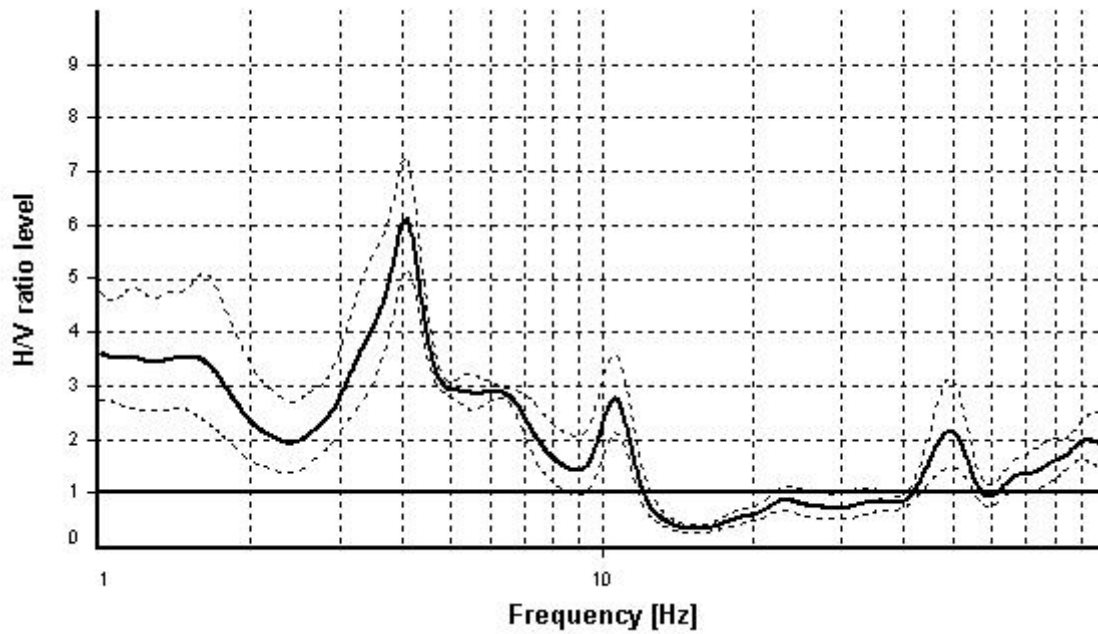
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

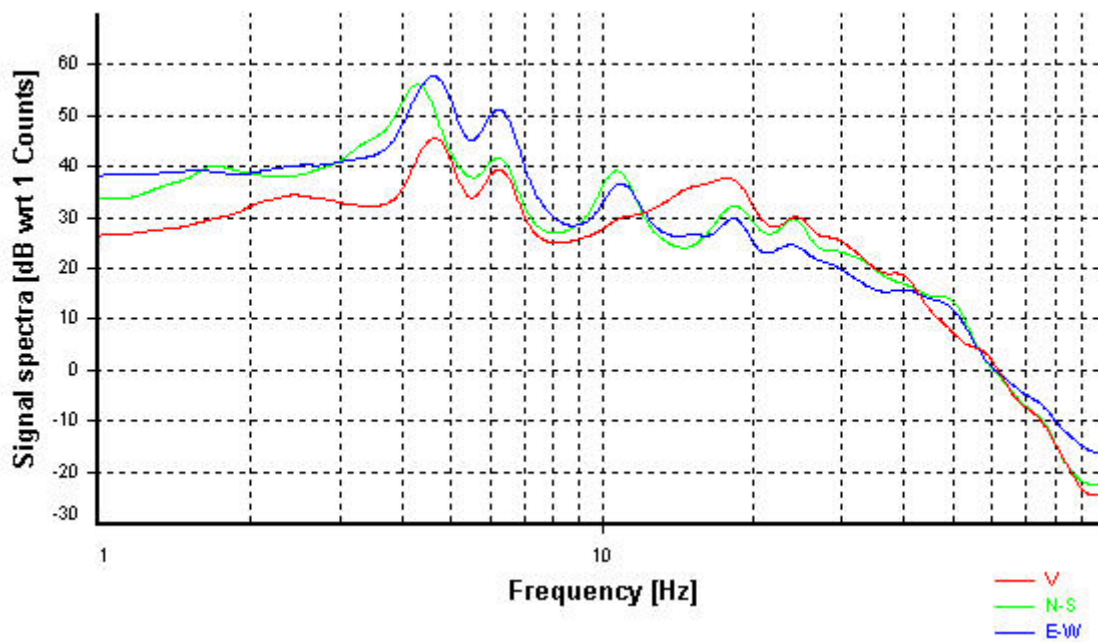
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

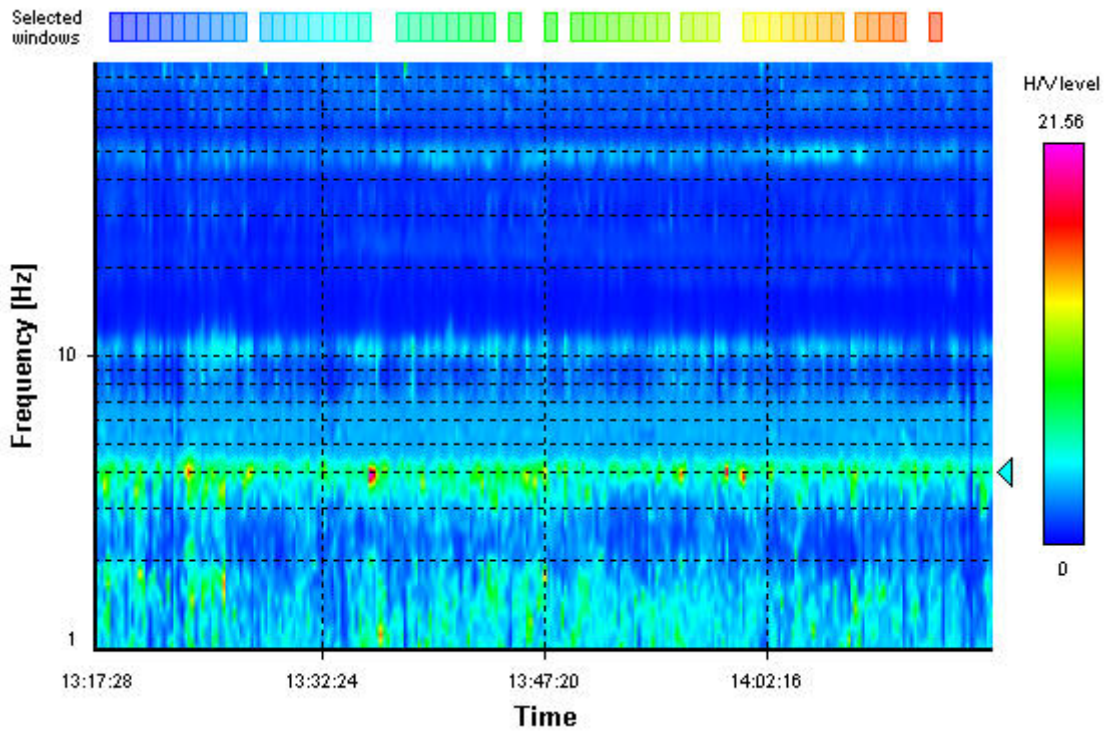
HVSR average



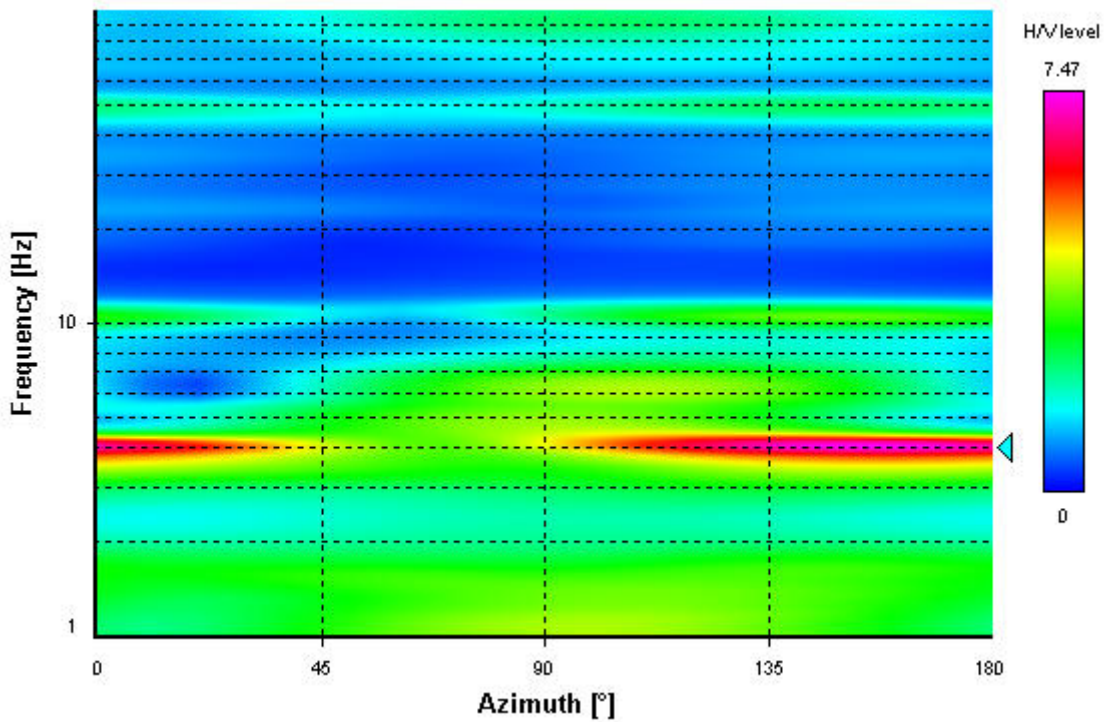
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



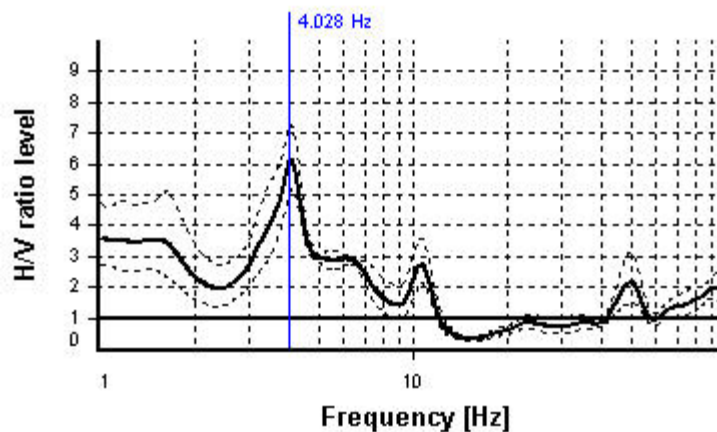
SESAME CRITERIA

Selected f_0 frequency

4.028 Hz

A_0 amplitude = 6.072

Average $f_0 = 4.036 \pm 0.154$



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	54 valid windows (length > 2.48 s) out of 54	OK
$n_c(f_0) > 200$	10876.28 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 271	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	3.08626 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	4.84402 Hz	OK
$A_0 > 2$	6.07 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	1.55% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.15358 < 0.20141	OK
$\sigma_A(f_0) < \theta(f_0)$	1.1931 < 1.58	OK
Overall criteria fulfillment		OK

STATION INFORMATION

Station code: Geobox

Model: SARA GEOBOX

Sensor: SARA SS05PACK (integrated 0.5 Hz sensors)

Notes: -

PLACE INFORMATION

Place ID: Norcia - Scuola Media - Testa - M2

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

Recording start time: 2016/09/13 14:54:29

Recording length: 30 min

Windows count: 17

Average windows length: 100

Signal coverage: 94.44%

99083 Counts

CHANNEL #1 [V]



-94545 Counts

162826 Counts

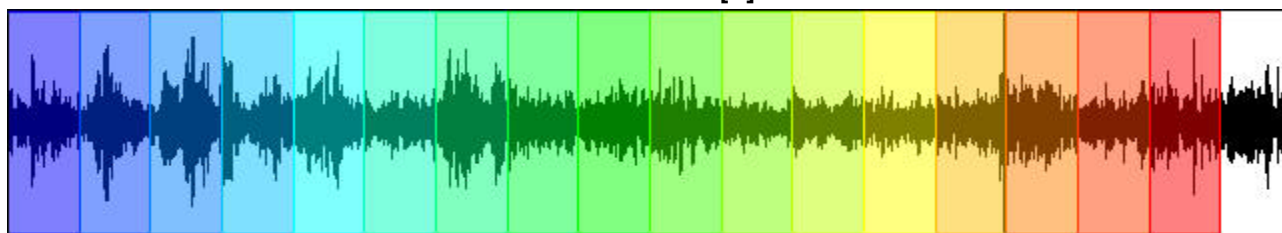
CHANNEL #2 [N]



-152638 Counts

67895 Counts

CHANNEL #3 [E]



-66667 Counts

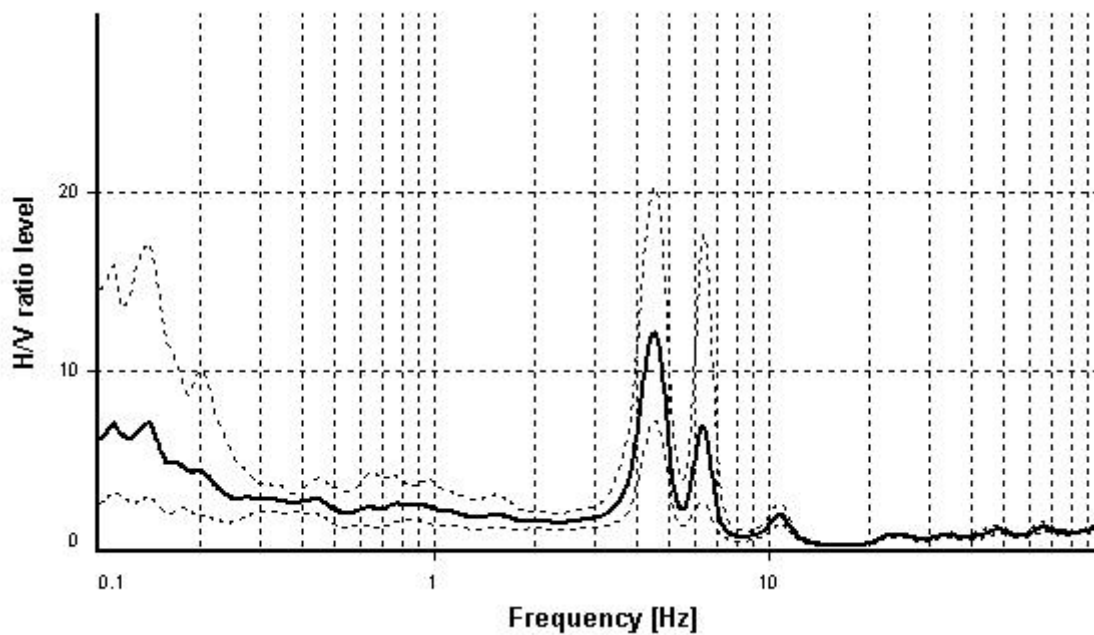
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 5%)

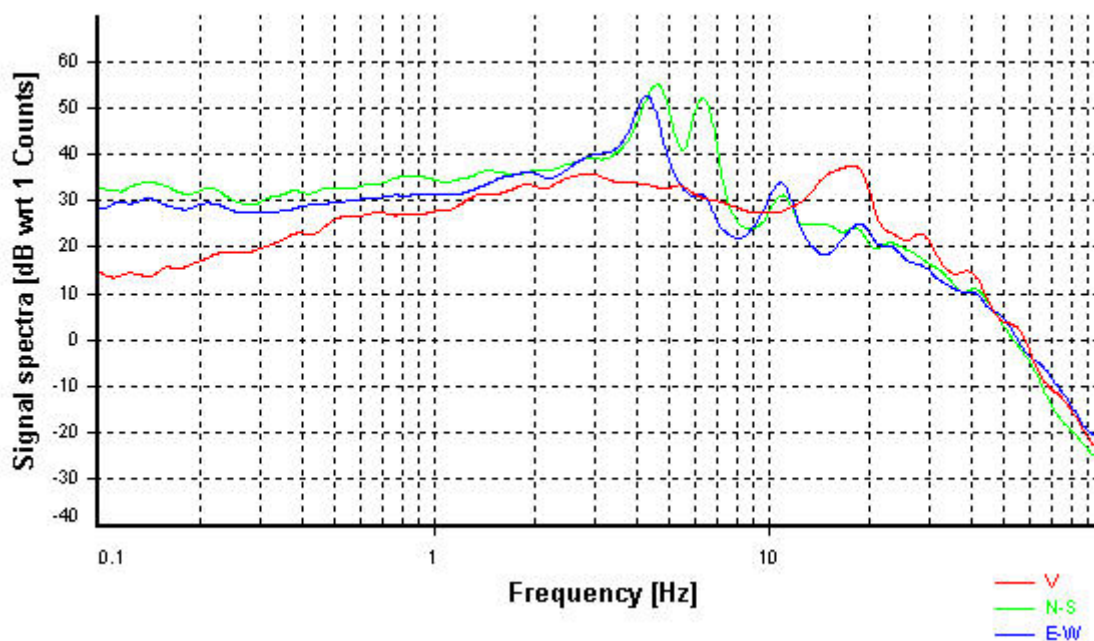
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

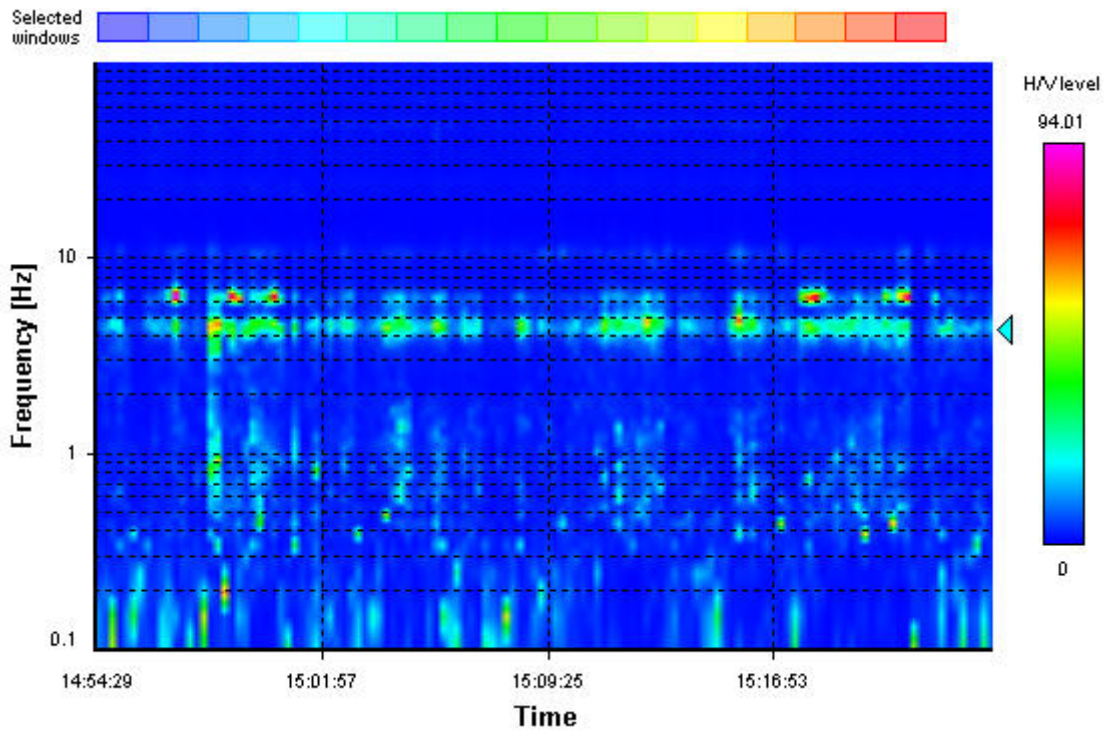
HVSR average



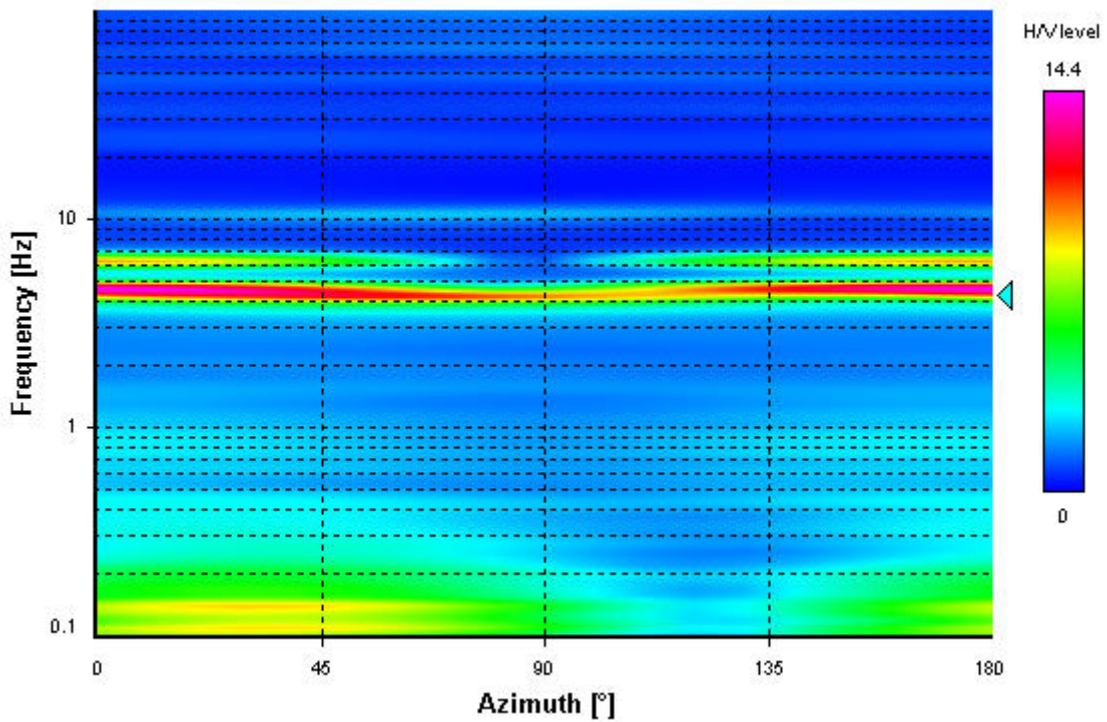
Signal spectra average



HVSR time-frequency analysis (14 seconds windows)



HVSR directional analysis



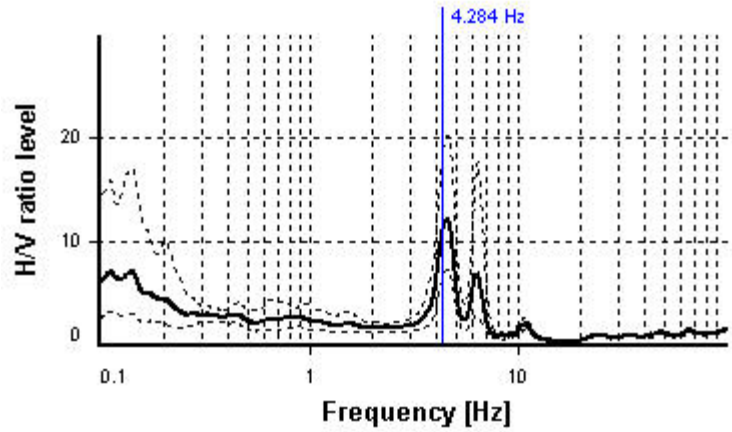
SESAME CRITERIA

Selected f_0 frequency

4.284 Hz

A_0 amplitude = 10.360

Average $f_0 = 4.978 \pm 0.784$



HVSr curve reliability criteria		
$f_0 > 10 / L_w$	17 valid windows (length > 2.33 s) out of 17	OK
$n_c(f_0) > 200$	7282.19 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 26 times in 181	NO
HVSr peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	3.93646 Hz	OK
$\exists f^+$ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	5.1117 Hz	OK
$A_0 > 2$	10.36 > 2	OK
$f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	6.34% > 5%	NO
$\sigma_f < \varepsilon(f_0)$	0.78393 >= 0.21418	NO
$\sigma_A(f_0) < \theta(f_0)$	1.71345 >= 1.58	NO
Overall criteria fulfillment		NO

STATION INFORMATION

Station code: -

Model: -

Sensor: -

Notes: -

PLACE INFORMATION

Place ID: Norcia - Valle

Address: -

Latitude: -

Longitude: -

Coordinate system: -

Elevation: 0 m s.l.m.

Weather: -

Notes: -

SIGNAL AND WINDOWING

Sampling frequency: 200 Hz

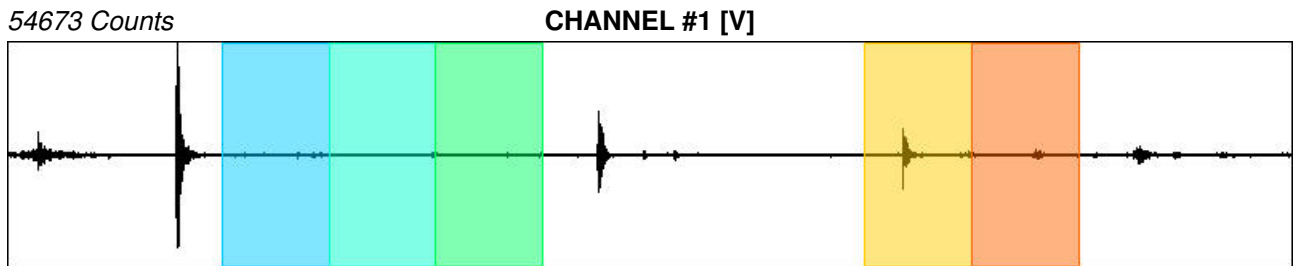
Recording start time: 2016/09/13 19:00:16

Recording length: 19.99 min

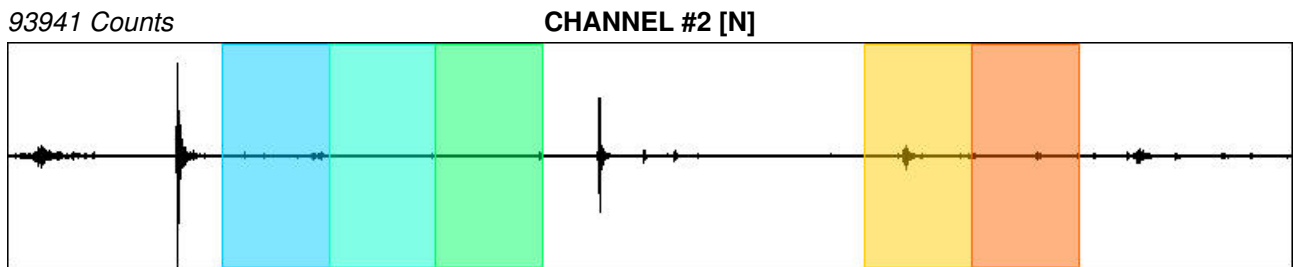
Windows count: 5

Average windows length: 100

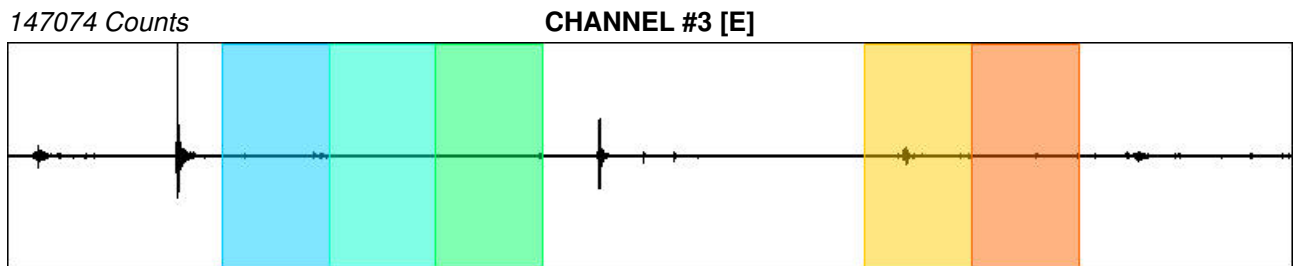
Signal coverage: 41.68%



-45412 Counts



-112629 Counts



-55634 Counts

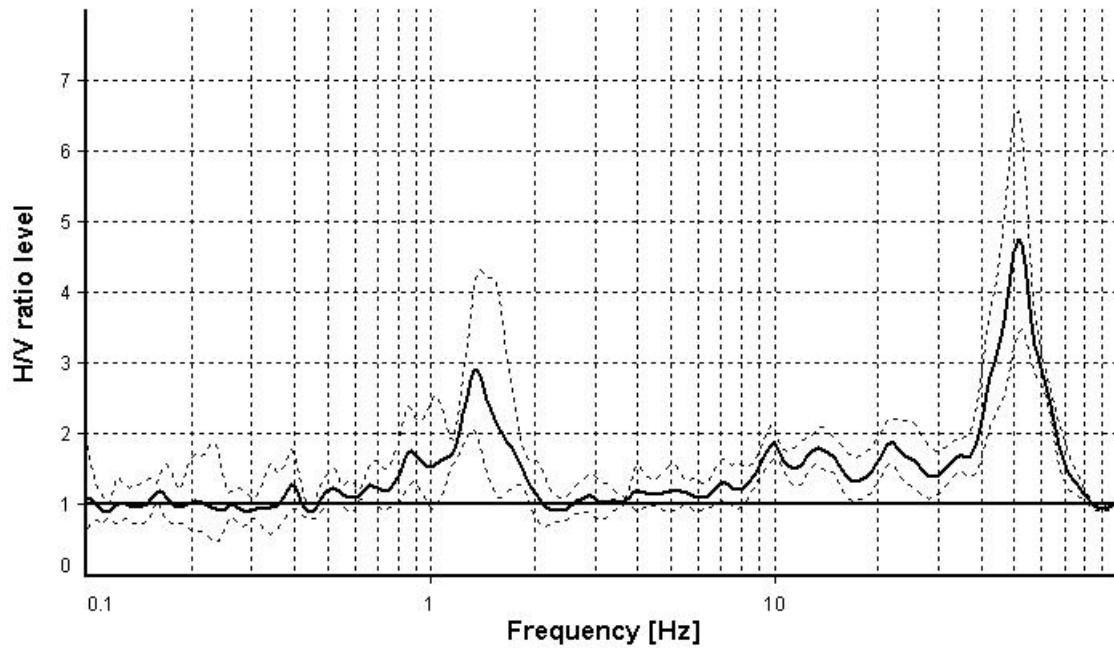
HVSR ANALYSIS

Tapering: Enabled (Bandwidth = 50%)

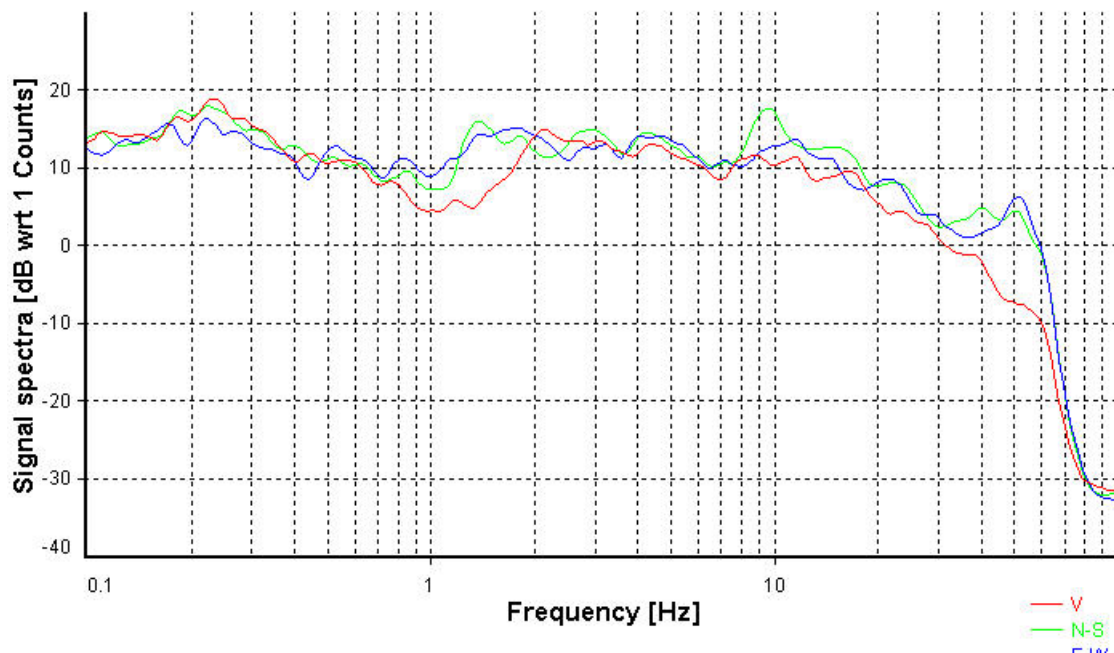
Smoothing: Konno-Ohmachi (Bandwidth coefficient = 40)

Instrumental correction: Disabled

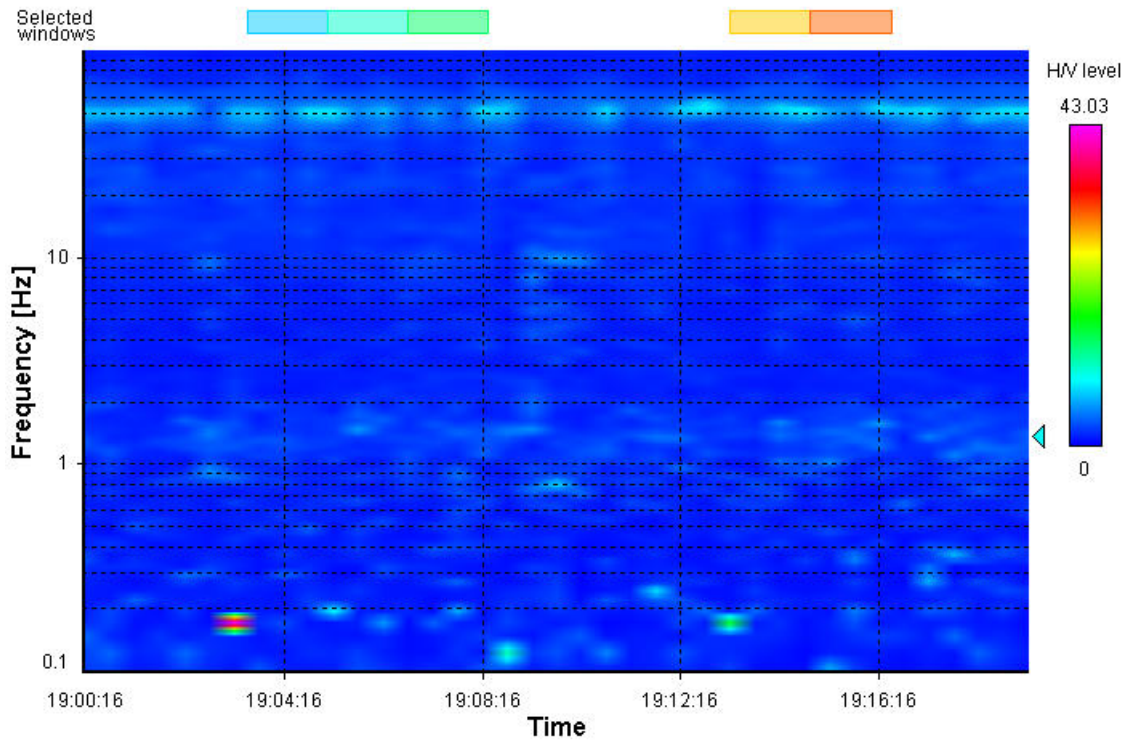
HVSR average



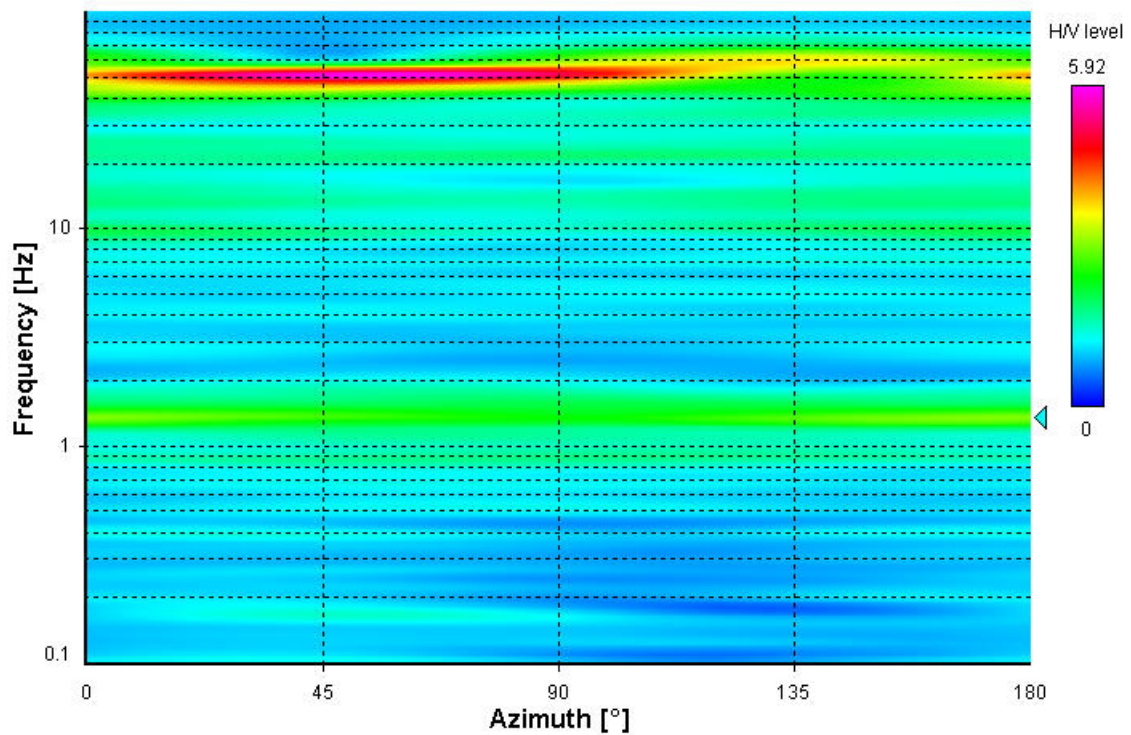
Signal spectra average



HVSR time-frequency analysis (30 seconds windows)



HVSR directional analysis



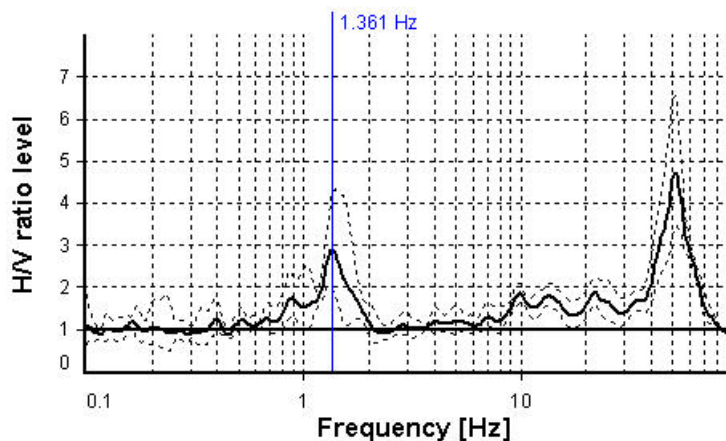
SESAME CRITERIA

Selected f_0 frequency

1.361 Hz

A_0 amplitude = 2.899

Average f_0 = 1.349 ± 0.064



HVSR curve reliability criteria		
$f_0 > 10 / L_w$	5 valid windows (length > 7.35 s) out of 5	OK
$n_c(f_0) > 200$	680.38 > 200	OK
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$	Exceeded 0 times in 61	OK
HVSR peak clarity criteria		
$\exists f$ in $[f_0/4, f_0] \mid A_{HV}(f) < A_0/2$	0.79985 Hz	OK
$\exists f'$ in $[f_0, 4f_0] \mid A_{HV}(f') < A_0/2$	1.88039 Hz	OK
$A_0 > 2$	2.9 > 2	OK
$f_{\text{peak}}[A_{HV}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	2.34% <= 5%	OK
$\sigma_f < \varepsilon(f_0)$	0.06441 < 0.13608	OK
$\sigma_A(f_0) < \theta(f_0)$	1.47153 < 1.78	OK
Overall criteria fulfillment		OK