Gabor domain analysis of Q in the near surface

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Outline

- Introduction.
- Theory.
- Acquisition and processing.
- Interpretation and conclusions.
- Acknowledgements.

Introduction

- Goal: Q for the Rothney Geophysical Observatory.
- From experience, $Q\left(\tau\right)_f$ estimation is difficult.
- Attempt $Q\left(f\right)_\tau$.
- Acquire multilevel VSP with V, H_1, and H_2 vibes.

Theory

- Planewave G in a homogeneous medium

$$G\left(\tau, f\right) = A\left(f\right)\, e^{-\beta(f)\,\tau}\, e^{i\,\phi(\tau,f)},$$

where $\beta\left(f\right) = \pi\, f/Q$ and, for $A > 0$

$$\boxed{\log\left\{\sqrt{G\left(\tau, f\right)\, G^{\dagger}\left(\tau, f\right)}\right\} = log\{A\left(f\right)\} - \beta\left(f\right)\, \tau}.$$

Acquisition

Acquisition

- Multilevel, 9C VSP plus a surface array.

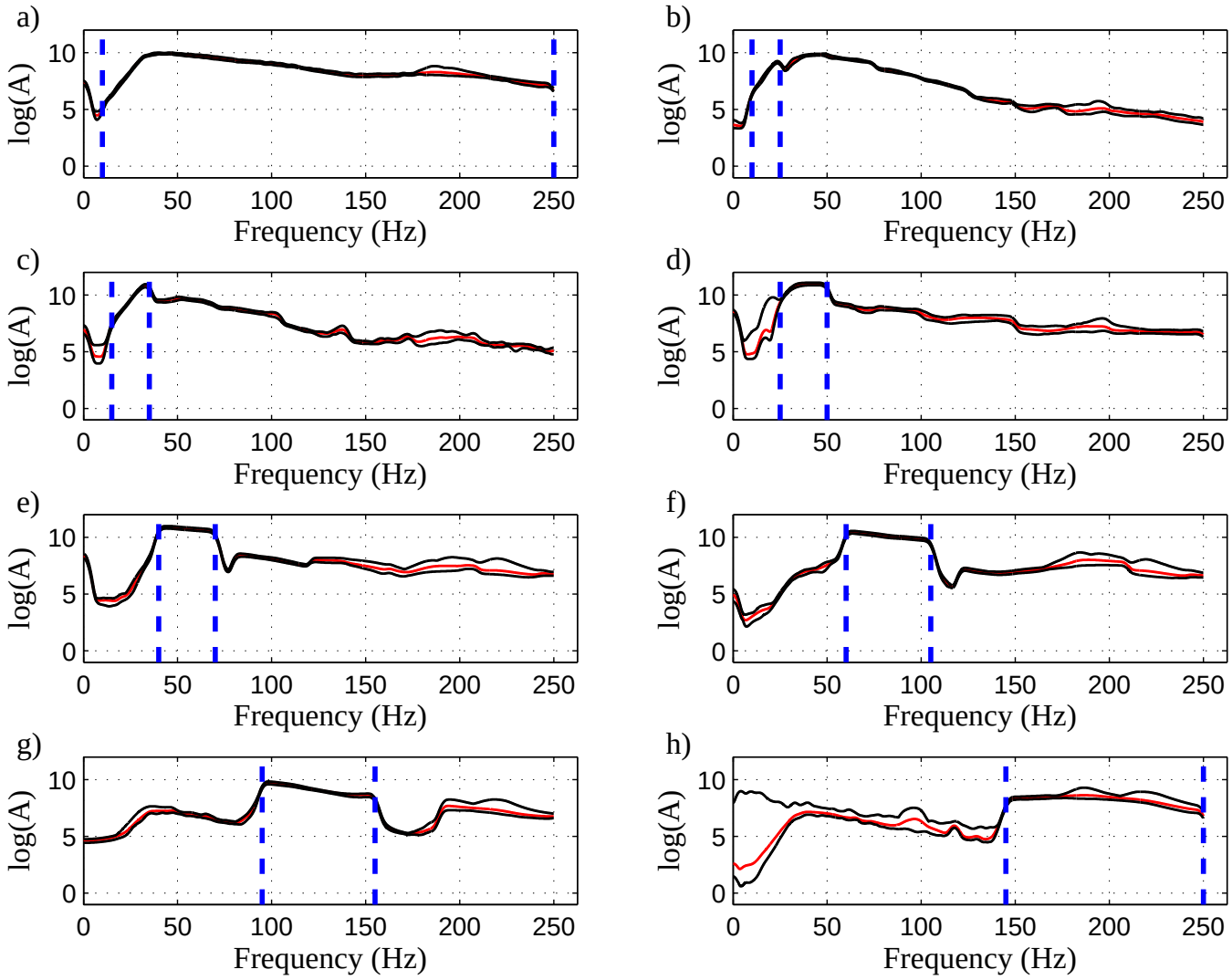
#	1	2	3	4	5	6	7
Depth (m)	95	90	80	70	55	30	10

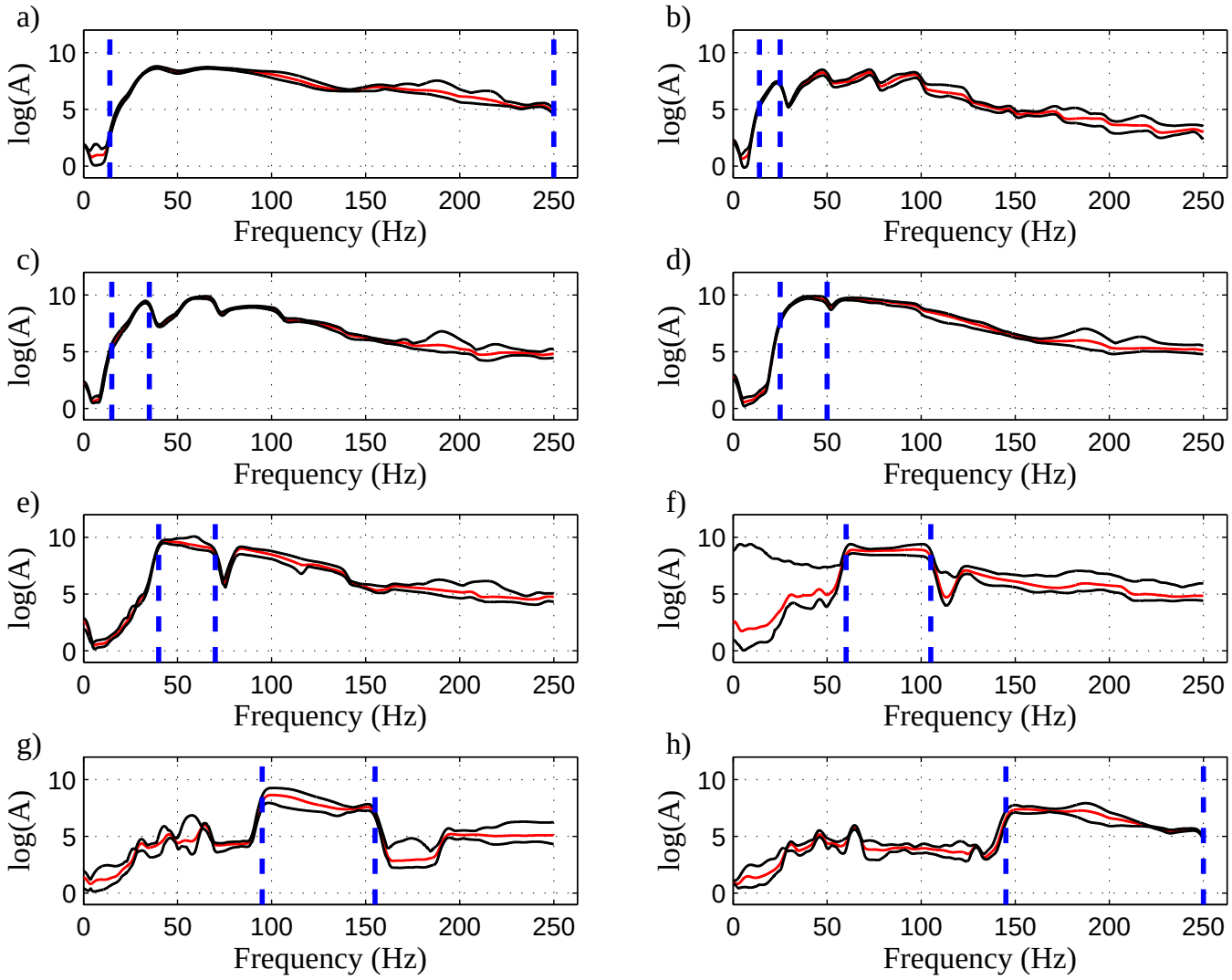
- Long, narrow band sweeps.

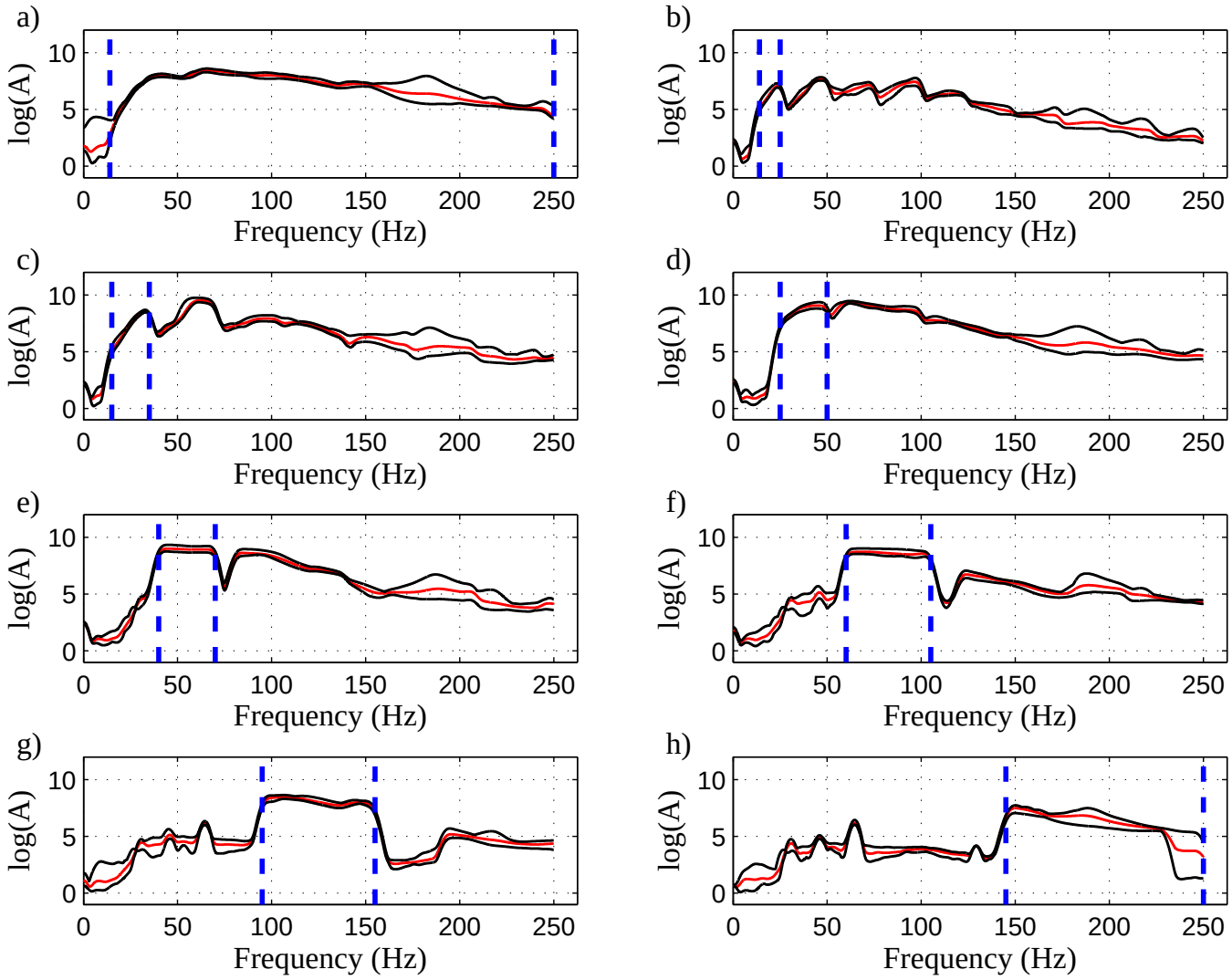
Sweep (Hz)	1	2	3	4	5	6	7	8
V	10-250	10-25	15-35	25-50	40-70	60-105	95-155	145-250
H_1	14-250	14-25	15-35	25-50	40-70	60-105	95-155	145-250
H_2	14-250	14-25	15-35	25-50	40-70	60-105	95-155	145-250

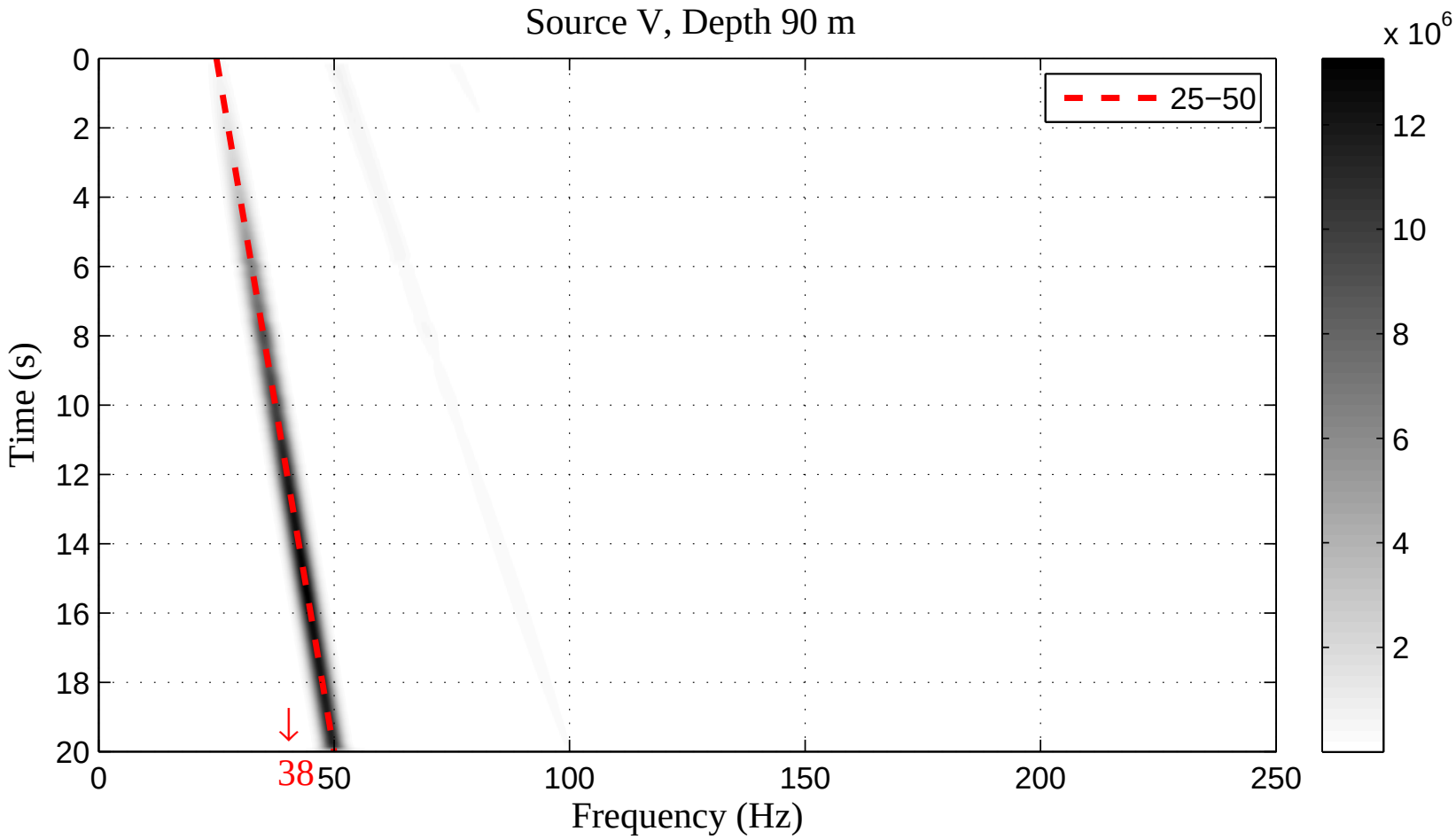
Data quality

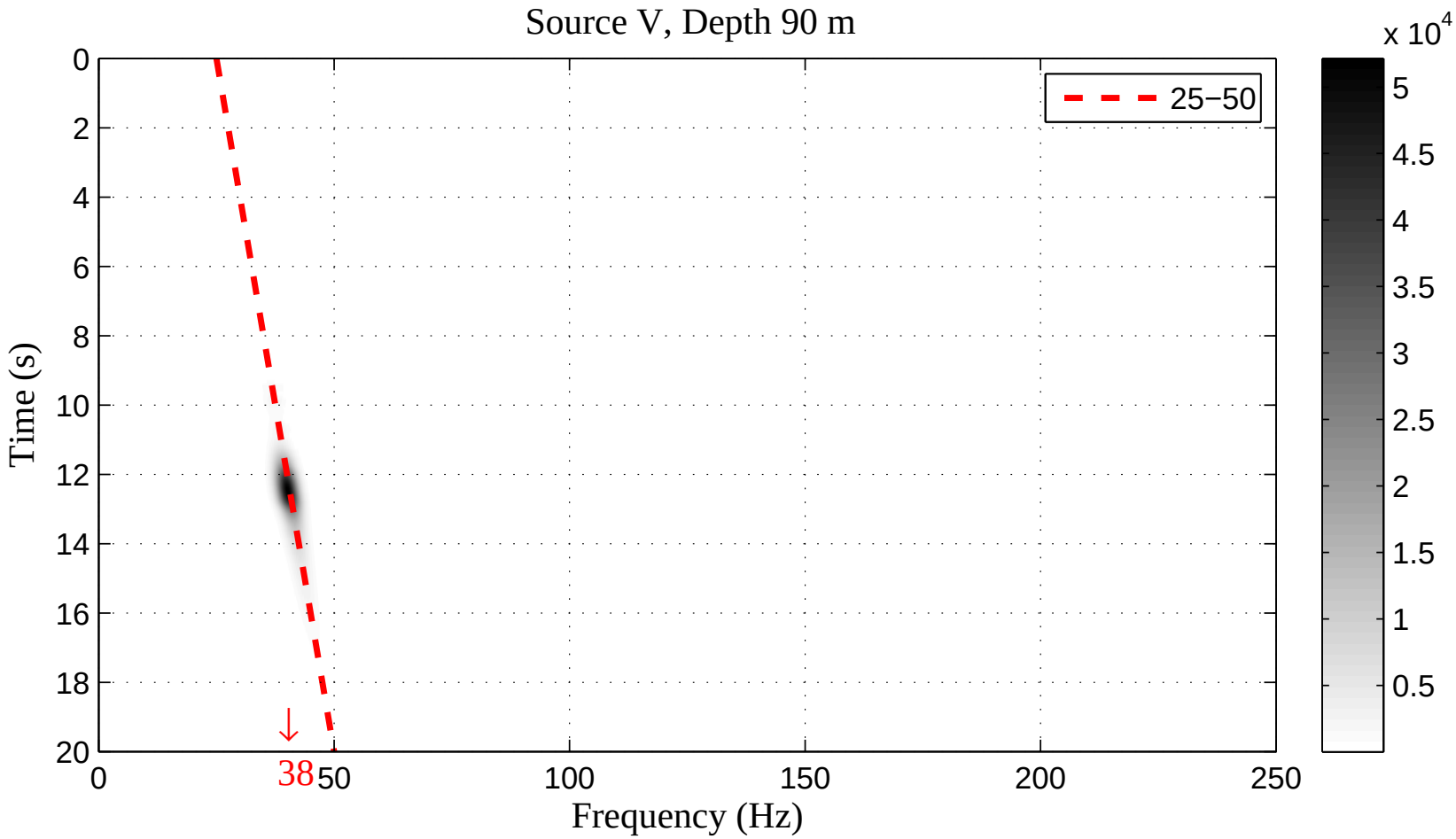
- Source repeatability.
- Baseplate harmonics.
- Downhole harmonics and noise.

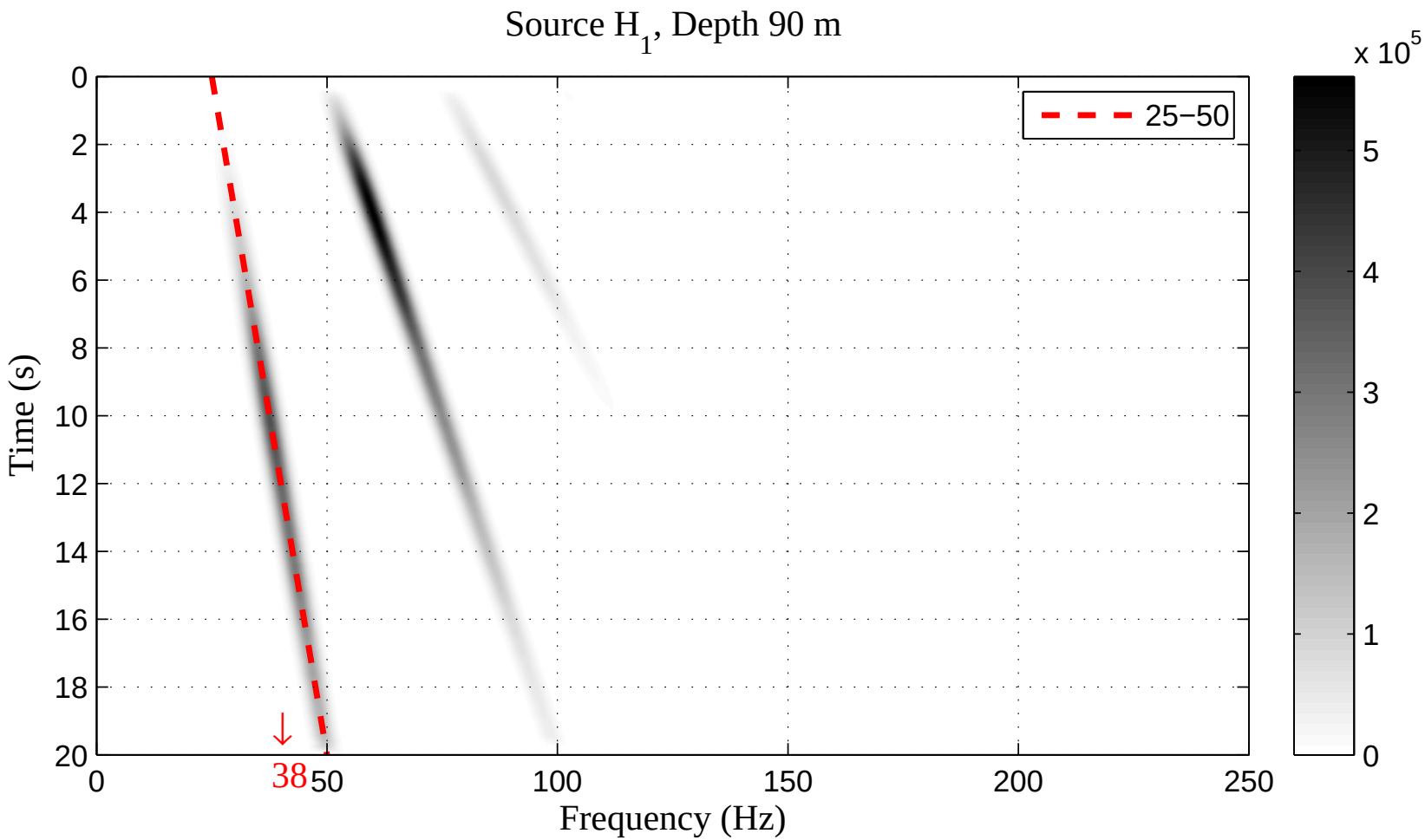

a)
b)
c)
d)
e)
f)
g)
h)
log(A)
Frequency (Hz)
0
5
10
50
100
150
200
250

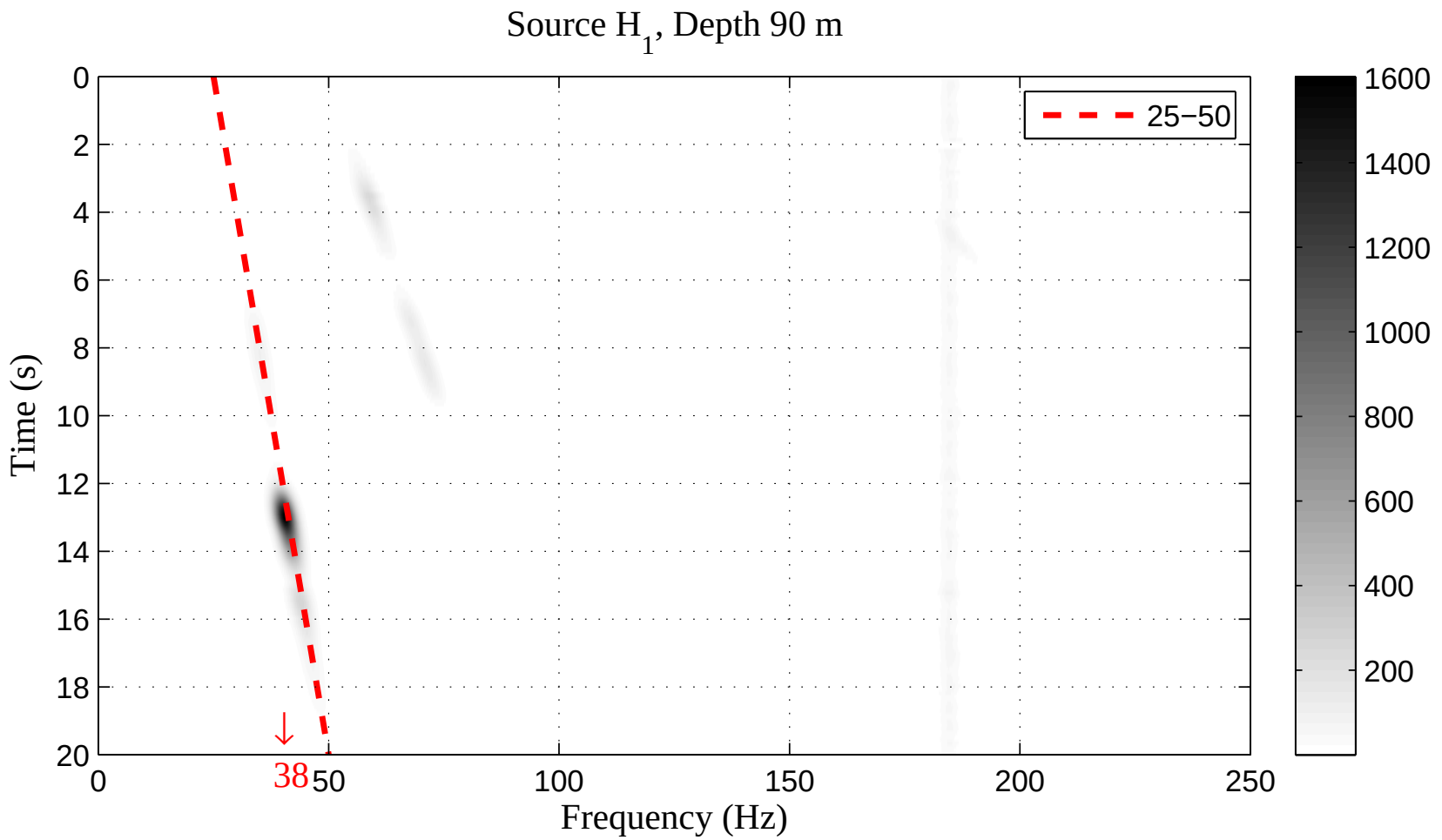

a)
b)
c)
d)
e)
f)
g)
h)
log(A)
Frequency (Hz)
0
5
10
50
100
150
200
250

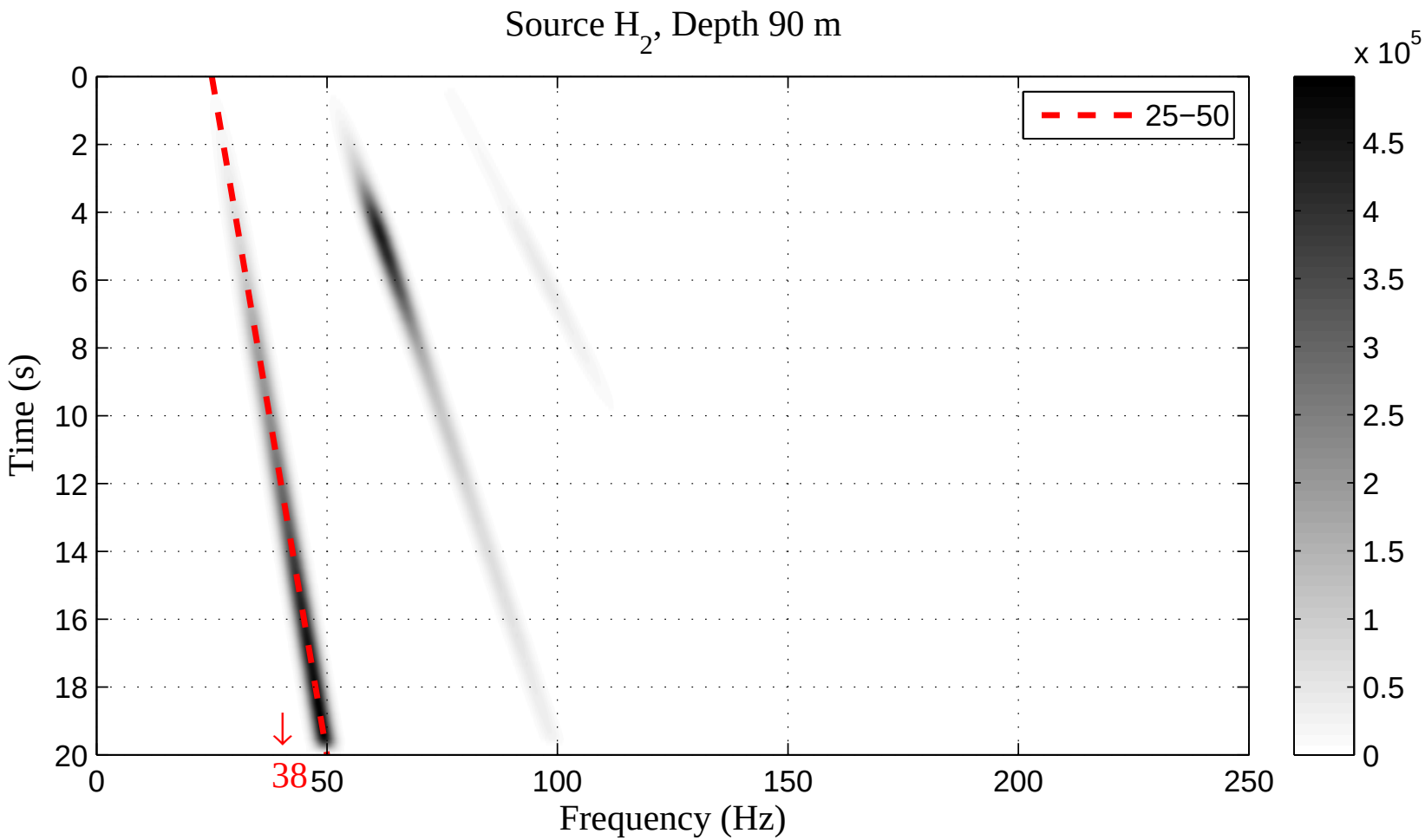

a)
b)
c)
d)
e)
f)
g)
h)
log(A)
Frequency (Hz)
0
5
10
50
100
150
200
250

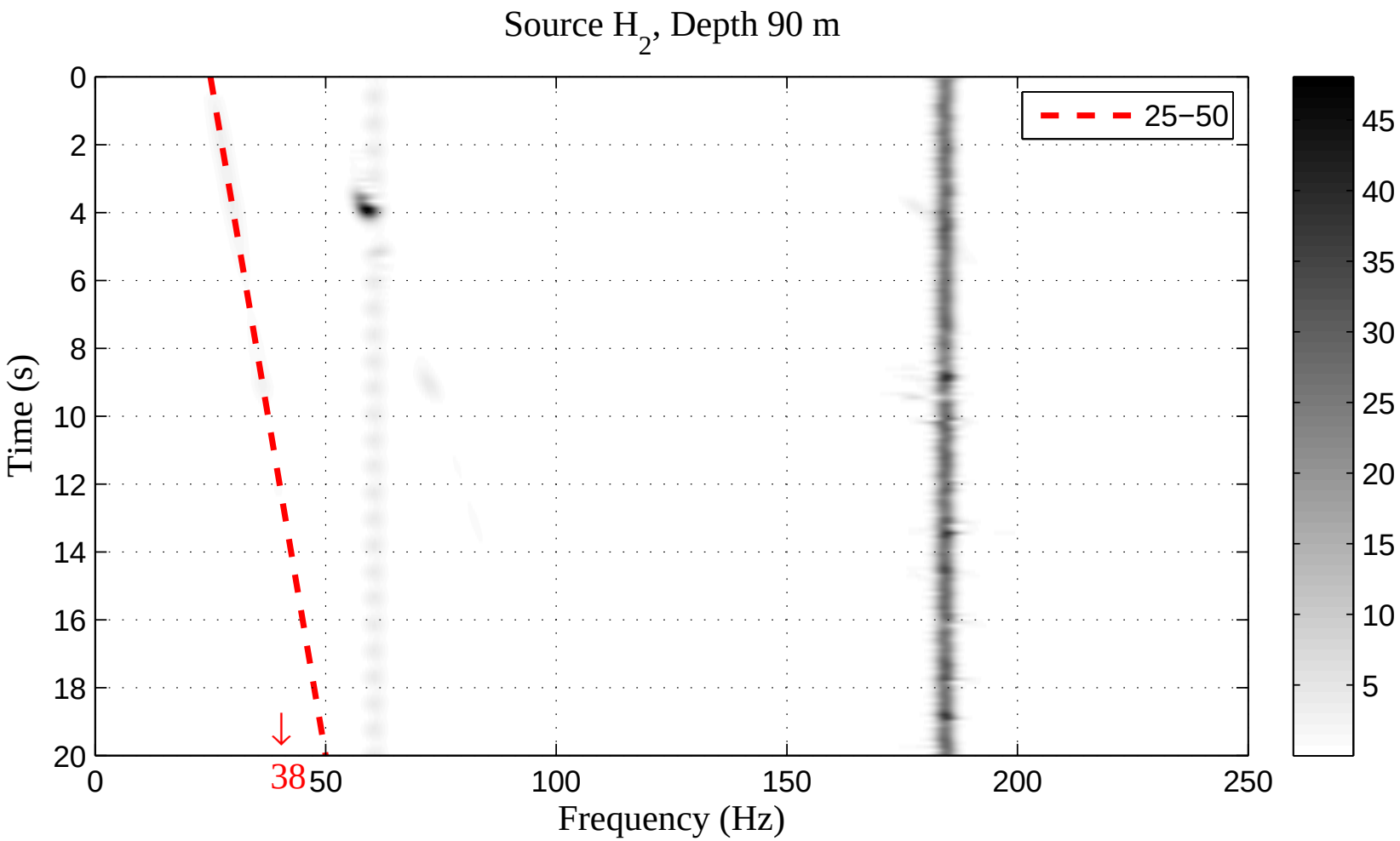

Source V, Depth 90 m
x 10^6
25–50
Time (s)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
38
50
100
150
200
250
12
10
8
6
4
2

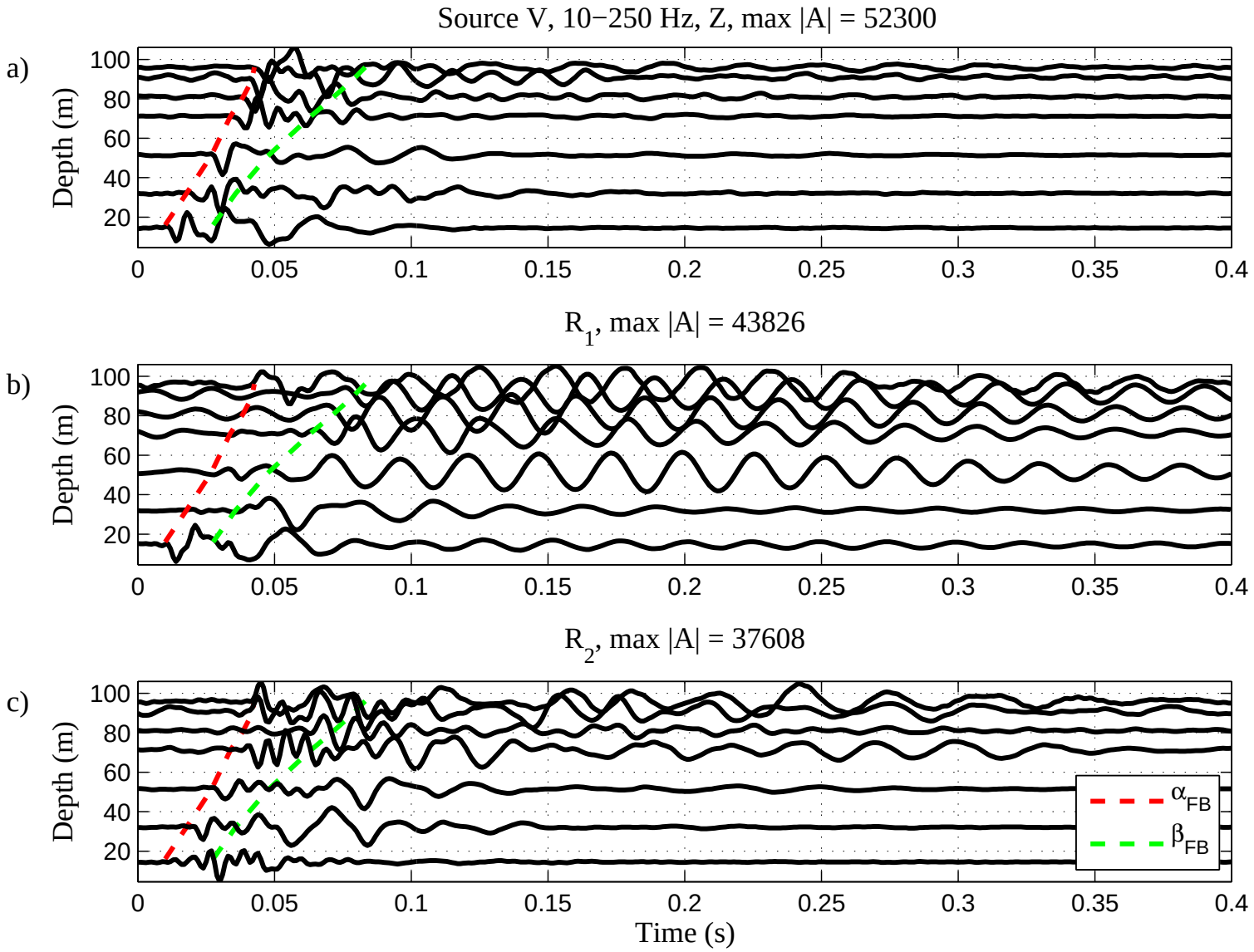

Source V, Depth 90 m
25–50
x 10^4
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Time (s)
0
2
4
6
8
10
12
14
16
18
20
38
0
50
100
150
200
250
Frequency (Hz)

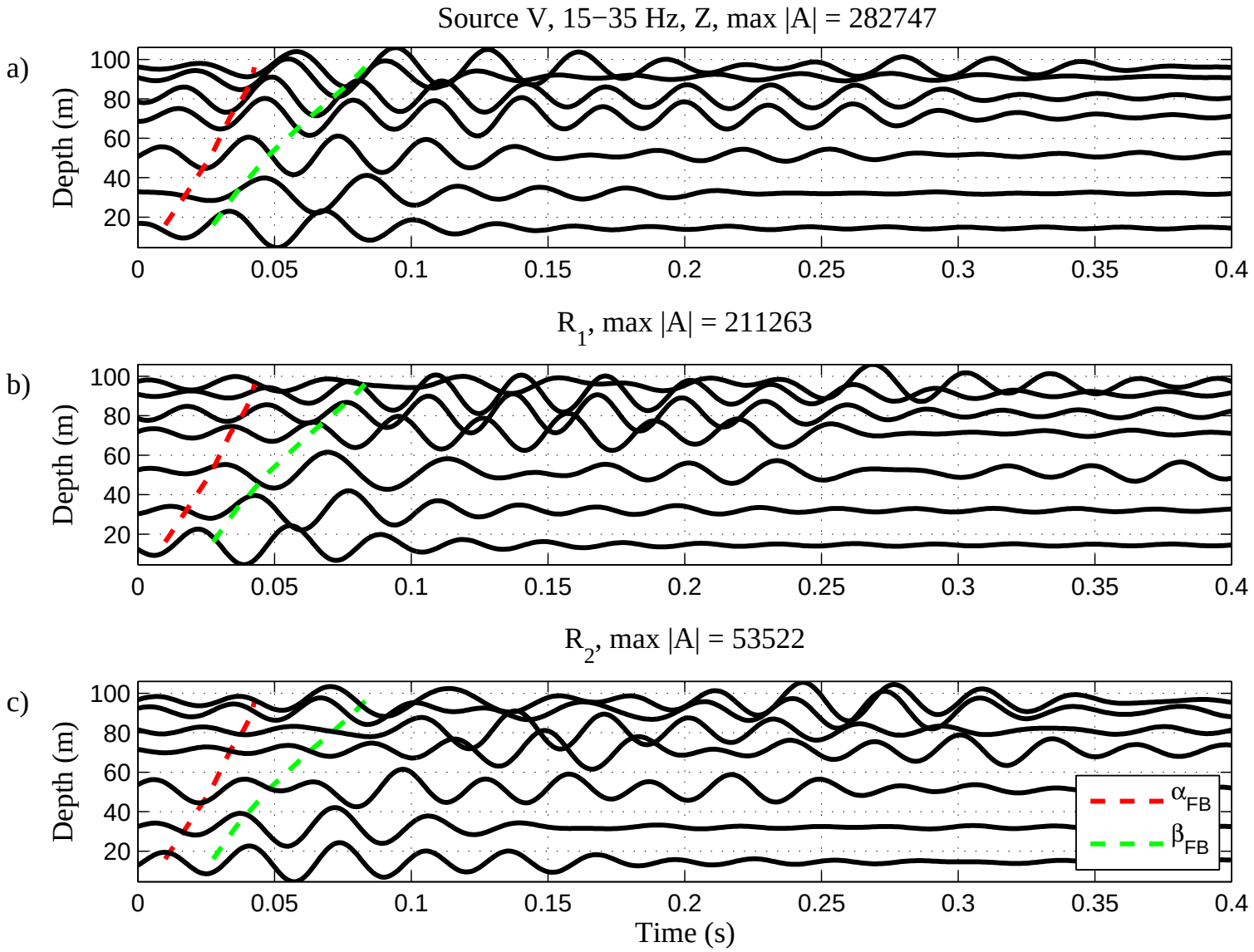

Source H1, Depth 90 m
x 10^5
25–50
Time (s)
Frequency (Hz)
38
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
5
4
3
2
1
0

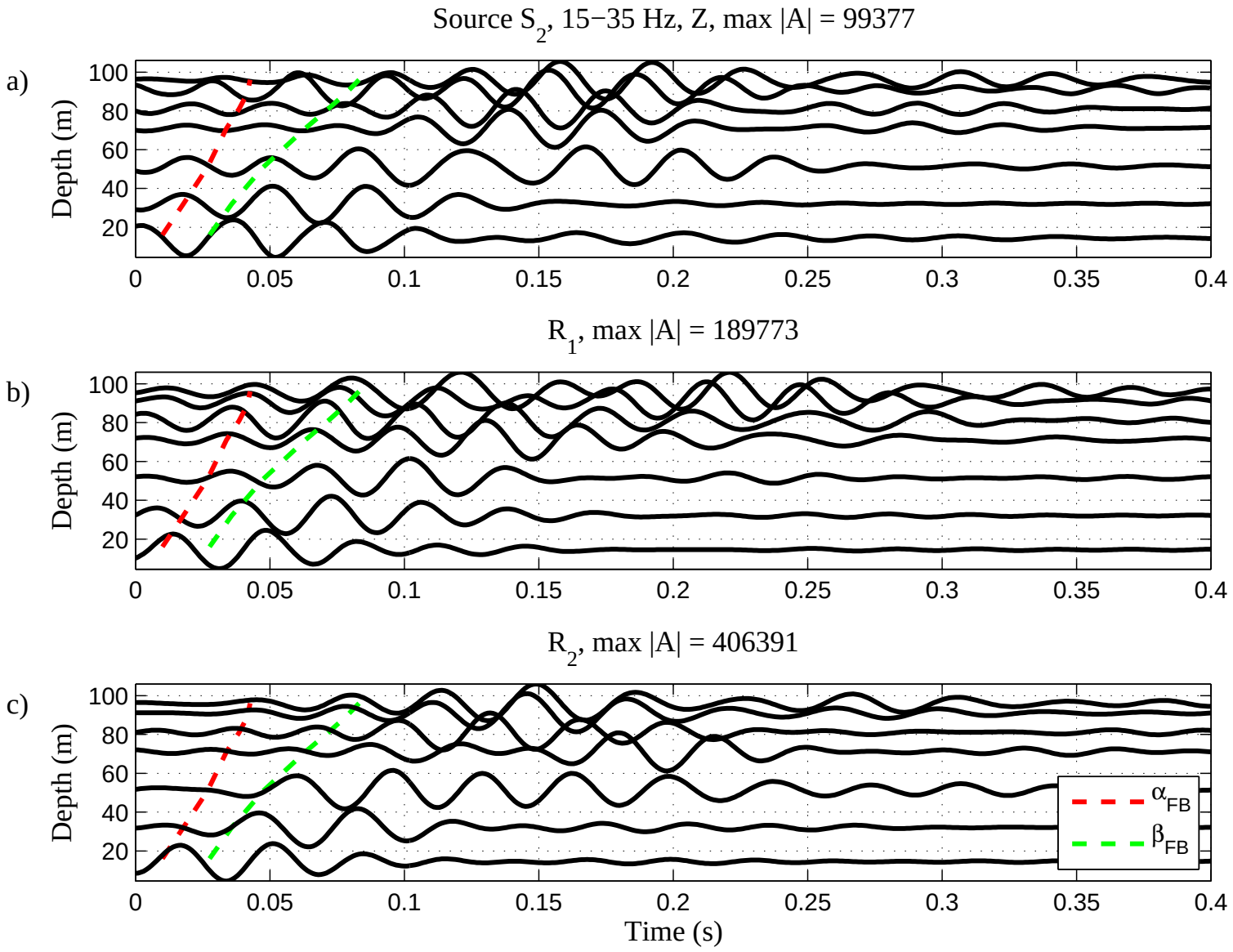

Source H1, Depth 90 m
25–50
38
Time (s)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
1600
1400
1200
1000
800
600
400
200


Source H2, Depth 90 m
x 10^5
25–50
Time (s)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
38
50
100
150
200
250
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Source H_2, Depth 90 m
25–50
38
Time (s)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
45
40
35
30
25
20
15
10
5

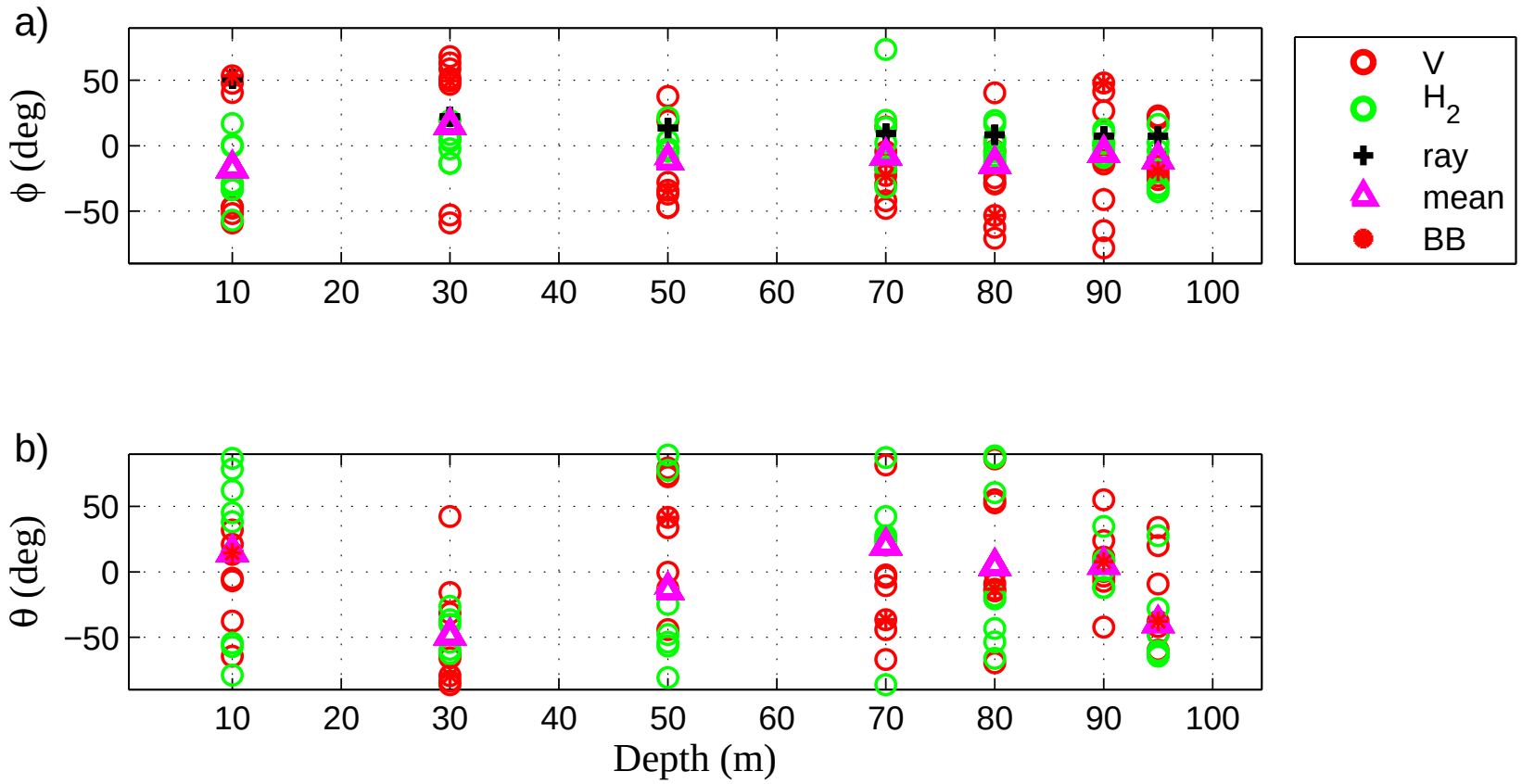

Source V, 10−250 Hz, Z, max |A| = 52300
a)
Depth (m)
100
80
60
40
20
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
R1, max |A| = 43826
b)
R2, max |A| = 37608
c)
αFB
βFB
Time (s)


Source V, 15−35 Hz, Z, max |A| = 282747
a)
Depth (m)
100
80
60
40
20
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
R1, max |A| = 211263
b)
Depth (m)
R2, max |A| = 53522
c)
Depth (m)
αFB
βFB
Time (s)


Source S2, 15−35 Hz, Z, max |A| = 99377
a)
Depth (m)
100
80
60
40
20
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
R1, max |A| = 189773
b)
Depth (m)
R2, max |A| = 406391
c)
Depth (m)
αFB
βFB
Time (s)

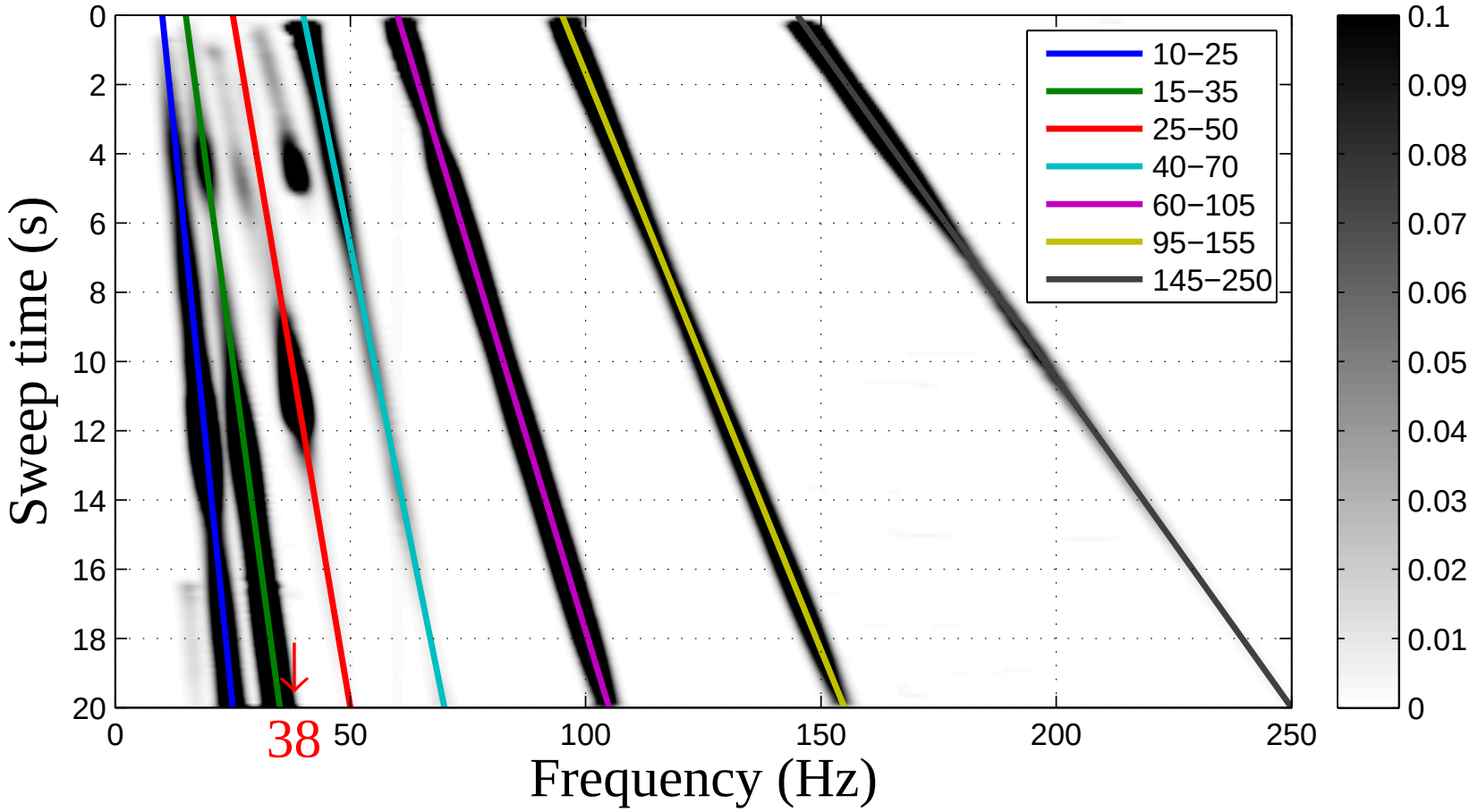
Processing

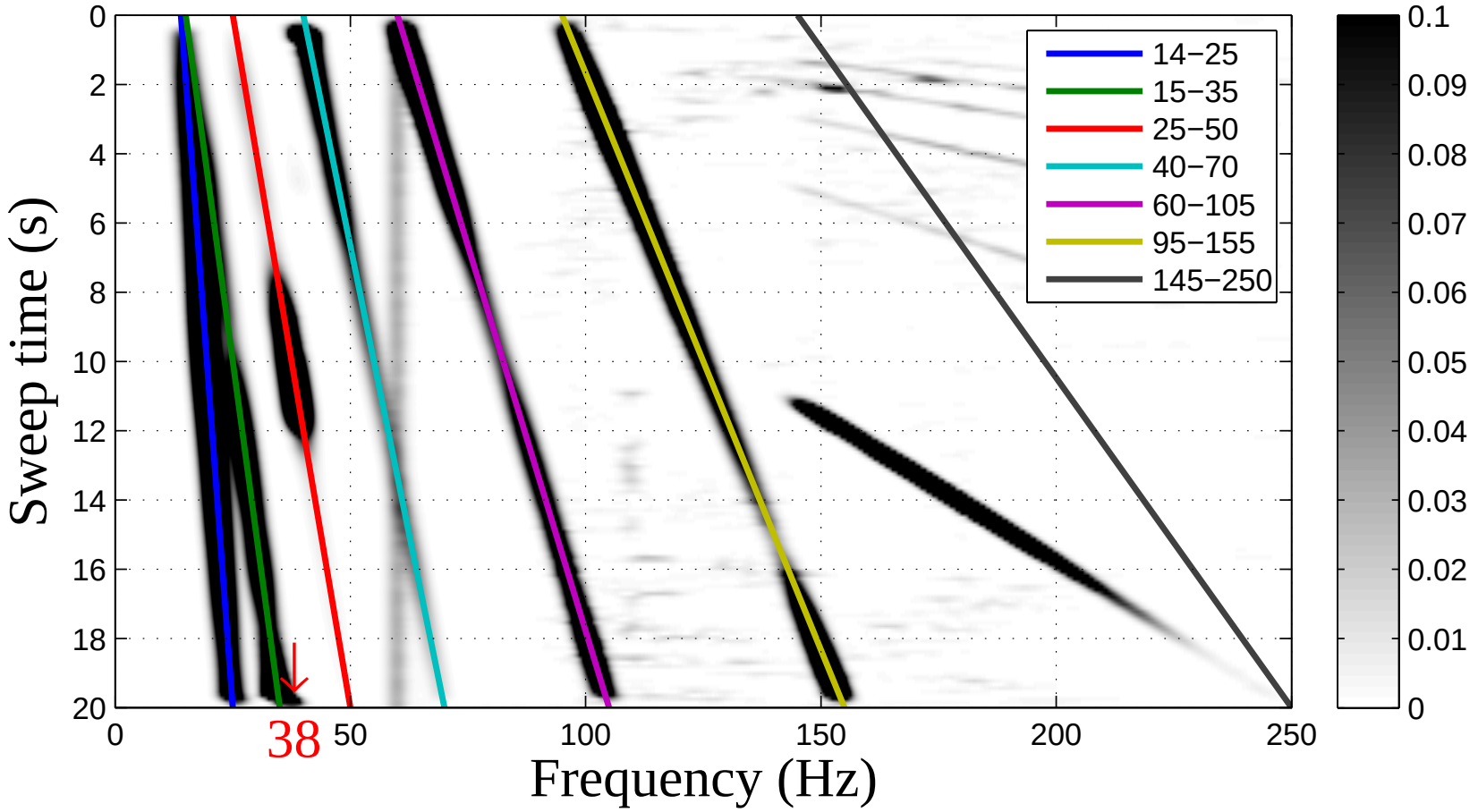
- Apply match filters derived from the surface array.
- Apply spherical divergence and sweep-filter.
- Rotate receivers to point at the source.

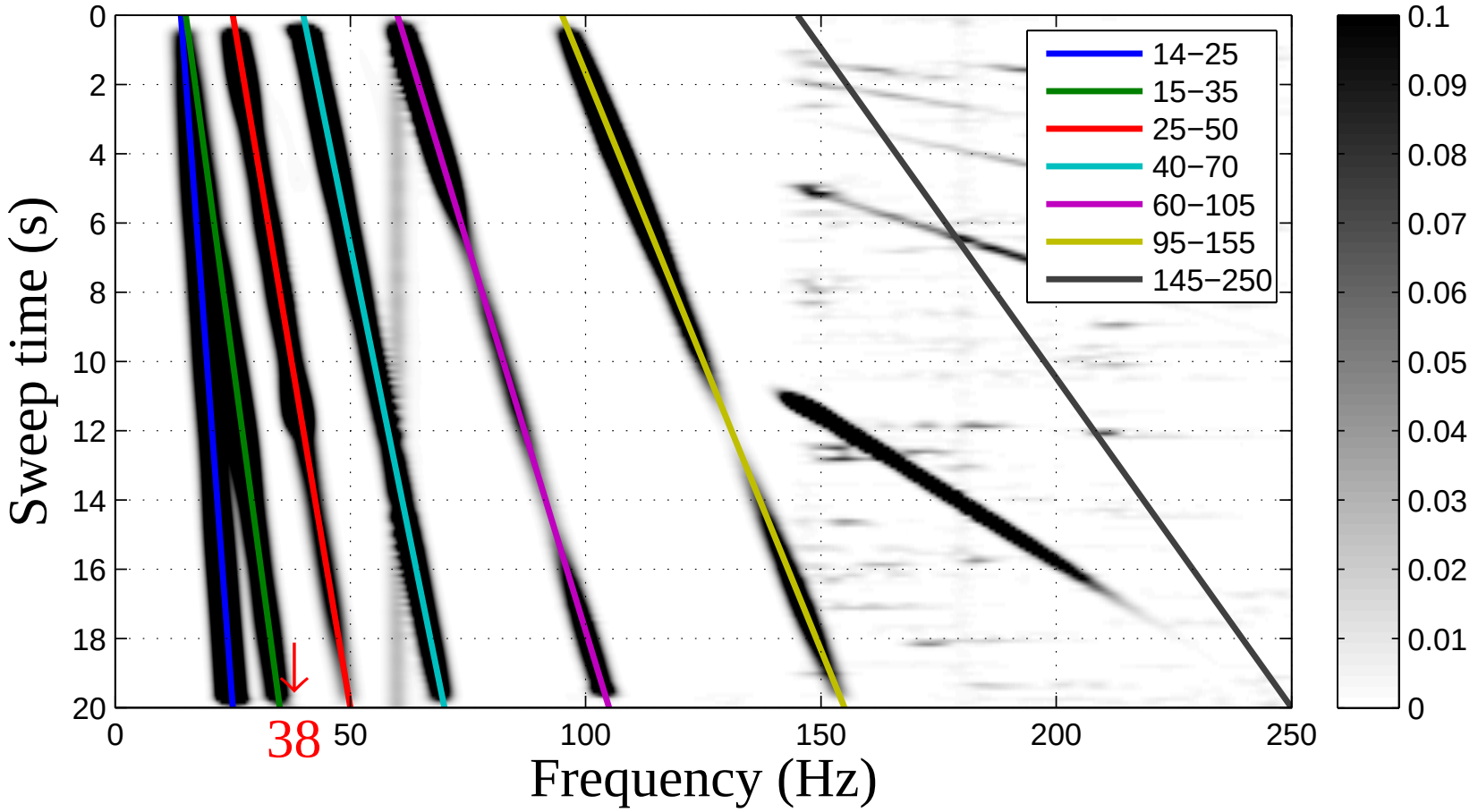

a)
ϕ (deg)
50
0
−50
10
20
30
40
50
60
70
80
90
100
V
H2
ray
mean
BB
b)
θ (deg)
50
0
−50
10
20
30
40
50
60
70
80
90
100
Depth (m)

Processing continued

- $\sum_{j=1}^{3} \log_e \left\{ \sqrt{G_j \, G_j^{\dagger}} \right\}$I, where j is the j^{th} receiver component.
- Sum along sweep time τ.

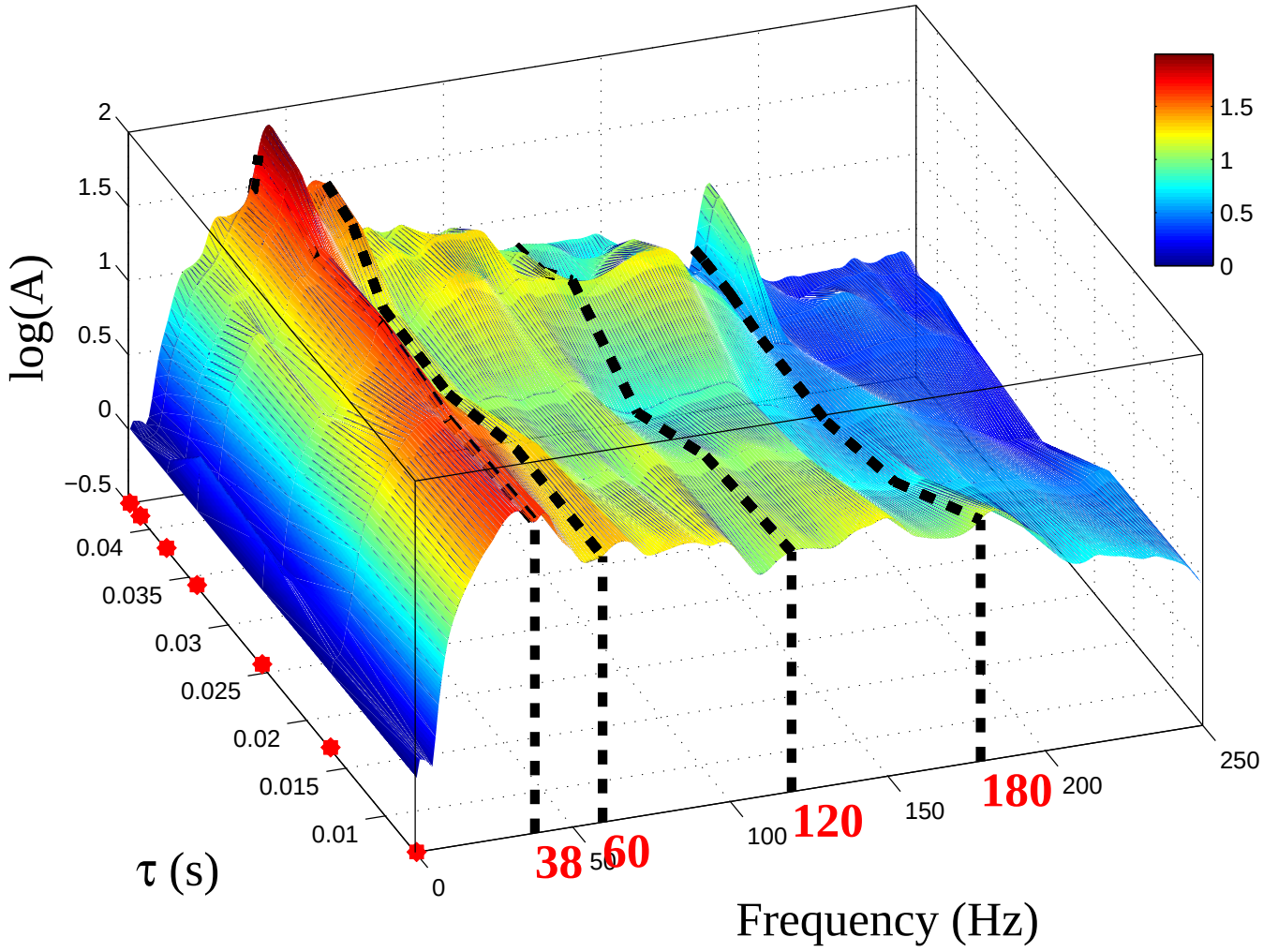

Sweep time (s)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
38
10–25
15–35
25–50
40–70
60–105
95–155
145–250
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

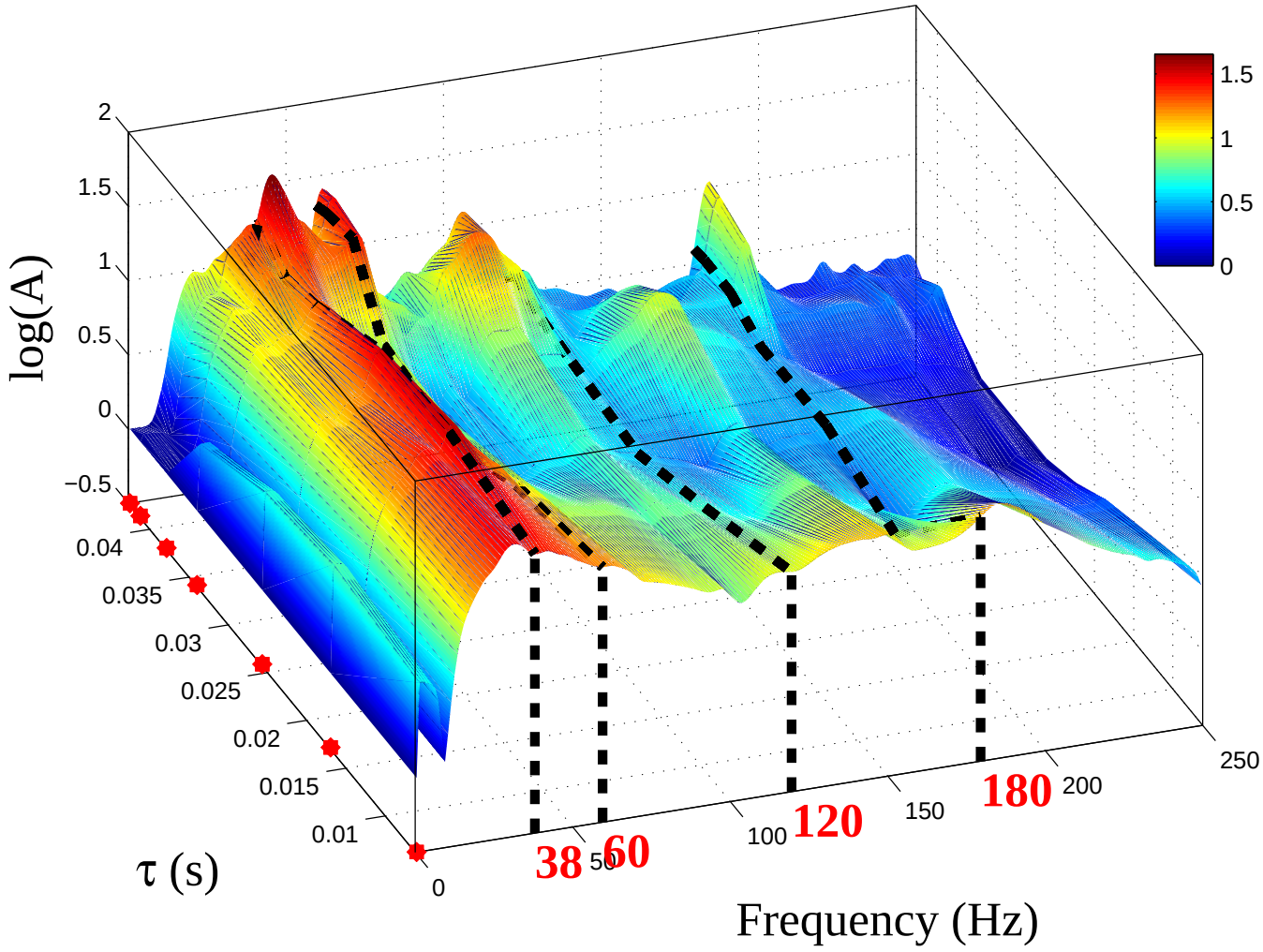

Sweep time (s)
0
2
4
6
8
10
12
14
16
18
20
Frequency (Hz)
0
50
100
150
200
250
38
14−25
15−35
25−50
40−70
60−105
95−155
145−250
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

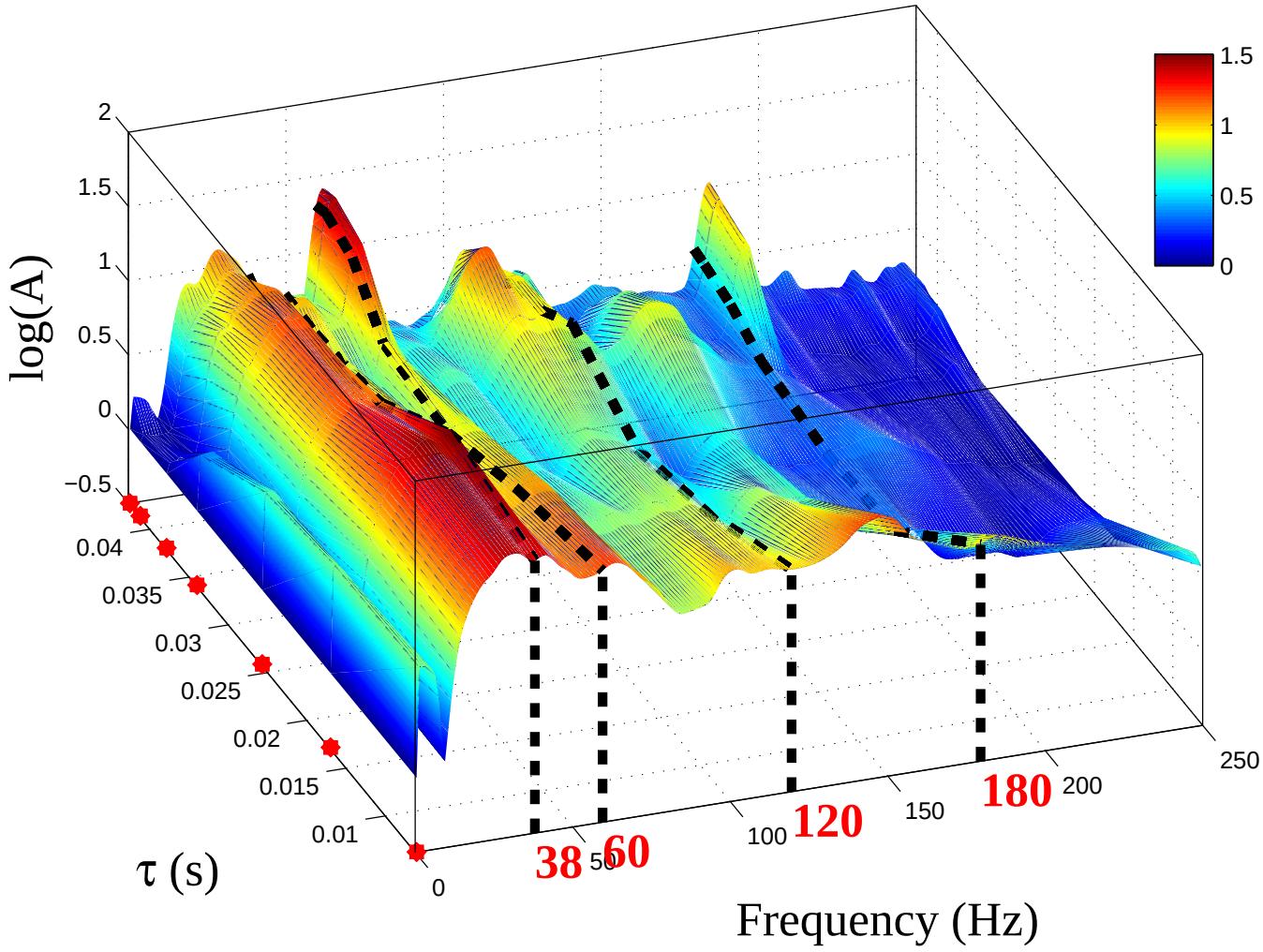

Sweep time (s)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
38
14−25
15−35
25−50
40−70
60−105
95−155
145−250
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

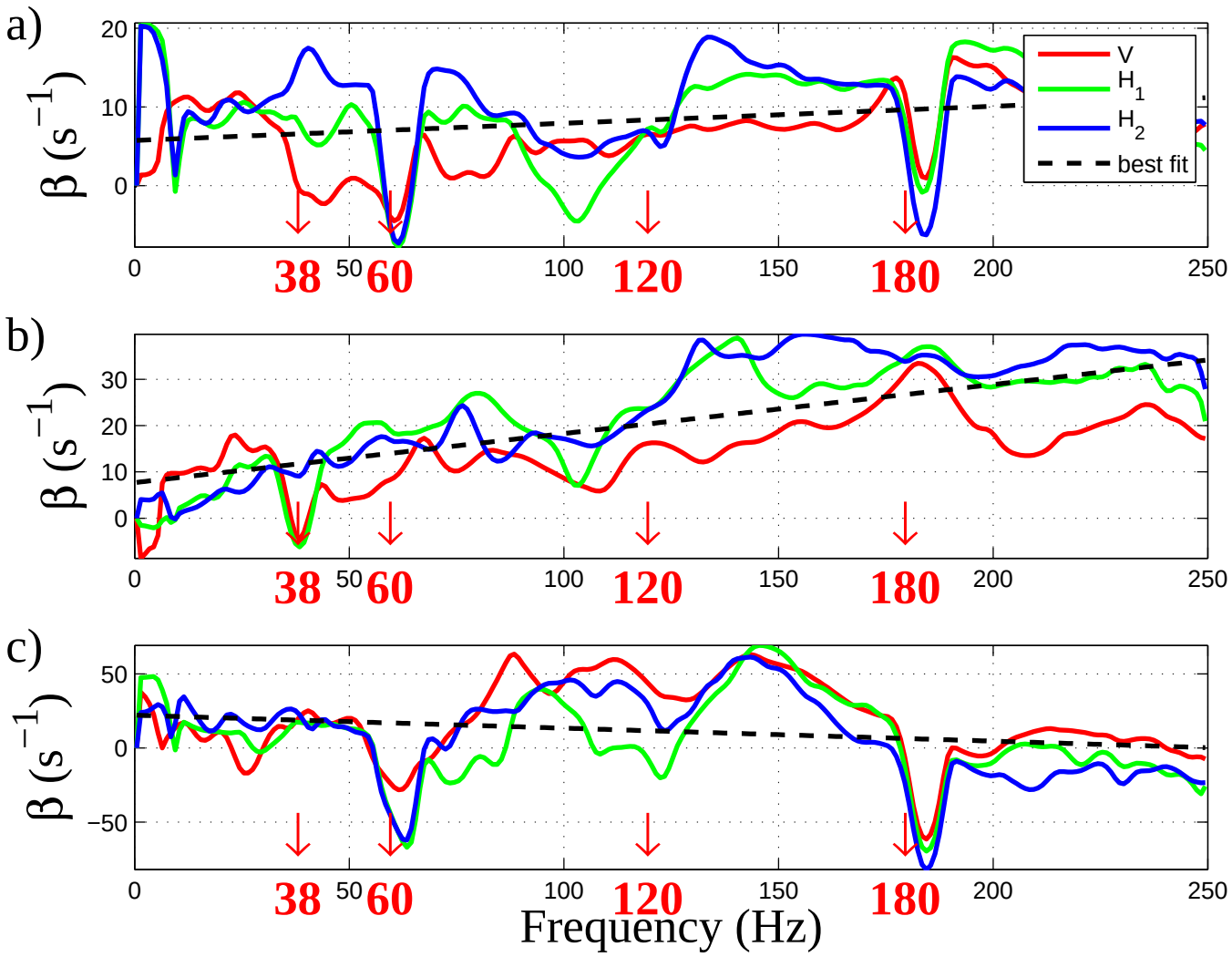
Interpretation

- Two units identified - saturated and unsaturated.


log(A)
2
1.5
1
0.5
0
−0.5
τ (s)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0
38
50
60
100
120
150
180
200
250
Frequency (Hz)
1.5
1
0.5
0


log(A)
2
1.5
1
0.5
0
−0.5
τ (s)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0
38
50
60
100
120
150
180
200
250
Frequency (Hz)
1.5
1
0.5
0


log(A)
2
1.5
1
0.5
0
−0.5
τ (s)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0
38
50
60
100
120
150
180
200
250
Frequency (Hz)
1.5
1
0.5
0


a)
b)
c)
β (s^{-1})
V
H$_1$
H$_2$
best fit
38
60
120
180
Frequency (Hz)

Conclusions

- $\Delta \log A$ correlates with expected watertable.
- β strong $\uparrow$ with f for unsaturated.
- β weak $\downarrow$ with f for saturated.
- Q estimates unreliable due to noise.
- Acquire 10 $\times$ # of $\tau\,(z)$, reduce noise.

Acknowledgements

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