Thesis discussion

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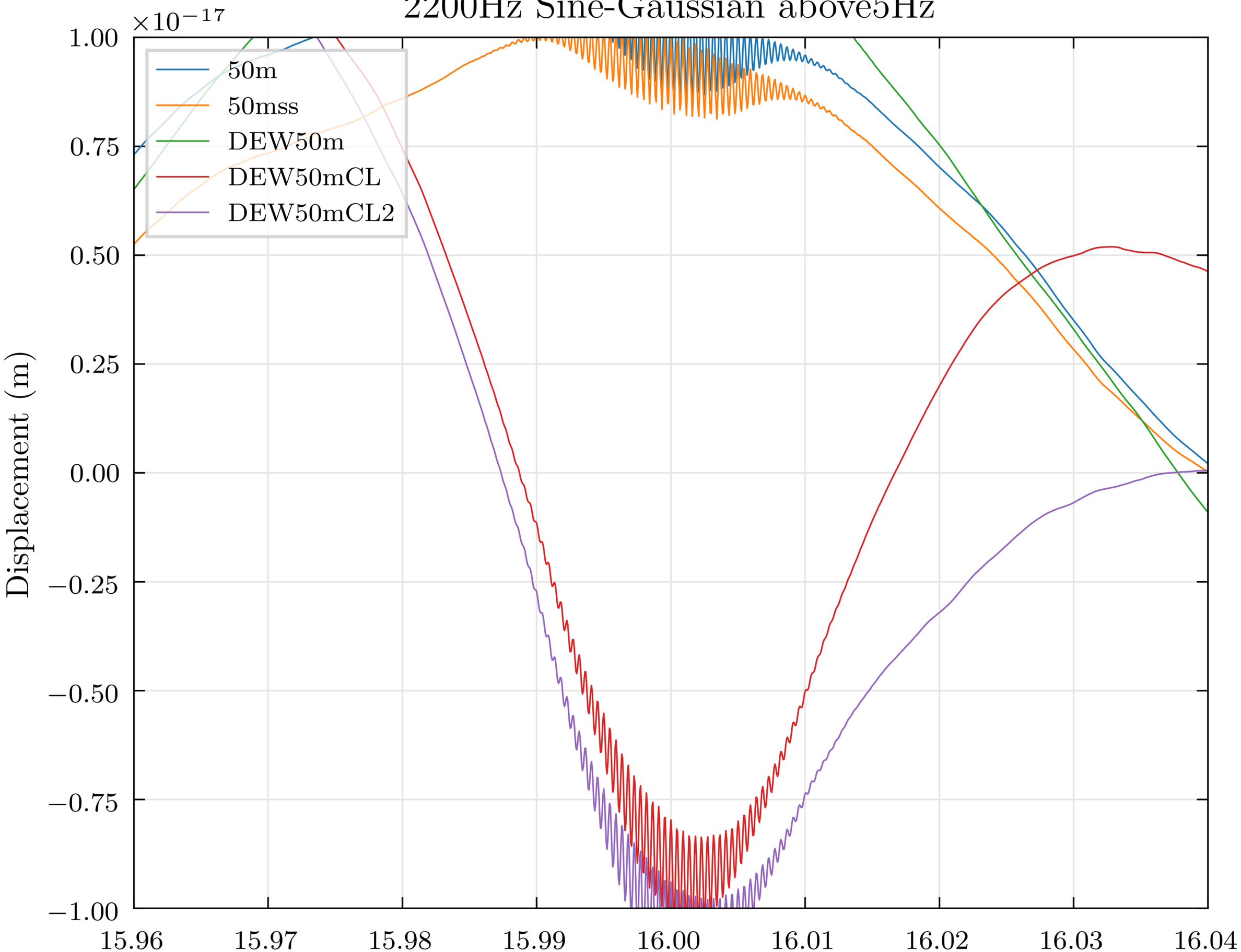
Problem of estimating ETM displacement from PD signal

Sine-gaussian signal


2200Hz Sine-Gaussian above5Hz
×10−17
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Displacement (m)
50m
50mss
DEW50m
DEW50mCL
DEW50mCL2
15.96
15.97
15.98
15.99
16.00
16.01
16.02
16.03
16.04

2200Hz Sine-Gaussian above10Hz

$\times 10^{-17}$

1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

Displacement (m)

50m
50mss
DEW50m
DEW50mCL
DEW50mCL2

15.96
15.97
15.98
15.99
16.00
16.01
16.02
16.03
16.04

2200Hz Sine-Gaussian above20Hz

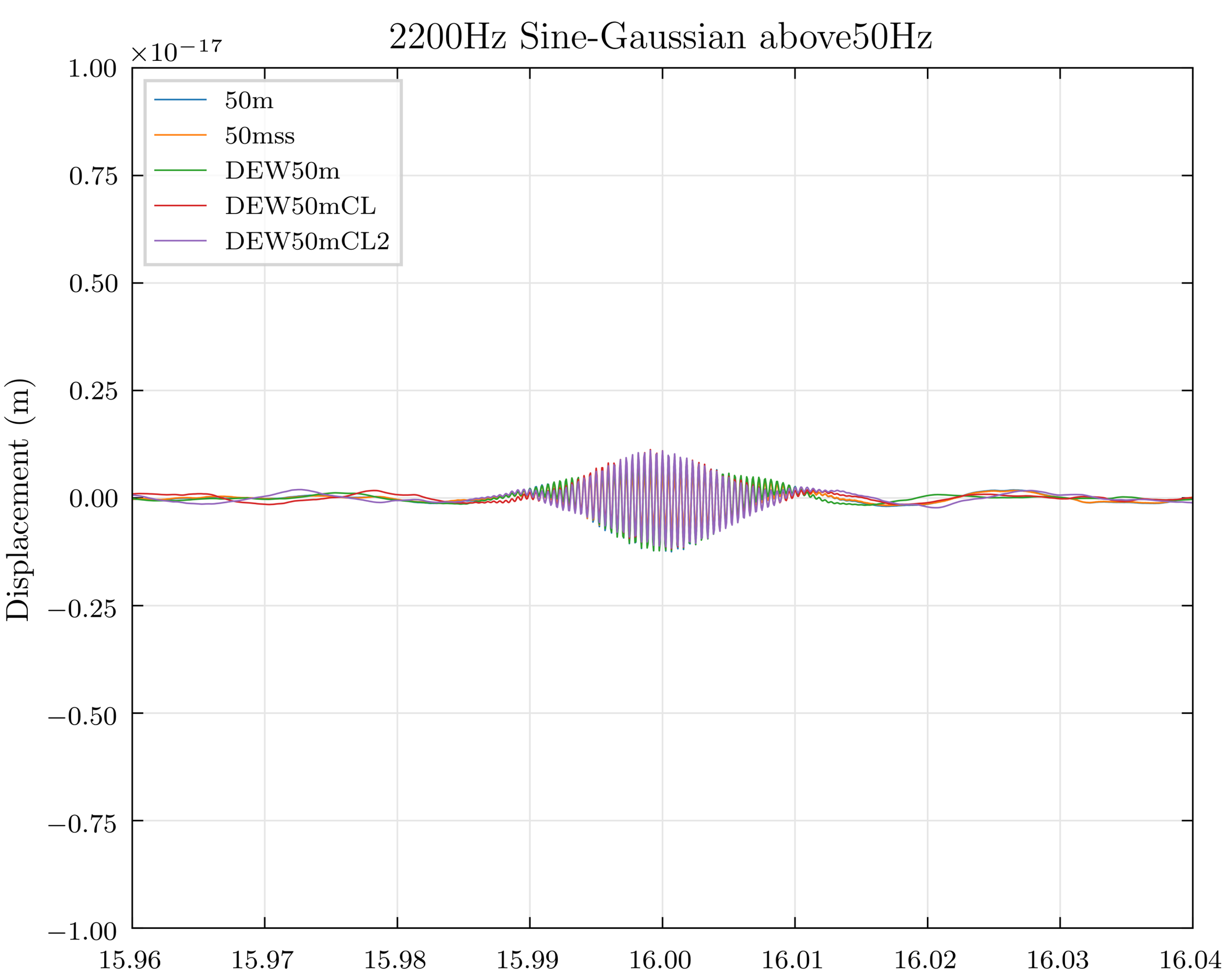
$\times 10^{-17}$

1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

Displacement (m)

50m
50mss
DEW50m
DEW50mCL
DEW50mCL2

15.96
15.97
15.98
15.99
16.00
16.01
16.02
16.03
16.04


2200Hz Sine-Gaussian above50Hz
$\times 10^{-17}$
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Displacement (m)
50m
50mss
DEW50m
DEW50mCL
DEW50mCL2
15.96
15.97
15.98
15.99
16.00
16.01
16.02
16.03
16.04

```
AMPLE_RATE = 16384
DURATION = 32 #second
f = np.append(np.arange(0, SAMPLE_RATE/2,1./DURATION),
              np.arange(-SAMPLE_RATE/2,0,1./DURATION))

f[0]=1
for i in range(len(f)):
#     if f[i]>-10 and f[i]<10:
#     if f[i]>-20 and f[i]<20:
#     if f[i]>-5 and f[i]<5:
    if f[i]>-50 and f[i]<50:
        f[i]=1000000.
```

```
def applyFDfilter(TDdata, FDfilter):
    fy = np.fft.fft(TDdata)
    fy = fy*FDfilter
    return np.fft.ifft(fy)

def ss(xin):
    return np.sin(xin*1.8)/1.8
#sg
k50m['d_sg'] = applyFDfilter(k50m['sg'], 1./f/f/DGSi)*3000./ExcGain
k50m['d_sg_ss'] = applyFDfilter(ss(k50m['sg']), 1./f/f/DGSi)*3000./ExcGain
kDEW50m['d_sg'] = applyFDfilter(kDEW50m['sg'], 1./f/f/DGSi)*3000./ExcGain
kDEW50mCL['d_sg'] = applyFDfilter(kDEW50mCL['sg'], 1./f/f/DGSi)*3000./ExcGain
kDEW50mCL2['d_sg'] = applyFDfilter(kDEW50mCL2['sg'], 1./f/f/DGSi)*3000./ExcGain
```

BBH signal

BBH 30Msolar above20Hz

$\times 10^{-17}$

Displacement (m)

template
50m
DEW50m
DEW50mCL
DEW50mCL2

1.0
0.5
0.0
−0.5
−1.0

−0.08 −0.06 −0.04 −0.02 0.00 0.02

OFSPD readout(V)

template
50m
DEW50m
DEW50mCL
DEW50mCL2

0.05
0.00
−0.05

−0.08 −0.06 −0.04 −0.02 0.00 0.02

Time (s)

BBH 20Msolar above20Hz

$\times 10^{-17}$

Displacement (m)

template
50m
DEW50m
DEW50mCL
DEW50mCL2

0.5
0.0
−0.5

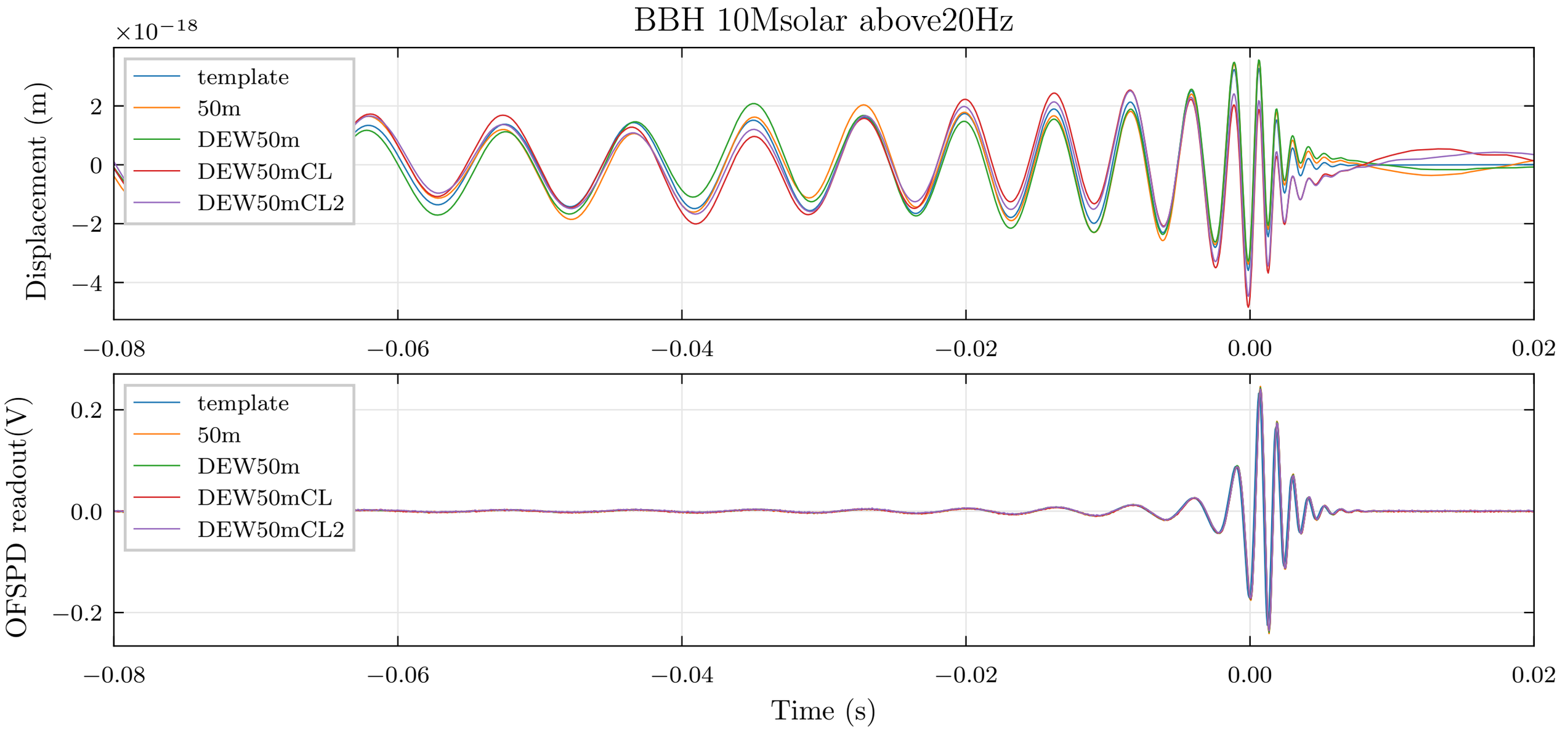
OFSPD readout(V)

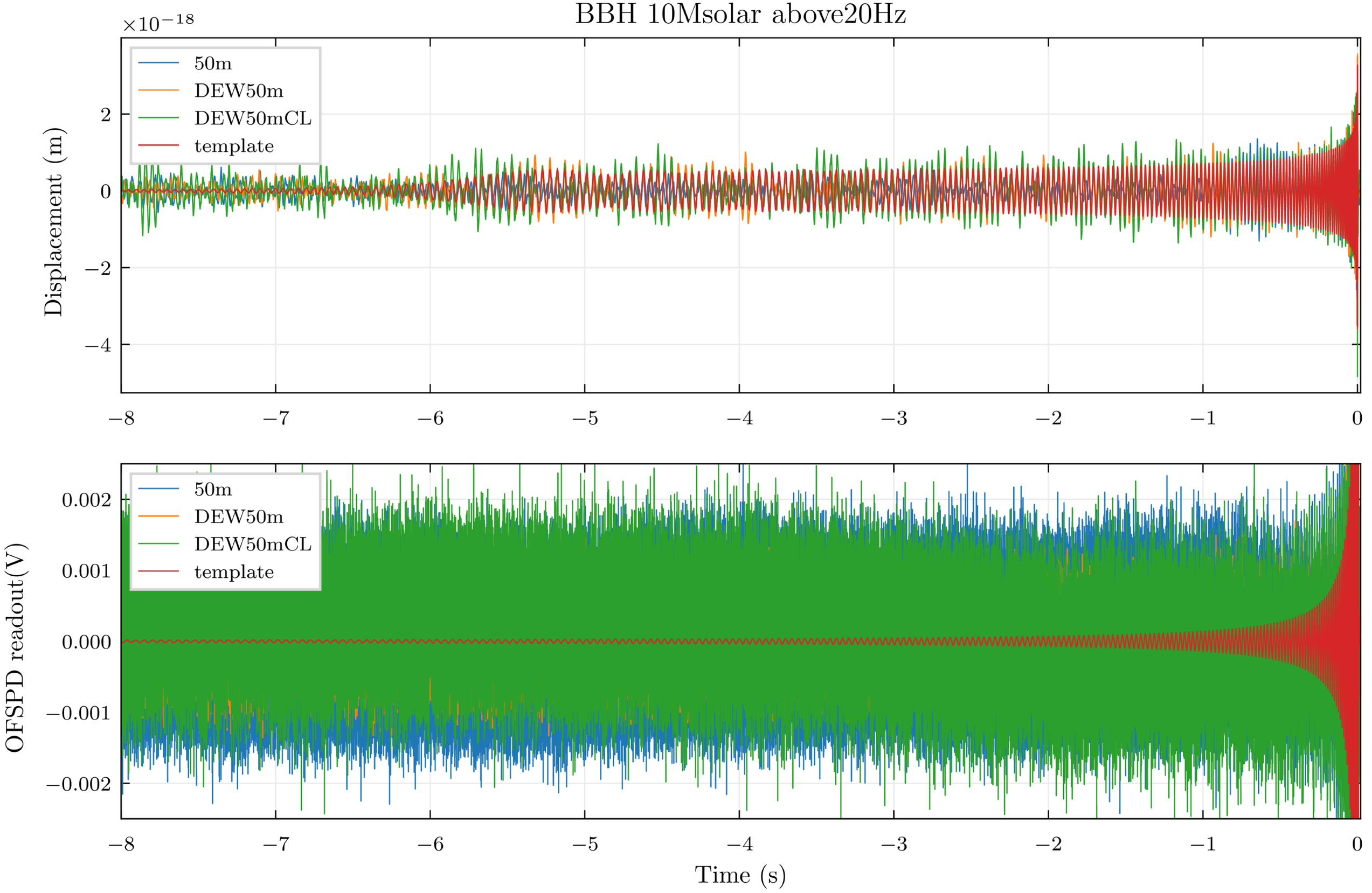
template
50m
DEW50m
DEW50mCL
DEW50mCL2

0.1
0.0
−0.1

−0.08 −0.06 −0.04 −0.02 0.00 0.02

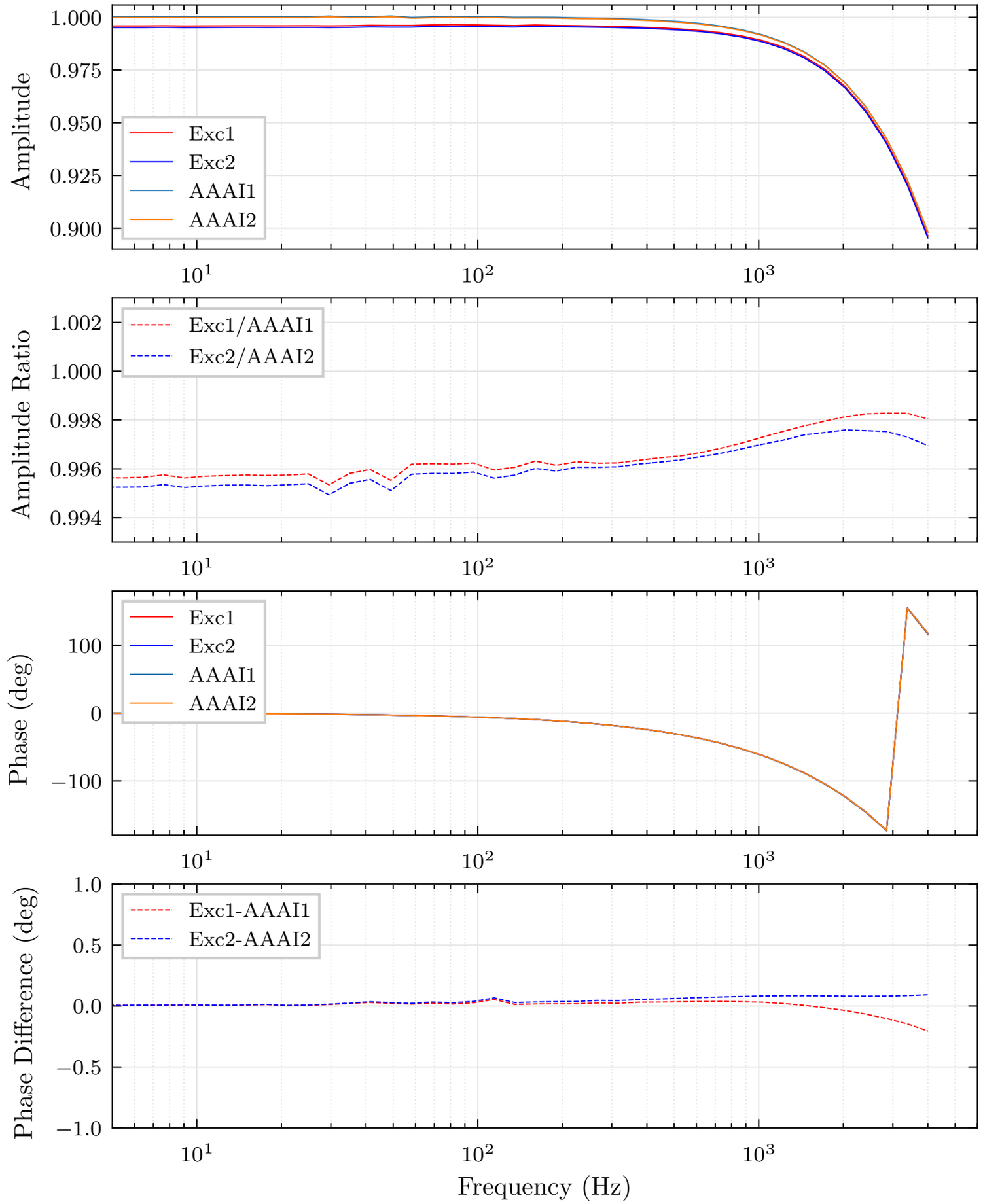
Time (s)


BBH 10Msolar above20Hz
$\times 10^{-18}$
Displacement (m)
template
50m
DEW50m
DEW50mCL
DEW50mCL2
2
0
−2
−4
−0.08
−0.06
−0.04
−0.02
0.00
0.02
OFSPD readout(V)
0.2
0.0
−0.2
Time (s)


BBH 10Msolar above20Hz
×10−18
Displacement (m)
50m
DEW50m
DEW50mCL
template
2
0
−2
−4
−8
−7
−6
−5
−4
−3
−2
−1
0
OFSPD readout(V)
0.002
0.001
0.000
−0.001
−0.002
Time (s)

- The result is not fairly represent the reality because we record the data without Whitening Filter. The noise of recorded OFSPD signal is dominated by ADC noise.

Transfer Function


Amplitude
1.000
0.975
0.950
0.925
0.900
Exc1
Exc2
AAAI1
AAAI2
10^1
10^2
10^3
Amplitude Ratio
1.002
1.000
0.998
0.996
0.994
Exc1/AAAI1
Exc2/AAAI2
Phase (deg)
100
0
−100
Phase Difference (deg)
1.0
0.5
0.0
−0.5
−1.0
Exc1-AAAI1
Exc2-AAAI2
Frequency (Hz)

Noise

KAGRA X-END

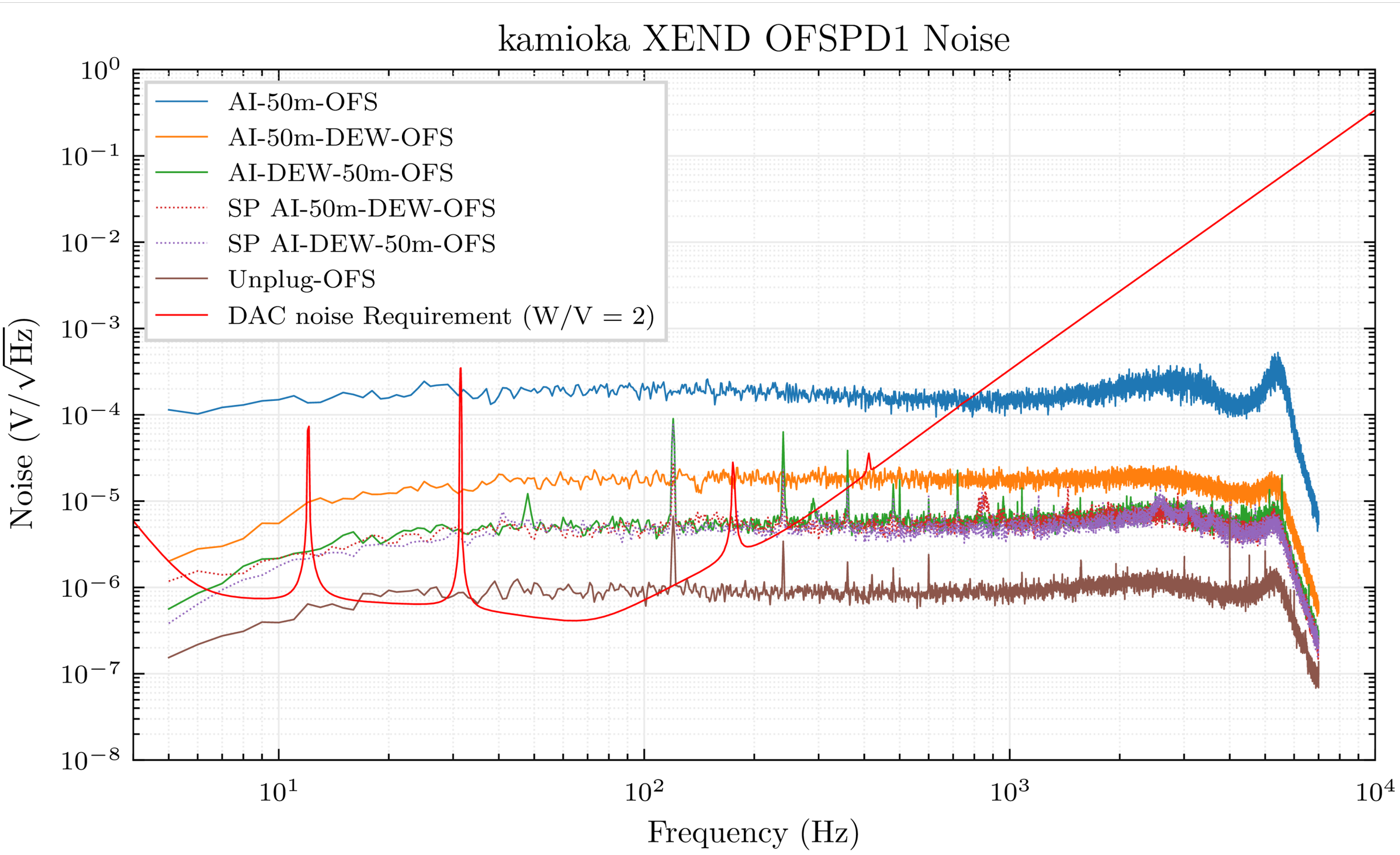
AI-50m-DEW-50m-AA
AI-50m-50m-AA
AI-2m-AA
AI-DEW-50m-50m-AA
AI-DEW-2m-AA
DAC noise Requirement (W/V = 2)

Noise (V/$\sqrt{\text{Hz}}$)

10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}

10^{1}
10^{2}
10^{3}
10^{4}

Frequency (Hz)


kamioka XEND OFSPD1 Noise
AI-50m-OFS
AI-50m-DEW-OFS
AI-DEW-50m-OFS
SP AI-50m-DEW-OFS
SP AI-DEW-50m-OFS
Unplug-OFS
DAC noise Requirement (W/V = 2)
Noise (V/√Hz)
Frequency (Hz)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^1
10^2
10^3
10^4

- Whenever DEW has been installed, the overall noise floor decrease.

- However, the suppression of noise seems “frequency independent” instead of following DEW transfer function once we connect the system to PCal OFS.

- This fact imply if we replace the DEW by a simple line driver (voltage follower with proper output impedance), we may get similar result.

- the noise floor of
  “AI-DEW-50m-OFS”
  “Same Power Supply AI-50m-DEW-OFS”
  “Same Power Supply AI-DEW-50m-OFS”
  are coincide with each other.