Hydrophone exposure data for air gun blasts on the Copepod Calanus finmarchicus

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Abstract

This document describes the hydrophone data associated with the article "Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sub-lethal effects on behaviour or gene expression, in the copepod Calanus finmarchicus". The data set includes the hydrophone data in hdf, scripts to read and visulize the data, and a summary of the data.

1 Hydrophones

A HD1-TC WesternGeco hydrophone was used to measure the sound pressure produced by the airguns used in our experiments. The positions at which the hydrophone was placed is illustrated in Fig 1. The nominal sensitivity of the hydrophone was $5.6 \cdot 10^{-11} V \mu Pa^{-1}$ with a flat frequency response between 0.7 Hz and 500 Hz. The fixed and variable gains were compensated for before sampling the voltage, and the voltage signal was converted to a 16 bit digital signal at a sample rate of 4 kHz (0.25 ms steps). To avoid aliasing, the signal was low-pass filtered using a finite impulse response filter with a cut-off at 500 Hz (-3 dB) and a slope or roll-off of 18 dB/octave (3rd order). The data is presented as pressure as a function of time in kPa and ms, respectively, c.f. Figure 2.

2 The data file

The data are stored in a self-documenting hdf5 file where each pressure-time timeseries are stored as a separate data set. The content of the file is (showing only dataset1):

```
Group '/'
Attributes:
    'description':  'Hydrophone exposures data for air gun
    blasts on the Copepod Calanus finmarchicus.'
Group '/dataset1'
    Attributes:
        'rawdata':  'Test 17'
        'year':  2009.000000
        'location':  'H'
    Dataset 'position'
        Size:  1x2
        MaxSize:  1x2
        Datatype:   H5T_IEEE_F64LE (double)
        ChunkSize:  []
        Filters:  none
        FillValue:  0.000000
        Attributes:
            'unit':  'm'
            'description':  'The location in horizontal-vertical
            range for the hydrophone placements. position(1) is
            horizontal range and pos(2)
            is vertical range.'
    Dataset 'pressure'
        Size:  1x4093
        MaxSize:  1x4093
        Datatype:   H5T_IEEE_F64LE (double)
```

```
            ChunkSize:  []
            Filters:  none
            FillValue:  0.000000
            Attributes:
                'unit':  'kPa'
        Dataset 'time'
            Size:  1x4093
            MaxSize:  1x4093
            Datatype:   H5T_IEEE_F64LE (double)
            ChunkSize:  []
            Filters:  none
            FillValue:  0.000000
            Attributes:
                'unit':  'ms'
```

Example matlab code to read the data:

```
dat = h5info('hydrophonedata.h5');
N = length(dat.Groups);
    % Data
    time{i} = h5read(filename,['/dataset',num2str(i),'/time']);
    pressure{i} = h5read(filename,['/dataset',num2str(i),'/pressure']);
    position{i} = h5read(filename,['/dataset',num2str(i),'/position']);
    % Attributes
    year_attrib{i} = h5info(filename,['/dataset',num2str(i)]);
    position_attrib{i} = h5info(filename,['/dataset',num2str(i),'/position']);
    dataset_attrib{i} = h5info(filename,['/dataset',num2str(i)]);
end
```

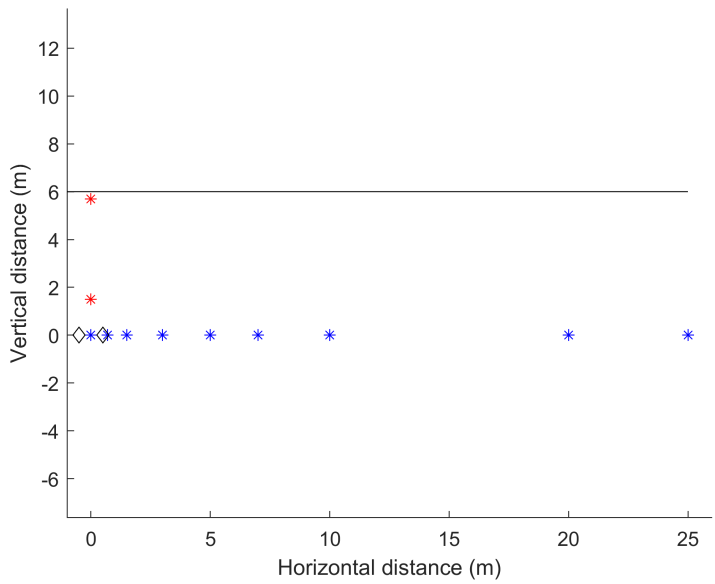


Figure 1: The position of the hydrophones. The air guns are shown as diamonds and the hydrophone location is shown as red and blue asterisks for the vertically and horizontally placed hydrophones, respectively. The position is given in the 'position' data set, c.f. the data set description.

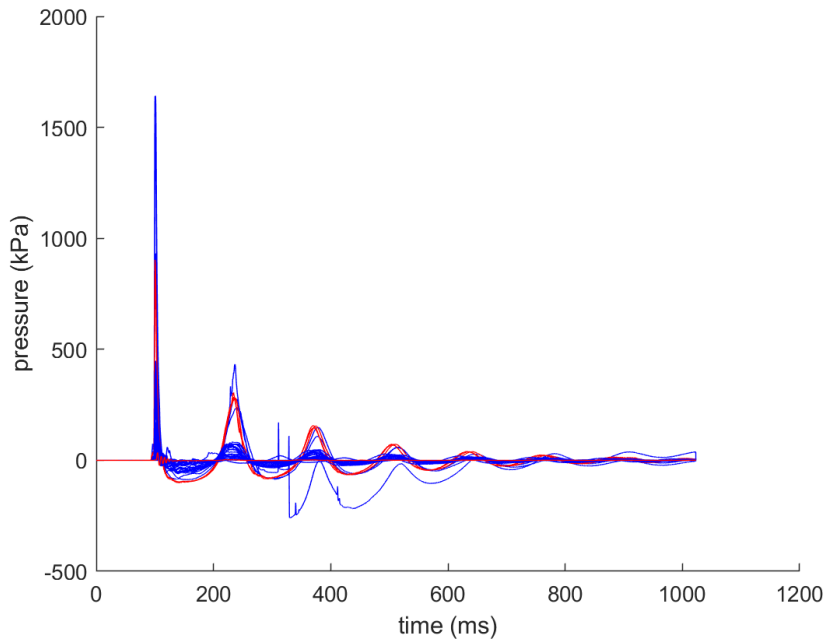


Figure 2: The indidual pulses in time domain. The data at the same depth as the air gun and the locations vertically above the air gun are given as blue and red curves, respectively.

3 Data processing

One matlab script (`SeismikkLarve_master.m`) and one matlab function (`SeismikkLarve_perpulse.m`) are provided to read the data and generate the figures in this document. Several summary statistics per pulse are generated, including A-duration, Rise time, Impulse, sound exposure level (SEL), peak to peak (p-p) and zero to peak pressures [Anon, 1986, Carey, 1995]. The impulse is defined as

$$I_{imp} = \int_0^{T_1} p(t)dt, \tag{1}$$

where T_1 is the duration of the from the initial rise of the pulse until first zero corssing [Carey, 1995, his eq.26]. This is calculated using the matlab `trapz` function

```
impulse = trapz(t(1:zerocr_i)*1e-3,(p(1:zerocr_i)));
```

where zerocr is the index for the first zero crossing. The SEL is a measure of the energy flux, i.e. the integrated intensity over the duration of the pulse

$$SEL = 10log_{10}\left[E_x/(1\mu Pa^2 s)\right], \tag{2}$$

where

$$E_x = \int_0^T p(t)^2 dt.$$

This is also calculated using the matlab `trapz` function on the pressure data in kPa, i.e

```
Ex = (trapz((t*1e-3),(p*1e3/1e-6).^2));
SEL = 10*log10(Ex);
```

where t is the time vector. The energy flux spectral density level (EFSDL) is defined as

$$EFSDL = 10\log_{10}\left[|\Pi(f)|^2/(1\mu Pa^2 s/Hz)\right] \tag{3}$$

where $\Pi(f)$ is the Fourier transform of the pressure data. This is calculated using matlab's fast fourier transform, i.e.

```
% (Two sided) Energy flux spectrum
EFSD2 = (Fs.^-2)*abs(Y).^2;

% (One sided) Energy flux spectrum
EFSD = 2*EFSD2(1:(N/2)+1);
EFSD(1) = EFSD2(1);

% (One sided) Energy flux spectrum level
EFSDL = 10.*log10(EFSD);
```

where Fs is the sampling frequency and N is the length of the signal. The pressure time data and the EFSDL level against frequency for the individual pulses are given in section 4. An overview of the metrics are given in Figure 3.

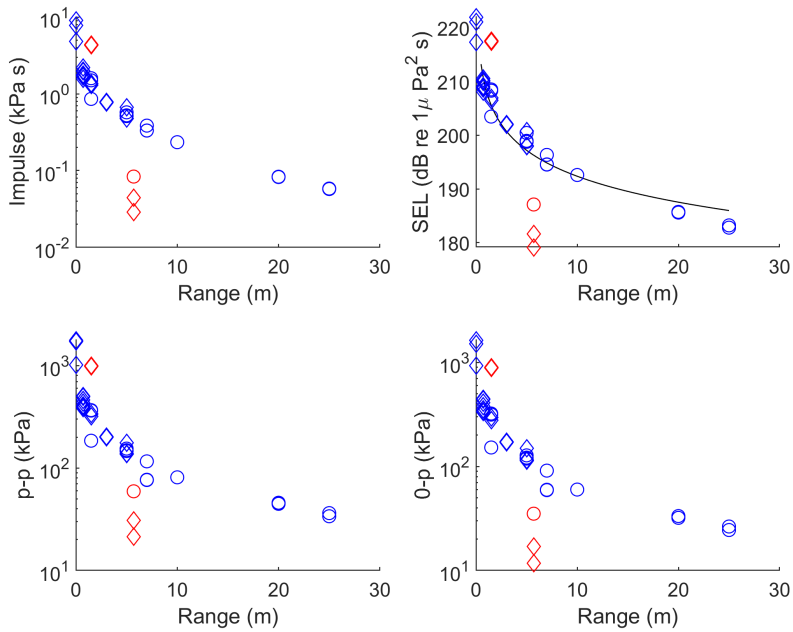


Figure 3: The impulse, sound exposure level (SEL), peak to peak (p-p) and zero to peak (0-p) pressures. The data at the same depth as the air gun and the locations vertically above the air gun is given in blue and red symbols, respectively. The 2009 and 2010 data is presented as diamonds and circles, respectively.

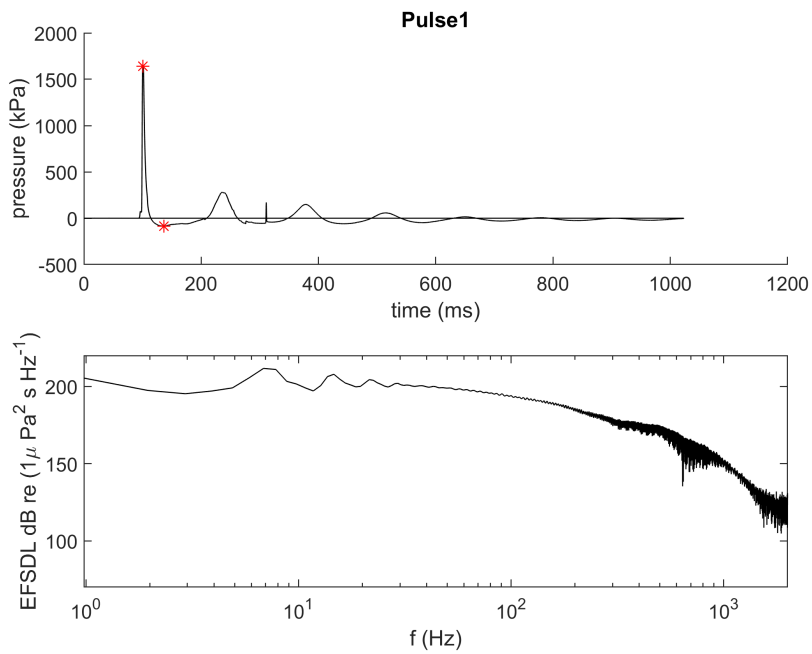
References

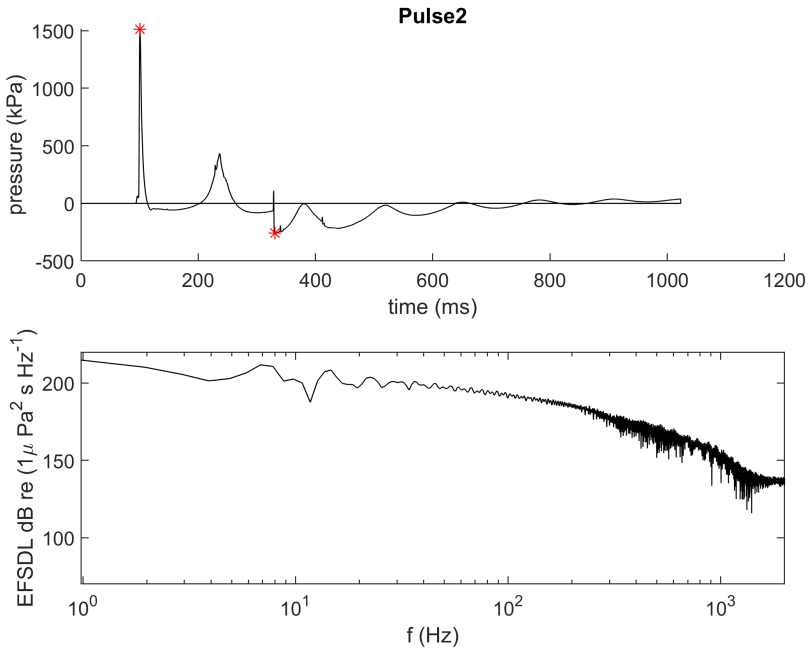
Anon. American National Standard: Methods for measurements of impulse noise, ANSI S12.7-1986.

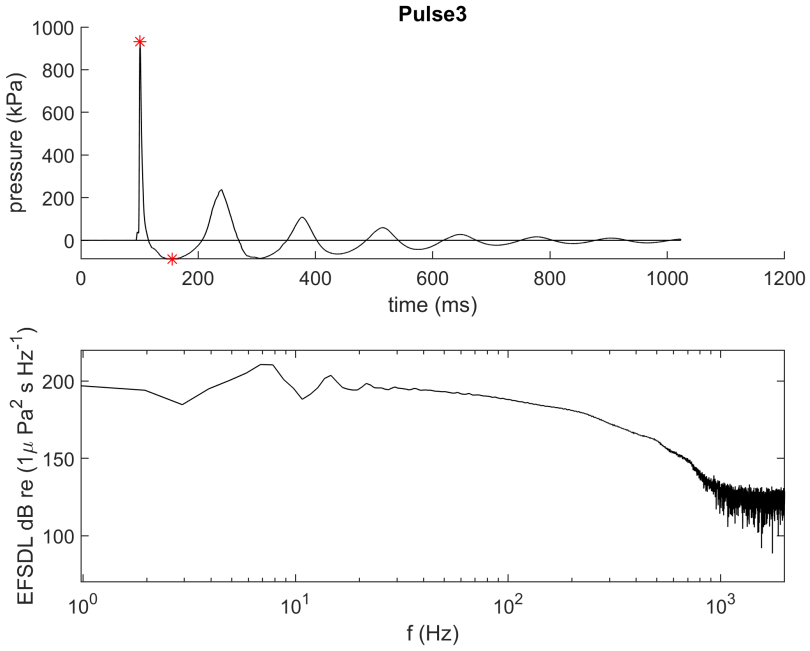
William M. Carey. Editorial Standard Definitions for Sound Levels in the Ocean. *IEEE Journal of Oceanic Engineering*, 20:109–113, 1995.

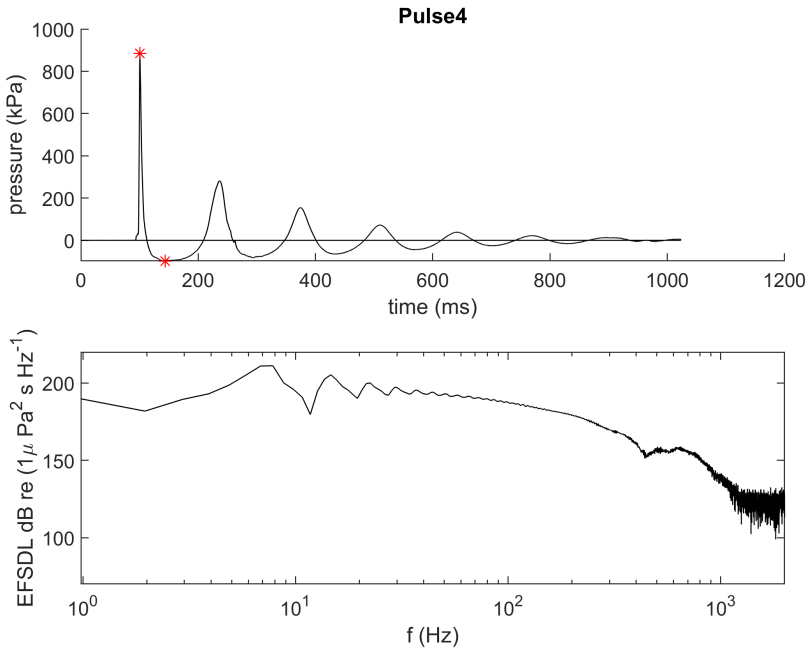
4 The individual pulses

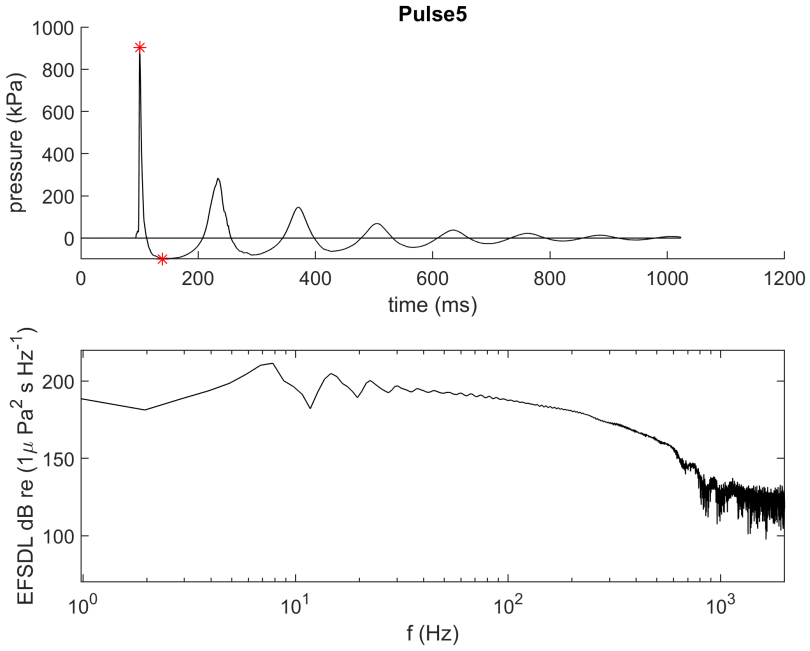
Plots of individual pulses and the corresponding EFSDL. The red asterisks denotes the maximum and minimum pressures used to calculate the peak-to-peak and zero-to-peak pressures.

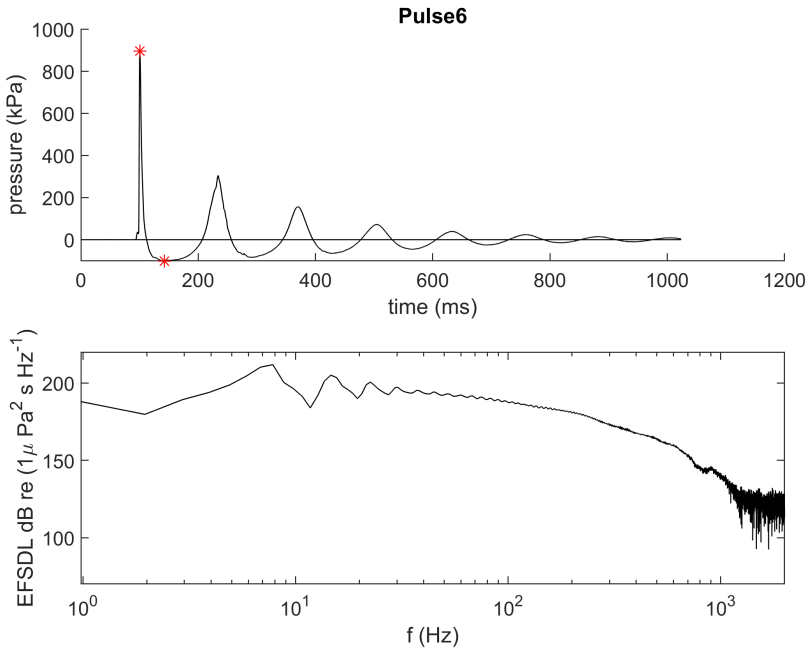


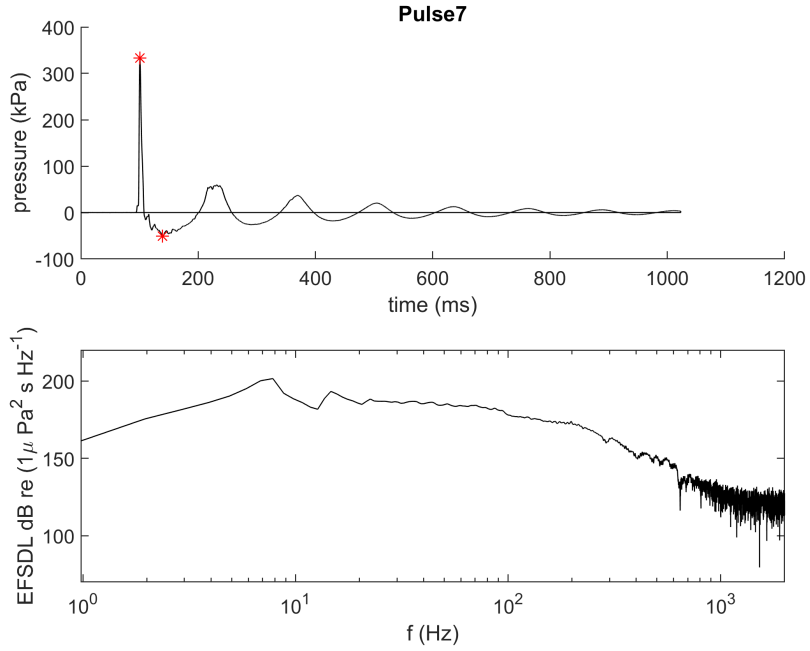

Pulse2
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)

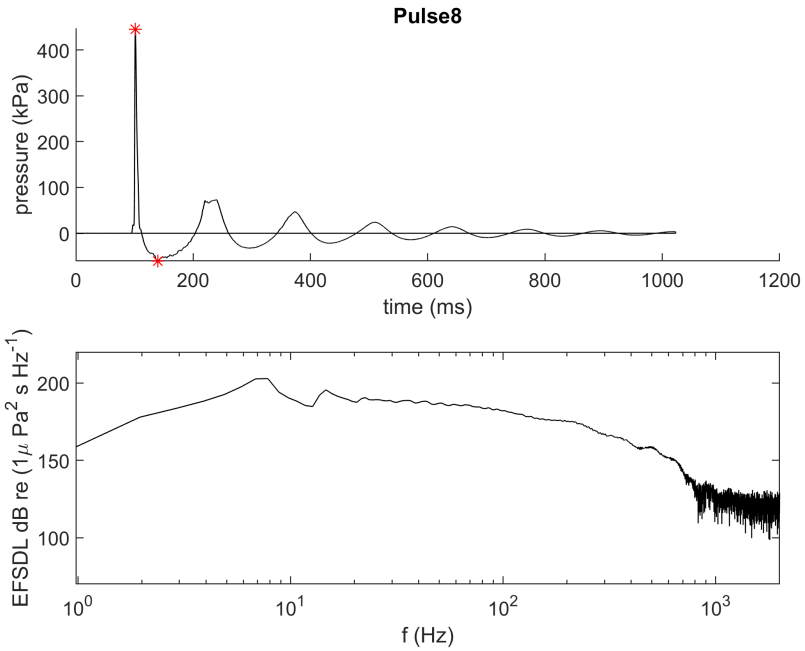

Pulse3
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)

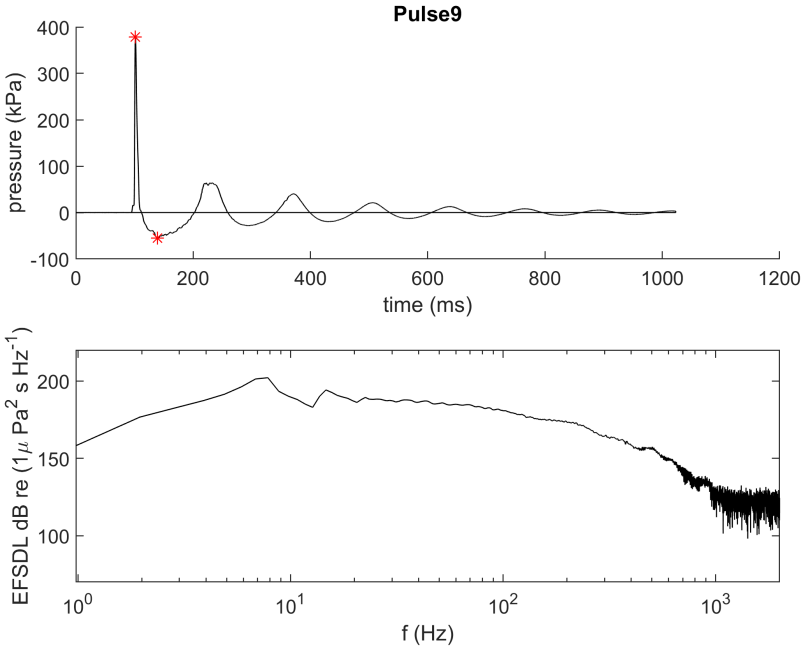

Pulse4
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)

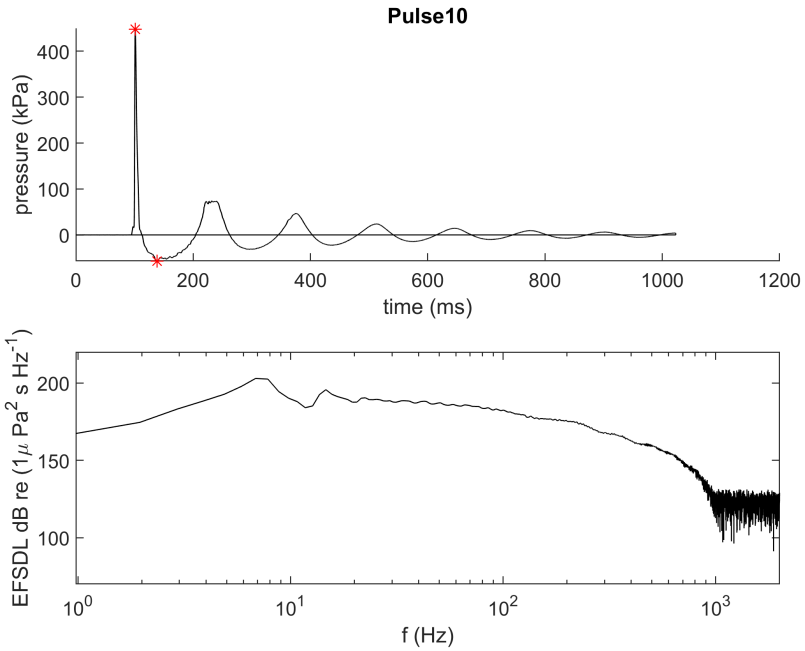

Pulse5
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)

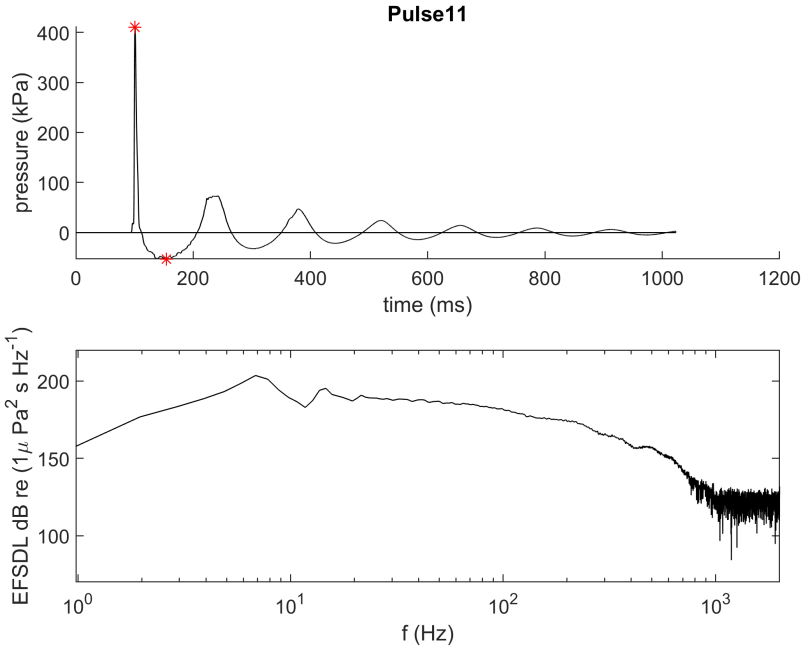

Pulse6
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)

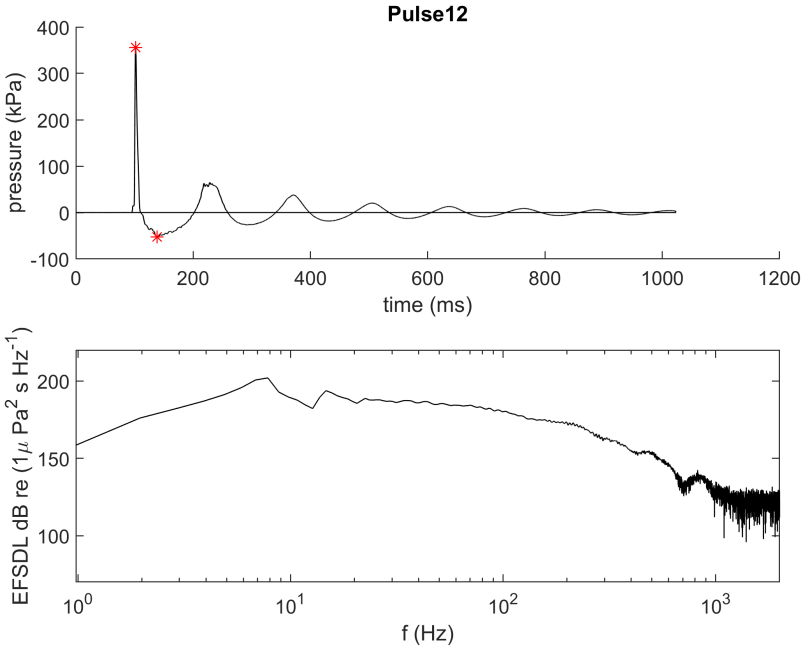

Pulse7
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)

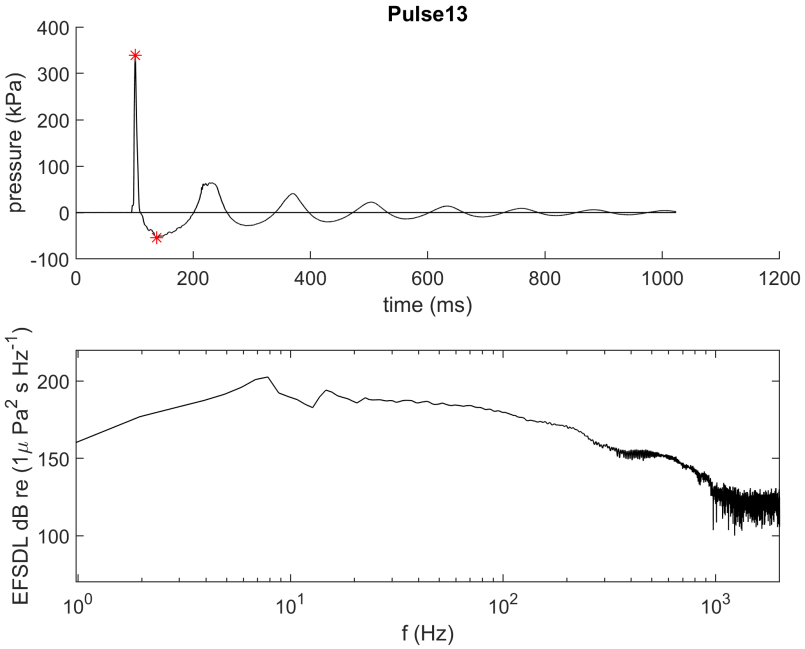

Pulse8
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)

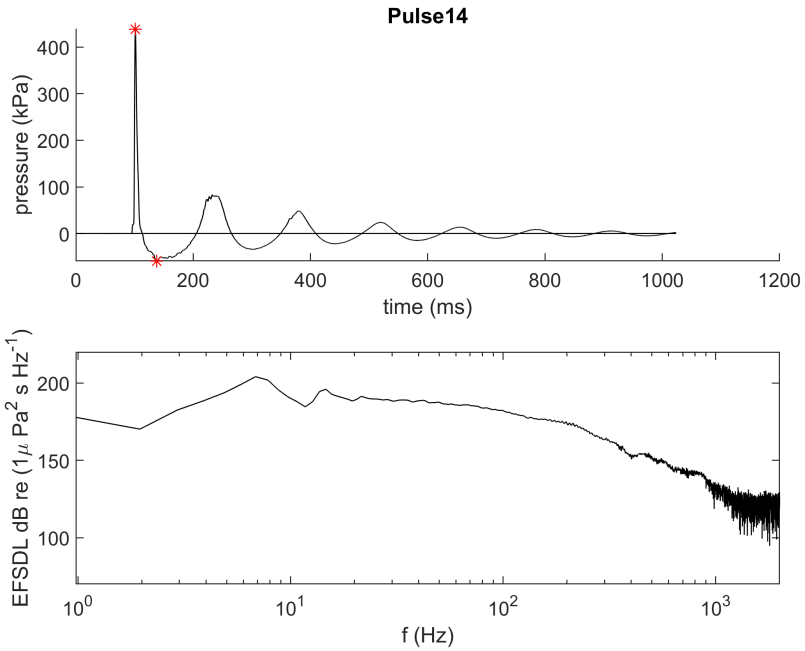

Pulse9
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)

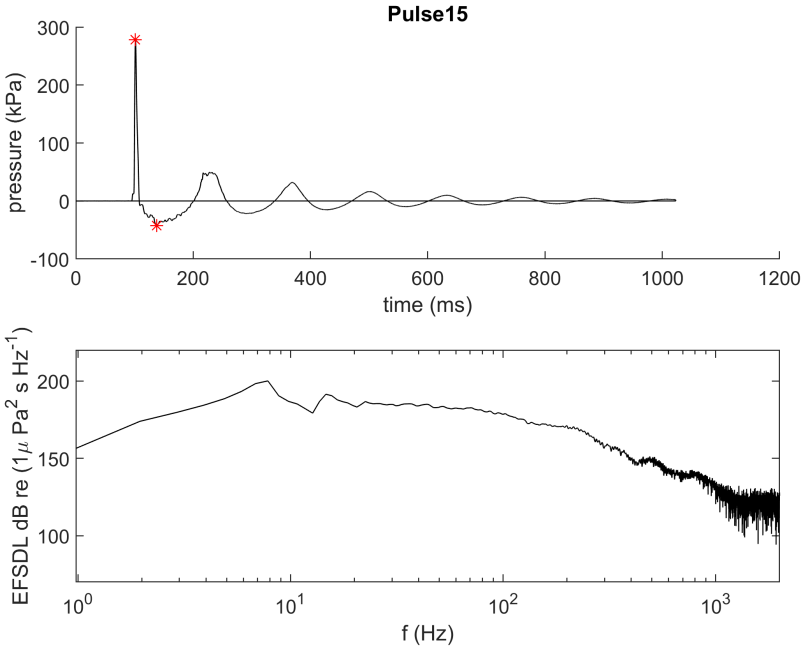

Pulse10
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)

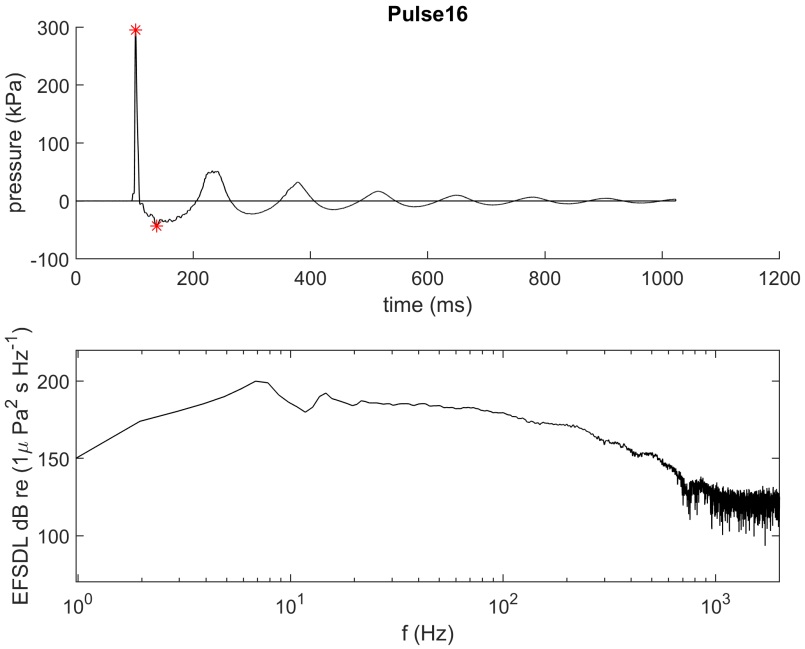

Pulse11
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)

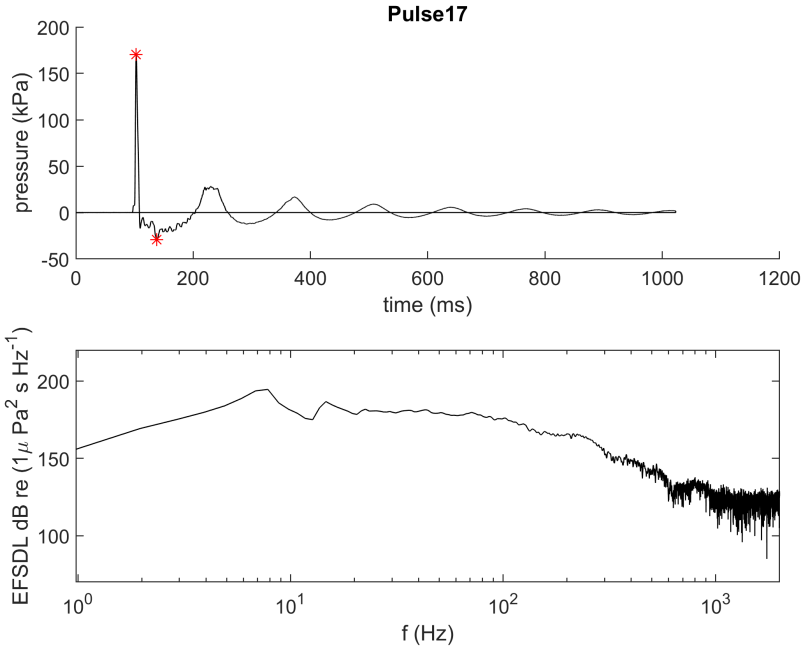

Pulse12
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)


Pulse13
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)


Pulse14
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)


Pulse15
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)


Pulse16
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)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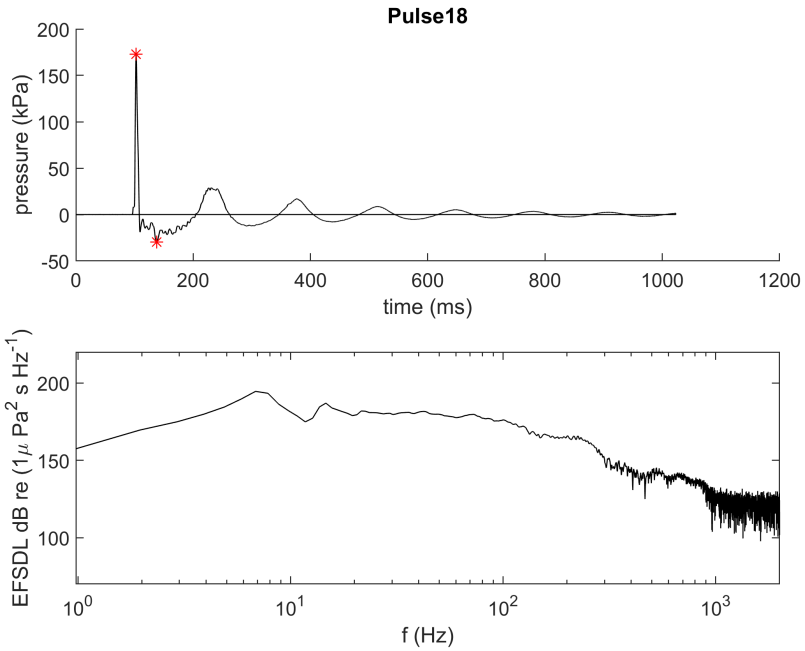
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)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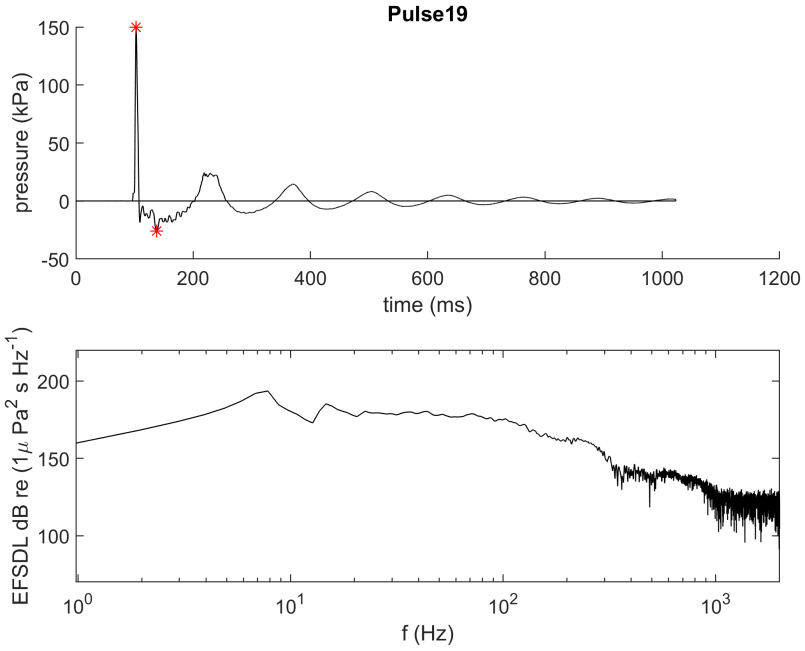
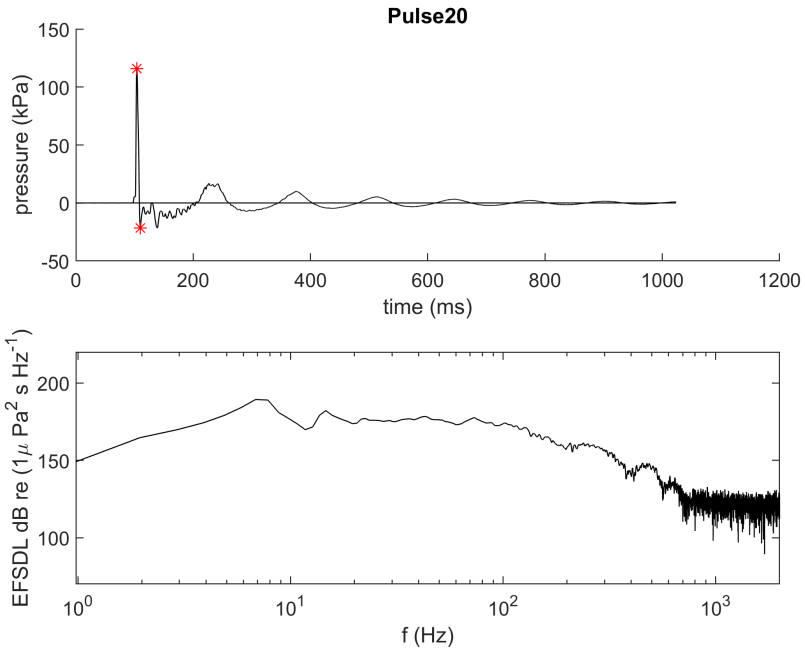
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)


Pulse19
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)


Pulse20
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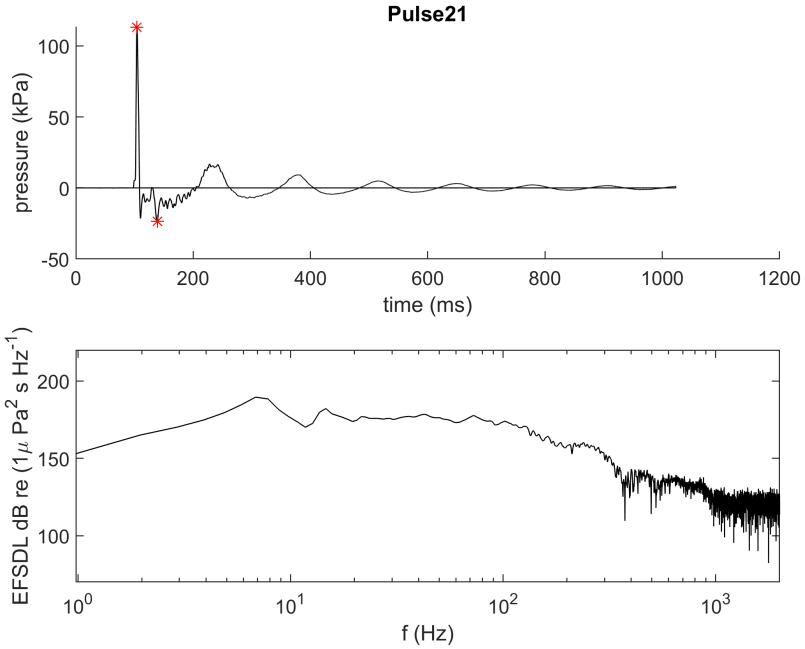
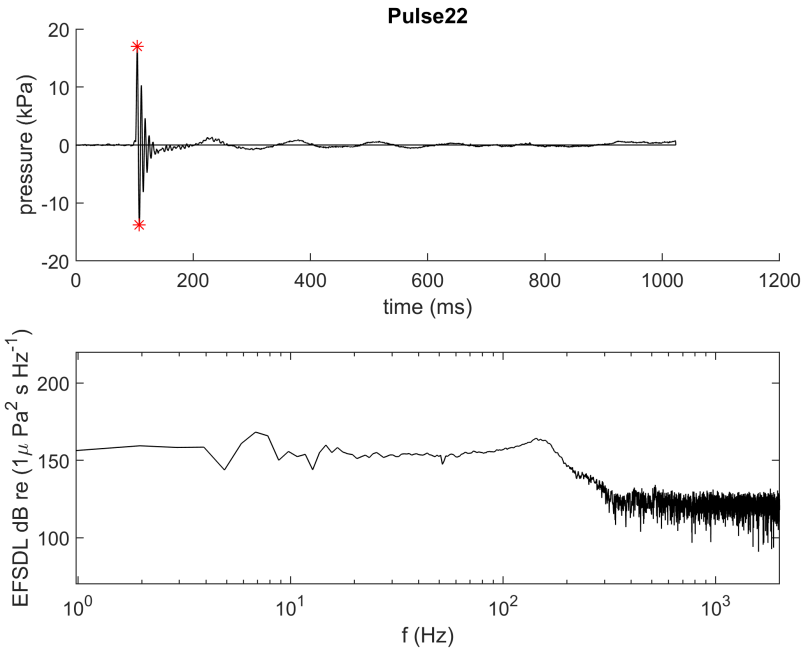
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)


Pulse21
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)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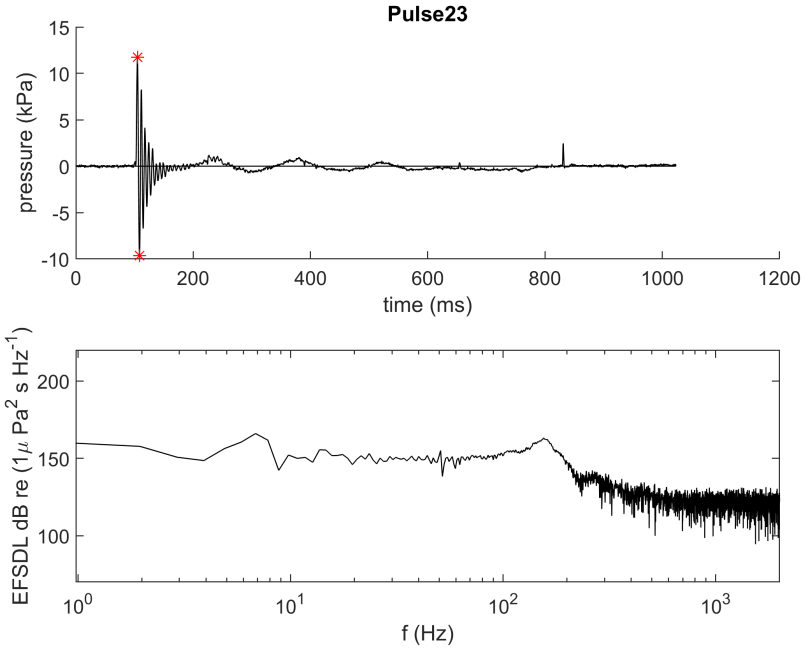
pressure (kPa)
time (ms)
EFSDL dB re (1 μ Pa^2 s Hz^-1)
f (Hz)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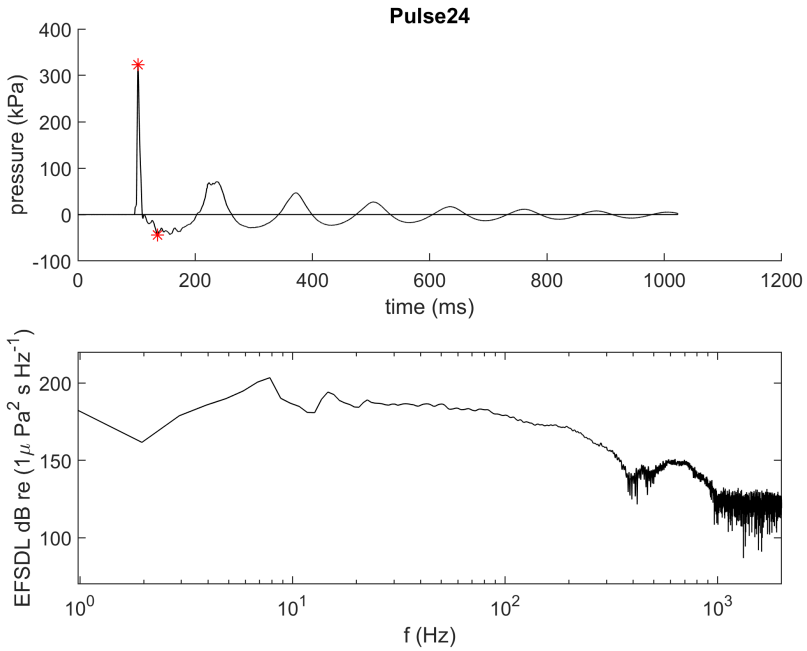
pressure (kPa)
time (ms)
EFSDL dB re (1 μ Pa^2 s Hz^-1)
f (Hz)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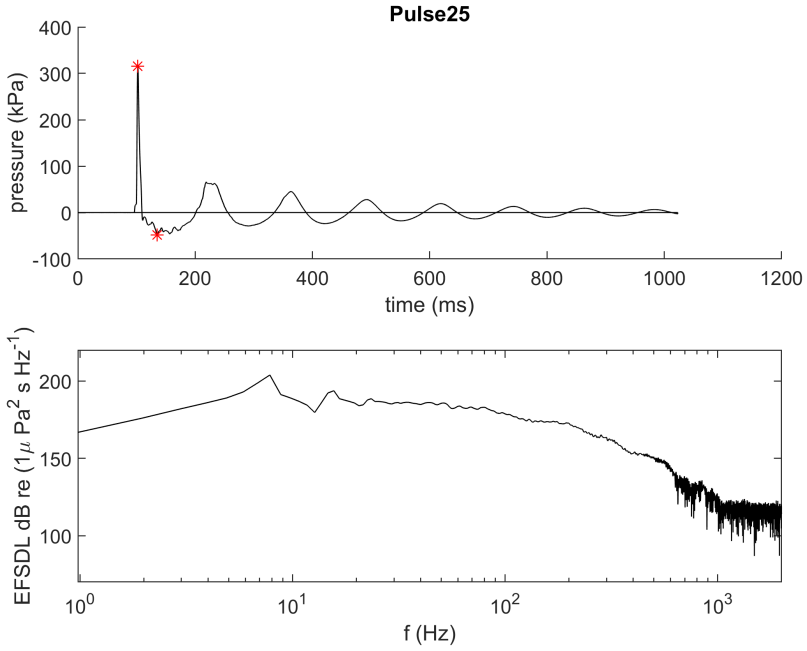
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)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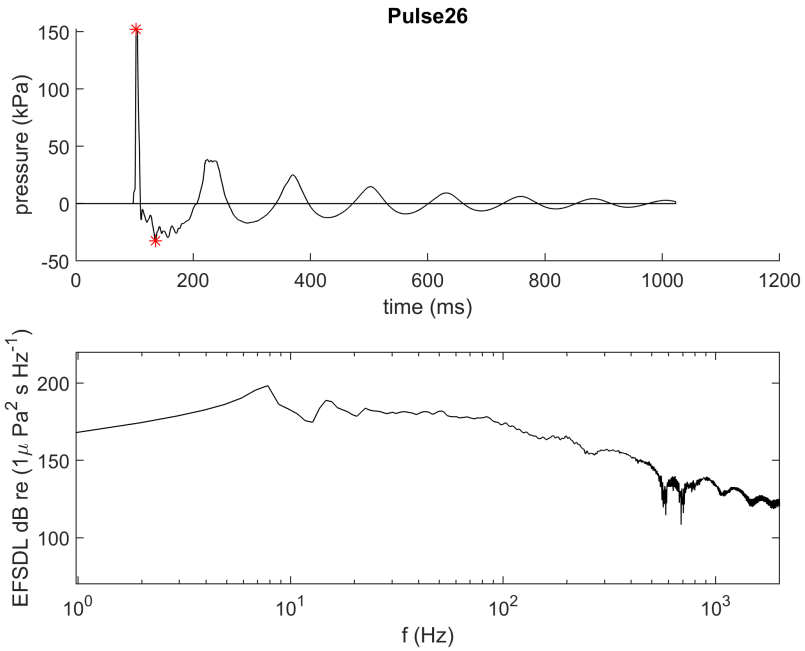
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)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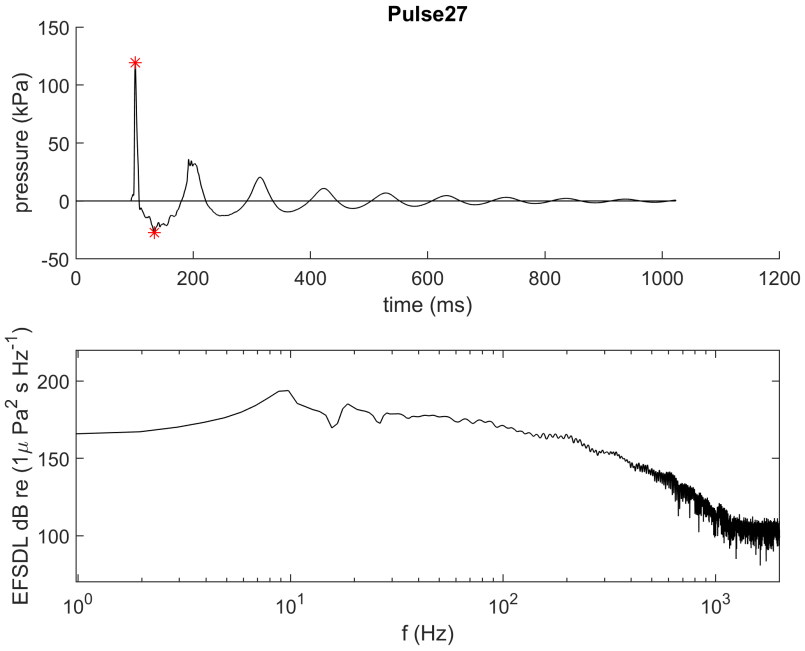
f (Hz)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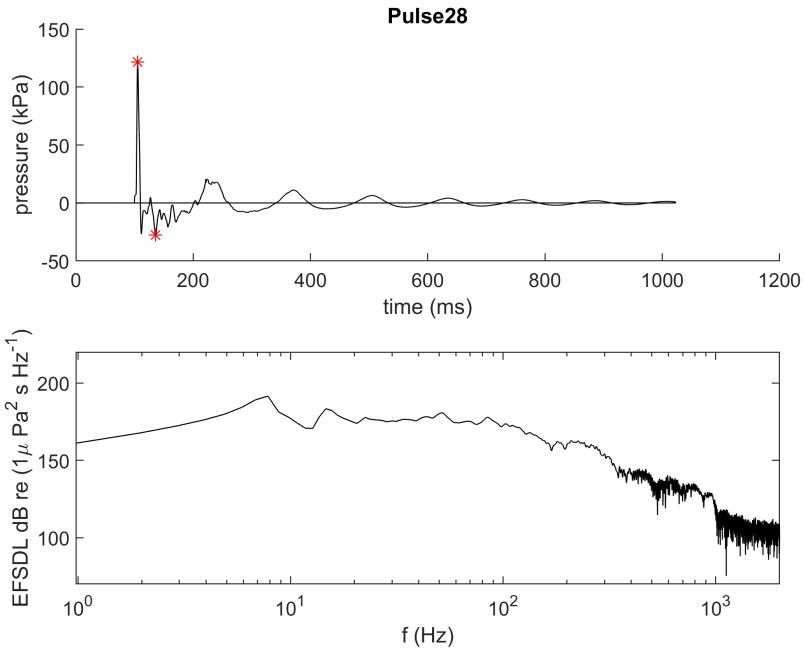
f (Hz)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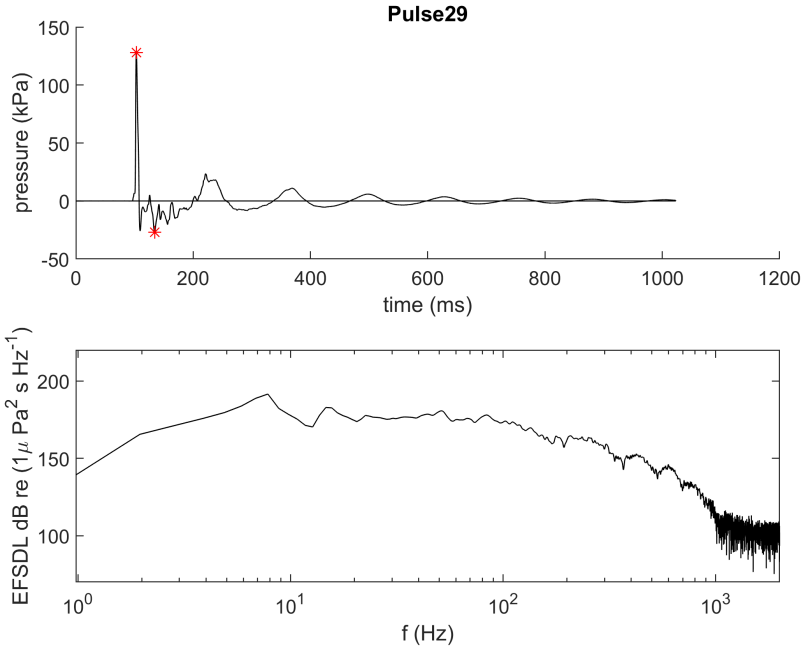
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)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pressure (kPa)
time (ms)
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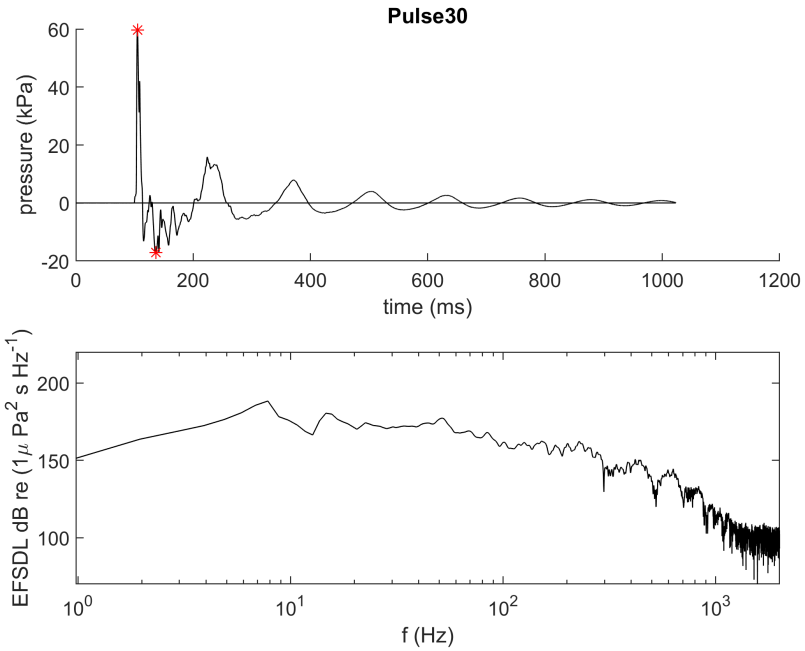
f (Hz)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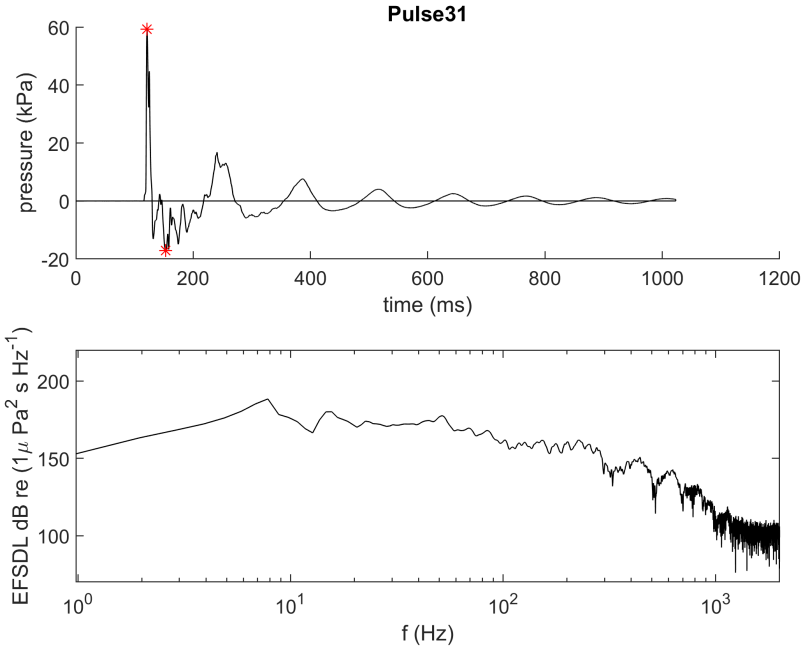
f (Hz)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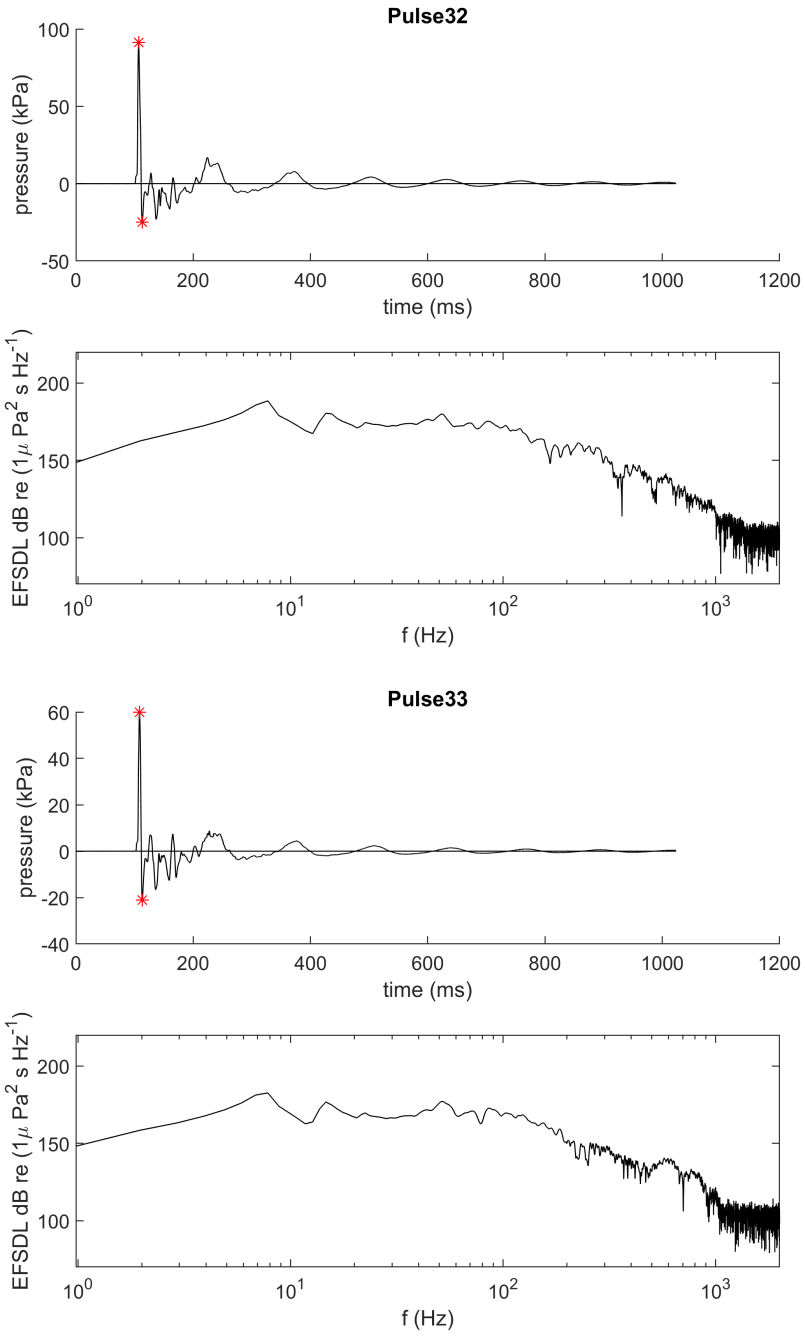
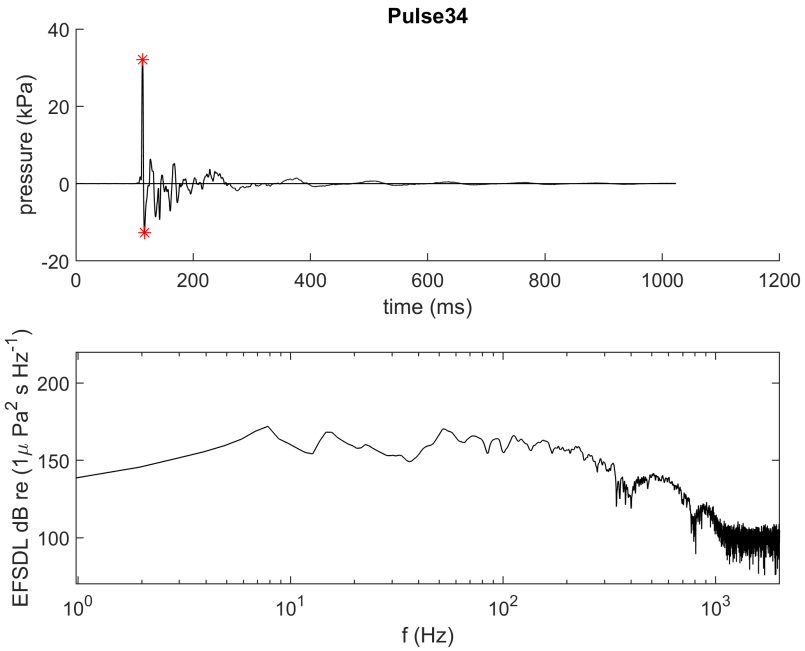
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa² s Hz⁻¹)
f (Hz)


Pulse32
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)
Pulse33
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)


Pulse34
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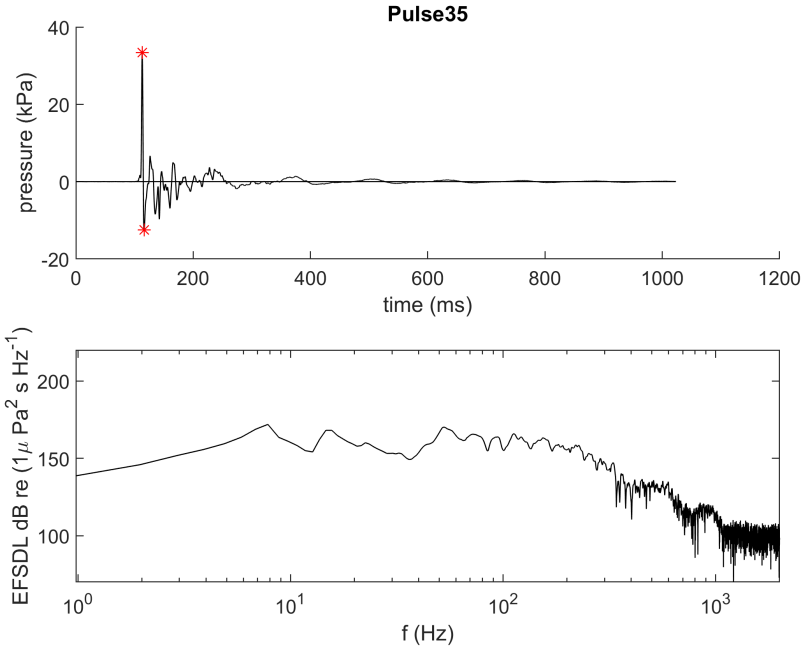
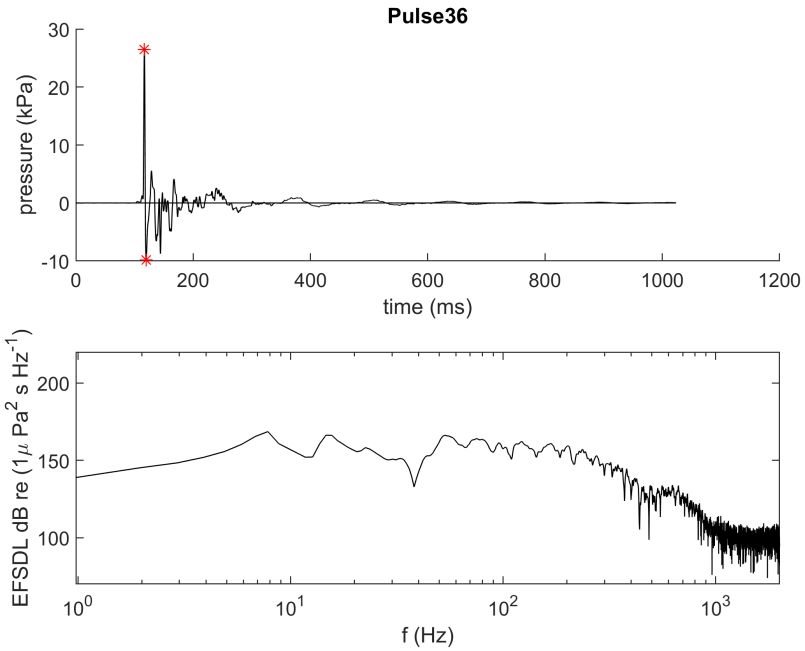
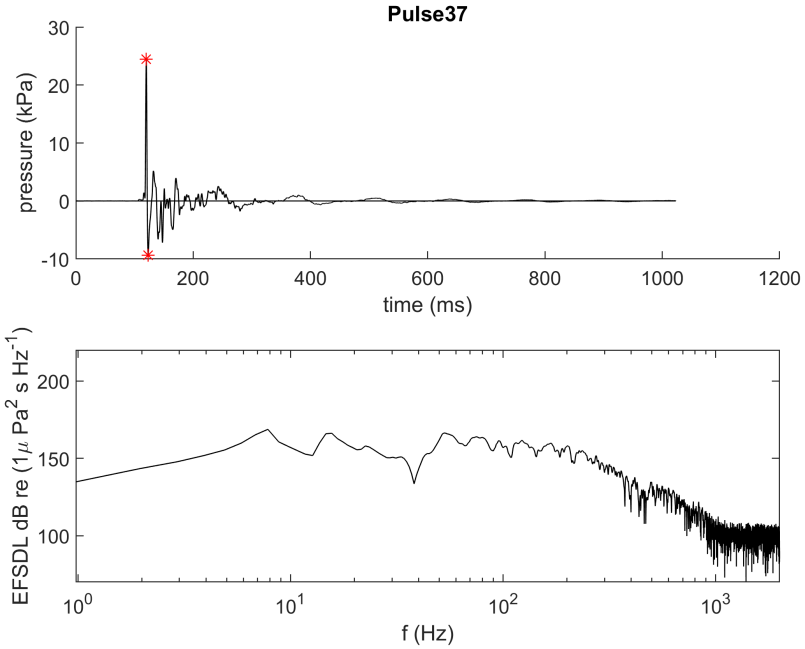
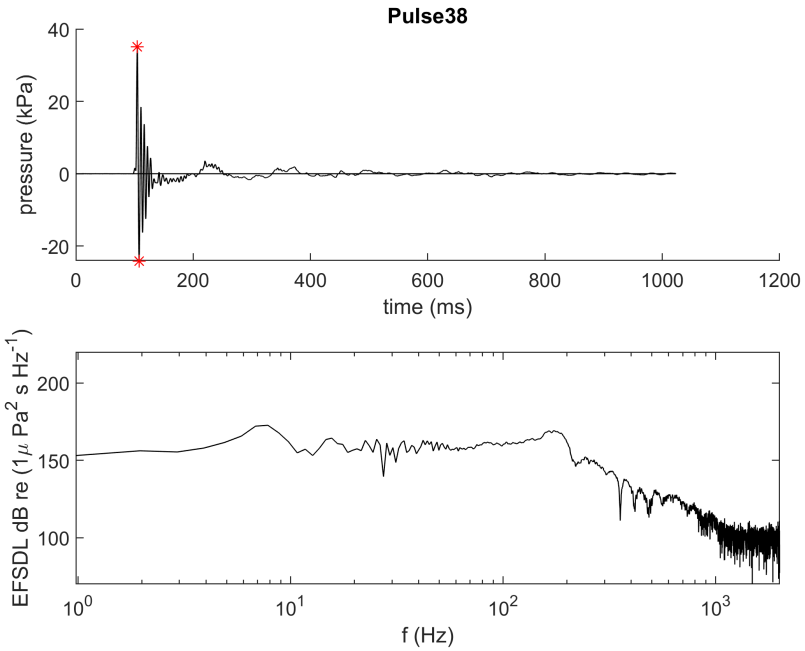
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)


Pulse35
pressure (kPa)
time (ms)
EFSDL dB re (1μ Pa^2 s Hz^{-1})
f (Hz)


Pulse36
pressure (kPa)
time (ms)
EFSDL dB re (1 μ Pa² s Hz⁻¹)
f (Hz)


Pulse37
pressure (kPa)
time (ms)
EFSDL dB re (1 μ Pa² s Hz⁻¹)
f (Hz)


Pulse38
pressure (kPa)
40
20
0
-20
0
200
400
600
800
1000
1200
time (ms)
EFSDL dB re (1 μ Pa^2 s Hz^-1)
200
150
100
10^0
10^1
10^2
10^3
f (Hz)