From this experiment, where the boundary conditions of the plate are changed and the PLB is broken on top of the plate (excitation of flexural modes), it really does not appear like the signal changes. The effect of reflections would assumed to be fairly negligible, and it does not appear like changing the structural dynamical properties influences the AE signals. At least in the sense of boundary conditions.

Load Data

In [71]:

```
from ae_measure2 import load_PLB
mypath = 'C:/Users/tul72/Box/aeml/data/natfreq/experiment07/20220702_experiment07.json'
data = load_PLB(mypath)
```

Separate out waveforms and metadata according to plate length

In [72]:

```
from plotting import create_figure, plot_signal
import matplotlib.pyplot as plt
import numpy as np

waves = data['waves']
location = data['location']
angle = data['angle']
length = data['length']
event = data['event']
sensor = data['sensor']

# 6 inch
w6in = [waves[(length=='6in') & (sensor==1)],waves[(length=='6in') & (sensor==2)],
        waves[(length=='6in') & (sensor==3)],waves[(length=='6in') & (sensor==4)]]
ev6in = event[(length=='6in') & (sensor==1)]
print(f"# of 6 in plate waves : {len(ev6in)}")

# 12 inch
w12in = [waves[(length=='12in') & (sensor==1)],waves[(length=='12in') & (sensor==2)],
        waves[(length=='12in') & (sensor==3)],waves[(length=='12in') & (sensor==4)]]
ev12in = event[(length=='12in') & (sensor==1)]
print(f"# of 12 in plate waves : {len(ev12in)}")

# 18 inch
w18in = [waves[(length=='18in') & (sensor==1)],waves[(length=='18in') & (sensor==2)],
        waves[(length=='18in') & (sensor==3)],waves[(length=='18in') & (sensor==4)]]
ev18in = event[(length=='18in') & (sensor==1)]
print(f"# of 18 in plate waves : {len(ev18in)}")

# 24 inch
w24in = [waves[(length=='24in') & (sensor==1)],waves[(length=='24in') & (sensor==2)],
        waves[(length=='24in') & (sensor==3)],waves[(length=='24in') & (sensor==4)]]
ev24in = event[(length=='24in') & (sensor==1)]
print(f"# of 24 in plate waves : {len(ev24in)}")
```

```
# of 6 in plate waves : 28
# of 12 in plate waves : 46
```

```
# of 18 in plate waves : 40
# of 24 in plate waves : 34
```

Plot the waves from each plate length, and ensure no signals need to be filtered

Signals should have already been filtered at this stage. This is just to double check.

In [73]:

```
# Signal Processing Parameters
sig_len = 4096
dt = 10**-7
duration = sig_len*dt*10**6 # convert to us
time = np.linspace(0,duration,sig_len) # discretization of signal time
```

Compute and Plot the Mean Waveforms for each Plate Length

In [74]:

```
# 6 in
mean_w6in = [np.mean(w6in[0], axis=0), np.mean(w6in[1], axis=0),
             np.mean(w6in[2], axis=0), np.mean(w6in[3], axis=0)]

# 12
mean_w12in = [np.mean(w12in[0], axis=0), np.mean(w12in[1], axis=0),
             np.mean(w12in[2], axis=0), np.mean(w12in[3], axis=0)]

# 18 in
mean_w18in = [np.mean(w18in[0], axis=0), np.mean(w18in[1], axis=0),
             np.mean(w18in[2], axis=0), np.mean(w18in[3], axis=0)]
# 24 in
mean_w24in = [np.mean(w24in[0], axis=0), np.mean(w24in[1], axis=0),
             np.mean(w24in[2], axis=0), np.mean(w24in[3], axis=0)]
```

Sensor 1

In [75]:

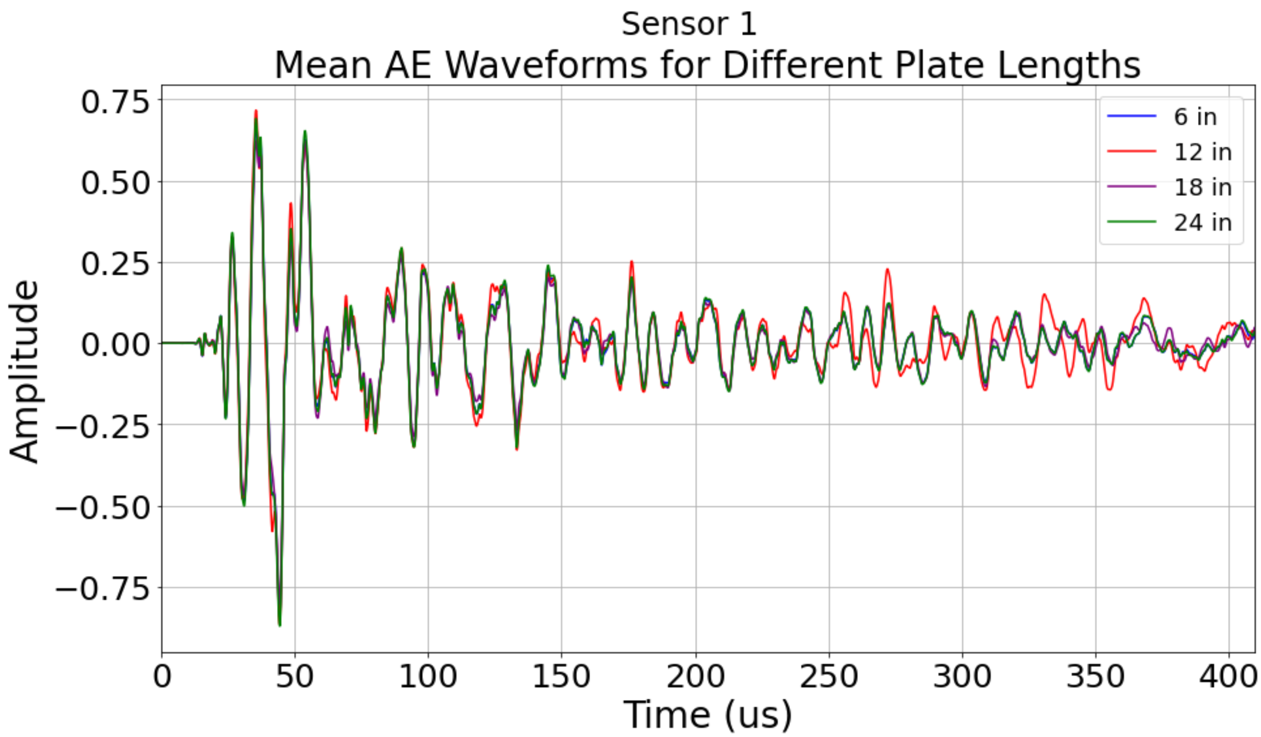
```
# Plot the averaged waveforms
fig,spec2 = create_figure('Sensor 1',columns=1,rows=1,width=15,height=8,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)

ax = fig.add_subplot(spec2[0,0])
ax.plot(time,mean_w6in[0],'-',label = '6 in', color='blue')
ax.plot(time,mean_w12in[0],'-',label = '12 in', color='red')
ax.plot(time,mean_w18in[0],'-',label = '18 in', color='purple')
ax.plot(time,mean_w24in[0],'-',label = '24 in', color='green')

ax.set_title('Mean AE Waveforms for Different Plate Lengths')

plt.legend()
ax.set_xlim([0,duration])
ax.set_xlabel('Time (us)')
ax.set_ylabel('Amplitude')
#ax.set_ylim([-0.9,0.65])
```

```
plt.grid()
plt.show()
```



Sensor 2

In [76]:

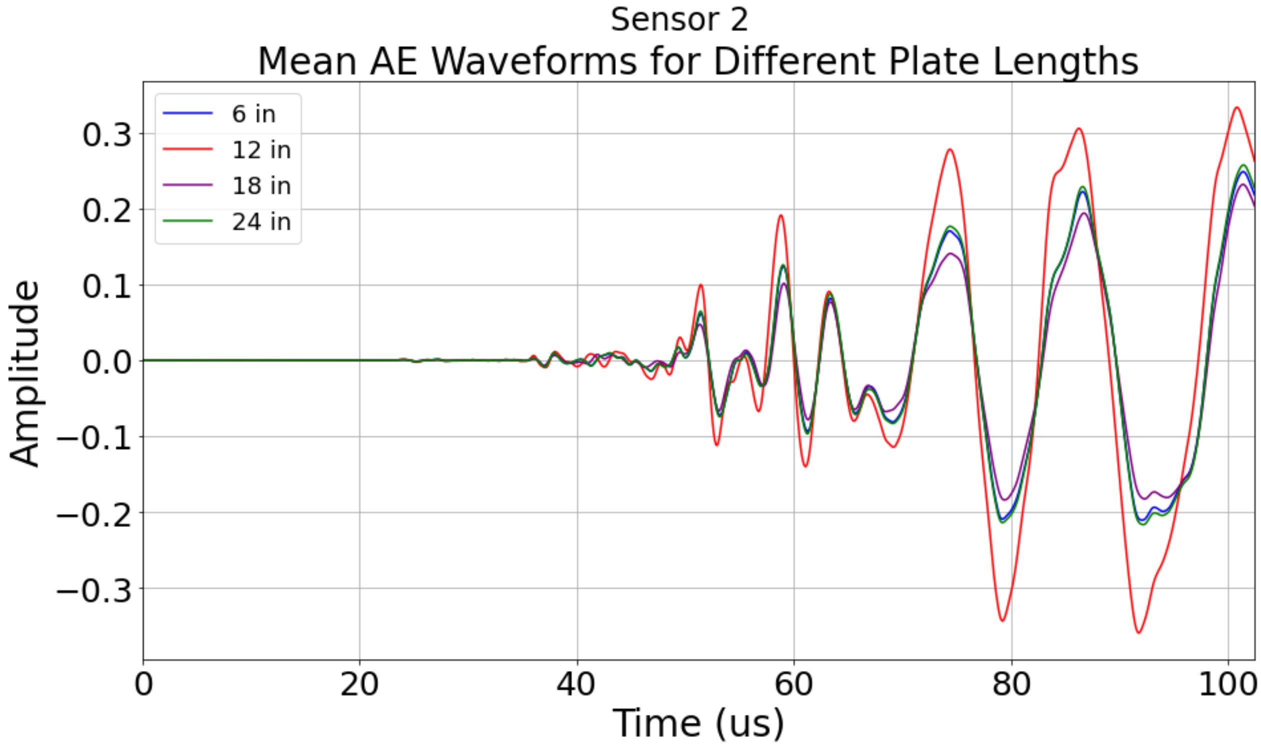
```
# Plot the averaged waveforms
fig,spec2 = create_figure('Sensor 2',columns=1,rows=1,width=15,height=8,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)

ax = fig.add_subplot(spec2[0,0])
ax.plot(time,mean_w6in[1],'-',label = '6 in', color='blue')
ax.plot(time,mean_w12in[1],'-',label = '12 in', color='red')
ax.plot(time,mean_w18in[1],'-',label = '18 in', color='purple')
ax.plot(time,mean_w24in[1],'-',label = '24 in', color='green')

ax.set_title('Mean AE Waveforms for Different Plate Lengths')

plt.legend()
ax.set_xlim([0,duration/4])
ax.set_xlabel('Time (us)')
ax.set_ylabel('Amplitude')
#ax.set_ylim([-0.9,0.65])

plt.grid()
plt.show()
```



Sensor 3

In [77]:

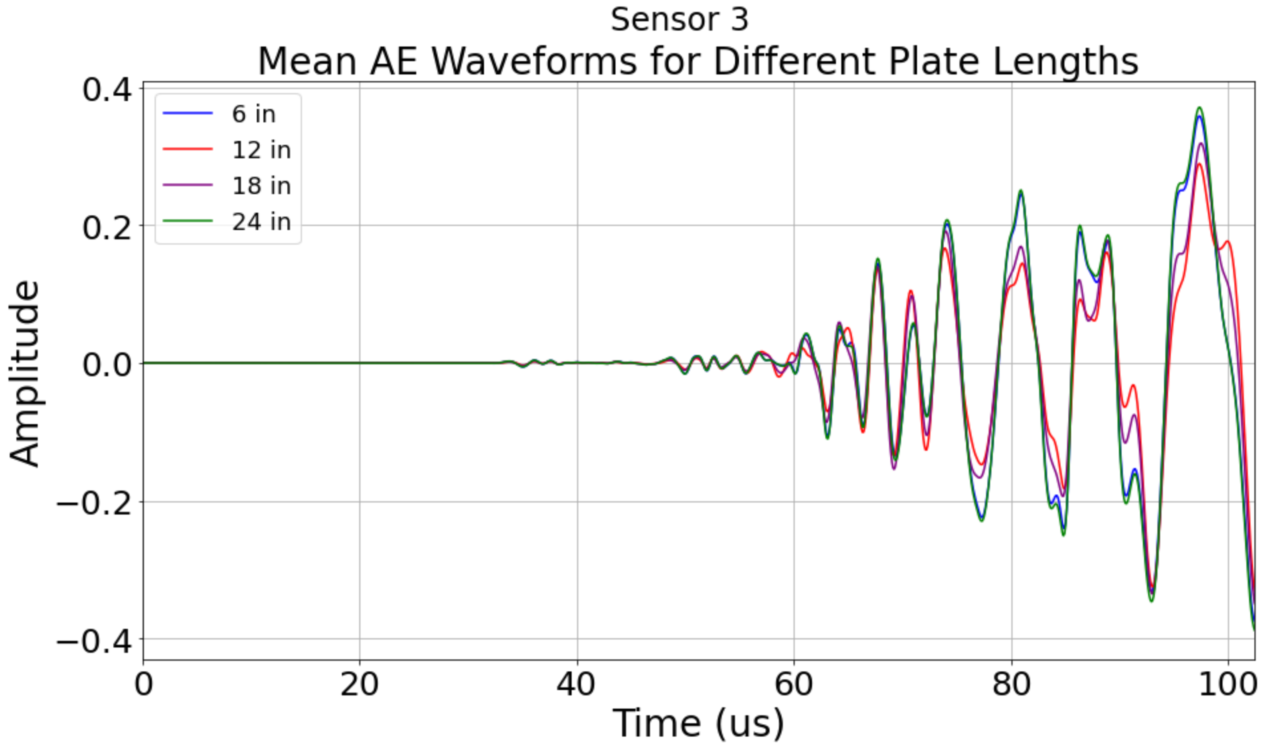
```
# Plot the averaged waveforms
fig,spec2 = create_figure('Sensor 3',columns=1,rows=1,width=15,height=8,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)

ax = fig.add_subplot(spec2[0,0])
ax.plot(time,mean_w6in[2],'-',label = '6 in', color='blue')
ax.plot(time,mean_w12in[2],'-',label = '12 in', color='red')
ax.plot(time,mean_w18in[2],'-',label = '18 in', color='purple')
ax.plot(time,mean_w24in[2],'-',label = '24 in', color='green')

ax.set_title('Mean AE Waveforms for Different Plate Lengths')

plt.legend()
ax.set_xlim([0,duration/4])
ax.set_xlabel('Time (us)')
ax.set_ylabel('Amplitude')
#ax.set_ylim([-0.9,0.65])

plt.grid()
plt.show()
```



Sensor 4

In [78]:

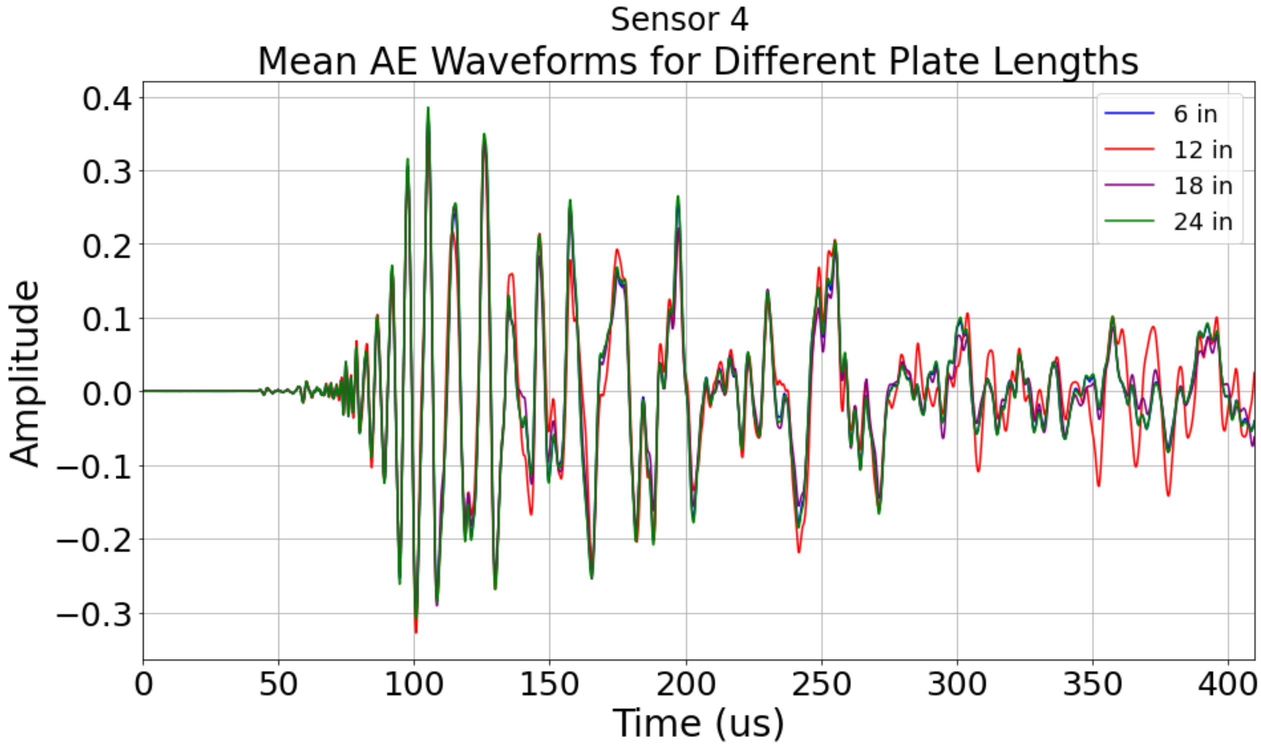
```
# Plot the averaged waveforms
fig,spec2 = create_figure('Sensor 4',columns=1,rows=1,width=15,height=8,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)

ax = fig.add_subplot(spec2[0,0])
ax.plot(time,mean_w6in[3],'-',label = '6 in', color='blue')
ax.plot(time,mean_w12in[3],'-',label = '12 in', color='red')
ax.plot(time,mean_w18in[3],'-',label = '18 in', color='purple')
ax.plot(time,mean_w24in[3],'-',label = '24 in', color='green')

ax.set_title('Mean AE Waveforms for Different Plate Lengths')

plt.legend()
ax.set_xlim([0,duration])
ax.set_xlabel('Time (us)')
ax.set_ylabel('Amplitude')
#ax.set_ylim([-0.9,0.65])

plt.grid()
plt.show()
```



Compute and Plot Mean FFT (Entire Waveform)

The FFTs here are computed on the entire raw waveform (this is necessary to average them all and visualize, otherwise the ffts would have different lengths). Later in the code, the waveforms are chopped down to only what's contained between the start and end (what's visualized in the previous plotting of raw waveforms) before computed frequency domain features.

In [79]:

```
# Compute FFTs
low_pass = 0                 # [Hz] ; low frequency cutoff
high_pass = 1000*10**3        # [Hz] ; high frequency cutoff\
dt = 10**-7                  # [seconds] ; sample period / time between samples
fft_units = 1000

from ae_measure2 import fft
```

In [80]:

```
# 6 in
fft6in = []
for sensor in w6in:
    fftsensor = []
    for idx,wave in enumerate(sensor):
        w,z = fft(dt, wave, low_pass, high_pass)
        fftsensor.append(z/max(z))
    fft6in.append(np.array(fftsensor))
mean_fft6in = [np.mean(fft6in[0], axis=0), np.mean(fft6in[1], axis=0),
             np.mean(fft6in[2], axis=0), np.mean(fft6in[3], axis=0)]
```

In [81]:

```
# 12 in
fft12in = []
for sensor in w12in:
    fftsensor = []
```

```
    for idx,wave in enumerate(sensor):
        w,z = fft(dt, wave, low_pass, high_pass)
        fftsensor.append(z/max(z))
    fft12in.append(np.array(fftsensor))
mean_fft12in = [np.mean(fft12in[0], axis=0), np.mean(fft12in[1], axis=0),
             np.mean(fft12in[2], axis=0), np.mean(fft12in[3], axis=0)]
```

In [82]:

```
# 18 in
fft18in = []
for sensor in w18in:
    fftsensor = []
    for idx,wave in enumerate(sensor):
        w,z = fft(dt, wave, low_pass, high_pass)
        fftsensor.append(z/max(z))
    fft18in.append(np.array(fftsensor))
mean_fft18in = [np.mean(fft18in[0], axis=0), np.mean(fft18in[1], axis=0),
             np.mean(fft18in[2], axis=0), np.mean(fft18in[3], axis=0)]
```

In [83]:

```
# 24 in
fft24in = []
for sensor in w24in:
    fftsensor = []
    for idx,wave in enumerate(sensor):
        w,z = fft(dt, wave, low_pass, high_pass)
        fftsensor.append(z/max(z))
    fft24in.append(np.array(fftsensor))
mean_fft24in = [np.mean(fft24in[0], axis=0), np.mean(fft24in[1], axis=0),
             np.mean(fft24in[2], axis=0), np.mean(fft24in[3], axis=0)]

w = w/fft_units; # khz
```

Sensor 1

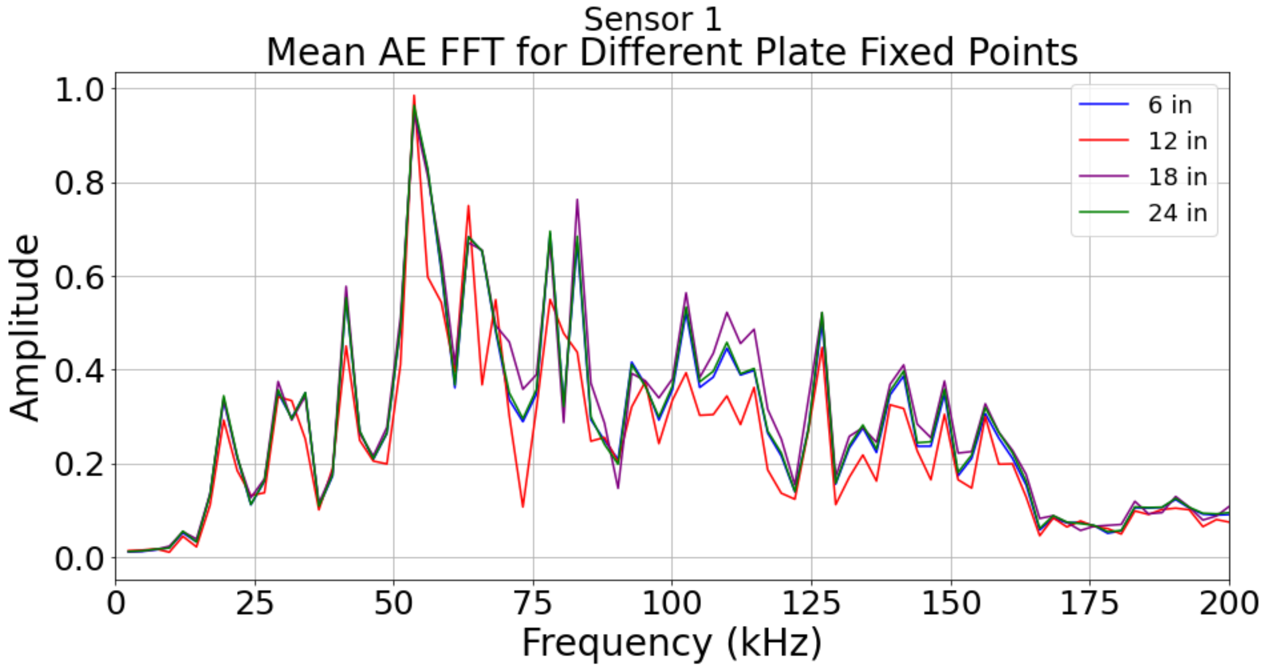
In [84]:

```
# Plot the averaged ffts
fig,spec2 = create_figure('Sensor 1',columns=1,rows=1,width=15,height=7,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)
ax = fig.add_subplot(spec2[0,0])
ax.plot(w,mean_fft6in[0],'-',label = '6 in', color='blue')
ax.plot(w,mean_fft12in[0],'-',label = '12 in', color='red')
ax.plot(w,mean_fft18in[0],'-',label = '18 in', color='purple')
ax.plot(w,mean_fft24in[0],'-',label = '24 in', color='green')

ax.set_title('Mean AE FFT for Different Plate Fixed Points')

ax.set_xlim([low_pass/fft_units,high_pass/fft_units])
ax.set_xlim([0,200])
ax.set_xlabel('Frequency (kHz)')
ax.set_ylabel('Amplitude')
plt.legend()

plt.grid()
plt.show()
```



Sensor 2

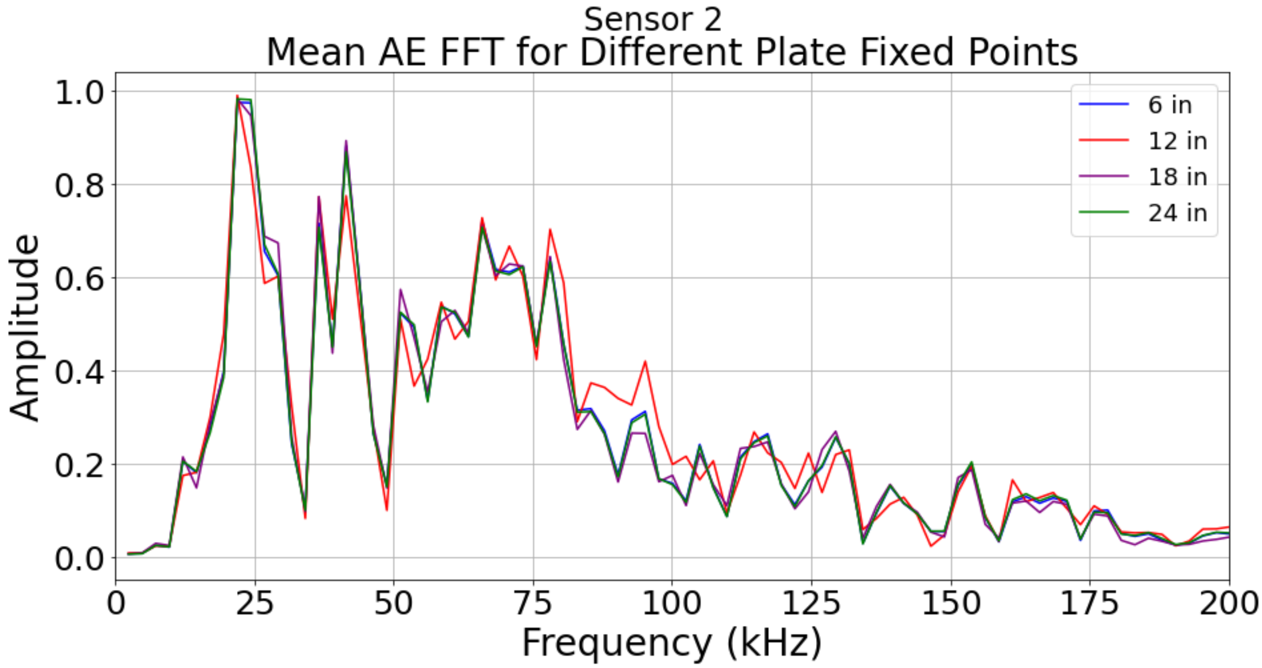
In [85]:

```
# Plot the averaged ffts
fig,spec2 = create_figure('Sensor 2',columns=1,rows=1,width=15,height=7,default_font_si
                          ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                          title_font_size=28)
ax = fig.add_subplot(spec2[0,0])
ax.plot(w,mean_fft6in[1],'-',label = '6 in', color='blue')
ax.plot(w,mean_fft12in[1],'-',label = '12 in', color='red')
ax.plot(w,mean_fft18in[1],'-',label = '18 in', color='purple')
ax.plot(w,mean_fft24in[1],'-',label = '24 in', color='green')

ax.set_title('Mean AE FFT for Different Plate Fixed Points')

ax.set_xlim([low_pass/fft_units,high_pass/fft_units])
ax.set_xlim([0,200])
ax.set_xlabel('Frequency (kHz)')
ax.set_ylabel('Amplitude')
plt.legend()

plt.grid()
plt.show()
```



Sensor 3

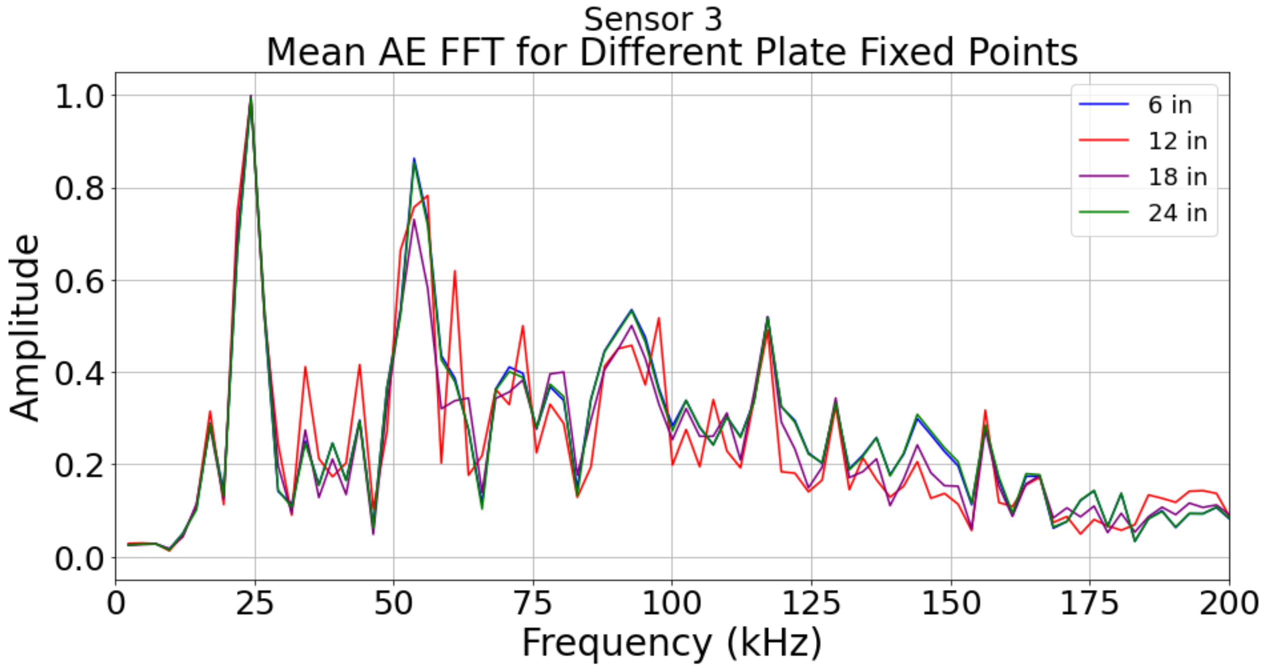
In [86]:

```
# Plot the averaged ffts
fig,spec2 = create_figure('Sensor 3',columns=1,rows=1,width=15,height=7,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)
ax = fig.add_subplot(spec2[0,0])
ax.plot(w,mean_fft6in[2],'-',label = '6 in', color='blue')
ax.plot(w,mean_fft12in[2],'-',label = '12 in', color='red')
ax.plot(w,mean_fft18in[2],'-',label = '18 in', color='purple')
ax.plot(w,mean_fft24in[2],'-',label = '24 in', color='green')

ax.set_title('Mean AE FFT for Different Plate Fixed Points')

ax.set_xlim([low_pass/fft_units,high_pass/fft_units])
ax.set_xlim([0,200])
ax.set_xlabel('Frequency (kHz)')
ax.set_ylabel('Amplitude')
plt.legend()

plt.grid()
plt.show()
```



Sensor 4

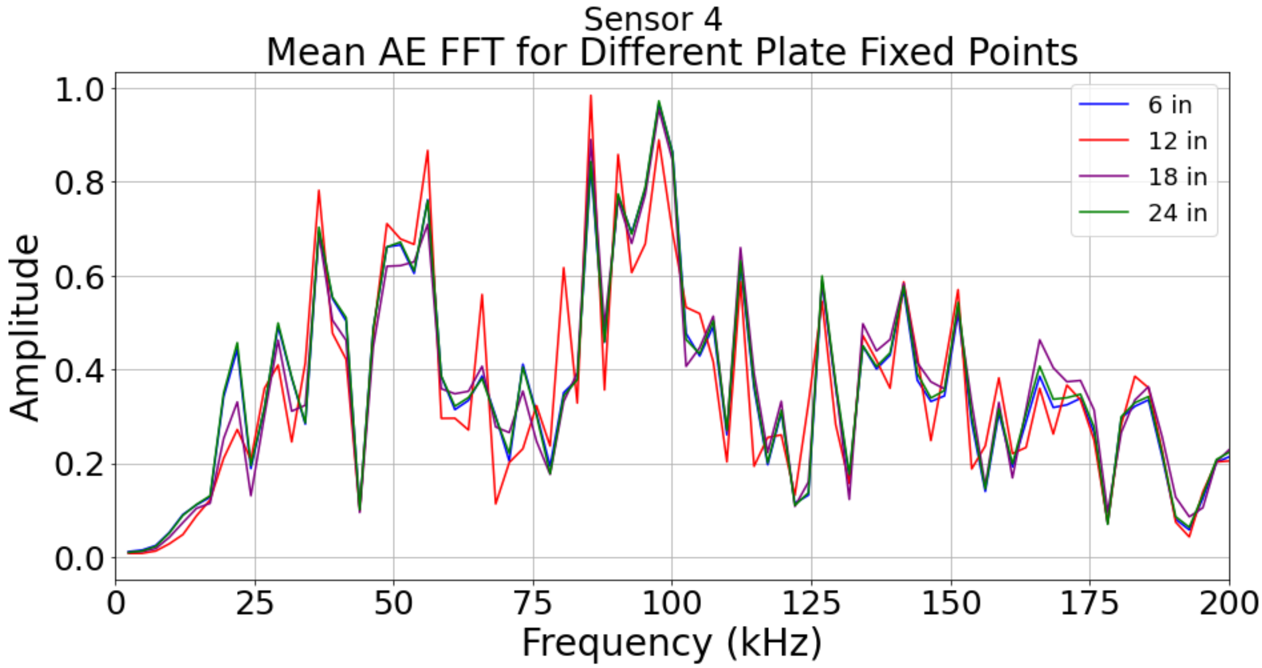
In [87]:

```
# Plot the averaged ffts
fig,spec2 = create_figure('Sensor 4',columns=1,rows=1,width=15,height=7,default_font_si
                         ,tick_font_size=25,legend_font_size=18,axes_font_size=28,
                         title_font_size=28)
ax = fig.add_subplot(spec2[0,0])
ax.plot(w,mean_fft6in[3],'-',label = '6 in', color='blue')
ax.plot(w,mean_fft12in[3],'-',label = '12 in', color='red')
ax.plot(w,mean_fft18in[3],'-',label = '18 in', color='purple')
ax.plot(w,mean_fft24in[3],'-',label = '24 in', color='green')

ax.set_title('Mean AE FFT for Different Plate Fixed Points')

ax.set_xlim([low_pass/fft_units,high_pass/fft_units])
ax.set_xlim([0,200])
ax.set_xlabel('Frequency (kHz)')
ax.set_ylabel('Amplitude')
plt.legend()

plt.grid()
plt.show()
```


Sensor 4
Mean AE FFT for Different Plate Fixed Points
Amplitude
Frequency (kHz)
6 in
12 in
18 in
24 in
0.0
0.2
0.4
0.6
0.8
1.0
0
25
50
75
100
125
150
175
200