```python
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

# 设置中文显示
plt.rcParams['font.sans-serif'] = ['SimHei']
plt.rcParams['axes.unicode_minus'] = False

# 读取数据文件
df = pd.read_csv('../../data/ads_20250511_021655_077.csv')

# 重命名列名
df.columns = ['timestamp','voltage', 'duration']

# 将时间戳转换为datetime类型
df['timestamp'] = pd.to_datetime(df['timestamp'])

specific_time = pd.to_datetime('2025-05-11T15:27:07.355Z')



plt.figure(figsize=(12, 6))
plt.plot(df['duration'] / 60000, df['voltage'], label='电压变化', color='b')  # 将ms转换为分钟
plt.xlabel('Duration (minutes)')
plt.ylabel('Voltage (mV)')
plt.legend()
plt.grid(True)
plt.show()

# 检查这个时间点是否在数据范围内
if specific_time >= df['timestamp'].min() and specific_time <= df['timestamp'].max():
    # 找到最接近的时间点
    closest_idx = (df['timestamp'] - specific_time).abs().idxmin()
    closest_point = df.iloc[closest_idx]

    # 绘制电压随时间变化的折线图，并标注特定时间点
    plt.figure(figsize=(12, 6))
    plt.plot(df['duration'] / 60000, df['voltage'], label='Voltage change', color='b')

    # 标注特定时间点
    plt.scatter(closest_point['duration'] / 60000, closest_point['voltage'],
                color='red', s=100, zorder=5)
    plt.annotate(f'1200Hz Sine Wave 10s, \n Voltage: {closest_point["voltage"]:.2f}mV',
                 xy=(closest_point['duration'] / 60000, closest_point['voltage']),
                 xytext=(closest_point['duration'] / 60000 + 0.5, closest_point['voltage'] + 2),
                 fontsize=10)

    plt.xlabel('Time (min)')
    plt.ylabel('Voltage (mV)')
    plt.legend()
    plt.grid(True)
    plt.show()
else:
    print("指定的时间点不在数据范围内！")
    print(f"数据时间范围: {df['timestamp'].min()} 到 {df['timestamp'].max()}")


# Check if this time point is within the data range
if specific_time >= df['timestamp'].min() and specific_time <= df['timestamp'].max():
    # Find the closest time point
    closest_idx = (df['timestamp'] - specific_time).abs().idxmin()
    closest_point = df.iloc[closest_idx]

    # Calculate the time window (5 minutes before and after the specific time)
    closest_duration_min = closest_point['duration'] / 60000  # Convert to minutes
    time_window_min = 5  # 5 minutes window

    # Filter data within the time window
    # min_duration = (closest_duration_min - (time_window_min - 1.7)) * 60000
    # max_duration = (closest_duration_min + (time_window_min + 1.4)) * 60000
    min_duration = (closest_duration_min - (time_window_min)) * 60000
    max_duration = (closest_duration_min + (time_window_min)) * 60000
    filtered_df = df[(df['duration'] >= min_duration) & (df['duration'] <= max_duration)]

    # Plot voltage changes over time, and mark the specific time point
    plt.figure(figsize=(18, 6))
    plt.plot(filtered_df['duration'] / 60000, filtered_df['voltage'], label='Voltage Change', color='b')

    # Mark the specific time point
    plt.scatter(closest_point['duration'] / 60000, closest_point['voltage'],
                color='red', s=100, zorder=5)
```

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        plt.annotate(f'1200Hz  Sine  Wave  10s,  \nVoltage:  {closest_point["voltage"]:.2f}mV',
                                xy=(closest_point['duration']  /  60000,  closest_point['voltage']),
                                xytext=(closest_point['duration']  /  60000,  closest_point['voltage']  -  0.7),
                                fontsize=10)

        #  Set  axis  labels  and  title
        plt.xlabel('Time  (min)')
        plt.ylabel('Voltage  (mV)')
        plt.title(f'Voltage  Data  Around  sound  situmilation')
        plt.legend()
        plt.grid(True)
        plt.show()
else:
        print("The  specified  time  point  is  not  within  the  data  range!")
        print(f"Data  time  range:  {df['timestamp'].min()}  to  {df['timestamp'].max()}")

#  Perform  STFT  (Short-Time  Fourier  Transform)  on  the  filtered  data
import  numpy  as  np
from  scipy  import  signal
import  matplotlib.pyplot  as  plt

#  Get  the  voltage  data  and  sampling  rate
voltage_data  =  df['voltage'].values
sampling_rate  =  1  /  (df['duration'].diff().mean()  /  1000)    #  Convert  to  Hz

#  Perform  STFT
f,  t,  Zxx  =  signal.stft(voltage_data,  fs=sampling_rate,  nperseg=256,  noverlap=128)

#  Create  a  DataFrame  to  store  all  STFT  data
#  The  shape  of  Zxx  is  (frequency  bins,  time  points)
#  We  need  to  reshape  the  data  correctly  to  avoid  dimension  mismatch

#  Plot  the  STFT  results  as  a  spectrogram
plt.figure(figsize=(18,  6))
plt.pcolormesh(t,  f,  np.abs(Zxx),  shading='gouraud')
plt.colorbar(label='Magnitude')
plt.ylabel('Frequency  (Hz)')
plt.xlabel('Time  (s)')
plt.title('STFT  Spectrogram  of  Voltage  Data  Overview')
plt.ylim([0,  0.07])    #  Limit  y-axis  to  0-0.2  Hz
plt.tight_layout()
plt.show()

#  Get  the  voltage  data  and  sampling  rate
voltage_data  =  filtered_df['voltage'].values
sampling_rate  =  1  /  (filtered_df['duration'].diff().mean()  /  1000)    #  Convert  to  Hz

#  Perform  STFT
f,  t,  Zxx  =  signal.stft(voltage_data,  fs=sampling_rate,  nperseg=256,  noverlap=128)

#  Create  a  DataFrame  to  store  all  STFT  data
#  The  shape  of  Zxx  is  (frequency  bins,  time  points)
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#  Plot  the  STFT  results  as  a  spectrogram
plt.figure(figsize=(18,  6))
plt.pcolormesh(t,  f,  np.abs(Zxx),  shading='gouraud')
plt.colorbar(label='Magnitude')
plt.ylabel('Frequency  (Hz)')
plt.xlabel('Time  (s)')
plt.title('STFT  Spectrogram  of  Voltage  Data  around  sound  situmilation')
plt.ylim([0,  0.07])    #  Limit  y-axis  to  0-0.2  Hz
plt.tight_layout()
plt.show()

#  Analyze  the  0.02Hz  frequency  band  before  and  after  sound  stimulation
import  pandas  as  pd
import  numpy  as  np
import  matplotlib.pyplot  as  plt

#  Find  the  closest  frequency  to  0.02Hz  in  the  STFT  results
target_freq  =  0.02
freq_idx  =  np.argmin(np.abs(f  -  target_freq))
actual_freq  =  f[freq_idx]
print(f"Analyzing  frequency:  {actual_freq:.4f}  Hz  (closest  to  0.02  Hz)")

#  Extract  the  magnitude  data  for  this  frequency
freq_magnitude  =  np.abs(Zxx[freq_idx,  :])

#  Create  a  time  axis  in  minutes  for  better  visualization
time_min  =  t  /  60
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# Plot the magnitude of the 0.02Hz component over time
plt.figure(figsize=(18, 6))

# Plot the magnitude
plt.plot(time_min, freq_magnitude, 'b-', linewidth=2, label=f'{actual_freq:.4f} Hz Component')

# Find the time of sound stimulation (assuming it's at the center of the filtered data)
sound_time = t.mean()
sound_time_min = sound_time / 60
plt.axvline(x=sound_time_min, color='r', linestyle='--', label='Sound Stimulation (estimated)')

# Calculate average magnitude before and after stimulation
before_mask = t < sound_time
after_mask = t >= sound_time

avg_before = np.mean(freq_magnitude[before_mask])
avg_after = np.mean(freq_magnitude[after_mask])

print(f"Average magnitude before stimulation: {avg_before:.4f}")
print(f"Average magnitude after stimulation: {avg_after:.4f}")
print(f"Change: {(avg_after - avg_before):.4f} ({(avg_after - avg_before)/avg_before*100:.2f}%)")

# Add horizontal lines showing the average values
plt.axhline(y=avg_before, color='g', linestyle=':', label=f'Avg Before: {avg_before:.4f}')
plt.axhline(y=avg_after, color='m', linestyle=':', label=f'Avg After: {avg_after:.4f}')

# Add annotations
plt.annotate(f"Avg: {avg_before:.4f}", xy=(time_min[len(time_min)//4], avg_before),
                         xytext=(time_min[len(time_min)//4], avg_before*1.1), color='g')
plt.annotate(f"Avg: {avg_after:.4f}", xy=(time_min[3*len(time_min)//4], avg_after),
                         xytext=(time_min[3*len(time_min)//4], avg_after*1.1), color='m')

# Set axis labels and title
plt.xlabel('Time (min)')
plt.ylabel('Magnitude')
plt.title(f'Magnitude of {actual_freq:.4f} Hz Component Before and After Sound Stimulation')
plt.grid(True)
plt.legend()
plt.tight_layout()
plt.show()

# Calculate energy (integral of magnitude squared) before and after stimulation
energy_before = np.sum(freq_magnitude[before_mask]**2)
energy_after = np.sum(freq_magnitude[after_mask]**2)

# Normalize by the number of samples to get average energy
num_samples_before = np.sum(before_mask)
num_samples_after = np.sum(after_mask)
avg_energy_before = energy_before / num_samples_before
avg_energy_after = energy_after / num_samples_after

print("\nEnergy Analysis:")
print(f"Total energy before stimulation: {energy_before:.4f}")
print(f"Total energy after stimulation: {energy_after:.4f}")
print(f"Average energy before stimulation: {avg_energy_before:.4f}")
print(f"Average energy after stimulation: {avg_energy_after:.4f}")
print(f"Energy change: {(avg_energy_after - avg_energy_before):.4f} ({(avg_energy_after - avg_energy_before)/avg_energy_before*100:.2f}%)")

# Power Spectral Density (PSD) Analysis
import matplotlib.pyplot as plt
import numpy as np

# Use the STFT data we already calculated earlier
# f, t, Zxx were calculated using signal.stft(voltage_data, fs=sampling_rate, nperseg=256, noverlap=128)

# Calculate power (magnitude squared)
power_matrix = np.abs(Zxx) ** 2

# Convert time to minutes for consistency with previous plots
time_min = t / 60

# Define the stimulation time point (assuming same as before)
stim_time = time_min[len(time_min) // 2]  # Middle point as stimulation time

# Create masks for before and after stimulation
before_mask_time = time_min < stim_time
after_mask_time = time_min > stim_time

# Calculate average PSD before and after stimulation
avg_psd_before = np.mean(power_matrix[:, before_mask_time], axis=1)
avg_psd_after = np.mean(power_matrix[:, after_mask_time], axis=1)
```

```
# Plot the power spectral density comparison
plt.figure(figsize=(18, 6))
plt.plot(f, avg_psd_before, 'g-', label='Before Stimulation')
plt.plot(f, avg_psd_after, 'm-', label='After Stimulation')

# Calculate and display the difference
psd_diff = avg_psd_after - avg_psd_before
plt.plot(f, psd_diff, 'b--', label='Difference (After - Before)')

# Set axis labels and title
plt.xlabel('Frequency (Hz)')
plt.xlim(0, 0.2)  # Limit x-axis to show only frequencies below 0.2 Hz
plt.ylabel('Power Spectral Density')
plt.title('Power Spectral Density Comparison Before and After Stimulation')
plt.grid(True)
plt.legend()

# Add text box with summary statistics
total_power_before = np.sum(avg_psd_before)
total_power_after = np.sum(avg_psd_after)
power_change = (total_power_after - total_power_before) / total_power_before * 100

stats_text = f"Total Power Before: {total_power_before:.2f}\n"
stats_text += f"Total Power After: {total_power_after:.2f}\n"
stats_text += f"Change: {power_change:.2f}%"

plt.annotate(stats_text, xy=(0.02, 0.95), xycoords='axes fraction',
             bbox=dict(boxstyle="round,pad=0.5", fc="white", alpha=0.8))

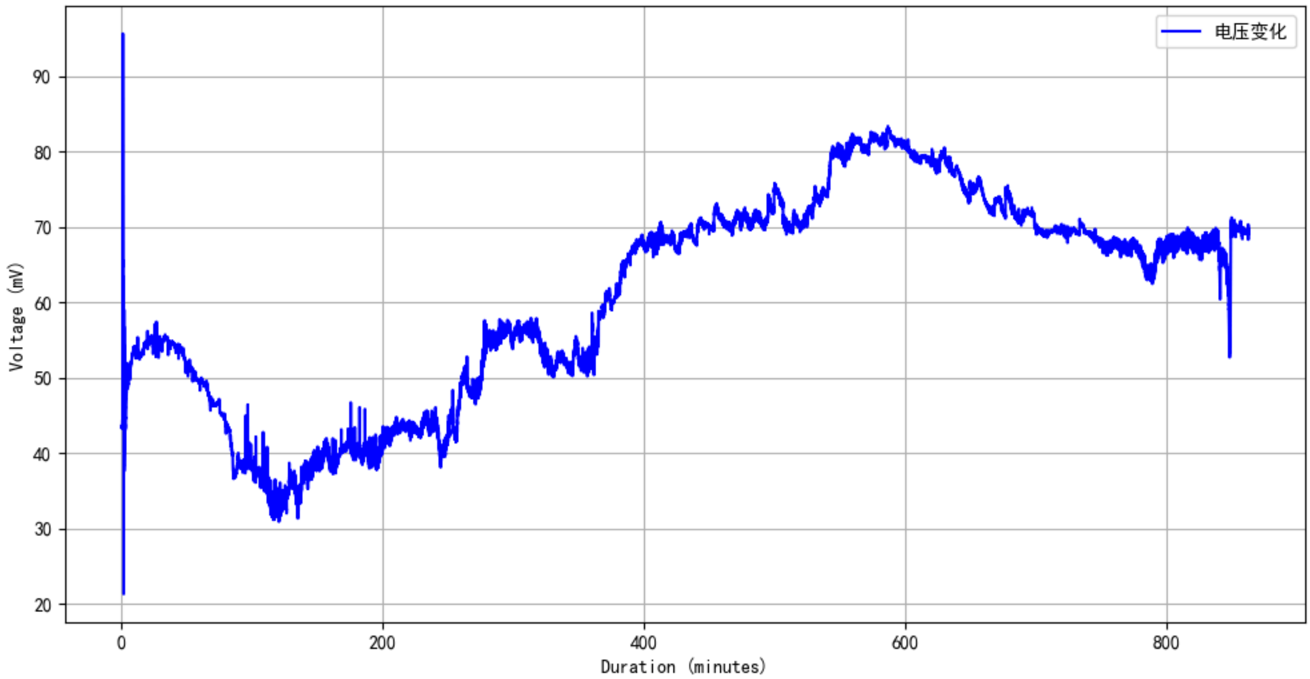
plt.tight_layout()
plt.show()

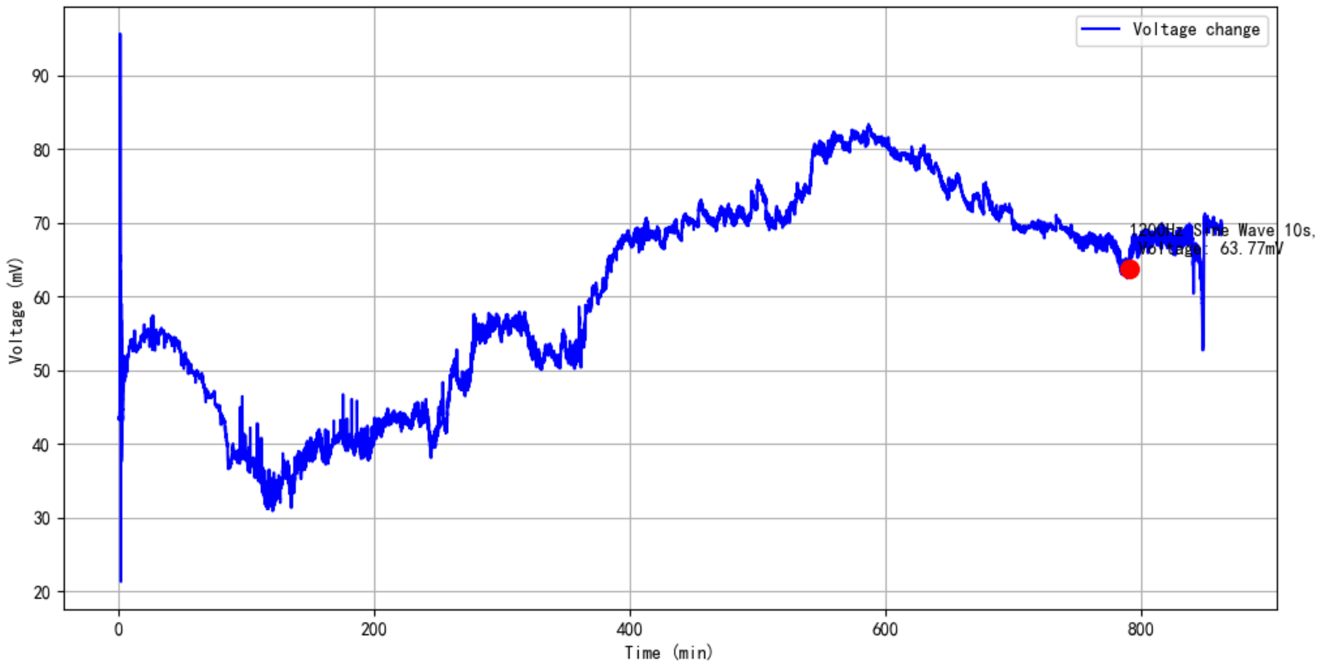
# Print detailed statistics
print("\nPower Spectral Density Analysis:")
print(f"Total power before stimulation: {total_power_before:.4f}")
print(f"Total power after stimulation: {total_power_after:.4f}")
print(f"Absolute power change: {total_power_after - total_power_before:.4f}")
print(f"Relative power change: {power_change:.2f}%")

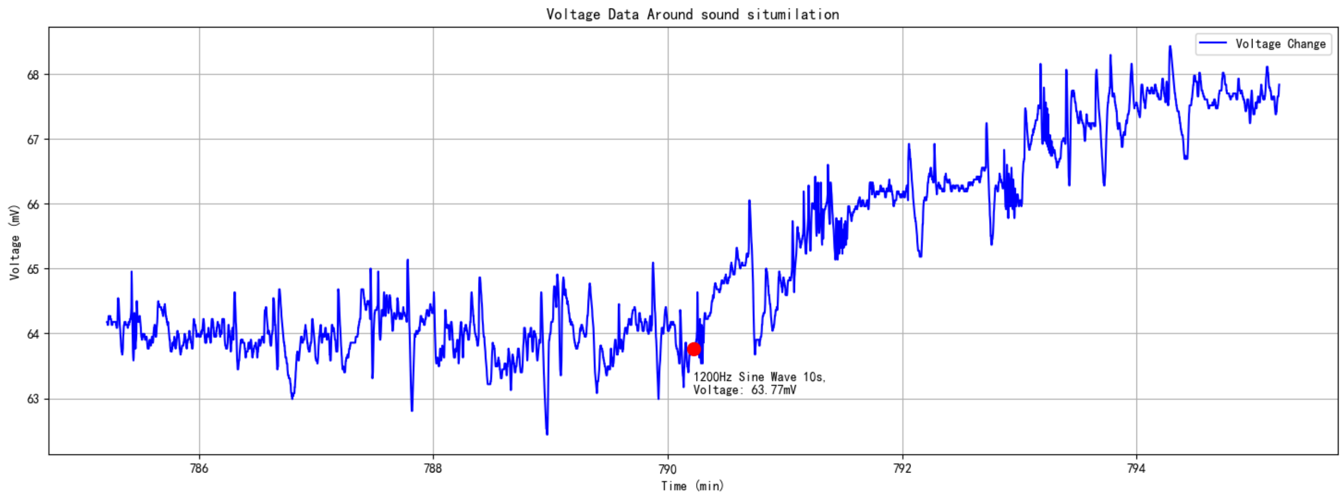
# Find frequency bands with the most significant changes
freq_change_percent = (avg_psd_after - avg_psd_before) / (avg_psd_before + 1e-10) * 100  # Avoid division by zero
significant_changes = pd.DataFrame({
    'Frequency': f,
    'Before': avg_psd_before,
    'After': avg_psd_after,
    'Absolute_Change': avg_psd_after - avg_psd_before,
    'Percent_Change': freq_change_percent
})

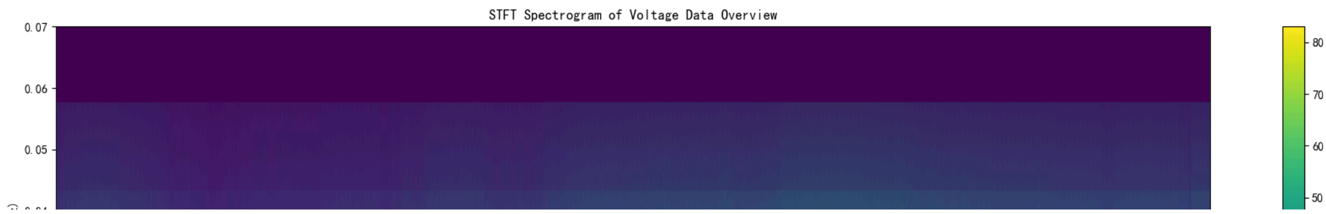
# Display top 5 frequencies with largest increase and decrease
print("\nTop 5 frequencies with largest power increase:")
print(significant_changes.sort_values('Percent_Change', ascending=False).head(5))

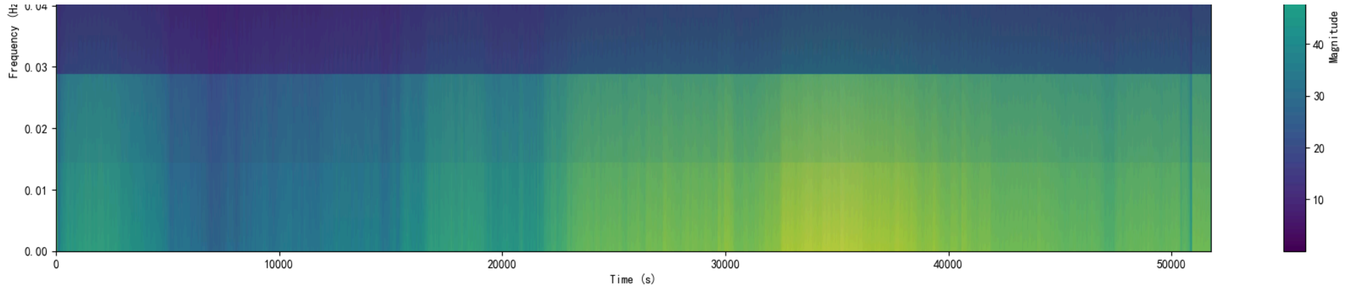
print("\nTop 5 frequencies with largest power decrease:")
print(significant_changes.sort_values('Percent_Change', ascending=True).head(5))
```

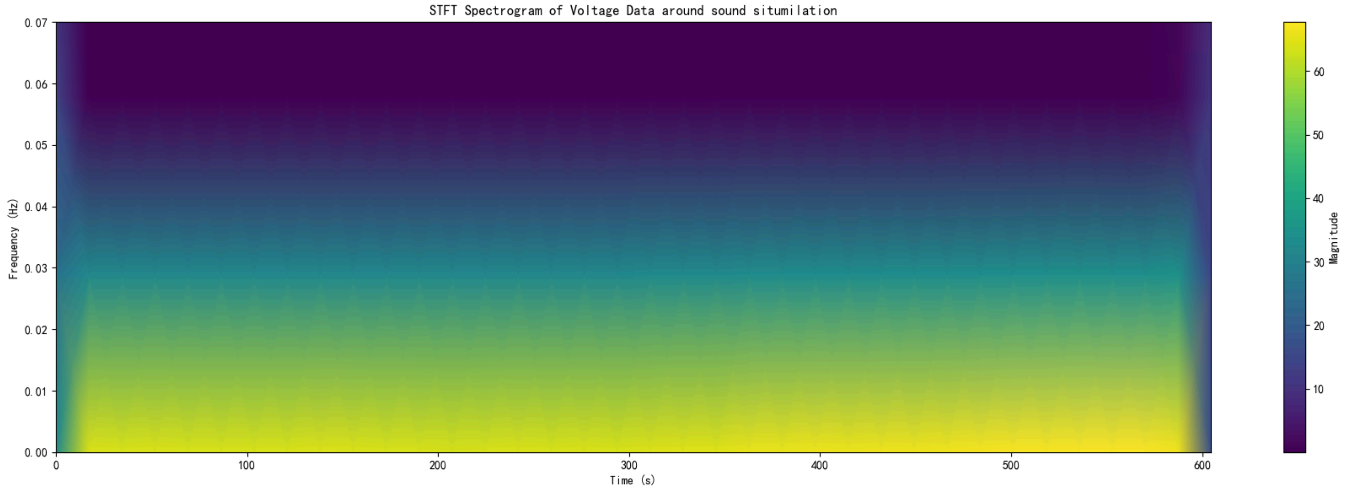

电压变化
Voltage (mV)
Duration (minutes)
0
200
400
600
800
20
30
40
50
60
70
80
90


Voltage change
1200Hz Sine Wave 10s,
Voltage: 63.77mV
Voltage (mV)
Time (min)
0
200
400
600
800
20
30
40
50
60
70
80
90

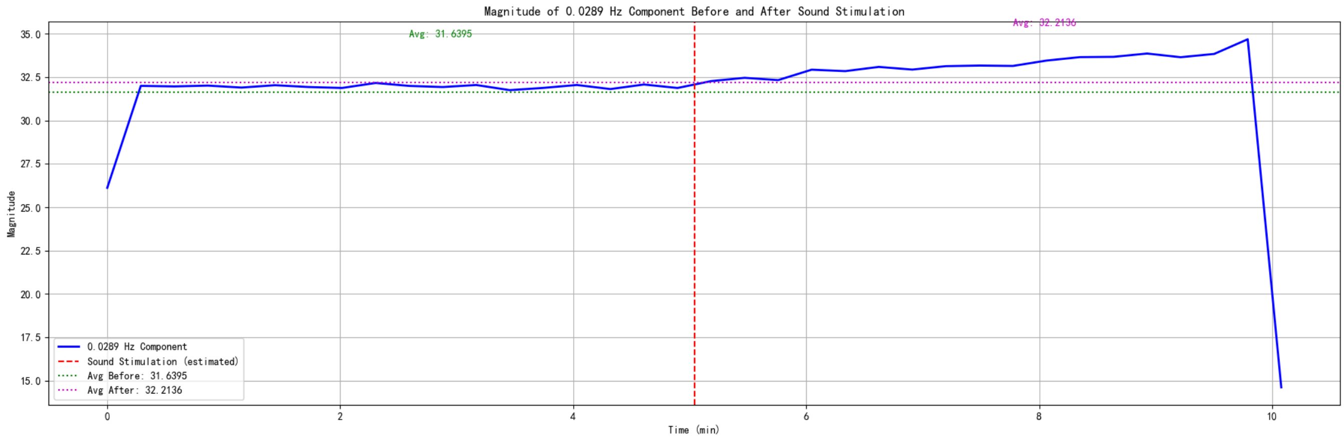

Voltage Data Around sound situmilation
Voltage Change
1200Hz Sine Wave 10s,
Voltage: 63.77mV
Voltage (mV)
Time (min)
786
788
790
792
794
63
64
65
66
67
68


STFT Spectrogram of Voltage Data Overview
0.07
0.06
0.05
80
70
60
50

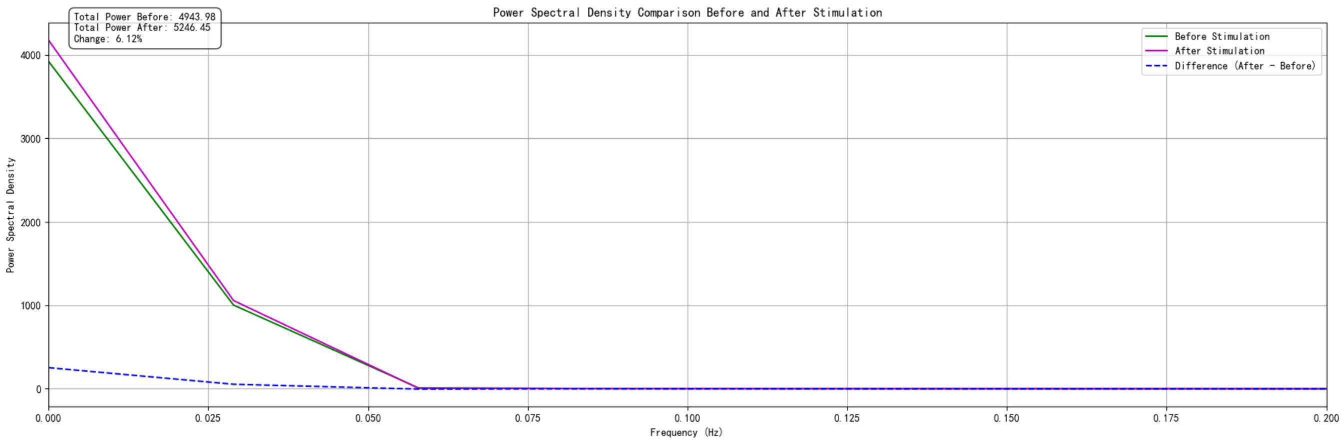




Analyzing frequency: 0.0289 Hz (closest to 0.02 Hz)
Average magnitude before stimulation: 31.6395
Average magnitude after stimulation: 32.2136
Change: 0.5740 (1.81%)



Energy Analysis:
Total energy before stimulation: 18051.5116
Total energy after stimulation: 19013.0944
Average energy before stimulation: 1002.8618
Average energy after stimulation: 1056.2830
Energy change: 53.4213 (5.33%)



Power Spectral Density Analysis:
Total power before stimulation: 4943.9769
Total power after stimulation: 5246.4520
Absolute power change: 302.4751
Relative power change: 6.12%

Top 5 frequencies with largest power increase:

	Frequency	Before	After	Absolute_Change	Percent_Change
0	0.000000	3921.311734	4174.265330	252.953596	6.450739
1	0.028939	1002.861753	1057.137070	54.275318	5.412044
3	0.086817	2.600391	2.646017	0.045627	1.754606
5	0.144695	0.926859	0.819737	-0.107122	-11.557554
16	0.463025	0.091042	0.078356	-0.012686	-13.934514

Top 5 frequencies with largest power decrease:

	Frequency	Before	After	Absolute_Change	Percent_Change
2	0.057878	10.317810	6.824787	-3.493023	-33.854304
4	0.115756	1.661592	1.186143	-0.475449	-28.614040
12	0.347269	0.169471	0.137660	-0.031811	-18.770625
25	0.723477	0.039597	0.032287	-0.007309	-18.459462
10	0.289391	0.235678	0.193035	-0.042643	-18.093865