

# eT-RT™ Audio Waveforms Analysis



[mmu-energy.com](http://mmu-energy.com)



[enquiry.energy@mmu.edu.my](mailto:enquiry.energy@mmu.edu.my)



+603 8312 5706

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## Executive Summary

In this study, 13 different eT-RT audio waveforms have been analyzed to extract the waveform features and to gain insight into the characteristics of each waveform. The digital audio files used in the analysis are in CD-quality formats. The audio waveforms are mostly nature sounds such as rain, ocean waves, forest, running water, etc. Useful signal features in time-, frequency-, and time-frequency domains are extracted and presented in graphs and tables for comparison. Some important results and findings are highlighted as follows: Some of the waveforms consist of repeating segments. All the waveforms exhibit characteristics of the so-called pink noise where the power spectral density (or power spectrum) is inversely proportional to the frequency of the signal. Previous studies show that pink noise improves sleep and memory by slowing and regulating brain waves. All waveforms have very high concentration of power in the low frequency region. Very low peak frequencies (0 to 15 Hz) are found in all waveforms except Audio Serotonin, Oxytocin and Endorphins. For these waveforms, the frequencies near to zero seemed to have been removed or suppressed. Some of the waveforms such as Audio GABA has consistent peak frequencies out of the low frequency region.

Some notable results for the audio waveform analysis are summarized in the following table. Further details are given in the Detailed Results and Analysis section of this report.

Waveforms	Repeating Segment	Fundamental frequency	90% power	Peak frequency	Spectral flatness & spread	Prominent energy band
Awaken the Mind (Huu Chant)	-	Low; constant	< 400 Hz	~180 Hz	Low	SLF (30-300Hz)
Awaken the Mind (Ocean waves)	13s	Low; varying	< 2 kHz	~2 Hz	Moderate	ELF (<30 Hz)
Audio Rejuvenation	-	Low; varying	< 3 kHz	~2 Hz	Low	ELF (<30 Hz)
Audio Serotonin	170s	Low; constant	< 5 kHz	~900 Hz	Moderate	SLF (30-300Hz)
Audio Oxytocin	-	Low; constant	< 6 kHz	~1300 Hz	Moderate	SLF (30-300Hz)
Audio Endorphins	585s	Low; constant	< 4 kHz	~1000 Hz	Low	SLF (30-300Hz)
Audio Dopamine	181s	Low; varying	< 4 kHz	~9 Hz	Moderate	ELF (<30 Hz)
Audio GABA	-	Low; constant	< 90 Hz	~2 Hz	Moderate	ELF (<30 Hz)
Digital C60	-	Low; constant	< 1 kHz	~15 Hz	Low	ELF (<30 Hz)
Digital CBD	-	Medium; constant	< 8 kHz	~2 Hz	Low	ELF (<30 Hz)
Digital Nootropic	-	Low; constant	< 50 Hz	~0.5 Hz	Low	ELF (<30 Hz)
Marine Phytoplankton	18s	Low; constant	< 100 Hz	~2 Hz	Low	ELF (<30 Hz)
Monatomic Gold	-	Low; constant	< 300 Hz	~12 Hz	Low	ELF (<30 Hz)



## Description of waveforms:

No.	Waveform	Filename	Format	Bits/sample or Bitrate	Sample rate (kHz)	Sound
1.	Awaken the Mind	Awakened Mind Huu Chant 20-min.wav	WAV	16	44.1	Huu chant
2.	Awaken the Mind	Awakened Mind Ocean 20-min.wav	WAV	16	44.1	Ocean waves
3.	Audio Rejuvenation	Audio Rejuvenation 20-min	WAV	16	44.1	Beach waves
4.	Neuro-Energetics (Audio Serotonin)	Audio Serotonin 20min	WAV	16	44.1	River
5.	Neuro-Energetics (Audio Oxytocin)	Audio Oxytocin 20-min	WAV	16	44.1	Rain
6.	Neuro-Energetics (Audio Endorphins)	Audio Endorphins 20-min	WAV	16	44.1	Ocean waves
7.	Neuro-Energetics (Audio Dopamine)	Audio Dopamine 20-min	WAV	16	44.1	Rain
8.	Neuro-Energetics (Audio GABA)	Audio GABA 20-min	WAV	16	44.1	Forest & sea waves
9.	Digital C60	Digital C60 20-min	WAV	16	44.1	River/sea waves
10.	Digital CBD	Digital CBD 20-min	WAV	16	44.1	Heavy rain
11.	Digital Nootropic	Digital Nootropic 20-min	WAV	16	44.1	Wind
12.	Marine Phytoplankton	Marine Phytoplankton 20-min	WAV	16	44.1	Under water
13.	Monatomic Gold	Monatomic Gold 20-min	WAV	16	44.1	Waves & Wind chimes

## Description of features:

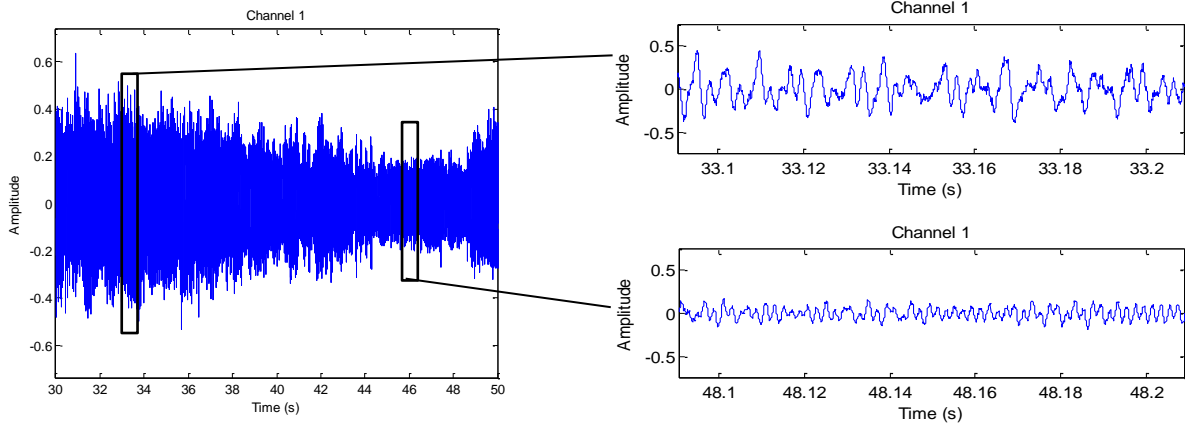
No.	Domains	Features	Brief description
1.	Time	Zero-crossing rate (ZCR)	<ul style="list-style-type: none"> <li>the number of times signal crosses the zero level in one second interval</li> <li>to estimate fundamental frequency</li> </ul>
		Short time energy (STE)	<ul style="list-style-type: none"> <li>average energy per frame/window</li> <li>to estimate signal energy change in time</li> </ul>
		Autocorrelation	<ul style="list-style-type: none"> <li>measures the similarity between the signal and a segment of the same signal</li> <li>to detect repeating segment (if any)</li> </ul>

2.	Frequency	Peak Frequency	<ul style="list-style-type: none"> <li>the frequency of maximum power</li> </ul>
		Short-time Fourier transform (STFT)	<ul style="list-style-type: none"> <li>Frequency versus time plot</li> <li>To analyze nonstationary aspects of a signal such as trends, discontinuities and patterns</li> </ul>
		Envelope Modulation Spectrum (EMS)	<ul style="list-style-type: none"> <li>represents the slow amplitude modulations in the signal across certain frequencies</li> </ul>
		Long-term Average Spectrum (LTAS)	<ul style="list-style-type: none"> <li>captures atypical spectral information from the signal.</li> </ul>
		Spectrum shape based features	<ul style="list-style-type: none"> <li>Spectral Centroid: center of mass of the spectrum</li> <li>Spectral roll-off: 85% of the signal energy is contained below roll-off point</li> <li>Spectral Spread: closely related to the bandwidth of the signal; Noise like signals have wide spectral spread</li> <li>Spectral Flatness: the measure of uniformity in the frequency distribution of the power spectrum; noise like sounds have spectral flatness close to one</li> </ul>
3.	Time-Frequency	Local Histogram	<ul style="list-style-type: none"> <li>Signal magnitudes distribution for a specific area in time-frequency domain</li> <li>Noise-like signal has a bell-shaped histogram</li> </ul>
		Low Frequency Analysis of 3D Spectrogram	<ul style="list-style-type: none"> <li>3D spectrogram provides clear visualization of time and frequency domain variation of the signal energy.</li> <li>The analysis is focused on the low-frequency region of the spectrogram.</li> </ul>

# Detailed Results and Analysis

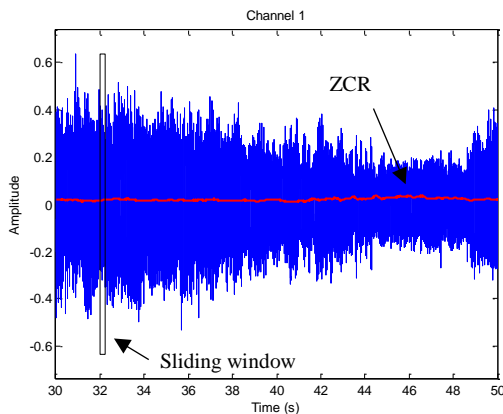
## 1) Awaken the Mind (Huu Chant)

### i) Time-domain features



The amplitude envelope changes in time according to the loudness of the sound. When zoomed in, the rate of amplitude fluctuation appears to be similar for both the loud and quiet regions.

### a. Zero Crossing Rate (ZCR)

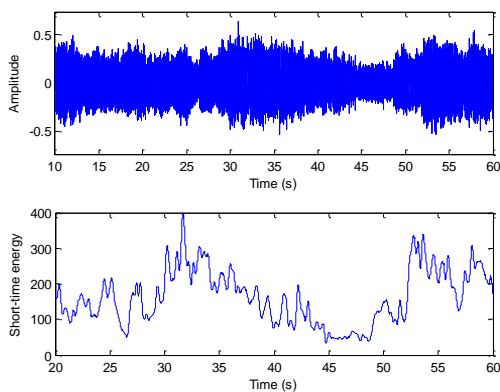


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (50s). Overall, the fundamental frequency of the sound is very low.

This sound shows very consistent long-term ZCR characteristic.

### b. Short time energy (STE)

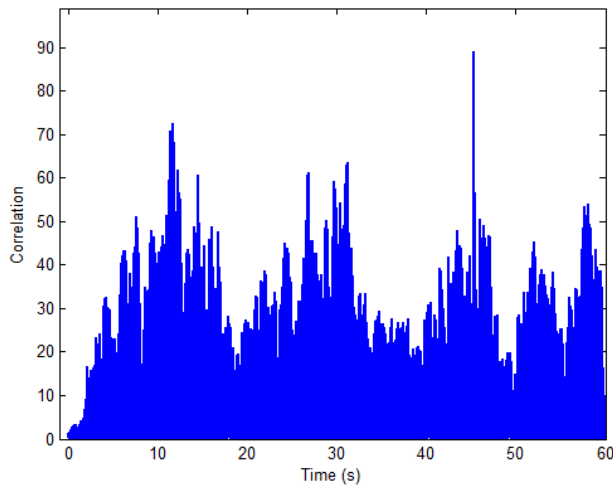


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE fluctuates according to the amplitude of the sound in a random manner.

### c. Auto-correlation

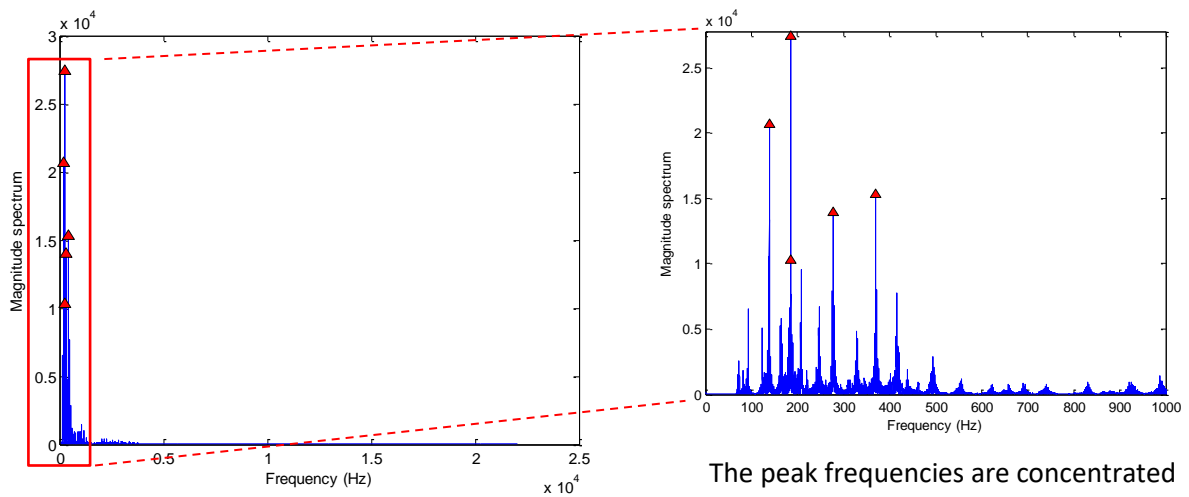


Segment/window size = 50,000 samples  
(~1.13s)

No repeating segment is observed in this sound.

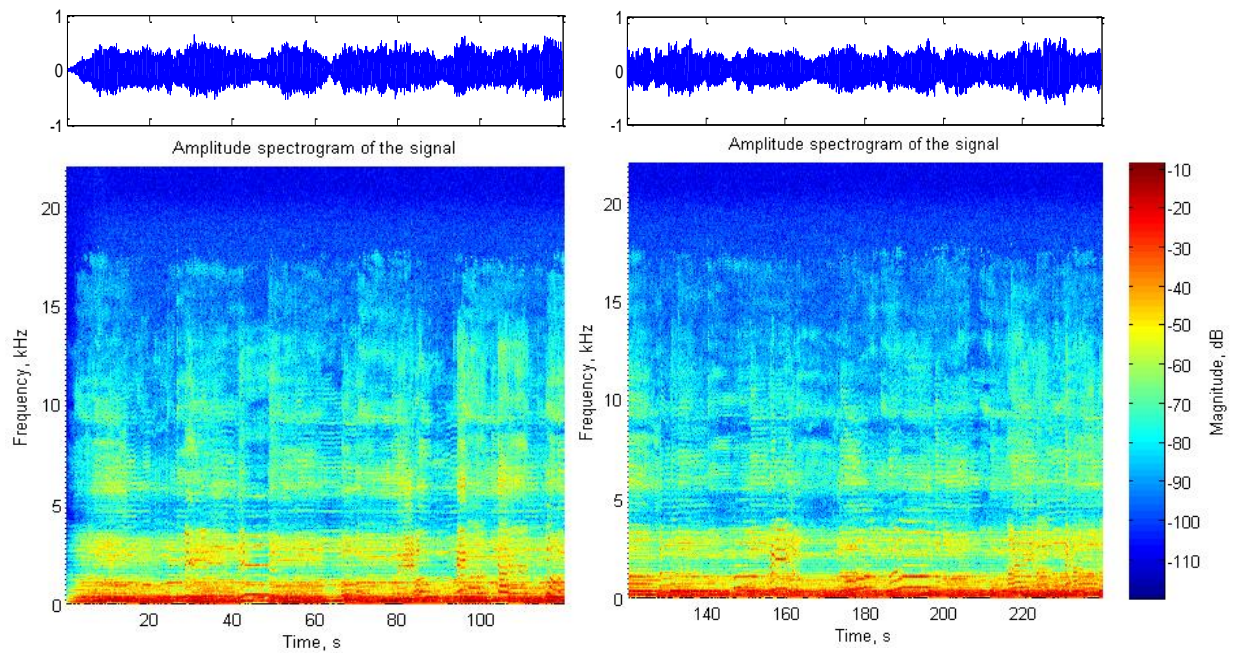
### ii) Frequency Domain Features

#### a) Peak Frequency



The peak frequencies are concentrated around 50 to 500 Hz. The highest peak is at 185 Hz.

#### b) Short-Time Fourier Transform (STFT)

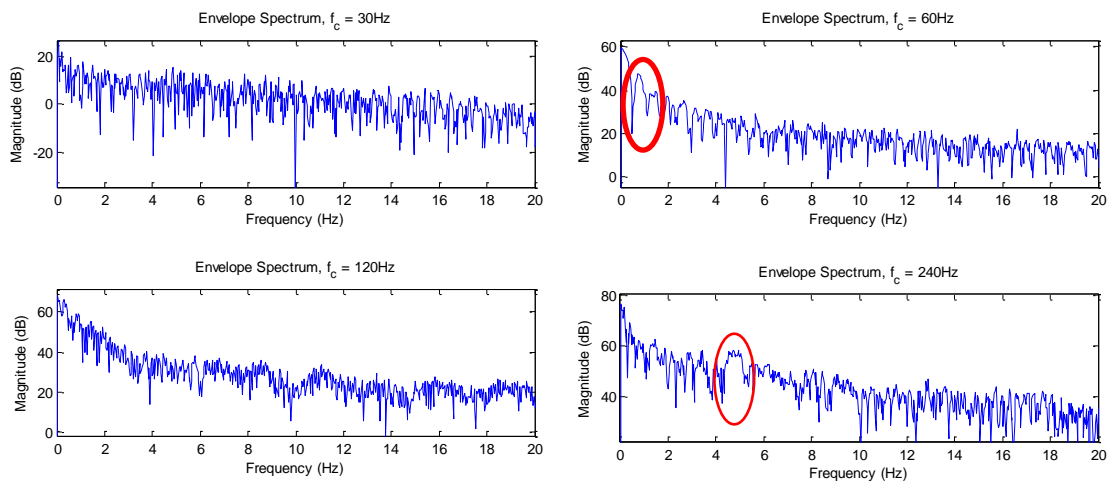


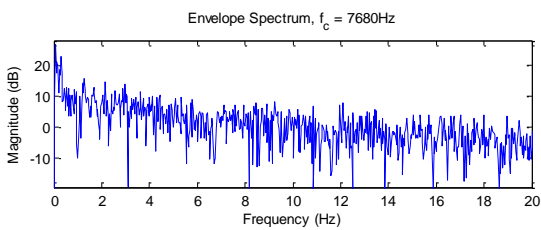
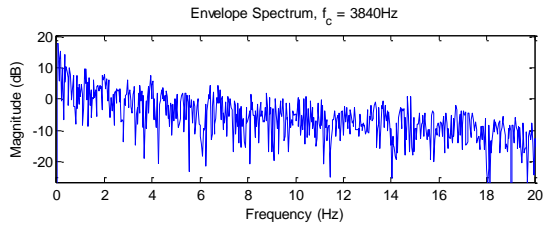
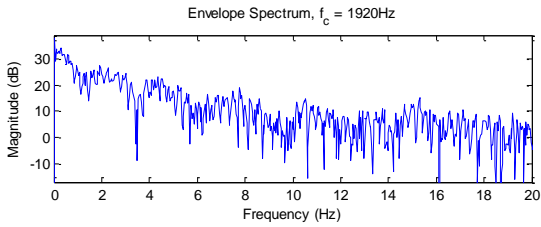
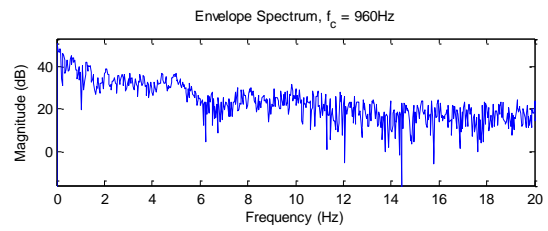
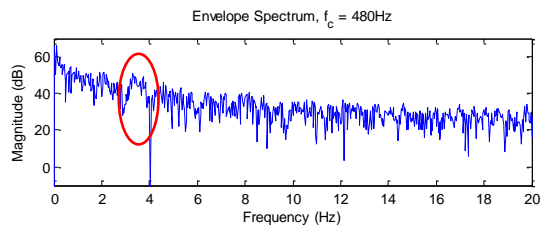
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum has constant long-term characteristics. Signal energy is concentrated below 1 kHz (dark red color region).

### c) Envelope Modulation Spectrum (EMS)

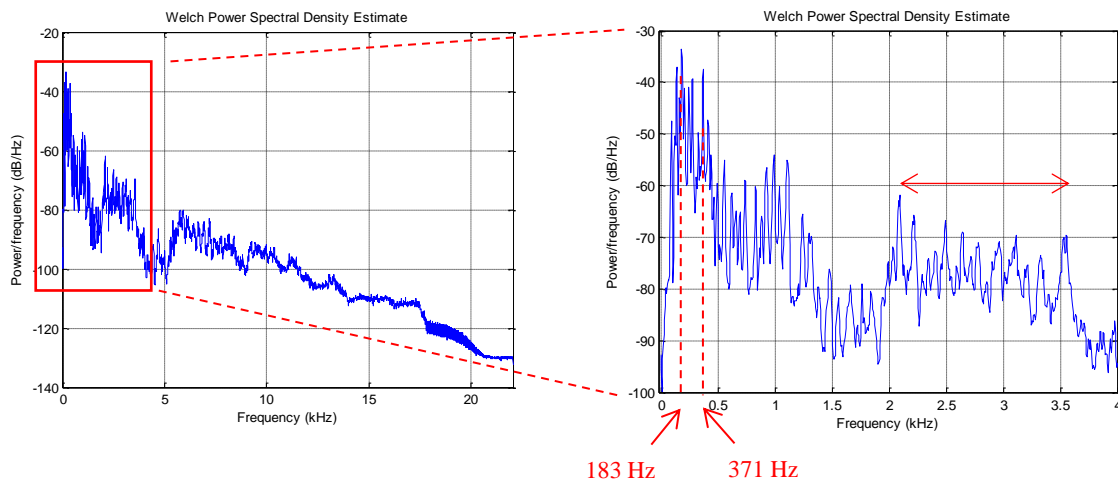
The original signal is first filtered into 9 octave bands with center frequencies of 30, 60, 120, 240, 480, 960, 1920, 3840, and 7680 Hz, using Butterworth filters. Then the envelope of the filtered signals is extracted using Hilbert transform. The mean is removed and the power spectrum for each of the bands is estimated by using DFT at frequencies 0–20 Hz. The results are given below:



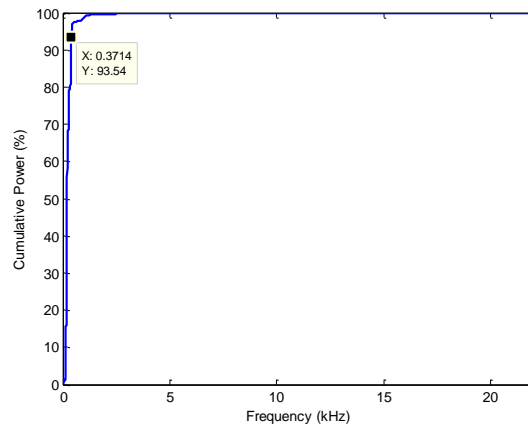


Three small peaks at about 0.8, 4.8 and 3.4 Hz are observed in band 60, 240 and 480 Hz respectively which indicates amplitude modulations in these frequency bands. The envelope spectrums of other bands have no obvious slow modulation.

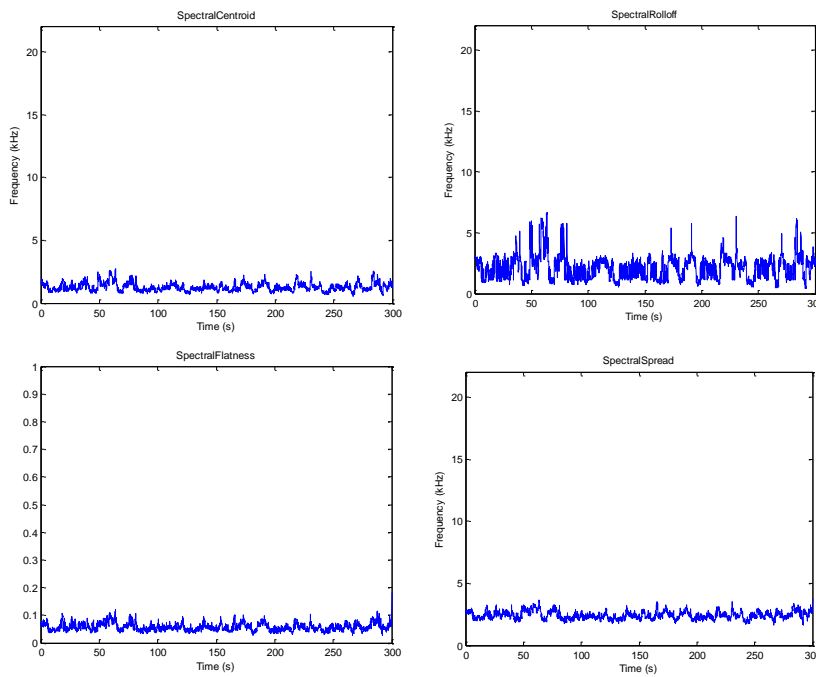
#### d) Long-term Average Spectrum (LTAS)



Two significant high-power frequencies at 183 and 371 Hz are observed in the power spectrum, in addition to a group of lower power frequencies from about 2 to 3.5 kHz. It's worth noting that 90% of the signal power is contained below 370 Hz.



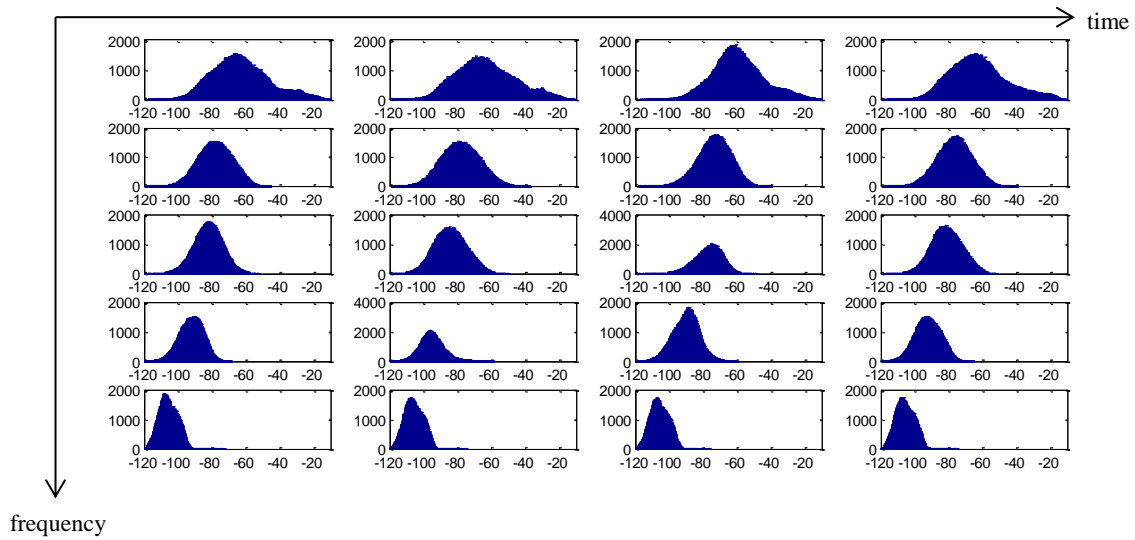
e) Spectrum shape based features



Features	Mean Value
Centroid	1271 Hz
Rolloff	2149 Hz
Flatness	0.0573
Spread	2433 Hz

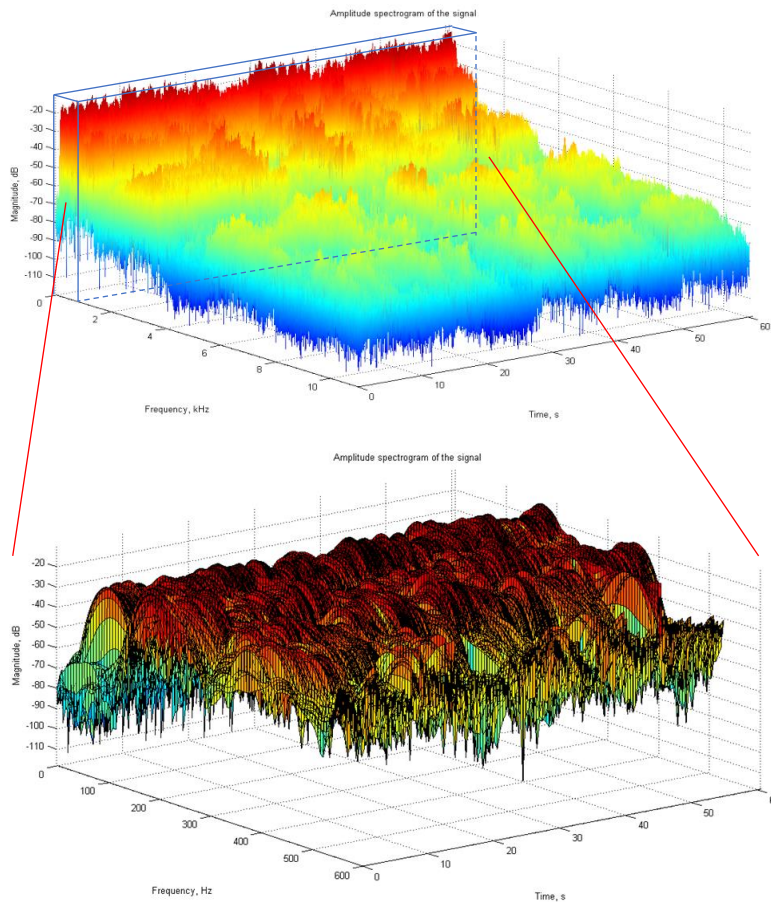
iii) Time-Frequency Domain Features

a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low frequencies section show less noise-like characteristics. The very-low frequency sections contain the highest energy.

### c) Low Frequency Analysis of 3D Spectrogram

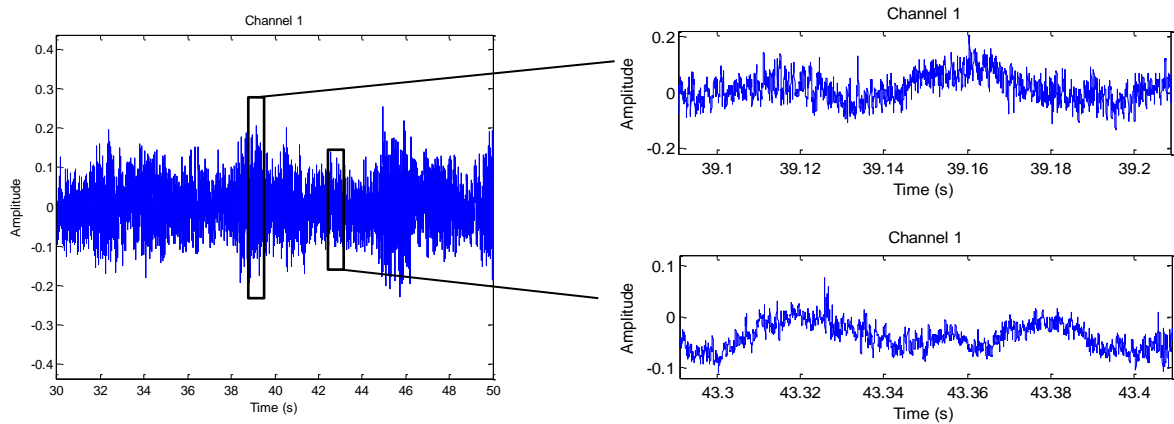


The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Super low

frequency (SLF) (30-300Hz) is very prominent in this signal. However, their magnitudes change slowly in time.

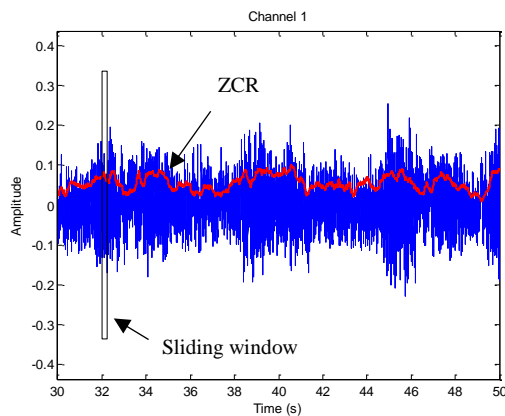
## 2) Awaken the Mind (Ocean waves)

### i) Time-domain features



The amplitude envelope changes in time according to the loudness of the sound. When zoomed in, the rate of amplitude fluctuation appears to be similar for both the loud and quiet regions.

### a. Zero Crossing Rate (ZCR)

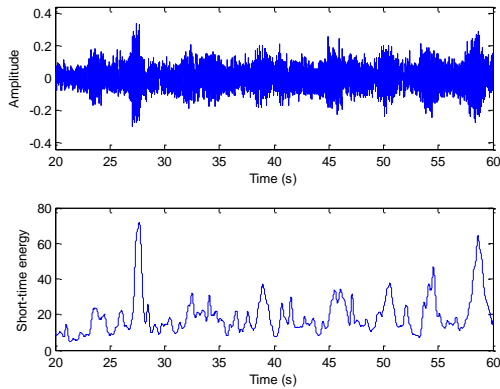


Window size = 10,000 samples (~0.23s)

ZCR is fluctuating throughout the section of the sound examined (50s). The fundamental frequency of the sound varies according to the amplitude.

The ZCR (and fundamental frequency) shows consistent up-then-down trends.

### b. Short time energy (STE)

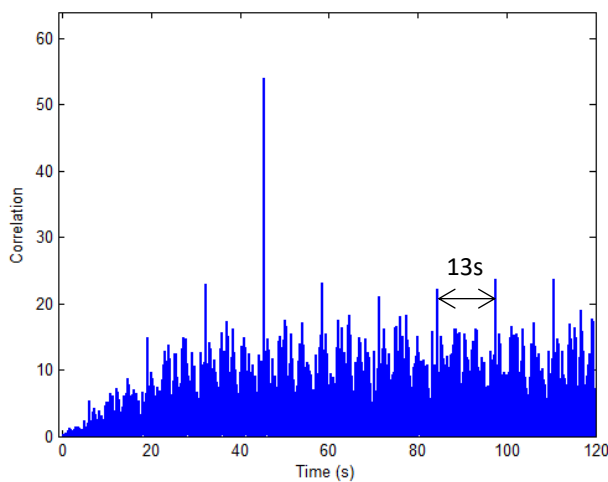


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE remains consistently low most of the times. Some large energy surges have been observed which appears to be amplitude dependent. Their occurrences are quite random.

### c. Auto-correlation

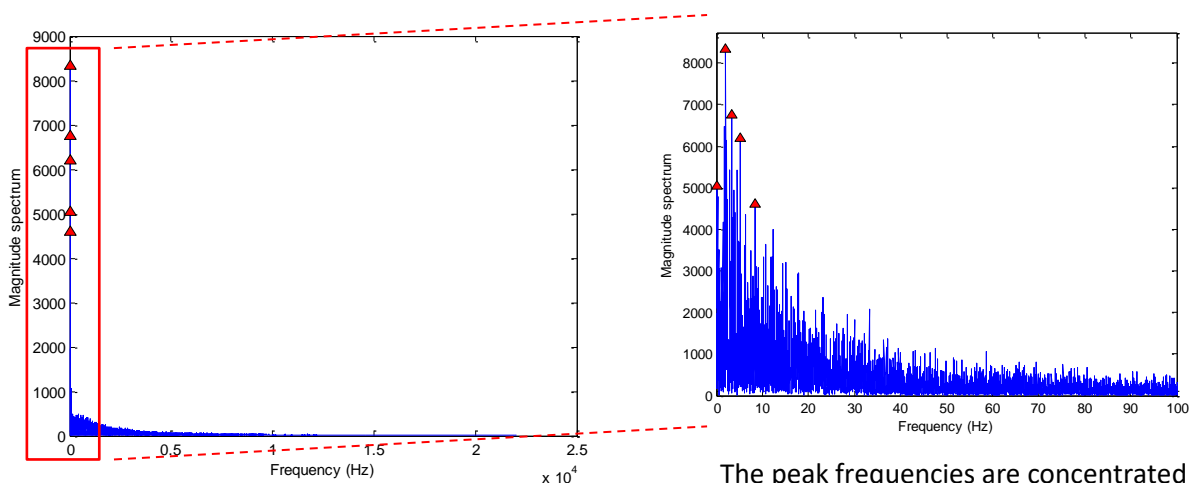


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 13s. In other words, a very similar (not entirely identical) segment of 13 second appeared repeatedly in this sound.

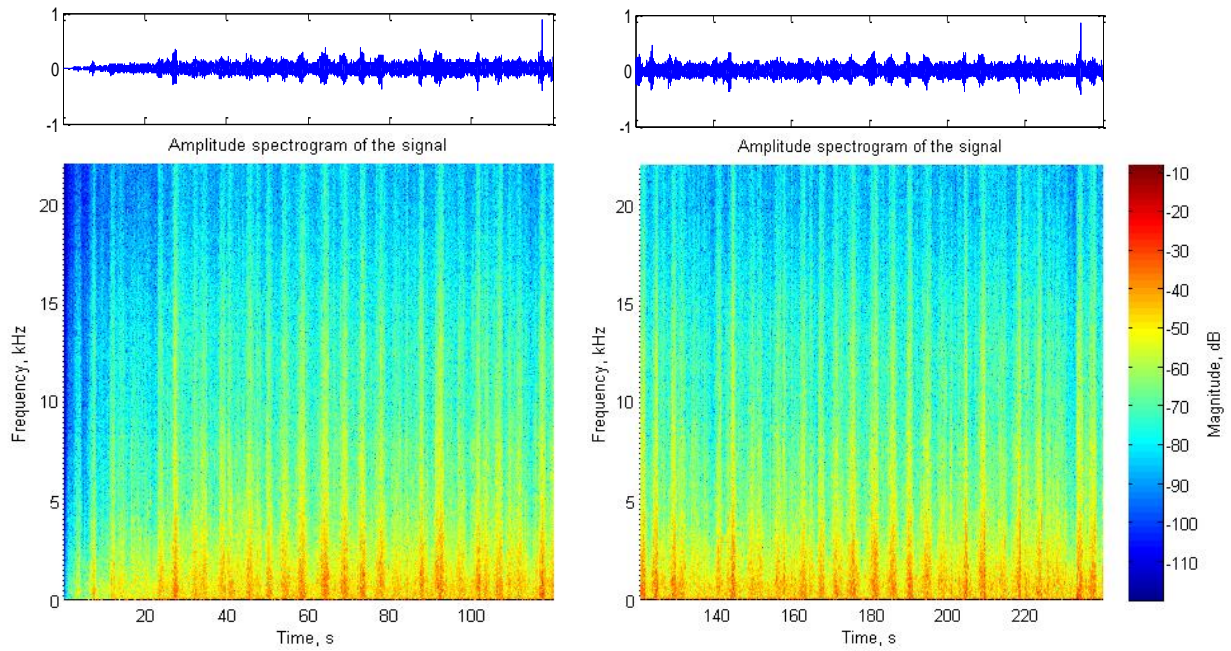
### ii) Frequency Domain Features

#### a) Peak Frequency



The peak frequencies are concentrated around 0 to 50 Hz. The highest peak is at 2 Hz.

#### b) Short-Time Fourier Transform (STFT)

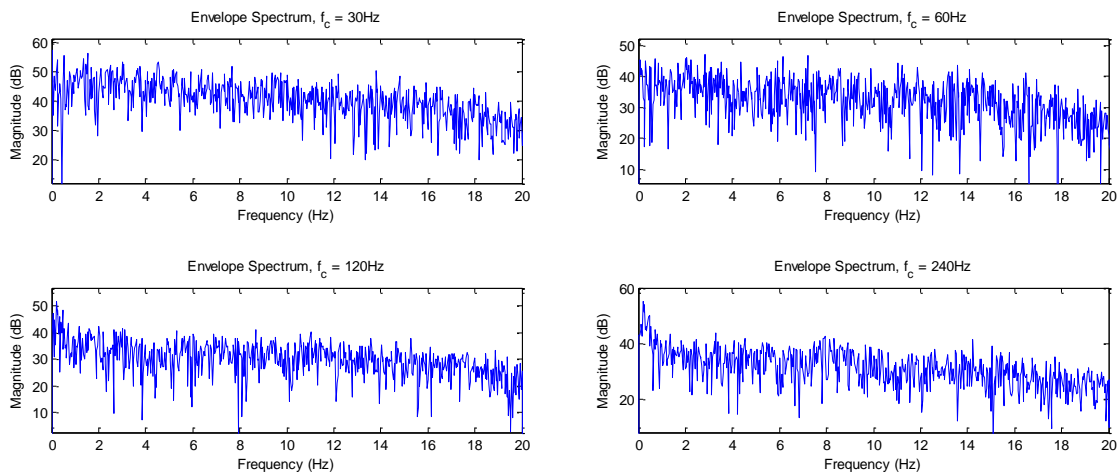


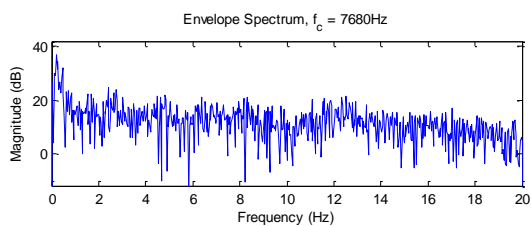
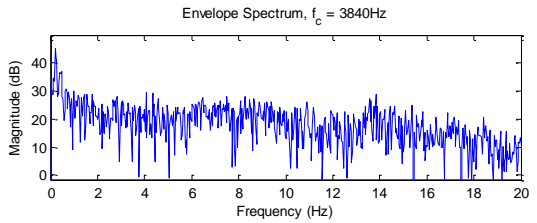
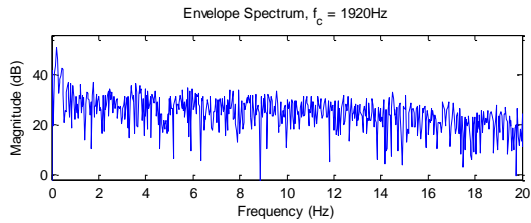
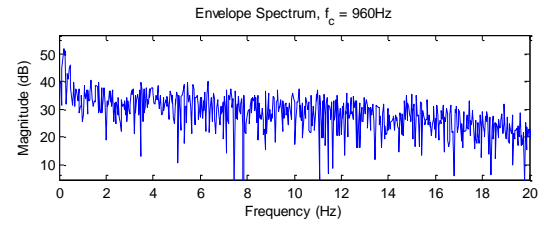
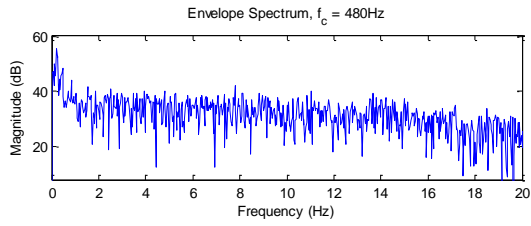
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum is changing randomly in time. Small short-term variation is due to the rise and fall of the ocean waves. Signal energy is mainly concentrated below 2 kHz most of the time (red color region).

### c) Envelope Modulation Spectrum (EMS)

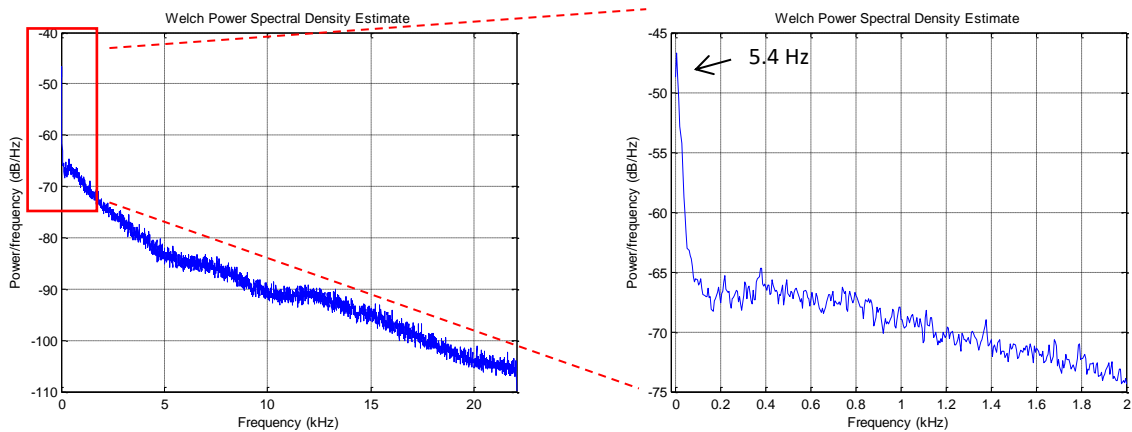
Same methodology as described in 1(c) has been used. The results are given below:



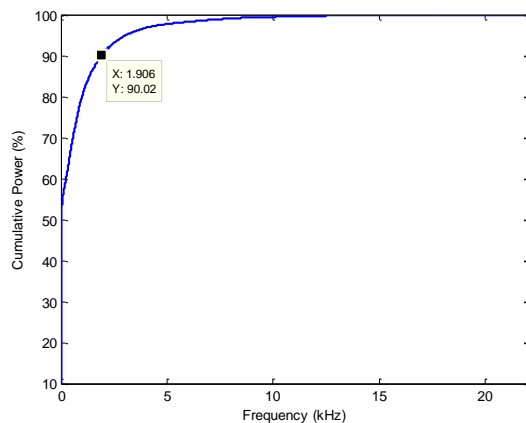


No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

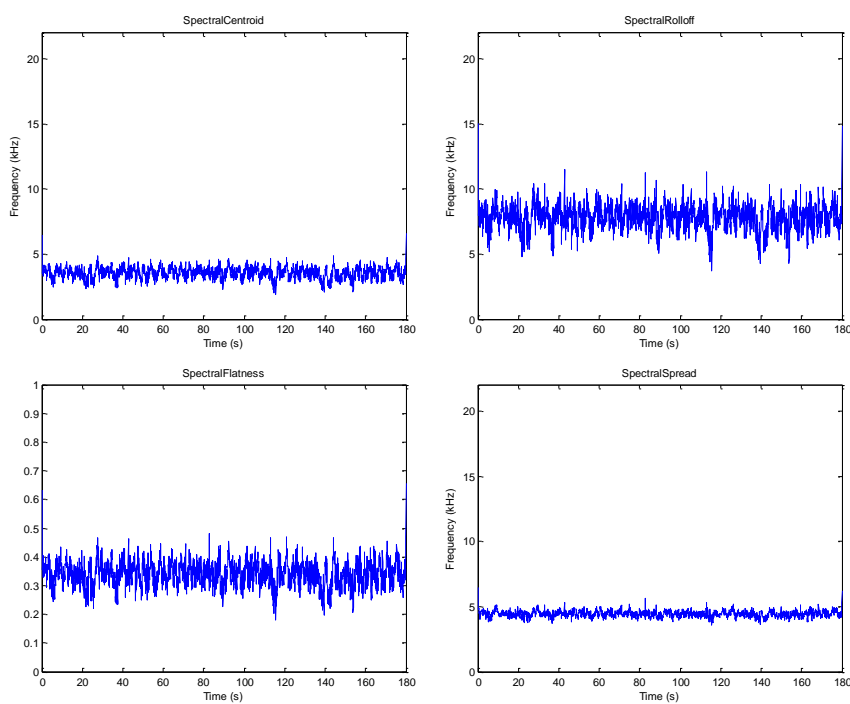
#### d) Long-term Average Spectrum (LTAS)



One significant frequency at 5.4 Hz is observed in the power spectrum. 90% of the signal power is contained below 1.9 kHz.



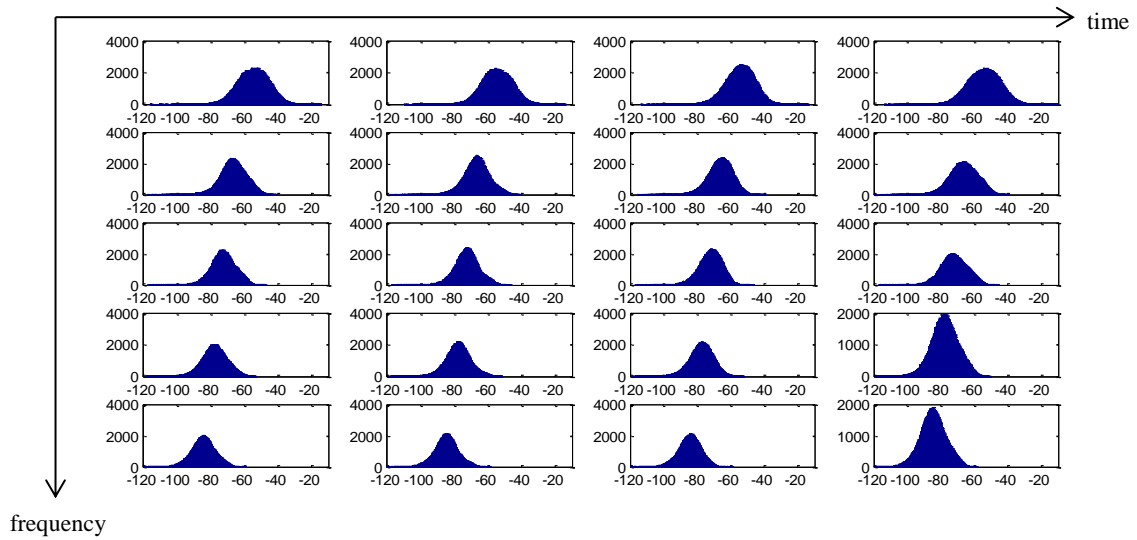
e) Spectrum shape based features



Features	Mean Value
Centroid	3562 Hz
Rolloff	7816 Hz
Flatness	0.3401
Spread	4434 Hz

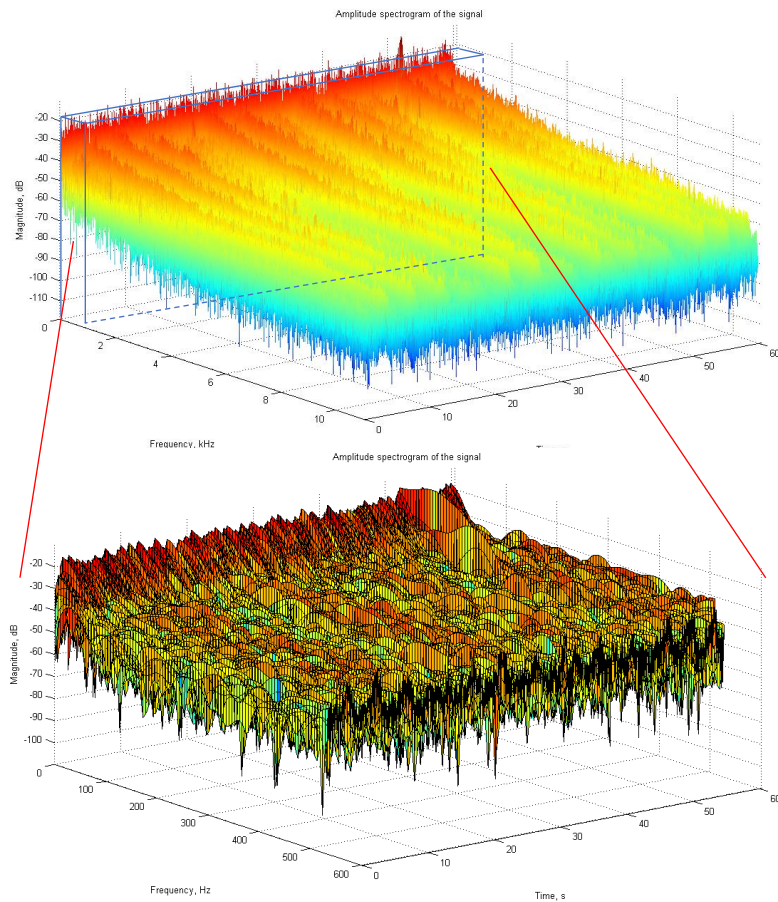
iii) Time-Frequency Domain Features

a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain the highest energy.

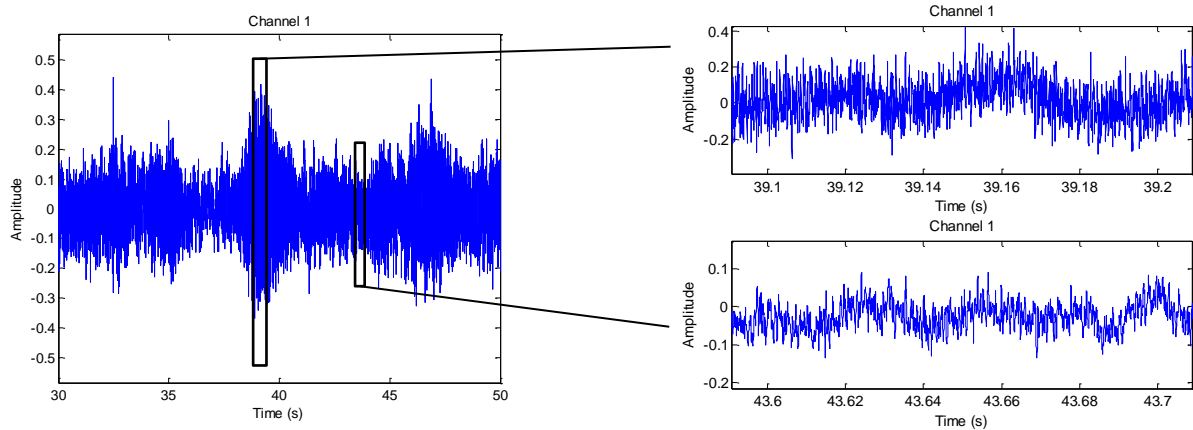
### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. The extremely low frequency (ELF) (< 30Hz) is very prominent in this signal.

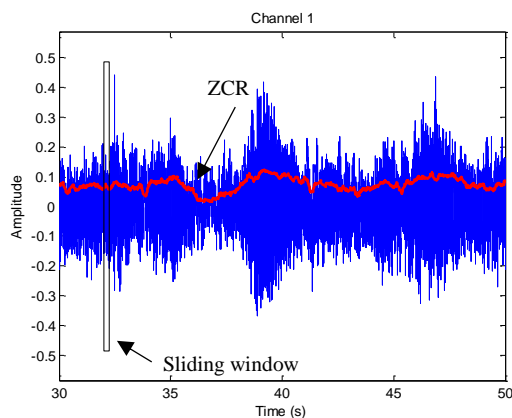
### 3) Audio Rejuvenation

#### i) Time-domain features



The amplitude envelope changes in time according to the loudness of the sound. When zoomed in, the rate of amplitude fluctuation appears to be similar in both the loud region and quiet region.

#### a. Zero Crossing Rate (ZCR)

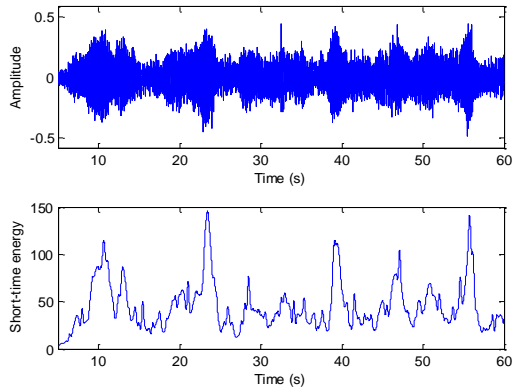


Window size = 10,000 samples (~0.23s)

ZCR shows short-term variation throughout the section of the sound examined (50s). Overall, the fundamental frequency of the sound is very low.

The ZCR (and fundamental frequency) is slightly dependent on the magnitude of the sound. The long-term characteristic is quite constant.

#### b. Short time energy (STE)

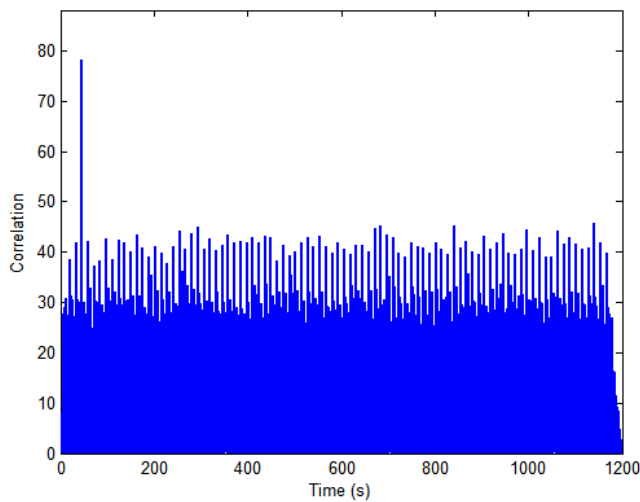


Window size = 10,000 samples (~0.23s)

Window type = Hamming

STE fluctuates according to the amplitude of the signal. The peak magnitudes of the energy surges appear to happen every 5 to 10 seconds.

### c. Auto-correlation

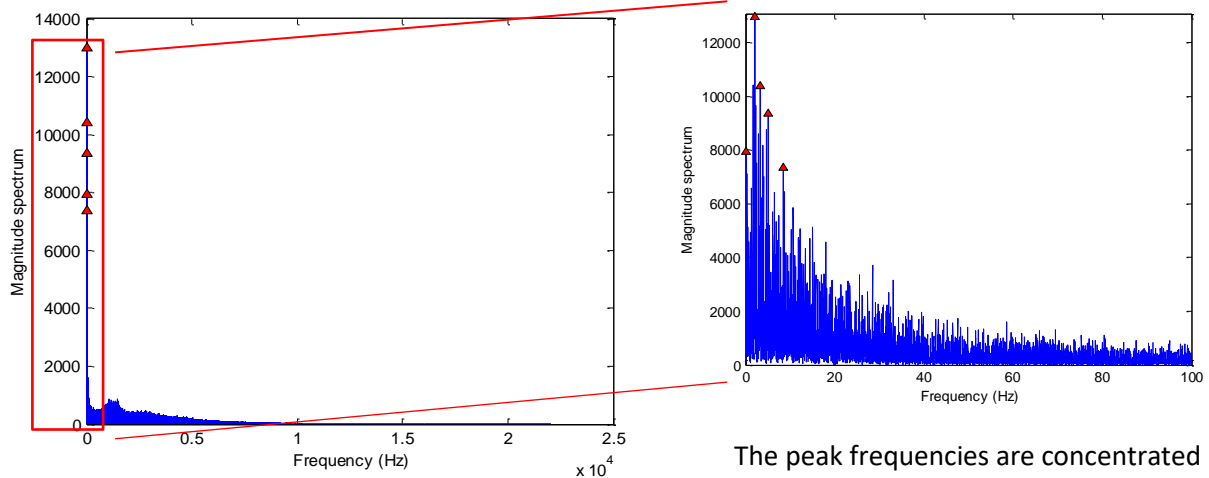


Segment/window size = 50,000 samples (~1.13s)

Only one peak is observed. In other words, there is no repeating segment in this sound.

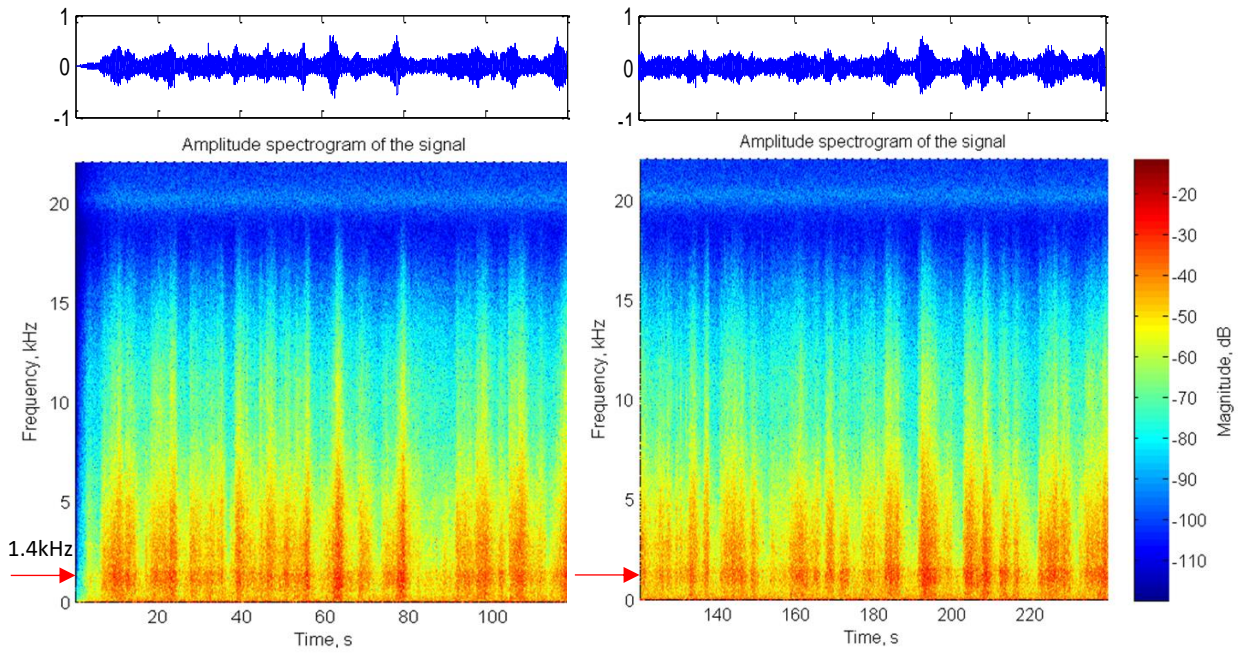
### ii) Frequency Domain Features

#### a) Peak Frequency



The peak frequencies are concentrated around 0 to 10 Hz. The highest peak is at 2 Hz.

#### b) Short-Time Fourier Transform (STFT)

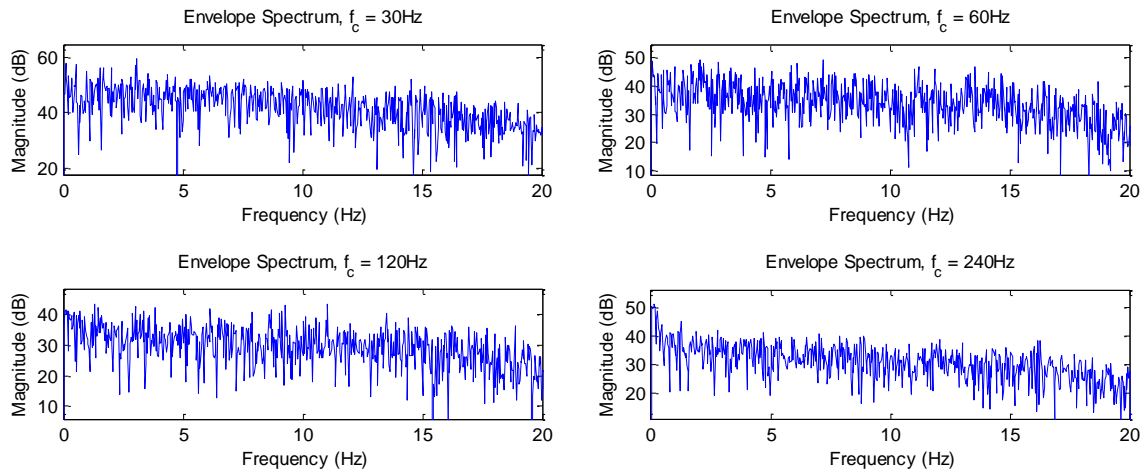


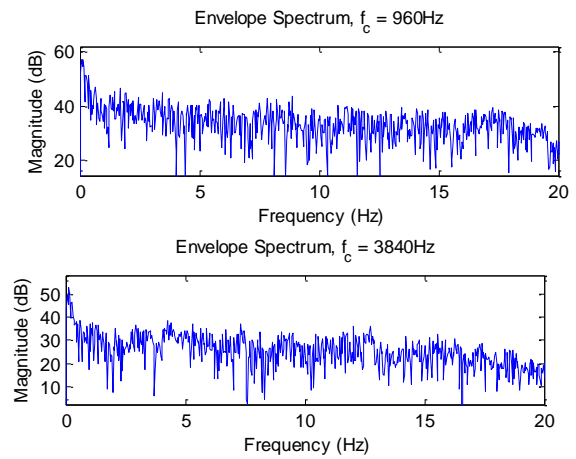
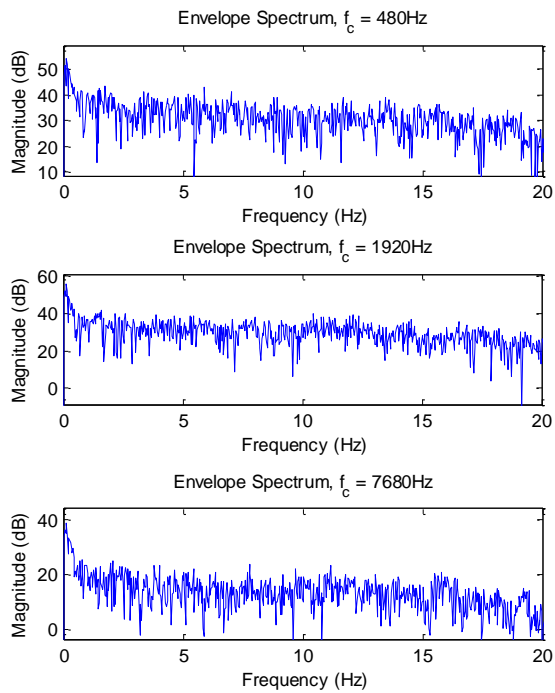
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum is changing in time. Nevertheless, the long-term characteristic is quite consistent. Short-term variation of spectrum is due to the rising and falling of the sea waves. Signal energy is concentrated in the low frequency region (below 5 kHz, red color region). A persistent frequency at about 1.4 kHz is observed.

### c) Envelope Modulation Spectrum (EMS)

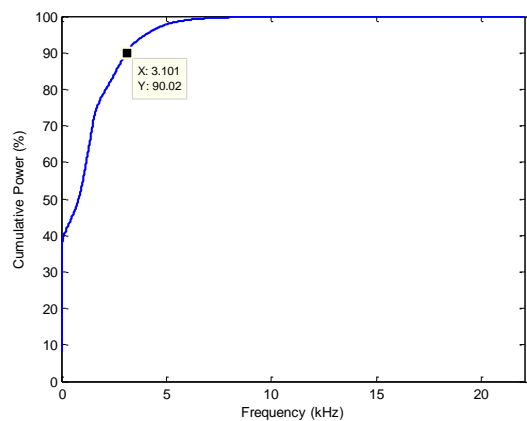
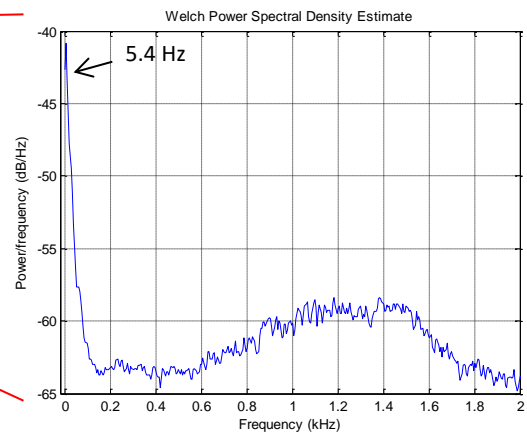
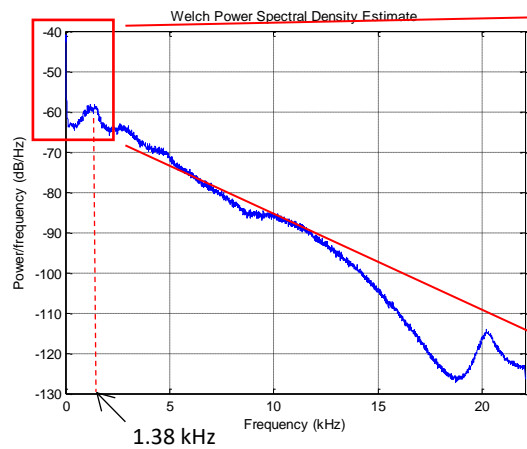
Same methodology as described in 1(c) has been used. The results are given below:





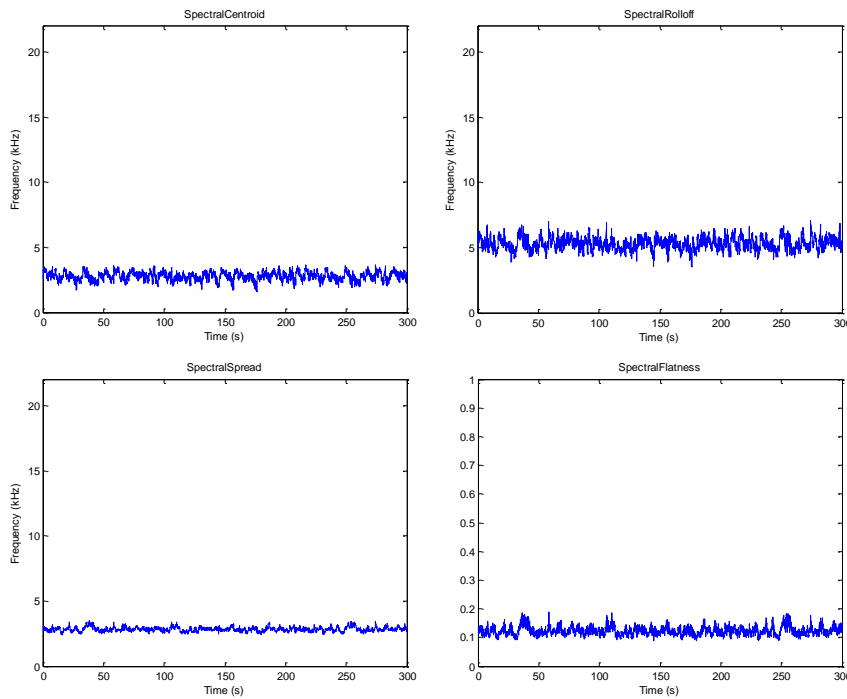
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



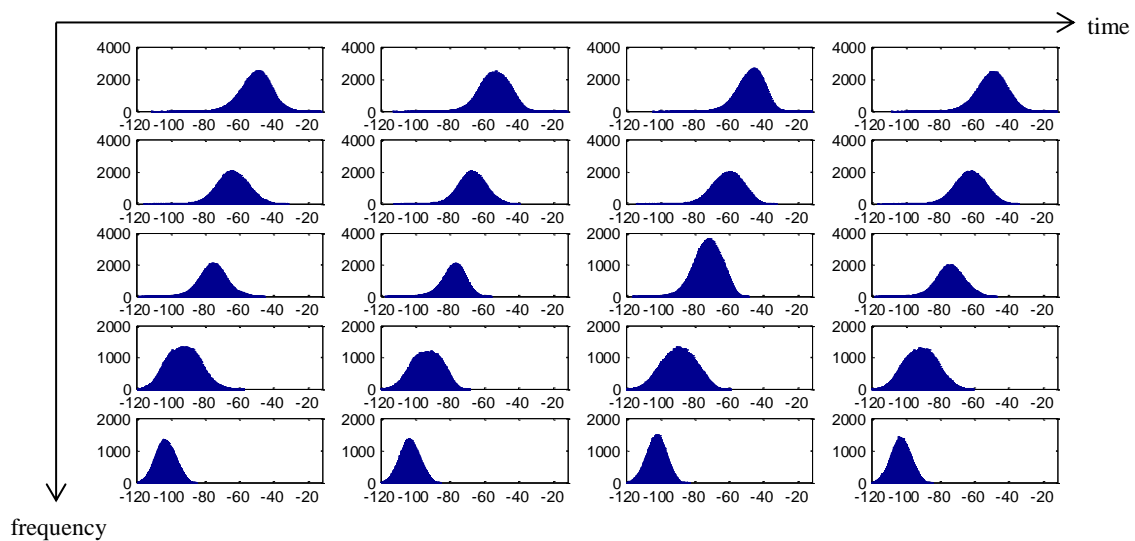
Two significant frequencies at 5.4 and 1.38 kHz are observed in the power spectrum. 90% of the signal power is contained below 3.1 kHz.

### e) Spectrum shape based features



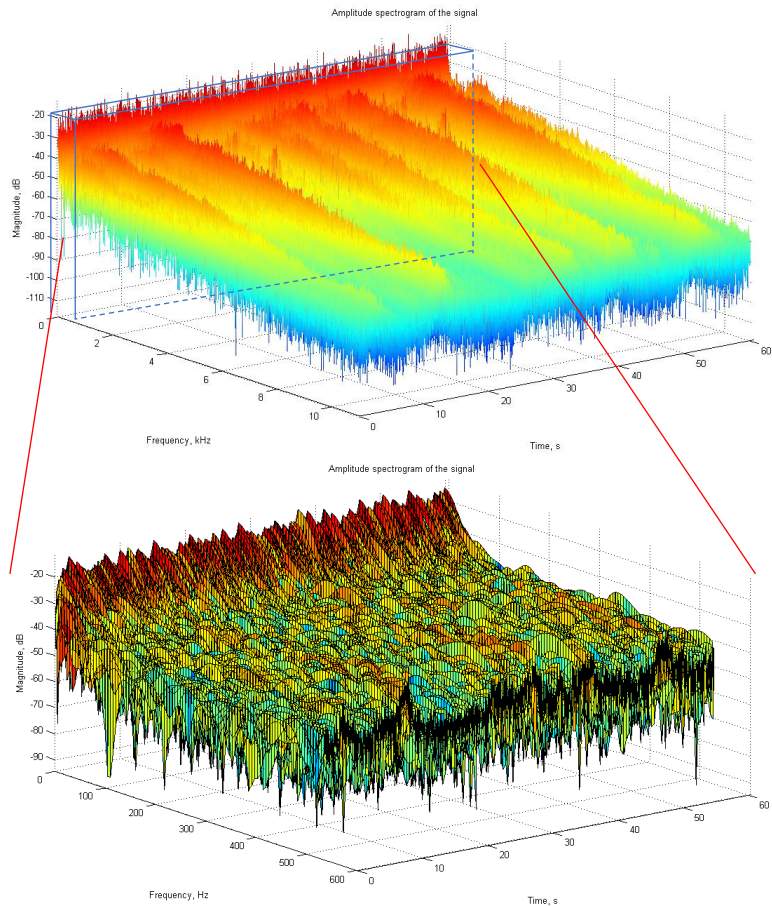
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

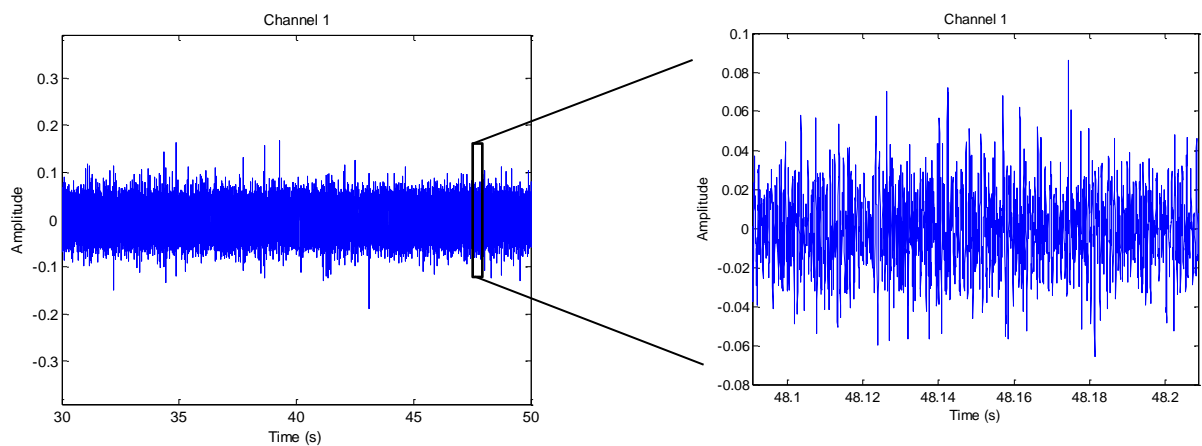
#### b) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. The extremely low frequency (ELF) (< 30Hz) is very prominent in this signal.

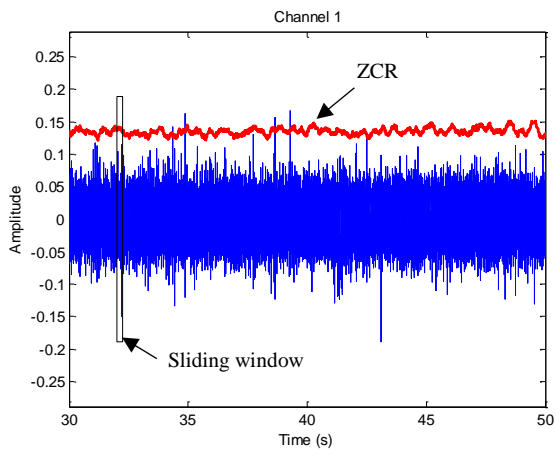
#### 4) Neuro-Energetics (Audio Serotonin)

##### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Even under very small time scale, the samples are very random and noise-like.

a. Zero Crossing Rate (ZCR)

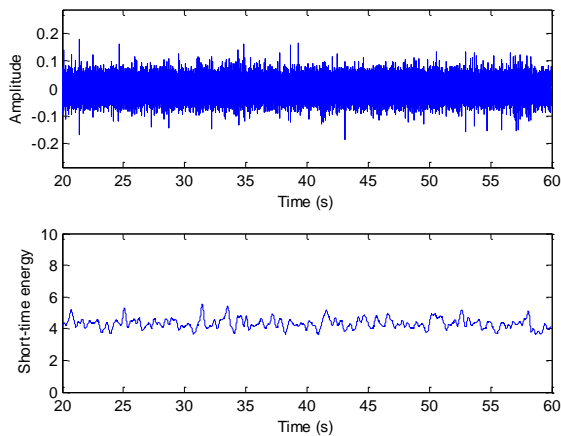


Window size = 10,000 samples (~0.23s)

ZCR is quite consistent throughout the section of the sound examined (50s). The fundamental frequency of the sound is not too low and has small variation across time.

This sound shows consistent long-term characteristic.

b. Short time energy (STE)

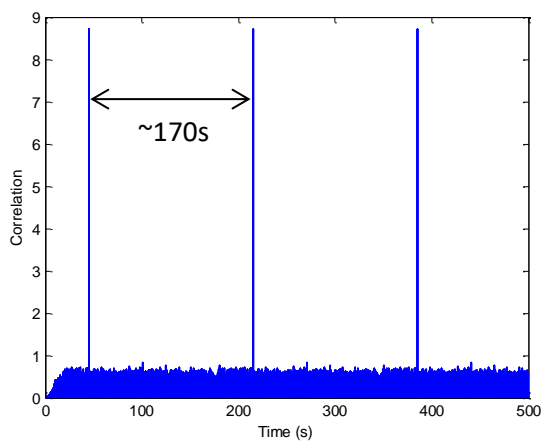


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE is quite constant and low. No large fluctuation of signal energy is observed.

c. Auto-correlation

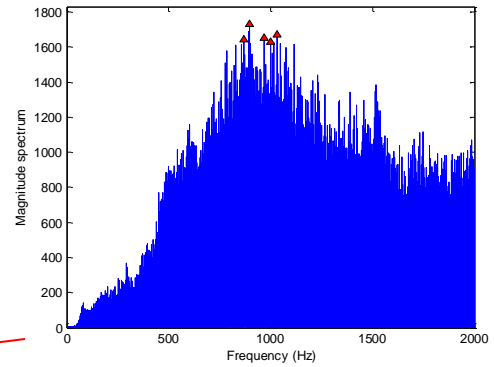
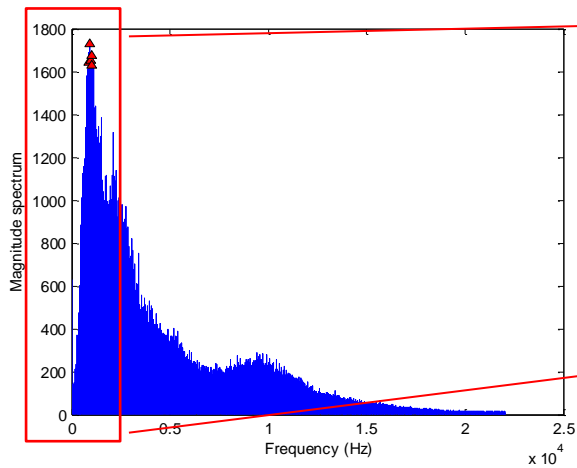


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 170s (or 2.83 minutes). In other words, identical segment of 2.83 minutes is repeated in this sound.

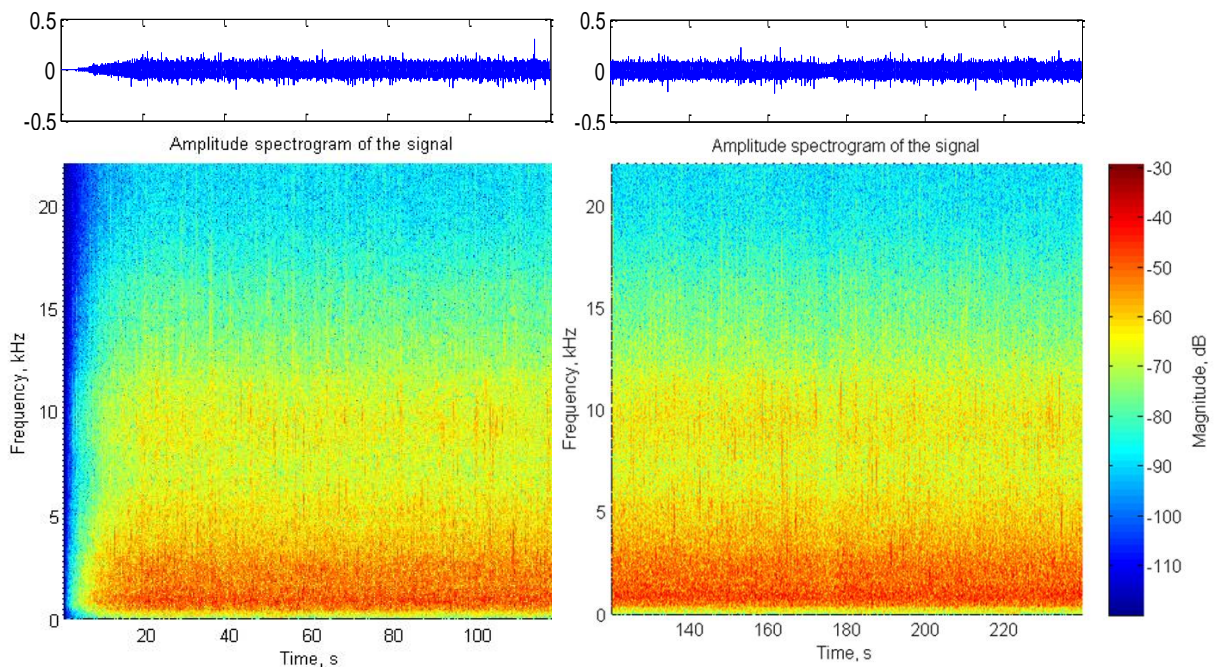
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 0.85 to 1.05 kHz. The highest peak is at 895Hz.

### b) Short-Time Fourier Transform (STFT)

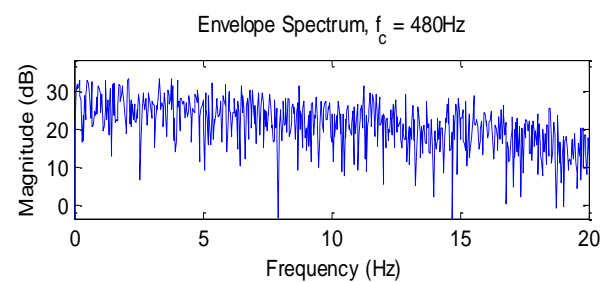
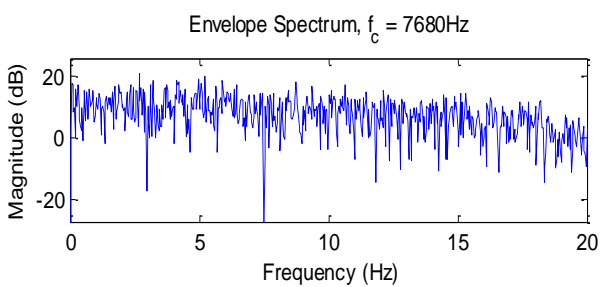
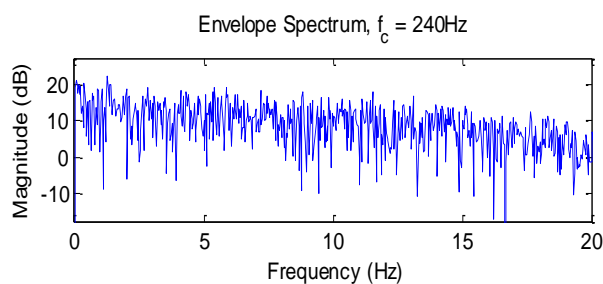
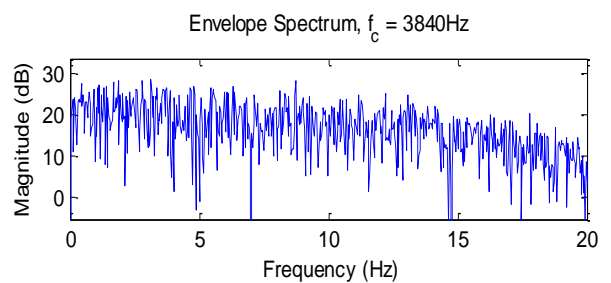
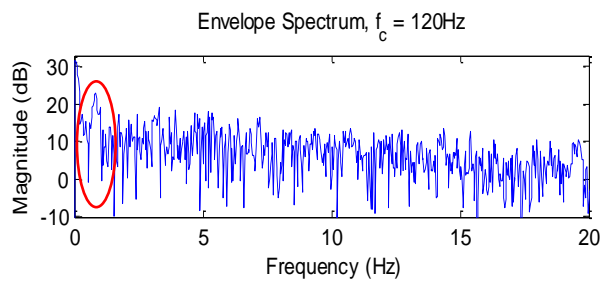
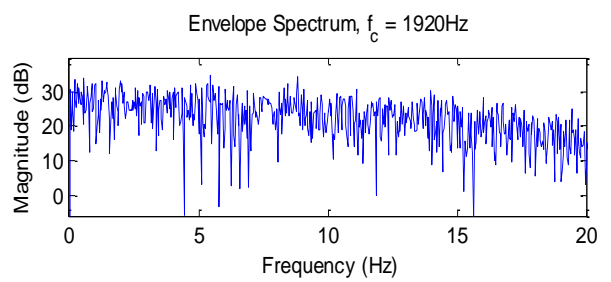
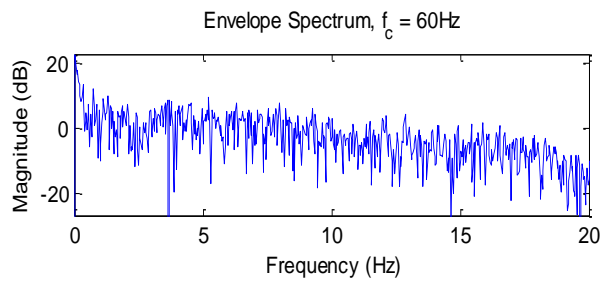
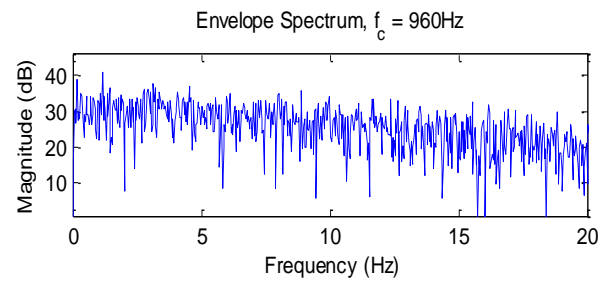
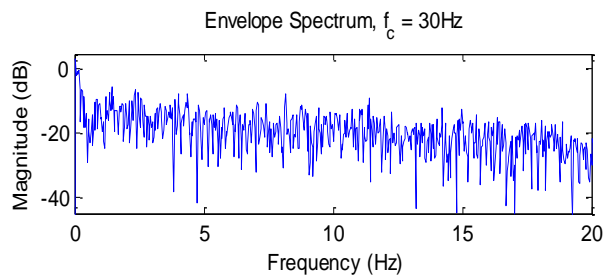


FFT size = 4096; window size = 1024 (~0.02s)

The spectrum has constant long-term characteristics. The energy of the sound is concentrated in below 5 kHz (red color region).

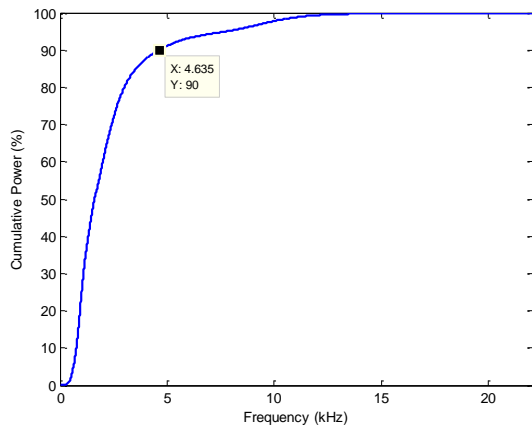
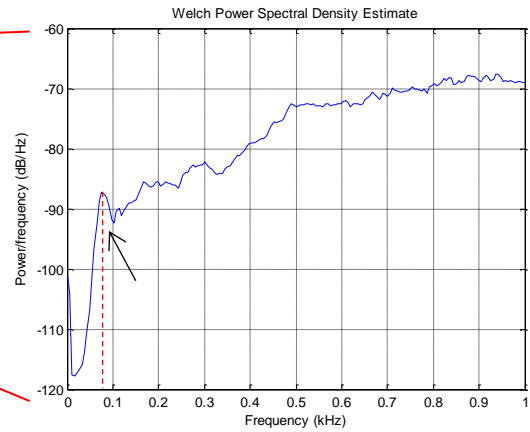
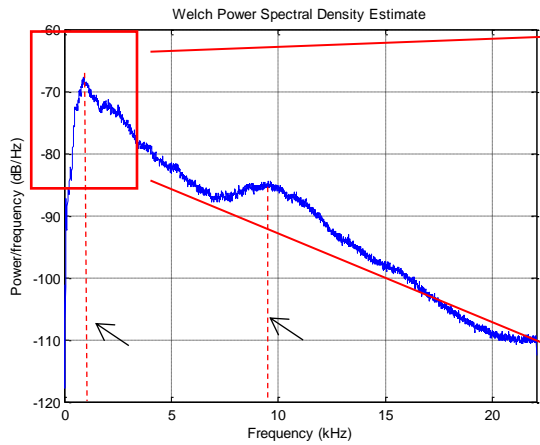
### c) Envelope Modulation Spectrum (EMS)

The original signal is first filtered into 9 octave bands with center frequencies of 30, 60, 120, 240, 480, 960, 1920, 3840, and 7680 Hz, using Butterworth filters. Then the envelope of the filtered signals is extracted using Hilbert transform. The mean is removed and the power spectrum for each of the bands is estimated by using DFT at frequencies 0–20 Hz. The results are given below:



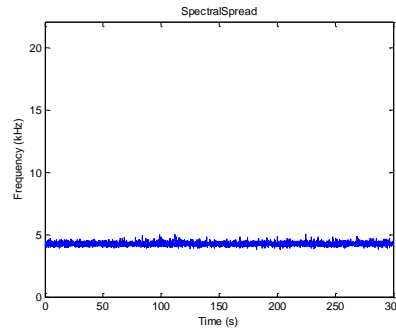
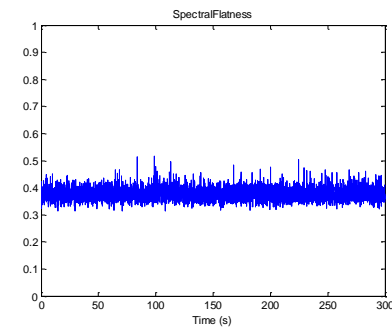
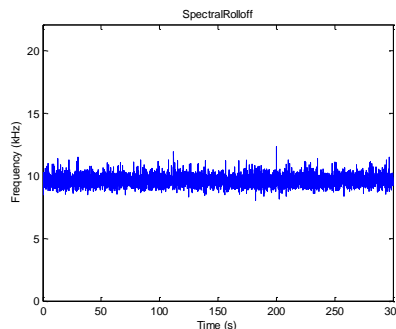
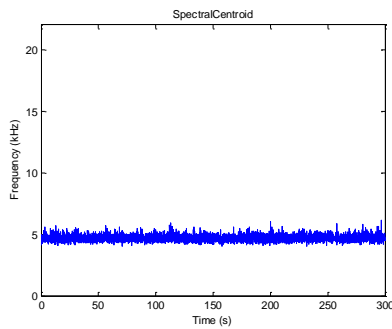
Only one small peak at about 0.8 Hz is observed in band 120 Hz. However, this amplitude modulation is not very significant. The envelope spectrums of other bands have no obvious slow modulation.

#### d) Long-term Average Spectrum (LTAS)



Three significant frequencies at 75, 942 and 9600 Hz are observed in the power spectrum. 90% of the signal power is contained below 4.6 kHz.

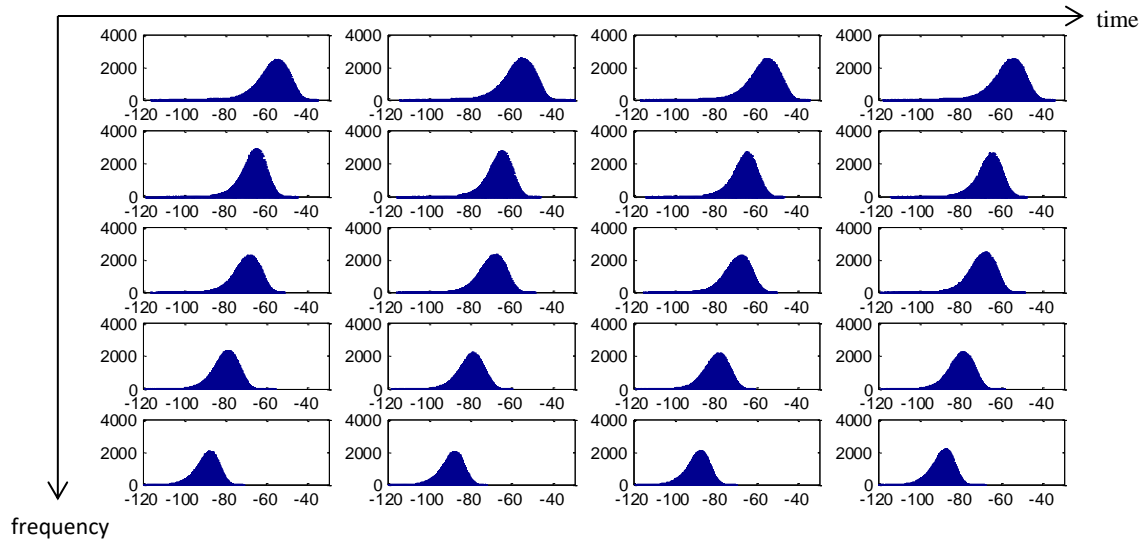
### e) Spectrum shape based features



Features	Mean Value
Centroid	4695 Hz
Rolloff	9621 Hz
Flatness	0.3771
Spread	4262 Hz

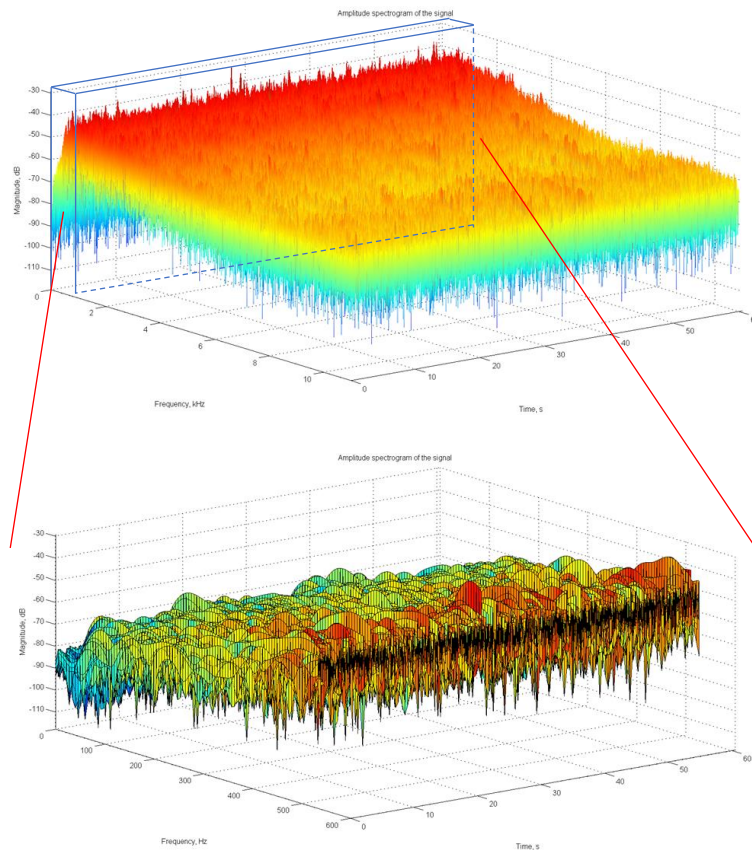
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

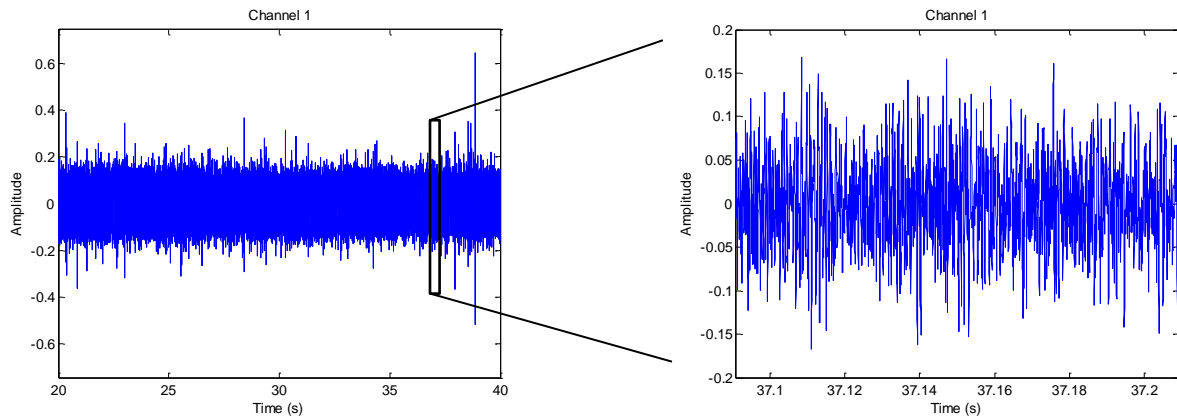
#### b) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal do not change significantly in time. The super-low frequency (SLF) (30-300Hz) is very prominent in this signal.

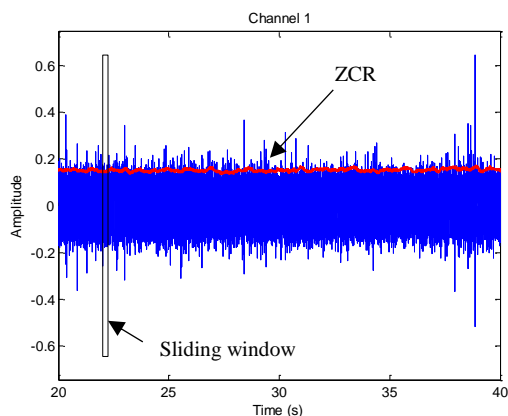
## 5) Neuro-Energetics (Audio Oxytocin)

### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Even under very small time scale, the samples are very random and noise-like.

#### a. Zero Crossing Rate (ZCR)

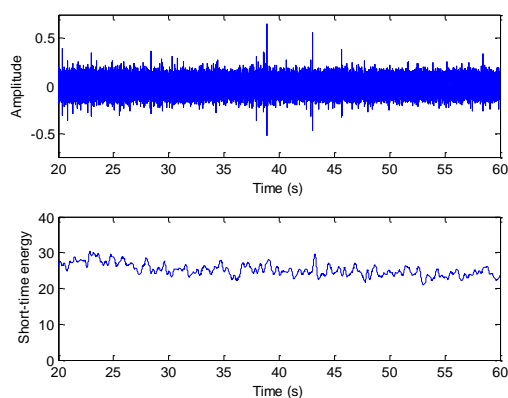


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (40s).

The fundamental frequency of the sound is very low. This sound shows constant long-term characteristics, very similar to noise

#### b. Short time energy (STE)

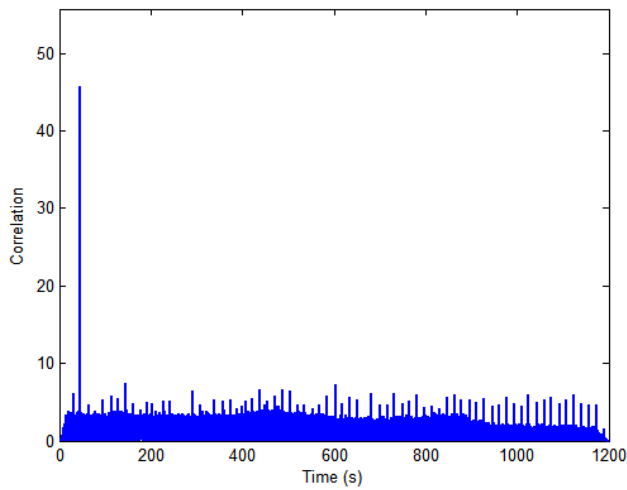


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE is quite constant and low. No large fluctuation of signal energy is observed.

#### c. Auto-correlation

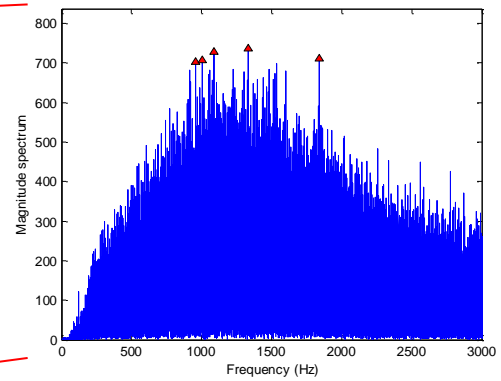
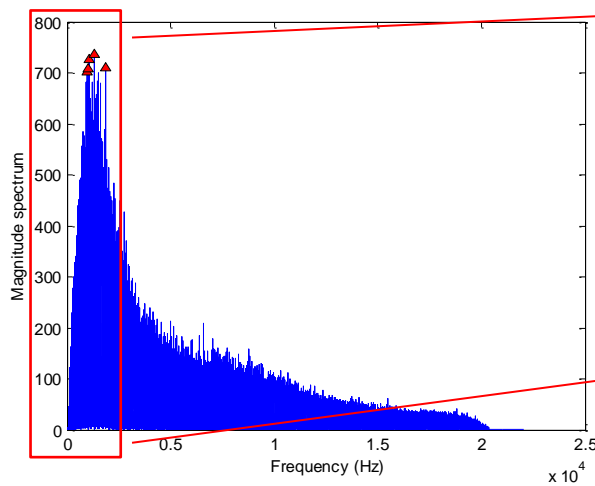


Segment/window size = 50,000 samples  
 (~1.13s)

Only one peak is observed. In other words,  
 there is no repeating segment in this sound.

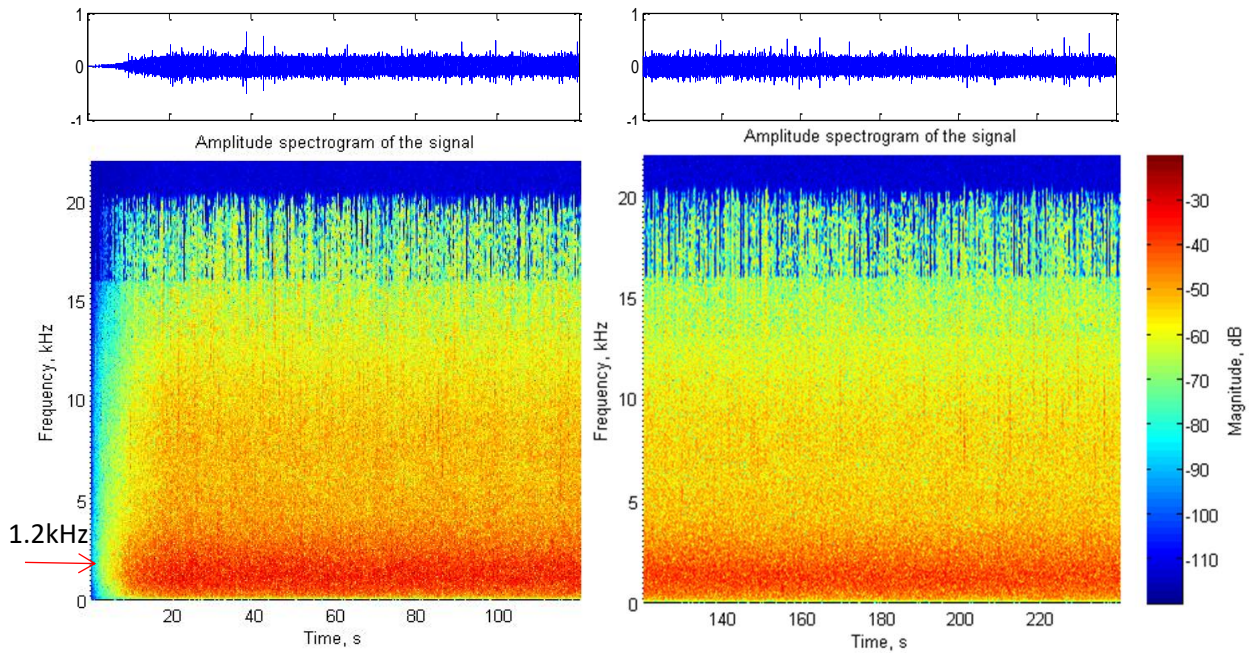
## ii) Frequency Domain Features

### a) Peak Frequency



The peak frequencies are concentrated  
 around 900 to 1800 Hz. The highest  
 peak is at 1335 Hz.

### b) Short-Time Fourier Transform (STFT)

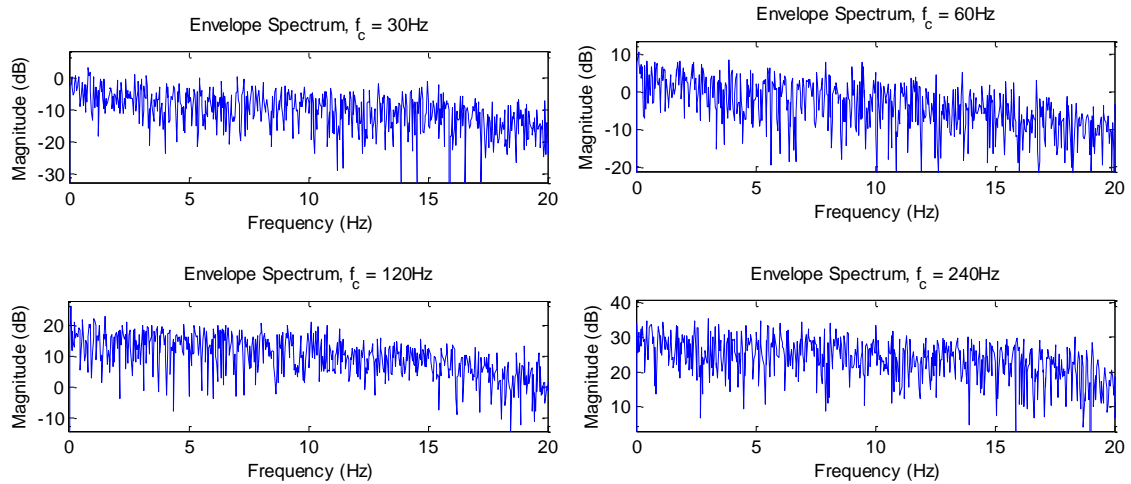


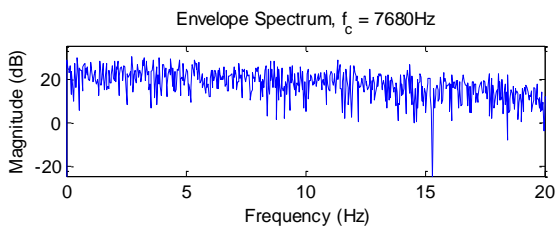
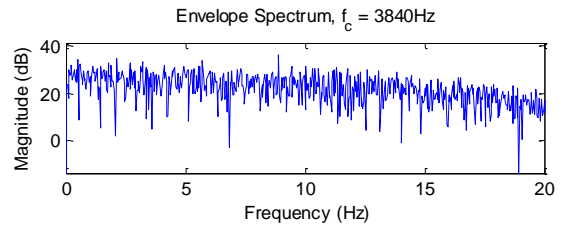
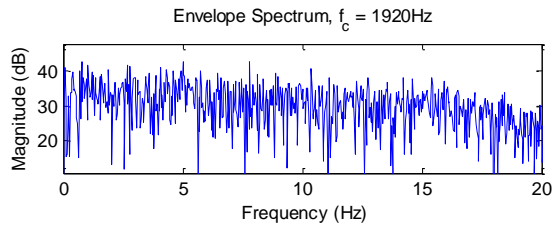
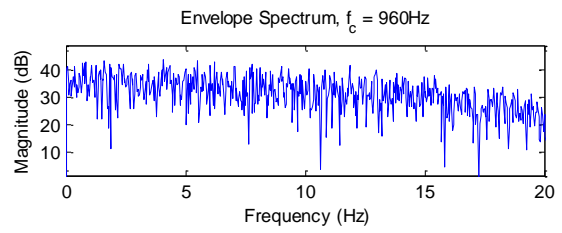
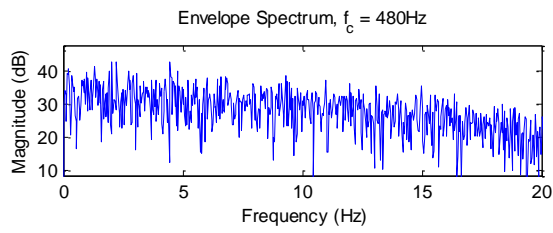
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum has constant long-term characteristics. Signal energy is concentrated below 5 kHz (red color region). Consistent high energy frequency is observed at about 1.2 kHz.

### c) Envelope Modulation Spectrum (EMS)

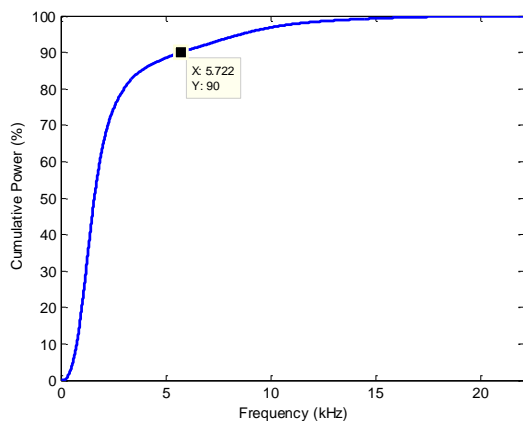
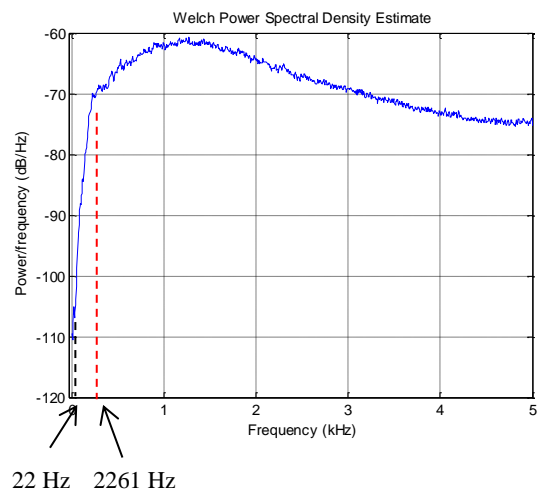
Same methodology as described in 1(c) has been used. The results are given below:





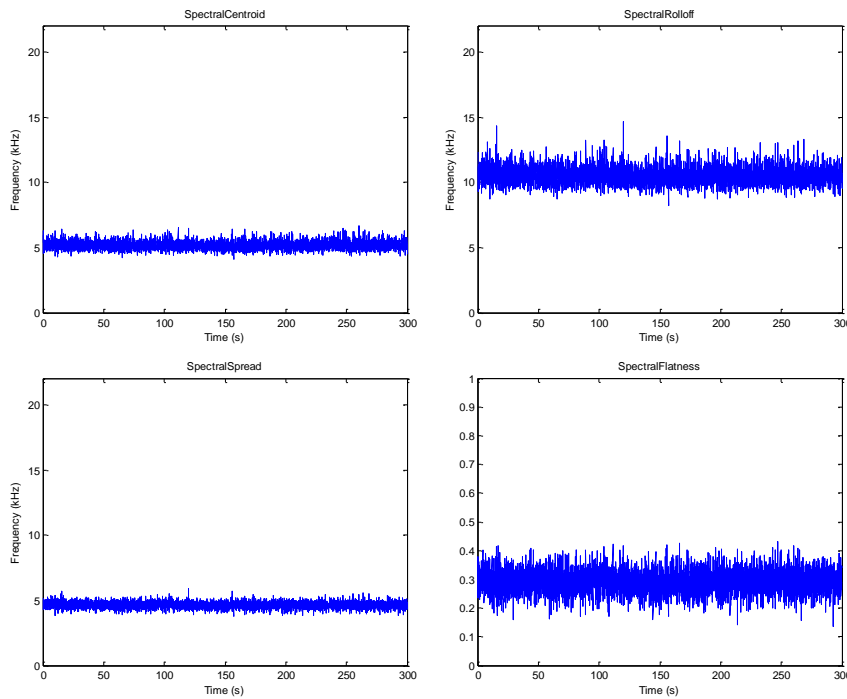
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



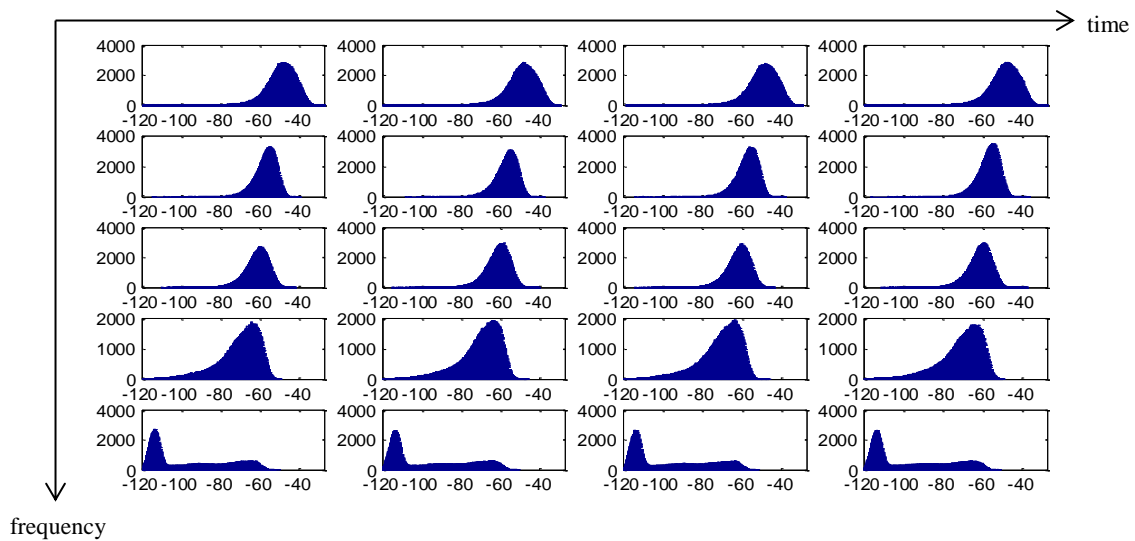
Two significant frequencies at 1276 and 2261 Hz are observed in the power spectrum. However, very low frequency up to about 22 Hz seems to be suppressed substantially. 90% of the signal power is contained below 5.7 kHz.

### e) Spectrum shape based features



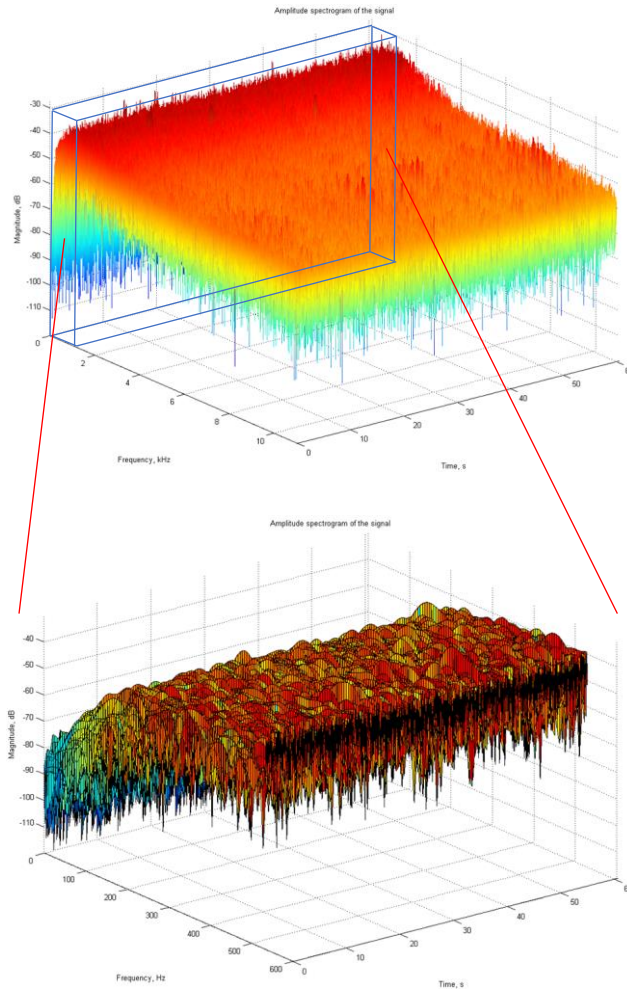
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low and medium-high frequencies sections show less noise-like characteristics. The very-low frequency sections contain highest energy

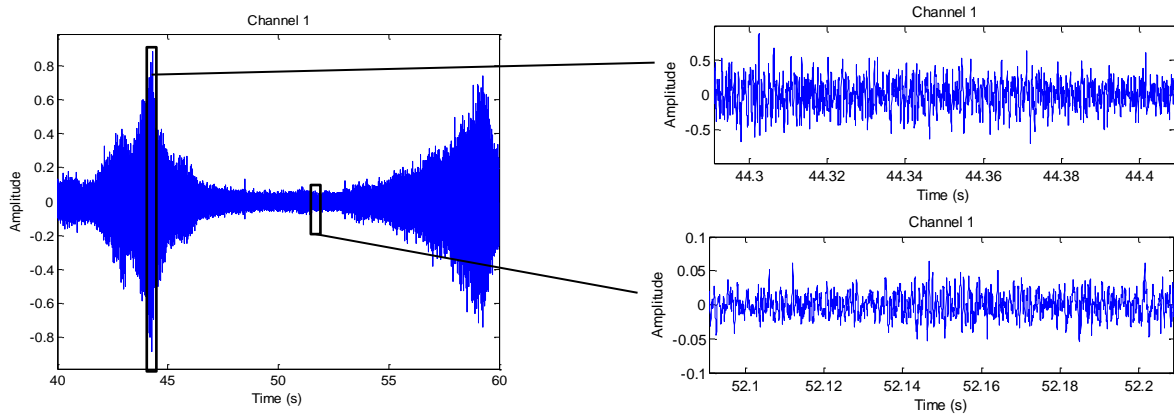
#### b) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal do not change significantly in time. The super-low frequency (SLF) (30-300Hz) is very prominent in this signal.

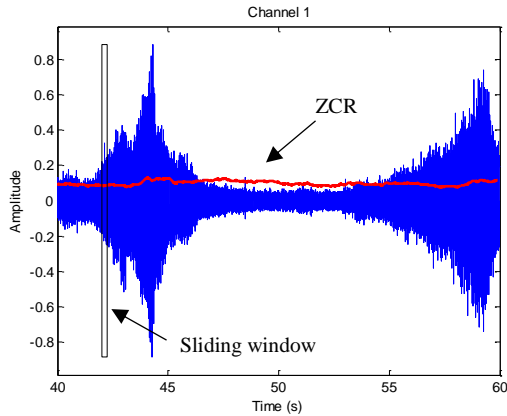
## 6) Neuro-Energetics (Audio Endorphins)

### i) Time-domain features



The amplitude envelope changes in time according to the loudness of the sound. When zoomed in, the rate of amplitude fluctuation appears to be similar for both the loud and quiet regions.

a. Zero Crossing Rate (ZCR)

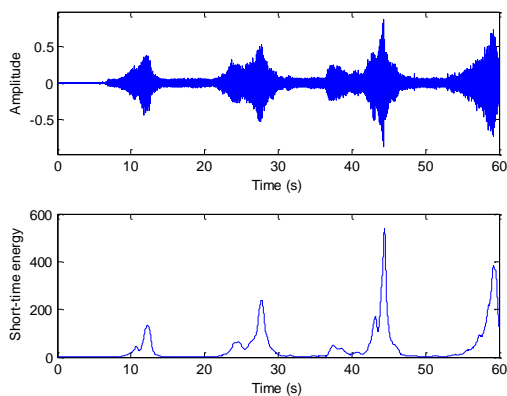


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (60s). Overall, the fundamental frequency of the sound is very low.

The long-term characteristic is quite constant.

b. Short time energy (STE)

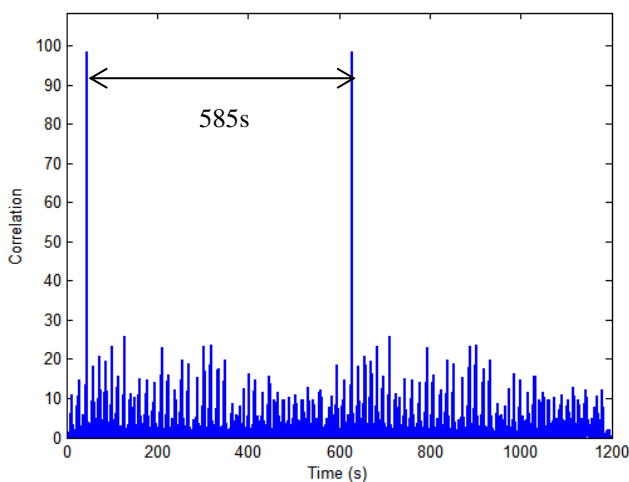


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE depends on the amplitude of the signal. The energy surge happens quite regularly in time. The time duration between the energy peaks is about 15 s.

c. Auto-correlation

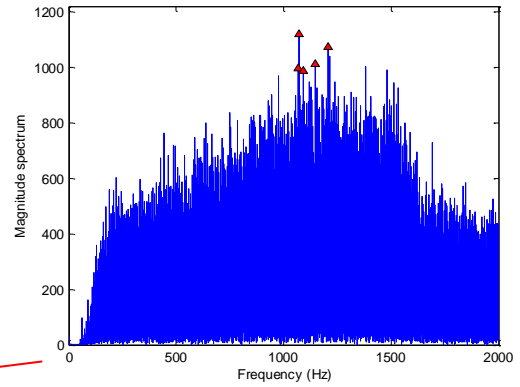
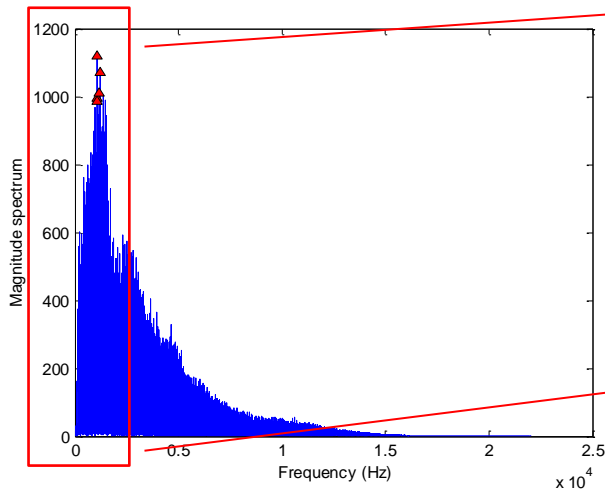


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 585s (or 9.75 minutes). In other words, identical segment of 9.75 min is repeated in this sound.

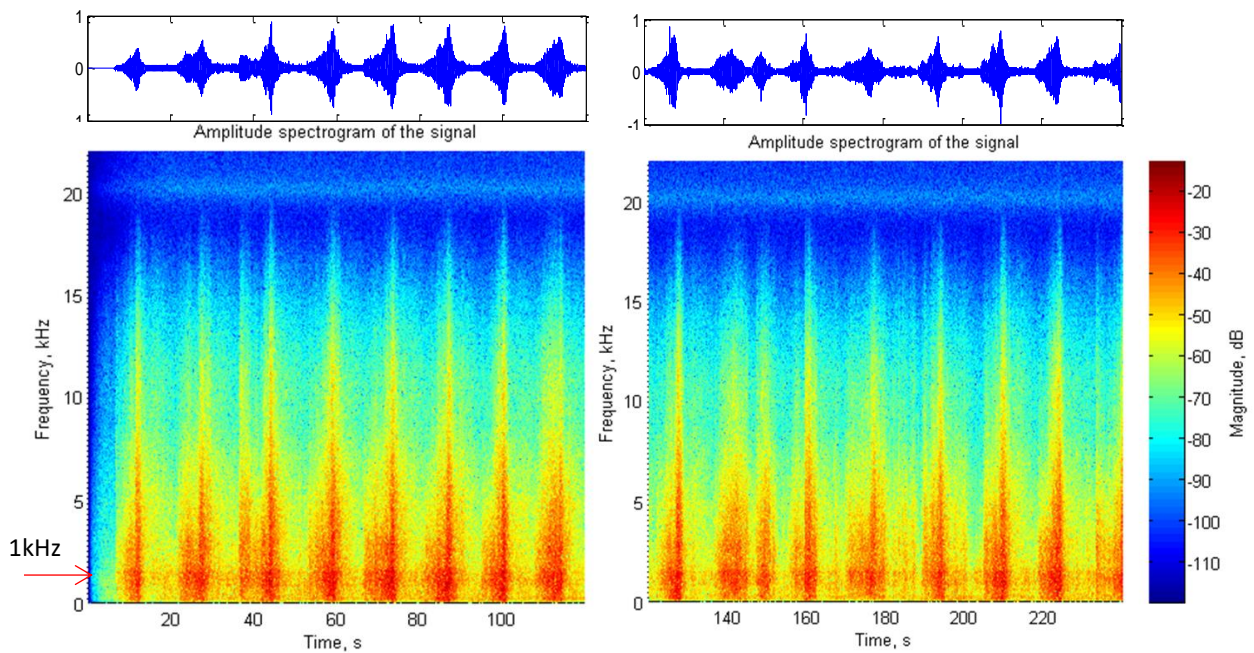
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 1000 to 1250 Hz. The highest peak is at 1070 Hz.

### b) Short-Time Fourier Transform (STFT)

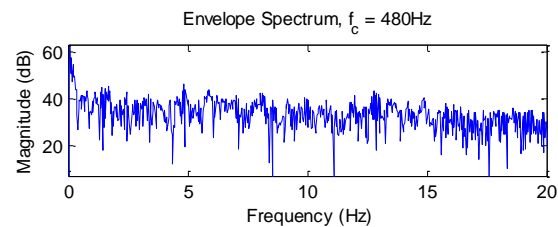
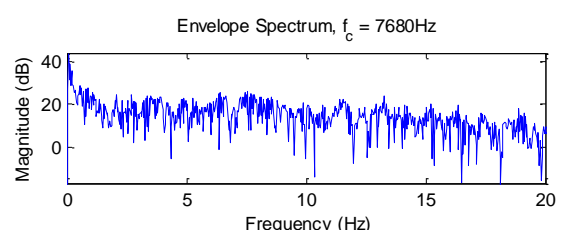
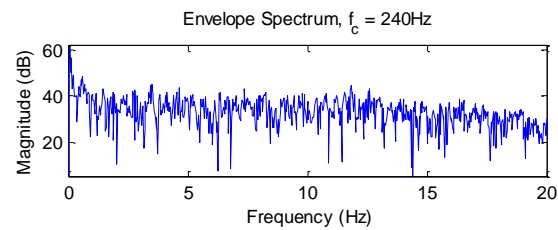
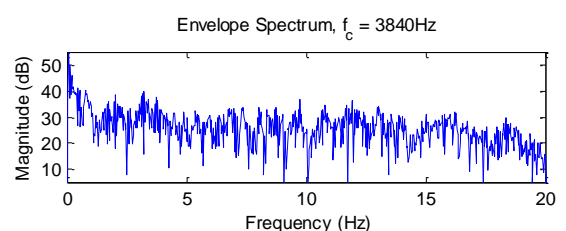
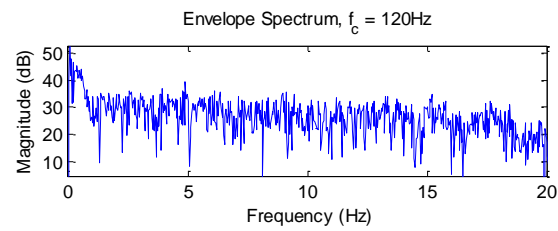
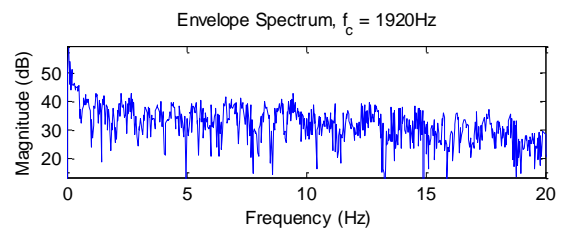
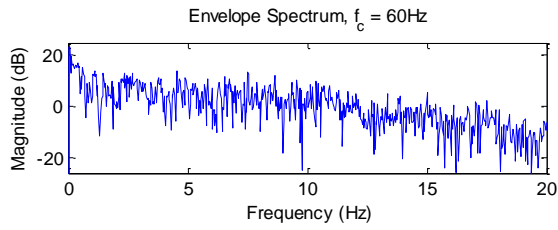
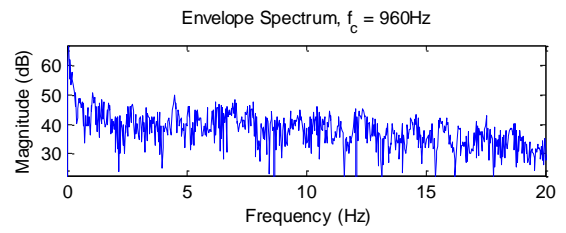
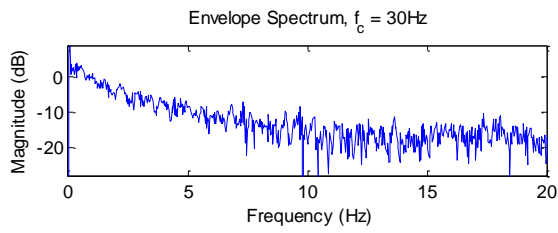


FFT size = 4096; window size = 1024 (~0.02s)

The spectrum is changing in time. Nevertheless, the long-term characteristic is consistent. Short-term variation of spectrum is due to the rising and falling of the ocean waves. Signal energy is mainly concentrated below 7 kHz (red color region). A consistent high energy frequency is observed at about 1 kHz.

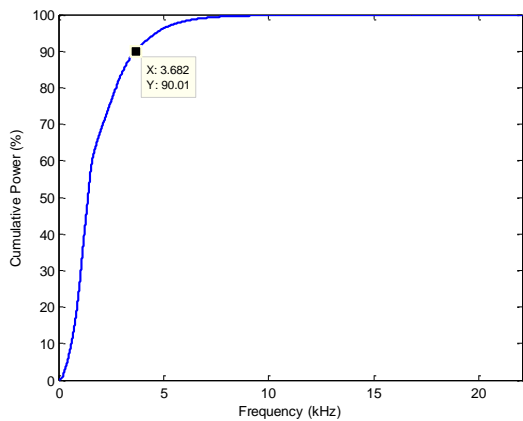
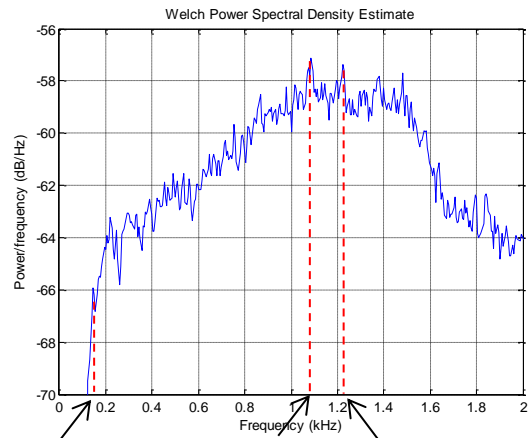
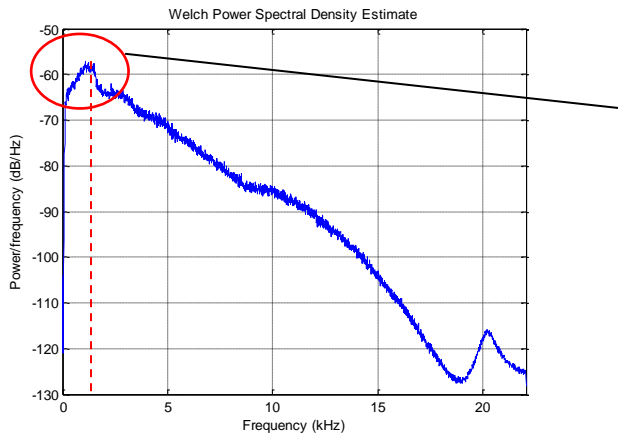
### c) Envelope Modulation Spectrum (EMS)

Same methodology as described in 1(c) has been used. The results are given below:



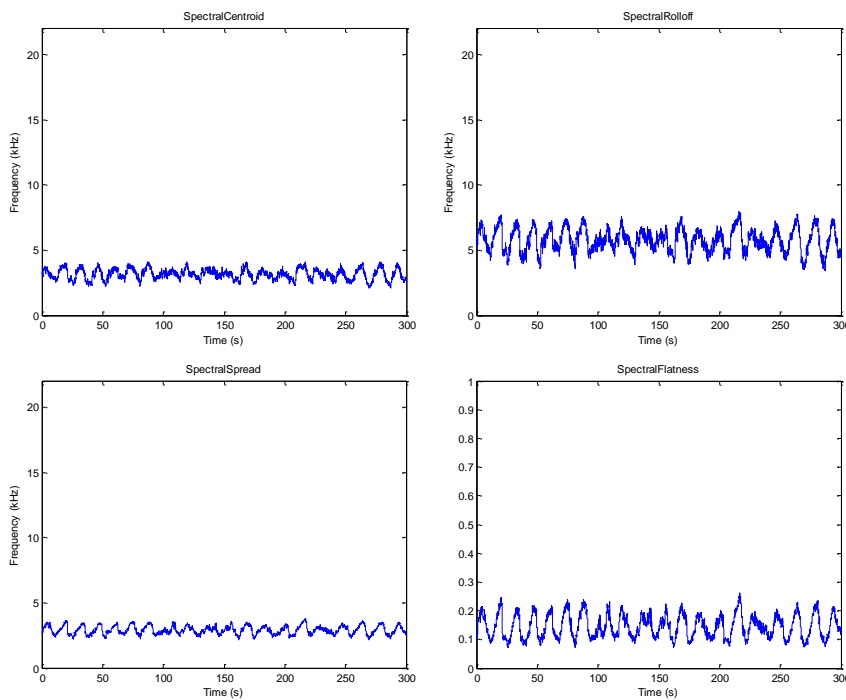
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



Three significant frequencies at 145, 1087 and 1222 are observed in the power spectrum. 90% of the signal power is contained below 3.7 kHz.

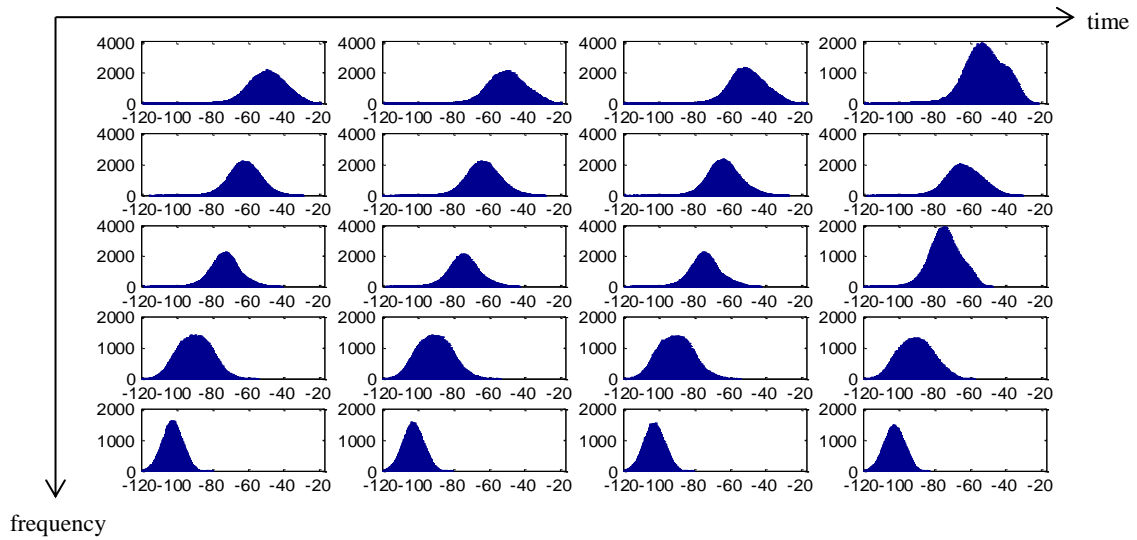
### e) Spectrum shape based features



Features	Mean Value
Centroid	3155 Hz
Rolloff	5771 Hz
Flatness	0.1460
Spread	2918 Hz

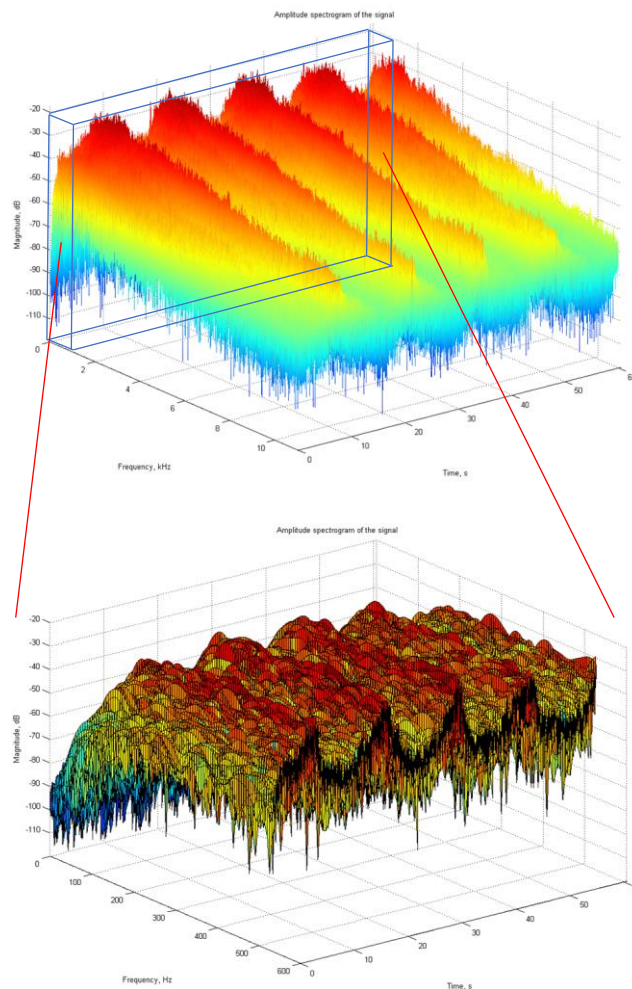
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

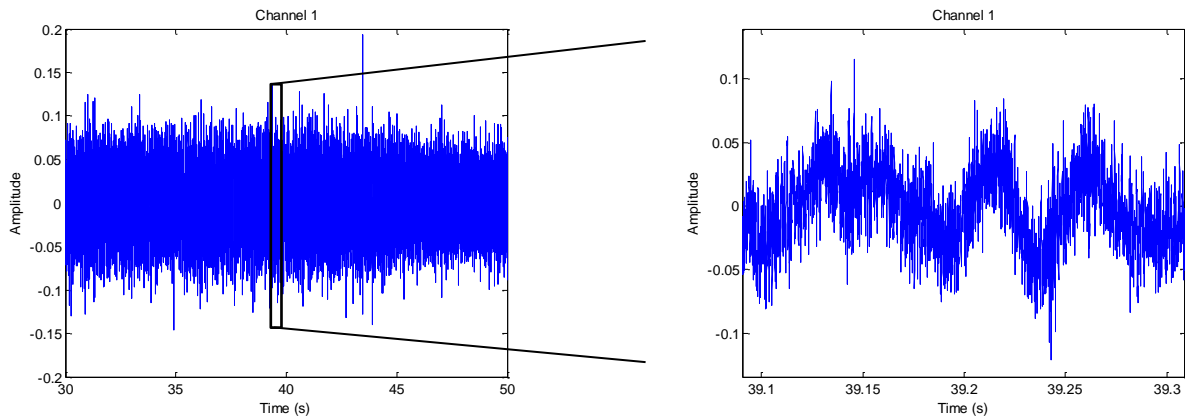
### b) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. The super-low frequency (SLF) (30-300Hz) is very prominent in this signal. However, their magnitudes change in time.

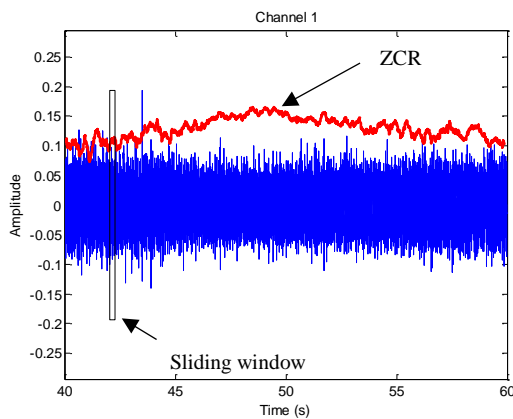
## 7) Neuro-Energetics (Audio Dopamine)

### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Noisy and slow amplitude fluctuation is observed under very small time scale.

#### a. Zero Crossing Rate (ZCR)

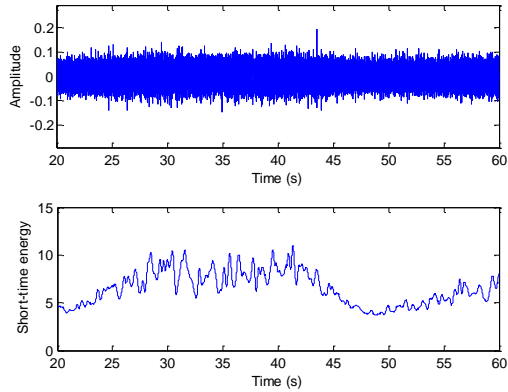


Window size = 10,000 samples (~0.23s)

ZCR is quite consistent throughout the section of the sound examined (60s). The fundamental frequency of the sound is not too low and has long-term variation across time.

This sound shows small short-term varying characteristics. Long-term characteristic is still quite constant.

#### b. Short time energy (STE)

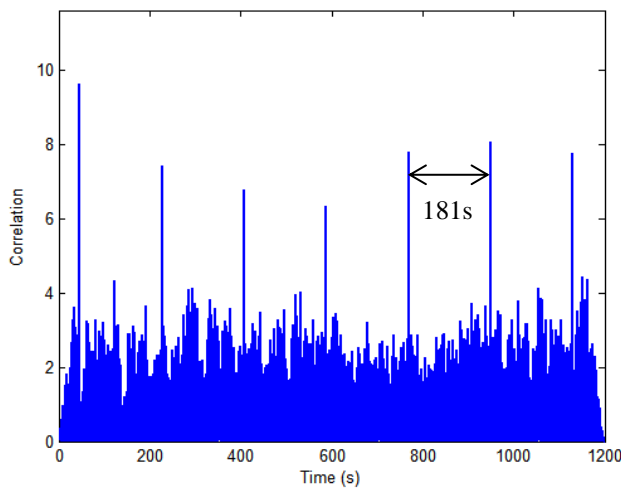


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE is quite constant. No sudden large fluctuation of signal energy is observed.

c. Auto-correlation

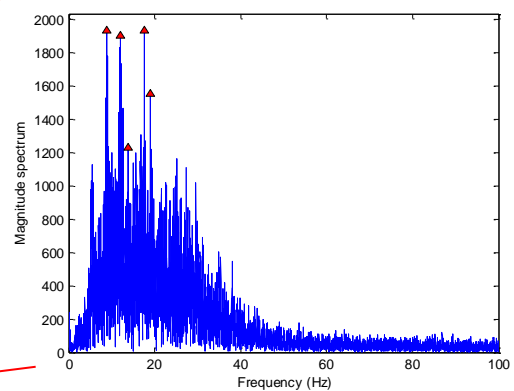
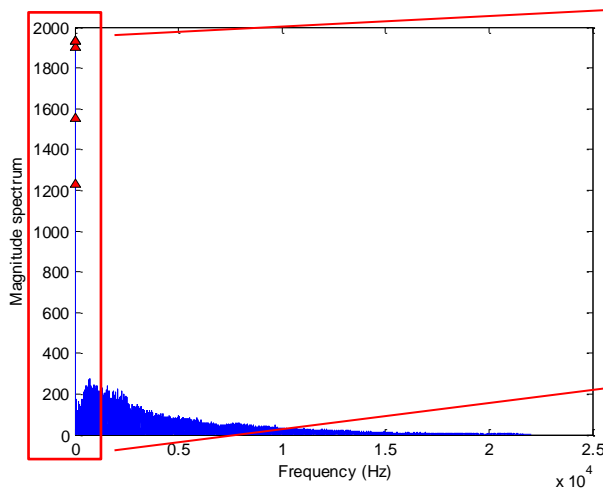


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 181s (or 3 minutes). In other words, identical segment of 3 minutes is repeated in this sound.

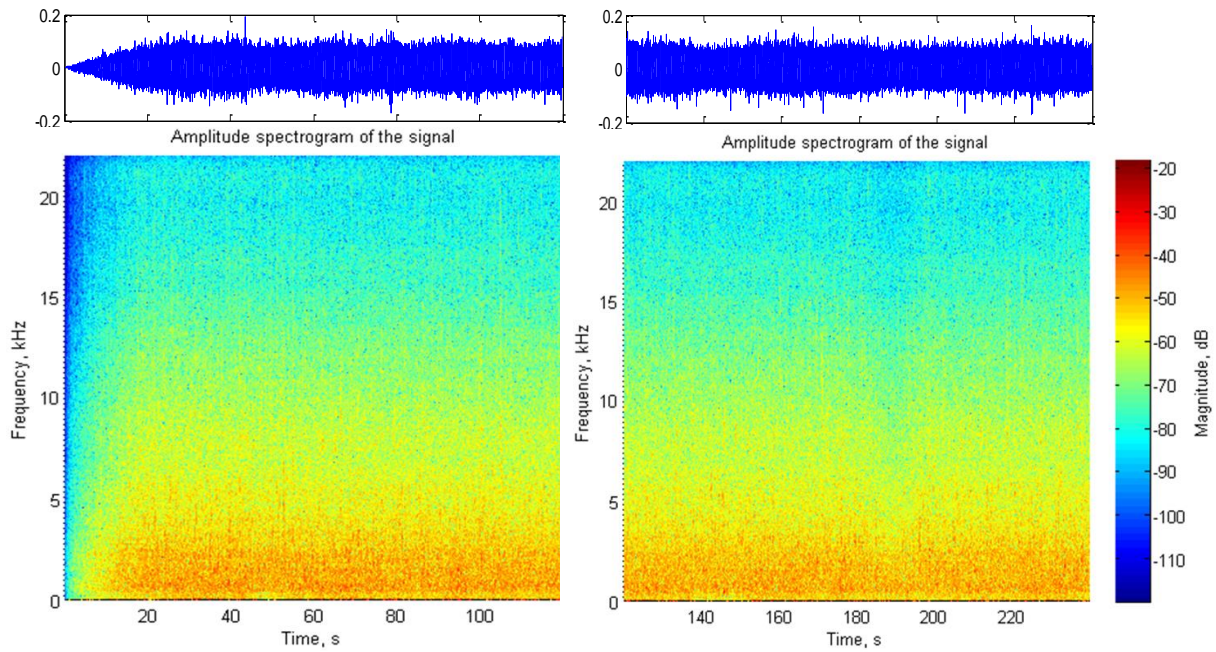
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 8 to 20 Hz. The highest peak is at 8.8 Hz.

b) Short-Time Fourier Transform (STFT)

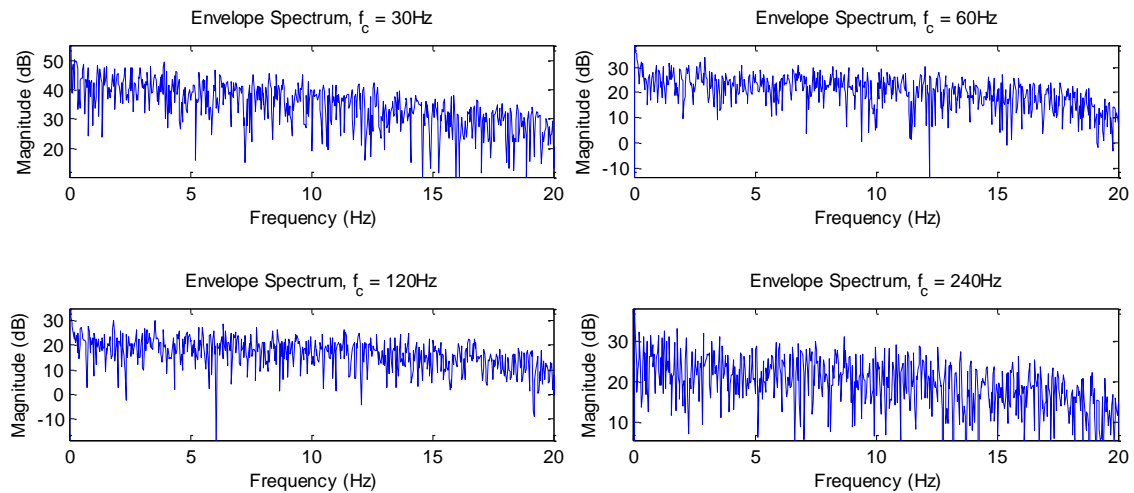


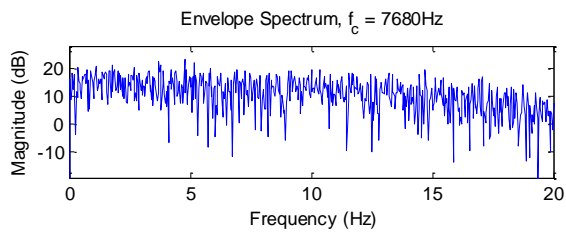
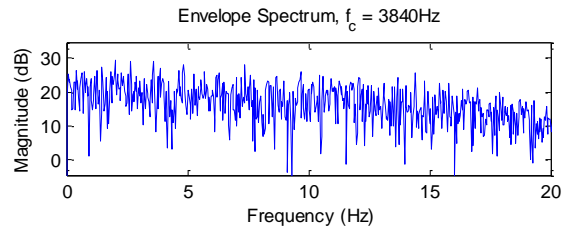
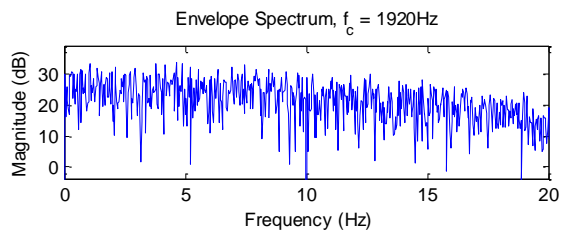
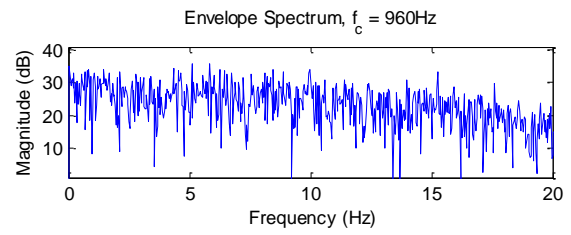
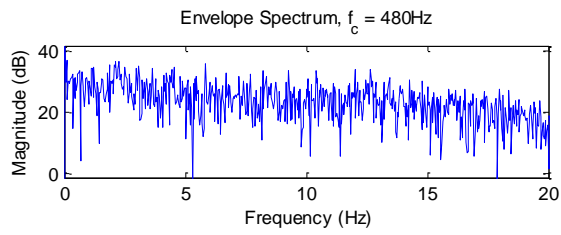
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum has constant long-term characteristics. Signal energy is concentrated below 2 kHz (red color region).

### c) Envelope Modulation Spectrum (EMS)

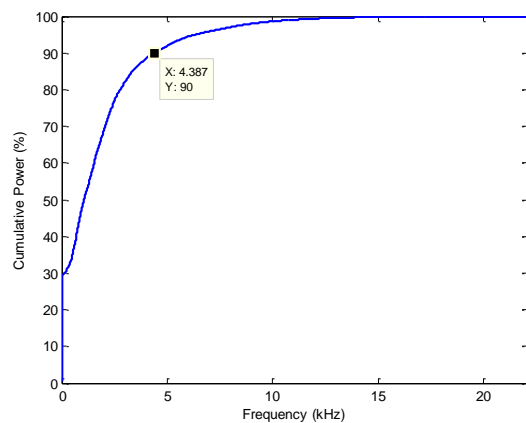
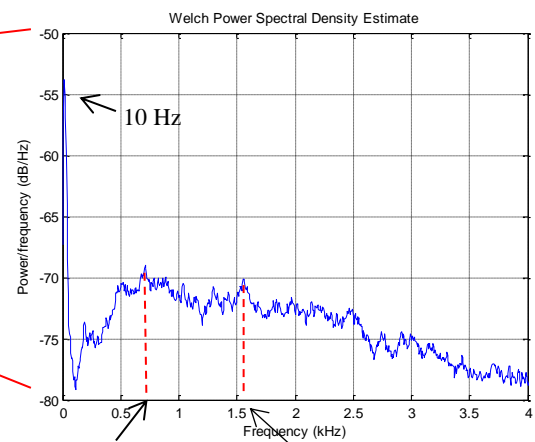
Same methodology as described in 1(c) has been used. The results are given below:





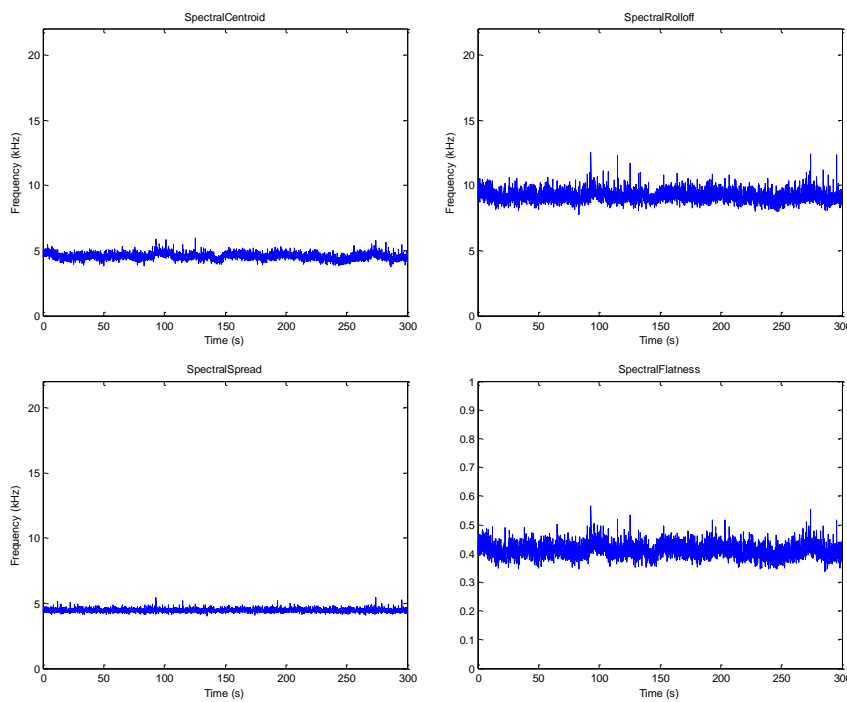
No obvious peak is observed in all the envelope spectrums above. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



Three significant frequencies at 10, 710 and 1556 Hz are observed in the power spectrum. 90% of the signal power is contained below 4.4 kHz.

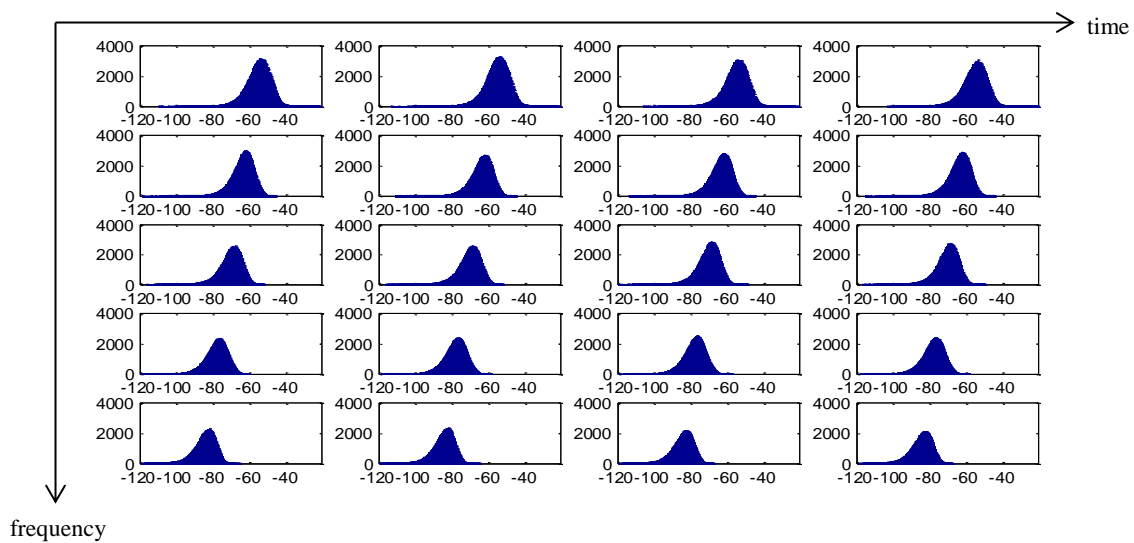
### e) Spectrum shape based features



Features	Mean Value
Centroid	4562 Hz
Rolloff	9186 Hz
Flatness	0.4113
Spread	4464 Hz

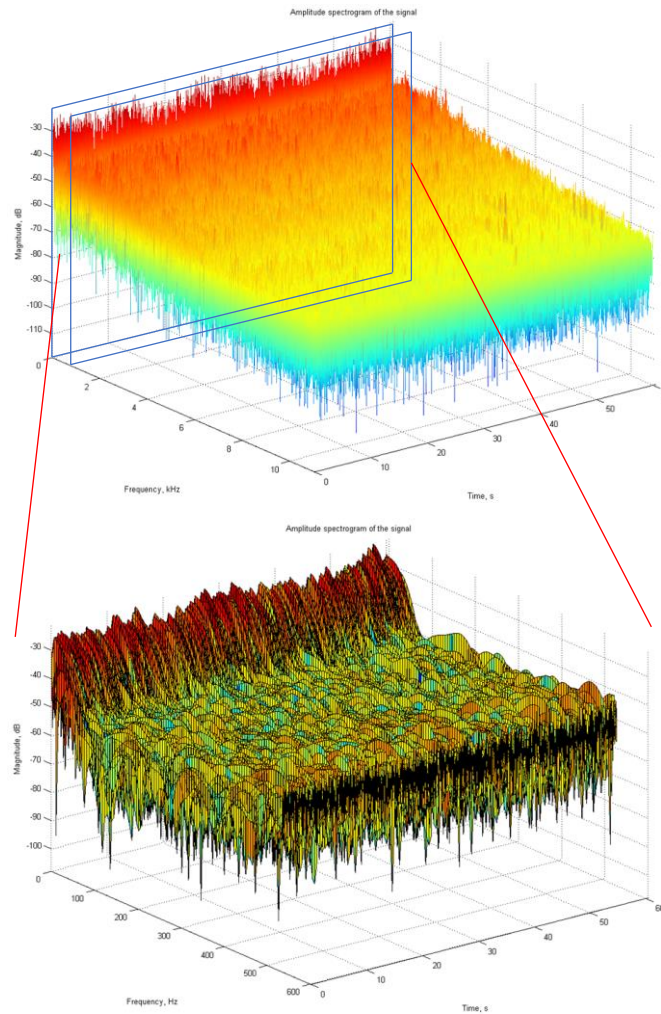
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

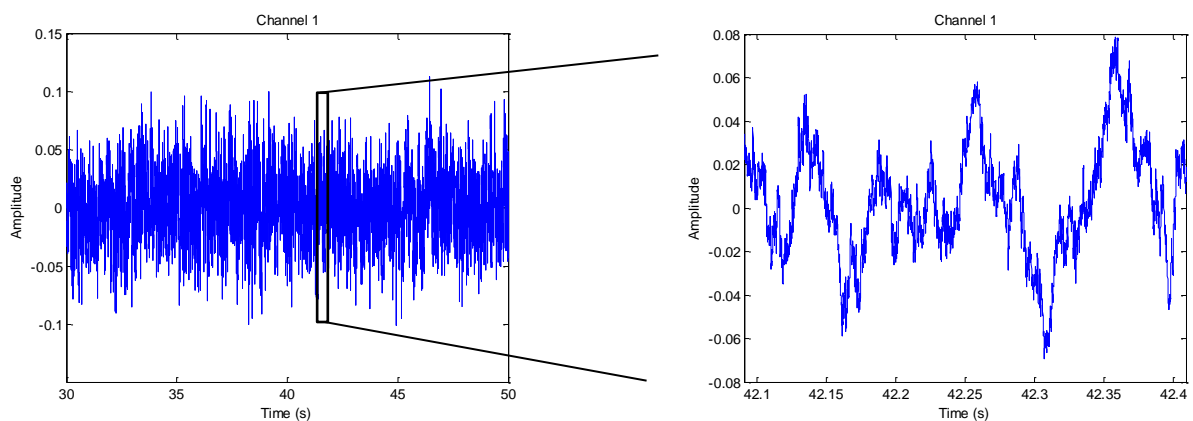
#### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. Their magnitudes are quite consistent in time.

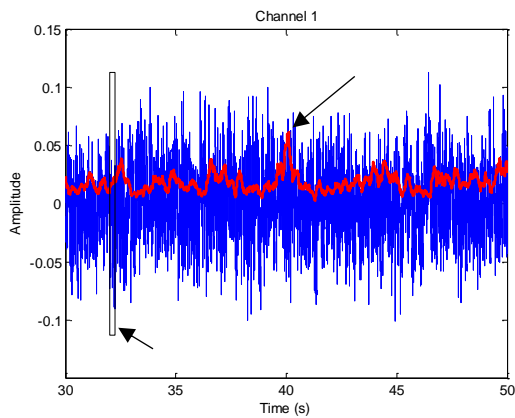
## 8) Neuro-Energetics (Audio GABA)

### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Slow amplitude fluctuation is observed under very small time scale.

a. Zero Crossing Rate (ZCR)

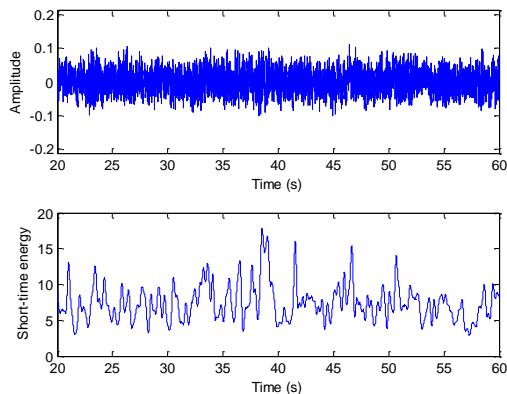


Window size = 10,000 samples (~0.23s)

ZCR is quite consistent throughout the section of the sound examined (50s). The fundamental frequency of the sound is very low and has small variation across time.

This sound shows small short-term varying characteristics. Long-term characteristic is still quite constant.

b. Short time energy (STE)

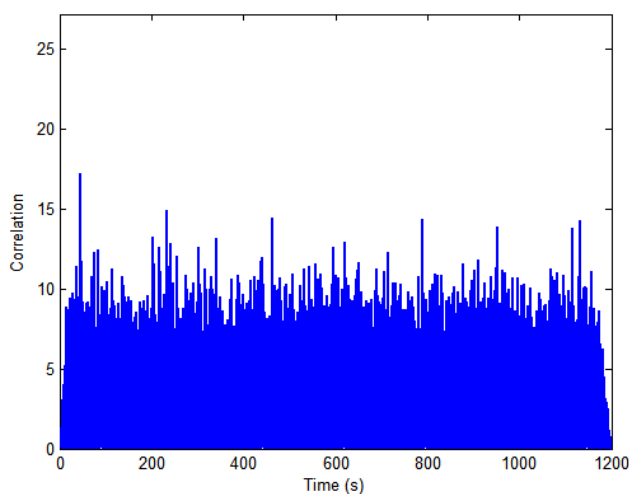


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE is fluctuating most of the times. Some energy surges have been observed. But their occurrences appear to be random.

c. Auto-correlation

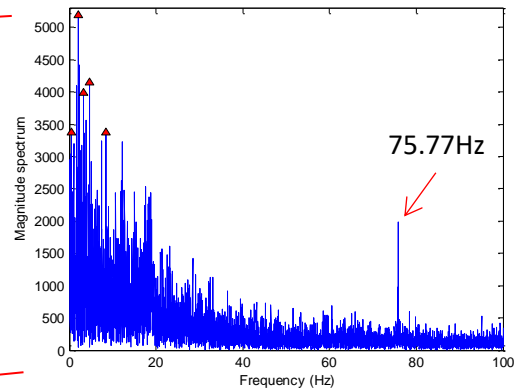
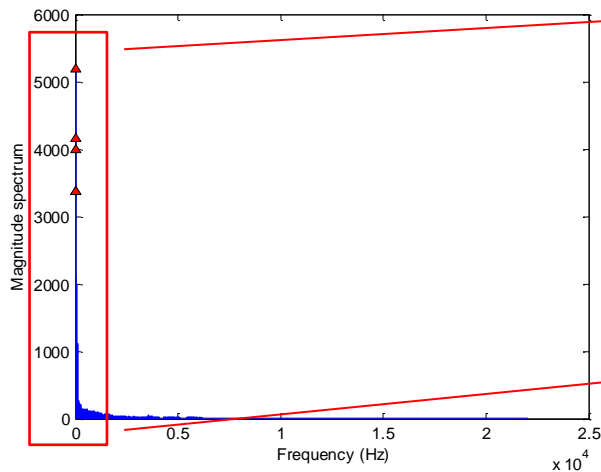


Segment/window size = 50,000 samples (~1.13s)

No repeating segment in this sound.

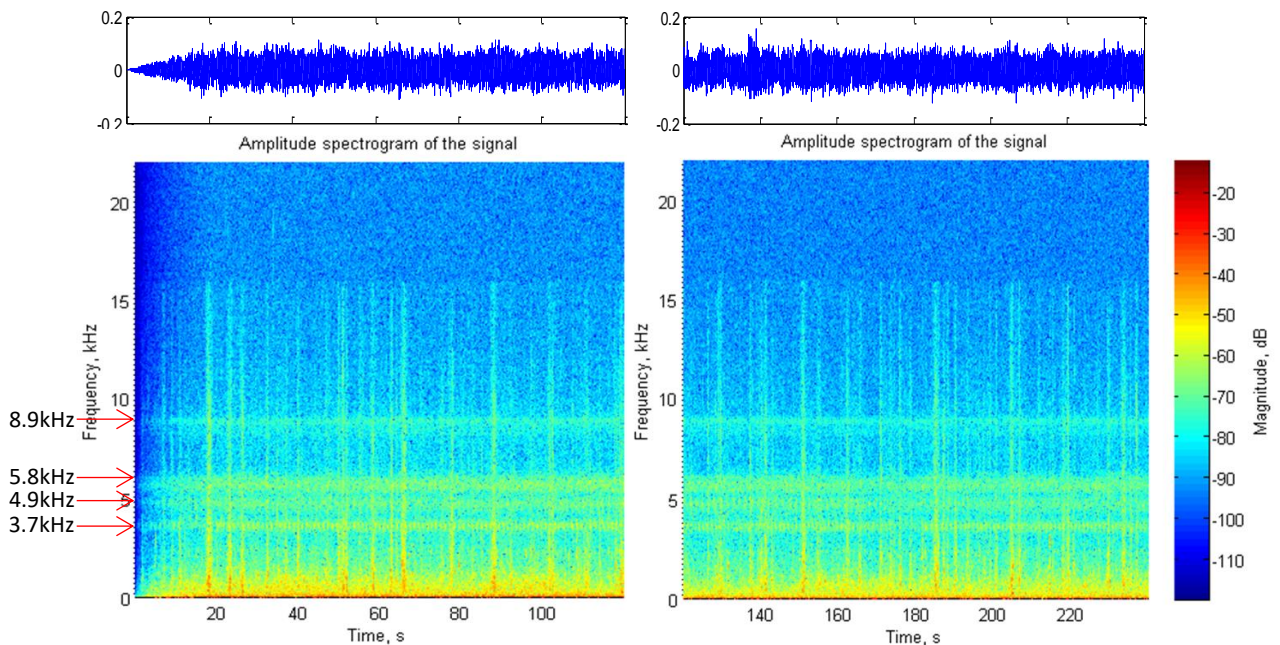
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 0 to 10 Hz. The highest peak is at 2 Hz.

### b) Short-Time Fourier Transform (STFT)

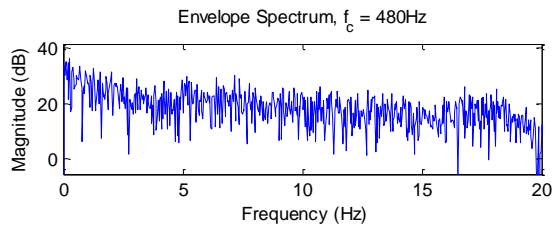
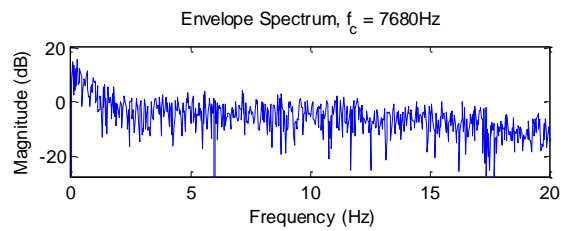
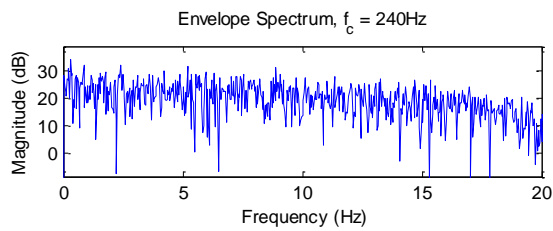
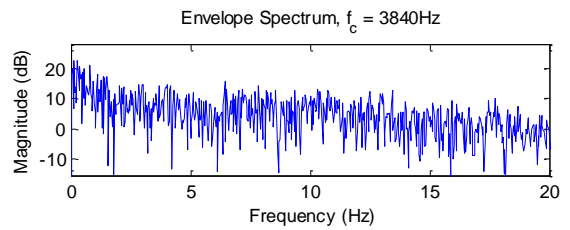
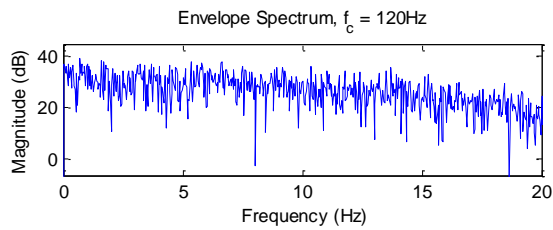
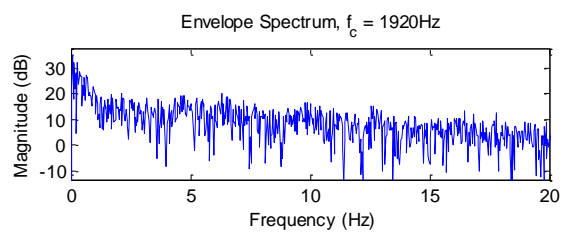
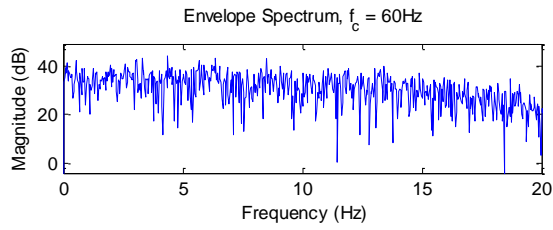
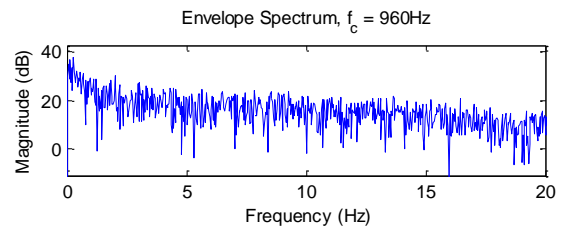
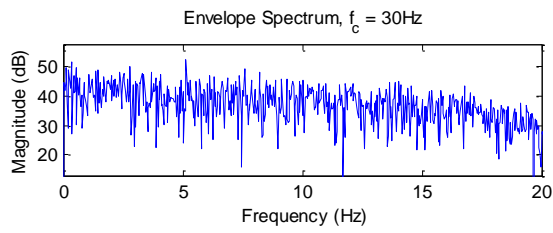


FFT size = 4096; window size = 1024 (~0.02s)

The spectrum is changing randomly in time. Short-term variation is due to the rise and fall of the sea/beach waves. Signal energy is mainly concentrated below 100 Hz most of the time (red color region). Some consistent energy frequencies are observed at about 3.7, 4.9, 5.8 and 8.9 kHz.

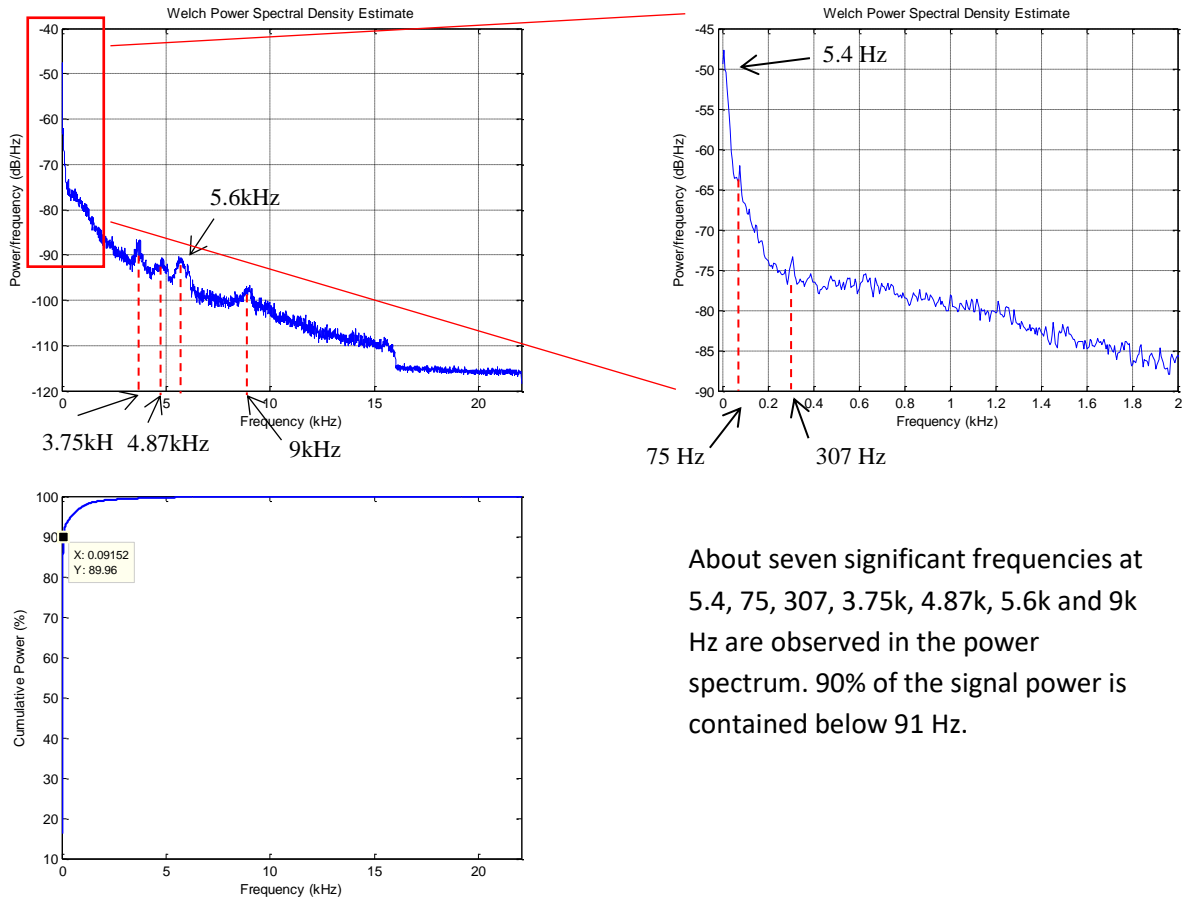
### c) Envelope Modulation Spectrum (EMS)

Same methodology as described in 1(c) has been used. The results are given below:



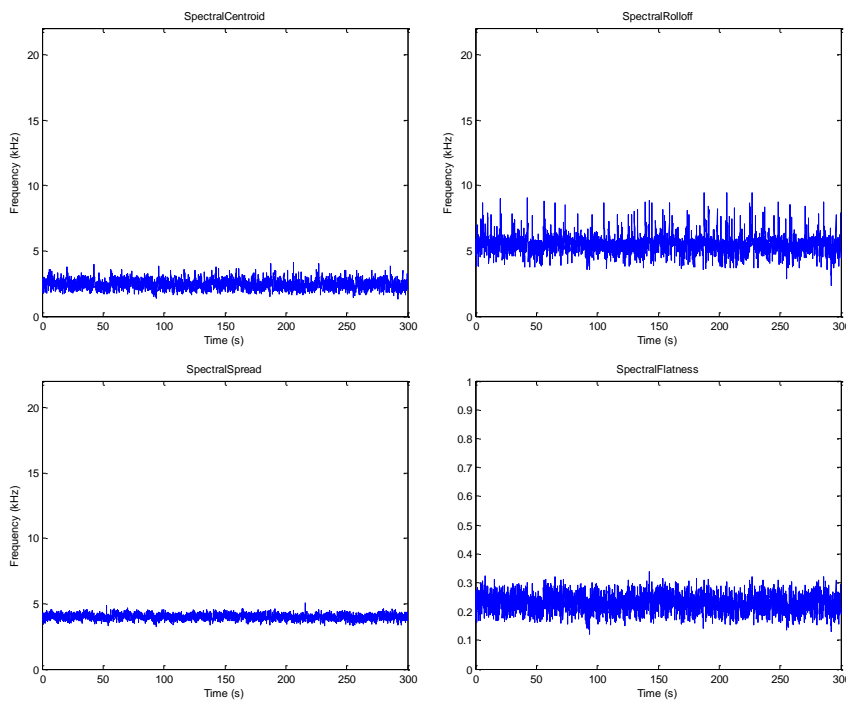
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



About seven significant frequencies at 5.4, 75, 307, 3.75k, 4.87k, 5.6k and 9k Hz are observed in the power spectrum. 90% of the signal power is contained below 91 Hz.

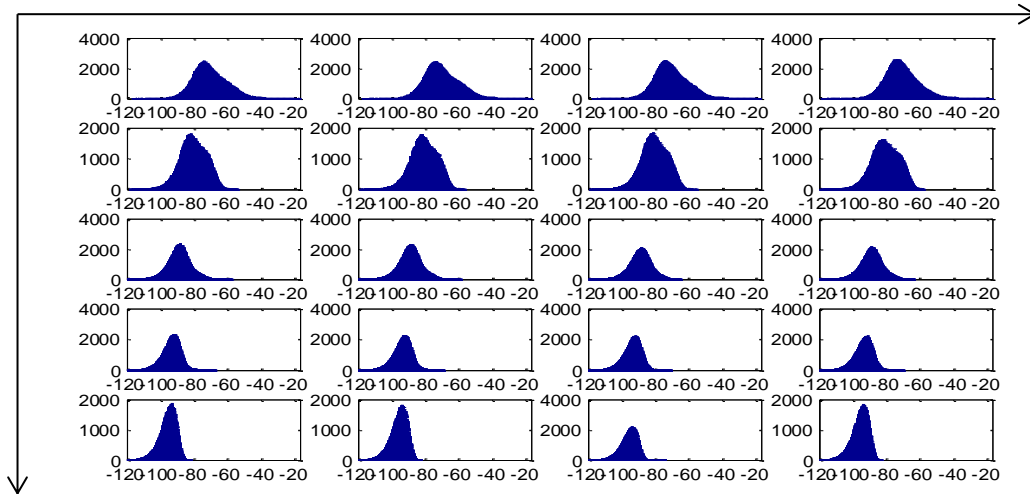
### e) Spectrum shape based features



Features	Mean Value
Centroid	2460 Hz
Rolloff	5557 Hz
Flatness	0.2291
Spread	4020 Hz

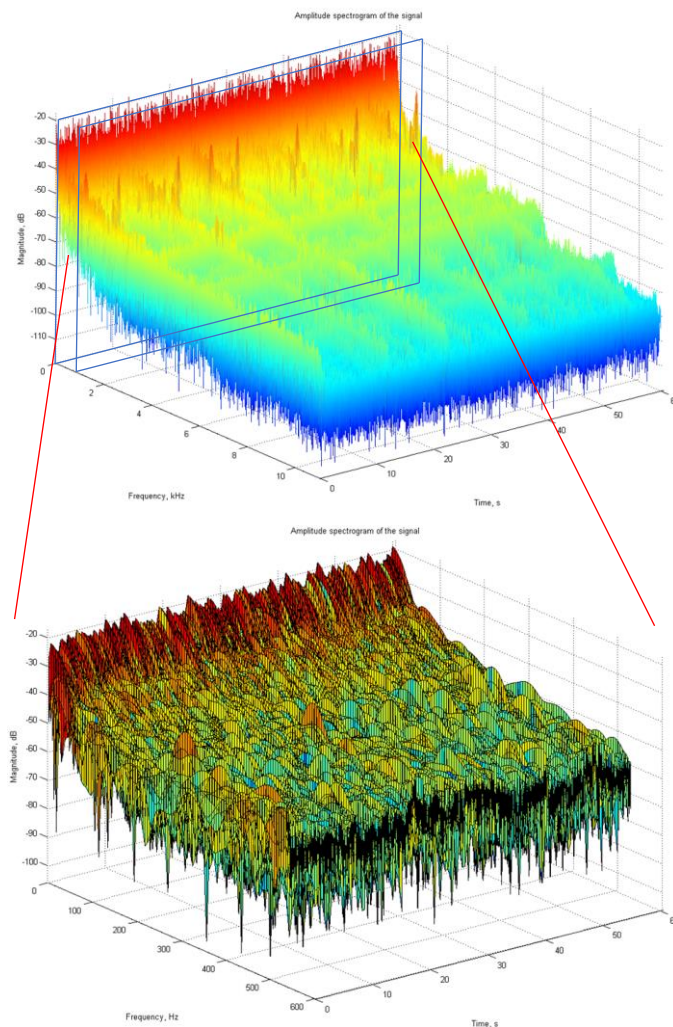
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

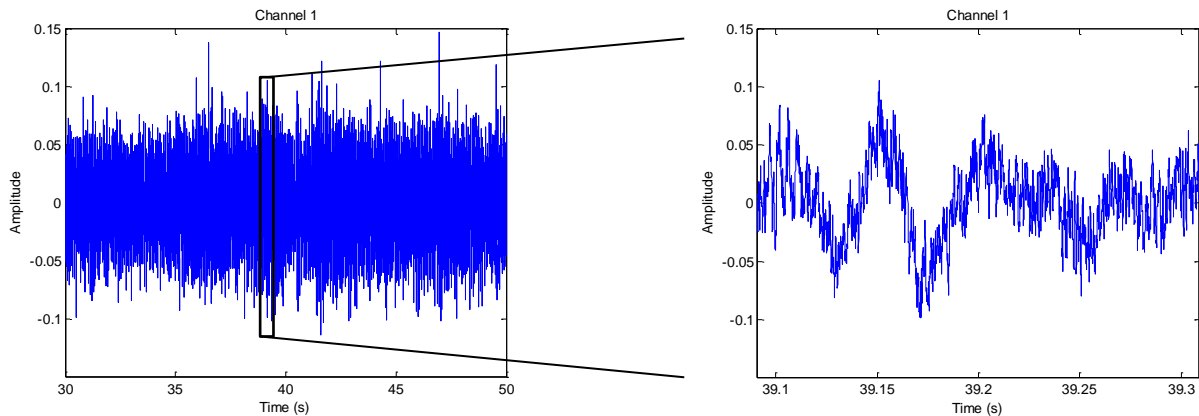
### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. Their magnitudes are quite consistent in time.

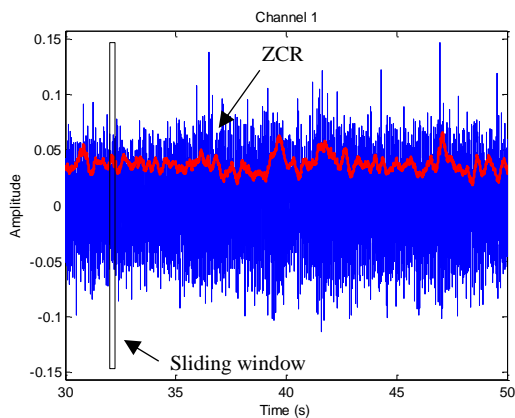
## 9) Digital C60

### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Noisy and slow amplitude fluctuation is observed under very small time scale.

#### a. Zero Crossing Rate (ZCR)

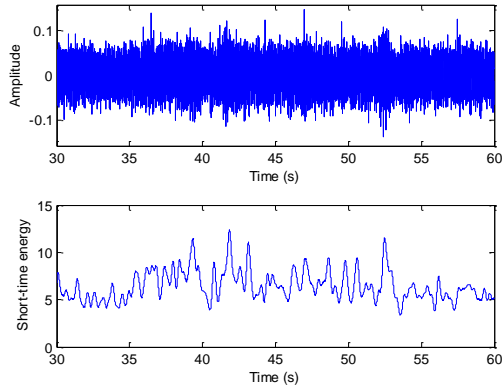


Window size = 10,000 samples (~0.23s)

ZCR is quite consistent throughout the section of the sound examined (50s). The fundamental frequency of the sound is quite low and has small variation across time.

This sound shows small short-term varying characteristics. Long-term characteristic is still quite constant.

#### b. Short time energy (STE)

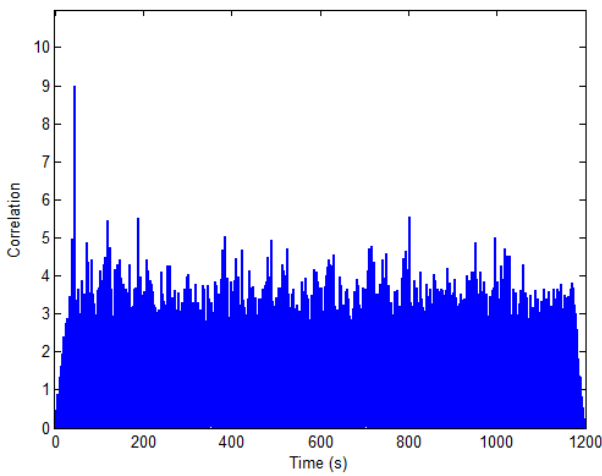


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE fluctuates slightly according to the amplitude of the signal. The peak magnitudes of the energy surges appear to be quite random.

c. Auto-correlation

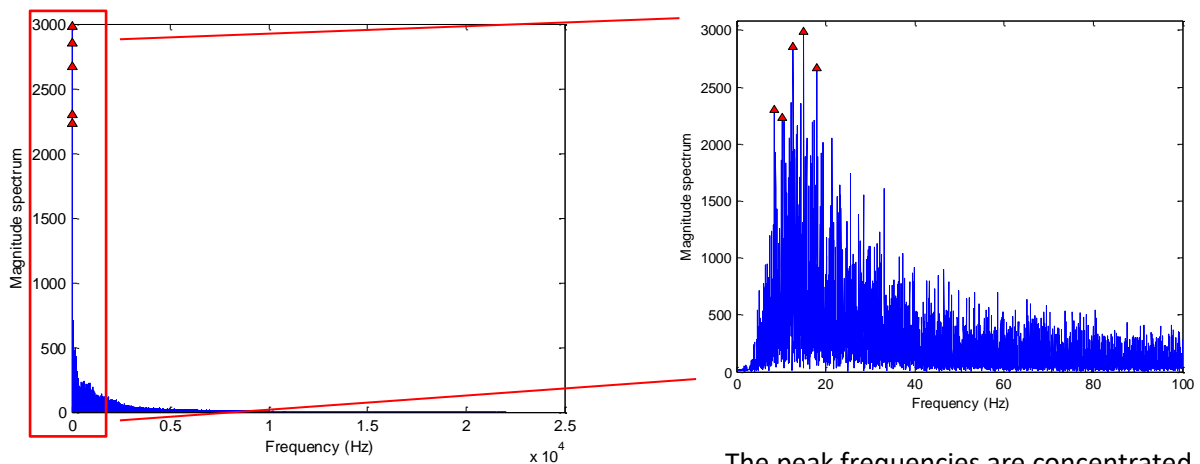


Segment/window size = 50,000 samples (~1.13s)

Only one peak is observed. In other words, there is no repeating segment in this sound.

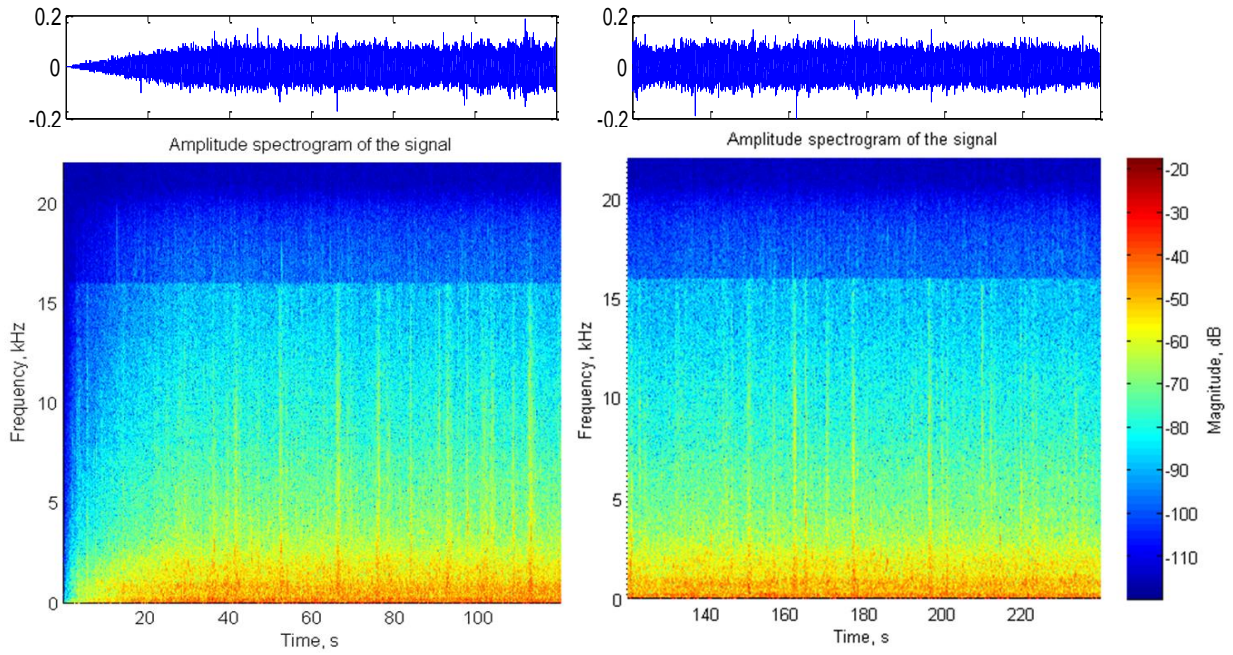
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 8 to 20 Hz. The highest peak is at 15 Hz.

b) Short-Time Fourier Transform (STFT)

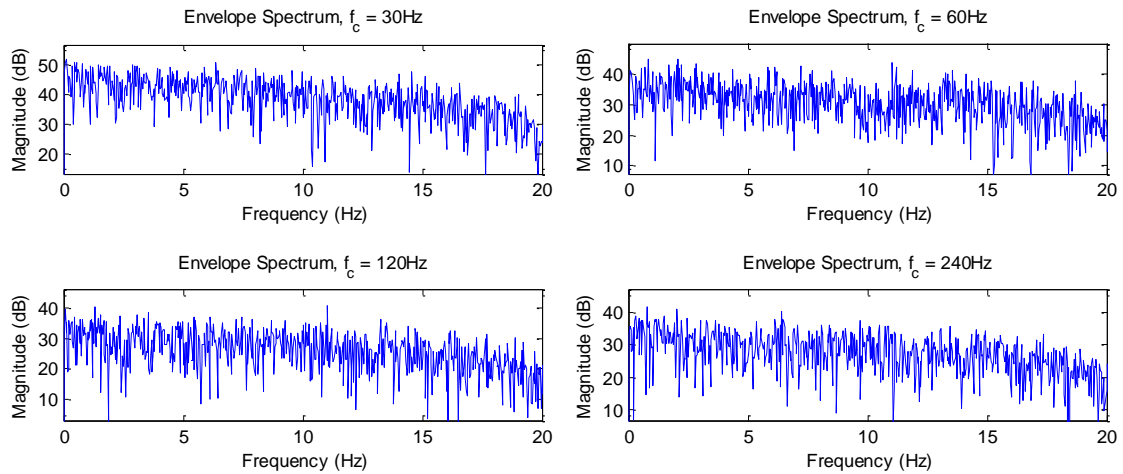


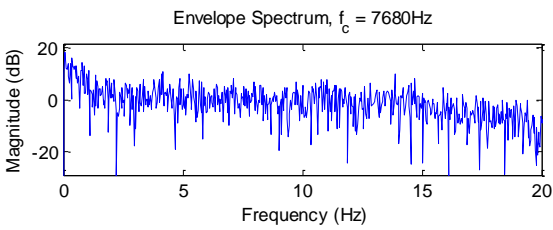
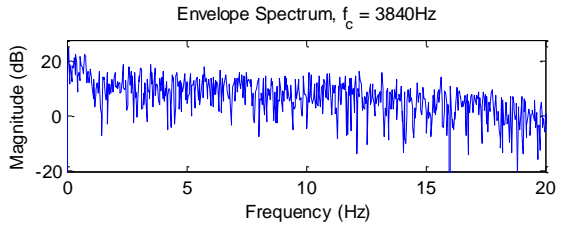
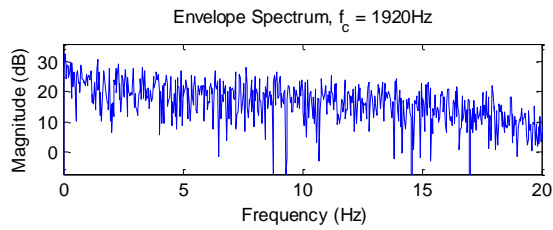
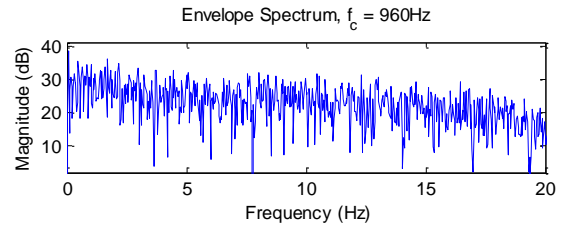
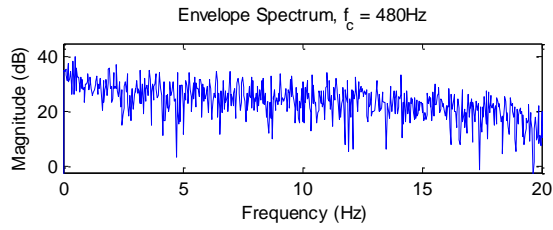
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum is changing slightly in time. Small short-term variation is due to the rise and fall of the sea/beach waves. Signal energy is mainly concentrated below 2 kHz most of the time (bottom red color region).

### c) Envelope Modulation Spectrum (EMS)

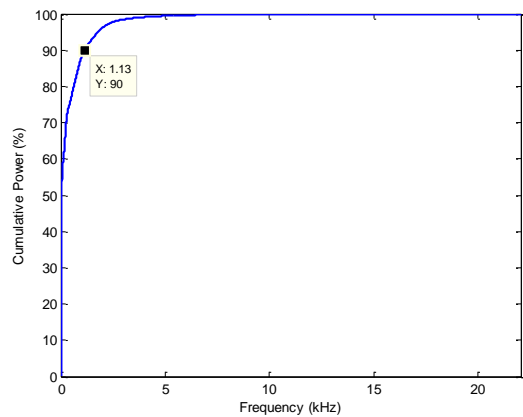
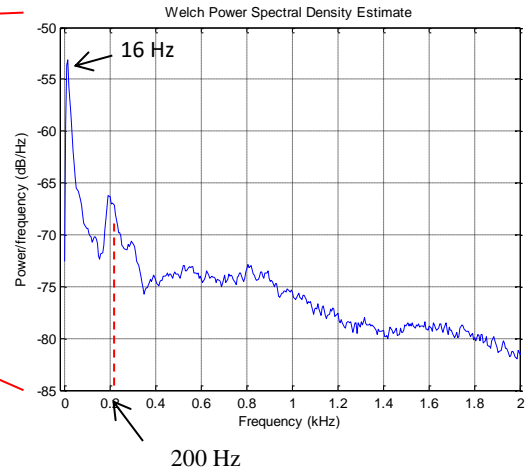
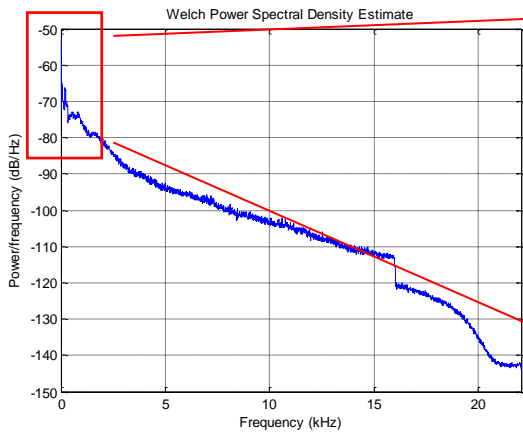
Same methodology as described in 1(c) has been used. The results are given below:





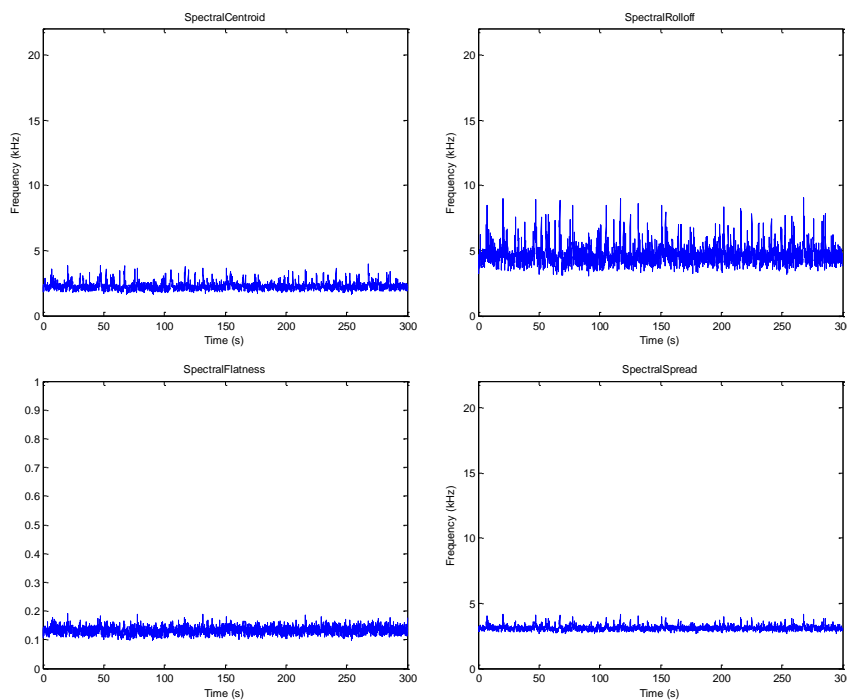
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



Two significant frequencies at 16 and 200 Hz are observed in the power spectrum. 90% of the signal power is contained below 1.13 kHz.

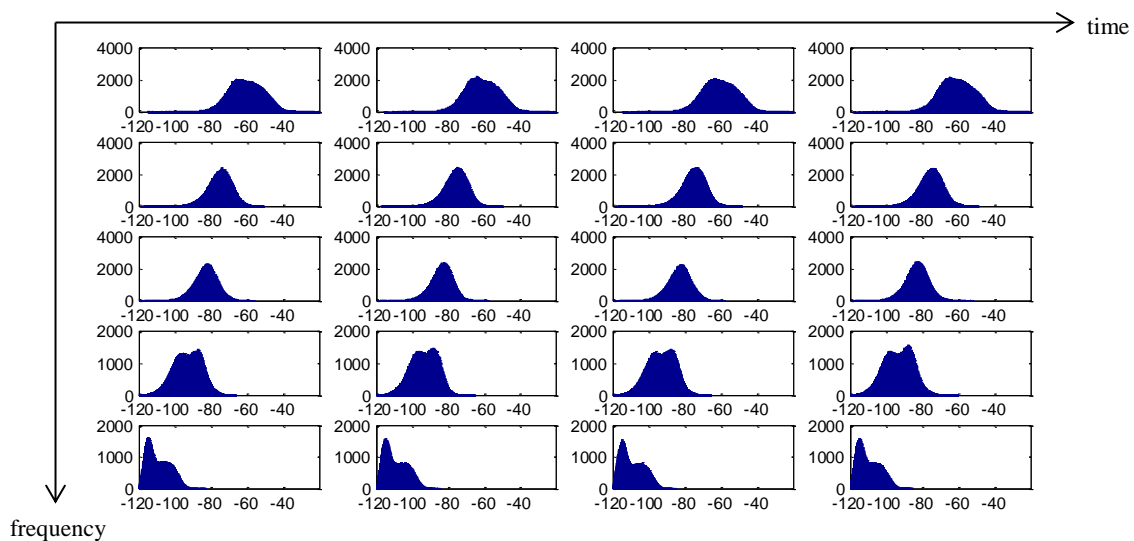
### e) Spectrum shape based features



Features	Mean Value
Centroid	2266 Hz
Rolloff	4688 Hz
Flatness	0.1329
Spread	3108 Hz

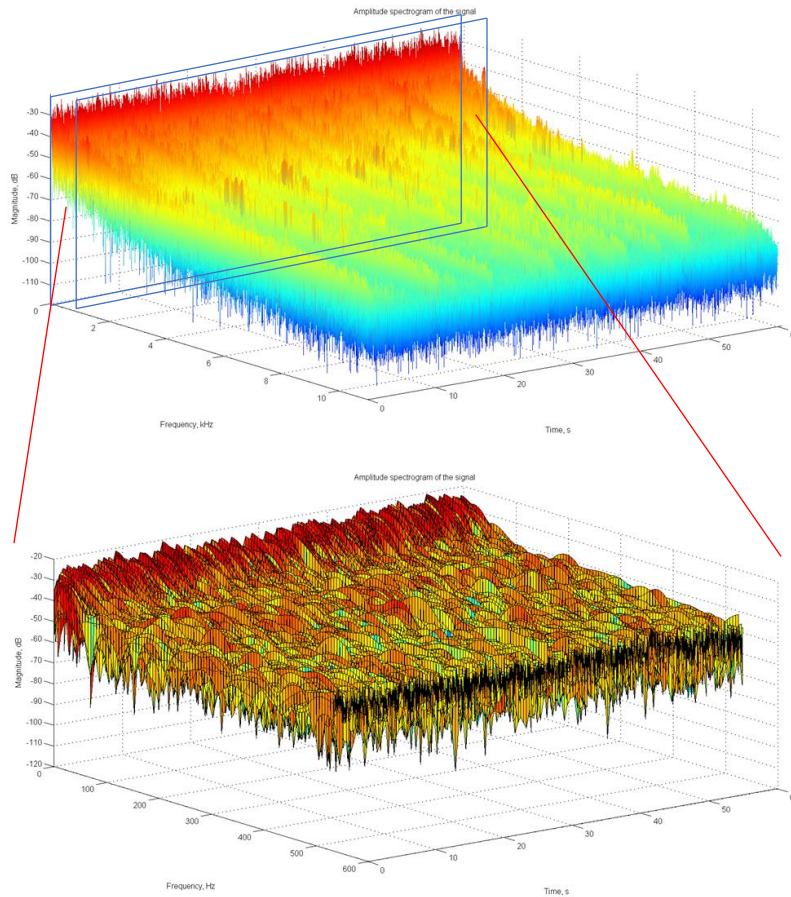
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low and medium-high frequencies sections show less noise-like characteristics. The very-low frequency sections contain highest energy.

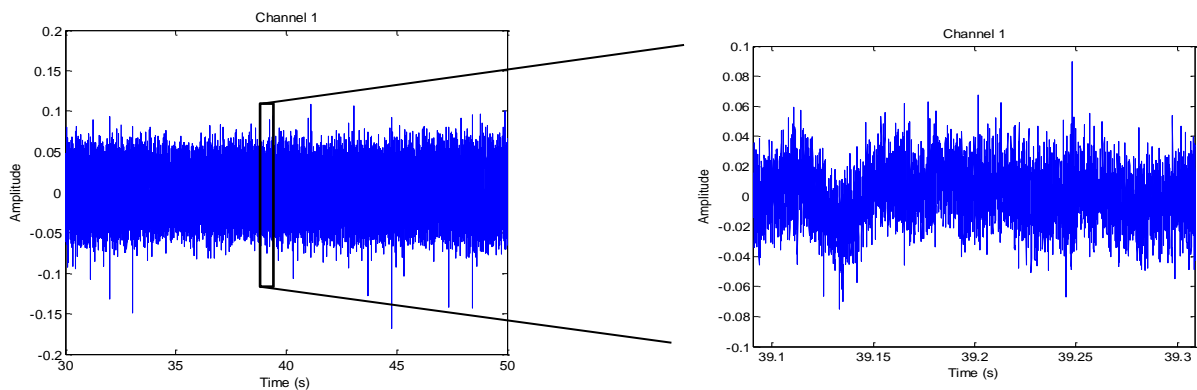
#### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. The extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. Their magnitudes are quite consistent in time.

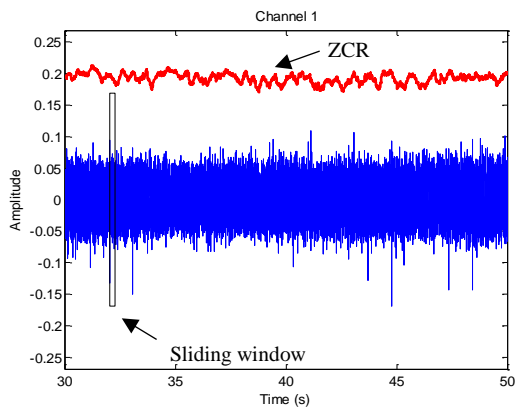
## 10) Digital CBD

### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Even under very small time scale, the samples are very random and noise-like. The amplitude fluctuation is faster in this case.

### a. Zero Crossing Rate (ZCR)

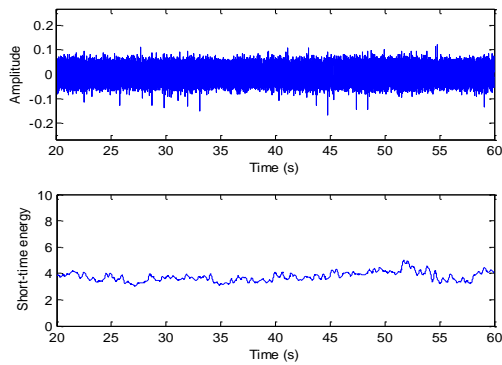


Window size = 10,000 samples ( $\sim 0.23s$ )

ZCR is consistently high throughout the section of the sound examined. The fundamental frequency of the sound is high and has small variation across time.

This sound shows small short-term varying characteristics. Long-term characteristic is still quite constant.

### b. Short time energy (STE)

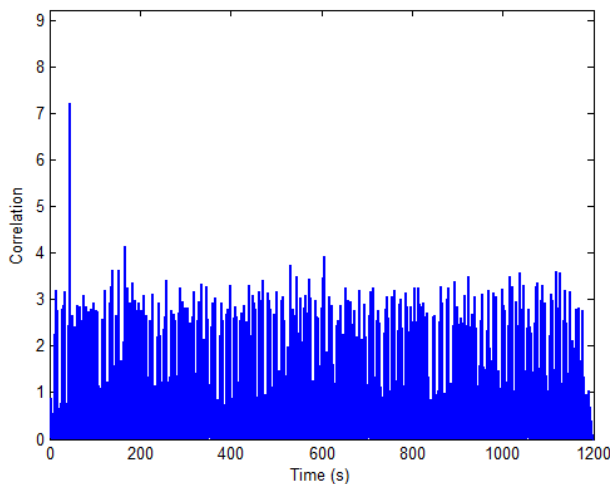


Window size = 20,000 samples ( $\sim 0.45s$ )

Window type = Hamming

STE is quite constant and low. No large fluctuation of signal energy is observed.

### c. Auto-correlation

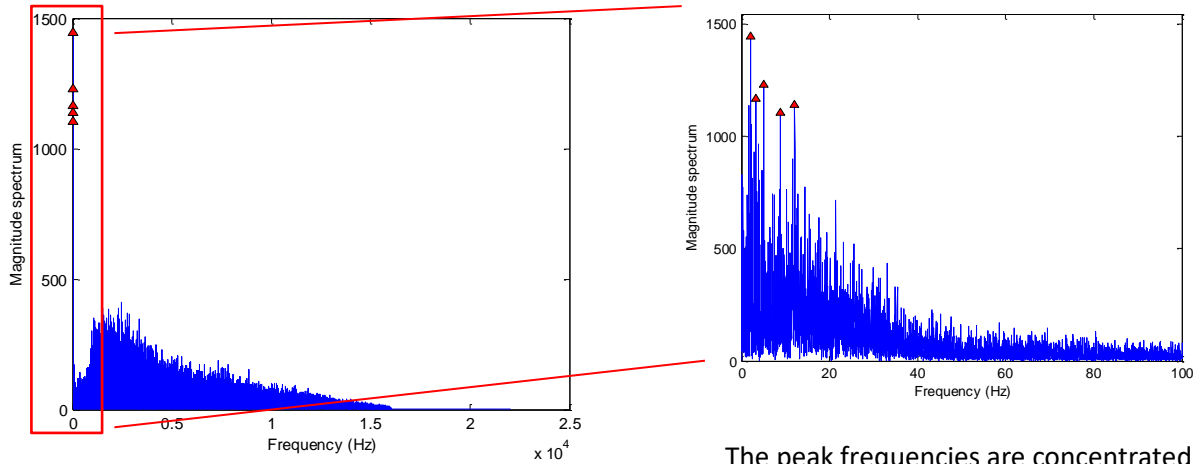


Segment/window size = 50,000 samples ( $\sim 1.13s$ )

Only one peak is observed. In other words, there is no repeating segment in this sound.

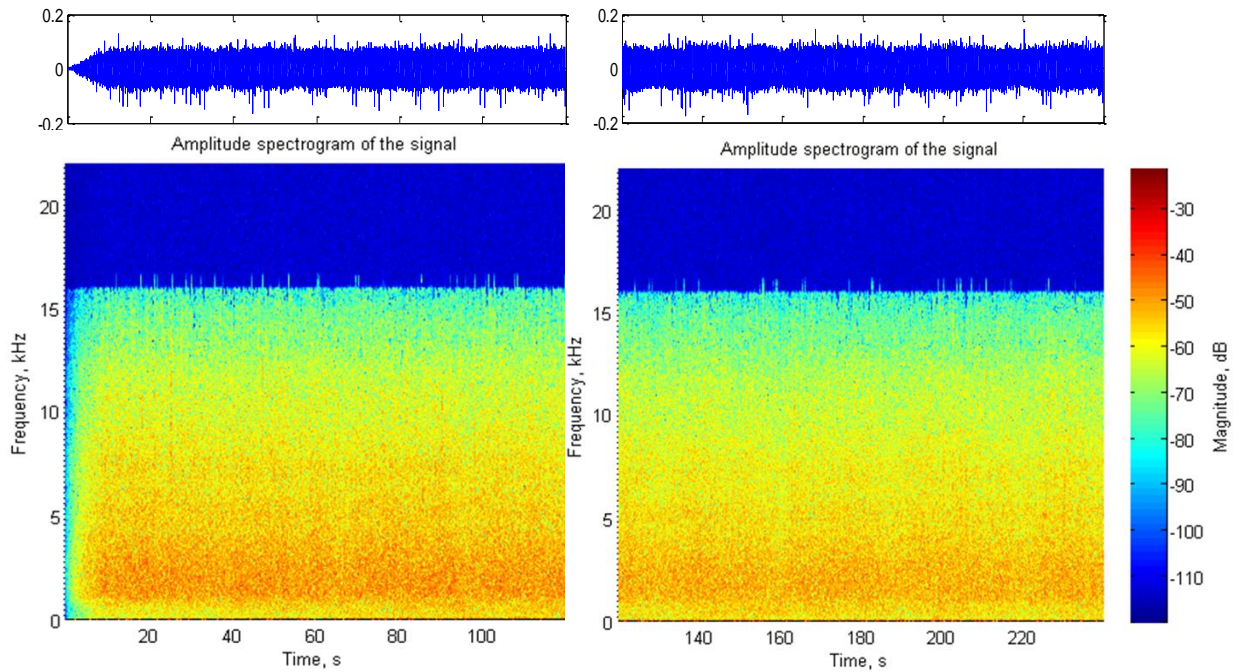
## ii) Frequency Domain Features

### a) Peak Frequency



The peak frequencies are concentrated around 0 to 15 Hz. The highest peak is at 2 Hz.

b) Short-Time Fourier Transform (STFT)

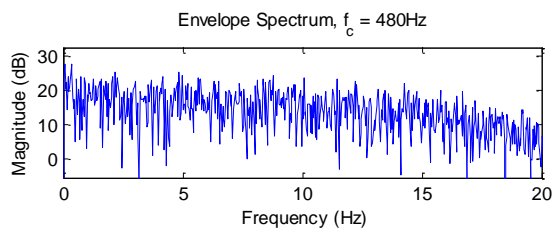
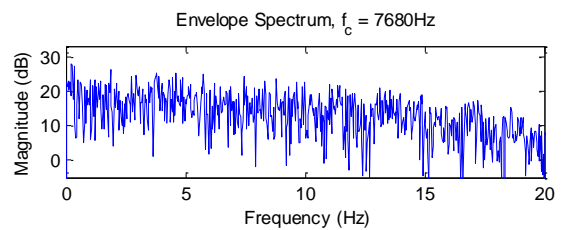
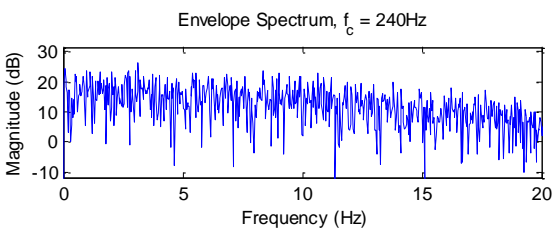
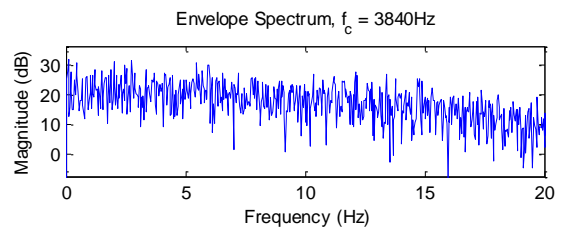
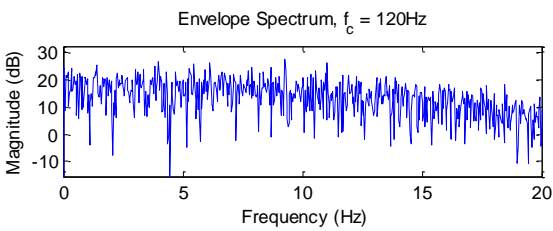
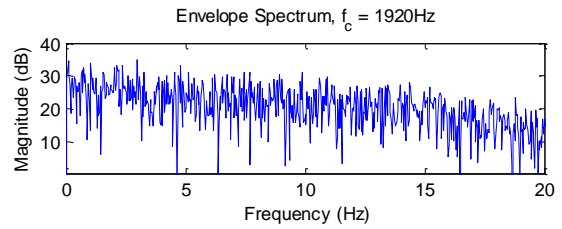
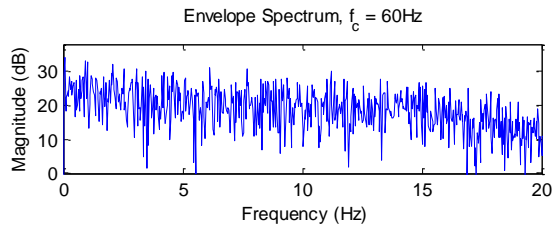
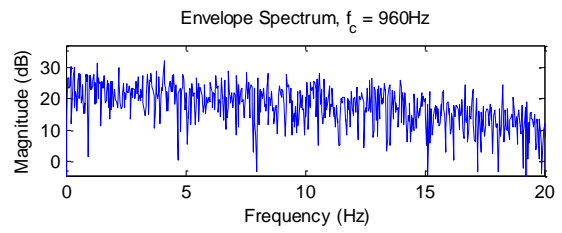
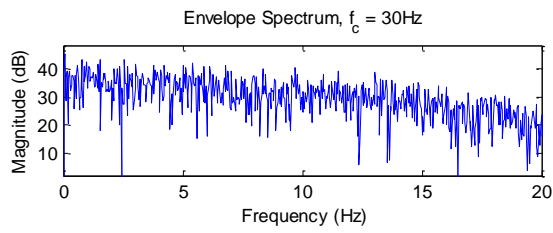


FFT size = 4096; window size = 1024 (~0.02s)

The spectrum has constant long-term characteristics. Signal energy is concentrated between 1 and 4 kHz (red color region).

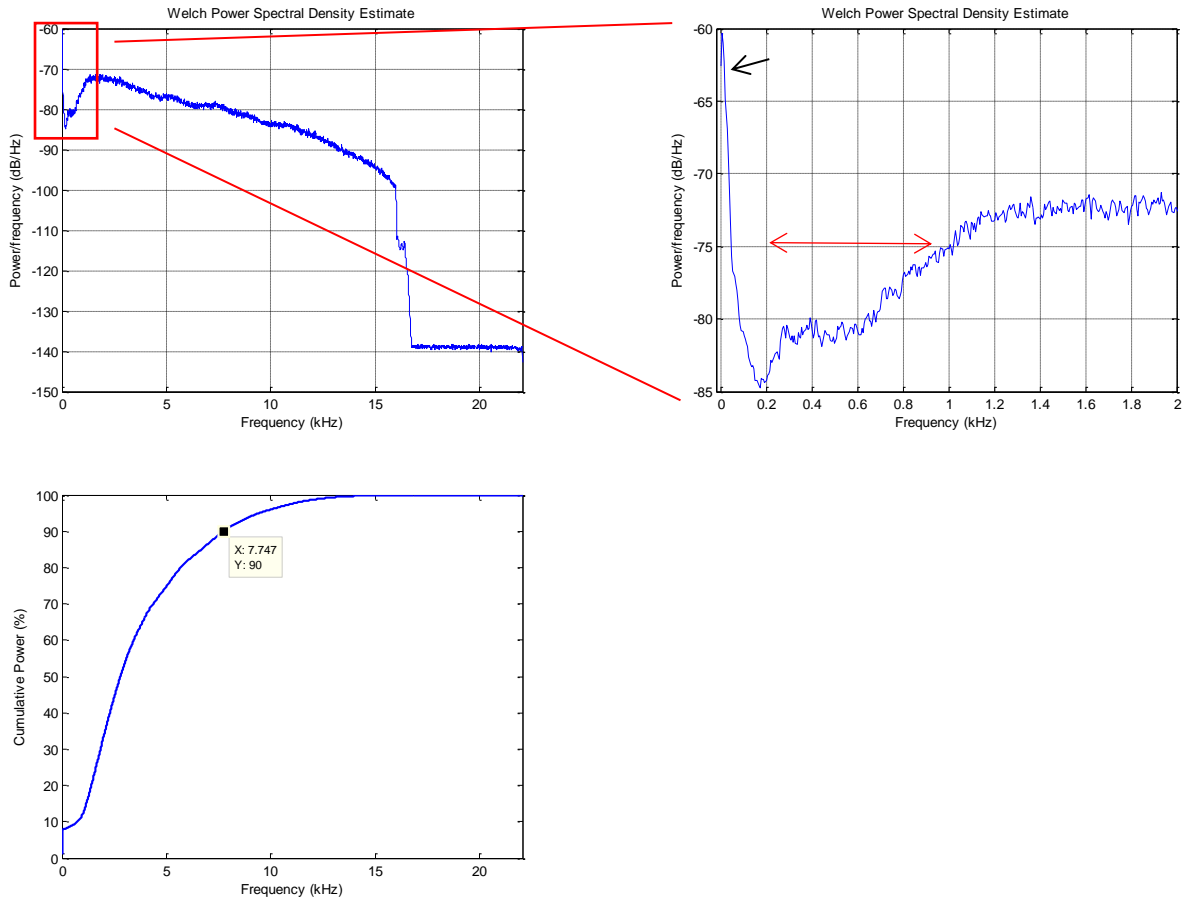
c) Envelope Modulation Spectrum (EMS)

Same methodology as described in 1(c) has been used. The results are given below:

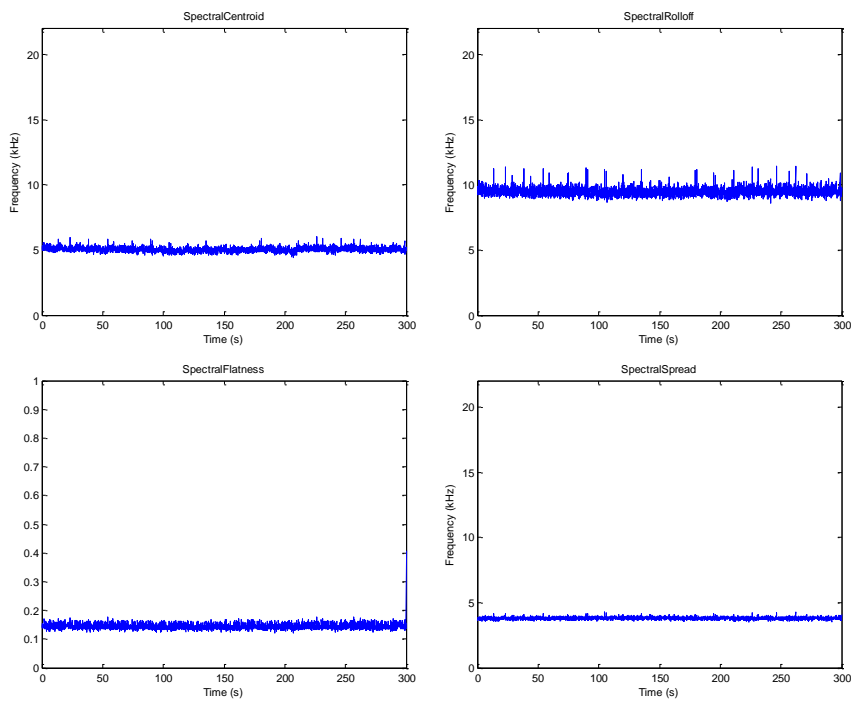


No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



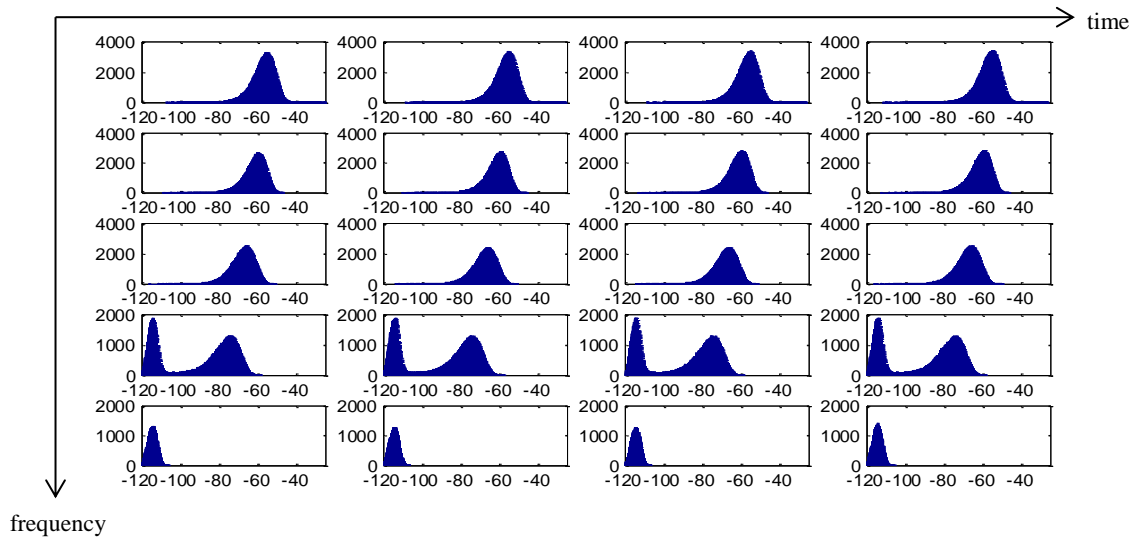
### e) Spectrum shape based features



Features	Mean Value
Centroid	5044 Hz
Rolloff	9490 Hz
Flatness	0.1434
Spread	3798 Hz

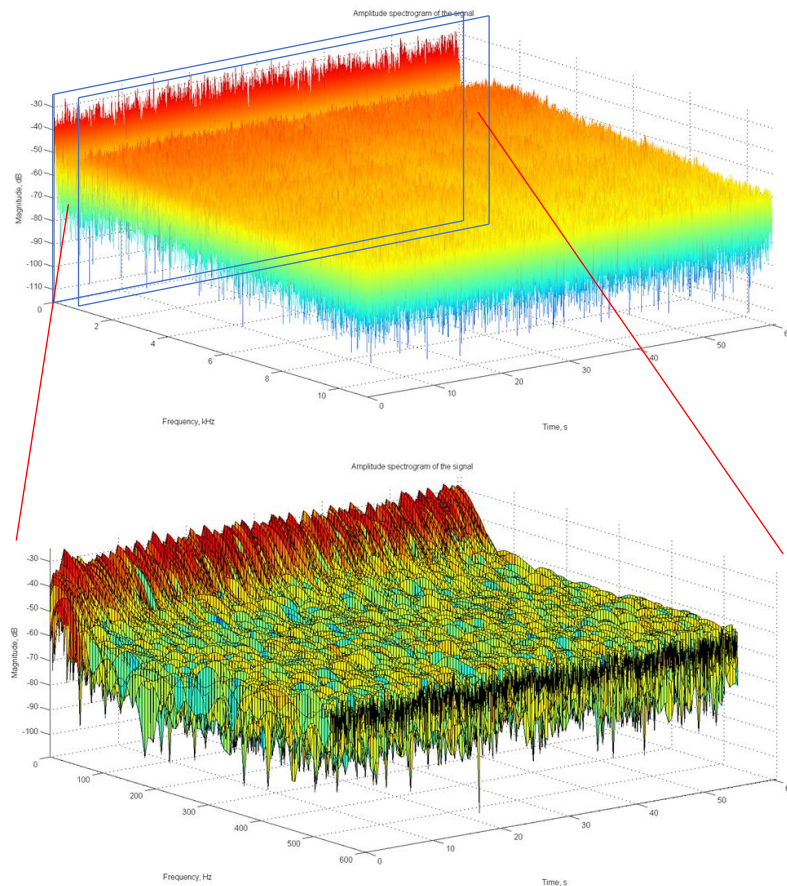
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The medium-high frequency sections appear to be less noise-like. The very-low frequency sections contain highest energy.

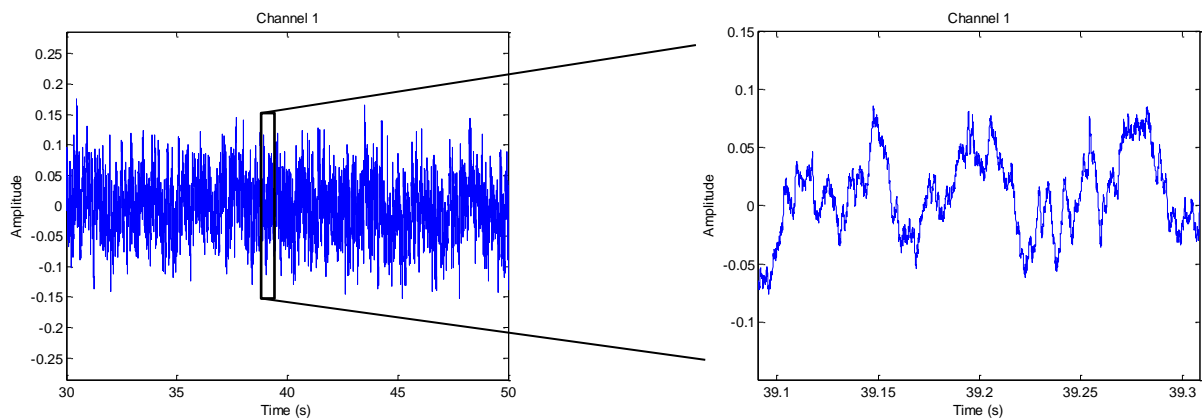
### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal are quite consistent in time. The extremely low frequency (ELF) (< 30Hz) is very prominent in this signal.

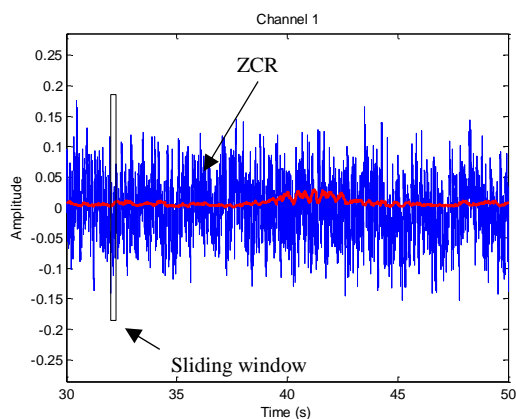
# 11) Digital Nootropic

## i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Slow amplitude fluctuation is observed under very small time scale.

### a. Zero Crossing Rate (ZCR)

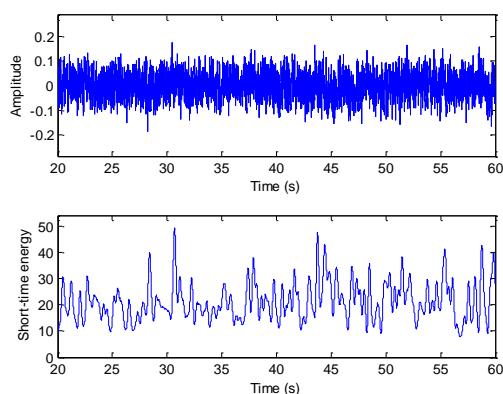


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (50s). The fundamental frequency of the sound is very low.

This sound shows constant long-term characteristics, very similar to noise.

### b. Short time energy (STE)

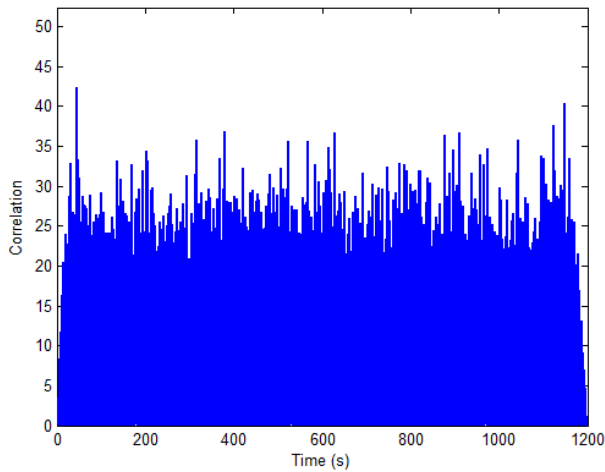


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE fluctuates most of the times. Some energy surges have been observed. But their occurrences appear to be random.

### c. Auto-correlation

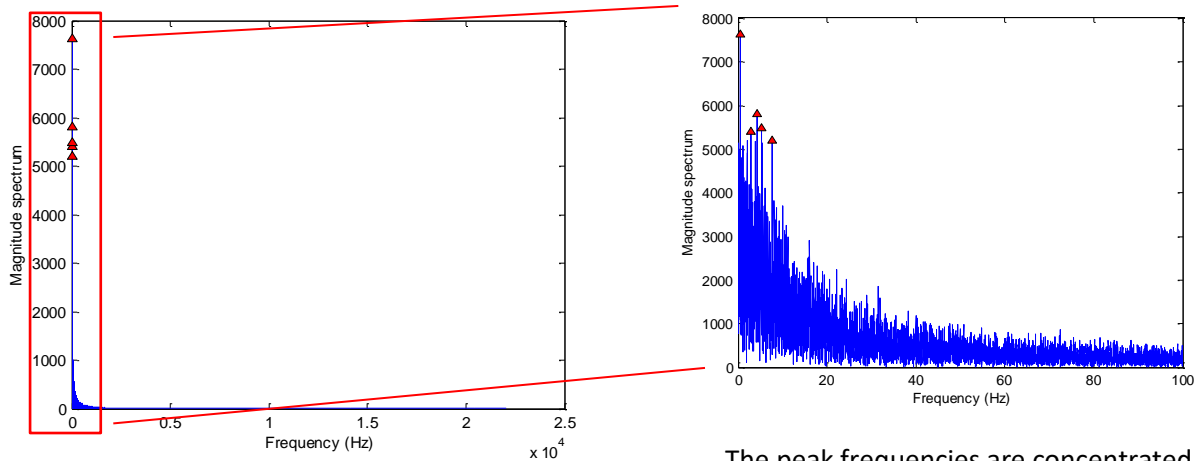


Segment/window size = 50,000 samples  
(~1.13s)

No repeating segment is found in this sound.

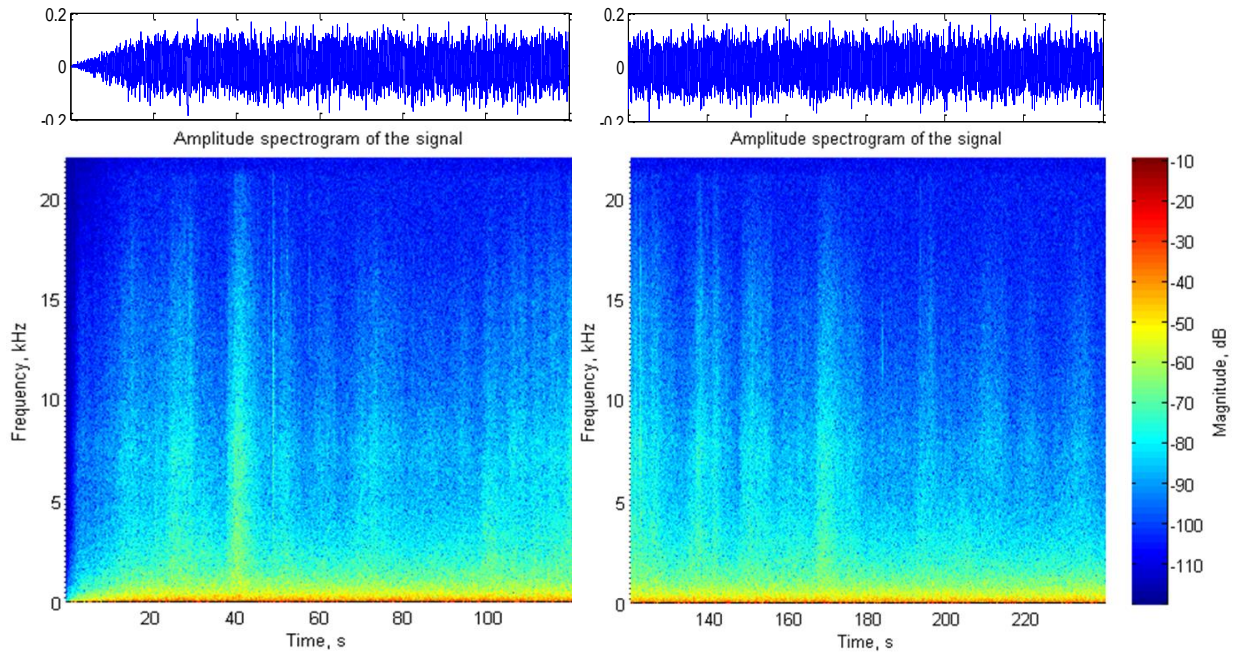
## ii) Frequency Domain Features

### a) Peak Frequency



The peak frequencies are concentrated around 0 to 10 Hz. The highest peak is at 0.48 Hz.

### b) Short-Time Fourier Transform (STFT)

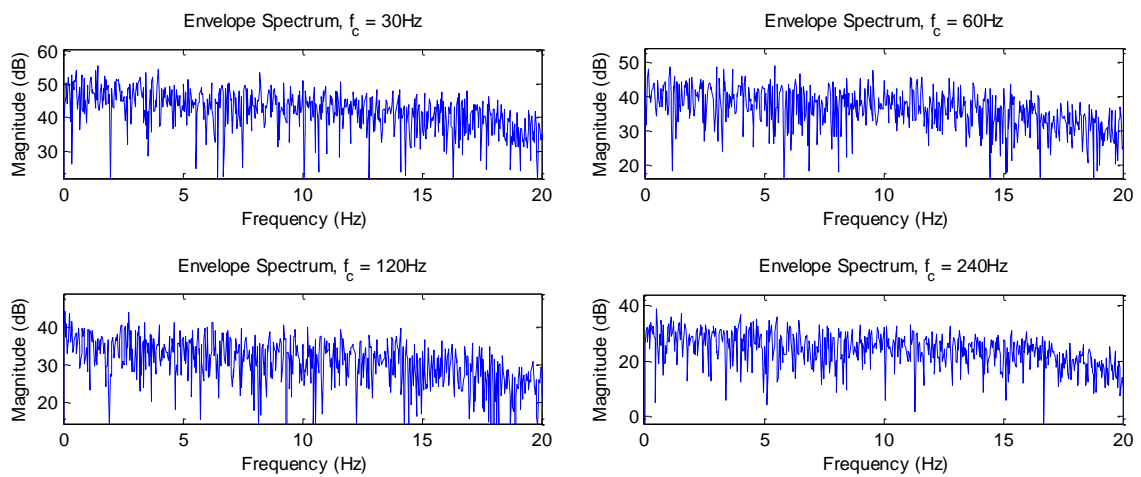


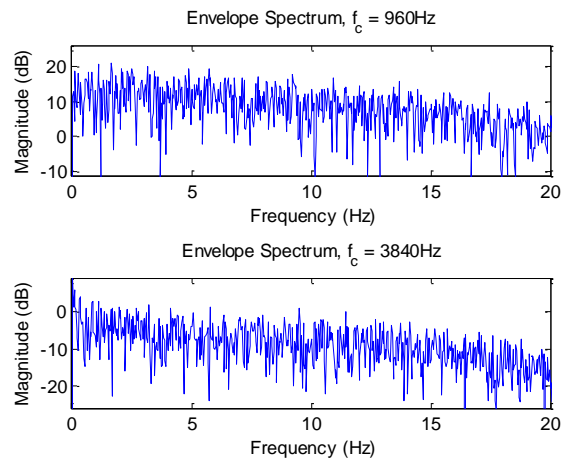
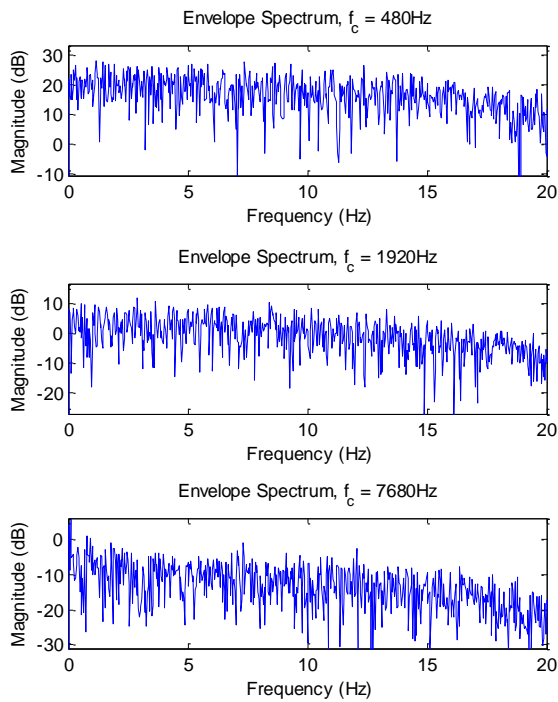
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum has constant long-term characteristics. Signal energy is concentrated below 0.1 kHz (bottom red color region).

### c) Envelope Modulation Spectrum (EMS)

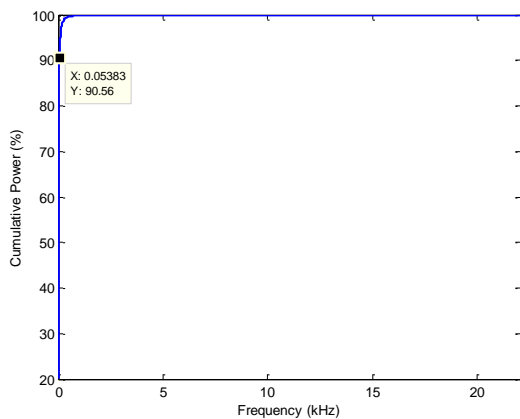
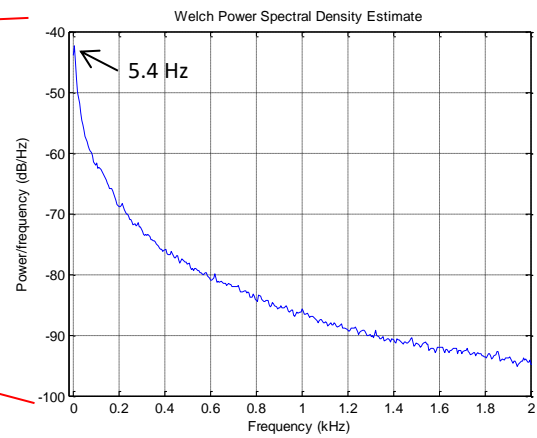
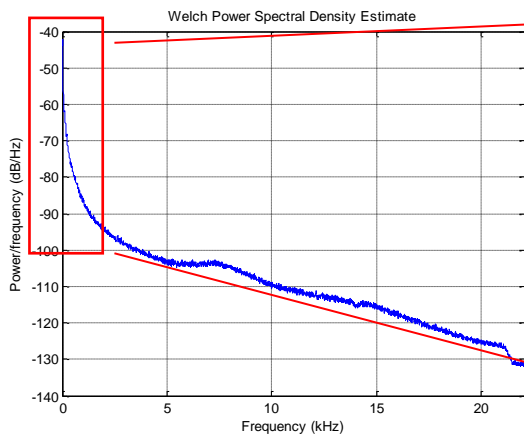
Same methodology as described in 1(c) has been used. The results are given below:





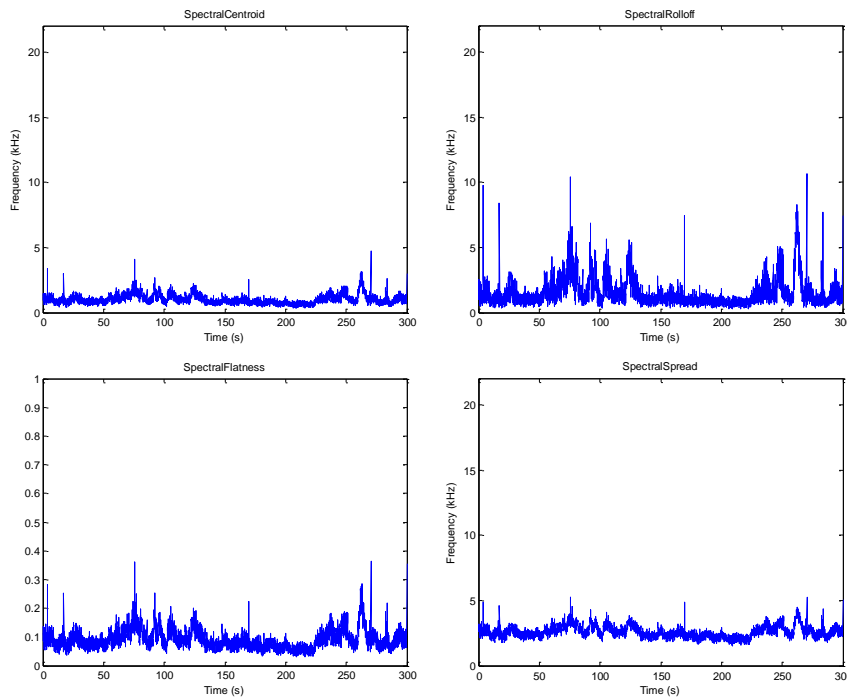
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



One significant frequency at 5.4 Hz is observed in the power spectrum. 90% of the signal power is contained below 54 Hz.

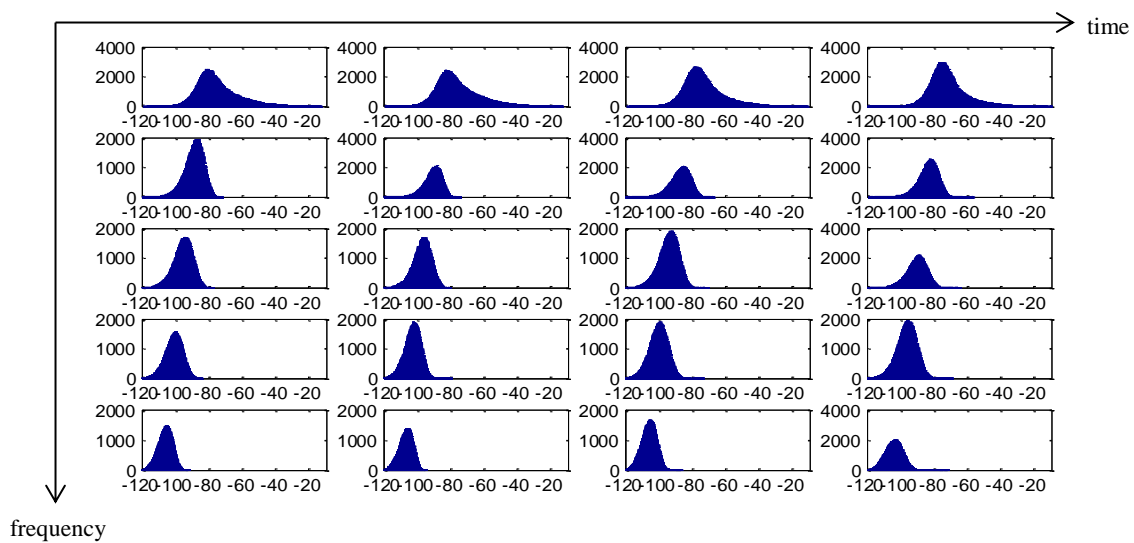
### e) Spectrum shape based features



Features	Mean Value
Centroid	1015 Hz
Rolloff	1508 Hz
Flatness	0.0909
Spread	2600 Hz

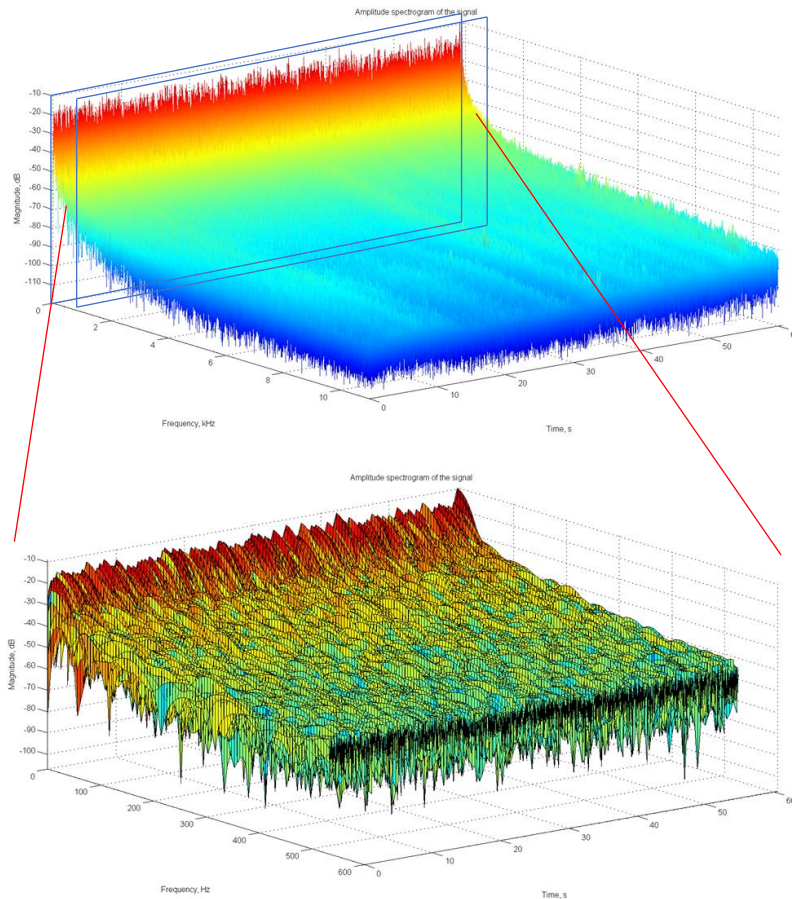
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

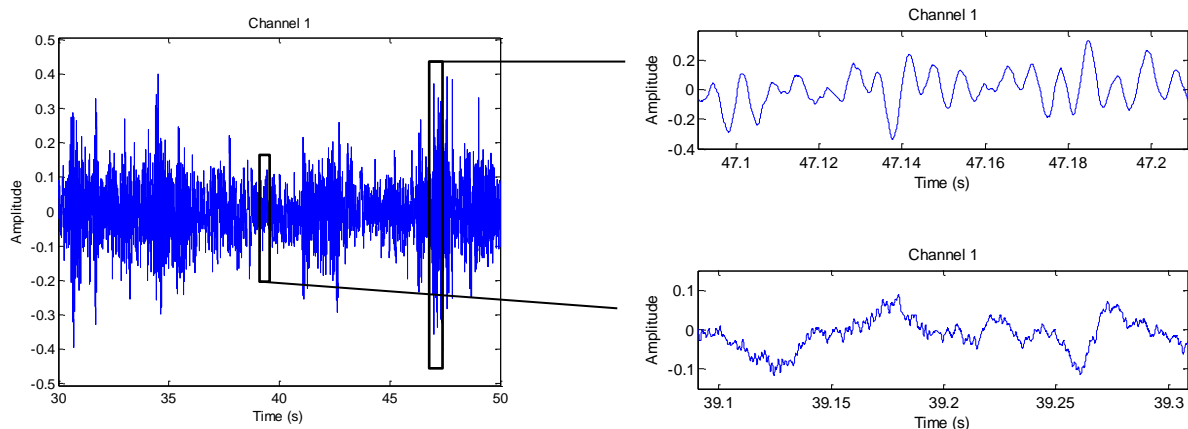
#### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal are quite consistent in time. The extremely low frequency (ELF) (< 30Hz) is very prominent in this signal.

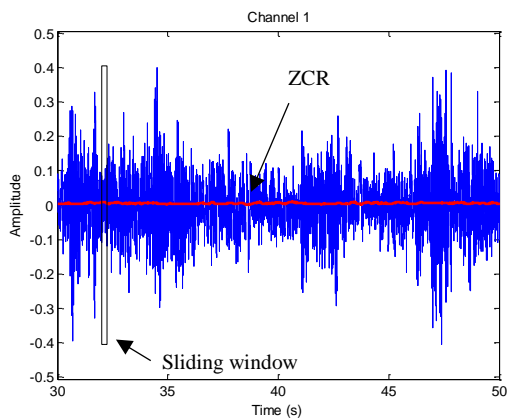
## 12) Marine Phytoplankton

### i) Time-domain features



The amplitude envelope changes in time according to the loudness of the sound. When zoomed in, the rate of amplitude fluctuation appears to be more random in the quiet region than the loud region.

a. Zero Crossing Rate (ZCR)

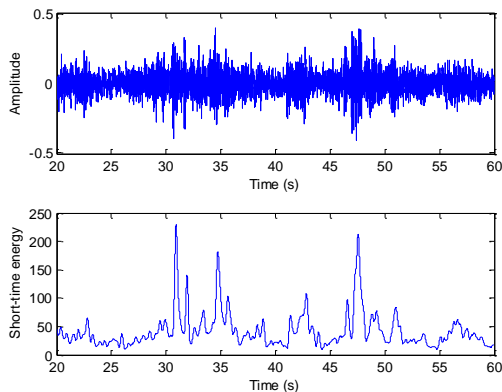


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (10s). The fundamental frequency of the sound is very low and close to zero.

The ZCR (and fundamental frequency) is not dependent on the magnitude of the sound. The long-term characteristic is constant.

b. Short time energy (STE)

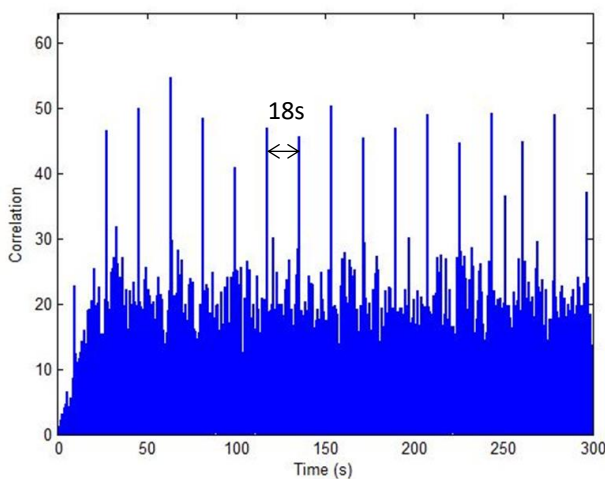


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE remains constant and low most of the times. Some energy surges have been observed. But their occurrences appear to be random.

c. Auto-correlation

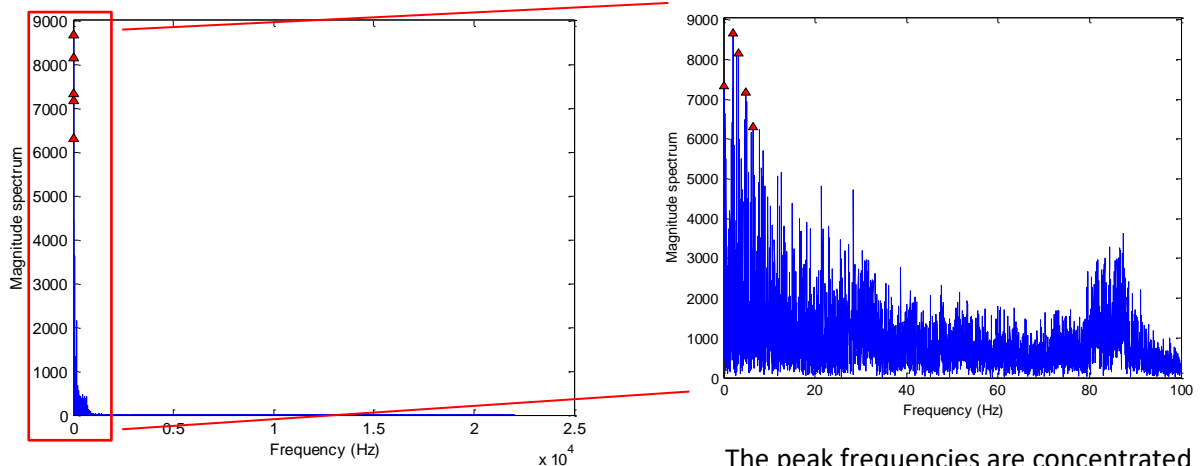


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 18s (or 0.3 minutes). In other words, identical segment of 0.3 minutes is repeated in this sound.

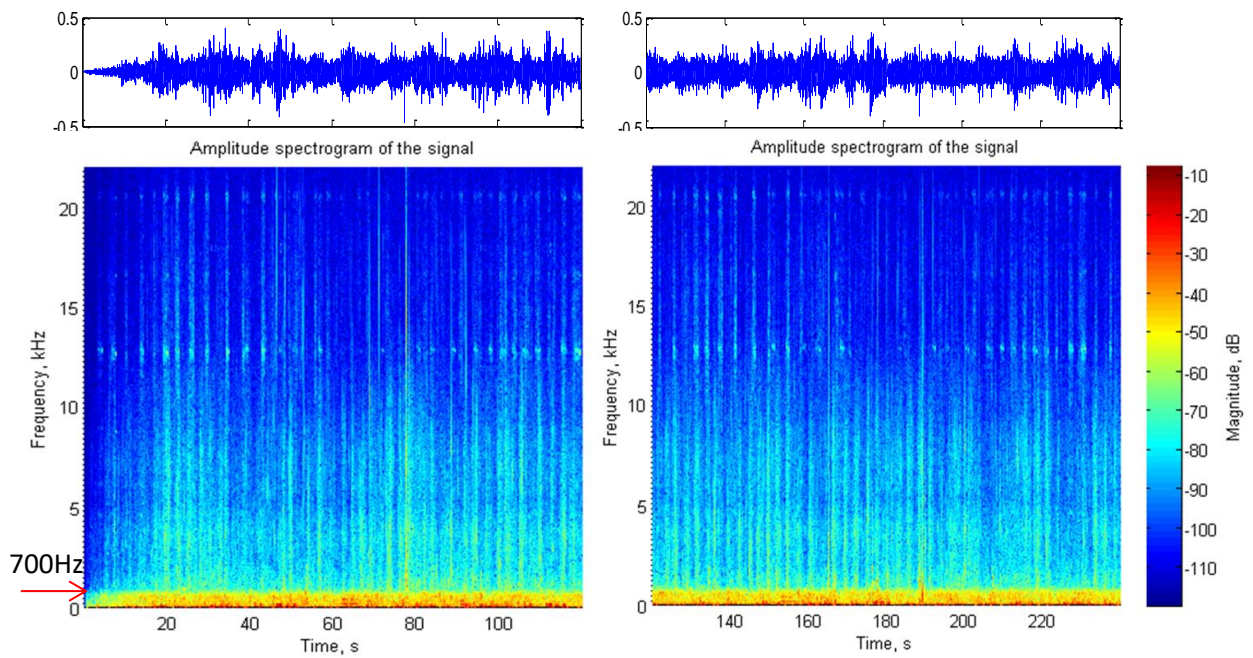
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 0 to 10 Hz. The highest peak is at 2 Hz.

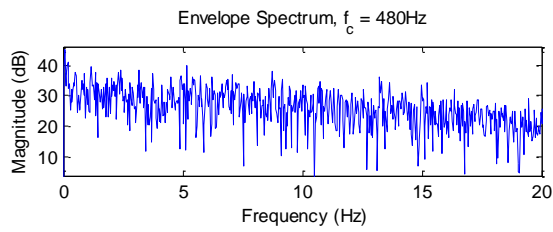
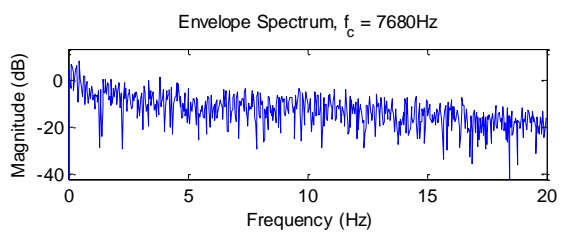
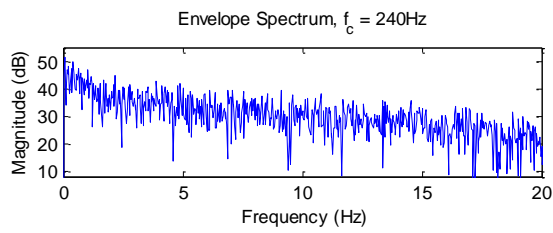
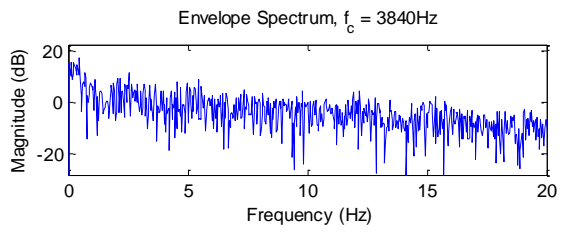
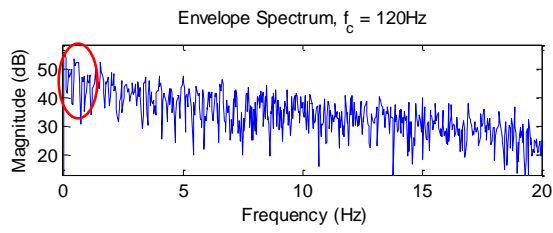
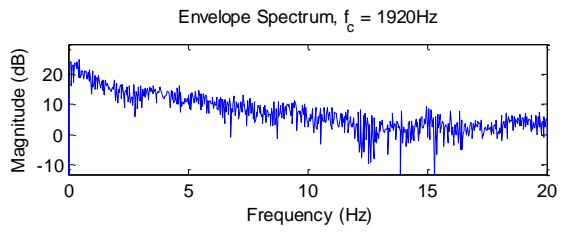
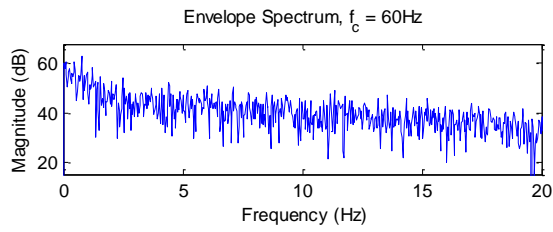
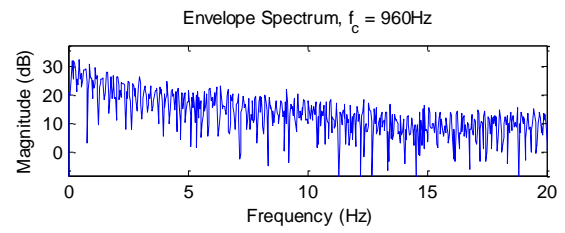
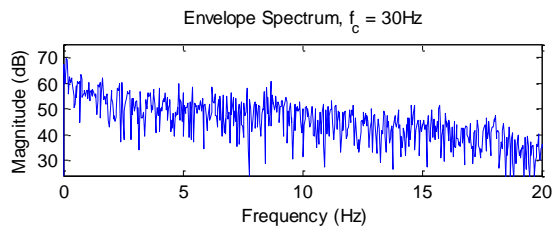
b) Short-Time Fourier Transform (STFT)



The spectrum has constant long-term characteristics. Signal energy is concentrated below 700 Hz (yellow/red color region).

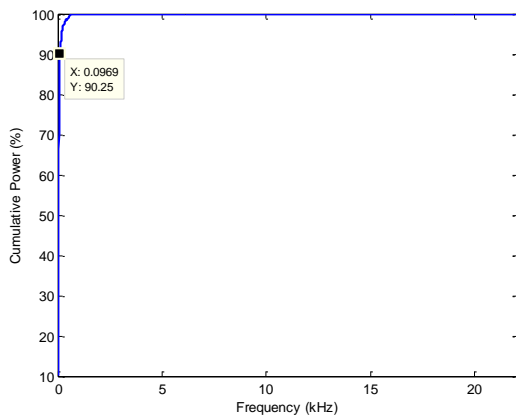
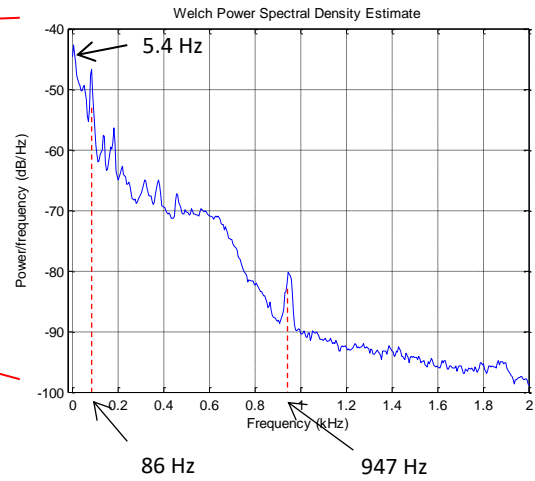
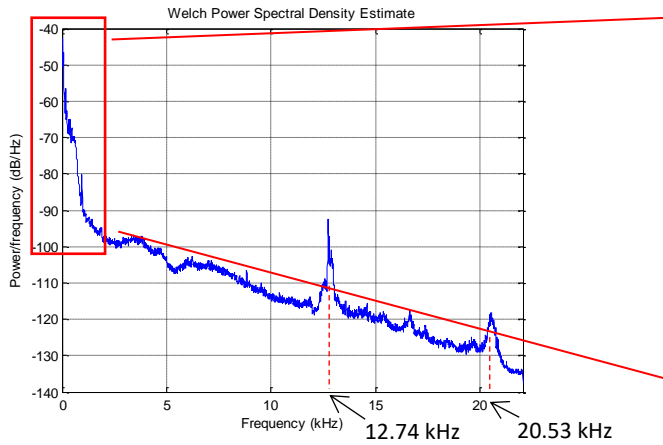
c) Envelope Modulation Spectrum (EMS)

Same methodology as described in 1(c) has been used. The results are given below:



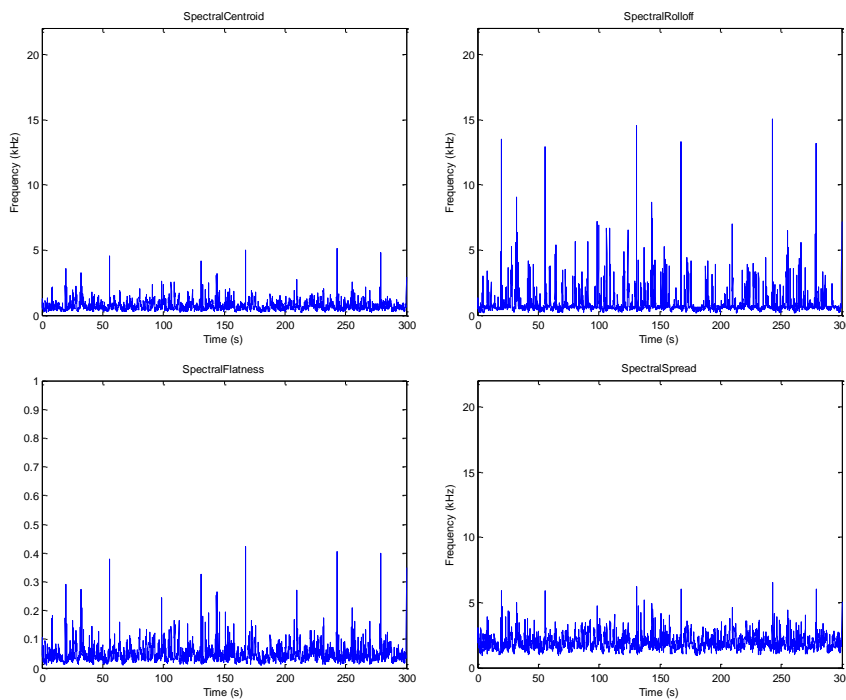
Only one small peak at about 0.55 Hz is observed in band 120 Hz. However, this amplitude modulation is not very significant. The envelope spectrums of other bands have no obvious slow modulation.

#### d) Long-term Average Spectrum (LTAS)



About five significant frequencies at 5.4, 86, 947, 12740 and 20530 Hz are observed in the power spectrum. However, 90% of the signal power is contained below 97 Hz.

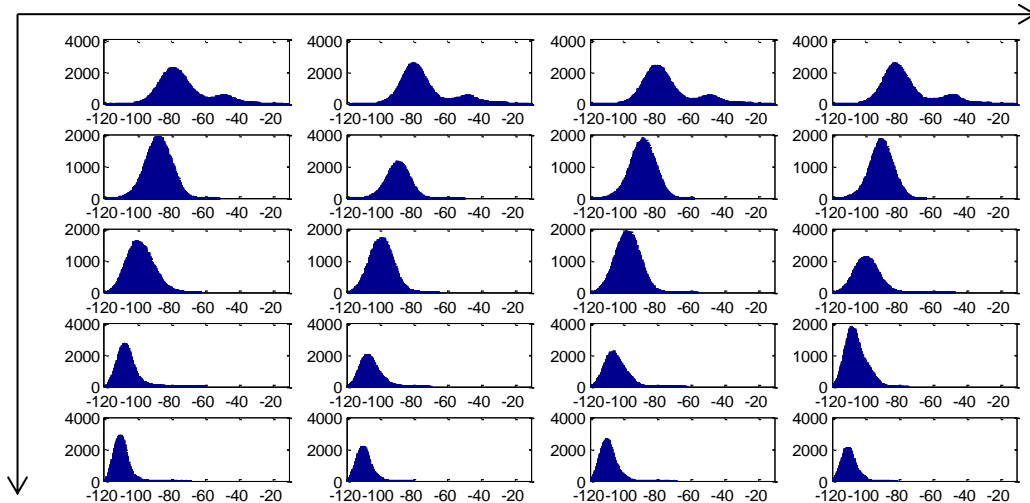
### e) Spectrum shape based features



Features	Mean Value
Centroid	700.74 Hz
Rolloff	863.8 Hz
Flatness	0.0474
Spread	1930 Hz

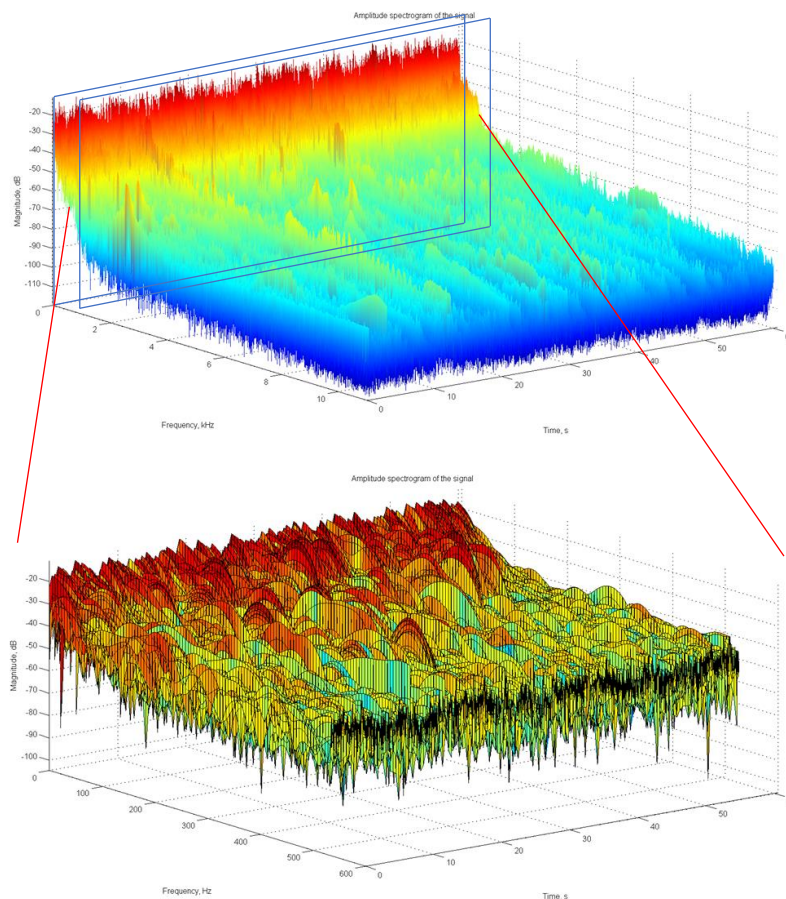
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low frequency sections show less noiselike characteristics. They also contain highest energy.

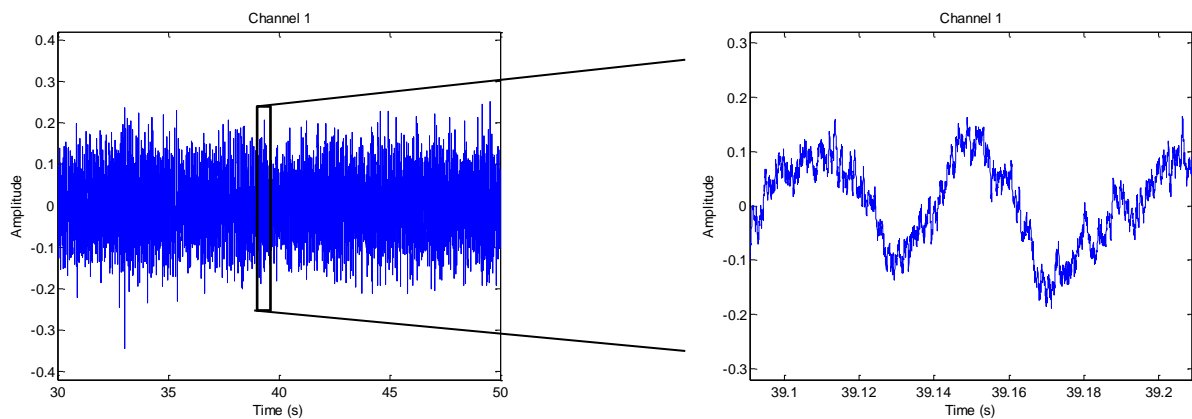
### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. Their magnitudes are quite consistent in time.

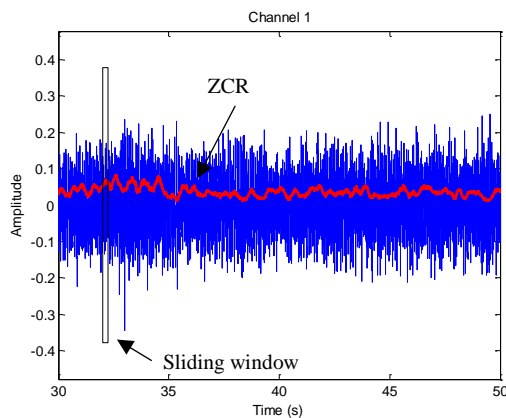
## 13) Monatomic Gold

### i) Time-domain features



The envelope of the time-domain samples is nearly constant and consistent, which is very similar to noise. Noisy and slow amplitude fluctuation is observed under very small time scale.

#### a. Zero Crossing Rate (ZCR)

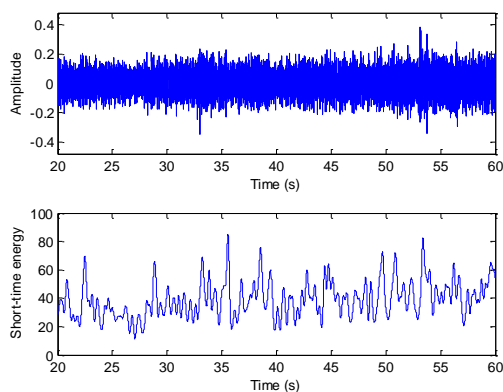


Window size = 10,000 samples ( $\sim 0.23s$ )

ZCR is quite consistent throughout the section of the sound examined (50s). The fundamental frequency of the sound is very low and has small variation across time.

This sound shows small short-term varying characteristics. Long-term characteristic is still quite constant.

#### b. Short time energy (STE)

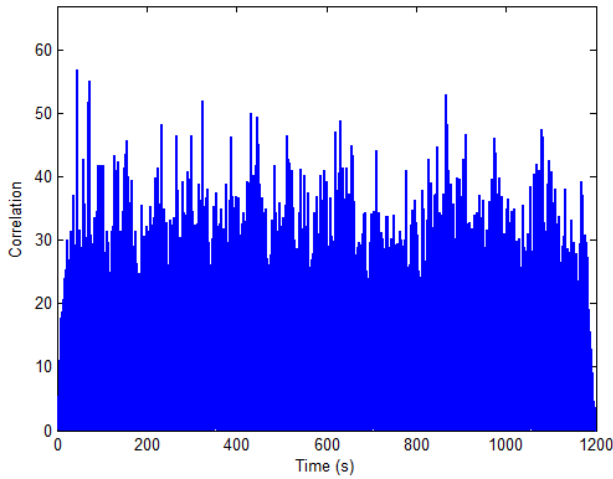


Window size = 20,000 samples ( $\sim 0.45s$ )

Window type = Hamming

STE fluctuates most of the times. Some energy surges have been observed. But their occurrences appear to be random.

#### c. Auto-correlation

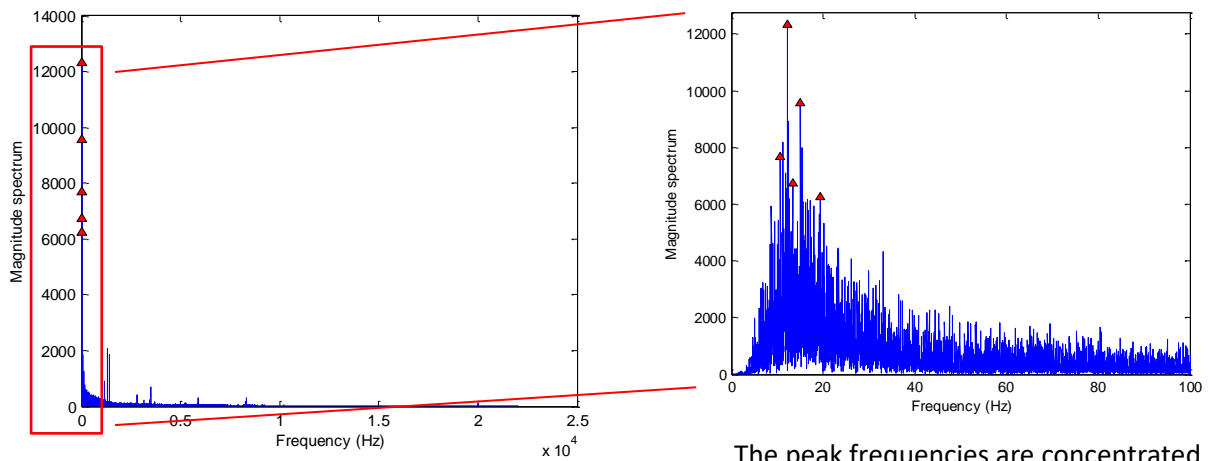


Segment/window size = 50,000 samples  
 (~1.13s)

No repeating segment is found in this sound.

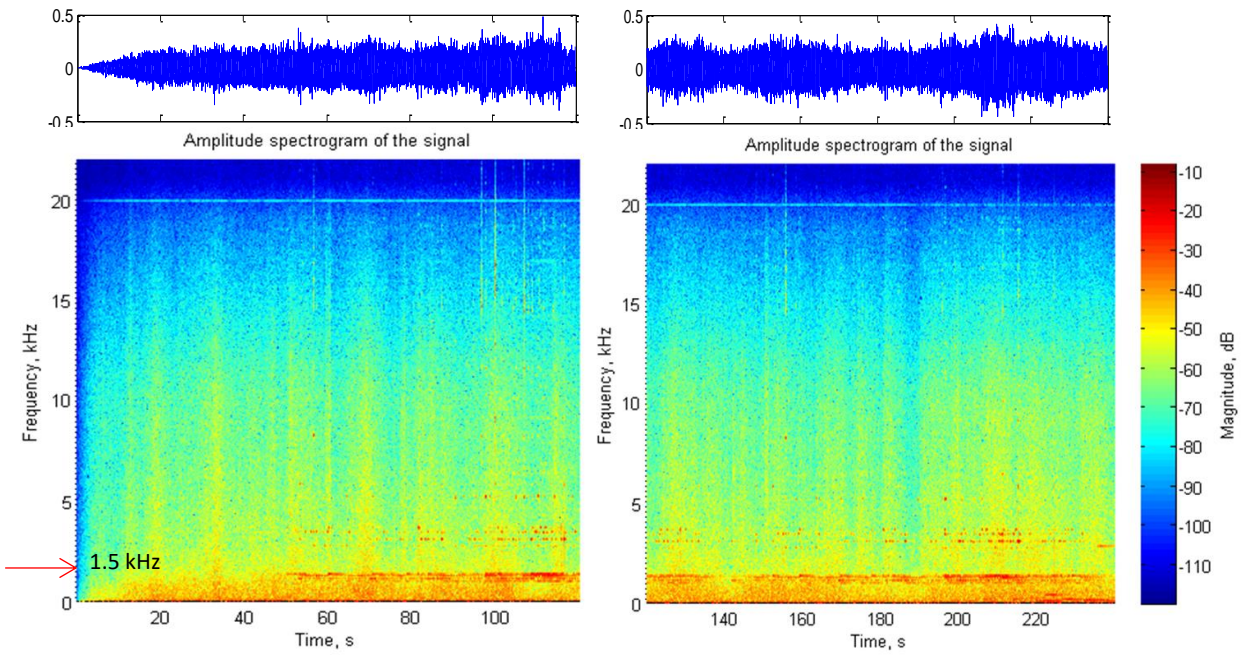
## ii) Frequency Domain Features

### a) Peak Frequency



The peak frequencies are concentrated around 10 to 20 Hz. The highest peak is at 12.3 Hz.

### b) Short-Time Fourier Transform (STFT)

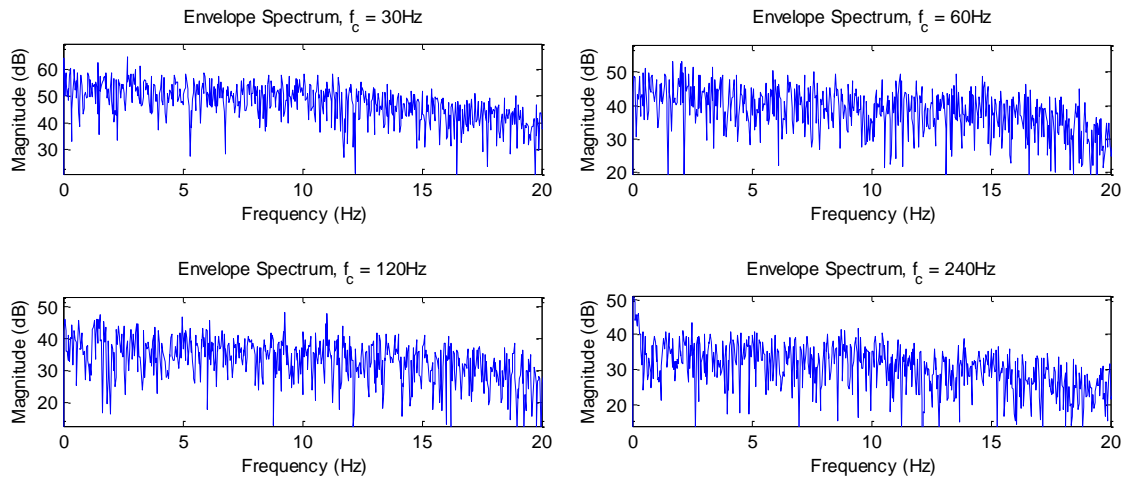


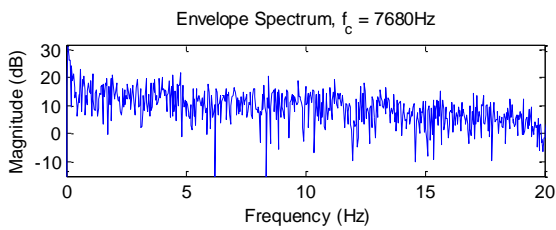
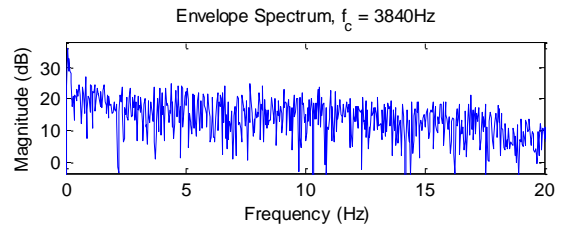
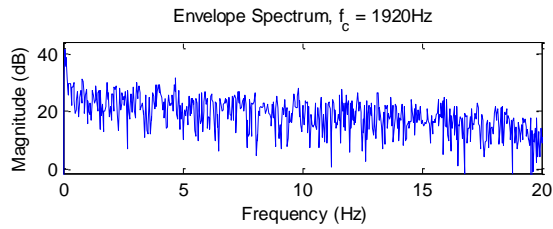
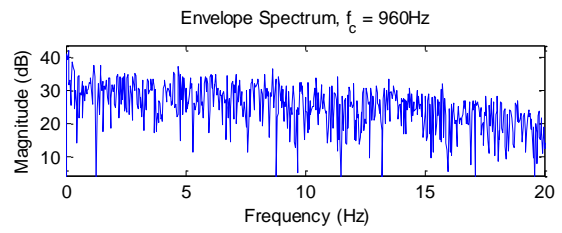
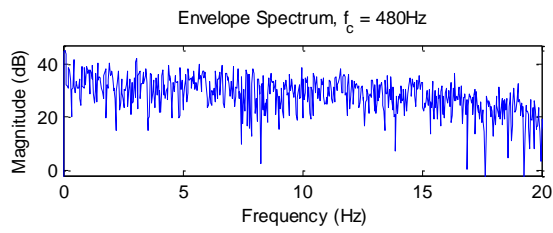
FFT size = 4096; window size = 1024 (~0.02s)

The spectrum is changing randomly in time. Short-term variation is due to the sound of ring/music tone. Signal energy is mainly concentrated below 1.5 kHz most of the time (red color region).

### c) Envelope Modulation Spectrum (EMS)

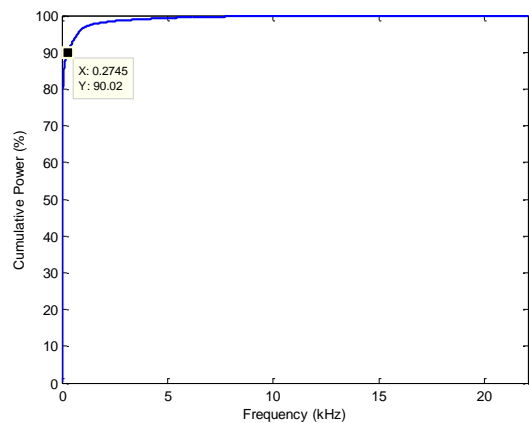
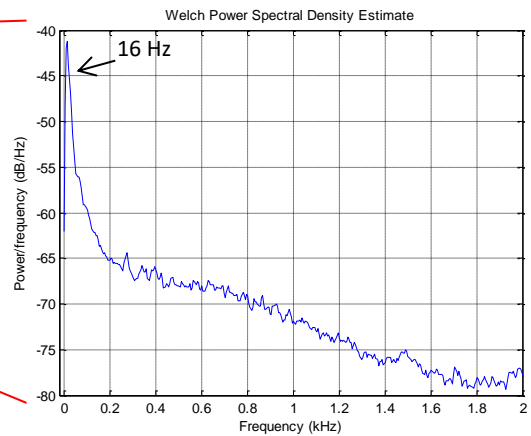
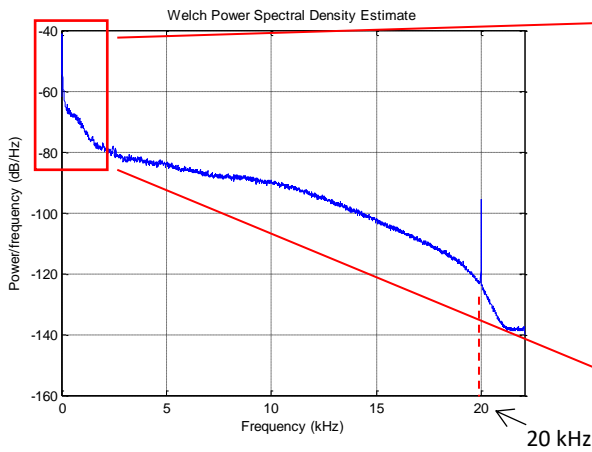
Same methodology as described in 1(c) has been used. The results are given below:





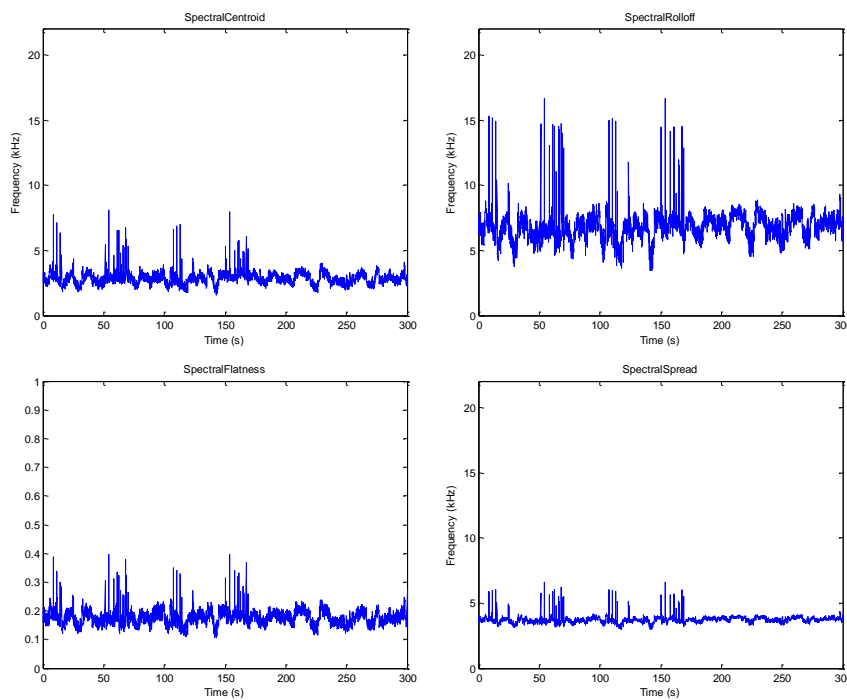
No obvious peak is observed in all the envelope spectrums above. The peak frequency near 0 Hz is too small to be useful. In other words, no obvious slow modulation is found in all the bands considered.

#### d) Long-term Average Spectrum (LTAS)



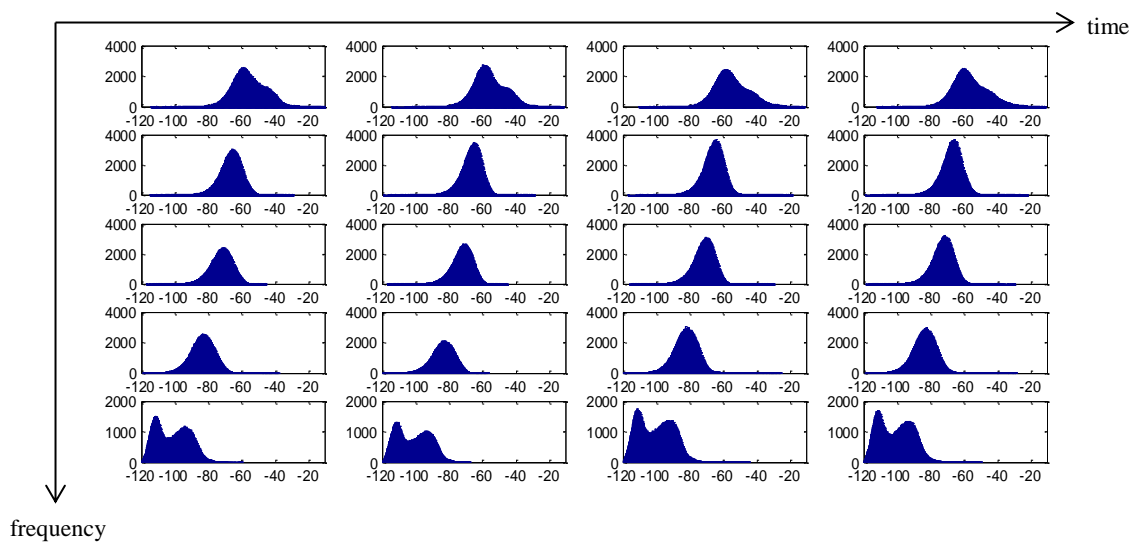
Two significant frequencies at 16 Hz and 20 kHz are observed in the power spectrum. 90% of the signal power is contained below 274 Hz.

### e) Spectrum shape based features



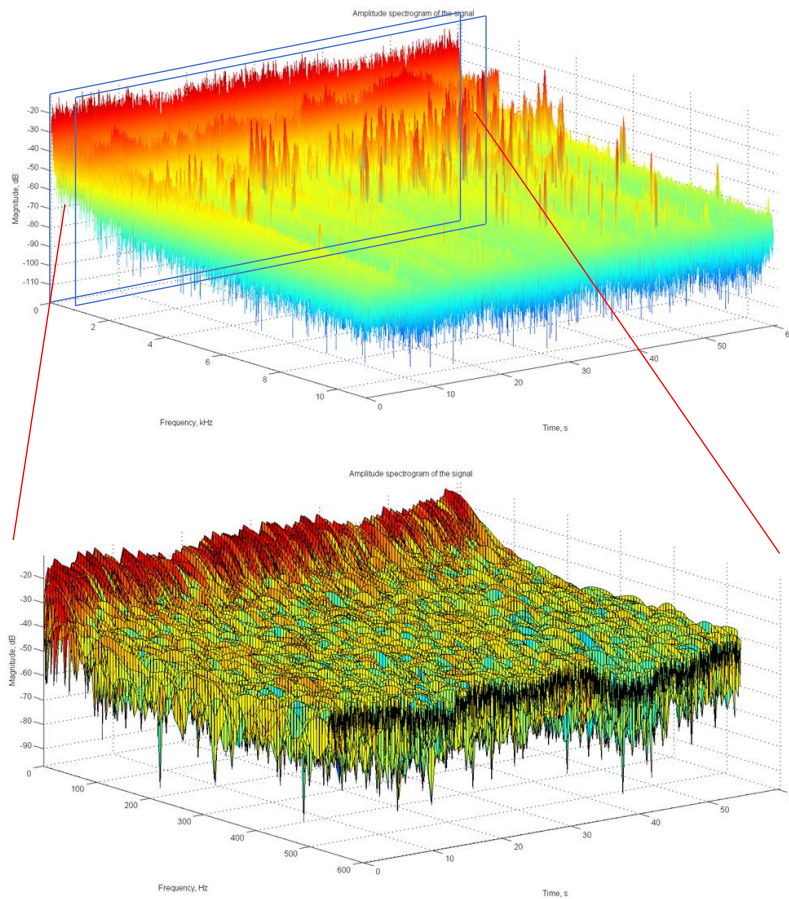
### iii) Time-Frequency Domain Features

#### a) Local Histogram



The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low frequency sections show less noiselike characteristics. They also contain highest energy.

#### c) Low Frequency Analysis of 3D Spectrogram



The top figure shows the 3D spectrogram for 0 to 10 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. Some random frequency peaks are observed.

## Conclusion

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Thirteen different waveforms of eT-RT have been analyzed in time-, frequency-, and time-frequency domains to gain insight into the unique characteristics of each waveform. It is found that all the waveforms have high concentration of power in the low frequency region (<3 kHz), except Neuro-Energetics (Audio Oxytocin) and Digital CBD. Audio Oxytocin has most of its power concentrated in the frequency region below 6 kHz, while Digital CBD in the frequency region below 8 kHz. These high energy bands may have been produced by post enhancement made to the waveforms. Very low peak frequencies (frequency with highest power) below 15 Hz are found for Audio Rejuvenation, Audio Dopamine, Audio GABA, Digital C60, Digital CBD, Digital Nootropic, Marine Phytoplankton, Monatomic Gold and Awaken the Mind. These frequencies are mostly out of an adult human hearing range.

**End of Report**