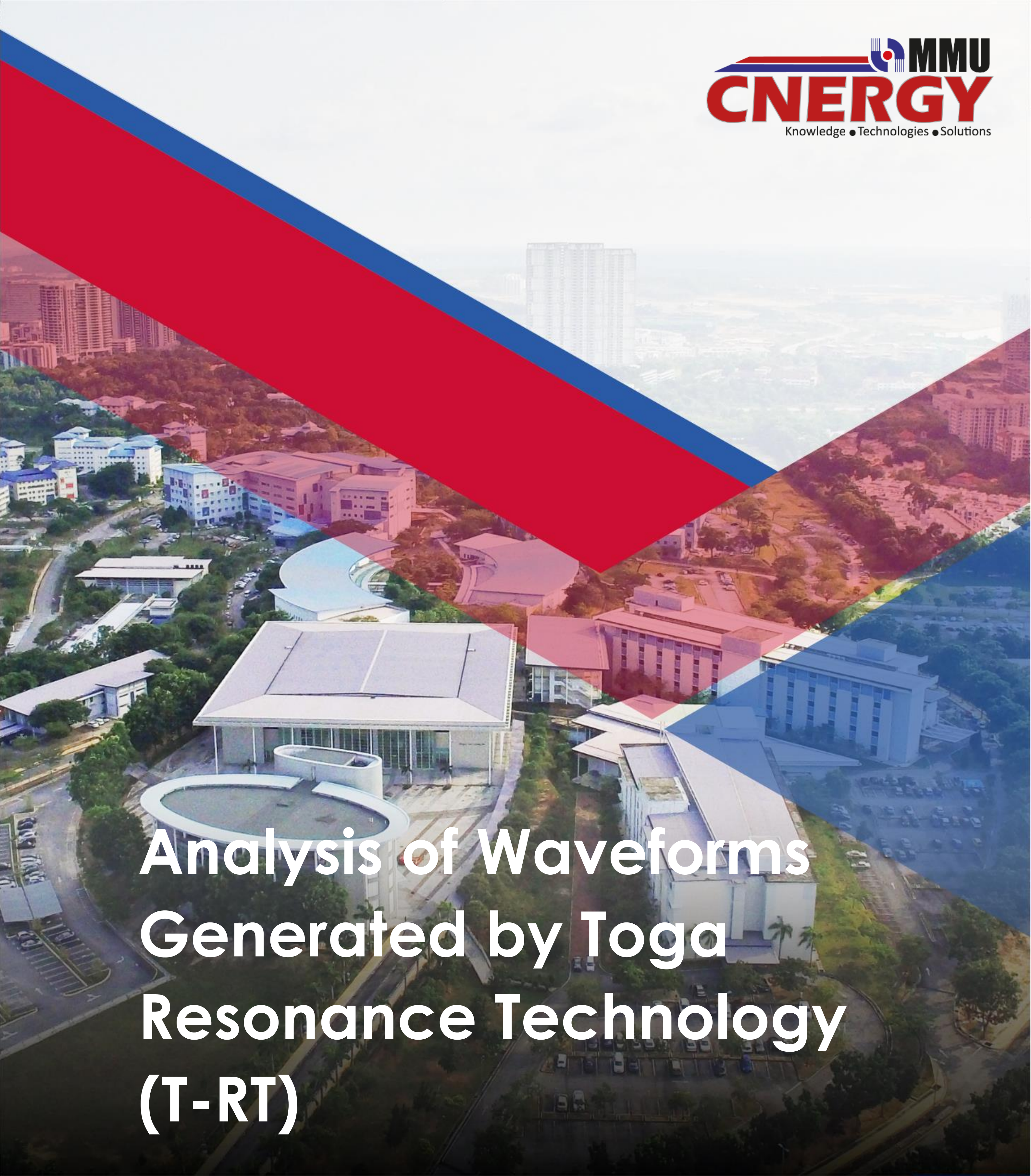

MMU CNERGY
Knowledge • Technologies • Solutions

Analysis of Waveforms Generated by Toga Resonance Technology (T-RT)

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Executive Summary

In this work, 9 different waveforms of T-RT 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 waveforms are sounds of nature such as rain, ocean waves, forest, running water, etc. Useful features in time-, frequency-, and time-frequency domains are extracted and presented in graphs and tables for comparison. Important results and findings are highlighted as follows: All the waveforms consist of repeated segments of different durations except T-Shield and Weight Loss. Quantum Healthcare and Sleep Enhancement have the shortest (15s) and longest (921s) repeating segments respectively. All the waveforms exhibit noise-like characteristics such as random amplitudes and uniform texture, especially Sleep Enhancement which has high spectral flatness and spread. It is well known that noise-like sounds have calming and relaxing effects. All waveforms have high concentration of power in the low frequency region (<3 kHz), except Quantum Nutrition and Sleep Enhancement. Quantum Nutrition has most of its power concentrated in the medium frequency region (6-8 kHz), while Sleep Enhancement has its 90% power below 10 kHz. Very low peak frequencies (5-100 Hz) are found for Sleep Enhancement, Relaxation, Quantum Healthcare, Headache Support, and Weight Loss. It is worth mentioning that frequency bands 50-60 Hz and 5-8 kHz of Quantum Healthcare could have been purposely suppressed. No slow (or low frequency) envelop modulation is detected in all the waveforms.

Some notable data for each waveform are summarized in the following table:

Waveforms	**Repeating Segment**	**Fundamental frequency**	**90% power**	**Peak frequency**	**Spectral flatness & spread**	**Prominent energy band**	**Remarks**
Mind Enhancement	127s	Low; constant	<2 kHz	~200 Hz	Low	SLF (30-300 Hz)	
Quantum nutrition	47s	Medium; constant	6-8 kHz	~7000 Hz	Low	VLF (3-30 kHz)	
Sleep enhancement	921s	Low; constant	<10 kHz	~30 Hz	High	SLF (30-300 Hz)	
Relaxation	156s	Low; constant	<2 kHz	~5 Hz	Low	ELF (<30 Hz)	
Quantum healthcare	15s	Low; varying	<1 kHz	~100 Hz	Moderate	SLF (30-300 Hz)	50-60Hz & 5-8kHz are suppressed
Headache support	150s	Low; constant	<2 kHz	~5 Hz	Low	ELF (<30 Hz)	
T-shield	-	Low; constant	<5 kHz	~1250 Hz	Moderate	SLF (30-300 Hz)	
Anti-aging	195s	Low; varying	<3 kHz	~700 Hz	Moderate	SLF (30-300 Hz)	
Weight loss	-	Low; varying	<2 kHz	~5 Hz	Moderate	ELF (<30 Hz)	

Waveforms and Features

Description of waveforms:

No.	Waveform	Filename	Format	Bits/sample or Bitrate	Sample rate (kHz)	Sound
1.	Mind Enhancement	Eliminate Brain Fog 20-min	MP3	320	44.1	Water/rain
2.	Quantum nutrition	Maca Root 20-min	MP3	320	44.1	Forest
3.	Sleep enhancement	Sleep Support 60-min	WAV	16	44.1	Rain
4.	Relaxation	Relaxation 20-min	MP3	320	44.1	Rain
5.	Quantum healthcare	Inflamation 20-min	MP3	320	44.1	Ocean waves
6.	Headache support	Headache Support 20-min	WAV	16	44.1	Rain
7.	T-shield	T-Shield 20-min	WAV	16	44.1	Heavy rain
8.	Anti-aging	Anti-Aging 20-min	WAV	16	44.1	Beach waves
9.	Weight loss	Weight Loss 20-min	WAV	16	44.1	Waves

Description of features:

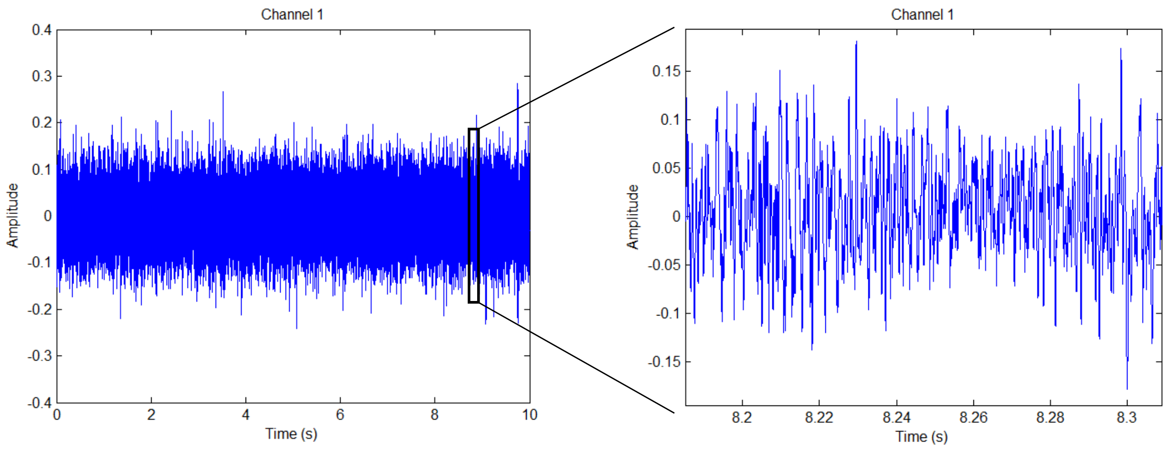
No.	Domains	Features	Brief description
1.	Time	Zero-crossing rate (ZCR)	• the number of times signal crosses the zero level in one second interval • to estimate fundamental frequency
		Short time energy (STE)	• average energy per frame/window • to estimate signal energy change in time
		Autocorrelation	• measures the similarity between the signal and a segment of the same signal • to detect repeating segment (if any)
2.	Frequency	Peak Frequency	• the frequency of maximum power
		Short-time Fourier transform (STFT)	• Frequency versus time plot • To analyze nonstationary aspects of a signal such as trends, discontinuities and patterns
		Envelope Modulation Spectrum (EMS)	• represents the slow amplitude modulations in the signal across certain frequencies
		Long-term Average Spectrum (LTAS)	• captures atypical spectral information from the signal.
		Spectrum shape based features	• Spectral Centroid: center of mass of the spectrum • Spectral roll-off: 85% of the signal energy is contained below roll-off point • Spectral Spread: closely related to the bandwidth of the signal; Noise like signals have wide spectral spread • Spectral Flatness: the measure of uniformity in the frequency distribution of the power spectrum; noise like sounds have spectral flatness close to

			one
3.	Time-Frequency	Local Histogram	• Signal magnitudes distribution for a specific area in time-frequency domain • Noise-like signal has a bell-shaped histogram
		Local Binary/Ternary Pattern	• Measures the local spatial information and gray scale contrast of the spectrograms of the audio signals
		Low Frequency Analysis of 3D Spectrogram	• 3D spectrogram provides clear visualization of time and frequency domain variation of the signal energy. • The analysis is focused on the low-frequency region of the spectrogram.
		Histogram of gradients feature, Scale invariant feature transform	• Employed on spectrograms of audio signals to detect local information • However, since all the spectrograms of the waveforms are homogeneous and consistent, except waveforms no. 5, 8 and 9, this analysis will only be applied to these waveforms.
4.	Cepstral and wavelet domains	Features in these domains involves nonlinear signal projections and transformations	• The data in these domains are difficult to interpret and do not provide further insights into the characteristics of the waveforms.

Detailed Results and Analysis

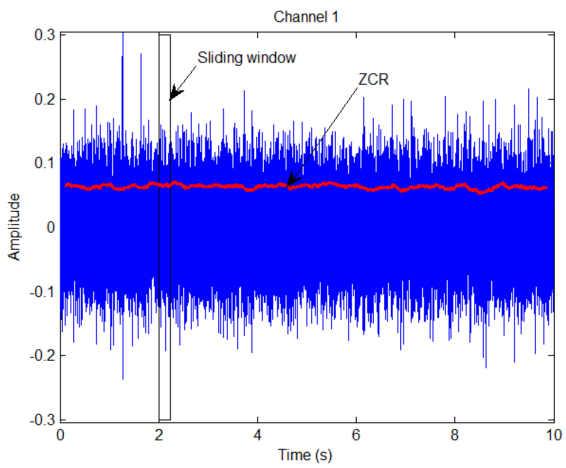
1) Mind Enhancement

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)

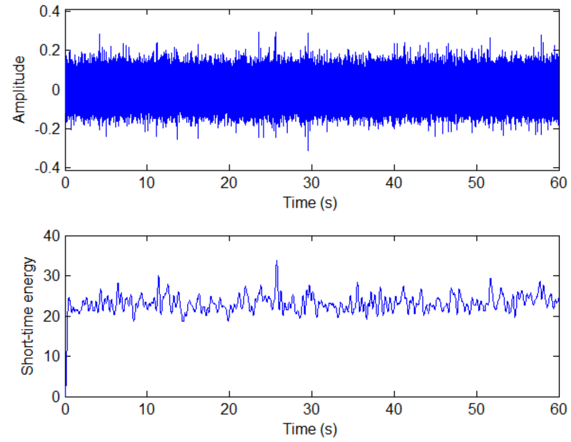


Window size = 10,000 samples (~0.23s)

ZCR is consistently low throughout the section of the sound examined. The fundamental frequency of this sound is very low.

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

b. Short time energy (STE)

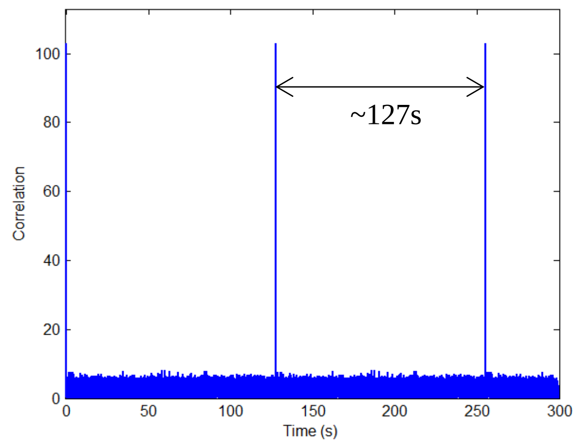


Window size = 20,000 samples (~0.45s)

Window type = Hamming

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

c. Auto-correlation

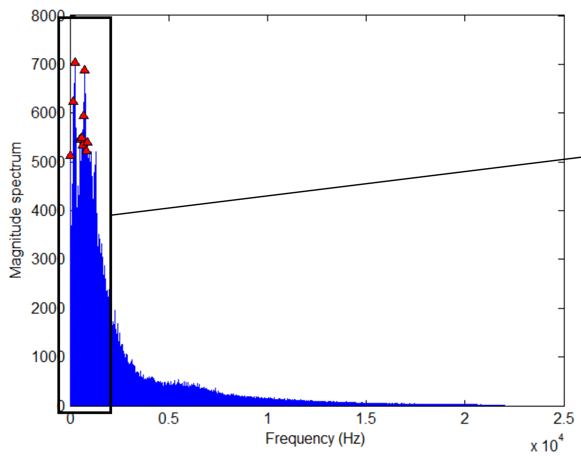


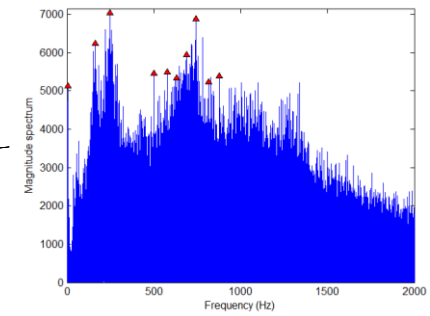
Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 127s (or 2.1 minutes). In other words, identical segment of 2.1 minutes is repeated in this sound.

ii) Frequency Domain Features

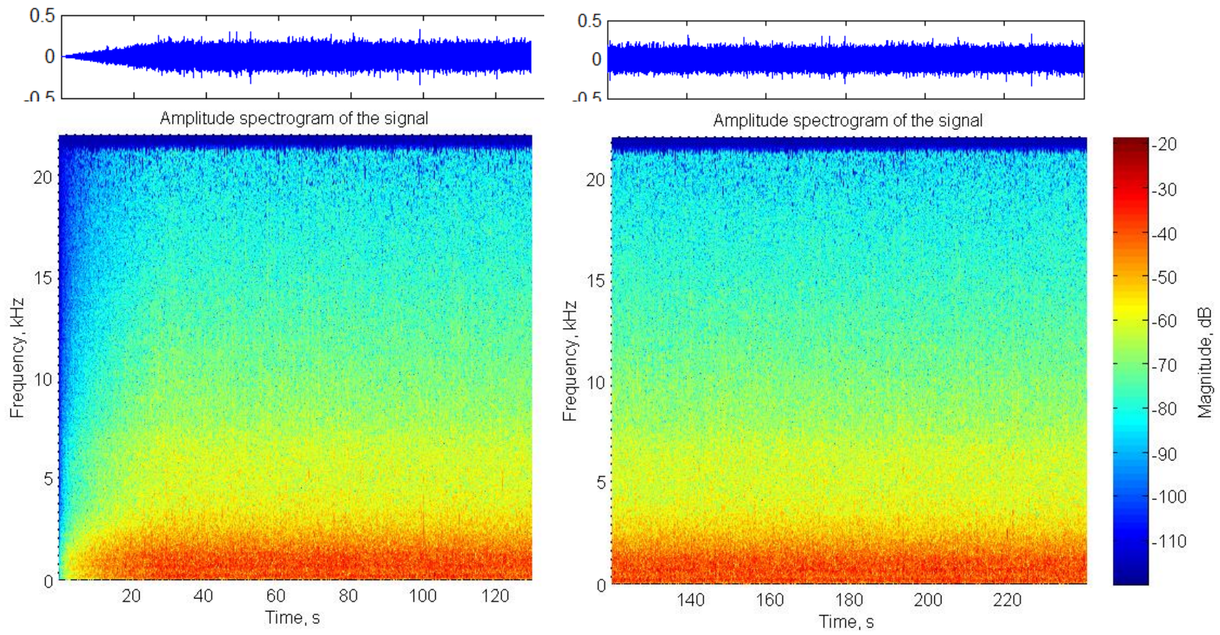
a) Peak Frequency





The peak frequencies are concentrated around 4, 163, 248, and 743 Hz. The highest peak is at 248 Hz.

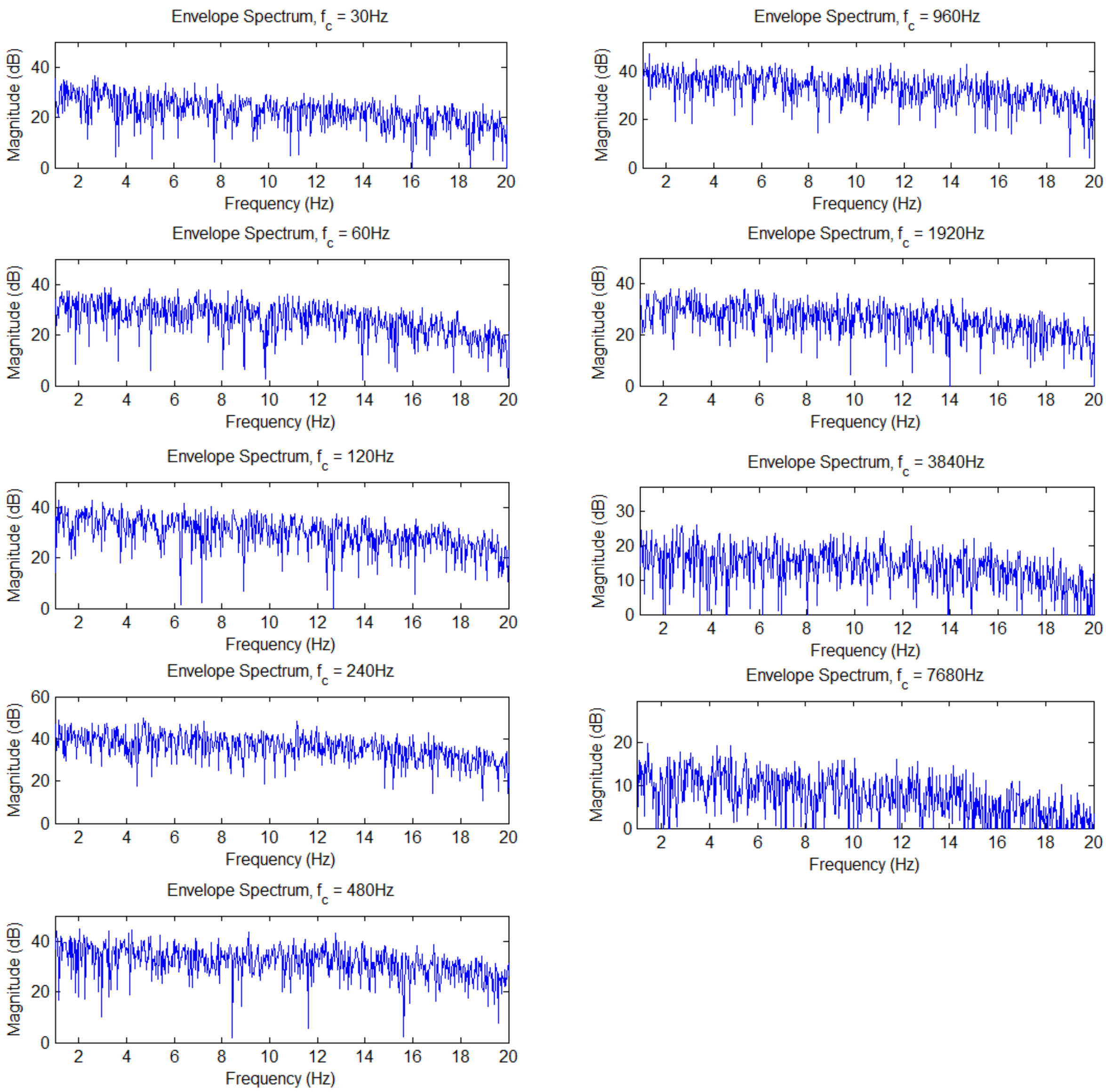
b) Short-Time Fourier Transform (STFT)



FFT size = 4096; window size = 1024 (~0.02s)
The spectrum has constant long-term characteristics. The energy of the sound is concentrated in below 2 kHz (red color region).

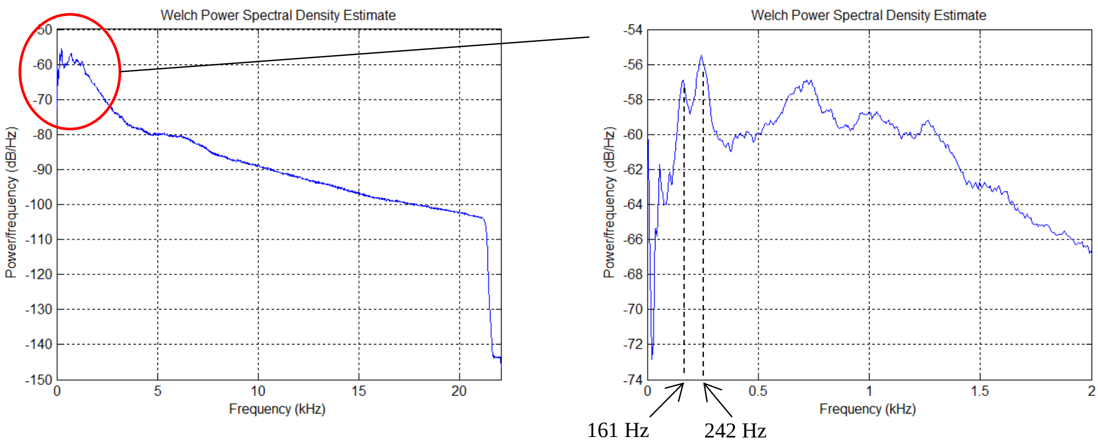
c) Envelope Modulation Spectrum (EMS)

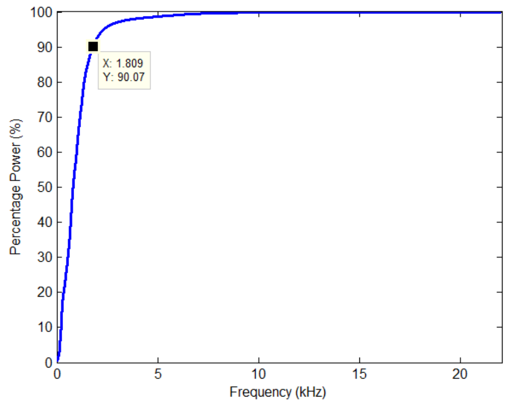
The original signal is first filtered into 9 octave bands with center frequencies of 30, 60, 120, 240, 480, 960, 1920, 3840, and 7680 Hz, using Butterworth filters. Then the envelope of the filtered signals is extracted using Hilbert transform. The mean is removed and the power spectrum for each of the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



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.

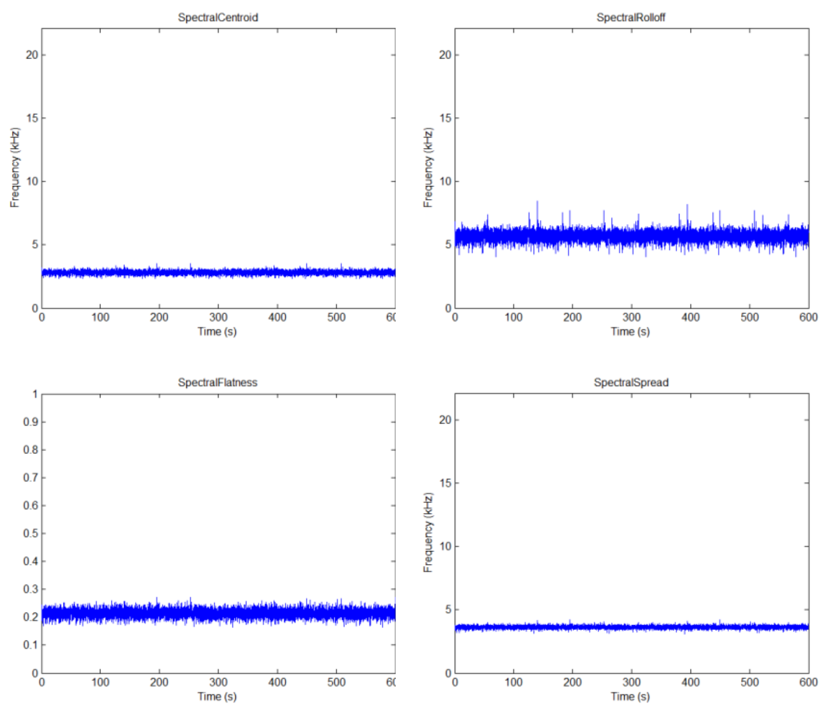
d) Long-term Average Spectrum (LTAS)





Two significant frequencies at 161 and 242 Hz are observed in the power spectrum. 90% of the signal power is contained below 1.8 kHz.

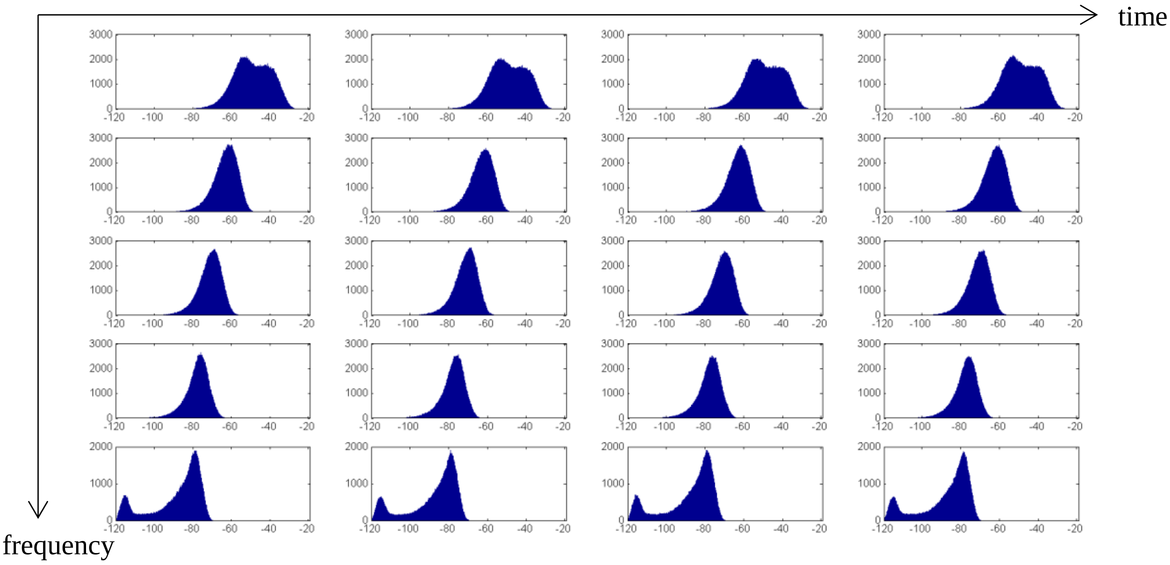
e) Spectrum shape based features



Features	Mean Value
Centroid	2814 Hz
Rolloff	5689 Hz
Flatness	0.2147
Spread	3626 Hz

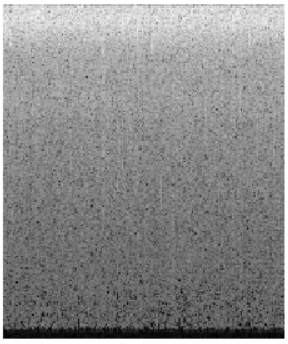
iii) Time-Frequency Domain Features

a) Local Histogram

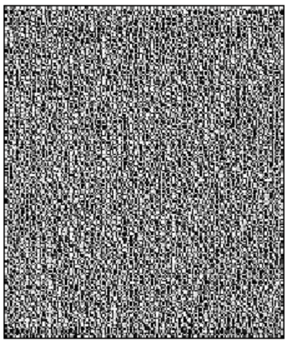


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very low frequency sections are less noise-like and contain highest energy.

b) Local Binary/Ternary Pattern



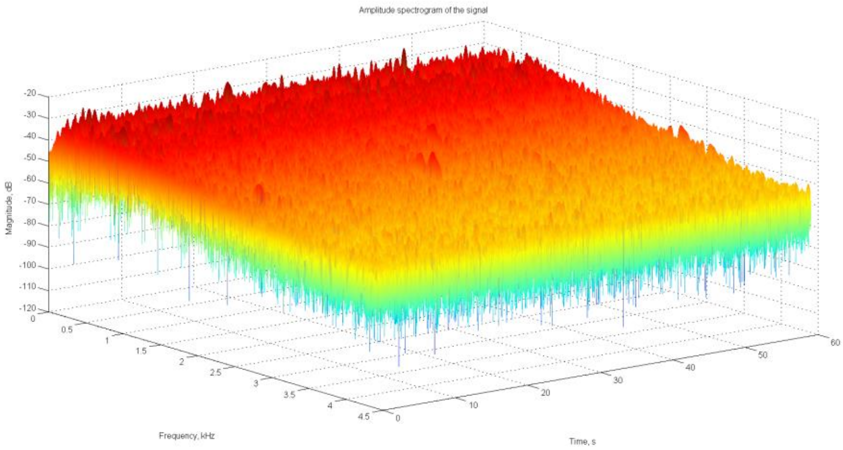
Spectrogram (Grayscale)

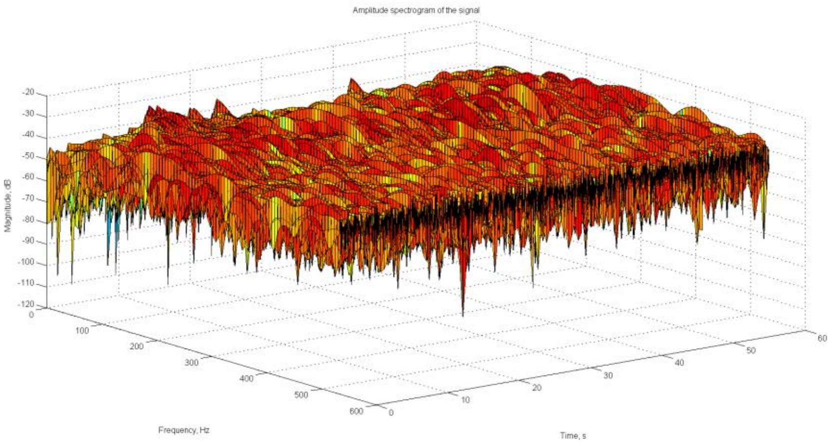


LBP

Based on the LBP, the texture of the sound appears to be very uniform.

c) Low Frequency Analysis of 3D Spectrogram

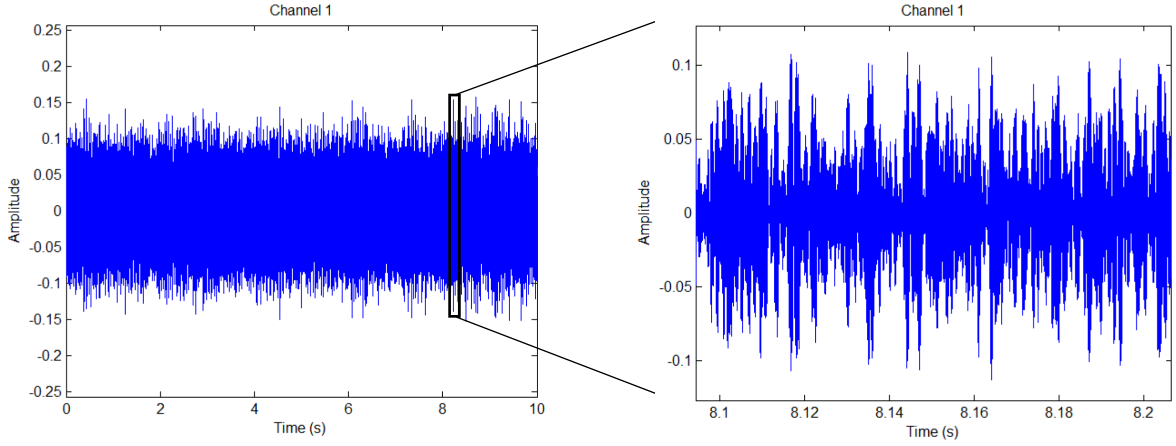




The top figure shows the 3D spectrogram for 0 to 4.5 kHz across 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal do not change significantly in time. Super low frequency (SLF) (30-300Hz) are very prominent in this signal.

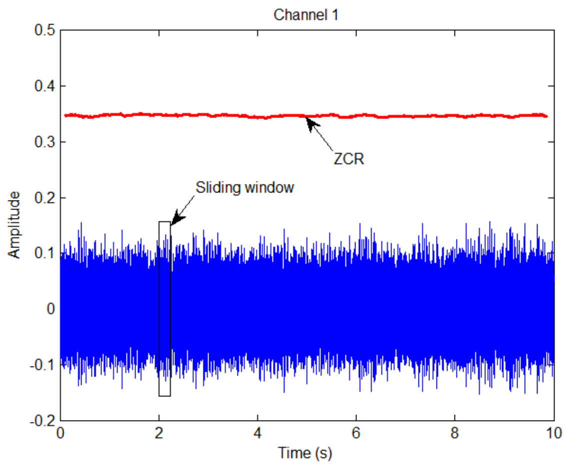
2) Quantum nutrition

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)

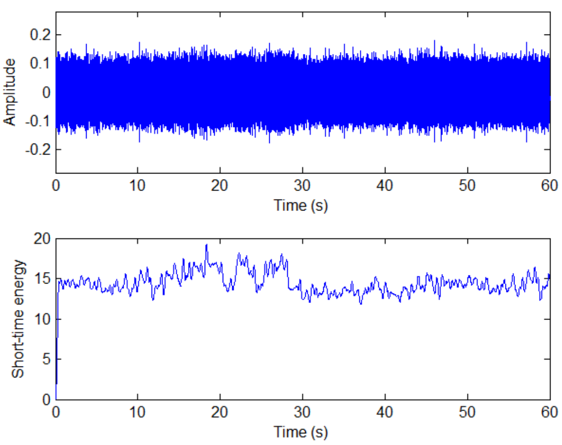


Window size = 10,000 samples (~0.23s)

ZCR is consistently high throughout the section of the sound examined. The fundamental frequency of the sound is high.

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

b. Short time energy (STE)

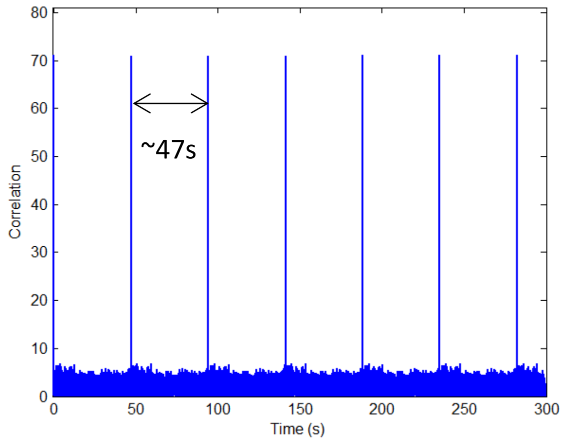


Window size = 20,000 samples (~0.45s)

Window type = Hamming

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

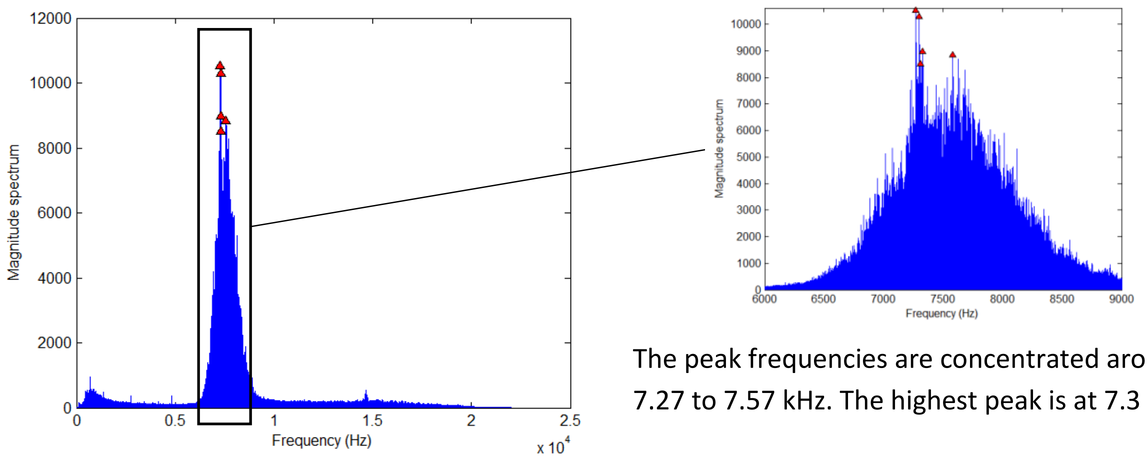
c. Auto-correlation



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

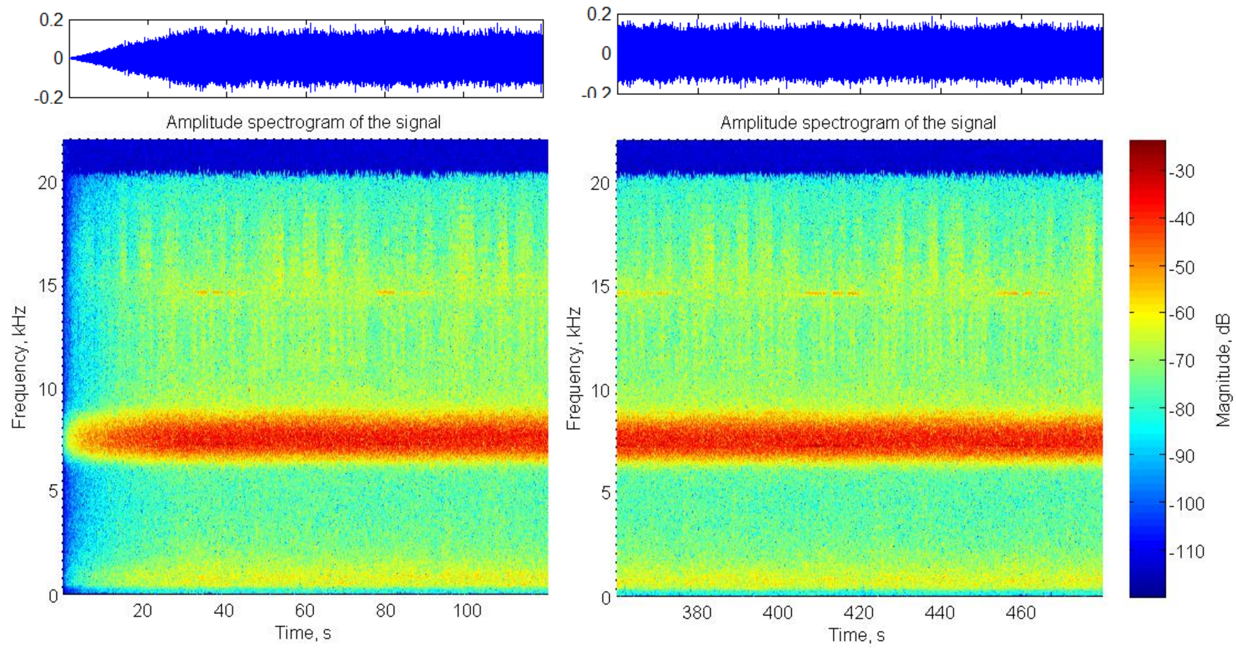
A peak is observed about every 47s. In other words, identical segment of 47s is repeated in this sound.

a) Peak Frequency



The peak frequencies are concentrated around 7.27 to 7.57 kHz. The highest peak is at 7.3 kHz.

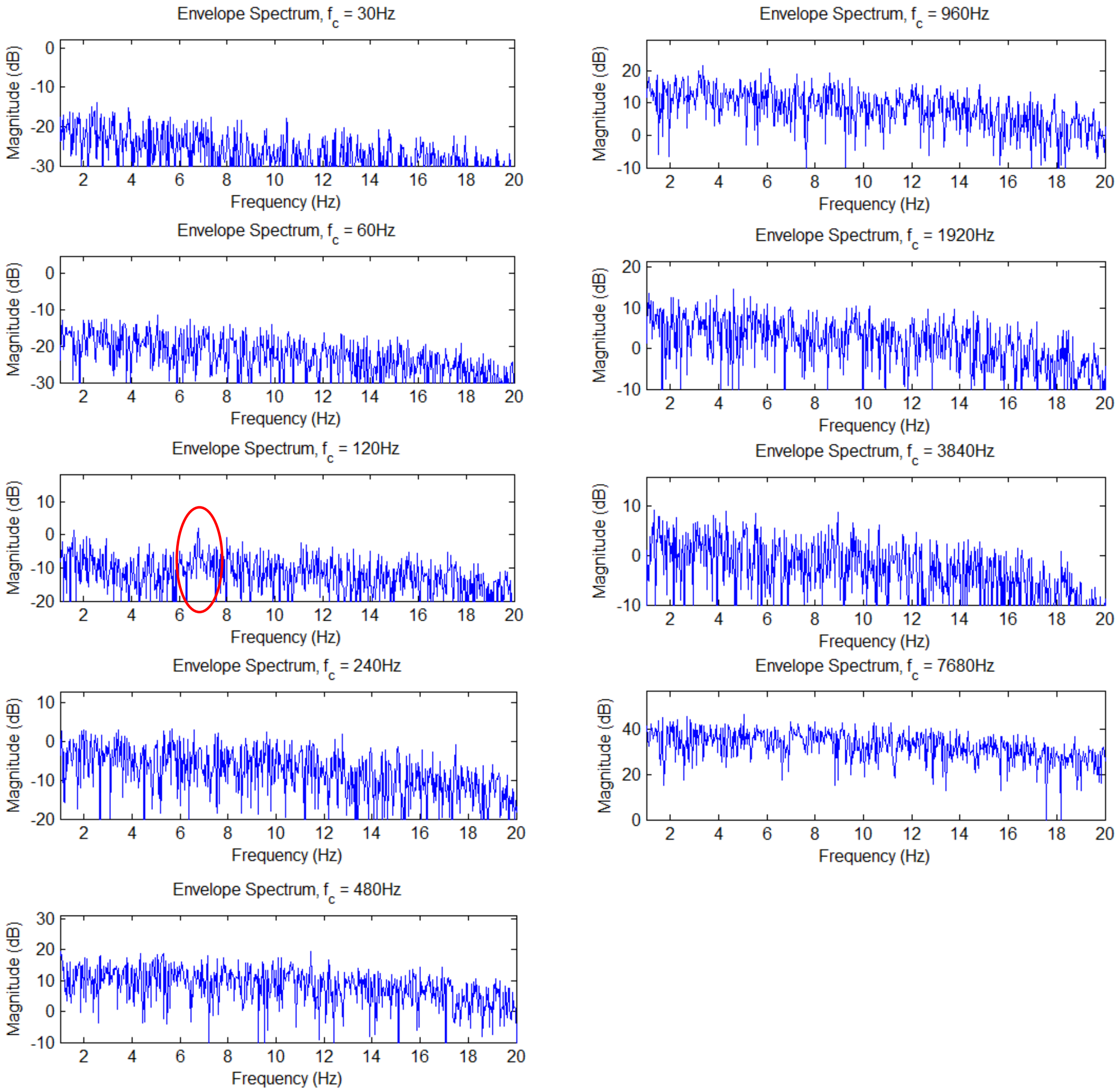
b) Short-Time Fourier Transform (STFT)



FFT size = 4096; window size = 1024 (~0.02s)
The spectrum has constant long-term characteristics. The energy of the sound is concentrated around 7 kHz (red color region).

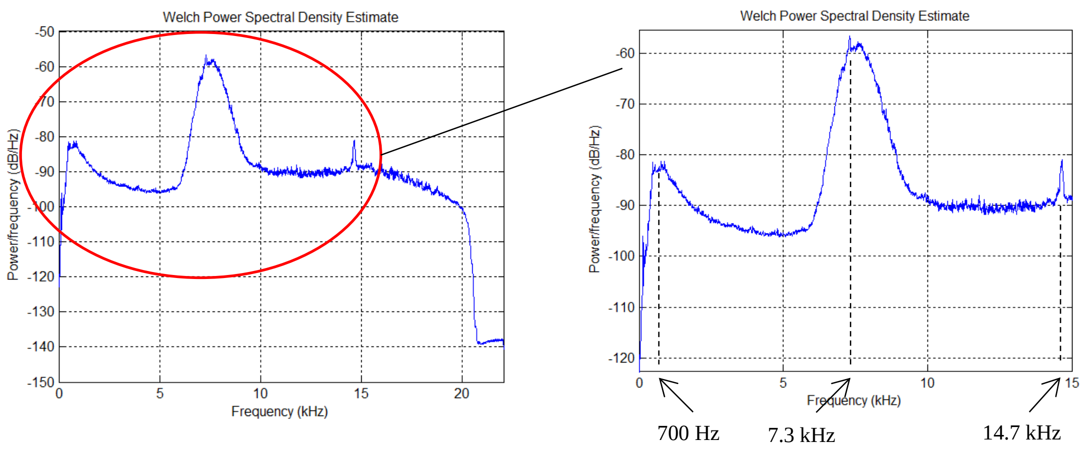
c) Envelope Modulation Spectrum (EMS)

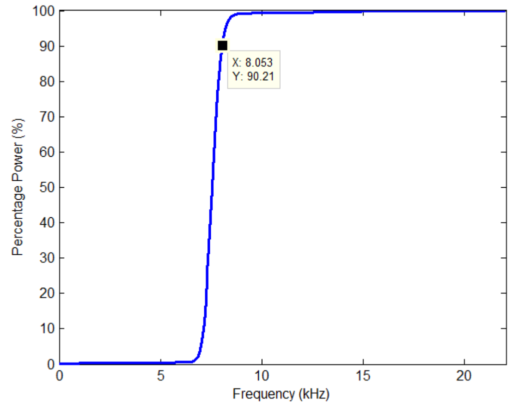
Same methodology as described in 1(c) has been used. The results are given below:



Only one small peak at about 7 Hz is observed in band 120 Hz. However, this amplitude modulation is not very significant. The envelope spectrums of other bands have no obvious

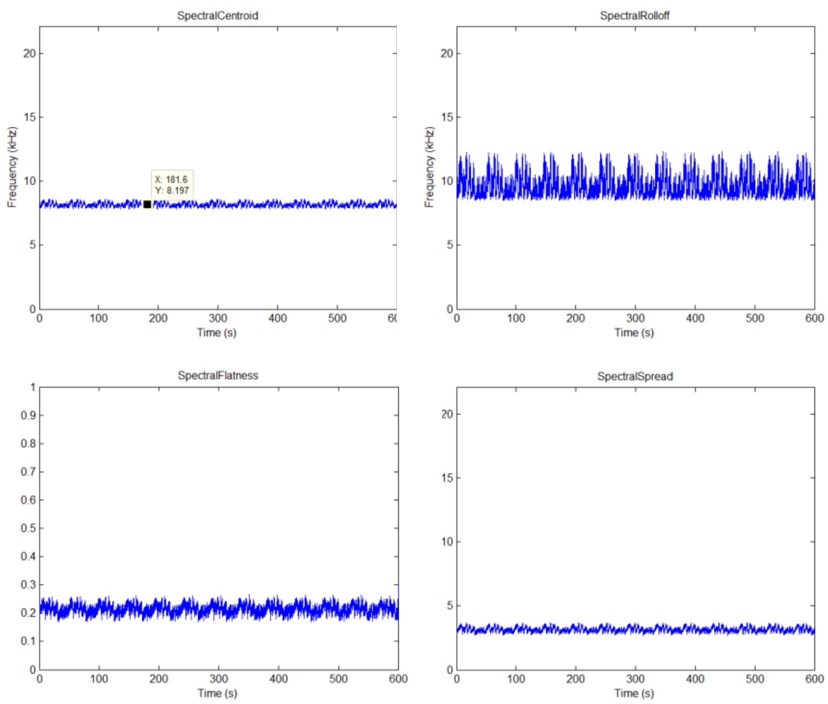
d) Long-term Average Spectrum (LTAS)





Three significant frequencies at 700 Hz, 7.3 kHz and14.7 kHz are observed in the power spectrum. Very low frequency up to about 60 Hz has been suppressed substantially. 90% of the signal power is contained between 6 to 8 kHz.

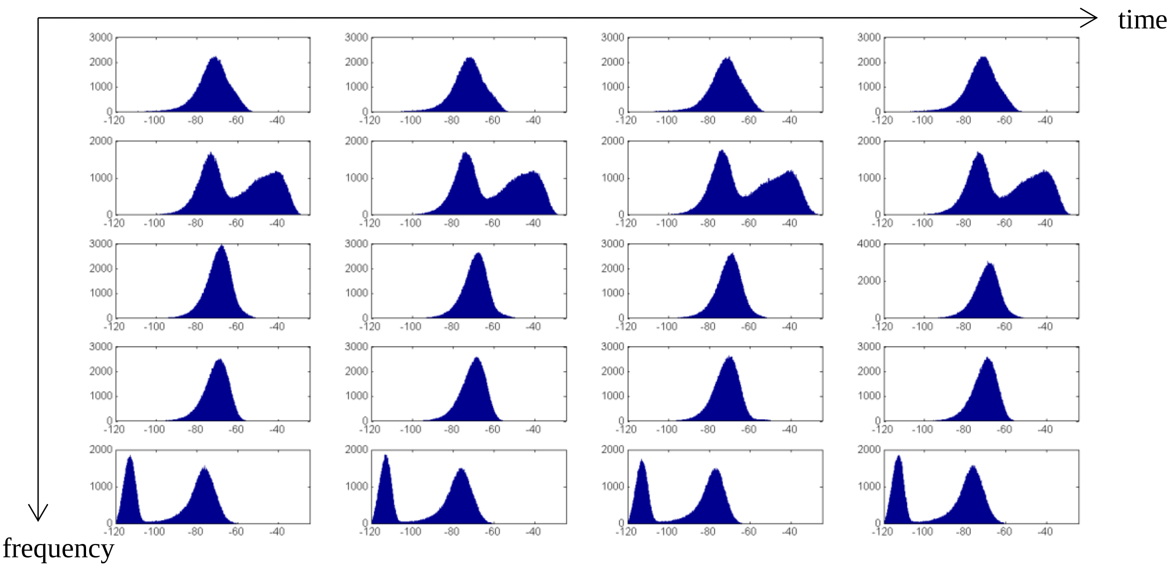
e) Spectrum shape based features



Features	Mean Value
Centroid	8158 Hz
Rolloff	9573 Hz
Flatness	0.2130
Spread	3142 Hz

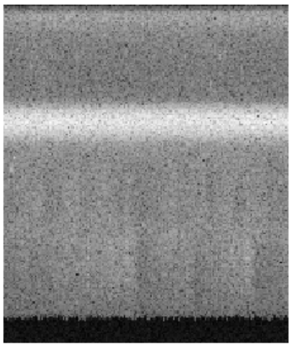
iii) Time-Frequency Domain Features

a) Local Histogram

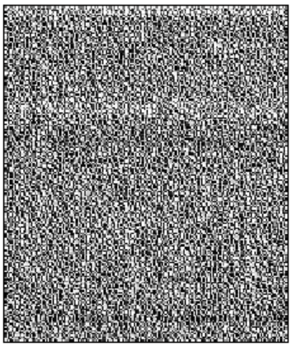


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The medium-low frequency sections are less noise-like and contain highest energy.

b) Local Binary/Ternary Pattern



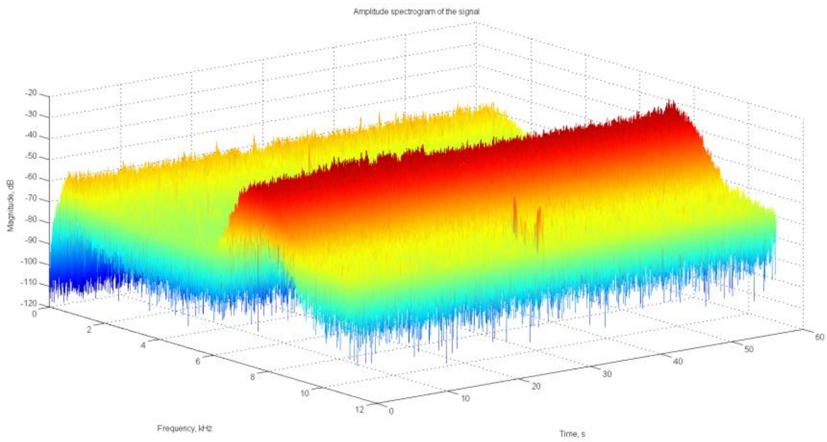
Spectrogram (Grayscale)

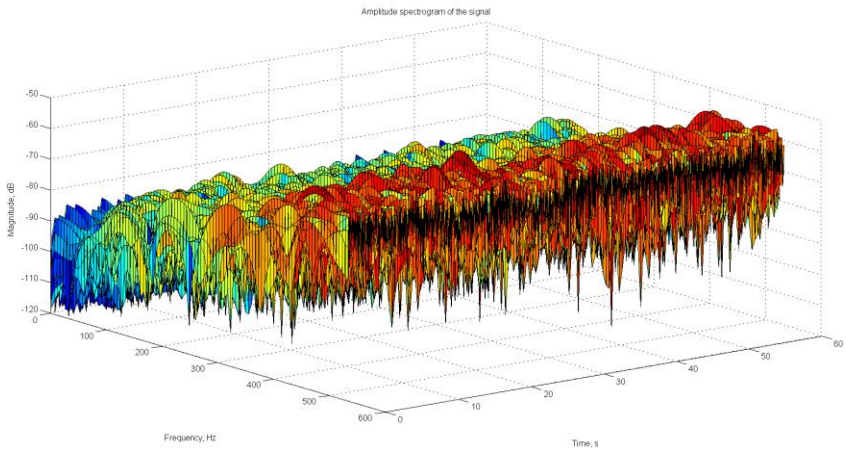


LBP

Based on the LBP, the texture of the sound appears to be very uniform.

c) Low Frequency Analysis of 3D Spectrogram

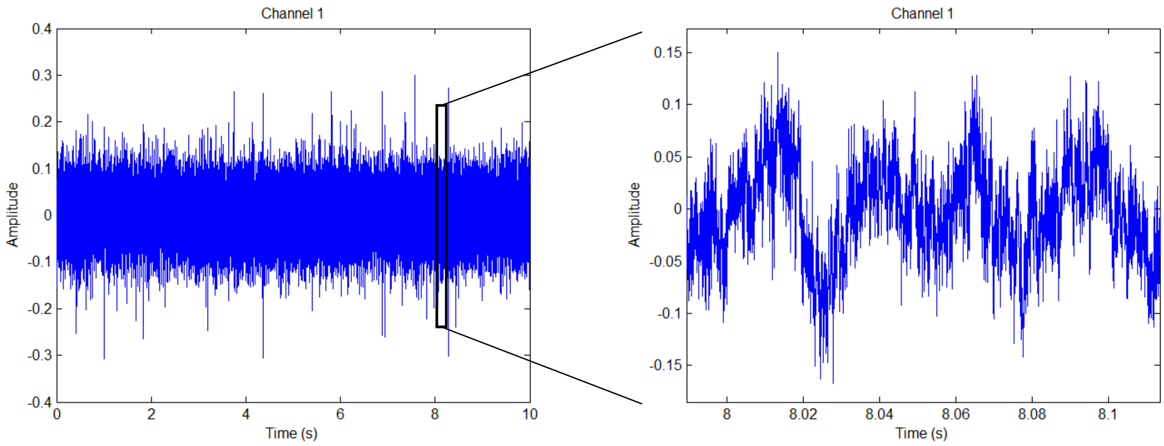




The top figure shows the 3D spectrogram for 0 to 12 kHz across 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal do not change significantly in time.

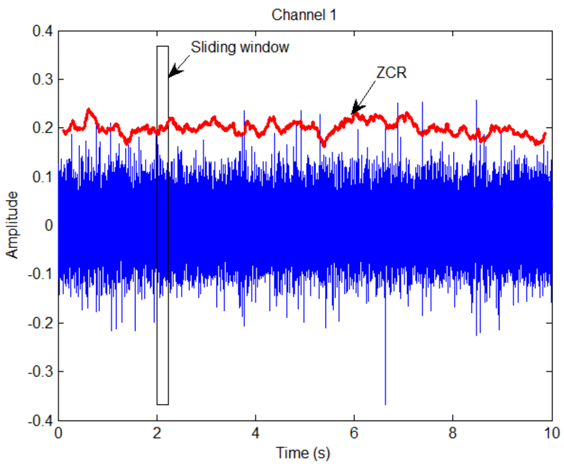
3) Sleep enhancement

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)

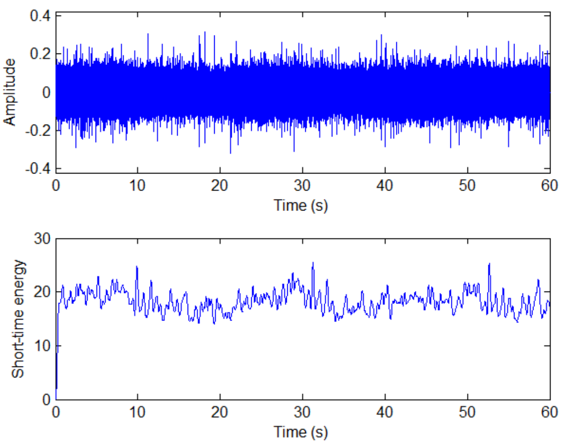


Window size = 10,000 samples (~0.23s)

ZCR is quite consistent throughout the section of the sound examined (10s). The fundamental frequency of the sound is not too 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)

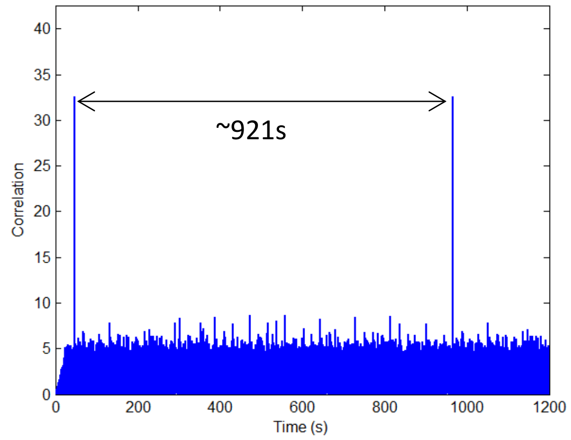


Window size = 20,000 samples (~0.45s)

Window type = Hamming

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

c. Auto-correlation

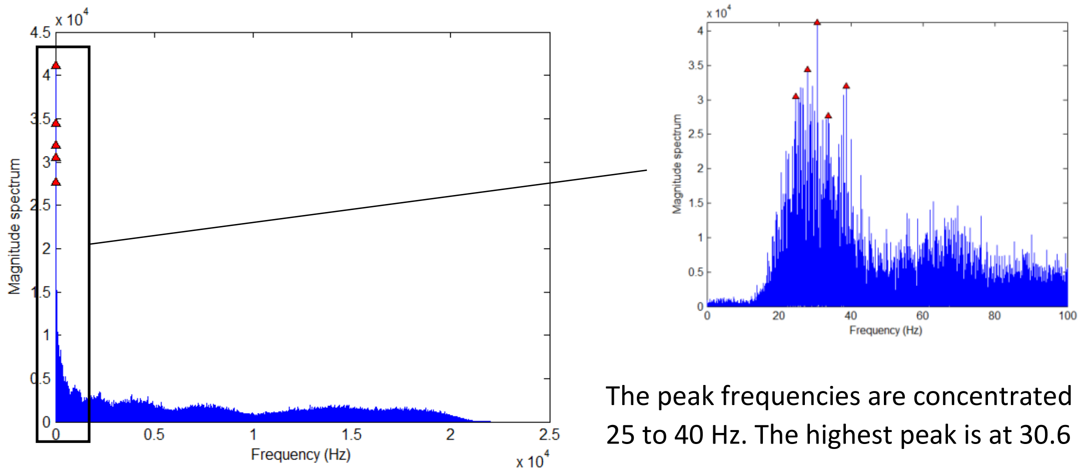


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 921s (or 15.4 minutes). In other words, identical segment of 15.4 minutes is repeated in this sound.

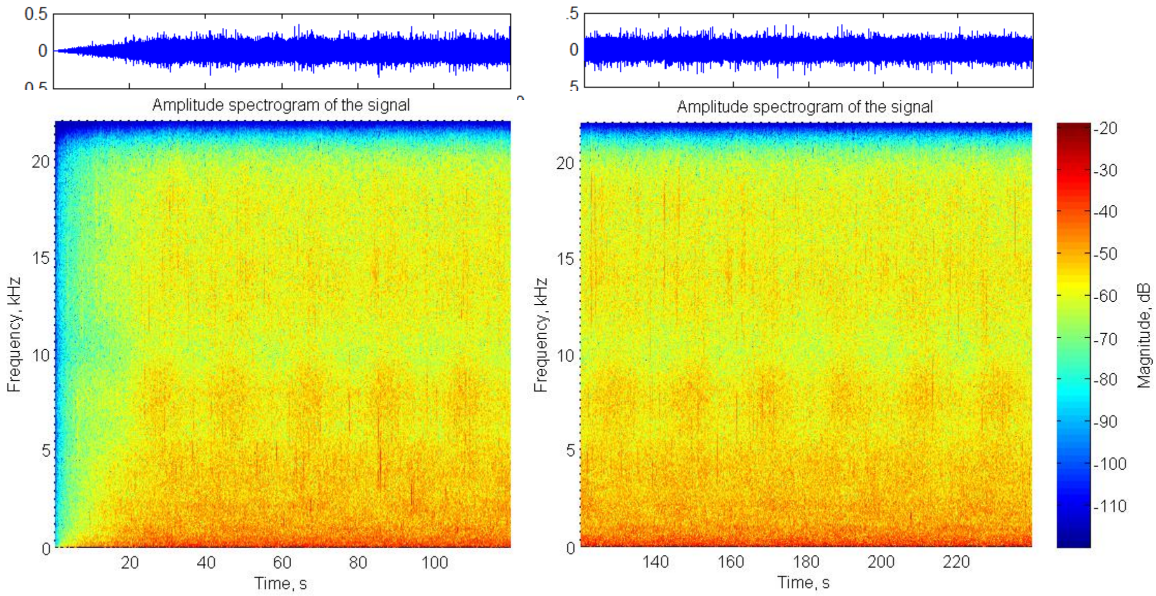
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 25 to 40 Hz. The highest peak is at 30.6 Hz.

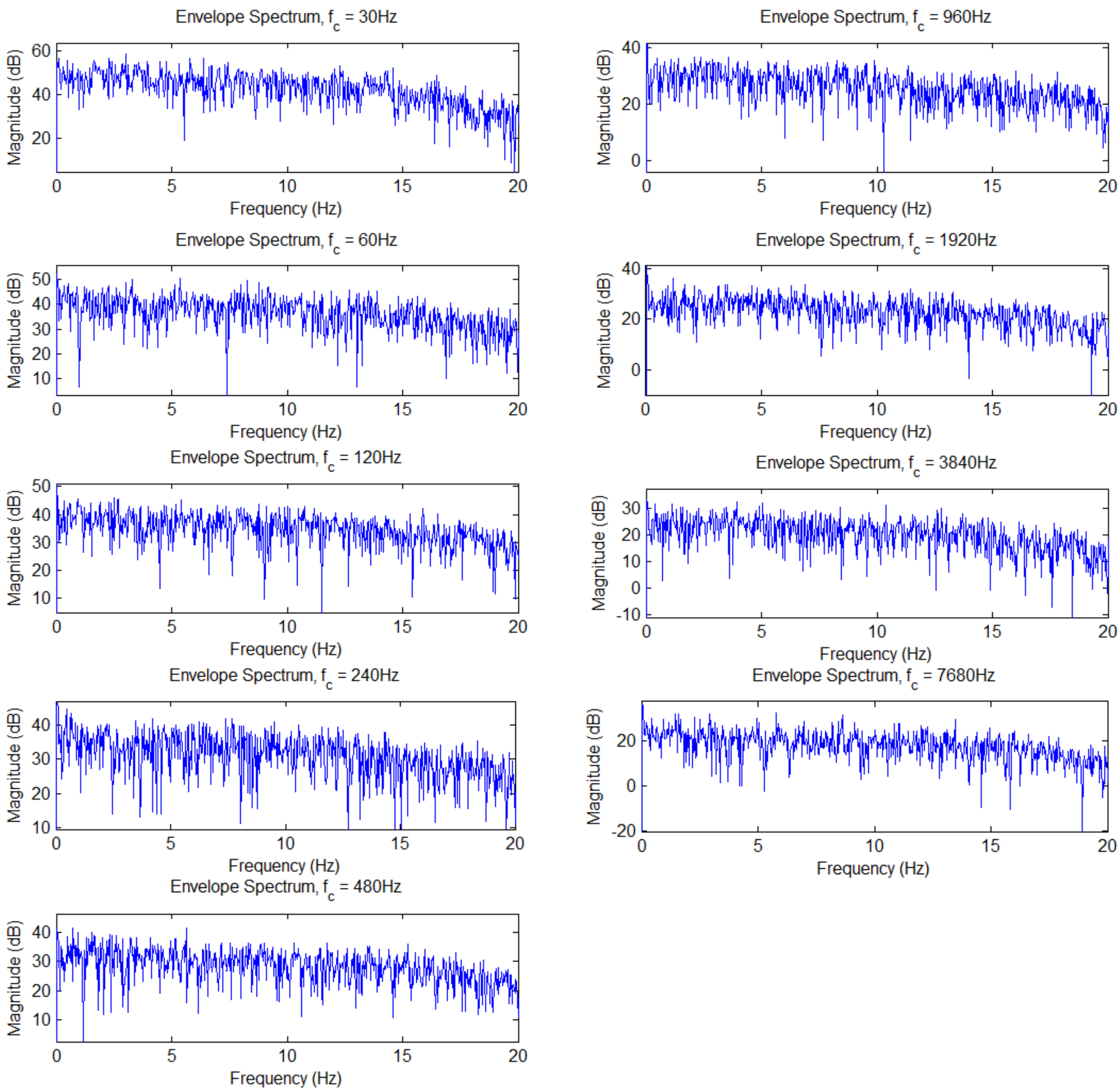
b) Short-Time Fourier Transform (STFT)



FFT size = 4096; window size = 1024 (~0.02s)
The spectrum has constant long-term characteristics. Small variation is observed in the short-term characteristics. The energy of the sound is quite evenly scattered. But some high energy is notice below 1 kHz (dark red color region).

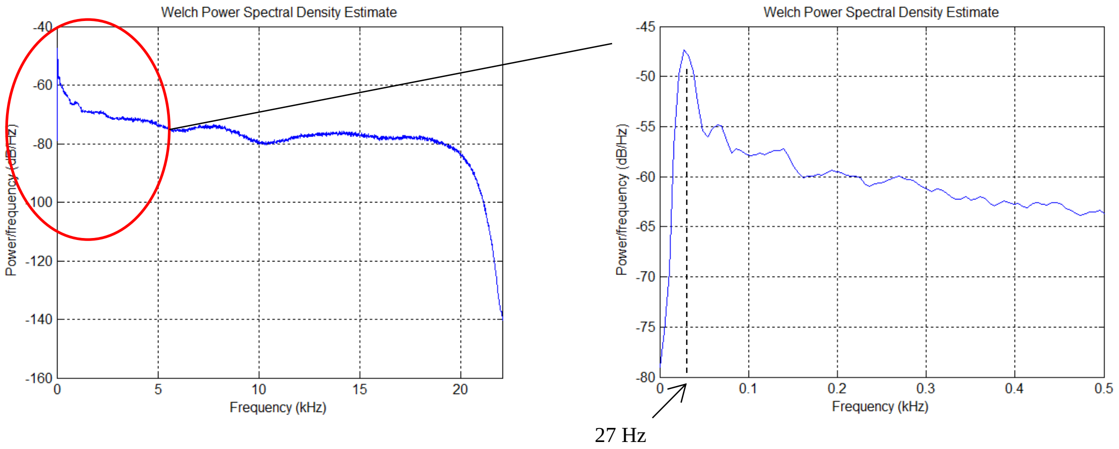
c) Envelope Modulation Spectrum (EMS)

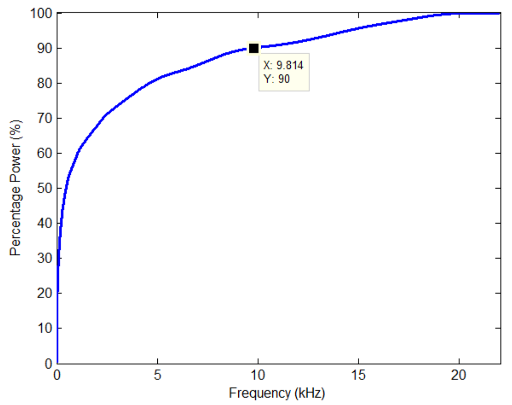
Same methodology as described in 1(c) has been used. The results are given below:



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.

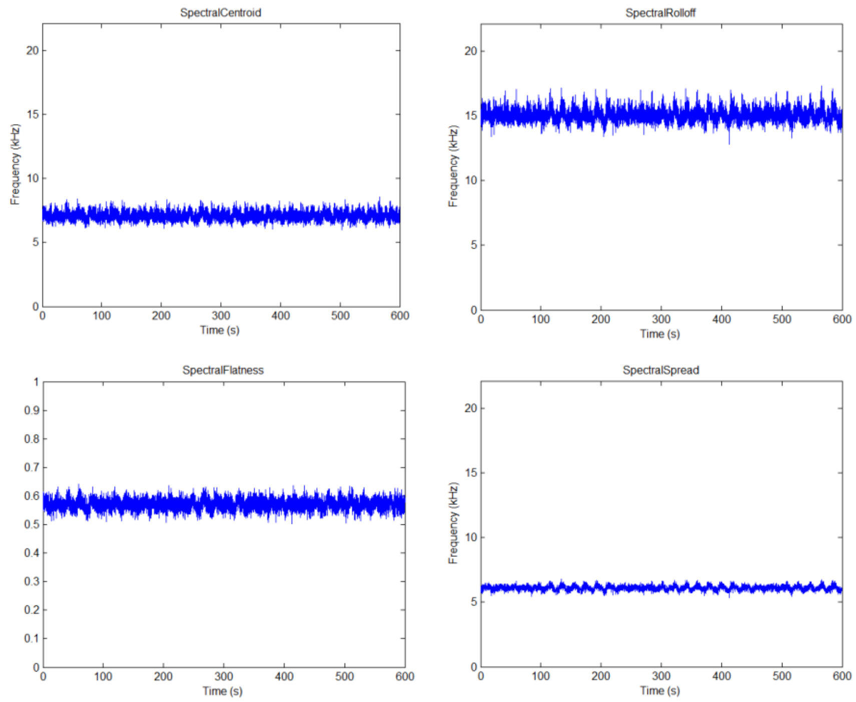
d) Long-term Average Spectrum (LTAS)





One significant frequency at 27 Hz is observed in the power spectrum. 90% of the signal power is contained below 9.8 kHz.

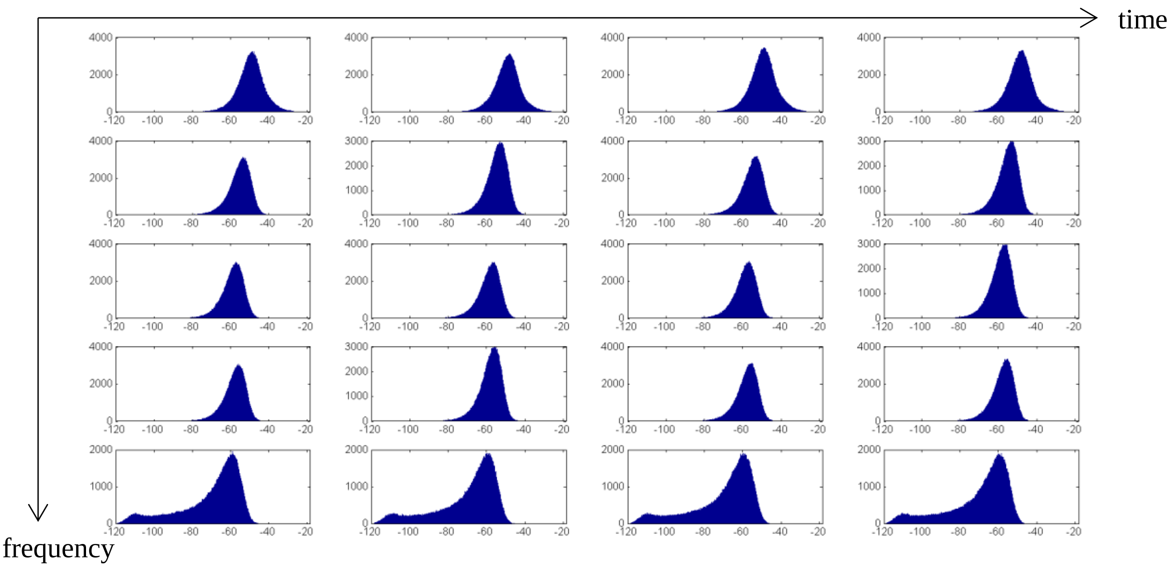
e) Spectrum shape based features



Features	Mean Value
Centroid	7048 Hz
Rolloff	15034 Hz
Flatness	0.57
Spread	6098 Hz

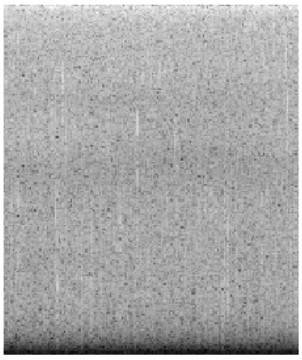
iii) Time-Frequency Domain Features

a) Local Histogram

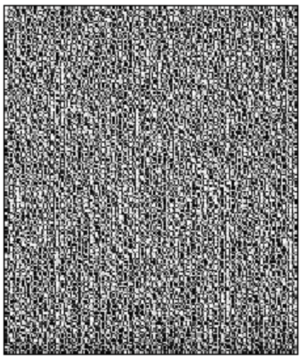


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

b) Local Binary/Ternary Pattern



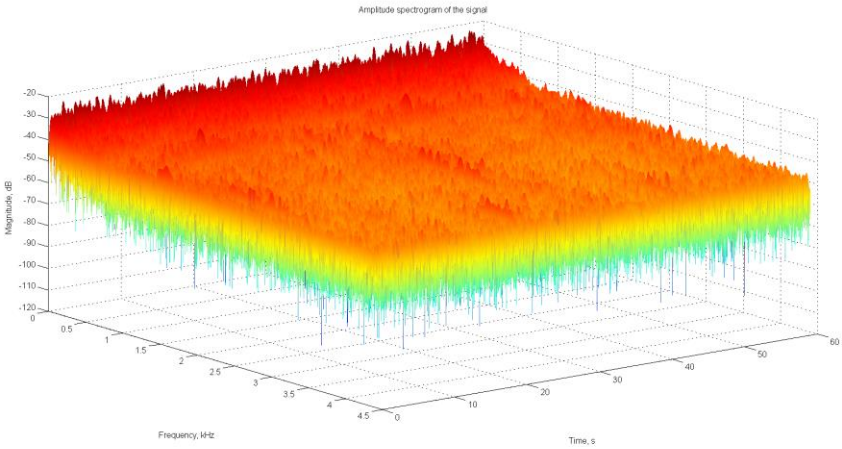
Spectrogram (Grayscale)

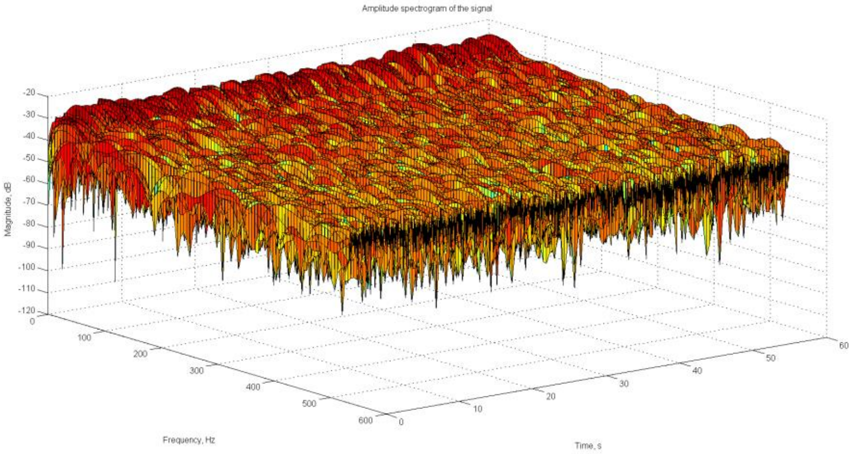


LBP

Based on the LBP, the texture of the sound appears to be very uniform.

c)

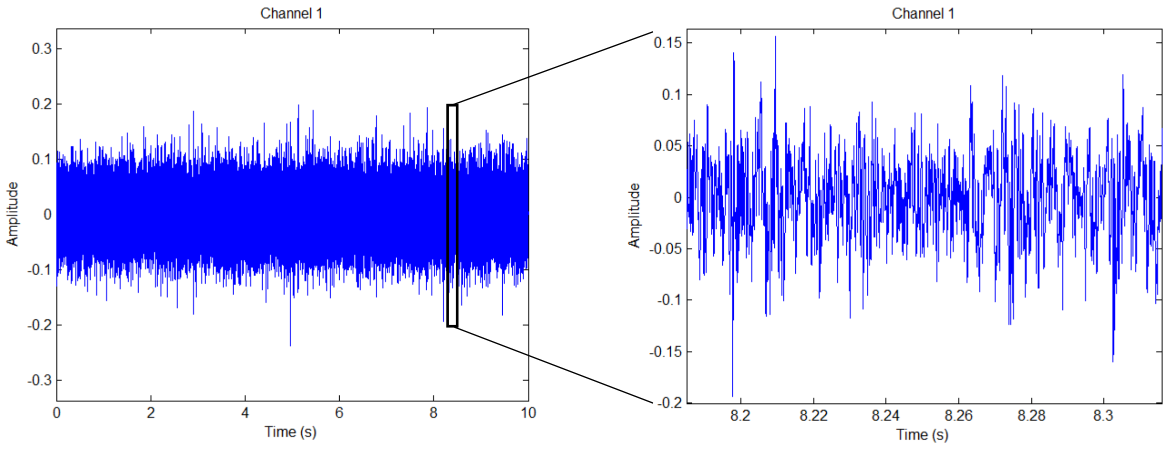




The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal do not change significantly in time. Super low frequency (SLF) (30-300Hz) is very prominent in this signal.

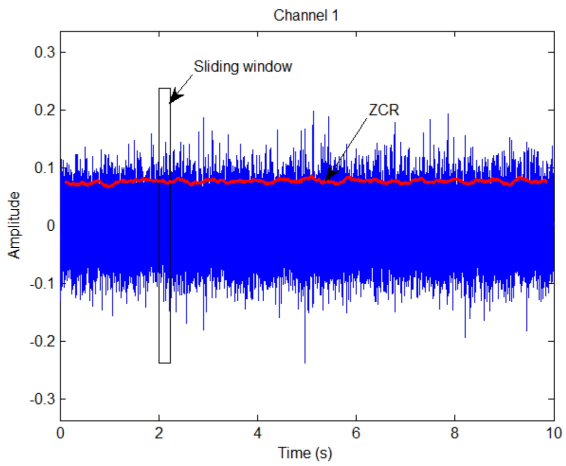
4) Relaxation

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)

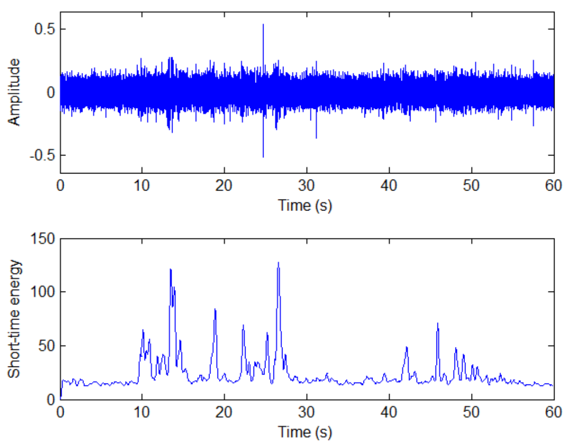


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (10s). 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)

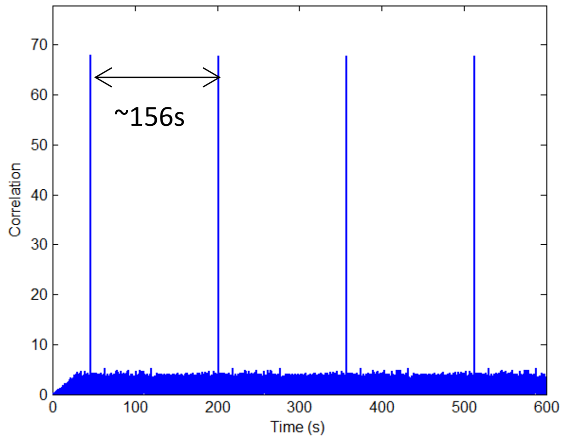


Window size = 20,000 samples (~0.45s)

Window type = Hamming

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

c. Auto-correlation

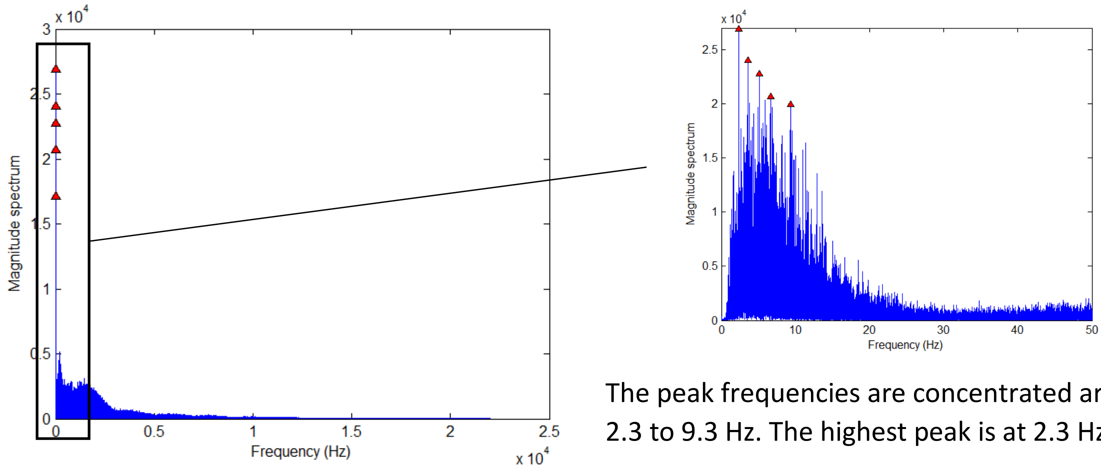


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 156s (or 2.6 minutes). In other words, identical segment of 2.6 minutes is repeated in this sound.

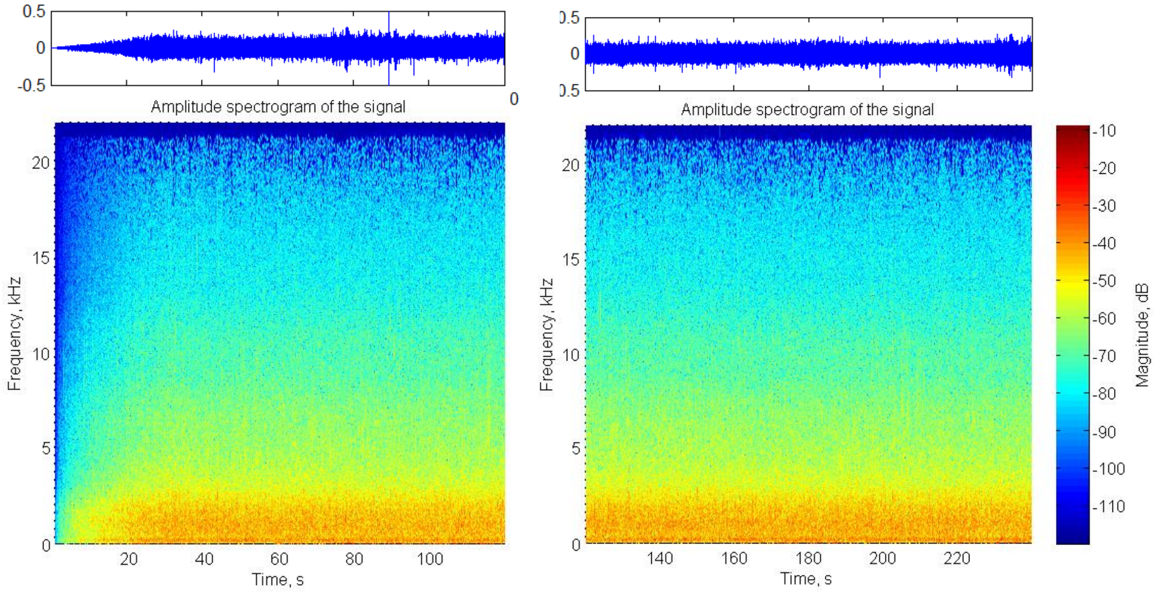
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 2.3 to 9.3 Hz. The highest peak is at 2.3 Hz.

b) Short-Time Fourier Transform (STFT)

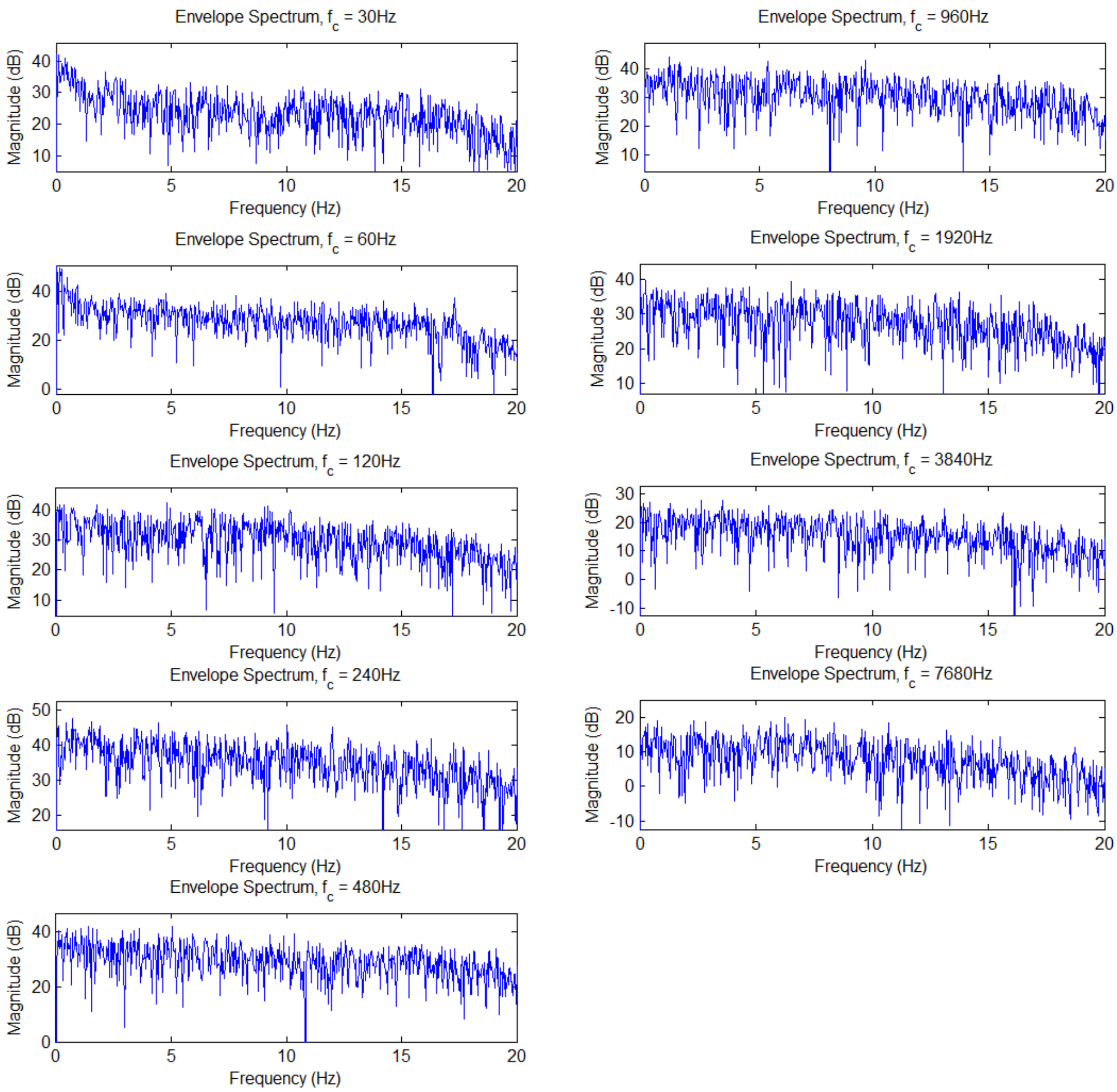


FFT size = 4096; window size = 1024 (~0.02s)

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

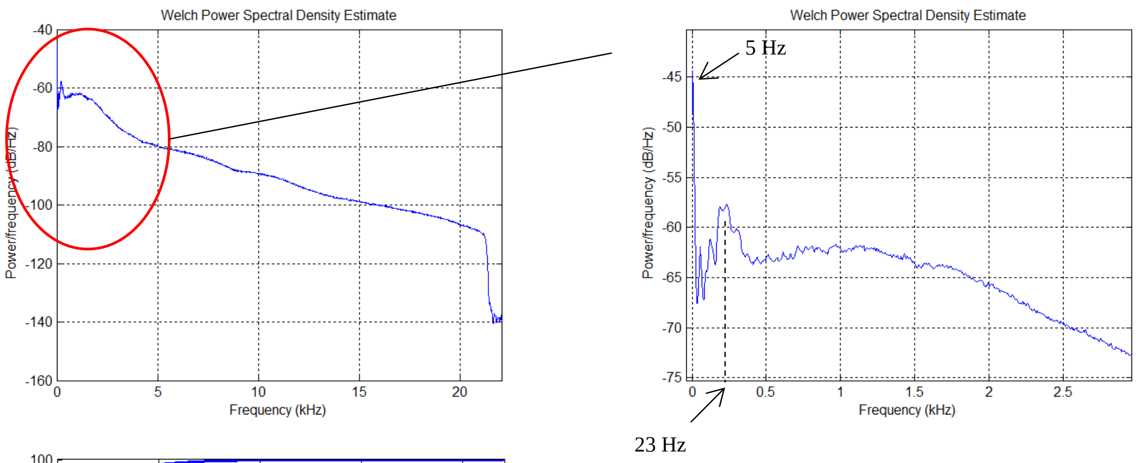
c) Envelope Modulation Spectrum (EMS)

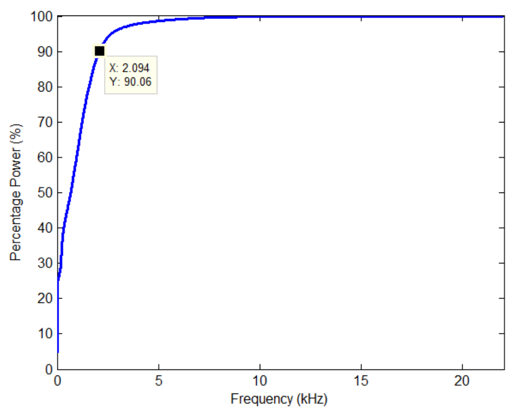
Same methodology as described in 1(c) has been used. The results are given below:



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.

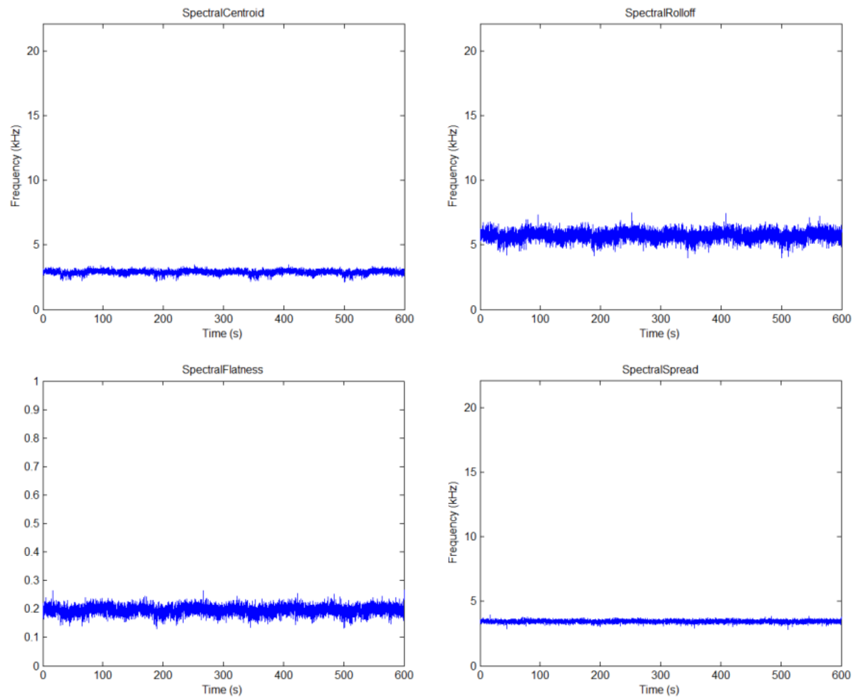
d) Long-term Average Spectrum (LTAS)





Two significant frequencies at 5 and 23 Hz are observed in the power spectrum. 90% of the signal power is contained below 2 kHz.

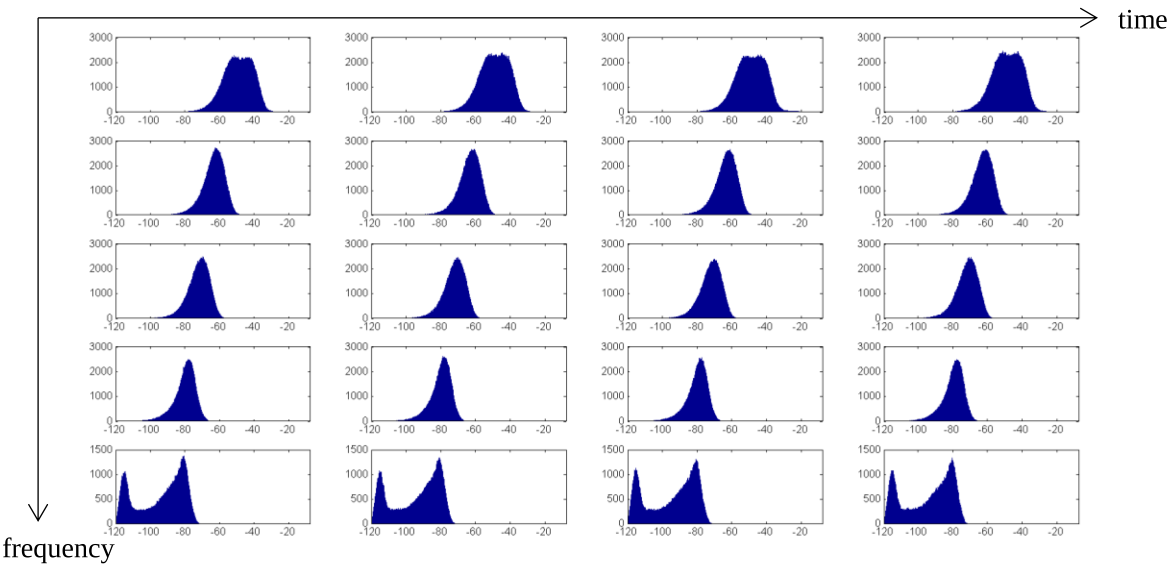
e) Spectrum shape based features



Features	Mean Value
Centroid	2894 Hz
Rolloff	5711 Hz
Flatness	0.1957
Spread	3439 Hz

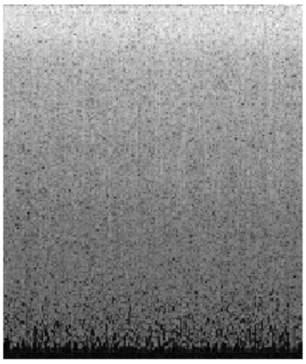
iii) Time-Frequency Domain Features

a) Local Histogram

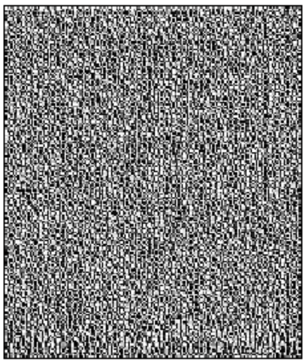


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low frequency sections show less noise-like characteristics. They also contain highest energy.

b) Local Binary/Ternary Pattern



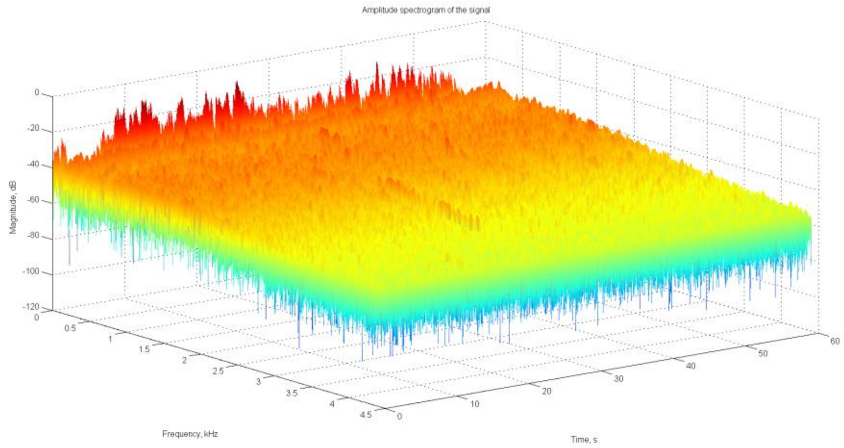
Spectrogram (Grayscale)

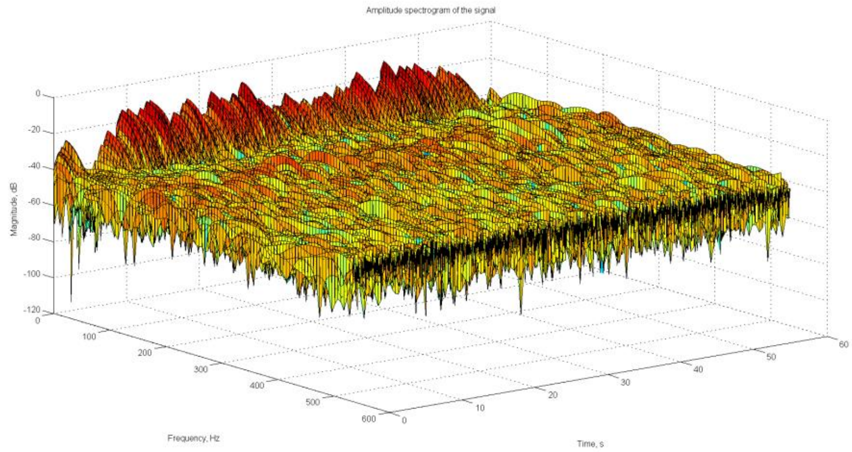


LBP

Based on the LBP, the texture of the sound appears to be very uniform.

c)

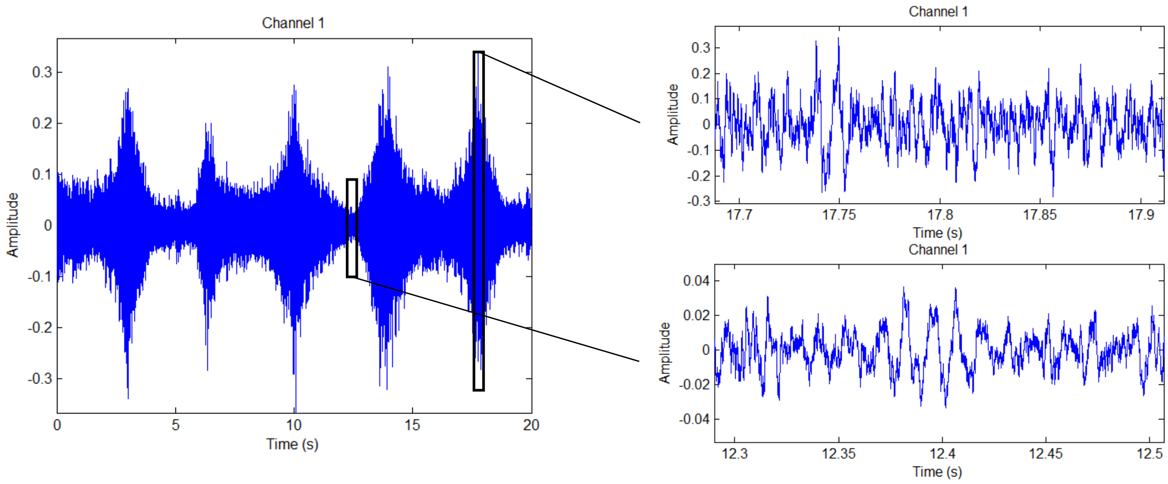




The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. However, their magnitudes change in time.

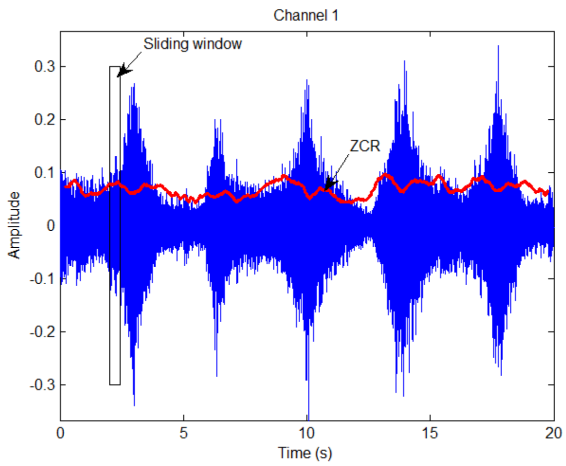
5) Quantum healthcare

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)

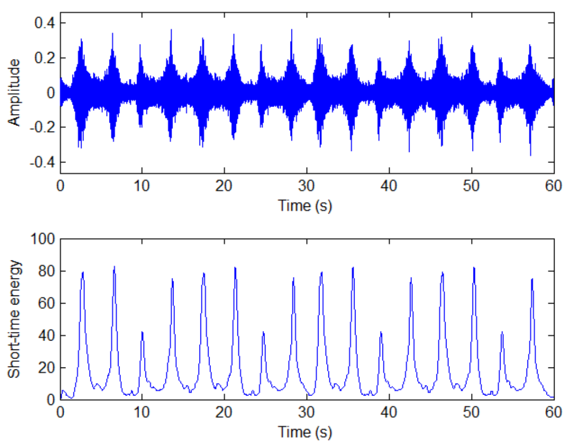


Window size = 20,000 samples (~0.45s)

ZCR shows short-term variation throughout the section of the sound examined (20s). 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)

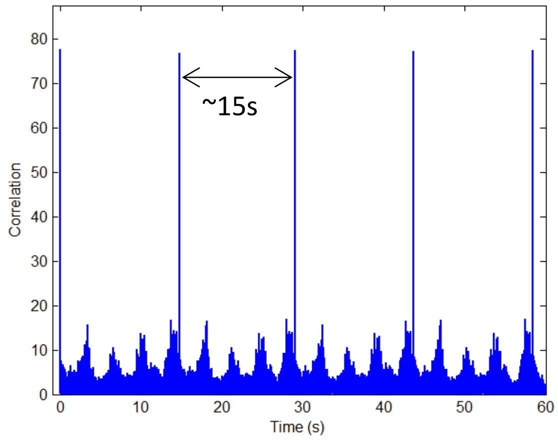


Window size = 20,000 samples (~0.45s)

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 3.64 s.

c. Auto-correlation

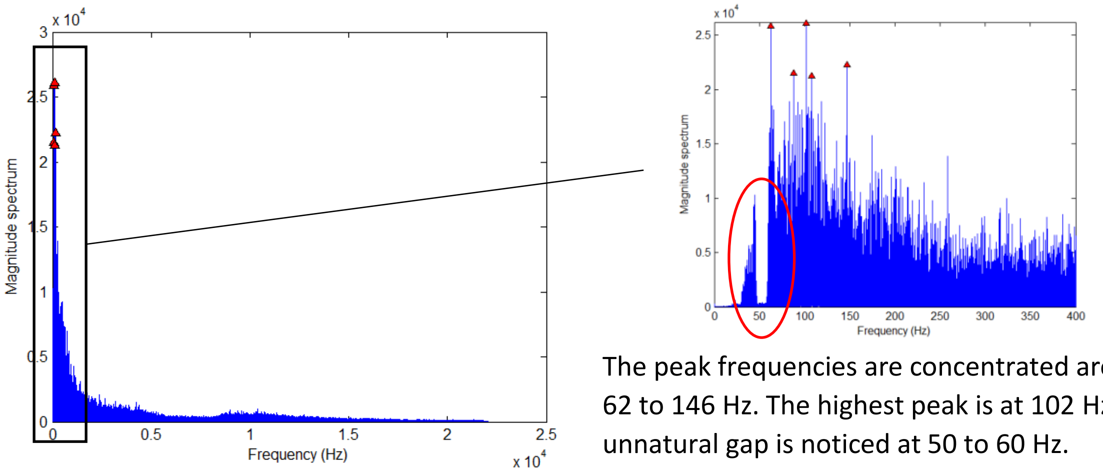


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 15s. In other words, identical segment of 15s is repeated in this sound.

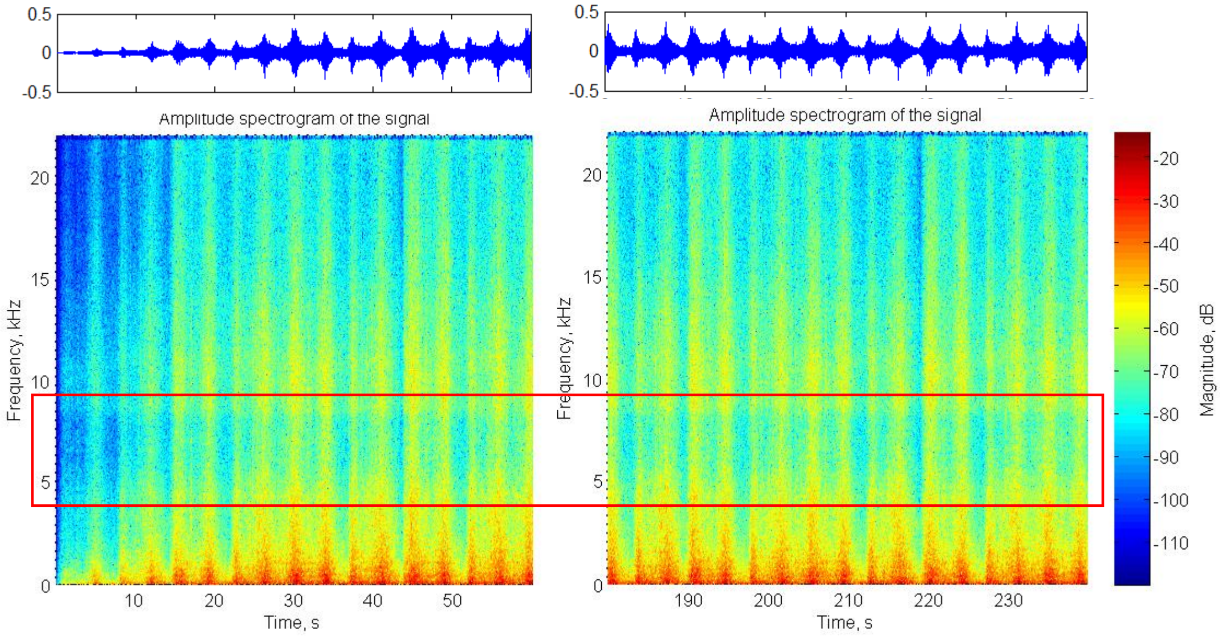
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 62 to 146 Hz. The highest peak is at 102 Hz. An unnatural gap is noticed at 50 to 60 Hz.

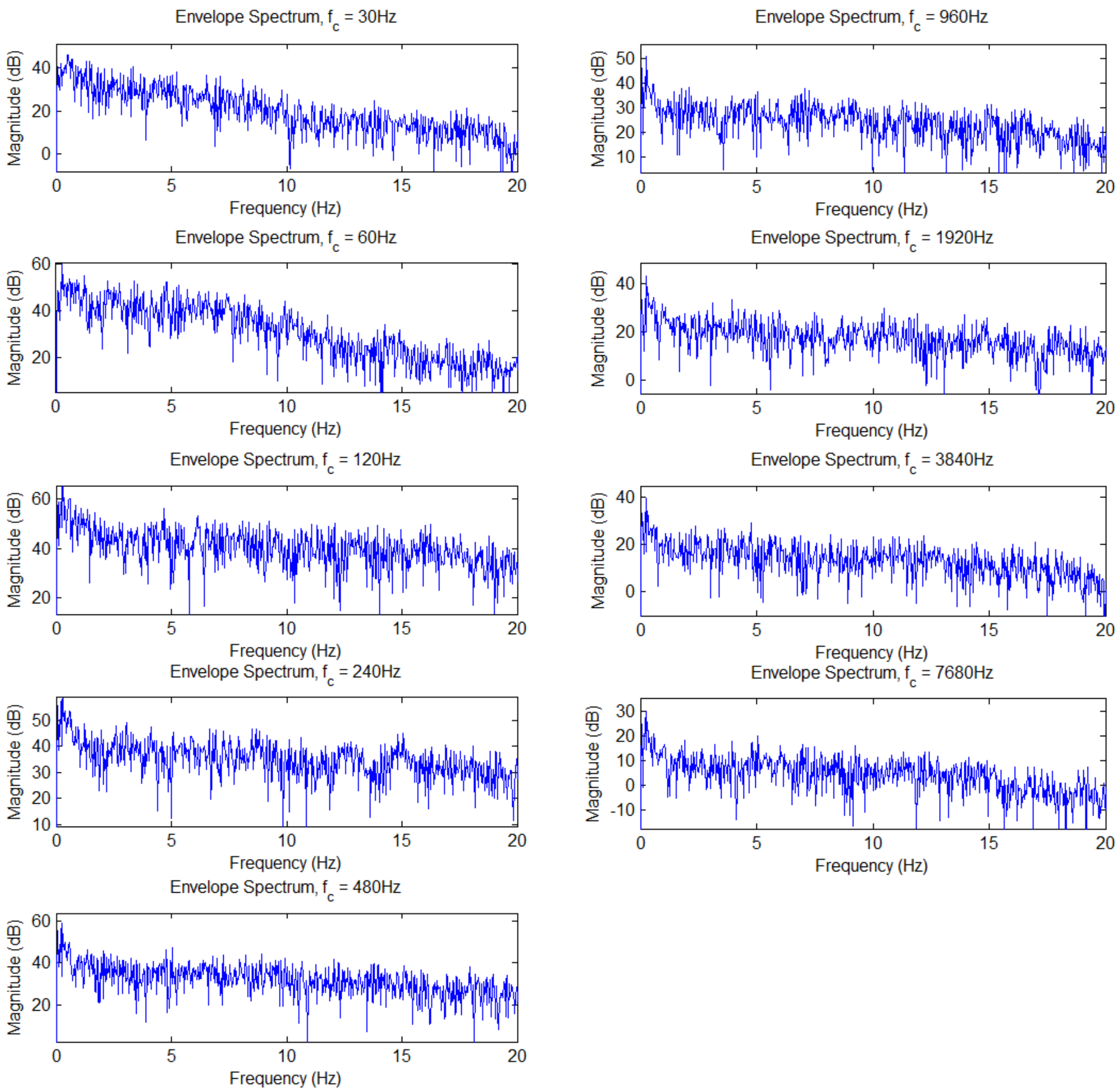
b) Short-time Fourier Transform (STFT)



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 5 kHz (red color region). It is also noticed that frequencies in the range around 5 to 8 kHz could have been unnaturally suppressed.

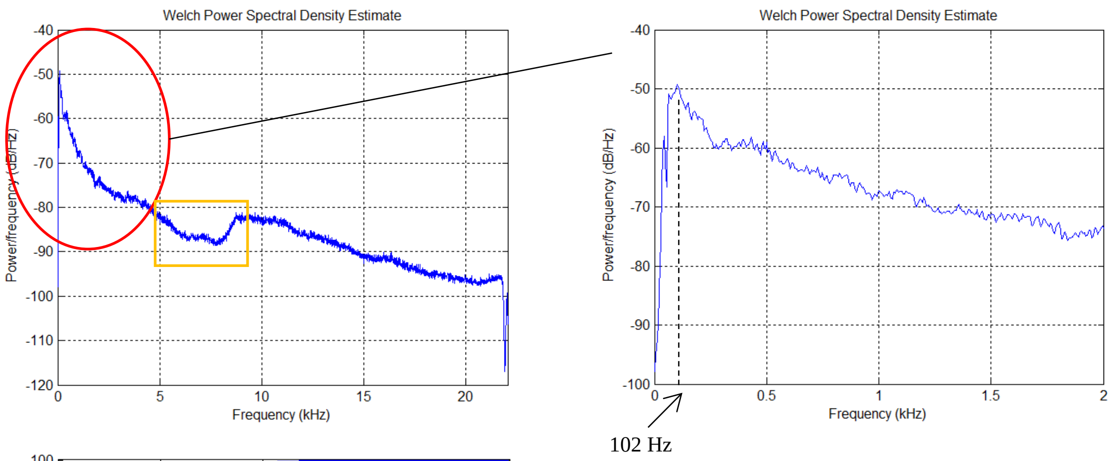
c) Envelope Modulation Spectrum (EMS)

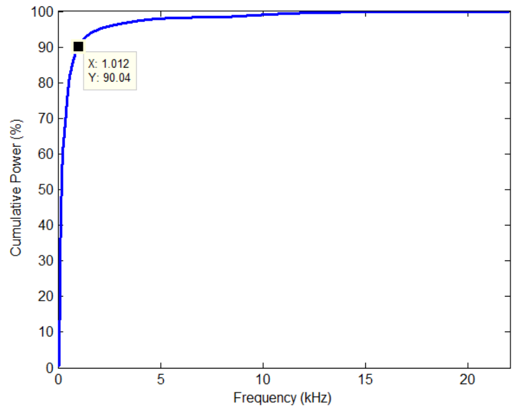
Same methodology as described in 1(c) has been used. The results are given below:



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.

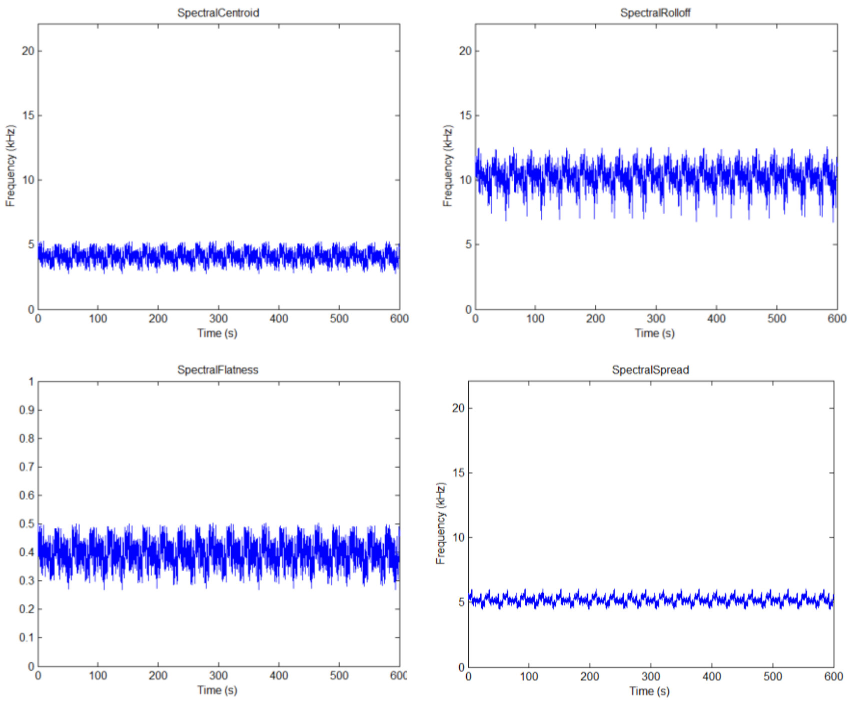
d) Long-term Average Spectrum (LTAS)





One significant frequency at 102 Hz is observed in the power spectrum. 90% of the signal power is contained below 1 kHz. It is also noticed that frequencies in the range of 5 to 8 kHz could have been suppressed.

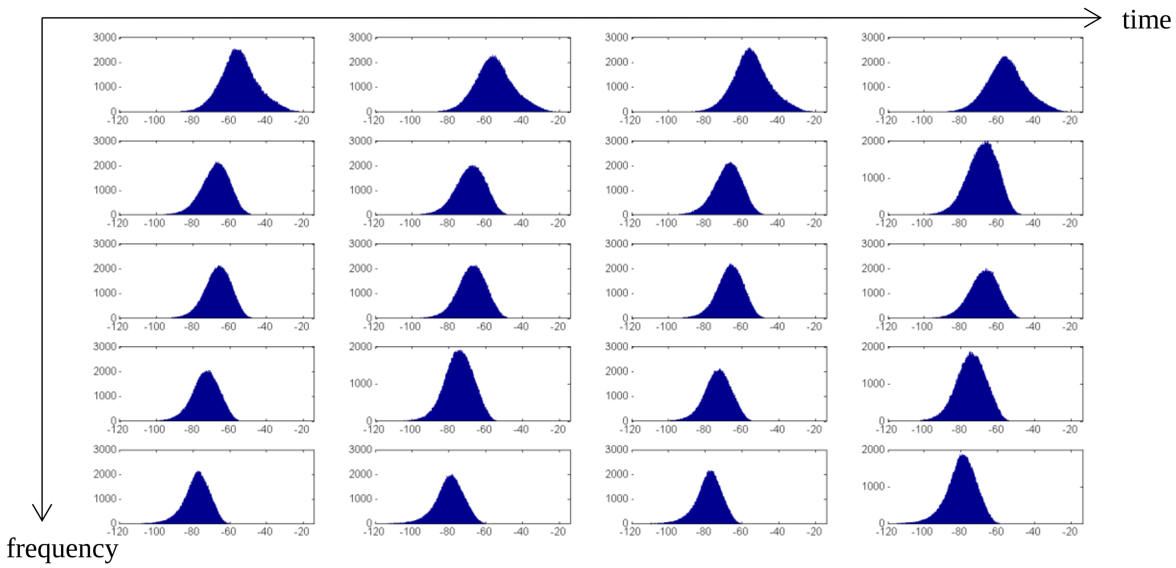
e) Spectrum shape based features



Features	Mean Value
Centroid	4112 Hz
Rolloff	10360 Hz
Flatness	0.3979
Spread	5197 Hz

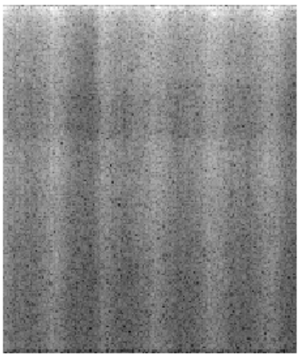
iii) Time-Frequency Domain Features

a) Local Binary Pattern (LBP)

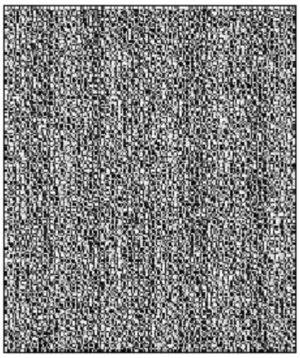


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

b) Local Binary/Ternary Pattern



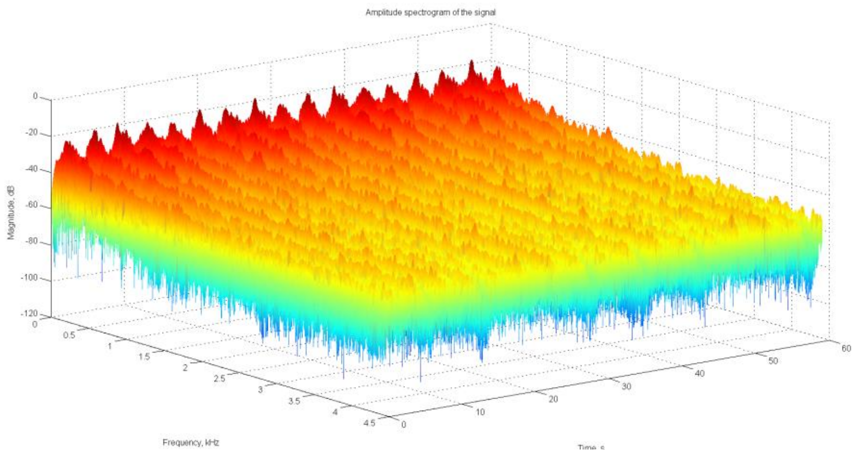
Spectrogram (Grayscale)

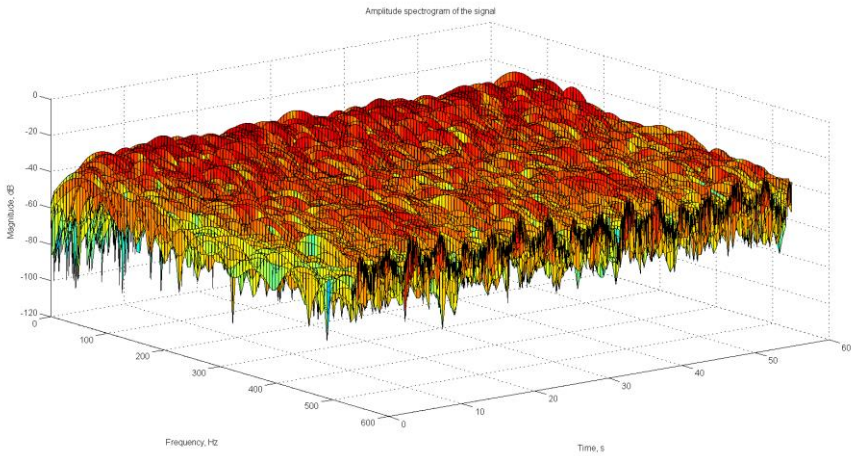


LBP

Based on the LBP, the texture of the sound appears to have a consistent pattern. This is due to the time-varying amplitude of the sound. Overall, the texture is still very noise-like.

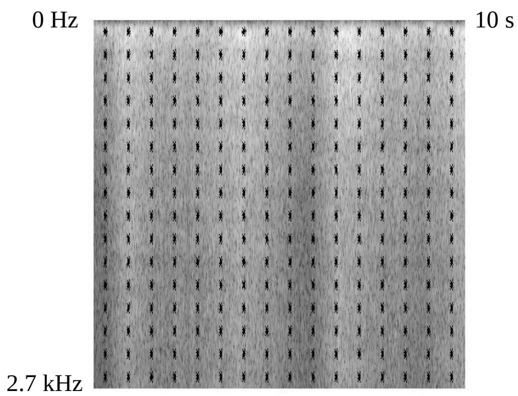
c)



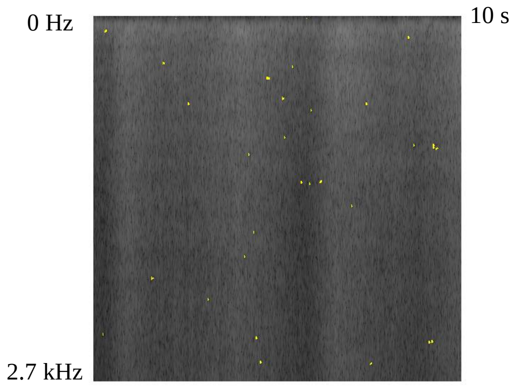


The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Super low frequency (SLF) (30-300Hz) is very prominent in this signal. However, their magnitudes change in time.

d) Histogram of gradients (HOG) and Scale invariant feature transform (SIFT)



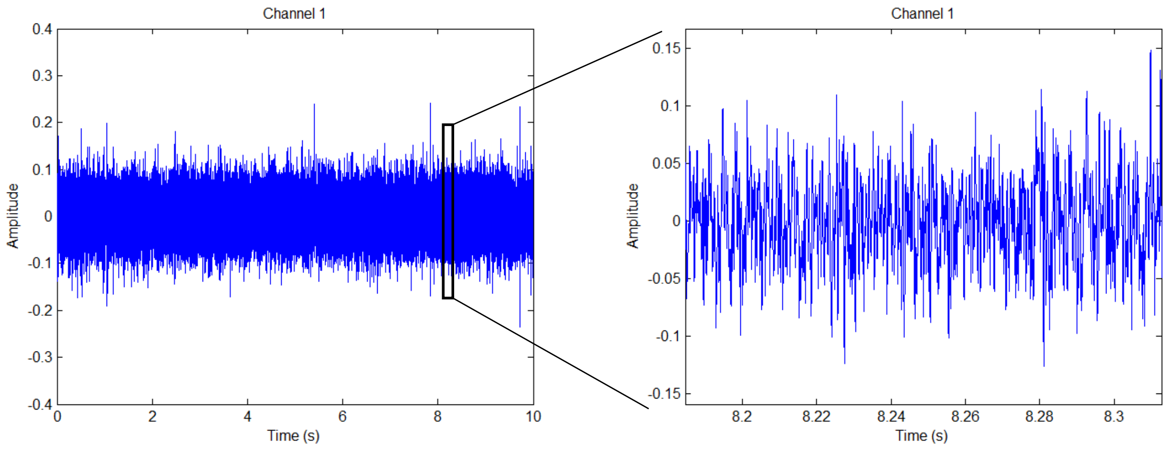
HOG



SIFT

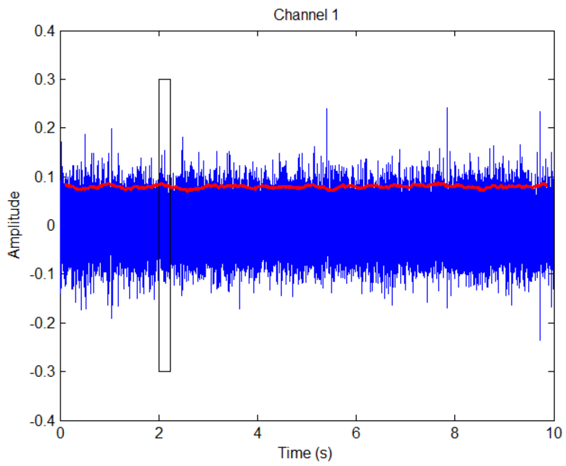
6) Headache support

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)

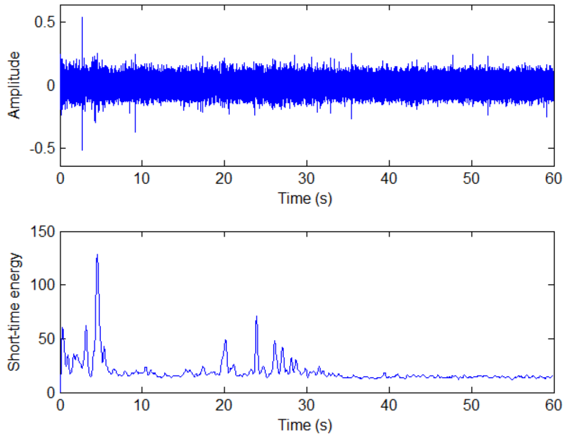


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (10s). 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)

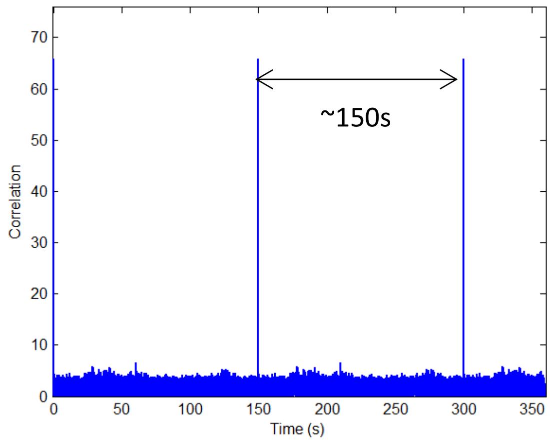


Window size = 20,000 samples (~0.45s)

Window type = Hamming

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

c. Auto-correlation

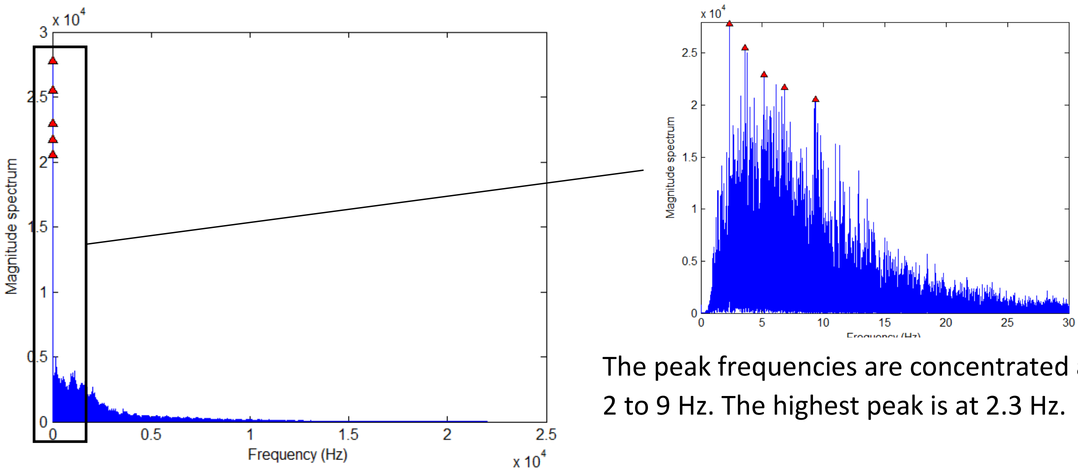


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 150s (or 2.5 minutes). In other words, identical segment of 2.5 min is repeated in this sound.

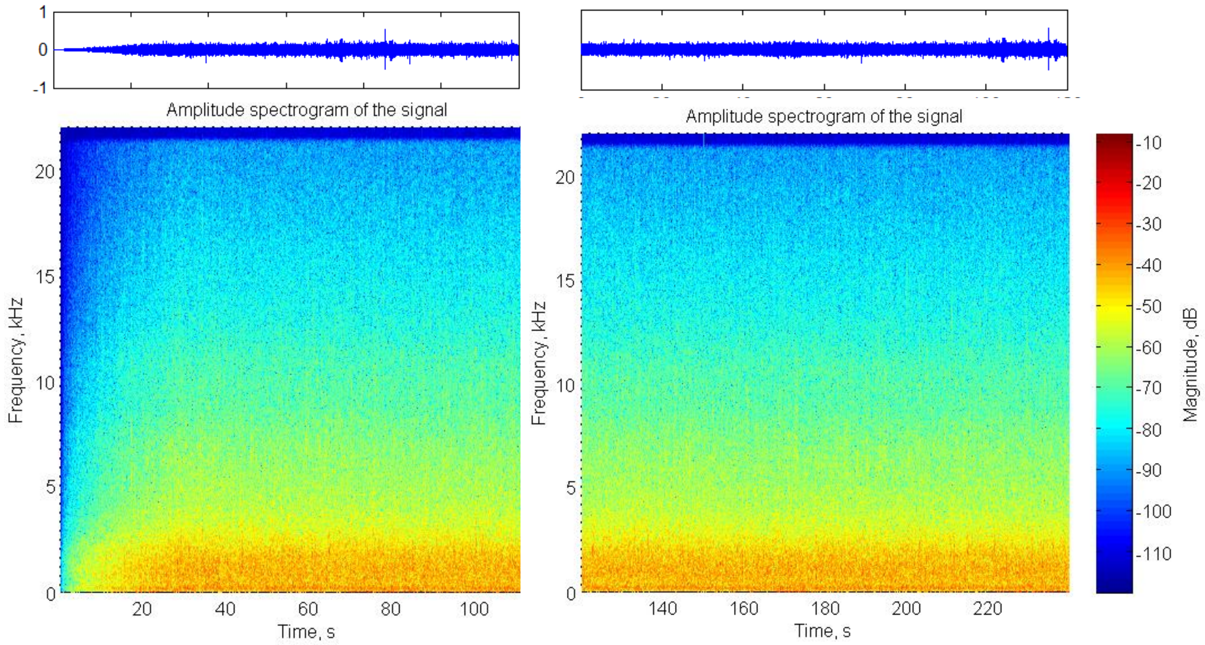
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 2 to 9 Hz. The highest peak is at 2.3 Hz.

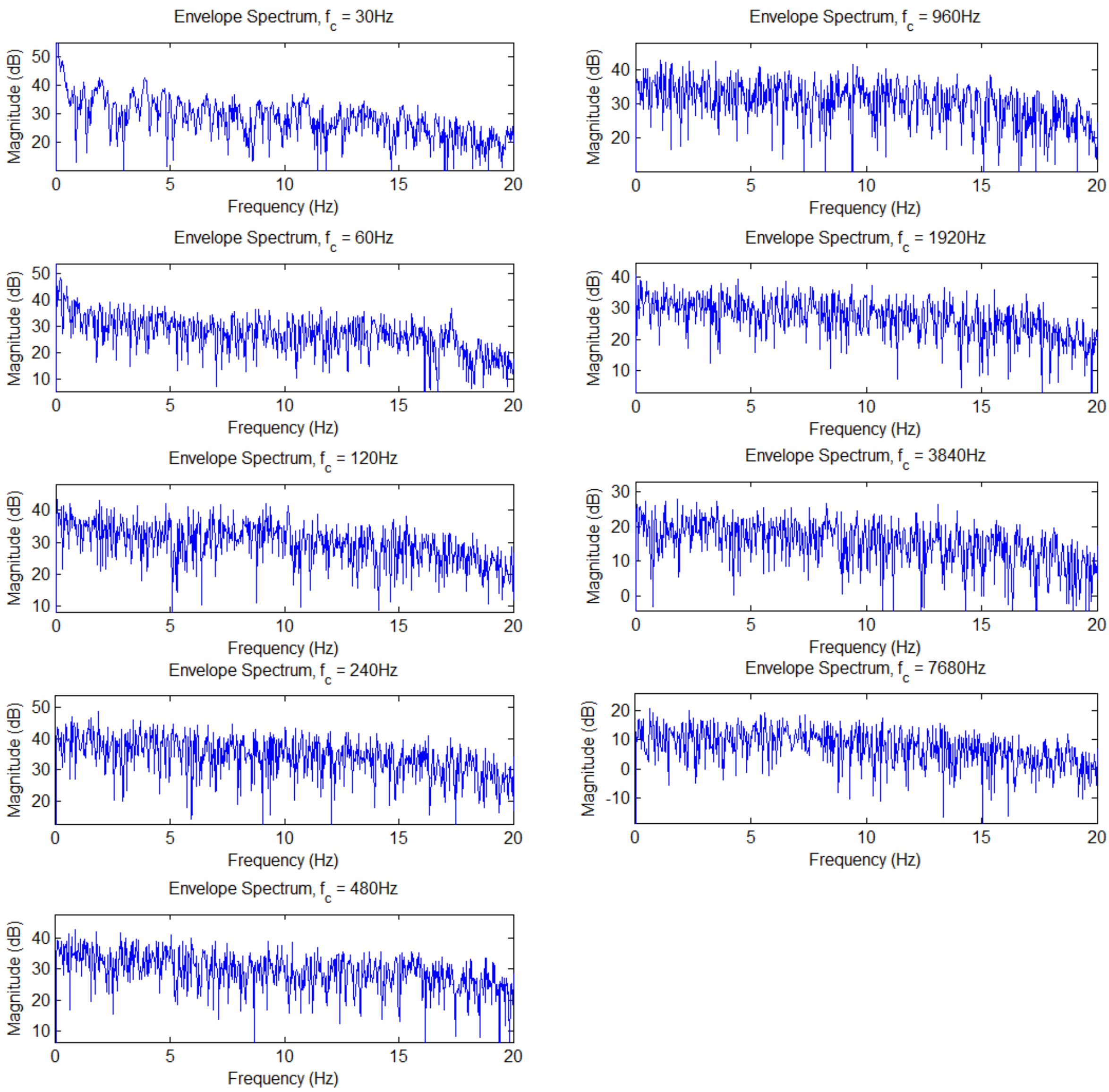
b) Short-time Fourier Transform (STFT)



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).

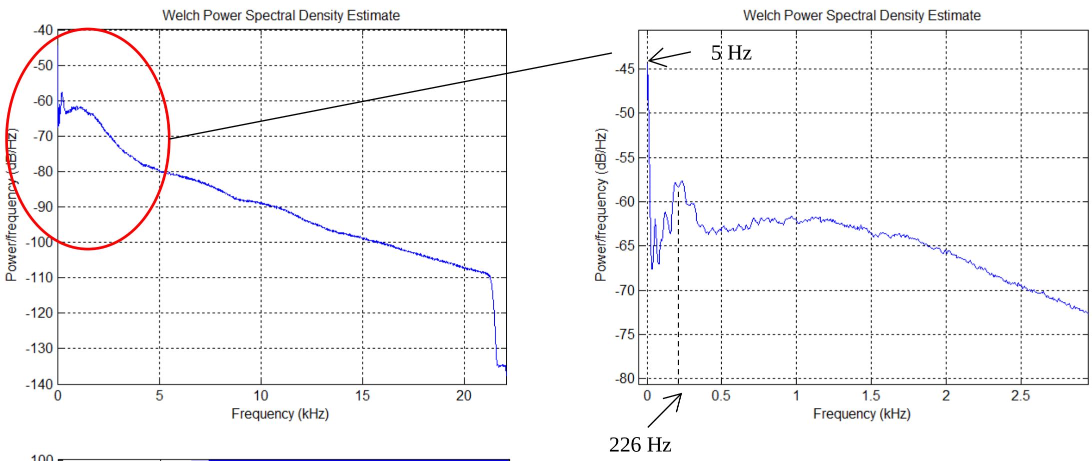
c) Envelope Modulation Spectrum (EMS)

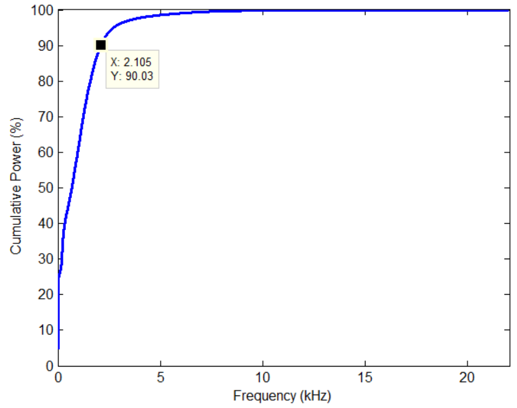
Same methodology as described in 1(c) has been used. The results are given below:



No obvious peak is observed in all the envelope spectrums above. 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.

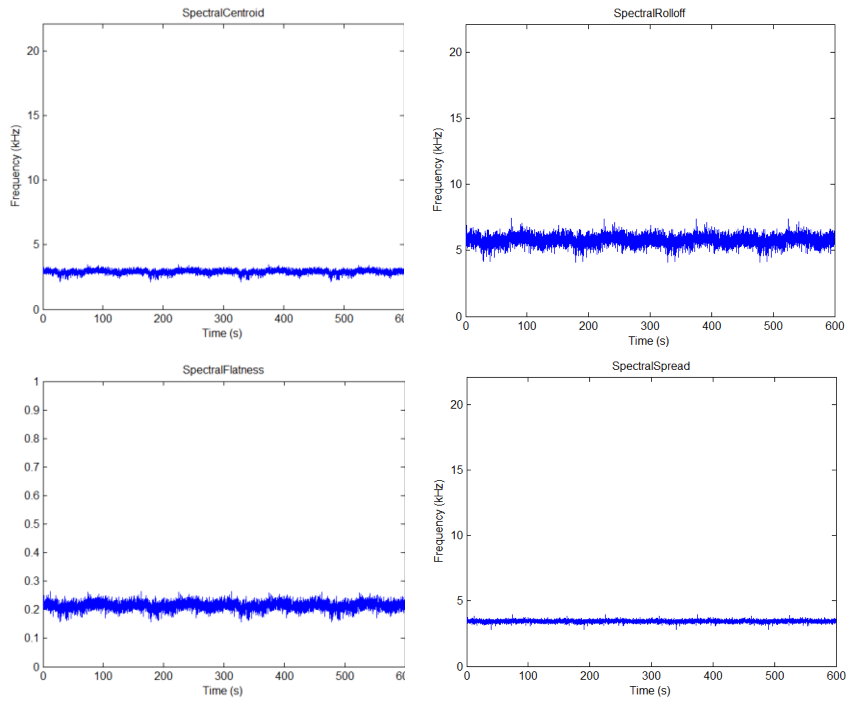
d) Long-term Average Spectrum (LTAS)





Two significant frequencies at 5 and 226 Hz are observed in the power spectrum. 90% of the signal power is contained below 2.1 kHz.

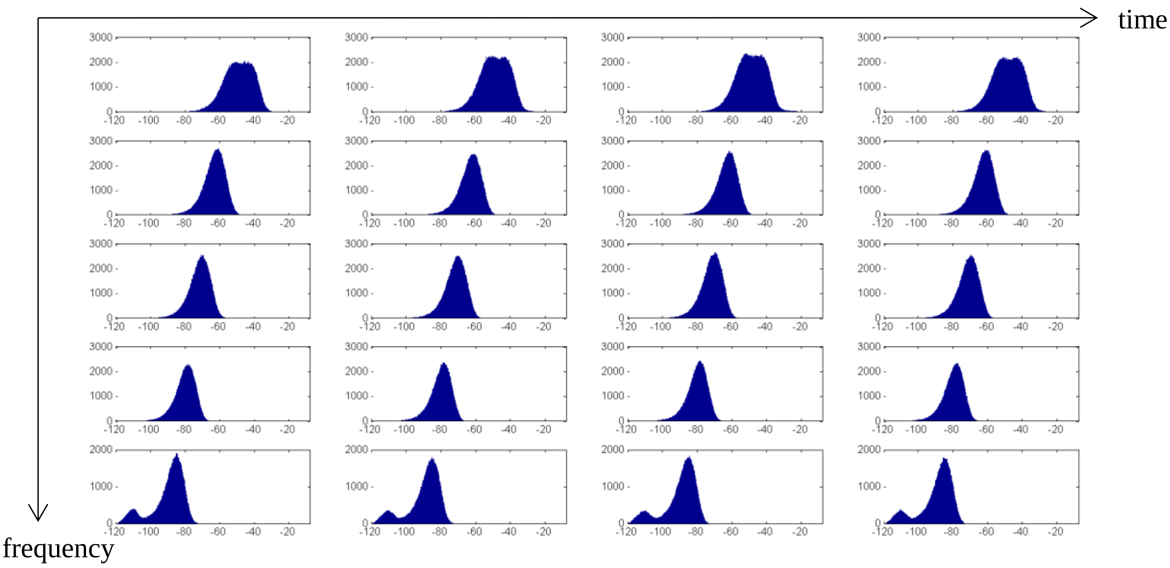
e) Spectrum shape based features



Features	Mean Value
Centroid	2908 Hz
Rolloff	5764 Hz
Flatness	0.2142
Spread	3445 Hz

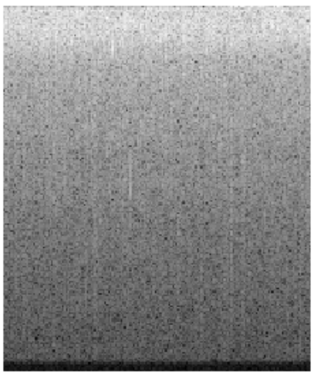
iii) Time-Frequency Domain Features

a) Local Binary Pattern (LBP)

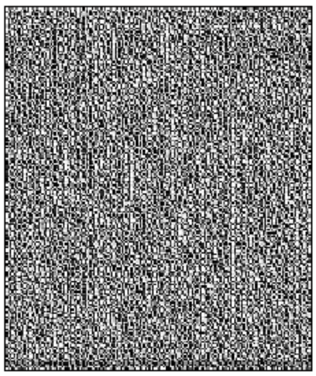


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low frequency sections show less noise-like characteristics. They also contain highest energy.

b) Local Binary/Ternary Pattern



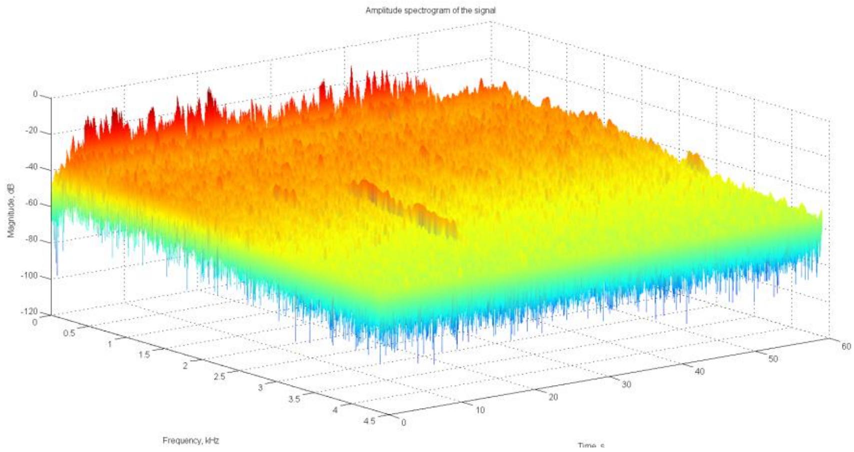
Spectrogram (Grayscale)

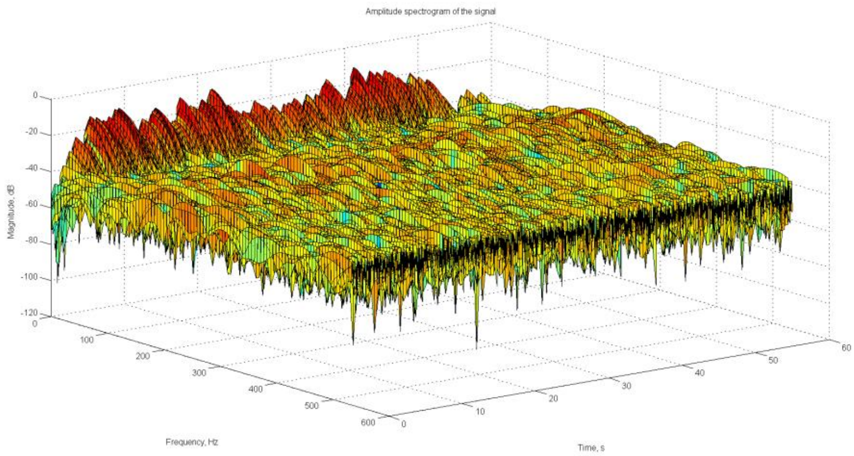


LBP

Based on the LBP, the texture of the sound appears to be very uniform.

c)

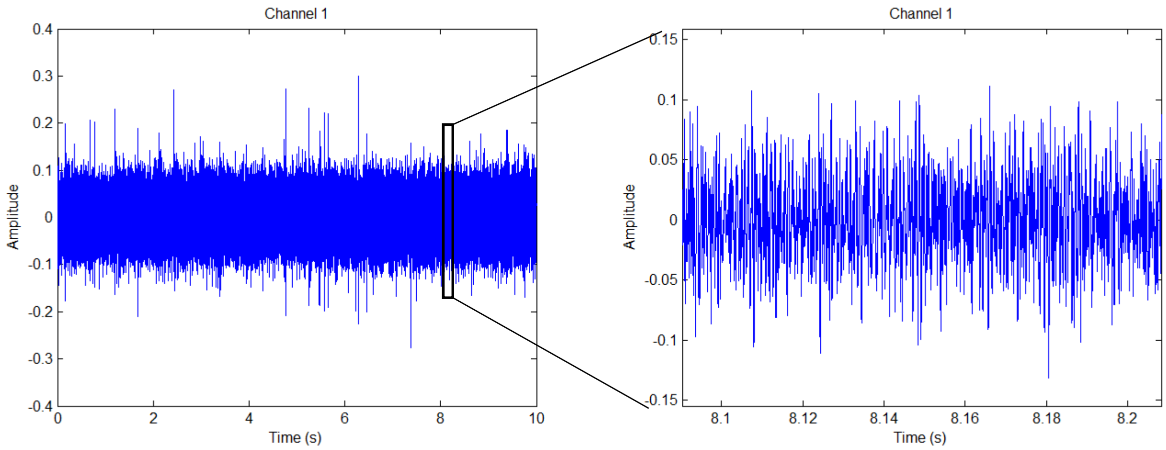




The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. Extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. However, their magnitudes change in time.

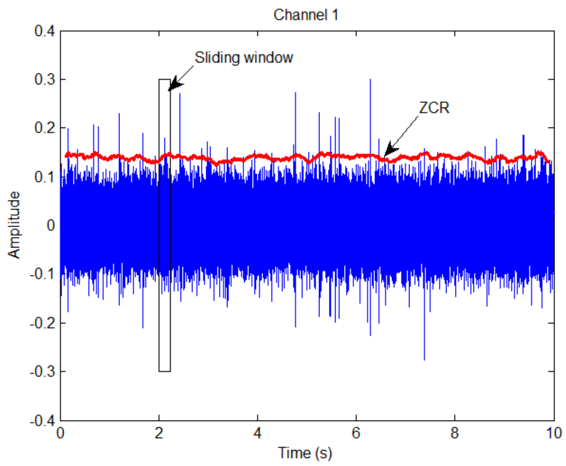
7) T-shield

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)

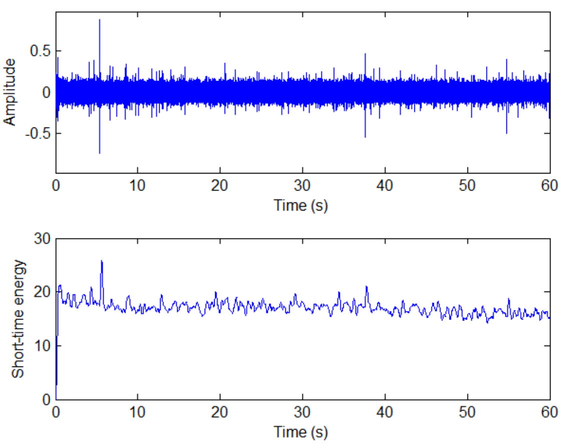


Window size = 10,000 samples (~0.23s)

ZCR is very consistent throughout the section of the sound examined (10s). 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)

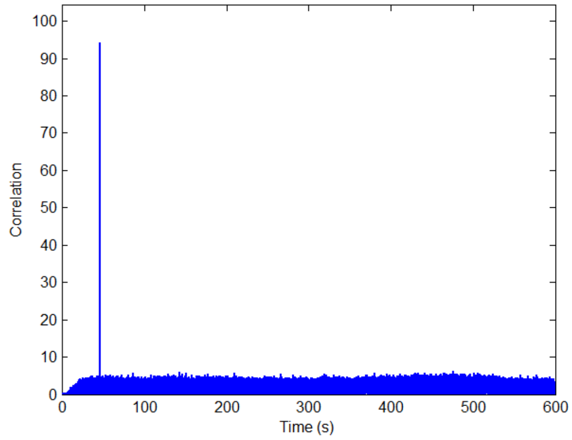


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE remains constant and low all the times. No large energy surge has been observed.

c. Auto-correlation

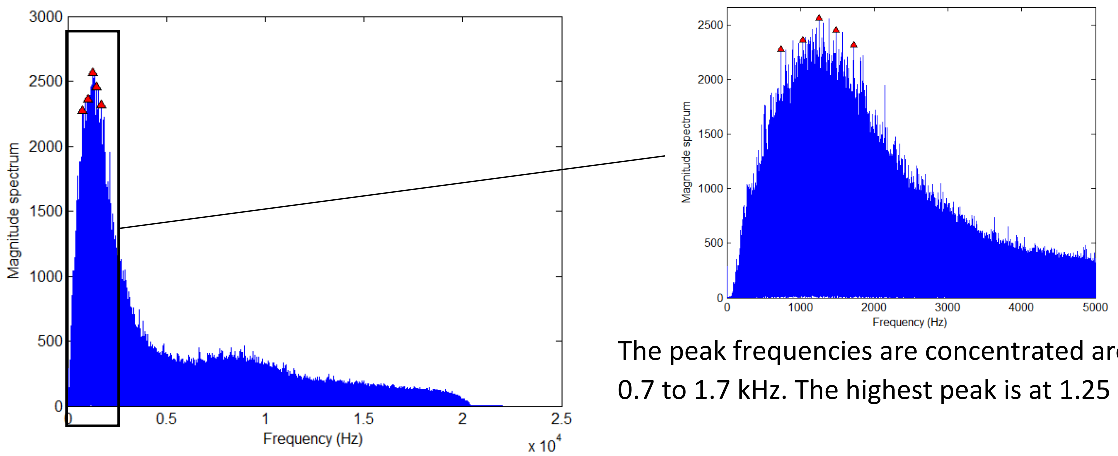


Segment/window size = 50,000 samples (~1.13s)

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

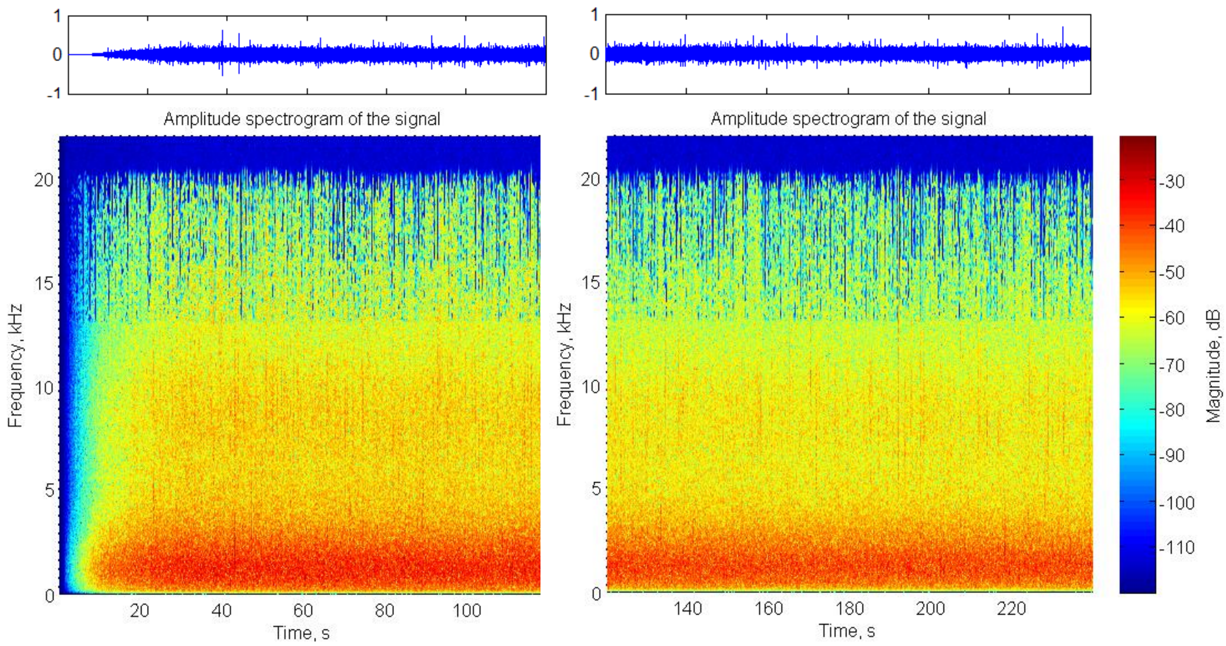
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 0.7 to 1.7 kHz. The highest peak is at 1.25 kHz.

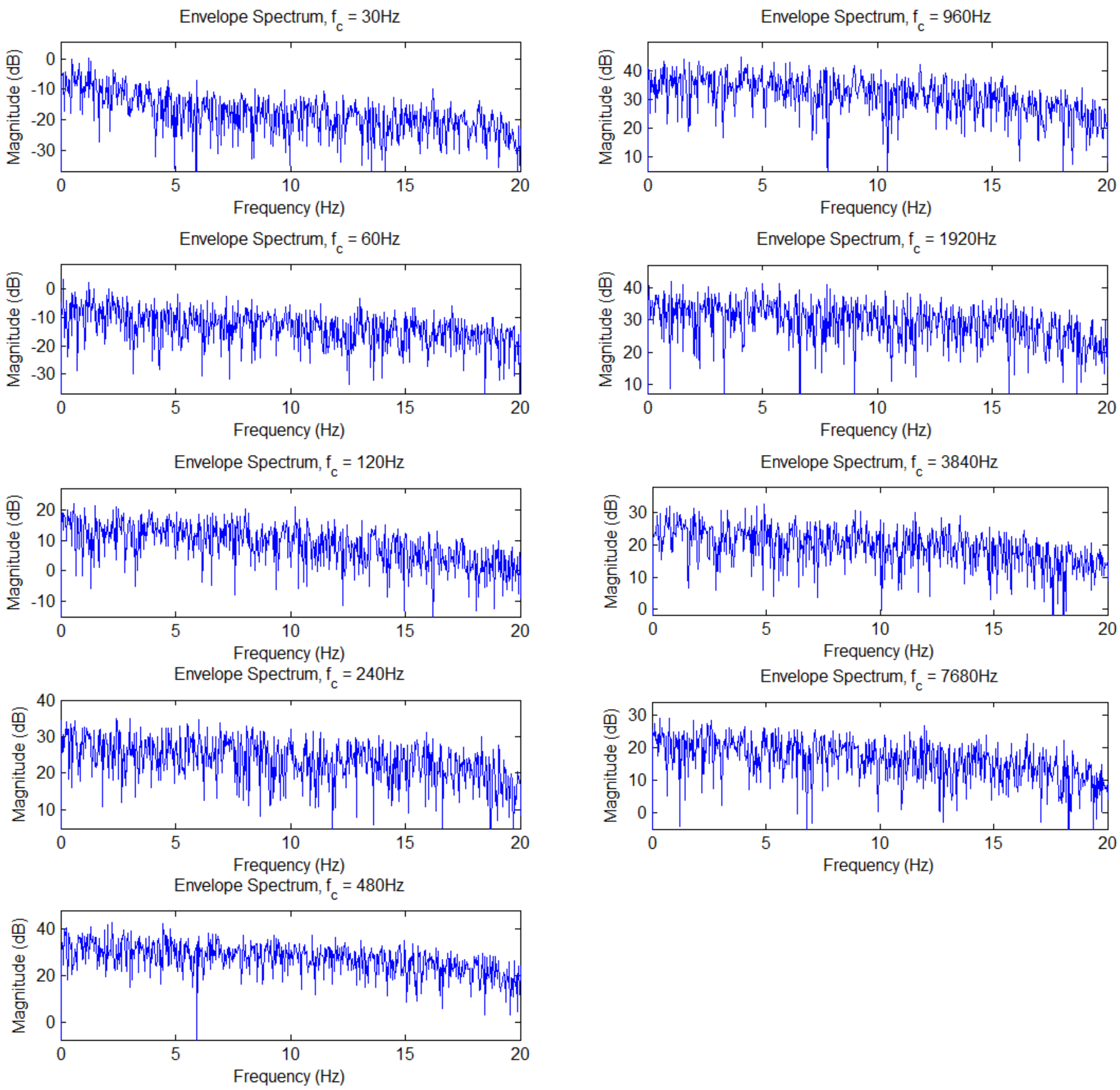
b) Short-time Fourier Transform (STFT)



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).

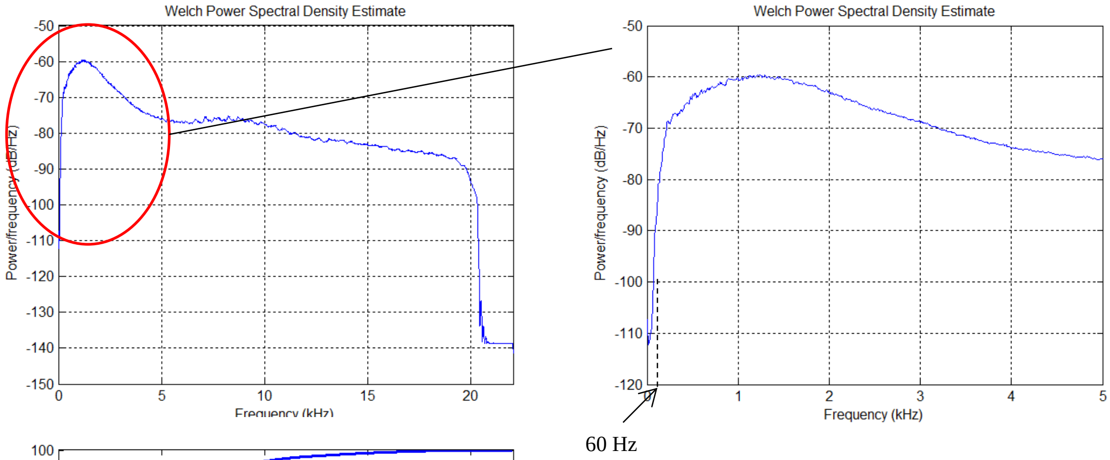
c) Envelope Modulation Spectrum (EMS)

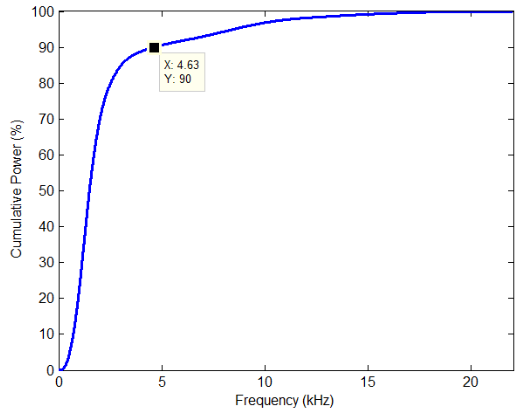
Same methodology as described in 1(c) has been used. The results are given below:



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.

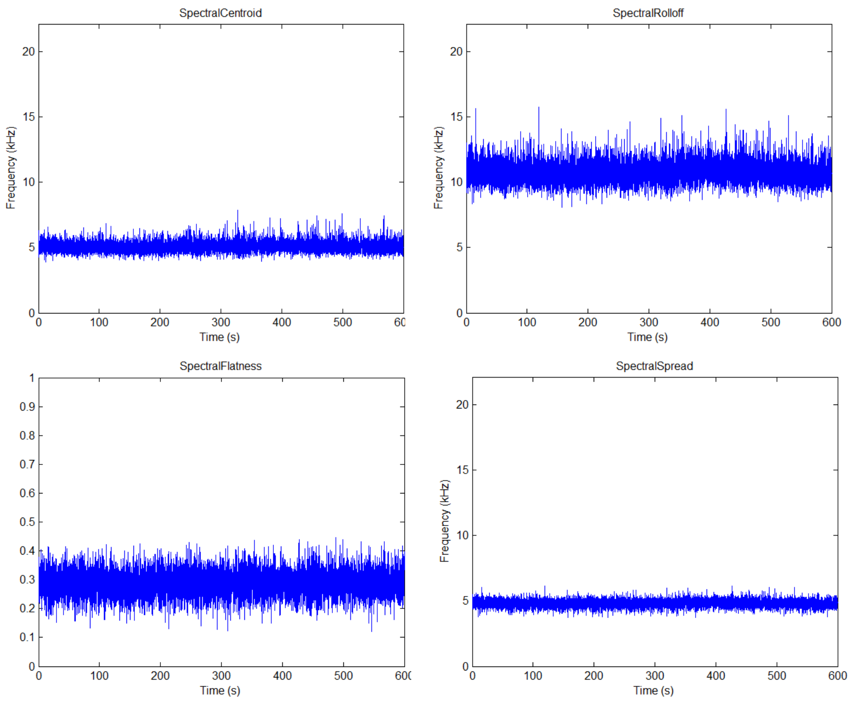
d) Long-term Average Spectrum (LTAS)





No atypical peak has been observed in the power spectrum. However, very low frequency up to about 60 Hz has been suppressed substantially. 90% of the signal power is contained below 4.6 kHz.

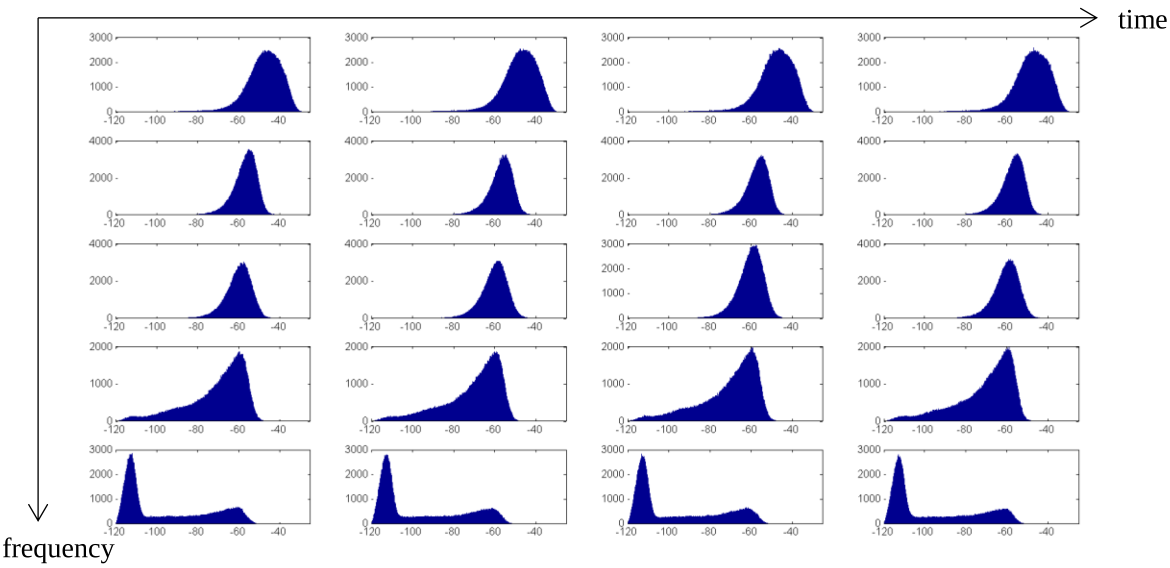
e) Spectrum shape based features



Features	Mean Value
Centroid	5070 Hz
Rolloff	10749 Hz
Flatness	0.2877
Spread	4828 Hz

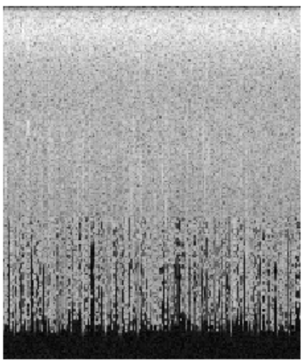
iii) Time-Frequency Domain Features

a) Local Binary Pattern (LBP)

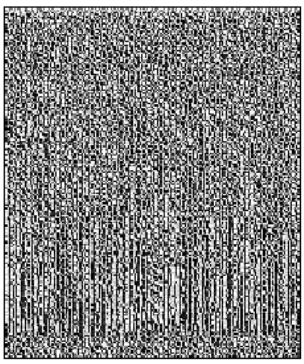


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. The very-low and medium-high frequencies sections show less noise-like characteristics. The very-low frequency sections contain highest energy.

b) Local Binary/Ternary Pattern



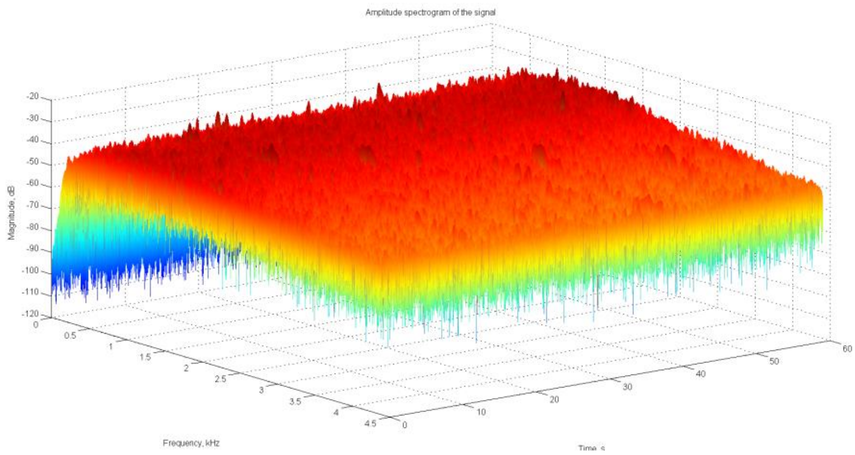
Spectrogram (Grayscale)

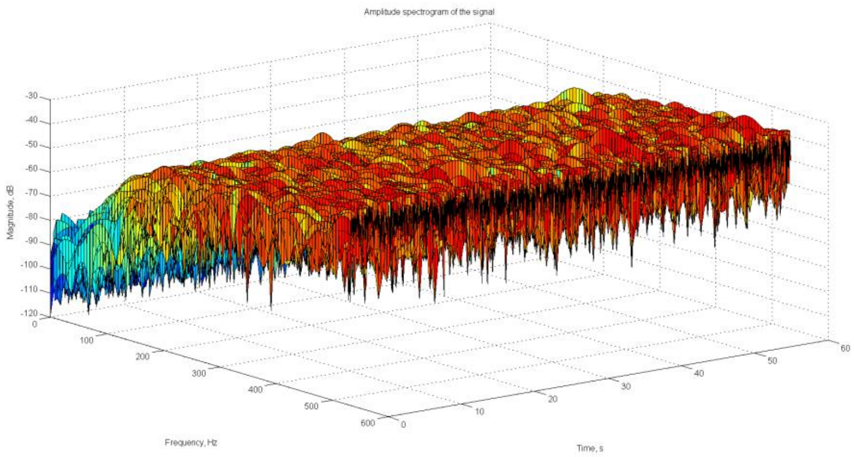


LBP

Based on the LBP, the texture of the sound appears to be very uniform for the lower frequency region. In the higher frequency region, some line patterns are observed. Overall, the texture is still very noise-like.

c)

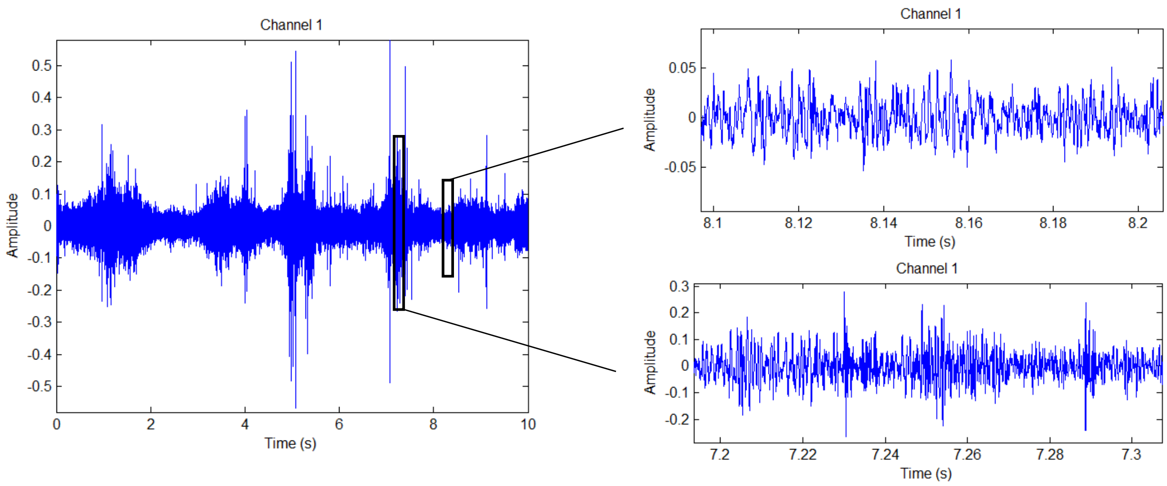




The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal do not change significantly in time. The super-low frequency (SLF) (30-300Hz) is very prominent in this signal.

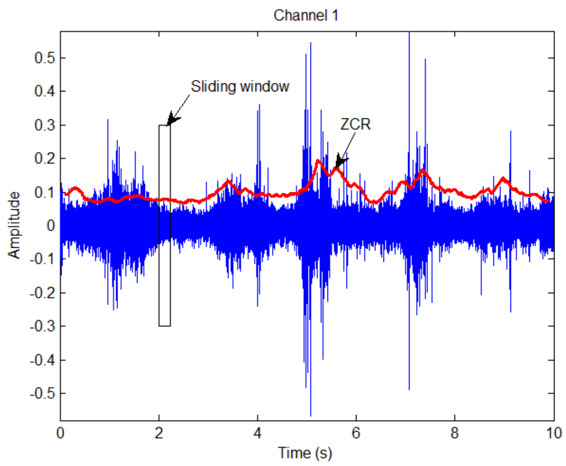
8) Anti-aging

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 higher for the loud regions compared to the quiet regions.

a) Zero Crossing Rate (ZCR)

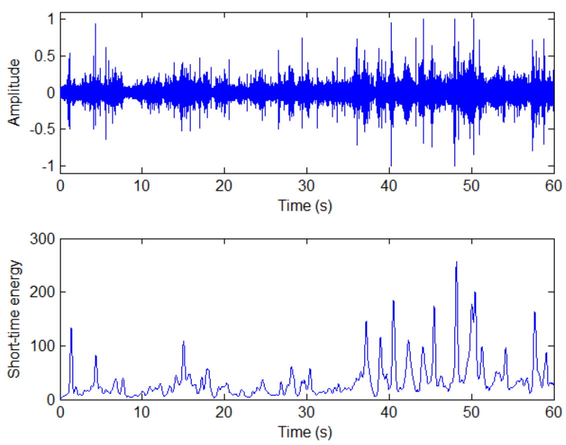


Window size = 10,000 samples (~0.23s)

ZCR is fluctuating throughout the section of the sound examined (10s). 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)

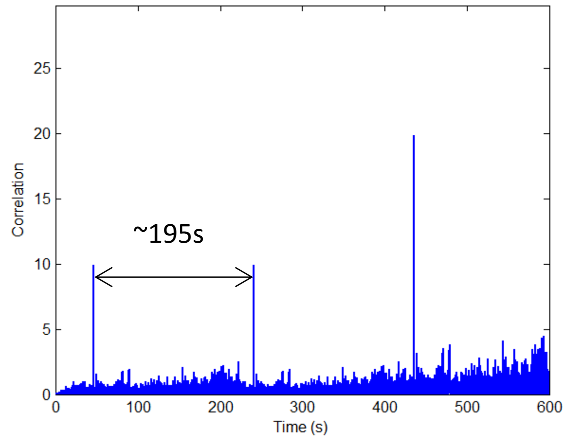


Window size = 20,000 samples (~0.45s)

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

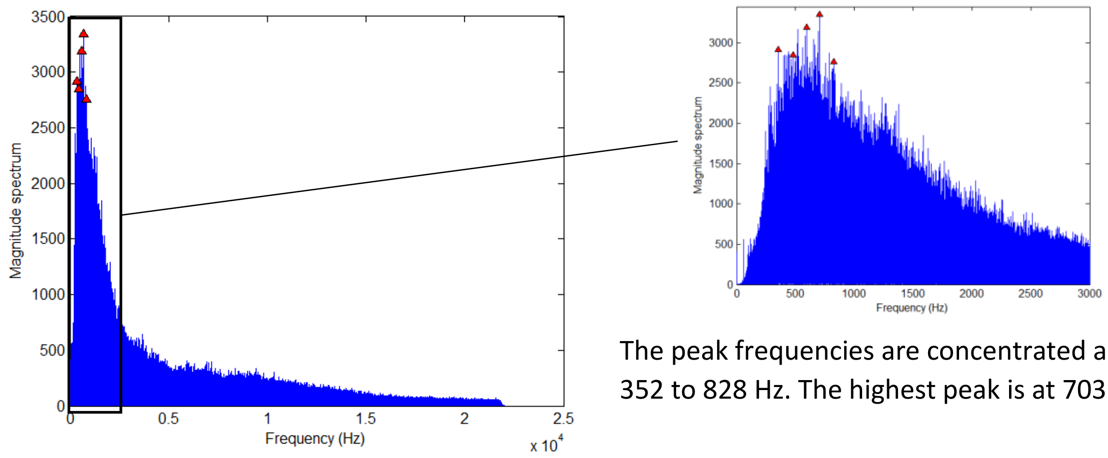


Segment/window size = 50,000 samples (~1.13s)

A peak is observed about every 195s (or 3.3 minutes). In other words, identical segment of 3.3 min is repeated in this sound.

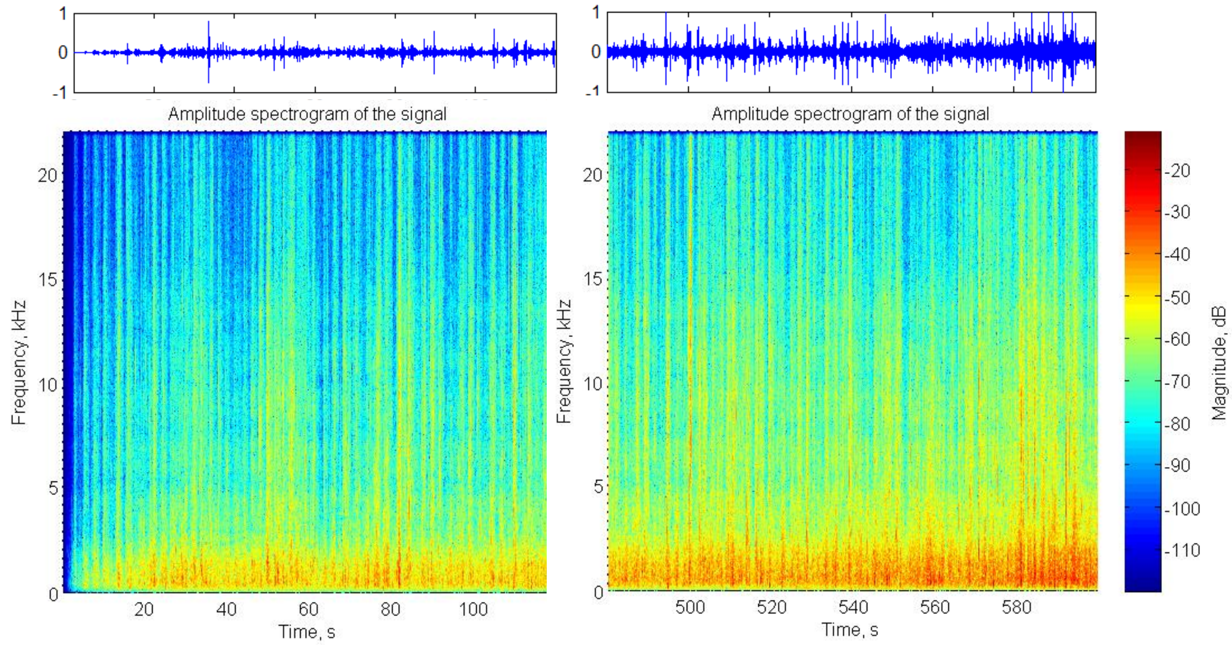
ii) Frequency Domain Features

a) Peak Frequency



The peak frequencies are concentrated around 352 to 828 Hz. The highest peak is at 703 Hz.

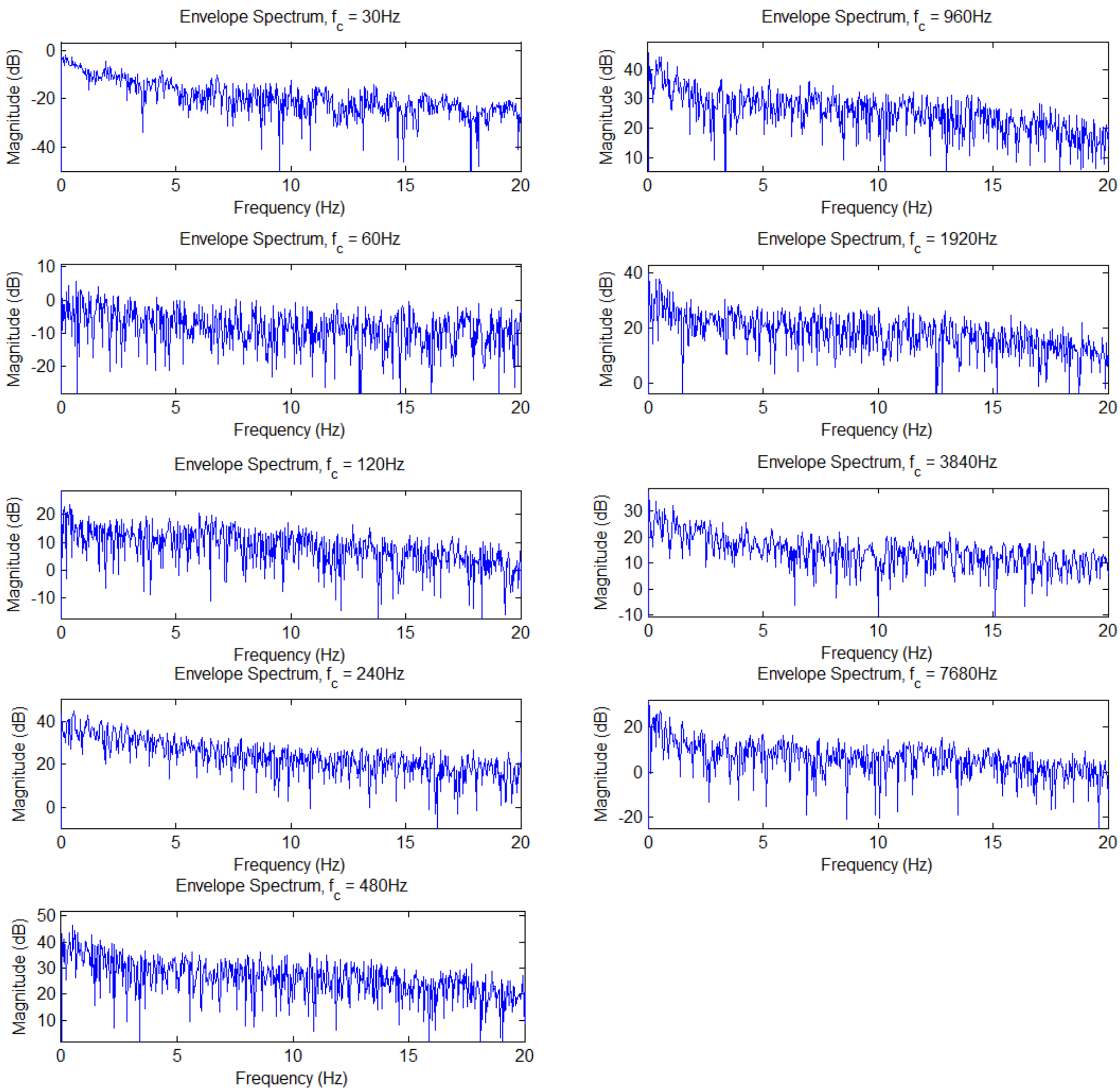
b) Short-Time Fourier Transform (STFT)



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 2 kHz most of the time (red color region).

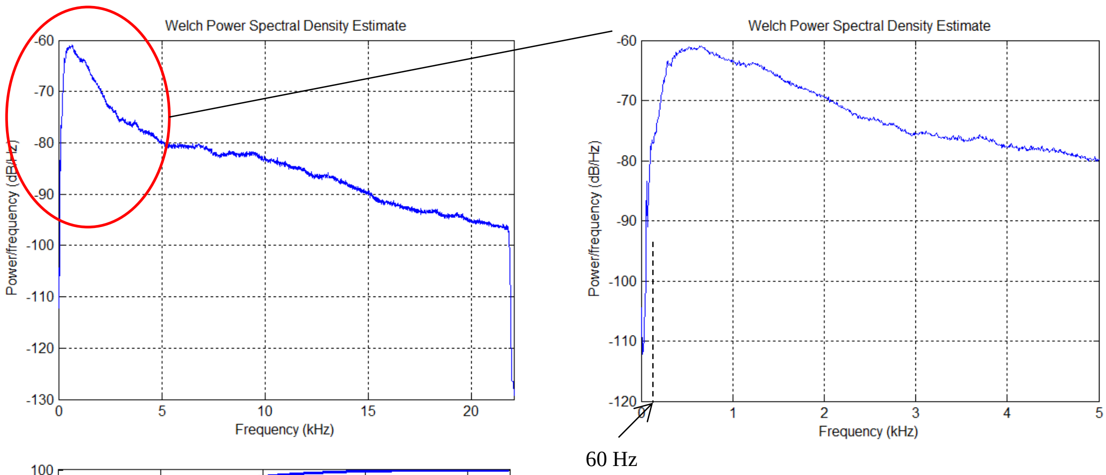
c) Envelope Modulation Spectrum (EMS)

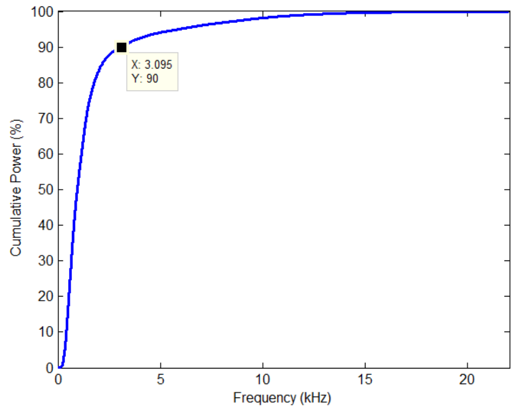
Same methodology as described in 1(c) has been used. The results are given below:



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.

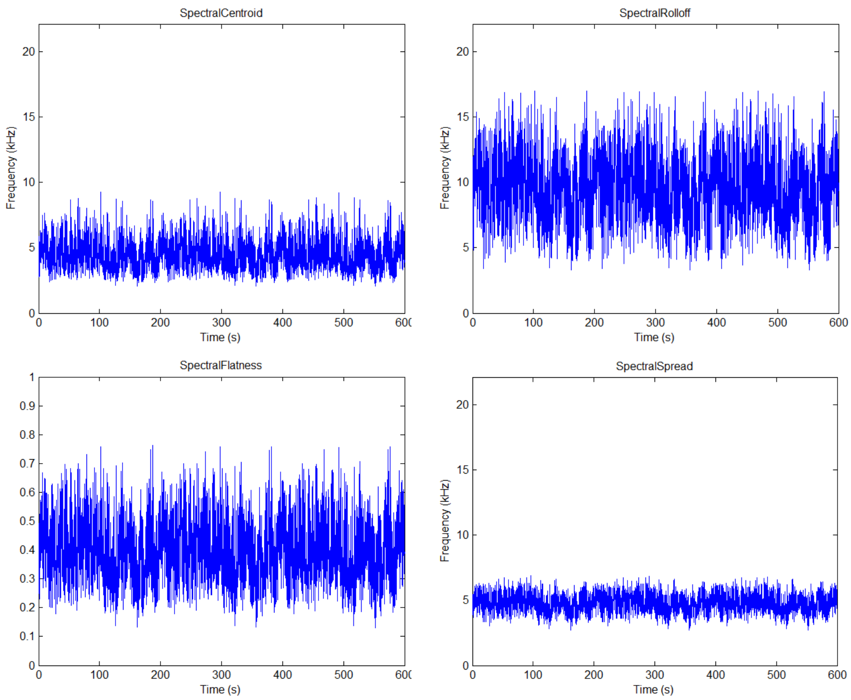
d) Long-term Average Spectrum (LTAS)





No atypical peak has been observed in the power spectrum. However, very low frequency up to about 60 Hz has been suppressed substantially. 90% of the signal power is contained below 3 kHz.

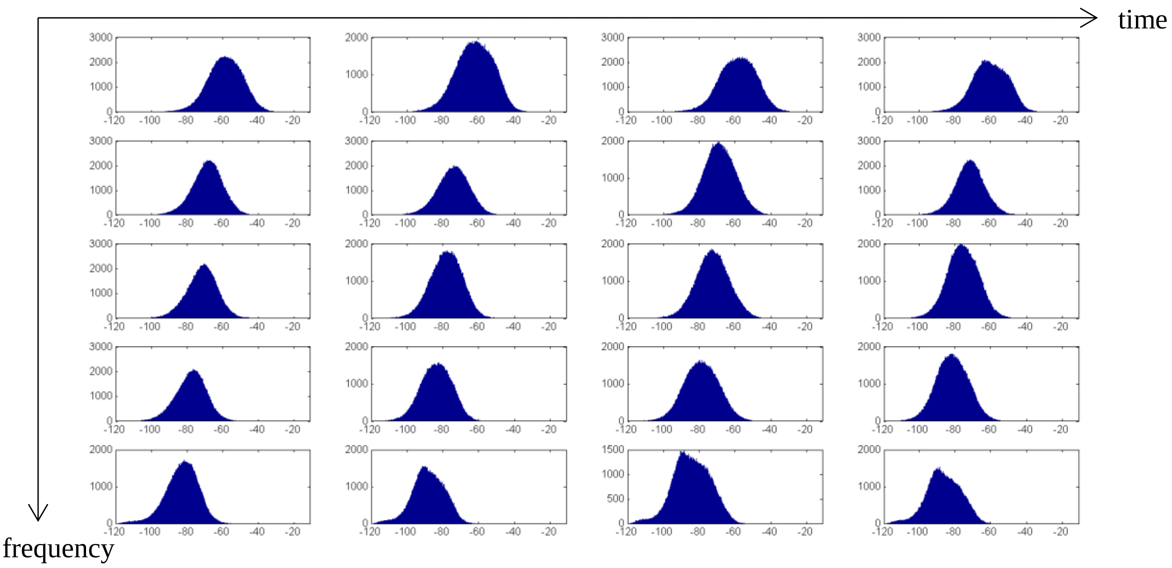
e) Spectrum shape based features



Features	Mean Value
Centroid	4364 Hz
Rolloff	9384 Hz
Flatness	0.3919
Spread	4736 Hz

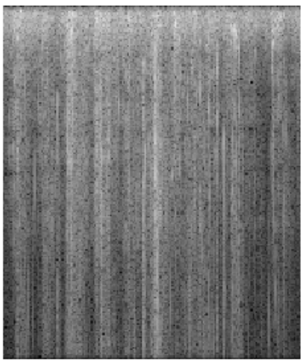
iii) Time-Frequency Domain Features

a) Local Binary Pattern (LBP)

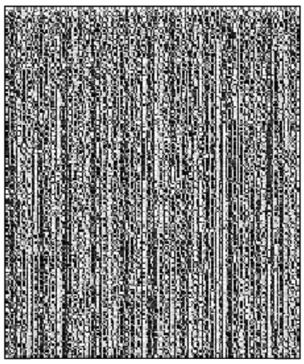


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

b) Local Binary/Ternary Pattern



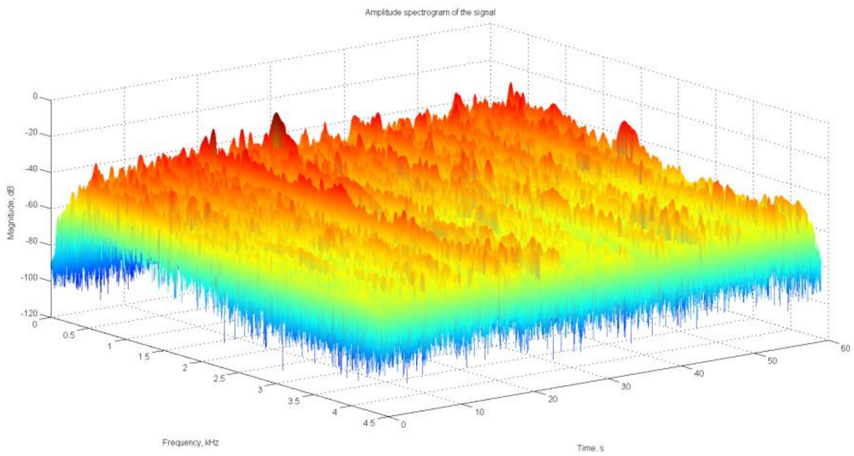
Spectrogram (Grayscale)

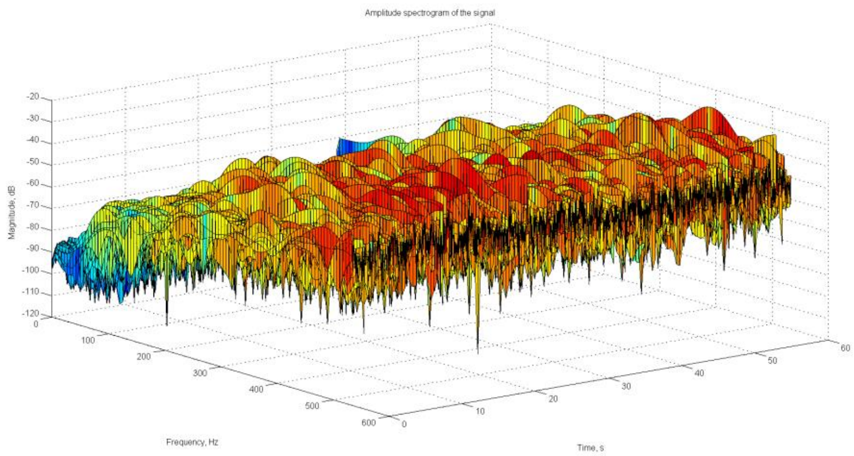


LBP

Based on the LBP, the texture of the sound appears to be rough in time. This is mainly due to the dynamic change in amplitude of the sound.

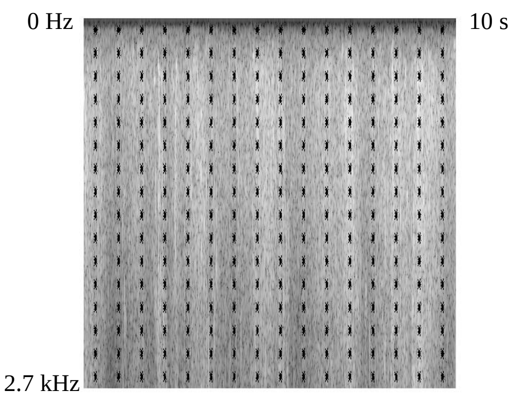
c)



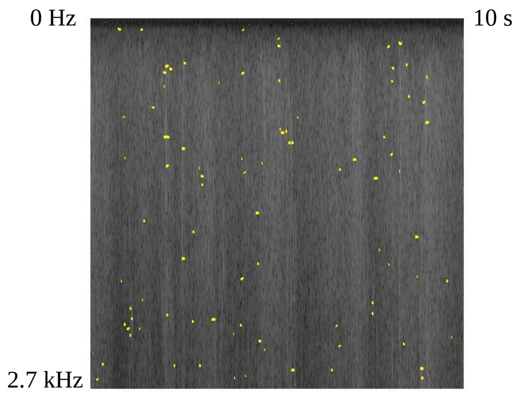


The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. The super-low frequency (SLF) (30-300Hz) is very prominent in this signal. However, their magnitudes change in time.

d) Histogram of gradients (HOG) and Scale invariant feature transform (SIFT)



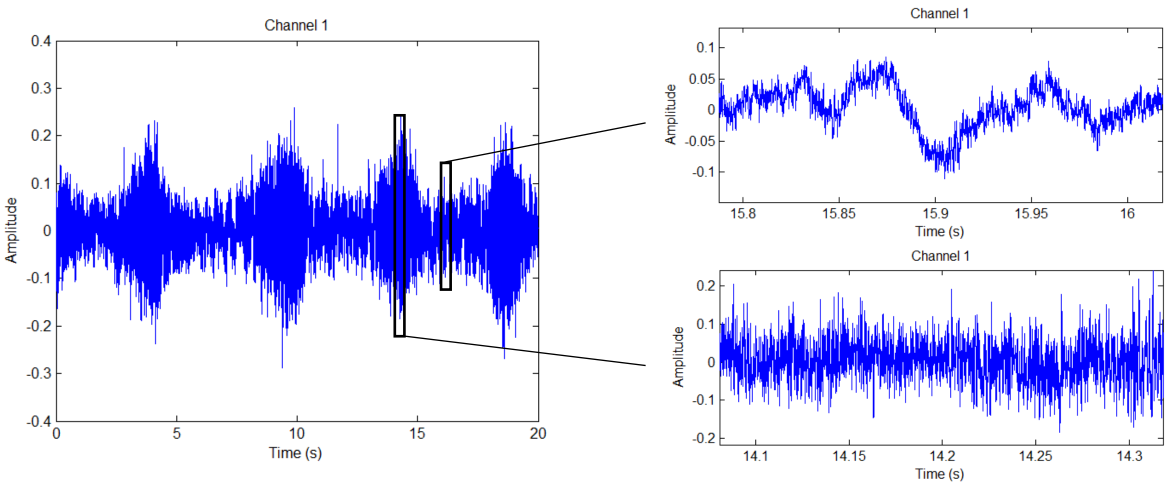
HOG



SIFT

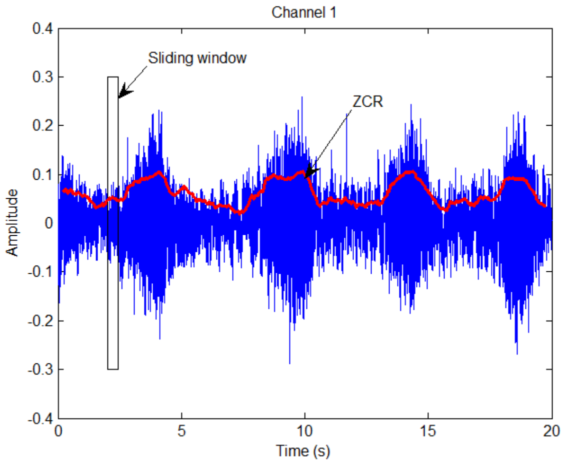
9) Weight Loss

i) Time-domain features



The amplitude envelope changes in time according to the loudness of the sound. When zoomed in, it can be observed that the rate of amplitude fluctuation in the loud regions appears to be much higher than that of the quiet regions.

a) Zero Crossing Rate (ZCR)

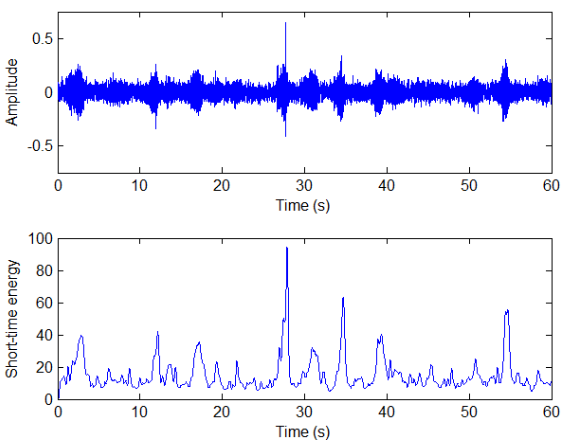


Window size = 20,000 samples (~0.45s)

ZCR is fluctuating throughout the section of the sound examined (20s). The fundamental frequency of the sound is strongly dependent on the amplitude.

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

b. Short time energy (STE)

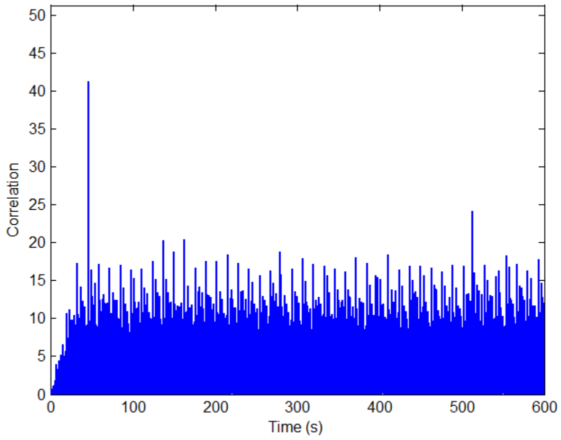


Window size = 20,000 samples (~0.45s)

Window type = Hamming

STE fluctuates according to the amplitude of the signal. The peak magnitudes of the energy surges appear to be quite random. Their time occurrences, however, are quite regular at about every 2.35 s.

c. Auto-correlation

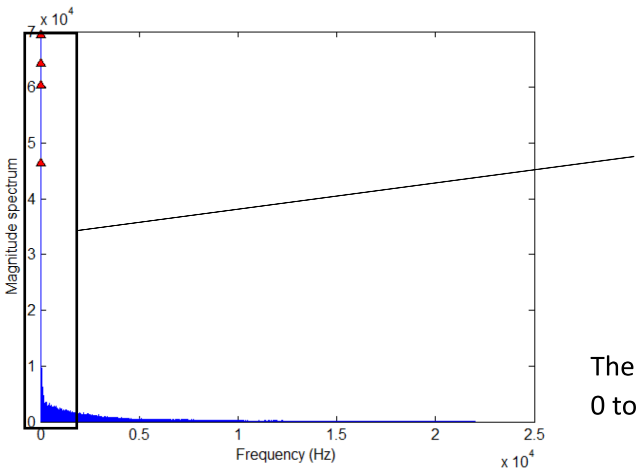


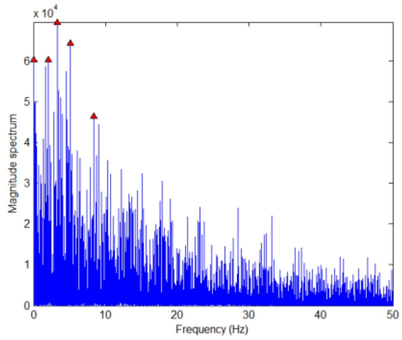
Segment/window size = 50,000 samples (~1.13s)

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

ii) Frequency Domain Features

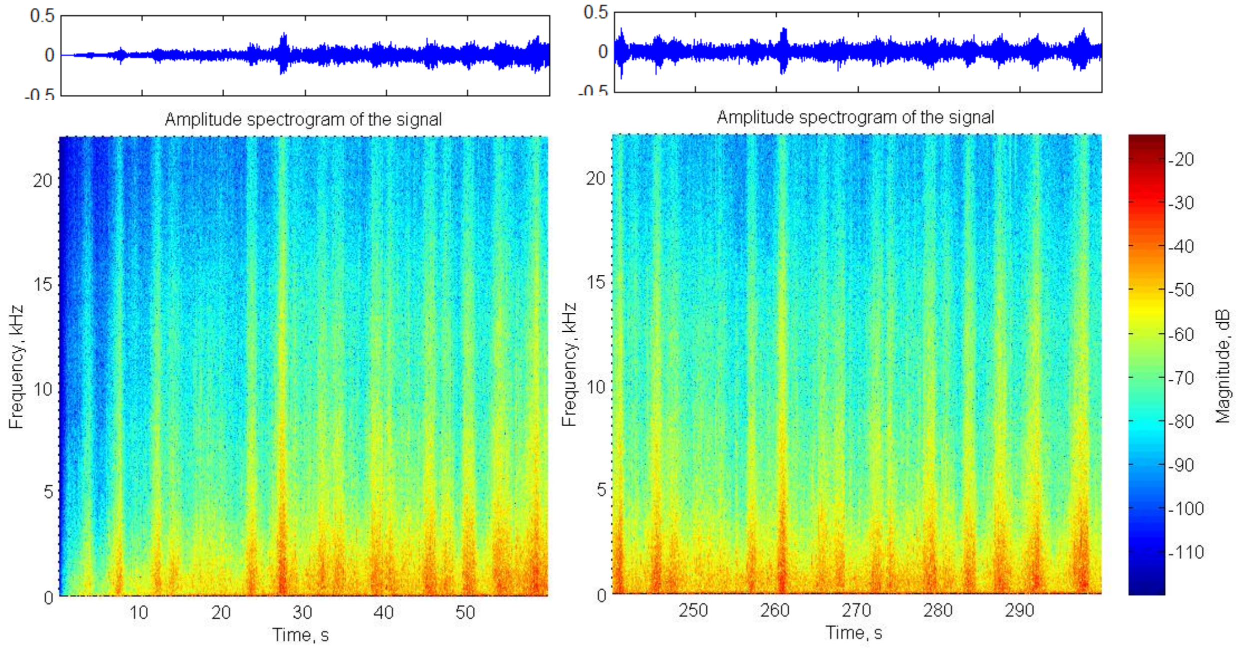
a) Peak Frequency





The peak frequencies are concentrated around 0 to 9 Hz. The highest peak is at 3.3 Hz.

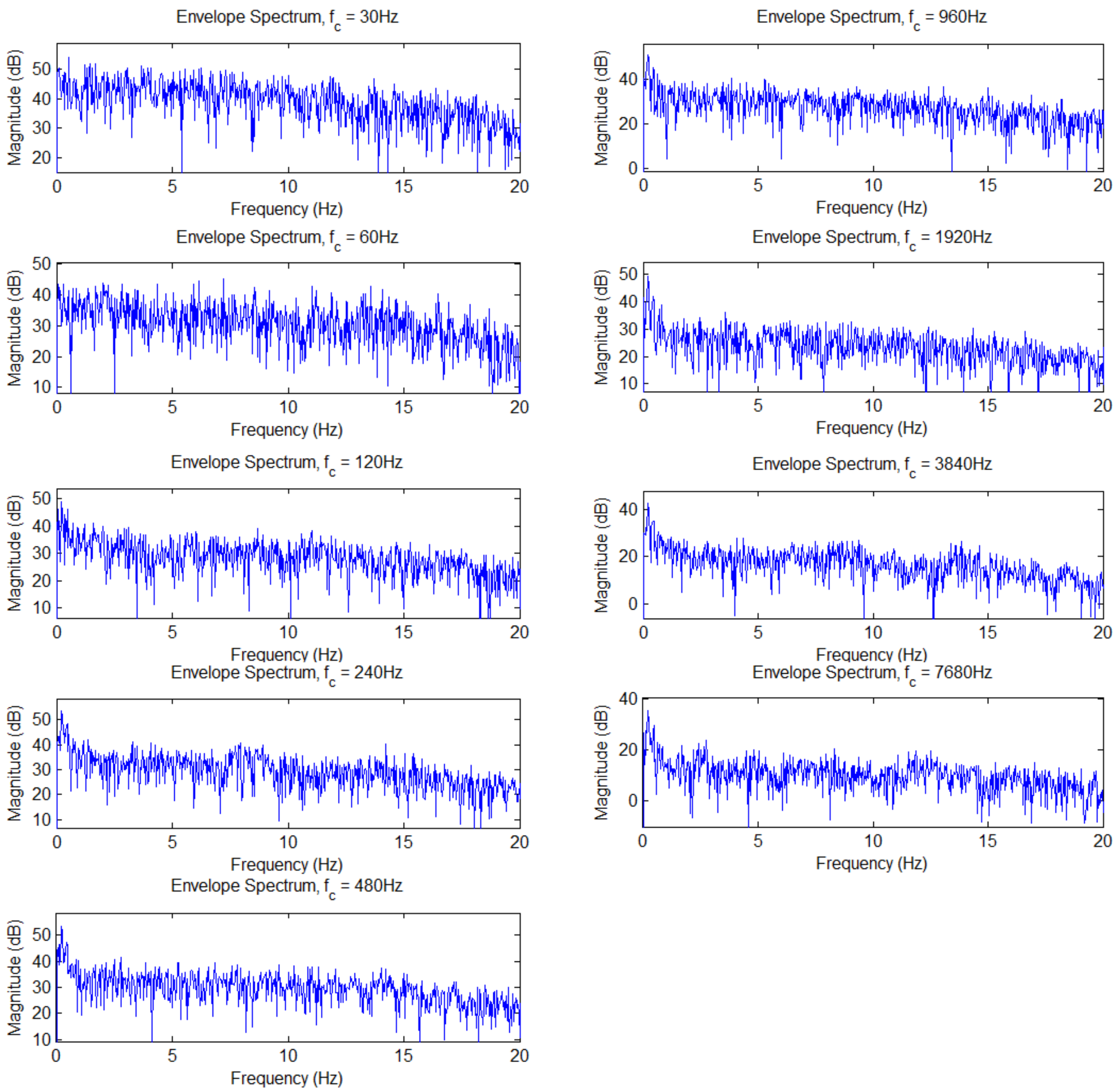
b) Short-Time Fourier Transform (STFT)



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). High energy is notice at very low frequency (less than 100 Hz) during the silent intervals.

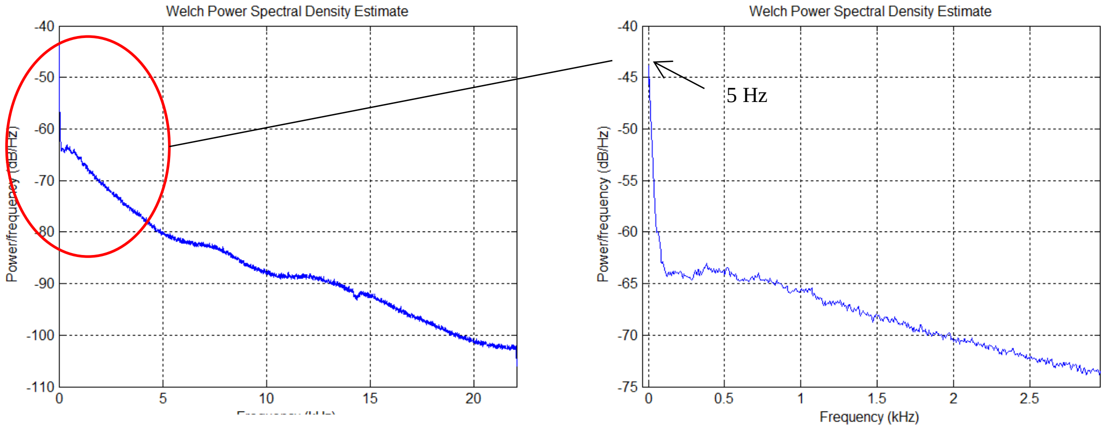
c) Envelope Modulation Spectrum (EMS)

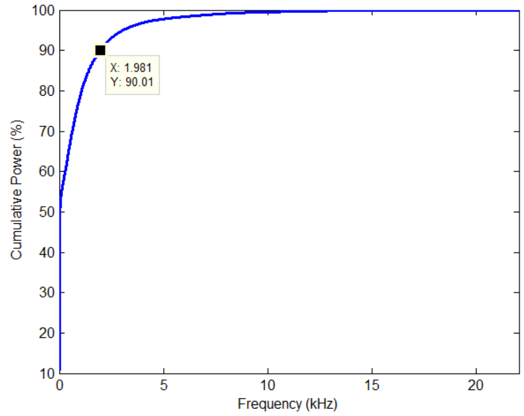
Same methodology as described in 1(c) has been used. The results are given below:



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.

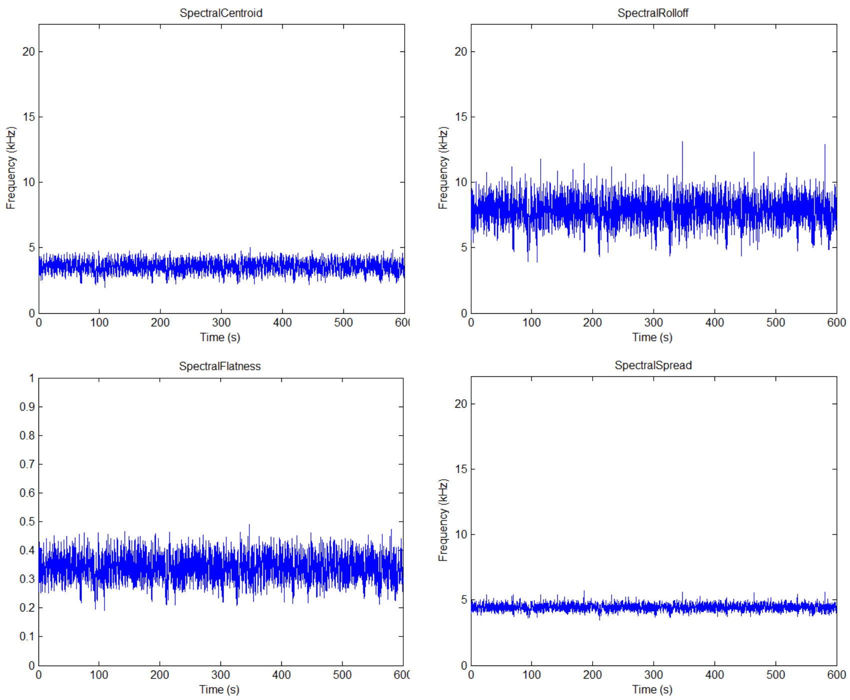
d) Long-term Average Spectrum (LTAS)





One significant frequency at 5 Hz has been observed in the power spectrum. 90% of the signal power is contained below 2 kHz.

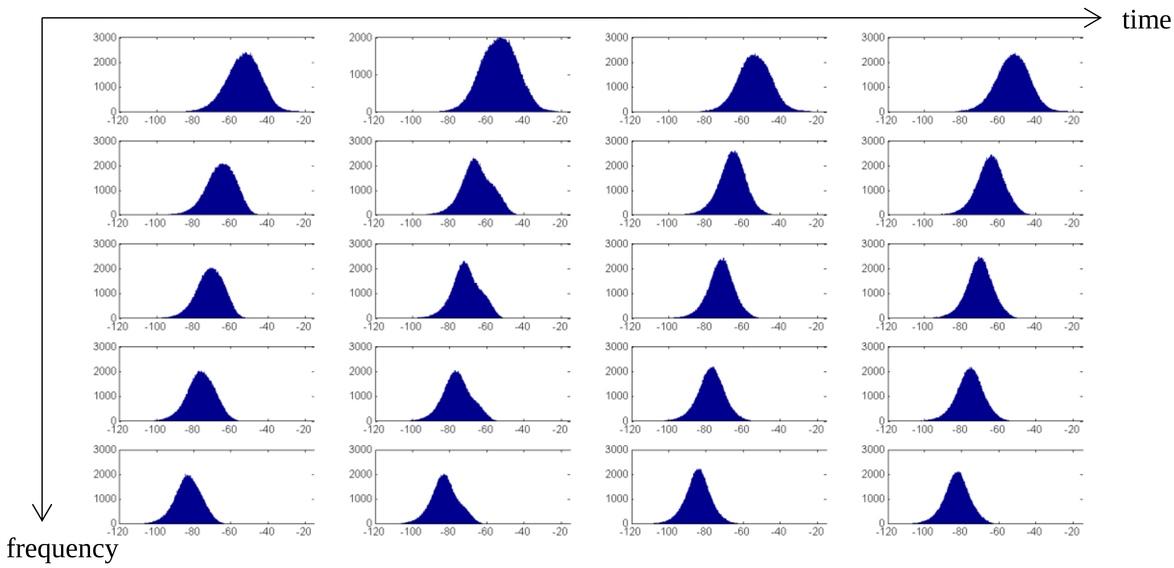
e) Spectrum shape based features



Features	Mean Value
Centroid	3548 Hz
Rolloff	7790 Hz
Flatness	0.3390
Spread	4433 Hz

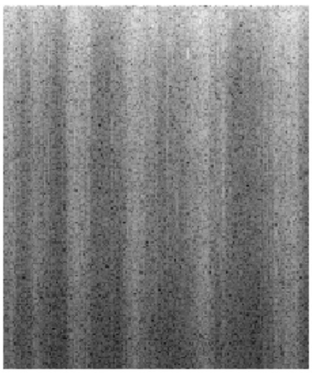
iii) Time-Frequency Domain Features

a) Local Binary Pattern (LBP)

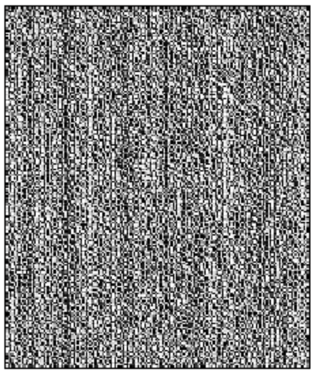


The spectrogram is first divided into 5x4 sections of equal size. Then the histogram of the magnitude for each section is plotted as above. All sections from very-low to medium-high frequencies appear to be noise-like. The very-low frequency sections contain highest energy.

b) Local Binary/Ternary Pattern



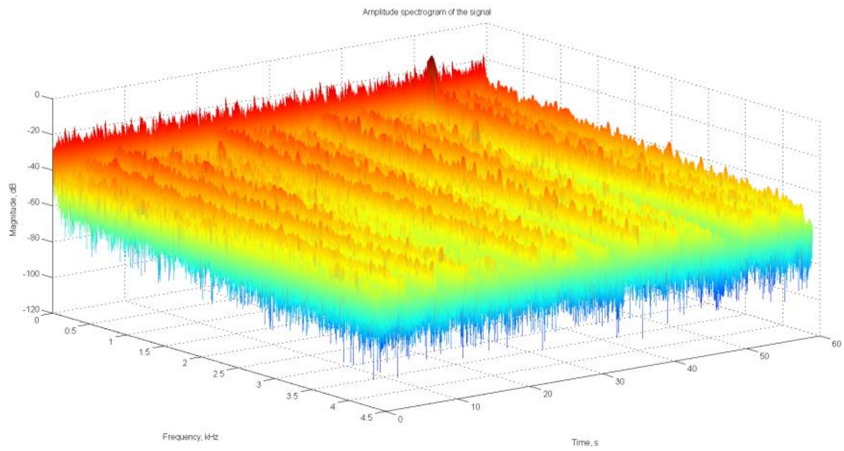
Spectrogram (Grayscale)

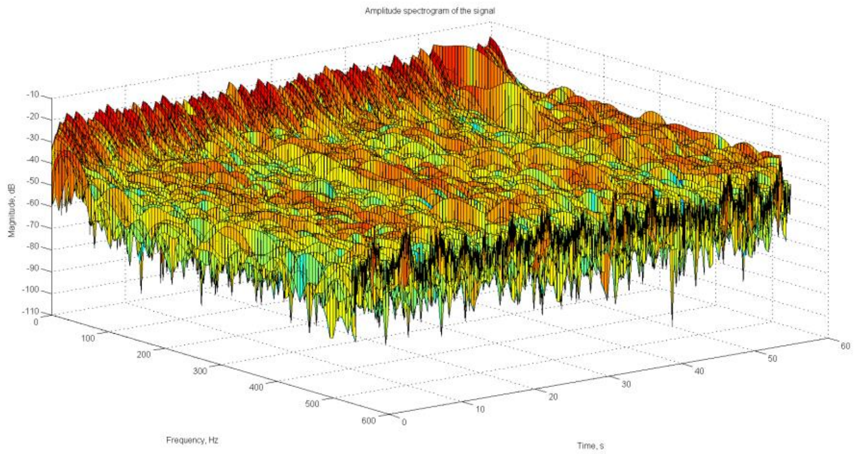


LBP

Based on the LBP, the texture of the sound appears to be quite uniform. The texture is slightly rough across time due to the change of amplitude of the sound. Overall, it is still very noise-like.

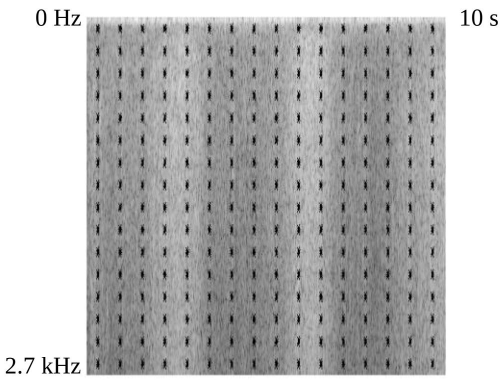
c)



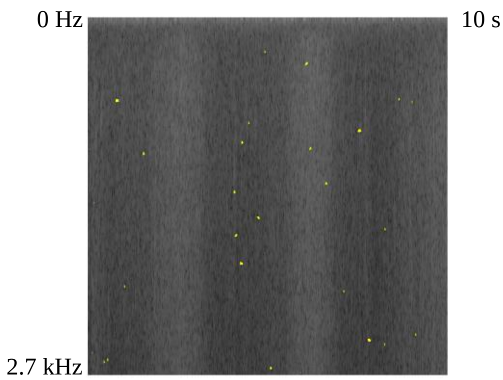


The top figure shows the 3D spectrogram for 0 to 4.5 kHz and 0 to 60 s. The bottom figure shows the same spectrogram for up to 600 Hz. The frequency components of the signal vary in time. The extremely low frequency (ELF) (< 30Hz) is very prominent in this signal. However, their magnitudes change in time.

d) Histogram of gradients (HOG) and Scale invariant feature transform (SIFT)



HOG



SIFT

Conclusion

Nine different waveforms of T-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 Quantum Nutrition and Sleep Enhancement. Quantum Nutrition has most of its power concentrated in the medium frequency region (6-8 kHz), while Sleep Enhancement has more uniformly distributed power. These high energy bands may have been produced by post enhancement made to the waveforms. It is also worth noting that, besides energy enhancement, frequency bands 50-60 Hz and 5-8 kHz of Quantum Healthcare could have been purposely suppressed. Very low peak frequencies (frequency with highest power) between 5-100 Hz are found for Sleep Enhancement, Relaxation, Quantum Healthcare, Headache Support, and Weight Loss. These frequencies are mostly out of an adult human hearing range.

Appendix (MATLAB Codes)

```
clear all;
close all;

% filename = 'Eliminate Brain Fog 20-min.mp3';
% filename = 'Maca Root 20-min.mp3';
% filename = 'Sleep Support 60-min.wav';
% filename = 'Relaxation 20-min.mp3';
filename = 'Inflamation 20-min.mp3';
% filename = 'Headache Support 20-min.wav';
% filename = 'T-Shield 20-min.wav';
% filename = 'Anti-Aging 20-min.wav';
% filename = 'Weight Loss 20-min.wav';
[y,Fs] = audioread(filename,[1+26460000*0 26460000*1]);
info = audioinfo(filename)
p = audioplayer(y,Fs);
% play(p, [1 N]);

T = 12; % samples for T seconds
N = get(p,'SampleRate')*T;
ch = 1;
A = max(abs(y(1:N,ch)));

%% Time series
% figure, plot((0:N-1)/(N-1)*T,y(1:N,ch));
% xlabel('Time (s)'); ylabel('Amplitude'); title('Channel 1');
% axis([0 T -A-0.1 A+0.1]);

%% Periodogram
% figure, periodogram(y(1:N,ch),[],'onesided',[],Fs);

%% Spectrogram
% Nfft = 2^9;
% figure, spectrogram(y(1:N,ch),hamming(Nfft),Nfft-500,Nfft,Fs,'yaxis');
% colorbar;

%% ZCR
% figure, plot((0:N-1)/(N-1)*T,y(1:N,ch));
% xlabel('Time (s)'); ylabel('Amplitude'); title('Channel 1');
% axis([0 T -A-0.1 A+0.1]);
% Nw = 10000;
% hold on;
% rectangle('Position', [2 -A Nw/Fs A*2])
% skip = 100;
% N2 = floor((N-Nw)/skip);
% ZCR = zeros(2,N2);
% count2 = 1;
% for count = 1:N2
%     x = y(count2:count2+Nw-1,ch);
%     ZCR(2,count) = sum(abs(diff(sign(x)))>0)/length(x);
%     ZCR(1,count) = count2 + Nw/2;
%     count2 = count2 + skip;
% end
% hold on, plot(ZCR(1,:)/Fs,ZCR(2,:),'r','LineWidth',2);

%% STE
% figure, subplot(2,1,1); plot((0:N-1)/(N-1)*T,y(1:N,ch));
% xlabel('Time (s)'); ylabel('Amplitude');
% axis([0 T -A-0.1 A+0.1]);
% winsize = 20000;
% xnew = y(1:N,ch).^2;
% win = hamming(winsize);
% out = conv(xnew,win);
% hold on, subplot(2,1,2); plot((0:N-1)/Fs,out(1:end-winsize+1));
% xlabel('Time (s)'); ylabel('Short-time energy');
% %axis([0 T 5 20]);
% [pks,locs] = findpeaks(out,'MINPEAKHEIGHT',15,'MINPEAKDISTANCE',50000);
% hold on; subplot(2,1,2); plot(locs/Fs,pks,'ro');

%% Autocorrelation
% [y2,~] = audioread(filename,[1+2e6 10e6]);
% x = y(1:N,ch);
% win = y2((1:20000),ch);
```

```
% [acor,~] = xcorr(x,win);
% figure, plot((0:N-1)/Fs,abs(acor(N:end)),'LineWidth',1.5);
% ylabel('Correlation'); xlabel('Time (s)');
% axis([-1 T 0 max(acor)+10]);

%% Peak Frequency
% yf = fft(y(1:N,ch));
% ym = abs(yf(1:N/2));
% f = (0:N/2-1)/(N/2)*Fs/2;
% figure, plot(f,ym);
% ylabel('Magnitude spectrum'); xlabel('Frequency (Hz)');
% [pk,locs] = findpeaks(ym,'NPeaks',5,'MINPEAKHEIGHT',4e4,'minpeakdistance',1/(Fs/2)*(N/2))
% pf = locs/(N/2)*Fs/2
% hold on; plot((locs-1)/(N/2)*Fs/2,ym(locs),'k^','markerfacecolor',[1 0 0]);
% % axis([0 2000 0 max(ym)+100]);

%% STFT
% n = 1;
% x = y((1:N)+N*n,ch);
% % define analysis parameters
% wlen = 1024;                        % window length (recomended to be power of 2)
% hop = wlen/2;                       % hop size (recomended to be power of 2)
% nfft = 4096;                        % number of fft points (recomended to be power of 2)
% % perform STFT
% win = blackman(wlen, 'periodic');
% [S, f, t] = stft(x, win, hop, nfft, Fs);
% % calculate the coherent amplification of the window
% C = sum(win)/wlen;
% % take the amplitude of fft(x) and scale it, so not to be a
% % function of the length of the window and its coherent amplification
% S = abs(S)/wlen/C;
% % correction of the DC & Nyquist component
% if rem(nfft, 2)                     % odd nfft excludes Nyquist point
%     S(2:end, :) = S(2:end, :).*2;
% else                                % even nfft includes Nyquist point
%     S(2:end-1, :) = S(2:end-1, :).*2;
% end
% % convert amplitude spectrum to dB (min = -120 dB)
% S = 20*log10(S + 1e-6);
% % plot time series
% figure(1)
% plot((0:N-1)/Fs,x); set(gcf,'Position',[100 100 560 100])
% % plot the spectrogram
% figure(2)
% surf(t+N/Fs*n, f/1e3, S)
% shading interp
% axis tight
% view(0, 90)
% %set(gca, 'FontName', 'Times New Roman', 'FontSize', 14)
% xlabel('Time, s')
% ylabel('Frequency, kHz')
% title('Amplitude spectrogram of the signal')
% hcol = colorbar;
% %set(hcol, 'FontName', 'Times New Roman', 'FontSize', 14)
% ylabel(hcol, 'Magnitude, dB')
% set(gcf,'color','w');

%% Envelope Modulation Spectrum (EMS)
% x = y((1:N)+2e6,ch);
% % anti-aliasing filter
% Fpass = 9000;        % Passband Frequency
% Fstop = 11000;       % Stopband Frequency
% Apass = 1;           % Passband Ripple (dB)
% Astop = 30;          % Stopband Attenuation (dB)
% match = 'stopband';  % Band to match exactly
% % Construct an FDESIGN object and call its BUTTER method.
% h  = fdesign.lowpass(Fpass, Fstop, Apass, Astop, Fs);
% Hd = design(h, 'butter', 'MatchExactly', match);
% y = filter(Hd,x);
% x = y(1:2:end); % downsampling
%
% % Bandpass filtering
% Fs = 22050;  % Sampling Frequency
% fc = 7680; % 30, 60, 120, 240, 480, 960, 1920, 3840, and 7680 Hz
% Fstop1 = fc-15;          % First Stopband Frequency
% Fpass1 = fc-10;          % First Passband Frequency
% Fpass2 = fc+10;          % Second Passband Frequency
```

```
% Fstop2 = fc+15;          % Second Stopband Frequency
% Astop1 = 60;          % First Stopband Attenuation (dB)
% Apass  = 1;           % Passband Ripple (dB)
% Astop2 = 60;          % Second Stopband Attenuation (dB)
% match  = 'stopband';  % Band to match exactly
% % Construct an FDESIGN object and call its BUTTER method.
% h  = fdesign.bandpass(Fstop1, Fpass1, Fpass2, Fstop2, Astop1, Apass, ...
%                       Astop2, Fs);
% Hd = design(h, 'butter', 'MatchExactly', match);
% y = filter(Hd,x);
% yf = fft(y);
% N2 = length(y);
% figure, plot((0:N2/2-1)/(N2/2-1)*Fs/2,abs(yf(1:N2/2)));
% xlim([fc-30 fc+30]);
%
% Y = hilbert(y);
% env = abs(Y);
% plot_param = {'Color', [0.6 0.1 0.2],'Linewidth',2};
% t = (0:N2-1)/Fs;
% figure, plot(t,y)
% hold on
% plot(t,env,plot_param{:})
% xlim([3 5]);
% hold off
% title('Hilbert Envelope')
%
% env2 = env - mean(env);
% envf = 20*log10(abs(fft(env2)));
% figure, plot((0:N2/2-1)/(N2/2-1)*Fs/2,envf(1:N2/2));
% xlim([0 20]);
% ylim([min(envf(5:600))+5 max(envf(5:600))+5]);
% title(['Envelope Spectrum, f_c = ',num2str(fc),'Hz']);
% ylabel('Magnitude (dB)');
% xlabel('Frequency (Hz)');
% set(gcf,'Position',[100 100 560 200])

%% LTAS
% x = y((1:N),ch);
% nwin = 8192;
% figure, pwelch(x,hanning(nwin),nwin/2,[],Fs,'onesided');
% % xlim([0/1000 3000/1000]);
% [Pxx,f] = pwelch(x,hanning(nwin),nwin/2,[],Fs,'onesided','power');
% out = cumsum(Pxx);
% figure, plot(f/1000,out/max(out)*100,'Linewidth',2);
% xlim([0 Fs/2/1000]);
% xlabel('Frequency (kHz)'); ylabel('Cumulative Power (%)')

%% Spectral shape based features
% x = y((1:N)+2e6,ch);
% cFeatureName = 'SpectralMfccs'; % SpectralCentroid, SpectralRolloff, SpectralSpread,
SpectralMfccs
% [v1, t] = ComputeFeature (cFeatureName, x, Fs);
% figure, plot(t,v1);
% % ylim([0 Fs/2/1e3]);
% xlim([0 T]);
% xlabel('Time (s)');
% ylabel('Frequency (kHz)');
% title(cFeatureName);
%
% cFeatureName = 'SpectralFlatness';
% [v, t] = ComputeFeature (cFeatureName, x, Fs);
% figure, plot(t,v);
% ylim([0 1]);
% xlim([0 T]);
% xlabel('Time (s)');
% title(cFeatureName);

%% Local Histogram
x = y((1:N)+2.9e6,ch);
% define analysis parameters
wlen = 1024*2;                        % window length (recomended to be power of 2)
hop = wlen/2;                        % hop size (recomended to be power of 2)
nfft = 4096*2;                        % number of fft points (recomended to be power of 2)
% perform STFT
win = blackman(wlen, 'periodic');
[S, f, t] = stft(x, win, hop, nfft, Fs);
% calculate the coherent amplification of the window
```

```
C = sum(win)/wlen;
% take the amplitude of fft(x) and scale it, so not to be a
% function of the length of the window and its coherent amplification
S = abs(S)/wlen/C;
% correction of the DC & Nyquist component
if rem(nfft, 2)                       % odd nfft excludes Nyquist point
    S(2:end, :) = S(2:end, :).*2;
else                                  % even nfft includes Nyquist point
    S(2:end-1, :) = S(2:end-1, :).*2;
end
% convert amplitude spectrum to dB (min = -120 dB)
S = 20*log10(S + 1e-6);
% plot the spectrogram
figure(1);
surf(t, f/1e3, S)
shading interp
axis tight
view(0, 90)
%set(gca, 'FontName', 'Times New Roman', 'FontSize', 14)
xlabel('Time, s')
ylabel('Frequency, kHz')
title('Amplitude spectrogram of the signal')
hcol = colorbar;
%set(hcol, 'FontName', 'Times New Roman', 'FontSize', 14)
ylabel(hcol, 'Magnitude, dB')
set(gcf,'color','w');

% [r,c] = size(S);
% figure, hist(reshape(S,r*c,1),1000);
% m = max(max(S));
% xlim([-120 m]);
%
% p1 = 5;
% p2 = 4;
% N1 = floor(r/p1);
% N2 = floor(c/p2);
% count = 1;
% figure;
% for k1 = 0:p1-1
%     for k2 = 0:p2-1
%         s = S(1+N1*k1:N1*(k1+1),1+N2*k2:N2*(k2+1));
%         subplot(p1,p2,count);
%         hist(reshape(s,N1*N2,1),1000);
%         xlim([-120 m]);
%         hold on;
%         count = count + 1;
%     end
% end

%% Local Binary/Ternary Pattern
% S2 = (S-min(min(S)))/(max(max(S))-min(min(S)))*255;
% figure, subplot(1,2,1); imshow(S2,[0 255]);
% [ltp_upper, ltp_lower] = LTP(S2, 0);
% % figure, subplot(2,1,1); hist(reshape(ltp_upper,[],1),256); xlim([0 256]);
% % hold on; subplot(2,1,2); hist(reshape(ltp_upper,[],1),256); xlim([0 256]);
% % figure, subplot(1,2,1); imshow(ltp_upper,[0 255]);
% hold on; subplot(1,2,2); imshow(ltp_lower,[0 255]);

%% HOG
x = S(1:round(end/8),1:end);
S2 = (x-min(min(x)))/(max(max(x))-min(min(x)))*255;
[hog1,visualization] = extractHOGFeatures(uint8(S2),'CellSize',[32 32]);
figure;
% subplot(1,2,1);
imshow(uint8(S2)); hold on;
% subplot(1,2,2);
plot(visualization);

%% SIFT
% x = S(1:round(end/8),1:end);
% S2 = (x-min(min(x)))/(max(max(x))-min(min(x)))*255;
% figure(2);
% surf(t, f(1:round(end/8))/1e3, S2)
% shading interp
% axis tight
% view(0, 90)
% out = SiftMain(S2);
```

```
%% Low frequency analysis
% figure;
% surf(t, f(1:end/2)/1e3, S(1:end/2,:))
% shading interp
% % axis tight
% % view(0, 0)
% set(gca,'Ydir','reverse')
% xlabel('Time, s')
% ylabel('Frequency, kHz')
% zlabel('Magnitude, dB')
% title('Amplitude spectrogram of the signal')
% set(gcf,'color','w');
%
% figure;
% surf(t, f(1:100), S(1:100,:))
% % shading interp
% % axis tight
% % view(0, 0)
% set(gca,'Ydir','reverse')
% xlabel('Time, s')
% ylabel('Frequency, Hz')
% zlabel('Magnitude, dB')
% title('Amplitude spectrogram of the signal')
% set(gcf,'color','w');


function [STFT, f, t] = stft(x, win, hop, nfft, fs)
% function: [STFT, f, t] = stft(x, win, hop, nfft, fs)
%
% Input:
% x - signal in the time domain
% win - analysis window function
% hop - hop size
% nfft - number of FFT points
% fs - sampling frequency, Hz
%
% Output:
% STFT - STFT-matrix (only unique points, time
%        across columns, frequency across rows)
% f - frequency vector, Hz
% t - time vector, s
% representation of the signal as column-vector
x = x(:);
% determination of the signal length
xlen = length(x);
% determination of the window length
wlen = length(win);
% stft matrix size estimation and preallocation
NUP = ceil((1+nfft)/2);     % calculate the number of unique fft points
L = 1+fix((xlen-wlen)/hop); % calculate the number of signal frames
STFT = zeros(NUP, L);       % preallocate the stft matrix
% STFT (via time-localized FFT)
for l = 0:L-1
    % windowing
    xw = x(1+l*hop : wlen+l*hop).*win;

    % FFT
    X = fft(xw, nfft);

    % update of the stft matrix
    STFT(:, 1+l) = X(1:NUP);
end
% calculation of the time and frequency vectors
t = (wlen/2:hop:wlen/2+(L-1)*hop)/fs;
f = (0:NUP-1)*fs/nfft;
end


function [ ltp_upper, ltp_lower ] = LTP(im, t)

    %// Get the dimensions
    rows=size(im,1);
    cols=size(im,2);

    %// Reordering vector - Essentially for getting binary strings
```

```
reorder_vector = [8 7 4 1 2 3 6 9];

%// For the upper and lower LTP patterns
ltp_upper = zeros(size(im));
ltp_lower = zeros(size(im));

%// For each pixel in our image, ignoring the borders...
for row = 2 : rows - 1
    for col = 2 : cols - 1
        cen = im(row,col); %// Get centre

        %// Get neighbourhood - cast to double for better precision
        pixels = double(im(row-1:row+1,col-1:col+1));

        %// Get ranges and determine LTP
        out_LTP = zeros(3, 3);
        low = cen - t;
        high = cen + t;
        out_LTP(pixels < low) = -1;
        out_LTP(pixels > high) = 1;
        out_LTP(pixels >= low & pixels <= high) = 0;

        %// Get upper and lower patterns
        upper = out_LTP;
        upper(upper == -1) = 0;
        upper = upper(reorder_vector);

        lower = out_LTP;
        lower(lower == 1) = 0;
        lower(lower == -1) = 1;
        lower = lower(reorder_vector);

        %// Convert to a binary character string, then use bin2dec
        %// to get the decimal representation
        upper_bitstring = char(48 + upper);
        ltp_upper(row,col) = bin2dec(upper_bitstring);

        lower_bitstring = char(48 + lower);
        ltp_lower(row,col) = bin2dec(lower_bitstring);
    end
end
```

End of Report