



The Importance of Speech Clarity in the Communication Process and the Effect of Noise on its Acoustic Properties

DAOUD Messaoud

University of Algiers 2 – Abou El Kacem Saadallah
(Algeria),

messaoud.daoud@univ-alger2.dz

Abstract ;

This research aims to highlight the importance of Speech clarity in the communication process by examining the impact of noise on the acoustic properties of speech. The study analyzes these properties to assess the extent to which noise impairs clarity, focusing on the central research question: What is the impact of noise on the acoustic characteristics of Speech and the quality of communication?

The study yielded several significant findings, most notably that noise directly affects and disrupts the acoustic features of speech. Moreover, the fundamental frequency is influenced by both the presence and variability of noise, resulting in intonational disturbances that play a crucial role in conveying meaning and communicative intent.

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1. Introduction

Language is one of the most fundamental means of social communication, given its vital role in self-expression and understanding others. It is directly linked to emotional, cognitive, and intellectual development, as it enables interaction between individuals and groups. The speaker's ability to connect with others through language allows for the transmission and reception of messages, a process that requires the presence of specific elements and appropriate conditions to ensure the effectiveness of communication.

Speech (voice) is considered one of the core components of the communicative process and plays a crucial role in language across various programs and communicative events directed at the listener, who perceives language primarily through sound. However, several factors may compromise speech quality, including environmental noise or technical malfunctions in transmission media, leading to disturbances in communication and reduced speech intelligibility. This raises the need to investigate the acoustic properties of sound and the extent to which noise affects them. Accordingly, this study seeks to address the following research question: What is the impact of noise on the acoustic characteristics of Speech and the overall quality of communication?

Research Objectives:

The primary objectives of this study can be summarized as follows:

- To highlight the importance of linguistic speech clarity in effective communication with the listener.
- To underscore the significance of employing acoustic phonetics in the analysis and processing of speech sounds for noise reduction.
- To utilize modern software tools in the analysis and enhancement of speech signals.

Significance of the Study:

The significance of this study lies in the integration of modern technological tools essential instruments of the contemporary era in the processing of speech, which represents a key component of the communication process with the listener. By conducting an acoustic analysis of speech, the study aims to extract its defining features, which in turn provide valuable insights into its quality. Among the primary parameters used to assess speech clarity and intelligibility are the fundamental frequency, formants, and intensity.

Research Methodology:

This study adopts a descriptive-analytical approach aimed at presenting the fundamental aspects of the acoustic properties of speech sounds. It involves the collection of various data specifically acoustic features and their subsequent analysis to extract key observations.

findings. The analytical component focuses on examining and interpreting speech signals using specialized

instruments and tools designed for acoustic analysis.

2. Speech and Its Acoustic Properties

2.1 Definition of Sound:

Sound is the auditory effect produced by waves generated from the vibration of a physical body. It is an external physical disturbance that affects all matter especially air whose particles are displaced and set into motion due to the vibration of the sound source (Khaoula, 2006, p. 45). Each air particle transfers its motion to the adjacent particle, resulting in a sequence of successive sound oscillations, each deriving from the preceding one as they propagate through the transmission medium. This sequence of oscillations is referred to as a *sound wave* (Omar, 1997, p. 27).

2.2 Characteristics of the Sound Wave:

a) Displacement:

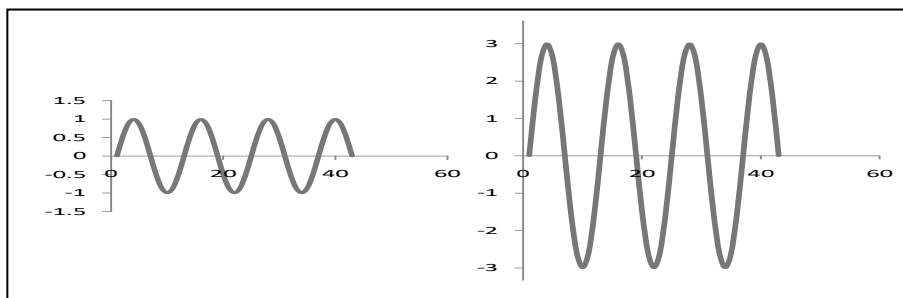
Displacement refers to the extent to which a particle moves from its resting position to a new location due to the vibration of the sound source (Saad, 2005, p. 29).

b) Amplitude:

Amplitude is the maximum displacement reached by a particle, representing the distance between the resting position and the furthest point the moving particle attains. This distance varies depending on the range of motion of the vibrating body from its equilibrium position to its endpoints. The amplitude increases or decreases according to the intensity of the force causing the vibration of the sound source. This phenomenon occurs within the transmission medium, where the sound wave expands or contracts in response to the strength of the vibration.

Amplitude directly affects the human auditory system: the greater the amplitude, the stronger and more intense the sound is perceived by the ear.

Figure 1: The Relationship Between Sound Intensity and Amplitude



The Relationship Between Sound Intensity and Amplitude:

a. A loud sound results from a large amplitude of vibratory motion.

b. A soft sound results from a small amplitude of vibratory motion. (NourAl-Din, 1992, p. 105)

c) Vibration:

Vibration is the motion performed by a body to produce sound. The object begins

moving from a resting position toward another point until it comes to a temporary stop, then returns to the initial position, surpasses it, and halts again at a second point before returning once more to the starting position. This cycle constitutes one complete movement, referred to as a vibration or oscillation. The repeated occurrence of such cycles is known as acoustic vibration or sound oscillation (Mahmoud & Abdullah, 2009, p. 134).

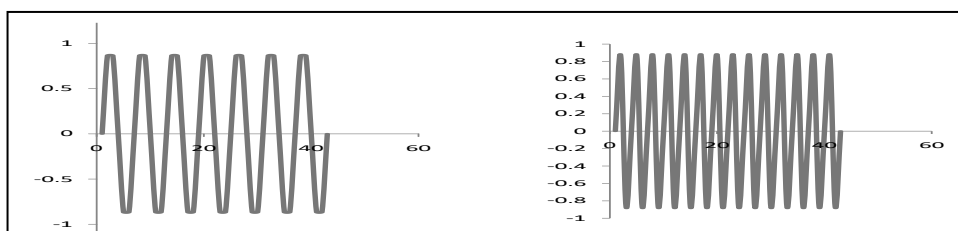
d) **Frequency:**

Frequency refers to the number of oscillations a particle completes in one second. Sounds vary in frequency, as each vibrating object possesses its own natural

frequency, which changes according to specific physical factors related to the vibrating body such as mass and length. In the case of strings, frequency is influenced by the degree of tension; in the case of resonating cavities, it is affected by mass, shape, and volume. Frequency is measured in Hertz (Hz) (Mansour, 2001, p. 105).

The frequencies of Speech waves typically range between approximately 50Hz and 10,000 Hz (Mansour, 2001, p. 110).

Figure 2: The Relationship Between Sound and Frequency



Sound is closely related to frequency, as:

- Low-frequency vibrations produce a **deep (low-pitched)** sound.
- High-frequency vibrations produce a sharp (high-pitched) sound. (NourAl-Din, 1992, p. 105)

e) **Pitch (Fundamental Frequency):**

Often referred to as pitch or sonic sharpness, this property is defined by physicists as the auditory attribute that enables the ear to distinguish sounds or tones as being either high (sharp) or low (deep) (NourAl-Din, 1992, p. 154).

From a physical perspective, the distinction between high-pitched and low-pitched sounds is attributed to the frequency of the sound wave. This frequency represents the fundamental frequency in complex waves. The higher the frequency, the higher the perceived pitch; conversely, the lower the frequency, the deeper or more guttural the sound becomes (Omar, 1997, p. 30).

In the case of human voice, its frequency is determined by the vibration of the vocal folds. The faster the vocal folds vibrate, the higher the pitch of the voice. The vibration speed of the vocal folds varies

from one individual to another, depending on their size and tension (Mahmoud & Abdullah, 2009, p. 154).

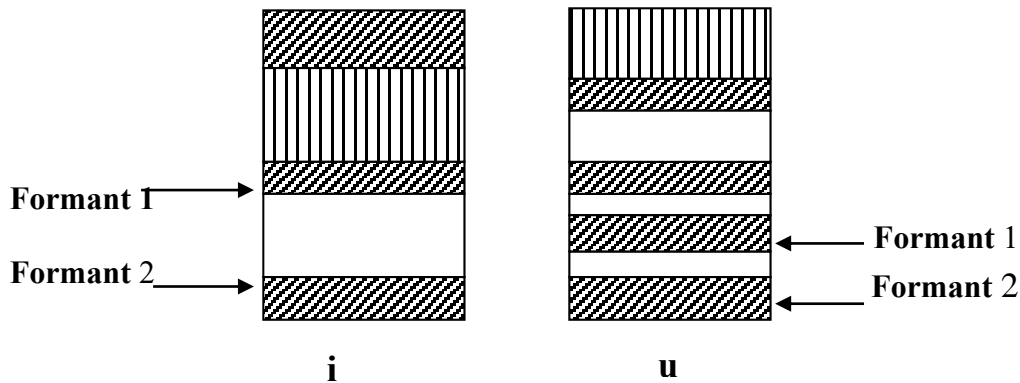
f) *Spectral Representation of Linguistic Sounds:*

The spectral bands that appear as horizontal black stripes in a spectrogram namely the first formant (F1), second formant (F2), and third formant (F3) play a crucial role in the identification of voiced sounds, which involve the vibration of the vocal folds. These include

vowel sounds, nasal sounds such as /n/ and /m/, lateral sounds like /l/, and non-turbulent continuants. Additionally, spectrographic analysis can also aid in the examination and description of certain fricative sounds, such as /h/ and /x/ (the voiceless uvular fricative).

The following figure illustrates a spectrogram of the vowels /i/ (kasra) and /u/ (damma), showing the formation of formant bands. The key spectral features can be observed as follows:

Figure 3: Spectrogram of the vowels /i/ and /u/



Source: (Omar, 1997, p. 41).

1. The first and second formants (F1 and F2) are widely spaced in the vowel /i/, whereas they are very close together in the vowel /u/.

2. The higher formant bands appearing in the upper portions of both spectrograms are speaker-specific markers; they carry **no** linguistic value (NourAl-Din, 1992, p. 123).

Additionally, some linguistic sounds appear in spectrograms as irregular dots or lines, and this visual representation is particularly useful for the analysis of fricative sounds, as well as the bursts

associated with plosive and trilled consonants, such as /r/ (Mahmoud & Abdullah, 2009, p. 172).

g) *Time:*

The temporal measurement of sound waves is expressed in milliseconds, which represent one-thousandth of a second (Mansour, 2001, p. 105). In spectrographic analysis using a sonograph, time is represented along the horizontal axis.

Time plays a significant role in identifying and describing speech sounds in general, and is particularly crucial for analyzing sounds that involve a complete closure of

the vocal tract followed by a sudden release, resulting in what is known as a plosive burst, as observed in the articulation of the consonant /d/ (Mahmoud & Abdullah, 2009, p. 167).

Moreover, time is essential for determining the transition duration between one sound and another, providing insight into coarticulation and temporal dynamics in speech production (Mahmoud & Abdullah, 2009, p. 168).

3. Investigating the Impact of Noise on the Acoustic Properties of Linguistic Sound

3.1 Description of the Research Tool and Preparation of Speech Samples

a. Research Tool:

The primary tool used in this study is Praat, a software application for the analysis, processing, and annotation of sound waves. The version employed in this research is 6.1.25. While Praat is primarily utilized in the fields of phonetics and phonology, it is also widely adopted across other branches of linguistics.

Praat is a highly specialized and versatile tool. Its main features include the following (Kebir, 2019, pp. 5,6):

- It is compatible with a wide range of operating systems, including various distributions of Linux, Macintosh, and Windows.
- It can be integrated with other software applications.

- It offers ease of programming and customization and is continuously updated and maintained.

- It supports the editing of audio files up to 2 GB in size (approximately 3 hours of audio), with capabilities for adding effects and making detailed modifications.

- It allows for sound isolation and the restoration of old recordings with ease.

- It provides tools for spectral analysis of audio files.

- It enables speech synthesis and the assembly of spoken segments.

- It allows users to generate high-resolution images suitable for inclusion in theses and academic publications.

b. Preparation of Speech Samples:

A corpus consisting of a set of sentences was selected for this study. These sentences were first recorded in optimal conditions free from any noise or interference and then re-recorded in noisy environments containing varying degrees of background noise and distortion. The recordings were made using a computer and saved in WAV format, in order to allow for subsequent processing using the Praat software, which was selected as the primary tool for acoustic analysis and signal processing.

This stage is of critical importance, as recording conditions must be carefully controlled to minimize the influence of external factors on the accuracy of the measured acoustic values. The sentences were recorded with specific parameters

defined in advance, as outlined in the following table:

Table 1: Selected Parameters for Corpus Development

Parameter	Value
Sampling Rate	11025 kHz, 16-bit
File Format	Mono, WAV

After completing the recording process and preparing the speech samples, we utilized the Praat software to analyze these samples through spectrograms, which allow for the clear identification of the onset and offset of each sound. Additionally, various acoustic properties such as intensity, formants, and duration were extracted for each condition. These measurements were then used for comparative analysis and interpretation.

3.2 Presentation and Analysis of Results:

In order to achieve the objectives of this study concerning the impact of noise and interference on the acoustic properties of speech, we present below the results of the analysis of a set of physical sound parameters. These results compare the first recording, conducted under optimal, noise-free conditions, with the second recording, performed in a noisy environment with background interference. The aim of this comparison is to examine the validity of our hypothesis, which posits that noise has a measurable effect on the acoustic features of linguistic sound.

a. Spectrographic Analysis of the Speech Sample for the Sentence “Ayyuhā al-Mustami‘ūna al-Kirām”

Figure 4: Spectrogram of the Speech Sample for the Sentence “Ayyuhā al-Mustami‘ūna al-Kirām” Recorded in an Optimal Acoustic Environment

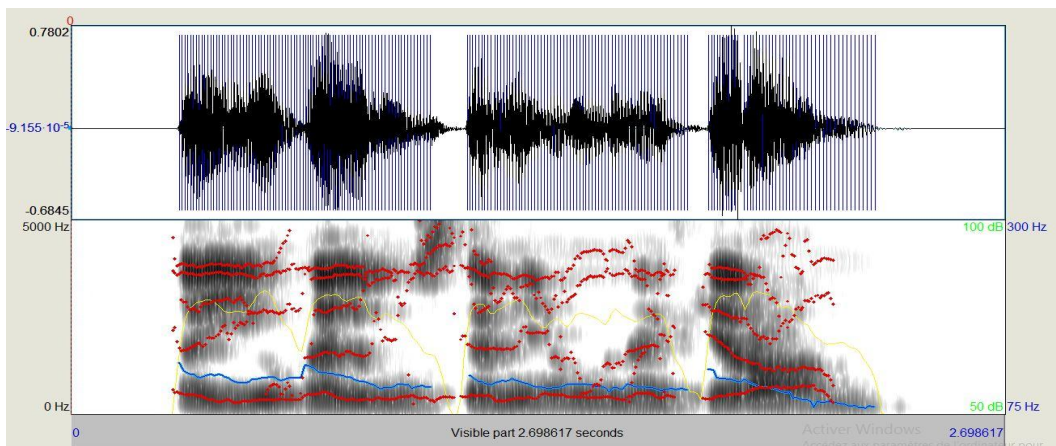
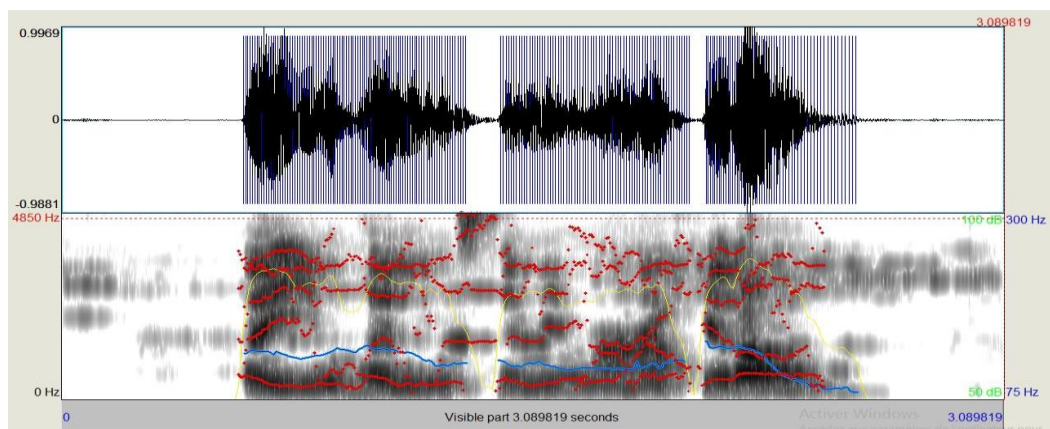


Figure 5: Spectrogram of the Sentence “Ayyuhā al-Mustami‘ūna al-Kirām” with Background Noise



By visually observing and comparing the two spectrograms of the sentence “*Ayyuhā al-Mustami ūna al-Kirām*”, one recorded under optimal acoustic conditions and the other in a noisy environment, we can identify several differences. Notably, the formants, which appear as parallel black bands in the spectrogram of the sentence recorded in suitable conditions, are clear, continuous, and free from any distortions or interruptions.

In contrast, the formants in the spectrogram of the sentence recorded in the noisy environment exhibit numerous breaks and distortions, appearing as curved or irregular lines. This can be explained by the interference of the sound waves formed by the vocal tract resonances with the external noise, which in turn affects the stability and clarity of the formant values.

Moreover, the duration required to pronounce the sentence varies significantly: the speaker in the noisy environment took 2.77 seconds, whereas the speaker in the quiet environment pronounced it in 2.06 seconds. This indicates that the speaker exposed to noise experienced greater difficulty in

articulation, requiring more effort to produce the sentence accurately, which resulted in a longer utterance duration.

Additionally, numerous gaps can be observed in the spectrogram under noisy conditions, which are absent in the spectrogram of the speaker in the optimal environment. These gaps are likely due to extra effort and controlled breathing, as the speaker in the noisy setting had to pause more frequently, taking extra time to initiate and sustain each syllable or segment. In contrast, the speaker in the quiet environment delivered the sentence fluently, without noticeable interruption or hesitation.

b. Physical Properties of Vowels (Fatha, Damma, and Kasra):

Using Praat software for acoustic analysis, we obtained the physical properties of the vowel sounds, which are presented in the following tables:

Table 2: Physical (Acoustic) Properties of Vowel Sounds

Vowel		Duration (s)	Intensity (dB)	Formant (Hz)			
				F1	F2	F3	F4
[a] ^{◌َ}	Quiet	0.093	78.26	473.30	1656.87	2567.73	3530.96
	Noisy	0.090	78.29	482.37	1665.42	2754.14	3570.38
[u] ^{◌ُ}	Quiet	0.090	81.52	355.78	1167.29	2916.18	3629.95
	Noisy	0.099	83.24	390.52	737.50	2863.74	3556.68
[i] ^{◌ِ}	Quiet	0.070	73.56	377.60	1993.13	2606.47	3121.12
	Noisy	0.081	79.65	429.54	1948.72	2859.62	3497.04

Note:

- (quiet) refers to recordings made in optimal (quiet) conditions.
- (noisy) refers to recordings made in noisy conditions.
- F1–F4 are formant frequencies representing resonant frequencies of the vocal tract.
- dB = decibels (intensity), s = seconds (duration).

When examining the varying values of the formants (F1, F2, F3, F4), it becomes evident that each of these values is affected when the sentence is recorded in a noisy environment, compared to those recorded in optimal acoustic conditions. For example, in the case of the vowel [a] (fatha), the formant values in the quiet environment were:

F1 = 473.30 Hz, F2 = 1656.87 Hz, F3 = 2567.73 Hz, F4 = 3530.96 Hz,

whereas in the noisy environment, they shifted to:

F1 = 482.37 Hz, F2 = 1665.42 Hz, F3 = 2754.14 Hz, F4 = 3570.38 Hz.

This variation helps explain the perceived reduction in sound clarity, despite the speaker's increased articulatory effort to produce clear speech. This additional effort is also reflected in the intensity values, where the intensity in the quiet condition was 78.26 dB, slightly lower than 78.29 dB recorded under noisy conditions.

Furthermore, the duration of vowel production is also influenced by the speaker's condition. The increased muscular effort and articulatory control exerted in noisy environments in an attempt to produce more intelligible speech result in longer vowel durations. As shown in the table, the duration of the same vowel sound was greater in the noisy recording compared to its counterpart in the ideal acoustic setting.

4. CONCLUSION:

Given the crucial role that sound and speech play in human communication and

their significant impact on the listener this study has addressed the importance of analyzing the acoustic properties of speech sounds. Such analysis provides valuable insight into how noise affects speech clarity and quality, which in turn can support the development of effective mechanisms for addressing these issues through acoustic evaluation and signal processing, drawing upon the capabilities offered by modern technological advancements.

This study has led to the following key findings:

- Noise significantly affects the acoustic properties of speech and interacts with the speech signal.
 - Sound intensity tends to increase in noisy environments, reflecting the greater vocal effort required by the speaker to maintain intelligibility.
 - The fundamental frequency is disrupted by background noise, leading to intonation irregularities, which in turn affect the transmission of meaning and communicative intent.
 - The true vocal level of the speaker is influenced by the degree of background noise and environmental interference.
- Conduct further research on intonation patterns, given their crucial role in verbal communication and addressing the listener effectively.
 - Pay close attention to acoustic features when adding any form of sound effects or modifications to audio recordings.

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Recommendations:

- Emphasize the integration of technological tools in the analysis of Speech to preserve its quality, especially as sound serves as a medium for safeguarding cultural heritage.