

# Assessment of recording chain configuration during logatome and sentence lists recording

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**Abstract**—Sentence and logatome lists are commonly used in the evaluation of speech signal quality and intelligibility in communication systems and recording applications. The reliability of such assessments depends not only on the test material itself but also on the configuration of the recording chain and measurement setup.

This paper presents an analysis of the influence of selected elements of the recording chain configuration on the spectral properties of recorded speech signals. The study focuses on the impact of microphone stand design, spatial arrangement of microphones, and polar patterns on the recorded signal. Measurements were conducted under controlled conditions in an anechoic chamber to isolate the effects of the recording system from room acoustics.

The analysis includes comparative frequency response measurements for different stand configurations, including systems with and without damping elements, as well as an investigation of the proximity effect for various polar patterns of a studio microphone. The results indicate that in near-field conditions the geometry of the recording setup and microphone characteristics dominate the spectral response, while the influence of stand structure remains limited. At greater distances, structural elements may introduce measurable deviations in the mid- and high-frequency range.

The study confirms known theoretical models under controlled conditions and provides practical insights into the design and reliability of measurement setups used in speech signal acquisition.

**Keywords**—logatome, sentence list, microphone stand, polar patterns, Audio recording authentication

## I. INTRODUCTION

SENTENCE and logatome lists [1], [2] are essential tools in evaluating speech intelligibility and signal quality within modern communication systems. The accuracy and repeatability of such measurements depend not only on the phonetic properties of the test material but also on the specific technical configuration of the recording chain. In practical scenarios, factors such as microphone placement, directivity, and the presence of structural elements, including stands and mounting systems, can significantly influence the spectral properties of the recorded signal through secondary acoustic effects such as diffraction, local reflections, and acoustic shadowing.

This study assesses the impact of selected microphone mounting systems on the frequency response of a measurement microphone [3]. The influence of mechanical support structures on the measurements results remains insufficiently investigated under controlled conditions. This study specifically evaluates how two distinct tripod designs and the application of damping

materials, such as acoustic foam, affect measurement repeatability and spectral integrity.

The proximity effect, a fundamental phenomenon in pressure-gradient transducers [4], [5], [6], [7], results in a significant increase in low-frequency response as the sound source approaches the microphone diaphragm. This study examines this effect across various polar patterns — including cardioid, supercardioid, figure-eight, and wide cardioid — at multiple source-to-capsule distances. The magnitude of this effect is dictated by the ratio of the gradient component to the pressure component [6], [8], [9]; it is most pronounced in the figure-eight pattern and absent in omnidirectional microphones, which function as pure pressure transducers. For speech analysis, this effect is particularly problematic as it boosts the 70–300 Hz band, potentially "thickening" the voice and masking critical higher-frequency formants, which can lead to the misinterpretation of logatome spectra [10].

In contrast to omnidirectional microphones like the used measurement microphone [3], which record changes in sound pressure alone and exhibit spectrum changes resulting solely from free-field propagation, studio microphones with switchable polar patterns allow for direct observation of the proximity effect. Analysis of the spectra recorded with measurement microphones showed that in free-field conditions and with the capsule in a fixed position, the presence of stand components does not significantly affect the frequency response in the near field.

By performing measurements under controlled conditions in an anechoic chamber using a reference sound source and a standardized measurement system, this research quantitatively evaluates the interplay between stand geometry, spatial orientation, and microphone directivity. The objective is to determine how these variables influence the spectral properties of speech, and the reliability of recordings used in voice transmission quality assessment. To guide this evaluation, the following research hypotheses were formulated:

H1: Microphone stand geometry does not significantly affect spectral characteristics under near-field conditions.

H2: The application of damping materials to mounting structures reduces high-frequency disturbances caused by local reflections.

H3: The proximity effect is primarily a function of microphone directivity and source distance, independent of the stand configuration.

H4: In far-field conditions, structural mounting elements introduce measurable spectral deviations and acoustic shadowing.

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This work focuses strictly on the physical parameters of the signal and the hardware setup. Complementary subjective quality evaluations and speech intelligibility analyses for these specific recording conditions are addressed by the authors in separate publications. The findings ultimately aim to provide guidelines for professional voice-over recordings and the creation of reference materials where spectral accuracy and conscious control of microphone operating modes are paramount.

## II. DESCRIPTION OF THE MEASURING SYSTEM

In order to examine the impact of the tripod design on the frequency characteristics of the measurement microphone[3], two independent measurement systems were constructed, differing in geometry and microphone placement relative to the sound source.

System A was based on a classic microphone stand, to which a 70 cm long stereo bar was attached. A single measurement microphone was placed at one end of the crossbar, while at the other end a small stereo bar was attached with two microphones: a studio microphone and a second measurement microphone. The entire assembly was placed at a height of 150 cm above the ground.

System B was constructed as a structure consisting of two separate microphone stands, connected into a single system by two small stereo bars. This solution made it possible to position the microphones in a spread configuration, resembling the letter 'Y', while maintaining the same lateral distance between the microphones (50 cm) and the same height (150 cm).

Both measurement systems were designed to replicate the actual conditions in which the voice-over material was recorded and to enable analysis of the impact of structural elements (arms, joints, bases) on the recorded sound signal.

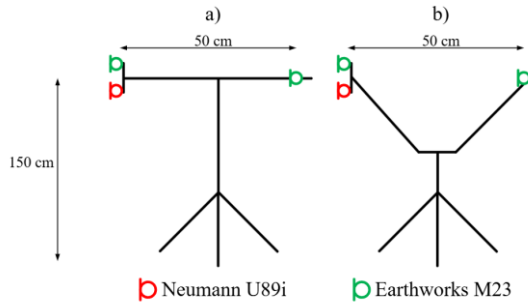


Fig. 1. Diagram of two types of microphone stand configurations used in the study: a) system A, b) system B

The measurements were taken in the anechoic chamber in order to ensure free field conditions and eliminate the influence of acoustic reflections. A two-way speaker system was used as the sound source to assess the influence of the tripod design on the differential frequency responses of the speaker system obtained by measurement microphones [3] mounted on the tested microphone stand. Differential characteristics were obtained as a difference between frequency response obtained by measurement microphone 2 m away from speaker system and measurement microphone placed 2,5 m away from measured speaker system.

A sweep signal (sinusoidal chirp) with a constant voltage corresponding to 1 W for the woofer and 0.3 W for the tweeter was used to power the system. Power amplifier [11] controlled the speaker set, and the recording was made via the high-quality audio interface [12]. The microphones were connected to the IN7–IN10 inputs of the interface.

The measurement reference point was set on the tweeter axis. The ¼" measurement microphones were placed 2 m away and 2.5 m away from the sound source. All measurement microphones were calibrated using a pistonphone[13], emitting a 250 Hz calibration signal at a level of  $L_{SPL} = 124$  dB.

Signal recording and analysis were performed using audio measurement software [14]. The obtained frequency responses were normalized to 0 dB at 160 Hz to allow comparison of the response shapes of different stand configurations and their effect on the microphone's frequency response.

The measurement setup is shown in Fig. 2.

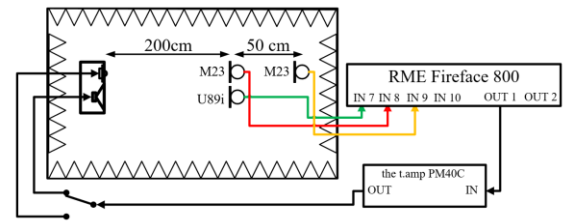


Fig. 2. Measuring system for testing the influence of microphone stand

Furthermore, using the setup shown in Fig. 2, measurements were taken of the proximity effect on the frequency response of the studio microphone. The microphone array was positioned at distances of 5 cm, 10 cm, 15 cm, and 20 cm from the woofer of the speaker system used. Measurements were taken for all possible polar patterns of the studio microphone [15].

### A. Single tripod with stereobar (System A)

The first of the analyzed voice recording systems was a system using a single microphone stand equipped with a crossbar (a so-called stereo bar) to which the measuring microphones were attached. This design allowed for a constant, precisely defined distance between the microphones, which was important for the repeatability and comparability of the recorded data.

The use of a single stand limited the number of degrees of freedom of the entire system, making it possible to quickly and stably set up the system in various measurement conditions without having to calibrate the position of the microphones each time. This solution greatly facilitated the transfer of the system between the rooms under test (anechoic chamber, recording studio, acoustic chamber) and minimised the risk of geometric setting errors that could affect the recording results.

An additional advantage of the system was the high repeatability of the recordings obtained – both in terms of the position of the microphones relative to the sound source and their angle of placement. This solution made it possible to obtain consistent data in different acoustic environments, which is an important foundation for the subsequent comparative analysis of the impact of recording conditions on the quality and intelligibility of speech recordings. This setup is shown in Fig. 3.



Fig. 3. Microphone arrangement using a single stand without damping foam on the beam (System A)

#### B. Single stand with stereobar with damping foam (System A with foam)

The beam was covered with specialized acoustic foam with strong sound-absorbing properties in the mid and high frequency range (1–10 kHz). The purpose of this measure was to minimize the impact of acoustic wave reflections from the metal and plastic structural elements of the microphone stand, which can cause local interference, changes in polar patterns and disturbances in the linearity of the measurement microphone's frequency response. In the context of precise acoustic measurements, even slight reflections from structural elements can lead to unwanted resonances or drops in the spectrum, which affects the reliability and repeatability of the results.

It was claimed that applying a damping layer directly to the stereo bar would reduce these effects without changing the geometry of the measurement system or moving the microphones. Additionally, this measure was supposed to allow for a more objective assessment of the influence of the stand itself on the frequency characteristics, while eliminating errors resulting from secondary near-field reflections. As a result, the obtained frequency characteristics better reflect the actual properties of the microphones in the specified measurement position.



Fig. 4. Microphone arrangement using a single stand with damping foam on the beam (System A)

Acoustic foam used in the system was employed to reduce sound wave reflections from the stand's structural elements. However, the manufacturer does not provide any detailed data on its acoustic absorption characteristics, such as absorption coefficients. For this reason, the material was subjected to preliminary impedance measurements and a subjective assessment of its attenuation effectiveness in the mid and high

frequency bands. The measurement was intended to estimate the effect of the foam on the reduction of reflection and interference phenomena that could interfere with the measurement results of the microphone's frequency characteristics.

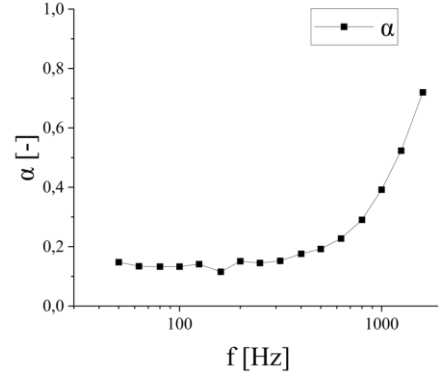


Fig. 5. Characteristics of the absorption coefficient in the third octave bands of polyurethane foam used to cover the tripod

To check the influence of foam absorption on microphone stand the measurements of the absorption coefficient were carried out in accordance with PN-ISO 10534-2:2003 [16], using an impedance tube [17].

The results obtained showed that the foam has moderate absorption capacity in the mid and high frequency ranges, which confirmed its suitability for use as a reflection-damping material in the measurement system.

#### C. Double tripod (System B)

The second microphone system tested was a design based on two microphone stands connected by a short stereo bar. This solution was designed to minimize the presence of reflective elements in the vicinity of the distant measuring microphone, which was particularly important for precise frequency response measurements. The use of two independent stands made it possible to move part of the structure away from the axis of acoustic wave propagation and reduce potential reflections from mechanical elements.

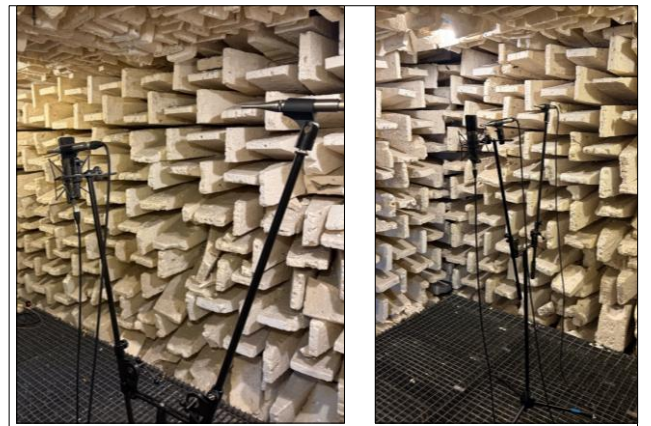


Fig. 6. Microphone arrangement using a double stand

Despite its favourable acoustic properties, this system proved to be more difficult to operate in mechanical terms. The multitude of degrees of freedom and independent adjustment points increased the risk of setting errors and reduced the repeatability of measurements between successive sessions.

This required particular care during each assembly and additional control of the geometry of the measurement system.

### III. FREQUENCY CHARACTERISTICS – COMPARATIVE ANALYSIS OF TRIPOD SYSTEMS

Figure 7 shows a comparison of the differential frequency characteristics (frequency characteristic obtained with measurement microphone 2 m from loudspeaker system to frequency characteristic obtained with measurement microphone 2,5 m from loudspeaker system) of two-way loudspeaker system for three microphone array configurations. The distances between the measured loudspeaker system and the measurement microphones were selected to ensure far-field placement. This positioning effectively eliminates near-field acoustic disturbances and minimizes the sensitivity of the output results to minor variations in stand geometry. To eliminate amplitude differences, calibration was restricted solely to this measurement point using a pistonphone generating a sound pressure level of 124 dB. The red curve (labelled System A) represents the differential frequency characteristics of two-way loudspeaker system for microphone configuration with stand A, in which the microphones were mounted on a crossbar without the use of damping foam. This configuration showed the most balanced frequency response, confirming its high suitability for measurement and recording purposes.

For the same tripod design, but with added damping foam (orange color, labelled System A with foam), significant changes were observed above 1 kHz, indicating a clear damping intrusion in the system. The drops in the 2–5 kHz range suggest that the foam may have introduced undesirable acoustic energy absorption effects in the close surrounding of the microphone.

The navy-blue characteristic (designation: System B) corresponds to the configuration of tripod B, which was designed to minimise reflections from the stereobar. The foam used to cover the metal bar was supposed to dump the sound waves striking the beam. Despite its design, the differential characteristics proved that system B is less favourable – it shows significant disturbances in the mid and high frequencies, which may indicate the occurrence of interference or acoustic shadow phenomena.

It is worth emphasizing that the conducted study constitutes a preliminary stage in the development of a comprehensive Polish speech recording database. The project involves eight speakers, and the recording process is expected to last several dozen hours over the course of multiple weeks.

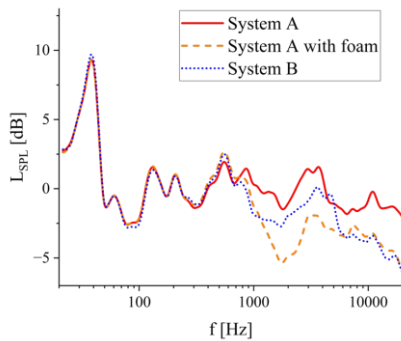


Fig. 7. Differential characteristics obtained for individual microphone stand configurations

Given this extended time frame, a key requirement for the selected setup is high measurement repeatability. Although the stand in configuration B allows better results in individual trials, it proved unsuitable for long-term studies. Its complex structure (including the need to assemble multiple arms and the risk of changes in element angles) makes it difficult to maintain identical acoustic and geometric conditions over time.

Therefore, despite its theoretical advantages, the more stable configuration A was ultimately selected.

### IV. COMPARISON OF THE IMPACT OF TRIPOD DESIGN ON SPEECH SIGNAL SPECTRA

In order to assess the impact of the microphone stand on speech signal spectra, measurements were carried out under controlled conditions in an anechoic chamber. A mouth simulator [18] was used to reproduce speech material, enabling repeatable and precise reproduction of the actual speech sound source [19], [20], [21].

The recording was made using a ¼" measurement microphone [3], positioned at two distances from the simulator: 15 cm (close) and 65 cm (far), and a studio microphone [15] at the same distance as first measurement microphone. For these measurement points, no microphone calibration using pistonphone was performed. The recordings included selected logatomes from a pre-prepared test list.

The experiment was repeated for three different modifications of microphone stands to assess whether their design (shape, material, presence of arms and booms) could affect the recorded speech signal spectrum, e.g. through reflections, diffraction or local attenuation.

The connection diagram shows how the experiment was carried out: all microphones were connected to an interface [12], and the mouth simulator was powered by a power amplifier [11]. This measurement setup ensured a high level of control over the listening conditions and repeatability of the measurements.

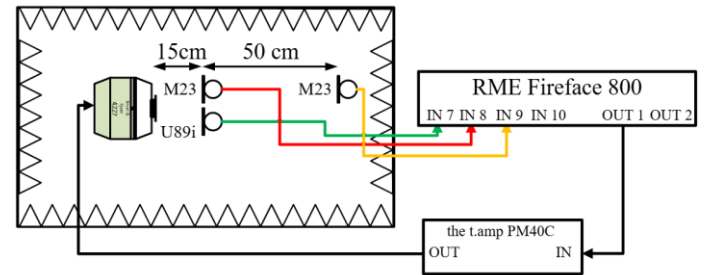


Fig. 8. Diagram of the measuring station for testing the impact of the microphone stand on the speech signal spectrum

An analysis of the differential characteristics shown in Figure 9 showed that the use of a tripod with a beam and a double tripod does not significantly affect the spectral characteristics recorded by microphones placed at the same distance of 15 cm from the mouth simulator. Regardless of the tripod design, the spectral curves remain convergent, and the differences between them are within the limits of measurement uncertainty. This means that the presence of additional structural elements, such as beams, booms or double mounts, does not generate noticeable disturbances in the acoustic field in the immediate vicinity of

the microphone, provided that the capsule remains in a fixed position.

In the context of the proximity effect, it is important to note

TABLE I  
PRESSURE AND GRADIENT COMPONENTS RATIO

| Polar Pattern   | a   | b   |
|-----------------|-----|-----|
| Omnidirectional | 1   | 0   |
| Wide cardioid   | 0.7 | 0.3 |
| Cardioid        | 0.5 | 0.5 |
| Supercardioid   | 0.3 | 0.7 |
| Figure eight    | 0   | 1   |

that at a distance of 15 cm from the sound source, directional microphones exhibit an increased level of low-frequency components, resulting from an increase in the acoustic pressure difference between the front and rear of the diaphragm. It is worth noting, however, that in the case of a boom stand and a double stand, the proximity effect is not modified depending on the stand design – its course and amplitude remain consistent with the reference characteristics for a microphone positioned in the same position without additional elements in the vicinity. This means that for the near field (15 cm), the dominant factor shaping the signal spectrum is the source-microphone geometry itself, rather than the presence of the stand.

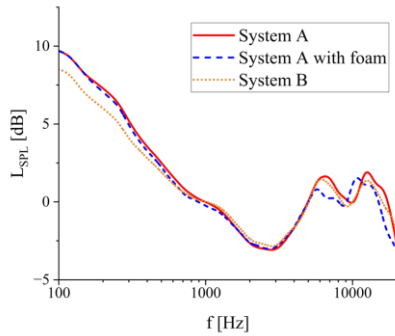


Fig. 9. Differential characteristics of logatom spectra for M23 and U89i microphones at a distance of 15 cm from the mouth simulator

The differential spectral characteristics of recorded signals shown in Figure 10 illustrate the effect of the distance between the microphone and the sound source, as well as the tripod design, on the recorded speech signal spectrum. The analysis was performed for an measurement microphone positioned 65 cm from the mouth simulator, with reference to the characteristics obtained with the same type of microphone at a distance of 15 cm. Due to the omnidirectional characteristics of the measurement microphones and the absence of a proximity effect, the spectral differences are mainly due to the attenuation of acoustic energy with increasing distance and wave interactions (diffraction, reflection, absorption).

In the low frequency band (up to approx. 300 Hz), all spectral characteristics show a uniform level decrease, with no significant differences between the stands, confirming that the stand design does not interfere with the propagation of long waves. In the mid-frequency range (300 Hz–2 kHz), the deviations do not exceed  $\pm 1$ –2 dB and are random in nature, which may be the result of minimal microphone shifts or scattering on the stand components. The most noticeable

changes occur in the band above 2 kHz. This is particularly evident in the case of a configuration with a tripod equipped with damping foam (blue curve), where a systematic decrease in signal level is observed from approximately 1 kHz. The foam, placed to reduce reflections from the tripod beam, in practice causes partial absorption of medium and high frequencies and creates a local acoustic shadow in the path of sound propagation to the microphone 65 cm away. This effect is particularly noticeable in the 2–5 kHz range, which is important for the formant structure of speech, where the attenuation level reaches several decibels.

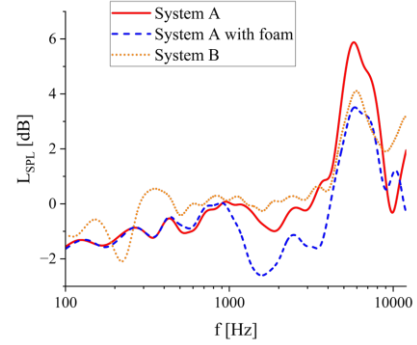


Fig. 10. Differential characteristics of logatome spectra for M23 measurement microphones at distances of 15 cm and 65 cm from the mouth simulator

#### V. THE INFLUENCE OF POLAR PATTERNS AND DISTANCE FROM THE SOUND SOURCE ON THE PROXIMITY EFFECT FOR A LECTURER MICROPHONE.

In voice-over recordings, accurate reproduction of voice tone and clarity is one of the key factors determining the quality of sound transmission [22]. The right choice of microphone and its correct positioning in relation to the sound source are essential for maintaining natural and consistent sound recording. One of the important acoustic phenomena affecting voice recording is the proximity effect, which consists of an increase of low-frequency components in the recorded signal as the microphone is moved closer to the sound source. The nature of this phenomenon is closely related to the polar patterns of the microphone and to the distance between the microphone diaphragm and the speaker's mouth. Understanding the relationship between these factors is important in the process of shaping the sound of the voice, as it allows the recording parameters to be optimised in terms of the desired tone, clarity and sense of space. The analysis of the impact of directionality and distance from the sound source on the proximity effect is therefore an important element of research into the properties of microphones used in voice-over production, where a balance between naturalness and fullness of sound is particularly desirable.

Mathematically, this relationship can be described by the following expression [23], [24], [25], [26] for the boost level ( $L_{BOOST}$ ):

$$L_{BOOST} = 20 \log \left( a + b \cdot \frac{\sqrt{1+(kr)^2}}{kr} \right) \quad (1)$$

Where:

$k = \frac{2\pi f}{c}$  describes the wavenumber,

$r$  – distance microphone – sound source [m],

f – frequency [Hz], a – pressure component ratio (0 – 1),  
b – gradient component ratio (0 – 1)

Figure 11 presents a comparative analysis of the calculated proximity effect (equation (1)) for five different microphone polar patterns (pressure and gradient components ratio shown in table 1) at a fixed distance of 5 cm. It illustrates a clear hierarchy in low-frequency enhancement, where the magnitude of the boost is directly linked to the specific directivity of the capsule.

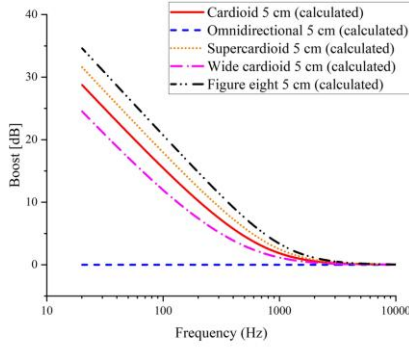


Fig. 11. Calculated proximity effect boost for 5 cm distance between sound source and microphone

To evaluate the influence of studio microphone characteristics on the recording of logatom lists, a series of comparative tests were conducted. The methodology involved measuring the difference in Sound Pressure Level (SPL) between a measurement microphone and the studio microphone under test, both placed at an identical reference point.

The measurements were performed on-axis relative to the studio microphone's capsule. To analyze the proximity effect and its interaction with various polar patterns, the distance between the microphone and the artificial mouth (sound source) was varied at increments of 5, 10, 15, and 20 cm. This setup allowed for a precise quantification of spectral coloration induced by source proximity across different directional settings.

Figures 12, 13, 14, 15 and 16 show the effect of sound source distance on the frequency response of the studio microphone [15] for different polar patterns settings. All characteristics have been limited to the 70 Hz – 1 kHz band, as the proximity effect manifests itself only in the low frequency range and disappears with increasing frequencies. Each graph shows a set of differential characteristics for several distances between the microphone and the loudspeaker, allowing comparison of the proximity effect depending on the type of

polar patterns and the distance between the sound source and the microphone.

Figure 12 shows the effect of distance on the proximity effect for a cardioid microphone polar pattern. At the shortest distance from the source, the signal level in the 70–300 Hz band is clearly amplified relative to the reference microphone. As the distance increases, the amplitude of the signal amplification in this range decreases systematically, while above 500 Hz the characteristics remain convergent. This phenomenon is consistent with the assumption that cardioid is a gradient-pressure system.

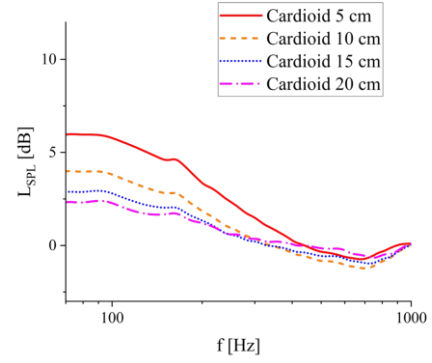


Fig. 12. Effect of distance from sound source on proximity effect for Neumann U89i microphone (cardioid polar pattern)

Figure 13 shows the differential characteristics of a microphone operating in omnidirectional mode at various distances from the sound source. No low-frequency boost is observed across the entire band up to 1 kHz, which is due to the purely pressure-based operation of the omnidirectional characteristic. Changes in signal level are only the result of propagation attenuation with increasing distance, and not the proximity effect.

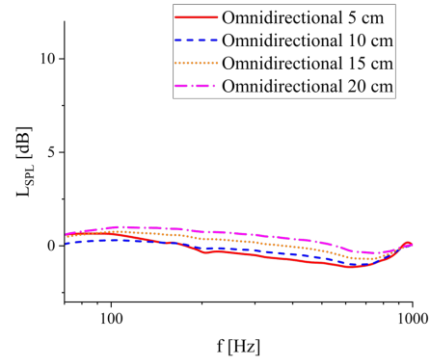


Fig. 13. Effect of distance from sound source on proximity effect for Neumann U89i microphone (Omnidirectional polar pattern)

Figure 14 shows the effect of distance on the frequency response of the microphone in the supercardioid setting.

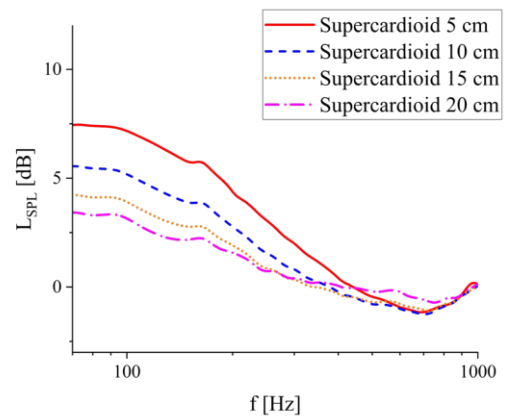


Fig. 14. Effect of distance from sound source on proximity effect for Neumann U89i microphone (Supercardioid polar pattern)

Compared to cardioid, a stronger proximity effect is observed — for the shortest distance, the boost in the 70–300 Hz band is more pronounced, which results from a greater contribution of the pressure gradient component. As the distance increases, this boost disappears and the characteristics above approx. 500 Hz remain convergent.

Figure 15 shows the changes in the frequency response of the U89i microphone in wide cardioid mode. The proximity effect is present, but less intense than in a classic cardioid. Low-frequency gain (below approx. 200 Hz) is noticeable at short distances, but the amplitude of the boost is lower. For frequencies above 400–500 Hz, the frequency characteristics remain almost identical, indicating the dominant contribution of the pressure component.

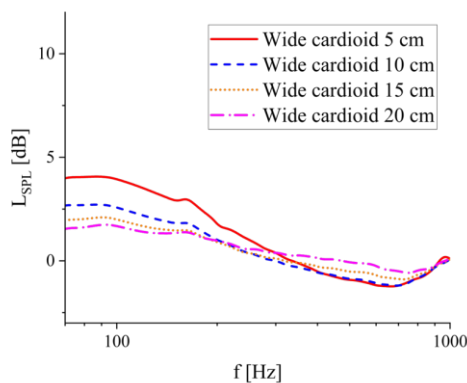


Fig. 15. Effect of distance from sound source on proximity effect for Neumann U89i microphone (Wide cardioid polar pattern)

Figure 16 shows the differential characteristics of a microphone operating in figure-of-eight mode at various distances from the source. In this configuration, the proximity effect is most noticeable among all characteristics — at close range, the signal level in the 70–300 Hz range is significantly increased. As the distance increases, this gain rapidly decreases, and above approximately 500 Hz, the characteristics converge. This is consistent with the theory that first-order gradient (figure-8) microphones exhibit the strongest proximity effect.

The graphs illustrate the effect of the distance of the sound source and the selected polar pattern (omnidirectional, cardioid, hypercardioid, figure-8) for the Neumann U89i microphone on the shape of the microphone's frequency response.

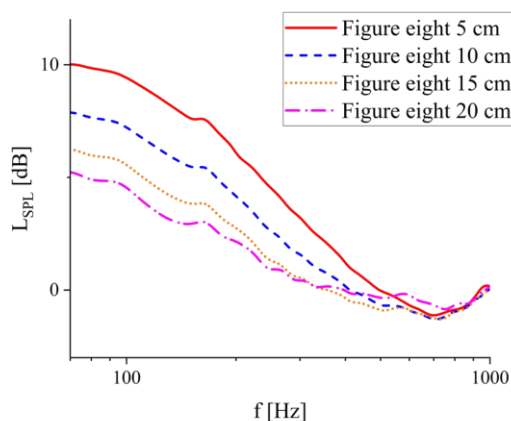


Fig. 16. Effect of distance from sound source on proximity effect for Neumann U89i microphone (Figure - eight polar pattern)

### Conclusions:

- For polar pattern (cardioid, hypercardioid, figure-8), the proximity effect is clearly noticeable – close distance (e.g. 5 cm) results in a significant boost in the low frequency range (up to 10 dB in the 100–300 Hz range).
- A microphone in omnidirectional mode does not exhibit the proximity effect – the spectrum remains stable regardless of distance.
- As the distance between the source and the microphone increases (e.g. 15 cm, 30 cm, 50 cm), the effect gradually disappears – all polar patterns approach a neutral frequency response.
- The strongest amplification of low frequencies is observed for the figure-8 pattern, which is consistent with theory – bidirectional microphones are most susceptible to the proximity effect.

In voice-over practice, this effect is sometimes used deliberately – e.g. to deepen and warm the sound of the voice. However, too much of it can result in a recording that is too 'heavy' and boomy, so it is crucial to choose the right microphone, directionality mode and distance from the mouth.

Figure 17 shows the frequency response of the Neumann U89i microphone for different polar patterns, recorded on the microphone capsule axis at a distance of 5 cm from the mouth simulator. In the analysed range up to 1 kHz, a clear dependence of the low frequency level on the type of polar patterns can be observed. The highest gain in the 70–300 Hz band occurs for the figure-of-eight pattern, which results from its purely gradient mode of operation. Cardioid, supercardioid and wide cardioid characteristics exhibit a proximity effect of varying intensity, proportional to the share of the pressure gradient component in a given pressure-gradient system. In the case of omnidirectional characteristics, which are purely pressure-based, no significant boost in low frequencies is observed. Above approximately 700 Hz, the graph for all characteristics converge to similar values, confirming that the proximity effect is limited to the lower band.

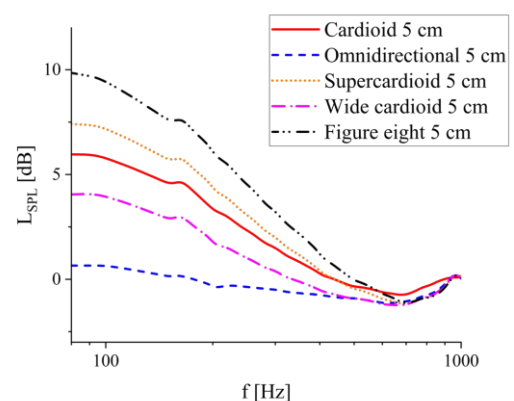


Fig. 17. Influence of the polar patterns of the Neumann U89i microphone on the proximity effect (distance 5 cm)

Conclusions – influence of polar patterns on the proximity effect (distance 5 cm):

The proximity effect is strongly dependent on the polar patterns of the microphone. The Neumann U89i microphone exhibits varying amplification in the low frequency range depending on the selected characteristic.

The greatest low-frequency gain is observed for the figure-8 polar pattern. In the band below 200 Hz, there is a significant level boost – reaching up to 10 dB compared to the omnidirectional polar pattern – which confirms the strong proximity effect typical of microphones with full gradient directivity.

The omnidirectional characteristic shows the smallest proximity effect. The amplification of low frequencies is practically imperceptible, which is consistent with the physical properties of pressure microphones – the proximity effect does not occur in their case.

Cardioid characteristics occupy an intermediate position. The greater the gradient component in the characteristic design, the more pronounced the proximity effect – which is confirmed by the analysis of the graph for these settings.

The proximity effect is concentrated in the low band (<300 Hz), while above 500 Hz the characteristics converge. This phenomenon causes the tone of voice to change as the microphone is brought closer, which is of practical importance in voice-over and vocal recordings.

## VI. CONCLUSION

The conducted research made it possible to determine the impact of the microphone stand design, distance from the sound source, and microphone polar patterns on the spectral structure of speech signals and logatomes recorded in an anechoic chamber. Analysis of the spectra recorded with the measurement microphone [3] showed that in free field conditions and with the capsule in a fixed position relative to the sound source, the presence of the stand components does not significantly affect the frequency response of the signal. Differences between configurations only appear the mid and high frequency bands. In particular, the use of damping foam on the tripod beam caused a local attenuation of the signal level above 1 kHz, which should be associated with partial wave absorption and the formation of an acoustic shadow along the propagation path.

In the case of the studio microphone [15] microphone, equipped with switchable polar patterns, a clear dependence of the frequency response on the distance from the sound source and the type of polar patterns was demonstrated. In accordance with the theory of gradient pressure microphones, a proximity effect was observed for cardioid, wide cardioid, supercardioid and figure 8 polar patterns. Proximity effect leads to increase in signal level in the low frequency range (70–300 Hz) as the distance from the source decreased. This phenomenon was most pronounced for the figure-eight characteristic, moderate for cardioids and supercardioids, and least pronounced for wide cardioids. In omnidirectional mode, which corresponds to a pure pressure microphone, the proximity effect did not occur. Above a frequency of approximately 500 Hz, the characteristics for different distances remained convergent, confirming that the proximity effect is a phenomenon limited to the lower range of the speech band.

The empirical measurements obtained during this study, as illustrated in the plotted spectral data, provide a critical verification of the theoretical proximity effect model. While the mathematical derivation for a cardioid pattern predicts an aggressive boost that continues to climb into the sub-bass region, the measured response at 5 cm demonstrates a distinct

stabilization. Specifically, the observed boost reaches its maximum of approximately +6 dB at 100 Hz before plateauing. This suggests that the microphone's physical design—incorporating acoustic resistance and mechanical damping—effectively limits the extreme low-frequency deviations that the theoretical  $\frac{1}{kr}$  relationship would otherwise produce.

The results obtained indicate that in measurements with an omnidirectional microphone, which is free of proximity effect, the shape of the signal spectrum depends primarily on free-field propagation, while the design of the stand does not constitute a disturbing factor in the near field. With regard to studio microphones with variable polar patterns, the choice of distance and microphone operating mode has a direct impact on the reproduction of sound color and should be consciously controlled, especially in voice-over recordings and reference materials used to assess speech transmission quality.

For high-precision acoustic measurements, the physical interaction between the microphone stand and the sound field is highly dependent on the source-to-capsule distance. Under near-field conditions, the structural components of a standard microphone stand do not exert a statistically significant influence on the frequency response.

Consequently, the distance between the speaker and the microphone serves as the primary variable controlling the magnitude of spectral coloration. Experimental data confirms that the 70–300 Hz frequency range is exceptionally sensitive to minor spatial deviations; for instance, increasing the distance from 5 cm to 10 cm yields a measurable 2 dB reduction in the low-frequency boost for directional patterns. To ensure a linear spectral response that accurately reflects the speaker's natural timbre, a minimum distance of 20 cm is recommended. Maintaining this distance, supported by a rigid and non-reflective stand configuration, is essential to minimize proximity-induced distortion and ensure the repeatability of recordings used in speech transmission quality assessments.

Regarding the research hypotheses formulated at the beginning of this study, the obtained experimental results allowed for their definitive verification. The hypothesis if the structural components of the microphone stand exert no significant influence on the spectral structure of the signal under near-field conditions was confirmed. Only local, high-frequency alterations resulting from the application of damping foam were observed. Furthermore, the hypothesis concerning the occurrence and magnitude of the proximity effect as a function of the studio microphone's polar pattern was fully validated by the collected empirical evidence. Measurements confirmed the theoretical assumptions regarding the absence of this phenomenon in the omnidirectional mode and its varying degrees of manifestation across pressure-gradient patterns. Simultaneously, the findings highlighted the stabilizing effect of the actual capsule design in constraining the theoretical sub-bass boost.

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