The effects of holding positions on the frequency response of dynamic vocal microphones

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Abstract

This study examines the effects of different holding positions of the microphone body and capsule on the frequency response of dynamic vocal microphones. Microphones enable the amplification and recording of sound by converting sound waves into electrical signals. Based on their operating principles, microphones are divided into two primary types: electromagnetic and electrostatic. The sample for this study consists of dynamic microphones, which fall under the category of electromagnetic microphones. Dynamic microphones are commonly preferred in live performances and studio recordings due to their durability, affordability, and low self-noise levels. In this study, the effects of various grip positions on frequency response were analyzed using the Shure SM-58 model dynamic microphone, which is widely used in both studio and live sound environments. The selected grip positions include the standard stand position, fully enclosed capsule grip, semi-open capsule grip, and body grip. These positions comprise the sample for the study. The research was conducted in a controlled studio environment, isolated from external factors and with appropriate acoustic conditions. Audio samples were collected by having a professional vocalist sing the G4 note (392 Hz) on the syllable “na” for 5 seconds. The recordings, conducted at an industry-standard 96 kHz sampling rate and 24-bit resolution, were repeated for each grip position and digitally transferred as .wav files. The .wav files were normalized in Audacity in preparation for Fast Fourier Transform (FFT) analysis. During the data analysis process, the normalized .wav files were analyzed via FFT implemented in Python. The data were examined by analyzing the first seven harmonics within three octaves above the G4 note (392 Hz). Referring to the standard stand position, the Fully Closed Grip Position on the Capsule exhibited a significant reduction in lower frequencies alongside an increase in upper frequencies. Similarly, the Capsule Half-Open Grip Position resulted in decreased low and mid frequencies, with a corresponding rise in high frequencies. Observations from the Microphone Body Grip Position also indicated a decrease in lower frequencies and an enhancement in upper frequency regions. Based on these findings, this study aims to provide vocal performers, recording engineers, and researchers in music technology with insights into achieving higher precision and professionalism by understanding how appropriate microphone holding techniques influence the sound’s balance.

Keywords

dynamic microphones, frequency analysis, frequency response, microphone holding positions

Introduction

The transmission and perception of sound have played a significant role throughout history and have evolved further with technological advancements. Microphones are one of the essential pieces of equipment for amplifying and transmitting sound. They took their place in history when Emile Berliner patented the carbon microphones in 1877 (Eargle, 2012: 2). Durmaz defines the microphone as “an electro/electro-mechanical circuit element that converts molecular vibrations in an acoustic environment into electrical signals” (Durmaz, 2009: 217). As the first link in the chain of transferring sound waves to digital or analog media, the microphone is one of the most crucial devices used in studio environments (Önen, 2007: 106). Essentially, a microphone is a transducer that converts sound waves into electrical signals (Huber & Runstein, 2005: 116). The widespread use of electric microphone recordings in 1925 marked the beginning of a new era in the history of sound recording (Ünlü, 2016: 20-49). Microphones fundamentally convert acoustic energy into electrical energy and are categorized into two types based on their operating principles: electromagnetic and electrostatic. Dynamic and ribbon microphones fall under the electromagnetic category, while condenser and electret condenser microphones belong to the electrostatic group (Önen, 2007: 105). Dynamic microphones are among the most popular types of microphones frequently used on stage and in amateur studios. A dynamic microphone consists mainly of a diaphragm, coil, and magnet system. When sound waves cause the diaphragm and coil to vibrate, they act like an electromagnet, inducing an electrical current in the coil (Rosinski, 2022: 21). The microphone's response to sudden transitions and high-frequency signals depends on the weight of its moving parts. In dynamic microphones, the diaphragm and coil move together and are relatively heavy, resulting in a frequency response that drops above 10 kHz. These microphones also possess a resonant frequency between 1–4 kHz, positively influencing voice intelligibility. Due to these characteristics, they are frequently preferred by vocalists, especially in live performances (Owsinski, 2005: 2-3). In this context, sound samples were collected using the Shure SM-58, a dynamic vocal microphone widely preferred in live performances.

In addition to their electronic and mechanical components, microphones have an outer surface that can be held by hand, known as the housing, which directly affects the microphone's operation. This component, with its physical structure around the diaphragm, helps define the microphone's character and its intended usage based on its physical shape. Additionally, it influences how vibrations are transmitted to the diaphragm (Işıkhan, 2013: 231).

Understanding the effects of microphone holding positions on frequency response is of critical importance for sound engineers and performing artists. Lyons (2001: 125) explains that Fast Fourier Transform (FFT) analysis is a widely used method in signal processing, converting signals from the time domain to the frequency domain, allowing for the analysis of the signal's frequency components. This analytical method has been recognized in various studies as an ideal tool for quantitatively evaluating the impact of microphone holding positions on sound quality.

In this study focusing on the frequency response of dynamic microphones and aims to determine how different grip positions, such as closing or opening the microphone capsule, affect the frequencies perceived by the microphone. The findings will provide valuable information that will help sound engineers and performing artists make more informed decisions in terms of microphone use.

Objective of the Study

The primary objective of this research is to examine the effects of different holding positions on the frequency response of dynamic vocal microphones. Dynamic microphones are essential audio equipment frequently preferred in live performances and studio recordings due to their durability and ability to withstand high sound pressure levels. However, there is limited information on how these microphones respond to different holding positions in terms of frequency response.

This study makes a significant contribution to the audio technology literature by analyzing the effects of microphone hand positions on practical applications. The results will help sound engineers and artists make more informed decisions regarding microphone use, thereby enhancing the quality of performances. Therefore, the research findings aim to contribute to the development of better and more informed practices in the fields of audio engineering and performing arts, ultimately serving to improve overall sound quality.

'Microphone grip positions have a direct impact on the tonal quality and clarity of sound. Eargle (2012) states that 'The way a microphone is held can significantly affect tonal characteristics and clarity, especially in dynamic and hand-held types' and that this effect is produced by changes in resonance and directional response' (Eargle, 2012, p. 135).

Understanding how microphone grip affects sound quality and the overall success of a performance during live performances and studio recordings is a critical factor for sound engineers and performing artists. This study provides practical recommendations for more informed and effective microphone use by supporting the effects of microphone holding positions on frequency response with quantitative data.

Research Problem

The problem statement of this research was defined as: 'How do different holding positions of dynamic vocal microphones affect the microphone's frequency response?' and four different microphone holding positions were analyzed to explore answers to this question.

Method

This study employs a quantitative research model to examine the effects of different holding positions on the frequency response of dynamic vocal microphones. Within this scope, descriptive methods and content analysis have been utilized. The study was conducted in a controlled studio environment, where a *quasi-experimental research design* was implemented to obtain numerical data, allowing for objective control of variables (Creswell & Creswell, 2018). For data analysis, the FFT (Fast Fourier Transform) method was used (Kammler, 2000: 291). FFT is a mathematical computation method that separates signals into their frequency components (Downey, 2014: 13). Fourier Transform converts a signal from its time and spatial representation to a frequency-based representation, with broad applications in fields such as Engineering, Physics, Mathematics and Computer Science. By converting sound signals from the time domain to the frequency domain, FFT analysis enables a detailed examination of the frequency response under various microphone holding positions. This method is widely used in sound engineering and signal processing as it allows for a numerical evaluation of each holding position's effects by separating the signal into its frequency components (Marks II, 2008: 3). Using this approach, microphone holding positions were treated as the independent variable, while the microphone's frequency response was the dependent variable, aiming to reveal the specific effects of holding positions on sound frequencies through objective data.

In the study, sound recordings were taken and analyzed using four different holding positions: the standard stand position, fully enclosed capsule grip, semi-open capsule grip, and body grip.

In the experimental design, the microphone holding positions identified as independent variables—standard stand position, fully enclosed capsule grip, semi-open capsule grip, and body grip—were systematically applied, and separate sound recordings were taken for each technique. The widely preferred SM58 dynamic microphone model was used for the recordings. The sound recordings were performed by a professional vocalist, who sang the G4 note at 392 Hz on the syllable "na" for 5 seconds for each holding position. This process was repeated for the four different holding positions (standard stand position, fully enclosed capsule grip, semi-open capsule grip, and body grip). Recordings were take using Logic Pro X DAW at a 96 kHz sampling rate and 24-bit resolution, with a Shure SM58 microphone, through an Orion 32+ AD converter and a Grace Design M801 microphone preamp. All recordings were conducted in an acoustically controlled studio environment, such as an anechoic chamber.

The recorded sounds were edited and normalized using Audacity software before analysis. Each recording was prepared for FFT analysis. Frequency analyses were performed using the Python programming language with FFT codes specifically compiled for this study. In the FFT code, a window interval of 200 Hz was applied, with a resolution of sample rate / 1, and the analysis range was set between 300 Hz and 3200 Hz.

The human ear can generally resolve only the first five to seven harmonics. This is true when the frequency resolution is greater than the spacing between harmonics, which exceeds the critical bandwidth. Beyond the seventh harmonic, individual harmonics are no longer resolved separately, as the critical bandwidth surpasses the frequency gap between harmonics (Howard & Angus, 2009:140). Zeren (2000: 274) notes that if a complex sound is sustained long enough, only the first six partials are perceptible, while the seventh is extremely difficult to detect, even in electronically generated pure complex sounds. Therefore, in the analysis of the sound files, the range up to three octaves above the fundamental frequency (392 Hz G4), extending to 3136 Hz (G7), was considered. FFT analyses have revealed, in detail, the effects of each hand position on the microphone's frequency response.

After obtaining quantitative data, the results were interpreted within a qualitative framework. At this stage, practical issues and solutions that sound engineers and performing artists may encounter in real-world applications were emphasized. The research findings were examined in detail to understand the effects of microphone holding positions on the tonal quality, clarity, and overall performance of the sound.

Results

Standard Stand Position

In this microphone position, the microphone's response within the test environment was measured. This data allows for a comparison of the three other holding positions in relation to the standard stand position.

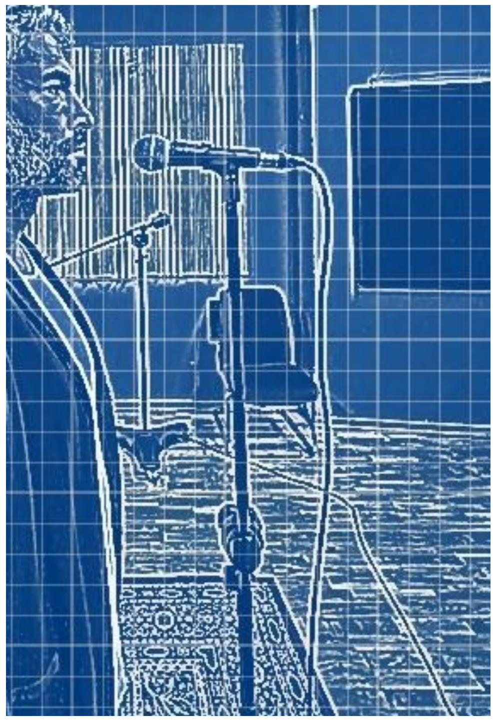

Figure 1. Standard stand position

The microphone was positioned in the standard stand position (figure 1), placed on a mount on the stand. This method of microphone placement is commonly preferred in live events and studio applications. In this setup, the capsule and body of the microphone are not subject to any manipulation, and it is considered a placement that allows the microphone to deliver its optimal performance.

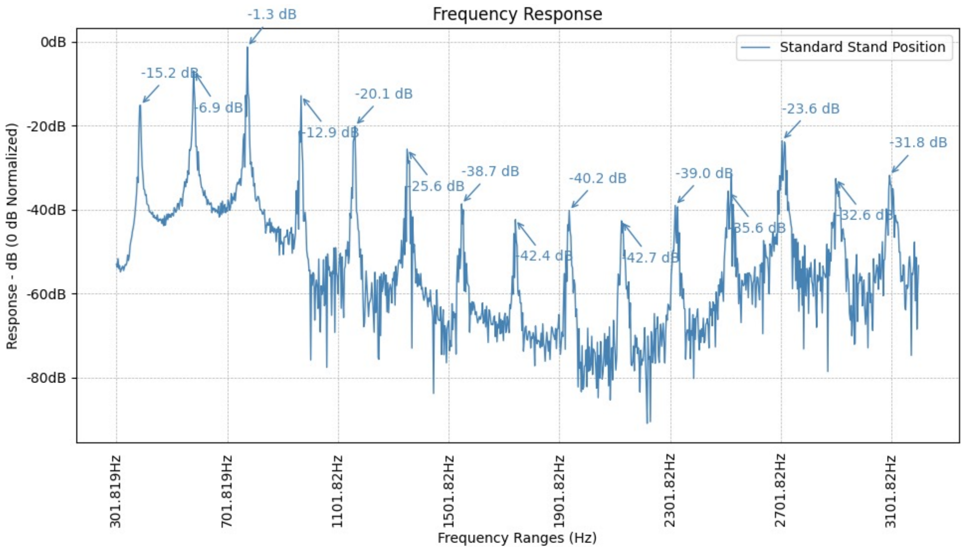

Figure 2. FFT standard stand position

The data obtained from the standard stand position (figure 2) serves as a reference for different holding positions. When conducting FFT analysis, the data for the G4 note at 392 Hz was found to be significant within the range of 300 Hz to 3136 Hz, and all analyses were carried out using this range. The data recorded in the standard stand position, without any external manipulation, was regarded as the baseline data and used as the reference value for the microphone's standard response.

Fully Enclosed Capsule Grip

In this position, the front part of the microphone capsule was left open, while the surrounding area of the capsule was enclosed by hand (figure 3), and a sound sample was recorded. In this grip, the microphone is held in such a way that the hand fully encloses the capsule circumferentially. This microphone holding position is commonly preferred in live events.

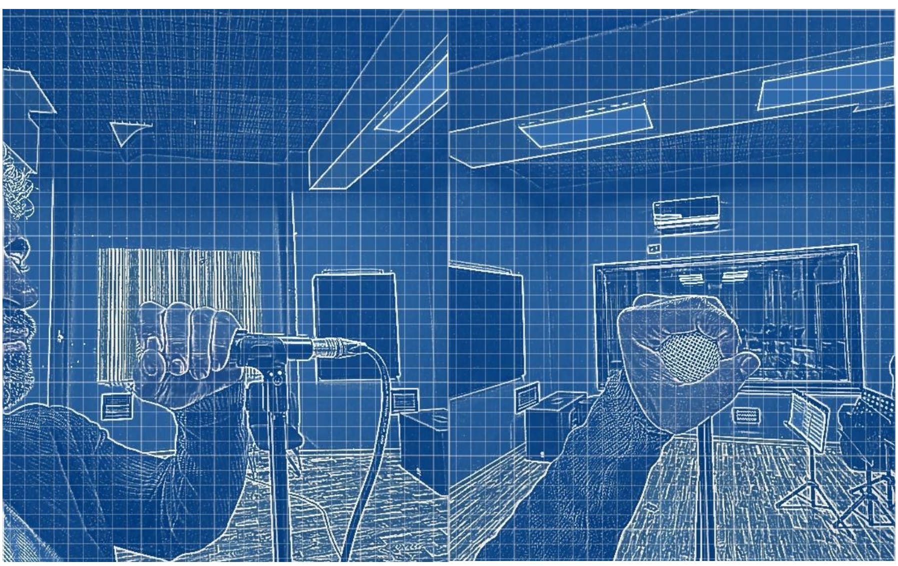

Figure 3. Fully enclosed capsule grip

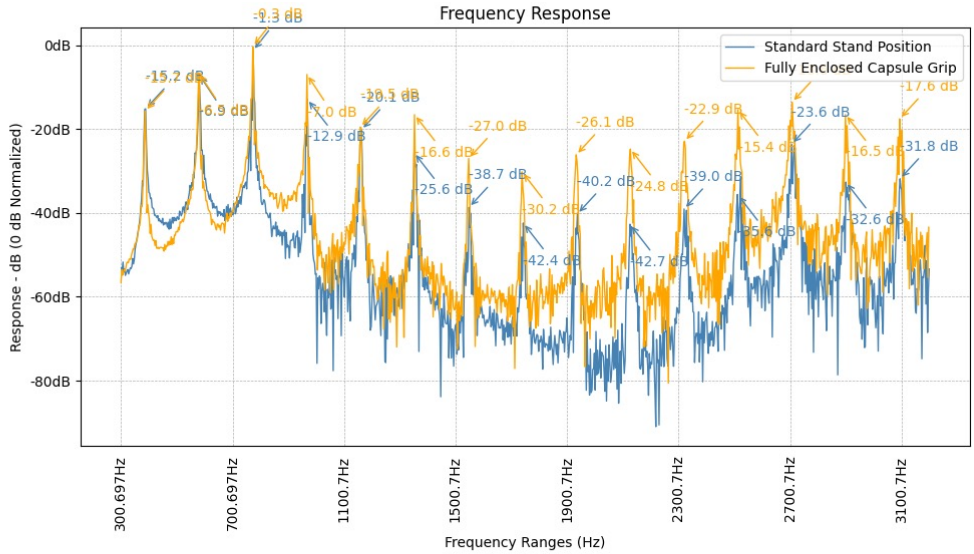

Figure 4. FFT fully enclosed capsule grip

Table 1. FFT first seven harmonics for fully enclosed capsule grip

	Harmonic 1	Harmonic 2	Harmonic 3	Harmonic 4	Harmonic 5	Harmonic 6	Harmonic 7
SSP	-15,16487	-6,944243	-1,272283	-12,8926	-20,14848	-25,61112	-38,65569
FECG	-15,6657	-6,54615	-0,324933	-6,972554	-19,51257	-16,56303	-27,00436
Diff(dB)	-0,500834	0,3980934	0,9473504	5,9200487	0,6359058	9,0480933	11,651323

SSP: Standard Stand Position **FECG:** Fully Enclosed Capsule Grip **Diff:** Difference

The data obtained from the fully enclosed capsule grip (figure 3), when analyzed against the standard stand position (figure 1) for the first seven harmonics, showed that as the frequency drew away from the fundamental frequency, the gains became significant enough to affect the structure and perceived quality of the sound. Notably, the dB differences observed in the 4th, 6th, and 7th harmonics are particularly striking.

Semi-Open Capsule Grip

In this holding position, the front part of the microphone capsule was left open while the surrounding area was enclosed by hand, and a sound sample was recorded. The vocalist held the microphone by enclosing the capsule's entire middle surrounding area using his hand. This microphone holding position is commonly preferred in live events. In this position, the hand fully encloses the capsule from the sides, which is also generally preferred for live performances.

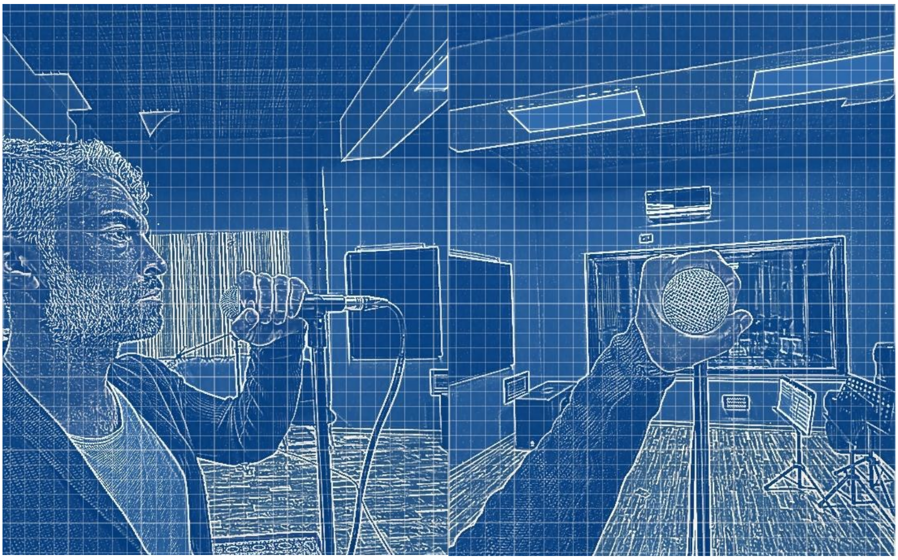

Figure 5. Semi-open capsule grip

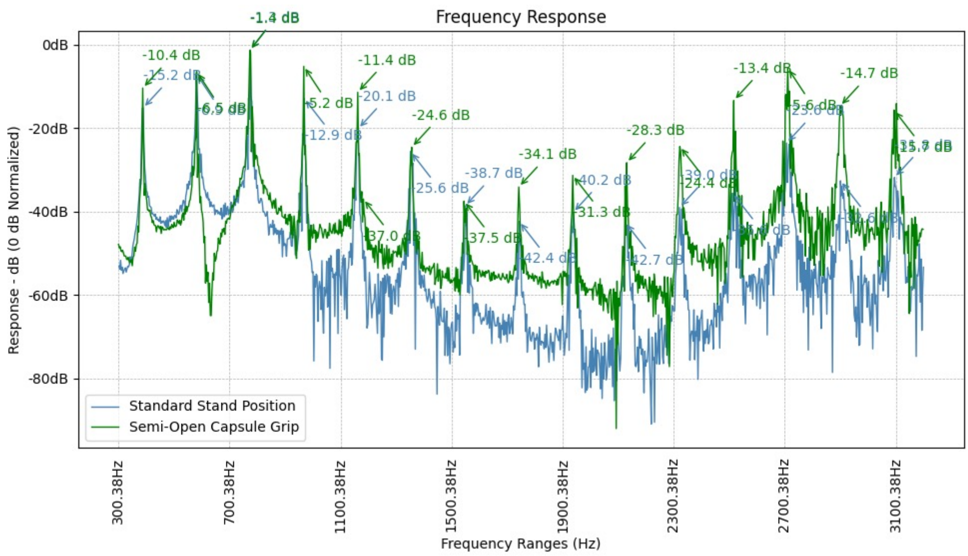

Figure 6. FFT semi-open capsule grip

Table 2. FFT first seven harmonics for semi-open capsule grip

	Harmonic 1	Harmonic 2	Harmonic 3	Harmonic 4	Harmonic 5	Harmonic 6	Harmonic 7
SSP	-15,16487	-6,944243	-1,272283	-12,8926	-20,14848	-25,61112	-38,65569
SOCP	-10,3974	-6,451023	-1,358821	-5,198873	-11,40483	-24,59267	-37,51785
Diff(dB)	4,7674667	0,49322	-0,086537	7,6937299	8,743649	1,0184485	1,1378417

SSP: Standard Stand Position **SOCP:** Semi-Open Capsule Grip **Diff:** Difference

The data obtained from the semi-open capsule grip (figure 5), when analyzed against the standard stand position (figure 1) for the first seven harmonics, showed that as the frequency deviated from the fundamental frequency, the gains became significant enough to affect the structure and perceived quality of the sound. Notably, the dB differences observed in the 1st, 4th, and 5th harmonics are particularly striking.

Body Grip

In this holding position, a sound sample was recorded by holding the microphone by its body, without any interference with the capsule area.

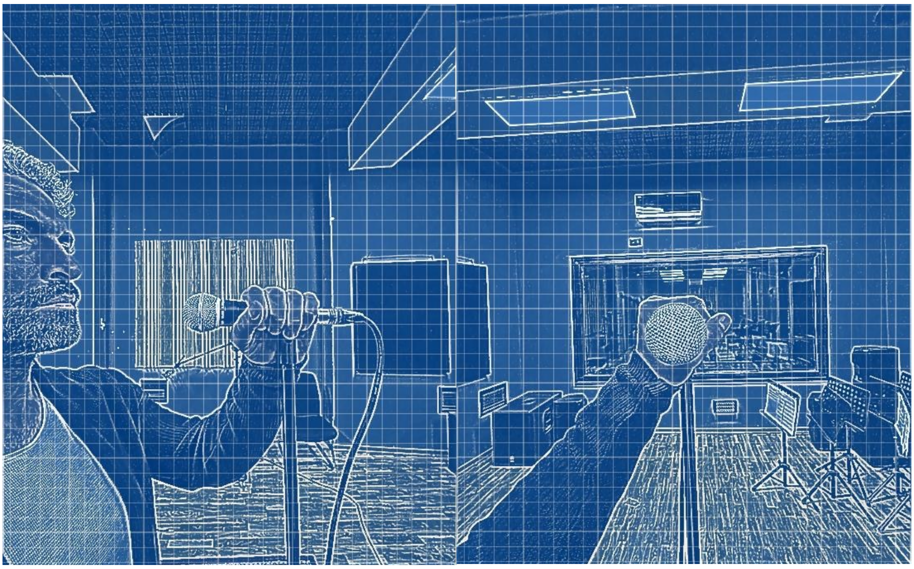

Figure 7. Body grip

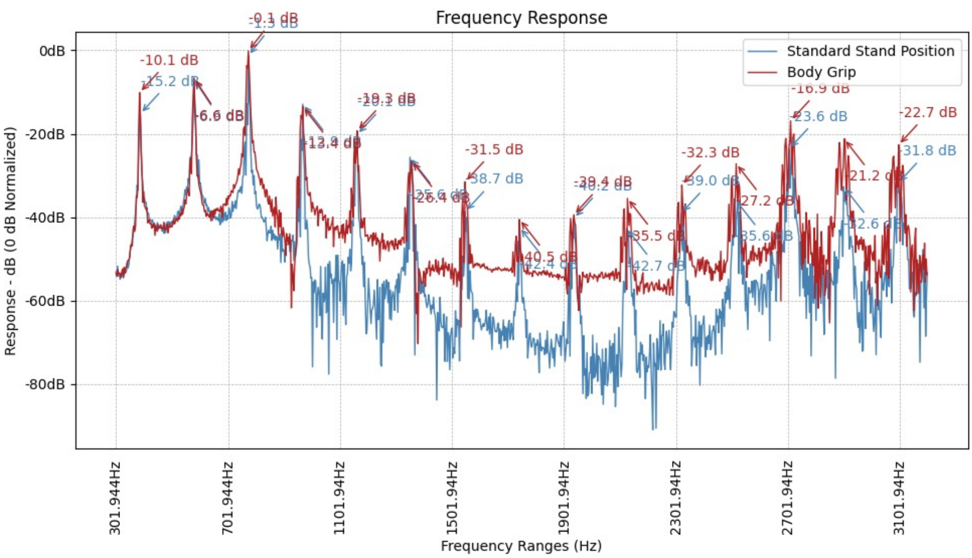

Figure 8. FFT body grip

Table 3. FFT first seven harmonics for body grip

	Harmonic 1	Harmonic 2	Harmonic 3	Harmonic 4	Harmonic 5	Harmonic 6	Harmonic 7
SSP	-15,16487	-6,944243	-1,272283	-12,8926	-20,14848	-25,61112	-38,65569
BG	-10,11211	-6,637057	-0,13028	-13,43508	-19,29768	-26,44805	-31,51292
Diff(dB)	5,0527572	0,3071863	1,1420035	-0,542473	0,8508009	-0,836928	7,1427638

SSP: Standard Stand Position **BG:** Body Grip **Diff:** Difference

The data obtained from the body grip (figure 7), when analyzed against the standard stand position (figure 1) for the first seven harmonics, showed that as the frequency deviated from the fundamental frequency, the gains became significant enough to affect the structure and perceived quality of the sound. Notably, the dB differences observed in the 1st and 7th harmonics are particularly striking.

To provide an overall assessment of all holding positions together, the data from each graph were superimposed for a comprehensive evaluation. The following graph displays all the holding positions used as samples in this study.

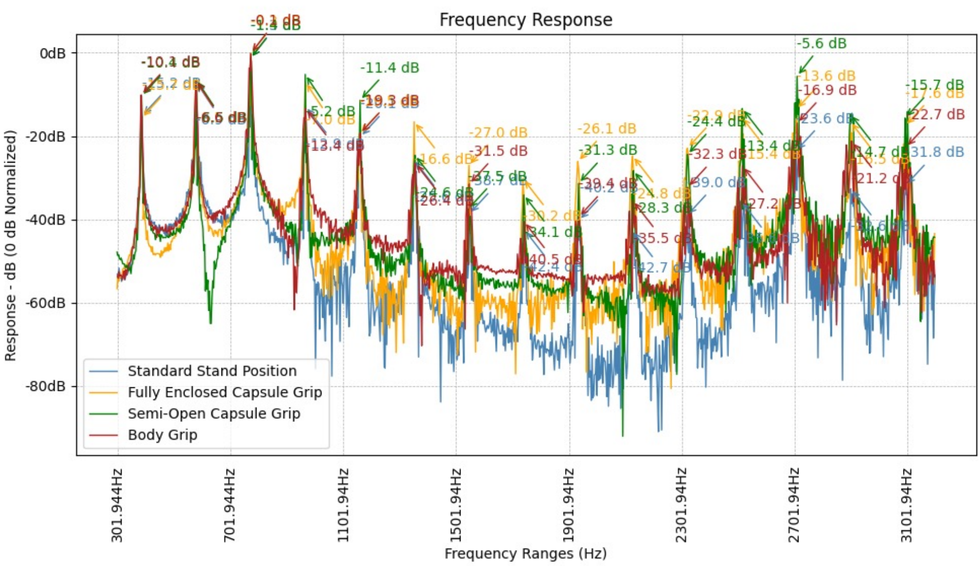

Table 9. FFT overall assessment of all holding positions

Table 4. FFT first seven harmonics for all holding positions

	Harmonic 1	Harmonic 2	Harmonic 3	Harmonic 4	Harmonic 5	Harmonic 6	Harmonic 7
SSP	-15,16487	-6,944243	-1,272283	-12,8926	-20,14848	-25,61112	-38,65569
FECG	-15,6657	-6,54615	-0,324933	-6,972554	-19,51257	-16,56303	-27,00436
SOCP	-10,3974	-6,451023	-1,358821	-5,198873	-11,40483	-24,59267	-37,51785
BG	-10,11211	-6,637057	-0,13028	-13,43508	-19,29768	-26,44805	-31,51292

SSP: Standard Stand Position **FECG:** Fully Enclosed Capsule Grip **SOCP:** Semi-Open Capsule Grip **BG:** Body Grip

As seen in Table 4, holding positions have significant effects on the frequency response of dynamic vocal microphones. This effect causes the analyzed sound waves to be transmitted to the microphone capsule in either a higher-pitched or lower-pitched form than normal. Therefore, if attention is not paid to the holding position while using dynamic vocal microphones, it may not be possible to achieve optimal performance from the microphone.

Discussion

This study examined the effects of microphone holding positions on frequency response and compared the findings with similar studies in the literature. The results show that each microphone placement can significantly impact both sound quality and frequency response.

Zhang, Zheng, and Mi (2024) investigated the effects of microphone placement on sound pressure levels and frequency, emphasizing that microphone positioning increases losses at low frequencies. This finding aligns with our observations that changes in microphone grip position cause distortion at low frequencies. Similarly, Gentner et al. (2024) demonstrated the negative effects of incorrect speaker placement and calibration on sound quality. Both studies confirm the significant impact of microphone grip position on overall sound quality and frequency response (Zhang et al., 2024; Gentner et al., 2024).

In their research on dramatic and lyrical singing in Western classical music, Echternach et al. (2024) emphasized the effects of microphone placement on sound pressure levels and resonant frequencies. Similarly, our study shows that microphone grip position causes comparable changes in resonant frequencies. Additionally, Ma (2023) highlighted how microphone placement affects the naturalness of recorded sound in the context of Beiguan opera. Both studies demonstrate the significant impact of microphone grip position on the characteristics of recorded sound (Echternach et al., 2024; Ma, 2023).

Awan and colleagues (2024) examined the effects of microphone placement on acoustic parameters such as cepstral analysis and harmonic-to-noise ratio, finding that microphone position significantly impacted these measurements. Müller et al. (2023) analyzed the relationship between speaker head orientation and microphone placement, noting that distortions in low frequencies were observed depending on the microphone's position. Finally, Parsa, Jamieson, and Pretty (2001) investigated significant differences in frequency response between various microphone types, and our study's findings align with these results (Awan et al., 2024; Müller et al., 2023; Parsa et al., 2001).

Conclusion and Recommendations

An examination of the data obtained from this study reveals that holding positions of dynamic vocal microphones result in significant changes in the microphone's frequency response. Depending on the position where the microphone's body and capsule sections are held, increases in certain frequency ranges and decreases in others were identified. For example, when using the standard stand position as a reference and analyzing the first seven harmonics, the other three positions exhibited gains that significantly affected the structure and perceived quality of the sound as the frequency deviated from the fundamental frequency. Notable dB differences were observed in the fully enclosed capsule grip for the 4th, 6th, and 7th harmonics; in the semi-open capsule grip for the 1st, 4th, and 5th harmonics; and in the body grip for the 1st and 7th harmonics.

Within the analyzed range of 392 Hz to 3136 Hz, differences in holding positions resulted in general variations compared to the standard stand position. Additionally, significant changes were observed in the 800–2300 Hz range, which is considered crucial for human voice perception. These changes may cause the lower and upper frequency regions of the sound to be transmitted in different ways. Therefore, it is believed that proper microphone holding techniques have a substantial impact on how the user's voice is perceived. When the capsule is fully enclosed, the increase in low frequencies and the suppression of high frequencies become factors to consider in live performances and studio recordings. Just as the microphone's proximity to the sound source influences frequency balance, the way it is held also plays a critical role in determining the overall quality of the sound.

The effects of microphone holding positions on frequency response and overall sound quality should be considered in both stage performances and recording studios. Future studies can explore the impact of different microphone types and holding positions on sound in greater detail, providing further guidance on this topic. Professionals in sound engineering and the performing arts can use the findings of this research to optimize sound quality and minimize unwanted sound characteristics, achieving higher-quality results in both studio recordings and live performance settings. Additionally, a detailed examination of microphone holding positions can serve as a valuable resource for sound engineering education programs, enhancing the expertise of future sound engineers.

Recommendations for Researchers

The data obtained from this study suggests that new research can be conducted on different types of dynamic microphones used in live performances and studio recordings. The capsule diameter of the Shure SM-58 microphone used in our study is 25.4 mm (Web1). Different microphone models with this capsule size can be analyzed for their intended use, investigating how various capsule materials or production technologies provide different responses in the same environment. Microphones are generally classified in the industry according to three different diaphragm sizes: small, medium and large. Small diaphragm microphones typically have a diameter of 5/8 inch (approximately 15-16 mm), while medium diaphragm microphones have a diameter between 5/8 inch and 3/4 inch (approximately 16-19 mm). Large diaphragm microphones have a diameter larger than 3/4 inch, usually around 25 mm or 1 inch (Web2). Researchers can classify microphones based on their diaphragm sizes and examine the different responses of microphones with similar structures but varying diaphragm sizes. Such a study could provide valuable insights into how diaphragm diameter and materials used impact microphone performance.

Recommendations for Practitioners

This study aims to guide sound engineers and live performance artists by offering more accurate vocal techniques for microphone usage. Additionally, it seeks to assist vocal performers by indicating the frequency responses obtained from different hand positions on the microphone, helping them determine the most suitable hand position for their needs. The data obtained from this study serves as a guide to selecting the correct microphone holding position in both recording studios and live performance stages, enabling higher quality and more professional results. In this context, it is recommended to use the information provided here to determine the proper holding position for improved sound quality and performance.

Limitations

This research is limited to the Shure SM-58 model, one of the most preferred dynamic vocal microphones for live performances. Additionally, to make the study more universally applicable, the sound range was restricted to the 4th octave (3136 Hz), and the G4 note at 392 Hz was chosen as the sample for data collection. During the recordings, four different hand positions commonly encountered in live performances (standard stand position, fully enclosed capsule grip, semi-open capsule grip, and body grip) were selected. All hand positions were individually compared to the standard stand position, as it involves no manipulation. Only FFT analysis was used for processing and interpreting the data.

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Websites / Online Resources

Web 1. https://www.shure.com/en-US/docs/guide/SM58

Web 2. https://www.sinbosenaudio.com/info/what-are-the-dimensions-of-a-microphone-diaphragm-and-how-do-they-differ-sinbosen-i00093i1.html

Appendixes

Appendix 1. FFT Code

```
import matplotlib.pyplot as plt
import numpy as np
from scipy.io import wavfile
from numpy.fft import fft
import matplotlib.ticker as ticker
from scipy.interpolate import make_interp_spline
from scipy.signal import find_peaks
# Read the audio file
def read_wav_file(file_path):
    sample_rate, data = wavfile.read(file_path)
    return sample_rate, data
# Calculate and limit the frequency response
def calculate_frequency_response(sample_rate, data, start_frequency=300, frequency_
interval=200, max_frequency=3200):
    n = len(data)
    fft_result = fft(data)
    frequencies = np.fft.fftfreq(n, 1 / sample_rate)
    magnitude = np.abs(fft_result)
    mask = (frequencies >= start_frequency) & (frequencies <= max_frequency)
    filtered_frequencies = frequencies[mask]
    filtered_magnitude = 20 * np.log10(magnitude[mask])  # Convert to dB
    max_magnitude = max(filtered_magnitude)
    normalized_magnitude = filtered_magnitude - max_magnitude
    return filtered_frequencies, normalized_magnitude
# Plot frequency response and exclude peaks within certain frequency ranges
def plot_frequency_response_with_peaks(frequency, response, label, color, exclude_
ranges=None):
    smooth_frequency = np.linspace(min(frequency), max(frequency), 1000)
    spline = make_interp_spline(frequency, response, k=3)
    smooth_response = spline(smooth_frequency)
    line, = plt.plot(smooth_frequency, smooth_response, color=color, linewidth=1, label=label)
    peaks, _ = find_peaks(smooth_response, height=-43)
    peak_frequencies = smooth_frequency[peaks]
    peak_responses = smooth_response[peaks]
    if exclude_ranges:
        mask = np.ones(len(peak_frequencies), dtype=bool)
        for start, end in exclude_ranges:
            mask &= (peak_frequencies < start) | (peak_frequencies > end)
        peak_frequencies = peak_frequencies[mask]
```

```
        peak_responses = peak_responses[mask]
    for i, (peak_freq, peak_resp) in enumerate(zip(peak_frequencies, peak_responses)):
        offset = 20 if i % 2 == 0 else -30
        plt.annotate(f'{peak_resp:.1f} dB', xy=(peak_freq, peak_resp), xytext=(0, offset),
                     textcoords='offset points', color=color,
                     arrowprops=dict(arrowstyle='->', lw=1, color=color))
# Display frequency intervals at the bottom
def add_frequency_intervals(frequency):
    min_freq = min(frequency)
    max_freq = max(frequency)
    tick_values = np.arange(min_freq, max_freq + 200, 400)  # Every 400 Hz
    plt.xticks(tick_values, rotation=90)
    plt.gca().tick_params(axis='x', which='both', bottom=False)
    plt.xlabel('Frequency Ranges (Hz)')

# Main processing function - analyzes 4 audio files
def analyze_four_audio(files, colors, exclude_ranges=None):
    plt.figure(figsize=(10, 6))
    for i, (file_path, label) in enumerate(files):
        sample_rate, data = read_wav_file(file_path)
        frequency, response = calculate_frequency_response(sample_rate, data)
          plot_frequency_response_with_peaks(frequency, response, label, colors[i], exclude_
ranges=exclude_ranges)
   plt.gca().xaxis.set_major_formatter(ticker.FuncFormatter(lambda x, _: '{:g}Hz'.format(x)))
   plt.gca().yaxis.set_major_formatter(ticker.FuncFormatter(lambda x, _: '{:g}dB'.format(x)))
    plt.ylabel('Response - dB (0 dB Normalized)')
    plt.title('Frequency Response')
    plt.grid(True, which="both", ls="--", linewidth=0.5)
    plt.legend()
    add_frequency_intervals(frequency)
    plt.show()
# Specify file paths and labels for analyzing four audio files
audio_files = [
    ('0standart_standt_position.wav', 'Standard Stand Position'),
    #(1fully_enclosed_capsule_grip.wav', 'Fully Enclosed Capsule Grip'),
    #('2semi_open_capsule_grip.wav', 'Semi-Open Capsule Grip'),
    #('3body_grip.wav', 'Body Grip')]
# Define colors manually
colors = ['steelblue', 'orange', 'green', 'firebrick']
areas
analyze_four_audio(audio_files, colors, exclude_ranges=exclude_ranges)
```

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