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Analysis of frequency and resonance patterns in Bengali folk and classical music: An LTAS Approach

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Abstract
The human singing voice varies significantly across musical genres due to differences in stylistic, cultural, and technical demands. This study aims to analyze and compare the vocal characteristics of Bengali folk songs and classical songs using trained female singers under real-life performance conditions. A total of 80 trained female vocalists aged 18–30 years were selected and divided into two groups: one performing Bengali folk (Baul style) and the other performing classical-based Rabindra Sangeet. Acoustic analysis was conducted using PRAAT software, focusing on Long-Term Average Spectrum (LTAS). The findings revealed distinct spectral differences between the two genres, particularly in frequency distribution and amplitude peaks. Folk singing demonstrated a broader resonance pattern, while classical singing exhibited controlled tonal refinement. The study highlights how vocal technique, cultural context, and musical structure influence acoustic properties of the singing voice.

Keywords: Bengali folk music, Baul singing, Rabindra Sangeet, vocal acoustics, Long-Term Average Spectrum (LTAS), PRAAT analysis, frequency distribution, resonance patterns, singing voice, acoustic analysis, vocal characteristics, classical music, comparative study, female singers.

Introduction

Music is a powerful medium of cultural expression, and vocal music represents one of the most direct forms of human communication (Juslin and Laukka, 2003) [4]. In Bengal, two prominent musical traditions—folk music and classical-based compositions—demonstrate distinct stylistic and expressive features (Jhingan, 2011) [3].

Bengali folk music, including Baul, Bhatiyali, and Bhawaiya, is deeply rooted in rural life and reflects spontaneous emotional expression, simple melodic structures, and natural vocal production (Kandoker, 2019) [5]. In contrast, classical-based genres such as Rabindra Sangeet are influenced by structured ragas, refined vocal techniques, and controlled articulation (Bandukwalla, 2024) [1].

Bengali folk music is characterized by natural expression, flexible rhythm, and emotional storytelling, whereas classical forms emphasize discipline, tonal precision, and aesthetic refinement (Ghosh, 2024) [2].

Understanding the acoustic differences between these two traditions is essential for vocal pedagogy, musicology, and performance science (Rooney, 2016) [6]. The primary objective of this study is to analyze and compare the vocal characteristics of Bengali folk and classical songs by examining how these distinct musical traditions influence voice production (Tarai *et al.*, 2024) [7]. The research specifically aims to investigate acoustic differences using trained female singers under controlled recording conditions, ensuring reliability and consistency in vocal performance. Furthermore, the study seeks to evaluate key acoustic parameters such as frequency distribution and resonance patterns through Long-Term Average Spectrum (LTAS) analysis, providing a scientific basis for comparison. Ultimately, the research intends to understand how variations in musical style—ranging from the natural, expressive qualities of folk music to the structured and refined techniques of classical singing—affect the physiological and acoustic aspects of vocal output.

Methodology

1. Research Design

An experimental comparative research design was employed in this study to systematically investigate the differences in vocal characteristics between Bengali folk and classical singing styles. This design enabled the controlled comparison of two distinct musical groups by minimizing external variables and ensuring uniform recording conditions. By assigning trained female singers to specific categories—folk (Baul style) and classical (Rabindra Sangeet)—the study facilitated an objective evaluation of acoustic parameters. The experimental approach also allowed for precise measurement of vocal features using standardized tools, thereby enhancing the reliability and validity of the findings.

2. Sample Selection

The study comprised a total of 80 trained female singers selected to ensure consistency in vocal training and performance quality. The participants belonged to the age group of 18–30 years, representing a young adult population with relatively stable vocal characteristics. The sample was divided into two equal groups for comparative analysis: Group A included 40 singers performing Bengali folk music in the Baul style, while Group B consisted of 40 singers trained in classical singing, specifically Rabindra Sangeet. This structured grouping enabled a balanced comparison between the two musical genres while maintaining uniformity in sample size and demographic characteristics.

3. Data Collection

Data were collected through systematic recording of vocal performances under controlled environmental conditions to ensure consistency and minimize external noise interference. A standardized microphone setup was used for all recordings to maintain uniform sound quality and avoid variability due to recording equipment. Each participant was instructed to perform a pre-selected song appropriate to their respective genre—Bengali folk (Baul style) or classical (Rabindra Sangeet). The recordings were conducted following identical procedures for all singers, thereby ensuring reliability and comparability of the acoustic data obtained for further analysis.

4. Acoustic Analysis

The acoustic analysis of the recorded vocal samples was carried out using PRAAT, a widely recognized tool for speech and voice analysis. The primary parameter evaluated in this study was the Long-Term Average Spectrum (LTAS), which provides a comprehensive representation of the distribution of acoustic energy across different frequency ranges. Through LTAS analysis, key vocal variables including frequency range, amplitude (measured in decibels), and resonance patterns were examined. This approach enabled an objective assessment of vocal quality and allowed for a detailed comparison of acoustic characteristics between Bengali folk (Baul style) and classical (Rabindra Sangeet) singing styles.

5. Statistical Analysis

Statistical analysis of the collected data was performed using IBM SPSS Statistics to ensure accurate and reliable interpretation of the results. Descriptive statistics, including mean and standard deviation, were calculated for all acoustic parameters such as frequency range, amplitude, and resonance characteristics. Furthermore, comparative analysis was conducted between the two groups—Bengali folk (Baul style) and classical (Rabindra Sangeet)—to identify significant differences in vocal attributes. This statistical approach facilitated objective evaluation and supported the validation of the study findings.

Table 5: LTAS Analysis of Bengali Folk and Classical Singing (Mean ± SE)

Parameter	Folk (Baul Style) (Mean ± SE)	Classical (Rabindra Sangeet) (Mean ± SE)
Peak Frequency Range (Hz)	2800 ± 200	3000 ± 180
Amplitude (dB)	16.0 ± 0.5	15.0 ± 0.4
Resonance Pattern	Broad	Controlled

The results presented in Table 5 highlight clear acoustic distinctions between Bengali folk (Baul style) and classical (Rabindra Sangeet) singing, reflecting differences in vocal technique and stylistic expression. The peak frequency range is slightly higher in classical singing (3000 ± 180 Hz) compared to folk singing (2800 ± 200 Hz), suggesting that classical vocalists utilize more focused resonance and refined control over higher harmonics. This may be attributed to formal training and the influence of raga-based structures, which emphasize tonal precision and clarity.

In contrast, the amplitude values indicate that folk singers produce slightly higher vocal intensity (16.0 ± 0.5 dB) than classical singers (15.0 ± 0.4 dB). This higher amplitude in Baul singing reflects a more open-throated, natural projection style that prioritizes emotional expression over technical restraint. Folk music, being rooted in rural and spontaneous traditions, often encourages unrestricted voice production, resulting in stronger and more direct sound output.

Furthermore, the observed difference in resonance patterns—broad in folk singing and controlled in classical singing—reinforces the distinction between the two genres. The broad resonance in Baul style suggests wider distribution of acoustic energy across frequencies, contributing to a raw and expressive vocal quality. Conversely, the controlled resonance in Rabindra Sangeet indicates deliberate vocal shaping, where singers manage breath support, articulation, and vocal tract configuration to achieve a balanced and aesthetically refined tone.

Overall, these findings demonstrate that musical style significantly influences vocal acoustics. While Bengali folk singing emphasizes naturalness, emotional depth, and vocal openness, classical singing is characterized by precision, control, and structured resonance. The results are consistent with previous acoustic studies and confirm that both traditions exhibit singer's formant characteristics, albeit with distinct spectral patterns.

Table 2: Comparative Interpretation

Parameter	Folk Singing (Baul)	Classical Singing (Rabindra Sangeet)
Vocal Style	Natural, spontaneous	Structured, controlled
Frequency Range	Moderate	Slightly higher
Resonance	Broad, open	Focused, refined
Emotional Expression	High	Balanced
Technical Control	Less formal	Highly trained

The comparative analysis between Bengali folk (Baul) and classical (Rabindra Sangeet) singing reveals distinct differences in vocal production, stylistic approach, and acoustic characteristics. Folk singing is characterized by a natural and spontaneous vocal style, where singers rely more on intuitive expression rather than formal training. This results in a moderate frequency range and a broad, open resonance pattern, allowing the voice to project freely with minimal technical constraints. The emotional expression in Baul singing is notably high, as it is deeply rooted in personal, spiritual, and social experiences, often conveyed through an uninhibited vocal approach.

In contrast, classical singing, particularly Rabindra Sangeet, demonstrates a structured and controlled vocal style shaped by systematic training and musical discipline. The slightly higher frequency range observed in classical singers

indicates better control over pitch and harmonic placement. The resonance is more focused and refined, achieved through proper breath support, vocal tract shaping, and adherence to musical aesthetics. Emotional expression, although present, is balanced and carefully modulated within the framework of the composition. Additionally, classical singing exhibits a high level of technical control, reflecting rigorous training and adherence to established musical principles.

Overall, this comparison underscores that while folk singing prioritizes emotional authenticity and natural voice production, classical singing emphasizes precision, control, and artistic refinement. These differences highlight the influence of cultural context and training on vocal acoustics and performance style.

Conclusion

The present study provides a comprehensive comparative analysis of vocal characteristics in Bengali folk (Baul style) and classical (Rabindra Sangeet) singing using trained female vocalists. The findings clearly demonstrate that significant acoustic differences exist between the two musical traditions, particularly in terms of frequency range, amplitude, and resonance patterns. Folk singing exhibited a broader and more open resonance with slightly higher amplitude, reflecting its natural, spontaneous, and emotionally expressive nature. In contrast, classical singing showed a more controlled and refined resonance with a slightly higher frequency range, indicating the influence of structured training and technical precision.

The LTAS analysis further confirmed the presence of distinct spectral patterns in both styles, highlighting how musical genre directly shapes vocal production mechanisms. These differences emphasize that while folk music prioritizes emotional authenticity and free vocal expression, classical music is rooted in discipline, balance, and aesthetic refinement. Overall, the study underscores the importance of acoustic analysis in understanding vocal diversity and contributes valuable insights to the fields of musicology, vocal science, and performance studies. The findings also reinforce that cultural context and training play a crucial role in shaping the acoustic identity of singing voices.

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