

## MULTITRACK RECORDING DYNAMICS IN A SOUND ENGINEER'S WORKFLOW WITH LARGE MUSICAL ENSEMBLES: PHASE COHERENCE AND ACOUSTIC ISOLATION STRATEGIES

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### Abstract

Within the operational framework of capturing large musical ensembles, the sound engineer encounters complex acoustic phenomena, primarily microphone bleed and phase cancellation, which severely compromise the spatial integrity of multitrack recordings. The research object encompasses a prospective acoustic analysis of 45 synchronous recording sessions involving symphony orchestras and big bands at the State Conservatory of Uzbekistan between 2021 and 2025. Empirical data dictate that uncompensated acoustic spill across 24- to 64-channel arrays induces comb filtering, reducing the intelligibility of transient-heavy instruments by an average of 12.4 dB. Through objective A/B testing and algorithmic time-delay compensation routing within the Digital Audio Workstation (DAW), a deterministic protocol for phase alignment was established. Measurements indicate that applying the 3:1 distance rule in conjunction with precise spot-microphone delay adjustments (calculated via the speed of sound at 343 m/s) improved the overall phase correlation index from 0.42 to +0.88 on the standard +1/-1 phase meter scale. Practical analyses demonstrate that over-reliance on cardioid polar patterns without considering off-axis coloration leads to spectral degradation during the mixing phase. This study formulates an algorithmic methodology for spatial microphone placement and digital phase coherence optimization. The dynamics of the obtained results provide a definitive framework for reducing inter-channel crosstalk, thereby ensuring a broadcast-compliant stereophonic and immersive acoustic image for large-scale ensemble productions.

перекрестных помех, гарантируя трансляционную стереофоническую и иммерсивную акустическую картину для масштабных коллективных записей.

**Keywords:** Multitrack recording, phase coherence, microphone arrays, comb filtering, acoustic bleed, orchestral recording, time-delay compensation, signal-to-noise ratio.

### Introduction

The integration of high-resolution digital multitrack recording systems into the classical and large-ensemble music production workflow has fundamentally altered the parameters of acoustic capture. Recording an orchestra or a big band numbering 40 to 100 musicians synchronously in a single acoustic space presents the most formidable

technical challenge in audio engineering. Global industry statistics from the Audio Engineering Society (AES) indicate that nearly 35% of large ensemble recordings suffer from irreversible spectral masking due to improper management of acoustic spill (bleed) across multiple open microphones. The scientific gap in contemporary audio literature lies in the specific time-domain optimization of spatially distributed microphone arrays within mid-sized, acoustically complex conservatory halls, where reverberation times (RT60) are not strictly standardized.

When a sound engineer deploys a main stereo array (such as a Decca Tree or AB configuration) combined with numerous close-proximity spot microphones for individual instrumental sections, the physical distance between these transducers causes identical sound waves to arrive at the digital converters at disparate times. This temporal discrepancy manifests as comb filtering—a destructive interference phenomenon that hollows out the fundamental frequencies of the instruments. Analyzing the operational workflow of sound engineers at the State Conservatory of Uzbekistan offers a critical opportunity to define a systematic, mathematically sound approach to routing, acoustic isolation, and phase alignment in large-scale multitrack scenarios.

### **Materials and Methods**

The research design was structured as a prospective, quantitative acoustic analysis. The observation period spanned from 2021 to 2025, encompassing 45 synchronous multitrack recording sessions of large musical ensembles (symphony orchestras, academic choirs, and jazz big bands) within the main acoustic halls of the State Conservatory of Uzbekistan. The channel counts for these sessions ranged from 24 to 64 simultaneous inputs operating at a 96 kHz / 24-bit resolution.

The primary measurement apparatus included SMAART v9 for dual-channel FFT acoustic analysis and iZotope Insight 2 for post-capture phase correlation monitoring. The methodological intervention involved establishing a rigorous 3:1 spatial distance rule (the distance between two microphones must be at least three times the distance from each microphone to its intended source) and applying exact digital time-delay compensations. The delay formula  $D = d / c$  (where  $D$  is delay in seconds,  $d$  is distance in meters, and  $c$  is the speed of sound at 343 m/s) was utilized to align spot microphones to the main Decca Tree array. Mathematical-statistical processing of the acoustic data was conducted in IBM SPSS (version 26.0). The difference between the unaligned and aligned phase coherence values was evaluated using the paired Student's t-test. The statistical reliability threshold was strictly set at  $p < 0.01$  within a 95% CI.

### **Results**

Empirical data demonstrate that the implementation of the algorithmic time-delay compensation protocol radically transformed the spectral integrity of the multitrack stems. Prior to phase alignment, the combined multitrack bus exhibited an average phase correlation index of  $0.42 \pm 0.11$  on the standard +1/-1 stereo correlation scale. Following the exact calculation and routing of millisecond delays to the spot microphones (e.g., delaying the woodwind section spot mics by 14.5 milliseconds to align with the main omnidirectional array), the correlation index surged to a stable  $0.88 \pm 0.04$  ( $p < 0.001$ ).

Acoustical measurements of the transient response revealed that low-frequency string instruments (violoncellos and contrabasses) suffered an average loss of 12.4 dB at their fundamental frequencies (between 60 Hz and 120 Hz) due to destructive interference caused by spill into the adjacent brass section microphones. By enforcing the 3:1 distance ratio and employing bidirectional (figure-8) polar patterns to exploit their absolute lateral null points (off-axis rejection), the signal-to-noise ratio (target instrument versus acoustic bleed) within individual channels improved by an average of 18.2 dB ( $p < 0.01$ ). Furthermore, the spatial depth of the resulting stereophonic image was preserved without the necessity of excessive artificial reverberation during the post-production phase.

### **Discussion**

The dynamics of the obtained results are firmly grounded in the fundamental principles of electroacoustics and wave propagation. The destructive comb filtering observed in the uncalibrated multitrack sessions occurs because an audio signal captured by a distant microphone mixes with the same signal captured by a closer microphone, creating alternating peaks and nulls in the frequency spectrum. The human auditory system relies heavily on the Haas effect (precedence effect) to localize sound sources. When multiple unaligned microphones reproduce the same transient attack within a 1 to 30-millisecond window, the brain perceives a smeared, unfocused acoustic image. Comparative analysis with international orchestral recording standards, such as those pioneered by Decca Records or Abbey Road Studios, highlights the necessity of treating the multitrack array not as isolated channels, but as an interdependent acoustic ecosystem. Local sound engineers historically attempted to solve microphone bleed by aggressively equalizing out the offending frequencies. However, cutting frequencies using minimum-phase digital equalizers introduces its own set of phase shifts, exacerbating the problem. The empirical evidence from this study dictates that addressing bleed through physical polar-pattern manipulation (utilizing the physical nulls of cardioid and figure-8 microphones) and strict mathematical time-alignment completely negates the need for destructive equalizations.

**Scientific Novelty and Practical Significance**

For the first time within the specific acoustic parameters of Central Asian conservatory halls, the precise correlation between spatial microphone geometry, digital time-domain compensation, and multitrack phase coherence has been mathematically proven and standardized. The algorithmic models developed during this research serve as a fundamental, actionable blueprint for sound engineers. Implementing this deterministic routing methodology minimizes post-production mixing time by up to 40% and guarantees a broadcast-ready acoustic product that translates flawlessly across high-fidelity commercial platforms.

**Conclusion**

Recording a large musical ensemble demands absolute mastery over spatial acoustics and digital signal flow. Eliminating the spectral degradation inherent in 64-channel synchronous captures cannot be achieved through post-processing plugins, but strictly through proactive acoustic impedance management. Applying deterministic time-delay protocols to spot microphones and strategically exploiting microphone polar patterns eradicates destructive comb filtering at the source. The integration of these mathematically verified multitrack strategies ensures maximum transient punch, pristine phase coherence, and a profoundly accurate stereophonic representation of the orchestral performance.

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