Quantum Circuit Execution as Compositional Process: From Hilbert Space to Listening Space

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Abstract

This paper presents a methodology for quantum computer music composition in which quantum circuit execution serves as a primary compositional agent operating in symbiosis with human creative direction and artificial intelligence collaboration. Rather than employing quantum computers as sophisticated random number generators or data sources for sonification, this approach directly transduces quantum state evolution in Hilbert space into audio waveforms in the listening space. The waveforms are transductions—not sonifications of data about quantum systems, but direct translations of quantum state evolution into acoustic waveforms. Interference patterns emerging from parametric quantum circuits are extracted, with entanglement topology serving as a fundamental compositional parameter. Eight distinct entanglement schemas—Star, Chain, Ring, Pairs, Tree, GHZ, Gradient, and Islands—each generate eight correlated waveforms, yielding sixty-four source files combined and transformed into finished compositions. Reflections from Hilbert Space, a collection of seven compositions for high-order Ambisonics spatial audio totaling approximately 76 minutes, demonstrates this framework. The collection progresses from initial explorations through methodological development to hardware validation, with five works employing the transduction methodology—four derived from quantum simulation and one from execution on Quantum Inspire's Tuna-9 processor. Each of these five derives from just 0.64 seconds of source material, revealing the compositional depth accessible through quantum interference patterns.

Keywords: Quantum Computer Music, Entanglement, Spatial audio, Ambisonics, Quantum Computational Creativity, Human-AI Collaboration

Introduction

The impetus for the following research and creative practice was a deep intuition that the advent of accessible quantum computing opens a vast potential for creative expression. If the continuing current results of classical computing are any indication, quantum computing will offer several orders of magnitude more opportunities… most of which are currently unimaginable. Along with these opportunities come an equal number of challenges, for which solutions are only beginning to be found. Indeed, we are literally experiencing the birth of a quantum shift in our computational capabilities. This paper delineates an initial foray into this infinite, and infinitesimal, sea of exploration and discovery before us.

The relationship between quantum mechanics and music composition is being explored through various approaches. Many treat quantum systems as sophisticated sources of quasi-random number generation or as sonification tools, overlooking a deeper correspondence between quantum interference phenomena and acoustic wave behavior. This paper proposes the latter framework, in which quantum circuit execution is part of a symbiotic compositional process. Rather than sonifying quantum data, this methodology transduces quantum state evolution into audio waveforms. The physics of quantum evolution generate source musical material directly, with human creativity, in collaboration with artificial intelligence, shaping the conditions, constraints, and final realization.

This paper presents a model in which three distinct agents collaborate in the compositional process, each contributing capabilities the others lack. In this model, three interconnected phases constitute the compositional process. The first phase, circuit configuration, involves the composer working in collaboration with AI to conceptualize, design, and program the quantum circuit topology, specifying entanglement relationships, gate sequences, and parameter ranges. This phase encodes compositional intent into quantum architecture. The second phase, circuit execution, occurs when the quantum system executes the circuit and interference patterns emerge from the mathematics of superposition and entanglement according to the properties of quantum mechanics. This phase generates material the collaborators could not anticipate. The third phase is editorial curation during which the composer selects, transforms, and arranges the resulting auditory material while maintaining the underlying quantum relationships. Through time

stretching, frequency manipulation, amplitude balancing, and spatial orchestration the composer shapes the raw quantum output into a finished composition.

Theoretical Foundations

Quantum State Representation

In quantum mechanics, a qubit exists in superposition existing in superposition as a linear combination of basis states until measurement collapses it to a discrete value. For a single qubit, the state $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ represents a probability amplitude distribution across basis states, where $|\alpha|^2 + |\beta|^2 = 1$. The evolution of these amplitudes through quantum gates creates the interference patterns central to this compositional methodology.

For an 8-qubit system, the state space encompasses $2^8 = 256$ possible measurement outcomes. Each quantum state is fully described by 256 complex probability amplitudes, forming a point in a 256-dimensional complex vector space known as the Hilbert space. As the quantum circuit executes with varying parameters, this point traces a trajectory through Hilbert space, and the measurement statistics at each point encode the interference relationships between qubits.

Entanglement as Compositional Structure

Quantum entanglement occurs when the quantum states of two or more qubits become correlated in ways that cannot be described independently. Measuring one qubit instantaneously affects the probability distribution of the others (Horodecki et al. 2009). This non-local correlation provides the fundamental mechanism for creating related but distinct audio waveforms. When qubits are entangled, their measurement outcomes exhibit statistical dependencies that persist regardless of the physical separation between them; this correlation structure translates directly into amplitude relationships between audio channels. Different entanglement topologies, how qubits are connected through entangling gates, produce different correlation patterns, and thus different timbral relationships between voices in the resulting composition.

Quantum Interference and Audio Generation

Quantum interference arises when probability amplitudes associated with different quantum states combine, allowing constructive or destructive effects depending on their relative phases (Feynman 1985). In a parameterized quantum circuit, as the rotation angle θ sweeps through its range, the interference between entangled qubits creates smoothly varying probability distributions. These distributions, when measured repeatedly and averaged, produce continuous waveforms that encode the entanglement structure.

Entanglement between qubits creates non-local correlations that persist regardless of spatial separation (Bell 1964). This property ensures that the waveforms extracted from each qubit are not independent random sequences but are fundamentally linked through their shared quantum state. The correlation structure imposed by entanglement becomes the structural scaffold of the composition.

Historical Context

Quantum computing applications in music have been explored through various approaches. Miranda's foundational work established frameworks for quantum music composition, including algorithmic methods and quantum-inspired techniques (Miranda 2017; Miranda 2022). Other approaches have employed quantum quasi-random number generation for stochastic composition, variational quantum circuits for sound synthesis optimization, and other similar quantum algorithms for music composition.

The present work differs fundamentally by treating the quantum circuit itself as the compositional material rather than as a tool for processing external musical inputs. The methodology foregrounds the intrinsic wave-like behavior of quantum systems, transducing interference patterns in Hilbert space directly to interference patterns in acoustic space rather than employing quantum resources for representational purposes.

Circuit Design

Central to this approach is circuit design and the treatment of entanglement topology as a compositional parameter. Just as a more traditional composer might choose between homophonic and polyphonic textures, the quantum composer selects among entanglement configurations that encode distinct harmonic relationships between voices.

Each of eight quantum circuit schemas generates eight correlated waveforms. Within each schema, qubit 0 serves as the fundamental, analogous to a fundamental frequency in acoustic timbre, while qubits 1-7 function as ancillaries, analogous to partials. The strength of entanglement between each ancillary qubit and the fundamental determines the ancillary's relative amplitude—stronger entanglement produces higher amplitude. The composite of all eight waveforms thus creates a timbral signature unique to each schema, with the entanglement topology functioning as a spectral determinate.

Circuit Architecture

Each circuit follows a three-layer structure. The superposition layer applies Hadamard gates (H) to all qubits, creating equal superposition and initializing the system in a state with maximum uncertainty. The entanglement layer employs two-qubit gates (primarily $R_{ZZ}(\theta)$) to create entanglement according to stipulated topologies; the entangling gate strength is parameterized, allowing the entanglement to evolve as θ sweeps across its range. The rotation layer applies single-qubit R_Y rotations to differentiate the trajectories of individual qubits, ensuring each waveform develops distinct characteristics while remaining correlated through entanglement.

The parameter θ sweeps from 0 to 2π in 2,400 discrete steps. At each step, the circuit is executed 1,024 times (shots), and the expectation value $\langle Z \rangle$ for each qubit is computed from the measurement statistics. This expectation value, ranging from -1 to $+1$, becomes the amplitude of that qubit's waveform at that moment.

Entanglement Topologies

Eight distinct entanglement schemas have been defined, each producing characteristically varying sonic material. Each schema generates eight waveforms (one per qubit).

Schema 1, Star (Trajectory Focus), entangles all ancillary qubits directly with a central fundamental qubit, with no inter-ancillary connections. This hub-and-spoke structure allows the fundamental's trajectory to dominate while ancillaries serve as amplitude-weighted shadows. Figure 1 illustrates this topology.

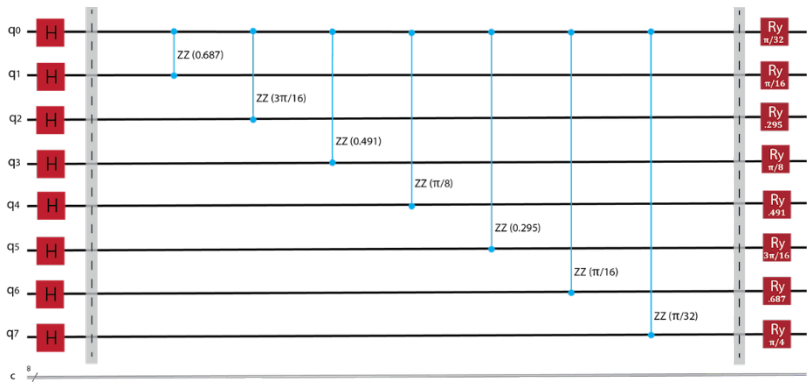

Figure 1. Star entanglement topology. Qubit 0 serves as a central hub with direct connections to all ancillary qubits; no inter-ancillary entanglement exists.

Schema 2, Chain (Phase Cascade), creates sequential entanglement (0↔1↔2↔...↔7) in a linear propagation structure where phase shifts accumulate along the chain, producing temporal smearing and echo-like relationships between voices. Figure 2 illustrates this topology.

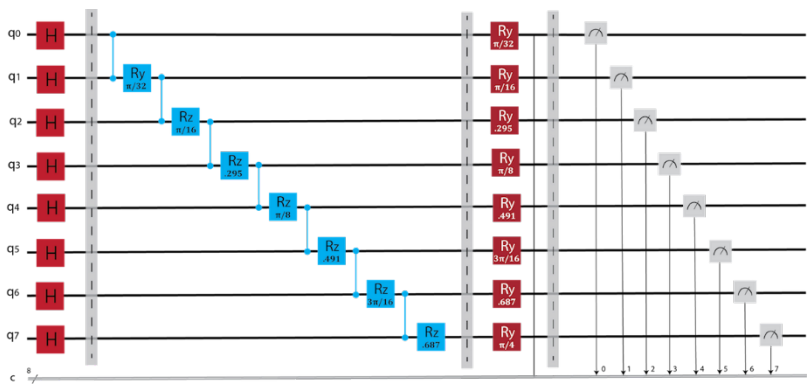

Figure 2. Chain entanglement topology. Sequential connections (0↔1↔2↔...↔7) create linear propagation where phase relationships accumulate along the chain.

Schema 3, Ring (Spectral Resonance), closes the chain into a ring by connecting qubit 7 back to qubit 0. The closed loop creates feedback-like correlation patterns akin to harmonic series relationships. Figure 3 illustrates this topology.

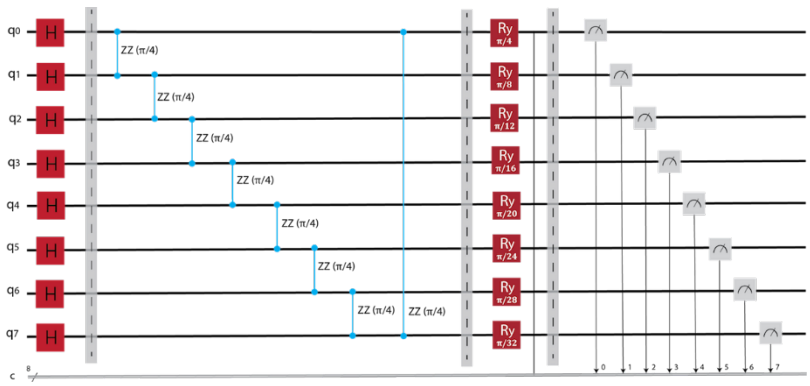

Figure 3. Ring entanglement topology. The chain structure closes by connecting qubit 7 back to qubit 0, creating circular correlation patterns.

Schema 4, Pairs (Dialogue), establishes four independent entangled pairs, (0,1), (2,3), (4,5), (6,7), creating four distinct voices, each internally correlated but independent between pairs, enabling contrapuntal textures. Figure 4 illustrates this topology.

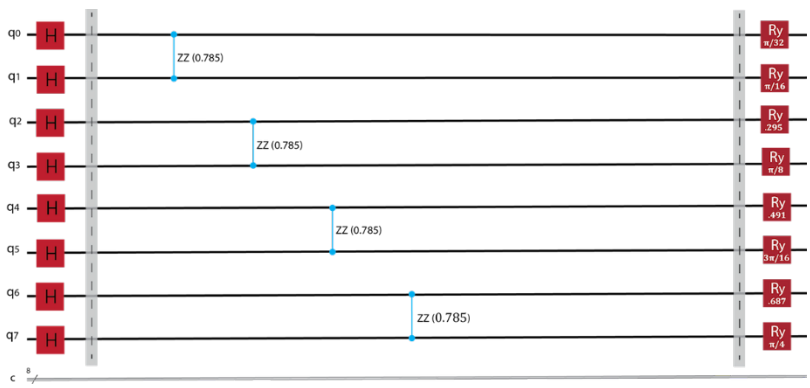

Figure 4. Pairs entanglement topology. Four independent entangled pairs (0,1), (2,3), (4,5), (6,7) with no inter-pair connections.

Schema 5, Tree (Timbral Branching), employs hierarchical binary branching to create family relationships: siblings share strong correlation, cousins less so. Entanglement strength decreases with tree depth, creating natural timbral groupings. Figure 5 illustrates this topology.

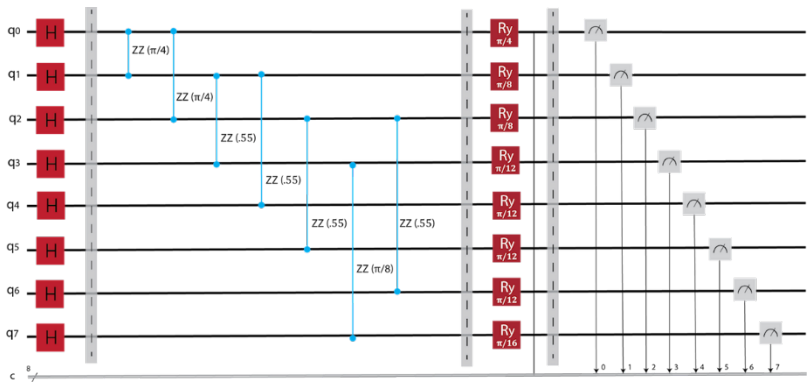

Figure 5. Tree entanglement topology. Hierarchical binary branching from qubit 0, with entanglement strength decreasing at each level of depth.

Schema 6, GHZ (Heterophony), implements the Greenberger-Horne-Zeilinger state (Greenberger, Horne, and Zeilinger 1989), entangling all eight qubits maximally to create near-unison behavior with subtle quantum fluctuations. This produces heterophonic texture, voices moving together with minute variations. Figure 6 illustrates this topology.

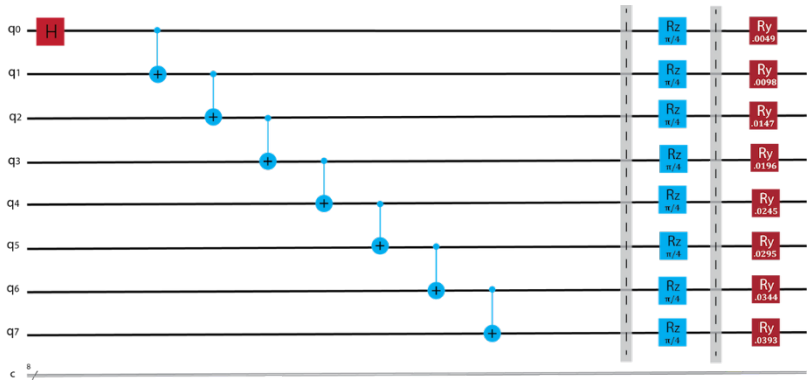

Figure 6. GHZ entanglement topology. Greenberger-Horne-Zeilinger state implementation with maximal entanglement across all eight qubits.

Schema 7, Gradient (Spectral Decay), applies linear decay of entanglement strength from qubit 0, creating a natural amplitude hierarchy analogous to harmonic series roll-off, with the fundamental dominating and higher partials progressively weaker. Figure 7 illustrates this topology.

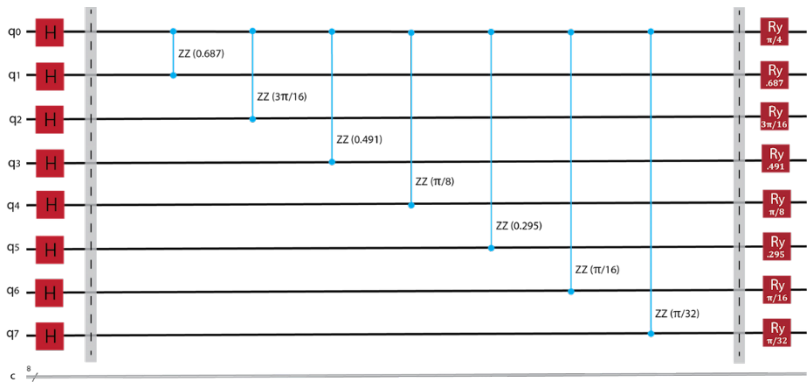

Figure 7. Gradient entanglement topology. Linear decay of entanglement strength from qubit 0, creating progressive amplitude hierarchy.

Schema 8, Islands (Counterpoint), establishes two isolated 4-qubit clusters with no inter-cluster entanglement, creating genuinely independent voices suitable for contrapuntal treatment. Figure 8 illustrates this topology.

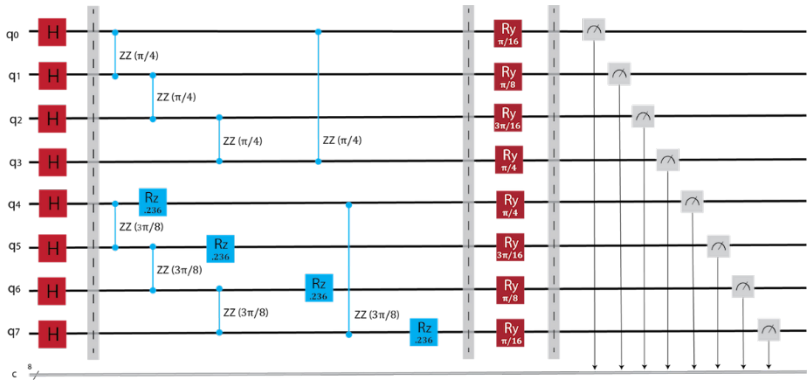

Figure 8. Islands entanglement topology. Two isolated 4-qubit clusters (0,1,2,3) and (4,5,6,7) with no inter-cluster entanglement.

Implementation

Quantum Simulation

Initial development and testing utilized IBM's Qiskit framework with the Aer simulator, allowing rapid iteration of circuit designs without quantum hardware access constraints. The simulator provides noise-free execution, producing the theoretical interference patterns predicted by quantum mechanics. This idealized output serves as a reference point against which hardware execution results can be compared.

Hardware Validation

Hardware validation was conducted using Quantum Inspire's Tuna-9 processor, a 9-qubit transmon system in a diamond configuration. All eight schemas were executed, totaling 19,200 quantum circuits (2,400 parameter steps × 8 schemas), with 1,024 shots per circuit. Execution required approximately 12 hours, with data saved incrementally to accommodate platform calibration cycles.

Systematic comparison between simulated and hardware-generated waveforms revealed consistent patterns across all schemas. Quantum hardware universally compresses amplitude ranges. Simulation waveforms swing ±1.0 while quantum hardware outputs remain within approximately ±0.5. However, the nature of transformation varies dramatically by entanglement topology.

Ring and Chain topologies showed strong shape preservation. Both simulation and hardware traces follow similar trajectories, rising and falling together, with hardware adding textural complexity atop the underlying structure (Figure 9). The sequential entanglement propagation in these topologies appears robust to quantum hardware noise.

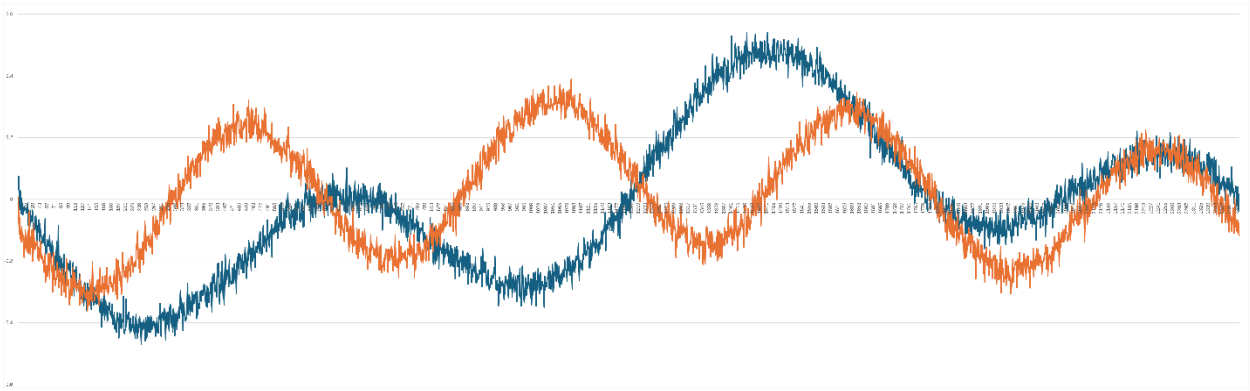

Figure 9. Quantum (orange) vs Simulation (blue) Waveforms – Chain qubit_07

Star topology produced dramatic transformation. Where simulation predicts relatively flat trajectories near zero for the fundamental qubit, hardware execution generated sweeping arcs with full amplitude excursion (Figure 10). The hub-and-spoke structure, requiring all ancillary qubits to connect through a central node, appears to accumulate hardware effects that fundamentally reshape the waveform character. For compositional purposes, this yields two

distinct timbral palettes from a single topology—the smooth simulation version and the dramatically textured hardware version.

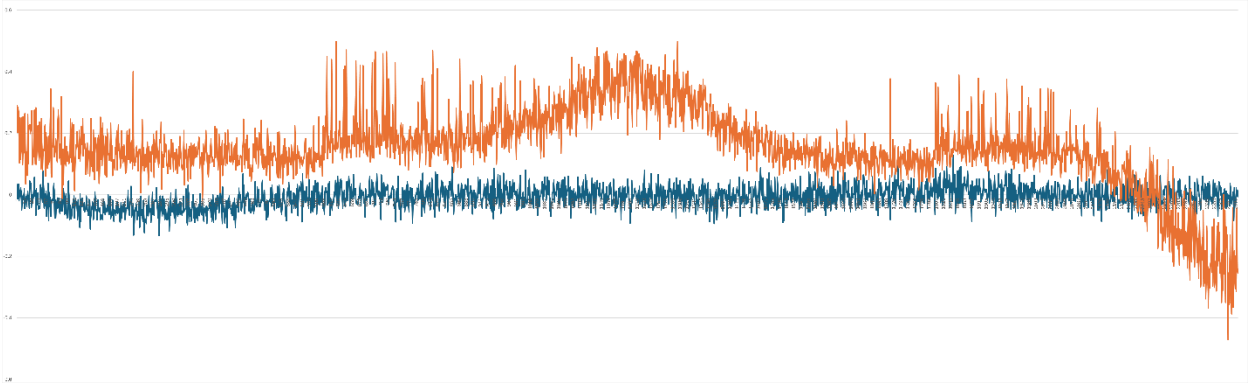

Figure 10. Quantum (orange) vs Simulation (blue) Waveforms—Star qubit_00

Gradient topology revealed amplified decay effects. The mid-gradient qubits (Q1-Q4) exhibited the richest gestural character with irregular peaks, varied attacks, full amplitude range—while distant qubits (Q6-Q7) collapsed below the hardware noise floor. The entanglement gradient is not merely preserved but exaggerated by quantum hardware execution.

GHZ topology, with its maximal entanglement, produced nearly identical results in both environments—stationary noise with minimal structure. The only systematic difference was a DC offset pattern that traced the CNOT propagation path through the circuit.

These findings establish that entanglement topology determines not only the simulated interference patterns but also how those patterns transform through real quantum hardware. For compositional purposes, moderate asymmetric entanglement (Star, Gradient, Tree) produced the most fertile material, while maximal entanglement (GHZ) collapses to undifferentiated noise in both environments.

Audio Post-Processing

Raw quantum waveforms require transformation for compositional use. The extraction process produces .01-second-long waveforms. These serve as source material for several post-processing techniques. Primary among these are extreme time-stretching to expose structure inaudible at original durations and frequency transposition to raise sub-audible material into perceptible registers. Without both transformations, the compositionally relevant content remains hidden.

Crucially, both can be applied without disturbing the quantum-derived relationships. Additional techniques include amplitude balancing between the eight voices within each schema, layering and combination of waveforms from different schemas, and spatial positioning within Ambisonics sound fields. The composer exercises editorial discretion in these transformations while preserving the underlying interference patterns, which remain quantum derived. Essentially, this is an act of mining emergent quanta (Rhoades 2020a). Quantum mechanics, the composer, and AI collaboration create material that is examined, extracted, and developed for compositional qualities in line with compositional intent.

Spatial Audio Integration

The eight waveforms from each schema map naturally to spatial audio configurations. For this 32-channel work, the target medium is 5th-order Ambisonics, which encodes three-dimensional sound fields for reproduction over high-density loudspeaker arrays (Rhoades 2020b). The ICST Ambisonics package in Max/MSP enables precise positioning of each quantum-derived voice within a spherical sound field. The methodology functions as direct transduction: interference patterns in the 2^8-dimensional Hilbert space convert to acoustic interference patterns in the 3-dimensional listening space.

Results

Waveform Characteristics

The extracted waveforms exhibit rich spectral content derived from quantum interference. Each entanglement topology produces a distinctive sonic signature. Star topology generates hierarchical timbres with a dominant fundamental, while the pairs topology creates distinct dialogues between correlated voices. The gradient topology naturally produces timbres resembling acoustic instruments, with amplitude roll-off creating familiar spectral envelopes.

Correlation Analysis

Cross-correlation analysis confirms that the entanglement structure is preserved in the audio domain. Strongly entangled qubit pairs show high correlation coefficients (>0.8), while independent or weakly entangled qubits show near-zero correlation. This mathematical

relationship translates to perceptual grouping in which correlated waveforms sound "related" while independent waveforms occupy distinct perceptual streams.

Schema-Specific Results

Of the eight entanglement schemas, four produced waveforms of particular compositional interest. Schema 1 (Star), with its hub-and-spoke entanglement topology, yielded waveforms with clear hierarchical structure; the fundamental qubit's dominance created a stable timbral center around which ancillary trajectories provided spectral complexity. Schema 2 (Chain) produced phase-cascade effects audible as temporal smearing and echo-like resonances, with the correlation propagation along the chain manifesting as distinctive spatial depth in the processed audio. Schema 3 (Ring), with its circular entanglement, created feedback-like correlation patterns that, when temporally expanded, revealed rich harmonic interrelationships; the closed-loop topology produced some of the most spectrally complex material. Schema 8 (Islands) generated genuinely independent voice groups from its two isolated 4-qubit clusters, enabling natural contrapuntal relationships; the absence of inter-cluster entanglement preserved distinct timbral identities suitable for polyphonic treatment.

Schemas 4 (Pairs), 5 (Tree), 6 (GHZ), and 7 (Gradient) produced usable material but with less distinctive character for the present compositional objectives. The maximal entanglement of Schema 6 (GHZ), while theoretically interesting, resulted in near-homogeneous waveforms with limited timbral variation between qubits.

Compositional Application

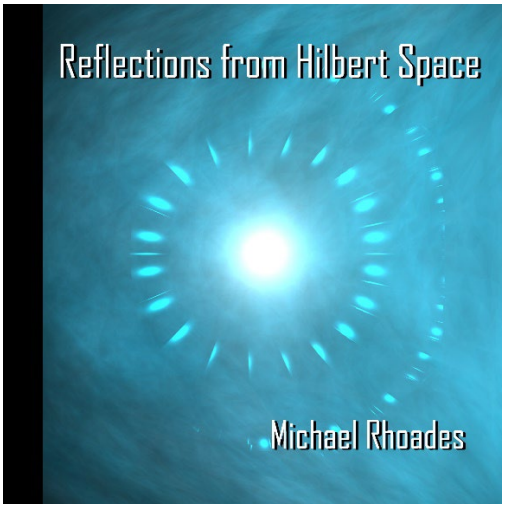

Figure 11. Reflections from Hilbert Space—visual artwork for the collection.

This research and creative praxis resulted in the creation of seven quantum computer music compositions. The title of the collection is *Reflections from Hilbert Space* (Figure 11). Each composition is described sequentially, in the order of creation, to establish the flow of progress through the research.

The audio waveforms that serve as source material for Reflections from Hilbert Space were derived from quantum simulation using Qiskit Aer on a local workstation or from quantum hardware execution on Quantum Inspire's Tuna-9 processor. This collection of seven compositions totals approximately 76 minutes and traces an arc from initial aesthetic exploration through methodological development to hardware validation. The collection opens with a preparatory work establishing the sonic territory, followed by an early quantum hardware sonification study, then four simulation-based compositions developing the transduction methodology, and culminates in a fully quantum hardware-derived work. Five compositions employ the transduction methodology, each deriving from 64 waveforms one-hundredth of a second in length—four from simulation, one from quantum hardware. This 0.64 seconds of raw quantum-derived material yielded over an hour of finished music, demonstrating the compositional depth accessible through careful investigation of quantum interference patterns. The resulting sonic palette ranges from passages of haunting beauty to textures exhibiting edgy and raw qualities—emerging from a bottom-up approach that directly transduced quantum interference mathematics to audio waveforms rather than from deliberate timbral design.

The collection opens with "Looking Toward Hilbert Space," composed during the early stages of this research. While not directly derived from quantum circuit execution, it was created using a generative MAX patch ("titled an Eternal Song, version 5") and reflects the aesthetic sensibilities that would guide the subsequent quantum-derived works. It establishes the sonic territory the collection explores. It is a preparation for the work to follow.

"Quantum Etude_00" represents the first direct engagement with quantum hardware—a 24-second sonification of waveform interference patterns during circuit execution using IBM's Heron-series 156-qubit processor. This brief study established the workflow and validated the concept, though it employed sonification rather than the transduction methodology that would define later works. It is presented as 8-channel spatial audio.

The Superstring Octet marks the methodological breakthrough: direct transduction from simulated Hilbert space to listening space. It employs layered composite waveforms from Schemas 1, 2, 3, and 8, arranged and mixed to 32-channel output using digital audio workstation techniques. Amplitude relationships were derived from entanglement correlation strengths, guiding the relative levels of fundamental and ancillary voices within each schema. The final eight waveforms were exported as 48 kHz/24-bit WAV files and played back through a MAX patch connecting each waveform to a static 5th order Ambisonics sound sphere using the ICST Ambisonics package, with 32 sound spheres arranged in either cuboidal or polar diffusion patterns. This and all subsequent works in the collection are presented as 32-channel spatial audio.

In the composition "Collapsing Waves", each of the 64 samples is processed independently through a generative MAX patch. This approach enables real-time recombination of simulated quantum-derived material according to algorithmic processes, creating a second layer of generative composition atop the quantum foundation. The patch alters frequencies while maintaining quantum-derived relationships, applying effects including delay, echo, chorus, and comb filtering in varying combinations, and employing granular synthesis techniques with varied ADSR envelopes. Additionally, the patch routes samples through Ambisonics algorithms that transform the diffuse spatial orchestration into discrete audio objects moving throughout the listening space. The patch records its processed outputs to 64 discrete channels, which are then imported into a DAW where musically relevant material is extracted for final mixing.

The "Entangled Ambience” composition extends this generative approach but presents the output without editorial intervention. The raw simulation-based quantum waveforms undergo playful manipulation while maintaining their original entanglement-derived relationships, offering listeners an immersive quantum audio environment in its unmediated form.

The "Song of Interference" takes the opposite approach from the preceding generative works. Rather than processing all 64 samples, it employs only the 8 composite waveforms and strictly maintains the timbral relationships encoded by entanglement topology. Where "Collapsing Waves" and "Entangled Ambience" explore freedom within quantum-derived constraints, "Song of Interference" honors the entanglement structure as the primary compositional architecture. In this sense, it is the purist realization, where the entanglement topology speaks most directly without the mediation of generative processes.

Finally, "The Infinite and the Infinitesimal" is a fully quantum-derived work. Using Quantum Inspire's Tuna-9 backend, each of the 64 audio waveforms was transduced directly from quantum interference over a 12-hour circuit execution in five batches. This over 18-minute-long composition is the crowning achievement of this research project. Though the waveforms differed from simulations due to hardware noise and momentary decoherence—appearing more complex—they sounded smoother and more refined. This composition demonstrates that the initial intuition—that quantum computing opens exciting new worlds of quantum computational creativity—was not misguided and certainly justified the depth and breadth of endeavor involved.

To listen to these compositions, see the links in Additional Resources.

Observations

These compositional approaches function as transducers, converting quantum wavefunction activity in Hilbert space directly to acoustic phenomena in listening space. The compositions maintain the mathematical relationships established by the quantum entanglement structure while realizing them in perceptually accessible form. Listeners report hearing "organic" timbres despite the entirely mathematical origin of the material, suggesting that quantum interference patterns may share structural characteristics with natural acoustic phenomena. Nonetheless, the resulting compositions from this approach are quite unique, being a departure from any previous

compositional methodologies. As such they present a new form of musical expression and listeners must be open to them. For those who are, this is a new musical world.

Discussion

Symbiotic Creativity

The methodology presented here distributes creative agency across three participants. The human composer contributes aesthetic judgment, structural intuition, cultural knowledge, and editorial discretion. The quantum system contributes interference patterns governed by physical law, producing material no human could deterministically specify. The AI collaborator contributes pattern recognition across large parameter spaces, rapid prototyping of circuit variations, and analysis capabilities that support human decision-making.

This distribution does not diminish human creativity but rather repositions it. The composer operates as architect (designing entanglement topologies), curator (selecting from quantum-generated possibilities), and editor (shaping raw material into finished form). The quantum system operates as a collaborator with genuine agency. Its outputs are determined by physics, not programming.

Limitations and Future Work

Current quantum hardware introduces noise that, while sometimes compositionally interesting, limits reproducibility. Future work in the field of quantum computing will further explore noise-robust circuit designs and error mitigation strategies. The 8-qubit limitation constrains the complexity of entanglement topologies; access to larger processors would enable richer correlation structures. This constraint is primarily a financial one, as quantum computational execution time remains very expensive. Additionally, real-time quantum execution for live performance, within this paradigm, remains impractical with current technology but represents an exciting future possibility as quantum computing, now in its infancy, matures.

Broader Implications

This methodology suggests possibilities beyond music. Any domain where wave interference is meaningful including optics, signal processing, architectural acoustics, and others, might benefit from quantum-derived interference patterns. The symbiotic model of human-AI-quantum

collaboration may prove applicable to other creative and scientific endeavors where the intersection of human intuition and physical law generates novel possibilities. The role of the composer evolves accordingly as programmer, constrainer, editor, and listener, discovering within the quantum-derived material "that which I never knew existed or even could exist."

Conclusion

This paper has presented a methodology for music compositional practice in which quantum circuit evolution serves as a generative source in collaboration with human creativity and AI assistance. By treating entanglement topology as a compositional parameter and transducing interference patterns directly into audio waveforms, a pathway from quantum mechanics to musical material is established that preserves mathematical structure rather than merely representing data. The eight entanglement schemas provide diverse starting points for composition, each encoding different correlation structures that manifest as distinct timbral relationships.

The resulting collection, *Reflections from Hilbert Space*, demonstrates that quantum phenomena can serve not merely as random number sources or procedural tools, but as genuine creative collaborators operating according to physical law. The symbiotic model, human, AI, and quantum system, suggests new possibilities for creative practice in which the boundaries between composer, instrument, and material become productively blurred.

As quantum computing technology matures, the methodology presented here offers a framework for artistic engagement with these systems that honors both their scientific reality and their creative potential. The quantum computer becomes not just a powerful calculator but a participant in the musical act, contributing material that emerges from the mathematics of nature itself.

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Additional Resources

Researchers and Artists

Omar Costa Hamido: https://omarcostahamido.com

Eduardo Reck Miranda: https://www.youtube.com/watch?v=U_axiArEKak

Tools and Platforms

QAC Toolkit for Max: https://www.quantumland.art/qac

IBM Quantum Computing: https://quantum.cloud.ibm.com/

Quantum Inspire: https://www.quantum-inspire.com/

Anthropic Claude: https://claude.ai

This Project

Michael Rhoades: https://perceptionfactory.com/quantum-computing-sonifications/

Reflections from Hilbert Space: https://perceptionfactory.com/reflections-from-hilbert-space-2026/

Declarations

Funding for this research [to be confirmed prior to publication]. The author declares no competing interests. Ethics approval and consent for publication are not applicable to this work. Quantum circuit specifications and generated waveform data will be made available upon request, and Python/Qiskit code for circuit generation and waveform extraction will be made available in a public repository. AI assistance (Claude, Anthropic) was used for code development, conceptual refinement, and manuscript preparation as part of the symbiotic collaborative methodology described herein; all scientific content, compositional decisions, and final manuscript approval were performed by the author.

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