Short Article

ISSN 2767-3901

International Journal of Theoretical & Computational Physics

Fractal Quantum Entanglement and Information Theory Using the McGinty Equation

Chris McGinty

Founder of Skywise.ai, Greater Minneapolis-St. Paul Area, USA.

***Correspondence author**
Chris McGinty,
Founder of Skywise.ai,
Greater Minneapolis-St. Paul Area,
USA.

Submitted : 05 Feb 2025 ; Published : 28 Apr 2025

Citation: Chris McGinty (2025). Fractal Quantum Entanglement and Information Theory Using the McGinty Equation. *I J T C Physics,* Special Issue :1-2. DOI : https://doi.org/10.47485/2767-3901.1059

Abstract

This hypothesis explores the application of the McGinty Equation to fractal quantum entanglement and information theory, proposing that the entanglement entropy and information flow in quantum systems exhibit fractal properties. The primary objective is to understand how fractal geometry influences quantum entanglement, information transmission, and processing, offering new insights into quantum communication, computation, and the fundamental limits of information theory.

Introduction

Quantum entanglement is a cornerstone of quantum information theory, playing a crucial role in quantum communication, computation, and cryptography. Traditionally, entanglement is analyzed within the framework of smooth spacetime. This hypothesis extends the framework by incorporating fractal dimensions, suggesting that the structure of entanglement and information flow may follow fractal patterns. By applying the McGinty Equation, we aim to investigate how fractal geometry impacts the properties and behavior of entangled quantum systems.

Mathematical Framework

Fractal-modified Entanglement Entropy

S_E = -Tr(ρ ln ρ) . |x|^d_f

where S_E is the entanglement entropy, ρ is the reduced density matrix, and d_f is the fractal dimension.

Fractal-modified Mutual Information

I(A:B) = S_A + S_B - S_AB . |x|^d_f

where I(A:B) is the mutual information between subsystems A and B, S_A and S_B are the entropies of subsystems A and B, and S_AB is the entropy of the combined system.

Fractal-modified Quantum Channel Capacity

C = max_ρ [S(E(ρ)) - S(ρ)] . |x|^d_f

where C is the quantum channel capacity, E is the quantum channel, and S is the von Neumann entropy.

Expected Results

Entanglement Entropy S

S_E . |x|^d_f

Quantum Information Transmission

I(A:B) α |x|^d_f

Quantum Channel Capacity Modifications

C α |x|^d_f

Experimental Proposals

1. Quantum Communication Experiments: Measure the capacity and fidelity of quantum communication channels to detect fractal influences in information transmission.
2. Quantum Entanglement Studies: Investigate the scaling of entanglement entropy in various quantum systems to observe fractal patterns.
3. Quantum Computing Simulations: Develop simulations to model quantum algorithms with fractal-modified entanglement and information processing.
4. Quantum Cryptography Experiments: Test the security and efficiency of quantum cryptographic protocols under fractal-modified conditions.

Computational Tasks

1. Simulation of Fractal Quantum Information Systems: Implement simulations to model the behavior of entangled quantum systems with fractal dimensions.
2. Monte Carlo Methods: Use Monte Carlo integration to study the properties of fractal-modified quantum information processes.
3. Numerical Solutions: Solve the fractal-modified equations for entanglement entropy, mutual information, and quantum channel capacity numerically.

Theoretical Developments Needed

- Develop a comprehensive theory of fractal quantum information theory.
- Extend existing models of quantum entanglement and information theory to incorporate fractal dimensions.
- Formulate new mathematical tools to describe fractal-modified entanglement and information processes.

Key Research Focus Areas

- Precision measurements of entanglement entropy and information transmission in fractal-modified quantum systems.
- Development of mathematical models for fractal quantum information theory.
- Experimental validation of fractal patterns in quantum communication and computation.
- Theoretical work on integrating fractal dimensions with quantum information theory.

Conclusion

This hypothesis proposes a novel framework for understanding quantum entanglement and information theory through fractal dimensions. By exploring the unique properties of entanglement entropy, mutual information, and quantum channel capacity, we aim to uncover hidden aspects of information processing in quantum systems, providing new insights into the fundamental limits of quantum communication and computation.

References

1. McGinty, C. (2023). The McGinty Equation: Unifying Quantum Field Theory and Fractal Theory to Understand Subatomic Behavior. *International Journal of Theoretical & Computational Physics, 5*(2), 1-5.
2. Nielsen, M. A., & Chuang, I. L. (2010). Quantum computation and quantum information. Cambridge University Press.
3. Horodecki, R., Horodecki, P., Horodecki, M., & Horodecki, K. (2009). Quantum entanglement. Reviews of Modern Physics, 81(2), 865.
4. Mandelbrot, B. B. (1982). The Fractal Geometry of Nature. W. H. Freeman and Company.
5. Nottale, L. (2011). Scale Relativity and Fractal Space-Time: A New Approach to Unifying Relativity and Quantum Mechanics. Imperial College Press.
6. Calcagni, G. (2010). Fractal universe and quantum gravity. *Physical Review Letters, 104*(25), 251301.
7. Calabrese, P., & Cardy, J. (2009). Entanglement entropy and conformal field theory. *Journal of Physics A: Mathematical and Theoretical, 42*(50), 504005.
8. Ryu, S., & Takayanagi, T. (2006). Holographic derivation of entanglement entropy from the anti–de Sitter space/conformal field theory correspondence. *Physical Review Letters, 96*(18), 181602.
9. Amico, L., Fazio, R., Osterloh, A., & Vedral, V. (2008). Entanglement in many-body systems. *Reviews of Modern Physics, 80*(2), 517.
10. Holevo, A. S. (1998). The capacity of the quantum channel with general signal states. *IEEE Transactions on Information Theory, 44*(1), 269-273.
11. Schumacher, B., & Westmoreland, M. D. (1997). Sending classical information via noisy quantum channels. *Physical Review A, 56*(1), 131.
12. Bennett, C. H., & Wiesner, S. J. (1992). Communication via one-and two-particle operators on Einstein-Podolsky-Rosen states. *Physical Review Letters, 69*(20), 2881.
13. Ekert, A. K. (1991). Quantum cryptography based on Bell's theorem. *Physical Review Letters, 67*(6), 661.
14. Lloyd, S. (1997). Capacity of the noisy quantum channel. *Physical Review A, 55*(3), 1613.
15. Vedral, V., Plenio, M. B., Rippin, M. A., & Knight, P. L. (1997). Quantifying entanglement. *Physical Review Letters, 78*(12), 2275.
16. Brandão, F. G., & Plenio, M. B. (2008). Entanglement theory and the second law of thermodynamics. *Nature Physics, 4*(11), 873-877.
17. Hayden, P., Horodecki, M., & Terhal, B. M. (2001). The asymptotic entanglement cost of preparing a quantum state. *Journal of Physics A: Mathematical and General, 34*(35), 6891.
18. Hastings, M. B. (2007). An area law for one-dimensional quantum systems. *Journal of Statistical Mechanics: Theory and Experiment, 2007*(08), P08024.
19. Eisert, J., Cramer, M., & Plenio, M. B. (2010). Colloquium: Area laws for the entanglement entropy. *Reviews of Modern Physics, 82*(1), 277.
20. Verstraete, F., Murg, V., & Cirac, J. I. (2008). Matrix product states, projected entangled pair states, and variational renormalization group methods for quantum spin systems. *Advances in Physics, 57*(2), 143-224.