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Asa Bruss *

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Keywords: analog computation; resonant computing; discrete fourier transform (DFT); tensioned membranes; physical signal processing; membrane resonance; wave-based computation; hardware accelerators; nonlinear systems; acoustic logic

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An Analog Resonant Architecture for Performing the Discrete Fourier Transform Using Tensioned Membrane Arrays

Asa Bruss

Independent Researcher, USA; brussa@ontolotron.org

Abstract: We present a novel analog computational architecture that performs the Discrete Fourier Transform (DFT) by leveraging a vertically stacked array of tensioned membranes, each tuned to a specific resonant frequency. Instead of relying on digital sampling and arithmetic operations, this system physically decomposes input waveforms into frequency components via selective resonance. Energy from the input waveform accumulates in the corresponding resonant membrane, allowing instantaneous analog computation of frequency coefficients. The architecture offers a scalable, low-power alternative to traditional digital FFT hardware and enables new modes of computation in environments where physical interaction, sensory feedback, or low-latency analog processing is critical.

Keywords: analog computation; discrete Fourier transform; resonance; tensioned membranes; physical computing; waveform decomposition; vibroware

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1. Introduction

The Discrete Fourier Transform (DFT) is a fundamental operation in signal processing, used to decompose signals into frequency components. While digital implementations such as the Fast Fourier Transform (FFT) are ubiquitous, they require sampling, quantization, and iterative computation. In contrast, natural physical systems often exhibit direct responses to frequency inputs through resonance. This work introduces a computation model that replaces arithmetic with physical dynamics, using membrane resonance as a frequency-selective medium to perform DFT analogously. [1]

2. System Architecture

The proposed architecture consists of a vertical stack of thin, tensioned membranes (e.g., mylar, polymer, or electroactive film), each mechanically or electromagnetically tuned to a distinct natural frequency. When a composite waveform is injected into the base of the stack, each membrane selectively resonates with its matching frequency component. The amplitude of membrane vibration or deformation serves as a physical analog to the magnitude of the corresponding DFT coefficient. Optional phase information can be extracted via angular displacement within orbital mounting tracks.

3. Physical Computation of the DFT

The DFT is traditionally defined as:

$$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-2\pi ikn/N}$$

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In this system, the membrane tuned to frequency f_k acts as a physical basis function. The input waveform $x(t)$, composed of multiple frequency components, excites the membranes simultaneously. Each membrane accumulates vibrational energy proportional to the energy present in its matched frequency component, effectively implementing the DFT through material resonance.

4. Readout and Signal Interpretation

The output is collected by measuring each membrane's curvature amplitude, vibration strength, or induced tension shift. These measurements correspond to $|X_k|$, the magnitude of the DFT spectrum at each bin. Phase information may also be derived using optical or mechanical tracking of membrane edge displacement. The result is a fully parallel, real-time transform engine embodied in passive mechanical materials.

5. Advantages and Applications

This architecture removes the need for clocks, ADCs, and iterative logic, replacing them with intrinsic material behavior. [2] It enables ultra-low-power, high-speed analog signal decomposition, ideal for audio analysis, biological sensing, cryptographic preprocessing, and environments requiring physical interaction between computation and signal source. [3]

6. Conclusion

We demonstrate that tensioned membrane arrays offer a viable and powerful analog mechanism for performing the DFT. By leveraging resonance as a computational substrate, this approach opens new paths in the design of physical processors that solve traditionally digital problems via material coherence and waveform structure.

7. Implementation Feasibility and Comparative Advantages

Materials and Fabrication:
The core physical components of the Vibroware architecture are simple, low-cost, and widely available. Tensioned membranes can be manufactured from industrial materials such as Mylar, polyethylene, or electroactive polymers. These materials are already produced at scale for commercial applications ranging from packaging to flexible electronics, making the hardware foundation of Vibroware orders of magnitude cheaper and more accessible than the cryogenically cooled superconductors or nanofabricated qubits required in quantum systems.

Scalability and Integration:
Unlike quantum processors, which require ultra-pure environments, decoherence shielding, and atomic-scale fabrication, Vibroware systems can be assembled using conventional materials science and precision mechanical engineering. Individual membrane stacks can be mass-produced as modular analog signal processors and deployed in networks for parallel operation. The stackable, passive nature of the system allows for easy vertical integration in server chassis, low-power edge processors, and specialized hardware accelerators.

Deployment Contexts:
Vibroware-based DFT units could be integrated into:

- **Data centers** as low-latency analog pre-processors for high-volume signal processing (e.g., audio/video compression, sensor fusion, anomaly detection)
- **Edge computing devices** in industrial or medical settings where high-resolution frequency decomposition is needed without heavy processing overhead

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- **Embedded systems** where size, power, and durability constraints make digital hardware impractical or inefficient
- **Security modules**, where hardware-embedded spectral signatures act as cryptographic or biometric keys

References

1. A. V. Oppenheim and R. W. Schafer, *Discrete-Time Signal Processing*, 3rd ed., Pearson, 2009.
2. S. He, M. Torkelson, "A High-Performance FFT Processor for OFDM Applications," *IEEE Journal of Solid-State Circuits*, vol. 38, no. 3, pp. 561-573, March 2003.
3. J. Preskill, "Quantum computing in the NISQ era and beyond," *Quantum*, vol. 2, p. 79, 2018.