

Evaluating the voltage conversion efficiency and dimensions of Barium Titanate for implantable neurostimulation applications

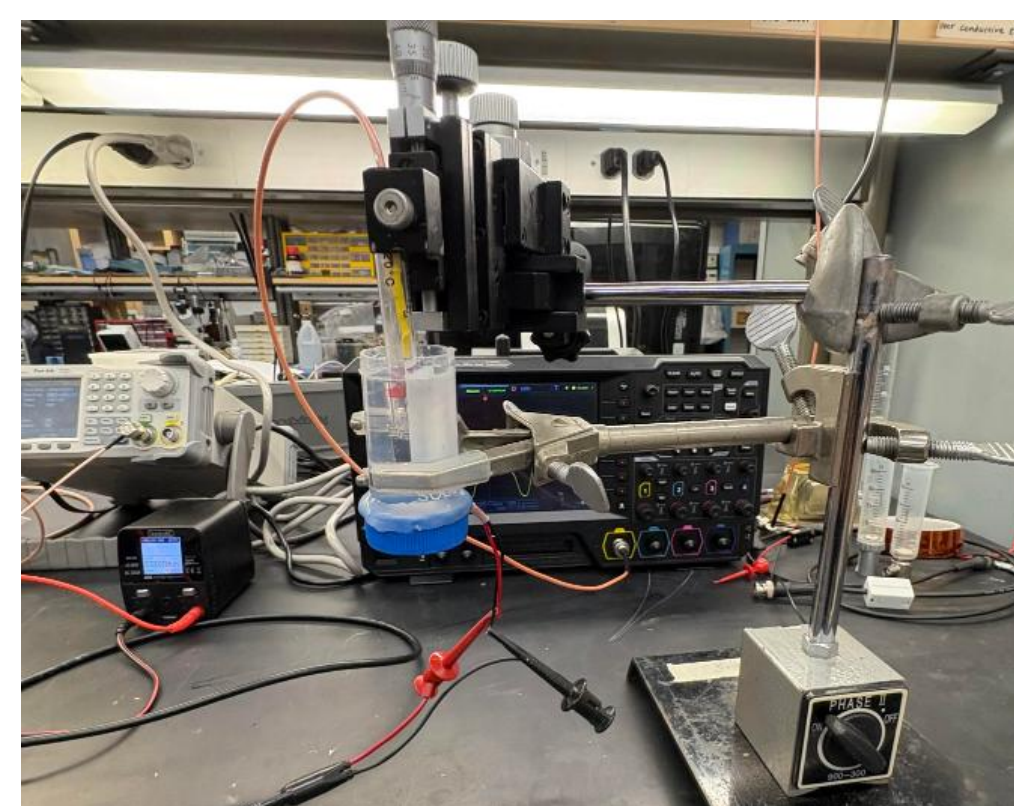
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INTRODUCTION

- Piezoelectric materials convert mechanical energy to electrical energy & utilized in the electrical, biomedical, energy harvesting spaces, and for neurostimulation applications [1].
- PZT (Lead Zirconate Titanate) is a common form of piezoceramic; however, the material has biocompatibility concerns.
- Barium Titanate (BaTiO₃) is a form of piezoceramics & a lead-free alternative [2].
- BaTiO₃ & PZT have specific d₃₃ values and as research shows, modified versions of BaTiO₃ could produce a comparable d₃₃ value to PZT (~300 pC/N) [3].
- The project aims to evaluate the specific dimensions of BaTiO₃ and analyze the material's voltage efficiency and signal attenuation coefficient for the ultimate purpose for neurostimulation applications.

METHODS



Water Testing of Fabricated PZT & BT Devices

- BT (3 mm x 4 mm x 1.15 mm)
- PZT (3 mm x 4 mm x 1.0 mm)
- 2MHz Resonant Frequency



Phantom Slab Testing of Fabricated PZT & BT Devices

- BT (4 mm x 3 mm x 2.2 mm) with 1.2kΩ Load
- PZT (3 mm x 1.5 mm x 0.5 mm)



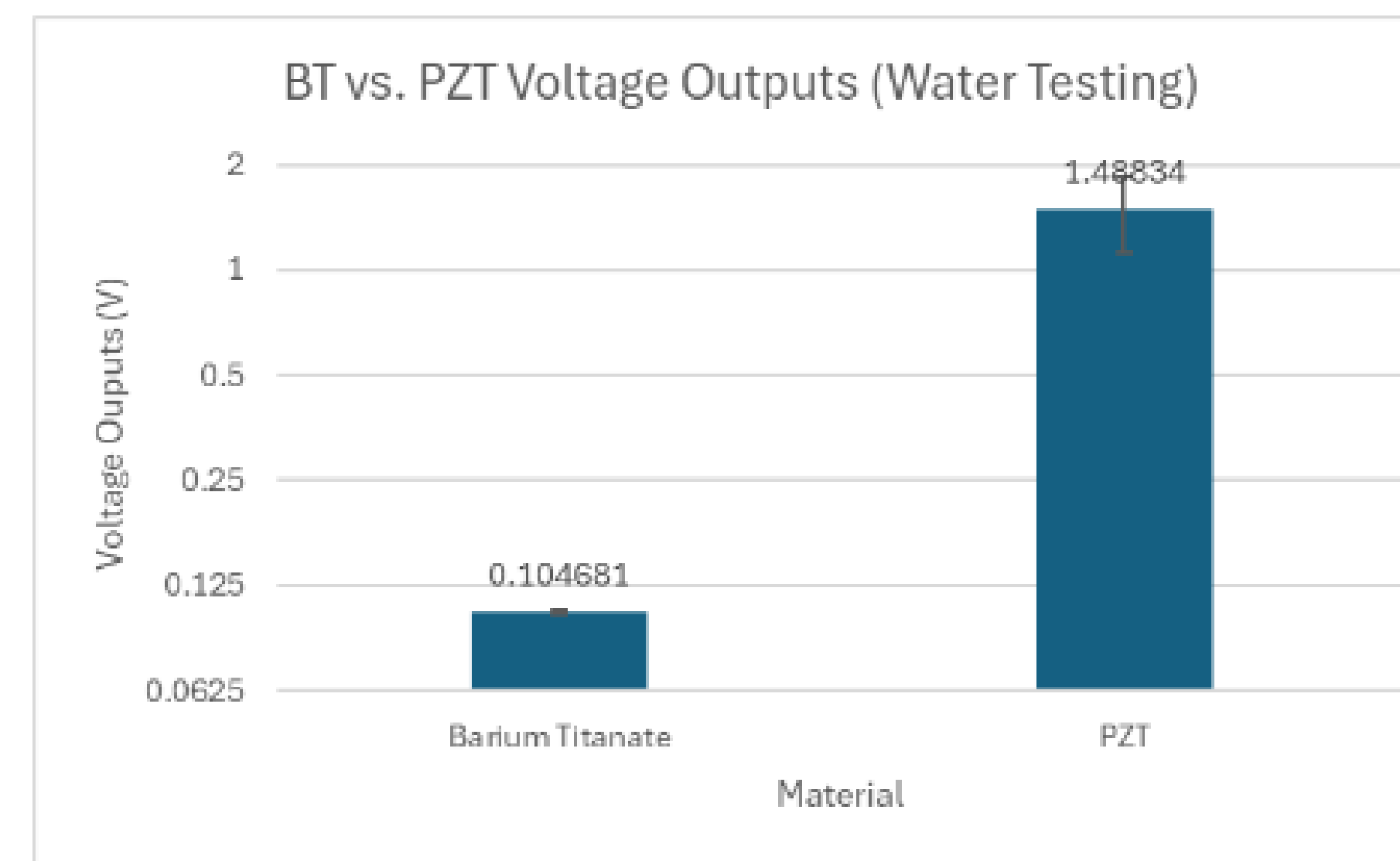
Real Tissue (Beef Slices) Testing of Fabricated of BT Device

- BT (4 mm x 3 mm x 2.2 mm) with 1.2kΩ Load
- 1 MHz Resonant Frequency

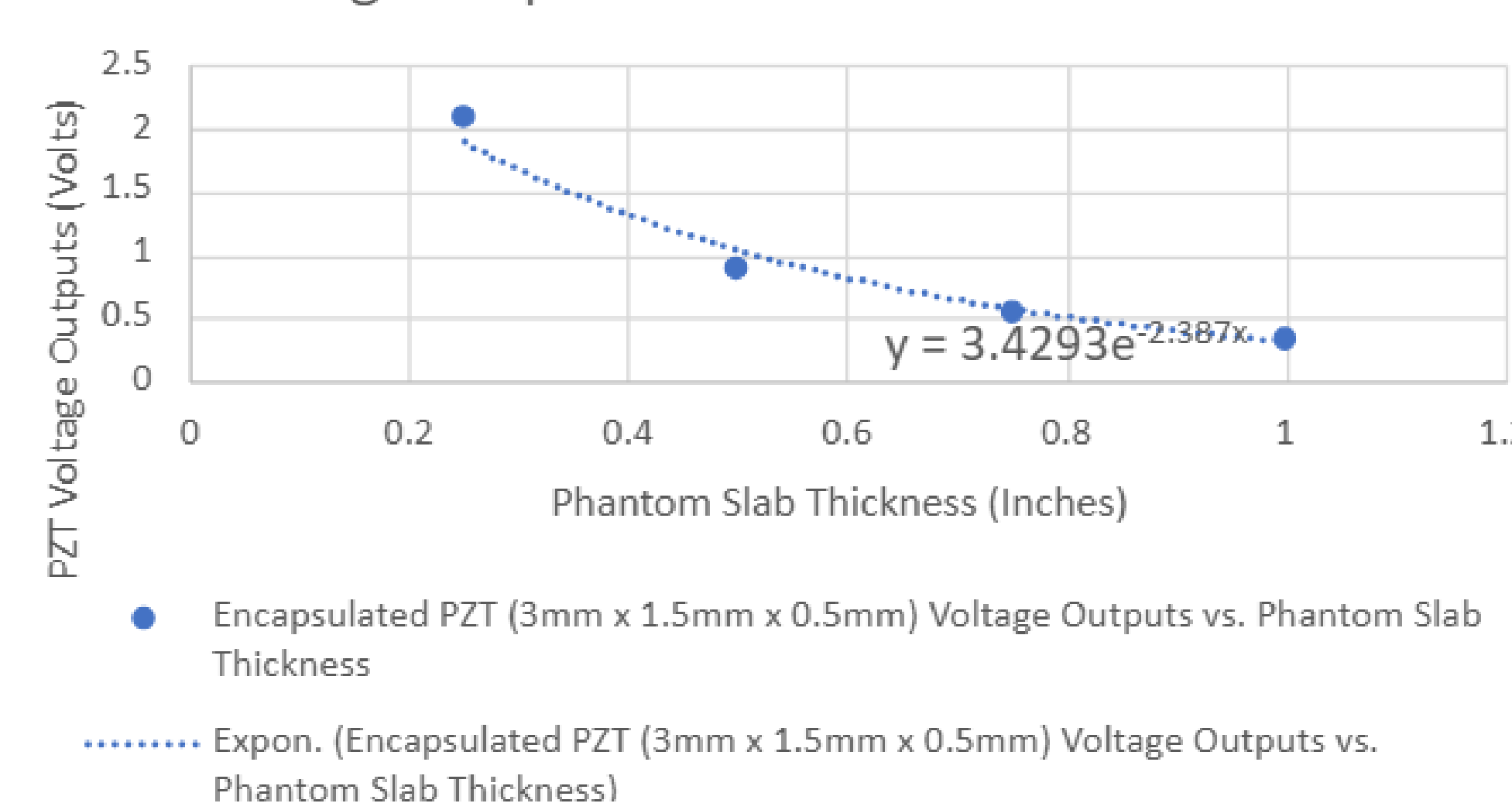
RESULTS

A

Fig A : BT vs. PZT Voltage Outputs (Water Testing) showcases the BT has an average voltage output of 0.104681 ± 0.00156 V and PZT of 1.48834 ± 0.36785 V



Encapsulated PZT (3mm x 1.5mm x 0.5mm) Voltage Outputs vs. Phantom Slab Thickness

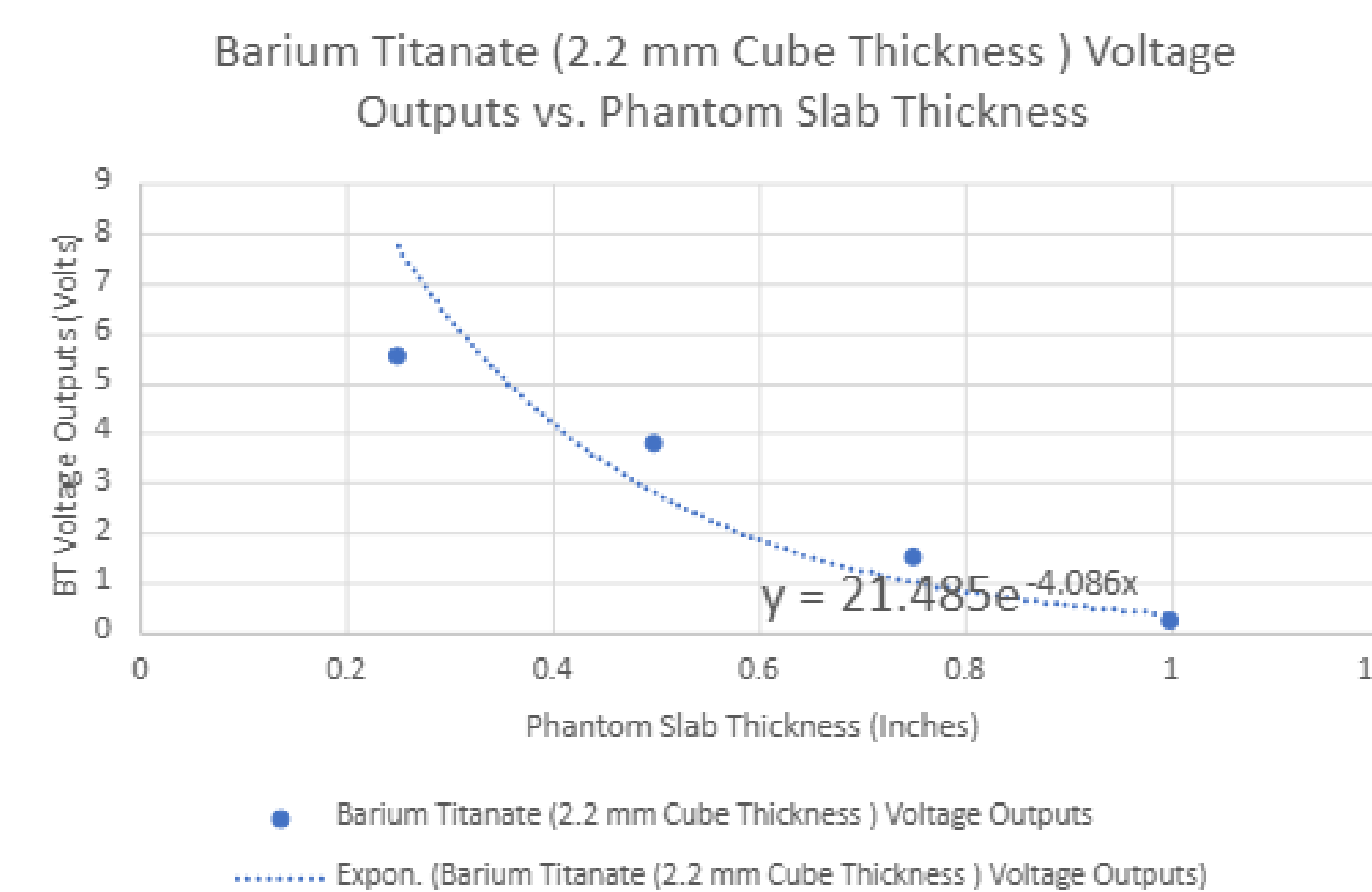


B

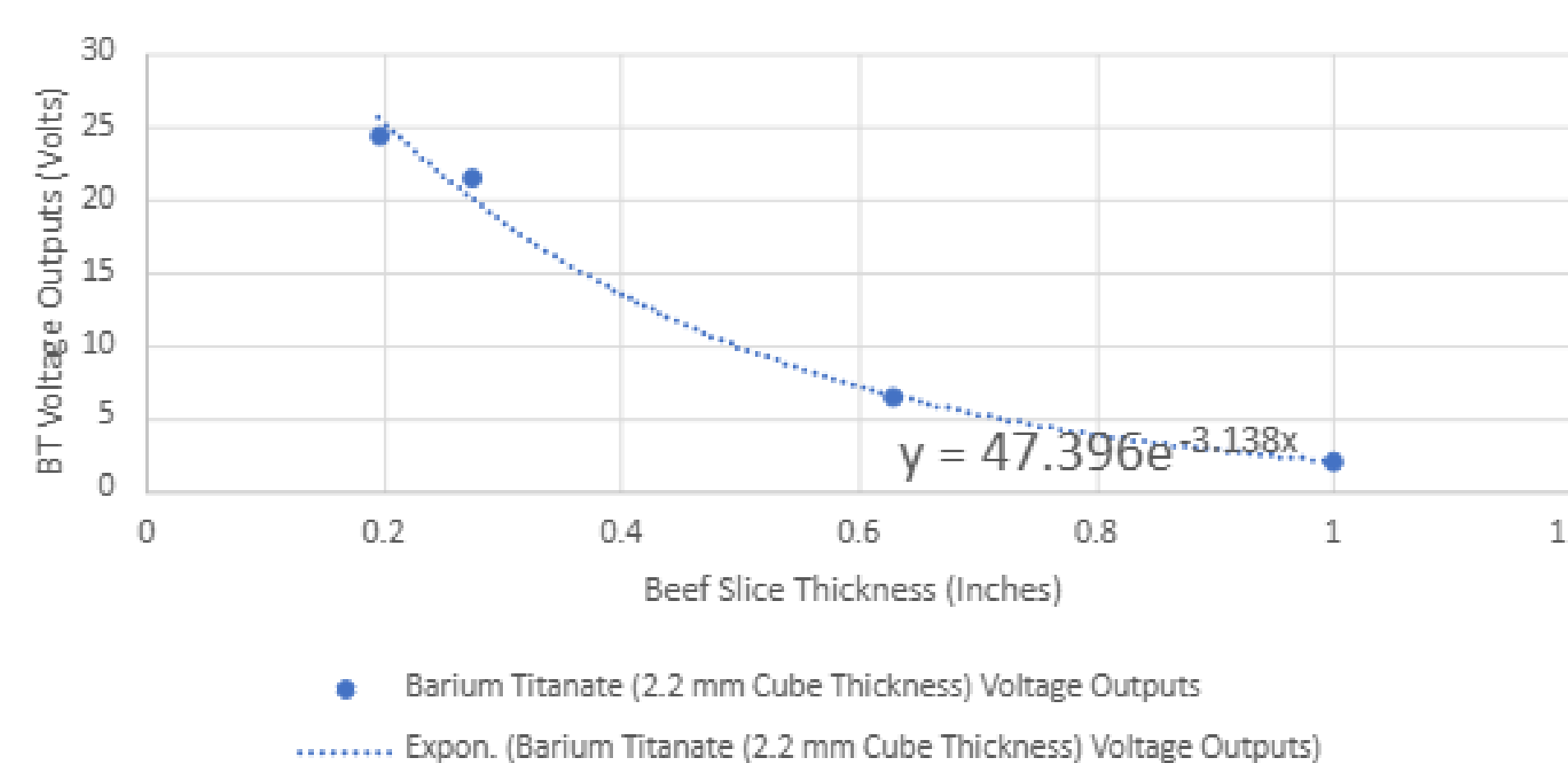
Fig B: Encapsulated PZT of 0.5 mm thickness's Voltage outputs vs. Added Phantom Slab. The applied exponential curve was $y = 3.429e^{-2.387x}$. The signal attenuation coefficient is 2.387 per inch, and after a total of 1-inch phantom slab, only 9.2% of the signal remains.

C

Fig C: Soldered BT of 2.2 mm thickness's Voltage outputs vs. Added Phantom Slab. The applied exponential curve was $y = 21.485e^{-4.086x}$. The signal attenuation coefficient is 4.086 per inch, and after a total of 1-inch phantom slab, only 1.68% of the signal remains.



Barium Titanate (2.2 mm Cube Thickness) Voltage Outputs vs. Beef Slice Thickness



D

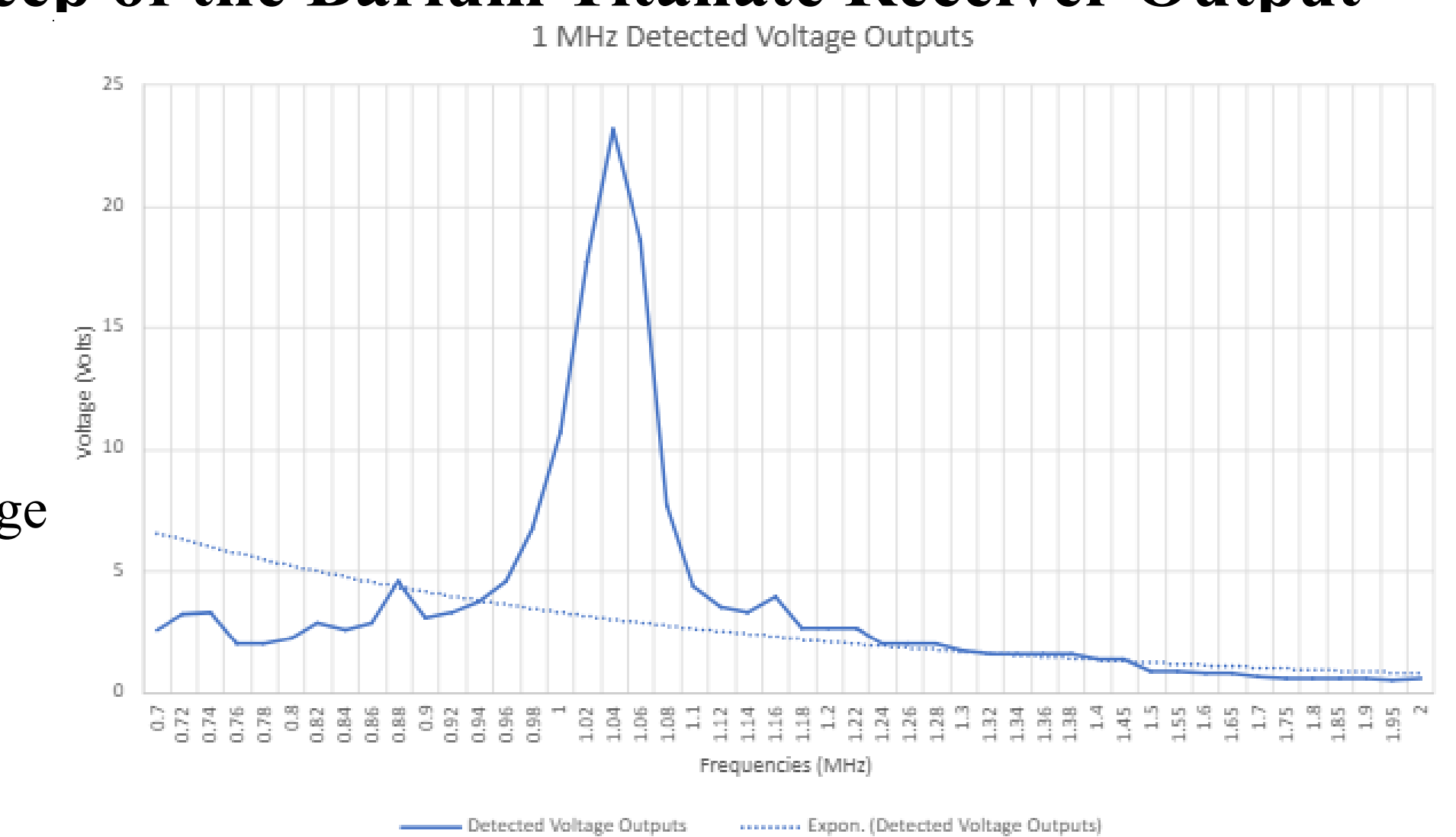
Fig D: Soldered BT of 2.2 mm thickness's Voltage outputs vs. Added Beef Slices. The applied exponential curve was $y = 47.396e^{-3.138x}$. The signal attenuation coefficient is 3.138 per inch, and after a total of 1-inch beef slices, only 4.3% of the signal remains.

RESULTS

Frequency Sweep of the Barium Titanate Receiver Output

E

Fig E: The frequency which produces the highest detected voltage output (1.04 MHz produces 23.17V)



SUMMARY, CONCLUSIONS AND FUTURE DIRECTIONS

- Despite the lower d₃₃ coefficients of BaTiO₃, the material's voltage outputs appear to be useful for neurostimulation purposes
- The signal attenuation coefficient, utilizing the 1.793 MHz ultrasound, which passes through a 1-inch phantom slab was found to be 2.387 in⁻¹ (PZT) and 4.086 in⁻¹ (BaTiO₃)
- The signal attenuation coefficient, utilizing the 1 MHz ultrasound, which passes through a 1-inch beef slice was found to be 3.138 in⁻¹ (BaTiO₃)
- Mimicking and utilizing real life tissue provided very different yet significant readings. The system is quite pressure dependent, so for future experimentation, ensure there is controlled positioning and alignment applications

REFERENCES

- [1] Y. Wu *et al.*, "From electricity to vitality: the emerging use of piezoelectric materials in tissue regeneration," *Burns & Trauma*, vol. 12, Jan. 2024, doi: <https://doi.org/10.1093/burnst/tkae013>.
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- [3] J. Gao *et al.*, "Recent progress on BATIO3-Based Piezoelectric ceramics for actuator applications," *Journal Article*, Jul. 2017, doi: [10.3390/act6030024](https://doi.org/10.3390/act6030024).

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