Wirelessly Powering Biomedical Implants Through Magnetoelectric Transducers

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SETTING THE STANDARD

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Project Objectives and Goals

- **Goal:** Safely power small biomedical implants wirelessly
- **Objective 1:** Optimize the coil transmitter subject to safety and practical system constraints
- **Objective 2:** Optimize the magnetoelectric (ME) receiver parameters to maximize the power delivered to the implant

Background

- The wireless power transfer system (WPTS) contains (i) a ME receiver consisting of laminated composite of two magnetostrictive and one piezoelectric layers, and (ii) an electromagnetic solenoid coil transmitter that generates a magnetic field used for power transfer.
- The ME receiver enables operating at lower frequencies thereby reducing losses
- There is assumed to be zero coupling between the transmitter and receiver due to the large size difference

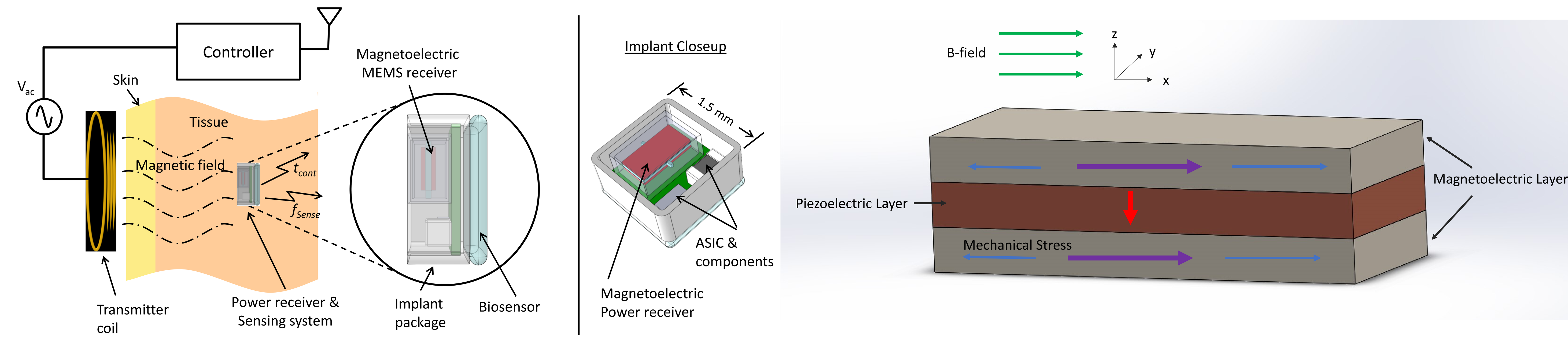


Fig. 1 **Left:** A full system representation for a ME WPTS powering an implant.
Right: A ME transducer produces a current voltage when stressed by an applied B-field

Analytical Modeling and Experimental Setup

- **Objective 1:** A mathematical model's of the WPTS transmit coil's B-field was constructed and a optimization algorithm was used to find the optimal parameters for the WPTS transmitter subject to:
  - i. B-field human exposure limits
  - ii. Either geometric or electrical current constraints

Data and Results

- **Objective 1:** The optimal design of the WPTS T_x is a solenoid whose parameters depends on the chosen constraints .
- **If the size of the transmitter is the limiting constraint:**
  - The current of the T_x coil is equal to $I = B_{safe} * \frac{R}{\frac{1}{2}\mu}$
  - The maximum achievable B-field can be expressed as a ratio, Γ, less than one multiplied by the B-field safety limit shown in Fig.2.
  - $\Gamma = \frac{a^3}{(1+a^2)^{\frac{3}{2}}}$ where the size constraint, a, is a multiple, i.e. 2x, of the implant distance , $Z_{implant}$
- **If the current is the limiting constraint:**
  - The radius of the T_x depends on the distance of the implant relative to a critical distance,
  - If the implant is located at a distance less than Z_{crit}, the radius is equal to $R_{opt} = \sqrt{2}Z_{crit}$
  - Else the optimal radius is $R_{opt} = \sqrt{2} * Z_{implant}$
  - $Z_{crit} = \frac{\frac{1}{2}\mu I}{B_{safe}\sqrt{2}}$

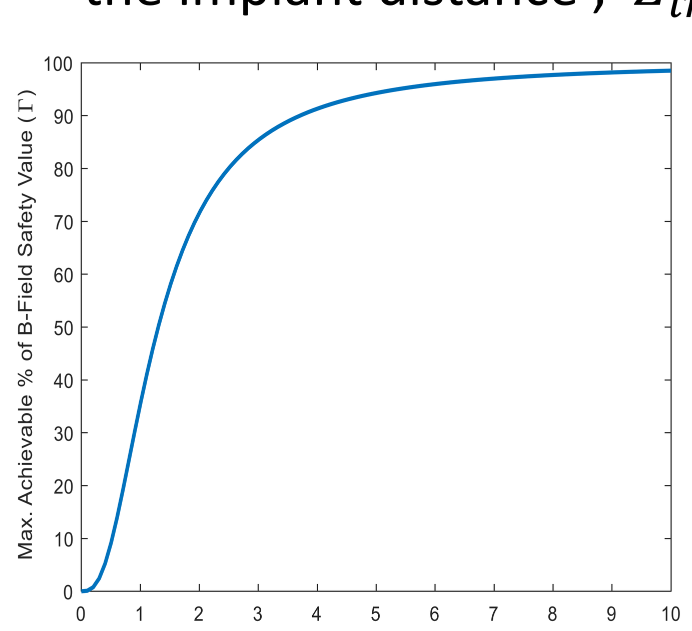
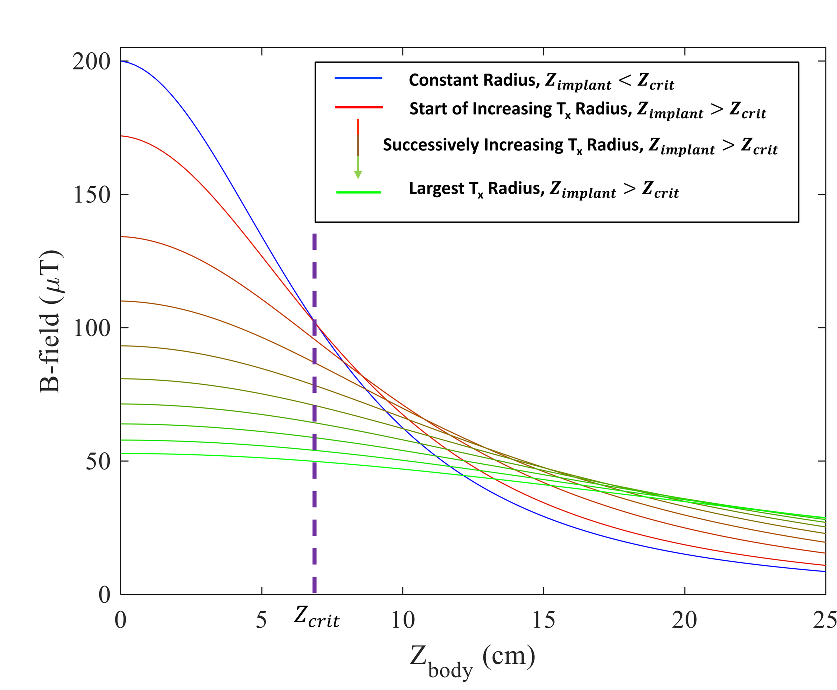


Fig. 2 The maximum achievable B-field as a function of a size constraint. For a size constraint of 2, Γ = 71 %, for a size constraint of 4, Γ = 91 %,

Fig. 3 The B-field produced by an optimal coil vs. implant depth, $Z_{implant}$, for a 30 A current limit. The blue line is the max B-field for any implant under Z_{crit}. Past Z_{crit}, the B-field flattens as the radii of the optimal coils increases.



Experimental Validations of the ME effects

Objective 2:
Based on the two-port theory, the explicit analytical solutions of, (i) the ME coefficient (defined by the derivative of the generated electric field with respect to the applied magnetic field), and (ii) the power transferred to a load resistance, are derived and rigorously validated by experiments.

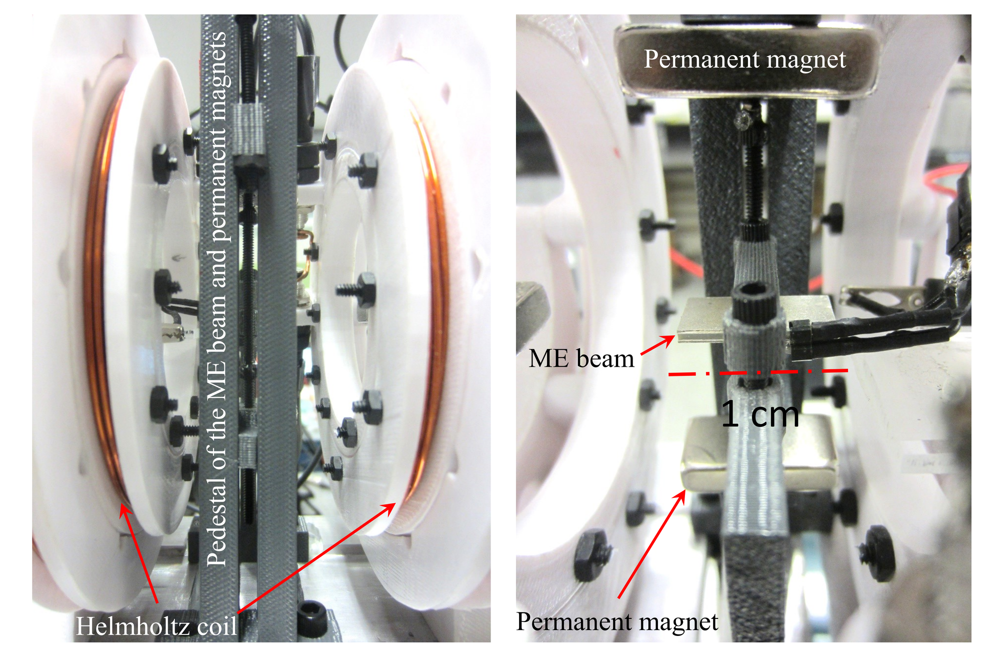


Fig. 4 Experimental setup. **Left:** a Helmholtz coil is utilized as a transmitter. **Right:** Permanent magnets are used as DC field bias and a ME beam, 1 x 0.5 cm, with two Galfenol and one PZT layers.

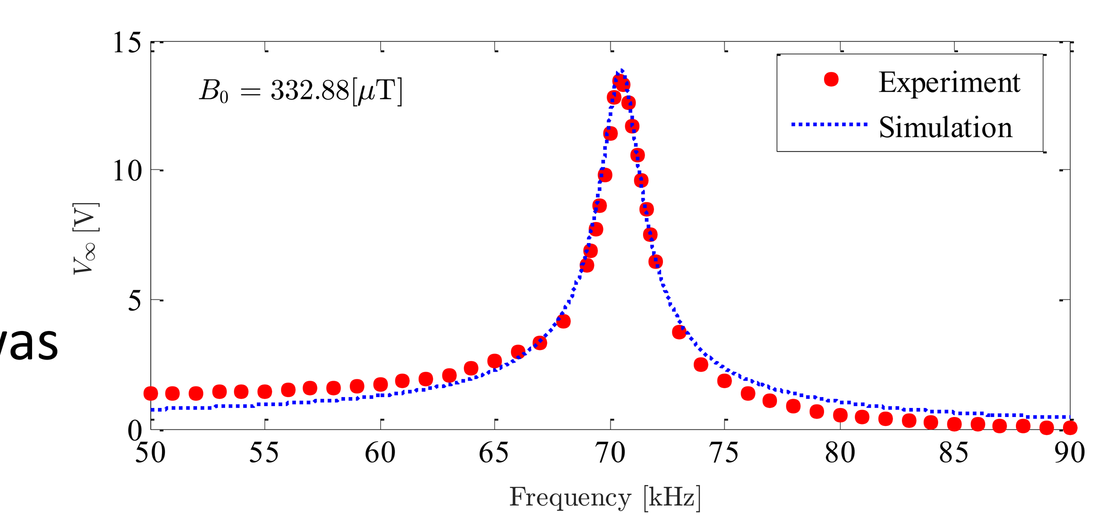


Fig. 5 Frequency response comparisons between the experimental data and simulation results by the model..

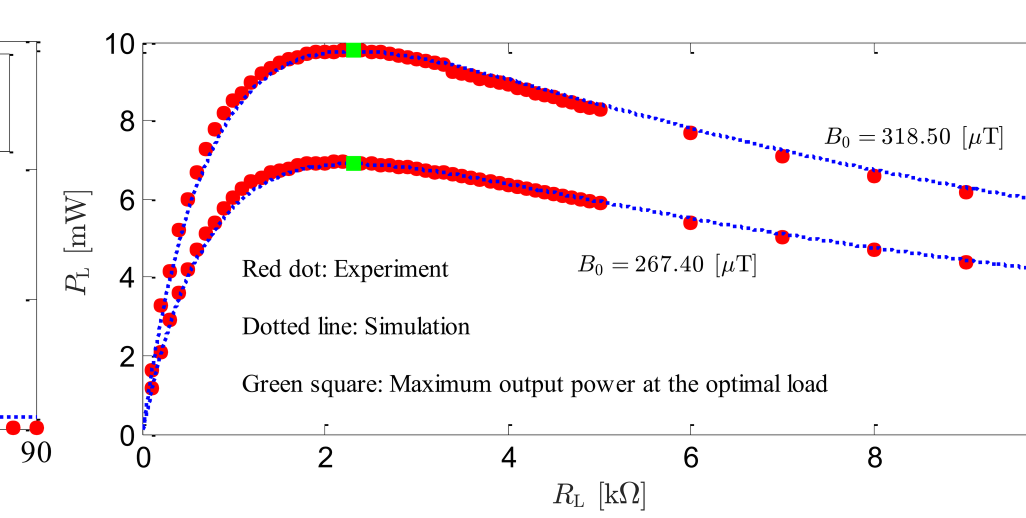


Fig. 6 Output power as a function of load resistance with different applied B-field amplitudes.

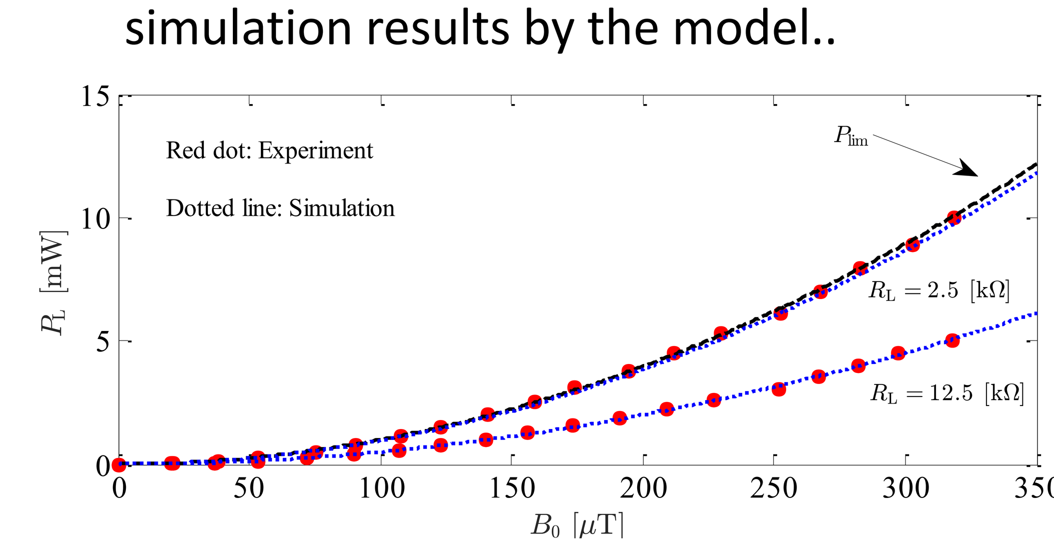


Fig. 7 Output power as a function of applied B-field amplitudes, in comparison with the limit on transferable power.

Conclusion

- We experimentally validated a model describing the physical insight of the ME effects.
- A thorough analysis and guidelines for designing an optimal transmit coil were discussed. Experimental validations of the findings were presented.

Future Studies

- Optimize the receiver parameters for maximum output power based on the validated model.
- Investigate the performances of the optimal system with optimal transmit coil and receiver.

Publications/References

E. Andersen, B. D. Truong, and S. Roundy, "Optimal Coil Design for Wireless Powering of Biomedical Implants Considering Safety Constraints," in *IEEE MTT-S Wireless Power Transfer Conference*, 2019, no. 2.

Rupp, T., Truong, B. D., Williams, S., & Roundy, S. (2019). Magnetoelectric Transducer Designs for Use as Wireless Power Receivers in Wearable and Implantable Applications. *Materials*, *12*(3), 512

Acknowledgement

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