Acoustic power transfer: the optimal electric loads of piezoelectric receivers

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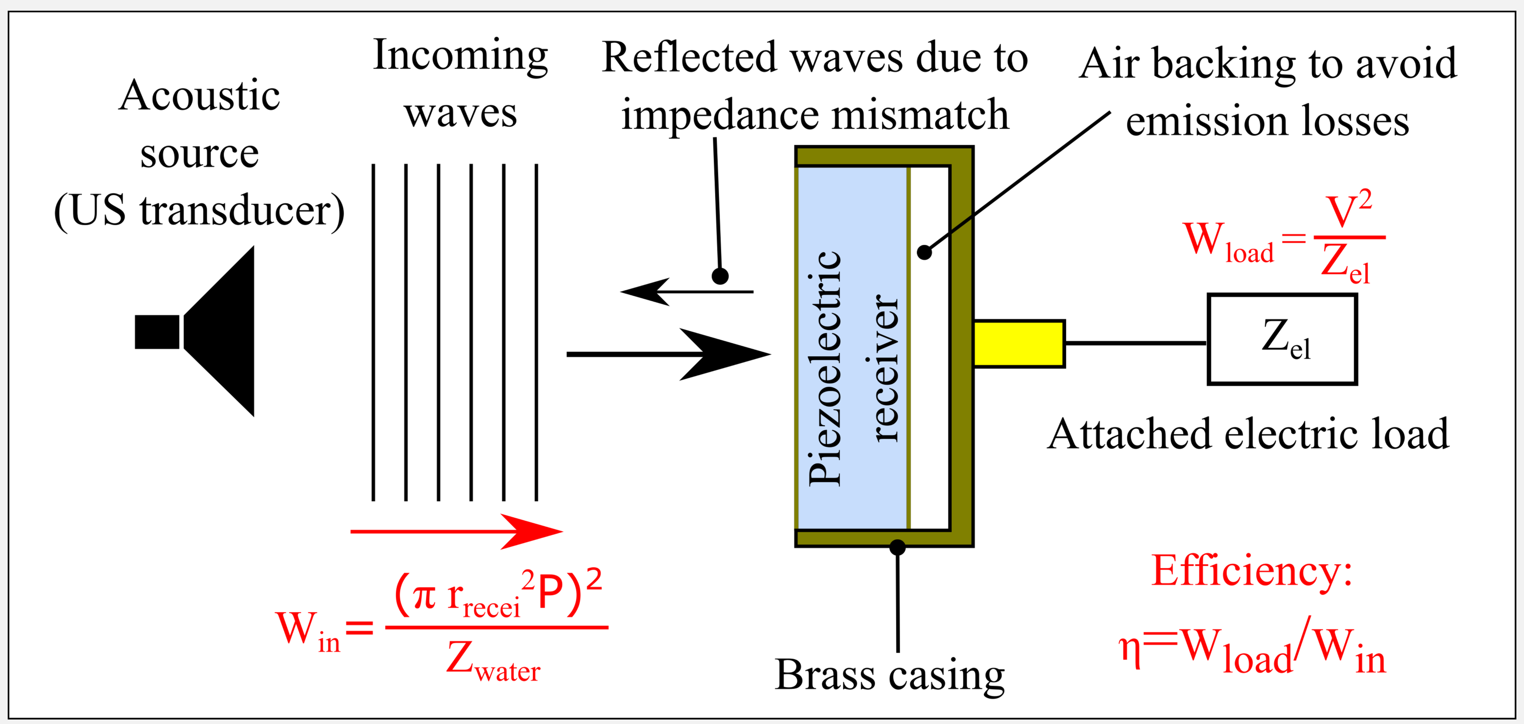
Motivation

Acoustic power transfer is an alternative to inductive wireless power transfer with some advantages, for example:

- Free choice of transmission frequency
- Larger transmission distances
- Can travel through metallic walls

Fundamentals of acoustic power receivers

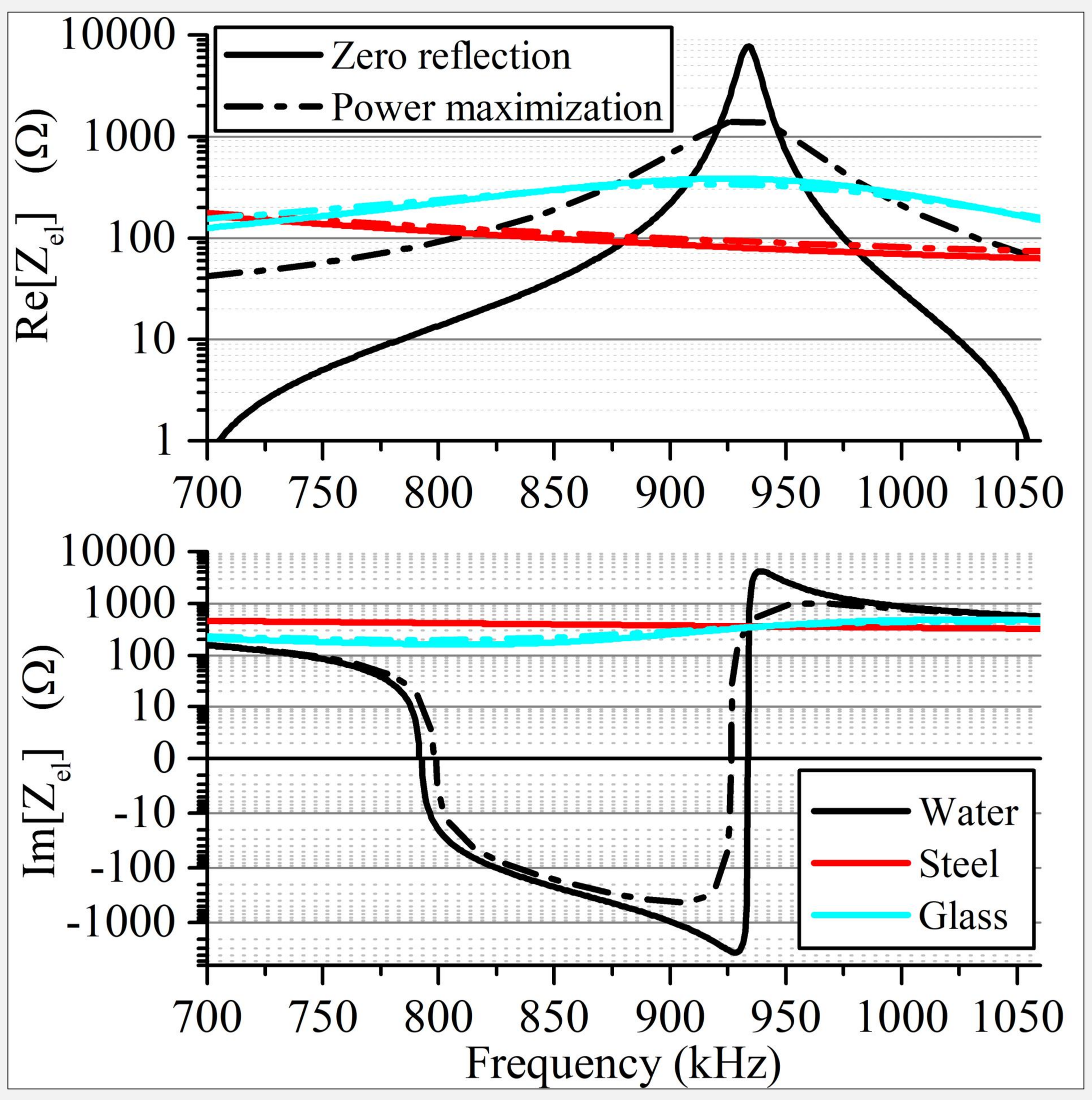
- **Goal:** Maximize the power at the load W_{load} to power implants or sensors wirelessly



- **Critical variables** that influence the efficiency:
  - Acoustic attenuation (Q_m) & dielectric losses (δ_{tn})
  - Front acoustic impedande mismatch (Reflection R)
  - Air at the back → Perfect reflection and no losses
- **Common receiver types:** pure PZT plates and composite polymer-PZT transducers

Optimal electric loads at the receiver [1,2]

- There are **two types** of optimal loads in the literature:
  Zero Reflection: supress the reflections at the receiver
  Power maximization: maximize the power at electric load
- Predictions for different front & back material combinations



- The optimal loads diverge when the losses in the receiver are high and the acoustic impedance mismatch is large

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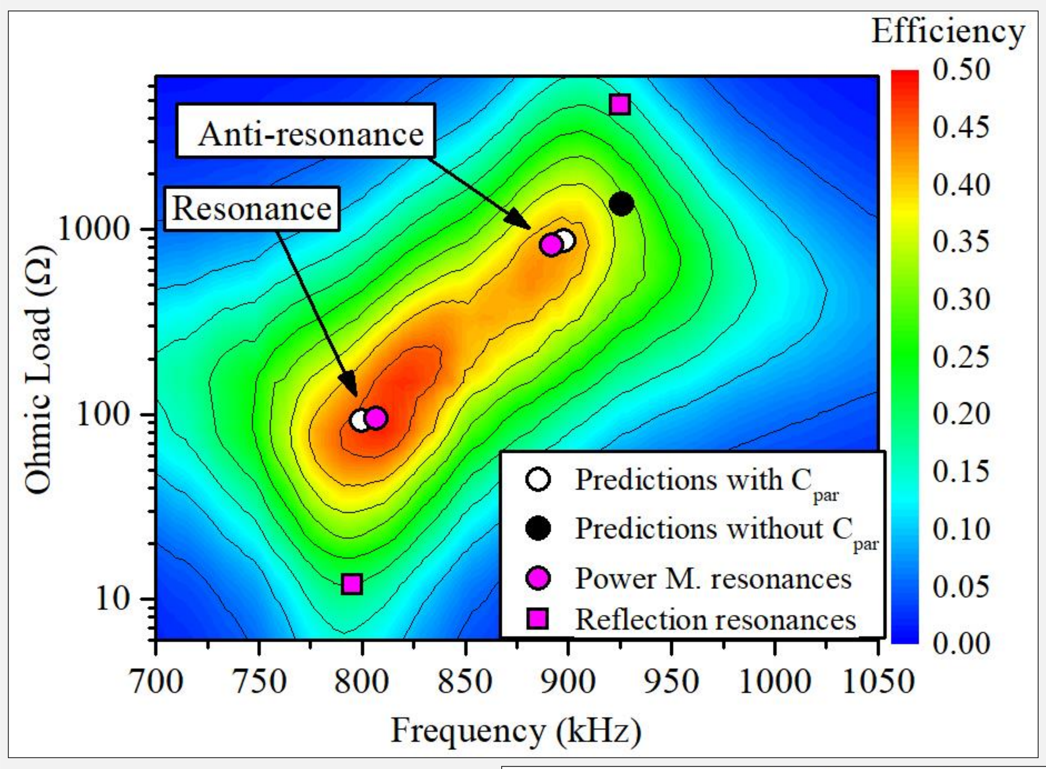
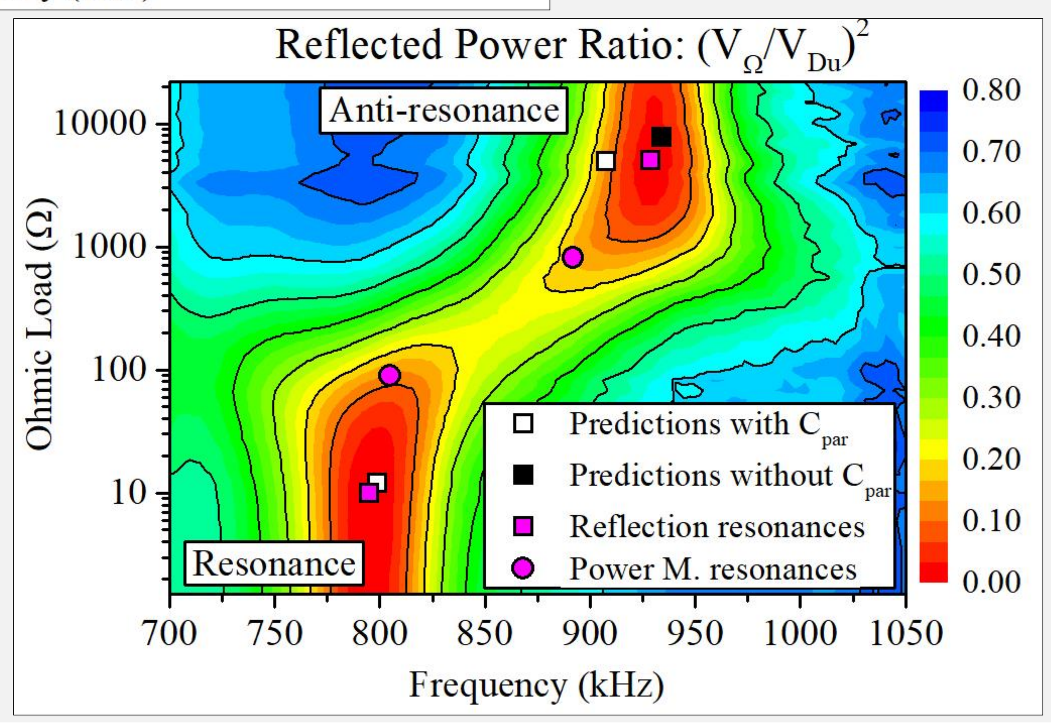
- **With Zero Reflection loads:**
  - ✓ Acoustic impedance mismatch is zero → No reflections
  - ✓ No standing wave is created between emitter and receiver
  - ✓ Energy transmission is distance independent
  - ▪ The receiver efficiency is not maximized
- **With Power Maximization loads:**
  - ✓ Efficiency is maximum→ more power for the devices
  - ▪ Acoustic mismatch → Reflections + Standing-waves
  - ▪ Standing-waves lead to pressure peaks → dangerous
  - ▪ Energy transmission could depend on the distance

Experimental results in water [3,4]

- 1-3 composite as receiver with high losses (Q_m=25)
- Reflection coefficient with water: R=-0.89



- 48% efficiency with optimal loads
- Ohmic values at the resonances (only in water)
- 130pF parasitic capacitance C_{par} was observed



- 98.5% reflection suppression at the resonances
- Power Maximization and Zero Reflection loads are different

Conclusions

There are **two types** of optimal electric loads that:

1. Supressing the reflections does not maximize the efficiency but achieves a distance independent energy transmission
2. Maximizing the power dissipation at the load could create standing-waves that may affect the acoustic power transfer

References

[1] Gorostiaga M et al. 2017 Analytic Model for Ultrasound Energy Receivers and their Optimal Electric Loads *Smart Mater. Struct.*

[2] Gorostiaga M, et al 2016 Optimal electric load prediction from the KLM model for ultrasound energy receivers *2016 IUS* pp 1–4

[3] Gorostiaga M, Wapler M C and Wallrabe U 2017 On the Optimal Electric Loads for Ultrasound Energy Receivers *IEEE ISAF-IWATMD-PFM 2017*

[4] Gorostiaga M et al. 2017 Analytic Model for Ultrasound Energy Receivers and their Optimal Electric Loads II: Experimental validation (Accepted for publication) *Smart Mater. Struct.*

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