On the Optimal Electric Load for Ultrasound Energy Receivers

M. Gorostiaga, M. C. Wapler, and U. Wallrabe
Department of Microactuators, IMTEK - University of Freiburg
Georges-Köhler-Alle 102, Freiburg, Germany D79110
wallrabe@imtek.uni-freiburg.de

In ultrasound energy transfer, the electric load at the receiver is critical for an optimized energy transfer between the emitting and receiving transducers. In this contribution, we discuss the concept of the *optimal* electric load, comparing the two different calculation approaches presented in literature. On the one hand, the zero reflection condition tunes the electric load to match the acoustic impedance of the receiver at the front face to the acoustic impedance of the transmission medium [1]. On the other hand, the power maximization approach maximizes the power dissipated at the attached electric load of the receiver [2]. So far, these two approaches have not been compared in the literature.

In [3], we saw that the power maximization and the zero reflection conditions predict an optimal electric load for each frequency, which becomes purely resistive at the special cases of the resonance and the anti-resonance. However, we found small differences in the predictions by both approaches due to the dielectric and acoustic losses in the receiver. In these preliminary experiments, we only measured the power maximization approach, and since the test-transducer had very low losses, the predictions by the two approaches were too close to clearly distinguish them experimentally. Therefore, in this paper we aim to experimentally validate the difference between the power maximization and the zero reflection conditions with a 1-3 composite disc transducer with high losses.

To compare the zero reflection and power maximization approaches, we predicted the optimal loads of the receiver, with water at the front side and air at the back side using the KLM model. The KLM model is an equivalent circuit used to simulate ultrasound transducers, which allows to straightforwardly introduce different acoustic boundary conditions and additional electric components. In the experiments, we made frequency sweeps of 75 frequencies between 0.7MHz and 1.05MHz with wave bursts sent from a distant emitter towards the receiver through water. Furthermore, for simplicity and to identify the loads at the resonance and the anti-resonance, we only tested pure ohmic loads attached at the receiver starting at 1.5Ω until 22kΩ. To see the difference between the power maximization and zero reflection approaches, on the one hand we measured the power dissipated at the attached electric load divided by the power of the incoming waves characterized with a hydrophone (figure 1). On the other hand, we measured the reflections by the receiver using the emitter as a hydrophone (figure 2), and we then compared the reflections by the loads (V_Ω) to the open-circuit and short-circuit cases (V_{Ref}).

The measurements confirm that although the zero reflection loads (12 and 2.2kΩ) maximize the energy transfer into the receiver by suppressing the reflections (figure 2), the maximum dissipation at the electric load is achieved by the power maximization loads (100 and 1.0kΩ) with less available power in the receiver (figure 1). These results lead us to conclude that the power dissipation in the receiver with air-backing also depends on the attached electric load, which is divided among the acoustic attenuation, dielectric losses and the electric load.

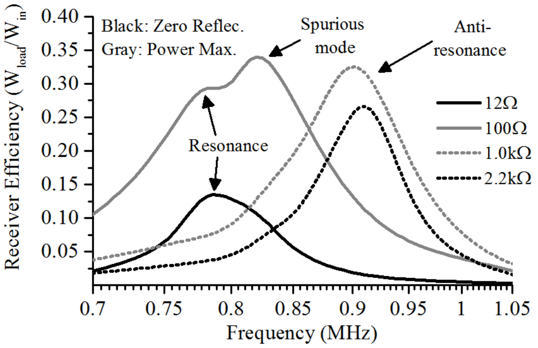

Figure 1: Comparison of the measured efficiency for the optimal loads at the respective resonances.

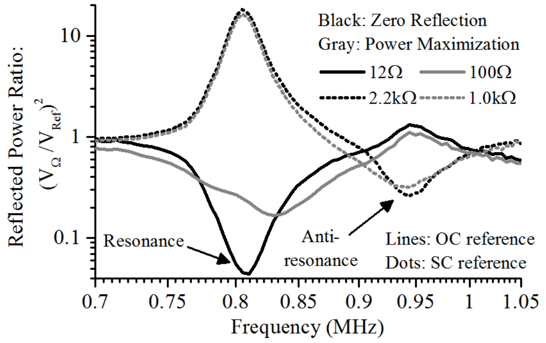

Figure 2: Measured reflected power ratios for the optimal loads at the respective resonances.

[1] S. Ozeri and D. Shmilovitz, *Ultrasonics*, May 2014.
[2] S. Shahab and A. Erturk, *Smart Mater. Struct.*, vol. 23, no. 12, p. 125032, Dec. 2014.
[3] M. Gorostiaga et al, in *2016 IEEE International Ultrasonics Symposium (IUS)*, 2016, pp. 1–4.