

Supplemental material : Experimental setup for power estimation

We present the procedure employed for determining the electric power P absorbed by the piezoceramic transducer during high-frequency actuation, usually called real power.

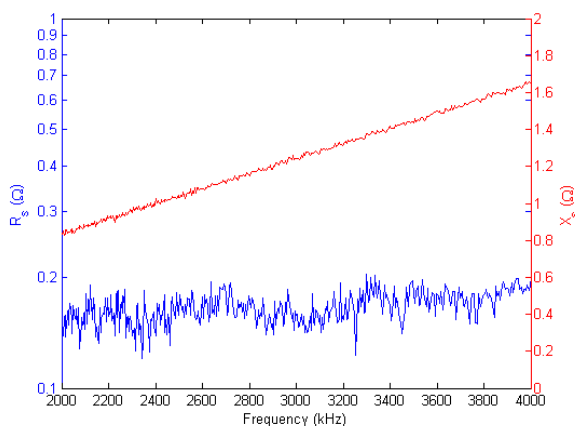


FIG. 1. Frequency-dependent, complex impedance $Z_s = R_s + jX_s$ of the shunt resistance. Scale on the left, blue curve: R_s ; scale on the right, red curve: X_s .

In general, high-frequency electric power measurement are made difficult because of spurious reactances associated to wire coupling, cables and antenna effects. In order to minimise these issues, we proceed in two steps.

First, we determine the frequency-dependent complex electric impedance of the piezoceramic Z_p and of a standard, low-impedance "shunt" resistance (*DALE* RH-50) Z_s using a *Hewlett Packard* HP4195 spectrum analyzer equipped with an additional impedance measurement module. The variation versus frequency f of Z_p and Z_s are shown in figures 1 and 2, respectively.

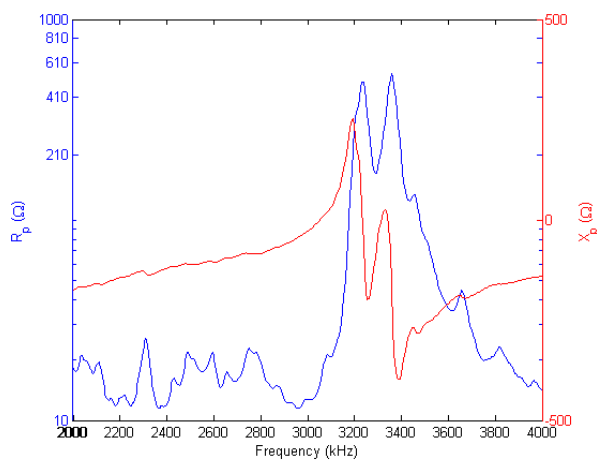


FIG. 2. Frequency-dependent, complex impedance $Z_p = R_p + jX_p$ of the piezoceramic. Scale on the left, blue curve: R_p ; scale on the right, red curve: X_p .

Then, the piezoceramic and the shunt resistance are wired in series with a function generator coupled with an *AR 75A250A* power amplifier (see figure 3), and the frequency-dependent real power P is deduced from the value of the voltage U_s measured using an oscilloscope (*Tektronix DPO 4032*) wired in parallel with the shunt resistance over the whole frequency range of interest using

$$P = \frac{1}{2} \frac{|U_s|^2}{|Z_s|^2} R_p, \quad (1)$$

where R_p is the real part of Z_p . We stress that Z_p and Z_s are determined at low voltage ($\sim 1V$). For the determination of P , we assume that both impedances are not modified in operating conditions at higher voltages.

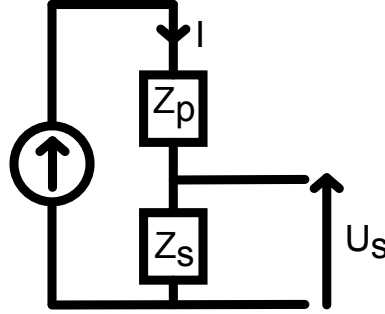


FIG. 3. Electric circuit used for measuring the active power P .

The resulting variation versus f of the active power P is shown in figure 4.

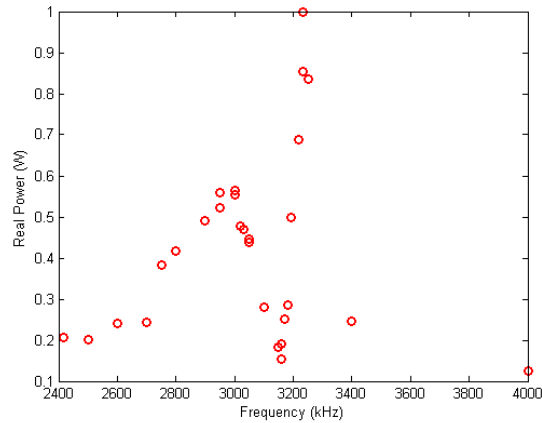


FIG. 4. Real power as a function of frequency.