

# Extending Geophone Sensitivity for Induced Seismicity Recording

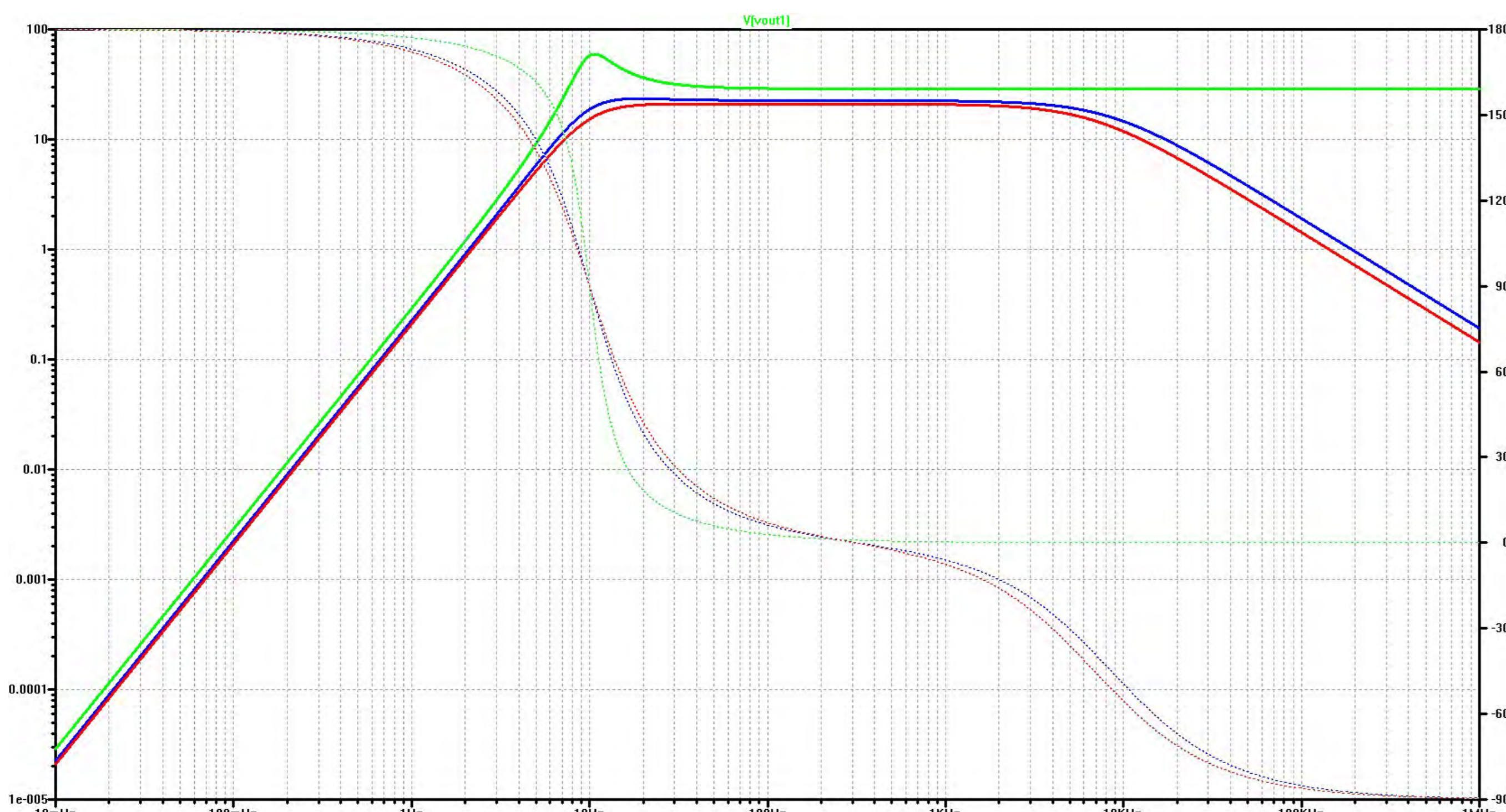
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## 1. What is the problem ?

Geophone sensors are compact, and their package is compatible with a downhole sensing application. However:

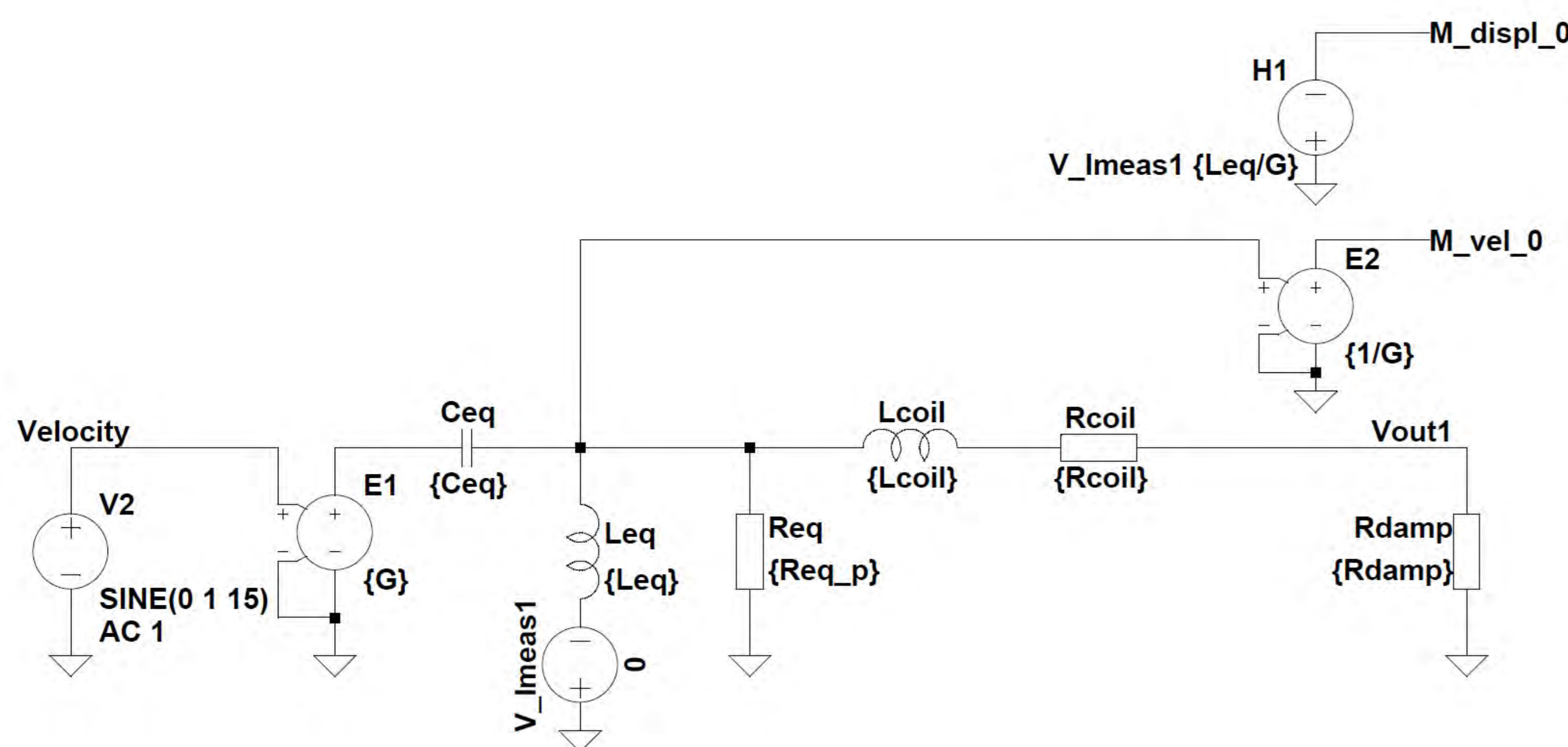
- Bandwidth is limited towards small frequencies by the suspension resonance, which may be weakly damped
- Below this resonance the frequency response falls off with 40dB/dec, thereby strongly reducing sensitivity and thus resolution .

Standard geophone frequency response curve:



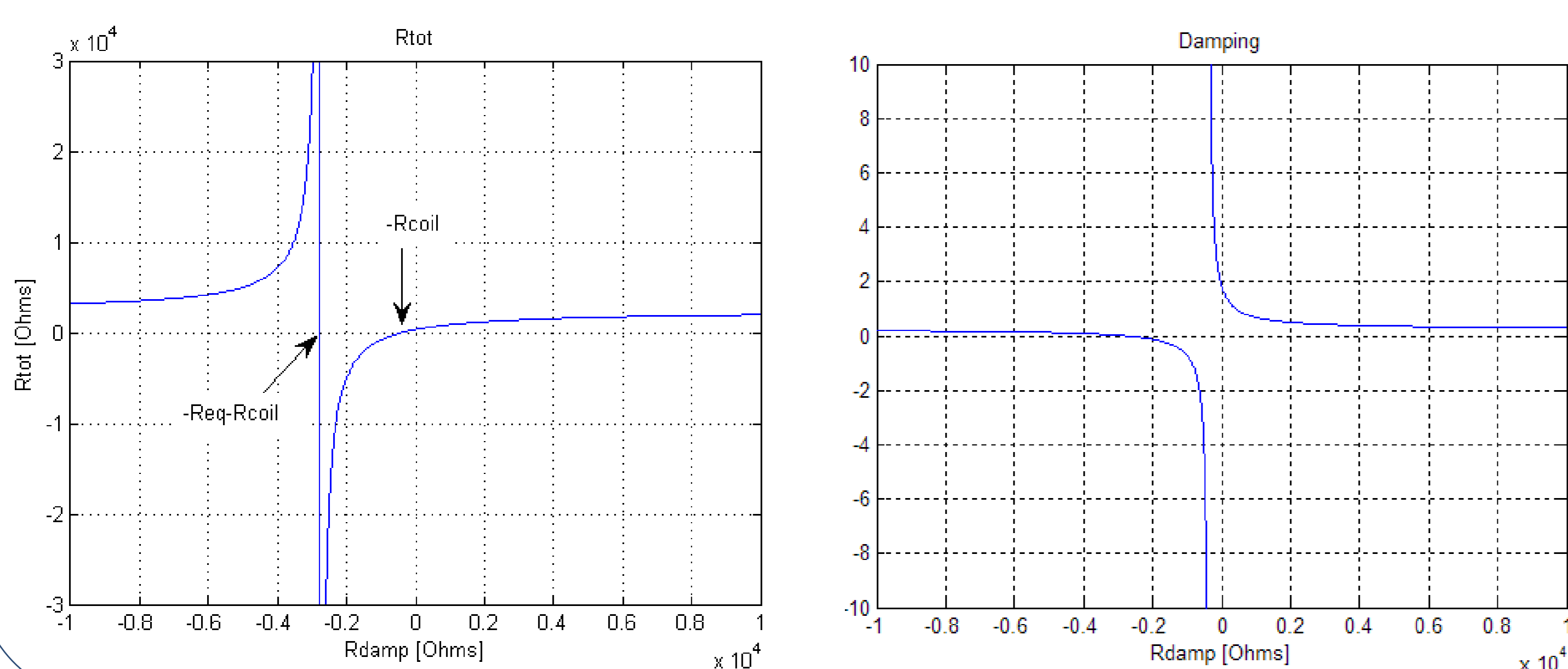
## 2. Geophone equivalent electric circuit model

The circuit model proposed hereunder comprises as well the electric circuit part, and the mechanical suspension part. Also, the couplings between them are included as controlled sources.



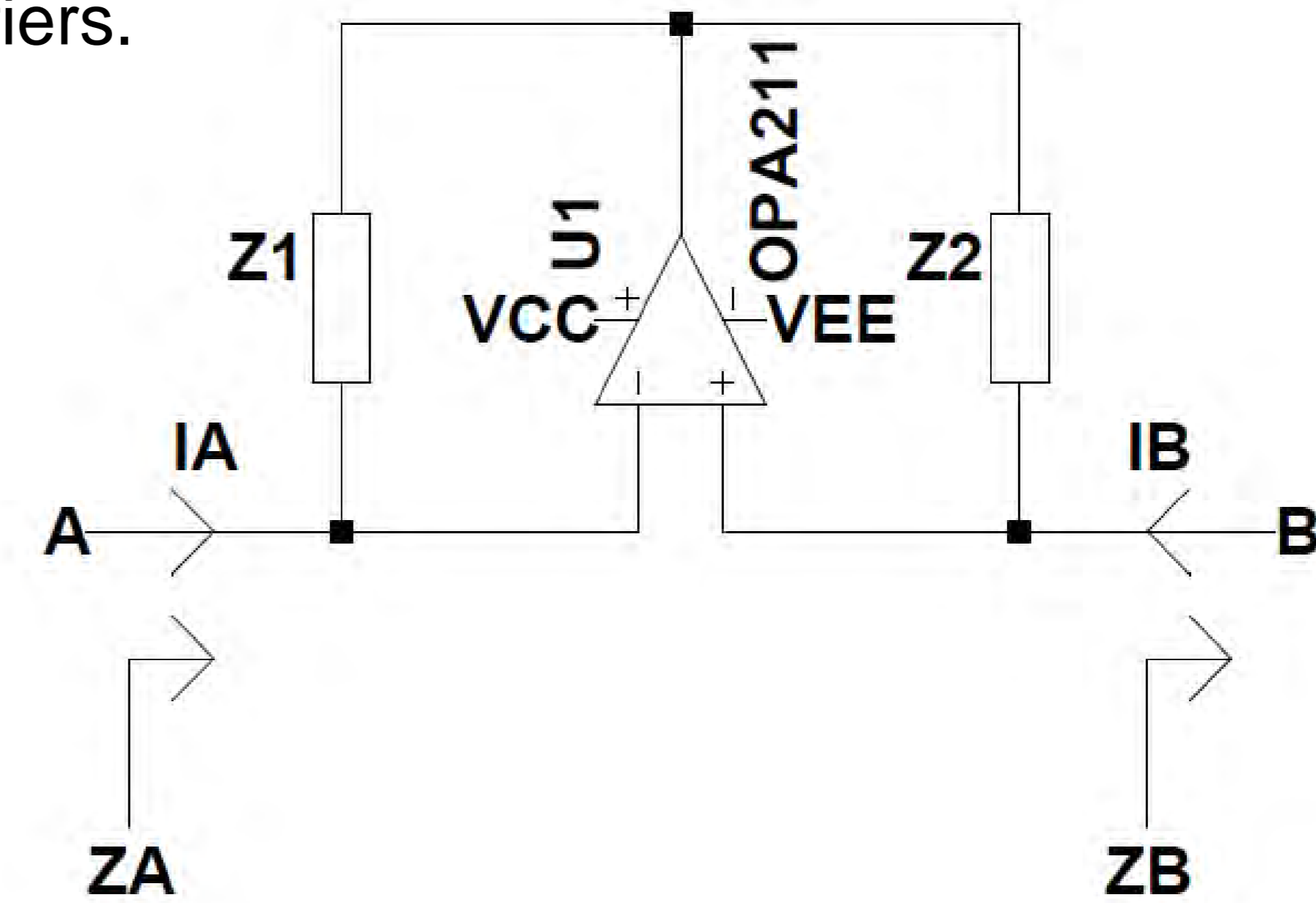
## 3. Damping and overdamping

- To modify the mechanical damping characteristic of a geophone, the standard approach is to terminate it with a load resistor. The smaller the resistor value, the stronger the damping effect becomes.
- If the resistance is made zero (short circuit), the strongest passive damping is achieved. The output short circuit current represents then the measured signal.
- By making the resistance value negative, overdamping is realized. In this case, a roll-off of 20dB/dec of the geophone frequency response can be achieved, thus reducing its loss of sensitivity at low frequencies.



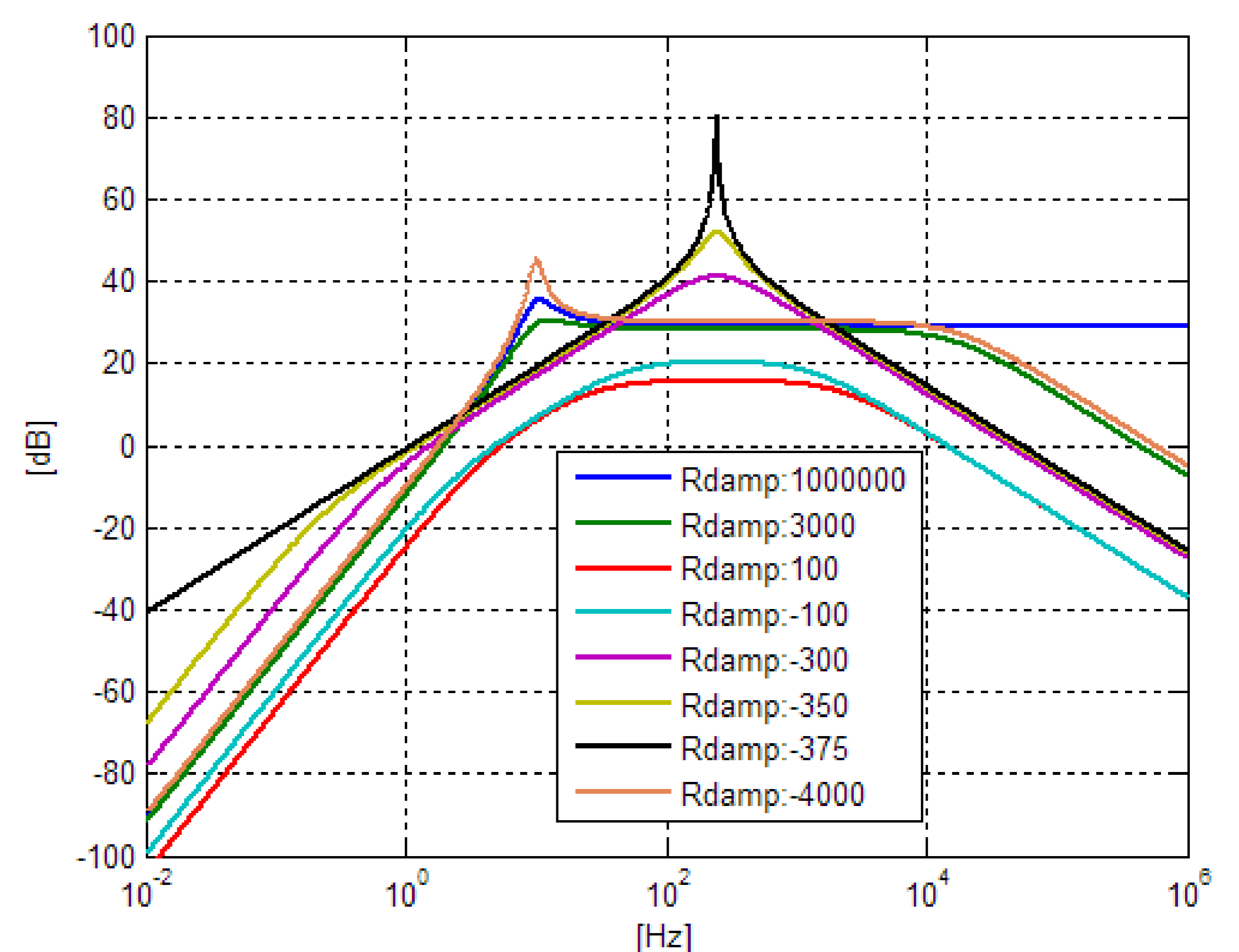
## 4. Negative impedance converter

- A negative impedance converter (NIC) is an electronic circuit realizing a negative resistance or impedance value. It is an active circuit.
- The NIC can be thought of as being composed by gyrators, a theoretical circuit element realized with an operational amplifiers.



## 5. Modified geophone frequency response

As a function of damping resistances, positive and negative, modified geophone frequency responses are shown below.



## 6. Integration of the frequency response

- To further improve the low frequency sensitivity, the output of the geophone can be integrated before digitization, as shown below.
- Alternatively, a first order low-pass or second order band-pass filter can be used.
- A similar high-pass effect is obtained if the NIC is used to compensate not only the resistance, but also the inductance of the coil.

