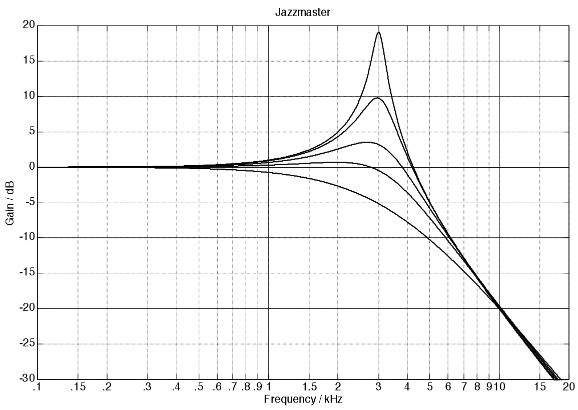
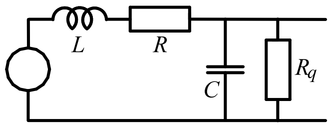
5.5.4 Resonance quality factor *Q*

The interaction between inductivity of the pickup (approx. 2 – 10 H) and the capacitance of the cable (approx. 300 – 600 pF) forms a resonator with a resonance frequency in the range of 2 – 5 kHz. The **quality factor** *Q* is a measure for the resonance dampening. A strong dampening results in a low quality factor, weak dampening makes for a high quality factor. A small *Q*-factor must not be equated with 'bad'. A high *Q*-factor implies that the pickup frequency response has a strong resonance emphasis at the resonance frequency. Its effect can be equated to that of an equalizer boosting a certain frequency band (presence filter). Give that the equivalent circuit of the pickup includes only *one single* coil, *one single* capacitor plus resistors, the resonance quality factor can be stated unambiguously. If, however, skin effects and eddy current losses require a more complex equivalent circuit, it is necessary to define several poles with several *Q*-factors. A *single* value for the *Q*-factor can only be specified as an approximation.





$$H = \frac{1}{1 + \frac{p(RC + L/R_q)}{1 + R/R_q} + \frac{p^2 LC}{1 + R/R_q}}$$

$$Q = \frac{\sqrt{LC(1 + R/R_q)}}{RC + L/R_q}$$

Fig. 5.5.7: Varying resonance emphasis for a Jazzmaster pickup. Different parallel resistors result in different resonance dampening, or different resonance quality factors *Q*.

Fig. 5.5.7 shows the low-pass transmission of a **Jazzmaster** pickup. Setting the denominator-polynomial to zero results in two poles of the transfer function (2nd-order low-pass). Different resonance dampening can be achieved by varying the parallel resistance R_q. The *Q*-factors associated with the 5 graphs in the figure are: 9,0 ; 2,5 ; 1,4 ; 0,9 ; 0,5. The highest *Q*-factor ($Q = 9$) belongs to the lowest dampening with an emphasis of 19,1 dB. This behavior can be achieved by loading the pickup exclusively with a 600-pF-capacitor. The results would be, however, not very usable since it produces a shrill, whistling guitar sound. In normal use the pickup is not just working in conjunction with a purely capacitive load but also with parallel resistors constituted by the volume- and tone-controls plus the input impedance of the amplifier. With these components, we arrive at a $Q \approx 3$. The **resonance emphasis** seen in Fig. 5.5.7 can approximately be estimated via 20 lg(*Q*) in dB. For low *Q*-factors, this approximation becomes increasingly inaccurate, though.

The resonance *Q*-factor is the second-most important transmission parameter right after the resonance frequency. The above calculation shows, however, that the *Q* is dependent on the connected circuitry. Already a change in length of the guitar cable results in a change of the *Q*-factor (see also Fig. 9.14). Consequently, specifying a *Q*-factor value is problematic: the *Q*-factor of the disconnected pickup does not allow for any conclusions regarding the *Q*-factor of the installed pickup. Even the *Q*-factor of the pickup combined with the other components in the guitar is not very meaningful. Only after additionally specifying cable and amplifier, a value for the *Q*-factor can purposefully be interpreted.

Even more problematic is specifying the *Q*-factor for pickups which contain further metal parts on top of magnet and coil. From a systems-theory point-of-view they represent systems with an order of higher than 2. Stating a single *Q*-factor value is insufficient. The specification of a resonance emphasis in dB is ambiguous, as well, since despite equal emphasis different band-widths are possible. **Fig. 5.5.8** compares a measured and a calculated transmission curve. For both cases, *low-pass* behavior (not band-pass) was taken as a basis, and *one single* coil of a Gibson Humbucker was measured. The slugs (polepieces) make for pronounced eddy-current losses with skin-effects contributing, and thus a system of higher order results. The 2nd-order transfer function shown in comparison has in principle a similar shape but clearly differs.

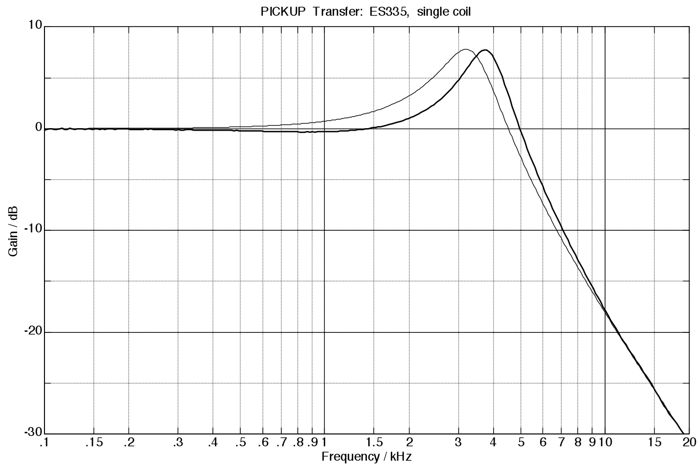


Fig. 5.5.8: comparison of a measured transmission curve (bold) with a calculated curve (fine). Despite the same emphasis height and equal asymptotes, the shapes are different.

In closure it needs to be noted that – in contrast to the resonance quality factor Q – the quality factor Q_L of the coil itself has even less significance. In the *RL*-series equivalent circuit of a coil the *Q*-factor of the coil is defined by $Q_L = 2\pi f L / R$. It is dependent on the frequency and therefore subject to an arbitrary frequency definition. For example, DUCHOSSOIR defines the coil-*Q*-factor at 1 kHz and lists *Q*-factors of 2,1 to 3,5 for the Stratocaster pickup. **Fig. 5.5.9** shows how small the effect of the coil-*Q*-factor is on the transmission behavior. Increasing the coil resistance *R* by 50% decreases Q_L by 33% but changes the resonance emphasis only very little.

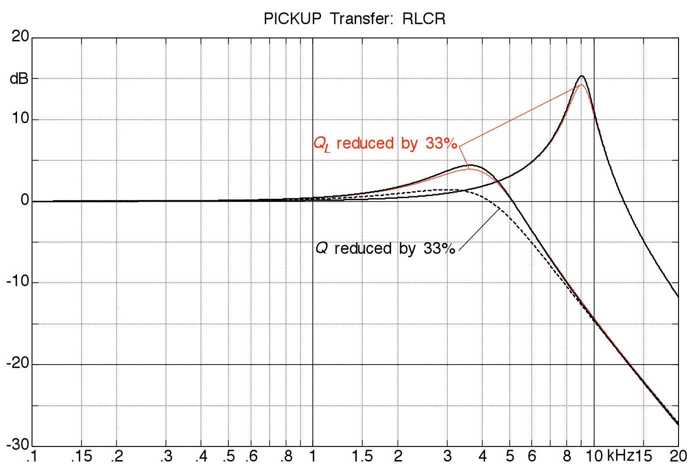


Fig. 5.5.9: transfer Function. Disconnected Stratocaster pickup (resonance at 9 kHz), and with 111 kΩ load plus 600 pF cable capacitance. The thin lines show the transmission behavior with a coil resistance increased by 50% i.e. a coil-Q-factor reduced by 33%. For comparison, a 33% reduction of the Q-factor is shown by the dashed line.