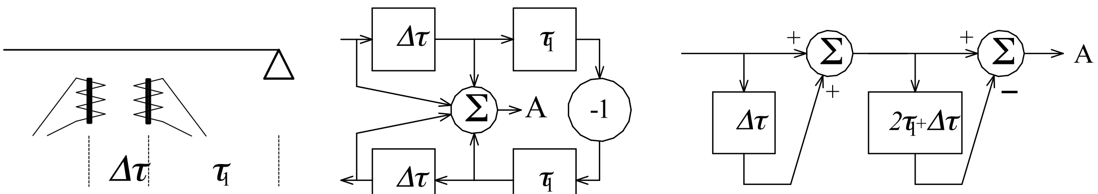
2.8.3 String with humbucking pickup

In the hum-cancelling humbucking pickup, two coils are connected in opposite phase. In order for the electrical output signals to interact constructively, the magnetic permanent flux is reversed in one of the coils. Many pickups (e.g. Gibson) generate the permanent field using a bar magnet located under the coils; the field is conducted through the coils using so-called pole-pieces. Other designs (e.g. Fender) use 6 individual magnets in each coil; in one of the coils, the north-pole is directed upwards, in the other it is the south-pole. The two coils are usually connected serially in opposite phase; opposite-phase parallel connection is less common.

The humbucker samples a wave running along the string at two adjacent areas. The distance between the two pole-pieces is 18 mm for the Gibson Humbucker – there are, however, also very narrow humbuckers that fit into the housing of a regular single-coil pickup.

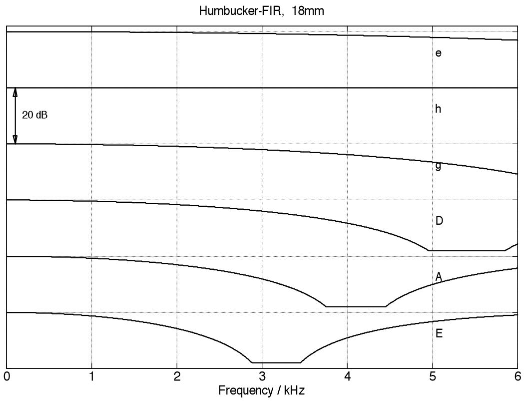


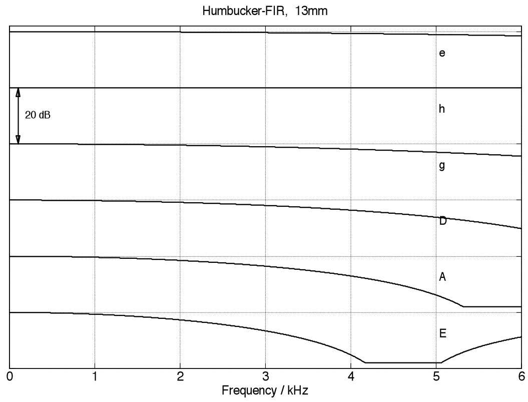
$$\underline{H}(j\omega) = 1 + e^{-j\omega\Delta\tau} - e^{-j\omega(\Delta\tau+2\tau_1)} - e^{-j2\omega(\Delta\tau+\tau_1)} = \left(1 + e^{-j\omega\Delta\tau}\right) \cdot \left(1 - e^{-j\omega(2\tau_1+\Delta\tau)}\right)$$

Fig. 2.36: Signal flow diagram for a humbucking pickup with two equivalent coils.

In **Fig. 2.36**, τ_1 represents the (single) delay time between the coil located closer to the bridge and the bridge, while $\Delta\tau$ is the delay between the two coils. Using suitable conversion, we arrive at a simple ladder-network of two FIR-filters. The first filter models – with same-phase superposition – the delay time $\Delta\tau$ between the coils; the other filter emulates – using opposite-phase superposition – double the delay time between the middle of the humbucker and the bridge. The humbucker positioned at a location x differs from a single-coil pickup located at the same position only in the $\Delta\tau$-filter. The modeling as ladder network offers the considerable advantage that the overall transfer function can be represented as the product of the individual transfer functions. Given a humbucker with a distance between pole-pieces of 18 mm, we get an additional **signal cancellation** for the E_2-string in the range around 3 kHz; for the higher strings, the humbucker-minimum is located at correspondingly higher frequencies. The exact frequency of the minimum depends not only on the pole-piece distance, but also on the dispersion (Chapter 1.3)

As is shown in **Fig. 2.37**, the differences between single-coil pickup and humbucker are string-specific: for the E_4-string, only small variations in the treble range will be recognizable, while for the E_2-string, the humbucker will absorb the 3-kHz-range that is important to obtain a brilliant sound. Reducing the distance of the two humbucker coils to 13 mm (as it was done e.g. in the **Mini-Humbucker** fitted to the Les Paul Deluxe) will shift all interference-minima toward higher frequencies. A particularly small distance of the coils (7 – 9 mm) is realized in the single-coil format; still, a treble loss remains for the low strings.





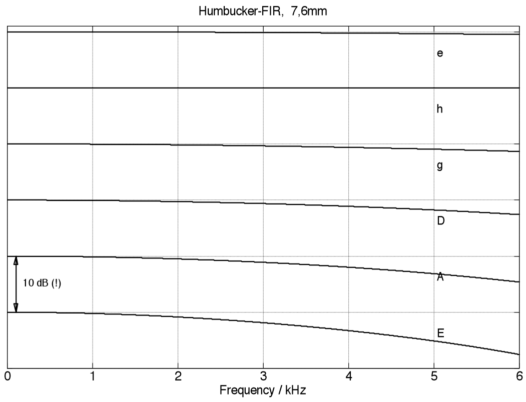


Fig. 2.37: Comb filtering caused by the humbucker delay time $\Delta\tau$. Distance of the poles typical for the Gibson Humbucker: 18mm; for the Mini-Humbucker: 13mm. 7,6mm can be found in humbuckers in single-coil format (e.g. DP-184). The minima of the comb-filter graphs were cut to obtain a clearer representation. Dispersion was considered (Chapter 1.3).

If the two humbucker coils do not feature the same sensitivity in both coils, we get differences in particular in the range of the humbucker-minimum (**Fig. 2.38**). Such **imbalances** have their roots in different numbers of the turns of the coils (deliberately produced for the *Burstbucker*) and/or in the field guides: the pole pieces in the shape of slugs have a different magnetic resistance compared to the threaded pole-screws. For differing coils, the SFD may not be separated into two FIR-filters, and thus Fig. 2.38 shows the frequency responses of the overall signal flow diagram.

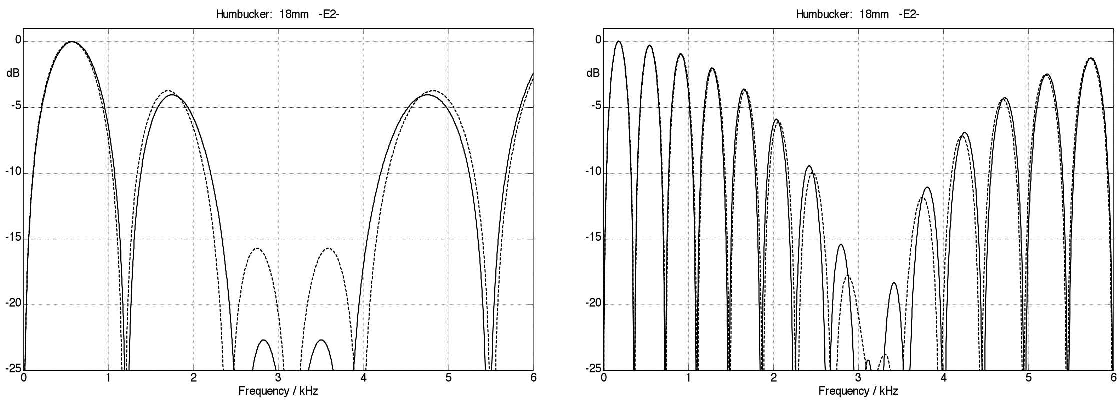


Fig. 2.38: Magnitude frequency responses for unmatched humbucker coils. Left: bridge humbucker (distance to bridge 45 mm); right: neck humbucker (distance to bridge 147 mm). The sensitivity of the coil with threaded pole pieces (screws) is better by 1 dB compared to the "slug"-coil (——), or smaller by 1 dB (---). Dispersion was considered (Chapter 1.3).

For a Gibson ES-335 TD (E_2-string), **Fig. 2.39** considers the transfer function of the equivalent circuit established in Fig. 2.36. In **Fig. 2.40**, the RLC-transfer-function (Chapter 5-9) is added in. Via **Fig. 2.41**, we can compare a measurement. For all graphs, dispersive wave propagation was included.

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Fig. 2.39: Gibson ES335, E_2-string, model without RLC-filter. Left: bridge pickup. Right: neck pickup.

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Fig. 2.40: ES335, E_2-string, model with RLC-filter and 707-pF-cable. Left: bridge pickup. Right: neck pickup.

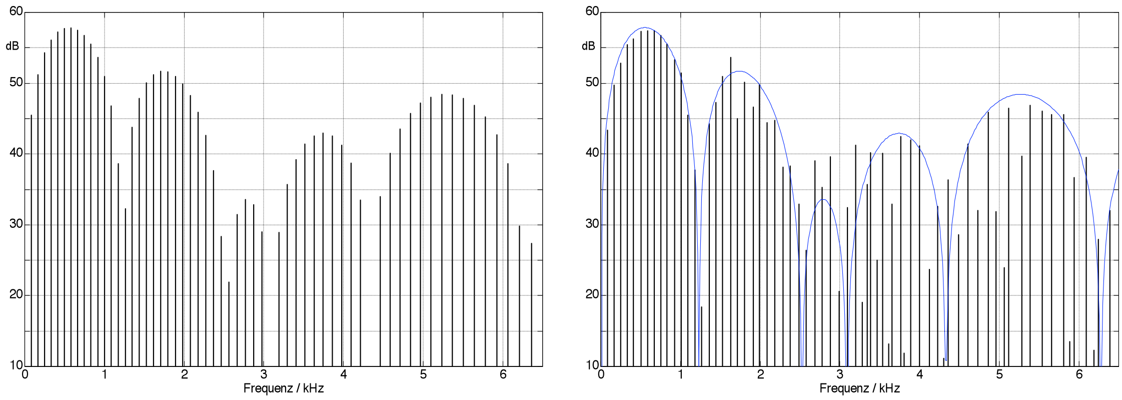

Fig. 2.41: ES335, E_2-string plucked directly at the bridge; bridge pickup. Left: model calculation; right: measurement. The differences do not refute the basic model assumptions; rather, they indicate how important the modeling of both strain-wave and bearing impedances is – this was not included here.

 Translation by Tilmann Zwicker