6.10 Differences to the magnetic pickup

Compared to guitars that use one or more magnetic pickups as transducers for the sound, guitars fitted with a piezo pickup sound different (when operated with an amplifier). There are mainly two reasons for this: the transmission range of the pickup, and its position on the guitar. The lower cutoff-frequency of the transmission is sufficiently low for both transducer-types; the upper limit, however, differs: it is 20 kHz for the piezo pickup but only 2 – 5 kHz for your regular magnetic pickup. It would not be a particular problem to radically change the treble response: without any capacitive loading, the magnetic pickup can deliver signals up to 15 kHz as well, and conversely an increase in the mass of the bridge for the piezo pickup can reduce its upper cutoff frequency. However, the piezo pickup typically will "give more treble" than the magnetic pickup.

The magnetic pickup is **positioned** about 3 – 15 cm away from the bridge – mounting it *within* the bridge is disadvantageous because here the string-velocity that needs to be captured is almost zero. The piezo pickup, on the other hand, can only be mounted in the bridge (if we disregard transducers stuck to the guitar top as they have become less important). According to the theory of linear time-invariant systems [6], every signal exciting the strings can be interpreted as the sum of super-positioned impulses. Each of these impulses runs along the strings as a wave (Chapter 2) and is reflected at the bridge and at the nut (or fret). Within *one* round (1 period) it therefore passes the position of the magnetic pickup *twice*. The delay time between both passes results from twice the distance between pickup and bridge, divided by the phase-velocity of the transversal waves♣. Since the transversal wave captured by the magnetic pickup is reflected at the bridge with opposite phase, the double-sampling acts like a filtering with sine-magnitude frequency response (comb-filter):

$$\underline{H} = 1 - e^{-2p\tau} = (e^{p\tau} - e^{-p\tau}) \cdot e^{-p\tau} \quad \rightarrow \quad |\underline{H}| = 2\sin(\omega\tau) \qquad \text{Comb-filter}$$

In this equation, τ stands of the (single) travel time between pickup and bridge. Disregarding any dispersion-effects, the zeroes of the comb-filter lie at the integer multiples of $f_0 = f_G \cdot M/d$, with f_G = fundamental frequency of the string, M = scale, d = distance between pickup and bridge (**Fig. 6.28**). Due to the dispersive propagation of the transversal waves, we get a spreading of the zeroes towards high frequencies (Chapter 1.3).

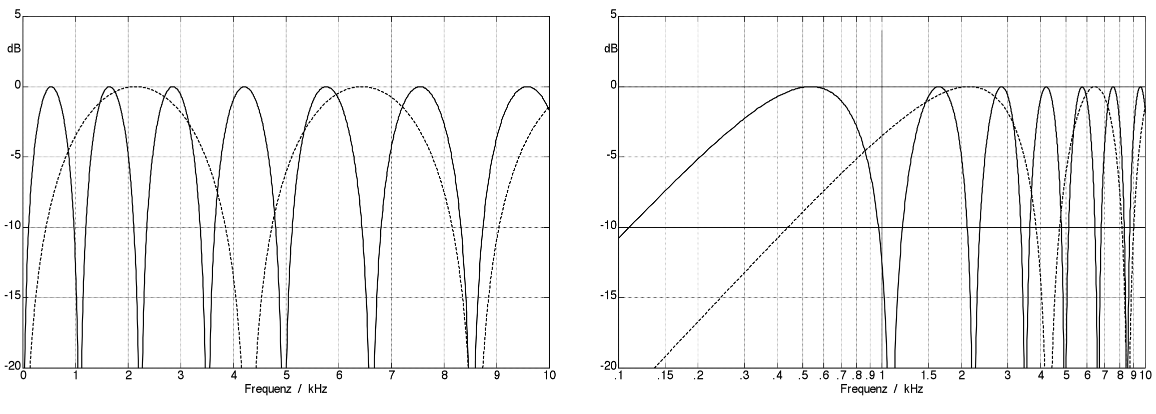

Fig. 6.28: Normalized comb-filter frequency responses. E_2-string (——), E_4-string (----); d = 5 cm, M = 65 cm. "Frequenz" = frequency.

♣ We could also use twice the distance between pickup and <u>nut/fret</u> here; the results would be different at first but can be reformulated into an equivalent model..

Because misunderstandings can easily happen when we term the transmission coefficient of a magnetic pickup as “comb-filter-like”, let’s be precise: the transmission coefficient of velocity→voltage is of a low-pass characteristic if “velocity” indicates the local string velocity over the magnet of the pickup. With respect to the velocity of the transversal *wave*, the mentioned comb-filter comes into play in addition to the low-pass characteristic (low-pass and comb-filter serially connected), if one oscillation period is observed as the timeframe. For the steady state (very long time-window, no dampening), this frequency-continuous transmission function is to be sampled at the locations of frequencies of the partials (frequency-discretization).

For the **piezo pickup**, it is force at the bridge rather than the velocity that forms the input signal to the transducer – though of course for both the initial source is the wave travelling on the string. To compare with the magnetic pickup, it is conducive to specify the same input signal for both transducers, for example the (particle) velocity of the transversal wave. Since the wave-impedance is real, we have proportionality between the velocity of the propagating wave and the respective force; and because the force-wave is reflected at the bearing with the same phase, the bearing-force is also proportional to the velocity of the transversal wave. We arrive at the following **conclusion**: starting from the transversal-wave velocity (the particle velocity of a propagating transversal wave), the piezo pickup mounted in the bridge practically transmits independently of the frequency. If the electrical load-impedance requires it, we may need to consider a high-pass with a cutoff-frequency of about 200 Hz in some circumstances (Chapter 6.5). Conversely, the magnetic pickup will generate string-specific comb-filtering. The further the pickup is located away from the bridge, the closer the “prongs” of the comb-filter will be (**Fig. 6.29**).

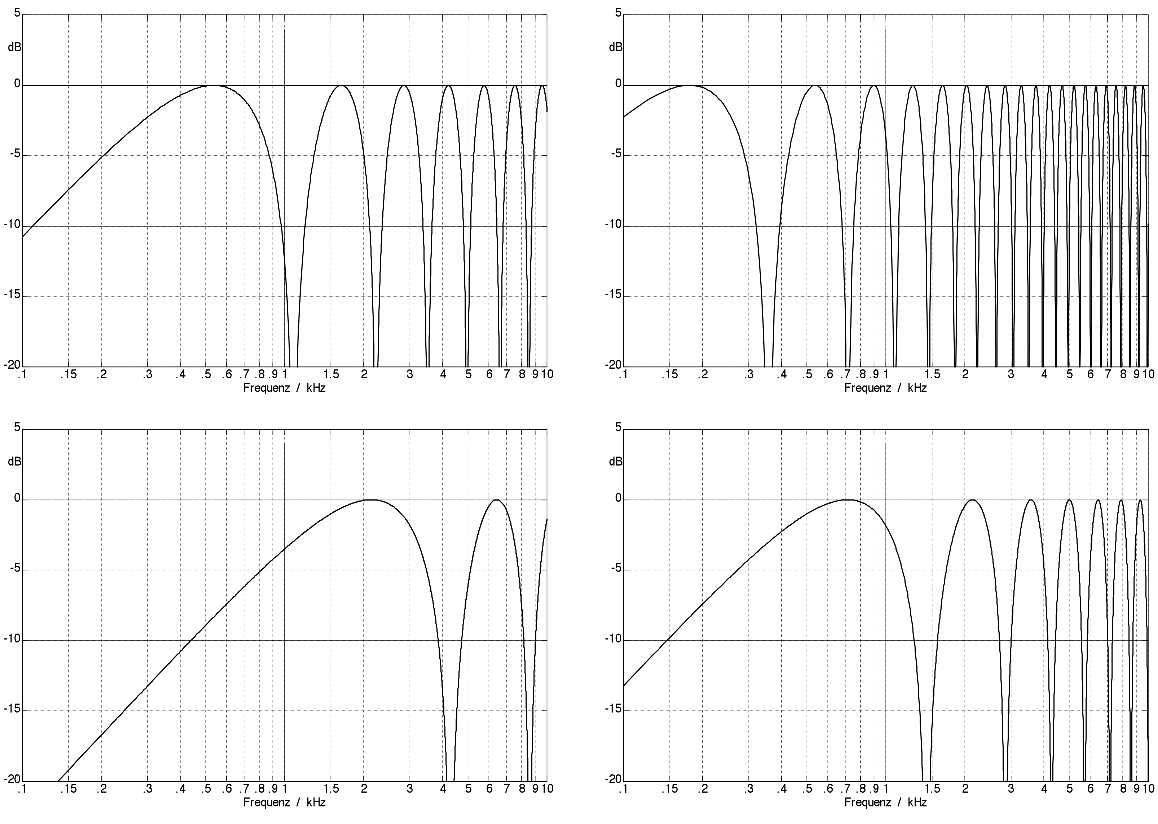

Abb. 6.29: Normalized frequency responses of the comb-filter. E_2-string (top), E_4-string (bottom); M = 65 cm. d = 5 cm (left), d = 15 cm (right). “Frequenz” = frequency.

