7.7.3 Winding attenuation

When considering internal damping of a string, its structure must be taken in to account. Solid strings (most often E4, B3, G3) are made of solid wire of spring steel whereas bass strings (E2, A2, D3) are wound. The G-string may be plain or wound. Strictly speaking, the term "internal damping“ only identifies the dissipation losses *in the metal*. Within the wound string, however, there are also the contact surfaces between core wire and winding wire, and here (as well as between the turns of the winding) **friction** is generated and consequently energy dissipation (= damping). Measurements of the decay behavior of new strings indicate that the decay times of partials in *solid* strings are close to the values calculated on the basis of the model. *Wound* strings, however, may be described using the formula given in Chapter 7.7.2. If the outer diameter is used (as it is with solid strings), the calculation for high-frequencies results in much too short decay times, but taking a reduced "effective“ diameter will yield an arbitrary result.

That a simple formula for wound strings cannot exist, is shown by the following experiment: on a US-Stratocaster, two brand-new D-strings from two different manufacturers were measured (**Fig. 7.65**). Although the analysis for the two strings was done one right after the other, on the same guitar, and using the same slot in the nut, the decay times differ very significantly. This can only be explained by significant differences exhibited in the windings of the two strings. It is far beyond of the aim of the present work to investigate the material-specific and structure-specific reasons of these differences; instead, the empirically found **best-case measured values** are given in the following diagrams, facilitating orientation and assessment of the results. The majority of the measured decay times were shorter than the given orientation values, but in individual cases they were slightly longer.

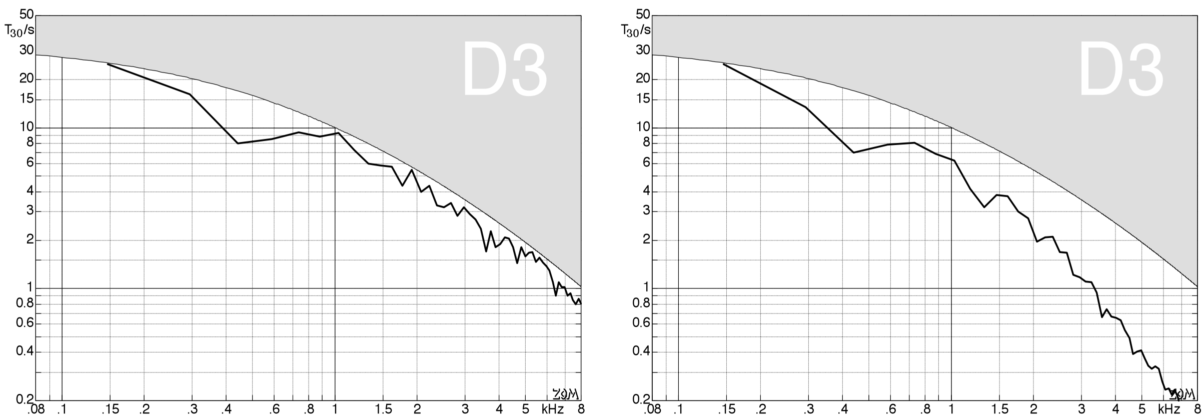

Fig. 7.65: Decay times of partials, Stratocaster; comparison of two D-strings (0.026" each, wound, brand-new). The grey area (“orientation line”) estimates an upper limit of T_{30} due to radiation and internal damping.

In **Fig. 7.66**, the decay times of the partials of the open strings are given for all 6 strings of a 10/46-string-set (10, 13, 17, 26, 36, 46). As we will have to explain later in Chapter 7.7.4.1, it is appropriate to derive the damping of the string oscillation from the energy-related sum of the oscillations normal and parallel to the fretboard – the curves in Fig. 7.66 were established that way. For a number of selective minima, the cause is known; these minima were removed (not considered) – they will be analyzed in depth in the following. The causes for the global decay processes shown in Fig. 7.66 essentially are attenuation by radiation, and internal dissipation in the case of solid strings; in the case of wound strings, damping due to the winding weighs in, as well. Damping due to bridge, guitar neck and guitar body leads to small, frequency-selective peaks – a separate section will be dedicated to them below.

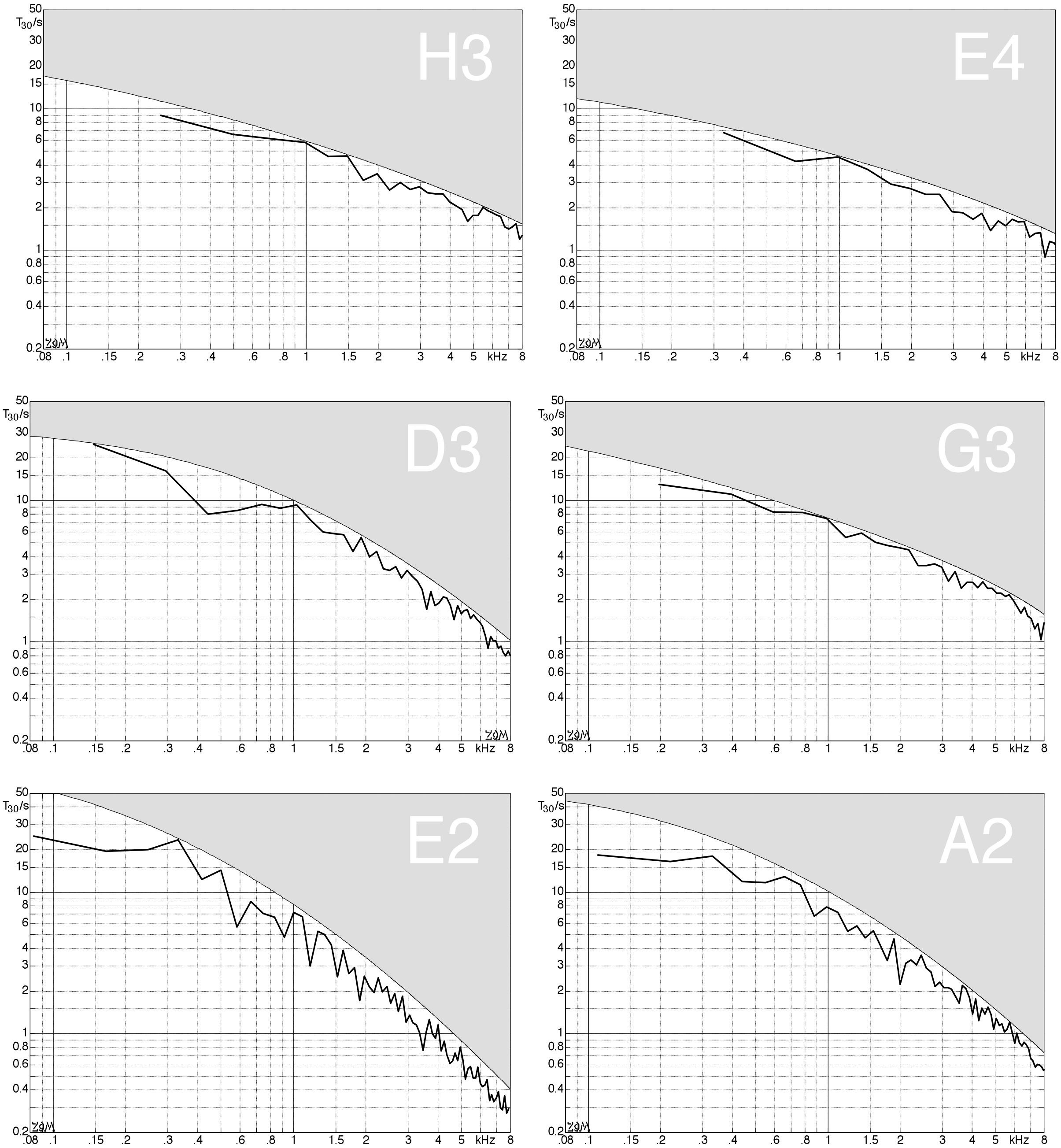

Fig. 7.66: Decay times of partials, US-Stratocaster, best-case. Factory-fresh strings (10, 13, 17, 26, 36, 46). The region marked in grey (estimate of upper limit due to radiation and internal damping of the string, "orientation line") was seldom if ever reached during any measurement.

In order to prevent misunderstandings, we need to remind ourselves again that **Fig. 7.66** does not show spectra but decay times. During the decay time T_{30} the level of the respective partial is reduced by 30 dB. In the case of the low E-string (E_2) it takes 25 s until the level of the fundamental (82.4 Hz) is reduced by 30 dB. It takes nearly the same time until the level of the 4th partial (330 Hz) decreases by 30 dB – for the 12th partial (1 kHz), however, the same drop takes a mere 7 s. The graph does not tell us how loud the partials are – or, rather, which level they start to ring with. The level of a partial is easily changed e.g. by filters, but the decay time is not – as such the decay times represent a much more guitar-specific parameter than the spectrum. Mind you: it's guitar-specific, but also highly string-specific. The global tendency of the high-frequency drop-off clearly is string-specific, a relation to specifics of the guitar only can be attributed to the small variations in the progression of the curve. In fact, exactly this is the subject of the next Chapter 7.7.4.

