7.7.4 Bearing absorption

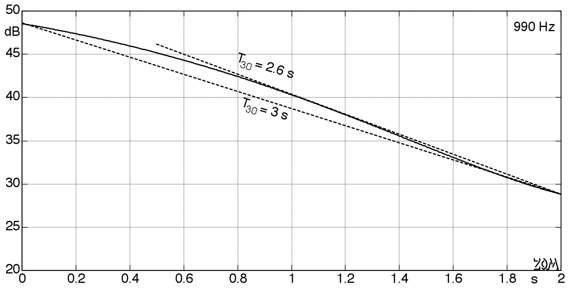
In Chapter 2, the discussion has focused in detail on describing the string as a mechanical line along which waves are running. The reflection process occurring at both bearings (bridge, and nut or fret) is defined by the **characteristic wave impedance** of the string, and by the respective particular **bearing impedance** (or admittance). Typically, the bearings are rigid - thus having a very high mechanical impedance – so that nearly the whole wave energy will be reflected. However, a small percentage will be absorbed at the bearing, and this is where the designs of bridge and nut/fret come in, as well as the materials used for these components. The guitar neck and its resonances [Fleischer] need to be looked into at some point, and subsequently, at the very last, one may also wonder about the wood of the guitar body. First, however, term "bearing absorption" must be clarified – because a simple punctiform impedance is not good enough. Instead, we can isolate several absorption processes, each of them to be discussed in their own subchapters.

7.7.4.1 Coupling of transversal waves

The magnetic pickup customarily deployed on electric guitars transforms into an electrical voltage predominantly those string oscillations that occur perpendicular to the fretboard (Chapter 5). Therefore, it is obvious when performing measurements to pluck the string normal to the fretboard, and to measure the fretboard-perpendicular string-oscillation component e.g. using a laser vibrometer. In the simple model, an exponential decay of the velocity of the partial is assumed:

$$v(t) = v_i \cdot \exp(-t/\tau) \qquad \tau = \text{amplitude-time-constant}$$

Because the instantaneous power is proportional to the square of the velocity, its decay needs to be described by a power-time-constant – that is half as big as the amplitude-time-constant. Thus, if we talk merely about a "time constant", there is a risk of confusion. However, the specification of the **decay time T_{30}** (during which the level is reduced by 30 dB) is clear; it will be applied in the following. The decay time T_{30} is 3.45 times the amplitude-time-constant or 6.9 times the power-time-constant. However, not all analyses of partials show a purely exponential decay. In **Fig. 7.67**, the measured decay of the 4th partial of a B-string of a Stratocaster is shown. An analysis encompassing 2 s shows a progressively decreasing curve to which a single gradient can only hardly be related – both inserted approximation lines mightily reek of being arbitrary. Enlightenment in the truest sense of the word is provided by a second laser-vibrometer that upgraded our lab-setup to a **2D-measuring-station**. The fretboard-normal and the fretboard-parallel string oscillations perfectly complemented each other to sum up (in terms of the energy) to an exponential decay that would do justice to any textbook, and featuring a decay time (5.7 s) significant longer than the one initially expected.



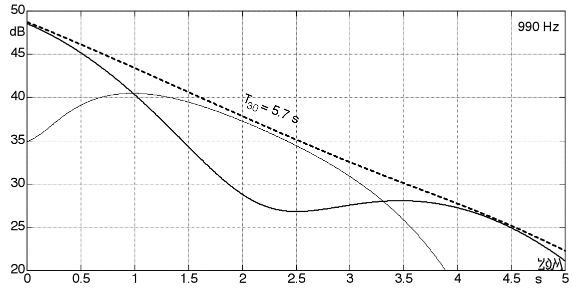


Fig. 7.67: Decay of the 4th partial of the B-string (Stratocaster). On the right, the level of the fretboard-parallel oscillation is plotted in addition, and also the level of the sum (----).

The interpretation of these measuring results may vary depending on the question. The fretboard-normal oscillation the pickup senses – only this being relevant to the sound – reaches a minimum after 2.5 s. The related loss in level of 22 dB must not be considered as an energy drop of 99.4%, because a part of the energy is not yet "lost" but stored temporarily in the orthogonal oscillation mode. After another 2.5 s, the level therefore has not decreased by 44 dB in total but only by 26 dB. However, this does not at all help the guitar player who wants to play a tone that lasts 2.5 s – he simply feels the **sustain** of this particular partial as being all too short. Let's assume that in particular this partial is of eminent importance, and let us hold fast onto this: the decay time measured in one oscillation plane must not just blindly be converted into dissipation parameters.

Conspicuously, the decay analyses of the investigated American Standard **Stratocaster** showed that in particular the B-string featured strong beats of partials. Now, of course every 'in-the-know' guitar player is aware that these beats, this 'chorus-like warble', belongs to the specific charm of the Strat, and – being privy to it all – our man knows the (supposed) cause: it's the magnets! These conniving guys sneakily exert a vicious pull on the strings and 'hinder them to decay freely'. We do not know the originator of the moderately intelligent term '**Stratitis**' for this 'illness' of the Strat … but that's probably for the best. In Chapter 4.11, we had already explained that pickup magnets in fact may change the decay characteristic of individual partials – however, this mainly affects the fundamental. To be on the safe side, the pickups had been lowered as much as possible before the measurement specified in Fig. 7.67 was taken – in other words: it's not **the magnets**, they are not responsible for this beating. **Fig. 7.68** shows further levels of partials of this B-string – all fraught with various beats. If one does not have unlimited possibilities for modal analysis (one does not: the Free State of B. in the south of the country G. needs cut back and saving money after the latest banking disaster), only simple approaches remain for such studies. In the present case: we lift the B-string out of its groove in the nut, move it sideways by a millimeter, re-tune, and repeat the measurements. And behold: the beats were yesterday. If only all analyses were that easy.

In its original state (**Fig. 7.68**, left-hand section), the B-string of the investigated Stratocaster generates audible beats that one may love or hate. Still: this characteristic definitively must not be attributed to the specially selected and long stored wood of this American dream – the mundane source is in the **nut**. No, don't even go there and say that this nut has been filed down with love and given brilliant workmanship exactly in such way that these beats result, because only they would generate that authentic ´Strat-sound´. Once the measurements had been carried out, the B-string was allowed back into its original groove and was re-tuned … and there they were back again: the beats. However, they were not the same anymore – a closer look showed deviations in frequency and amplitude of the beating. Thus, this sound characteristic has to be seen as accidental and fragile – a result of a naturally always tolerance-affected manufacturing. In the case of the investigated Stratocaster, only the B-string showed such strong beats, all other strings behaved completely inconspicuously. It is, however, to be expected that among the many Strats manufactured to this day today there are more than a few that feature more than one string generating stronger beats, and perhaps these are in fact exactly those holy cows a lot of money is shelled out for. The top nut, stupid ...

No, of course the nut is not the only reason for certain sound characteristics, it is essentially involved in sound shaping, though. At the beginning of the 21st century, aficionados still commemorate those fair maidens (or ladies) who – by hand! – wound Fenders' first pickups (hail oh Mary, Gloria, Abigail!); however, that kind of honor and appreciation is denied to that master nut-slotter *(translator' question: would that be a nutter, then?)*. By Leo, he would have deserved it, too.

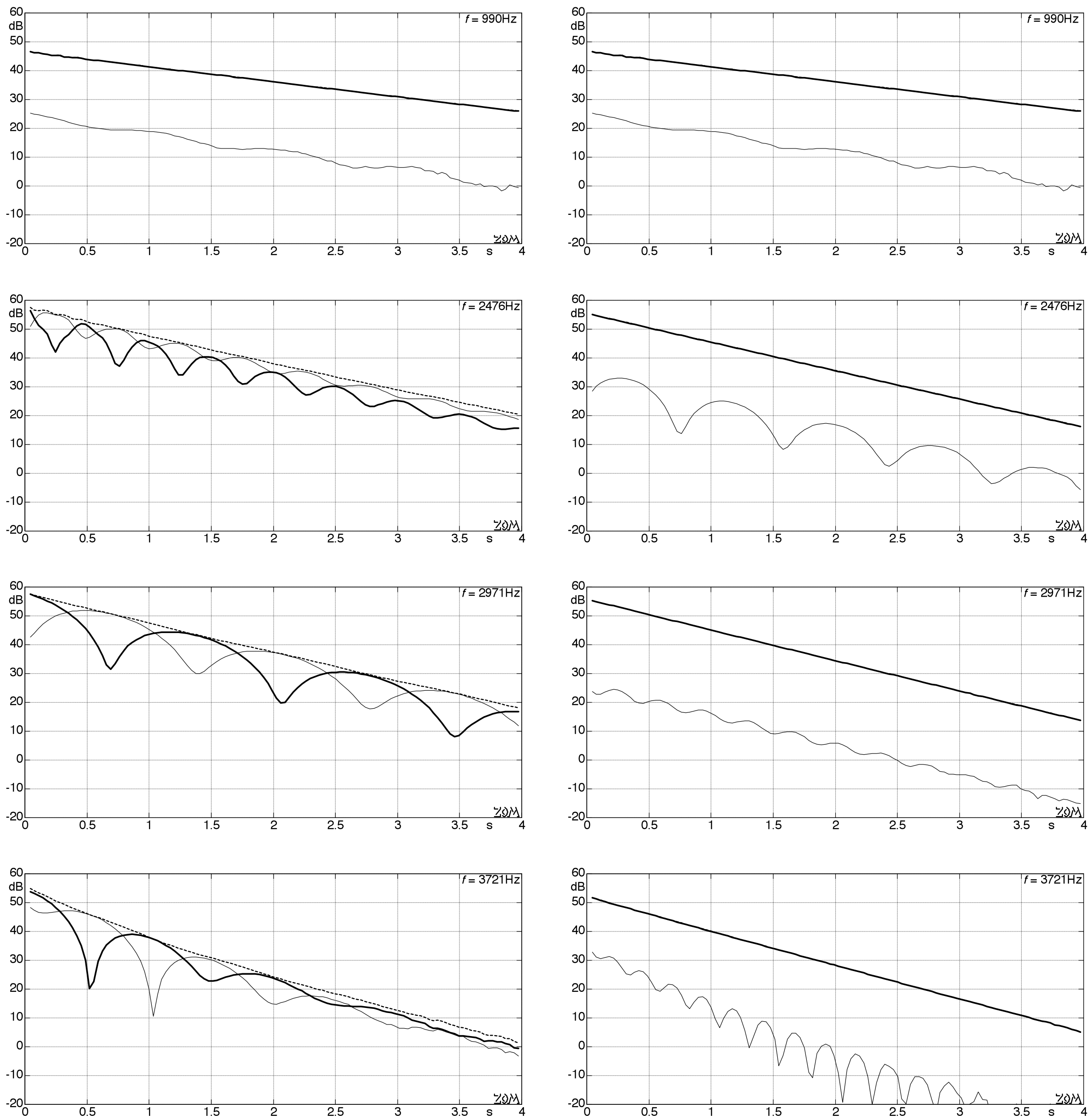


Fig. 7.68: Level of partials, B-string, Stratocaster. Left: string in the saddle groove. Right: string beside the groove. Bold line: fretboard-normal string oscillation. Thin line: fretboard-parallel string oscillation. ---- = Sum.

Before thinking about how the wood of the guitar body could affect the string oscillation, we should first consider those components that are in direct contact with the strings. These are in fact the nut (or fret) and the bridge saddles – but not any pieces of ash or alder. If the string does not rest on a line that is perpendicular to its longitudinal axis, a coupling of the oscillation planes may result. The same might happen if the compliance of the support is direction-dependent. The coupling of the transversal oscillations as it is caused at the string bearing is shown in **Fig. 7.69** as an **orbit-diagram** (abscissa = fretboard-parallel oscillation, ordinate = fretboard-normal oscillation). In the upper-left diagram we can see how the string first begins to oscillate vertically, but then subsequently shifts the oscillation plane first to the left, and then to the right. After about 370 ms, the vertical oscillation has nearly decayed to zero, and the oscillation energy has mainly been transferred to the orthogonal component. This is completely different for the B-string when positioned *beside* the groove of the headstock saddle: it substantially keeps its oscillation plane, because the coupling between both oscillation modes is much smaller (bottom images).

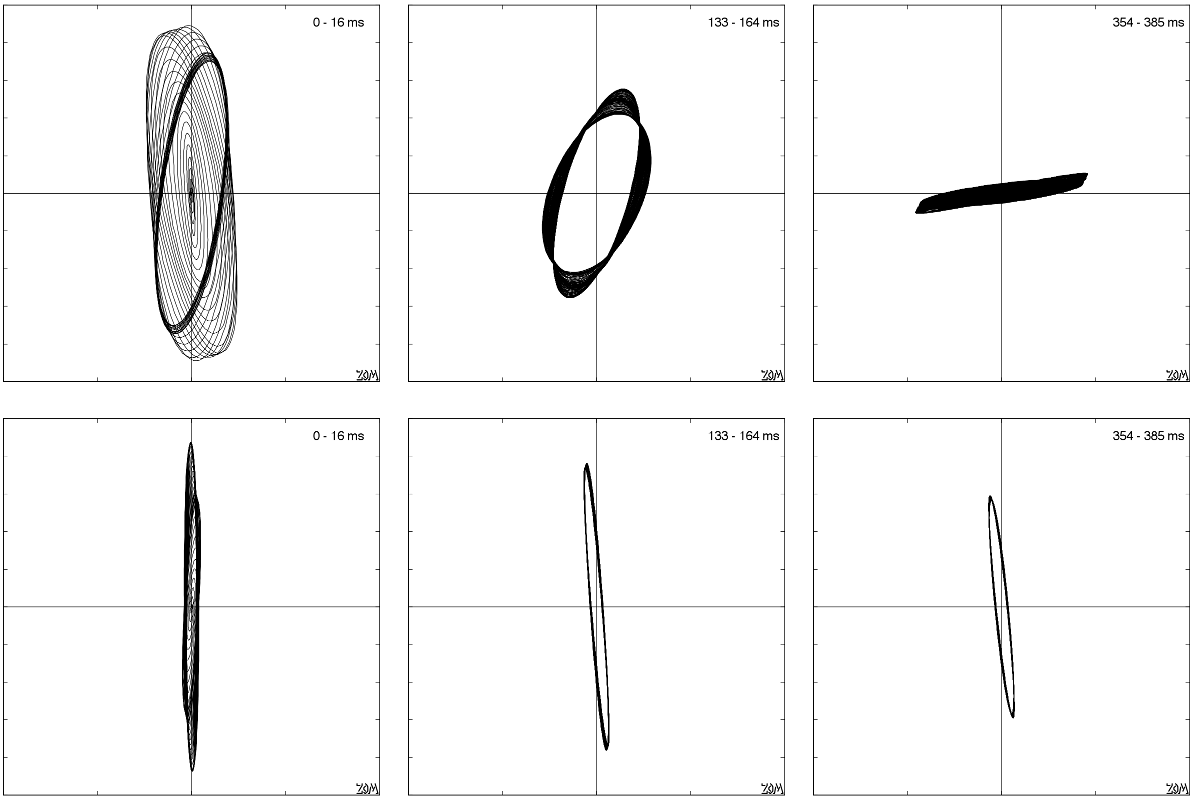


Fig. 7.69: Orbit-diagrams (vertical vs. horizontal movement). B-string, Top: bearing in the nut-groove, bottom: bearing beside the nut-groove. Stratocaster, 10th partial of the B-string (2476 Hz). The analysis had been run with signals that were similar but not identical to those used for Fig. 7.68.

When investigating damping (dissipation processes), we need to analyze both oscillation planes. If merely the voltage generated by the pickup is of interest, only the fretboard-normal oscillation-component is essential. That common magnetic pickups can pick up not only transversal oscillations but also longitudinal oscillations is explained in Chapter 2.9, while the directional characteristic of these pickups is looked into in Chapter 5.11.

The mode coupling at the *headstock saddle* (nut) of the B-string found in the above example is, of course, only relevant as long as the open B-string is plucked. As soon as the string is pressed down on the fretboard by a finger, the fret that is next to it takes over the bearing function. Furthermore, corresponding coupling may just as well occur at the *bridge saddle* - and this will have effects also when the string is fretted. The **bridge construction** of most electric guitars encourages the assumption that the designers did not worry about mode coupling, but predominantly considered as their task the adjustability of the action, and lowest possible production costs. On the Jazzmaster (planned to be Fender's top model), Leo Fender guided the strings at the bridge by means of screw threads. However, he did not use screws with six different threads – no, three different threads had to be enough. As generally known, the strings have six different diameters, and therefore the fit for the strings will turn out to be very different from string to string … What? Fit?? On the Tune-O-Matic bridge, Gibson guides the strings by means of bridge saddles looking fishily similar – all six of them! The guys at Rickenbacker lay the strings into small rollers, probably hoping that the gap damping won't become all that pronounced. And surely: there are six identical rollers! Obviously, not all builders of electric guitars were aware to the same degree of the function of the guitar bridge in terms of vibration technology.

More details regarding bridge constructions are compiled in Chapter 7.10.

