7.9 The Wood Determines the Sound?

Mahogany! Maple! Rosewood! Men oft believe, if only they hear wordy pother, that there must surely be in it some thought or other [Goethe]. And the usual thinking is: *"the electric guitar is a musical instrument made of wood. In all musical instruments made of wood, the wood determines the sound. The more noble the wood, the more noble the sound."* Goethe's witch's kitchen – a suitable location for deception and magic – holds more such articles of faith, but let us keep some distance from alchemy, and give physics the priority here: how does the body of the guitar vibrate, and in what way will the vibration of this body influence the sound? In the material-science course, every luthier learns about different tonewoods and their sound-determining material-parameters: *"the denser the wood, the more brilliant, treble-rich the sound; the higher the stiffness, the longer the sustain (P. Day)."* As if that were self-evident, this statement and similar ones are based on the assumption that the findings that are valid for violins and acoustic guitars apply to electric guitars, as well. If we now add that board of experts who listen to an electric guitar first of all without amplification, we quickly arrive at a conglomerate of teachings that, between them, could not be more contradictory. All the while two simple principles would really help us:

1) Compared to the acoustic guitar, the electric guitar functions very differently. Findings derived from the one type of guitar may not be sight-unseen applied to the other type.

2) There is a connection between the vibration of the strings and the (airborne) sound directly radiated by the electrical guitar. There is also a connection between the vibration of the strings and the sound radiated by the loudspeaker – but this latter connection is very different from the former.

The fundamental differences between acoustic and electric guitar become evident when we look at the energy flow: being plucked, the guitar string receives energy that is in part converted in to sound energy, and in part into caloric energy (heat). A – not untypical – excitation energy of E = 3.6 mWs corresponds to the billionth part of one kilowatt-hour (kWh); that's really very little compared to household appliances but still enough to generate a sound that is clearly heard. With an acoustic guitar, this energy can generate an SPL of about 94 dB at the ear of the player; a Les Paul only reaches about 64 dB. A level difference of 30 dB translate onto a power relationship of 1000 to 1, which confirms quantitatively what was qualitatively already known: the electric (solid-body) guitar is a very inefficient sound source – at least as far as the directly radiated primary sound is concerned. However, the electric guitar is of course not intended to generate primary sound – it is there to generate electrical voltage. The big difference between the two modes of operation: in the acoustic guitar, the sound energy needs to travel "through" the body i.e. "through" the wood, while in the electric guitar the part of the sound energy that is "reflected from the wood to the string" is captured. Any conjecture that, in the electric guitar, the vibration energy needs to be also fed to the guitar body as much as possible, is wrong. *"The biggest part of the string vibration should be conducted into the body. If the latter is fed with unrestrained vibration energy, a maximum of tone and sustain develops [G&B 12/05]."* How should the string ring for a long time (i.e. have a lot of sustain), if its vibration energy has gone into the guitar body? The law of energy conservation dictates that energy cannot appear out of nowhere. The excitation energy is present only once; the part of it that is fed to the guitar body is missing to keep the string ringing. The banjo is a good example for an instrument that withdraws a lot of energy from the string within a short time. However the sound of a banjo (and in particular its sustain!) is not much like that of an electric guitar.

From a systems-theory point-of-view, the string represents a **mechanical waveguide** on which waves propagate. As these waves impinge on the bridge and the nut (or the fret where the string is fretted), one part of the energy in the wave is reflected, the other part is absorbed by the bridge/nut/fret (and adjacent structures). Again, the law of conservation of energy holds: the sum of the reflected and of the absorbed energy corresponds to the energy in the wave impinging on the bridge/nut. We get a high rate of absorption if the wave impedance and the impedance of bridge/nut/fret have comparable values. The **wave impedance** of the string (see Chapter 2) depends on the diameter and on the material: typical would be 0.2 Ns/m (E_4-string) to 1 Ns/m (E_2-string). These are very small values compared to typical bridge impedances (100 – 1000 Ns/m). The situation is comparable to an airborne wave that hits onto a concrete wall: because the wave impedances again differ by several orders of magnitude, almost all of the sound energy is reflected. The same happens with the string: the vibration of the string is, for the most part, not fed to the guitar body but it is reflected. In the solid-body guitar, a **degree of reflection** of 99.9% for low-frequency partials is not untypical: of the vibration energy arriving from the direction of the nut, 99.9% are reflected and only 0.1% are absorbed. There is no other way a vibration could remain for any extended periods of time: if for the E_2-string 50% of the energy would be absorbed at each reflection, only 0.1% of the initial energy would remain after only 10 reflections – and 10 reflections have happened after a mere 60 ms for the E_2-string! Given a 99.9%-reflection, 37% of the initial energy will remain after 1000 reflections (that's 6 s)♣. Therefore, a simple connection exists between the decay time (the **sustain**) and the degree of absorption: the higher the degree of absorption, the shorter the sustain. And here we arrive at an explanation that is not so easy to refute: if the sound depends on the sustain, and the sustain depends on the absorption, and the absorption depends on the bridge/nut/fret, then the wood of the guitar body will determine how the guitar sounds, won't it, after all?!

Given the intense and controversial discussions about the "tonewood"-topic, let us make a bit of room for some fundamental considerations: if a string is struck once, its vibration energy decreases over time. The main reasons for this decay are: sound radiation directly from the string, internal absorption within the string, and absorption at the string bearings. The *first* effect is so small that it is normally neglected. The *second* effect is significant in the middle to high frequency range for unwound strings; this is elaborated in Chapter 7.7. The *third* effect is the only one that can be connected to body-parameters. If we neglect the first two effects, the string vibration – and thus a component of the sound – indeed is completely determined by the guitar body. That is defining the "body" very extensively, though: it would have to include everything that abuts to the string, in particular the bridge that for example consists of 18 individual components in the case of the Gibson ABR-1 bridge. There is much wailing all over the place that the super-rare tonewoods of the early Les Pauls are not available anymore, and thus the sound of these originals will never be duplicated. Interestingly though, the question rarely asked is to which extent the individual pieces of the **ABR-1 bridge** were deburred, and how clean the force fit between the movable bridge saddles and the base is. The bearing impedances at the bridge and at the nut (or respective fret on the neck) strongly influence the decay of the individual partials of the sound. Before the vibration energy arrives in the body, it needs to traverse the bridge/nut/fret; the stronger these elements reflect the vibration, the less important the material of the guitar body is.

All this is, however, valid for the acoustic guitar, as well – so what is basically different in its sound generation compared to the electric guitar?

♣ We have neglected other mechanisms of absorption in this example.

In the acoustic guitar, the **sound to be radiated** needs to first get from the bridge, via the body, to the radiating surface; therefore the build of the body has an effect on the sound from the very first millisecond. The top of the acoustic guitar, its bracing, its shape, the location of the bridge – all this influences the radiated airborne sound from the first moment on. The retroactive effect of these details onto the degree of reflection is, however, rather small. In fact, it needs to be small so that a vibration can happen in the first place. It is exactly at this point where the experienced master-builder is required: the optimization of that wooden transmission-filter requires much specialist knowledge and – no contest – special materials. While the guitar body shapes *radiated* sound from the very first moment, what happens to the *string* is quite different: its vibration is at first not much influenced by the body – only with time, the absorption at the bearings takes an effect. That is why two electric guitars fitted with the same magnetic pickup and the same strings, and plucked in an identical manner, will sound very similarly at the first moment. That's irrespective of what wood they are made of[♣]. The may differ in their acoustical sound because the mechano-acoustical filter may differ drastically depending on the circumstances, but the retroactive effect of this filter onto the string vibration is rather small in typical electric guitars. It is not conducive to cite that famous rubber-guitar that supposedly had a terrible sound (if it existed at all in reality): presumably its bridge impedance was not several orders of magnitude above the wave-impedance, presumably its degree of absorption was bigger that 0.1% … presumably that guitar made from rubber is pure fiction.

The fundamental differences between the "electric" and the "acoustic" sound in electric guitars may be explained by an **example**: two electric guitars reflect the wave energy in the same way at 300 Hz, while at 600 Hz, one of the two (Git_1) reflects 99.9%, and the other (Git_2) reflects 99.6%. Idealized, the energy lost by the string is completely radiated as airborne sound. Given identical string excitation, these two guitars will radiate the same sound energy at 300 Hz, while at 600 Hz, the radiated sound energy will differ by a factor of 4. Git_2 radiates the latter range more loudly; a four-fold higher energy at 600 Hz corresponds to a level difference of 6 dB. Apart from the differences in the radiated airborne sound, the differing absorption will also result in a difference of how quickly the string vibration decays: Git_1 still features 95% of the original vibration energy after 50 reflections, while in Git_2, only 82% remain. Expressed in levels, the 600-Hz-level drops by 0.22 dB during the first 50 reflections in Git_1, and by 0.87 dB in Git_2. The airborne sound between the two guitars therefore differs by 6 dB from the first instant, while the electrical sound is identical at first and changes by 0.6 dB by the 50th reflection. If we now drop the idealizing assumption that all absorbed energy is converted to airborne sound, and if we allow **dissipation** (the absorbed energy is partially converted into heat), then larger as well as smaller level differences could be generated in the airborne sound. To carry things to extremes: both guitars are picked in identical manner by a small actuator, but one of the guitars is located in a guitar case (the lid of which does not touch the strings). How would now the electrical sound differ? And how the acoustic, airborne sound?

The **conclusion** of these considerations can therefore only be: the geometry and the material of the guitar body do shape the radiated airborne sound from the first moment on – but regarding the attack of the "electrical sound" that is highly important for the perception of the sound, there is only minor influence. The airborne sound radiated by an electric guitar does correlate with the pickup voltage, but in a highly individual manner.

♣ Provided that the string can vibrate freely and does not hit the frets.

The following example will show how much the spectra of the airborne sound can change while the pickup signal remains identical: for a **Squier Super-Sonic** (similar to a Strat), the pickup signal and two microphone signals were recorded at the same time (**Fig. 7.91**). One microphone was at the position where the ear of the guitarist is usually located, the other microphone recorded the airborne sound in front of the guitar at 50 cm distance. The two airborne sounds differ significantly because the guitar operates as a dipole in several frequency ranges, and destructive interferences (cancellations) happen in the plane of the guitar body. These differences in (airborne) sound become also audible if the guitar is rotated slightly around its longitudinal axis while playing: the sound immediately changes. That the electrical sound does not change should be clear even to the most ardent skeptic. And a last example: the airborne sound of the Squier changes as well when its body is set onto a tabletop, because the radiating surface is enlarged. It would also be possible to say that the body is enlarged. This change does, however, not have any audible effect on the electrical sound.

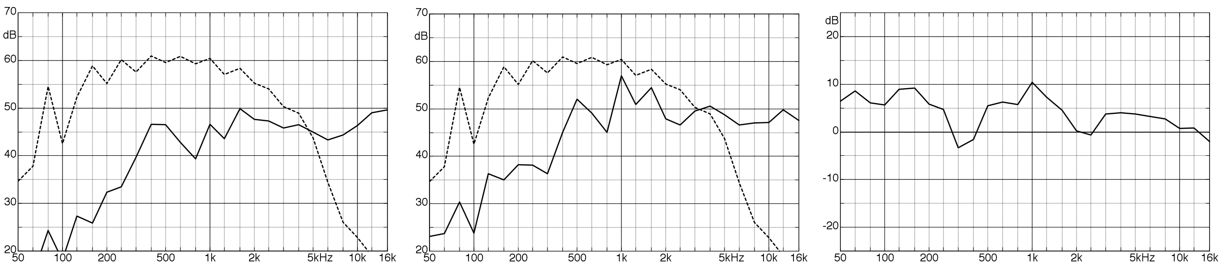

Fig. 7.91: 1/3rd-octave spectra of a Squier Super-Sonic: airborne sound (——), pickup voltage (----). Microphone located in the plane of the guitar body (left), microphone located in front of the guitar (center), level difference of the spectra of the airborne sound (right).

If the wood of the guitar body had a significant influence on the "electrical sound" of an electric guitar, we would find a clear mapping between type of wood and sound attributes in the corresponding specialist literature. Such mappings do exists but they show an astonishing variation from source to source. For example, the sound attributes for alder read: *sweet; mellow; warm; many harmonics; restrained share of treble; gentle; fat bass; rather subtle share of bass; strong mids; well-rounded share of mids; much sustain; accentuated; squishy; good presence; undifferentiated; balanced; full sound; thinner in its sound compared to basswood*. How can a type of wood generate both an accentuated and a squishy sound? How can it support a fat bass with a rather subtle share of bass? Sure, the above terms have not originated with the same author, that's a cross-section through many specialist articles. There are several explanations for these clearly contradictory evaluations: it is not elaborated whether the electrical or the acoustical sound is referred to, because (allegedly) everybody knows that there is no big difference between the two: *the electrified plank-guitar primarily is an acoustic instrument. The wood makes for the character of the sound; the pickups only have a small share. And thus a humbucker cannot exorcise the characteristic sound- and attack-evolution from the Strat with an alder- or ash-body (G&B, 2/2000)*. The experts may borrow approaches found in **violin-making**, because: what holds for the violin cannot be wrong for the guitar, can it? Of course, the number of strings does differ slightly, and size and weight are admittedly not the same, either. And, well … Stradivari did not actually build electrified plank-violins, and there are no frets on a violin, either. But: both are made from wood! Still: *the apparently valid formula that old wood always is suitable wood is only correct in part. We need to look more closely – which leads us directly to the Italian or alpine violin builders. ... Only so-called tonewood gives us, after processing, in the end those clean, vocal tones, a dynamic and prompt response, and this hauntingly beautiful scope, or power of self-assertion.*

Scope! In an electric guitar! Indeed, the pictures to which the cited text relates show Les Pauls and Stratocasters. The dogma of the sound of tonewood is deep-seated – so deep-seated, that many an author will do a true backwards somersault, and vote for and against at the same time: *every piece of wood has its own sound,* we read in a book about electric guitars. A few pages on, the author opines (in the same book): *the sound of the electric guitar depends largely on the pickup*, but announces in the next edition: *the body has – in the solid guitar, as well – a decisive influence on the sound*. Six pages on, we read in the same book: *the different sound of electric guitars is, to a large extent, due to the pickups*. It gets even more extreme in a different book: *solid-body guitars may be manufactured in nearly all sizes and shapes – significant effects on the sound should not be expected*. The same author states 65 pages on: *the sound characteristic of the electrical guitar is significantly determined by the selection of the wood. Pickups and amplifier support the sound of the guitar but rarely influence or characterize it fundamentally.* In test reports, the contributors seem to be caught in this corset, too. On the one hand, we find: *Of course, the wood of the guitar body decisively characterizes the Fender-sound. Ash sounds brighter and with more harmonics compared to alder, and it features longer sustain.* On the other hand, referring to ash-Strat vs. alder-Strat: *there are only minute differences in sound.* Alder-Strat vs. poplar-Strat: *they differ only in the finest degree.* Mahogany-Squier vs. basswood-Squier: *almost identical sound*. (citation from reviews published in Gitarre & Bass).

How far the wood of the guitar body in fact determines the (electric) sound of the electric guitar shall be investigated first given the boundary condition that the string can decay freely (i.e. it does not hit the frets). Corresponding measurements were taken with a **Les Paul '59** (Historic Collection) that was fitted with a solid 26-mil-string as a D-string (fundamental frequency = 200 Hz). This string was excited, next to the nut, with a short impulse; the fretboard-normal velocity was measured next to the bridge saddle using a laser-vibrometer. **Fig. 7.92** shows the spectra of the first 21 ms of these velocity signals. The short length of the analysis-interval results in a relatively broad leakage (i.e. a broadening of the spectral lines). The excitation impulse approximately corresponds to half a sine wave; the spectral envelope can be described as superposition of two si-functions. The lower line in the figure depicts a calculation according to the correspondingly simplified model. There is relatively good correspondence; the measurement results deviate only at a few places – and the following elaborations focus on these discrepancies.

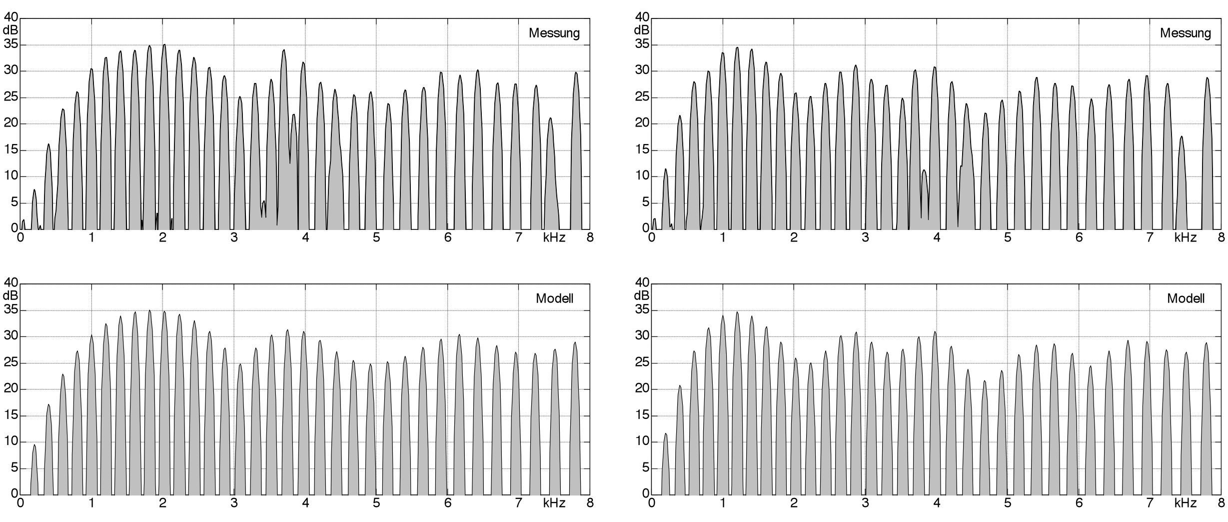

Fig. 7.92: Spectra of the first 21 ms after plucking the string. Two different excitations (left/right).
The lower row shows the spectra calculated according to a simplified model. "Messung" = Measurement

All measurements confirm the hypothesis that the **attack-spectrum** is predominantly determined by the string excitation. The difference between the spectra shown left and right in Fig. 7.92 mainly consists in that the place of excitation was shifted by a few millimeters; as a result the impulse-length and –envelope were changed. There are two places in the spectrum (3.7 kHz, 7.4 kHz) where the measurements deviate from the model envelope in a two-fold fashion: both the *frequency* of the partials and the *level* of the partials are not as calculated, and in addition a partial at 3.8 kHz becomes visible that does not fit into the frequency grid. All these deviations are clearly affiliated with the bearing of the string – but not necessarily with the wood of the guitar body. Deviations in the frequency of the partials have already been discussed in Chapter 2.5: a spring-like bearing that bounces up and down extends the effective string length and decreases the vibration frequency, while a bearing characterized by a mass effectively shortens the string and increases the vibration frequency. Additional partials also have already been deduced in Chapters 2.5 and 7.5: as result of the bearing impedance containing an all-pass characteristic. The bearing impedance is, after all, not infinite but depends in a complicated fashion on the frequency. Its frequency-dependent imaginary part renders the effective string-length frequency dependent; this leads to **detuning of the partials**. The frequency-dependent real part results in frequency dependent **decay-constants of the partials**. All these aspects are string-specific effects of the bearings – the exact source of which is to be documented in the following decay-analyses.

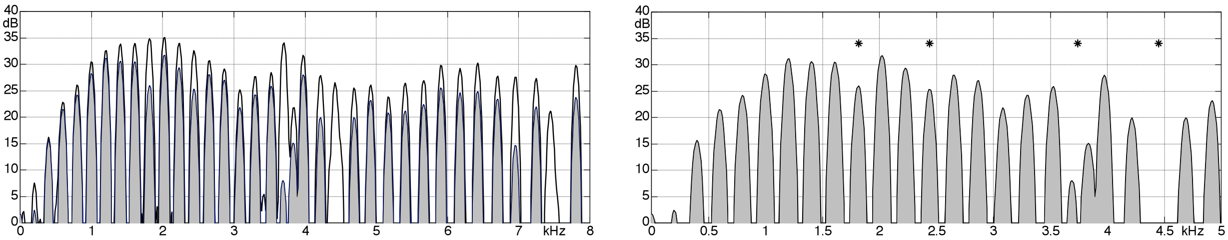

Fig. 7.93: Two superposed spectra, measured at a time interval of 100 ms. Frame = 21 ms, Kaiser-Window. In the right-hand picture, only the spectrum measured after 100 ms is shown. * = areas of high damping.

Fig. 7.93 shows the measurement results of the string-decay analysis. A signal section of a length of 21 ms recorded immediately after the plucking of the string was transformed into the frequency domain via DFT-analysis; a second section recorded 100 ms later was treated the same way. Comparing the two spectra (white vs. grey), we recognize the particularly fast decaying partials: the strongest damping is found at 4.4 kHz – it shall be looked at in the following. The second-strongest damping happens **at about 3.8 kHz**. Its cause becomes clear as we look at the first few milliseconds of the signal (**Fig. 7.84**). Even before the relatively slow flexural (transversal) wave reaches the measuring point (this happens at about 1 ms), a faster **longitudinal wave** has already been reflected multiple times. Its effect is visible to the laser-vibrometer only as an evoked transversal wave; this was already extensively elaborated in Chapter 7.5.2. Since the impedance for longitudinal waves is about 20 times that of the impedance for transversal waves [see appendix], the former wave-type finds much more favorable matching at the bearing i.e. it is much more strongly damped.

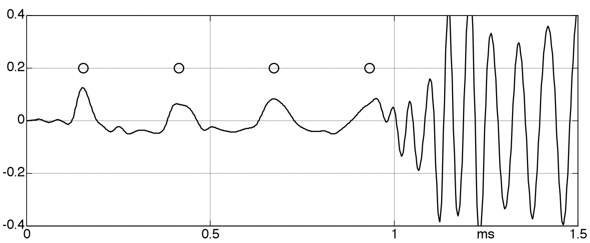

Fig. 7.94: Measured lateral (particle-) velocity of the string vibration. The circles mark the period of an oscillation at 3800 Hz.

 Translated by Tilmann Zwicker

The simple formula for the fundamental frequency of the longitudinal wave confirms the approximate location of the frequency; but it gives, compared to the measurement, somewhat too large a value: for a string length of 63 cm and a propagation velocity of 5 km/s we should arrive at about 4 kHz, and not 3.8 kHz. However, on the one hand we do not know the exact density and E-modulus of the string. On the other hand, the impedance of the bearing determines the phase of the reflection for longitudinal waves, and with it the exact oscillation frequency. To re-check, the length of the string was shortened by 6% via application of a capo, which increased the frequency of the observed irregularity from 3.8 kHz to 4 kHz. Very generally, the following holds for this and all following interpretations: the investigated irregularities do not result from definite, isolated effects, but from an interaction of many components. Mono-causality must not be expected here.

Let us now look at the extreme damping of the **partial at 4.4 kHz**, the level of which drops by 50 dB during the first 100 ms. Cause of this attenuation is the resonance of the transversal wave carried on the remainder of the string on the other side of the bridge. At the bridge of the '59 Les Paul, the strings form a sharp bend as they run across an adjustable bridge saddle that is shaped like a mono-pitch roof. The remaining piece of string (residual string) ends after about 3 cm at the stop-tailpiece. Since, as a 1st-order approximation, we can assume the bridge to be immobile with respect to lateral movement, any flexural wave should in fact be reflected at the bridge. However, due to the non-negligible bending stiffness of the string, there will be a **bending-coupling** of the two sections of the string, as discussed at length in Chapter 2. It can be easily verified that the fundamental frequency of the residual string amounts to 4.4 kHz by directing the laser vibrometer to it. Further confirmation is given by a small metal clamp that is set onto the residual string, detuning its resonances – indeed the damping effect shifts from 4.4 kHz to 4.6 kHz (**Fig 7.95**).

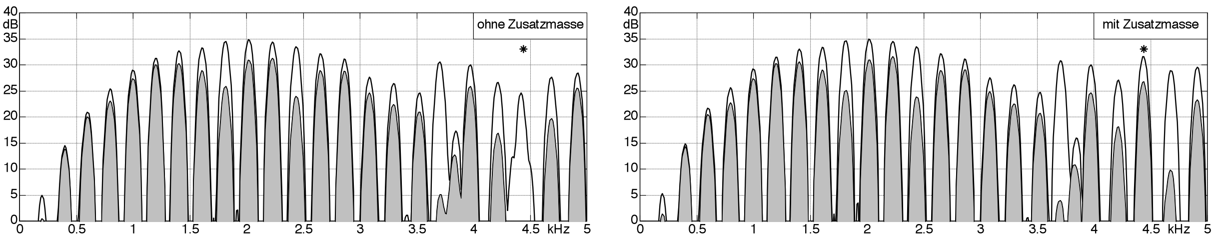

Fig. 7.95: Change in damping of the partial via an additional mass on the residual string. ∗ = 4.44 kHz.

Next, the attenuation of the 12th partial (**2.44 kHz**) catches our eye. At 10 dB /100 ms, it is not as pronounced as the damping experienced by the partial discussed above, but still clearly stronger than for most other partials. Deploying the metal clamp on the residual string has no effects on this partial … the cause for this damping is an Eigen-resonance of the famous Gibson-bridge (ABR-1). This resonance can again be shown with a small clamp that is this time fitted to the bridge (**Fig. 7.96**). Adding such extra masses is a simple and quick alternative to high-effort scanning analyses. While it does not enable us to determine the shape of the vibration of the bridge, we can easily verify its involvement in the damping of the partial. Before this measurement, the bridge-piece had been slightly readjusted to optimize the intonation – already that had effects on the decay of several partials. Attaching a small clamp to the ABR-1-bridge detuned the bridge resonances and led to a further change in the decay of the partials. With this modification of the bridge, both the damping at 2.44 kHz and at 1.82 kHz can be traced to resonances of the bridge – although these resonances always needs to be seen in their connection to the residual string and the tailpiece.

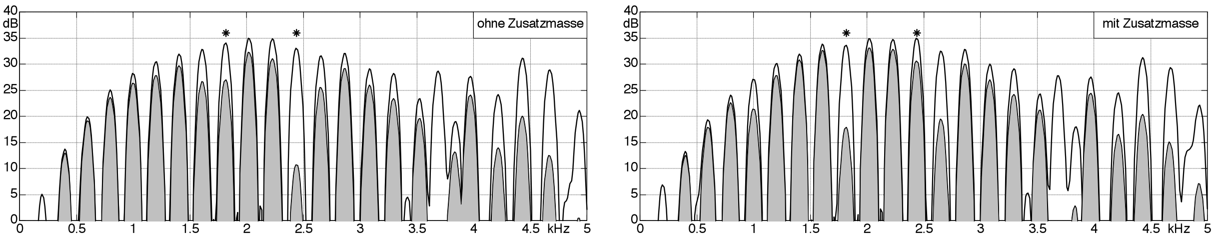

Fig. 7.96: Changes in the attenuation of partials by attaching an add'l mass to the bridge. ∗ = 1.82 / 2.44 kHz.

As has already often been expressed: **damping** in musical instruments is not necessarily a bad thing. The character of the instrument expresses itself in the damping of individual partials: **it's the imperfection that results in individuality**. Simpler said: the picking and the pickup yield a spectral envelope, and the string bearing determines the decay of the partials. Not the analyzer but only the listener decides what's good or bad; and what is actually audible, as well. Not all effects visible in an FFT-spectrum are audible, too.

Whether a partial is at all audible to begin with depends on so many parameters that just on this subject, whole volumes are compiled [12]. If the 2.66-kHz partial decays faster than the 2.44-kHz partial, this is just about audible under laboratory conditions. A fundamental good-guitar/bad-guitar discussion must never be started on such a basis. To bear in mind the heading of this chapter: none of these effects is due to the wood of the guitar body – these are artifacts due to strings and bridge, and they are quite substantial just looking at the physical parameters. From the viewpoint of subjective perception, they are "almost insignificant", however. The resonances of the Gibson bridge attenuate the partials slightly above and slightly below 2 kHz, and lead to a coloring that speech-scientists would attest a trend either upwards to the "i" or downwards to the "a", because the 2nd formants of these vowels lie above and below 2 kHz, respectively (Fig 8.44). Attenuation at higher frequencies quickly looses any significance for a guitar fitted with humbuckers, because the transmission range of these pickups does not extend much beyond 2,5 kHz. The main effect therefore lies with the bridge resonances, and of course with the resonances of the guitar neck as the measurements in Chapter 7.7.4.4 have shown. It is impossible to build a resonance-free **neck**: density and E-modulus result in masses and springs, and from this inevitably resonances. **Fig. 7.97** shows three Eigen-shapes of a beam clamped at one end. Transferred to the guitar, we would have the body on the left side and the headstock on the right side. Real neck-resonances deviate somewhat from this idealized picture, because the body does not represent an entirely immobile clamp for the neck, because the cross-section of the neck is location dependent, and because on top of the bending movement depicted here, there is also torsion of the neck [Fleischer 2006].

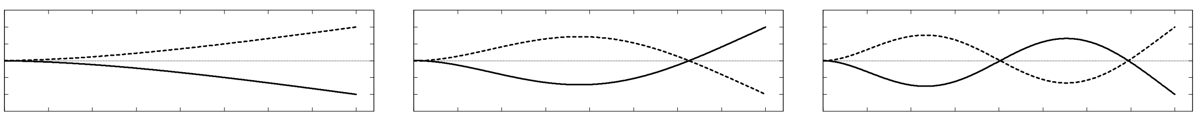

Fig. 7.97: Shapes of Eigen-oscillations of a beam clamped at one end.

Not considering extra long baritone guitars and short 24"- or 22.5" guitars, the neck-lengths of most guitars are very similar, and consequently we find similar Eigen-resonances. Not identical, but similar. The neck-width may vary by 5%, the thickness of the neck by 10% – these are not dramatic variations. The material and thickness of the fretboard will also modify the neck-resonances somewhat, as will size and (a-) symmetry of the headstock.

 Translated by Tilmann Zwicker

Comparing different guitars, Fleischer [2001] identifies the asymmetry of the headstock as the source of torsion-resonances: *below the lowest guitar tone (83 Hz), a bending vibration exists that has no direct effect regarding the tone generation. Towards higher frequencies, two characteristic bending-vibration shapes have been established that have frequencies of about 200 Hz and 450 Hz for guitars with substantially symmetric build. Due to additional torsion-vibrations, the former resonance splits up into two variants in guitars with asymmetric headstock. The frequencies of the two variants can be up to 50 Hz lower or higher than those of the "homogeneous" main vibration. A splitting-up of the second of the mentioned resonances (450 Hz) was only found in one extremely asymmetric guitar (Gibson Explorer).* At its Eigen-frequency, the neck can be made to co-resonate particularly easily – if the excitation does not happen at the location of a node of vibration. If, however, the place of excitation (the bearing of the string) is located at an anti-node, a lot of vibration energy can be transmitted from the string to the neck – which strongly dampens the vibration of the string. For the open A-string, this case does happen for the second partial (220 Hz): the decay analyses depicted in Chapter 7.7 show a relatively fast decay for this partial, the main cause being the neck resonance. However, not only the nut also the **fretting hand** can act as an absorber if it touches the rear of the neck. The same holds even for the guitarist's **belly** – it will always somehow touch the guitar body. Has anyone compared the belly-admittance of a gaunt teenager with that of, say, a portly elder bluesman? No? But you did compare the wood of the '61 Strat with that if the '64, didn't you? *The true connaisseur can hear entirely different characteristics in a '61 Strat compared to a '64 [G&B 3/06]. (Translator's remark: in German, the English term anti-node translates into what would literally translate as "oscillation-belly" – which makes for a great pun here in the German version that makes no sense in its translation ("excitation of an oscillation-belly") ... and does end with an apology to the great B.B. ...*

Let's summarize: the guitar body gives support to neck and bridge, and therefore is not entirely uninvolved. However, the body represents a practically immobile base for the bridge, as long as we deal with solid-body guitars (as they were considered here). Towards the neck, the body is not totally static, and therefore the exact resonance of the neck depends on the body, as well. However, before you run along to speculate about ash/alder differences, do not forget to take a look at how the neck is mounted: remains of lacquer, shims placed in between, uneven contact surfaces, and loose screws are potential sources for problems, just like bridges and bridge saddles resting on hollows, or bridge saddles with bad notches. A cheap plank of wood sourced from your local hardware store can be the basis for a great guitar, while AAAAA-wood seasoned for 80 years may lead to disaster if there is *only one single* mistake made in a joint somewhere. Of course, 80-year-seasoned wood, combined with error-free, master luthier-y … that creates space for that 5-figure-stuff, and why not?!

The thinner the string, the less it is affected at all by the resistive component of the bearing-admittance (or -impedance). This implies that the thicker the string, the more likely are selective drops in the decay times due to the bearing. A set of 12s on an acoustic guitar will be more strongly influenced in its vibration behavior by the guitar body than the set of 009s on a Strat. Thus, if you chop up your SJ-200 to mount a Strat-pickup, sound differences to the original Strat are easily conceivable. Within the group of solid-body electrics, however, the wood the body is made of plays a highly subordinate role for the electric sound – here it is (besides the guitarist) indeed the pickup that determines the sound. On the following pages, the citations from literature that were already introduced in the introduction are again listed. If the wood were actually and clearly a determining factor for the sound, these opinions should not diverge so strongly.

Thicker neck = advantageous regarding the sound (G&B 8/02).
Extremely thin neck = round, fat primary tone **(**Jimmy-Page-Modell, G&B 10/05).
A thin neck does not feature any acceptable vibration behavior (G&B 3/97).
The Ibanez JEM 777 has an extremely **thin neck-construction**: the basic sound character is vigorous and earthy (Fachblatt, 6/88).
Thin necks do not sound right. A nicely vibrating mass in the neck makes for more than 30% of the tone. Go for a build that's as light as possible, because the best sound is generated close to the breaking point of the materials (LuK-Guitars, G&B 1/06).
Something that's not true at all is that **thick necks** sound better than thin ones. I have built the same guitar with a thick and a thin neck, and could not find any difference. Luthier Thomas Kortmann (gitarrist.net).
Thin neck: the smaller the mass that needs to be moved, the more directly and quickly articulation and tonal expression get off the starting blocks (G&B 3/05).
Zappy and direct in its response, every note takes off in a quick and lively manner, despite the **immense neck-bulk** (that needs to be set in motion to start with) (G&B 9/05).
It is of sonic advantage that the neck weighs in with a lot of mass (G&B, Fender special edition).

Bolt-on neck = shortening of the tone (Meinel).
A **bolt-on neck** can yield long sustain, too (Lemme).
Indeed, **glued-in** and **bolt-on necks** feature equal decay times (G&B 3/97).

Generally, **maple necks** are known to give the instruments a percussive touch (G&B 4/06).
The "Slab-Board" (**rosewood fretboard**) is one of the secrets of the highly praised, crystal clear vintage sound especially of Fender guitars (Day/Rebellius).
The neck fitted with a **rosewood fretboard** has a fuller sound than a one-piece maple neck (G&B 5/07).
The sound of the **slab-boards** is particularly fat; mids of enormous depths (G&B 5/07).
A **one-piece maple-neck** sounds just like a neck fitted *with* a fretboard (Lemme).
I like fretboards made from **maple** much better than the ones made from rosewood since the former have a much tighter, stronger sound (Eric Johnson, G&B special Fender-edition).
The **maple fretboard** results in a clearer sound, the **rosewood** fretboards sounds "meatier" (Duchossoir, Strat).

Without doubt, using **Brazilian Rosewood** for the neck decisively contributes to the sound of the PRS-513 (G&B, 2/05).
It is certainly not exaggerated that **Rio-rosewood** generates a "full octave of additional harmonics" (Day et al.).
Rio-rosewood is much harder and quicker in the response compared to East-Indian types (G&B 4/09).
But – that's all horseshit, isn't it? Old Indian rosewood sounds just as nice as **Rio-rosewood**, after all (G&B 5/06).

It appears that the **material used for the neck** in fact exerts even more influence on the primary sound than the wood of the body (G&B 4/08).

Solid-body guitars, however, may be built in almost all shapes and sizes – we should not expect significant effects on the sound from this (Day et al. p.140).
Looking at the process of the sound generation, it quickly becomes clear that the condition, and the type of **wood** used, exerts an influence on the sound of the instrument just as massive as its design. (the same author, the same book, p. 206).

Wood does not influence the sound (May, p. 144).
Wood influences the sound (May, p. 145).
High-grade wood is unnecessary (May, p.86).
The influence of the **wood** on the sound should not be underestimated (G&B 3/97).
The sound of an electric guitar depends mostly on the **pickup** (Lemme).
To a relatively strong degree, the sound of an electric guitar depends on the **wood** (Meinel).
The experts agree that the sound of a solid-body guitar is predominantly determined by the **electronics** (Carlos Juan, Fachblatt Musikmagazin, 1996).
The sound does not mainly depend on the pickup – rather, the **wood** generates the basis; therefore you should listen to an electric guitar without amp first (Jimmy Koerting, Fachblatt).
Pickups transform the vibrations they come upon into sound, and are not generating sound themselves (G&B 5/06).
p.205: the type of construction has a massive influence on the **sound**. p.140: All sizes and shapes in solid-body guitars, without significant effects on the **sound**. (Both: E-Gitarren).
Wood not only determines the color of the sound but mainly the **information of the string vibration**. (G&B 02/00).

It's probably known that **light tonewoods** feature particularly good vibration- and sound-characteristics – this does not hold universally, though. Many a 4½-kilogramm-guitar has turned out to be extremely resonant (G&B 2/06).
The denser the wood, the more brilliant, treble-rich the sound; the higher the stiffness, the longer the sustain (P. Day).
The older the wood, the drier it becomes. The lack of liquid makes for more vibration, this is to be equaled with more sound (Marc Ford, G&B 8/07).
Besides, I actually think that the component **wood** is, in general, overrated (Ulrich Teuffel, G&B 5/04).

Bob Benedetto, whom many (practically all) take to be the best luthier alive, states: "popular opinion demands wood that has slowly grown (slow growth shows in narrow tree rings). According to my knowledge, that is a myth. … some of my best guitars are made from spruce that some would take as substandard. Check out the old masterpieces from Stradivari or Guaneri – they are made from wood with wide tree rings, as well. Maybe we have fallen, for years, for the advertisement in the brochures of a few companies that promote wood with narrow grain. … Once I went to a wood supplier in Pennsylvania and bought the worst wood I could find. I built a guitar from it that sounds excellent – after all, Scott Chinery bought it." (G&B 9/02).
A connection between the width of the tree rings and the acoustically important characteristics of **resonance woods** cannot be specified (D. Holz, IfM Zwota).
The latest investigations in the Institute for Musical Instrument Making essentially confirm this (G. Ziegenhals, IfM Zwota).

Bob Taylor is said to have stated that his 300-series beginner guitars offer 90% of the sound of the 900-series premium guitars at not even 1/3rd of the cost. Such a comment clarifies that it is predominantly the design and the build of the guitar that characterize the sound to a much greater extent than the **woods** used (Gerken et al.).
Taylor builds good guitars because we now how to do it. To prove that, we have built an acoustic guitar from an old, rotten pallet we found in the garbage. The top was from a scrapped plank of which we could not really determine the wood. We so elaborately glued together the top from 6 slats that it is hard to even detect that, and the holes from the nails … were highlighted with small aluminum discs. This pallet-guitar was one of the most noticed guitars at the winter-NAMM-show (Bob Taylor, ISBN 3-932275-80-2).

The Platinum Beast sounds powerful, warm and balanced, with velvety brilliance and delicate harmonics; the Evil Edge Mockingbird sounds somehow feeble, deprived of mids, with somewhat more succinct bass, but instead much more brilliant and harmonically richer. Thanks to the hot humbuckers, this all sounds **entirely different when connected to the amp**, because – hard to believe – both instruments now sounded almost identical (G&B 8/06).
Comparison: Gibson New Century X-Plorer vs. V-Factor: surprisingly, the differences in sound we found in the dry-test showed up much less when connected to the amp (G&B 7/06).

Ash-Strat vs. **poplar**-Strat: only “minute differences” (G&B Fender special edition).
Alder-Strat vs. **poplar**-Strat: differ only in the “finest nuances” (G&B 10/04).
Squier-Stratocaster: comparison: **mahogany** body vs. **basswood** body: using the middle or neck pickup, the two guitars sound almost identical (G&B 5/06).
"The 94-Amber (pickup) indeed transports a pronounced **Strat-tone** – and it does that as a full-size humbucker and implanted into a **Les Paul** of 4 kg and typical mahogany/maple-combination. … In particular the neck pickup reminds us – in its tonal color – of an ultra-fat, Texas-Blues-heavy Stratocaster – an awesome sound that we would have never connected to a Les Paul” (G&B 11/07).
A **Strat** will never become a Les Paul, even with a **humbucker** (G&B 2/00).
By far the “Strat-iest” Gibson sound that I have every heard. Nighthawk (G&B 5/09).
Still, the PRS EG surprises with incredibly authentic **Strat-sounds**; mahogany neck, rosewood fretboard, mahogany body (G&B 9/05).

"The purely acoustical comparison gives opposite insights compared to the earlier comparison of the Mexico Classics. Now the 50s-version delivers the more balanced, open and zappy sonic picture while the 60’s-version sounds more mid-focused, warmer and somehow more well-behaved.” (G&B 2/02). About the cited Mexico Classic, we read: “The 50’s Strat generates a strong, mid-focused sound picture, defined by crisp, concise bass, delicate harmonics and a certain warmth. More brilliance, a more lively harmonic spectrum, more open mids, and a somewhat gentler bass is what the 60’s Strat offers”. However, there is also: “the A/B-test indeed reveals **only tiny differences**.” (G&B, Fender special edition, Mexico-Classics comparison). In both comparisons, the 50’s-Strat features a one-piece maple neck the upper surface of which forms the fretboard, while the 60’s-Strat has a one-piece maple-neck with a glued-on rosewood fretboard.

Hairline cracks are of the highest importance for the sonic results (G&B 2/07).

We were able to borrow a ‘56 and a **’58 Les Paul Standard,** and fabricated exact templates of the original shapes and contours. In the process we realized that the Historic-Collection-model had slight differences to the two originals. … Since it was not possible to change anything about the Silhouette (*the Historic-Collection-model is meant here*), at least the contour of the top was to be matched. Using a violin-maker’s device, we took the exact contour of the old Les Pauls and shaped an exact model from wood. From this model, we then shaped the new contour. This was an elaborate procedure because work had to be done using the smallest wood planes and card scrapers. ... (Pipper, G&B 12/06).

... they have made them a molten calf, and have worshipped it, and have sacrificed thereunto, and said, these be thy gods, ..., (The Bible, Exodus 32.8).

Alder: silky, mellow, warm, tender, many harmonics, restrained share of treble, fat bass, rather subdued share of bass, strong mids, round share of mids, much sustain, succinct, squishy, good presence, undifferentiated, balanced, full sound, a sound thinner than that of basswood, faster response than basswood.

Basswood: mellow & low mids, squishy, good response, undifferentiated, somewhat mid-laden, similar to alder, relatively little sustain, warm sound that lacks zappy-ness, unobtrusive, forceful, rather dull-sounding.

Poplar: clear treble, more airy than basswood, unobtrusive, round sound, like basswood but thinner, the tonal characteristics correspond to those of alder but lack warmth and brilliance, more crisp than basswood.

Maple: rich in attack, brilliant, rich in harmonics, lively, much sustain, not warm, warm bass, lacking warmth, mid-emphasizing sound, hard sound, singing tone.

Ash: mellow, rocking, soft, bass-y, brilliant, no pronounced share of mids, balanced, lively, powerful, tight, warm bass, long sustain, dry, airy, hard-wood-y, rich in attack, strong assertiveness (because ash is of stiff structure), responds considerably faster than alder, brighter and richer in the harmonics than alder.

Swamp ash: balanced, perfect balance of brilliance and warmth

Mahogany: mellow, low-mid emphasis, very bass-y, good sustain, delicate brilliance, silky, warm sound, warm mids.

Rosewood: powerful, harmonic sound, airy basic character, loose and full bass range, sparkling treble, Rio-rosewood generates a full additional octave of harmonics.

Neil Young: I am convinced that very note ever played on a guitar somehow remains in it. While it does leave the guitar body as sound, it still is within the wood. Everything that happens on a guitar remains in it and sums up to an overall experience (G&B 12/05). **Chris Rea:** it's funny – often the cheapest guitars sound the very best. … the Epiphone Byrdland is 4000 pounds cheaper than the Gibson Byrdland, and I cannot feel any difference – apart from the logo on the headstock (G&B 12/05). **Richie Sambora** re. the topic of "sound": "You still hear, however, that **Hendrix** went directly through the amp. It's his fingers. The same with **Jeff Beck**: you may use his rig and his guitar, but you will never sound the same. It's in the fingers." (G&B 11/02) **Van Halen**: it's not a question of equipment – it's the fingers (G&B 7/04). **Eric Johnson**: the source of more than 75% of the sound is in the fingers (G&B 5/01). **Jeff Beck**: no shenanigans, no mumbo-jumbo – just the fingers (G&B 3/07). **Jaco Pastorius**: piss off the amp and piss off the instrument. It's all in your hands (G&B 1/06). **Victor Bailey**: once I had the opportunity to play **Jaco Pastorius'** Jazz-Bass; you cannot imagine how terrible it was: lousy action, didn't sing at all. I was thoroughly disappointed. Jaco noticed that, grabbed the bass and played. It sounded gorgeous: the bass sang and growled (G&B 1/06). Snowy White: **Peter Green** sold his Les Paul to **Gary Moore**. I jammed with Gary once and it sounded o.k. But since it left the hands of Peter, it's just an ordinary guitar – nothing special anymore. A guitar is fabulous only as long as somebody fabulous plays it (G&B 11/07). **Jan Akkerman**: it all comes down to your hands (G&B 1/07).

The largest part of the **string vibration** is to be transmitted to the guitar body. If the latter is supplied with unrestrained vibration energy, a maximum of tone and sustain develops. (G&B 12/05). Because the nut should transmit the vibration energy as fully as possible to the neck (G&B 6/07).
The design shows considerable resonance characteristics; after every picking attack it vibrates intensely and clearly noticeable. (G&B 9/06).
From a **vibration engineering point-of-view**, the MTM1 ranks at the highest level, because the whole design resonates intensely to the last wood fiber after each picking attack, and a slowly and steadily decaying sustain results (G&B 8/06).
Although the Lag **vibrates** with marked intensity, and lively after each picking of a string, only a somewhat anemic sound reaches the ear … The bridge pickup, for example, pushes through to the ear in a powerful and assertive manner. … The single coil at the neck pushes the low end and the lower mids with much power (G&B 12/06).
Picking up the **Pensa-Suhr**-guitar and playing it unamplified, a reasonably trained ear immediately hears that this is gonna be good. … Both standing up and sitting down, you feel already in your **belly** the fantastic vibration behavior of the excellently matched woods (Fachblatt, 6/88).

Since a relatively large **body mass** (3,9 kg) needs to be excited to vibrate, the response seems a bit ponderous, and the tones do not get off the starting blocks as quickly (G&B 7/06).
The guitar vibrates intensely, responds directly and dynamically, every chord and every tone unfolds zappily and lively. Weight: 4,15 kg (G&B 8/06).
Less mass can more easily be made to vibrate (Kortmann, gitarrist.net).
Despite the enormous wood-mass (3,85 kg), almost every tone responds zappily and dynamically, and unfolds very swiftly (G&B 7/06).
Thinner guitar body = less bass (G&B 4/04).
Sparingly varnished guitar body = rounder, more succinct tone (G&B 7/05).
A more slender guitar body makes for a more slender tone, too (G&B 7/02).

The tone of a **guitar with a fully hollow body** is fragile and has an enormous momentum (G&B 8/06).
Guitar with hollow body = more mellow sound (May).
Brian Setzer is known for his extremely powerful, in fact brash sound that only **archtops** with suitable pickups can offer (G&B 8/06).
Semiacoustic guitars sound brighter, more transparent, more brilliant (E-Gitarren).
335-Sound: a warm, fat sound that is highlighted, due to the semiacoustic build, particularly in attack and response (G&B 1/07).
In the hands of Alex Conti, the **335** sounds not much different than his Les Paul. The fingers make much more of a difference than one would think (Richie Arndt G&B 9/07).
Danelectro: **hollowbody**, decent sustain, probably thanks to the maple neck with the luscious rosewood fretboard (G&B 12/06).

Cavities (in the solid-body guitar) have no impact on the sound (Lemme). To improve the body's resonance, the core body is drilled with eleven 1,5"∅ cavities". (Duchossoir, Tele).
The cavities in the Les Paul have no effect on the sound-characteristic of that model – we have tested this (Henry Juskiewicz, president of Gibson; Les Paul Book). The Les Paul Custom Classic receives an additional percussive and crisp touch from the milling in the wood. The Gibson Custom Shop now offers some models as so-called chambered variants. What was introduced simply as a means to save weight back in the day now receives an entirely new, tonal significance (G&B 8/07).

The electrified plank-guitar is predominantly an **acoustic** instrument. The wood makes for the character of the sound; the pickups contribute only a very small part. And so a humbucker cannot exorcise the characteristic unfolding of sound and attack from a Strat with an alder or ash body (G&B 02/00). **Edward van Halen**: the boys in the band didn't like the sound of the Stratocaster because it is naturally so thin. So I mounted a humbucker (G&B 9/02).
Gary Moore: some people think they hear a Stratocaster on "Ain't Nobody" – however, in reality that's my own signature Les Paul, (G&B 7/06).
Jimmy Page recorded the entire first Led-Zeppeling album using a **Telecaster**; the guitar sound on that album is exactly like that of a Les Paul (G&B Fender special issue).
Mark Knopfler: if I want a thicker sound, I use my Les Paul – that's not to say, though, that I couldn't do the same thing with a Stratocaster. Even if **B.B. King** plays a Fender, it still sounds like a Gibson Lucille (G&B 9/06).

Les Paul Custom: one-part mahogany body (The Gibson).
Around 1952, the Gibson designers produced prototypes of their first solid-body guitar, the Les Paul, completely made of mahogany. This design did not satisfy them tonally, though, but rather motivated them to carry out further experiments with other types of wood. The result was a mahogany body with a maple top (Day et al.).
Les Paul: back then my idea was to build the whole guitar – i.e. headstock, neck and body – from one and the same piece of wood. They didn't do it. When I asked the president of Gibson why not, he said: "because it is more inexpensive this way" (G&B 9/05).
Gibson Les Paul: "The rims of the electronics compartment and switch chamber again reveal appalling workmanship: they are partially downright frayed, and the impression rises that the wood to be removed was blasted away. ... Just about tolerable to me is the pickup switch that due to the curvature of the top lives in its chamber in a totally crooked manner, touching the milled wall …" (G&B 12/06). Only the price seems to be on target: 2655,-- Euro.
Lester Polfus answering the question whether he had ever imagined that the Les Paul could be such a successful guitar: "Of course. I believed in this guitar from the very start" (G&B Gibson special edition). But then, he also says: "Never ever. I would not have thought that this guitar could be that popular 60 years on" (G&B 9/05).

The image of **old Les Pauls** was forged systematically by the pertinent dealers; they simply imputed the vintages 1958/1959 with a legendary sound (Carlos Juan, vintage dealer, in Fachblatt Musik-Magazin, 1996).
Investigating the term "**vintage**" more closely, it turns out to be substantially an empty catchword that frequently serves to sell questionable product at inflated prices (Lemme).
Most **vintage** instruments are not suitable for serious stage work in their original condition, and as they are being made workable, they are not vintage anymore. The opinion that everything becomes wonderful or improves because it is 50 years old or carries a spaghetti-logo, is itself long in need of repair (Carlos Juan, vintage dealer, in Fachblatt Musik-Magazin, 1996).
Kevin Walker: I would never buy a Gibson built later than 1972. … only the vintage stuff has the good sound (G&B 5/06).

Well … it's a piece of wood with 6 strings on it – that must not be overrated. **Pat Metheny** on his guitar (G&B 6/08).

Certain is that nothing is certain, and therefore I am wary – just to be safe (loosely translated, after the Bavarian poet **Karl Valentin**).