0.4 The sound of the unamplified guitar

How does the expert test an electric guitar? By first listening to it without amplification (dry). "It is certain, that – contrary to common belief – the desired sound in electric guitars and basses does not predominantly depend on the pickups. Rather, the wood creates the basis. A guitar made from plywood will not sound good even with the best of pickups. When a customer approaches me here in the 'Guitar Garage' in Bremen and wants to discuss pickups, I first listen to the instrument without an amp" [Jimmy Koerting, Fachblatt Musikmagazin]. Or: "For the first assessment of the sound quality we need neither towering amps nor distortion devices, a small combo suffices. Of course, it would be even better to test the tonal behavior in a quiet corner playing 'dry', purely acoustically, and check with regard to attack, balance and sustain" [G&B 3/97]. How then can two guitars that differ in their 'dry' sound be unable to make this difference heard via the amplifier? "Surprisingly, the differences in sound show up to a much lesser degree when played through the amp, compared to the 'dry' test" [G&B 7/06]. Compared were: Gibson New Century X-Plorer and V-Factor. From another comparison test: "The Platinum Beast sounds (dry) powerful, warm and balanced, with a velvety brilliance and delicate harmonics. The Evil Edge Mockingbird somehow comes across as feeble, poor in the mids, with somewhat more pronounced bass, but instead is more brilliant and richer in harmonics. Thanks to the hot humbuckers, everything sounds very different when connected to the amp because – hard to believe – both instruments now sound all but identical" [G&B 8/06].

Extreme examples seem not to be of any help here. Plywood (or even rubber!) is called into action to serve as body-wood in order to justify the significance of, and necessity for, high-grade woods for the guitar body. That's the one extreme: with a totally unsuitable (highly absorbing) body, you cannot build a good guitar. Ergo-1: the wood is more important than the pickups. The other extreme: you switch a trebly ("underwound") Strat pickup for a bassy, treble-devouring Tele-neck-pickup boasting a thick brass cover, and postulate Ergo-2: the pickup is more important than the wood. Both considerations are too lopsided.

From the point of view of systems theory, the vibrating string is a generator that on the one hand excites the body and the neck to vibrate, both of which themselves radiate airborne sound. On the other hand, the relative motion between string and pickup generates the induced voltage. Airborne sound and voltage are therefore correlated – they result from one and the same source. If the string vibration dies off already after a few seconds, the pickup cannot make for a gigantic sustain. Or maybe it can, after all? Within certain limits it could indeed – in combination with a suitable amplifier (+ loudspeaker). If the amplifier limits the signal (overdrive, crunch), it actually changes the decay behavior. That's the decay behavior that is *audible via the loudspeaker*, because the decay of the string vibration is not changed, anyway. Or is it?? Now, the situation begins to become multitudinous … and exactly for this reason we find so many contradictory opinions in guitar literature. If guitar and loudspeaker are located close together, feedback can certainly influence the string vibration, too. Which may be the reason for the expert-advice to first listen without an amplifier. Still: no guitarist will buy an electric guitar to always play in unamplified fashion. At some point, plugging-in will happen, and now the predictions from the 'dry' test are supposed to by vindicated. The probability of a favorable ending of the experiment is not entirely at zero – electric and acoustic sounds are somehow related (cor-related!), but how exactly cannot be seen at first glance.

Let us imagine a simple **experiment**: the pickups of a Stratocaster are screwed directly into the wood – this is to fully secure them in place. Oh, you reason that this step alone already changes the sound? Hm. Anyway, this special sound is taken as the reference. We have guitar, pickups – and now we get to the exceptional: once we play with pickguard, and once without. It's a *plastic* pickguard so that no metal layer can cause any eddy-current damping. Is a difference in sound audible if the guitar is played with pickguard, and then without? In the acoustic sound: definitely yes, in the electric sound: definitely no. If the pickguard is present, it is caused to vibrate via the guitar body. Having weakly damped natural frequencies (Eigenmodes), it can radiate audible sound in several frequency ranges. Do these vibrations of the pickguard act retroactively onto the strings. In theory: yes, because "All things are bound together. All things connect." (causality statement by Chief Seattle, sometime in the mid 1800's). Practically: no, since between pickguard and strings we have the guitar body which weighs in at a serious multiple of the mass of the pickguard. The string vibrations are influenced by the pickguard to such an insignificant extent that the electrical sound is not audibly changed. The radiated airborne sound, however, does of course change. Or another **example**: a singer performs in a concert hall. Listener A listens in the concert hall while listener B listens from the neighboring room via an open door. Now we close the door – what does change? A lot for listener B, practically nothing for listener A. Very theoretically we can again call for Chief Seattle's lemma, and demand a correction value for the wall absorption, but in this case there is no practical effect, as much as we might agree the Chief in general.

What's the singer got to do with the electric guitar? In both cases there are different transmission paths which change the sound conducted by them in a different manner. Knowledge about one transmission path does in general not allow for any conclusion about the other. The listener in the concert hall cannot be certain whether the other one (The Man Outside…) can hear anything at all. For the guitar, that implies: what can the nice acoustic sound do for me, if the pickup coil is ruptured? Careful though, were getting again into the domain of extreme positions. So let's assume an incomplete sound-insulation for listener B. He/she will then be able to give some statements: when is there singing, or a pause. Maybe he/she even recognizes which one of three singers is in the process to try to get to the high C at the given moment: the little one, the handsome one, or Fat Lucy. Issues with intonation will be audible even through the closed door, as long as the insulation is not complete. And even more so, if these issues are present in the expectation of the listener in the first place.

The thing with the expectations needs to be considered for the guitar, as well: it is astonishing how some guitar testers fall victim to their own conviction. Irrevocable **credo**: *"of course, the original Les-Paul-mix consisting of mahogany neck with rosewood fretboard and mahogany body with thick maple top will result in the one-and-only Les Paul sound"*. That's exactly how this needs to be written – in this case in a comparison test for guitars[♣]. And then a copy with an alder body (stigmatized with "**!**" in the test report) dares to sound good – even commands the tester's respect. *"... come alder ... come mahogany, it is anyway able to convince us with a first-class sound"*. Well, well, don't you exaggerate! Don't forget: we are talking about alder here! And lo and behold: *"...all in all a bit subdued and a little bit shy." There you go – typically alder!* However, oh great Polfuss, what happens only one column later, with the Fame LP-IV that's also in the test group? *"Those who dig a typical powerful, no-frills Les Paul sound, you should check out the Fame LP-VI. It indeed sounds the most authentic. Its sound is very close to the original in every range."* **Question:** according to the test-info, the Fame LP-IV has a maple neck, an oak fretboard, an alder body and a mahogany top. Did I get something wrong here?

[♣] G&B 7/02

However, why don't we postpone the discussion on materials to later and return to the question: how far is the conclusion from the 'dry' test to the electric sound legitimate? Apparently there are "**robust"** signal parameters that win out in any signal path, and "**fragile**" parameters that change as they pass through a transmission medium. Pitch is fairly robust: whether the guitar is amplified or not, you will hear if it is in tune. Maybe not to the last cent (of pitch!), as the psycho-acousticians know, but with adequate accuracy for these first considerations. The balance between treble and bass, however, depends on the tone control settings on the amp – that is a trivial as it is uncontroversial. As hard as the sound from the guitar body may try – it will loose out to the fully dimed bass knob. "That's not what we mean", the expert may object, "in the 'dry'-test I listed to the foundations of the sound – to the soul of the wood." Now, please: dear physi-cists and psycho-cists, don't you get malicious here! A guitar tester does not have to have too much of a grasp of either physics or psychology, and he may present such a statement. The **soul of the wood** does not present itself prima facie, though. Many séances are required during which the spirit can permeate the matter. A lot of knocking on wood will be necessary, a tuning fork will have to be pressed against the solid body of a Stratocaster (at least according to Fender advertising), and ear-training over many years will be mandatory. We should be able to reach a consensus at least when it comes to this latter point, shouldn't we? The discussion is, after all, not supposed to be about the guitar-o-phobe agnostic suffering from chronically progredient dysacusis. It is about the more or less pronounced aficionado of the instrument – who, with a more or less extensive auditive experience, may indeed hear details in the sound that are not accessible to the layperson.

Enter the following problem: how do we describe such details in the sound? That is a classic task of **pyschophysics** and psychometrics, and it often leads to a misunderstanding just as classic: a verbal description (dead, boxy sound) will be rejected at the scientific docking site as too ambiguous and imprecise, just as the exact description (degree of amplitude modulation of 8.43% at 944 Hz and with f_{mod} = 6,33 Hz) is rejected by the musical/mystical faction as figment-y and way too abstract. Any proposals of compromise trying to connect the two worlds are consistently dismissed by both factions. Well then: rather than talking about the soul'o'wood, quite often a dead, or lively, sound is cited. How are dead matter and alive matter different? Alive matter will move! Ah … you object already now because the pencil dropping from the table would then be alive? O.k. let's then turn to the basic philosophical consideration of life in particular and of existence in general … NOT! **Alive means movement** – done and dusted! To translate that to the guitar: an artificial tone with strictly harmonic partials that all decay with the same time-constant – that will sound dead. Conversely, if the partials decay with different speed and with various beats, a sensation of movement and lively-ness will result. Here, the term "movement" may certainly be looked at in its original meaning as change of location: as a sound source changes its location in a (sound-reflecting) room, time-variant comb-filters make for differences in the signal spectrum, and the movement in space causes the "movement" in sound. In primeval days it presumably was conducive to survival to prioritize moving sound emitters over ones fixed in place, and at the same time early linguists discovered that speech sounds can carry information only if they include change. Without entering too far into foreign territory: there would be sufficient reasons why human hearing is constantly on the hunt for spectral *changes*. Even if the electric guitar is somewhat younger than roaring tigers and vandals going "Arrrghh!", the hearing possesses this ability to analyzes and it will use it. A lively tone rich in beats sounds more interesting than a dead one – at least as long as instrument-typical parameters are being kept.

Similar to the string pitch, beatings of partials can be rather **robust** towards the transmission parameters, and therefore it certainly is imaginable, that the expert can derive criteria of the electric sound already from the 'dry' test. Now, what does this robustness of the signal parameters depend on? Frequency-dependent signal parameters, such as the spectrum, loose their individuality if the corresponding frequency-dependent system parameter (the transmission function) has a similar shape. Three examples:

1) psycho-acoustics [12] describe the balance of trebly and bass-y spectral contingents with the perceptional characteristic "**sharpnes**s": sounds with an emphasis on treble have a strong sharpness. Turning down the treble control decreases the sharpness. Significant for the calculation of the sharpness is not so much the spectral detail, but the (smoothed) shape of the spectral envelope. To be more precise: sharpness is derived from the weighted loudness/pitch-diagram which will capture the frequency range relevant for the electric guitar at merely around 20 sampling points. Using the same spectral resolution, transmission frequency responses of guitar amplifiers may also be represented (**Fig. 0.2**). Looking at the relationship between the two datasets we can conclude that the sharpness of the 'dry' guitar sound will in general not correspond to the sharpness of the amplified sound. Put another way: changing the controls of the amplifier, we can change the sharpness of the sound – from this angle, sharpness is not a robust signal parameter.

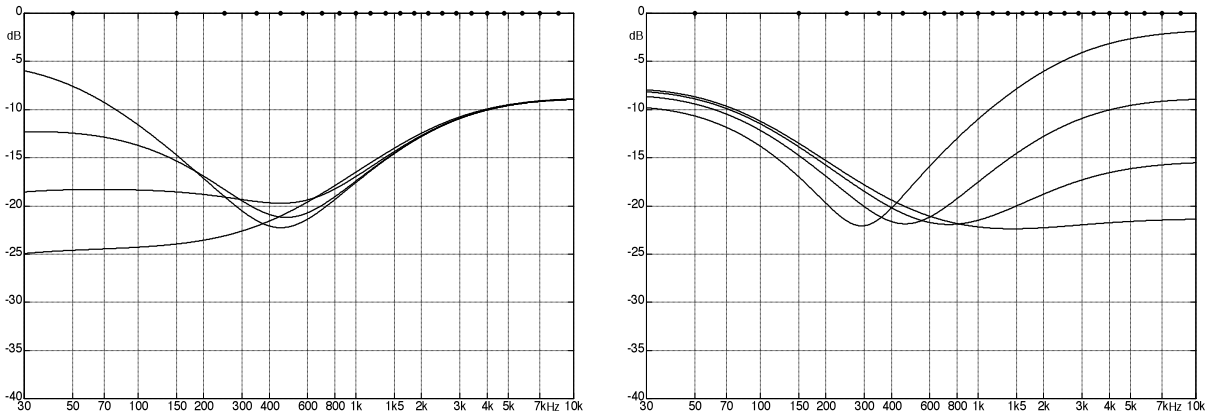

Fig. 0.2: Tone control of a Fender amplifier (transmission factor). The points at the upper picture frame mark the critical-band grid (discretization of the abscissa for calculation of sharpness).

2) **Beats** between partials may be described as amplitude fluctuations in the time domain, while they can be seen as sum of closely adjacent partials in the frequency domain. For example, two same-level partials of slightly different frequency (e.g. 997 Hz and 1003 Hz) lead to the perception of a 1000-Hz-tone fluctuating in loudness with 6 Hz [3]. To change this beating, a highly frequency-selective operation needs to be carried out that would be untypical for tone controls on amps. As such, beats between partials are therefore robust relative simple tone-control networks.

3) The spectrum of a quickly **decaying** sine tone (**Fig. 0.3**) is predominantly limited to a narrow frequency range. Changes in the decay characteristic will therefore need to be carried out also via highly frequency-selective changes. In other words: a linearly operating, guitar-amp-typical tone-control network will leave the decay behavior of single partial practically unaffected; the decay behavior is robust in this respect.

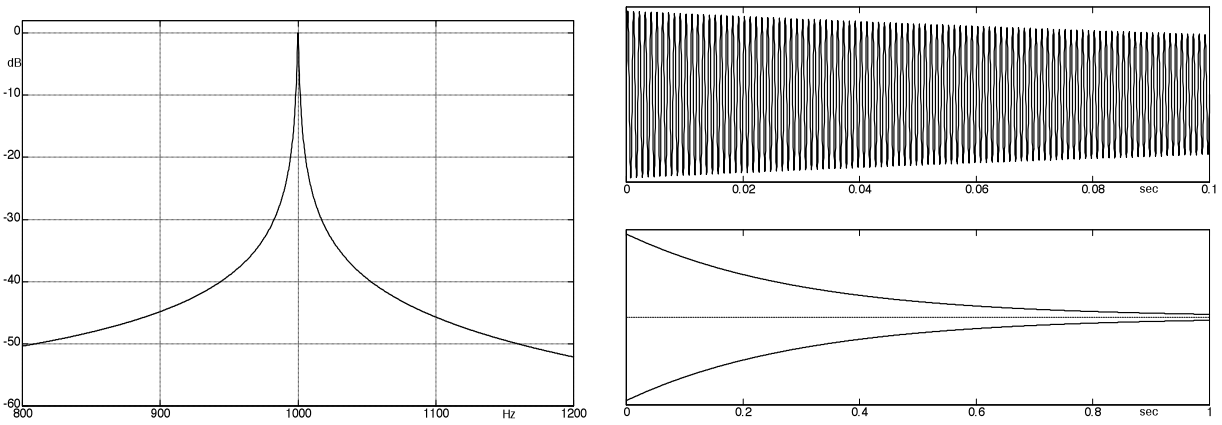

Fig. 0.3: Decaying sine-oscillation, $f = 1000$ Hz, time constant $\tau = 0{,}3$ s.

These simplified presentations do need to be supplemented by a few points: it's not just the transmission factor of the guitar amp that changes the spectrum given by the stings – the loudspeaker (incl. its enclosure), too, acts as a filter, and in the detail its transmission curve is more frequency dependent than that of a tone-control network. The speaker membrane does not reach the high resonance Q-factors of decaying guitar partials; for that it would have to itself produce clearly perceivable tones – which it exactly does not. The last filter in the transmission path is the room with it reflecting surface. Its effect is not entirely negligible even for the 'dry' test, and when playing through amp and speaker, the speaker distance weighs in as another variable. However, as long as we stay within close range of the loudspeaker, the effects of the room may be regarded as being equivalent for both playing situations.

Special consideration needs to be given to those effects that result in more than what a simple tone control does. The addition of artificial reverb can extend decay processes and feign liveliness that is not included in the original signal in such a form. Chorus/phaser/flanger are time-variant filters of a high Q-factor, and their use always targets changes in the fine-structure of the partials. Compressors (in particular the multi-channel variant) change the decay constants of individual groups of partials. Overdrive has similar effects but adds extra partials. It is thus certainly possible to influence the signal parameters that have been categorized as 'robust' above. Still, without radical effects we can be successful within certain limits to infer the sound of the amplified electric guitar from the unamplified guitar. Which of the many beat- and decay-parameters, however, would be important for that 'good' sound … that is only appraisable implicitly, in the best case. Moreover, we then get into the wide-open field of temporal and spectral masking [12], and therefore we can only draw the fundamental conclusion that **the sound of the unamplified guitar should in principle not be evaluated**. In particular in view of the expert's special knowledge (that has been accumulated over decades), and his/her specially trained ear, this rule does allow for exceptions … in individual cases, and for that expert, the 'dry' test may reveal "everything", after all. The group of such experts who may take advantage of that exception comprises: guitars testers of all guitar magazines, all guitar sales personnel, all guitarist who have had, or have wanted to have a guitar for more than a year, an all listeners (both CD and vinyl) who have the exact sound of Jeff Beck's signature guitar still ringing in their ears (see Chapter 7). And please, dear experts that now have received such extensive legitimization for your obviously indispensable 'dry' tests: we now should have consensus that the assessment of tactile vibrations is nonsense, shouldn't we?!

Concluding the topic of **guitar testing**, here are a few further citations:

Yamaha Pacifica guitars (maple neck, alder body) in a comparison test: "Acoustically, the basic characteristics of the Pacificas are readily comparable. Plugged in, however, they differentiate themselves rather clearly corresponding to the pickup complement" [G&B 6/04].

Gibson Les Paul Faded Double-Cutaway: "Right from the first plucking of the strings, it is clear that there is less damping of the resonance characteristics of the wood due to the low-key varnishing, The guitar resonates from head (machine heads) to toe (strap-pin) so intensely that I could even sense it in my own body" [G&B 6/04].

Ibanez IC400BK: "The slight underexposure of the E_6-string found in the 'dry' test is suddenly gone as the pickups provide support." [G&B 6/04].

Squier-Stratocaster, comparison: **mahogany** body vs. **basswood** body: Using the middle and neck pickup, respectively, both guitars sound nearly identical." [G&B 5/06].

"Grabbing the **Pensa-Suhr** guitar and playing it unamplified, any reasonably trained ear immediate hears what it's at. … Both seated and standing up, you feel the fantastic vibration behavior of the excellently tuned woods in your **belly**" [Fachblatt, 6/88].

"Despite the humbucker, a Strat can (sonically) never become a Les Paul" [G&B 2/00]. **Ozzy Osbourne** about Joe Holmes: "I don't actually like Fender guitars. But Joe gets this fulminant Gibson sound with them" [G&B 2/02]. "**Jimmy Page** recorded the complete first Led Zeppelin album using a Telecaster. The guitar sound on that album is exactly that of a Les Paul." (G&B Fender special issue). **Mark Knopfler**: "If I want a fatter sound, I'll use my Les Paul – it is simply more dynamic. That does not mean, however, that I could not do the same thing with a Stratocaster." [G&B Fender-Heft]. **Gary Moore:** "some people believe that you hear a Stratocaster on 'Ain't nobody', but in reality it's my own signature Les Paul." [G&B 7/06 p.91].

High mass of wood (**3,9 kg**): Due to the big mass of wood, the response seems to be a bit ponderous, and the notes do not get off the starting blocks as quickly. [G&B 7/06].
Still heavier (**4,15 kg**): The guitar resonates intensely, has a direct and dynamic response; every chord and tone unfolds crisply and with great liveliness [G&B 8/06].
Despite the enormous mass of wood (**3,85 kg**) almost every note responds crisply and dynamically, unfolding very swiftly [G&B 7/06].
"Less mass can be made to vibrate more easily" [Thomas Kortmann, gitarrist.net].
A slender guitar **body** makes for a slender tone [G&B 7/02].
Thinner **body** = less bass [G&B 4/04].

Fat neck = sonically advantageous [G&B 8/02]. **Thin neck** = round, fat sound [G&B 10/05]. **Thin neck**: The less mass that needs to be moved, the more direct and quickly response and unfolding of the tone get off the starting blocks. [G&B 3/05]. **Crisp** and direct in the response, every tone gets off the starting blocks quickly and with great livelihood, **despite the immense mass of wood** (that indeed needs to be set in motion to begin with!) [G&B 9/05]. **A thin neck** has no acceptable vibration-characteristic whatsoever [G&B 3/97). Of sonic advantage is that the **neck** weighs in with **a lot of mass** [G&B Fender special issue). The **Ibanez JEM 777** features an extremely thin neck-construction: the sound character is powerful and earthy [Fachblatt, 6/88]. Of course the **neck shape** also contributes to the sonic character [G&B, 12/06]. What is not true at all is that **fat necks** sound better than thin ones. I have built the same guitar with a fat neck and a thin neck, and could not detect any difference [luthier Thomas Kortmann, Gitarrist.net]

Nay, that's past praying for [Shakespeare].

