8.7.2 The sound of the un-amplified guitar

How does the expert test an electric guitar? He first listens to it without amplification (i.e. “dry”). “It is certain that – contrary to common opinion – the desired sound of electric guitars and electric basses is not mainly dependent on the pickups. Rather, the wood forms the basis. If a customer travels to see me in the ‘Guitar Garage’ in Bremen and seeks to discuss pickups, I first listen to the instrument without amplifier.” (Jimmy Koerting, Fachblatt Musikmagazin). Or: “For a first evaluation of the sound quality we do not need amplifier towers nor distortion boxes – a small combo entirely suffices. It would of course be even better to test the sonic behavior in a quiet corner, dry, purely acoustically, regarding response, balance, and sustain.” (G&B 3/97). But why then are two guitars that sound differently dry, not able to feature these differences anymore when played through an amp? “Surprisingly, the differences in sound show up – compared to the dry-test – much less when connected to an amp”. G&B 7/06, comparison: Gibson New Century X-Plorer vs. V-Factor. Or, from a different comparison: "The Platinum Beast sounds dry powerful, warm and balanced, with velvety brilliance and tender harmonics, while the Evil Edge Mockingbird is sonically somehow feeble, poor in the mids, with somewhat more pronounced bass, but also clearly more brilliant and harmonically richer. Connected to an amp, and thanks to the hot humbuckers, everything is different though: hard to believe, but the two instruments now sound almost identical.” G&B 8/06.

Extreme examples will not serve to help in this case. Plywood (or even rubber!) is used as material for the (solid) guitar body in order to justify significance and necessity of high-grade body-woods. That is one extreme: using a totally unsuitable (absorbing) body, a good guitar cannot be built; ergo-1: the wood is more important than the pickups. The other extreme: a brilliant (“under-wound”) Strat-pickup is swapped for a muffled, treble-eating Tele-neck-pickup with a cover made of thick brass, and the result is the statement ergo-2: the pickup is more important than the wood. Both approaches are too lopsided.

From the point of view of system theory, the vibrating string is a generator that on the one hand excites guitar body and neck to vibrate and thus to radiate airborne sound. On the other hand, the relative movement between string and pickup induces a voltage. Airborne sound and voltage are therefore correlated because of the excitation from the same source. If the string-vibration dies down already after a few seconds, the pickup cannot generate a gigantic sustain. Or can it? Within certain limits, indeed, it could – in cooperation with a suitable amplifier (+ loudspeaker). The decay behavior is changed if the signal experiences limiting via the amplifier (overdrive, crunch, distortion). This is the decay behavior audible *via the loudspeaker*, because the decay of the string vibration is not changed. Or is it? Things begin to become unfathomable, and exactly for this reasons we find such contradictory opinions in guitar literature. If guitar and loudspeaker are positioned closely together, feedback may certainly influence the string vibration, as well. Maybe this is where the expert advice comes from: first listen to the guitar without amp. However: hardly any guitar player will buy an electric guitar to play it un-plugged forever. Sooner of later he will plug it in, and then the forecasts from the dry-test are supposed to prove to be true. The likelihood of a fortunate result of that experiment is indeed not entirely zero: electrical sound and acoustical sound are somehow related (correlated) – but in which way exactly is unclear to begin with.

Let's imagine a simple **experiment**: the pickups of a Stratocaster are screwed directly into the wood so that they have a clearly defined position. Will already that change the sound? Anyway, let us assume this special sound to be the reference. Guitar, pickups, and now on to the peculiarity: once with pickguard, and once without. That's a pickguard made purely from plastic so that no metal layer may generate any eddy-current damping. Now, do we hear a difference in sound if that guitar is played with pickguard compared to being played without? In the acoustic sound: definitely yes – in the electric sound: definitely no. Via the body, the pickguard – if present – is made to vibrate. It has weakly damped natural modes (eigenmodes) and is able to radiate audible sound in several frequency ranges. Do these pickguard-vibrations act back to the string? Theoretically: yes, because "all things are connected" (as already reportedly pointed out to the US Government by Chief Seattle as early as 1854/5). Practically no, because between string and pickguard we find the body that weighs in with many times over of the mass of the pickguard. The string vibrations are changed by the pickguard only in such an insignificant degree that the electrical sound does not change audibly. However, the radiated airborne sound does. Or another **example**: singers perform in a concert hall, and listener A listens in that hall while listener B listens from an adjoining room via the open door. Now, the door is closed – what changes? For listener B, a lot – but for listener A, almost nothing. Very theoretically, we can again call in Chief Seattle and demand a correction factor for the wall absorption that the closed door has modified, but in practice not all of such lemmas have been rewarding, as the in the chief's case rather unfortunate history has shown.

What is the connection between the singer and the above electric guitar? In both cases there are two different transmission paths that modify the sound they carry in different ways. Knowing about one transmission path does not allow – in the general case – for any conclusions on the other transmission path. The listener in the concert hall cannot even be certain that the other listener (The Man Outside …) hears anything. This implies for guitars: what use is the great acoustical sound if the pickup winding is broken. Caution, though: we are again entering territory of extreme positions. Thus, not assuming a complete sound insulation for listener B, the latter will be able to make some statements: when singing is going on, when it is paused. Maybe, listener B can even recognize which one of the three sound sources is trying to get to that high C: the little one, the pretty one, or *Fat Lucy* (also called the stage-panzer). Any problems with intonation are perceived through the closed door, as well, as long as the latter in not totally soundproof – and if such problems are present within the expectations of the listener in the first place.

The thing with the expectations can be observed with guitars, also: it is astonishing how some guitar tester become victims of their own convictions. Irrefutable **credo**: "Of course, the original Les-Paul-mix of rosewood fretboard and mahogany body fitted with a thick maple cap – that gives us the unique Les-Paul-sound". That's just how it needs to be written – in this case in a comparison test (G&B 7/02). And then a copy with an alder body (stigmatized with a "!" in the test) dares to sound good. It even commands the tester's respect. "*... it can, in any case – be it alder or mahogany – convince with a first-class clean sound...*" Well, well – let's not exaggerate here! Don't forget, its alder!! And lo and behold: "*... overall somewhat subdued and a bit shy.*" There we are: typical alder. However, oh great Polfuss, what happens only a column further, with the Fame LP-IV also included in the test? *"Those who go for a typical forceful Les-Paul-sound without frills should check out the Fame LP-IV. Indeed, it sounds the most authentic. In all areas, its sound is very similar to that of the original*". **Question**: according to the test, the Fame LP-IV sports a maple neck, an oak fretboard, an alder body, and a mahogany cap – did I get anything wrong here?

Let us postpone the discussion on materials to later, though, and return to the question of how far the conclusion from the "dry" test to the electrical sound is admissible. Apparently there are "**robust**" signal parameters that win through on every transmission path, and "**fragile**" parameters that change on their way through the transmission medium. The pitch is quite robust: whether a guitar is in tune is audible both "dry" and amplified. Not to the last cent, as psychoacousticians know, but with a precision adequate for some first considerations. The sonic balance between treble and bass, however, depends on the tone settings of the connected amp – that much is as uncontested as it is trivial. The "dry" sound can make every effort: it can never hold its own against a fully turned-up bass control. "Anyway, that's not what we mean", the expert will object, "in the dry-test I can hear the fundamentals of the sound, and the soul of the wood." Please, dear scientists and dear psychologists – no malice now … it's o.k. to state something like that here, as a guitar tester who does neither have to understand much about physics nor of psychology. However, the **soul of the wood** does reveal itself to the seeker not a prima vista; it does require many séances in which the spirit penetrates the matter; much knocking on wood needs to happen, and a tuning fork must to be pressed against the solid body of a Stratocaster (in the Fender ads, anyway), and many years of ear training are necessary. At least for this last point we should be able to reach a consensus, shouldn't we? This is not supposed to be about the guitar-o-phobe agnostic with progressive dysacusis, but about the more or less pronounced aficionado of the instrument. Those who – with their more or less extensive listening experience – indeed hear details in the sound not accessible to the layperson.

Problem: how do you describe such sound-details? This is the classic conceptual formulation and task of **psychophysics** and psychometrics that frequently leads to similarly classical misunderstandings. A verbal description (dead, woolly sound) is rejected at the physical docking-port as much too ambiguous and imprecise, just like the exact physical description (8,43% degree of amplitude-modulation at 944 Hz with f_{mod} = 6,33 Hz) is objected to by the artistic/mystical faction as pipe-dream-y and too abstract. Logically, any proposals of compromise trying to bridge the two realms are dismissed by both sides. Well then: rather than the wood's soul, often a dead or a lively sound is mentioned. What distinguishes live from dead matter? The matter that is alive – it moves! And already we have the first objections, because that would define the pen dropping from the table as alive? O.k., so we turn to a fundamental philosophical contemplation of life in particular, and of the universe and everything in general … NOT! No, really not. **What is alive does move**. Period. Conferred to the guitar sound: an artificial tone with its strictly harmonic partials all decaying with the same time constant, sounds dead. However, if the partials decay with different speeds and with different beats, the impression is one of movement and life. In this, the term "movement" may indeed be seen in its original meaning as change in location: when a sound source changes its position in a (sound-reflecting) room, time-variant comb-filters vary the signal spectrum – the movement in space has the effect of a "movement" in the sound. Way back in prehistoric times it was presumably in support of survival if moving sound sources were given a higher priority than static sources; at the same time early researchers in communication discovered that speech sounds will only convey information if they include variations. Without pushing too far into foreign territory: there would be enough reasons why the human auditory system continuously hunts for spectral *changes*. Even though electric guitars are younger that roaring tigers and vandals screaming "arrrghh!", our hearing has its capability to analyze, and it takes advantage of it. A lively tone rich in beats sounds more interesting than a dead sound – at least as long as instrument-typical parameters are maintained.

Similarly to the pitch of the string, the beats between partials can be rather **robust** relative to the transmission parameters, and therefore it is imaginable that the expert may be able to deduce criteria for the electrical sound from the "dry" test. On what does the robustness of the signal parameters depend? Frequency-dependent signal parameters – such as the spectrum – loose their individuality if the corresponding frequency-dependent system parameter (the transfer function) has a similar shape. Three examples follow:

1) Psychoacoustics [12] describes the balance between high and low spectral components as "**sharpness**": treble-emphasizing sounds have a high sharpness; turning down the treble control reduces the sharpness. Spectral details are not as essential for the calculation of sharpness as the basic (smoothed) run of the spectral envelope. To be more precise: the sharpness is taken from the weighted loudness/critical-band-rate diagram which has a mere 20 sampling points in the frequency range important for electric guitars. (Transmission-) frequency-responses of guitar amplifiers can be represented with the same increments (**Fig. 8.45**), and from the kinship of the two data-sets we can conclude that the sharpness of the "dry" guitar sound in general does not correspond to the sharpness of the amplified sound. In other words: changing the tone controls on the amplifier allows for changing the sharpness – from this point of view, sharpness is not a robust signal parameter.

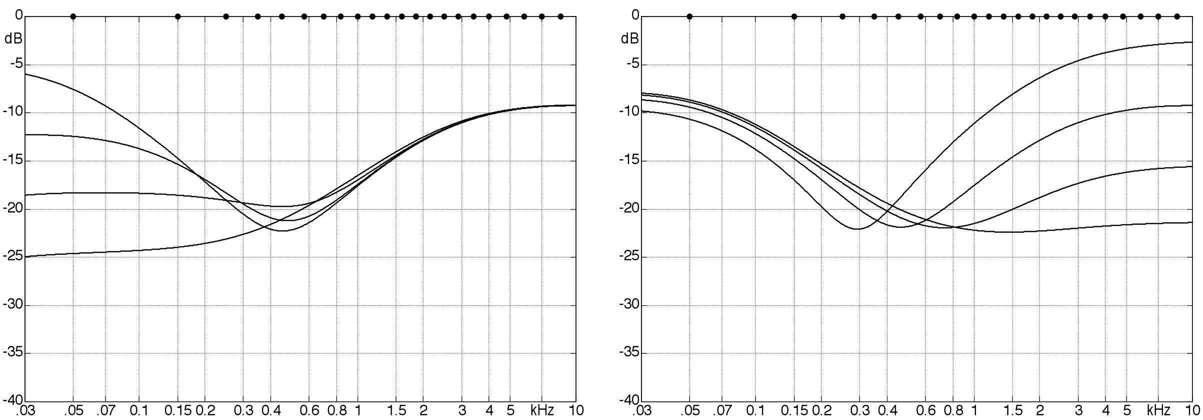

Fig. 8.45: Tone control of a Fender amplifier (transmission factor). The dots on the top mark the critical-band grid (discretization of the abscissa in order to calculate sharpness).

2) Beats between partials can in the time domain be described as amplitude fluctuations, and in the frequency domain as the sum of closely neighboring partials. For example, two partials of equal level but slightly differing frequencies (e.g. 997 Hz, and 1003 Hz) lead to the auditory perception of one single 1000-Hz-tone fluctuating in loudness with 6 Hz [3]. In order to change this beating, a highly frequency selective operation is necessary. Such an operation is untypical for tone controls in amplifiers. From this point of view beats in partials are robust relative to simple tone-control networks.

3) The spectrum of a quickly **decaying** sine-tone (**Fig. 8.46**) is largely limited to a narrow frequency range. Any changes in the decay behavior need to be done using highly frequency-selective methods, too. In other words, a linear, guitar-amp-typical tone control network will practically not change the decay-behavior of individual partials – the decay behavior is robust in this respect.

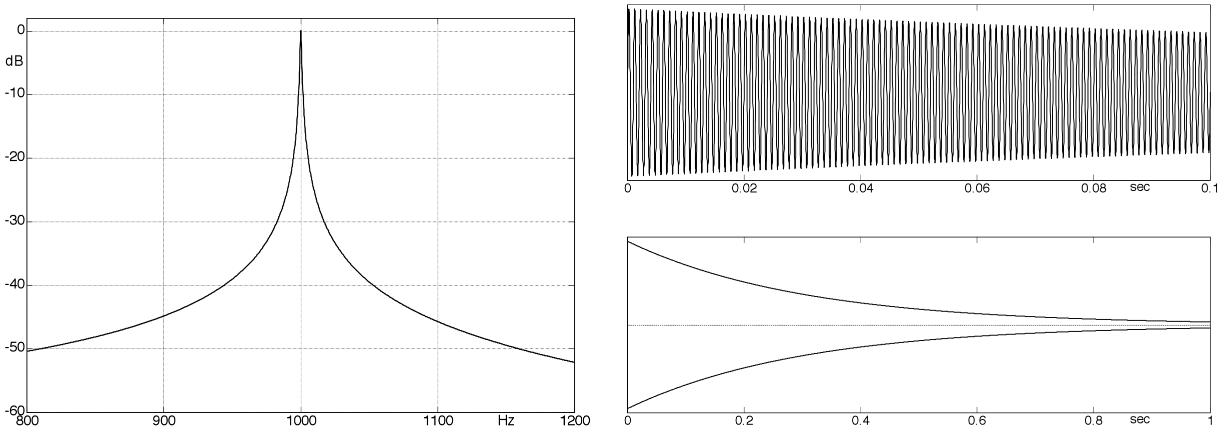

Fig. 8.46: Decaying sine-oscillation, f = 1000 Hz, time-constant τ = 0,3 s.

These simplified representations do, however, require supplements in some points. It is not only the transfer factor of the guitar amplifier that changes the spectrum of the string oscillation. The loudspeaker (including its enclosure) acts as filter, as well; in the detail, its transmission curve is of stronger frequency dependence than the tone-control network is. Still, a loudspeaker membrane does not reach the high (resonance) Q-factors of decaying guitar partials – it would have to generate clearly audible natural tones for that, and this it does exactly NOT do. The last filter in the transmission path is the room with its reflective borders. Its effect cannot be neglected even in the "dry" test; when playing connected to the amp/speaker, the distance to the speaker needs to be added in as variable, as well. As long as one remains within the near-field of the loudspeaker, the effect of the room can be regarded as equal for both playing situation in a first-order approximation.

Special consideration is required for effects that achieve more than what simple tone control does. Adding artificial reverb can extend decay processes and feign life that is not included in the original in that form. Chorus/phaser/flanger are time-variant filters with high (resonance) Q-factors – their use always aims at changing the fine structure of the partials. Single band, and in particular multi-band, compressors change the decay time constant of individual groups of partials. Overdrive has similar effects but adds in additional partials. It is therefore very well possible to also influence the signal parameters designated as robust above. However, even without deploying radical effects one may – within certain limits – extrapolate from the sound of the unamplified guitar to the sound of the amplified guitar. Which of the many beat- and decay-parameters are crucial to the 'good' sound, though, is at the most implicitly appraisable … and we have not even touched the wide field of frequency- and time-related masking [12]. Therefore, only this principle can hold: **the unamplified sound of an electric guitar should basically not be evaluated**. Only for the expert, and in consideration of his/her special knowledge and listening-experience accumulated over decades the exception, this rule allows the exception that the "dry" test reveals "everything", after all, in the individual case. Experts who may claim this exception for themselves are: testers of all guitar magazines, all guitar sales-personnel, all guitar players who have had of who have wanted to have a guitar for more than a year, and all listeners to CD's who still have the sound of Jeff Beck's signature guitar ringing in their ears (see Chapter 7). And please, dear experts who have now received so much legitimization for your obviously indispensable "dry" tests: that the assessment of tactile vibrations is nonsensical – that should by now be o.k. for a consensus, should it not?

Concluding the topic of guitar tests, a few citations in the following:

Yamaha Pacifica-guitars (maple neck, alder body) in a comparison test: "The acoustically quite comparable basic characteristics of the Pacificas differentiate themselves rather clearly according to their pickups, after all. (G&B 6/04)."

Gibson Les Paul Faded Double-Cutaway: "Already with the very first striking of the string it becomes clear that the economy-varnishing curbs the resonance properties of the woods to a lesser degree. The guitar vibrates from the feet (strap-knob) to the tips of the hair (machine heads) so intensely that you can feel this even in your own body; (G&B 6/04)."

Ibanez IC400BK: "The slight underexposure of the E_6-string as it appears in the dry test has suddenly disappeared with the support of the pickups; (G&B 6/04)."

Squier-Stratocaster, comparison: **mahogany**-body vs. **basswood**-body: using the neck- or the middle-pickup, both guitars sound almost identical (G&B 5/06).

"Picking up the **Pensa-Suhr**-guitar and playing it un-amplified, the reasonably learned ear immediately hears where this is at. … both standing up and sitting down, you feel already in your belly the fantastic vibration-behavior of the outstandingly matched woods." (Fachblatt, 6/88).

"Despite using humbuckers, a Strat will never turn into a Les Paul"; G&B 2/00. **Ozzy Osbourne** on Joe Holmes: "In fact, I normally don’t like Fender guitars. But Joe gets this fulminant Gibson sound out of them"; (G&B 2/02). "**Jimmy Page** recoded the whole of the first Led-zeppelin album using a **Telecaster**; the guitar sound on this album is exactly that of a Les Paul"; (G&B Fender-special-issue). **Mark Knopfler**: "If I look for a thicker sound, I use my Les Paul; it simply is more dynamic. That doesn’t mean that I couldn’t do the same thing with a Stratocaster"; (G&B Fender-special-issue). **Gary Moore:** "Some people think that a Fender Stratocaster is heard on 'Ain't nobody'; actually, that is my own Gibson Signature Les Paul"; G&B 7/06 p.91.

Big mass of wood (**3,9 kg**): Due to the big mass of wood, the response seems a bit ponderous and the notes don’t get off the starting blocks that fast; (G&B 7/06).
Even heavier (**4,15 kg**): the guitar vibrates intensely, responds directly and dynamically, each chord or note unfolds crisply and lively; (G&B 8/06).
Despite the enormous mass of wood (**3,85 kg**), almost every note responds crisply and dynamically, and unfolds very swiftly; (G&B 7/06).
The lower **mass** can be more easily made to vibrate; (Thomas Kortmann, gitarrist.net).
A slender guitar **body** also creates a slender sound; (G&B 7/02).
Thinner **body** = less bass; (G&B 4/04).

Thick neck = sonic advantages; (G&B 8/02). **Thin neck** = round, fat tone; (G&B 10/05). **Thin neck**: the lower the mass that needs to be moved, the more direct and quickly response and tone-unfolding get off the starting blocks; (G&B 3/05). **Crisp** and direct in the response, every note gets quickly and lively away from the starting blocks, **despite the immense mass of the neck** (that needs to be first set into motion, after all); (G&B 9/05). **A thin neck** has no acceptable vibration behavior whatsoever; (G&B 3/97). Sonically advantageous is that the **neck** weighs in with **a lot of mass**; (G&B Fender-special-issue). The **Ibanez JEM 777** sports an extremely thin neck design: the basic tonal character is powerful and earthy; (Fachblatt, 6/88). Of course, the **shape of the neck** contributes to the tonal character of the guitar, as well; (G&B, 12/06). What is absolutely not true is that **thick necks** will sound better than thin ones. I have already built the same guitar with the thick and a thin neck and could not find any difference; (Luthier Thomas Kortmann, gitarrist.net)

