7.8.2 "Stratone"

A citation from the German magazine “Gitarre & Bass”, issue 05/2007: *For the sound, density, elasticity and hardness are decisive. Compared to ash, alder features a 10 – 20 % smaller density, i.e. a smaller weight relative to the volume – resulting in a faster response. The oscillation excited by the guitar string needs to push less mass. Furthermore, the smaller mass of alder results in a higher Eigen-resonance of the body. Resonances in particular absorb much oscillation energy, and so these frequencies disappear first. Ash, however, sounds brighter, and richer in harmonics.*

The faster response of alder mentioned above is further supported by the material’s higher elasticity. While the density describes the amount of mass per cm^3*, the modulus of elasticity describes the maximum pressure that wood can mount against an external force without any permanent deformation.*

Alder’s higher elasticity (relative to ash) has the effect of a cushioning of the vibration and thus of extraction of energy from the string, resulting in a shorter response time (i.e. harder attack), but also in a shorter sustain.

From the point-of-view of sound, the hardness of wood is considered in conjunction with the density. Harder woods, especially those with a high density, react substantially more sluggishly to vibrations than softer woods, and extract less energy from the string. The string shows a slower transient response but holds the vibration for a longer time. In the present case, ash is categorized as medium-hard to hard (i.e. with longer sustain), and alder as soft.

Compared to a Stratocaster made of alder, ash sounds harmonically richer and has longer sustain. On the flip-side, the response of alder is more direct, the guitar reacts more dynamically.

So much for the first part of the article, titled *Body*. Stating: *Alder has a smaller density relative to ash* – is that already incorrect? No, that’s o.k. as such, especially in a magazine article with the required reasonable length. Of course, there is not “the” alder nor “the” ash – we find black, white, green and red alder, and black, white and green ash (the latter also termed red or swamp ash), and of course the climatic conditions under which the trees grow will vary resulting in different physical parameters. So, only a radical simplification is the way out, if you do not want to “go down for the third time” already in the first paragraph, with special literature describing not just three but “65 different types of ash”. Given this simplification, alder has a 10 – 20% smaller density: 0.55 g/cm^3 versus 0.69 g/cm^3. We most humbly add that according to datasheets there is also heavy alder at 0.86 g/cm^3, and light ash at 0.41 g/cm^3. In dried condition, that is, because humidity will also influence the density.

However, whether a smaller density will result in a faster **response** is unfounded speculation. *The oscillation excited by the guitar string needs to push less mass.* O.k., so what? A mass alone will not define any attack-time. And most of all: it is the vibration of the string that the pickup of the Stratocaster investigated here samples, and not the vibration of the body. *Furthermore, the smaller mass of alder results in a higher Eigen-resonance of the body.* Huh? How does that work? A resonance frequency depends on both mass and stiffness, and nothing has been said about the latter so far. Body resonances exist – no contest there. But they exist already from a few hundred Hertz, and their impact on the string vibration remains purely speculative in the article to begin with.

The faster response of alder mentioned above is further supported by the material's higher elasticity. While the density describes the amount of mass per cm^3*, the modulus of elasticity describes the maximum pressure that wood can mount against an external force without any permanent deformation.* We are now leaving the area of journalistic freedom and encounter the first grave error that unfortunately exposes the author as rather ignorant and apparently missing crucial knowledge. To confuse elasticity and mechanical strength – that must not happen. The E-modulus – abbreviated from "modulus of elasticity" (or Young's modulus) – is a characteristic variable in the area of elasto-mechanics. Elasticity is the characteristic of a solid body to resist a deformation caused by external forces given linear, reversible behavior. Now, the modulus of elasticity is NOT the limit of the linear behavior but specifies the behavior far below the limit of linearity (i.e. at small loads). Indeed, while this modulus of elasticity does have, with N/mm^2, the same unit as the pressure, it does in no way specify a maximum allowable pressure. Dear young friend who writes about limit values in such an easygoing way, have you at all considered that this would-be limit-pressure for ash would be approximately reached if the mass of a car (1300 kg) pushes down on 1 mm^2!? Or if 9 combat tanks weigh in on the surface of one Euro (translator's remark: that's about as many tanks loaded onto the surface of one quarter US-$)!? No way, not even high-grade steel could withstand that. The E-modulus is a kind of specific stiffness: for alder about 9000 N/mm^2, for ash about 13000 N/mm^2. *Alder's higher elasticity (relative to ash) has the effect of a cushioning of the vibration and thus extraction of energy from the string, resulting in a shorter response time (i.e. harder attack), but also in a shorter sustain.* Indeed, alder features a smaller E-modulus, i.e. a smaller stiffness and thus a higher flexibility (which we could call elasticity) – but besides that, things already go awry again: extraction of energy, i.e. **dissipation**, will happen only in resistive elements (friction resistances) and not in springs. With the E-modulus, a parameter for spring stiffness was chosen, and not one for losses. How fast the vibration energy of the string is converted into heat depends on several parameters (see Chapter 7.7), the E-modulus alone does not help us here.

Since we have at our disposal now a specific stiffness (= E-modulus) on top of the volume-specific mass (= density), let's have another look at the resonance frequency. Assuming a piece each of ash and alder with the same dimensions, the mass of the piece of ash will be larger than that of the piece of alder – at least given the simplifications discussed above. However, not only is the mass of the ash larger but the stiffness of the material is also higher, and since the resonance frequency is dependent on the quotient of stiffness over mass, the resonance remains the same in a first-order approximation. No further speculations are allowable because both density and E-modulus vary – the piece of alder will therefore not universally have the higher resonance frequency.

From the point-of-view of sound, the hardness of wood is considered in conjunction with the density. Harder woods, especially those with a high density, react substantially more sluggishly to vibrations than softer woods, and extract less energy from the string. The string shows a slower transient response but holds the vibration for a longer time. In the present case, ash is categorized as medium-hard to hard (i.e. with longer sustain), and alder as soft. Ash is harder that alder, that much is correct. Any connection to transient processes (that is the term systems-theory has for "attack" and "decay") is totally speculative und unfounded. A transient process cannot be explained by a single material parameter. Which system should be in transient, anyway: the string or the body? If the body reacts sluggishly, the string should be able to respond quickly, shouldn't it?

Compared to a Stratocaster made of alder, ash sounds harmonically richer and has longer sustain. On the flip-side, the response of alder is more direct, the guitar reacts more dynamically. At last, here we have a statement that does not ride on any pseudo-scientific reasoning, and, as a subjective opinion, it does not make itself very vulnerable. It the author perceives it that way, he certainly may write it down. It is, however, clear from what follows that the unamplified sound radiated from the solid body is meant – but that sound is so unimportant that it does not take long to deliberate whether the descriptions are correct.

So what remains as a first **appraisal** before we turn to the neck of the guitar? There are some reasonably correct statements regarding density, stiffness, and hardness, we read some unfounded or even incorrectly reasoned assumptions regarding resonances and transient processes, and we find speculations about the holiest of all cows – the sustain – without a single word about material-specific damping parameters. But let's see how things progress:

From 1959, a rosewood ***fretboard*** *was used because of its higher durability. Taken by itself, the higher density and hardness of the rosewood would point to a more pronounced content of harmonics. However, the overall construction with the glued-on fretboard results in an additional disruption of the sound propagation within the wood – this makes for a softer and slower string attack in the rosewood-fitted neck compared to a solid maple neck.* Are you sure about that? Is it the string that is excited by the guitar body? It is almost as if the guitar player hits the guitar, the body of which needs to start vibrating in order to then make the strings vibrate. Just to be clear: the guitarist deflects the string with the pick, or fingernail, etc., and as soon as he lets the string go, it commences to vibrate. The latter happens very, very quickly, and completely independently of the guitar body during the first few milliseconds. That a string will start to vibrate more slowly and mellow – that is nonsense. *From 1959 – 1962, the interface between the maple neck and the rosewood fretboard was flat (slab-board). The sound becomes particularly meaty and fat, and gives an enormous depth to the characteristic mids.* In the book by Day/Rebellius, that reads rather differently: *the "slab-board" is one of the secrets of the renowned, old, crystal-clear vintage sound.* And then we find other verdicts, as well: *the direct A/B-comparison between a poplar-Strat with one-piece maple neck and an ash-Strat with maple/rosewood neck indeed reveals only minute differences (Gitarre & Bass, Fender special edition).* Even more radical is the statement by Lemme: *a one-piece maple neck and a neck with (extra) fretboard sound identical [Lemme, 2003].*

And on we go to the "**playing-in**": *scientifically, playing a stringed instrument for a long time implies, first of all, that the instrument is subject to vibrations for a longer time.* Hard to believe: that is actually totally correct! But then: *the effects are almost impossible to capture analytically because a piece of wood excited by the corresponding vibrations would have to be compared to an identical piece of wood that has been merely stored and not played.* Or as alternative: we would have to construct a setup that allows for a reproducible picking of the string both before and after the "playing-in". That would not be impossible – but it is not entirely trivial, either. Let us remember, though, that the energy transferred from the player to the string is very small (typically a few mWs per struck string). If we would take the above conjectures about non-reversible deformations seriously (granted – that sounds a bit polemic here), then *permanent deformations* would occur only at more than 13000 N/mm^2. So: no worries, mate, in reality only about 0.1 N/mm^2 weigh down on the wood, and that is even less than the compressive strength specified in datasheets (around 50 N/mm^2). We do not want to dispute generally that a guitarist may perceive outrageous improvements in the sound after a period of "playing-in", but the reasons for that can be highly diverse.

So much for the first part of this "specialist article" about the Strat. Given what we have established so far, it ends with an outright threat: *in the following issues I will report on the development of the mechanical components and the electronics of the Stratocaster.* This then reads as follows: *until the beginning of the 1970's, bent steel was used for the* ***bridge saddles****. The elaborate manufacturing process resulted in particularly dense material. Afterwards, the bridge saddles were first made of brass, then of coated, cast zinc. Relevant to the sound is the density of the materials – it dropped with each successive version of the bridge saddles. The densest material then is the steel. Zinc is even lighter than brass. According to generally valid material science, a less dense material absorbs less energy than a denser one.* Excuse me?! The density of brass is, according to generally valid books on material science, 8.1 – 8.6, while that of steel is 7.7 – 8.0, and that of cast zinc is about 6.7, each with the unit kg/dm^3. How much energy a material absorbs (i.e. converts into heat) depends not primarily on its density but on its internal damping parameters. The latter are, however, nowhere specified in the text – rather there is speculation about frequency dependencies: *less density and mass result in fewer harmonics*. In other words: higher density supposedly will give more harmonics. A few lines on, however, we read: *a Strat with bridge saddles made from steel that sounds too twangy and sharp can sound milder and more balanced with bridge saddles made of brass.* How can that be? Brass is, in this group of materials, the one with the highest density! It is hard to avoid the impression that the term "density" has been misunderstood. What happens if you compress a material? It becomes denser! And what were the bridge saddles of old Strats made from (according to Duchossoir)? From "**pressed steel**"! Well then … pressed steel, that's compressed i.e. mightily dense, isn't it? No Sir, it ain't – you failed to understand what the term actually means. *Pressed steel* means: the part is made of punched-out steel bent into shape. That is what the bridge saddles of old Strats were made of, and how they were made – in sharp contrast to the block-shaped pieces introduced later that – simply due to larger volume – featured more mass. The latter aspect is, however, totally ignored, just like the unavoidable friction occurring in the gaps between the parts of the bridge assembly.

It does get still worse, though: *Compared to a block of cast steel as it has been used since the 1970's, the earlier, cut-out block contains less oxygen and therefore has more mass.* **Oxygen** within a block of steel: now that's not something the metallurgist likes – at all. From way back, our memory switches on a red warning lamp when oxygen and iron show up in combination: RUST! The generally valid material science comments: the oxygen bonded to the iron atoms is present as FeO-slag after solidification of the molten mass, and can partially be released to other metals (e.g. Al) as desoxidisation happens. In any case, the share of oxygen remaining in steel is so small that it cannot have any substantial effects on the density. That's what material science says. The Stratone-author, however, says: *predominantly, the cut steel-block makes itself felt via additional harmonics and stronger attack*. Rather on the side, we are informed that the cast-iron block is thinner by 2 mm compared to the cut block. That could also have an effect on the mass, couldn't it? Nobody denies that the tremolo block can influence the sound, but ludicrous conjecture (*the behavior is similar for metal and wood*) does not help to get to the bottom of that. Quite amusing: another G&B-expert states in G&B 7/2005 that **titanium** would be the best material for the trem-block. Titanium, however, has – at 4.5 kg/dm^3 – an even smaller density than cast zinc, and therefore there should cause a treble loss, according to the first author. Far from it, though: *due to the titanium block, the sound is richer in harmonics.* Despite the fact that the titanium block – precisely weighed – *is roughly 120 g lighter than the original.* Isn't that strange? What does hold here: *less mass = additional harmonics* (G&B 7/2005), or *less mass = less harmonics* (G&B 6/2007)? In any case, we get: less mass = more money, because titanium was never cheap – 330 Euro, to be precise. That's just for the trem-block, not for the guitar, and including stainless-steel screws … for titanium screws would have cost another 40 Euro extra.

Before we call in frequency spectra to corroborate this G&B-mess of loosely collected conjecture, let's digress a little into vibration engineering. We read: *the **nut** is supposed to transfer the vibration energy as completely as possible into the neck.* Sure: the neck should vibrate tremendously, and the string should transfer its vibration energy as completely as possible to the neck, and consequently stop vibrating … This would follow from the well-know physics-law of conservation of energy. Because when the string has transferred all its vibration energy to the neck, it has no vibration energy anymore itself. Too bad, we would have gladly granted it that extra sustain, the holiest of cows. But more about that later.

Now, the Stratone-author does not limit himself to conjecture about the scientific reasons for differences in sound, but he procures 7 different Strats, and analyses their sound: *for the recording of the unamplified sound of the guitars, a Rhøde NT2 condenser microphone was positioned at 10 cm distance pointing to a spot between neck pickup and heel of the neck.* Then analysis was done using short-term DFT. The spectra depicted in the magazine are without scaling on the ordinate and can therefore not purposefully be evaluated. However, the sound files were also available at www.gitarrebass.de, and with these a scaled analysis could be carried out. We will not right now go into whether it is meaningful at all to analyze the purely acoustic sound of these solid body guitars; let's just look how the measurements and the G&B-statements line up.

Subject to analysis are alder-Strats built in 1959, 1962, 1972, and 1974, as well as ash-Strats built in 1972 and 2005. The 1995 alder-Strat was not evaluated – its file differed too much from the others. In the following analyses, **ash-Strats** are designated with an S and **alder-Strats** with an L. Under scrutiny is the G&B-statement: *compared to the alder-Stratocaster, the ash-Stratocaster sounds richer in its harmonics and has a longer sustain.* In **Fig. 7.88**, the analyses of the first 4.5 s of sound are shown. And here we already run into the first problems: the sounds result from an E-major chord played across all 6 strings – but the author was not aware that he should strike all 6 strings as similarly as possible for all test sounds. And so the plectrum gets caught a bit in this string or that string, or it audibly strikes the pickguard. Well, we have to live with these inadequacies – no other recordings have been published. Let us regard the first statement: *compared to the alder-Strat, the ash-Strat sounds richer in its harmonics.* The 1/3rd-octave spectra averages over the first 4.5 s do not confirm this assumption: it's the 1972-alder-Strat that featured the strongest treble. In the summation level, the assumption regarding the sustain cannot be confirmed, either: an alder-Start is ahead only between 0.5 and 1.2 s, from then on there is no difference remaining between 2 ash- and 2 alder-Strats. Since for all guitars the higher-frequency partials decay more quickly than the lower-frequency partials, a faster decay of the overall level is to be expected for more trebly sounds (slightly simplifying things): the more the higher partials define the overall sound, the faster the latter decays.

Of course, one may object to these analyses that neither the summation level nor the averaging over 4.5 s is very meaningful. Narrow-band level measurements, encounter other problems, however: the levels of individual partials decay only in exceptional cases according to a simple exponential function, and beats often occur due to circular wave polarization and due to bearing impedances dependent on the direction of the oscillation (Chapter 1.6). Moreover, there are interactions between the partials of individual strings that can lead to pronounced beating. **Fig. 7.89** shows the 1/3rd-octave levels for the individual guitars. The 1/3rd-octave level at 80 Hz approximately captures the E_2-fundamental that may decay both for the alder- and the ash-Strats with or without strong beating – no confirmation is found in these measurements that ash-Strats would have a longer sustain.

The comparison at 125 Hz is different in that with one single exception, all 1/3rd-octave levels decay with practically the same speed, but again there is no longer sustain apparent for ash. Yet different again is the situation for the 160-Hz-level: all 6 measurement-curves differ significantly – as it is the case at 500 Hz, as well. Given such strong level-fluctuations, a general statement in the sense of *ash-Strats have a longer sustain* has no foundation.

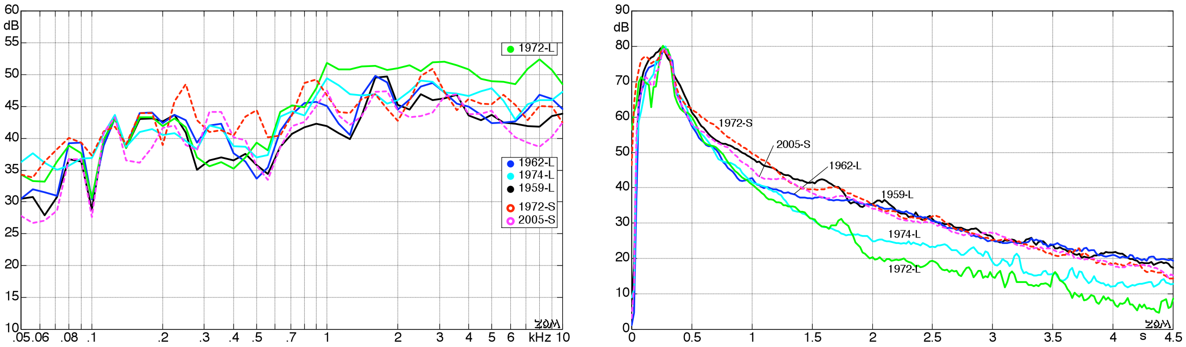

Fig. 7.88: 1/3rd-octave spectra (left) und overall level (right); sound-files acc. to G&B 5/2007 p.212, normalized.

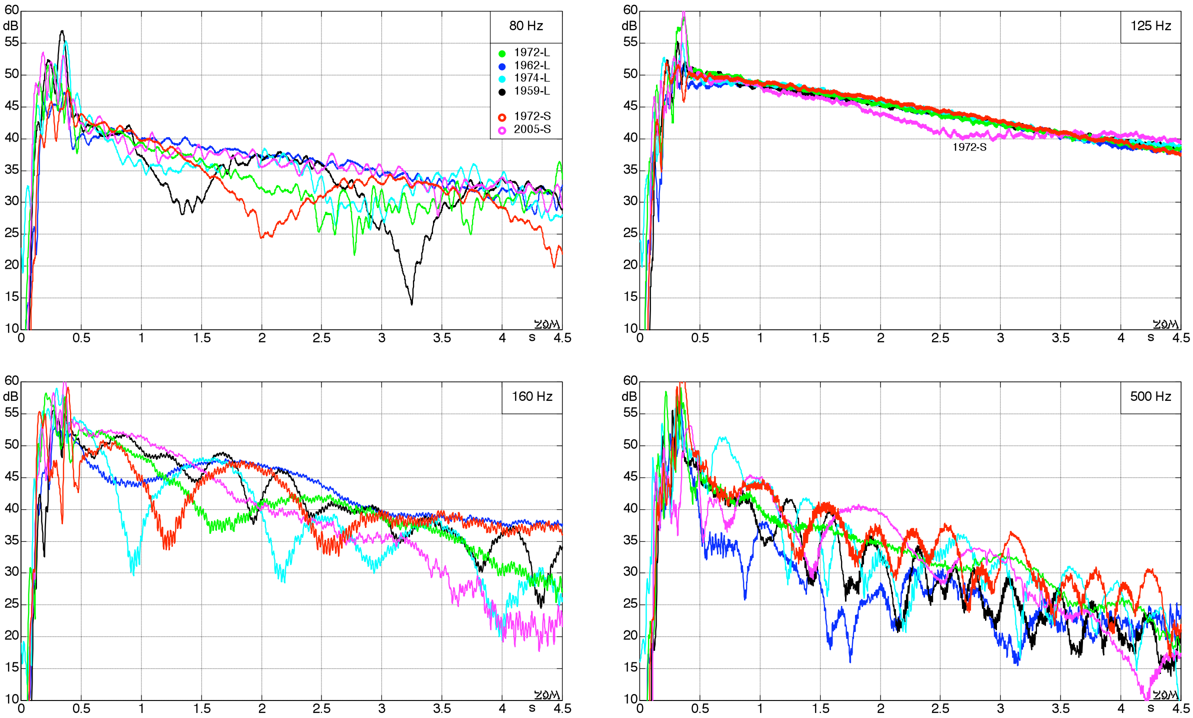

Fig. 7.89: Decay of individual 1/3rd-octave levels. Since in these curves only the decay (or the slope) is of interest, they were vertically shifted for best possible evaluation and comparison.

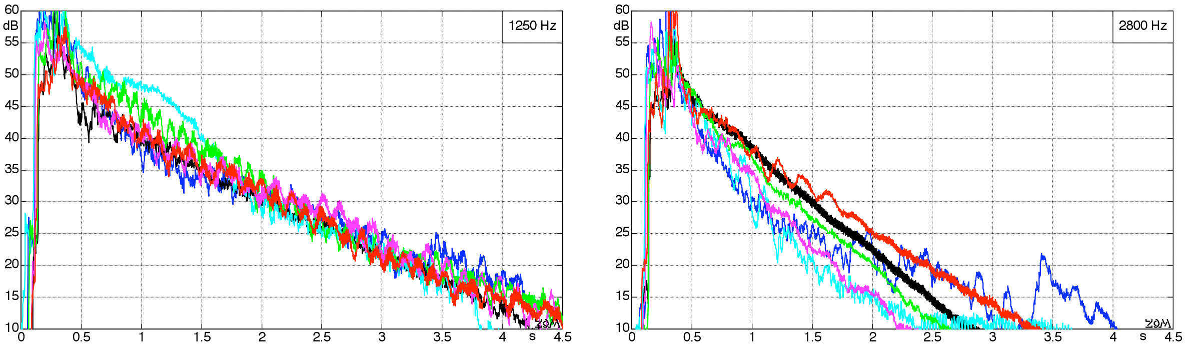

Fig. 7.90: Decay of individual 1/3rd-octave levels, compare to Fig. 7.89.

It does not make any sense to measure the beating-parameters, because with a minimal detuning of one or more strings, the beating will change. Such beats also show up in the waterfall-spectra published in the G&B-article albeit there is no scaling. As we move towards higher frequencies (**Fig. 7.90**), the beating decreases in strength (many partials per 1/3rd-octave), but again the statement regarding the difference in sustain cannot be confirmed. At 1.25 kHz, the ash-Strats correspond to two alder-Strats, and at 2.8 kHz already the two ash-Strats (red/magenta) differ significantly from each other. **Conclusion**: the level measurements cannot support any significant difference in sustain between ash and alder. Even before we advance to the core question of whether parameters in the airborne sound have any relevance for the pickup signal, we have to recognize that already the statements about the parameters of the airborne sound fail to bear objective scrutiny. Therefore, dear Strat-analysts: don't forget to always put a scale to the ordinate – then you will see this result yourselves, too.

While it is highly commendable that statements regarding the wood are deduced from results of experiments, the framework for these experiments still needs to fit, and the investigated guitars must exclusively differ in the wood. In the present experiments, they do not – as the G&B-author attests. Most important for the decay process of the string vibration is the distance of the string to the frets, and the initial displacement of the string. No information at all is given about the condition of the frets, and we can only surmise that the guitars were not refretted before the experiments. Not even regarding the action (distance from string to frets or to fretboard) there is any information, and the author is silent about the age of the strings, as well. So what's the point here? If we carry out such experiments, it is mandatory to restring all guitars with the same kind of strings, and the action needs to be adjusted to be as similar as possible. The strings must be reproducibly picked with a suitable device, and even the support for the guitar is significant: already lightly gripping the guitar neck with thumb and 1st finger (without even touching the strings) changes the decay behavior quite substantially (compare to Chapter 7.7). However: even with perfect conditions, what actually is the connection of the airborne sound recorded at a distance of 10 cm from the guitar to the voltage generated at the output jack? That is the central question here … but the answer shall be put on the backburner because there is a lot of text regarding the guitar electrics still to be looked at. *The signal runs through a capacitor that presently has a value of 0.022 µF. In combination with the coil it forms a band-pass.* Close, but topologically this is a low-pass (series-L and parallel-C). *Our comparisons show that the more massive build (of the capacitor) promotes a more musical effect due to fewer frequency cancellations in the pass-band. The sonic image of the larger capacitor seems fuller and denser.* What rubbish – here a blind man judges colors. The pass-band is in fact characterized by passing signals, not cancelling them. Also, what is actually the pass-band of this *band*-pass? What does *a more massive build* indicate? Smaller, i.e. less (geometric) volume? Ceramics rather than foil? Or more weight? Very puzzling, this …

Regarding the **pickup**: *sonically relevant is not only the main resonance that can be calculated mathematically, but also the countless ancillary resonances and cancellations. The winding is mainly responsible for this ... back in the day it was customary to guide the wire in such a way that overlaps would result i.e. that not all turns were exactly in parallel. This method is called biphilar winding.* Okay … phew … after we've all managed to compose ourselves again, and have not incurred any permanent damage by this blow, let's get this straight: a bifilar winding is set up if induction is not desired – in short. The term is bifilar (not biphilar) because two threads (Latin: filum = thread) are wound. Using today's terminology we would say: two parallel wires with connected beginning are wound. The two ends then make for the connection poles. A coil with two opposed windings will result i.e. one without inductance (idealized).

Had the pickup a bifilar winding, no voltage could be induced. What the author means to address is “wild winding” or “cross-winding”, in contrast to “winding in layers”. Differences exist between how old and new pickups were wound – no contest there – but there was never ever a bifilar-ly wound pickup. *Still, a clear sonic tendency of the biphilar winding can be recognized: our investigations show that the magnetic field takes on more homogenous characteristics compared to a machine-wound coil. Certain level-values of the resonances are simply not exceeded.* Level-values of resonances? Does the man mean the Q-factor of the resonance? Why doesn't he then just use that term? And what are those resonances that allegedly occur in *countless* numbers? They may not be countable as we progress towards infinity – with a pickup, though, 10 kHz is the utmost limit. Even if we think 20 kHz is required: there are not countless resonances. It is indeed not possible to model every pickup as a 2nd-order-system (i.e. with one single resonance), but with a 4th-order-model we get extremely close. However, apparently, something else is meant: *the result of the machine-winding is a frequency graph with very narrow and very loud level peaks ... Moreover the coil is more loosely wound by hand, resulting in more resonance frequencies in the treble range.* Here we can't help but suspect that when regarding spectra he has not really understood, the author interprets maxima generated by the string-partials as pickup resonances. Or does he imply that the hand-wound coil has a lower winding-capacitance resulting in a main resonance of higher frequency? The term “winding capacitance” doesn't appear anyhere, though – but we do find: *from a higher inductance, an upward-shift of the main resonance results.* Wrong again: the resonance frequency drops with rising inductance. Why is it actually absolutely necessary for a person to write a “specialist article” in a so-called “specialist magazine” if that person is not at all, in any way, a specialist in the given specialist area?

And we get to the **wire**: *given a diameter of 0,0030", the wire was, 46 years ago (i.e. 1961, thicker by 0,0004" compared to today. Combined with the fact that today 400 more turns are included, a smaller inductance results, i.e. a lower output voltage of the old pickup.* Whether a diameter with or without insulation is meant remains unclear. Duchossoir opines that from the 1950's to the 1990's, 42-AWG was used always, i.e. 63,5 µm Cu … may the better man win. The number of turns varies so strongly over the years (according to Duchossoir: from 7600 to 9000) that “400” should be interpreted rather generously. And at last the **insulation**: *not only the thickness of the coating has an effect on the sound, but the material, as well, because the material surrounding the copper within the coil has, acting as a dielectric, a direct influence on the magnetic field.* Nope – again close but no cigar: dielectrics act in a polarizing fashion in the electric field, while in the magnetic field, the permeability is the quantity with direct influence. *The Formvar coating consisting of a resin composite makes for a more open and lively sound than the chemical Polysol layer.* Of course: the chemical stuff doesn't sound right! What does the chemical scientist comment regarding Formvar, though? Formvar lacquers contain polyvinyl-acetal to which phenolic resin is added. And phenolic resin is counted as a … chemical synthetic.

A person testing a guitar is certainly at liberty to write as a conclusion of his labors: *I like the 1962 Strat the best.* However, as soon as this subjective evaluation is being substantiated with misunderstood scientific principles, the dulling of the reader's mind begins. Mistakes happen, of course. The admitance, the cahtodyne, the E-modul – even biphilar would not be worth a single line if it were just a spelling mistake. Specialist magazines with a good reputation have an editorial office and proof reading where most of the smaller errors are caught and ironed out. They also have a reviewer who will point out subject-specific deficiencies.