5.5.9 DC-resistance vs. loudness

In chapter 5.5.1 it was already noted that the dc resistance of a pickup has little bearing on its loudness. While it is of course true for an individual pickup that unwinding a few thousand turns will reduce both the resistance and the loudness, it must not be concluded that a 7-kΩ-pickup is generally louder than a 5-kΩ-pickup. Unfortunately, this is however exactly what is suggested in many tests which e.g. read: *"the guitar is equipped with two different pickups. While the alnico-2-magnet at the neck makes for singing highs, its colleague at the bridge with the ceramic magnet yields a brutal punch. Our measurements reveal just how significant this difference is: 12 kΩ (bridge) versus 8kΩ (Neck)."* Does that mean the "colleague" at the bridge is 50% louder? Another example from a guitar comparison: *" the pickups of this guitar have the lowest output power of all candidates: they show merely 8 kΩ; all others are at 10 – 18 kΩ."* And one last example: *"the neck pickup corresponds in its power to a Gibson PAF (8 kΩ)."* From a physics point-of-view, such texts are more than problematic.

Pickups are almost always wound with copper magnet wire, and therefore only the wire cross-section and the wire length figure for the **DC resistance** R_{DC}. Measuring the resistance is easy – even inexpensive R_{DC}-instruments have a tolerance better than 1%, and 1‰ is achievable without much effort. If indeed such a high accuracy is the objective, the temperature needs to be specified exactly as well within a ¼°C. Test reports often include four-figure resistance details: for the Gibson **498-T** e.g. 12,23 kΩ, or – in another guitar – 13,40 kΩ. The reader is however left in the dark about whether such differences are due to the instrumentation (which is almost never specified at all), or due to manufacturing scatter ... or at least in part due to the often applied practice not to disconnect the volume potentiometer for the measurement: this changes the reading of a 13,00-kΩ-resistance to 12,67 kΩ (for a 500-kΩ pot) or to 12,36 kΩ (for a 250-kΩ pot), after all. Such small differences would not be of any significance if they were not the reason to draw the conclusion that with 13,40 kΩ that last bit of "punch" would be achieved which the 12,23-kΩ-contestant unfortunately missed. Reading such a test report, indeed not few guitarists will invest $200 to profit from that "punch".

The pickup industry happily picks up on this resistance diversification and offers a vast variety of pickups. The Gibson **BurstBucker** is available in three versions: slightly underwound, normal, and slightly overwound. The DC resistances differ by 7% each – and these are not unavoidable manufacturing tolerances but deliberate production♣. Or so the Gibson advertisements state. On the other hand, the Gibson **498-T** is only available in a single version. Tests in a German music magazine (in Summer 2003 and Winter 2005) report that there are resistance tolerances of 9,6% between two specimen of this pickup.

In many test reports the DC-resistance of a pickup receives a multi-digit specification; however, it is quite often not designated with "resistance" but with "**output power**". The skillful reader will interpret this as loudness und is generally not entirely wrong with this approach. Indeed an **SDS-1** (9,1 kΩ) will yield more output voltage as a vintage Strat pickup with its modest 5,8 kΩ. On that basis, a Gibson **Tony-Iommi**-Signature pickup would really hit home, wouldn't it, having not less than 17,8 kΩ DC resistance! That's almost the double "output power" relative to the SDS-1. However, given the same string vibration, the Tony-Iommi generates <u>less</u> voltage than the SDS-1, its high resistance does not increase the transmission coefficient T_{Uv}. The latter value – defined as quotient of pickup voltage and string velocity (chapter 5.4.5) – is well suited to investigate correlations between the DC resistance and transducer efficiency.

♣ The '57-Classic-Plus sports as little as "3% more winding" versus the '57-Classic [Gibson special issue of the German "Gitarre & Bass" magazine].

The frequency dependence of the transmission coefficient H_{Uv} follows a more or less complicated low-pass function (chapter 5.9.3). For the Stratocaster pickup we obtain a simple 2nd-order low-pass with a resonance emphasis of about 5 dB (**Fig. 5.5.18**). Increasing the number of turns by 10% (e.g. from 7600 to 8360 turns) will increase the DC resistance by 10%, as well. Calculating more precisely and considering that the additional turns are located on top of the coils and will therefore be a bit longer we obtain an 11% increase of the DC resistance. The effects of the CD resistance on the transmission function are, however, so small that over-exaggerated requirements as to the precision are not purposeful. The inductivity of the pickup will rise by about 23% (chapter 5.5.2), the capacitance is determined predominantly by the cable, and equally the load resistance. All these contributions combined will result in an increase of the transmission factor (the log of the transmission function) by 0,9 dB while the resonance frequency drops by 10%. In a direct listening comparison these changes will be just about noticeable with the increased number of turns the pickup features a little less brilliance. In the treble range we even incur a very small loudness drop while a minimal loudness increase happens in the low end. From a psychoacoustic perspective [12] the most appropriate parameter to describe these changes would be the sharpness: it drops with increasing number of turns.

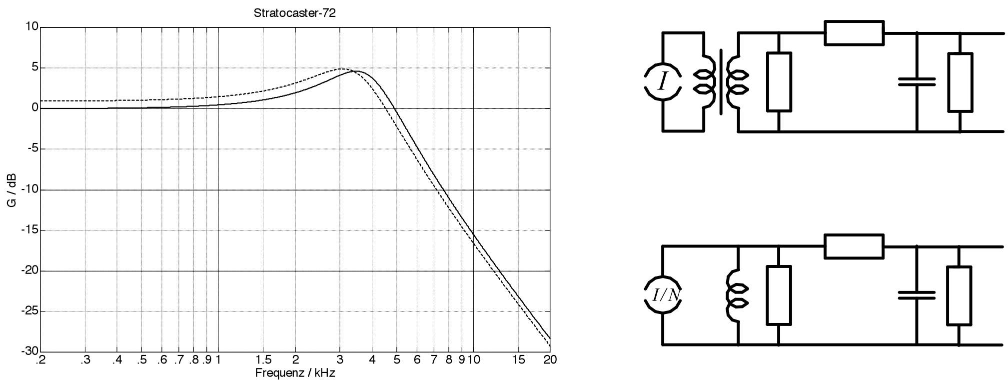
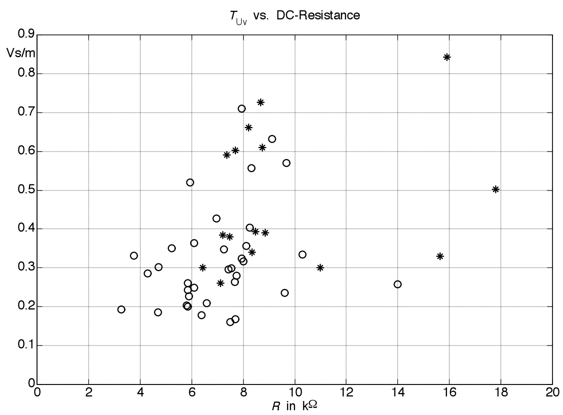


Fig. 5.5.18: changes of the transmission factor $G_{Uv} = 20 \cdot \lg(H_{Uv})$dB for a 10% increase of the number of turns N.

To conclude any assessments of loudness based on the pickup DC resistance is difficult because the former depends on so many parameters. Other than the frequency response of amplifier and loudspeaker, the room acoustics also determine the final perception of the sound, and added to this are subjective preferences (e.g. attack vs. sustain). For the following analysis (**Fig. 5.5.19**) we will therefore not evaluate the loudness but the low-frequency transmission coefficient T_{Uv} and compare it with the DC resistance (see also chapter 5.4.5).



The large scatter of the pairs of values clearly shows that the transmission coefficient and the DC resistance correlate only little. For identical DC resistances the transmission coefficient can vary as much as a factor of 4!

Fig. 5.5.19: Comparison between low-frequency transmission coefficient and the DC resistance. Transmission data as in chapter 5.4.5. o = singlecoil, * = humbucker.