5.3 Hum-compensated Single-coil Pickups

Magnetic pickups convert alternating magnetic fields into electrical alternating fields. If these fields are generated by a transformer, an electric motor, a monitor working based on magnetic deflection, or similar source of magnetic fields, the conversion happens nonetheless – how should a pickup know that these are unwanted signals? A possibility to attenuate such interference was discussed in chapter 5.2 – another approach is taken by so-called **stacked single-coils** also known as stacked humbuckers or co-axial humbuckers. Viewed from the direction of the strings, such a pickup looks like a normal single-coil. However, in its interior *two* coils are at work, and the designation single-coil is therefore not entirely correct. Or maybe it is, after all, because only one coil senses the vibration of the strings; the other coil compensates the hum voltage. Thus: humbucker – but a special one, specifically a co-axial one.

Co-axial indicates that both coils are wound around the same axis; they do not, however, lie in the same plane (as they could if they had different diameters of the winding). Rather, two similar coils are 'stacked" on top of each other: one closer to the strings, one further away. As we will see in chapter 5.4.3, the *alternating* magnetic flux circulates only close to the strings, i.e. it does not penetrate the whole magnet with the same strength. For this reason, only the coil windings positioned close to the string receive a significant part of the alternating flux. the **interference field** of an external interference source creates an entirely different situation: its virtually parallel field lines penetrate the whole of the winding and therefore induce approximately the same voltage in every turn irrespective of the distance to the string♣. Dividing the coil into one half closer to the strings and a second half facing away from the strings, and at the same time connecting the two partial coils out-of-phase, will result in a compensation of the interference voltage while the useful signal is attenuated only a little.

Compared to the uncompensated single-coil pickup, the co-axial humbucker shows several differences: there is no hum but more space is required plus the sound is different. The space requirement it rarely problematic but the altered transmission characteristic continues to be fodder for extensive discussions. In order to clarify the context, it is helpful to separate the pickups into two groups: there are those with elongated, slim coil shapes (such as e.g. the Stratocaster pickup), and those with wide, flat coils (e.g. the P-90, **Fig. 5.3.1**).

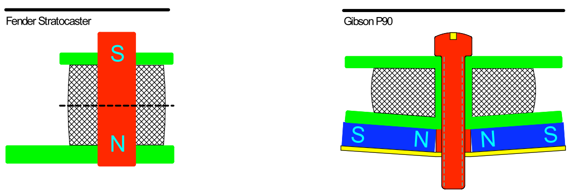


Fig. 5.3.1: different winding-shapes in single-coil pickup

Let us assume that the winding of the Stratocaster pickup shown in Fig. 5.3.1 would be divided at half its height such that two coils result. The induced voltages are, however, not divided in a 50:50-ratio, but – due to the location-dependent alternating flux-density – by 75:25. The upper winding (closer to the strings) receives a voltage which is 3 times that of the lower winding. Connecting both halves of the winding out-of-phase to compensate the hum decreases the string-induced voltage by half. The pickup is softer in loudness than an uncompensated single-coil would be.

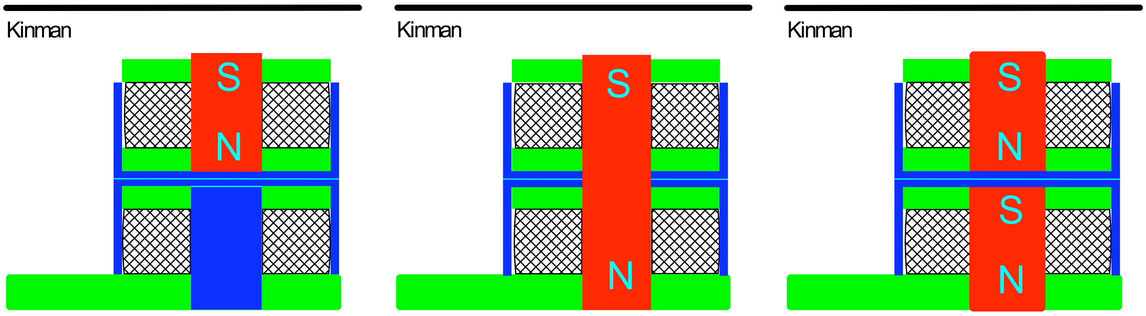
♣ the voltage induced into the winding depends *dB*/*dt* and on the area of the winding

Not only the loudness changes but also the sound-spectrum. This is because the phase-switch reduces the inductivity of the pickup. The **inductivity** is the quotient of coil flux and current [e.g. 18]. If the two anti-phase-connected halves of the coil were in the same place – this only works as a though-experiment – then the excitation current flowing through both coils would generate no magnetic field at all and the inductivity of this 'bifilar'-wound coil would be zero. In reality the two halves of the coil are at different locations and the magnetic flux (generated by the excitation current) in one coil would not fully compensate the flux in the other. The inductivity therefore is not zero but smaller than for an in-phase connection. Smaller inductivity implies a higher resonance frequency (chapter 5.9), and consequently the conclusion is: due to the phase reversal, the pickup sound softer and with more emphasis on treble. Whether this is perceived as advantage or disadvantage is a matter of individual assessment. However, often a direct comparison with the uncompensated original pickup is done, and the scathing verdict is: the hum-compensation kills the sound.

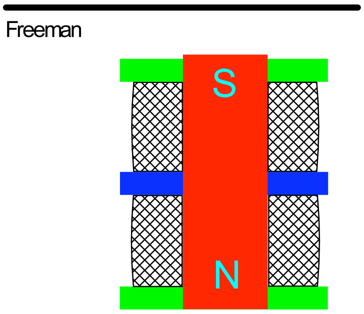
So far our considerations showed two effects of the phase reversal: weaker output voltage and smaller inductivity. Simple corrective measures for this are: increased number of turns and improved decoupling of the two halves of the coil. The coupling of the coils is determined by the distance in space of the coils, and the **permeability** of the coil core. Soft iron pole-pieces passing through the coils are rather disadvantageous in this respect, while the relatively small permeability of customary pickup magnets on the other hand diminishes the coupling of the two coil fields and reduces the disadvantages of the phase reversal. An even better decoupling is achieved by a metal plate with high permeability separating – as flux-guiding yoke – the two coil halves. Optionally, this plate can be bent to a u-shape. With magnetic decoupling and an increased number of turns, co-axial humbuckers achieve a similar transmission characteristic as single-coils. Complete identity is however impossible: the spatial distribution of the magnetic flux (inc. all skin-effects) is different, and due to the higher number of turns (plus 50% or more) the dc resistance changes. The latter does not only have an effect at 0 Hz, but may influence the resonance emphasis (chapter 5.9).

For pickups constructed like the **P-90** (Fig. 5.3.1) the division of the coil as just shown is not purposeful: the coil is more shallow than the one in the Stratocaster pickup and therefore both halves of a divided coil would be close to the strings, i.e. in the alternating magnetic field. Furthermore 6 screws (pole-pieces) would make for a relatively strong coupling of all windings. Possibly for this reason, Gibson did not divide up the coil present in the **P-100** but installed a second coil below the magnets which now serve as a magnetic shield as well. A series connection of the coils would have doubled the already rather high inductance (approx. 7 H) and reduced the resonance frequency by 30%; apparently this was not desirable. For the P-100 the coils are therefore not connected in series but in parallel (and anti-phase). Of course, this has consequences as well: the resonance frequency is now higher compared to the P-90. Obviously the musicians were not excited – production has since ceased.

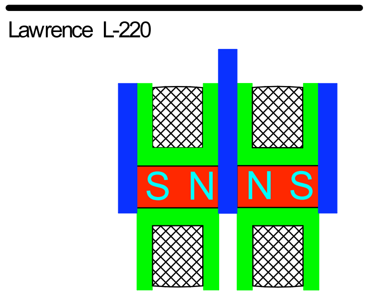
Fig. 5.3.2 shows cross-sections of well-known co-axial humbuckers. Almost all have received patent protection. US patent protection, that is. The question regarding the necessary individual inventive step would probably only have come up in pedantic old Europe.



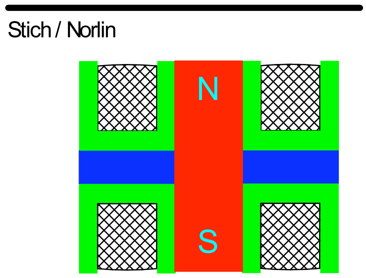
Kinman, 15.03.1996, US-Pat. Nr. 5668520, 5834999, 6103966.



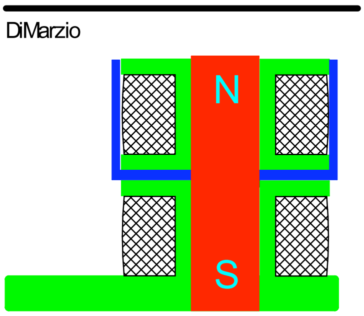
Freeman, 21.12.1970,
US-Pat. Nr. 3657461



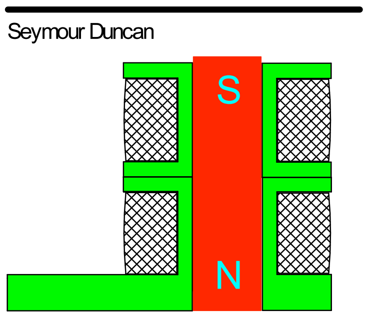
Bill Lawrence L-220. The axis of the coils run horizontally (Stich).



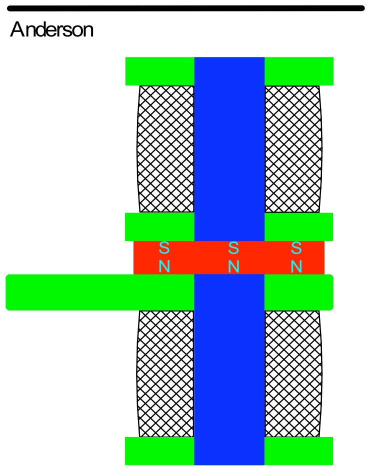
Stich, 05.08.1974, US-P. 3902394, horizontal axis of the coils.



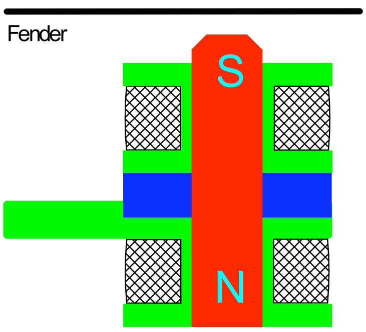
DiMarzio, 06.08.1982,
US-Pat. Nr. 4442749.



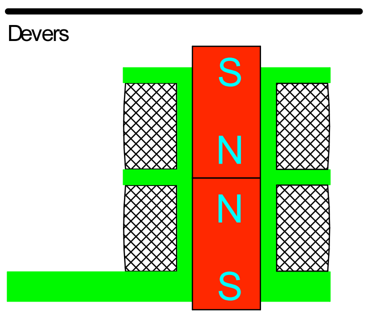
Seymour Duncan, 15.08.1983,
US-Pat. Nr. 4524667.



Anderson, 14.01.1991,
US-Pat. Nr. 5168117.



Fender, 28.01.1998,
US-Pat. Nr. 6291758



Devers, 17.05.1999,
US-Pat. Nr. 6846981

Fig. 5.3.2: Various co-axial humbuckers; dates given are those of the patent filing

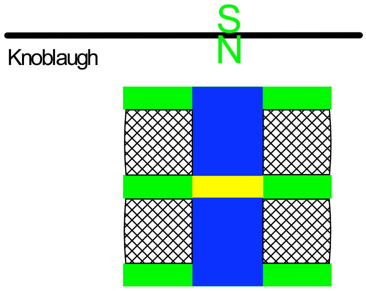


Fig. 5.3.3: One of the first co-axial humbuckers, US-Pat. 2119584. Both coils contain a core of layered transformer laminates; the cores are separated by a nonmagnetic spacer. Prior to use first a direct current had to be fed to the upper coil to magnetize the strings. Day of filing for the patent: 9.12.1935.

Fig. 5.3.3 shows that Gibson is not the inventor♣ of the humbucking principle: even before the famed PAF, there was the trendsetting idea to interconnect two coils in anti-phase. Seth Lover, designer of Gibson's humbucker, was himself informed about competing pickup developments: *"People had been working on double coil pickups since the 1930s [13]"*. As early as 1935, Arnold **Lesti** filed an application for a pickup with tow side-by-side coils (US-Patent 2026841 = Re.20070) and describes the principle of interference: *"And since these coils are wound in opposite directions, the interfering stray currents are neutralized"*. On tp of that, it would be possible to imply that Gerald **Tuininga** attempted - in his patent application filed in 1929 and leading up to US patent 1838886 – to compensate interference with the use of two coils: "*The advantage of using this style of transmitter is that no other electric current caused by foreign sound or vibration can in any way enter into the circuit"*.

In 1929, descriptions of patent applications as this one comprised only little more that one page in letter format, so we should not be too small-minded and start splitting coil wire ... *er*: hairs. Still, the circuit included in the patent description seems incorrectly drawn. If both coils indeed had the same direction of their winding the wanted signals would cancel each other out while the interference would double. Inverting one of the coils – which would have been the only way back then it would have worked in the breadboard setup – one obtains a fully functioning humbucker. Mind you, it would still needed firing up an electromagnet via a battery. That we are not burdened by such cumbersome procedures anymore today – that we owe to inventors such as **Seth Lover** (patent application in 1955). Or **Leo Fender**, who filed an application for his humbucker in 1956. Or **Ray Butts**, who filed the one for his Gretsch-Humbucker in 1957. Or **Oskar Vierling**, who as early as 1927 published the basic principle of the electromagnetic string pickup with the German patent office in Berlin.

Whether – as Day et al. surmise – **Bill Lawrence** put together already in 1948 the "probably world's first humbucker" is questionable. It would be possible: Lawrence was born 1931. On the other hand, he himself dates the beginning of his entrepreneurial activities to 1965: "Electrosounds in Munich, Germany". Back then Bill Lawrence was still called Willi Lorenz Stich, and one of his partners was Jzchak Wajcman. It was the same Jzchak who would later push Lawrence into a $ 1.156.250,00 bankruptcy [Guitar Player, September 1979, cited in billlawrence.com]. Incidentally, the St. Lorenz, alias Laurenz, alias Laurentius, alias Lawrence was "burned to death on an gridiron". You lucked out, Bill! (using this expression since B.L. later lived in the US .... for you British readers this would have to read: "You had a lucky escape, William!").

♣ In their advertisements for strings, Gibson indeed merely claim to be the "inventor of the Humbucker" ... and not the "inventor of the humbucking principle"