Guitar Pickups Magnetic Fields 2

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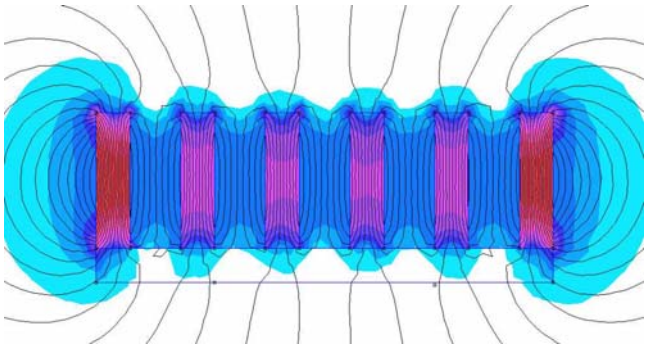
Single Coil, 6 Rod Magnets - Magnetic Fields

Looking at a standard six magnet single coil pickup as though we are looking across under the strings (x-z projection), we get Finite Element Moment analysis picture in 2D that shows the six magnets and the intense magnetic fields that leaks between them:

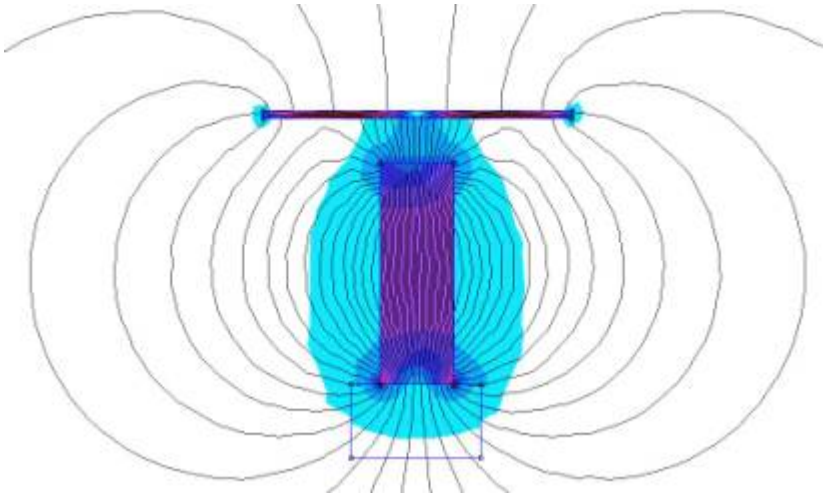


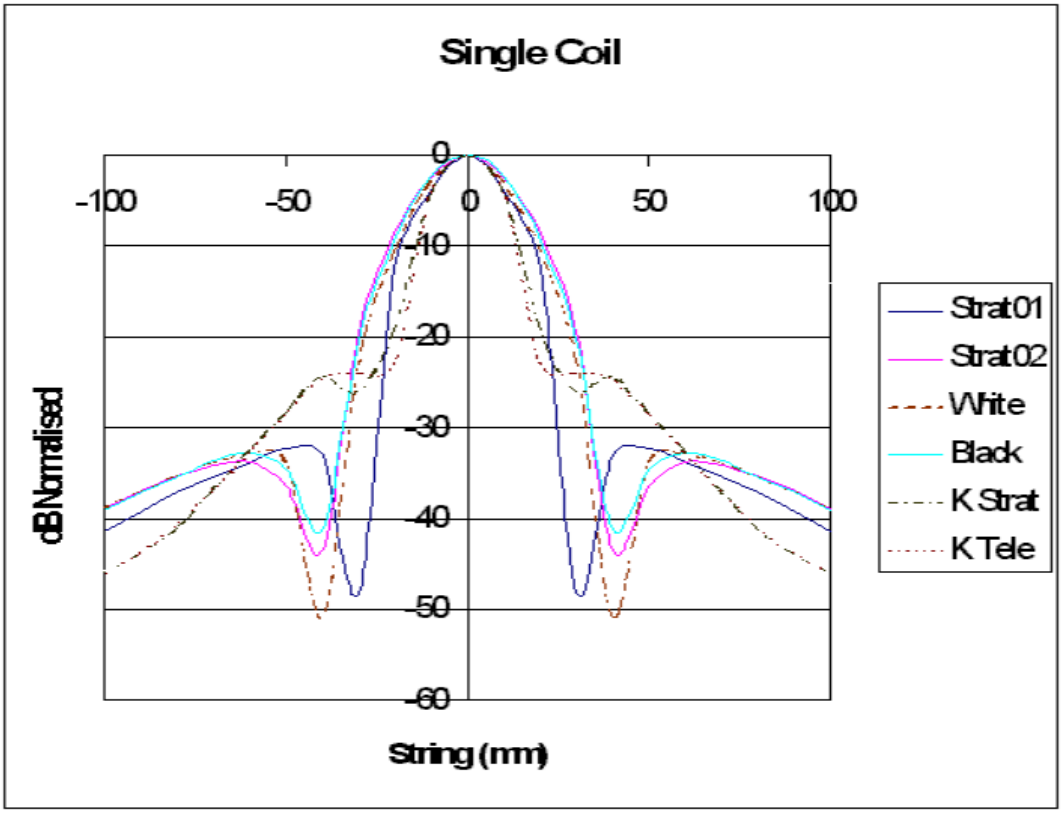
These pictures form an interesting scenario as the six magnets as shown with the 2D map in the lower picture above, have a lot of fields lost between them in magnetic leakage. This 2Dcpicture also indicates that even if the pickup were inverted then the sensitivity could be very similar to the top side.

This will help to explain why in general single coil pickups are very sensitive to external fields like fluorescent lights and SCR / TRIAC dimmed lights with nearby power cables.

To all intents and purposes the fields look much stronger in the ends and much weaker in the centre - but this is an illusion caused by only looking at one 2D magnetic slice, which is right in the middle of the pickup.

If we were to twist the analysis by 90 degrees and look end-on through the middle of the pickup, then we would see only one of the six magnets as they would all be in line, like the picture below as a 2D map:



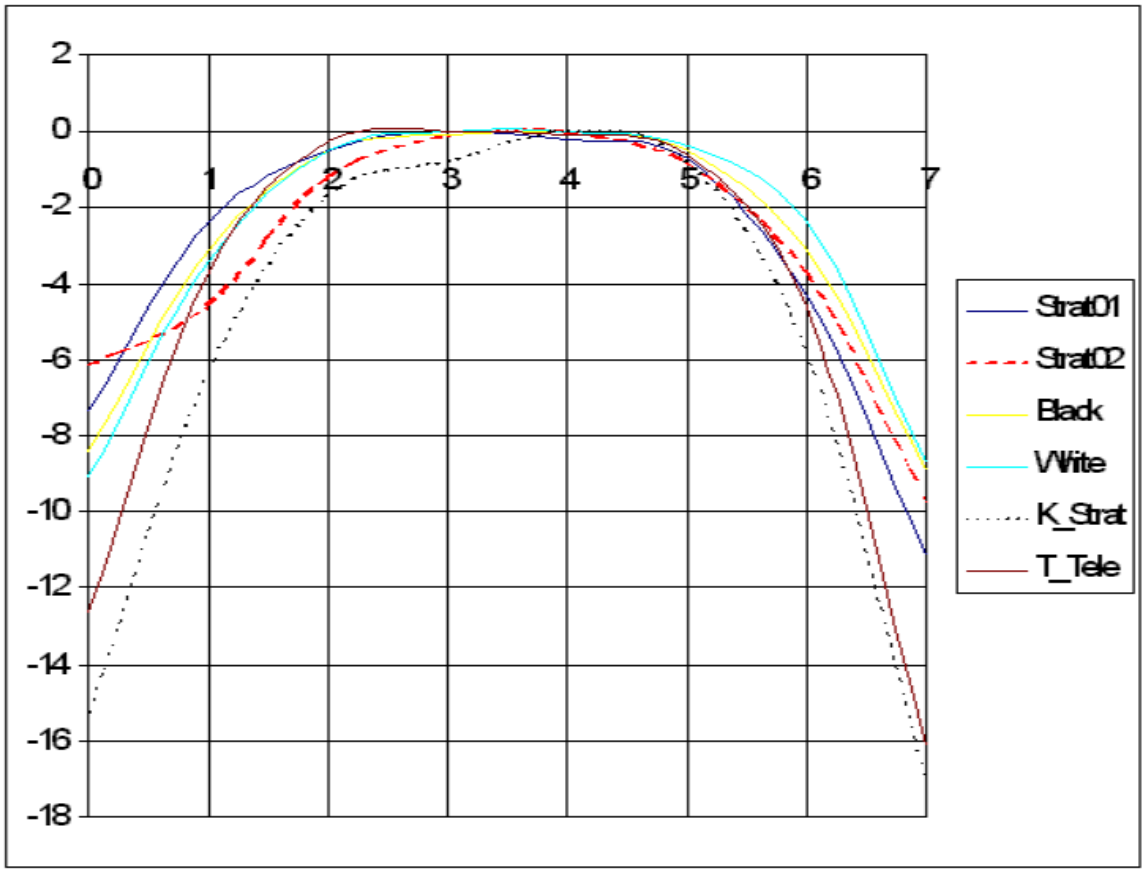


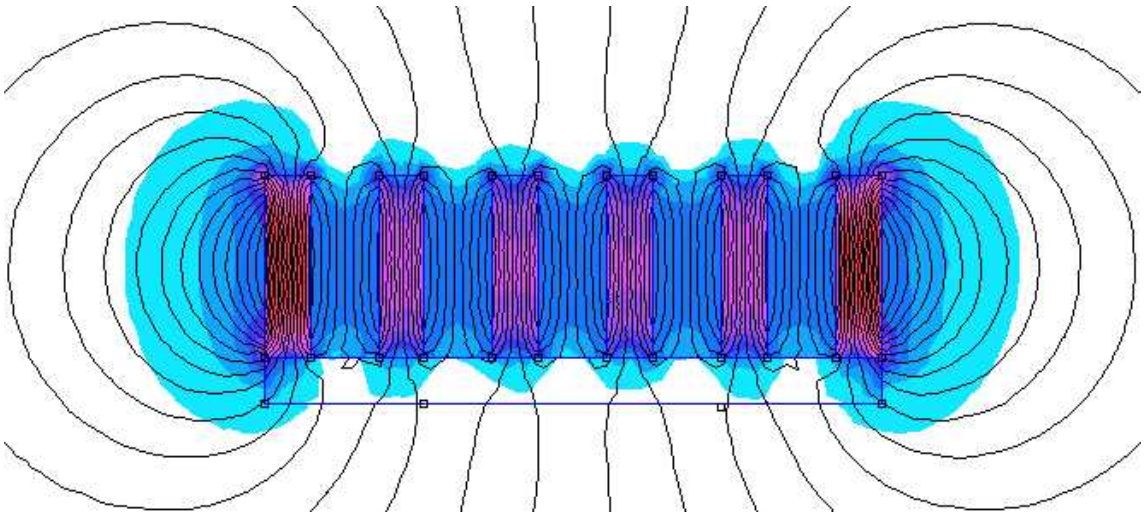
The two pictures above shows the cross-section of the Stratocaster or other single coil pickup and the general sensitivity chart aligned centre of the magnetic field. This should show just how sensitive the relative string movement is, along the string.

By the 30 mm position off-centre from the pickup the field from the lower end of the magnet effectively cancels the detected string movement and as we move further, the sensitivity comes up to about 32 dB then gradually falls away with distance.

Lateral Sensitivity

So now we know that the magnetic field strength has a direct bearing on the part of the vibrating string, and it is nominally limited to about 15 mm either side of the pole-piece centres. If we go back 90 degrees and look across the strings then the relative sensitivities are like the picture below:





The two pictures above are rather interesting as they show the relative sensitivity of a range of pickups along the face of the pickups, where the strings are numbered 1

through to 6 and for thoroughness the spacing was extended outside the face area to include strings 0 and 7.

What has to be understood is that relative levels are not easily distinguished and a difference of 3 dB is virtually undetectable.

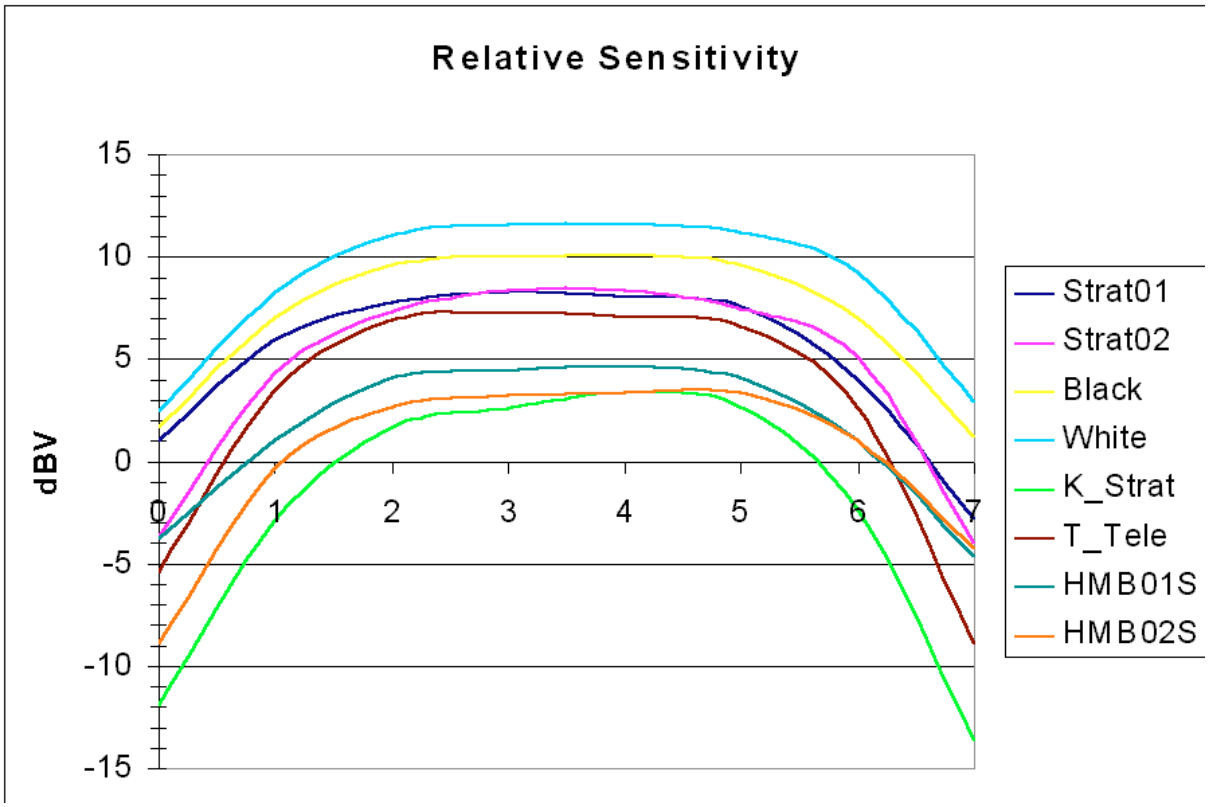
The outer-most strings appear to be a slightly less sensitive on all these pickups (be they single coil or humbucker structure) and surprisingly, these sensitivities are relatively consistent when normalised on the 4th string as a common point.

We can now see the similarity of the pickup sensitivity compared with the string position and the magnetic field 'slice' through the centres of the six pole pieces. (Imagine the strings are over the tops of the pole pieces!)

Where the field wraps itself around the ends, the sensitivity would be weaker for vertically moving strings, but for horizontally moving strings the sensitivity will be a little greater – and this may be a sensitivity/position compensating factor.

Relative Sensitivity

If we compare the sensitivity of each pickup under constant conditions then we get quite a surprise. The two pickups (Black and White) showed up to be the most sensitive to field changes in the string area, then the two standard Strat pickups with almost identical responses about 3 dB quieter, then the Kinman Tele almost as sensitive as the two Strats, and then the two Humbucker pickups about 4 dB quieter than the standard Strat pickups, with the Kinman Strat vertical humbucker which was marginally quieter than the weaker Humbucker.

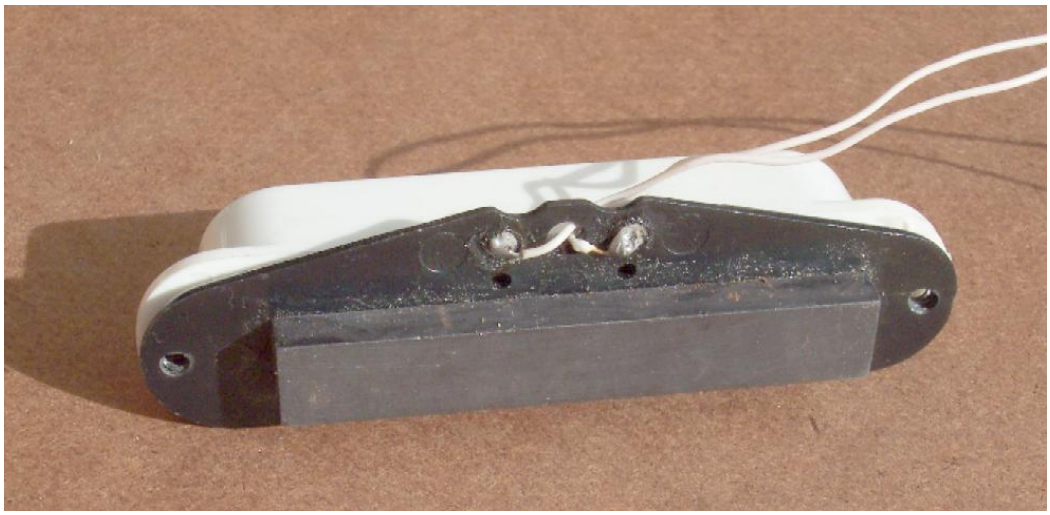


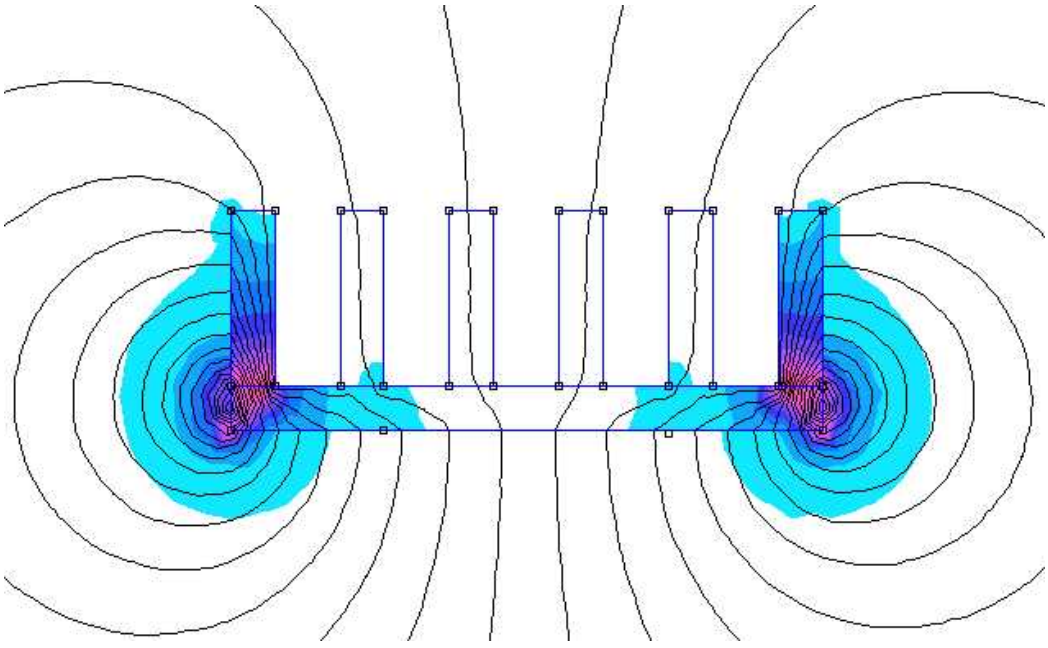
The above graph shows the relative sensitivities of all these test pickups in relation to each other and the overall difference in sensitivity is in the order of 9 dB, which is quite large. I was expecting about 6 dB overall.

Considering the wide manufacturing approaches, it is surprising that most pickups fit into a very common area, and the overall difference in sensitivities is about 9 dB, and when considered that the distance from string to magnet is a critical factor for absolute level, then these differences could well be less than 6 dB. Each 'family' of pickups have curves that very closely align.

Single Coil, 6 Iron Rods, 1 Flat Magnet - Magnetic Fields.

The next version of Stratocaster single coil design pickup types has a ferrite magnet and six soft iron pole pieces





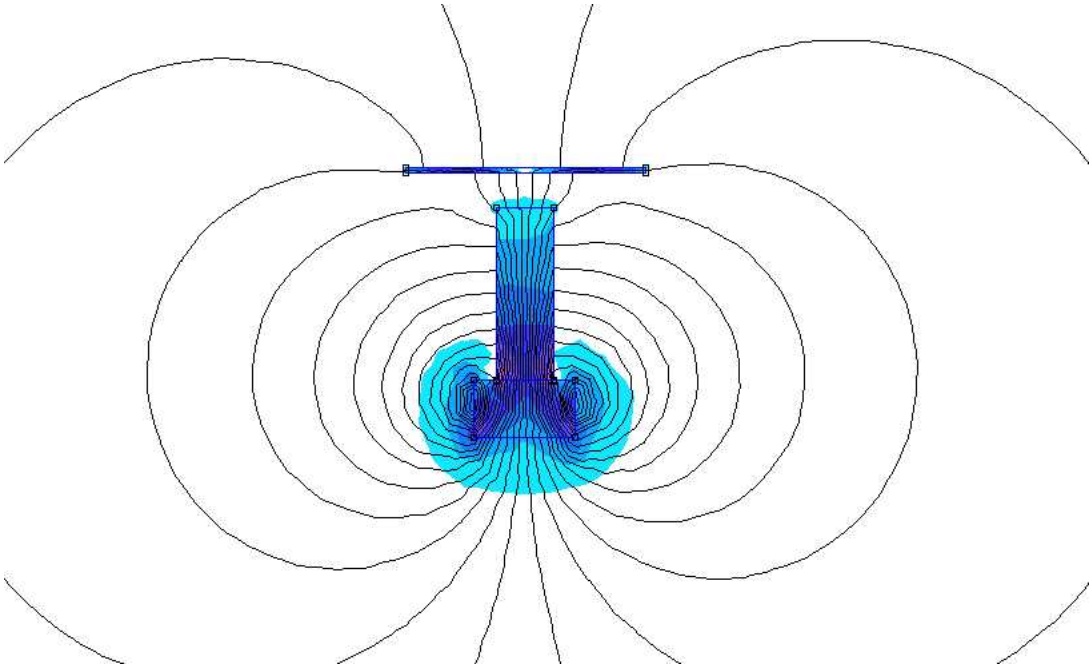
In this case the (ferrite) magnet is sitting under the six soft iron pole pieces and the strings sit a few mm over the soft iron pole pieces. The 2 Dimensional FEM analysis picture above really needs some explanation to tell what is going on:

The six soft iron pole pieces are central to the picture in a row, and each rod does not appear to have their top ends closed. The (ferrite magnet is sitting under the six soft iron poles and this magnet has the North Pole on the top (touching the six pole pieces) and the south pole is the bottom face.

There are no strings shown in this picture but if they were to be shown then they would like six “office pins” sticking out of the picture just over each soft iron rod.

What is confusing about this picture is that the magnetic field appears to be intense at the ends of the flat magnet and virtually no intensity in the middle.

The issue is that the 2D picture is going through the centre middle of the magnet and rods, and in the middle of the magnet there is very little static magnetic field. The picture below shows the same pickup but from an end-on (90 degree change in view) perspective at the middle of the pickup:



You can see here that there is an intense magnetic field around the edges of the flat bar magnet, and that the north pole (in this case) is extended up through the soft iron rod towards the string.

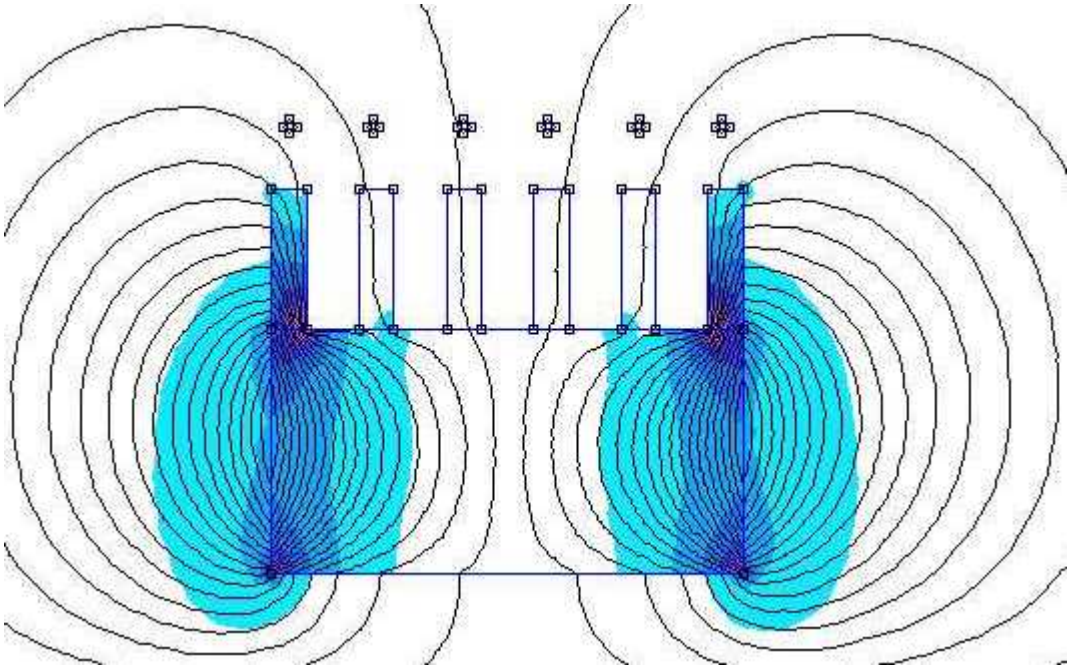
The big change in magnetic intensity is around the flat ferrite magnet, and there does not appear to be much change in magnetic intensity over the poles - where the strings are!

This magnetic lack of intensity at the required area is the reason why these types of magnetic pickups are not as sensitive as their six magnet rod cousins. It would be a fair guess that these pickups probably also suffer more from external magnetic noise sources than their six-magnet cousins.

Single Coil, 6 Iron Rods, 1 Deep Magnet - Magnetic Fields.

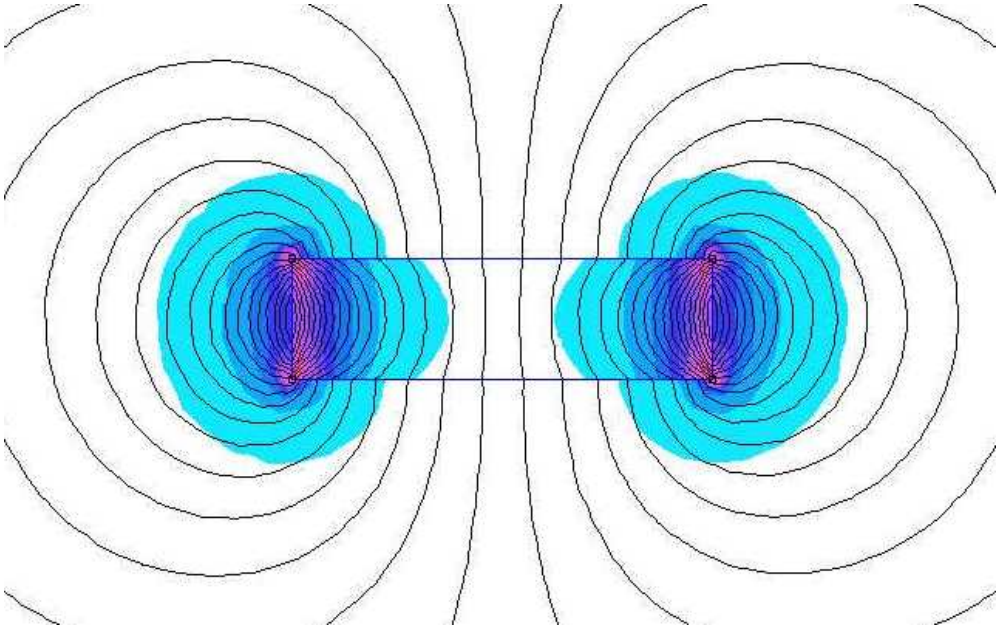
As a variation on the thin flat ceramic magnet at the base of the pickup, a much deeper magnet was positioned in place.

Effectively this makes no difference at all as the magnetic field is now extended over the deeper magnet, and again the biggest magnetic differential is at the base of the pickup away from the strings so this will be rather insensitive as it's flat magnet cousin.



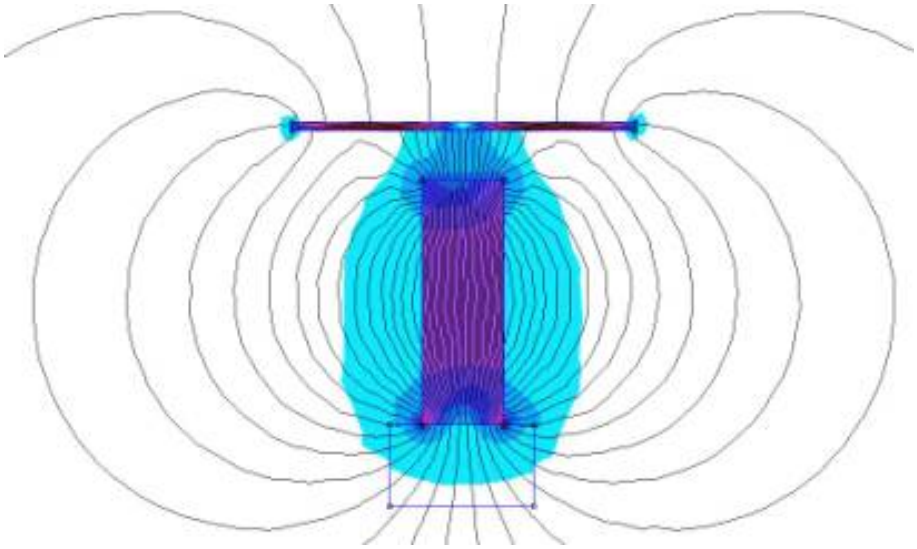
Single Coil, 1 Deep Magnet - Magnetic Fields.

Another alternative is to look at a single magnet instead of several pole pieces. To date most pickup manufacturers seem to be stuck on the approach of a pole piece (or two) pole pieces for each string – and the approach seems questionable. Take the case of a single long magnetic strip across six strings, the representation could look like this:



In this case the poles are along the top and bottom of the strip ferrite magnet, and the magnetic field is that seen through the centre of the strip magnet.

At the ends of the magnet the field seem intense, but remember this 2D map is through the middle of the magnet. Slightly towards and away from this plane, the face edges of this magnet will also have fierce / intense magnetic potential differences that are not shown on this 2D map



If the North is the top-side and the South is the bottom-side (and it is easier seen if expanded by clicking on it)! On the left hand and right hand ends, the magnetic field is more intense as it wraps itself around the ends to make a circuit – this is happening all along the sides too – but this depiction does not show that - but this is shown in the right hand picture!

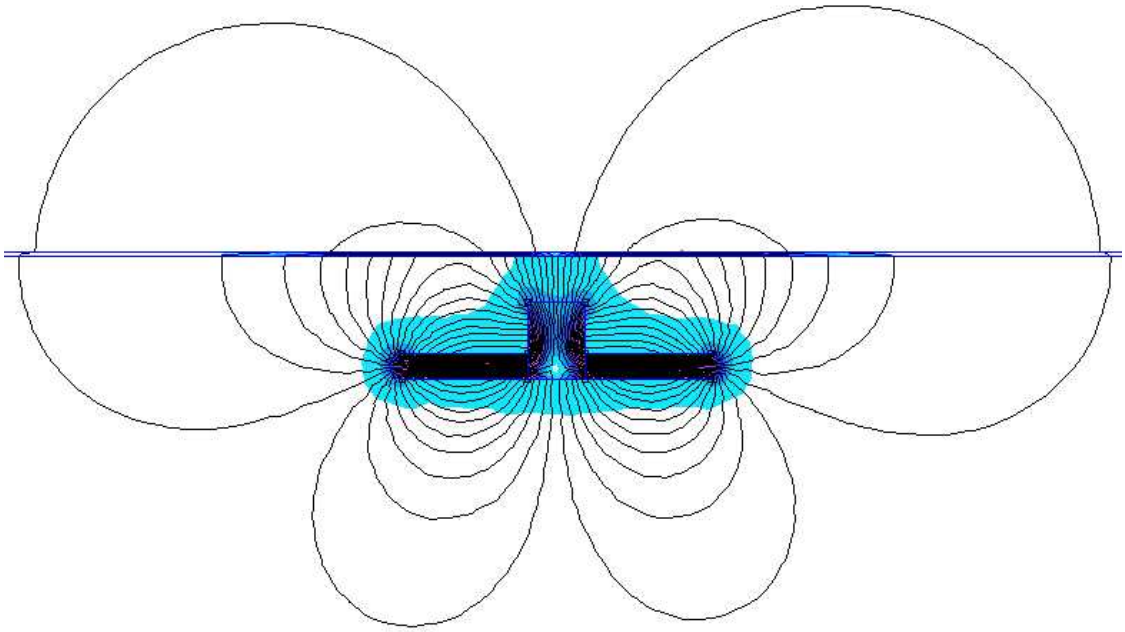
Compare this to the pictures above this one and it has to be appreciated that the 6 rod designs above have ‘very busy’ magnetic fields leaking back around the pole pieces – and not going anywhere near the strings. If the length (seen here as height) is increased, then the field intensifies, making it appear stronger at an equivalent (string) position.

This type of pickup should be comparatively sensitive and because of that, the coil windings could be minimised so the resistance and inductance would be reduced, making the connectivity to tone and volume controls that much easier, and provide a very wide range of tonal range.

This would also explain why vertical hum buckers (Kinman variety) appear to be less sensitive (but remember the test apparatus is an electromagnetic field and not a moving string), than a multi-rod single coil variety.

Single Coil, Two Lateral Magnets (P90) - Magnetic Fields

The P90 pickup is at the best an enigma to explain as it has two magnets in opposition to (facing) each other into a mild steel block and six iron screws to set the "sensitivity" for the strings to the pickup.



This picture over-justifies the performance capability of the P90 as the centre mild steel square rod is not much thicker than the flat magnets, so the field does not really have that much "carry" into the strings. This analysis does, however open up a large range of innovative ideas for restructuring pickups to be both efficient and sensitive.

Comments and Corrections are welcome