Survey of the Properties of Ferrite Rods

A simulation survey by Dieter Stotz using Quickfield©

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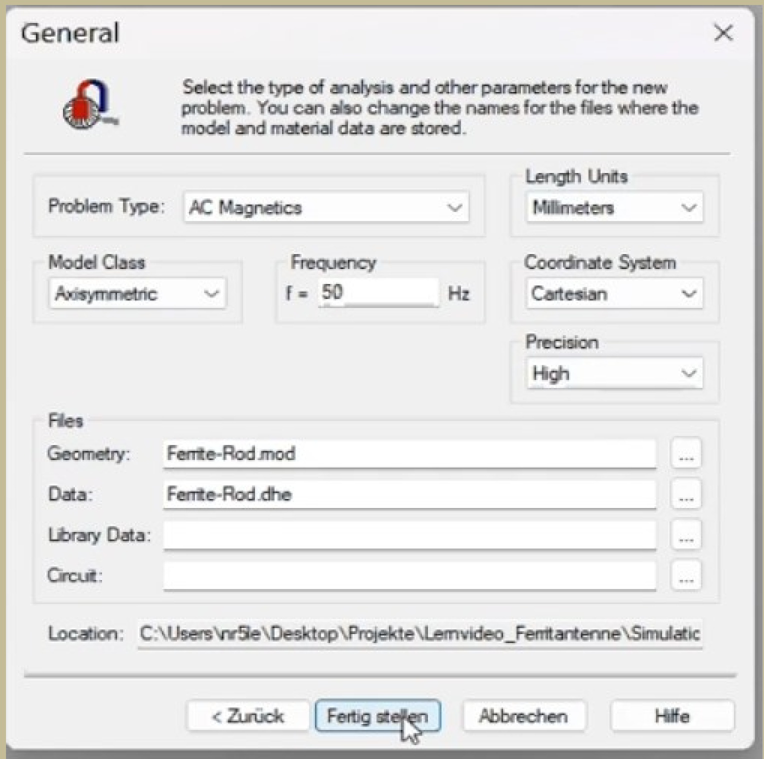
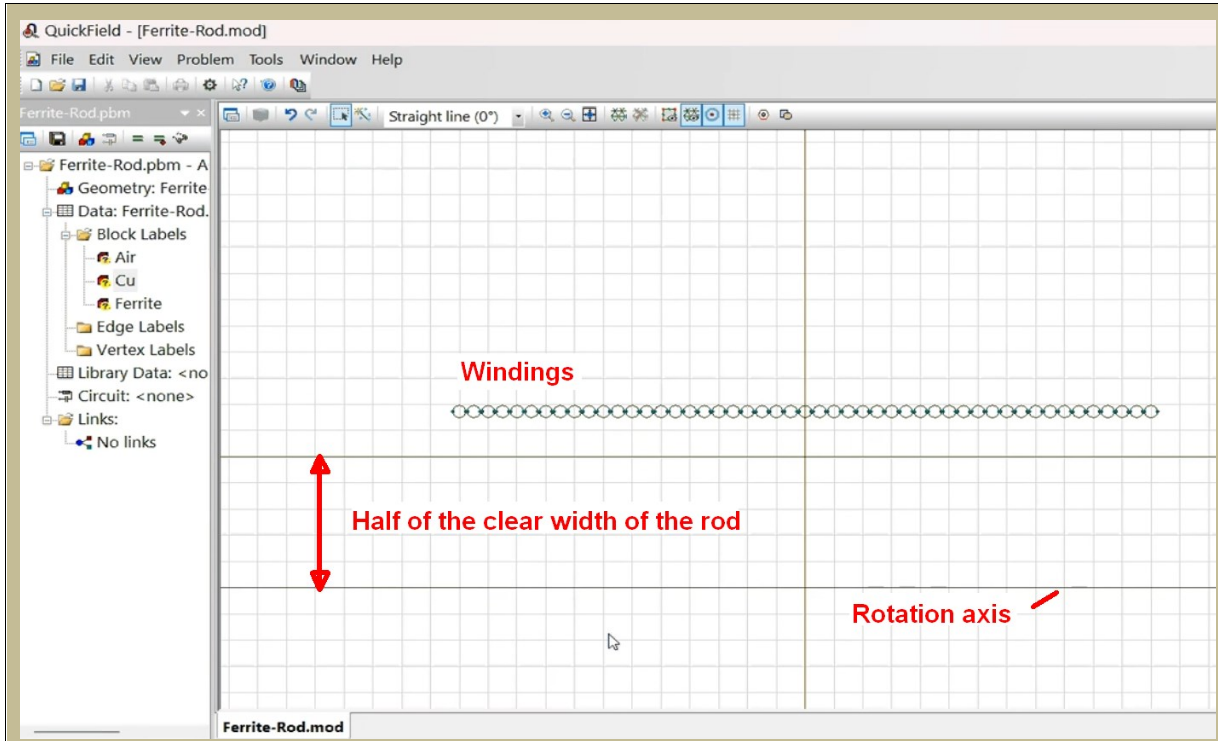
We want to have a look on ferrite rods, especially in the application of LF antennas. Special aspects are inductance and inductance quality, shielding against E-field-interfering and influence to the wanted signal, directivity, and the shape of the ferrite rod.

AC Magnetics / Axisymmetric	AC Conduction / Axisymmetric	AC Magnetic / Plane-parallel



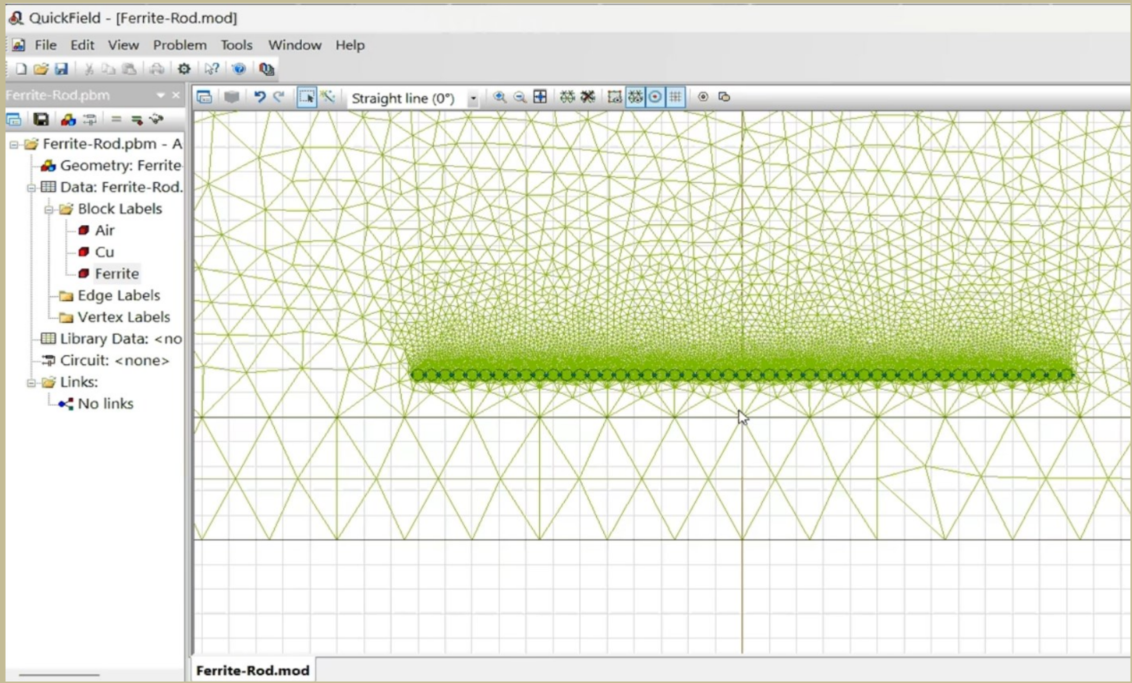
The first step is to create a new model, which includes everything regarding geometry, material and material properties. In the above picture there is a new problem created, whose type is *AC Magnetics*, the class *Axisymmetric*, initially frequency and so on.



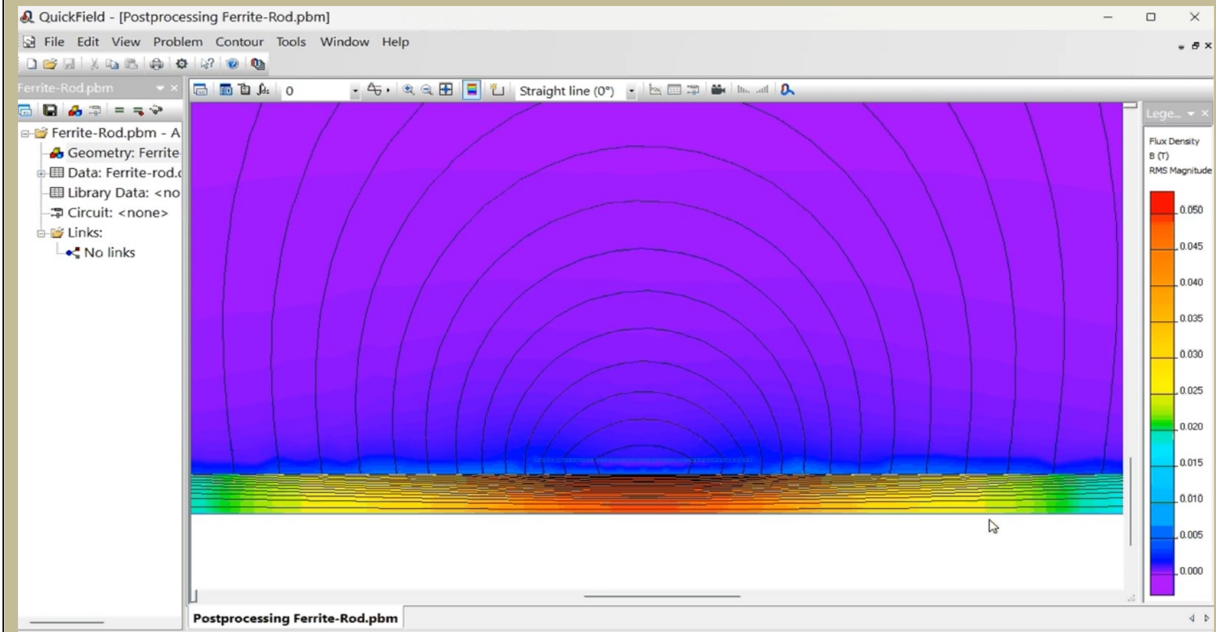
Going to the item Geometry, there is a window to draw all the parts, to name their materials and to define the materials' properties.

The lowest horizontal line represents the rotation axis. This is suitable for axisymmetric parts only. This is the case for a cylindrical ferrite rod with a coil of copper wire. So the higher horizontal line is the boundary of the rod.

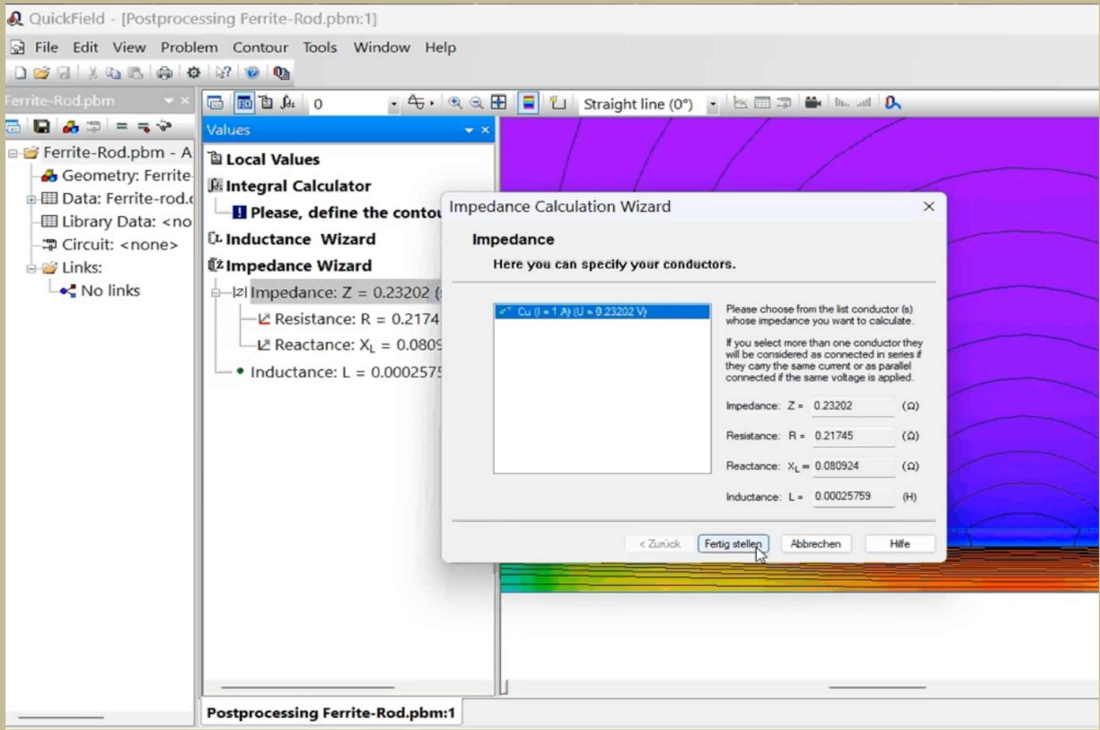
Clicking on the question marked three materials we must define properties. In this case it is AIR with permittivity 1 and zero conductivity. Copper also has the permittivity 1, but the conductivity is about 60 millions S/m. For ferrite we assume a permittivity of 200 and zero conductivity (which depends on the type of ferrite, though). After we made these entries, the question marks disappear.



The properties are defined as said before. The mesh is done, now the whole arrangement can be solved.



And this is the result of the distribution of the magnetic flux density. In opposite of a toroid the magnetic loop is open by a rod, thus the flux density is not homogeneous in between the rod.

<table>
<tr>
<td>
</td>
<td>The impedance of the coil can be investigated. And the inductance as well.</td>
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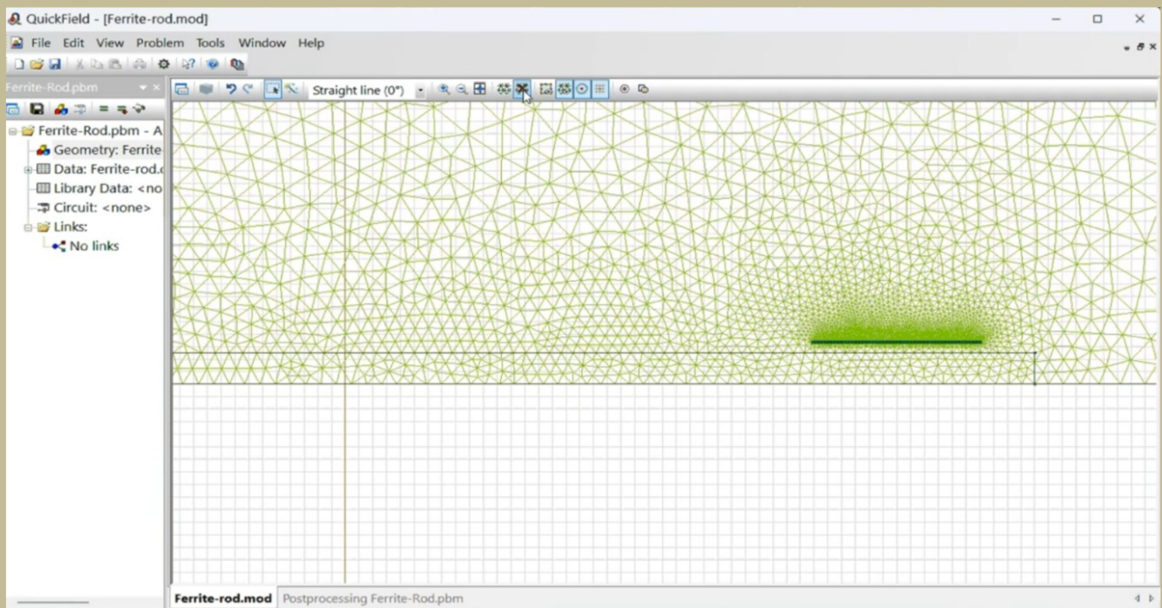
<td>
</td>
<td>We shift the coil to the end of the rod and want to know, if the inductance changes.</td>
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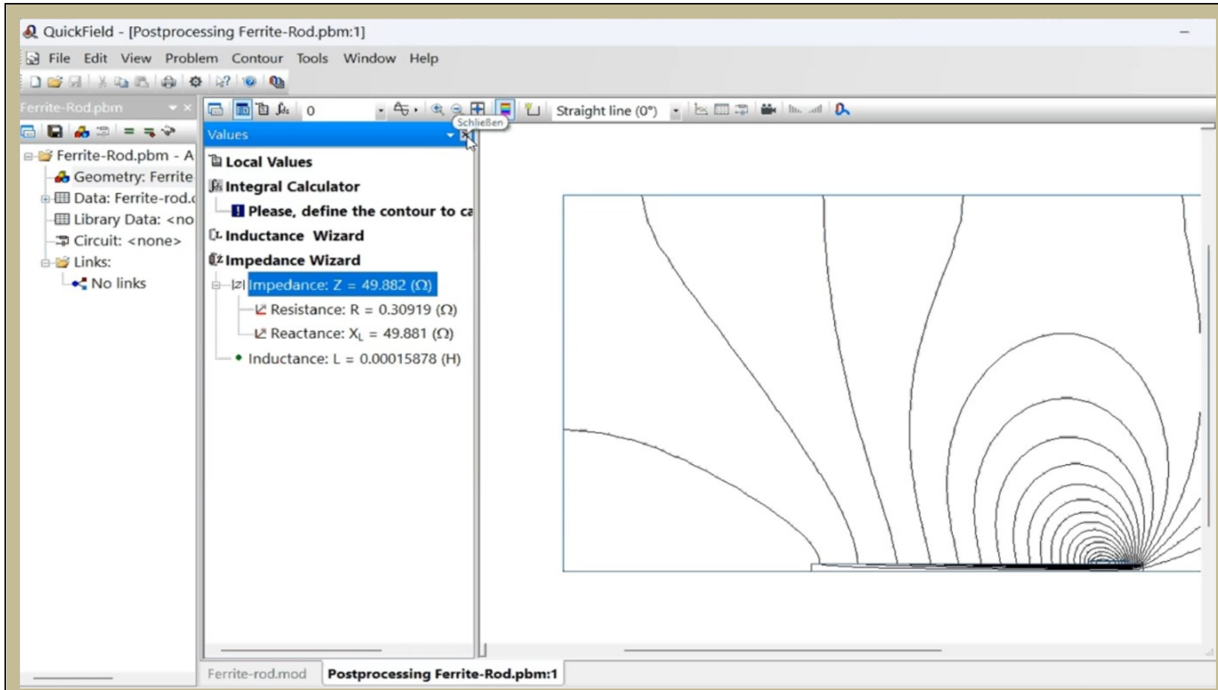
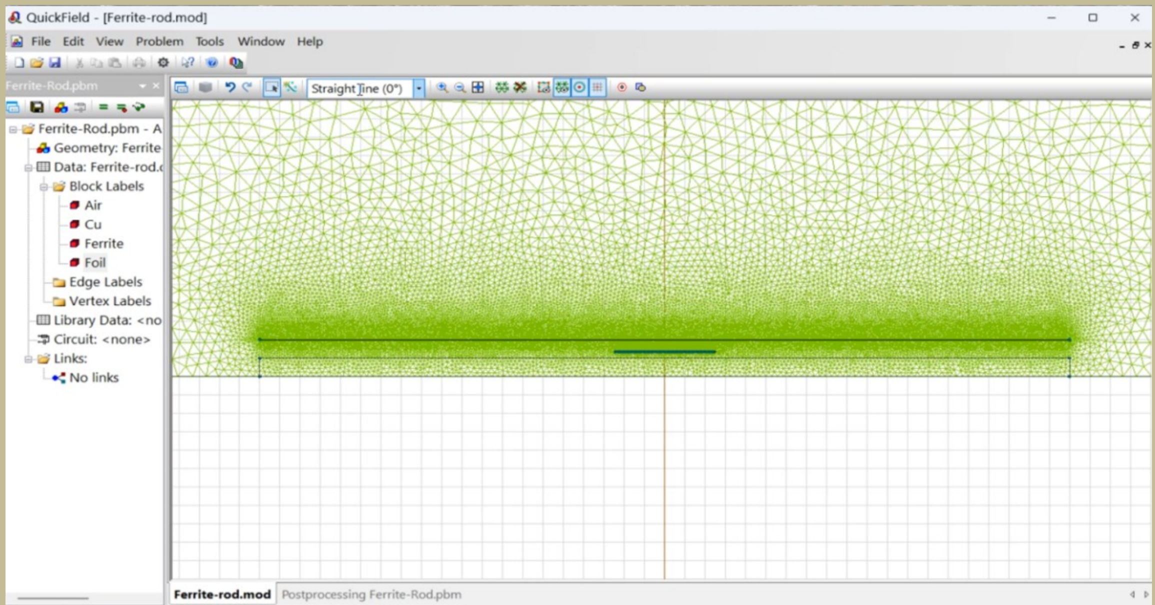
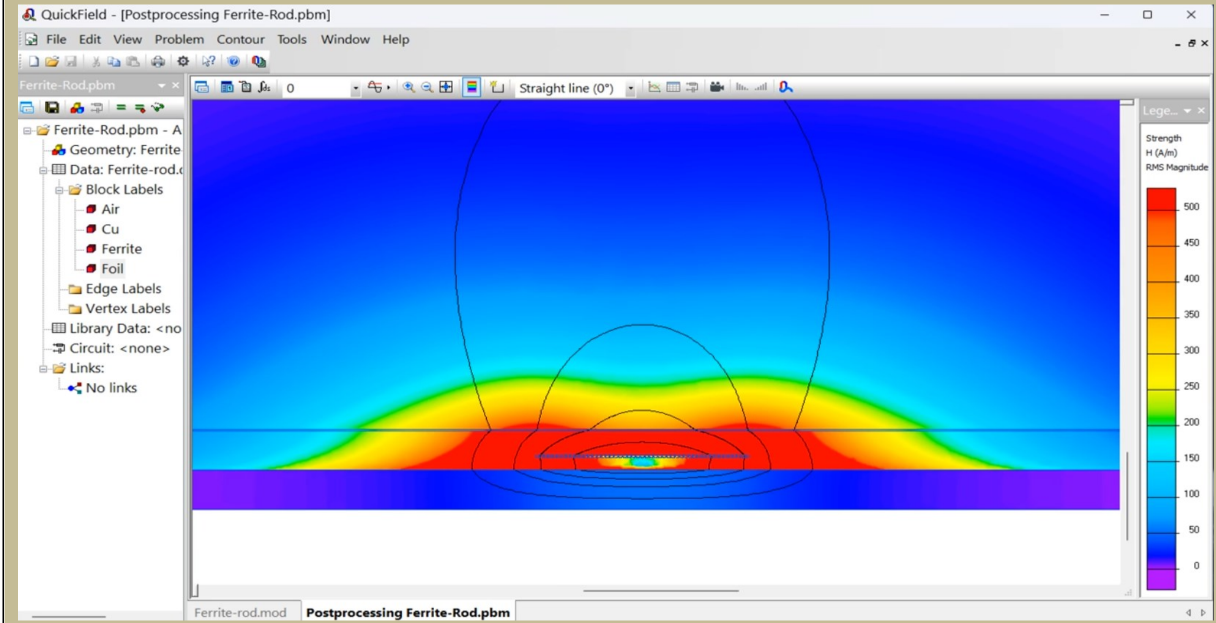


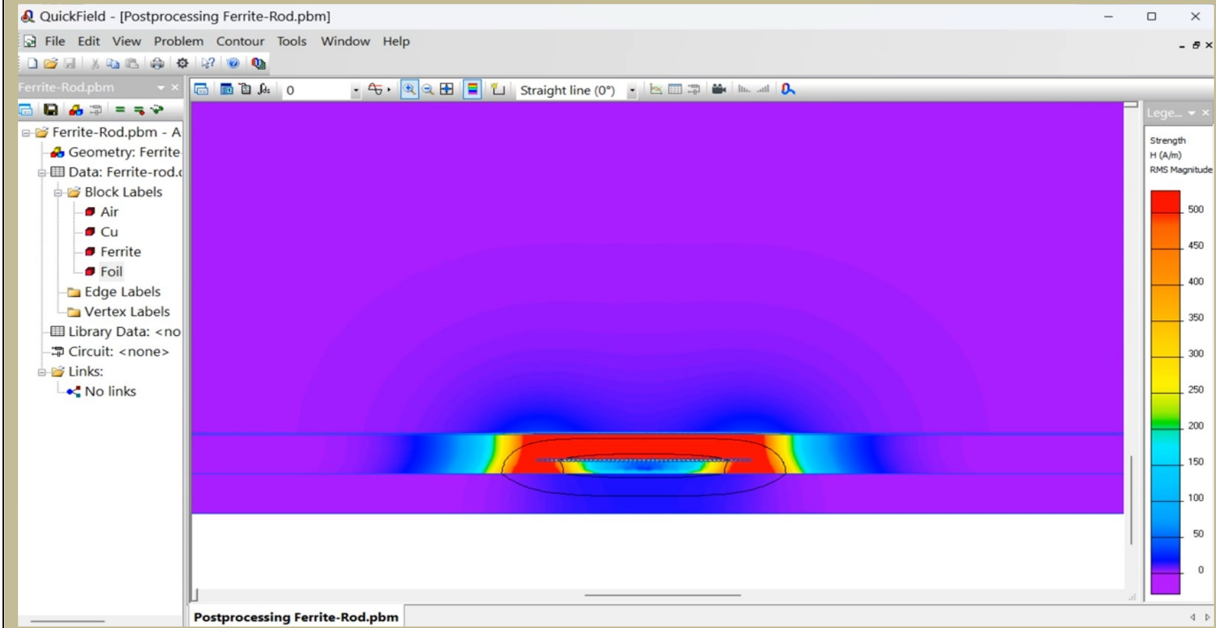
Indeed, the inductance decreases from 258 µH, when the coil is centered, to 159 µH, when the coil is at the end.



We added a conductive foil in order to examine a shielding for disturbing E-fields. But before we want to know, how strong the influence is to the wanted signals of the H-field.
The foil has a conductivity of 100 000 S/m, which is still a weak conductivity in comparison to copper with 60 millions S/m.

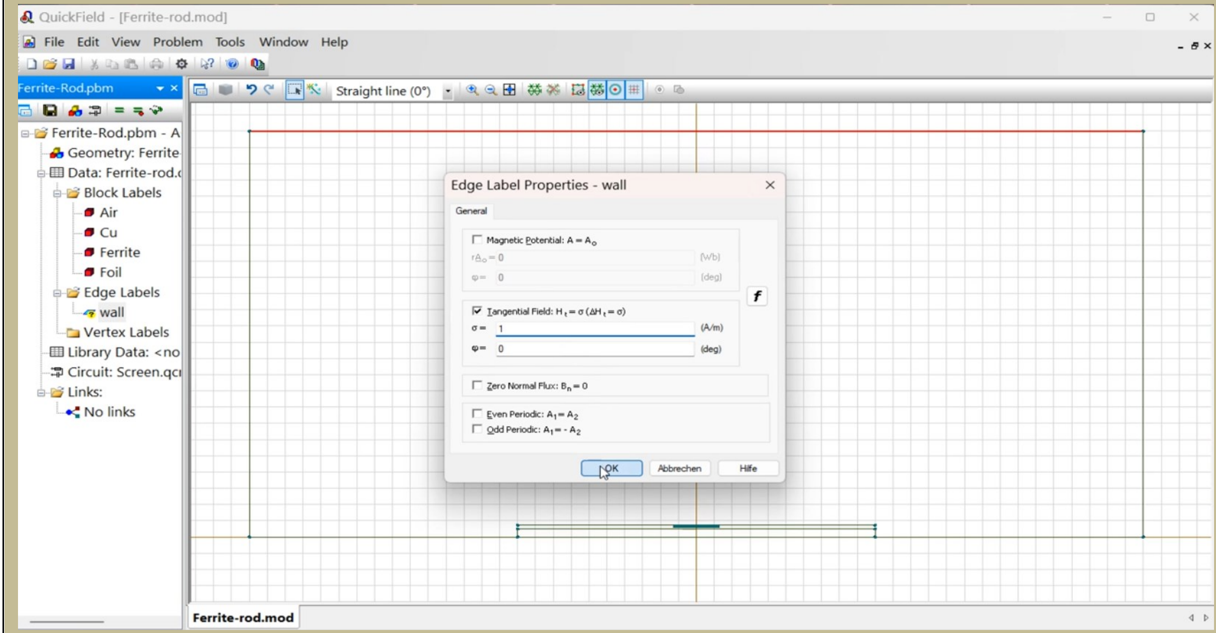


The H-field is attenuated very strongly.



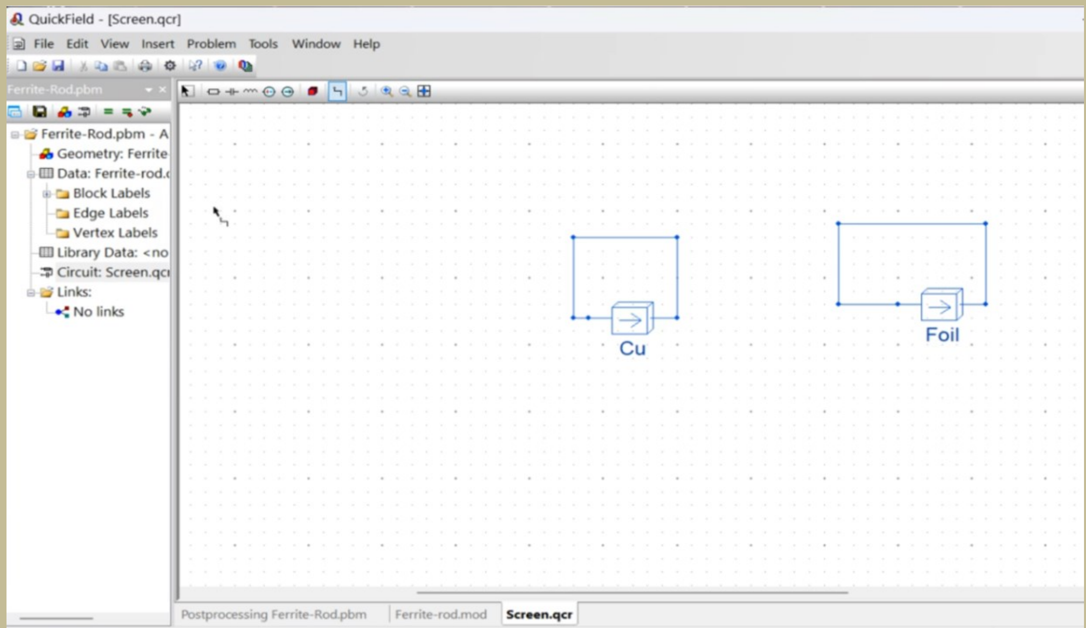
When we repeat this with a foil out of copper, then almost nothing reaches the outside area.

Consider that look at the direction from rod to outside. In the end we want to see the direction vice versa in order to examine the reception properties with and without a screening foil.

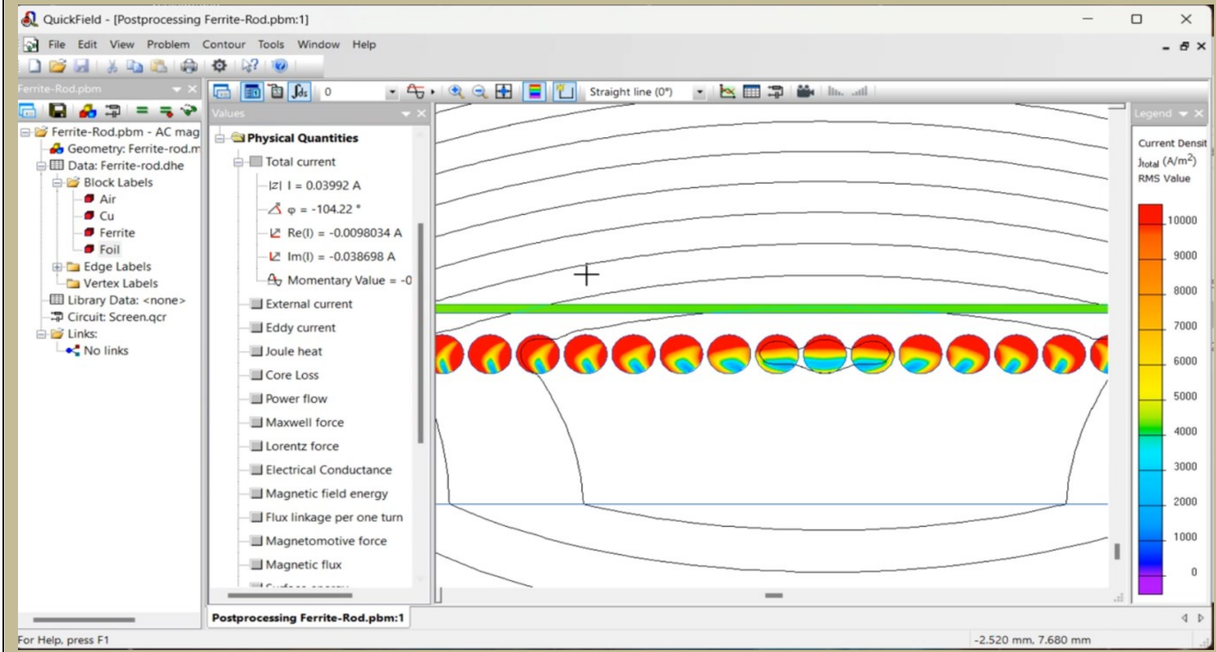


We declare the front-end wall as an emitter of a magnetic field with the value of H = 1 A/m.

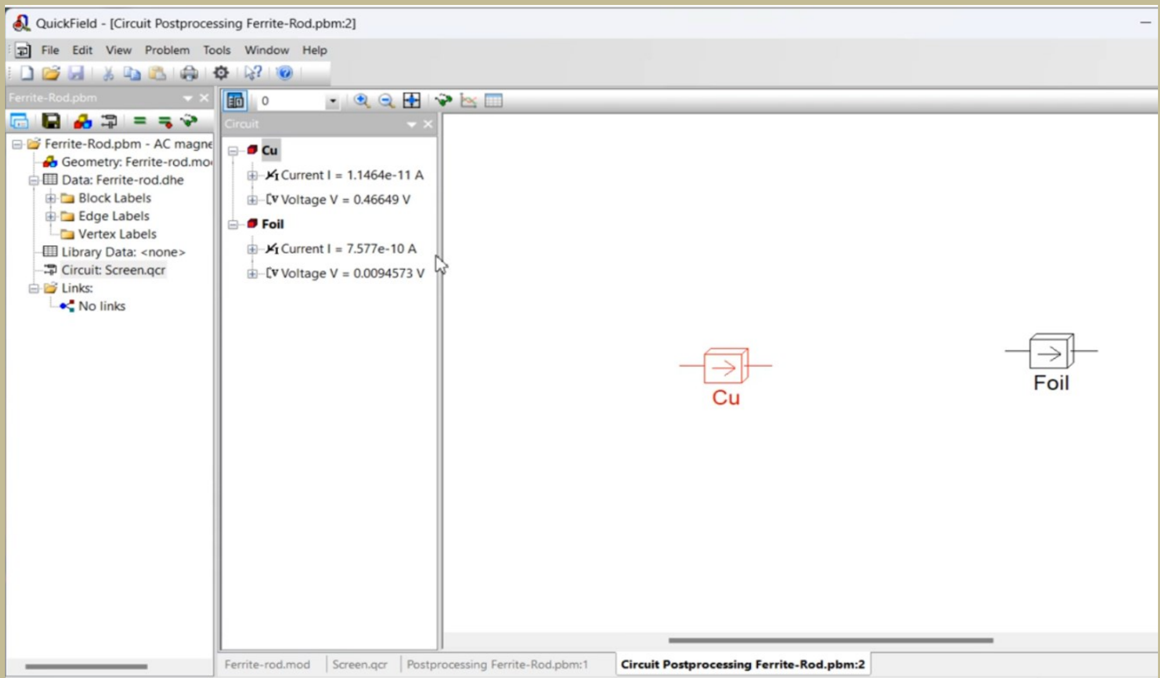
The foil’s conductivity is set to 10^3 S/m.



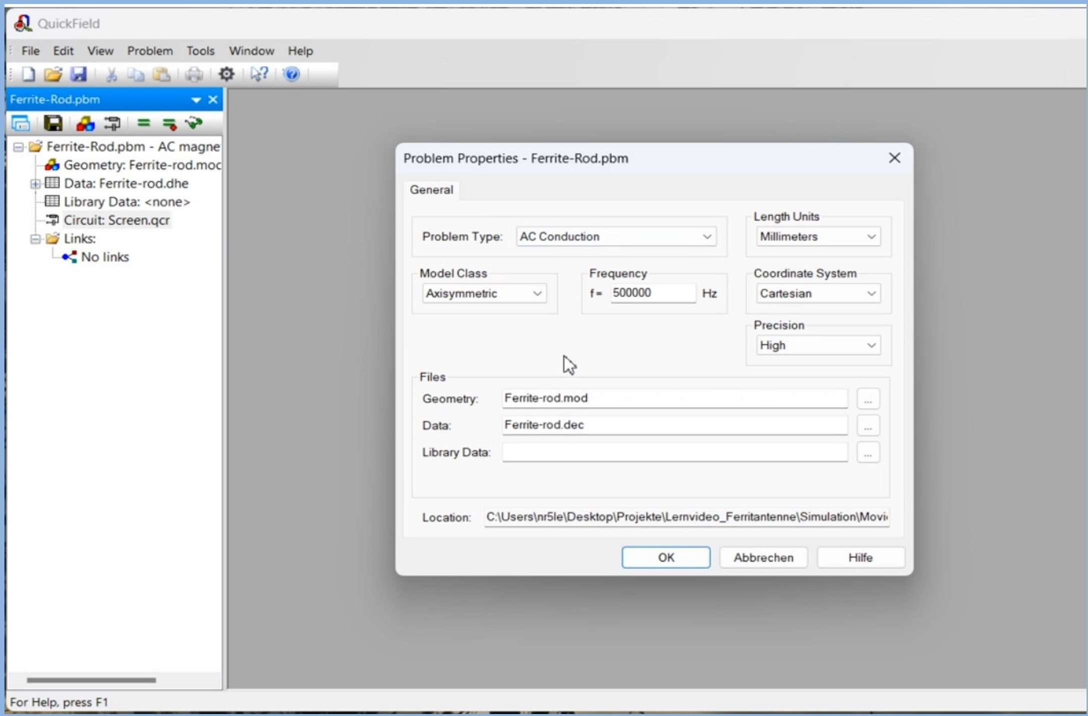
As a criterion for the attenuation by the shielding foil we add a circuit, representatively standing for the coil (Cu) and the foil.



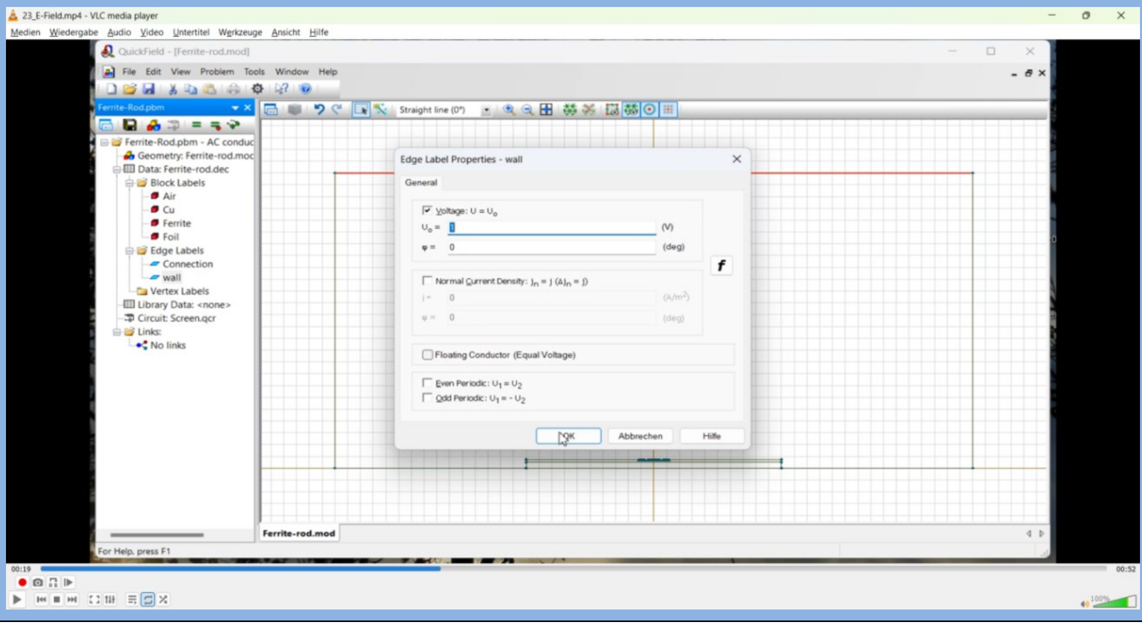
The coil's current is about 1.9 mA and it is almost independent on the foil's conductivity, while the foil current goes high to about 40 mA. Further increase to a foil conductivity of 10^5 S/m let's the coil's current decrease to 0.54 mA and the foil's current increase to 180 mA.



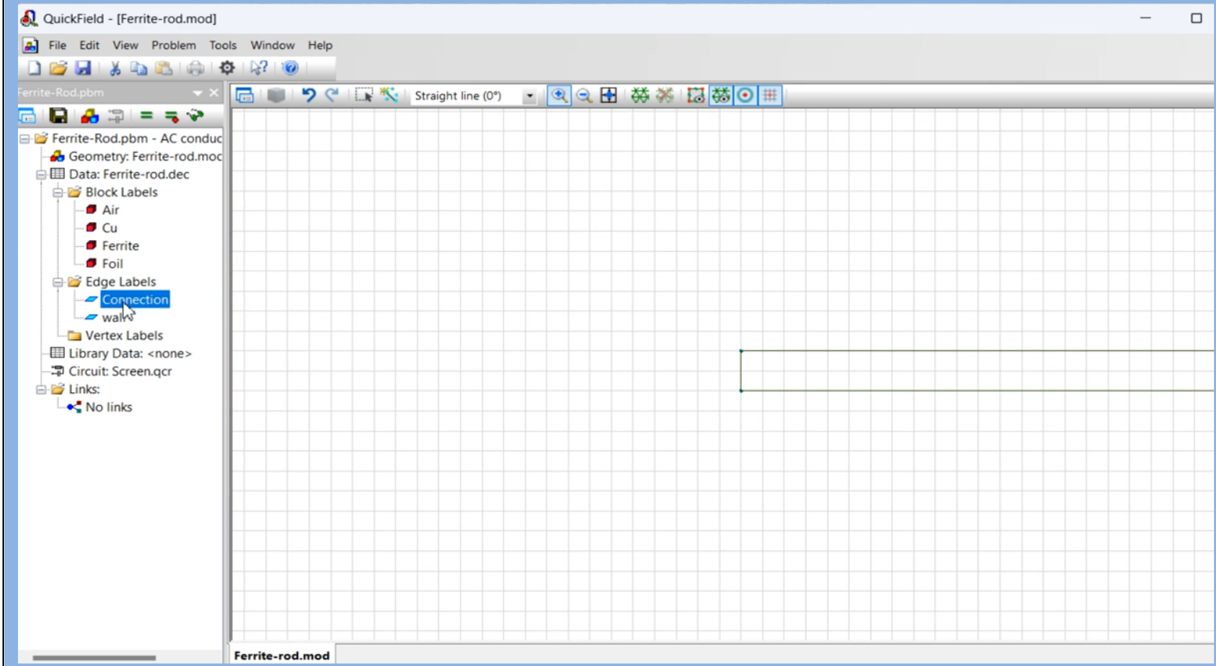
We remove the shorts now in order to measure the voltages across the coil and the foil.
The ratio between coil voltage and foil voltage is nearly exactly 49, the ratio of windings ratio of both.



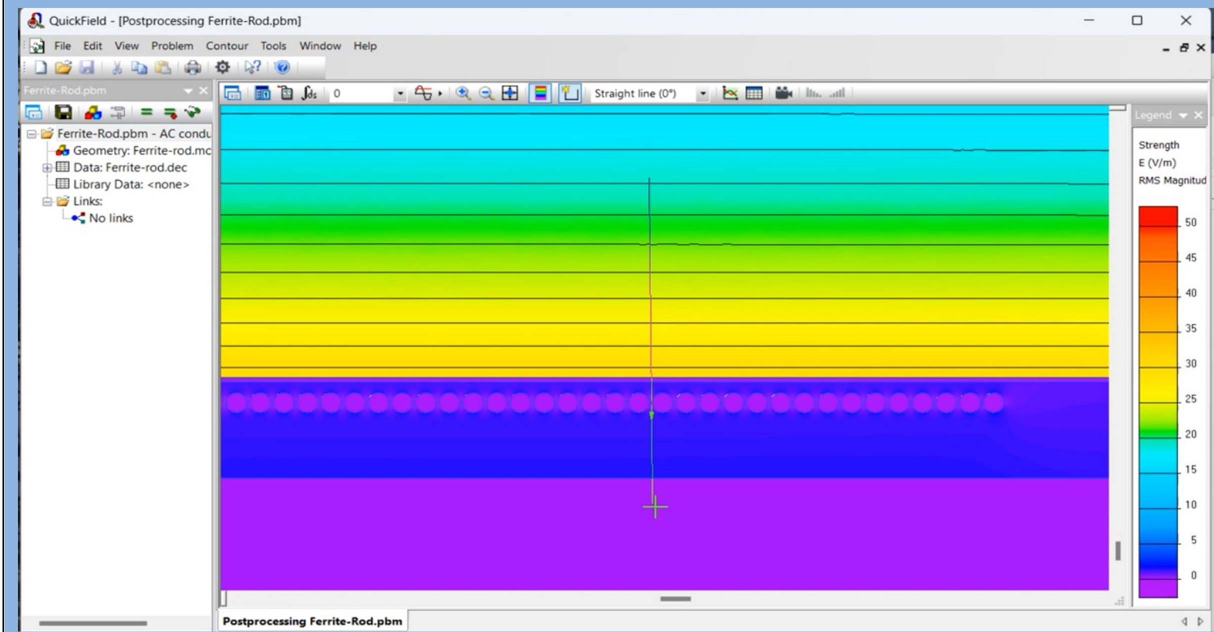
Next step is to look at E-field effects. To do so we have to switch from *AC Magnetics* to *AC Conduction*.



The front wall gets a voltage potential against the foil, which is conductive too.

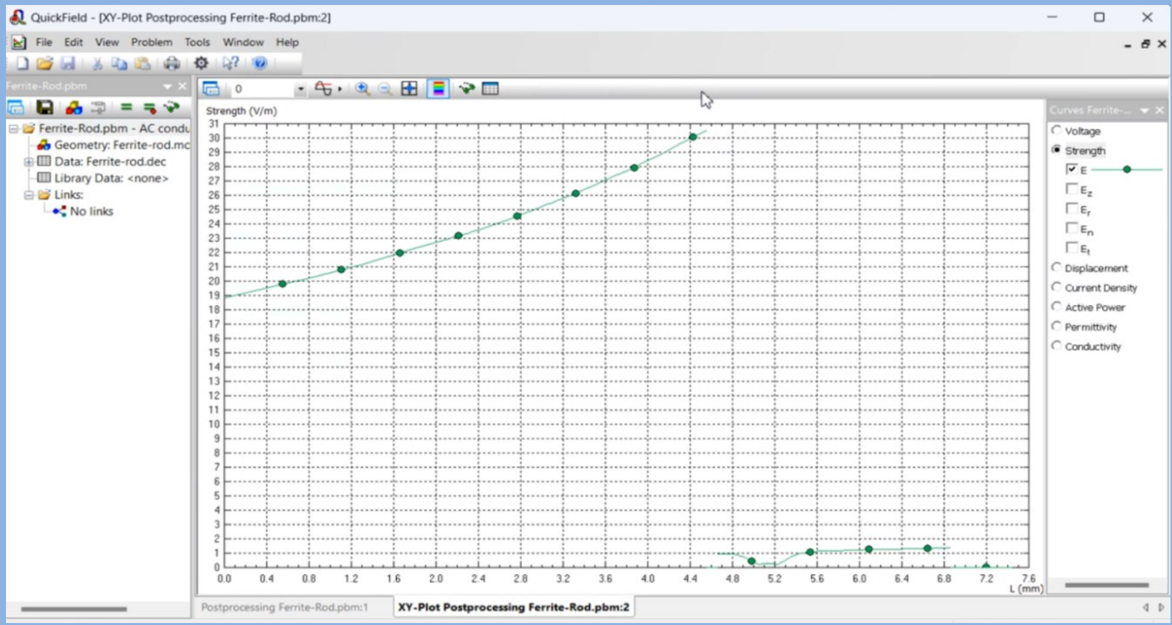


The foil has to be contacted and it gets a voltage of zero.

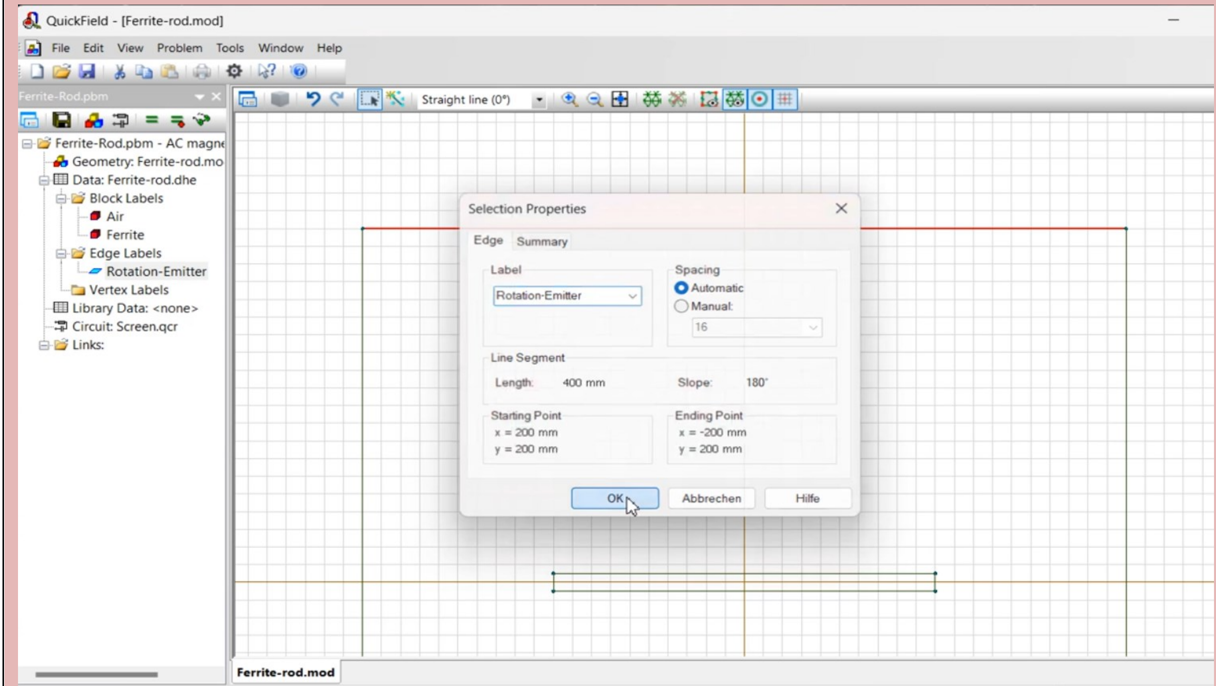


Between the ferrite rod and the foil there is almost nothing left of the E-field, which dominates outside.

The diagram illustrates the course of the E-field strength.



At a certain vertical position there is a hard jump to almost zero.



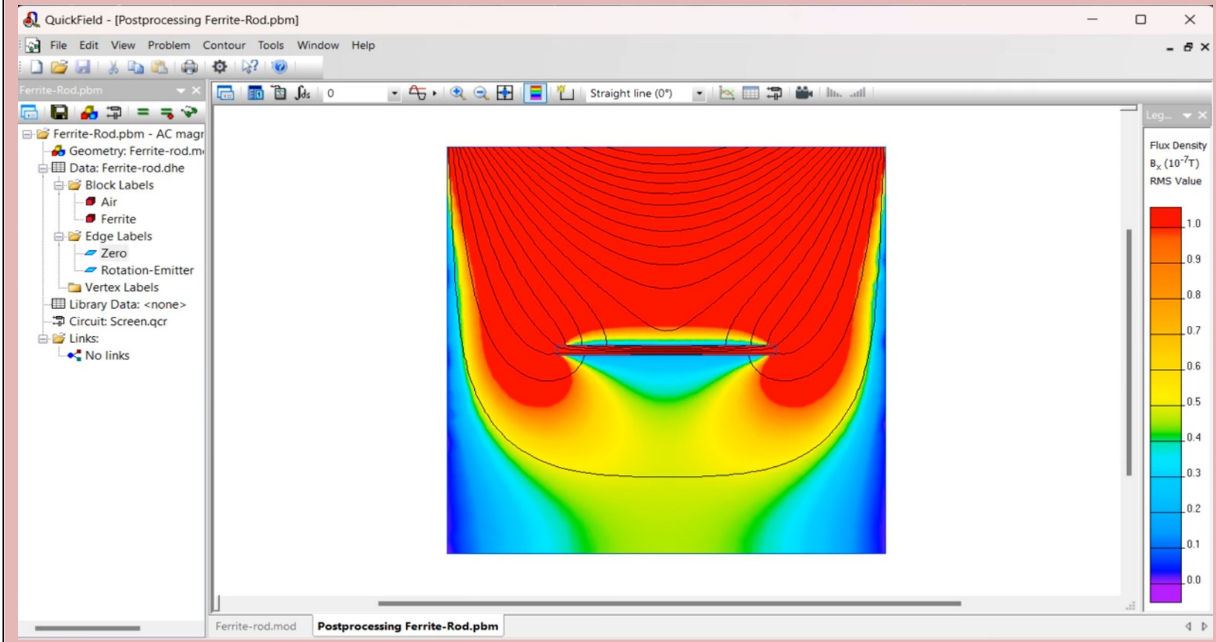
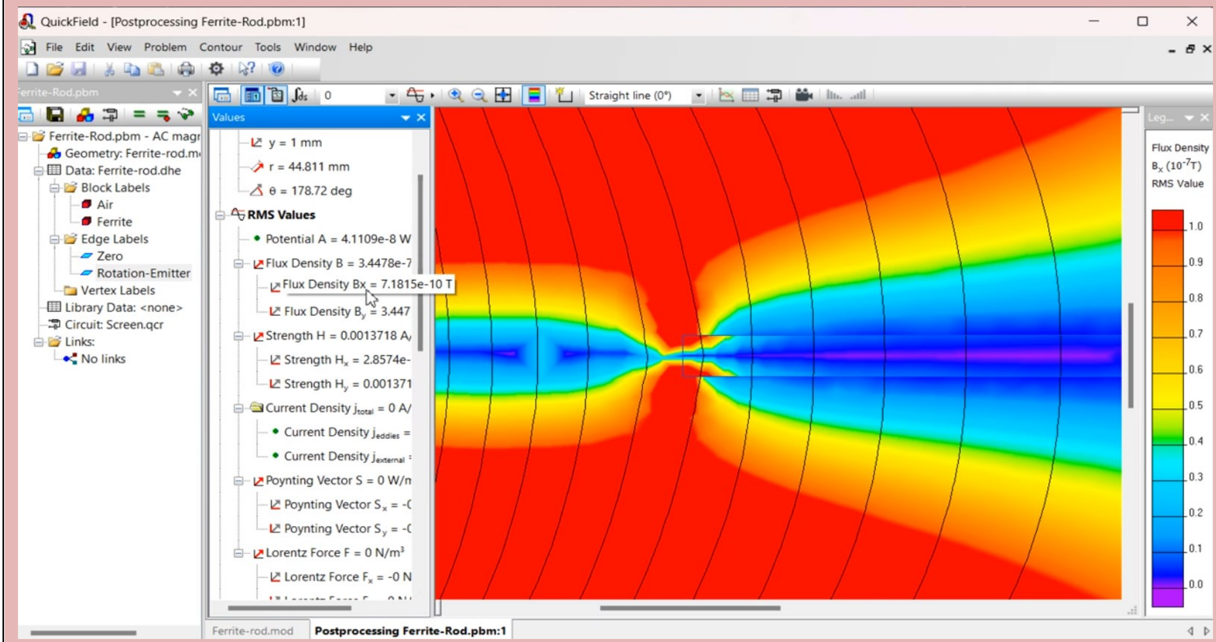
The model shall be transferred to *Plane-parallel* and *AC Magnetics* now, as we want to get directional characteristic. We get something like a cage, where the rod is embedded.

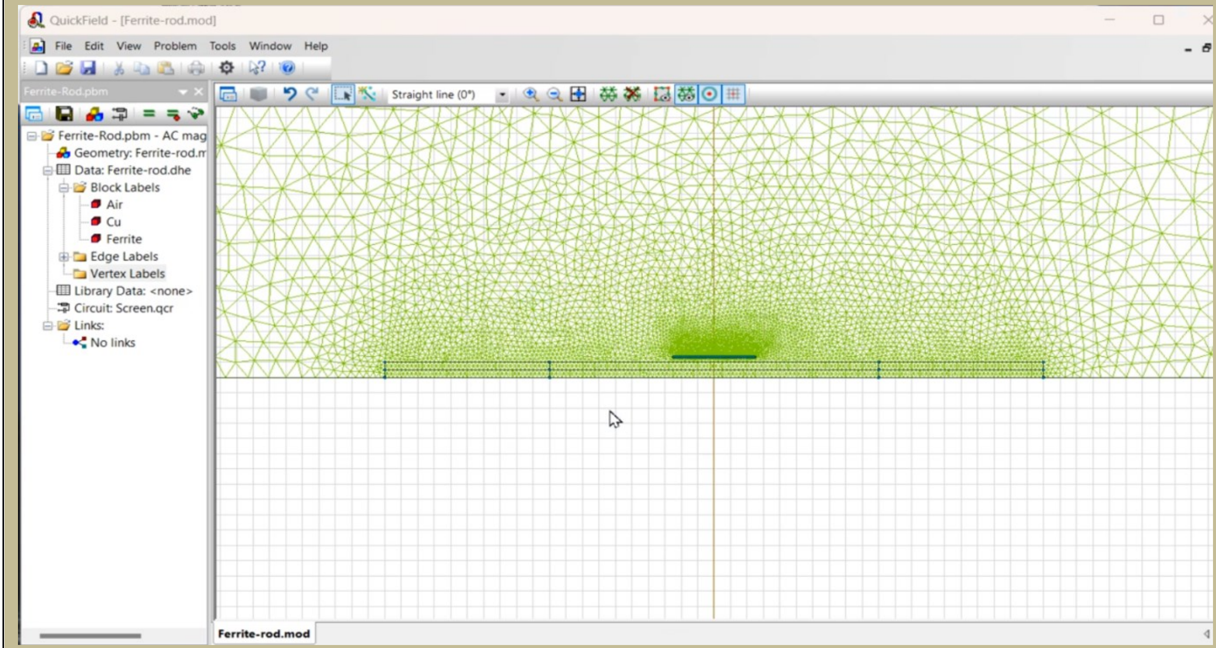
In this assembly you cannot construct the windings of the coil, but we don't need it anyway, because the magnetic field in the rod is in focus here. Afterwards it is easy to determine the induced voltage in the coil:

$$U = -N \cdot \mathrm{d}\Phi/\mathrm{d}t$$

with N the number of windings, and in Φ the frequency is included.

This requires to give the symmetrical outside walls magnetic potentials. The target is to give one wall (either the front one or the lateral one) a magnetic potential and each other three walls zero potential. Criterion is then the flux density in the ferrite rod. The first case is to take the front wall with magnetic potential.

	Frontally beaming makes a very strong flux density of about $3{\cdot}10^{-6}$ T.
	Laterally beaming makes a flux density of about $7{\cdot}10^{-10}$ T. Of course this value is strongly dependent on the measuring place. In this case it could be better to measure the integral value of the flux all along the rod's cross section.



We go back to the axisymmetric model again. Our intention now is to survey the influence of the rod's geometry to the electrical results. For this the rod will be divided horizontally and vertically. This way the rod can be decreased in length and/or taken as a hollow tube.

Length	Filling	Voltage under load	Inductivity / µH	rel. Voltage	rel. Inductivity
100%	100%	0,863	257	1,00	1,00
100%	50%	0,779	232	0,90	0,90
50%	100%	0,460	197	0,53	0,77
50%	50%	0,435	186	0,50	0,72

Each combination of length and hollowness is used here and the results can be seen in the table.

Summary

a) The center position of the coil makes the best electrical quality. (But there are situations, where it is necessary to shift the coil in order to make an adjustment in frequency. Consider that the ferrite material represents permeability tolerances, and bigger capacities are hardly adjustable.)

b) To suppress influences of the electrical field it is advisable to use a foil of a material with weak conductivity like graphite (besides an electrical compensation). A foil of copper can be used too, but it is necessary to have it as an open winding, otherwise it would act as a short circuit winding. Nevertheless the former (graphite foil) is better, because there are weak eddies only.

c) The length of the rod results in an impact on gain, which is almost linear, while hollow rods are negligible worse versus a solid one.

d) Notice that this simulation did not incorporate the capacity effects between the windings nor the magnetic loss of the ferrite material.