# Method of producing Radially Wound Electromagnets

Created By: Jason Owens
E-Mail: Jdo300@sbcglobal.net
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In this document, I will explain the method by which I am able to produce air-cored coils with a radial magnetization.

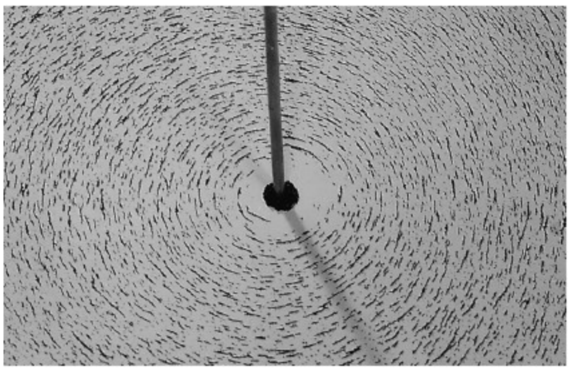

Fig 1. Iron filings around a wire showing the field lines.

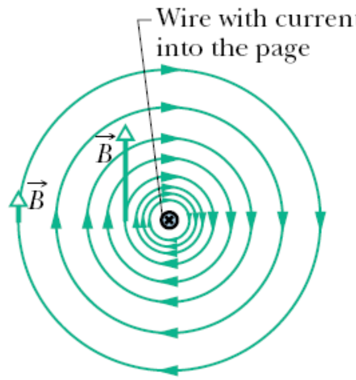


Fig 2. Magnetic field diagram

We know from electromagnetics that when I current flows through a copper wire, that there exists a magnetic B field directed at 90 degree to the direction of current flow in the wire. When a length of wire is then wrapped into a simple loop, the resulting magnetic field produced by that loop has a net direction.

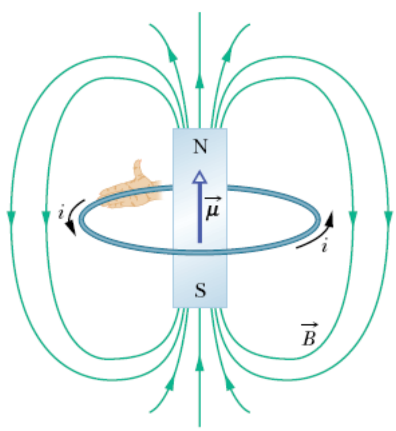


Fig 3. Magnetic field due to current in a loop of wire

The magnitude of the B field at the center of the loop is determined by the following equation:

$$B = \frac{\mu_0 |i|}{2R}$$

Where $\mu_0$ is the magnetic permeability constant, $i$ is the current through the loop, and R is the radius of the loop. One would naturally expect that the strength of the B field inside the coil would increase by adding more loops of wire and more layers of wire on the coil. Here is a simulation done in FEMME that pictorially shows the field lines of a standard air-cored solenoid:

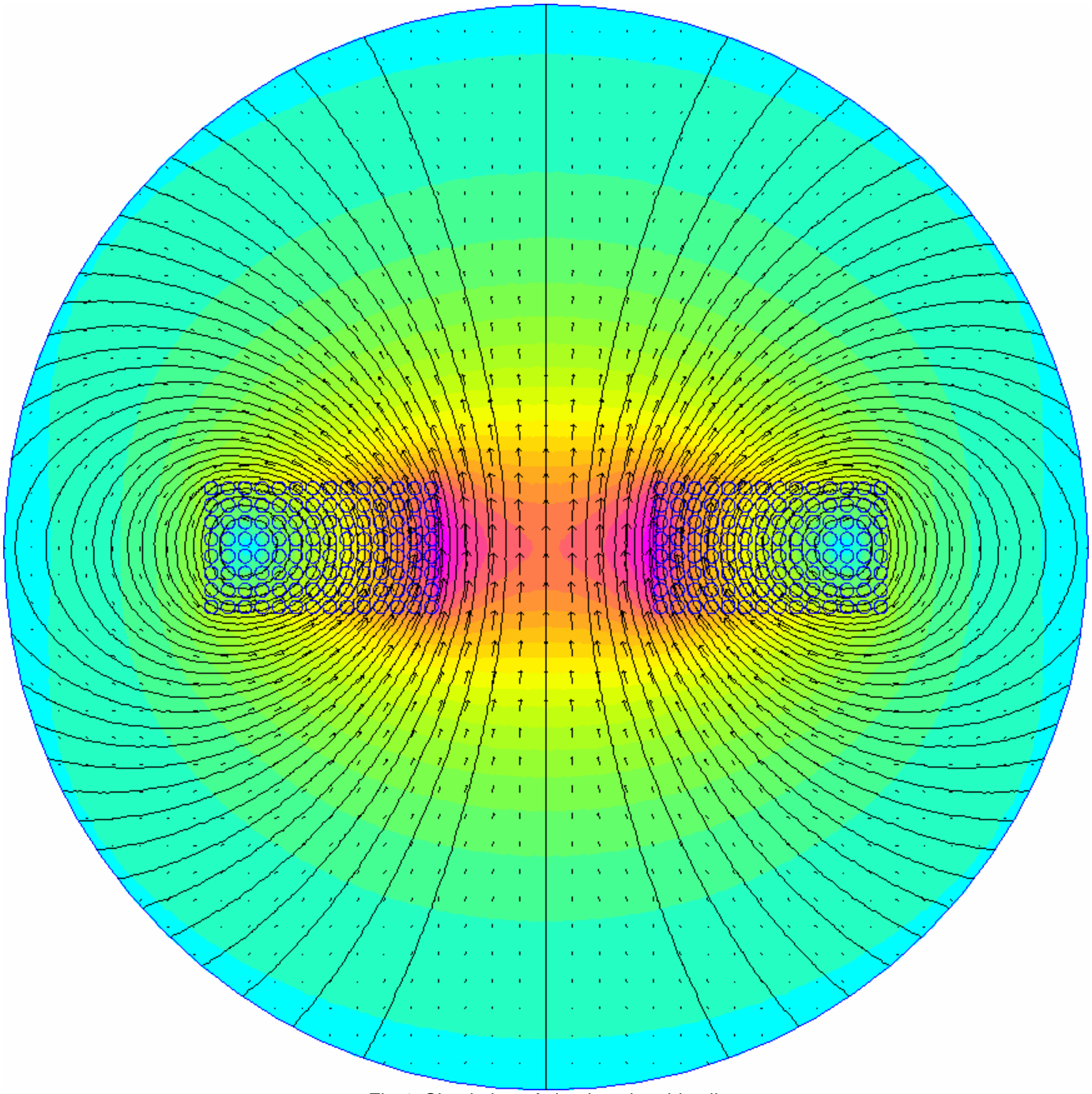

Fig 4. Simulation of simple solenoid coil.

This shows the cross-section of the solenoid with the North pole above and South pole below the bundle of wires.

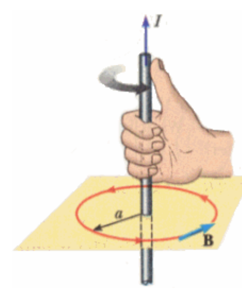


Fig 5. The right hand rule

So if we wanted to turn this simple coil into a radially wound one, how would we accomplish this? Well, keep in mind that the rotation of the magnetic field around a wire is determined by the right hand rule. So if the current in the wires of the above coil are directed out of the page, then the magnetic force lines will be directed in the counter-clockwise direction; the opposite is true for currents directed into the page.

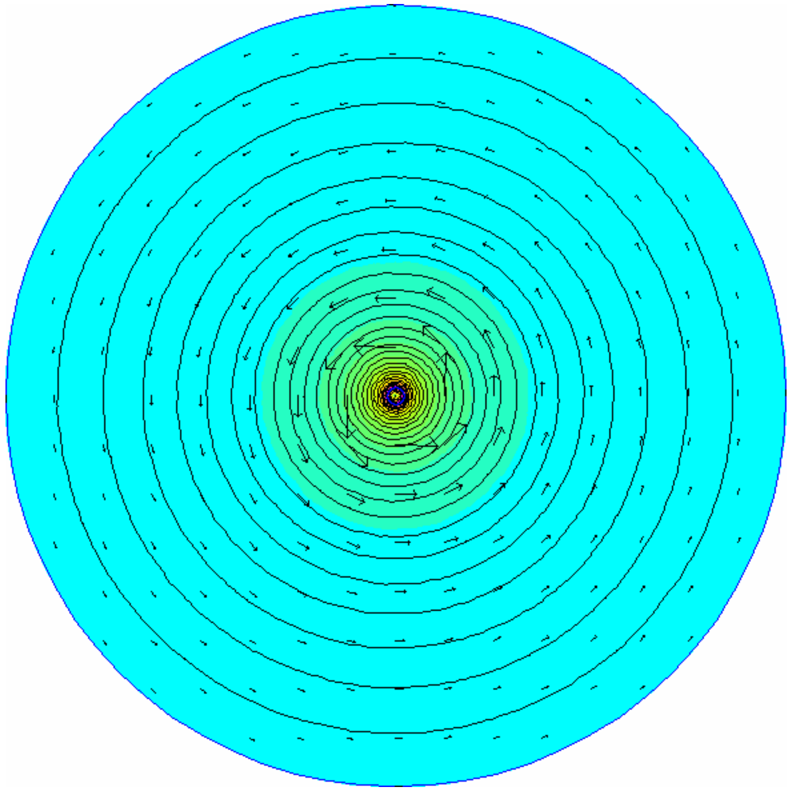

Fig 5. Simulation of single wire with current directed out of the page

So if we turn this length of wire into the cross-section of a loop of wire, we get this.

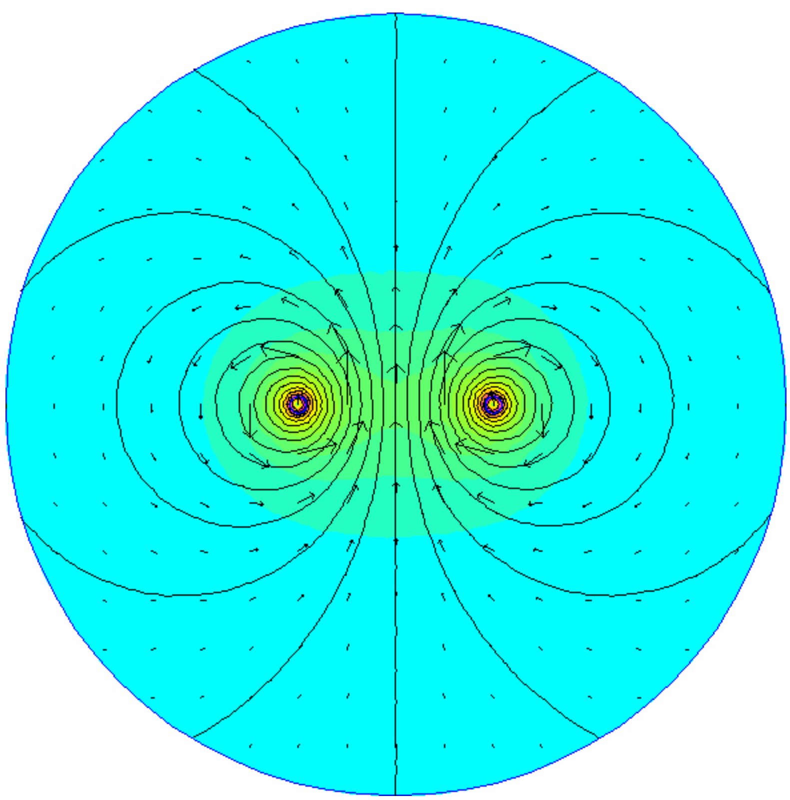

Fig 6. Simulation of simple coil loop

We have the same situation as that pictured in Figure 3. Now let’s add one more loop of wire underneath the first one.

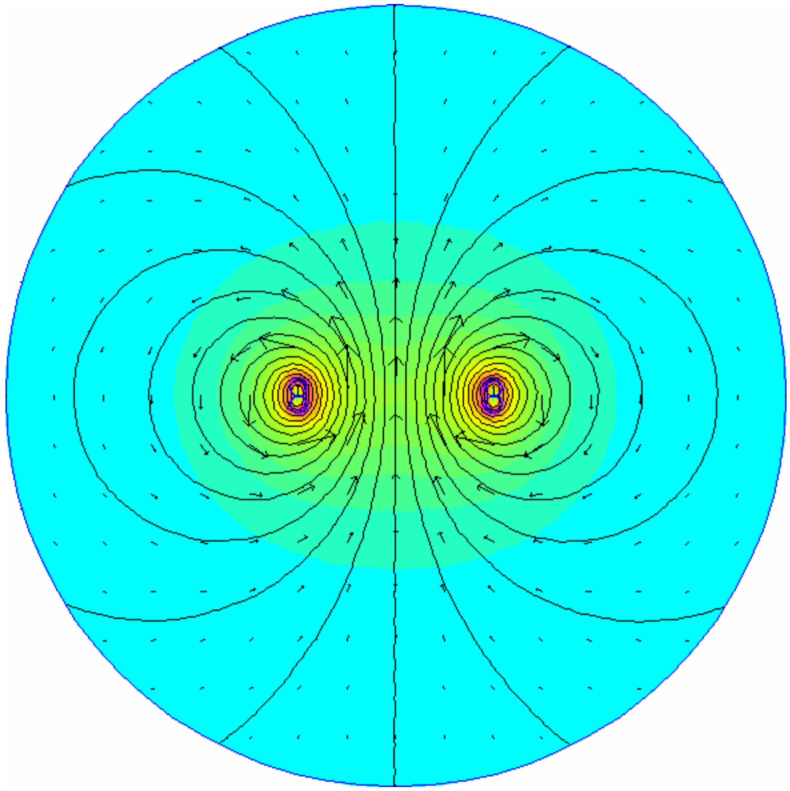

Fig 7. Simple two-loop coil

In this case the magnetic field is still oriented in the same direction but the overall strength of the coil has doubled. Now see what happens when we run the current in the bottom loop in the opposite direction of the current in the top loop.

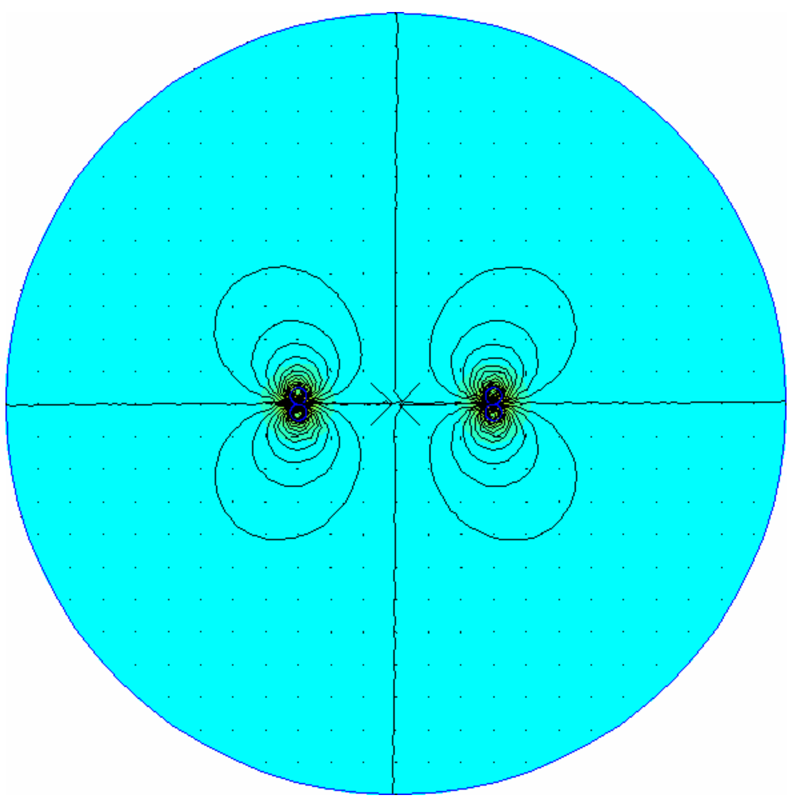

Fig 8. Wire loops with opposing currents.

So what has happened now? At first glance, it would appear that the two loops have canceled out each other's fields because the overall flux density has diminished significantly. However, only the vertical components of the B field have been canceled. The horizontal components are still there though they are weak. So how does one take advantage of these weak fields? Simply add more horizontal wires to strengthen the horizontal B field.

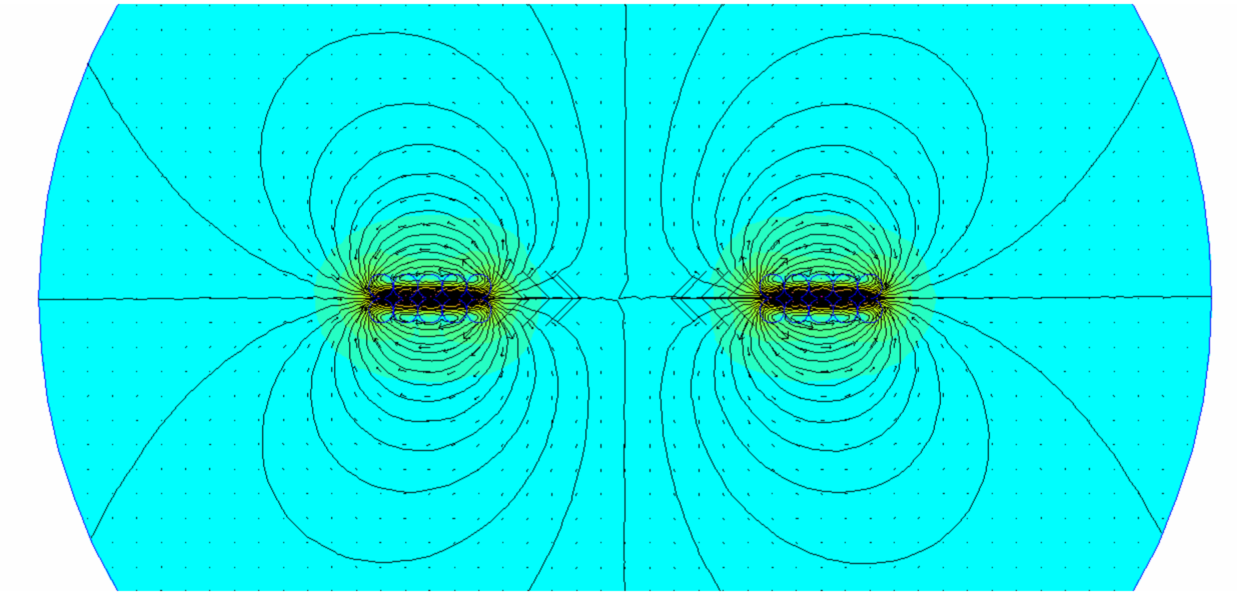

Fig 9. Wire loops with layers extended in the horizontal direction.

Now we can clearly see that there is a radial field produced in the coils. If we take this to the next level. We can even angle the field in the center of the coil simply by controlling the amount of current in the top and bottom loop. Now, if we convert the coil in Figure 4 to a radial coil, the field in Figure 10 is what we will get.

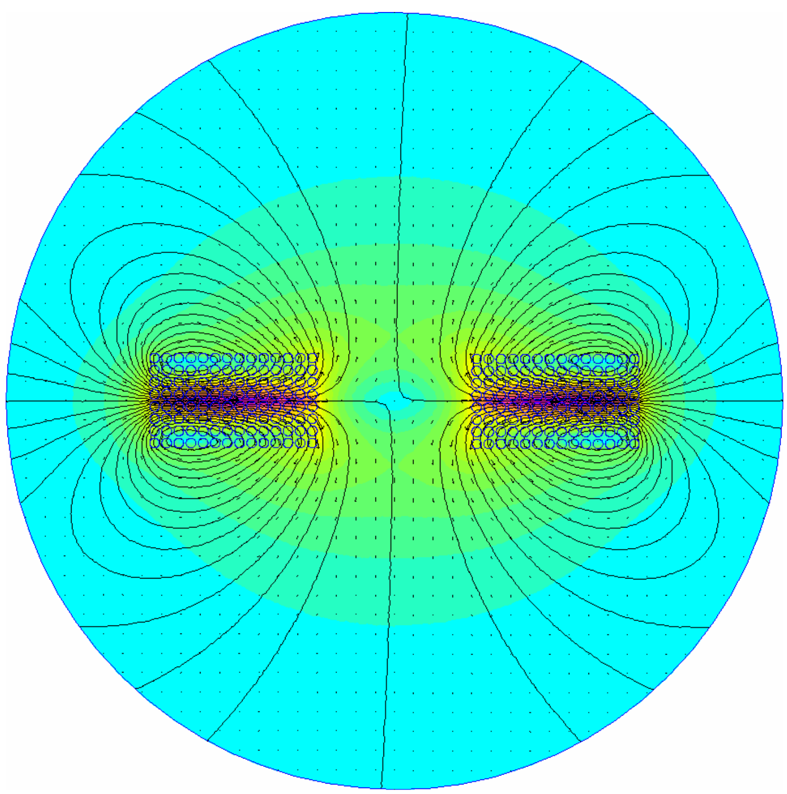

Fig 10. Large radial coil