

Theory of Operation of Helmholtz Coils

The Helmholtz Coils use two identical coils of conductive wire to produce a three dimensional region containing a uniform magnetic field. It achieves such a goal by positioning the coils so that certain field components cancel each other out while other components reinforce each other.

The main parts of the Helmholtz Coils are the two coils of wire. Since the coils are identical in every way, (wire material, wire gauge, resistance, radius R), feeding the same current to both coils will create two identical magnetic fields. The key characteristic of the Helmholtz Coils is how the two coils are placed. Each coil lies along the same axis, and the separation between the coils is equal to each coil's radius.

When current passes through the coils, the ensuing magnetic fields then interact in important ways in the space between the two coils. Applying the Right Hand Rule, one sees that the fields perpendicular to the common axis run into each other and cancel each other out. The same rule also shows that the fields parallel to the common axis run in the same direction, reinforcing each other. All the canceling and reinforcing leaves a uniform field in a cylindrical volume between the two coils. Specifically, the volume has a radius (r) equal to 25% of coil radius (R) and a length equal to 50% of the distance between the two coils.

Applying the Biot-Savart Law and simplifying the relation between input current and magnetic field strength in the uniform region becomes:

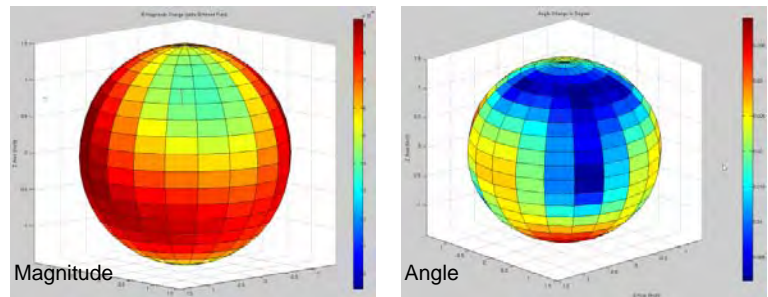
$$B = (0.8991 \times 10^{-6} nI)/R, \text{ Where:}$$

B = field in Tesla;

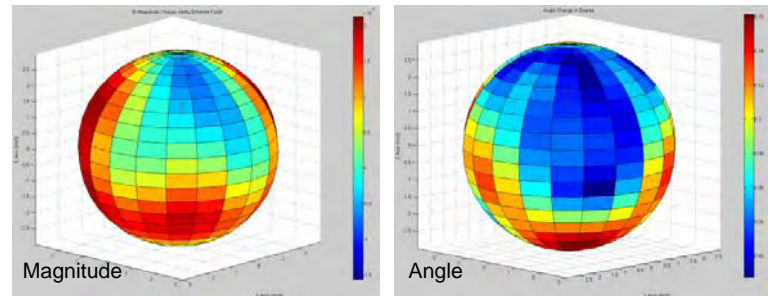
n = number of turns in a coil;

I = current in amperes;

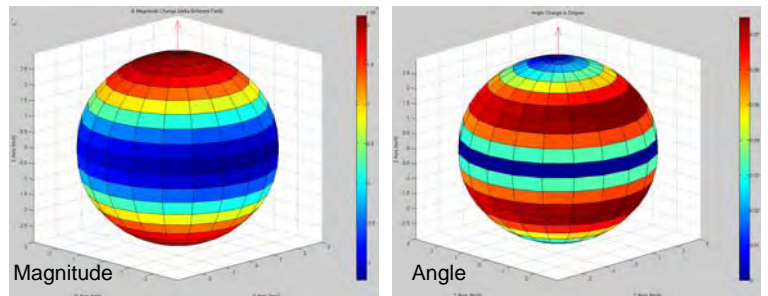
R = coil radius in meters.



$B_0=(1,1,1)$ Oe at origin, sphere dia 3", max $\Delta mag=0.1\%$, max $\Delta angle=0.04$



$B_0=(1,1,1)$ Oe at origin, sphere dia 6", max $\Delta mag=0.2\%$, max $\Delta angle=0.16$



$B_0=(0,0,1)$ Oe at origin, sphere dia 6", max $\Delta mag=0.2\%$, max $\Delta angle=0.08$

Magnetic uniformity map of a 3-axis Helmholtz Coil system made by Micro Magnetics in Fall River, Massachusetts.