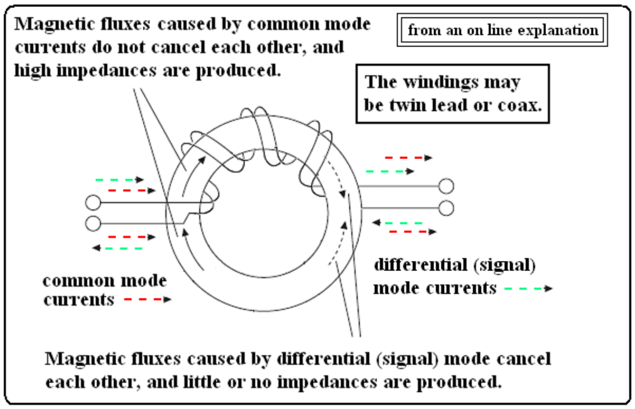
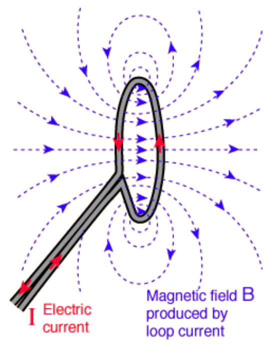
How Common Mode Chokes Work

Dallas Lankford, 7/4/09, rev 7/7/09



A simplified explanation is given in the box at left. However, a more accurate explanation may be of use in some cases. Let us consider the case of two coils wound side by side on a ferrite toroid. The case of two side by side coils on a cylinder of ferrite is not much different. For the differential (signal) mode two equal currents flow through the two wires in oppisite directions, while for common mode the currents flow in the same direction. The currents are alternating currents, so the diagram at left is for a given instant in time. According to Ampere's Law, a current through a wire produces a magnetic field, and the strength of the magnetic field depends on the amplitude of the current. For a circular turn of wire the magnetic field with curent in the direction indicated, the magnetic field is as shown below.



In the case of differential (signal) mode, if the two wires almost coincide, then the differential currents produce almost identical magnetic fields, except that the magnetic field due to one of the wires is in the opposite direction from the field due to the other wire. A magnetic field is a vector field, and two vectors of equal magnitude and opposite directions add to 0. If the magnetic fields were identical in magnitude and opposite in direction, then the following argument would apply.

The magnetic flux Φ_B through a surface S is defined as the integral of the magnetic field over the area of the surface

$$\Phi_B = \iint_S \mathbf{B} \cdot d\mathbf{S},$$

where $\mathbf{B}$ is the magnetic field, $\cdot$ denotes the dot product, and $d\mathbf{S}$ is an infinitesimal vector whose magnitude is the area of a differential element of S, and whose direction is the surface normal.

Thus the magnetic flux Φ_B would be 0.

For a fixed area and varying current, Faraday's Law is $Emf = -N \frac{d\Phi_B}{dt}$ where N is the number of turns of wire of the coil, Φ_B is the magnetic flux through the surface determined by one turn of the coil (all of the surface areas are assumed to be equal, and the material enclosed by the coil is assumed to be uniform), and Emf is the induced voltage which opposes the applied voltage.

Thus the induced voltage Emf for each wire would be 0.

The inductance L of a coil is defined by $L \frac{dI}{dt} = -Emf$ where I is the current through the coil, and Emf is as defined above.

Thus the inductance of each coil would be 0, and no choking action for the signal would be produced. Because the opposing magnetic fields are not identical (the two wires cannot occupy the same space, and materials such as ferrite are not perfectly uniform), it can be shown that there are instead two small inductances, one for each wire, and thus a small but generally negligible choke for each wire.

In the case of common mode, the two coils produce almost identical magnetic fields B , so the flux for both coils is approximately $2\Phi_B$ where Φ_B is the magnetic flux for one coil without the presence of the other (or without any current passing through it). By Faraday's Law, the induced voltage for each coil is approximately 2Emf where Emf is the induced voltage for one coil without the presence of the other.

Thus the inductance of each coil of the common mode choke is 2L where L is the inductance of one coil without the presence of the other. So each coil of the common mode choke has twice the choking action of one coil without the presence of the other. I found this so unexpected that I wanted to verify it. The verification was simple. Connect the input wires together and the output wires together and measure the parallel inductance of the paralleled coils. I did that and got an inductance L where L was also the inductance of one of the coils alone. This proves (by measurement) that the inductance of each common mode choke is 2L (because if you wound two coils with with inductance L on separate toroids, you would find that the measured parallel inductance would be 0.5 L).

Here is a common mode choke which I sometimes use for evaluation in the MW band with antennas, preamps, and receivers. It is 27 turns of RG-316/U on an Amidon FT-114-J, and has a measured common mode inductance of 6.8 mH using an AADE L/C meter. The AADE meter made this measurement at about 70 kHz. Assuming that the inductance remains the same at 1 MHz, the choking action for each common mode path is 6800 ohms. This and similar chokes seldom have any observable effect on man made noise at my location with my antennas. Perhaps this is because all of my antennas use twin lead lead in, not coax. I have also tried twin lead common mode chokes and have never observed any reduction of man made noise when using them. I have also tried common mode chokes on switching power supplies, wireless routers, and similar devices, and have never observed any reduction of their RFI by the use of such chokes. I have, however, eliminated their RFI by suitably shielding them when the shield is appropriately grounded. The cable ties in the photo at left are only to keep the leads compact so that the photo is smaller than otherwise.