### 4.3.2 Cancelling the Field With an Equal but Opposite Field

An enclosure made of copper has a permeability that is almost the same as air and therefore will not impede the flow of magnetic flux passing through it, nor will it divert it. If the copper forms a complete closed loop around the source of R.F. magnetic field, eddy currents will be induced into the copper. The direction of induced eddy currents will be in the opposite direction to the original current whose field induced it. Therefore the sense of magnetic field generated by the induced eddy current is in the opposite direction to the original field and can be used to cancel its effects.

### 4.3.3 Cancelling Fields Whose Direction of Travel are at Right Angles to the Axis of an Air Wound Coil

Figure 4.64 (adapted from ref. 29) is a cross sectional view of a single layered air wound coil fully enclosed by a copper shield in which 'G' is an element of wire at the centre of the coil and 'H' is an element of a side of the shield which is parallel with the coil axis. A current flowing out of the page through element 'G' will produce lines of magnetic flux centred on 'G' with a clockwise direction. If the current through 'G' was increasing the field centred on 'G' would be expanding that is, moving away from 'G'. This expanding field induces a current into element 'H' that will flow into the page. The magnetic field associated with the current in element 'H' is centred on 'H' and has a counter-clockwise direction. If there were no ohmic losses in the complete loop of which element 'H' is a part, then the magnetic field centred on 'H' would be equal but of opposite direction to the field centred on 'G' external to the shield. The complete loop for 'H' is formed by the four sides of the enclosure parallel to the coil axis. The two fields external to the shield would cancel thus providing a high degree of isolation. In the real world element 'H' has distributed resistance and a small amount of self-inductance which limits the current that can flow in the loop. The field centred on 'H' therefore does not quite have the same magnitude as 'G' external to the shield and leaves a portion of 'G' unchecked. Best possible shielding is obtained when the enclosure material has a very low distributed resistance and low self-inductance. The graph at the bottom of the figure 4.64 is representative of the magnitude and direction of the flux density. It can be seen that the flux external to the shield is almost equal but with opposite direction, their sum approximating zero. The field from 'H' internal to the shield is in the same direction to that centred on 'G' and induces a current into element 'G' that is in the same direction as the current flowing through it. This is negative mutual induction and has the effect of reducing the self-inductance of element 'G'.

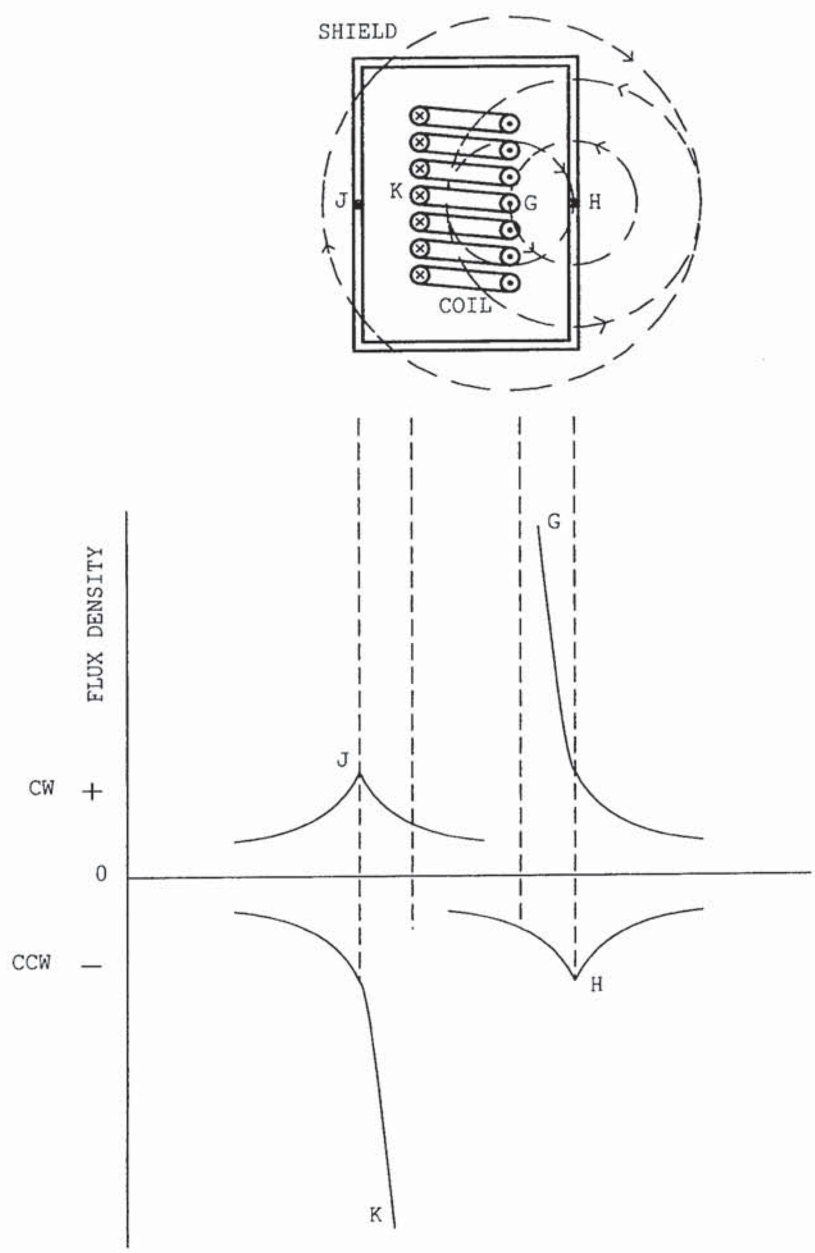


**Figure 4.64** *Field strength distribution around element 'G' of a coil and element 'H' of the copper shield. Instantaneous R.F. currents and magnetic fields are shown*

### 4.3.4 Cancelling Fields Whose Direction of Travel are in-line with the Axis of an Air Wound Coil

Figure 4.65 is the same coil and enclosure as above where 'A' is an element of an end turn of the coil and 'E' is an element of the end section of the shield in-line with the coil diameter. The same increasing current is flowing as above and the field centred on 'A' generated by a current flowing out of the page has a clockwise direction and is expanding. The rate of change of flux induces a current into 'E' that is flowing into the page. Lines of flux centred on 'E' will have a counter-clockwise direction. Field lines external to the shield will be equal but of opposite direction and their effects cancel. This is shown in the graph at the bottom of figure 4.65. A similar analysis carried out on element 'B' which is on the opposite side of the same turn and lies on the diameter with 'A' will show the results in the graph at the top of figure 4.65. The current flowing in 'E' is into the page and the current in 'F' is out of the page. If a more detailed analysis were to be carried out it would be seen that the induced current into the shield flows in a circle whose centre lies on the axis of the air wound coil enclosed within the shield. It will also be seen that the direction of the circular current flow in the ends of the shield is opposite to the circular path the current follows as it travels through the helix of the coil. Figure 4.66 shows the circular path of the induced current in the end section of the shield. It can be seen that it is part of the total loop current circulating around the four sides of the enclosure. Positions of 'F', 'E' and 'H' are indicated.

The ability of the end sections of a shield to provide their own closed loop for the induced currents caused by fields whose direction of travel is in-line with the axis of the coil, indicates that only end sections of a shield are required if the air wound coils of a filter are mounted in-line on the same axis. By connecting these end sections to ground they also function as a Faraday shield reducing the capacitive coupling between the coils. The induced circular current in the end sections is zero at the point of the axis of the coil building to its maximum where the end section is the closest to the wire of the coil. Any electrical connection required through the shield to the coil should be made through the part of the end section that has minimum circulating current, that is, the part of the end section that lies on the axis of the coil. This ensures minimum disturbance to the circulating eddy currents and hence has minimum effect on the shield's effectiveness. This construction guide is valid for fully enclosed shielding or shielding employing only end sections.

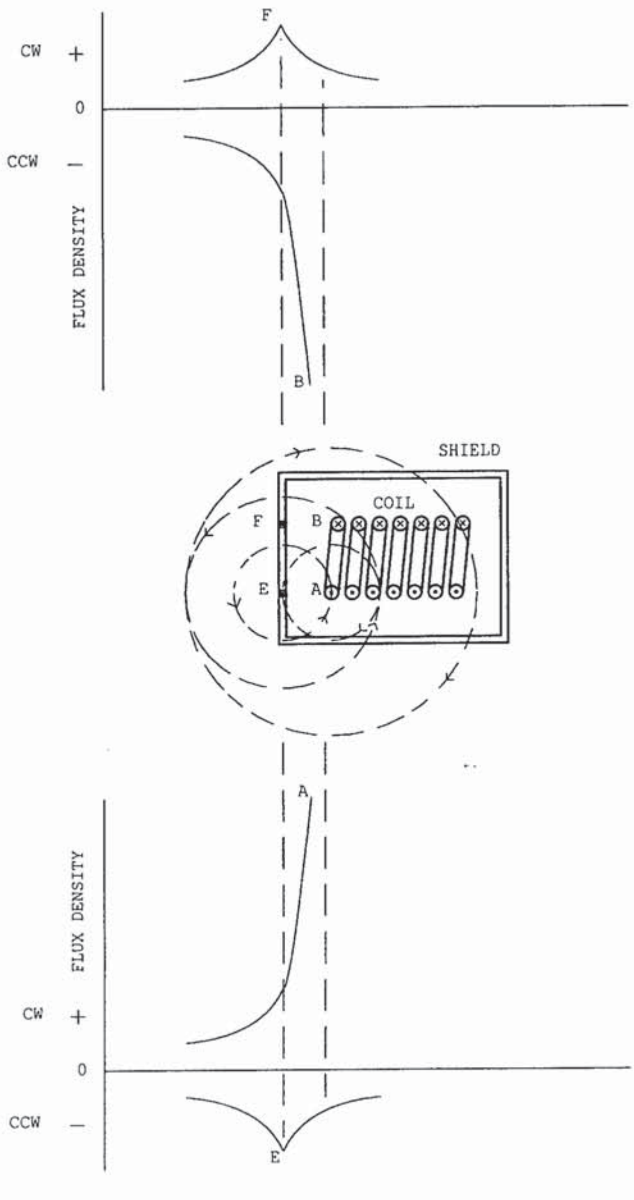


**Figure 4.65** *Field strength distribution around element 'A' of a coil and element 'E' of the copper shield. Instantaneous R.F. currents and magnetic fields are shown*

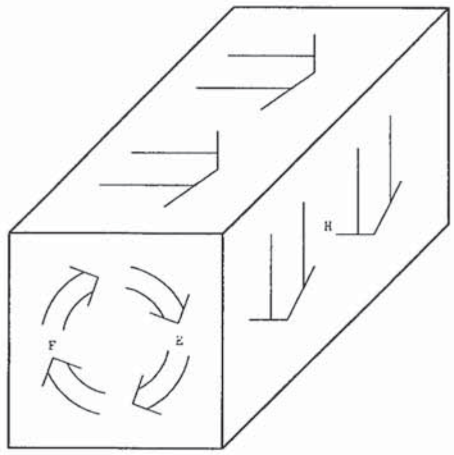


*__Figure 4.66__ Direction of instantaneous R.F. currents induced into a fully enclosed copper shield surrounding an air wound helical coil. Note the positions of 'E', 'F' and 'H' from the previous diagrams*

### 4.3.5 Summarising Shielding

The overall effect the conducting shield has on the coil is to lower its Q through energy lost in the resistive path of the induced circulating eddy currents in the shield, a decrease in inductance through negative mutual induction with the shield and, a decrease in the coil's self-resonant frequency by increasing the distributed capacitive coupling via the shield. The latter has the effect of increasing the coil's apparent inductance.

Materials to be used as shields placed around coils operating at R.F. frequencies should be non-magnetic with a very low resistivity. The shield can be considered as a closed single turn loop that has eddy currents induced into it by a traversing magnetic field. As such, steps should be taken to maximise the Q of the loop by keeping its resistive losses to a minimum. This ensures the external counter magnetic field generated by the eddy currents closely matches the field that produced it thereby neutralising its effects external to the enclosure and providing a high degree of isolation. The material most often used by this author when constructing prototype enclosures for filters is one ounce double sided tin plated PCB. When using this material, attention has to be paid to the construction to ensure a fully enclosed conducting path exists in the three planes of the internal walls.