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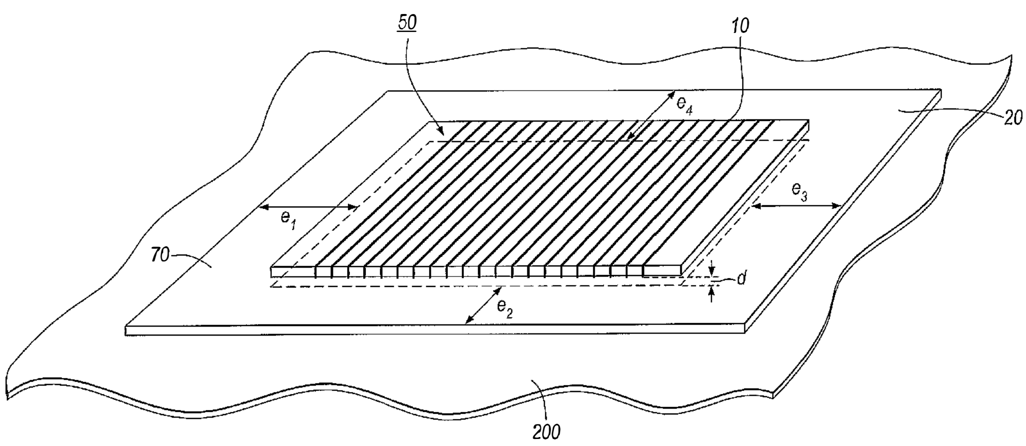

(57) Abstract: An inductive power transfer unit is adapted to be placed when in use on a support surface (200). A flux generating unit (50) extends in two dimensions over the support surface, and generates flux at or in proximity to a power transfer surface of the unit so that a secondary device placed on or in proximity to the power transfer surface can receive power inductively from the unit. A flux shield (70), made of electrically-conductive material, is interposed between the flux generating unit and the support surface, the shield extending outwardly (e_1 - e_4) beyond at least one edge of the flux generating unit. Alternatively, the flux shield may have one or more portions which extend over one or more side faces of the inductive power transfer unit or which extend between the side face(s) and the flux generating unit. The flux shield may be supplied as a removable accessory which attaches to the outside of the inductive power transfer unit.

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INDUCTIVE POWER TRANSFER UNITS HAVING FLUX SHIELDS

This invention relates to inductive power transfer units having flux shields.

Inductive power transfer units, as described for example in the present applicant's published International patent publication no. WO-A-03/096512, the entire contents of which is hereby incorporated into the present application by reference, seek to provide a flat or curved power transfer surface over which a substantially horizontal alternating magnetic field flows. This field couples into any secondary devices placed upon the power transfer surface. In some variants this field may rotate in the plane of the surface to provide complete freedom of positioning for any secondary device placed on the surface to receive power. The secondary devices are, for example, built into portable electrical or electronic devices or rechargeable batteries which can be removed from the surface when not receiving power.

Depending on the design of the flux generating unit (magnetic assembly) of such power transfer units, they may also emit flux in directions other than desired horizontal surface field. For example a "squashed solenoid" design of flux generating unit emits flux symmetrically above and below it.

In Figure 1, a flux generating unit 50 comprises a coil 10 shaped into a flat solenoid wound around a former 20. The former 20 is in the form of a thin sheet of magnetic material. This results in a substantially horizontal field across the upper surface of the flux generating unit, but also an equal field across the lower surface. The field lines of both fields extend generally in parallel with one another over the respective surfaces, substantially perpendicularly to the coil windings. A secondary device 60 is shown in place over the upper surface.

Figure 2 shows a similar arrangement to that of Figure 1, but with an additional coil 11 wound, in an orthogonal direction to the winding direction of the coil 10, around the former 20. By driving the two coils 10 and 11 in a suitable manner, the flux generating unit may create a field which is substantially horizontal over the power transfer surface (upper surface) and which rotates in the plane of that surface. In typical usage, the flux above the upper surface provides the functionality that the user desires (powering the secondary device 60), but the flux present at other surfaces may not be useful and can cause undesired effects.

Figure 3 shows a side view Finite Element analysis of the flux lines generated by the flux generating unit 50 in Figure 1 at an instant in time. The lines travel through the centre of the solenoid and then divide to return over and under it through the air. A secondary device 60 is shown placed on top of the unit 50.

One undesired effect occurs particularly when the primary unit is placed upon a ferrous metal surface, for example a mild steel desk or part of a vehicle chassis. The permeability of mild steel is sufficiently high that it provides a return path for the flux which is of considerably lower reluctance than the alternative path through air. Therefore the flux is "sucked" down into the metal desk. Figure 4 shows another Finite Element analysis view when a metal desk 200 is brought under the flux generating unit. The high permeability of the metal offers the flux lines a much lower-reluctance path than air to return from one end of the flux generating unit 50 to the other, and so they travel within the desk rather than through the air. This is undesirable for two reasons:

- A significant proportion of the flux generated by the inductive power transfer unit (primary unit) is flowing into the metal desk instead of flowing into any secondary devices on the upper surface of the unit, therefore the system becomes less efficient (consumes the more power) and the power received by the secondary device varies.
- The flux flowing through the metal desk causes core losses, for example via hysteresis and / or eddy current loss , which cause it to heat up.

It is known that when conductive materials, for example copper or aluminium, are placed into an alternating magnetic field, the field induces eddy-currents to circulate within them. The eddy currents then act to generate a second field which - in the limit of a perfect conductor - is equal and opposite to the imposed field, and cancels it out at the surface of the conductor. Therefore these conductive materials can be seen as "flux-shields" – the lines of flux in any magnetic system are excluded from them. This may be used to shield one part of a system from a magnetic field and consequently concentrate the field in another part. GB-A-2389720, which is a document published after the priority date of the present application but having an earlier priority date, discloses a flux generating unit in the form of a printed circuit board having an array of spiral conductive tracks for generating flux above the upper surface of the unit. A ferrite sheet is placed under the board, and a conductive sheet is placed under the ferrite sheet, to provide a flux shield. The ferrite sheet and conductive sheet are of the same dimensions, parallel to the sheets, as the board.

According to a first aspect of the present invention there is provided an inductive power transfer unit, adapted to be placed when in use on a support surface, comprising: a flux generating means which, when the unit is placed on the support surface, extends in two dimensions over the support surface, said flux generating means being operable to generate flux at or in proximity to a power transfer surface of the unit so that a secondary device placed on or in proximity to the power transfer surface can receive power inductively from the unit; and a flux shield, made of electrically-conductive material, arranged so that when the unit is placed on the support surface, the shield is interposed between the flux generating means and the support surface, the shield extending outwardly beyond at least one edge of the flux generating means.

According to a second aspect of the present invention there is provided an inductive power transfer unit, adapted to be placed when in use on a support surface, comprising: a flux generating means which, when the unit is placed on the support surface, extends in two dimensions over the support surface, said flux generating means being operable to generate flux at or in proximity to a power transfer surface of the unit so that a secondary device placed on or in proximity to the power transfer surface can receive power inductively from the unit; and a flux shield, made of electrically-conductive material, having one or more portions which extend over one or more side faces of the unit or which extend between said one or more side faces and said flux generating means.

In cases where the flux generating unit operates by creating a field which alternates back and forth in one linear dimension, the conductive shield will have induced in it an equal and opposite alternating linear field, which acts to cancel the field near the shield. In cases where the unit operates by creating a rotating field in the plane of its laminar surface, the conductive shield has induced in it a field which also rotates, again cancelling the field.

Such power transfer units are advantageous because they allow the flux to be concentrated in directions in which it is useful, improving the flux-efficiency of the unit, and to be shielded from directions where it can cause side-effects, for example by coupling into a metal desk under the unit.

In addition, the flux shield increases the coupling between the flux generating unit and the secondary device(s) by forcing most of the flux to go over the power transfer surface. Therefore less drive current is needed in the flux generating unit to create a given flux density in the secondary device(s). Accordingly, provided that losses in the flux shield are minimised, the system as a whole becomes more efficient.

To ensure that the apparatus runs cool and is power-efficient, I^2R losses (losses caused by circulating currents dissipating as heat) in the conductive shield must be kept small:

- The conductive shield is advantageously made of a highly conductive material, for example copper or aluminium sheet of sufficient thickness to ensure that the eddy-currents induced therein do not suffer from excessive resistance and therefore create heat. The flux density, and therefore the eddy currents, may vary across different parts of the apparatus, and therefore the necessary thickness, or material, may also vary.
- The spacing between the shield and the electrically-driven conductors of the flux generating unit can be optimised. The larger it is (i.e. the greater the

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