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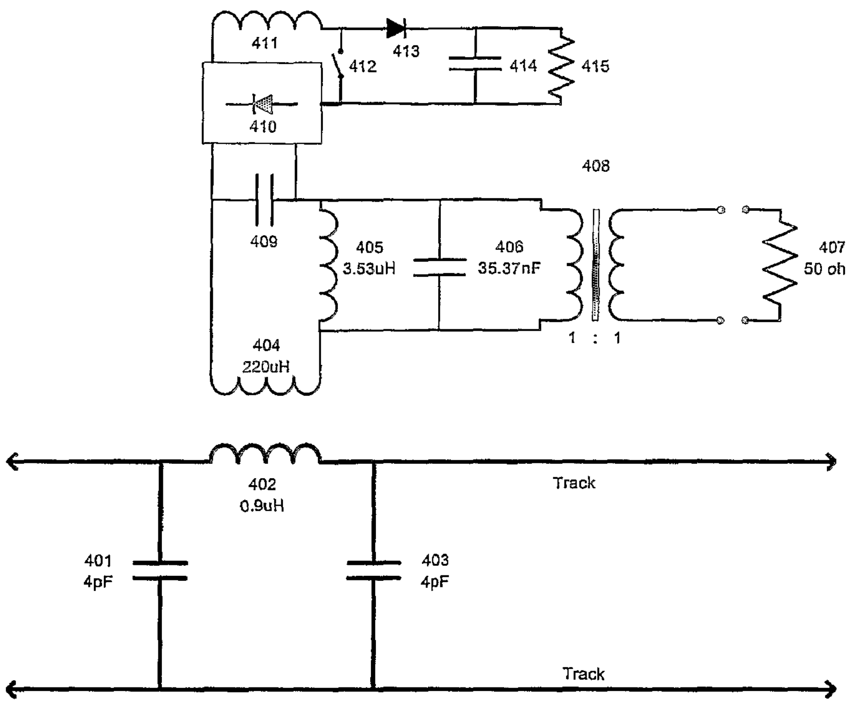
(54) Title: COMMUNICATIONS FOR INDUCTIVE POWER SYSTEMS



(57) Abstract: A communications system for use with an inductive power transfer system carries the communication signals on the same cables as the power, with the frequency of the communications system being greater than that of the power system. The signals are treated separately with low cost inductor (405) and capacitor (406) or ceramic filters all tuned to the higher communications frequency.

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Declaration under Rule 4.17:

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Communications for Inductive Power Systems

TECHNICAL FIELD

This invention relates to inductive power transfer from a trackway to mobile units, and to the transfer of communications data to and from the mobile units.

BACKGROUND

Typically an inductive power transfer system has power supplied at a specified frequency to a cable track terminated at the far end by a short-circuit. Mobile pickups are coupled to the track to pick up the inductive field and use this power to perform some operation – typically powering the vehicle containing the pickup.

These vehicles may need to be controlled for speed, direction, or for some subsidiary operation such as a process control and to this end, among others, a communication channel may be required.

PRIOR ART

It is known to provide communications over a normal mains power line, either as a low communication rate audio signal to control switching apparatus or as higher frequency signals to provide communications. The power mains is not a short circuited line as is the power line of an inductive system, nor is it subject to the major current and voltage fluctuations an inductive system provides as part of its normal working environment. Hence techniques appropriate to power line communications are not adapted to work in an inductive power system.

It is also known to provide communications to and from vehicles using an inductive pickup track, see for instance NZ Patent 501864, which describes a wireless transmission trackway separately associated with an inductive power trackway.

It is also known to use a broadcast communication system such as IEEE 802.11b to communicate with remote mobile devices using inductive power transfer. This known system effectively uses two independent systems, a track for power transfer and a totally separated communication system.

THE PROBLEM

The dual communication/power systems referred to above require much additional hardware and may be difficult to set up. Also as they radiate the communications information quite widely it is difficult to isolate communications information in one IPT system from information in another close to it without adding signal coding, and coding adds to the information overhead thereby reducing the effective data rate. Again any communications system associated with an IPT system is working in an electrically noisy environment since the transients associated with the system are considerable and this in itself presents problems.

Any attempt to reduce the communications power in the above systems will provide problems when the pickup deviates any distance from the communications cable, for instance as when the pickup proceeds along a chord through a track corner. With a short range communication system the signal is lost, while with a higher power longer range system there must be more complexity provided to give separation of similar signals from other systems received at the pickup.

The inventive communications system described here has some very advantageous features. Both the power frequency and the communications frequency are propagated along the same track conductors, both are detected or received by the same pick-up coils, and low cost L, and C circuits in conjunction with the pick-up coils may be used to separate the communications frequency from the power frequency.

The use of the same pick-up coil for both communications and power ensures that the communication signal will always be usable as long as power is available. There will be no communication drop outs due to distance of a separate communications antennae or pickup from the power track.

OBJECT

It is an object of the invention to provide a communications system for an inductive power transfer (IPT) system which utilises much of the hardware existing for the IPT system and which isolates information to that particular system, or one which will at least provide the public with a useful choice.

STATEMENT OF INVENTION

In one aspect the invention relates to a communication system for an inductive power transfer (IPT) system in which alternating current power is supplied to an inductive power track loop at a power frequency for transfer to inductively coupled pickups and in which at least one communications signal is imposed on the inductive power track at a communications frequency which differs from that of the power transfer frequency wherein the communications signal is received at a supplied device via the same inductively coupled pickup as that which receives the power for the device.

Preferably the track loop is terminated for the power transfer frequency in a short circuit, but is terminated in a specified impedance for the communications frequency.

Preferably the termination impedance at the communication frequency is the characteristic impedance for the track loop.

Preferably the end of the track remote from the power supply forms a single turn transformer primary winding and the transformer has at least one secondary winding which reflects the characteristic track impedance into the track at the communications frequency.

Preferably the pickup is separately tuned to be resonant at both the power transfer frequency and the communications frequency.

Preferably the communications frequency is at least an order of magnitude greater than that of the power transfer frequency.

Preferably the power frequency is 20KHz and the communications frequency is 450KHz and is frequency shift modulated.

Preferably the communications system utilises a non-regulated frequency band with a power output below the maximum internationally specified.

Preferably at a pickup the communications frequency is not terminated in its characteristic impedance.

Preferably the communication signal originates at a track power supply facility.

Preferably the IPT communications frequency input is isolated from the power transfer frequency input.

Preferably the IPT system has at least one power pickup and the pickup, while receiving power, can receive at and/or transmit on the communications frequency.

Preferably power and communication signals are separated in the pickup by at least one filter.

Preferably when the communications signal originates at a mobile device it is delivered to the track through the pickup.

In another aspect the invention relates to a method of communicating with a mobile device supplied with power from an IPT system utilising an inductive power pickup wherein the communications signal is impressed on the inductive power track loop and is received at the mobile device through the pickup.

Preferably the communication signal is filtered from the power signal in the pickup.

Preferably a communication signal may be transmitted into the track from a mobile device through the pickup.

DRAWINGS DESCRIPTION

These and other aspects of this invention, which would be considered as novel in all aspects will become apparent from the following description, which is given by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows an IPT system with the extra components needed to operate a communications system on the same hardware as the IPT power system. These components are detailed in the subsequent figures.

Figure 2 shows a circuit for filtering power source noise and harmonics from a trackway.

Figure 3 shows a circuit for injecting and receiving communications signals into and from the trackway.

Figure 4 shows the components required in the pick-up to transmit and receive communications signals simultaneously with power signals.

Figure 5 shows a trackway termination for power and communications signals.

Figure 6 shows an alternative trackway termination using a transformer.

Figure 7 shows a frequency spectrum of a working communications link on a track.

Figure 8 shows the modulation of a working communications link.

DESCRIPTION OF THE INVENTION

In Figure 1 item 101 is the HID/IPT power supply which is the source of power to the inductive power transfer system, typically a current source of 80A at 10KHz. The output of the power supply is on litz wires 106 and 107 which conceptually run through all the other components 102,103,104, and 105. The power is generated in 101 and passes along the litz wires 106,107 to the track termination 105 which is a short circuit at the power frequency. The track is not terminated in its characteristic impedance at the power frequency because of the losses involved.

Item 102 detailed in Figure 2 is a noise filtering circuit to prevent unwanted harmonics from the power supply 101 from propagating and interfering with the communications signals. Inductors 201 and 202 provide significant impedance at the high communications frequency. Inductor 203 and capacitor 204 are series resonant at the communications frequency, thus providing a low impedance to, and greatly attenuating, any power supply harmonics at the communications frequency. Inductor 205 with capacitor 206, and inductor 207 with capacitor 208 form two parallel resonant circuits at the communications frequency. These blocking filters prevent power frequency harmonics at the communication frequency from propagating along the track and prevent communications signals injected downstream of these circuits from being short-circuited by the parallel resonant circuit 203 and 204.

Additional capacitors may be connected from the power supply output terminals to an earth to further reduce the power frequency harmonics.

Component 103 shown in detail in Figure 3 shows how communications signals are injected and received from the track. Communications signals are at a much higher frequency than the power signals and a typical frequency would be 450 kHz, this frequency being internationally available for short range transmissions. Inductor 301 with capacitor 302 is series resonant at the communications frequency but is a high impedance at the power frequency. Transformer 303 operates at the communications frequency to send and receive signals directly to and from the track. The transformer 303 is terminated with a 200 Ω resistor 304 which is the characteristic impedance for the trackway at the communications frequency.

The pick-up and communications system is shown in Figure 4. At the power frequency – typically 10-20 kHz - pick-up inductor 404 is tuned with capacitor 409. The voltage across capacitor 409 is rectified by rectifier 410 and passes to inductor 411. Switch 412 provides decoupling control such that the output voltage on capacitor 414 driving load resistor 415 can be controlled. Diode 413 prevents switch 412 from discharging capacitor 414 in a known manner.

The communication circuitry in Figure 4 is essentially completely independent of the power frequency. Inductor 405 with capacitor 406 is resonant at the communications frequency – typically 450 kHz - but is a low impedance at the power frequency. Thus communications signals coupled into the inductor 404 appear across capacitor 406, while power signals coupled into 404 appear across capacitor 409. The voltage on 406 is isolated with transformer 408 and is connected to a transmitter/receiver with a nominal impedance of 50 Ω.

In operation the injection circuit of Fig 3 causes differential currents at the communications frequency to flow in the litz wires 106 and 107, and their extensions, and these currents cause a voltage to be produced on inductor 402 which voltage is mutually coupled to inductor 404, and thence produces a voltage at the communications frequency at the output of transformer 408.

In the trackway there is a characteristic impedance of 200 Ω corresponding to an inductance of approximately 1 μH/metre and a capacitance of 25 pF/metre. However in the immediate vicinity of the pick-up the track inductance is increased by the permeable material in the pick-up and even though the pickup is only the order of 0.3 m long its inductance is close to 0.9 μH. Thus to model the pick-up in PSPICE, or other modelling programmes, the track circuit of inductor 402 with capacitors 401 and 403 can be used. These lumped parameter components do not physically exist but they give a good lumped-parameter approximation to the distributed trackway parameters under the pick-up coil 404. The coupling factor between inductors 402 and 404 is approximately $k = 0.85$ giving a mutual inductance between them of 12 μH.

The trackway termination 105 may be achieved with the circuit of Fig 5 or the circuit of Figure 6. In Figure 5 inductor 502 is parallel resonant with capacitor 501 at the communications frequency so that the trackway is terminated with resistor 503, 200 Ω, at the communications frequency. But at the power frequency inductor 502 is a very low impedance so that the trackway is essentially short-circuited.

An alternative termination circuit may be implemented with a toroidal transformer 601. Here the litz wire can be threaded through the transformer without a break. The tuned circuit is now capacitor 602 and inductor 603, with resistor 606. Using a 1:10 turn transformer the impedances of all the components are increased 100 times compared with the component values in Figure 5. The lower current inductor 603 is usually more convenient to make and its value is less affected by stray inductance than would be one directly at the cable end (502), so that this alternative circuit may be preferred.

Because the track is terminated in a short circuit at the power frequency standing waves are created, and compensation capacitors (not shown) must be placed in series with the track conductors at intervals along the track to keep these within bounds. At the communications frequency the trackway is terminated in its characteristic impedance at both ends and there are no standing waves requiring compensation capacitors.

The communications signal is also detected by all the other pick-up coils in the IPT system so that pickup-to-pickup communications is also possible. The resistor 407 in the pick-up circuits must be kept small since if it is large then a large impedance may be reflected back into the track compromising the ability of communications signals to propagate. With the given components the 50 Ω resistor reflects a resistance of approximately 0.14 Ω on to the track. For 100 pick-ups this corresponds to an impedance of 14 Ω, which is still small compared with the characteristic impedance of 200 Ω. Larger resistor values for 407 would give higher output powers in the communications channel but would also cause mis-matching in the trackway.

With this circuitry the power and communications frequencies propagate independently both in the trackway and in the pick-ups. Both power and communications systems may be designed using simple circuit concepts of inductance and mutual inductance, as though the other signal was not present. Independence in the signals is maintained using simple tuned L, and C circuits where all are tuned at the higher communications frequency keeping the parts small in size and low cost. This approach requires that the power and communications frequencies be separated by approximately one order of magnitude to provide no appreciable interaction between tuning of power components and communications components. Relatively closer power and communications frequencies may be used, but the interaction resulting requires more attention to component design and gives appreciable interaction between power and communications outputs.

Fig 7 shows a frequency spectrum of a working IPT track with a power frequency of 20KHz for the frequency band from 100KHz to 1MHz. An unmodulated 460KHz communications carrier is shown with a marker imposed on it between spurious artefacts emitted by the power supply around the 100KHz and 1MHz frequency bands. This clearly shows that a communications signal at this frequency is readily separated from the spurious signals emitted by the power supply.

Fig 8 shows, to a different scale, a communications signal frequency shift keyed with a 25KHz modulation limit and 10KHz modulation in a working track. The signal is more than 15dB above the transient noise level at the end of a 15 metre track for a communications frequency of 450KHz.

Typical currents for the communications signal are in the 1 to 5mA range, which is some 5 orders of magnitude less than the power current.

The switching frequency of the pick-up controller and the amount of power being transferred have no effect on the communications signals, despite the fact that it is normal for the power taken through an individual pickup to vary from almost nil to several kilowatts, while the voltage on the track itself (having a relatively high source impedance) will vary drastically with load.

Where an inductive power track gives way to another, for instance at a separate manufacturing track branch or at the end of a track, a separate communications signal can also be provided from the new track.

The communications signal will normally be a digital signal but may be anlaog. The signal may be directed to controlling the mobile device on which the pickup is mounted, but it may equally well provide an indication from the mobile device to a control system, for instance relaying an image of an object blocking the track.

VARIATIONS

While the communications frequency is described as 450KHz any frequency which is more than twice the power frequency may be adequate, with the proviso that if the frequency is too high it will be difficult to compensate for minor changes in cable layout and other local variations in impedance, and if it is too low it will be difficult to separate it from the power frequency – especially with simple tuned LC circuits. In these circumstances the designs of all the tuned circuits will have to take the power frequency into account at the same time.

Tuned circuits of a parallel inductor and capacitor at the communications frequency may be replaced with ceramic filters.

Multiple communications channels at differing frequencies may be used, thus providing increased bandwidth.

As shown the pick-up is parallel tuned but a series tuned pick-up may also be used with minor modifications.

INDUSTRIAL APPLICABILITY

The invention is applicable to the transfer of information to and from devices using an inductive power transfer system to provide a reliable method of communicating with these. It extends to the provision of systems to couple information to and from such a track and to correctly terminate the track at the communications frequency.

CLAIMS

1. A communication system for an inductive power transfer (IPT) system in which alternating current power is supplied to an inductive power track loop at a power transfer frequency for transfer to inductively coupled pickups and in which at least one communications signal is imposed on the inductive power track at a communications frequency which differs from that of the power transfer frequency wherein the communications signal is received at a supplied device via the same inductively coupled pickup as that which receives the power for the device.

2. A communication system for an IPT system as claimed in claim 1 wherein the track loop is terminated for the power transfer frequency in a short circuit, but is terminated in a specified impedance for the communications frequency.

3. A communication system for an IPT system as claimed in claim 2 wherein the termination impedance at the communications frequency is the characteristic impedance for the track loop.

4. A communications system for an IPT system as claimed in claim 2 wherein the end of the track remote from the power supply forms a single turn transformer primary winding and the transformer has at least one secondary winding which reflects the characteristic track impedance into the track at the communications frequency.

5. A communications system for an inductive power transfer system as claimed in claim 1 wherein the pickup is separately tuned to be resonant at both the power transfer frequency and the communications frequency.

6. A communication system for an IPT system as claimed in claim 1 wherein the communications frequency is at least an order of magnitude greater than that of the power transfer frequency.

7. A communications system for an IPT system as claimed in claim 6 wherein the power frequency is 20KHz and the communications frequency is 450KHz and is frequency shift modulated.

8. A communication system for an IPT system as claimed in claim 1 wherein the communications system utilises a non-regulated frequency band with a power output below the maximum internationally specified.

9. A communication system for an IPT system as claimed in claim 1 wherein at a pickup the communications frequency is not terminated in its characteristic impedance.

10. A communication system for an IPT system as claimed in claim 1 wherein the communication signal originates at a track power supply facility.

11. A communication system for an IPT system as claimed in claim 10 wherein the communications frequency input is isolated from the power transfer frequency input.

12. A communication system for an IPT system as claimed in claim 1 wherein the IPT system has at least one power pickup and the pickup, while receiving power, can receive at and/or transmit on the communications frequency.

13. A communication system for an IPT system as claimed in claim 12 wherein power and communication signals are separated in the pickup by at least one filter.

14. A communication system for an IPT system as claimed in claim 11 wherein when the communications signal originates at a mobile device it is delivered to the track through the pickup.

15. A method of communicating with a mobile device supplied with power from an IPT system utilising an inductive power pickup wherein the communications signal is impressed on the inductive power track loop and is received at the mobile device through the pickup.

16. A method of communicating with a mobile device as claimed in claim 15 wherein the communication signal is filtered from the power signal in the pickup.

17. A method of communicating with a mobile device as claimed in claim 15 wherein a communication signal may be transmitted into the track from a mobile device through the pickup.

18. An inductive power transfer (IPT) system including an inductive power track loop in which alternating current power is supplied at a power transfer frequency, and at least one inductively-coupled resonant pick-up capable of extracting power from the loop, wherein the or each pick-up, while receiving power at the power transfer frequency, can inductively

receive or transmit a communications signal to or from the loop on at least one communications frequency which differs from the power transfer frequency.

19. An IPT system as claimed in claim 18 wherein the pickup is also resonant at at least one communications frequency.

20. An inductive power pickup for an inductive power transfer (IPT) system wherein the pickup is adapted to couple to an inductive power track loop in which alternating current is supplied at a first power transfer frequency and also at a second communications frequency and to inductively derive power from the power transfer frequency and at least one communications signal from the communications frequency.

21. An inductive power pickup for an IPT system as claimed in claim 20 wherein the pickup is resonant at both the power and the communications frequencies.

22. An inductive power pickup as claimed in claim 20 wherein the inductive power pickup is also adapted to transmit at least one communications signal to the track loop at a communications frequency.

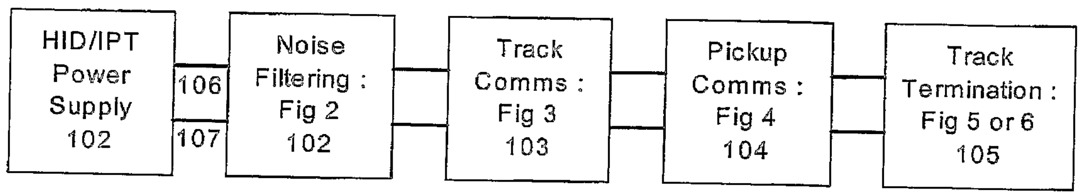

Fig 1

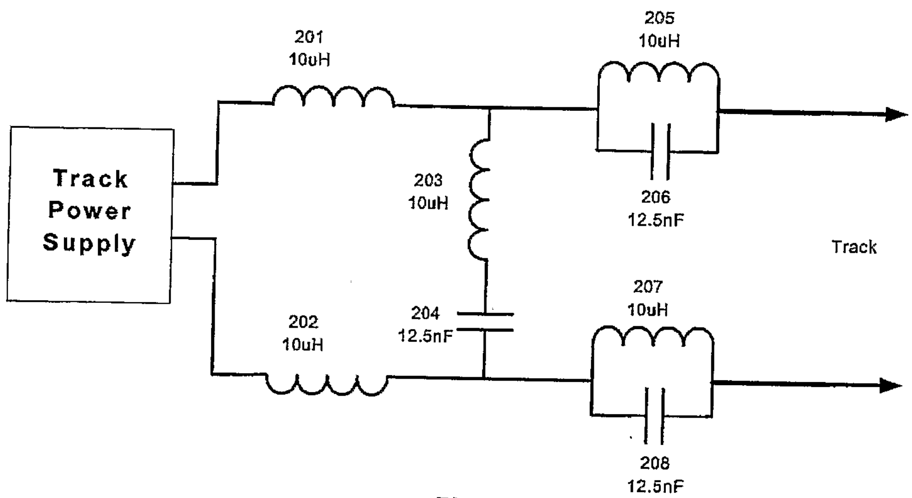

Fig 2

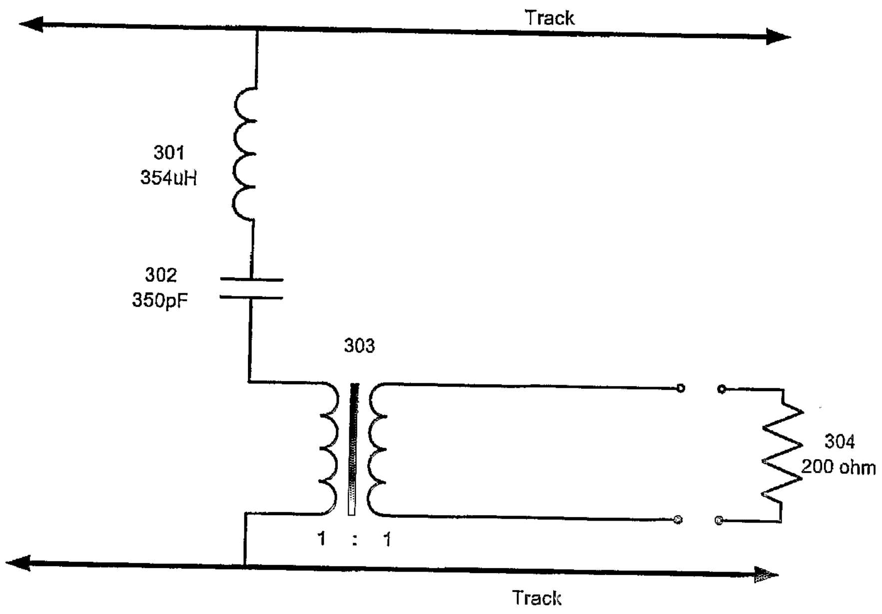

Fig 3

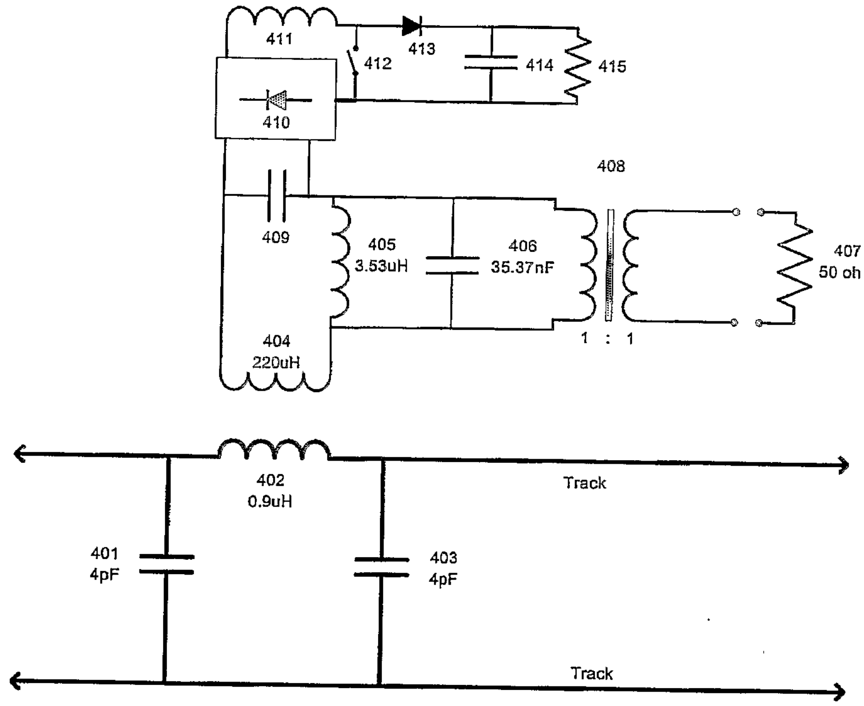

Fig 4

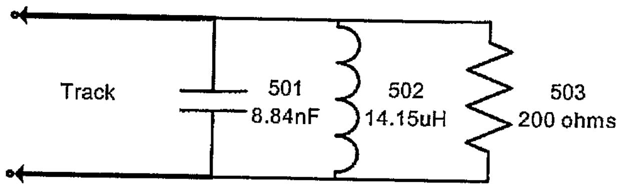

Fig 5

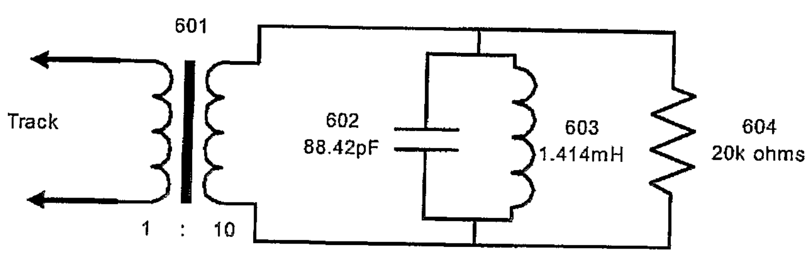

Fig 6

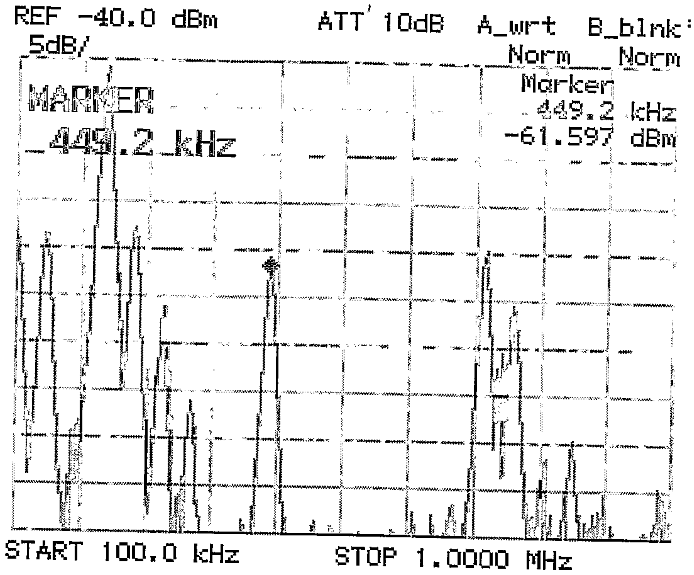
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Fig 7

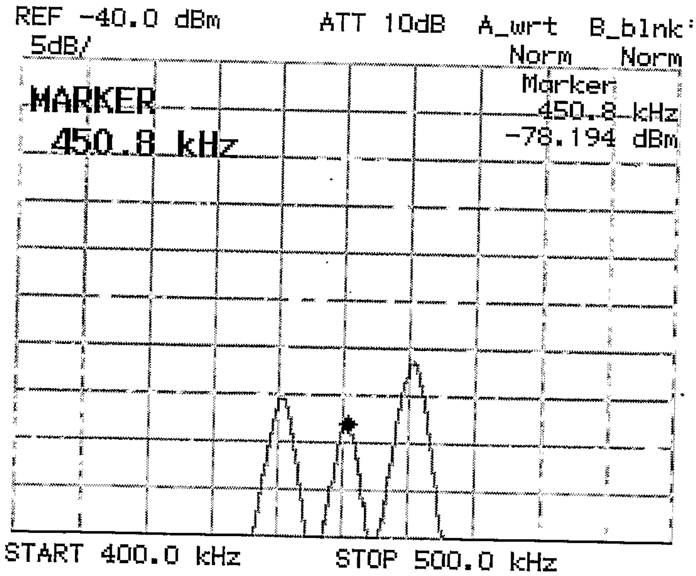
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Fig 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2004/000068

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: H01F 38/14, H02J 17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI, esp@cenet IPC: H02J 3/-, 4/-,.5/-, 17/-, H02M 1/-, 5/-, 11/-, H01F 38/-, B60L 9/-, H02J 1/- & keywords: INDUCTIVE POWER TRANSFER, CONTACTLESS ENERGY TRANSFER, PICK-UP, RESONANT, COMMUNICATION and similar terms and phrases.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent Abstract Accession No. 98-313496/28, Class W02 W05 DE 19649682 A1 (SCHLEIFRING & APP GMBH) 4 June 1998 See abstract and machine translation of the document, especially column 3 lines 17-34	1-22
X	WO 1999/50806 A1 (CUNNINGHAM) 7 October 1999 See whole document	1, 6, 9-20,22
X	Derwent Abstract Accession No.2002-699569/76, Class U24, DE 10112892 A1 (VAHLE GMBH & CO KG PAUL) 10 October 2002 See abstract and machine translation of the document, especially column 3 line 47 – column 4 line 51 and claims 1-6	1, 6, 9-20,22

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Date of the actual completion of the international search 31 August 2004	Date of mailing of the international search report 08 SEP 2004
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **BAYER MITROVIC** Telephone No : (02) 6283 2164

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Patent Document Cited in Search Report		Patent Family Member	
DE	19649682		
WO	9950806	AU	31768/99
DE	10112892		

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