(12)Indian Patent Application

(21) Application Number: 202041010346

(22) Filing Date: 11/03/2020 (43) Publication Date: 17/09/2021

(71) Applicant(s): L&T TECHNOLOGY SERVICES LIMITED

(72) Inventor(s): Narayanasamy, Ayyam
Umashankar, M
Sayeeram, Sivakumar

(51) International Classifications: H02J 7/02 H05B 33/08 H02J 50/10 H02J 50/40 H02J 50/90

(54) Title: A WIRELESS CHARGING SYSTEM

(57) Abstract: A wireless charging system (100) is disclosed that includes a plurality of primary coils (102). At least a portion of each primary coil (102) may magnetically couple with a secondary coil (112) for charging a battery electrically coupled to the secondary c oil (112) via inductive charging or resonant charging. At least one light source (104) is coupled to each primary coil that may emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of the primary coil with the secondary coil (112). A color sensor (106) may sense this color or intensity, and correspondingly generate a first control signal. A control device (110) coupled to the color sensor (106) may receive the first control signal, and trigger one or more control actions based on the first control signal to reconfigure at least one of the plurality of primary coils (102).

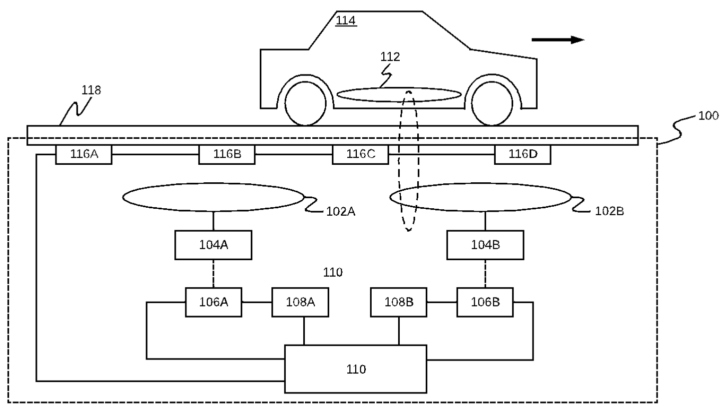


FIG. 1

FORM 2

THE PATENTS ACT 1970

(39 Of 1970)

&

The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

A WIRELESS CHARGING SYSTEM

2. APPLICANT(S)

(a)	NAME	:	**L& T TECHNOLOGY SERVICES LIMITED**
(b)	NATIONALITY	:	**INDIAN**
(c)	ADDRESS	:	**DLF IT SEZ Park, Block-3, 2nd Floor, 1/124, Mount Poonamallee Road, Ramapuram, Chennai – 600 089, Tamilnadu, INDIA**

3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is performed**.**

TECHNICAL FIELD

This disclosure relates generally to wireless power transmission, and more particularly to a method, a control device, and a system for performing wireless charging of a battery of a moving body, such as an electric vehicle.

BACKGROUND

Electrical vehicles (EV) have been lately gaining popularity with consumers. The EVs generally operate on rechargeable batteries. However, the current EVs suffer from the limitations of low distance range, and, therefore require frequent charging of the batteries. The EV, or to say the batteries of the EV, may be charged either through wired mechanism or wireless mechanism. For example, the wireless charging may be performed through inductive charging or resonant charging, based on mutual induction between primary coil and a secondary coil. It may be desirable to charge the EV while the EV is on the move, so as to make the process of charging the EV time efficient. To this end, a wireless charging system may include a number of primary coils positioned under a road, that may inductively couple with the secondary coil positioned inside the EV, while the vehicle is on the move. The charging of the battery of the EV may be achieved upon an extent of inductive coupling between the primary coil and the secondary coil, i.e., an extent of intersection of the magnetic field or magnetic flux generated by the primary coil with the secondary coil.

However, as the EV moves on the road, the extent of intersection of the magnetic flux generated by the primary coil with the secondary coil may continuously keep varying. This poses a number of limitations in performing wireless charging of the vehicle while the vehicle is on move, For example, the wireless charging system may implement various sensors for managing the continuously varying intersection. However, these wireless charging systems with these various sensors prove to be costly and therefore require a large investment. There is, therefore, a need of an effective and cost-effective wireless charging system.

SUMMARY

In one embodiment, a wireless charging system is disclosed. The wireless charging system may include a plurality of primary coils. At least a portion of each of the plurality of primary coils may be configured to magnetically couple with a secondary coil for charging a battery electrically coupled with the secondary coil via one of inductive charging or resonant charging. A position of the secondary coil may be dynamically changeable with respect to each of the plurality of primary coils. The wireless charging system may further include at least one light source coupled to each primary coil of the plurality of primary coils. The at least one light source may be configured to emit a light

of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of the primary coil with the secondary coil. The wireless charging system may further include a color sensor configured to sense the color or an intensity of the light emitted by the light source, and further configured to generate a first control signal corresponding to the sensed color or the sensed intensity of light. The wireless charging system may further include a control device coupled to the color sensor. The control device may be configured to: receive the control signal from the color sensor, and trigger one or more control actions based on the control signal to reconfigure at least one of the plurality of primary coils to perform one of inductive coupling or resonant inductive coupling with the secondary coil.

In another embodiment, a control device for performing wireless charging a battery of a moving body is disclosed. The control device may include a processor and a memory communicatively coupled to the processor. The memory stores one or more processor-executable instructions which upon execution by the processor, cause the processor to receive a control signal from a color sensor. The color sensor may be configured to sense a color or an intensity of the light emitted by a light source. The at least one light source may be configured to emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of a primary coil with a secondary coil. The at least one light source may be coupled to each primary coil of the plurality of primary coils. The secondary coil may be positioned in the moving body. The position of the moving body may be dynamically changeable with respect to each of the plurality of primary coils. The color sensor may be further configured to generate the first control signal corresponding to the sensed color or the senses intensity of light. The one or more processor-executable instructions upon execution by the processor, may further cause the processor to trigger one or more control actions based on the control signal to reconfigure at least one of the plurality of primary coils to perform one of inductive coupling or resonant inductive coupling with the secondary coil.

In a yet another embodiment, a method of wirelessly charging a battery of a moving body is disclosed. The method may include receiving a control signal from a color sensor. The color sensor may be configured to sense a color or an intensity of the light emitted by a light source. The at least one light source may be configured to emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of a primary coil with a secondary coil positioned inside the body. The position of the moving body may be dynamically changeable with respect to each of the plurality of primary coils. The at least one light source may be coupled to each primary coil of the plurality of primary coils. The color sensor may be further configured to generate the first control signal corresponding to the sensed color or the sensed intensity of light. The method may further include triggering one or more control actions based on the control signal to reconfigure at least one of the plurality of primary coils to perform one of inductive coupling or resonant inductive coupling with the secondary coil.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

FIG. 1 illustrates a wireless charging system for charging a battery of a vehicle, in accordance with some embodiments of the present disclosure.

FIG. 2 is a block diagram of the wireless charging system for charging a battery of a moving body, in accordance with some embodiments of the present disclosure.

FIG. 3 illustrates a process of selectively activating and deactivating a primary coil, during wirelessly charging of the battery of the vehicle by the wireless charging system, in accordance with an embodiment of the present disclosure.

FIGS. 4-5 illustrate processes of selectively activating and deactivating a portion of the primary coil, during wireless charging of the battery of the vehicle by the wireless charging system, in accordance with some embodiments of the present disclosure.

FIG. 6 illustrates a process of changing inclination of the primary coil relative to the secondary coil, during wireless charging of the battery of the vehicle by the wireless charging system, in accordance with another embodiment.

FIG. 7 is a flowchart of a method of wirelessly charging a battery of a moving body, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

Exemplary embodiments are described with reference to the accompanying drawings. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the spirit and scope of the disclosed embodiments. It is intended that the following detailed description be considered as exemplary only, with the true scope and spirit being indicated by the following claims. Additional illustrative embodiments are listed below.

Referring to FIG. 1, a wireless charging system 100, or simply a system 100 is illustrated, in accordance with an embodiment of the present disclosure. By way of an example, the system 100 may be used for dynamic wireless charging of a battery of a moving body, such as a vehicle, particularly an electric vehicle (EV), when the vehicle is on the move. The system 100 may be based on inductive charging, or resonant charging, or a combination of both the inductive charging and the resonant charging.

As it will be understood by those skilled in the art, inductive charging is based on electromagnetic induction, by way of which, energy is transferred from a primary coil to a secondary coil. An alternating current (AC) is run through a primary coil, and the moving electric charge creates a magnetic field. The magnetic field fluctuates in strength since the AC may be continually changing amplitude. This fluctuating magnetic field generates an electromotive force (EMF) which induces an AC in the secondary coil. It may be noted that for the inductive charging to work effectively, the primary coil and the secondary coil should be positioned in close proximity (in order of few millimeters). In other words, the effectiveness of inductive charging decreases as the separation between the primary coil and the secondary coil increases. The resonant charging may be achieved when the primary coil and the secondary coil operate at (identical) resonant frequencies, even when the primary coil and the secondary coil are separated by relatively larger distance (in terms of tens of centimeters). As it will be further appreciated, the inductive charging may require a significant extent of intersection of magnetic field generated by the primary coil with the secondary coil. However, the resonant charging may require a relatively lower extent of intersection of the magnetic field generated by the primary coil with the secondary coil.

In some embodiments, as shown in FIG. 1, the system 100 may include a plurality of primary coils, for example, primary coils 102A, 102B, … and so on (hereinafter, collectively referred to as plurality of primary coils 102). For example, the plurality of primary coils 102 may be positioned beneath a horizontal surface 118, for example, a road. The magnetic fields of the plurality of primary coils 102 may be configured to intersect with a secondary coil 112 for charging a battery electrically coupled to the secondary coil 112. By way of an example, the secondary coil 112 may be positioned in a vehicle 114 configured to run on the road. It may therefore be understood that the position of the secondary coil 112 may keep dynamically changing relative to each of the plurality of primary coils 102, as the vehicle 114 moves on the surface 118.

As such, when the secondary coil 112 comes in proximity to a primary coil of the plurality of primary coils 102, the changing magnetic flux generated by the primary coil may induce AC in the secondary coil 112, which may be then channelized to charge batteries (not shown in FIG. 1) of the vehicle 114. In particular, the secondary coil 112 may include a rectifier arrangement (not shown in FIG. 1). This rectifier arrangement may convert the AC power generated in the secondary coil into DC power. This DC power may be used to charge the batteries of the vehicle 114.

The system 100 may further include at least one light source 104 coupled to an associated primary coil of the plurality of primary coils 102. For example, as shown in FIG. 1, a light source 104A may be coupled to the primary coil 102A. Similarly, a light source 104B may be coupled to the primary coil 102B, and so on (hereinafter, the at least one light source may be referred collectively or individually as light source 104). It should be noted that the light source 104 may be configured to emit a light of a predefined color corresponding to an extent of intersection of the magnetic field generated by the associated primary coil with the secondary coil 112. In some embodiments, the light source 104 may include one or more Light Emitting Diodes (LED). For example, the light source 104 may include the one or more LEDs and a sensor which detects the extent of intersection of the magnetic field generated by the associated primary coil and the secondary coil 112. This sensor may further trigger the one or more LEDs to emit light of the predefined color corresponding to the extent of intersection. Further, each of the one or more LEDs may be capable of emitting light of various different colors. In some embodiments, the at least one light source 104 may be configured to emit a light of a predefined intensity corresponding to an extent of intersection of magnetic field of the primary coil with the secondary coil 112.

The system 100 may further include one or more one color sensors 106A, 106B, … and so on (hereinafter, the color sensors may be referred collectively or individually as color sensor 106). The color sensors 106 may be configured to sense the color of the light emitted by the light source 104. For example, as shown in FIG. 1, a color sensor 106A may sense the color of the light emitted by the light source 104A, and a color sensor 106B may sense the color of the light emitted by the light source 104B, and so on. In some embodiments, the color sensor 106 may be a SPECTRO sensor, or any other color sensor known in the art. The color sensor 106 may be further configured to generate a control signal based on the sensed color. Further, in some embodiments, the color sensor 106 may be configured to sense an intensity of the light emitted by the light source 104, generate a first control signal corresponding to the sensed intensity of light.

The system 100 may further include a control device 110. The control device 110 may be communicatively coupled to each of the color sensors 106. In some embodiments, the control device 110 may further be communicatively coupled to each of the plurality of primary coils 102. The control device 110 may receive the control signal from the color sensor 106. As it will be understood, the control signal received from the color sensor 106 may be indicative of the extent of intersection of the magnetic field generated by the associated primary coil with the secondary coil 112. Upon receiving the control signal, the control device 110 may trigger a control action based on the control signal. For example, the control action may include selectively activating and deactivating a primary coil of the plurality of primary coils 102. Upon activation, the primary coil may generate an associated magnetic field that, upon inductive coupling or resonant inductive coupling of the primary coil and with secondary coil, may charge a battery attached to the secondary coil 112.

By way of selectively activating or deactivating a primary coil from the plurality of primary coils 102, the control device 110 may cause to start or stop, respectively, inductive coupling or resonant inductive coupling of the one or more secondary coils with the primary coil. It may be understood that as the vehicle 114 displaces from one position to another, the extent of intersection of the secondary coil 112 with magnetic field generated by a primary coil may also change, and at one point, the extent of intersection may reduce so much that the charging of the battery attached to the secondary coil 112 may become negligible. In such scenarios, it may be desirable to deactivate this primary coil, so as to save electrical losses. To this end, the system 100 may include a switch 108 corresponding to each of the plurality of primary coils 102. The switch 108 may be communicatively coupled with each of the plurality of primary coils 102 and the control device 110. For example, as shown in FIG. 1, a switch 108A may be coupled to the primary coil 102A, a switch 108B may be coupled to the primary coil 102B, and so on (hereinafter, the switches may be referred collectively or individually as switch(es)108).

It may be noted that the system 100 may further include a power source (not shown in FIG. 1) for supplying power to the plurality of primary coils 102. Upon receiving the power supply from the power source, the plurality of primary coils 102 may produce magnetic field and magnetic fluxes, when current passes through the plurality of primary coils. For example, the power source may be an alternating current (AC) power source or a direct current (DC) power source. The AC power source may directly provide power to the plurality of primary coils 102. The DC power source may provide power to the plurality of primary coils 102 via an inverter circuit. The inverter circuit may receive the DC supply and convert it into AC supply. The inverter circuit may be selected from, but not limited to, a sine wave inverter, a square wave inverter, or a modified sine wave inverter.

It may be further noted that the switch 108 may make or break paths connecting the power source to an associated primary coil. Further, the switches 108 may operate according to control signal provided by the control device 110. In other words, the switches 108 may attain an open position or a closed position according to the control signal. For example, when a switch is in closed position, power may be supplied from the power source to an associated primary coil, and when the switch is in open position, power may not be supplied from the power source to the associated primary coil.

Upon sensing the color of the light emitted by the light source 104 (i.e., receiving a light signal), the color sensor 106 may parse the light signal into a plurality of spectral components. Further, the color sensor 106 may perform digitalization of the light signal and transmit a digitalized signal to the control device 110. For example, as shown in FIG. 1, the extent intersection of the magnetic field generated by the primary coil 102A with the secondary coil 112 is higher as compared to extent of intersection of the magnetic field generated by the primary coil 102B with the secondary coil 112. As such, the light source 104A may emit a light of a first predefined color, for example red color, and the light source 104B may emit a light of a second predefined color, for example yellow color. In another example, the light source 104 may include three different LEDs of color red, yellow and green, such that the red light glows when the extent of the intersection is up to 30%, the yellow light glows when the extent of the intersection is between 30% to 60%, and the green light glows when the extent of the intersection is more than 60%.

As mentioned above, in some embodiments, the light source 104 may be configured to emit a light of a predefined intensity corresponding to the extent of intersection of magnetic field generated by an associated primary coil with the secondary coil 112. Accordingly, the color sensor 106 may be further configured to sense an intensity of light emitted by the light source 104, and generate a control signal based on the sensed intensity of light.

In some embodiments, the system 100 may additionally include one or more proximity sensors 116A, 116B…and so on (hereinafter, collectively referred to as one or more proximity sensors 116). For example, the system 100 may include one proximity sensor corresponding to each primary coil. The one or more proximity sensors 116 may be configured to detect proximity of each of the plurality of the primary coils 102 with the secondary coil 112 (or the vehicle 114). Upon detecting the proximity, each of the one or more proximity sensors 116 may send the proximity information to the control device 110. As such, the control device 110 may the trigger one or more control actions, based on the one or more control actions triggered by the color sensors 106 and/or the one or more control actions triggered by the one or more proximity sensors 116. The one or more control actions may be directed at reconfiguring at least one of the plurality of primary coils (102) to perform one of inductive coupling or resonant inductive coupling with the secondary coil. For example, as the vehicle 114 moves from one position to another, the extent of intersection of the secondary coil 112 with magnetic field generated by each of the primary coils 102A and 102B may start changing. Correspondingly, the color of the light emitted by the light sources 104A and 104B may also change. Accordingly, the control device 110 may trigger one or more control actions to reconfigure at least one of the plurality of primary coils 102.

It may be noted that by using a combination of color sensors 106 and the proximity sensors 116, accuracy of the system 100 is improved. Further, in case a color sensor or the light source stops working due to a fault, the proximity sensors may work as a backup mechanism for charging the battery of the vehicle, and vice versa.

Referring now to FIG. 2, a block diagram of the wireless charging system 100 is illustrated, in accordance with an embodiment of the present disclosure. The wireless charging system 100 may include a control device 110. The control device 110 may be a computing device having data processing capability. Examples of the control device 110 may include, but are not limited to a server, a desktop, a laptop, a notebook, a netbook, a tablet, a smartphone, a mobile phone, an application server, a sever, or the like. The control device 110 may further include a data storage 208. For example, the data storage 208 may store control signal data and control action data. The control device 110 may be communicatively coupled to the data storage 208 via a communication network 206. The communication network 206 may be a wired or a wireless network and the examples may include, but are not limited to the Internet, Wireless Local Area Network (WLAN), Wi-Fi, Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX), and General Packet Radio Service (GPRS).

The wireless charging system 100 may further include the one or more one color sensors 106, the one or more proximity sensors 116, and the one or more switches 108 corresponding to the plurality of primary coils 102. As will be described in greater detail in conjunction with FIG. 2 to FIG. 6, in order to perform wirelessly charging batteries of a moving body like a vehicle, the control device 110 may receive a first control signal from a color sensor 106. The color sensor 106 may be configured to sense a color or intensity of the light emitted by at least one light source 104. The at least one light source 104 may be configured to emit a light of a predefined color or an intensity corresponding to an extent of intersection of magnetic field of a primary coil with the secondary coil 112. Further, the at least one light source 104 may be coupled to each primary coil of the plurality of primary coils 102. The secondary coil 112 may be positioned in the moving body whose position may keep dynamically changing relative to each of the plurality of primary coils 102. The color sensor 106 may be further configured to generate the first control signal corresponding to the sensed color. The control device 110 may further trigger one or more control actions based on the first control signal to reconfigure at least one of the plurality of primary coils 102 to perform one of inductive coupling or resonant inductive coupling with the secondary coil. As it will be explained in the subsequent sections, reconfiguring the at least one of the plurality of primary coils 102 may include: selectively activating and deactivating a primary coil of the plurality of primary coils 102, selectively activating and deactivating a portion of the primary coil of the plurality of primary coils 102, changing inclination of the primary coil of the plurality of primary coils 102 relative to the secondary coil 112, reconfiguring the at least one of the plurality of primary coils 102 to perform resonant inductive coupling when a speed of the vehicle is above a predefined threshold speed, and reconfiguring the at least one of the plurality of primary coils 102 to perform one of inductive coupling or resonant inductive coupling when the speed of the vehicle is at or below the predefined threshold speed.

It should be noted that inductive coupling may not be efficient when the distance between the primary coil and the secondary coil is substantially high. In such scenarios, the extent of intersection of magnetic flux generated by the primary with the secondary coil is not substantially high, thereby resulting in lower efficiency of energy transfer. As such, when the distance between the primary coil and the secondary coil is substantially high, resonant inductive coupling may be more desirable. It should be further noted that for performing resonant inductive coupling, the primary coil and the secondary coil should couple at the same electromagnetic frequency. In other words, the electromagnetic frequency of the primary coil should match with the electromagnetic frequency of the secondary coil. This can be achieved by employing an electronic circuit. Additionally, in some embodiments, this matching of the electromagnetic frequency of the primary coil and the secondary coil can be further amplified by using resonant circuits. Further, it may be desirable to switch between inductive coupling and resonant inductive coupling, using a switching system to selectively perform one of inductive coupling and resonant inductive coupling. As such, the electronic and/or the resonant circuit may be selectively activated and deactivated to drive the at least one of the plurality of primary coils 102 at a pre-defined electromagnetic frequency. The predefined electromagnetic frequency may be a resonant frequency of the secondary coil.

As it will be appreciated by those skilled in the art, electricity moving through wires (i.e., primary coil) creates an oscillating magnetic field which cause electrons in a nearby coil (i.e., secondary coil) to oscillate, thereby transferring power wirelessly. The transfer efficiency may be enhanced if both the primary coil and the secondary coil are tuned to the same magnetic resonance frequency and are positioned at the correct angle. As such, when a vehicle with the secondary coil (for example, at a charging station) is stationary, charging through inductive coupling may be preferred. As such, alternating current passes through an induction coil in the charging station or pad. The moving electric charge creates a magnetic field, which fluctuates in strength because the electric current's amplitude is fluctuating. This changing magnetic field creates an alternating electric current in the vehicle’s secondary induction coil, which in turn passes through a rectifier to convert it to direct current. Finally, the direct current charges a battery.

When the vehicle is moving slowly, charging through both inductive and resonant coupling may be preferred based on a position of the vehicle. Further, it may be noted that when the vehicle is moving at high speed, resonant coupling may be preferred. This is because the distance between the primary coil and secondary could may rapidly change, thereby making the inductive coupling less effective. Therefore, the at least one of the plurality of primary coils 102 may be reconfigured to perform resonant inductive coupling when the speed of the vehicle is above a predefined threshold speed. Further, the at least one of the plurality of primary coils 102 may be reconfigured to perform one of inductive coupling or resonant inductive coupling when the speed of the vehicle is at or below the predefined threshold speed.

To this end, in some embodiments, the control device 110 may receive the speed data of the vehicle. Accordingly, a communication channel may be established between the vehicle and the control device 110, using a suitable communication network, for example, a short-range wireless communication network like Bluetooth, ZigBee, NFC etc. The speed data may allow the control device 110 to further enhance the efficacy of decision making of switching between the inductive coupling or resonant inductive coupling. In some embodiments, when the speed of the vehicle is mid-range or high, the control device 110 may switch to resonant inductive coupling based on the speed data, irrespective of the color sensors and proximity sensors. However, when the speed of the vehicle is low, the control device 110 may rely on the color sensors and proximity sensors to determine position of the vehicle relative to the primary coils to perform one of inductive or resonant inductive coupling. Further, in some embodiments, in order to switch between the inductive coupling or resonant inductive coupling, a switch may be used.

In order to perform the above discussed functionalities, the control device 110 may include a processor 202 and a memory 204. The memory 204 may store instructions that, when executed by the processor 202, cause the processor 202 to wirelessly charge a battery of a moving body, such as a vehicle. The memory 204 may be a non-volatile memory or a volatile memory. Examples of non-volatile memory may include, but are not limited to a flash memory, a Read Only Memory (ROM), a Programmable ROM (PROM), Erasable PROM (EPROM), and Electrically EPROM (EEPROM) memory. Examples of volatile memory may include, but may be not limited to, Dynamic Random

Access Memory (DRAM), and Static Random-Access memory (SRAM). The memory 204 may also store various data (e.g., control signal data, control action data, etc.) that may be captured, processed, and/or required by the system 100. The wireless charging system 100 may interact with one or more external devices 210 over the communication network 206 for sending or receiving various data. Examples of the one or more external devices 210 may include, but are not limited to a remote server, a digital device, or another computing system.

It may be noted that as the vehicle 114 moves on the road, the position of the vehicle 114 may keep changing relative to each of the plurality of primary coils 102. For example, at one point of time, the vehicle may be positioned closer to the primary coil 102A. As such, at this point of time, the primary coil 102A may be magnetically coupled with the secondary coil 112, for charging the battery attached to the secondary coil 112. At another point of time, the vehicle may move away from the primary coil 102A to be positioned closer to the primary coil 102B, and the primary coil 102B may become magnetically coupled with the secondary coil 112. Therefore, as the vehicle progresses on the road surface, the plurality of primary coils may successively magnetically couple and decouple one by one with the secondary coil 112. In other words, a primary coil may magnetically couple with the secondary coil 112 when the distance between the primary coil and the secondary coil 112 decreases than a predetermined distance. Similarly, the primary coil may magnetically decouple from the secondary coil 112 when the distance between the primary coil and the secondary coil 112 increases beyond the predetermined distance.

Referring now to FIG. 3, a process 300 of selectively activating and deactivating a primary coil, during charging batteries of the vehicle 114 by the wireless charging system 100 is illustrated, in accordance with an embodiment of the present disclosure. In a first scenario 302, at time t1=t1, the vehicle 114 and therefore the secondary coil 112 is positioned closer to the primary coil 102A. The primary coil 102A may magnetically couple completely with the secondary coil 112 for charging the battery attached to the secondary coil 112. Accordingly, the light source 104A may emit a color of light indicative of high extent of intersection. The color sensor 106A may therefore generate control signals and send to the control device 110. The control device 110 may therefore, keep the primary coil 102A connected to the power source (i.e., activated) via the switch 108A. However, as the vehicle 114 moves, the distance between the secondary coil 112 and the primary coil 102A may start increasing, and simultaneously the distance between the secondary coil 112 and the primary coil 102B may start decreasing.

In a second scenario 304, at time t=t2, the vehicle 114 and the secondary coil 112 may be positioned closer to the primary coil 102B. Therefore, the control device 110 may receive the control signal from the color sensors 106A and 106B that may be indicative of the extent of intersection of magnetic field generated by each of the primary coils 102A and 102B, respectively with the secondary coil 112. For example, in this scenario, the control signal may be indicative of low extent of intersection of magnetic field generated by the primary coil 102A with the secondary coil 112, and high extent of intersection of magnetic field generated by the the primary coil 102B with the secondary coil 112. Upon receiving the control signal, the control device 110 may trigger a control action. This control action may cause to deactivate the primary coil 102A and activate the primary coil 102B. Therefore, at time t=t2, the primary coil 102B may magnetically couple completely with the secondary coil 112 for charging the battery attached to the secondary coil 112, and the primary coil 102A may remain deactivated.

In another embodiment, the control action may include selectively activating and deactivating a portion of the primary coil 102. Upon activation, the portion of the primary coil 102 is to generate an associated magnetic field, that, upon inductive coupling or resonant inductive coupling of the primary coil 102 with the secondary coil 112, may charge the battery attached to the secondary coil 112. It may be noted that in order to selectively activating and deactivating a portion of the primary coil 102, a suitable switch may be used. For example, such a switch may include a metal–oxide–semiconductor field-effect transistor (MOSFET), or an ignitron switch.

Referring to FIG. 4, a process 400 of selectively activating and deactivating a portion of primary coil, during charging of the battery of the vehicle 114 by the wireless charging system 100 is illustrated, in accordance with another embodiment of the present disclosure. In a first scenario 402, at time t=t1, the vehicle 114 and the secondary coil 112 may be positioned closer to the primary coil 102A. The primary coil 102A may magnetically couple completely with the secondary coil 112 for charging the battery attached to the secondary coil 112. As the vehicle 114 moves, the distance between the secondary coil 112 and the primary coil 102A may start increasing, and simultaneously the distance between the secondary coil 112 and the primary coil 102B may start decreasing.

In a second scenario 404, at time t=t2, the vehicle 114 and the secondary coil 112 may be positioned somewhere in the middle of the primary coil 102A and the primary coil 102B. Therefore, the control device 110 may receive the control signal from the color sensors 106A and 106 indicative of extent of intersection of magnetic field generated by each of the primary coils 102A and 102B, respectively, with the secondary coil 112. For example, in this scenario 404, the control signal may be indicative of medium extent of intersection of magnetic field generated by the primary coil 102A with the secondary coil 112, and medium extent of intersection of magnetic field generated by the primary coil 102B with the secondary coil 112. Upon receiving the control signal, the control device 110 may trigger a control action. This control action may cause to partially deactivate the primary coil 102A and partially activate the primary coil 102B. For example, as shown in FIG. 4, a left half of the primary coil 102A may be deactivated (represented by unshaded region in the FIG. 4), and left half of the primary coil 102B may be activated (represented by shaded region in the FIG. 4). As such, right half of the of the primary coil 102A may remain activated, and right half of the primary coil 102B may remain deactivated. Therefore, at time t=t2, a portion (half) of the primary coil 102A and a portion (half) of the primary coil 102B may magnetically couple with the secondary coil 112 for charging of the battery attached to the secondary coil 112.

It may be noted that, in some embodiments, instead of activating or deactivating a left half or right half of a primary coil, the control signal may cause to activate or deactivate a portion of the primary coil in a graded manner. Referring now to FIG. 5, a process 500 of selectively activating and deactivating a portion of the primary coils 102 is illustrated, in accordance with yet another embodiment. In a first scenario 502, at time t=t1, the vehicle 114 and the secondary coil 112 may be positioned closer to the primary coil 102A. The primary coil 102A may magnetically couple completely with the secondary coil 112 for charging the battery attached to the secondary coil 112. As the vehicle 114 moves, the distance between the secondary coil 112 and the primary coil 102A may start increasing, and simultaneously the distance between the secondary coil 112 and the primary coil 102B may start decreasing.

In a second scenario 504, at time t=t2, the vehicle 114 and the secondary coil 112 may be positioned farther away from the primary coil 102A and closer to the primary coil 102B, as compared to the position at time t=t1. For example, at time t=t2, there may be 70 percent intersection of magnetic field generated by the primary coil 102A with the secondary coil 112, and 30 percent intersection of magnetic field generated by the primary coil 102B with the secondary coil 112. Therefore, a control signals indicative of above scenario may be received from the light sensors 106A and 106B, respectively. Upon receiving the control signals, the control device 110 may trigger a control action which may cause to partially deactivate the primary coil 102A and partially activate the primary coil 102B. For example, as shown in FIG. 5, 30 percent length from left end of the primary coil 102A may be deactivated (represented by unshaded region in the FIG. 5), and 30 length percent from left end of the primary coil 102B may be activated (represented by shaded region in the FIG. 5). As such, 70 percent length from right end of the primary coil 102A may remain activated, and 70 percent length from right end of the primary coil 102B may be remain deactivated. Therefore, at time t=t2, 70 percent (portion) of the primary coil 102A and 30 percent (portion) of the primary coil 102B may magnetically couple with the secondary coil 112 for charging the battery attached to the secondary coil 112.

In a third scenario 506, at time t=t3, the vehicle 114 and the secondary coil 112 may be positioned yet farther away from the primary coil 102A and closer to the primary coil 102B, as compared to the position at time t=t2. For example, at time t=t3, due to the position of the secondary coil 112, there may be 40 percent intersection of magnetic field generated by the primary coil 102A with the secondary coil 112, and 60 percent intersection of magnetic field generated by the primary coil 102B with the secondary coil 112. Therefore, control signals indicative of above scenario may be received. Upon receiving the control signals, the control device 110 may trigger a control action which may cause to further partially deactivate the primary coil 102A and partially activate the primary coil 102B. For example, as shown in FIG. 5, 60 percent length from left end of the primary coil 102A may be deactivated, and 60 percent length from left end of the primary coil 102B may be activated. As such, 40 percent length from right end of the primary coil 102A may remain activated, and 40 percent length from right end of the primary coil 102B may be remain deactivated. Therefore, at time t=t3, 40 percent (portion) of the primary coil 102A and 60 percent (portion) of the primary coil 102B may magnetically couple with the secondary coil 112 for charging the battery attached to the secondary coil 112.

In yet another embodiment, the control action may include changing inclination of the primary coil of the plurality of primary coils 102 relative to the secondary coil 112. It should be noted that when the secondary coil 112 is positioned close to a primary coil 102, for example, right on top of the primary coil 102A, the extent of intersection of magnetic field of the primary coil with the secondary coil 112, and therefore, the efficiency of charging may be maximum. However, as the vehicle 114 moves and the distance between the secondary coil 112 and the primary coil 102 starts increasing, the efficiency of charging by that primary coil 102 may reduce. To this end, angle of inclination of the primary coil (of the plurality of primary coils 102) relative to the secondary coil 112 may be changed, as the position of the secondary coil 112 changes relative to the primary coil 102.

Referring now to FIG. 6, an exemplary process 600 of changing inclination of the primary coil relative to the secondary coil is illustrated, during charging of the battery attached to the secondary coil 112 by the wireless charging system 100, in accordance with another embodiment. In a first scenario 602, at time t=t1, the vehicle 114 and the secondary coil 112 may be positioned closer to the primary coil 102A, and the primary coil 102A may magnetically couple completely with the secondary coil 112 for charging the battery attached to the secondary coil 112. As the vehicle 114 moves, the distance between the secondary coil 112 and the primary coil 102A may start increasing, and simultaneously the distance between the secondary coil 112 and the primary coil 102B may start decreasing.

In a second scenario 604, at time t=t2, the vehicle 114 and the secondary coil 112 may be positioned somewhere in the middle of the primary coil 102A and the primary coil 102B. Therefore, the control device 110 may receive the control signal from the color sensors 106A and 106B that may be indicative of extent of intersection of magnetic field generated by each of the primary coils 102A and 102B, respectively, with the secondary coil 112. For example, in this scenario, the control signals may be indicative of medium extent (or, 50%) of intersection of magnetic field generated by the primary coil 102A with the secondary coil 112, and medium extent (or, 50%) of intersection of magnetic field generated by the primary coil 102B with the secondary coil 112. Upon receiving the control signals, the control device 110 may trigger a control action which may cause to turn the primary coil 102A clockwise and turn the primary coil 102B anticlockwise. For example, as shown in FIG. 6B, the primary coil 102A may turn clockwise by 30 degrees and the primary coil 102B may turn anticlockwise by 30 degrees. It may be noted that the system may use any rotating mechanism, such as a direct current (DC) motor for turning the primary coil 102. As a result of this turning (change in inclination of the primary coils 102A and 102B relative to the secondary coil 112), a higher extent of intersection of magnetic field of the primary coils 102A and 102B with the secondary coil 112 may be sustained for a longer duration of time, leading to higher efficiency of charging.

Referring now to FIG. 7, a flowchart of a method 700 of wirelessly charging a battery of a moving body is illustrated, in accordance with an embodiment of the present disclosure. In some embodiments, the method 700 may be performed by the control device 110 of the wireless charging system 100. For example, the body may be a vehicle moving on a road surface. The system 100 may include the plurality of primary coils 102A, 102B, and so on, positioned below the surface. The moving body may implement the secondary coil 112.

At step 702, a first control signal may be received by the control device 110 from a color sensor 106. The color sensor 106 may be configured to sense a color or an intensity of the light emitted by a light source 104. The at least one light source 104 may be configured to emit a light of a predefined color or an intensity corresponding to an extent of intersection of magnetic field of a primary coil with a secondary coil 112 positioned inside the body. The position of the body may be keep dynamically changing relative to each of the plurality of primary coils 102. Further, the at least one light source

104 may be coupled to each primary coil of the plurality of primary coils 102. The color sensor 106 may be further configured to generate the first control signal corresponding to the sensed color or the sensed intensity of light.

Additionally, in some embodiments, at step 704, a second control signal may be received by the control device 110 from one of one or more proximity sensors 116. It may be noted that, in some embodiments, the wireless charging system 100 may further include the one or more proximity sensors 116, along with the color sensors 106 and the light sources 104. Each of the one or more proximity sensors 116 may be configured to detect proximity of the secondary coil 112 with a primary coil of the plurality of the primary coils 102. Each of the one or more proximity sensors 116 may be further configured to generate a second control signal corresponding to the detected proximity of the secondary coil 112 with the primary coil of the plurality of the primary coils 102.

At step 706, one or more controls actions may be triggered based on at least one of the first control signal and the second control signal. In some embodiments, the one or more controls actions 706A may include selectively activating and deactivating a primary coil of the plurality of primary coils 102. Upon activation, the primary coil may generate an associated magnetic field that, upon inductive coupling or resonant inductive coupling of the primary coil and with secondary coil, may charge the battery attached to the secondary coil 112. This has already been explained in conjunction with FIG. 3. In some embodiments, the one or more controls 706B actions may include selectively activating and deactivating a portion of the primary coil. Upon activation, the portion of the primary coil is to generate an associated magnetic field that, upon inductive coupling or resonant inductive coupling of a primary coil and with secondary coil 112, may charge the battery attached to the secondary coil 112. This has already been explained in conjunction with FIGS. 4 and 5. In some embodiments, the one or more controls actions 706C may include changing inclination of the primary coil of the plurality of primary coils 102 relative to the secondary coil 112. This has already been explained in conjunction with FIG. 6. In some embodiments, the one or more controls actions 706D may include reconfiguring the at least one of the plurality of primary coils 102 to perform resonant inductive coupling when a speed of the vehicle is above a predefined threshold speed. In some embodiments, the one or more controls actions 706E may include reconfiguring the at least one of the plurality of primary coils 102 to perform one of inductive coupling or resonant inductive coupling when the speed of the vehicle is at or below the predefined threshold speed. Further, it may be noted that reconfiguring the at least one of the plurality of primary coils 102 to perform resonant inductive coupling may include selectively activating and deactivating a circuit to drive the at least one of the plurality of primary coils 102 at a pre-defined electro-magnetic frequency. The predefined electro-magnetic frequency may be a resonant frequency of the secondary coil.

The techniques described above relate to a wireless charging system. The above techniques provide, by implementing color sensors and proximity sensors, provide for a cost-effective and energy-efficient solution of dynamically charging batteries of moving bodies, for example of EVs, wirelessly. Further, by implementing resonant charging, the techniques eliminate the need of precise power saving areas. Furthermore, by implementing the wireless charging system below the road surface, the limitation posed by non-availability of real-estate, for example for charging stations, is overcome. Moreover, by using simple and cheaper color sensors and proximity sensors, the techniques do away with requirement of expensive sensors for managing the continuously varying intersection of magnetic field generated by the primary coils and secondary coil.

It is intended that the disclosure and examples be considered as exemplary only, with a true scope and spirit of disclosed embodiments being indicated by the following claims.

We claim:

1. A wireless charging system (100) comprising:

a plurality of primary coils (102), wherein at least a portion of each of the plurality of primary coils (102) is configured to magnetically couple with a secondary coil (112) for charging a battery electrically coupled to the secondary coil (112) via one of inductive charging or resonant charging, wherein position of the secondary coil (112) is dynamically changeable with respect to each of the plurality of primary coils (102);

at least one light source (104) coupled to each primary coil of the plurality of primary coils (102), wherein the at least one light source (104) is configured to emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of the primary coil with the secondary coil (112);

a color sensor (106) configured to sense a color or an intensity of the light emitted by the light source (104), and further configured to generate a first control signal corresponding to the sensed color or the sensed intensity of light; and

a control device (110) coupled to the color sensor (106), wherein the control device (110) is configured to:

receive the first control signal from the color sensor (106); and

trigger one or more control actions based on the first control signal to reconfigure at least one of the plurality of primary coils (102) to perform one of inductive coupling or resonant inductive coupling with the secondary coil.

2. The wireless charging system (100) as claimed in claim 1, wherein the light source (104) is a Light Emitting Diode (LED).

3. The wireless charging system (100) as claimed in claim 1, wherein:

the plurality of primary coils (102) is positioned below a surface of a road,

the secondary coil (112) is positioned inside a vehicle (114) configured to move on the surface of the road, and

the vehicle (114) is an electric vehicle (EV).

4. The wireless charging system (100) as claimed in claim 3, wherein reconfiguring the at least one of the plurality of primary coils (102) comprises:

reconfiguring the at least one of the plurality of primary coils (102) to perform resonant inductive coupling when a speed of the vehicle is above a predefined threshold speed;

reconfiguring the at least one of the plurality of primary coils (102) to perform one of inductive coupling or resonant inductive coupling when the speed of the vehicle is at or below the predefined threshold speed.

5. The wireless charging system (100) as claimed in claim 1, wherein reconfiguring the at least one of the plurality of primary coils (102) to perform resonant inductive coupling comprises:

selectively activating and deactivating a circuit to drive the at least one of the plurality of primary coils (102) at a pre-defined electro-magnetic frequency, wherein the predefined electro-magnetic frequency is a resonant frequency of the secondary coil.

6. The wireless charging system (100) as claimed in claim 1, further comprising one or more proximity sensors (116), wherein each of the one or more proximity sensors (116) is configured to:

detect proximity of the secondary coil (112) with a primary coil of the plurality of the primary coils (102); and

generate a second control signal corresponding to the detected proximity of the secondary coil (112) with the primary coil of the plurality of the primary coils (102).

7. The wireless charging system (100) as claimed in claim 1, wherein reconfiguring the at least one of the plurality of primary coils (102) further comprises at least one of:

selectively activating and deactivating a portion of the at least one of the plurality of primary coils (102) using switches, wherein upon activation, the portion of the at least one of the plurality of primary coils (102) generate an associated magnetic field; or

changing inclination of the at least one of the plurality of primary coils (102) relative to the secondary coil (112).

8. The wireless charging system (100) as claimed in claim 1, wherein the at least one light source (104) comprises a left light source (104A) and a right light source (104B), wherein the left light source (104A) is coupled to a left half of each primary coil and the right light source (104B) is coupled to a right half of each primary coil of the plurality of primary coils (102), wherein each of the left light source (104A) and the right light source (104A) is configured to emit a light of a predefined color or a predefined intensity corresponding to intersection of magnetic field of the left half and the right half, respectively, of the primary coil with the secondary coil (112).

9. A control device (110) for performing wireless charging a battery of a moving body, the control device comprising:

a processor (202); and

a memory (204) communicatively coupled to the processor (202), and storing one or more processor-executable instructions which upon execution by the processor (202), cause the processor (202) to:

receive a first control signal from a color sensor (106), wherein the color sensor (106) is configured to sense a color or an intensity of the light emitted by a light source (104), wherein the at least one light source (104) is configured to emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of a primary coil with a secondary coil (112), wherein the at least one light source (104) is coupled to each primary coil of the plurality of primary coils (102), wherein the secondary coil (112) is positioned in the moving body, wherein the position of the moving body is dynamically changeable with respect to each of the plurality of primary coils (102), and wherein the color sensor (106) is further configured to generate the first control signal corresponding to the sensed color or the senses intensity of light; and

trigger one or more control actions based on the first control signal to reconfigure at least one of the plurality of primary coils (102) to perform one of inductive coupling or resonant inductive coupling with the secondary coil.

10. A method (700) of wirelessly charging a battery of a moving body, the method (700) comprising:

receiving (702), by a control device (110), a first control signal from a color sensor (106), wherein the color sensor (106) is configured to sense a color or an intensity of the light emitted by a light source (104), wherein the at least one light source (104) is configured to emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of a primary coil with a secondary coil (112) positioned inside the body, wherein the position of the moving body is dynamically changeable with respect to each of the plurality of primary coils (102), wherein the at least one light source (104) is coupled to each primary coil of the plurality of primary coils (102), and wherein the color sensor (106) is further configured to generate the first control signal corresponding to the sensed color or the sensed intensity of light; and

triggering (706), by the control device (110), one or more control actions based on the first control signal to reconfigure at least one of the plurality of primary coils (102).

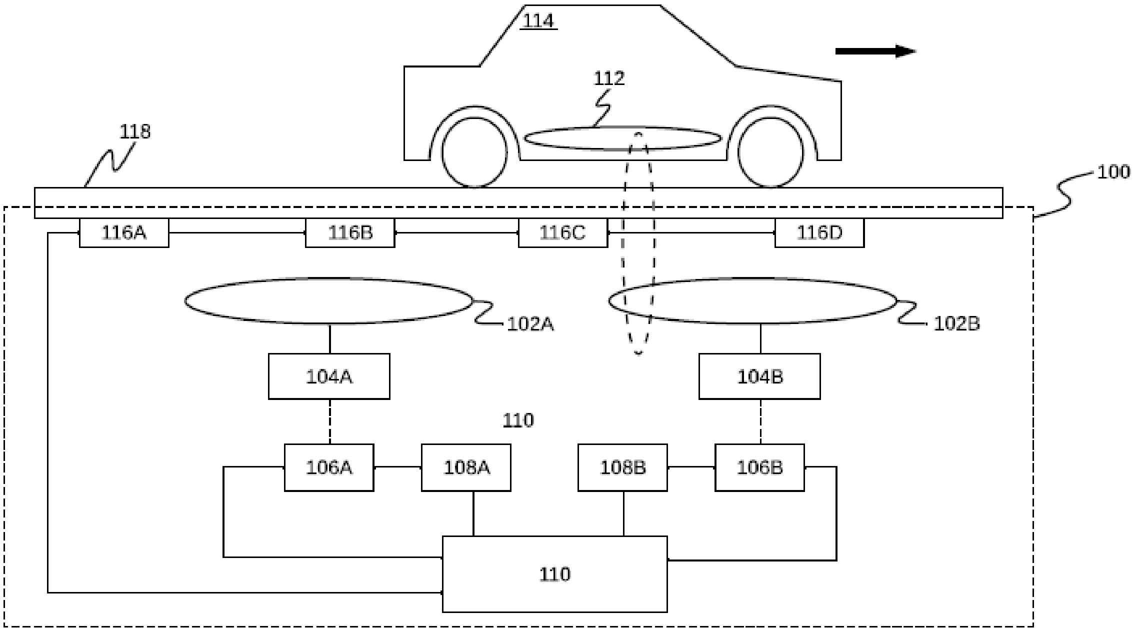
Dated this 11th day of March 2020

Mohammed Faisal (INPA No.: 1941)
Head, IPR Dept,
L&T Technology Services Limited
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai – 6000 089.

A WIRELESS CHARGING SYSTEM

ABSTRACT

A wireless charging system (100) is disclosed that includes a plurality of primary coils (102). At least a portion of each primary coil (102) may magnetically couple with a secondary coil (112) for charging a battery electrically coupled to the secondary coil (112) via inductive charging or resonant charging. At least one light source (104) is coupled to each primary coil that may emit a light of a predefined color or a predefined intensity corresponding to an extent of intersection of magnetic field of the primary coil with the secondary coil (112). A color sensor (106) may sense this color or intensity, and correspondingly generate a first control signal. A control device (110) coupled to the color sensor (106) may receive the first control signal, and trigger one or more control actions based on the first control signal to reconfigure at least one of the plurality of primary coils (102).



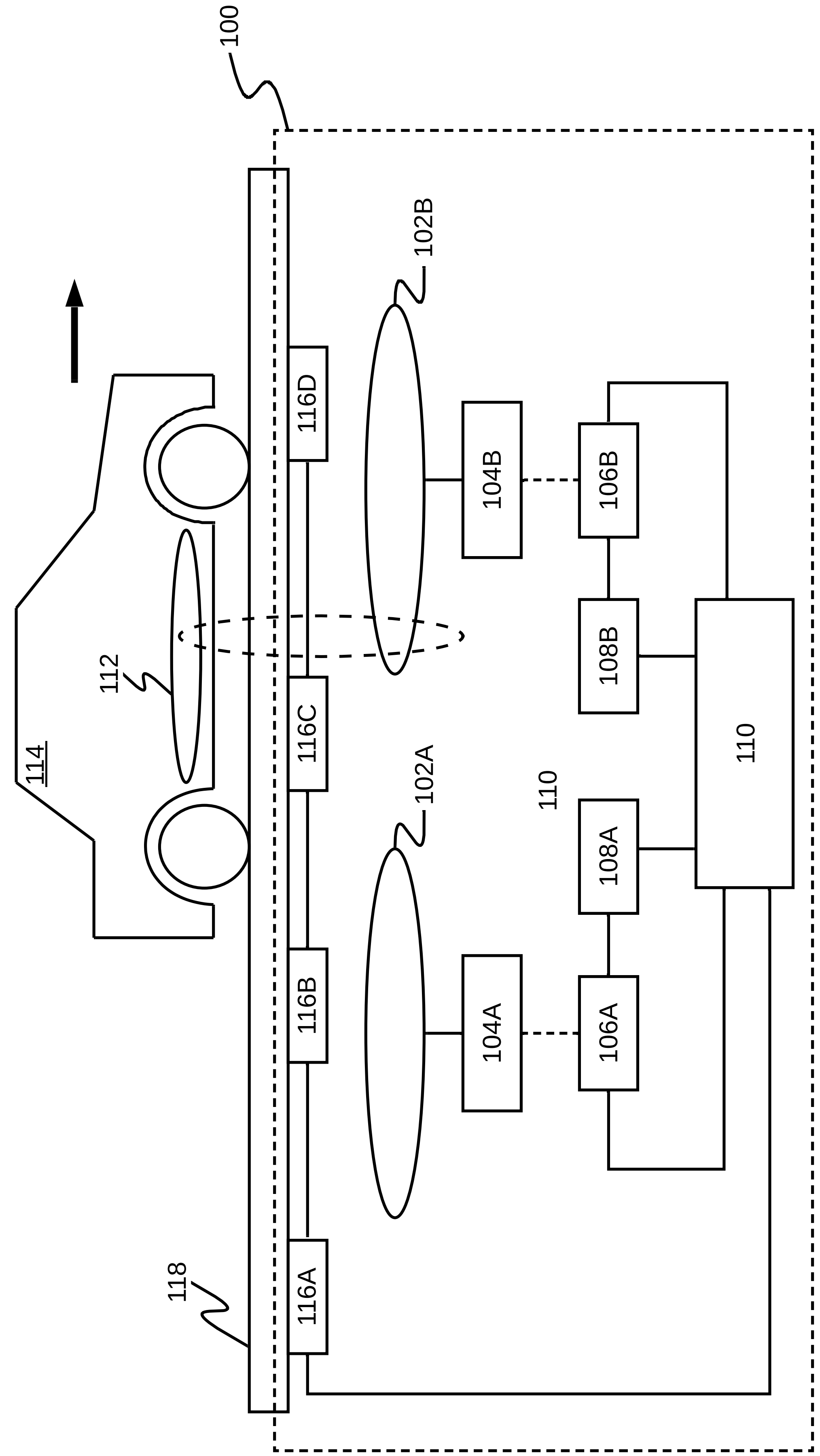


FIG. 1

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.

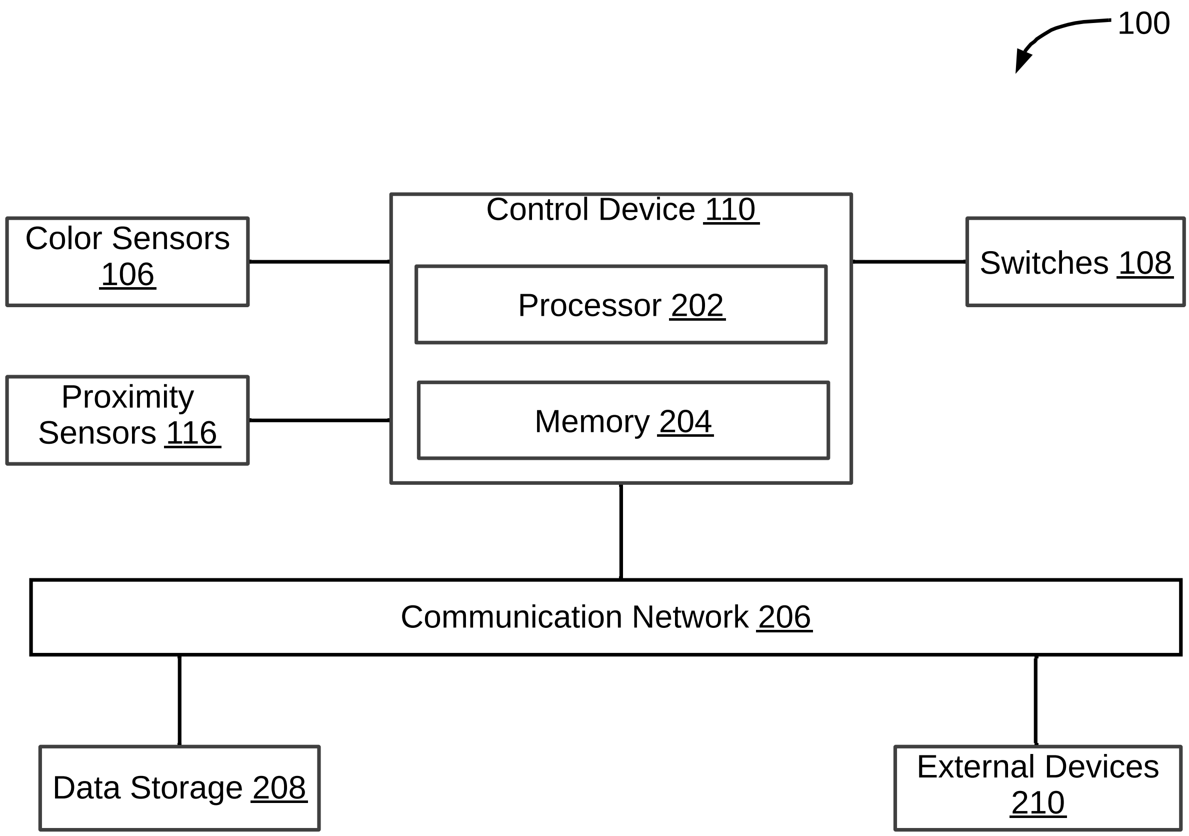


FIG. 2

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.

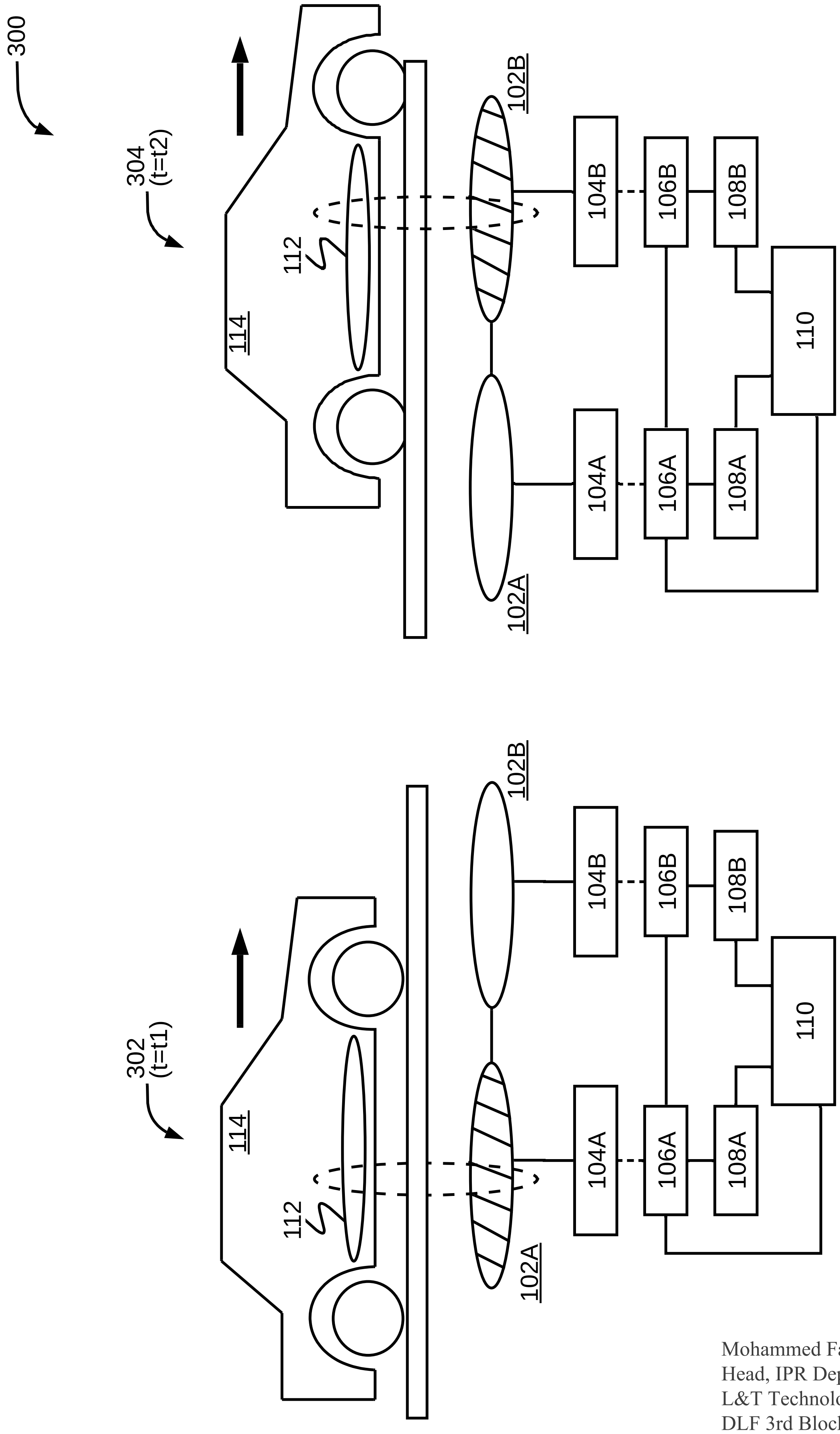


FIG. 3

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.

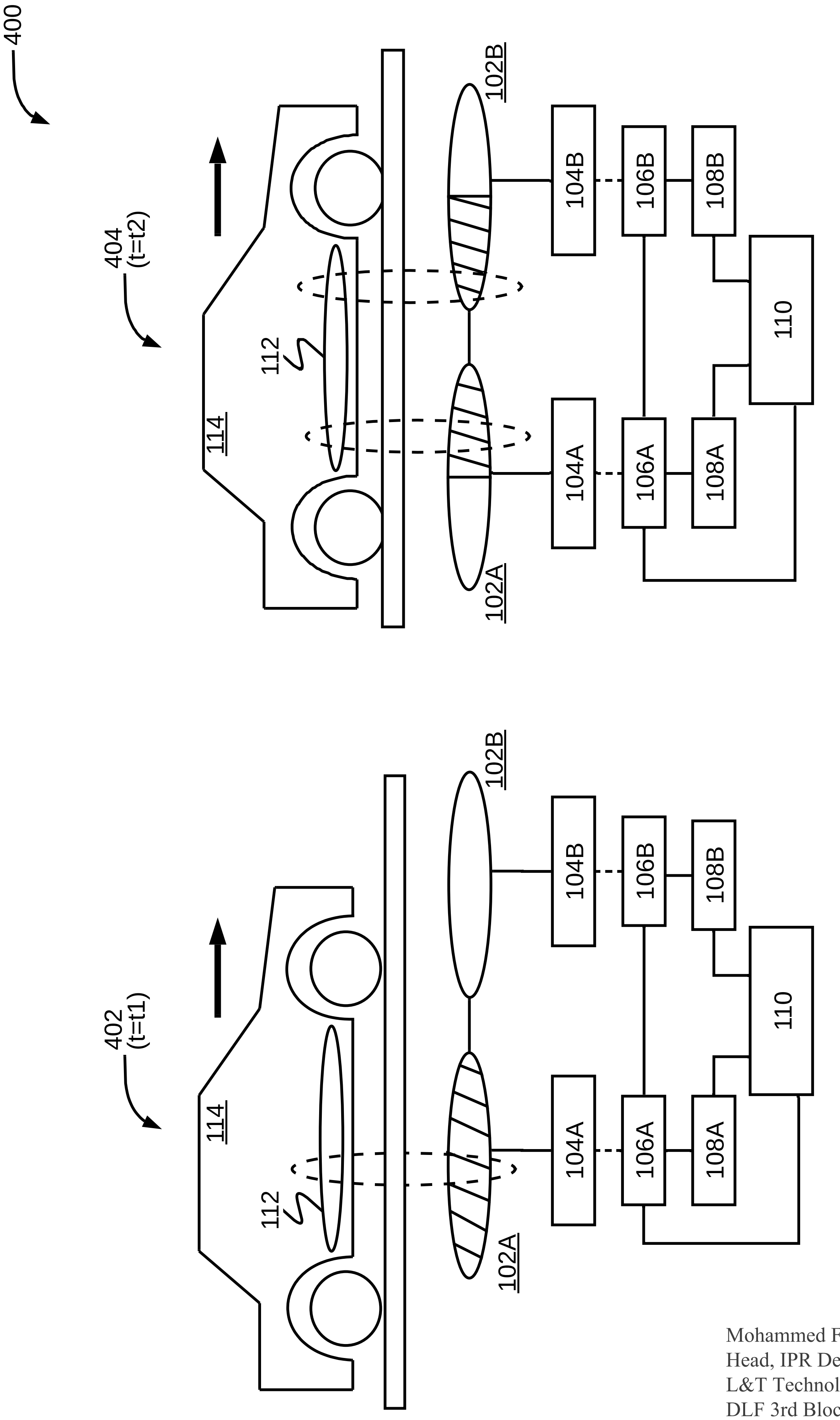


FIG. 4

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.

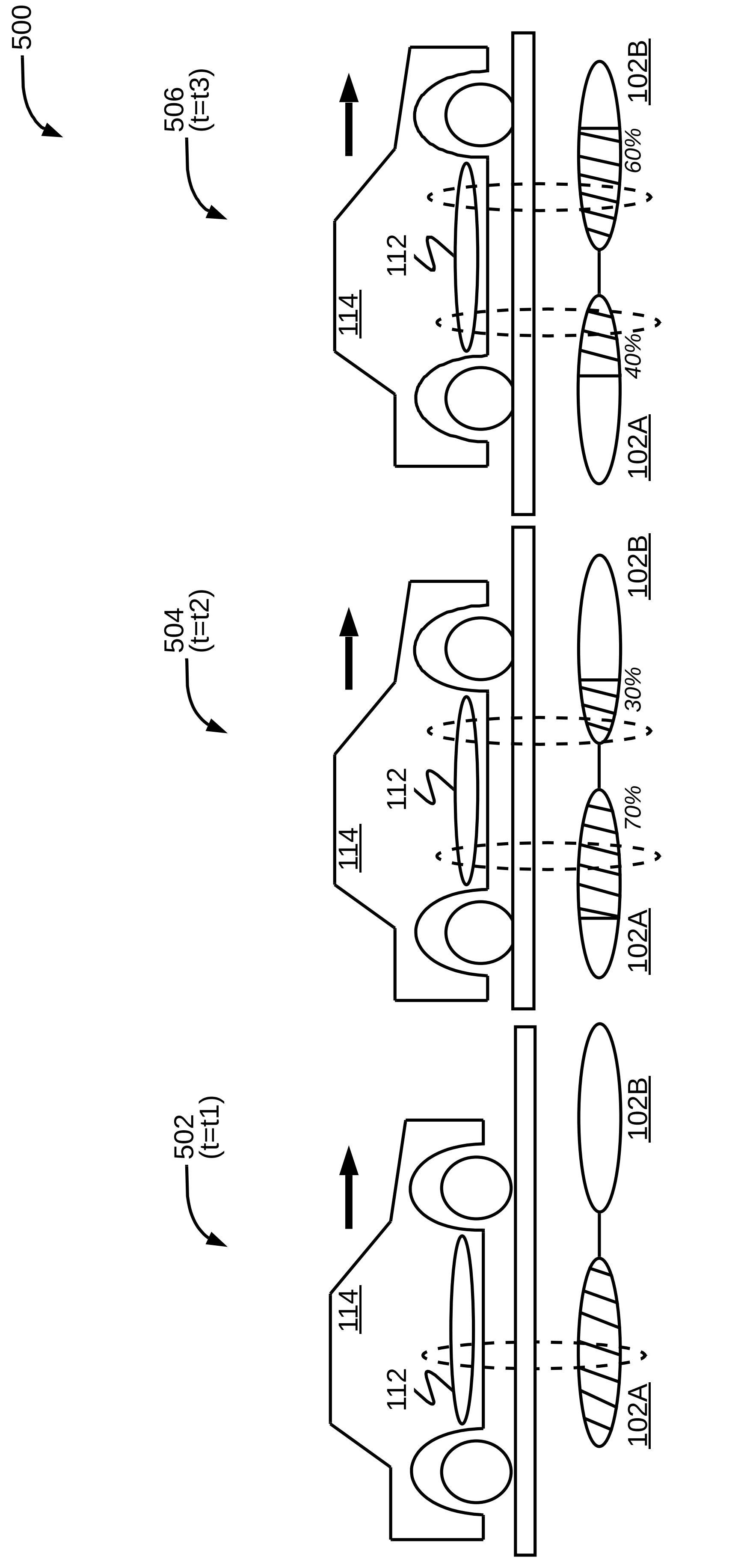


FIG. 5

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.

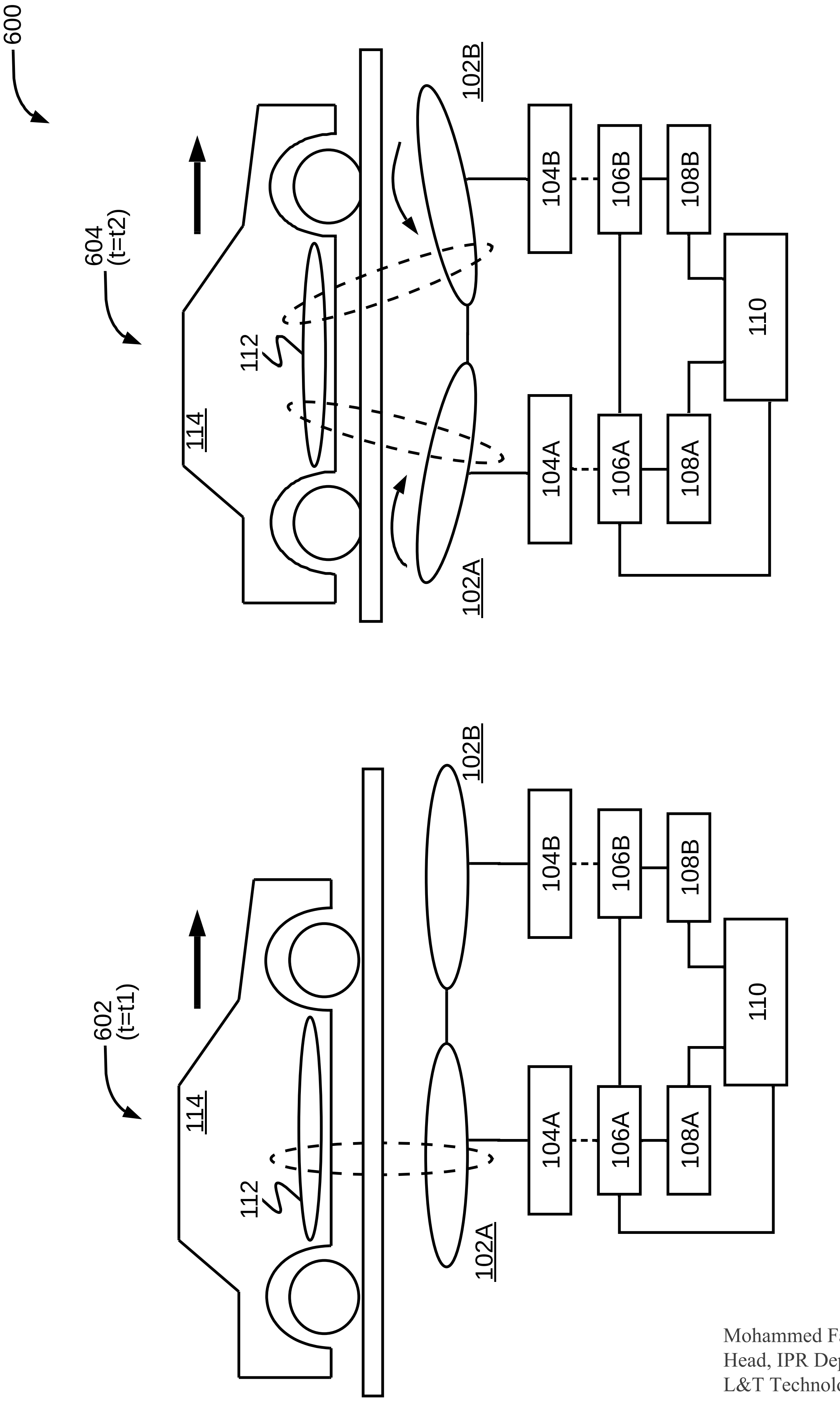


FIG. 6

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.

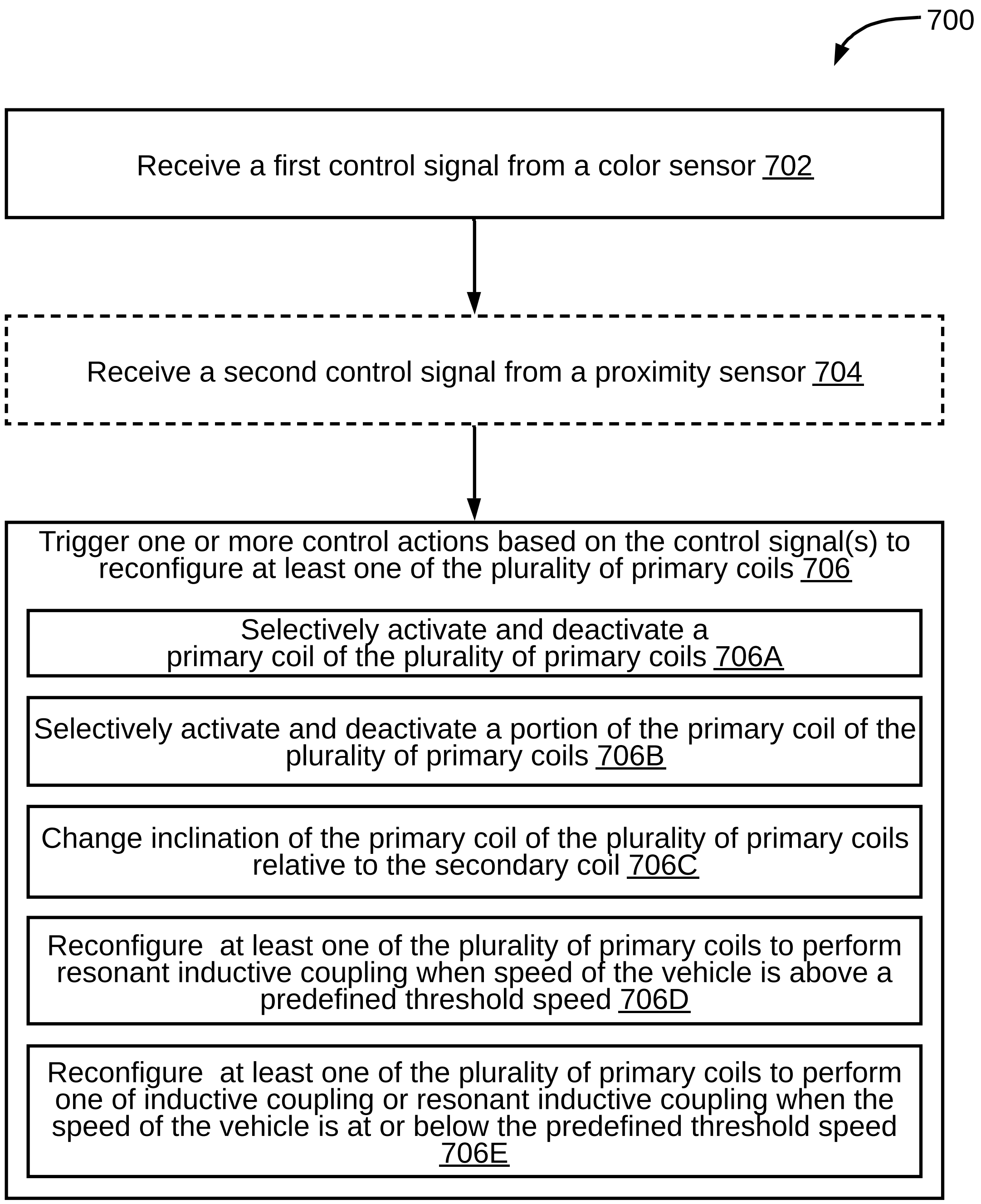


FIG. 7

Mohammed Faisal (INPA No: 1941)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai - 600089.