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Konet et al.

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(54) **ALIGNMENT METHOD FOR A VEHICLE WIRELESS CHARGING STRUCTURE**

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B60L 11/18 (2006.01)

(52) **U.S. Cl.**
CPC ***B60L 11/1831*** (2013.01); ***B60L 11/182*** (2013.01); ***B60L 11/1833*** (2013.01)

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CPC .. H02J 7/025; H02J 5/005; H02J 7/355; H02J 7/0042
USPC 320/104, 107, 108, 109; 307/104
See application file for complete search history.

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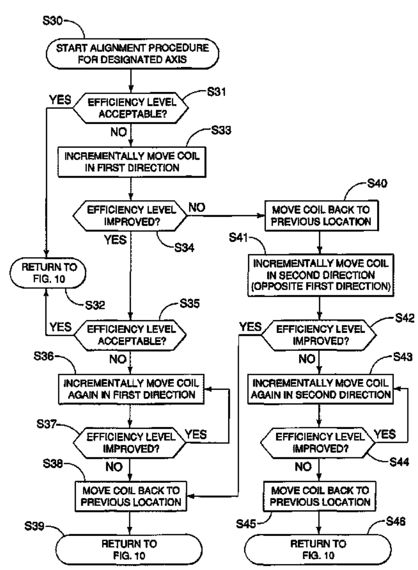
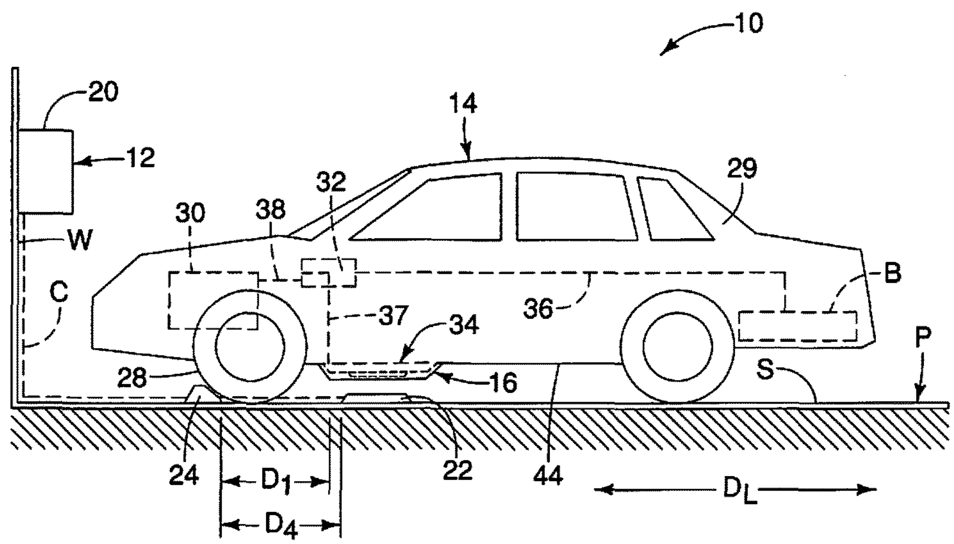
(57) **ABSTRACT**

An alignment method for a vehicle wireless charging system, that includes detecting reception of electromagnetic radiation received by a vehicle-side coil from a transmitter coil with the vehicle-side coil at a current position relative to the transmitter coil. Other steps include determining efficiency of electromagnetic radiation reception by the vehicle-side coil, and determining whether or not the efficiency of electromagnetic radiation reception by the vehicle-side coil achieves a predetermined level of reception efficiency. Further steps include repositioning the vehicle-side coil in response to determining that the efficiency of the electromagnetic radiation reception is less than the predetermined level of reception efficiency, and repeating the determining of the efficiency of electromagnetic radiation reception and the repositioning the vehicle-side coil until the determined efficiency is equal to or greater than the predetermined level of reception efficiency.

19 Claims, 11 Drawing Sheets

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20
12
14
29
32
30
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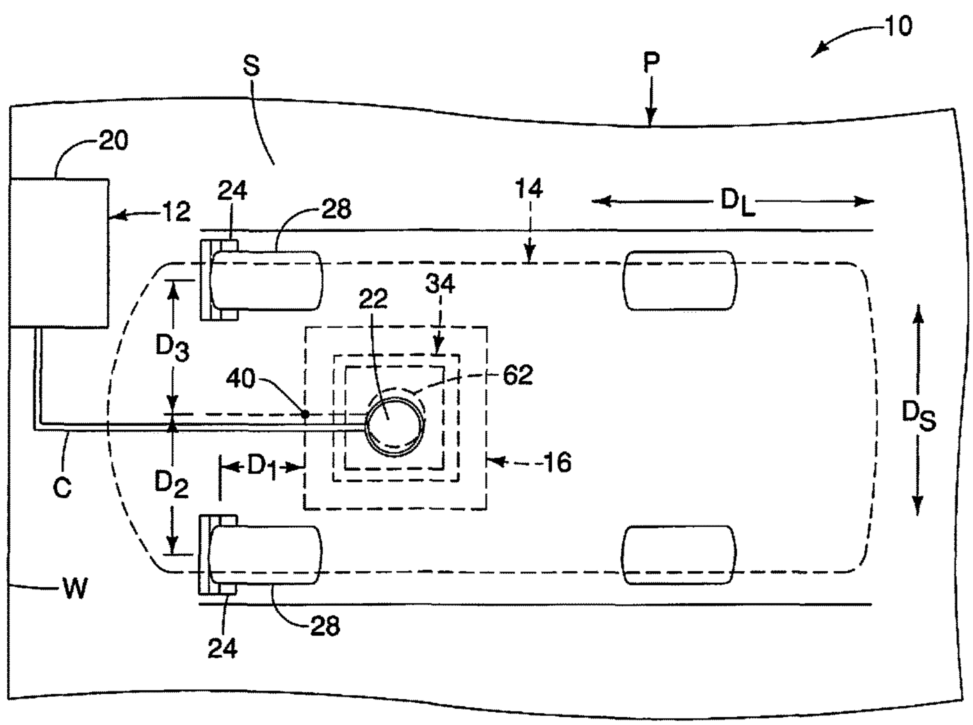
34
36
P
28
16
S
24
22
44
D_1
D_L
D_4

FIG. 1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C
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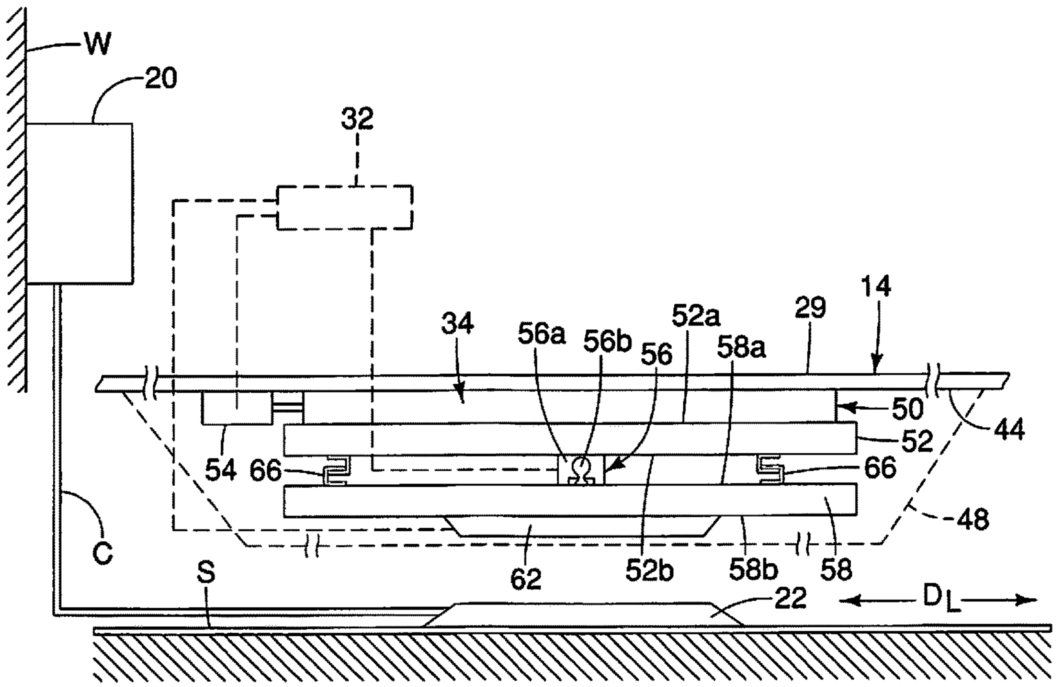
W
24
28

FIG. 2


W
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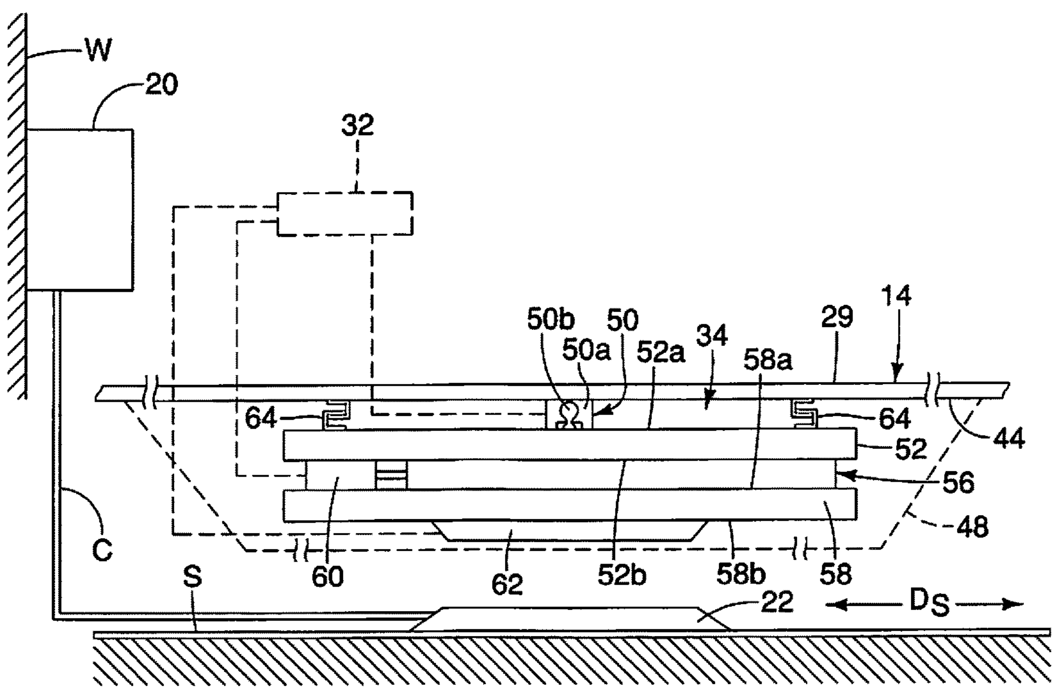
32
14
52a
29
34
56a
56b
56
58a
50
52
54
66
66
48
C
62
52b
58b
58
S
22
DL
44

FIG. 3


W
20
32
14
29
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50
50a
52a
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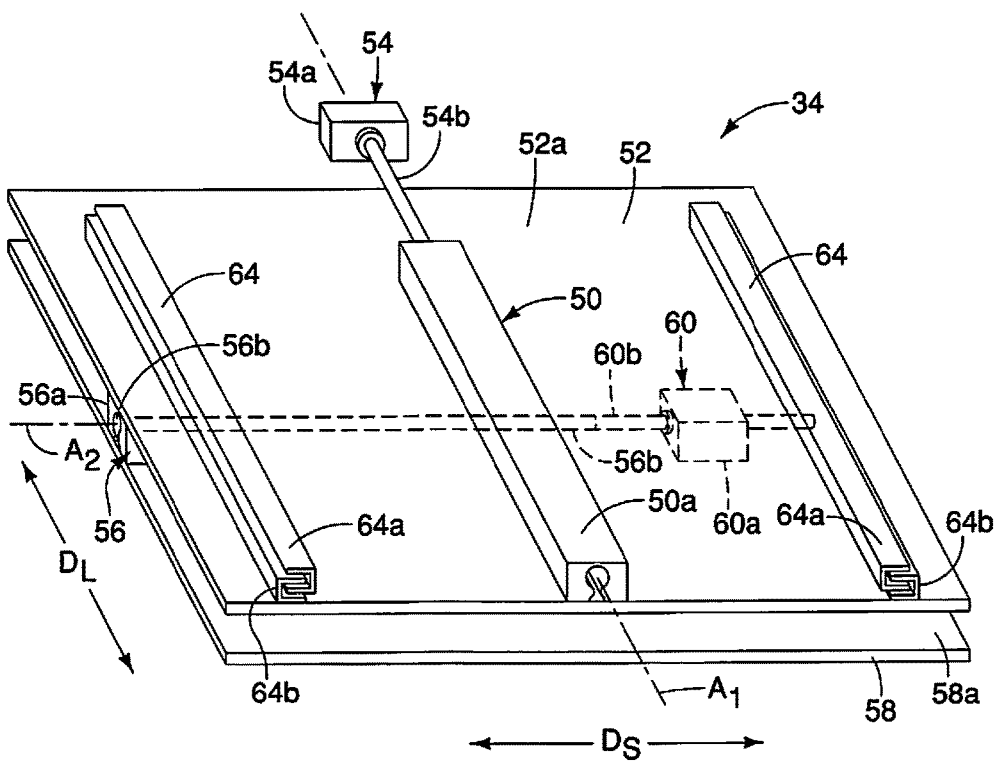
C
60
62
52b
58b
58
S
22
DS

FIG. 4


54
54a
54b
34
52a
52
64
64
50
60
56b
60b
56a
A2
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60a
50a
64a
64a
64b
DL
64b
A1
58
58a
DS

FIG. 5

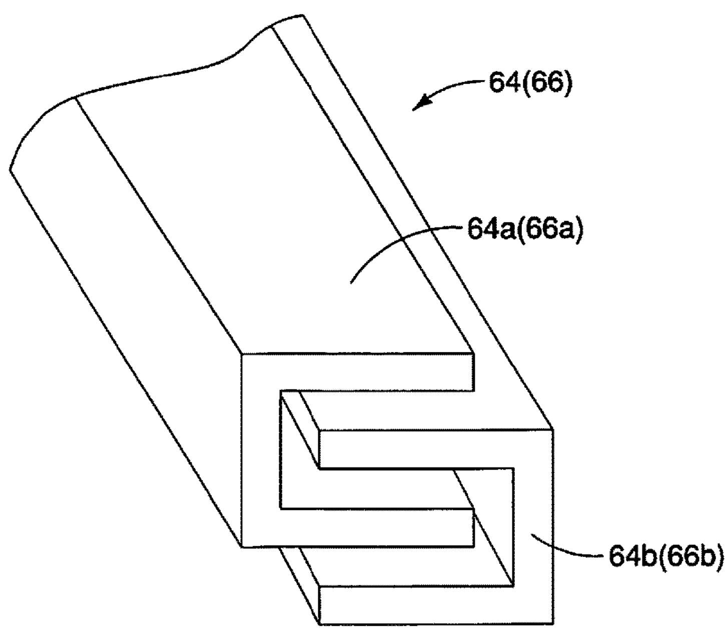
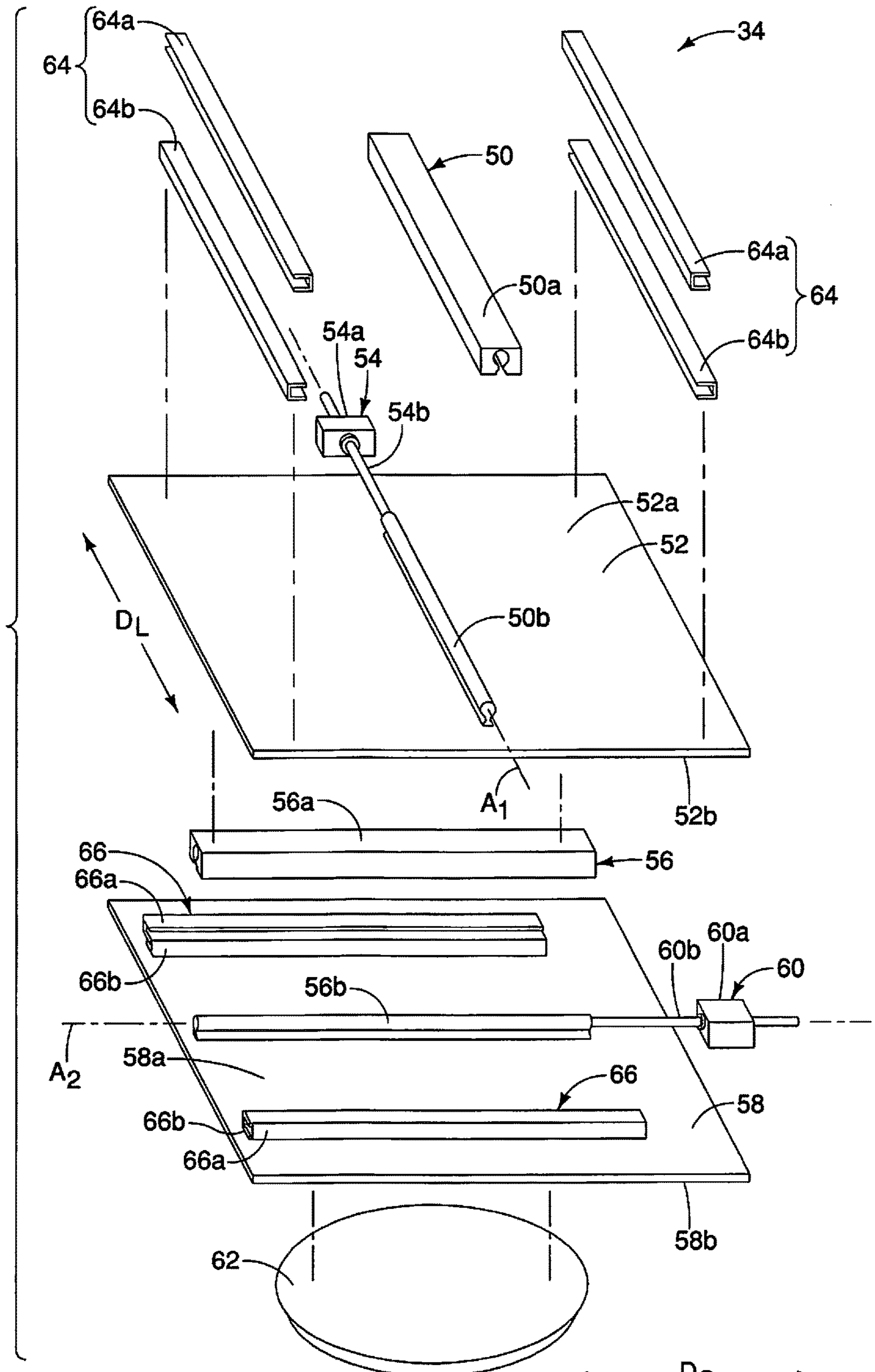

64(66)
64a(66a)
64b(66b)

FIG. 6


64a
64
64b
34
50
64a
50a
64
54a
54
64b
54b
52a
52
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50b
A_1
52b
56a
66
56
66a
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66a
58b
62
D_S

FIG. 7

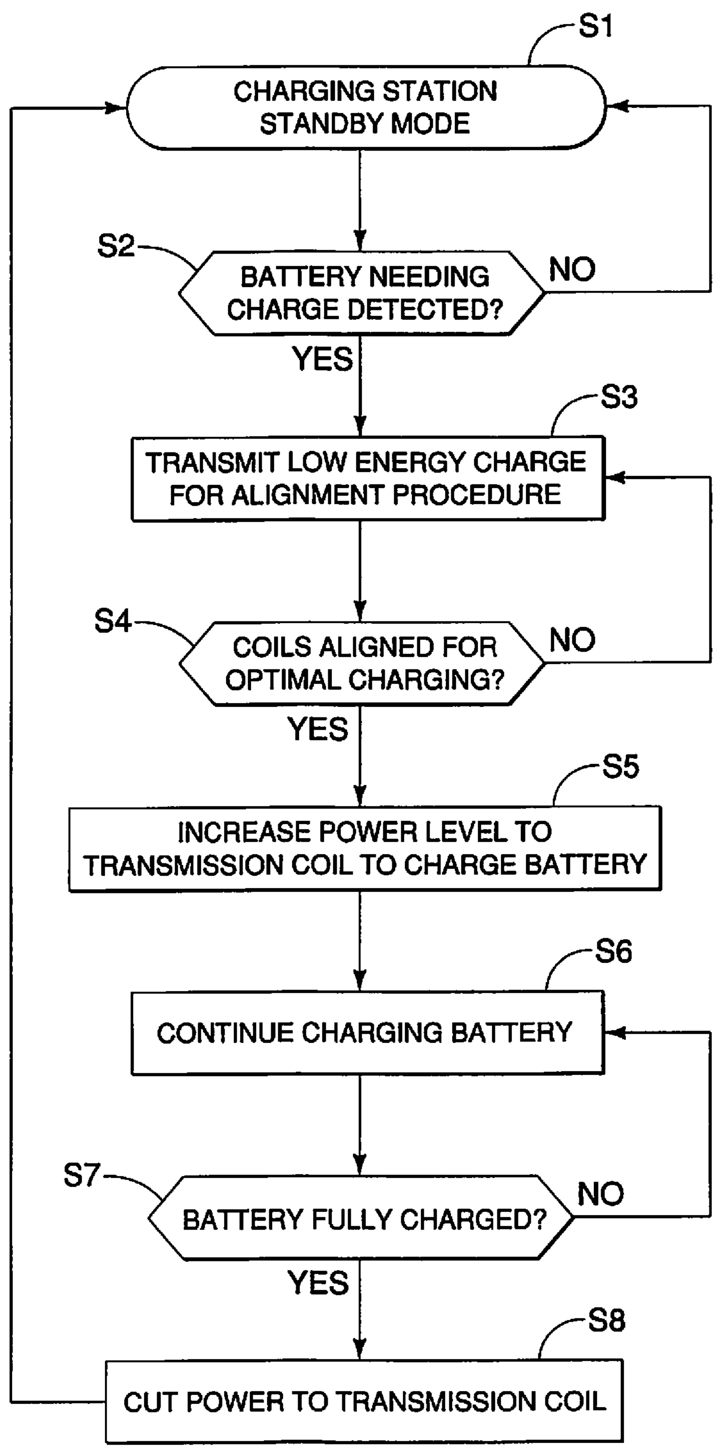

S1
CHARGING STATION STANDBY MODE
S2
BATTERY NEEDING CHARGE DETECTED?
NO
YES
S3
TRANSMIT LOW ENERGY CHARGE FOR ALIGNMENT PROCEDURE
S4
COILS ALIGNED FOR OPTIMAL CHARGING?
NO
YES
S5
INCREASE POWER LEVEL TO TRANSMISSION COIL TO CHARGE BATTERY
S6
CONTINUE CHARGING BATTERY
S7
BATTERY FULLY CHARGED?
NO
YES
S8
CUT POWER TO TRANSMISSION COIL

FIG. 8

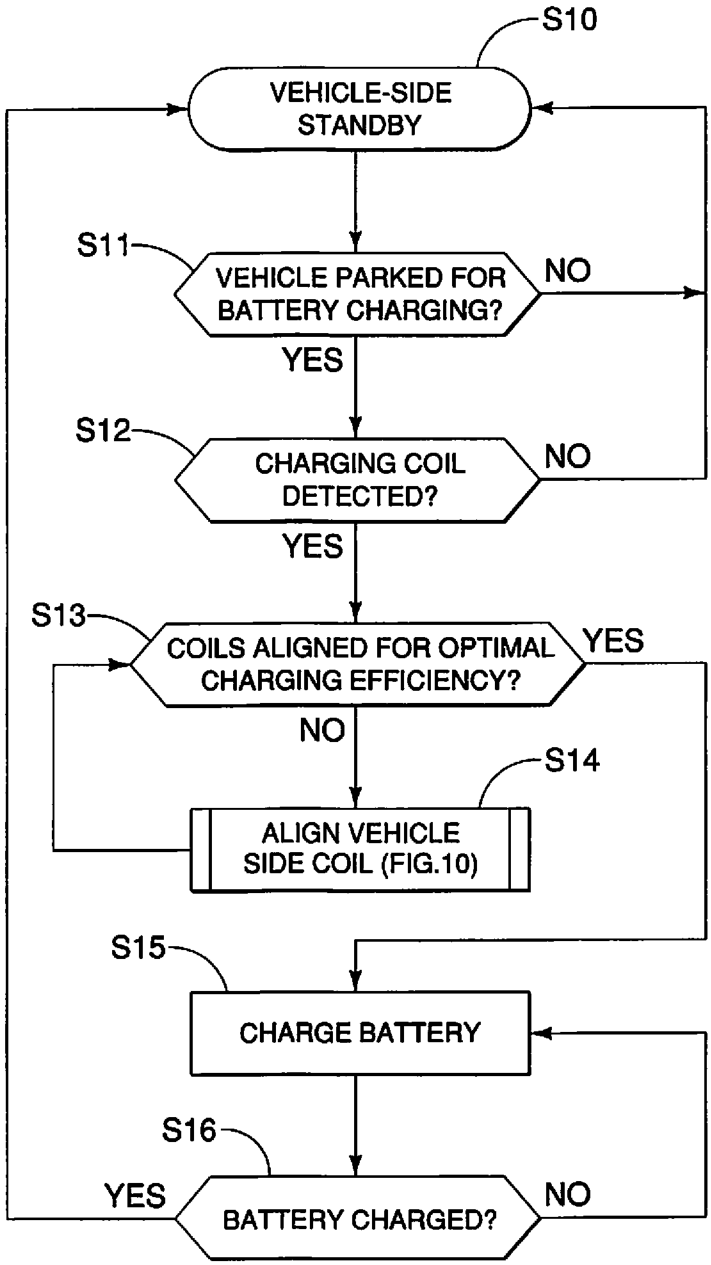

S10
VEHICLE-SIDE STANDBY
S11
VEHICLE PARKED FOR BATTERY CHARGING?
NO
YES
S12
CHARGING COIL DETECTED?
NO
YES
S13
COILS ALIGNED FOR OPTIMAL CHARGING EFFICIENCY?
YES
NO
S14
ALIGN VEHICLE SIDE COIL (FIG.10)
S15
CHARGE BATTERY
S16
YES
BATTERY CHARGED?
NO

FIG. 9

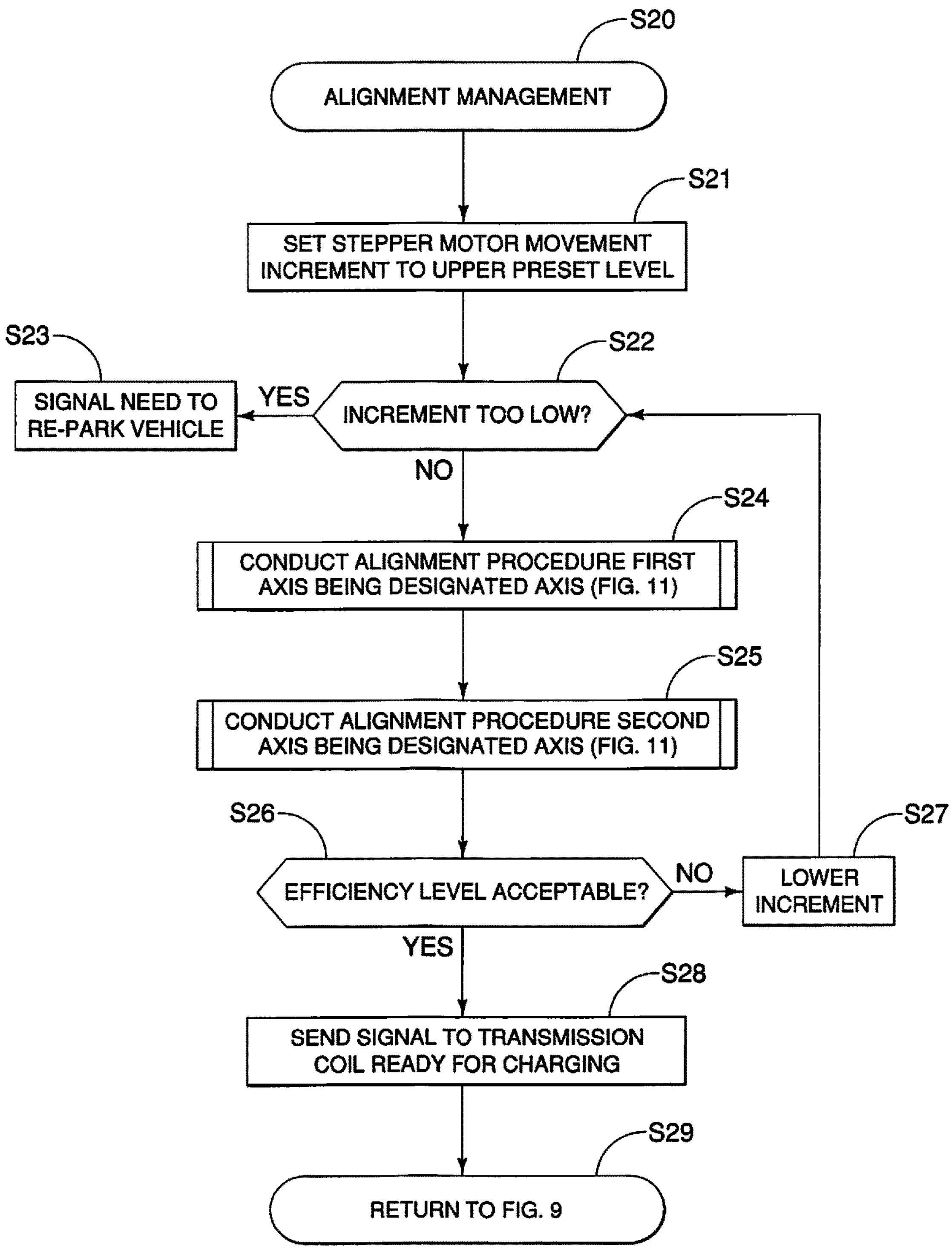

S20
ALIGNMENT MANAGEMENT
S21
SET STEPPER MOTOR MOVEMENT INCREMENT TO UPPER PRESET LEVEL
S23
SIGNAL NEED TO RE-PARK VEHICLE
YES
S22
INCREMENT TOO LOW?
NO
S24
CONDUCT ALIGNMENT PROCEDURE FIRST AXIS BEING DESIGNATED AXIS (FIG. 11)
S25
CONDUCT ALIGNMENT PROCEDURE SECOND AXIS BEING DESIGNATED AXIS (FIG. 11)
S26
EFFICIENCY LEVEL ACCEPTABLE?
NO
S27
LOWER INCREMENT
YES
S28
SEND SIGNAL TO TRANSMISSION COIL READY FOR CHARGING
S29
RETURN TO FIG. 9

FIG. 10

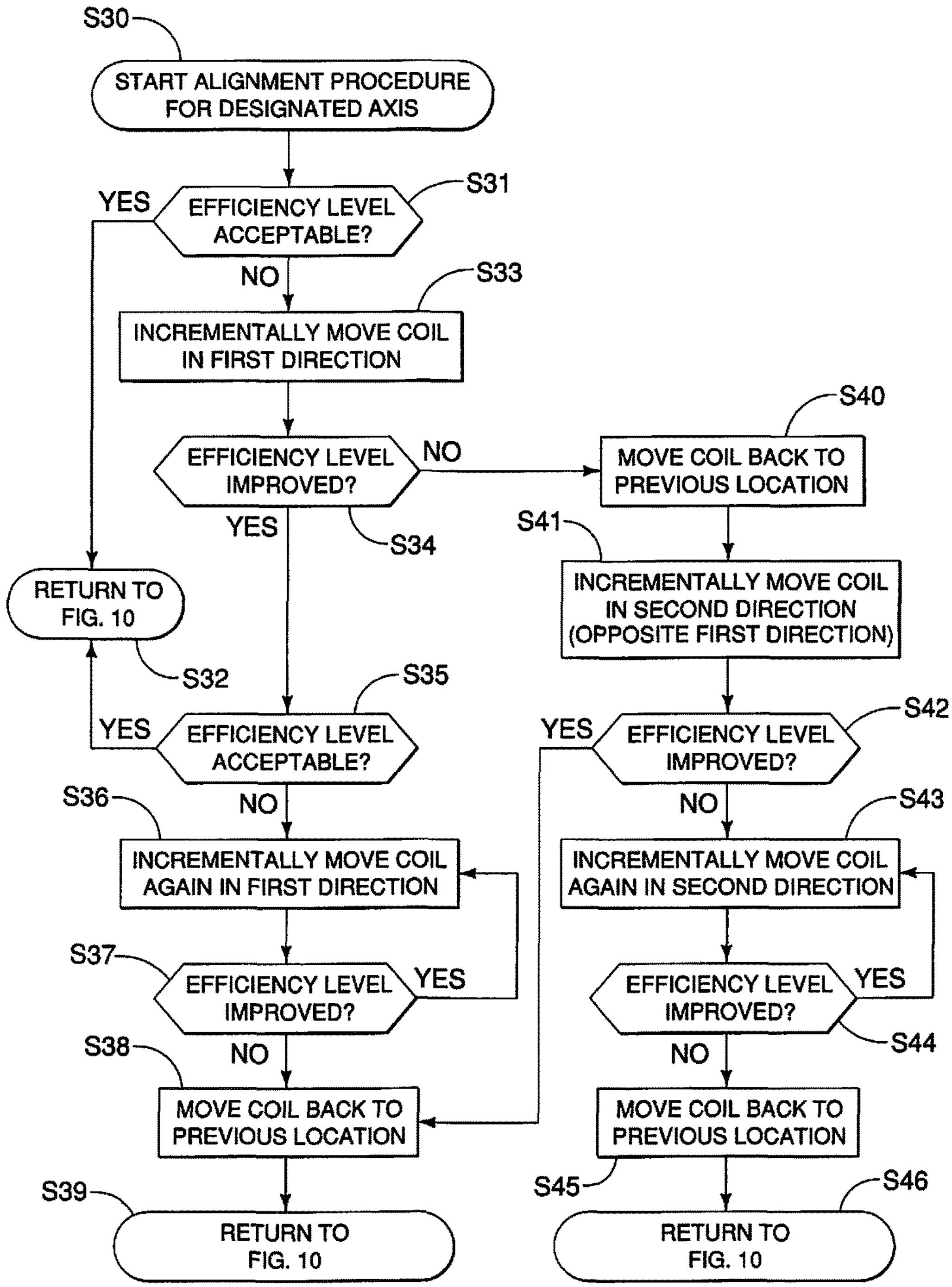

S30
START ALIGNMENT PROCEDURE FOR DESIGNATED AXIS
S31
EFFICIENCY LEVEL ACCEPTABLE?
YES
NO
S33
INCREMENTALLY MOVE COIL IN FIRST DIRECTION
EFFICIENCY LEVEL IMPROVED?
NO
YES
S34
S40
MOVE COIL BACK TO PREVIOUS LOCATION
S41
INCREMENTALLY MOVE COIL IN SECOND DIRECTION (OPPOSITE FIRST DIRECTION)
RETURN TO FIG. 10
S32
S35
EFFICIENCY LEVEL ACCEPTABLE?
YES
NO
S42
EFFICIENCY LEVEL IMPROVED?
YES
NO
S36
INCREMENTALLY MOVE COIL AGAIN IN FIRST DIRECTION
S43
INCREMENTALLY MOVE COIL AGAIN IN SECOND DIRECTION
S37
EFFICIENCY LEVEL IMPROVED?
YES
NO
EFFICIENCY LEVEL IMPROVED?
YES
S44
NO
S38
MOVE COIL BACK TO PREVIOUS LOCATION
MOVE COIL BACK TO PREVIOUS LOCATION
S39
RETURN TO FIG. 10
S45
S46
RETURN TO FIG. 10

FIG. 11

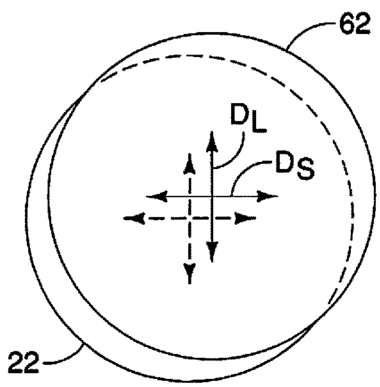


FIG. 12a

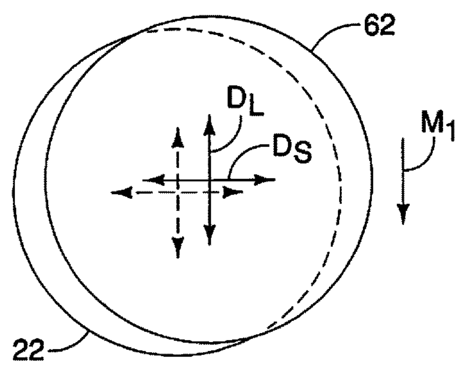


FIG. 12b

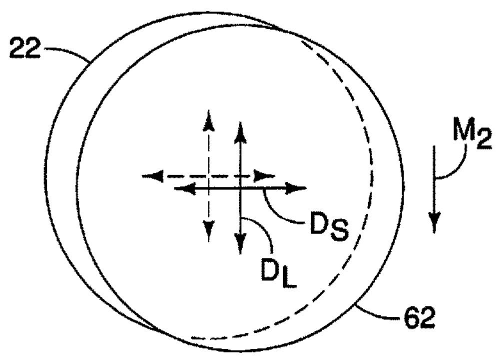


FIG. 12c

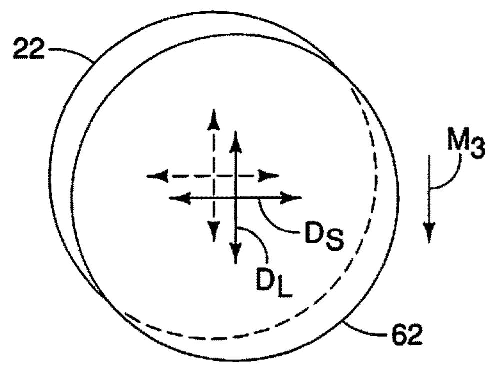


FIG. 12d

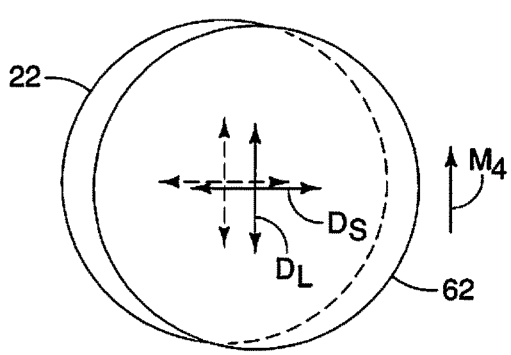


FIG. 12e

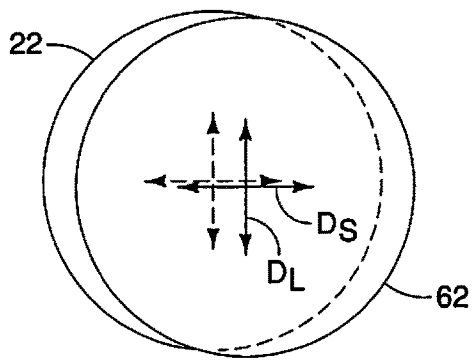


FIG. 13a

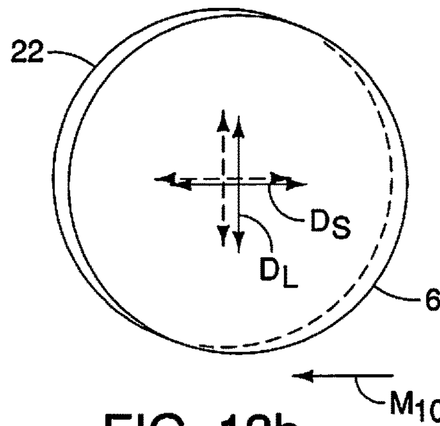


FIG. 13b

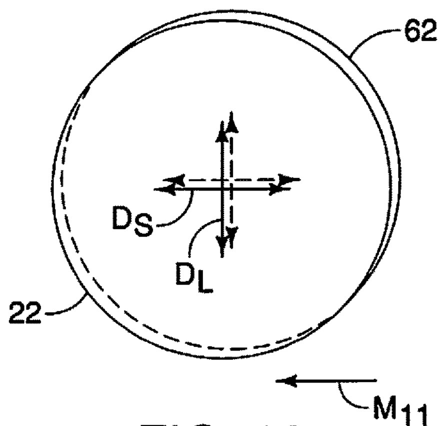


FIG. 13c

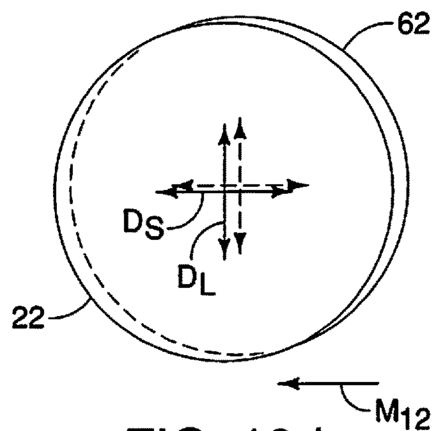


FIG. 13d

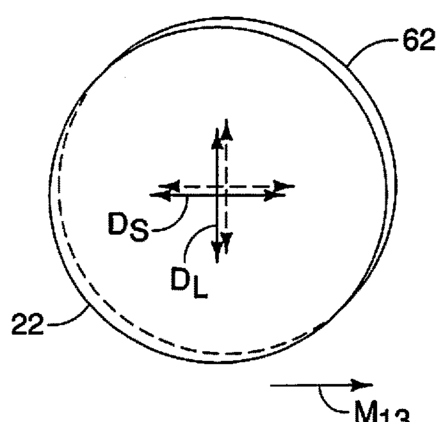
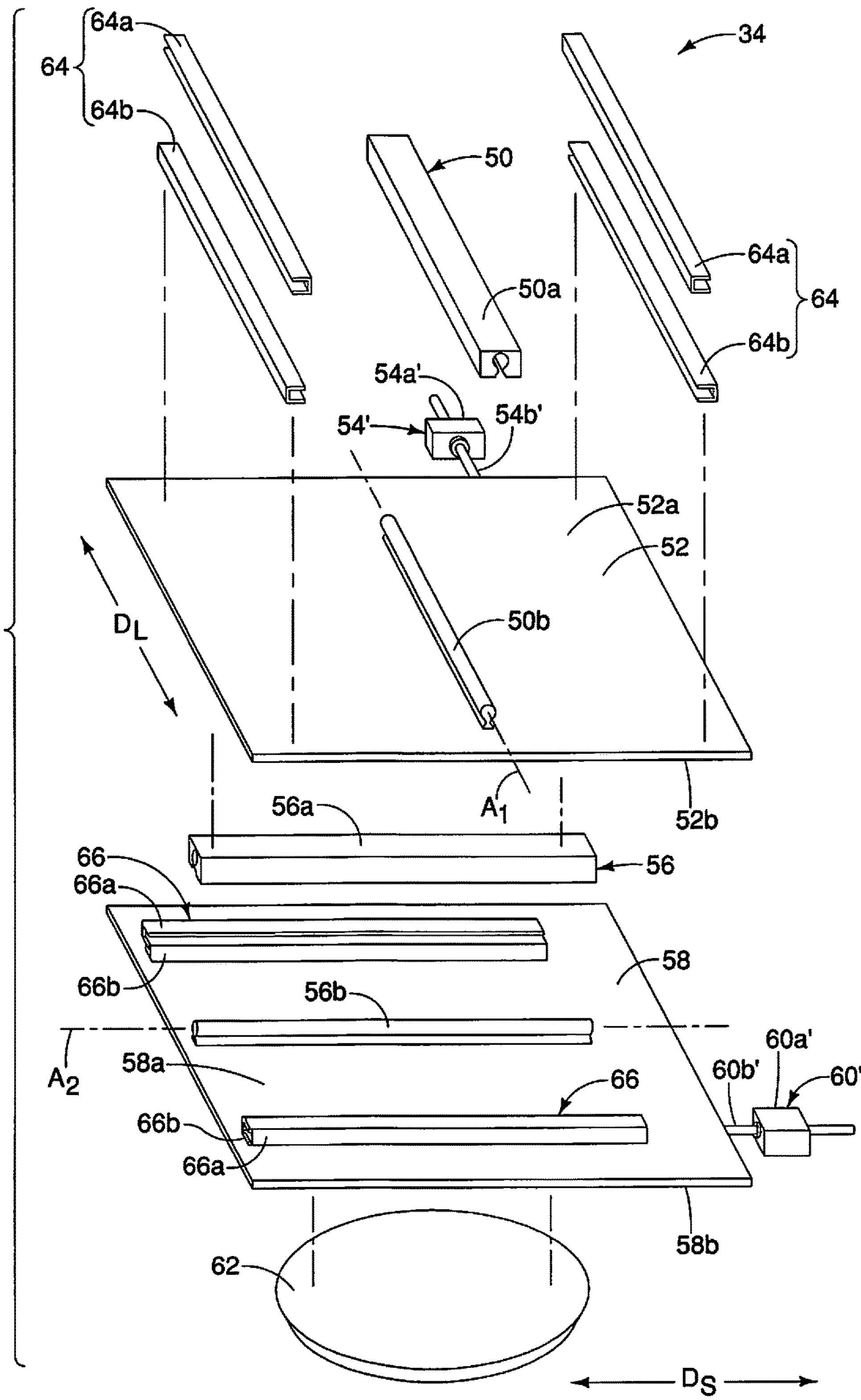


FIG. 13e


64a
64
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34
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64a
64
50a
64b
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54'
54b'
52a
52
DL
50b
A1
52b
56a
56
66
66a
58
66b
56b
60a'
A2
58a
60b'
60'
66
66b
66a
58b
62
DS

FIG. 14

ALIGNMENT METHOD FOR A VEHICLE WIRELESS CHARGING STRUCTURE

BACKGROUND

Field of the Invention

The present invention generally relates to an alignment method for a vehicle wireless charging structure. More specifically, the present invention relates to a method for aligning a vehicle-side induction coil with a fixed transmission coil in order charge a battery of the vehicle with optimal efficiency.

Background Information

A vehicle wireless charging system includes a charging station that is typically installed with a garage or carport and includes a transmission coil configured to emit electromagnetic radiation received by a receiving coil on a vehicle for purposes of recharging a battery of the vehicle. Such wireless systems typically include a positioning mechanism as a part of the charging station for aligning the transmission coil with the receiving coil on the vehicle after the vehicle has been parked within the garage or carport. A problem with such an arrangement is that when the receiving coil is located along an underside of the vehicle, the transmission coil and its positioning structure must be installed below an exposed surface of a floor of the garage or carport. The installation of the transmission coil and positioning structure below the level of the floor of the charging station can be costly and difficult.

SUMMARY

One aspect of the current disclosure is to provide a receiving coil installed to an underside of the vehicle that includes an alignment assembly with methodology for automatically aligning the receiving coil with a floor mounted transmission coil once the vehicle has been parked above the transmission coil.

In view of the state of the known technology, one aspect of the present disclosure is to provide an alignment method with a vehicle wireless charging system. The method includes detecting reception of electromagnetic radiation received by a vehicle-side coil from a transmitter coil with the vehicle-side coil at a current position relative to the transmitter coil. The method further includes determining efficiency of electromagnetic radiation reception by the vehicle-side coil, and determining whether or not the efficiency of electromagnetic radiation reception by the vehicle-side coil achieves a predetermined level of reception efficiency. The method further includes repositioning the vehicle-side coil in response to determining that the efficiency of the electromagnetic radiation reception is less than the predetermined level of reception efficiency, and repeating the determining of the efficiency of electromagnetic radiation reception and the repositioning the vehicle-side coil until the determined efficiency is equal to or greater than the predetermined level of reception efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the attached drawings which form a part of this original disclosure:

FIG. **1** is a side schematic view of a vehicle wireless charging structure including a transmission charging assembly and a vehicle, the transmission charging assembly having a power controller and a transmission coil installed to respective surfaces of a parking area, the vehicle having an

alignment assembly with a controller and a vehicle-side induction coil (a reception coil) in accordance with a first embodiment;

FIG. **2** is a top schematic view of the vehicle wireless charging structure showing the power controller and the transmission coil of the transmission charging assembly installed within the parking area, and showing the vehicle-side induction coil and the controller of the alignment assembly of the vehicle in phantom overlaying the transmission coil in accordance with the first embodiment;

FIG. **3** is a side schematic view of a portion of the vehicle wireless charging structure showing the alignment assembly with the vehicle-side induction coil located above the transmission coil in accordance with the first embodiment;

FIG. **4** is a front schematic view of the portion of the vehicle wireless charging structure shown in FIG. **3**, showing the alignment assembly with the vehicle-side induction coil located above the transmission coil in accordance with the first embodiment;

FIG. **5** is a perspective view of the alignment assembly shown removed from the vehicle showing a first track structure and linear support structures that support a first shield plate to an underside surface of the vehicle in accordance with the first embodiment;

FIG. **6** is a perspective view of one of the linear support structures of the alignment assembly shown removed from the alignment assembly in accordance with the first embodiment;

FIG. **7** is an exploded perspective view of the alignment assembly showing the first track structure, a pair of linear support structures, a first positioning device, the first shield plate, a second track structure, another pair of linear support structures, a second positioning device, a second shield plate and the vehicle-side induction coil in accordance with the first embodiment;

FIG. **8** is a flowchart depicting operational steps performed by the power controller of the transmission charging assembly during operation of the transmission coil in accordance with the first embodiment;

FIG. **9** is a flowchart depicting operational steps performed by the controller of the vehicle in determining whether or not a battery of the vehicle needs to be charged and whether or not the vehicle is parked above the transmission coil in accordance with the first embodiment;

FIG. **10** is a flowchart depicting operational steps performed by the controller of the vehicle in preparation for aligning the vehicle-side induction coil with the transmission coil in accordance with the first embodiment;

FIG. **11** is a flowchart depicting operational steps performed by the controller of the vehicle in the aligning of the vehicle-side induction coil with the transmission coil prior to charging of the battery in accordance with the first embodiment;

FIGS. **12***a* thru **12***e* are schematic views showing movement of the vehicle-side induction coil as performed by the controller in the steps depicted in FIG. **11** along a first axis (in a vehicle longitudinal direction) in accordance with the first embodiment;

FIGS. **13***a* thru **13***e* are further schematic views showing movement of the vehicle-side induction coil as performed by the controller in the steps depicted in FIG. **11** along a second axis (in a vehicle lateral direction) perpendicular to the first axis in accordance with the first embodiment; and

FIG. **14** is an exploded perspective view of an alignment assembly showing a first track structure, a pair of linear support structures, a first positioning device, a first shield plate, a second track structure, another pair of linear support structures, a second positioning device, a second shield plate and a vehicle-side induction coil in accordance with a second embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

Selected embodiments will now be explained with reference to the drawings. It will be apparent to those skilled in the art from this disclosure that the following descriptions of the embodiments are provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

Referring initially to FIG. **1**, a wireless charging structure **10** that includes a transmission charging assembly **12** and a vehicle **14** having a reception charging assembly **16** is illustrated in accordance with a first embodiment.

The wireless charging structure **10** is designed such that when the vehicle **14** is parked above a portion of the transmission charging assembly **12**, a battery B within the vehicle **14** can be charged. The vehicle **14** includes structure that automatically aligns the reception charging assembly **16** with the transmission charging assembly **12** such that transmission of energy from the transmission charging assembly **12** to the reception charging assembly **16** is optimized, thereby improving the process of re-charging the battery B, as is described in greater detail below.

As shown in FIGS. **1** and **2**, the transmission charging assembly **12** includes elements that are installed in a parking area P dimensioned to receive the vehicle **14**. The parking area P can be a driveway, a private garage space, a commercial garage space or carport and includes a horizontally oriented surface S and a vertical wall W. It should be understood from the drawings and the description herein that the surface S can be a level surface, but a level orientation is not required. The transmission charging assembly **12** can alternatively be installed to a parking area with a surface S that has a slight incline. In the depicted embodiment, the surface S is depicted as being level. The parking area P includes a space sufficiently large to receive the vehicle **14**.

As is further shown in FIGS. **1** and **2**, the transmission charging assembly **12** includes a power controller **20**, a transmission coil **22**, a pair of wheel chocks or stops **24** and a cable C connecting the power controller **20** to the transmission coil **22**. In the depicted embodiment, the power controller **20** is mounted to the vertical wall W. Alternatively the power controller **20** can be located remote relative to the parking area P, or can be a free-standing unit connected to household circuitry. For example, the power controller **20** can be installed in a closet, basement area or other enclosed area (not shown) remote from the parking area P. Further, the power controller **20** can be installed as a free-standing recharging station located in a commercial parking area with a dedicated parking space adjacent thereto.

The power controller **20** of the transmission charging assembly **12** includes a power supply (not shown) connected to, for example, a commercial electricity power source that is preferably 220 volts AC, but can provide current at voltage levels greater or less than 220 volts, depending upon available electric power. The power controller **20** also includes circuitry and pre-programmed control logic that enables the power controller **20** to wirelessly communicate with the reception charging assembly **16** of the vehicle **14** in a manner described in greater detail below.

The transmission coil **22** is fixedly and non-movably attached to the surface S within the parking area P at a predetermined location. The stops **24** are also fixedly attached to surface S of the parking area P, but can be configured for removal and repositioning. The stops **24** are installed to the surface S of the parking area P in predetermined locations relative to the transmission coil **22** and relative to the location of the reception charging assembly **16** of the vehicle **14**. Specifically, the stops **24** are positioned relative to the transmission coil **22** such that when the vehicle **14** is driven into the parking area P, front wheels **28** of the vehicle contact the stops **24** thereby restricting further movement of the vehicle **14**, thereby assisting the vehicle operator during parking maneuvers of the vehicle **14** such that the vehicle **14** is parked in or close to a predetermined location. This predetermined location is such that portions of the reception charging assembly **16** of the vehicle **14** are located above the transmission coil **22** in an approximate alignment position once parked. An example of the approximate alignment position is depicted in, for example, FIG. **12***a* and is described in greater detail below. As shown in FIG. **2**, the parking area P can also include lines that assist the vehicle operator in positioning of the vehicle **14** in the parking area.

As shown in FIG. **1**, the vehicle **14** includes a vehicle body structure **29**, a power plant **30**, the battery B and the reception charging assembly **16**. The reception charging assembly **16** includes a controller **32**, an alignment assembly **34** and cables **36**, **37** and **38**. The cable **36** connects the reception charging assembly **16** with the controller **32**. The cable **37** connects the controller **32** with the power plant **30** and the cable **38** connects the battery B with the controller **32** and the power plant **30**.

The power plant **30** is supported in a conventional manner within the vehicle body structure **20** and includes an electric motor that provides rotary power to the vehicle **14** in a conventional manner. Since electric motors for vehicles are conventional vehicle devices, further description is omitted for the sake of brevity. Alternatively, the power plant **30** can be a hybrid motor that includes an internal combustion engine that operates in concert with an electric motor in a conventional manner. The power plant **30** receives electric power from the battery B in a conventional manner.

The battery B is a rechargeable battery that is recharged by the reception charging assembly **16** in a manner described in greater detail below. Although not shown, the battery B can also be recharged via an electric connector (not shown) provided on the vehicle **14** such that the battery B is recharged via a direct electrical connection via the controller **32** and the electric connector. However, in the depicted embodiment, the battery B is primarily recharged via the wireless charging structure **10**, where electromagnetic energy is transmitted by the transmission coil **22** and is received by the reception charging assembly **16** of the vehicle **14** in a manner described in greater detail below.

The controller **32** includes voltage convertor circuit that converts alternating current transmitted by the transmission coil **22** into direct current used to charge the battery B. The controller **32** also includes circuitry (such as a microcomputer) that is programmed to operate the reception charging assembly **16** during an alignment process that is described in greater detail below. The circuitry of the controller **32** is also configured to communicate with the power controller **20** of the transmission charging assembly **12** via any of a plurality of communication methods and structures. For example, the power controller **20** and the controller **32** can each include wireless communication devices such as Bluetooth® devices, Wi-Fi devices, or can be configured to wirelessly communicate with one another via transmissions between the transmission coil **22** and the reception charging assembly **16**. Since such wireless communication capabilities are conventional technologies, further description is omitted for the sake of brevity.

As shown in FIGS. **1** and **2**, the alignment assembly **34** is mounted directly to the vehicle **14**. In the depicted embodiment, the alignment assembly **34** is mounted to the underside of the vehicle **14**, but can alternatively be mounted within the body structure of the vehicle **14**, so long as the alignment assembly **34** is mounted to a location of the vehicle **14** that does not interfere with reception of electromagnetically transmitted energy from the transmission coil **22**.

In the depicted embodiment, the alignment assembly **34** is fixedly attached to the underside of the vehicle **14**. The alignment assembly **34** is centrally located beneath, for example, the front seats (not shown) of the vehicle **14**. It should be understood from the drawings and the description herein that the actual installed location of the alignment assembly **34** can vary from vehicle to vehicle and is not limited to the depicted location. For example, the alignment assembly **34** can alternatively be installed to a front end, a rear end, a side panel or the roof panel of the vehicle **14** with the transmission coil **22** being installed to an appropriate corresponding location within the parking area P.

One aspect of the actual location of the alignment assembly **34** with respect to the vehicle **14**, is the location of the front wheels **28** relative to a reference point **40** on the alignment assembly **34**. For purposes of understanding the wireless charging structure **10**, the reference point **40** is a point along the front edge of the alignment assembly **34** that is centrally located with respect to the alignment assembly **34**. However, it should be understood from the drawings and the description herein, that the reference point **40** is an arbitrary point chosen for the expressed purpose of proper installation of elements of the wireless charging structure **10** with respect to one another, and is not an absolute fixed location.

A first distance D_1 is defined in a vehicle longitudinal direction D_L between a lower tread portion of the front wheels **28** and the reference point **40**. Second and third distances D_2 and D_3 are defined in vehicle lateral directions Ds (laterally side to side relative to the vehicle **14**) between a center of respective ones of the front wheels **28** of the vehicle **14** and the reference point **40**.

Further, the transmission coil **22** is provided with a similar reference point at a front edge thereof. In FIG. **2** the reference point **40** of the alignment assembly **34** and a reference point of the transmission coil **22** coincide. Therefore, only the reference point **40** is visible in FIG. **2**. When the transmission coil **22** and the stops **24** are installed to the surface S of the parking area P, the first, second and third distances D_1, D_2 and D_3 are used to position the transmission coil **22** and the stops **24** relative to one another.

Specifically, the relative positioning of the transmission coil **22** and the stops **24** is directly determined by the distances between the alignment assembly **34** and the front wheels **28** and relative to parking lines on the surface S of the parking area P. The stops **24** are installed to the surface S with a distance in the vehicle lateral direction Ls between respective centers thereof that is equal to the second distance D_2 plus the third distance D_3, as shown in FIG. **2**. Thereafter, the transmission coil **22** is positioned and fixedly installed with its front center (the reference point) being located in the vehicle lateral directions Ds the second distance D_2 from a first one of the front wheels **28** and is located the third distance D_3 from a second one of the front wheels **28**. Further, the transmission coil **22** is positioned relative to the vehicle longitudinal direction D_L with its front center (the reference point) being located the first distance D_1 from the surface of the stops **24**.

Consequently, when the vehicle **14** is parked on the surface S above the transmission coil **22**, with the front wheels **28** contacting the stops **24**, the alignment assembly **34** will be located above the transmission coil **22**. However, the location of the alignment assembly **34** may not be perfectly centered above the transmission coil **22** with the vehicle **14** parked due to the size of the vehicle **14** and the fact that the vehicle operator cannot see the alignment assembly **34** and the transmission coil **22** while parking the vehicle **14**. The final parked location of the vehicle **14** will likely vary slightly each time the vehicle **14** is driven and then returned and parked on the surface S. Therefore, once the vehicle **14** is parked, the alignment assembly **34** will overlap the transmission coil **22**, but will not necessarily be perfectly aligned therewith, for example, as depicted in FIG. **2**. If the alignment assembly **34** is not properly centered (or close to being centered within a predetermined tolerance) above the transmission coil **22**, then recharging efficiency may not be optimal. This situation is referred to as the above mentioned approximate alignment position, where the alignment assembly **34** is located above the transmission coil **22**, but is not precisely aligned within predetermined tolerances. Therefore, the alignment assembly **34** is configured to more closely align itself with the transmission coil **22**, as described in greater detail below.

A description of the alignment assembly **34** is now provided with specific reference to FIGS. **3**-**7**. The alignment assembly **34** is depicted schematically in FIGS. **3** and **4**, attached to an underside surface **44** of the vehicle **14**.

The alignment assembly **34** basically includes an outer cover **48**, a first track structure **50**, a first shield plate **52**, a first positioning device **54**, a second track structure **56**, a second shield plate **58**, a second positioning device **60** and a vehicle-side induction coil **62**.

The outer cover **48** is a protective cover that primarily serves to protect the various components of the alignment assembly **34**. The outer cover **48** is composed of, for example, a non-conductive material that does not interfere with the transmission and reception of electromagnetic radiation (power transmissions) from the transmission coil **22** to the vehicle-side induction coil **62**. The outer cover **48** is dimensioned and shaped to cover the first track structure **50**, the first shield plate **52**, the first positioning device **54**, the second track structure **56**, the second shield plate **58**, the second positioning device **60** and the vehicle-side induction coil **62**. Further the outer cover **48** is dimensioned such that it does not interfere with movement of any of the elements of the alignment assembly **34** throughout the entire range of movement of the first shield plate **52** and the second shield plate **58** during the alignment process described below. The outer cover **48** is directly attached to the underside surface **44** of the vehicle **14** via fasteners (not shown) in a conventional manner.

As shown in FIGS. **3**, **5** and **7**, the first track structure **50** includes a fixed track member **50*a*** and a slider **50*b*** that is installed within the fixed track member **50*a*** such that the slider **50*b*** can freely slide linearly along the fixed track member **50*a***. One of the fixed track member **50*a*** and the slider **50*b*** is coated with a frictionless material, such as, for example, polytetrafluoroethylene (PTFE) or other similar friction reducing material. In the depicted embodiment, the slider **50*b*** is retained within the fixed track member **50*a*** by narrowed lower ends that prevent lateral movement of the slider **50*b*** in directions perpendicular to the length of the fixed track member **50***a*. Specifically, since the fixed track member **50***a* extends in the vehicle longitudinal direction D_L, the first shield plate **52** is prevented from moving in the vehicle lateral directions Ds. However, the slider **50***b* can freely slide along the length of the fixed track member **50***a*. The fixed track member **50***a* is rigidly attached to the underside surface **44** of the vehicle body structure **29** via, for example, mechanical fasteners (not shown). The slider **50***b* is rigidly attached to an upper surface **52***a* (a first side) of the first shield plate **52** via, for example, mechanical fasteners (not shown).

The first track structure **50** can further include at least one and preferably two linear support structures **64** as shown in FIGS. **5-7**. The linear support structures **64** define additional track structures that are parallel to the fixed track member **50***a* and the slider **50***b* when all are installed within the alignment assembly **34**. Each of the linear support structures **64** includes an upper slider **64***a* and a lower slider **64***b*, as shown in FIG. **6**. The lower slider **64***b* can freely slide along the upper slider **64***a*. Surfaces of one or both of the lower slider **64***b* and the upper slider **64***a* that slidably contact one another can be provided with a frictionless material, such as, for example, polytetrafluoroethylene (PTFE) or other similar friction reducing material. The upper sliders **64***a* are fixedly attached to the underside surface **44** of the vehicle body structure **29** via, for example, mechanical fasteners (not shown). The lower sliders **64***b* are rigidly fixed to the upper surface **52***a* of the first shield plate **52** via, for example, mechanical fasteners (not shown).

The first track structure **50** (the fixed track member **50***a* and the slider **50***b*) defines a first axis A_1 (FIGS. **5** and **7**) that corresponds to and/or is parallel to the vehicle longitudinal direction D_L. More specifically, the slider **50***b* is movable along the first axis A_1. The slider **50***b* is configured to slide along the first axis A_1 along the length of the fixed track member **50***a*. The linear support structures **64** of the first track structure **50** extend parallel to the first axis A_1. Hence, the lower sliders **64***b* are configured to slide in directions parallel to the first axis A_1 along the upper sliders **64***a*. The linear support structures **64** provide support and add stability to movement of the first shield plate **52** along the fixed track member **50***a*. The linear support structures **64** also prevent rotation about the first axis A_1.

The fixed track member **50***a* and slider **50***b* are elements that provide precision positioning of the first shield plate **52** when the first shield plate **52** is moved and positioned by the actions of the first positioning device **54** (described in greater detail below). Whereas, the linear support structures **64** are provided for support of the first shield plate **52** and other elements supported by the first shield plate **52**.

The fixed track member **50***a*, the slider **50***b* and the linear support structures **64** support the first shield plate **52** such that the first shield plate **52** can be moved along the first axis A_1 (in the vehicle longitudinal direction D_L) and positioned with precision by the first positioning device **54**, as is described in greater detail below.

As mentioned above, the first shield plate **52** is fixed to the slider **50***b* and the lower sliders **64***b*. Consequently, the first shield plate **52** is movably connected to the underside surface **44** of the vehicle **14** for linear movement with respect thereto via the support of the sliding movement of the slider **50***b* along the fixed track member **50***a* and the sliding movement of the lower sliders **64***b* along the upper slider **64***a*. More specifically, the first shield plate **52** is supported by the first track structure **50** only for movement along the first axis A_1 (the vehicle longitudinal direction D_L).

The first shield plate **52** is made of a material or can include layer of a material that prevents transmission of electromagnetic radiation from a lower surface **52***b* (a second side) to the upper surface **52***a* (the first side) of the first shield plate **52**. The first shield plate **52** is longer in the vehicle longitudinal direction D_L and wider in the vehicle lateral directions Ds than the vehicle-side induction coil **62** and the transmission coil **22**, as is shown in FIGS. **3** and **4**. Hence, the first shield plate **52** extends outward beyond an outer periphery of the vehicle-side induction coil **62** throughout an entire range of movement of the first shield plate **52**. Consequently, the first shield plate **52** provides a shielding effect that prevents electromagnetic radiation from penetrating the vehicle body structure **29** and passing into the passenger compartment of the vehicle **14**.

The first positioning device **54** includes a housing **54***a* and a shaft **54***b*. In the depicted embodiment, the first positioning device **54** is basically a stepper motor or other positioning device that can precisely move and position an object connected thereto to a plurality of positions within a predetermined tolerance. In the alignment assembly **34**, the first positioning device **54** can achieve precise linear positioning movement of the first shield plate **52** to within, for example, ±1.0 mm. The shaft **54***b* of the first positioning device **54** is moved linearly via worm gears (not shown) and/or other linear movement structures to effect movement and positioning of the first shield plate **52**. Since stepper motors are conventional electro-mechanical devices, further description is omitted for the sake of brevity.

The housing **54***a* of the first positioning device **54** is fixedly attached to the underside surface **44** of the vehicle **14**. The shaft **54***b* is fixedly connected to the slider **50***b*. Since the slider **50***b* (which defines the first axis A_1) is attached to the first shield plate **52**, movement of the slider **50***b* by the first positioning device **54** causes corresponding linear movement of the first shield plate **52** along the first axis A_1 (in the vehicle longitudinal direction D_L).

A description of the second track structure **56** and the second shield plate **58** is now provided with specific reference to FIGS. **4-7**. The second track structure **56** includes a fixed track member **56***a* and a slider **56***b* that is installed within the fixed track member **56***a* such that the slider **56***b* can freely slide along the fixed track member **56***a*. One of the fixed track member **56***a* and the slider **56***b* is coated with a frictionless material, such as, for example, polytetrafluoroethylene (PTFE) or other similar friction reducing material. In the depicted embodiment, the slider **56***b* is retained within the fixed track member **56***a* by narrowed lower ends that prevent lateral movement (no movement in directions perpendicular to the length of the fixed track member **56***a*). The fixed track member **56***a* is rigidly attached to the lower surface **52***b* of the first shield plate **52** via, for example, mechanical fasteners (not shown). The slider **56***b* is rigidly attached to an upper surface **58***a* (a first side) of the second shield plate **58** via, for example, mechanical fasteners (not shown).

The second track structure **56** can further include at least one and preferably two linear support structures **66**. The linear support structures **66** define further track structures that are parallel to the fixed track member **56***a* and the slider **56***b* when all are installed within the alignment assembly **34**. Each of the linear support structures **66** includes an upper slider **66***a* and a lower slider **66***b*, as shown in FIG. **6**. The lower slider **66***b* can freely slide along the upper slider **66***a*. Surfaces of one or both of the lower slider **66***b* and the upper slider **66***a* that slidably contact one another can be provided with a frictionless material, such as, for example, polytetrafluoroethylene (PTFE) or other similar friction reducing material. The upper sliders **66***a* are fixedly attached to the lower surface **52***b* of the first shield plate **52** via, for example, mechanical fasteners (not shown). The lower sliders **66***b* are rigidly fixed to the upper surface **58***a* of the second shield plate **58** via, for example, mechanical fasteners (not shown). The linear support structure **66** also prevent rotation of the second shield plate **56** about the second axis A_2.

The second track structure **56**, including the fixed track member **56***a* and the slider **56***b*, extend along a second axis A_2 defined by the slider **56***b*. The second axis A_2 extends in the vehicle lateral directions Ds and is transverse and perpendicular to the first axis A_1 (the vehicle longitudinal direction D_L). The slider **56***b* is configured to slide along the second axis A_2 and along the length of the fixed track member **56***a*. Further, the linear support structures **66** are parallel to the slider **56***b* and the second axis A_2 such that the lower sliders **66***b* are configured to slide parallel to the slider **56***b* and along the upper sliders **64***a*. The linear support structures **66** provide support and add stability to movement of the second shield plate **58** along the fixed track member **56***a*.

The fixed track member **56***a* and slider **56***b* are elements that provide precision positioning of the second shield plate **58** when the second shield plate **58** is moved and positioned by the actions of the second positioning device **60**. Whereas, the linear support structures **66** are provided for support of the second shield plate **58** and other elements supported by the second shield plate **58**.

The fixed track member **56***a*, the slider **56***b* and the linear support structures **66** support the second shield plate **58** such that the second shield plate **58** can be moved along the second axis A_2 (the vehicle lateral direction D_S) and positioned with precision by the second positioning device **60**, as is described in greater detail below.

As mentioned above, the slider **56***b* and the lower sliders **66***b* are fixed to the upper surface **58***a* of the second shield plate **58**. Consequently, the second shield plate **58** is movably connected to the lower surface **52***b* of the first shield plate **52** for linear movement with respect thereto via the support of the sliding movement of the slider **56***b* along the fixed track member **56***a* and the sliding movement of the lower sliders **66***b* along the upper slider **66***a*. More specifically, the second shield plate **58** is supported by the second track structure **56** for movement along the second axis A_2 (the vehicle lateral direction D_S) relative to the first shield plate **52**.

Like the first shield plate **52**, the second shield plate **58** is made of a material or can include a layer of a material that prevents transmission of electromagnetic radiation from a lower surface **58***b* (a second side) to the upper surface **58***a* (the first side) of the second shield plate **58**. The second shield plate **58** is longer in the vehicle longitudinal direction D_L and wider in the vehicle lateral directions Ds than the vehicle-side induction coil **62** and the transmission coil **22**, as is shown in FIGS. **3** and **4**. Hence, like the first shield plate **52**, the second shield plate **58** extends outward beyond an outer periphery of the vehicle-side induction coil **62** throughout an entire range of movement of the second shield plate **58** relative to the first shield plate **52**. Consequently, the second shield plate **58** also provides a shielding effect that prevents electromagnetic radiation from penetrating the vehicle body structure **29** and passing into the passenger compartment of the vehicle **14**.

The second positioning device **60** includes a housing **60***a* and a shaft **60***b*. In the depicted embodiment, the second positioning device **60** is basically a stepper motor or other positioning device that can precisely move an object connected thereto to a plurality of positions within a predetermined tolerance. In the alignment assembly **34**, the second positioning device **60** can achieve precise linear positioning movement of the second shield plate **58** to within, for example, plus or minus 1.0 mm. The shaft **60***b* of the second positioning device **60** is moved linearly via worm gears (not shown) and/or other linear movement structures to effect movement and positioning of the second shield plate **58** relative to the first shield plate **52**. Since stepper motors are conventional electro-mechanical devices, further description is omitted for the sake of brevity.

The housing **60***a* of the second positioning device **60** is fixedly attached to the lower surface **52***b* of the first shield plate **52**. The shaft **60***b* is connected to the slider **56***b*. Since the slider **56***b* is rigidly fixed to the second shield plate **58**, movement of the slider **56***b* by the first positioning device **60** causes corresponding linear movement of the second shield plate **58** along the second axis A_2.

The first shield plate **52** and the second shield plate **58** are sized and configured such that at least one of (and in the depicted body both) the first shield plate **52** and the second shield plate **58** is positioned between the transmission coil **22** and the vehicle body structure **29** throughout the entire range of movement of the first shield plate **52** and the second shield plate **58** when the vehicle-side induction coil **62** is in at least partial alignment with the transmission coil **22**. The size and dimensions of the first shield plate **52** and the second shield plate **58** is such that they are both located between the vehicle body structure **29** and the transmission coil **22** with the vehicle-side induction coil **62** being positioned relative to the transmission coil **22** with the vehicle-side induction coil **62** having an efficiency of reception of electromagnetic radiation from the transmission coil that is equal to or greater to a predetermined level of efficiency, as described further below.

As shown in FIGS. **3** and **4**, the vehicle-side induction coil **62** is fixedly attached to the lower surface **58***b* (the second side) of the second shield plate **58**. The vehicle-side induction coil **62** is configured to generate electric current in response reception of electromagnetic radiation transmitted from the transmission coil **22**. The overall size and dimensions of the vehicle-side induction coil **62** are determined based upon the charging power needs of the battery B of the vehicle **14** and the capabilities of the transmission coil **22**. However, in the depicted embodiment the vehicle-side induction coil **62** has an outer diameter of between 25.0 cm and 35.0 cm. Further, the diameter of the vehicle-side induction coil **62** can be 30.0 cm.

A description is now provided of the operation of the wireless charging structure **10**. As shown in FIGS. **1** and **2**, the power controller **20** and the transmission coil **22** are electrically connected to one another by the cable C. As is explained below, the power controller **20** is configured to transmit and receive signals transmitted from the controller **32** of the vehicle **14**. The power controller **20** is also configured to control the level of electromagnetic energy (electromagnetic radiation) emitted by the transmission coil **22**. Further, as shown in FIGS. **1**, **3** and **4**, the controller **32** is electronically connected to the battery B, the first positioning device **54** (a stepper motor) and the second positioning device **60** (another stepper motor). The controller **32** is configured to operate the first and second positioning devices **54** and **60** to move and position the first shield plate **52** and the second shield plate **58** relative to the vehicle **14** in order to optimize the position of the vehicle-side induction coil **62** relative to the transmission coil **22**. In other words, the controller **32** is configured and programmed to align the center of the vehicle-side induction coil **62** with the center of the transmission coil **22** in order to maximize the vehicle-side induction coil **62** reception of electromagnetic radiation transmitted by the transmission coil **22**.

FIG. **8** is a flowchart that shows basic operational steps conducted by the power controller **20** in the control of the transmission coil **22**. The power controller **20** can include a power switch (not shown) or can include a power reduction circuit that powers down the power controller **20** when not in use for a predetermined period of time. In a power reduction mode, the power controller **20** is in a standby mode, as indicated in step S**1** in FIG. **8**. At step S**2**, the power controller **20** monitors the transmission coil **22** via, for example, wireless communication or by detecting electromagnetic field disturbances at the transmission coil **22** in order to determine whether or not a vehicle **14** with the vehicle-side induction coil **62** has parked over the transmission coil **22**, and further determines whether or not the battery B is in need of charging. The operation in step S**2** can include wireless communication signals sent back and forth between the vehicle-side induction coil **62** and the transmission coil **22** (i.e., "handshakes"). More specifically, the transmission coil **22** can receive signals transmitted from the vehicle-side induction coil **62** or other electronic communication circuitry (not shown) within the vehicle **14** in order for the power controller **20** to determine whether or not the vehicle **14** is parked in the parking area P and determine whether or not the battery B needs to be charged.

Further, the power controller **20** is activated and leaves the standby mode via any one of the following: a signal from a vehicle operator via a wireless communication device; a mechanical electrical switch on or adjacent to the power controller **20**; or detection by the power controller **20** of the presence of the vehicle-side induction coil **62** of the vehicle **14** being parked above the transmission coil **22**.

At step S**2**, if the power controller **20** determines that the vehicle **14** is present and that the battery B needs charging, operation moves to step S**3**. Otherwise, the power controller **20** returns to the standby mode in step S**1**.

At step S**3**, the power controller **20** sends a predetermined level of power to the transmission coil **22** causing the transmission coil **22** to transmit a low energy of electromagnetic energy charge to the vehicle-side induction coil **62** that signals the controller **32** via the vehicle-side induction coil **62**. In response, the controller **32** of the vehicle **14** checks the alignment between the transmission coil **22** and the vehicle-side induction coil **62** in the process described below with respect to the flowcharts depicted in FIGS. **9-11**.

At step S**4**, the power controller **20** checks to see if a signal has been received from the controller **32** indicating alignment between the transmission coil **22** and the vehicle-side induction coil **62**. The power controller **20** uses the signal in order to determine whether or not the transmission coil **22** and the vehicle-side induction coil **62** are acceptably aligned with one another. At step S**4**, if the power controller **20** determines that the transmission coil **22** and the vehicle-side induction coil **62** are not yet aligned, operation returns to step S**3** where the low level of electromagnetic energy continues to the transmitted by the transmission coil **22**. At step S**4** if the power controller **20** determines that the transmission coil **20** and the vehicle-side induction coil **62** are acceptably aligned, then operation moves to step S**5**. At step S**5**, the power controller **20** causes the transmission coil **20** to increase the level of transmission of electromagnetic energy to a level that enables charging of the battery B. At step S**6**, the power controller **20** continues to cause the transmission coil **20** to emit the increased level of transmission of electromagnetic energy in order to continue charging the battery B.

At step S**7**, the power controller **20** determines whether or not the battery B is fully charged or not based on a signal or signals from the controller **32** of the vehicle **14**. If the battery is not fully charged, control returns to step S**6** and the power controller **20** continues to cause the transmission coil **20** to emit the level of transmission of electromagnetic energy in order to continue charging the battery B. If the power controller **20** determines that the battery B is fully charged based on a signal or signals from the controller **32** of the vehicle **14**, then operation moves to step S**8**, where the power controller **20** reduces or completely cuts power to the transmission coil **20** thereby ceasing charging of the battery B. Thereafter operation returns to step S**1**, where the power controller **20** goes back to standby mode. It should be understood from the drawings and description herein, that the power controller **20** can also continue to monitor the status of the battery B, and perform periodic battery tending, where charging is resumed after a predetermined period of time to ensure the battery G is maintained at a maximum charge.

A description is now provided for operation of the reception charging assembly **16** of the vehicle **14** with specific reference to FIGS. **9-11**. During normal operation of the vehicle **14**, the reception charging assembly **16** is inactive and remains stationary relative to the vehicle **14**, except that the controller **32** monitors the condition of the battery B. Specifically, the controller **32** monitors the level of the charge being maintained by the battery B. If the battery B is nearing a depletion state, the controller **32** can provide such information to the vehicle operator indicating that battery charging will soon be necessary. Otherwise, the controller **32** is maintained in the standby mode, as indicated in step S**10** of FIG. **9**.

At step S**10**, the controller **32** leaves the standby mode automatically in the event that the vehicle **14** has been parked and shut off. Thereafter, the controller **32** moves to step S**11** where the controller **32** determines whether or not the vehicle **14** has been parked in a charging station, such as the parking area P depicted in FIG. **1**. As mentioned above, the stops **24** are installed to the surface S of the parking area P in order to provide the vehicle operator with an approximate location in which to park the vehicle **14**. Thus, when parking the vehicle **14**, it is assumed that the front wheels **28** of the vehicle **14** contact the stops **24**. When parked in this manner, the vehicle-side induction coil **62** should be located above the transmission coil **22**, but may not be perfectly aligned. The vehicle-side induction coil **62** is therefore in an approximate alignment position with at least a portion of the vehicle-side induction coil **62** overlapping the transmission coil **22**, as viewed from above, as shown in FIG. **2**.

In step S**11**, if the vehicle **14** has not been parked in the parking area P, operation returns to step S**10** and the standby mode. If the controller **32** determines at step S**11** that the vehicle **14** has been parked in a charging station, the controller **32** then determines whether or not the transmission coil **22** is present and activated by transmission of a low level of electromagnetic energy or radiation. The controller **32** and/or the vehicle-side induction coil **62** is configured to transmit signals to and receive signals from the transmission coil **22** and/or the power controller **20** in order to determine the status of the output of the transmission coil **22**.

At step S**12**, if the transmission coil **22** is detected to be emitting a low level of electromagnetic energy (radiation) for purposes of aligning the vehicle-side induction coil **62** with the transmission coil **22**, operation moves to step S**13**. If the controller **32** determines that no energy is being emitted by the transmission coil **22**, then operations return to step S**10** and the standby mode.

At step S**13**, the controller **32** determines whether or not the transmission coil **22** and the vehicle-side induction coil **62** are aligned within predetermined parameters to allow efficient charging of the battery B. If the transmission coil **22** and the vehicle-side induction coil **62** are not aligned to the predetermined parameters, then operation moves to step S**14** where the aligning procedures set forth in the flowcharts in FIGS. **10** and **11** are conducted, as described below. After the aligning procedures are completed, operation returns to step S**13**. If the transmission coil **22** and the vehicle-side induction coil **62** are not aligned to the predetermined parameters, operation can then again move to step S**14**. If the transmission coil **22** and the vehicle-side induction coil **62** are aligned to the predetermined parameters, then operation moves to step S**15**.

At step S**14**, a safeguard can be included that stops the alignment process from repeating indefinitely. The safeguard includes a signal to the vehicle operator that there may be a problem, such as the vehicle **14** may be parked in such a way that the vehicle-side induction coil **62** is too far away from the transmission coil **22** to enable optimal electromagnetic energy exchange between the transmission coil **22** and the vehicle-side induction coil **62**.

At step S**15**, the controller **32** and/or the vehicle-side induction coil **62** transmits a signal to the transmission coil **22** and/or the power controller **20** indicating that charging can commence. In response, as mentioned above with respect to step S**5** in FIG. **8**, the power controller **20** increases the output of electromagnetic radiation from the transmission coil **22** thereby enabling charging of the battery B. In step S**16**, the controller **32** determines whether or not the battery B is fully charged. If the battery is not fully charged, operation returns to step S**15** and charging continues. If the battery is fully charged in step S**16**, then the controller **32** and/or the vehicle-side induction coil **62** transmits a signal to the transmission coil **22** and/or the power controller **20** indicating that charging is completed. Thereafter, the controller **32** returns to the standby mode in step S**10**.

Upon moving from step S**16**, the controller **32** can be configured in any of a variety of manners. For example, as described further below, the controller **32** operates the first and second positioning devices **54** and **60**. At the conclusion of the charging operation at step S**16**, the controller **32** can operate the first and second positioning devices **54** and **60** to return to a start position where the vehicle-side induction coil **62** is centered with respect to the alignment assembly **34**.

Alternatively, upon moving from step S**16**, the controller **32** can be configured to lock the first and second positioning devices **54** and **60** thereby preventing any movement of the vehicle-side induction coil **62**. This locking procedure can be advantageous if the vehicle **14** is always parked in the same charging station. The vehicle operator may be able to park the vehicle **14** in a position within the parking area P such that the alignment procedure is minimal or not necessary when the vehicle **14** is parked.

Description now moves to the steps outlined in FIG. **10**, where the controller **32** manages the alignment procedure of the vehicle-side induction coil **62** relative to the transmission coil **22**.

At step S**20**, the controller **32** enters an alignment management mode from operations at step S**14** in FIG. **9**. Operation immediately moves to step S**21**. At step S**21**, the controller **32** sets a variable "increment" that corresponds to stepper motor movement to a predetermined upper preset level. This step defines the increment of movement each time each of the first and second positioning devices **54** and **60** is operated to reposition the first shield plate **52** and the second shield plate **58**. The upper preset level of the "increment" of movement of each of the stepper motors of the first and second positioning devices **54** and **60** is determined based upon the overall dimensions of the alignment assembly **34**, the precision and tolerances of the first and second positioning devices **54** and **60** and tolerances of the first and second track structure **50** and **56**. The upper preset level is provided in order to make the alignment process more efficient. For example, the upper present level can be between 2 mm and 20 mm, depending upon the overall tolerances of the various components of the alignment assembly **34**.

Step S**21** is basically an initialization of the variable "increment." The value of "increment" can be reduced by the controller **32** at step **27**, as is explained in greater detail below.

Once the variable "increment" has been initialized, operation then moves to step S**22** where the controller **32** determines whether or not the value of "increment" is too low or not. Initially, the value of "increment" is initialized at a maximum value defined as the upper preset level. The controller **32** is programmed with a minimum value of "increment" and the current value is compared with the minimum value. If the minimum values is equal to or greater than the current value of "increment" then operation moves to step S**23**, and a signal is sent to the vehicle operator that there is a problem with alignment, such as the vehicle-side induction coil **62** being too far out of alignment with the transmission coil **22** requiring re-parking of the vehicle **14** within the parking area P. If the minimum values is less that the current value of "increment" then operation moves to step S**24**.

At step S**24**, the controller **32** defines a "designated axis" for alignment movement as being the first axis A_1 (movement in the vehicle longitudinal direction D_L). Consequently, the first iteration of the steps in FIG. **11** will involve movement of the first shield plate **52** along the first track structure **50** via control of operation of the first positioning device **54**. Once the "designated axis" is defined as movement in the first axis A_1, operation moves to FIG. **11**, as described in greater detail below. The movements of the vehicle-side induction coil **62** conducted by the controller **32** with the "designated axis" for alignment movement being the first axis A_1 (the vehicle longitudinal direction D_L) are demonstrated in FIGS. **12***a* thru **12***e*, as is also described in greater detail below. When the first iteration of FIG. **11** is completed relative to the first axis A_1, control moves to step S**25**.

At step S**25**, the controller **32** defines the "designated axis" for alignment movement as being the second axis A_2 (extending in the vehicle lateral direction D_S). Consequently, the second iteration of the steps in FIG. **11** will involve movement of the second shield plate **56** along the second track structure **56** via control of operation of the second positioning device **60**. Once the "designated axis" is defined as movement along the second axis A_2, operation moves again to FIG. **11**, but with the controller **32** operating the second positioning device **60**. The movements of the vehicle-side induction coil **62** conducted by the controller **32** with the "designated axis" for alignment movement being along the second axis A_2 (in the vehicle lateral direction D_S) are demonstrated in FIGS. **13**a thru **13**e, as is also described in greater detail below. When the second iteration of FIG. **11** is completed relative to the second axis A_2 (the slider **56**b), control moves to step S**26**.

At step S**26**, the controller **32** determines whether or not the movements of the first and second positioning devices **54** and **60** were too large by evaluating the efficiency level. Specifically, if the movements of the first and second positioning devices **54** and **60** did not achieve adequate alignment, and may not have provided small enough movements to properly align the vehicle-side induction coil **62** with the transmission coil **22**, then the efficiency level will not be acceptable and the controller **32** moves to step S**27** where the controller **32** reduces the size of the variable "increment," thereby making each movement of the first and second positioning devices **54** and **60** smaller. The "increment" can initially be defined as, for example, 1 cm (10 mm), depending upon the tolerances of the overall apparatus and the tolerances of the first and second positioning devices **54** and **60**. Alternatively, the "increment" can be greater than 10 mm or less than 10 mm.

If at step S**26**, the controller **32** determines that the efficiency level is acceptable indicating that the movements of the first and second positioning devices **54** and **60** were acceptable, and the vehicle-side induction coil **62** and the transmission coil **22** are adequately aligned, control moves to step S**28**.

As step S**28**, the controller **32** sends a signal to the power controller **20** indicating that the vehicle-side induction coil **62** and the transmission coil **22** are properly aligned. At this point, the power controller **20** is waiting at step S4 in FIG. **8** and moves to step S5 where power to the transmission coil **22** is increased to a level corresponding to charging of the battery B. Once the controller **32** determines that the transmission coil **22** is emitting a charging level of electromagnetic radiation, the controller **32** enables the vehicle-side induction coil **62** to receive the power from the transmission coil **22**. The controller **32** further enables its circuitry to convert the alternating current energy transmitted from the transmission coil **22** to the vehicle-side induction coil **62** into direct current and providing that direct current to the battery B thereby charging the battery B. Operation then moves to step S**29** where the logic returns to FIG. **9** completes step S**14**.

A description is now provided of the operational steps depicted in FIG. **11**. The operational steps in FIG. **11** are used twice during the overall operation of the alignment assembly **34**. As mentioned above, at step S**24** in FIG. **10**, the "designated axis" is defined as being the first axis A_1. Therefore, movement and positioning of the vehicle-side induction coil **62** will be in the vehicle longitudinal direction D_L. Further, the controller **32** operates the first positioning device **54** to move and position the first shield plate **52** in order to align the vehicle-side induction coil **62** with the transmission coil **22** along the first axis A_1. Consequently, during the first iteration of the steps in FIG. **11**, the vehicle-side induction coil **62** is moved and positioned relative to the first axis A_1 (in the vehicle longitudinal direction D_L) as demonstrated in FIGS. **12**a thru **12**e. Thereafter at step S**25** in FIG. **10**, the "designated axis" is defined as being the second axis A_2. Therefore, movement and positioning of the vehicle-side induction coil **62** will be in the vehicle lateral direction D_S. Further, the controller **32** operates the second positioning device **60** to move and position the second shield plate **58**. Consequently, during the second iteration of the

steps in FIG. **11**, the vehicle-side induction coil **62** is moved and positioned along the second axis A_2 (in the vehicle lateral direction D_S) as demonstrated in FIGS. **13**a thru **13**e.

The following description of operations in FIG. **11** is carried out with the "designated axis" extending along the first axis A_1 (the slider **50**b), corresponding to the vehicle longitudinal direction D_L. At step S**30** in FIG. **11**, the controller **32** starts the alignment procedure for the designated axis. At this time, the transmission coil **22** is emitting a predetermined lowered level of electromagnetic radiation for purposes of aligning the vehicle-side induction coil **62** with the transmission coil **22** (as per step S3 in FIG. **8**). At step S**31**, the controller **32** measures the amount of electromagnetic radiation being received by the vehicle-side induction coil **62** and determines the efficiency of the reception of the electromagnetic radiation. The controller **32** is either pre-programmed with the predetermined lowered level of electromagnetic radiation and/or receives a signal from the power controller **20** with information regarding the predetermined lowered level of electromagnetic radiation.

At step S**31**, the controller **32** determines whether or not the efficiency of the reception of the electromagnetic radiation meets an acceptable predetermined efficiency level. If the efficiency level of the reception of electromagnetic radiation is at or above the acceptable predetermined efficiency level, then no alignment is necessary and control moves to step S**32** and returns to the operations in FIG. **10**. If the efficiency level of the reception of electromagnetic radiation is below the acceptable predetermined efficiency level, then alignment is necessary and control moves to step S**33**.

At step S**33**; the controller **32** operates the first positioning device **54** (the stepper motor) to move the slider **50**b in a first direction along the first axis A_1 (in the vehicle longitudinal direction D_L) a distance equivalent to the defined "increment." The shaft **54**a of the first positioning device **54** is fixed to the slider **50**b and the slider **50**b is fixed to the first shield plate **52**. Consequently, movement effected by the first positioning device **54** translates into a first movement M_1 of the vehicle-side induction coil **62** along the first axis A_1. FIG. **12**a shows an example of the position of the vehicle-side induction coil **62** relative to the transmission coil **22** when the vehicle **14** is parked in the parking area P. In FIG. **12**a, the vehicle-side induction coil **62** is in the approximate alignment position mentioned above, and is therefore mis-aligned with the transmission coil **22**. FIG. **12**b shows the vehicle-side induction coil **62** moved by operation of the first positioning device **54** at step S**33** as indicated by the first movement M_1. As can be seen by comparing FIG. **12**a with FIG. **12**b, the vehicle-side induction coil **62** has moved along the first axis A_1 (the vehicle longitudinal direction D_L).

Next, at step S**34** in FIG. **11**, the controller **32** determines whether or not the efficiency level has improved. If the efficiency level has not improved, operation moves to step S**40**, described further below. If the efficiency level has improved, operation moves to step S**35**.

At step S**35**, the controller **32** determines whether or not the efficiency level is now acceptable (at or above the acceptable predetermined efficiency level). If the efficiency level is acceptable, operation moves to step S**32** and back to the steps in FIG. **10**. If the efficiency level is not acceptable, operation moves to step S**36**.

At step S**36**, the controller **32** again operates the first positioning device **54** to move the slider **50**b again by a distance approximately equivalent to the defined "increment." FIG. **12**b shows the position of the vehicle-side induction coil **62** after the first movement M_1 is made at step S**33**. FIG. **12***c* shows the vehicle-side induction coil **62** after a second movement M_2 made at step S**36**. As can be seen by comparing FIG. **12***b* with FIG. **12***c*, the vehicle-side induction coil **62** has made the second movement M_2 further along the first axis A_1 (in the vehicle longitudinal direction D_L) relative to the transmission coil **22**.

Next at step S**37**, the controller **32** determines again whether or not the efficiency level has improved. If the efficiency level has not improved, operation moves to step S**38**, described below. If the efficiency level has improved, operation returns to step S**36**, where third movement M_3 of the vehicle-side induction coil **62** is made by the controller **32**. For demonstration purposes in the following description of FIGS. **12***c* and **12***d*, it is assumed that in step S**37** the controller **32** determined that the efficiency level improved and control has returned again to Step S**36** where the third movement M_3 of the vehicle-side induction coil **62** is conducted. FIG. **12***c* shows the position of the vehicle-side induction coil **62** after the second movement M_2 is made in the first passing through step S**36**. FIG. **12***d* shows the vehicle-side induction coil **62** after the third movement M_3 is made during a second passing through at step S**36**. As can be seen by comparing FIG. **12***c* with FIG. **12***d*, the vehicle-side induction coil **62** has moved further along the first axis A_1 (in the vehicle longitudinal direction D_L) relative to the transmission coil **22**. However, FIG. **12***d* appears to show that the vehicle-side induction coil **62** is now moved to a position that does not improve efficiency.

Operation again moves to step S**37** where the controller **32** determines that the efficiency level has not improved, operation now moves to step S**38**. At step S**38**, the controller **32** causes the first positioning device **54** to return the vehicle-side induction coil **62** back to its previous position via a fourth movement M_4, as shown in FIG. **12***e*. As is shown in FIG. **12***e*, the fourth movement M_4 is in a direction that is opposite the first movement M_1, the second movement M_2 and the third movement M_3.

Thereafter, operation moves to step S**39** where operations return to FIG. **10**.

Returning to Step S**34**, if the controller **32** determines that the efficiency level has not improved, operation moves to step S**40** where the vehicle-side induction coil **62** is moved back to its previous position (its initial position). Step S**40** thru step S**46** basically deal with the situation where the movement of the vehicle-side induction coil **62** to improve efficiency is in a direction corresponding the direction of the fourth movement M_4. Specifically, the first movement M_1, the second movement M_2 and the third movement M_3 are all movements in a first direction relative to the first axis A_1. The fourth movement M_4 is in a second direction opposite the first direction.

At step S**41**, the controller **32** causes the first positioning device **54** to move the slider **50***b*, the first shield plate **52** and the vehicle-side induction coil **62** in the second direction opposite the first direction along the first axis A_1 (a movement in the same direction as the fourth movement M_4). At step S**42**, the controller **32** determines whether or not the efficiency level has not improved. If the efficiency level has improved, operation moves to step S**38**. If the efficiency has not improved, operation moves to step S**43**.

At step S**43**, the controller **32** again causes the first positioning device **54** to move the slider **50***b*, the first shield plate **52** and the vehicle-side induction coil **62** in the second direction opposite the first direction along the first axis A_1 (a movement in the same direction as the fourth movement M_4). At step S**44**, the controller **32** again determines whether or not the efficiency level has not improved. If the efficiency level has improved, operation moves to step S**43**, such that steps S**43** and S**44** are repeated. If the efficiency has not improved, operation moves to step S**45**.

At step S**45** the controller, moves the slider **50***b*, the first shield plate **52** and the vehicle-side induction coil **62** back to a position prior to the most recent movement thereof. At step S**46**, operation returns to FIG. **10** and step S**25**.

At step S**25** in FIG. **10**, the "designated axis" is defined and the second axis A_2 and operation moves back again to the flowchart in FIG. **11**. All of the steps in FIG. **11** are repeated, but with all movements being made by the second positioning device **54** and along the second axis A_2 only. Since the steps in FIG. **11** are unchanged, except that movement is along the second axis A_2, further description is omitted for the sake of brevity. However, examples of the movements along the second axis A_2 of the vehicle-side induction coil **62** made during the second iteration of FIG. **11** are depicted in FIGS. **13***a* thru **13***e*.

Specifically, during the iteration of the steps in FIG. **11** with the "designated axis" being the second axis A_2, at step S**33** the controller **32** operates the second positioning device **60** (the stepper motor) to move the slider **56***b* in a first direction along the second axis A_2 (in the vehicle lateral direction D_S) a distance equivalent to the defined "increment." Movement of the shaft **60***a* of the second positioning device **60** (the shaft **60***a* is fixed to the slider **50***b* and the slider **50***b* is fixed to the first shield plate **52**) causes a first movement M_{10} of the vehicle-side induction coil **62** along the second axis A_2, from the relative positions shown in FIG. **13***a* to the positions shown in FIG. **13***b*.

FIG. **13***a* shows the vehicle-side induction coil **62** relative to the transmission coil **22** after completion of the alignment steps described above with respect to positioning movement with the first axis A_1 being the "designated axis." FIG. **13***b* shows the vehicle-side induction coil **62** moved by operation of the second positioning device **60** at step S**33** as indicated by the first movement M_{10} with the second axis A_2 being the "designated axis." As can be seen by comparing FIG. **13***a* with FIG. **13***b*, the vehicle-side induction coil **62** has moved along the second axis A_2 (the vehicle lateral direction Ds).

At step S**36** in FIG. **11** with the second axis A_2 being the "designated axis," the controller **32** again operates the second positioning device **60** to move the slider **56***b* again by a distance approximately equivalent to the defined "increment." FIG. **13***b* shows the position of the vehicle-side induction coil **62** after the first movement M_{10} made at step S**33**. FIG. **13***c* shows the vehicle-side induction coil **62** after a second movement M_{11} made at step S**36**. As can be seen by comparing FIG. **13***b* with FIG. **13***c*, the vehicle-side induction coil **62** has moved in the second movement M_{11} further along the second axis A_2 relative to the transmission coil **22**.

If the operation in step S**36** in FIG. **11** is repeated, a third movement M_{12} of the vehicle-side induction coil **62** along the second axis A_2 is made by the controller **32**, as indicated in FIG. **13***d*. If the controller has determined that the third movement M_{12} does not improve transmission efficiency, at step S**38**, the controller **32** causes the second positioning device **60** to return the vehicle-side induction coil **62** back to its previous position via a fourth movement M_{13}, as shown in FIG. **13***e*. As is shown in FIG. **13***e*, the fourth movement M_{13} is in a direction that is opposite the first movement M_{10}, the second movement M_{11} and the third movement M_{12}. In FIG. **11** at steps S**38**, S**40** and S**43**, with the second axis A_2 being the "designated axis," the controller **32** causes the second positioning device **60** to move the slider **56***b*, the second shield plate **58** and the vehicle-side induction coil **62** in a second direction opposite the first direction along the second axis A_2.

As described above, the controller **32** is configured to operate the first positioning device **54** to linearly move and position the vehicle-side induction coil **62** along the first axis A_1 in order to more closely align the vehicle-side induction coil **62** with the transmission coil **22** relative to the first axis A_1. Thereafter, the controller **32** is configured to operate the second positioning device **60** to move and position the vehicle-side induction coil **62** along the second axis A_2 in order more closely align the vehicle-side induction coil **62** with the transmission coil **22** relative to the second axis A_2. If first attempts at alignment fail to yield a predetermined efficiency level, the "increment" of movement along each of the first and second axis A_1 and A_2 can be reduced to further refine the movement of the vehicle-side induction coil **62** along each of the first and second axis A_1 and A_2.

The efficiency level used by the controller **32** at, for example, step S**26** in FIG. **10**, is preferably above 80% efficiency. Specifically, at least 80% of the electromagnetic energy outputted by the transmission coil **22** is received by the vehicle-side induction coil **62** and converted into direct current to charge the battery B. However, the efficiency level is more preferably 90%.

If a center of the vehicle-side induction coil **62** is not aligned with a center of the transmission coil **22** by, for example, 50% of the overall diameter of the transmission coil **22**, efficiency of energy transmittance can be below 60%, making consumption of energy to operate the transmission coil **22** very inefficient. If the center of the vehicle-side induction coil **62** is not aligned with a center of the transmission coil **22** by, for example, 25% of the overall diameter of the transmission coil **22**, efficiency of energy transmittance can be below 80%, making consumption of energy to operate the transmission coil **22** more efficient, but still not an optimal efficiency. After using the above described alignment procedures, efficiency is improved. In the preferred embodiment, a 90% rate of efficiency is expected. More specifically, an acceptable predetermined efficiency level is 90% where 90% of the electromagnetic radiation emitted by the transmission coil **22** is received by the vehicle-side induction coil **62**.

In the depicted embodiment, the transmission coil **22** and the vehicle-side induction coil **62** each have a diameter of approximately 31 cm (310 mm or approximately 1.0 foot in diameter). In the depicted embodiment, the vehicle-side induction coil **62** can be moved along the first axis A_1 (along the first track structure **50**) approximately 150 mm in each direction from a centered position (centered relative to the first track structure **50**). Thus, the vehicle-side induction coil **62** can be moved along the first axis A_1 a distance approximately equal to the diameter of each of the transmission coil **22** and the vehicle-side induction coil **62**. Similarly, the vehicle-side induction coil **62** can be moved along the second axis A_2 (along the second track structure **56**) approximately 150 mm in each direction from a centered position (centered relative to the first track structure **50**). Thus, the vehicle-side induction coil **62** can be moved along the second axis A_2 a distance approximately equal to the diameter of each of the transmission coil **22** and the vehicle-side induction coil **62**. Consequently, as long as the vehicle **14** is parked within the parking area P with at least a portion of the vehicle-side induction coil **62** overlapping with the transmission coil **22**, the controller **32** can manipulate the first and second positioning devices **54** and **60** to bring the vehicle-side induction coil **62** into alignment with the transmission coil **22**.

It should be understood from the drawings and the description herein, that above mentioned dimensions of the transmission coil **22**, the vehicle-side induction coil **62** and the elements of the alignment assembly **34** can be scaled and redesigned in order to accommodate the recharging needs of any of a variety of shapes and designs of vehicles that require regular recharging of batteries. Specifically, outer diameters of the transmission coil **22** and the vehicle-side induction coil **62** is not limited to the diameter mentioned above. The transmission coil **22** and the vehicle-side induction coil **62** need not be the same diameter and can be larger or smaller depending upon the recharging requirements of the vehicle. Further, the lengths of the first and second track structures **50** and **56**, and the overall dimensions of the first and second shield plates **52** and **58** can vary depending upon the desired position adjustment ranges of the first and second track structures **50** and **56**.

Further, the first and second track structures **50** and **56** depicted in the first embodiment can be re-designed and reconfigured depending upon the overall design of the wireless charging structure **10** and the vehicle **12**. For instance, in some designs only one of each of the linear support structures **64** and **66** might be necessary. Further, in the depicted embodiment, the first positioning device **54** is attached to the slider **50*b*** and directly moves the slider **50*b***, and, the second positioning device **60** is attached to the slider **56*b*** and directly moves the slider **56*b***. In an alternative embodiment (the second embodiment), the first positioning device **54** can be directly attached to the first shield plate **52** and the second positioning device **60** can be directly attached to the second shield plate **58**. As well, the first and second track structure **50** and **56** can be oriented to position the first and second shield plates **52** and **58** in directions other than those depicted in the drawings. For example, the first track structure **50** can be oriented to position the first shield plate **52** along the vehicle lateral directions D_S and the second track structure **56** can be oriented to position the second shield plate **58** along the vehicle longitudinal directions D_L.

Further, in the above described embodiment, the order of alignment can be reversed such that the second positioning device **60** is operated to adjust the position the second shield plate **58** and thereafter the first positioning device **54** is operated to adjust the position the first shield plate **52**.

Second Embodiment

Referring now to FIG. **14**, the alignment assembly **34** in accordance with a second embodiment will now be explained. In view of the similarity between the first and second embodiments, the parts of the second embodiment that are identical to the parts of the first embodiment will be given the same reference numerals as the parts of the first embodiment. Moreover, the descriptions of the parts of the second embodiment that are identical to the parts of the first embodiment may be omitted for the sake of brevity. The parts of the second embodiment that differ from the parts of the first embodiment will be indicated with a single prime (').

The alignment assembly **34** includes all of the features of the first embodiment, including the first track structure **50** (with the fixed track member **50*a*** and the slider **50*b***), the linear support structures **64** (with respective upper sliders **64*a*** and lower sliders **64*b***), the first shield plate **52**, the second track structure **56** (with the fixed track member **56*a*** and the slider **56***b*), the linear support structures **66** (with respective upper sliders **66***a* and lower sliders **66***b*), the second shield plate **58**, and the vehicle-side induction coil **62**. All of the above listed elements are as described above with respect to the first embodiment.

In the second embodiment, the first positioning device **54** is replaced with a first positioning device **54'** and the second positioning device **60** is replaced with a second positioning device **60'**.

The first positioning device **54'** includes a housing **54***a*' that is fixed to the underside surface **44** of the vehicle **14** and a shaft **54***b*' that is directly attached to the first shield plate **52**. Hence, the first positioning device **54'** directly moves and positions the first shield plate **52** along the first axis A_1. It should be understood from the drawings and the description herein that the first shield plate **52** is slidably supported by the first track structure **50** and is free to move along the first axis A_1 and is only constrained against such movement by the first positioning device **54'**.

Further in the second embodiment, the second positioning device **60'** includes a housing **60***a*' that is fixed to the first shield plate **52** and a shaft **60***b*' that is directly attached to the second shield plate **58**. Hence, the second positioning device **60'** directly moves and positions the second shield plate **58** along the second axis A_2. It should be understood from the drawings and the description herein that the second shield plate **58** is slidably supported by the second track structure **56** and is free to move along the second axis A_2 and is only constrained against such movement by the second positioning device **60'**.

The power controller **20** and the controller **32** each preferably includes a microcomputer with respective alignment control programs that control corresponding features of the wireless charging structure **10**, as discussed above. The power controller **20** and the controller **32** can each also include other conventional components such as an input interface circuit, an output interface circuit, and storage devices such as a ROM (Read Only Memory) device and a RAM (Random Access Memory) device. The microcomputers of the power controller **20** and the controller **32** are each programmed to control the respective portions of wireless charging structure **10**. The memory circuits store processing results and control programs such as ones for wireless charging operations that are run by the processor circuits. The power controller **20** is operatively coupled to the transmission coil **22** in a conventional manner and the controller **32** is operatively coupled to the alignment assembly **34** and the vehicle-side induction coil **62** in conventional manners. The internal RAM of each of the power controller **20** and the controller **32** store statuses of operational flags and various control data. The internal ROMs of each of the power controller **20** and the controller **32** store the wireless charging protocols and alignment movement controls for various the operations described above. It will be apparent to those skilled in the art from this disclosure that the precise structure and algorithms for each of the power controller **20** and the controller **32** can be any combination of hardware and software that will carry out the functions of the present invention.

The various features of the vehicle **14** are conventional components that are well known in the art. Since vehicle components are well known in the art, these structures will not be discussed or illustrated in detail herein. Rather, it will be apparent to those skilled in the art from this disclosure that the components can be any type of structure and/or programming that can be used to carry out the present invention.

GENERAL INTERPRETATION OF TERMS

In understanding the scope of the present invention, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "including," "having" and their derivatives. Also, the terms "part," "section," "portion," "member" or "element" when used in the singular can have the dual meaning of a single part or a plurality of parts. Also as used herein to describe the above embodiments, the following directional terms "forward," "rearward," "above," "downward," "vertical," "horizontal," "below" and "transverse" as well as any other similar directional terms refer to those directions of a vehicle equipped with the wireless charging structure **10**. Accordingly, these terms, as utilized to describe the present invention should be interpreted relative to a vehicle equipped with the wireless charging structure **10**.

The term "detect" as used herein to describe an operation or function carried out by a component, a section, a device or the like includes a component, a section, a device or the like that does not require physical detection, but rather includes determining, measuring, modeling, predicting or computing or the like to carry out the operation or function.

The term "configured" as used herein to describe a component, section or part of a device includes hardware and/or software that is constructed and/or programmed to carry out the desired function.

The terms of degree such as "substantially," "about" and "approximately" as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed.

While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. For example, the size, shape, location or orientation of the various components can be changed as needed and/or desired. Components that are shown directly connected or contacting each other can have intermediate structures disposed between them. The functions of one element can be performed by two, and vice versa. The structures and functions of one embodiment can be adopted in another embodiment. It is not necessary for all advantages to be present in a particular embodiment at the same time. Every feature which is unique from the prior art, alone or in combination with other features, also should be considered a separate description of further inventions by the applicant, including the structural and/or functional concepts embodied by such features. Thus, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. An alignment method for a vehicle wireless charging system, the method comprising:

detecting reception of electromagnetic radiation received by a vehicle-side coil from a transmitter coil with the vehicle-side coil at a current position relative to the transmitter coil;

determining efficiency of electromagnetic radiation reception by the vehicle-side coil;

determining whether or not the efficiency of electromagnetic radiation reception by the vehicle-side coil achieves a predetermined level of reception efficiency;

repositioning the vehicle-side coil in response to determining that the efficiency of the electromagnetic radiation reception is less than the predetermined level of reception efficiency; and

repeating the determining of the efficiency of electromagnetic radiation reception and the repositioning the vehicle-side coil until the determined efficiency is equal to or greater than the predetermined level of reception efficiency.

2. The method according to claim **1**, wherein

the repositioning the vehicle-side coil includes moving the vehicle-side coil along a first axis that is parallel to a main surface of the vehicle-side coil.

3. The method according to claim **2**, wherein

the repositioning the vehicle-side coil includes moving the vehicle-side coil along a second axis that is also parallel to a main surface of the vehicle-side coil and perpendicular to the first axis.

4. The method according to claim **1**, further comprising

maintaining the vehicle-side coil in a stationary position in response to the determined efficiency being equal to or greater than the predetermined level of reception efficiency.

5. The method according to claim **1**, further comprising

parking a vehicle above the transmitter coil of the wireless charging system prior to detecting reception of electromagnetic radiation, with the vehicle-side coil being mounted to an underside of the vehicle.

6. The method according to claim **1**, further comprising

moving the vehicle-side coil to a preselected position upon moving the vehicle away from the transmitter coil.

7. The method according to claim **1**, further comprising

maintaining the vehicle-side coil in position upon moving the vehicle away from the transmitter coil.

8. An alignment method for a vehicle wireless charging system, the method comprising:

detecting reception of electromagnetic radiation by the vehicle-side coil from the transmitter coil with the vehicle-side coil at a current position relative to the transmitter coil;

determining efficiency of electromagnetic radiation reception by the vehicle-side coil;

determining whether or not the efficiency of electromagnetic radiation reception by the vehicle-side coil achieves a predetermined level of reception efficiency;

repositioning the vehicle-side coil in a first adjustment direction in response to determining that the efficiency of the electromagnetic radiation reception is less than the predetermined level of reception efficiency while maintaining position of the vehicle-side coil in a second adjustment direction perpendicular to the first adjustment direction; and

repeating the determining of the efficiency of electromagnetic radiation reception and the repositioning the vehicle-side coil in the first adjustment direction until the determined efficiency is determined to be at a maximized level.

9. The method according to claim **8**, further comprising

redefining the current position of the vehicle-side coil based upon movement of the vehicle-side coil during the repositioning of the vehicle-side coil;

re-determining efficiency of electromagnetic radiation reception by the vehicle-side coil;

determining whether or not the efficiency of electromagnetic radiation reception by the vehicle-side coil achieves the predetermined level of reception efficiency;

repositioning the vehicle-side coil in the second adjustment direction in response to determining that the efficiency of the emission is less than the predetermined level of reception efficiency while maintaining position of the vehicle-side coil in the first adjustment direction; and

repeating the re-determining of the efficiency of electromagnetic radiation reception and the repositioning the vehicle-side coil in the second adjustment direction until the determined efficiency is determined to be equal to or greater than the predetermined level of reception efficiency.

10. The method according to claim **8**, further comprising

parking a vehicle above the transmitter coil of the wireless charging system prior to detecting reception of electromagnetic radiation, with the vehicle-side coil being mounted to an underside of the vehicle.

11. The method according to claim **8**, wherein

the repositioning the vehicle-side coil in the first adjustment direction includes operating a stepper motor coupled to the vehicle-side coil.

12. The method according to claim **8**, wherein

the repositioning the vehicle-side coil in the first adjustment direction includes operating a first stepper motor coupled to the vehicle-side coil and the repositioning the vehicle-side coil in the second adjustment direction includes operating a second stepper motor coupled to the vehicle-side coil.

13. The method according to claim **8**, wherein

moving the vehicle-side coil to a preselected position upon moving the vehicle away from the transmitter coil.

14. The method according to claim **8**, further comprising

maintaining the vehicle-side coil in a current position upon moving the vehicle away from the transmitter coil.

15. An alignment method for a vehicle wireless charging system, the method comprising:

emitting a first level of electromagnetic radiation from the transmitter coil;

detecting reception of the first level of electromagnetic radiation by the vehicle-side coil from the transmitter coil with the vehicle-side coil at a current position relative to the transmitter coil;

determining efficiency of electromagnetic radiation reception at the first level by the vehicle-side coil;

determining whether or not the efficiency of electromagnetic radiation reception at the first level by the vehicle-side coil achieves a predetermined level of reception efficiency;

repositioning the vehicle-side coil in response to determining that the efficiency of the electromagnetic radiation reception at the first level is less than the predetermined level of reception efficiency;

repeating the determining of the efficiency of electromagnetic radiation reception and the repositioning the vehicle-side coil until the determined efficiency of electromagnetic radiation reception at the first level is determined to be equal to or greater than the predetermined level of reception efficiency; and increasing the electromagnetic radiation from the transmitter coil to a battery charging level in response to the determined efficiency of electromagnetic radiation reception at the first level being equal to or greater than the predetermined level of reception efficiency.

16. The method according to claim **15**, wherein

the repositioning the vehicle-side coil includes moving the vehicle-side coil along a first axis that is parallel to a main surface of the vehicle-side coil, and

the repositioning the vehicle-side coil includes moving the vehicle-side coil along a second axis that is also parallel to a main surface of the vehicle-side coil and perpendicular to the first axis.

17. The method according to claim **15**, further comprising

maintaining the vehicle-side coil in a stationary position in response to the determined efficiency being equal to or greater than the predetermined level of reception efficiency.

18. The method according to claim **15**, further comprising

parking a vehicle above the transmitter coil of the wireless charging system prior to detecting reception of electromagnetic radiation, with the vehicle-side coil being mounted to an underside of the vehicle.

19. The method according to claim **15**, wherein

the repositioning the vehicle-side coil in response to determining that the efficiency of the electromagnetic radiation reception at the first level is less than the predetermined level of reception efficiency includes at least one of the following:

repositioning the vehicle-side coil in a first adjustment direction in response to determining that the efficiency of the electromagnetic radiation reception is less than the predetermined level of reception efficiency while maintaining position of the vehicle-side coil in a second adjustment direction perpendicular to the first adjustment direction; and

repositioning the vehicle-side coil in the second adjustment direction in response to determining that the efficiency of the emission is less than the predetermined level of reception efficiency while maintaining position of the vehicle-side coil in the first adjustment direction.

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