
WITRICITY CORP. (*PATENT OWNER*)

Case. No.: IPR2024-00105
U.S. Patent No. 10,027,184

March 5, 2025

Overview of the '184 Patent

'184 Patent

(57) **ABSTRACT**

A wireless energy transfer system includes a foreign object debris detection system. The system includes at least one wireless energy transfer source configured to generate an oscillating magnetic field. The foreign object debris may be detected by at least one field gradiometer positioned in the oscillating magnetic field. The voltage of the at least one field gradiometer may be measured using readout circuitry and a feedback loop based on the readings from the gradiometers may be used to control the parameters of the wireless energy source.

US010027184B2

(12) **United States Patent**
Verghese et al.

(10) **Patent No.:** US 10,027,184 B2
(45) **Date of Patent:** Jul. 17, 2018

(54) **FOREIGN OBJECT DETECTION IN WIRELESS ENERGY TRANSFER SYSTEMS**

(58) **Field of Classification Search**
CPC .. H02J 50/00; H02J 50/12; H02J 7/025; H02J 17/00; H02J 5/005; H02J 50/60; (Continued)

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(74) Attorney, agent, or firm—Please communicate with

ABSTRACT
(57)
A wireless energy transfer system includes a foreign object debris detection system. The system includes at least one wireless energy transfer source configured to generate an oscillating magnetic field. The foreign object debris may be detected by at least one field gradiometer positioned in the oscillating magnetic field. The voltage of the at least one field gradiometer may be measured using readout circuitry and a feedback loop based on the readings from the gradiometers may be used to control the parameters of the wireless energy source.

16 Claims, 10 Drawing Sheets

Gravity ↓

102

Side View

104

106

FOD is away from peak B-field and rolls off

Wireless charging systems that rely on an oscillating magnetic field between two coupled resonators can be efficient, non-radiative, and safe. Non-magnetic and/or non-

'184 Patent

Purpose of the '184 Patent is to detect FOD

'184 Patent

- FOD in the vicinity of a wireless power transfer system may be benign and/or interact with the oscillating magnetic field in a way that may perturb, block or reduce the magnetic field.” '184 Patent 1:54-57, 1:67 – 2:5.
- Examples of FOD that may be benign include “dirt, sand, leaves, twigs, snow, grease, oil, water, and other substances that may not interact significantly with a low-frequency magnetic field.” '184 Patent 1:57-60.
- Examples of other FOD that may interact with the magnetic field include metallic objects that the magnetic field can cause to heat up, such as “tools, coils, metal pieces, soda cans, steel wool, food (chewing gum, burgers, etc.) wrappers, cigarette packs with metal foil, and the like.” '184 Patent 1:45-48, 2:5-13.

'184 Patent



US010027184B2

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(54) **FOREIGN OBJECT DETECTION IN WIRELESS ENERGY TRANSFER SYSTEMS**

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Related U.S. Application Data

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(51) **Int. Cl.**
H01F 38/14 (2006.01)
H01F 37/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H02J 50/60** (2016.02); **B60L 11/182** (2013.01); **G01R 33/10** (2013.01); **G01V 3/10** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. **H02J 50/00**; **H02J 50/17**; **H02J 50/19**
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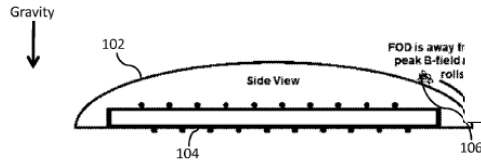
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(57) **ABSTRACT**
A wireless energy transfer system in debris detection system. The system includes a wireless energy transfer source configured to generate an oscillating magnetic field. The foreign object detected by at least one field gradient sensor. The voltage field gradient sensor may be measured; and a feedback loop based on the measurements may be used to control the wireless energy source.

16 Claims, 10 Drawing



What is claimed is:

1. A wireless energy transfer system with foreign object debris detection, the system comprising:

a wireless energy transfer source comprising a source resonator configured to generate an oscillating magnetic field; and

a foreign object debris detection system comprising:

at least one magnetic field sensor; and

at least one readout circuit configured to measure one or more electrical parameters of at the at least one magnetic field sensor,

wherein the at least one magnetic field sensor is positioned within the magnetic field of the wireless energy transfer system; and

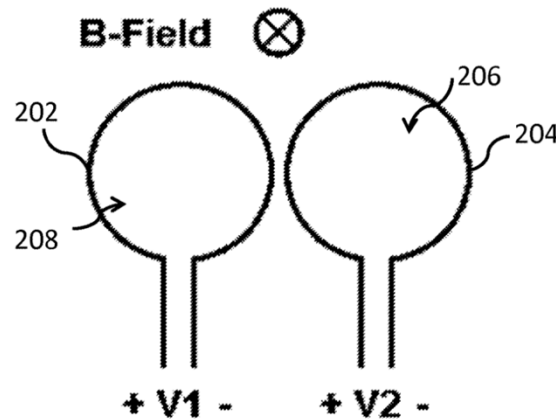
wherein the foreign object debris detection system is configured to verify that foreign object debris has not moved onto or over the source resonator during generation of the oscillating magnetic field.

'184 Patent

- FOD (e.g., metallic objects) of sufficient size, extent and/or material composition may perturb characteristics of the resonators or the energy transfer. '184 Patent 4:39-50. Horenstein Decl. ¶ 46.
- “A FOD object may change the impedance of a resonator for example.” '184 Patent 4:50-51.
- These perturbations and thereby the FOD may be detected by measuring electrical parameters of the resonators and/or characteristics of the energy transfer. '184 Patent 4:51-59. Horenstein Decl. ¶ 46.

'184 Patent

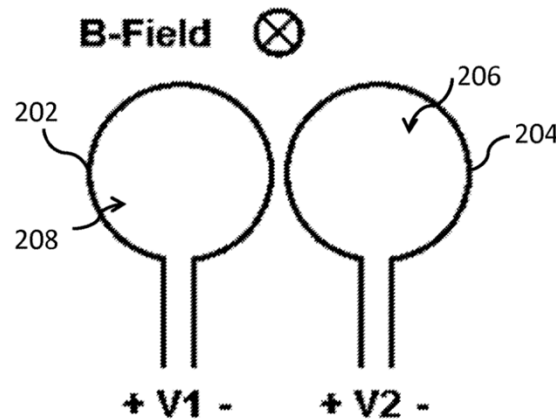
Fig. 2



- FIG. 2 illustrates a FOD sensor (magnetic field sensor) that may be realized by two wire loops 202, 204. '184 Patent 5:39-41.

'184 Patent

Fig. 2



- “During operation the wireless energy transfer system generates a magnetic field that passes through the two loops.” ‘184 Patent, 5:43-45; see *also* 5:25-38; Horenstein Decl. ¶ 37-51.

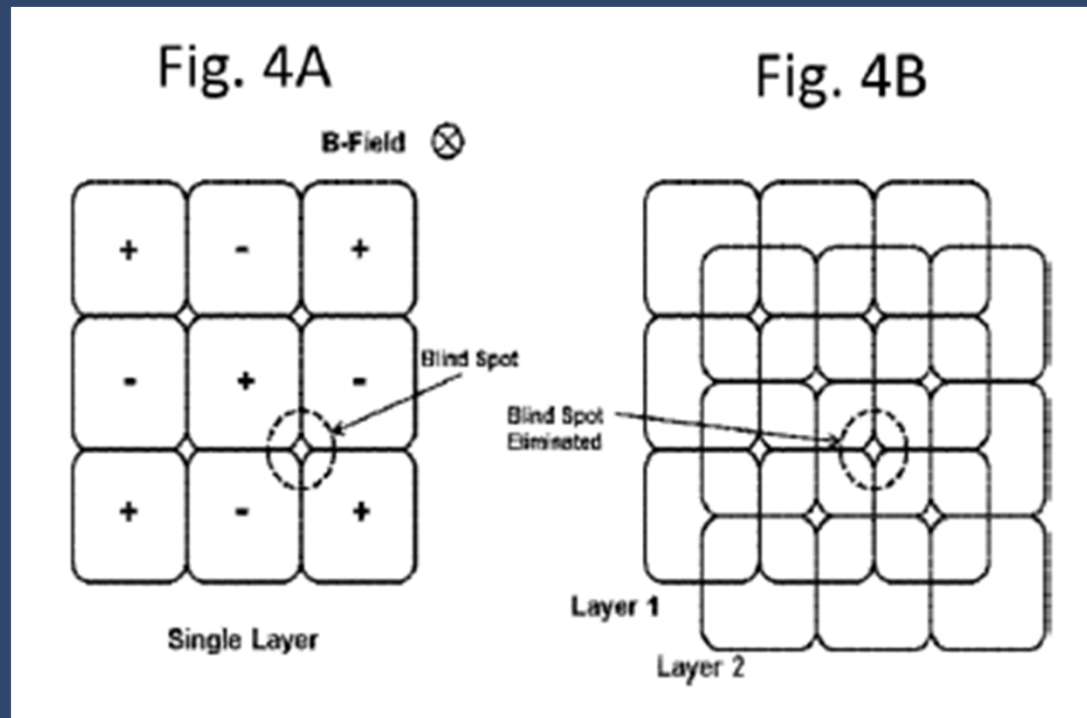
'184 Patent

- In the absence of FOD, if the loops are substantially uniform, then the difference between the voltages may be very small. '184 Patent 5:49-52; Horenstein Decl. ¶ 37-51.
- On the other hand, when a FOD is placed so that the FOD partially covers one of the loops but not the other loop, the FOD may deflect and/or absorb some of the magnetic flux, perturbing the magnetic field, and resulting in a larger difference between the voltages. '184 Patent 5:53-63; Horenstein Decl. ¶ 37-51.

'184 Patent

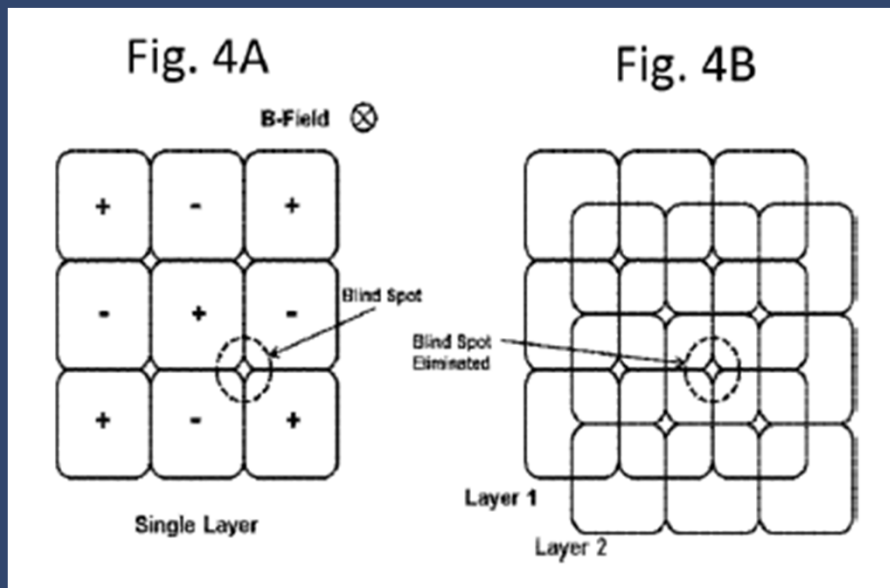
- The '184 patent provides a number of other embodiments in which the FOD sensor may be realized by one loop that is twisted into a number of lobes. '184 Patent Figs. 3A-3D; 6:43-49.
- “Each of these configurations can accomplish the goal of measuring *magnetic field perturbations due to the presence of metallic FOD.*” '184 Patent 7:8-10 (emphasis added); see *generally* 5:64 to 8:4; Horenstein Decl. ¶ 37-

'184 Patent



- Fig. 4B shows an embodiment with two offset arrays, and that may be used to eliminate blind spots. '184 Patent 7:28-46; Horenstein ¶

'184 Patent



- A POSA would have understood that the loop sensors are used to form an array that is placed over the resonator, and therefore *within* the magnetic field of the resonator. Horenstein ¶¶ 47-51; Sur-Reply at 7.
- Such an array is necessary if full detection coverage is to be monitored over the entire face of the resonator. Horenstein ¶¶ 47-51.

‘184 Patent – Power Modes

- **Low-power diagnostic tests can be performed without the vehicle present to check health and status of the charging station (infrequent) and to check for FOD prior to a vehicle driving over the source (more frequent). ‘184 Patent 11:42-45.**
- **After the vehicle arrives and is positioned over the source module, but prior to high-power charging, the FOD detector may verify that the source is still free of FOD. ‘184 Patent 11:46-48.**
- **During high-power charging the FOD detector can verify that no additional FOD has moved onto the coil. ‘184 Patent 11:40-50. Horenstein Decl. ¶ 37-51.**

'184 Patent

**Claim terms are to be given
their ordinary meaning.**

'184 Patent

Claim 1 of the '184 Patent requires that the magnetic field sensor be “positioned within the magnetic field” of the wireless energy transfer system.

What is claimed is:

1. A wireless energy transfer system with foreign object debris detection, the system comprising:
 - a wireless energy transfer source comprising a source resonator configured to generate an oscillating magnetic field; and
 - a foreign object debris detection system comprising:
 - at least one magnetic field sensor; and
 - at least one readout circuit configured to measure one or more electrical parameters of at the at least one magnetic field sensor,wherein the at least one magnetic field sensor is positioned within the magnetic field of the wireless energy transfer system; and
- wherein the foreign object debris detection system is configured to verify that foreign object debris has not moved onto or over the source resonator during generation of the oscillating magnetic field.

'184 Patent

- The purpose is for the magnetic field sensor to measure perturbations in the magnetic field of the wireless energy transfer system/resonator. '184 Patent 2:48-49; 5:25 to 6:42.
- “During operation the wireless energy transfer system *generates a magnetic field that passes through the two loops.*” '184 Patent 5:43-45 (emphasis added).
- The loop sensors in the '184 Patent are passive, requiring no power because their signals are induced by the magnetic field of the resonator. '184 Patent, 6:52-56; 7:15-16.
- A POSA in magnetic induction would understand that each sensor must be placed within the magnetic field of the resonator. Horenstein ¶ 38; Figure caption above ¶¶ 39, 40, 43; PO Sur-Reply at 7.

'184 Patent

FOD detected: magnetic fields AND metallic objects.

‘184 Patent

- ***Metallic objects* that the magnetic field can cause to heat up, such as “tools, coils, metal pieces, soda cans, steel wool, food (chewing gum, burgers, etc.) wrappers, cigarette packs with metal foil, and the like.” ‘184 Patent 2:11-13; see *also* 1:45-48.**

Fells

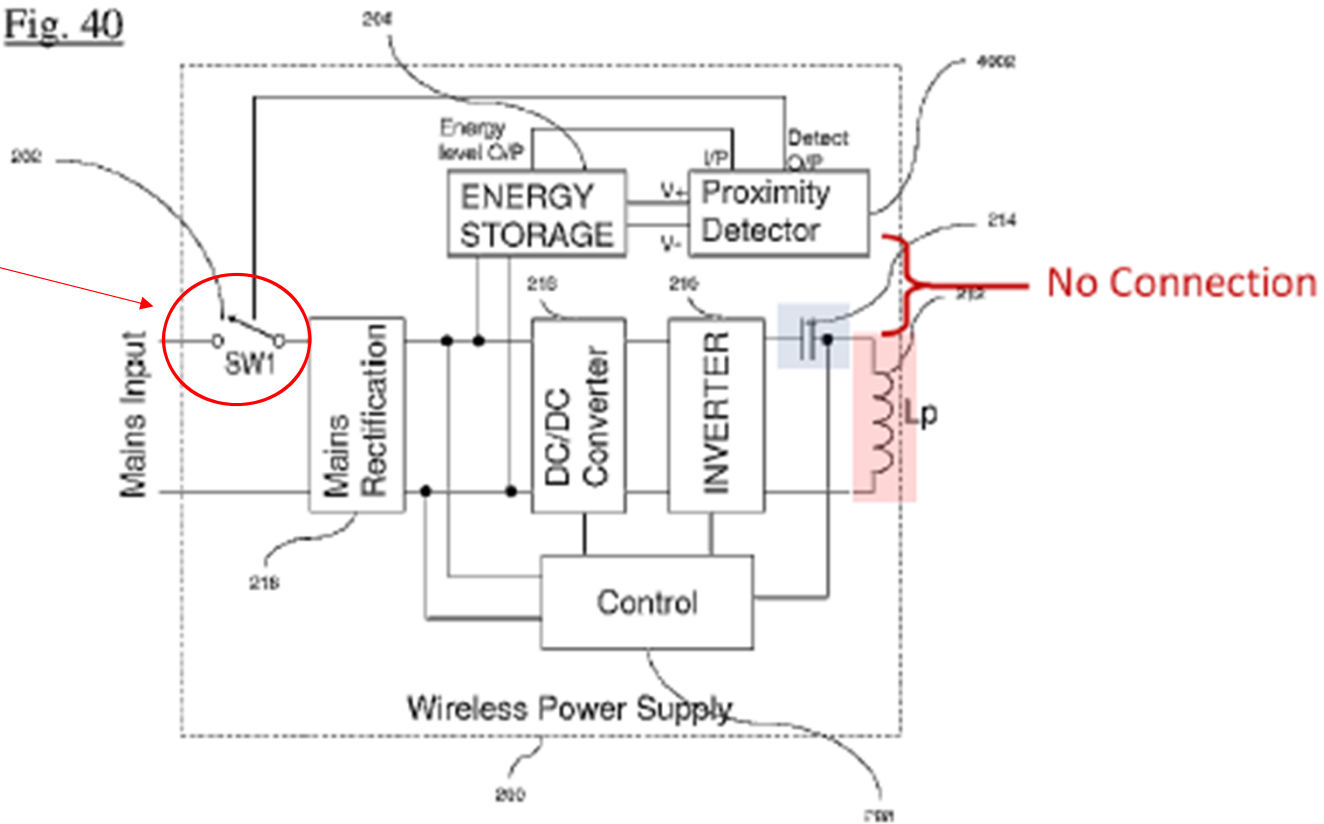
- The magnetic field sensor cannot be “within the magnetic field” of the wireless transfer system because the source resonator is not generating a magnetic field.
- Fells is a wireless charging system for a mobile phone.
- The purpose of Fells is to conserve energy by keeping the source resonator off (i.e., not generating a magnetic field) until after its “proximity detector” detects the magnetic field of a mobile phone approaching.
- After detecting the mobile phone, then Switch 1 (SW1) closes and the source resonator begins to produce a magnetic field to charge the mobile phone.

Fells

- Because the resonator is not producing a magnetic field until after detecting an approaching object, the magnetic field sensor cannot be “within the magnetic field of the wireless energy transfer system” as required by Claim 1. PO Response 29-35; Horenstein ¶¶ 110, 113; PO Sur-Reply 8-9.

Fells

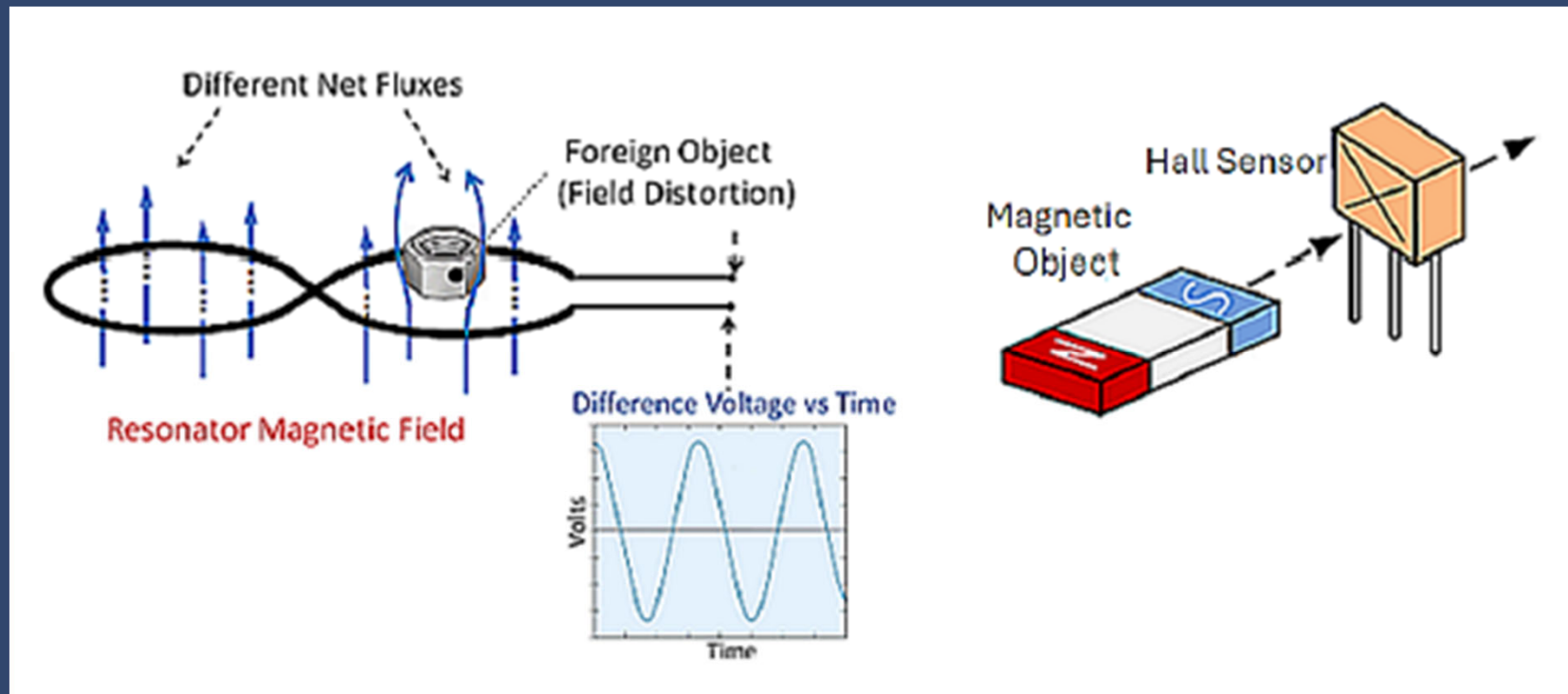
Fig. 40



Fells

- The proximity detector is powered by its own energy source that is separate from the primary coil/resonator. Fells [0191], [0246].
- Fig. 40: there is no connection between the proximity detector and the primary coil.
- The proximity detector “completely separate” from the primary coil. Fells [0288].
- Each of the sensors disclosed in Fells [0292] is powered by its own, separate Energy Storage element 204. Fig. 40.

Fells



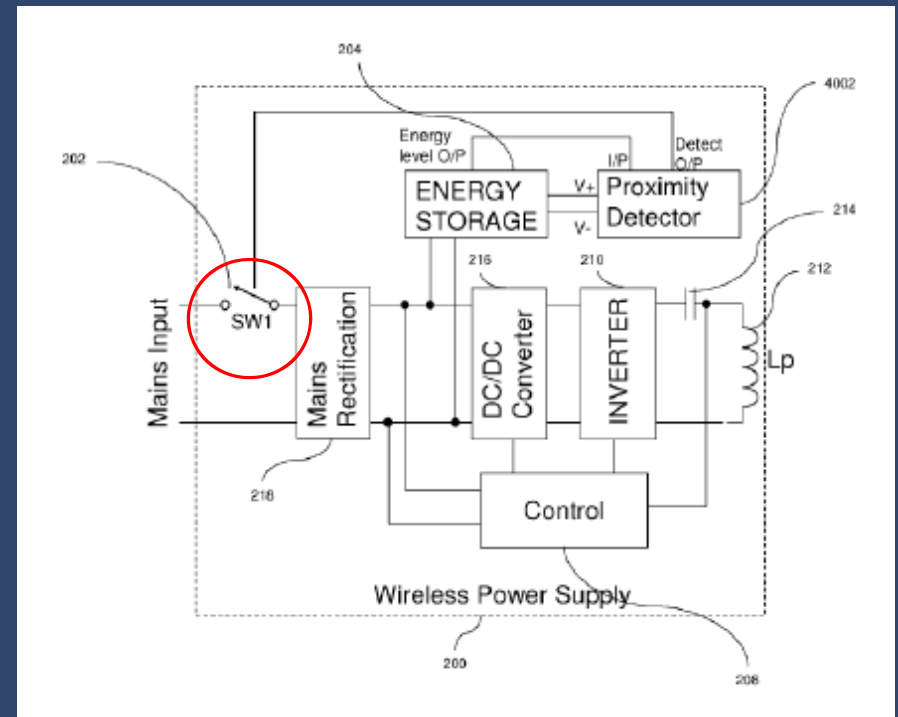
- Hall Effect sensor: A POSA would have known that a Hall Effect sensor senses magnetic fields, not metallic objects. Lenz pg. 979; Horenstein ¶ 96; PO Sur-Reply 9.

Fells

**The Primary Coil/Resonator is NOT activated
until after the proximity detector
detects a mobile phone.**

Fells – Fig. 40

The primary coil/resonator is not activated (i.e., does not have any power) until after the proximity detector detects a mobile phone (or object) and closes Switch 1 (SW 1). Fells [0191], [0206], [0246]; Horenstein ¶ 95; PO Sur-Reply 9.



Fells

- So the primary coil/resonator is not producing a magnetic field.
- Thus, the proximity detector can neither reside within, nor can it monitor, the magnetic field *of the primary coil/resonator*, ***because there is no magnetic field to monitor.*** Horenstein at 95; PO Sur-Reply 9.

Fells

**Hall Effect sensor in Fells measures changes
in the magnetic field of a mobile
phone/approaching object.**

Fells

- The ferrite core “within a portable device” refers to the fact that in a mobile phone, the circuitry around the ferrite core and other parts of the mobile phone can be magnetized, thus producing a magnetic field. Horenstein ¶ 96; Fells [0289]; PO Sur-Reply 10.
- For a magnetized mobile phone approaching the primary coil in Fells, a ferrite core inside the phone would “result in altering the magnetic field” seen by the Hall Effect device. PO Sur-Reply 10.
- Thus, the change in magnetic field contemplated by Fells is not the magnetic field of the primary coil/resonator. Horenstein ¶ 93; PO Sur-Reply 10.

Fells

The “magnetic field” in Fells is referring to the magnetic field produced by an approaching object.

Fells

- It was well known that a mobile phone set up for wireless charging contains a ferrite disk behind its secondary receiving coil (Horenstein ¶ 96), as well as one or more permanent magnets, e.g., in the core of the phone's loudspeaker or another permanent magnet placed inside the phone. Fells [0290]; PO Sur-Reply 11.
- Fells [0289] refers to Fells Fig. 40. Figure 40 shows a proximity detector 4002 that “is used to initially detect that a device [e.g. a mobile phone] or foreign object has been placed in the vicinity of the wireless power supply 200. PO Sur-Reply 11.

Fells

- It also detects if a device or foreign object is removed from the wireless power supply 200.” (Id. [0287]; PO Sur-Reply 11.
- Fells notes that “...Proximity Detector 4002 is completely separate from the primary coil 212 and therefore not connected to it.” Id. [0287]; Horenstein ¶ 79; PO Sur-Reply 11.
- Fells then provides a list of possible Proximity Detectors, including an “inductive proximity sensor”, a “capacitive proximity detector”, or a “Hall Effect sensor” in which, for the latter, there is a change in its output voltage in response to a change in magnetic field.” Fells [0289]; PO Sur-Reply 11.

Fells

- **Fells further teaches that a portable device may contain a permanent magnet to aid in its detection by the proximity sensor, which can be a Hall Effect sensor.**

Fells

“It is possible to have an element in the portable device which facilitates its detection. For instance, the device may contain a *permanent magnet*. When this magnet *is in proximity to the wireless power supply 200* it activates a switch within the wireless power supply 200 by magnetic attraction. Additional sense circuits that act as proximity detectors could include a *hall sensor...*” Fells [0290].

Fells

- The alteration to the magnetic field by a ferrite core, as disclosed in Fells [0289], thus refers to the alteration of the magnetic field produced by the mobile device. Horenstein, generally, at ¶ 96; PO Sur-Reply 12.
- A POSA would have known, for example, that every mobile phone contains a loudspeaker, and that loudspeakers always contain a permanent magnet. PO Sur-Reply 12.
- This is consistent with Fells' disclosure of a permanent magnet inside a portable device. Fells [0290]; PO Sur-Reply 12.

Fells

**A POSA would not place a Hall Effect sensor
on or in the magnetic field of the source
resonator.**

Fells

- Hall Effect sensor only detects magnetized objects, so it cannot detect metal objects.
- Purpose of '184 Patent is to detect FOD like metal objects, e.g., “tools, coils, metal pieces, soda cans, steel wool, food (chewing gum, burgers, etc.) wrappers, cigarette packs with metal foil, and the like.” ‘184 Patent 1:45-48, 2:5-13; Horenstein Decl. ¶ ____.
- Hall Effect sensor is not small, however, such that each sensor would obstruct the resonator. Horenstein ¶ 100.

Fells

- Requires using large numbers of Hall Effect sensors and spreading them over the face of the resonator.
- The resonator field will induce eddy currents in the silicon chip of a Hall Effect sensor, thereby incapacitating the ability of the Hall device to measure anything. Horenstein ¶ 100.
- Hall Effect sensors placed on top of the resonator would themselves become foreign object debris.
- Because the resonator field is so strong, the sensors would heat up, just like the gum wrappers mentioned frequently in the '184 patent. Horenstein ¶ 100.

Fells

Inductive proximity detector in Fells is not a magnetic field sensor.

Fells

- **A magnetic field sensor detects the presence or strength of external magnetic fields, which may be from permanent magnets or electromagnet. PO Response 25-29; PO Sur-Reply 14-15.**
- **In contrast, an inductive proximity sensor creates its own magnetic field and then detects the presence of metallic objects regardless of whether those objects are magnetic. PO Response 25-29; Horenstein Decl. ¶¶ 89-92; PO Sur-Reply 14-15.**

Fells

- Dr. Allen admits that “an Eddy-current sensor, I suppose, could be something loosely like [an inductive proximity sensor that does not constitute a magnetic field sensor].” Allen Depo. (Ex. 2015) 33:13-18; see also id. 34:9 – 35:6; PO Sur-Reply 14-15.
- Inductive proximity sensor’s magnetic field is sensitive to metallic objects but does not directly respond to external magnetic fields. PO Response 27; Horenstein Decl. ¶¶ 89-90; PO Sur-Reply 14-15.
- This is the opposite of magnetic field sensor in Claim 1, ‘184 Patent.

Fells

- **Dependent claims 8 and 11 depend from Claim 1; thus, Petitioner has failed to establish that the challenged dependent claims are unpatentable.**

Fells and Cook (Ground 2)

**Claims 2-7, 9, 10, and 16 are Patentable over
Fells and Cook (Ground 2).**

Cook (Ex. 1006)

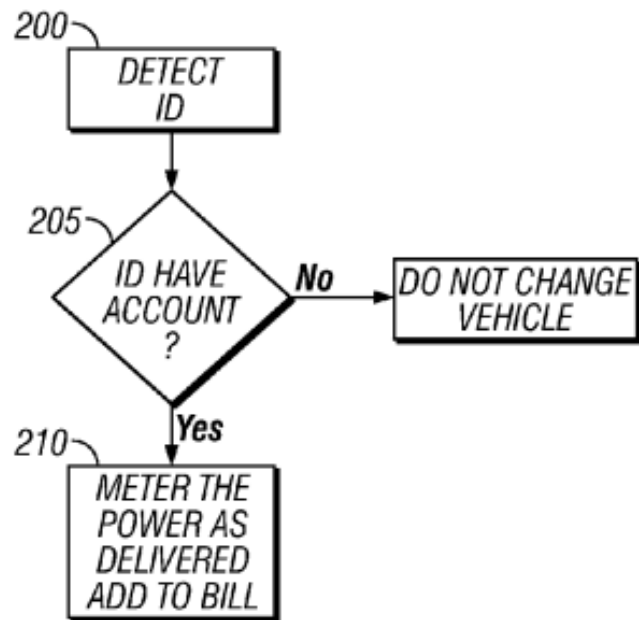


FIG. 2

- The vehicle includes an RFID device that uniquely identifies the vehicle. Cook ¶ 14; PO Response at 22.
- The send and receive device may detect a unique ID of the vehicle from the RFID device. PO Response at 22.
- When the vehicle's ID is detected by the charger, the system checks if the vehicle is associated with an account.
- Cook does not disclose checking for FOD.

Fells and Cook (Ground 2)

- **Claims 2-7, 9-10 depend from Claim 1.**
- **Cook does not cure the deficiencies of Fells.**
- **Thus, Petitioner has not met its burden to prove these claims are unpatentable.**

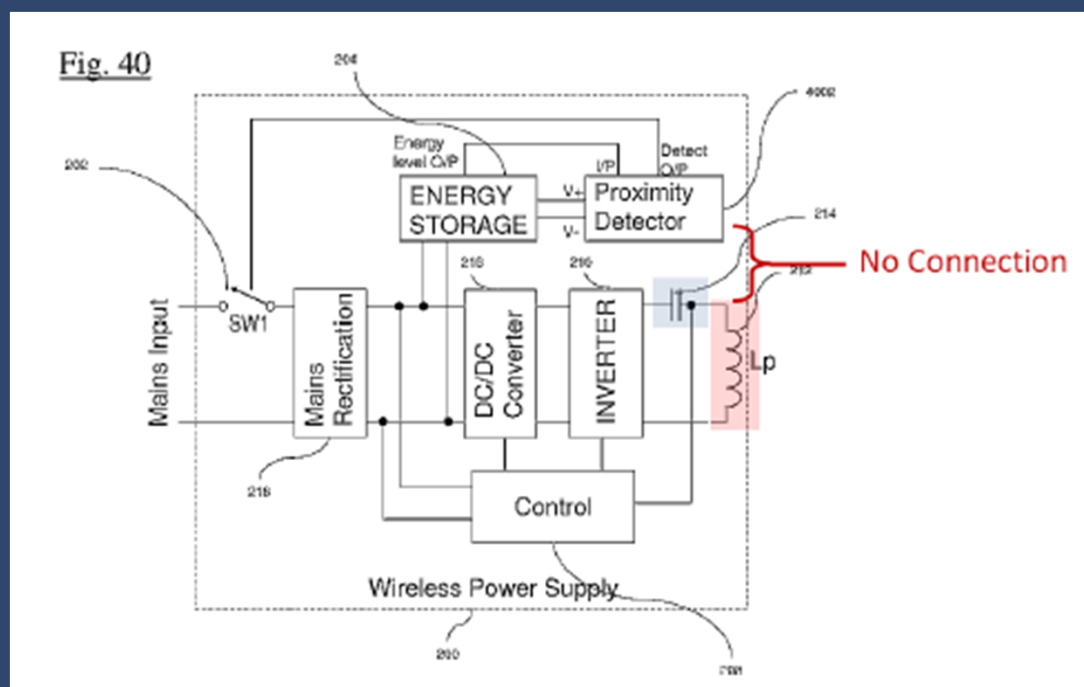
Fells and Cook (Ground 2)

Petitioner has not met its burden to prove that Claim 16 (“health and/or status check of a source resonator”) is unpatentable.

Fells and Cook (Ground 2)

- **Sense circuit calibration in Fells does not verify the functioning status of the source resonator. PO Response 45-46; Horenstein Decl. ¶ 106.**
- **Baseline induction measurement does not verify the functioning status of the source resonator. PO Response 45-46; Horenstein Decl. ¶ 106.**
- **Checking that the energy storage element is not fully depleted is not checking the health and/or status of the resonator.**

Fells and Cook (Ground 2)



- The sense circuit and energy storage element of Figs. 2 and 40 are completely separate from the source resonator.

Fells and Ono (Ground 3)

**Fells and Ono do not make Claim 12
unpatentable (Ground 3).**

Fells and Ono (Ground 3)

- **‘184 Patent Claim 12: The system of Claim 1 . . . “wherein the foreign object debris detection system is integrated into the enclosure.”**
- **Ono does not cure the deficiencies in Fells regarding the positioning of a magnetic field sensor required by Claim 1, and Petitioner does not argue that it does.**

Fells and Ono (Ground 3)

- Labeled, dotted lines are used to identify parts, not enclosures.
- A POSA would understand that Ono only discloses a housing, but does not show it *integrated into* the enclosure housing. PO Response 54-55; Horenstein ¶¶ 126-128.
- *CAE Screenplates, Inc. v. Heinrich Fiedler GmbH & Co.*, 224 F.3d 1308, 1317 (Fed. Cir. 2000) (“In the absence of any evidence to the contrary, we must presume that the use of different terms in the claims connotes different meanings.”).

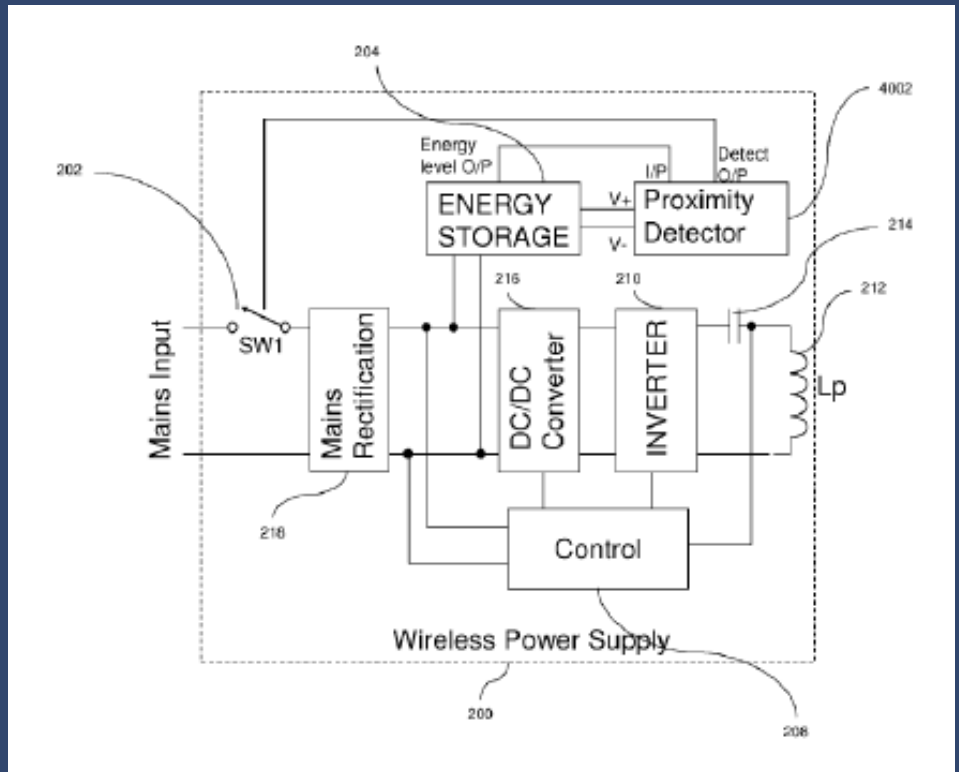


Fig. 40

Fells and Cook and/or Wang (Ground 4)

**Fells and Cook and/or Wang do not make
Claim 13 (dependent on Claim 1) unpatentable.**

Fells and Cook and/or Wang (Ground 4)

- The petitioner did not address Ground 4 in its Reply.
- Cook and/or Wang Thesis do not cure the deficiencies of Fells.