

EX. 2001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re *Inter Partes* Review of:)
U.S. Patent No. 8,466,654)
Issued: Jun. 18, 2013)
Application No.: 12/498,159)
Filing Date: Jul. 6, 2009)

For: Wireless High-Power Transfer Under Regulatory Constraints

Declaration of Mark N. Horenstein Regarding Certain Claim Terms Found in U.S.
Patent No. 8,466,654

DECLARATION OF DR. MARK HORENSTEIN

I, Dr. Mark N. Horenstein, declare as follows:

1. I am over the age of 18 years and am fully competent to make this declaration. I make the following statements based on personal knowledge and, if called to testify to them, could and would do so.

I. INTRODUCTION

2. I have been retained on behalf of WiTricity Corporation to study and provide my opinions concerning U.S. Patent No. 8,466,654 (the “’654 patent”) and the patentability of the claims challenged by Petitioner InductEV. In this declaration, I provide my opinions regarding the meaning of certain terms found in the challenged claims and in the prior-art references put forth by Petitioner. I herein provide my opinions in consideration of the state of the art at the time of the claimed inventions and the knowledge that a person having ordinary skill in the art (PHOSITA) would have had at the time of the claimed inventions.

3. My opinions and views set forth in this declaration are based on my education, training, and experience in the field of electrical engineering, inductive energy transfer, battery-powered electric vehicles (“EV”), and related technical areas, as well as the Petition and references listed therein, and other materials that are cited and discussed herein.

II. BACKGROUND & QUALIFICATIONS

4. My curriculum vitae (“vita”), which includes a summary of my background, experience, publications, and expert-witness experience is marked as Exhibit 2002.

5. I am a Professor of Electrical Engineering in the Department of Electrical and Computer Engineering at Boston University (now Emeritus) where I have been a faculty member since 1979. In addition to my primary academic appointment, I held various administrative positions at Boston University, including the Associate Dean for Graduate Programs and Research for the College of Engineering (1999-2007), Associate Chair for Undergraduate Programs for the ECE Department (1990-1998 and 2012-2015), as well as appointments at the ranks of Associate Professor (1985-2000) and Assistant Professor (1979-1985).

6. I have a Ph.D. in Electrical Engineering from the Massachusetts Institute of Technology (MIT) which I earned in 1978 while working in the Electric Power Systems Engineering Laboratory. I also hold an M.S. degree in Electrical Engineering from the University of California at Berkeley (1975), and an S.B. degree in Electrical Engineering from MIT (1973).

7. I am a Life Fellow of the Institute of Electrical and Electronic Engineers (IEEE) and have been a Registered Professional Engineer (Electrical) in the Commonwealth of Massachusetts. I hold certification from the National Association of Radio and Telecommunications Engineers.

8. I am the author of two textbooks: *Microelectronic Circuits and Devices, 2nd Ed.* (Prentice-Hall 1996) and *Design Concepts for Engineers, 5th Ed.* (Pearson Education, 2016). I have authored book chapters in two reference books related to electrical engineering. I have authored or co-authored over 70 journal articles on a variety of topics in my fields of expertise, and approximately 125 conference papers. I have advised various Ph.D. students performing research in my fields of expertise; these students have gone on to

hold positions in industry and academia.

9. The courses that I taught over the 40 years I spent as a regular faculty member at Boston University encompassed electromagnetics, antennas, and radio communication, as well as basic electrical circuits, analog and digital electronics, control circuits, power electronics, electric motors, electric machines, microcontrollers, robotics, and engineering design. I was named “Teacher of the Year” in Engineering at Boston University four times.

10. I am a named inventor on six U.S. patents. I have also provided technical expertise in the design and analysis of consumer and industrial electronic products, integrated circuits, power supplies, DC/DC converters, and electromagnetic devices.

11. I have considerable experience in the areas of transformers, antennas, wireless charging devices, battery charging methods, and power circuits in general. I also have extensive experience in the design, analysis, and testing of consumer electrical products, including power supplies, battery chargers, microcontroller-based systems, and control systems of all types. In support of my research in deformable mirror systems, I designed two different analog-multiplexed, high-voltage storage arrays. Similarly, as part of my work in developing self-cleaning solar panels, I have designed switching power supplies that produce low-frequency, 3-phase, 1.5-kV outputs which in turn are powered by low-voltage DC/DC power converters.

12. As part of my work overall in applied electromagnetics, I have designed DC power controllers for thermal management systems, power-amplifier circuits, and analog amplifiers. I also have designed and used transformers of all types, including ferromagnetic, ferrite, and air-core

varieties. I have practical knowledge of outdoor wiring methods and have wired numerous residential and industrial electric supplies, both indoor and outdoor. I have considerable hands-on experience in electrical wiring (e.g., 12-V DC, 120 VAC and 240 VAC) for commercial and residential purposes and a working knowledge of the National Electric Code (NEC) published by the National Fire Protection Association (NFPA-70).

13. At Boston University, I initiated and taught our department's course in power electronics which I devised and designed over a period of nine years. In support of this activity, I designed circuits for laboratory experiments in power electronics, including solar battery charging circuits, buck and boost converters and controllers, H-bridge DC/AC switching converters, and DC to AC-grid interface circuitry. Each year, my assigned capstone project has been the design (from basic parts) of an interface between a photovoltaic panel and the AC power grid.

14. My training and profession encompass broad areas of engineering. The opinions I express in this declaration involve the application of my engineering knowledge, expertise, and experience to the evaluation of U.S. Patent No. 8,466,654 with respect to various claim terms found therein.

15. The opinions proffered in this declaration are based on the documents I have reviewed, my experience and background in the field, my knowledge of electrical engineering, and my professional judgment.

16. In the course of conducting my analysis and forming my opinions, I have reviewed the Petition, references and materials cited therein, and the references listed below.

17. I am being compensated for services provided in this matter. I was recruited for this engagement by Cahn Litigation Services who is billing my time at a rate of \$400 per hour. I am also being reimbursed for reasonable expenses, such as travel expenses, should any arise. My compensation is not contingent on my opinions, on the outcome of any aspects of this matter, or on any of the technical positions that I explain in this declaration. I have no financial interest in Petitioner InductEV, the Patent Owner (who I understand to be WiTricity Corporation), or the '654 Patent.

III. ADDITIONAL EXHIBITS CONSIDERED

Exhibit No.	Description
2003	Wiley Electrical and Electronics Engineering Dictionary (2004 ed.) (selected pages)
2004	2004 McGraw-Hill Dictionary of Scientific and Technical Terms (5th Ed., 1994) (selected pages)

IV. BASES FOR OPINIONS EXPRESSED

18. The opinions set forth in this declaration are my own. My opinions are based on my review of the materials cited throughout this Declaration as itemized in the “Exhibits Considered” list provided above; my educational background; my experience working in the areas of inductive coupling and wireless charging, and my experience as a technical consultant providing expert testimony in numerous cases involving similar and/or related

technology.

V. SUMMARY OF OPINIONS

19. For reasons described in more detail in this Declaration, my overall opinion is that the terms “antenna” (as found in the ’654 patent), “transformer” (as found in Ross), and “core” (as found in both Odachi and Ross) describe antennas and transformers as two distinct structures used to effect wireless inductive coupling between two coils of wire.¹ An antenna achieves its coupling without the use of core material to contain magnetic field lines. In contrast, a transformer achieves coupling by way of a core structure, such as ferrite, that contains and guides lines of magnetic flux. Also, Ross does not disclose moving a transmitting or receiving antenna from a first alignment position to a second alignment position based on the degree of coupling measured at a receiving antenna.

VI. DEFINITIONS OF “ANTENNA” AND “TRANSFORMER”

A. WHAT IS AN ANTENNA?

20. The term “antenna” is used throughout the ’654 patent to describe the primary and secondary coils that effect inductive coupling between the source of power and the receiver of power in a wireless charging system. Figure 2 from the ’654 patent illustrates a “wireless power transfer system” embodiment. (’654 patent, 2:41-42). This figure, reproduced and annotated

¹ Ross and Odachi are prior-art references cited by Petitioner. (*See* III-Exhibits Considered.)

below, shows transmitter antenna 114 (red) and receiver antenna 118 (green).² It also shows the “radiated field 106” for providing energy transfer. (*Id.*, 2:14-15). A PHOSITA would recognize the icon ∇ to be that of an antenna, and the icon $\rangle\rangle\rangle$ to represent energy transfer from transmitting to receiving antennas by way of fields extending into the air.

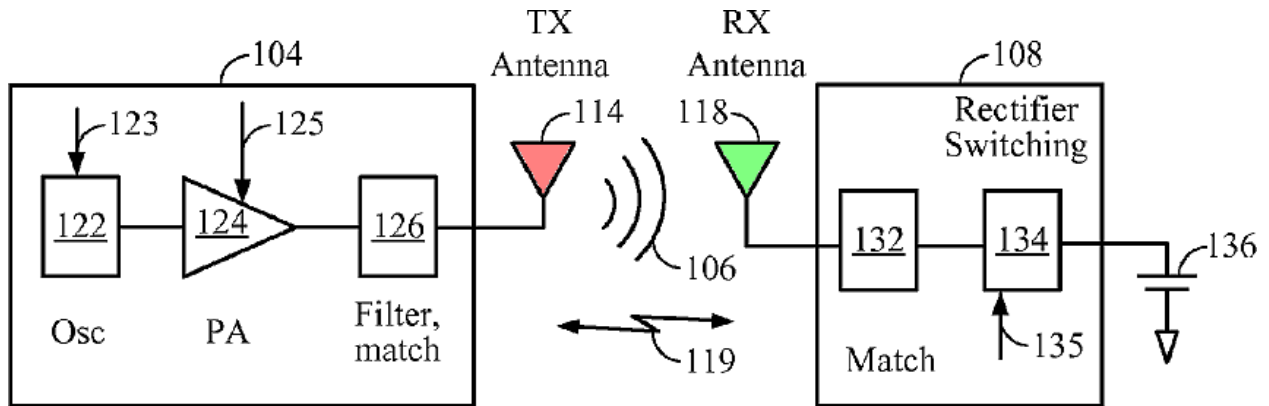


FIG. 2

'654 Patent, Fig. 2 (annotated)

21. Figure 4 from the '654 patent illustrates an example embodiment of the two antennas. The TX-RX combination consists of two flat coils of wire separated only by air, without any intervening solid material:

² Here TX and RX are the customary abbreviations for “transmitter” and “receiver” as used in the field of radio-frequency systems. (See, for example, IEEE Wiley Electrical and Electronics Engineering Dictionary at pg. 801.)

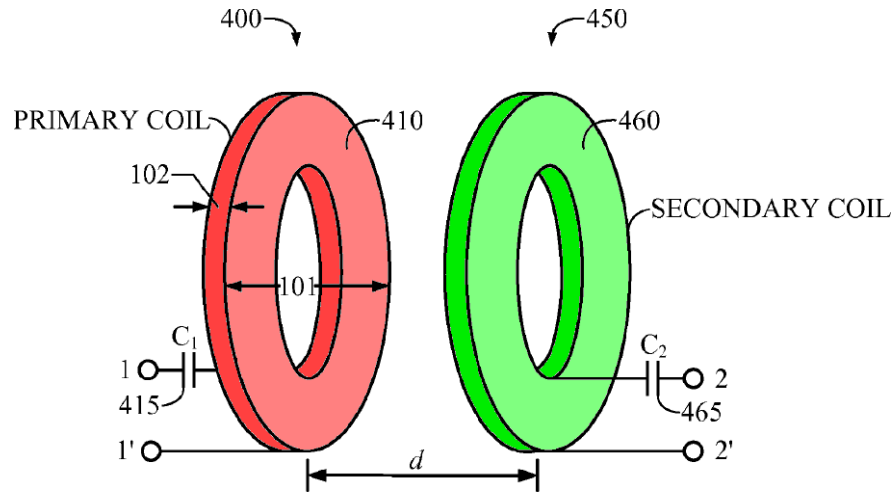


FIG. 4

'654 Patent, Fig. 4 (annotated).

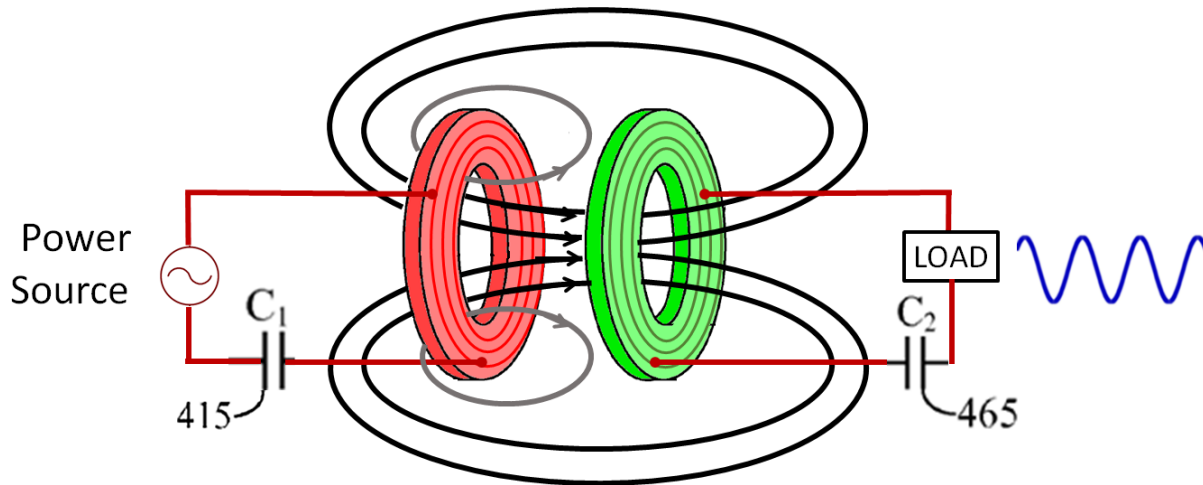
Upon reading the '654 patent, a PHOSITA would have understood the primary and secondary coils in Fig. 4 to be the TX and RX antennas, respectively, of Fig. 2.

22. When the primary antenna coil is energized by an AC power source, as shown below, magnetic flux lines (i.e., “a magnetic field”) are generated by the primary coil (primary coil shown in red color)³. These flux lines (shown in black color) circulate around the coil, as the laws of physics require. The magnetic field lines generated by the primary antenna coil pass through the secondary antenna coil (secondary antenna coil shown green color), inducing a voltage in the secondary coil that is applied to the load.⁴ In this way, power is transferred from the AC power source to the load by

³ The proper term for what is produced by current flowing in a coil of wire is “magnetic flux density”, but many practitioners simply refer to these flux lines by the more common term “magnetic field”. For simplicity, I use flux and magnetic field interchangeably in this declaration.

⁴ The process of magnetic induction between magnetic flux and a coil is based on Faraday’s Law, which is a fundamental law of physics.

inductive coupling:



Annotated adaptation of '654 Fig. 4

23. Note that only some of the flux lines produced by the primary coil go through the secondary coil. Some of the lines (shown in gray color) cannot extend sufficiently far and hence do not contribute to the inductive coupling. Such field lines are called “leakage flux”. Note that all flux lines extend into the air on their own. There is no containment structure that directs their paths. As further explained below, this lack of flux containment distinguishes antenna coil coupling from transformer coupling.

24. The magnetic flux lines generated by a TX antenna coil comprise the so-called “near field” of radio waves generated by the coil. Generally speaking, the near-field flux of a radio wave stays close to the coil, whereas the lower-power-density “far field” propagates long distances from the coil. Localized wireless power transfer systems, such as EV charging stations, rely primarily on the near field component of the field produced by the primary antenna. (In contrast, long-distance wireless communication such as WiFi relies primarily on the far-field component for data transmission.)

25. The authoritative IEEE Wiley Electrical and Electronics Engineering Dictionary defines an antenna as, “A device that radiates and/or receives radio waves. The same antenna can usually be used for both transmission and reception.” Ex. 2003 at 29. A similar definition can be found in the McGraw-Hill Dictionary of Scientific and Technical Terms. Ex. 2004 at 104. These definitions are all consistent with the above explanations.

26. Based on the ’654 patent specification and the well understood definition of “antenna,” one skilled in the art would understand a “transmitting antenna” as used in the wireless power transfer context of the ’654 patent to mean a primary coil that produces a near-field component of flux into free space that is intercepted by a secondary coil to effect resonant inductive coupling. One skilled in the art would similarly understand a “receiving antenna” as used in the wireless power transfer context of the ’654 patent means a secondary coil that intercepts and receives a near-field component of flux in free space that is generated by a primary coil to effect resonant inductive coupling.

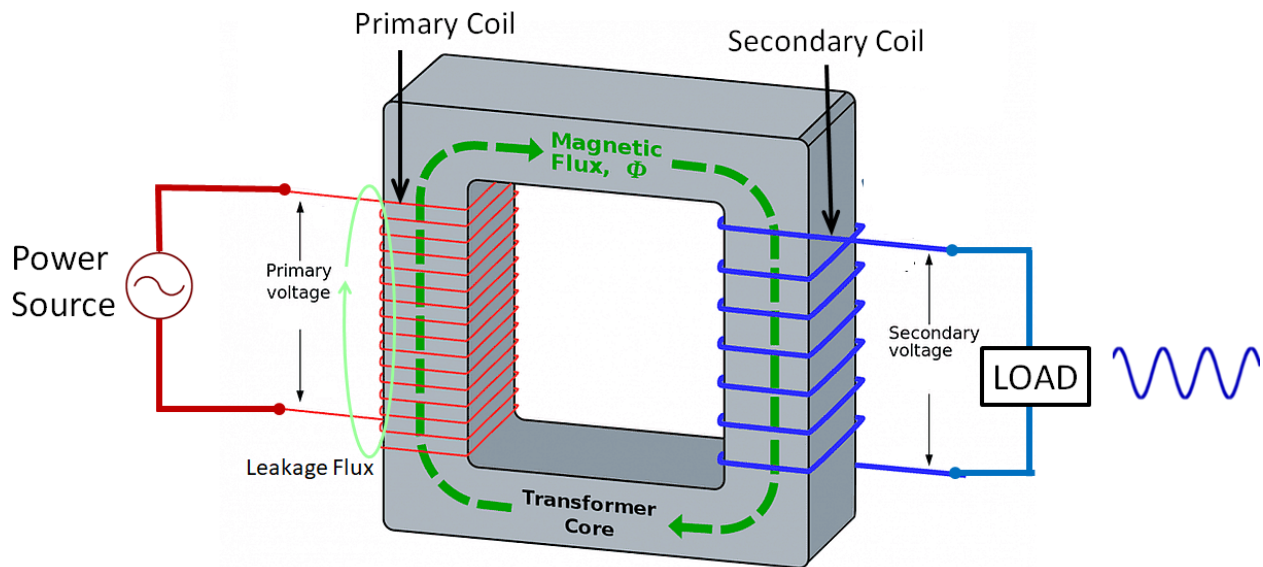
B. INDUCTIVE COUPLING USING A “TRANSFORMER” IS DIFFERENT THAN INDUCTIVE COUPLING USING ANTENNAS

27. The Wiley IEEE dictionary defines “transformer” as:

“A component or device which is utilized to transfer electrical energy from one circuit to another via magnetic or electromagnetic induction. A transformer has no moving parts and consists of two or more coils of wire **separately wrapped around a magnetic core.**” Ex. 2003 at 798.

Thus, in contrast to inductive coupling via antennas, a transformer achieves wireless inductive coupling by relying on a magnetic core structure, usually made from ferrite composite, but sometimes made from laminated steel. The core

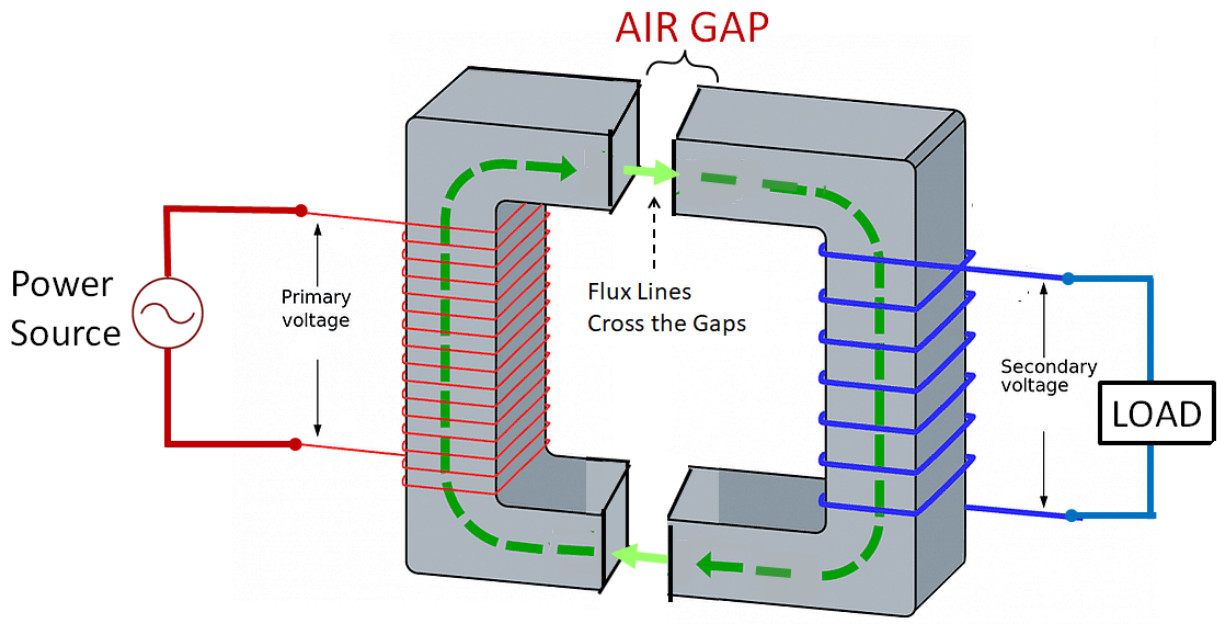
contains the magnetic flux lines, thus ensuring that almost all of them reach the secondary coil with relatively very little contributing to leakage flux. The figure below illustrates one common structure for a transformer based on a rectangular core. When energized, the primary coil (red) produces magnetic flux lines that pass through the secondary coil (blue), thereby inducing voltage across the latter.



Note that the flux lines (green) are essentially contained within the core (gray). This containment occurs because the core material, generally a ferrite composite, has a magnetic permeability factor μ on the order of 10,000 times that of air. The flux lines thus have a strong affinity for the ferrite and therefore do not venture outside the core structure. In a practical transformer, a small amount of flux (light green) will escape the core, but the effect of this leakage is negligible.

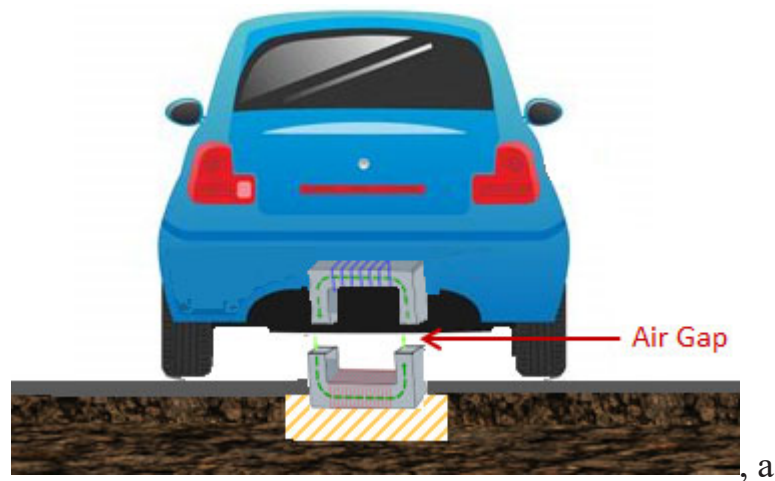
28. An exception to field containment by the body of the core occurs if there is a gap in the core, as would be required, for example, for wireless EV charging using a transformer. In such a case, the flux lines follow the path of “least resistance” and simply bridge the air gap but otherwise remain within the core, as shown below. Aside from their brief excursion into the air gap, the

flux lines in an air-gap transformer are otherwise contained within the core:



Transformer with an air gap

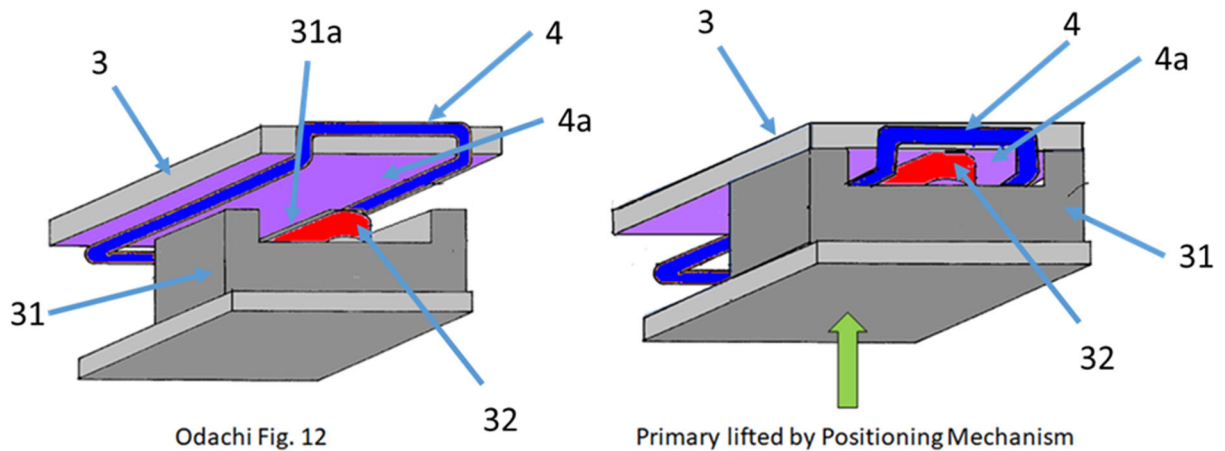
The figure below illustrates conceptually where the transformer air gap would be located in an EV charging system. The primary coil and core section are inside the charging box on the ground, while the secondary coil and core section are located inside the vehicle:



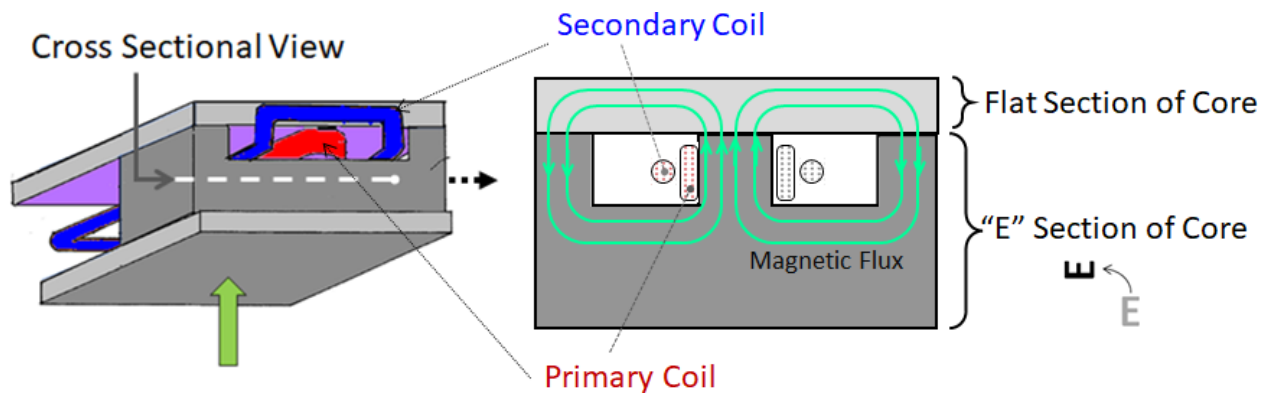
VII. ODACHI DOES NOT DISCLOSE A TRANSMITTING “ANTENNA” OR RECEIVING “ANTENNA”

29. Odachi discloses a traditional transformer structure in which a primary coil induces a current in a secondary coil by way of a common core. In particular, Odachi includes a primary inductive device 230, which includes a core 31 and a coil 32. Odachi, 8:16-19. As shown in an annotated version of Fig. 12 of Odachi below, the core 31 has an E-shaped cross-section, and the coil 32 is wound around the center projection 31a. A secondary coil 4 is located on the vehicle, and has a cavity 4a that allows the primary coil 32 and the center portion 31a of the primary core 31 to fit within the cavity 4a to “form a magnetic circuit” with both the primary and secondary coils wound around a core. Odachi, 8:43-48.

30. The figure below illustrates what happens when the lower E-core section and primary coil (red) of Odachi are lifted up into the secondary coil (blue) and upper core section. The entire structure forms a transformer with a completed core that has no air gap. The primary coil (red) and secondary coil (blue) both surround the central portion of the E-core:



31. The figure below clarifies how the coils and core portions of Odachi come together to form a complete transformer, and how the flux lines circulate within the E-core structure. The diagram shows a cross-sectional view through the center of the core, as illustrated in the diagram below. The magnetic flux produced by the primary (green arrows) goes through the secondary as it circulates around the core structure.

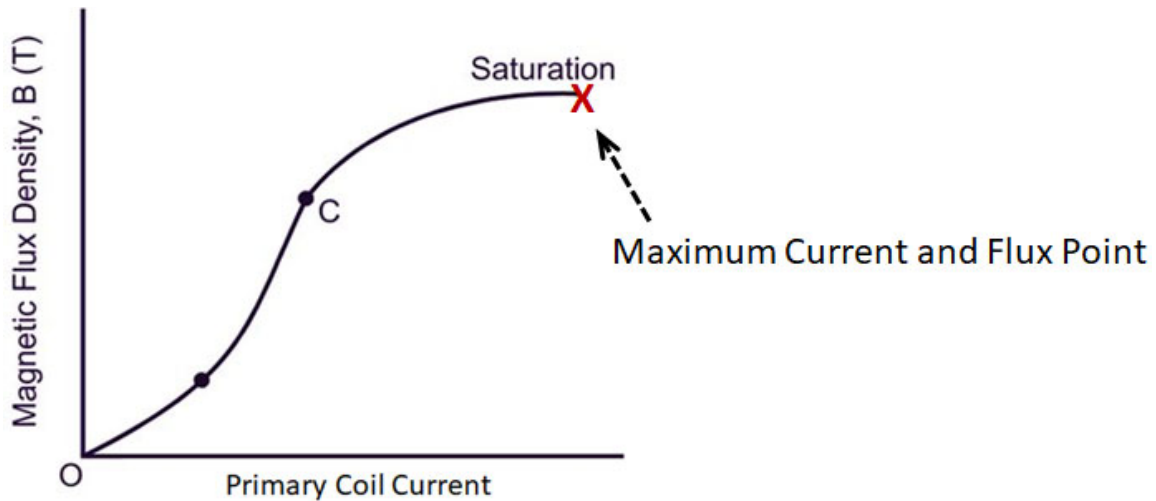


32. I note that Odachi makes no mention of primary or secondary antennas. Moreover, Odachi would not have devised the disclosed magnetic core structure if an air-core antenna-based system had been the goal.

33. In summary, in the field of wireless power transfer, a transformer is a device in which the magnetic flux lines produced by the primary coil are contained within a magnetic core. The core routes the flux lines from the

primary coil to the secondary coil, thereby ensuring that inductive coupling will be localized and be coupled at the maximum possible level. As previously shown, the primary coil may produce a small amount of “leakage flux” so that coupling is slightly below 100%, but most of the flux lines produced by the primary coil intersect the secondary coil. Additionally, no wave propagation is involved in the inductive coupling of a transformer. Rather, inductive coupling in a transformer relies solely on the routing of the magnetic flux constrained to remain in the core.

34. One challenge with using magnetic cores for inductive coupling is that the strength of the magnetic flux is limited by the ferrite material comprising the core. Such magnetic materials will magnetically saturate; that is, when the field strength reaches a material-dependent maximum, the field cannot be increased further. This saturation effect, depicted in the figure below, which is a plot of magnetic flux density versus coil current, limits the current level in a transformer to a specified value that depends on the properties of the core. Such limiting saturation does not occur in antenna-based inductive coupling, because the air has no magnetic saturation effect. That is, the phenomenon of saturation does not apply to air-coil antennas because there is no magnetic core material to saturate.



Illustrative plot of magnetic flux density in a core versus primary coil current. The flux density cannot be increased above the saturation level

35. More importantly, simply adding a compensation capacitor to a transformer coil, as Petitioner proposes by combining Wang with Odachi, does not result in a resonant antenna as required by, for example, claim 1 of the '654 patent. Petitioner asserts that Odachi's "primary inductive device or coupler 230" corresponds to the claimed "transmitting antenna." (Petition at 25). For the reasons I explained above, the primary inductive device or coupler 230 of Odachi is the primary coil of a transformer, not a "transmitting antenna." Compensating a transformer primary or secondary coil will set its power factor to unity⁵ but it will not convert the transformer coil into a transmitting or receiving antenna because the magnetic flux lines are still contained within the magnetic core.

⁵ Wang and Petitioner associate the terms "compensate" and "compensation" with the resonating capacitor. Compensation in resonant power-transfer circuits refers to setting a unity power factor at the driving frequency.

36. A compensated transformer coil becomes a resonant *circuit*, but not a resonant *antenna*. As explained above, the coils in Odachi are wound around magnetic cores that, when put together, yield a conventional transformer structure that contains the magnetic flux lines. The claimed “antennas” of the ’654 patent generate magnetic flux lines that are not contained within and directed by a core—the opposite of the coils in Odachi. These two structures are not the same; rather they have significantly different structures, significantly different electrical properties, and significantly different physical constraints.

37. Petitioner assumingly calls the coils in Odachi “antennas” (*Id.*). I note, however, that the term antenna does not appear anywhere in Odachi. Simply assigning the label “antenna” to Odachi’s transformer coils does not make them antennas.

VIII. ROSS DOES NOT DISCLOSE MOVING A TRANSMITTING OR RECEIVING ANTENNA FROM A FIRST ALIGNMENT POSITION TO A SECOND ALIGNMENT POSITION BASED ON A DEGREE OF COUPLING DETECTED AT THE RECEIVING ANTENNA

38. Ross is directed to a roadway-powered electric vehicle system that uses a transmitting coil 40 of a roadway power module 24 to transfer energy to a receiving coil 42 located on a vehicle. *See* Ross, 9:11-29. Ross explains that as a driver approaches a loading/unloading zone, an auto-positioning feature takes over to automatically steer the vehicle into a position within a rough tolerance of an optimal lateral position. Ross, 12:40-52. The auto-positioning feature uses vehicle sensors 60 to sense the position of the vehicle relative to the roadway power transmitting module, and typically includes optical sensors that look for markers placed on the roadway power transmitting module 24 embedded in the roadway. Ross, 12:40-52, 13:5-15.

Once the vehicle is stopped within a rough tolerance of the optimal lateral position, a horizontal coil positioning unit 46 further controls the lateral positioning of the coil 42 so it is more closely aligned with the optimal lateral position. Ross, 12:52-57. Once in the optimal lateral optimal position, a vertical positioning unit 48 lowers the coil 42 toward the coil 40. Ross, 12:57-62.

39. Ross explains that the horizontal coil positioning unit 46 moves the coil 42 to the second position “using conventional hydraulic and/or electronic positioning devices.” Ross, 12:52-57. Ross does not explain that the coil 42 is moved to the second position (i.e., the position closer to the optimal lateral position) in response to a degree of coupling detected at the receiving antenna, as recited in claim 13.

40. While the Petition relies on the above-described portion of Ross for explaining how the coil 42 is allegedly placed in the first and second positions (Pet. at 51-53), the Petition relies on a different portion of Ross that explains how the coil 42 is positioned within a rough tolerance of the optimal position while the vehicle is driven on the road. Pet. at 56. In particular, the Petition cites to a portion of Ross that explains that the position of the coil 42 is maintained within a rough tolerance of the optimal position by “monitoring the change in the amplitude of the inductively received power signal as the coil 42 is laterally moved in one direction or the other.” Pet. at 56 (quoting Ross, 13:20-32). But this portion of Ross does not disclose that the amplitude of the inductively received power signal is used to move the coil 42 from a first alignment position to a second alignment position that improves the degree of coupling in response to the detected degree of coupling in the first alignment position, as recited in claim 13. Rather the first and second alignment

positions that are allegedly disclosed by Ross relate to the car entering a loading/unloading zone using an auto-positioning feature. The portion of Ross relating to the amplitude of the inductively received power signal is separate from the auto-positioning feature, and is not used to adjust the positioning of the coil 42 from the first alignment position to the second alignment position that improves the degree of coupling. Instead, the amplitude of the inductively received power signal is merely used to maintain the coil 42 within a rough tolerance of the coil 40. Ross, 13:15-20.

[Signature page follows]

Executed on February 22, 2024, in the city of Boston, Massachusetts.



Dr. Mark N. Horenstein