
INDUCTEV (*PETITIONER*)
V.
WITRICITY CORP. (*PATENT OWNER*)

Case. No.: IPR2023-01182
Claim 17 of U.S. Patent No.: 8,461,719

November 13, 2024

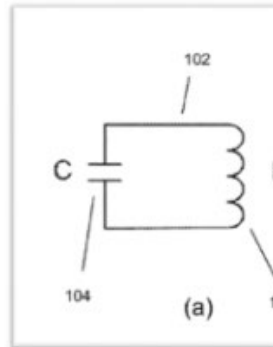
- Ground 3: Claim 16 is unpatentable under 35 U.S.C. § 103 over Cook-523 and Pohjonen.
- Ground 4: Claim 17 is unpatentable under 35 U.S.C. § 103 over Cook-523.

III. Background

A. The '719 Patent (Ex. 1001)

The '719 patent generally relates to wireless energy transmission between a "source resonator" and a "second" (or "device") resonator, and the size and design of the resonator's inductive and capacitive components.

A "resonator" is "a system that can store energy in at least two different forms, and where the stored energy is oscillating between a capacitor and an inductor.



III. Background

A. The '719 Patent (Ex. 1001)

The '719 patent generally relates to wireless energy transmission between a "source resonator" and a "second" (or "device") resonator, and the size and design of the resonator's inductive and capacitive components. '719 patent 3:48-64.

A "resonator" is "a system that can store energy in at least two different forms, and where the stored energy is oscillating between the two forms," such as a capacitor and an inductor.

wherein $\sqrt{Q_1 Q_2}$ is greater than 100, and wherein at least one of the resonators is enclosed in a low loss tangent material.

17. A system, comprising:

a source resonator having a Q-factor Q_1 and a characteristic size x_1 , and a second resonator having a Q-factor Q_2 and a characteristic size x_2 , and located a distance D from the source resonator;

wherein the source resonator and the second resonator are coupled to exchange energy wirelessly among the source resonator and the second resonator, and wherein $\sqrt{Q_1 Q_2}$ is greater than 100; and

wherein at least one of the resonators includes a coil of a plurality of turns of a conducting material connected to a network of capacitors, wherein the plurality of turns are in a common plane, and wherein a characteristic thickness of the at least one of the resonators is much less than a characteristic size of the at least one of the resonators.

* * * * *

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wherein the source resonator and the second resonator are coupled to exchange energy wirelessly among the source resonator and the second resonator, and wherein $\sqrt{Q_1 Q_2}$ is greater than 100; and

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B. The Term “Network of Capacitors” Should Be Construed To Mean “a Circuit Topology of Passive Components Including One or More Capacitors That Provides Two or More Degrees of Freedom”

Starting with the claim language itself, claim 17 recites that “at least one of the resonators includes a coil of a plurality of turns of a conducting material connected to a **network of capacitors**.” ’719 patent 99:1. “network” is defined as an interconnection of “resistances [capacitors], and mutual inductances” Terman-1943 (Horenstein Decl. ¶ 37. In the ’719 patent, a network of capacitors is referred to as “a circuit topology including one or more capacitors.” ’719 patent 52:32-38; Horenstein Decl. ¶¶ 38-40.

In context, as described in the specification, a resonator includes an inductive element, such as a coil or loop of a conducting material, and a capacitive element, such as a capacitor or network of capacitors, that provides capacitance that may be realized by a network. ’719 patent 20:12-17, 43:65 – 44:6. The inductive element provides primarily the reactive (imaginary) component of a complex impedance. Horenstein Decl. ¶ 41. The capacitance realized by the network may control the complex impedance, which requires that the network includes two or more degrees of freedom to control or regulate both the real and imaginary components of the complex impedance. ’719 patent 44:3-6, 42-46, 45:58-61, 69:56-60, Horenstein Decl. ¶¶ 41-42.

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The Term “Network of Capacitors” Should Be Construed To Mean “a Circuit Topology of Passive Components Including One or More Capacitors That Provides Two or More Degrees of Freedom”

Further, as disclosed, a magnetic resonator includes an inductive element, such as a coil or loop of conducting material, that provides primarily the reactive (imaginary) component of a complex impedance. *'719 Patent, 43:65 – 44:6.*

The magnetic resonator also includes a capacitance that may be realized using a network, and used to control or regulate the complex impedance. *'719 Patent at 20:12-17.*

**The network therefore requires two or more degrees of freedom to control or regulate both the real and imaginary components of the complex impedance.
Id. 44:3-6, 42-46; 45:58-61 and 64-66 ; 69:36-50; 56-60 ; Horenstein Decl. ¶¶ 41-42.**

coupled magnetic resonators, a high Q may be desired for the resonators. Therefore, the inductive element may be chosen to have low losses (high X/R).

Since the matching circuit may typically include additional sources of loss inside the resonator, the components of the matching circuit may also be chosen to have low losses. Furthermore, in high-power applications and/or due to the high resonator Q , large currents may run in parts of the resonator circuit and large voltages may be present across some circuit elements within the resonator. Such currents and voltages may exceed the specified tolerances for particular circuit elements and may be too high for particular components to withstand. In some cases, it may be difficult to find or implement components, such as tunable capacitors for example, with size, cost and performance (loss and current/voltage-rating) specifications sufficient to realize high- Q and high-power resonator designs for certain applications. We disclose matching circuit designs, methods, implementations and techniques that may preserve the high Q for magnetic resonators, while reducing the component requirements for low loss and/or high current/voltage-rating.

Matching-circuit topologies may be designed that minimize the loss and current-rating requirements on some of the elements of the matching circuit. The topology of a circuit matching a low-loss inductive element to an impedance, Z_0 , may be chosen so that some of its components lie outside the associated high- Q resonator by being in series with the external circuit. The requirements for low series loss or high current-ratings for these components may be reduced. Relieving the low series loss and/or high-current-rating requirement on a circuit element may be particularly useful when the element needs to be variable and/or to have a large voltage-rating and/or low parallel loss.

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The topology of the circuit matching a low-loss inductive element to an external characteristic impedance, Z_0 , may be chosen so that the field pattern of the associated resonant mode and thus its high Q are preserved upon coupling of the resonator to the external impedance. Otherwise inefficient coupling to the desired resonant mode may occur (potentially due to coupling to other undesired resonant modes), resulting in an effective lowering of the resonator Q .

For applications where the low-loss inductive element or the external circuit, may exhibit variations, the matching circuit may need to be adjusted dynamically to match the inductive element to the external circuit impedance, Z_0 , at the desired frequency, f . Since there may typically be two tuning objectives, matching or controlling both the real and imaginary part of the impedance level, Z_0 , at the desired frequency, f , there may be two variable elements in the matching circuit. For inductive elements, the matching circuit may need to include at least one variable capacitive element.

A low-loss inductive element may be matched by topologies using two variable capacitors, or two networks of variable capacitors. A variable capacitor may, for example, be a tunable butterfly-type capacitor having, e.g., a center terminal

for connection to a ground or other lead of a power source or load, and at least one other terminal across which a capacitance of the tunable butterfly-type capacitor can be varied or tuned, or any other capacitor having a user-configurable, variable capacitance.

A low-loss inductive element may be matched by topologies using one, or a network of, variable capacitor(s) and one, or a network of, variable inductor(s).

A low-loss inductive element may be matched by topologies using one, or a network of, variable capacitor(s) and one, or a network of, variable mutual inductance(s), which transformer-couple the inductive element either to an external circuit or to other systems.

In some cases, it may be difficult to find or implement tunable lumped element specifications sufficient to realize potentially high-speed, high-power matching circuitry. The topology of the circuit matching an external circuit may be chosen so that the matching circuitry is assigned to the external circuit, like, in the external circuit, the variations in resonant frequency of the inductive element at the desired frequency, f , may be reduced. Relieving the low series loss and/or high-current-rating requirement on a circuit element may be particularly useful when the element needs to be variable and/or to have a large voltage-rating and/or low parallel loss.

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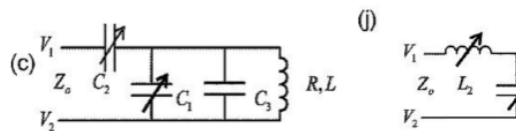
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element in the circuits similarly has an imaginary impedance $j\omega L$, i.e., a positive

reactance of ωL . Impedance matching to the resonator or diagram requires that all of the reactive components seen and V_2 , be canceled out by the "network of capacitors".

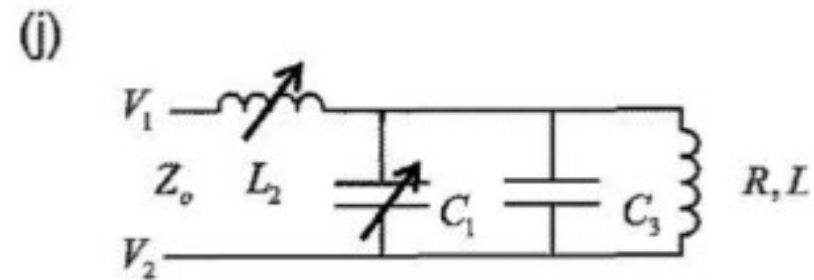
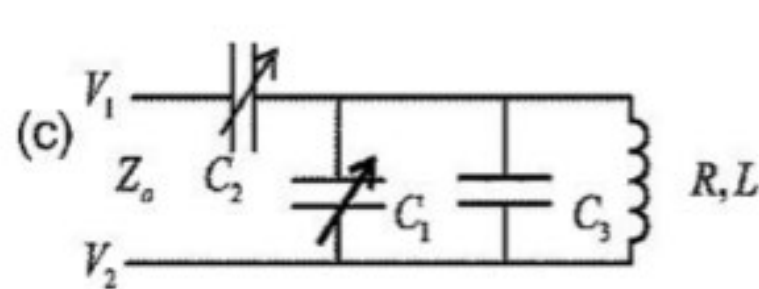
42. More generally, for each of the circuits shown so requires that the network provide two or more degrees adjustable reactive elements (i.e., adjustable capacitors and V_2 , be canceled out by the "network of capacitors". *Id.* 44:3-6, 42-46, 45:58-61, 69:56-60.) These degrees of control the real and imaginary parts of the complex impedance terminals, e.g., V_1 and V_2 , or V_1 and $-V_1$. These terminal pairs are found on the left-hand side of each circuit diagram. Two sample circuits, Figs. 30(c) and 30(j), are shown below for reference purposes:



'719 Patent, Figs. 30(c) and 30(j)

43. The circuits in Fig. 30 (a)-(f) are accompanied by a Smith Chart [see, e.g., Fig. 30(g)]. Figure 30(g) shows a Smith chart. The next figure below shows a version of the

Id. 44:3-6, 42-46, 45:58-61, 69:56-60.) These degrees of freedom are needed to control the real and imaginary parts of the complex impedance seen at the input port terminals, e.g., V_1 and V_2 , or V_1 and $-V_1$. These terminal pairs are found on the left-hand side of each circuit diagram. Two sample circuits, Figs. 30(c) and 30(j), are shown below for reference purposes:



'719 Patent, Figs. 30(c) and 30(j)

that are switched in or out of the circuit may be able to compensate for changes in resonator Q 's, impedances, resonant frequencies, power levels, coupling strengths, and the like, that might be encountered in test, development and operational wireless power transfer systems. Switched capacitor banks and other switched element banks may be used to achieve the convergence to the operating frequencies and impedance values required by the system design.

An exemplary control algorithm for isolated and coupled magnetic resonators may be described for the circuit and system elements shown in FIG. 47. One control algorithm first adjusts each of the source and device resonator loops "in isolation", that is, with the other resonators in the system "shorted out" or "removed" from the system. For practical purposes, a resonator can be "shorted out" by making it resonant at a much lower frequency such as by maximizing the value of $C1$ and/or $C3$. This step effectively reduces the coupling between the resonators, thereby effectively reducing the system to a single resonator at a particular frequency and impedance.

Tuning a magnetic resonator in isolation includes varying the tunable elements in the tuning and matching circuits until the values measured by the port parameter measurement circuitry are at their predetermined, calculated or measured relative values. The desired values for the quantities measured by the port parameter measurement circuitry may be chosen based on the desired matching impedance, frequency, strong coupling parameter, and the like. For the exemplary algorithms disclosed below, the port parameter measurement circuitry measures S -parameters over a range of frequencies. The range of frequencies used to characterize the resonators may be a compromise between the system performance information obtained and computation/measurement speed. For the algorithms described below the frequency range may be approximately $\pm 20\%$ of the operating resonant frequency.

Each isolated resonator may be tuned as follows. First, short out the resonator not being adjusted. Next minimize $C1$, $C2$, and $C3$ in the resonator that is being characterized and adjusted. In most cases there will be fixed circuit elements in parallel with $C1$, $C2$, and $C3$, so this step does not reduce the capacitance values to zero. Next, start increasing $C2$ until the resonator impedance is matched to the "target" real impedance at any frequency in the range of measurement frequencies described above. The initial "target" impedance may be less than the expected operating impedance for the coupled system.

$C2$ may be adjusted until the initial "target" impedance is realized for a frequency in the measurement range. Then $C1$ and/or $C3$ may be adjusted until the loop is resonant at the desired operating frequency.

Each resonator may be adjusted according to the above algorithm. After tuning each resonator in isolation, a second feedback algorithm may be applied to optimize the resonant frequencies and/or input impedances for wirelessly transferring power in the coupled system.

The required adjustments to $C1$ and/or $C2$ and/or $C3$ in each resonator in the coupled system may be determined by measuring and processing the values of the real and imaginary parts of the input impedance from either and/or both "port(s)" shown in FIG. 43. For coupled resonators, changing the input impedance of one resonator may change the input impedance of the other resonator. Control and tracking algorithms may adjust one port to a desired operating point based on measurements at that port, and then adjust the other port based on measurements at that other port. These steps may be repeated until both sides converge to the desired operating point.

S -parameters may be measured at both the source and device ports and the following series of measurements and adjustments may be made. In the description that follows, Z_0 is an input impedance and may be the target impedance. In some cases Z_0 is 50 ohms or is near 50 ohms. Z_1 and Z_2 are intermediate impedance values that may be the same value as Z_0 or may be different than Z_0 . $\text{Re}\{\text{value}\}$ means the real part of a value and $\text{Im}\{\text{value}\}$ means the imaginary part of a value.

An algorithm that may be used to adjust the input impedance and resonant frequency of two coupled resonators is set forth below:

- 1) Adjust each resonator "in isolation" as described above.
- 2) Adjust source $C1/C3$ until, at ω_0 , $\text{Re}\{S11\} = (Z_1 \pm \epsilon_{Re})$ as follows:
If $\text{Re}\{S11 @ \omega_0\} > (Z_1 + \epsilon_{Re})$, decrease $C1/C3$. If $\text{Re}\{S11 @ \omega_0\} < (Z_1 - \epsilon_{Re})$, increase $C1/C3$.
- 3) Adjust source $C2$ until, at ω_0 , $\text{Im}\{S11\} = (\pm \epsilon_{Im})$ as follows:
If $\text{Im}\{S11 @ \omega_0\} > \epsilon_{Im}$, decrease $C2$. If $\text{Im}\{S11 @ \omega_0\} < -\epsilon_{Im}$, increase $C2$.
- 4) Adjust device $C1/C3$ until, at ω_0 , $\text{Re}\{S22\} = (Z_2 \pm \epsilon_{Re})$ as follows:
If $\text{Re}\{S22 @ \omega_0\} > (Z_2 + \epsilon_{Re})$, decrease $C1/C3$. If $\text{Re}\{S22 @ \omega_0\} < (Z_2 - \epsilon_{Re})$, increase $C1/C3$.
- 5) Adjust device $C2$ until, at ω_0 , $\text{Im}\{S22\} = 0$ as follows:
If $\text{Im}\{S22 @ \omega_0\} > \epsilon_{Im}$, decrease $C2$. If $\text{Im}\{S22 @ \omega_0\} < -\epsilon_{Im}$, increase $C2$.

We have achieved a working system by repeating steps 1-4 until both $\text{Re}\{S11\}$, $\text{Im}\{S11\}$ and $\text{Re}\{S22\}$, $\text{Im}\{S22\}$ converge to $((Z_0 \pm \epsilon_{Re}), (\pm \epsilon_{Im}))$ at ω_0 , where Z_0 is the desired matching impedance and ω_0 is the desired operating frequency. Here, ϵ_{Im} represents the maximum deviation of the imaginary part, at ω_0 , from the desired value of 0, and ϵ_{Re} represents the maximum deviation of the real part from the desired value of Z_0 . It is understood that ϵ_{Im} and ϵ_{Re} can be adjusted to increase or decrease the number of steps to convergence at the potential cost of system performance (efficiency). It is also understood that steps 1-4 can be performed in a variety of sequences and a variety of ways other than that outlined above (i.e. first adjust the source imaginary part, then the source real part; or first adjust the device real part, then the device imaginary part, etc.) The intermediate impedances Z_1 and Z_2 may be adjusted during steps 1-4 to reduce the number of steps required for convergence. The desired or target impedance value may be complex, and may vary in time or under different operating scenarios.

Steps 1-4 may be performed in any order, in any combination and any number of times. Having described the above algorithm, variations to the steps or the described implementation may be apparent to one of ordinary skill in the art. The algorithm outlined above may be implemented with any equivalent linear network port parameter measurements (i.e., Z -parameters, Y -parameters, T -parameters, H -parameters, $ABCD$ -parameters, etc.) or other monitor signals described above, in the same way that impedance or admittance can be alternatively used to analyze a linear circuit to derive the same result.

The resonators may need to be retuned owing to changes in the "loaded" resistances, R_s and R_d , caused by changes in the mutual inductance M (coupling) between the source and device resonators. Changes in the inductances, L_s and L_d , of the inductive elements themselves may be caused by the influence of external objects, as discussed earlier, and may also require compensation. Such variations may be mitigated by the adjustment algorithm described above.

A directional coupler or a switch may be used to connect the port parameter measurement circuitry to the source reso-

approximately $\pm 20\%$ of the operating resonant frequency.

Each isolated resonator may be tuned as follows. First, short out the resonator not being adjusted. Next minimize $C1$, $C2$, and $C3$, in the resonator that is being characterized and adjusted. In most cases there will be fixed circuit elements in parallel with $C1$, $C2$, and $C3$, so this step does not reduce the capacitance values to zero. Next, start increasing $C2$ until the resonator impedance is matched to the "target" real impedance at any frequency in the range of measurement frequencies described above. The initial "target" impedance may be less than the expected operating impedance for the coupled system.

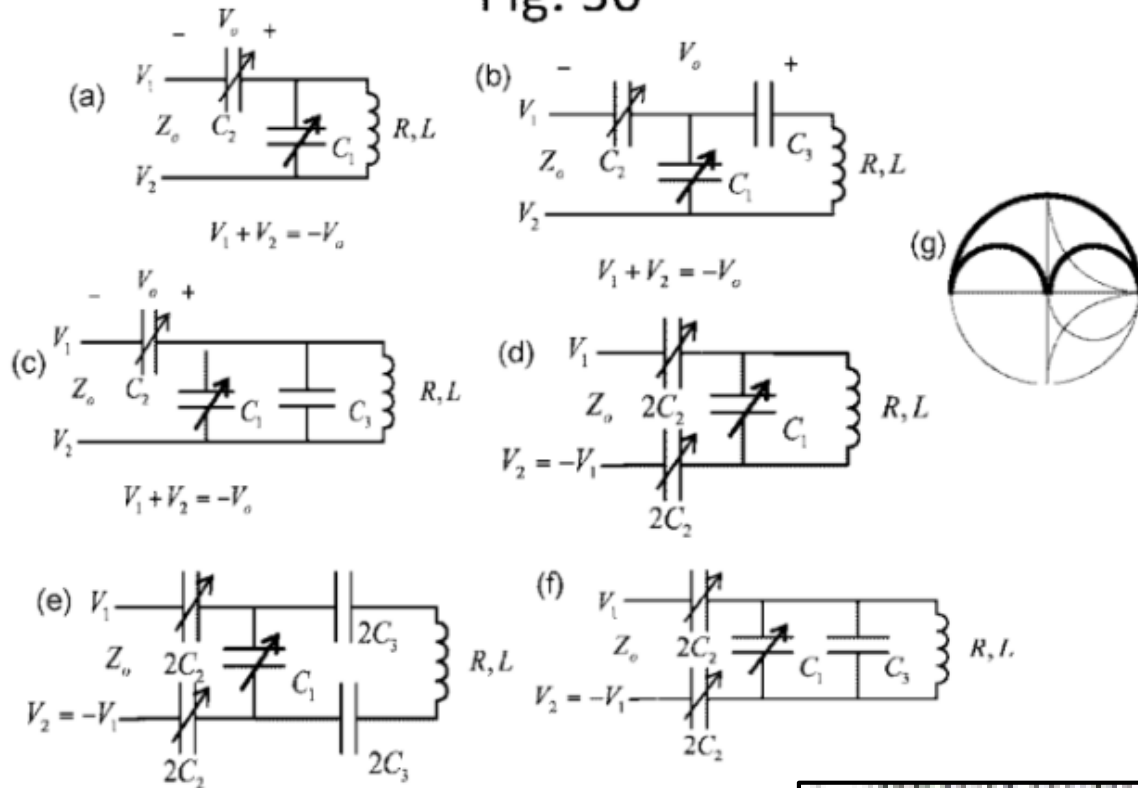
$C2$ may be adjusted until the initial "target" impedance is realized for a frequency in the measurement range. Then $C1$ and/or $C3$ may be adjusted until the loop is resonant at the desired operating frequency.

ring power in the coupled system.

The required adjustments to $C1$ and/or $C2$ and/or $C3$ in each resonator in the coupled system may be determined by measuring and processing the values of the real and imaginary parts of the input impedance from either and/or both "port(s)" shown in FIG. 43. For coupled resonators, changing

The '719 Patent provides several detailed examples of impedance-matching networks with two or more degrees of freedom – these include capacitors and/or inductors connected to an inductive element to create a magnetic resonator. '719 Patent, Figs. 30-35; Col. 51:45-57; Horenstein Decl. ¶¶ 41-49.

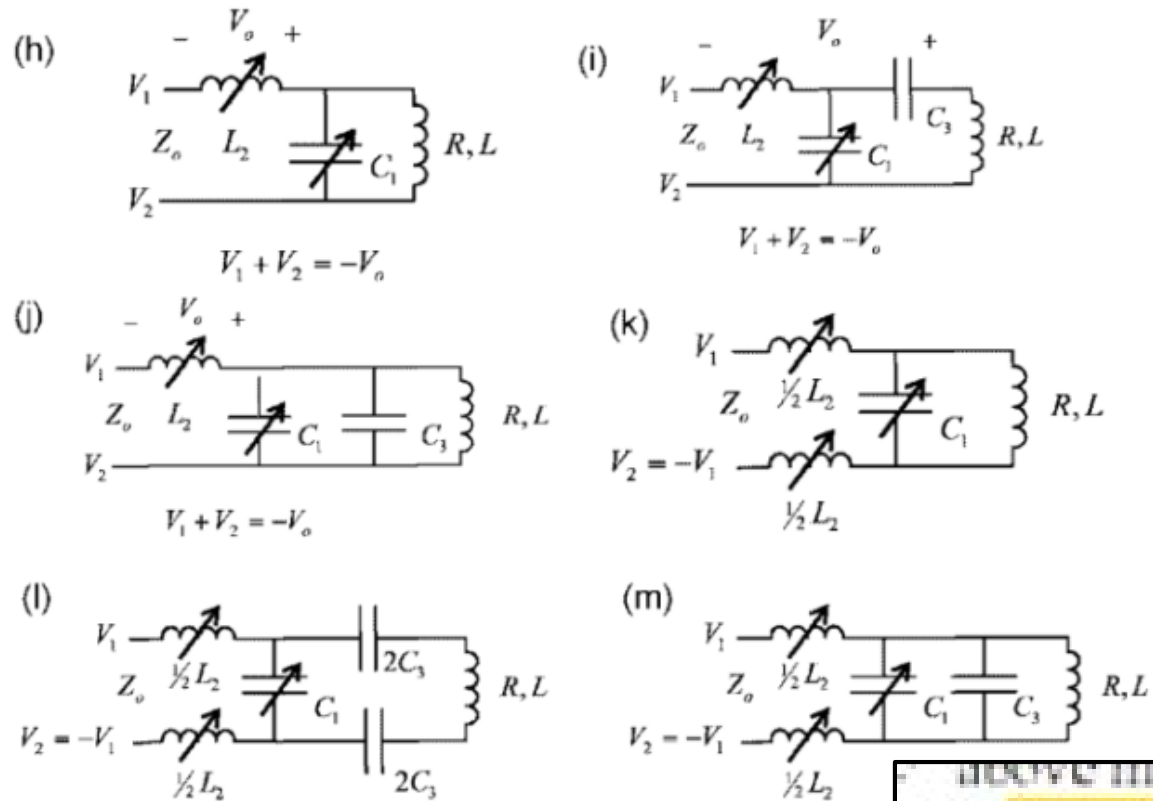
Fig. 30



above matching topologies with a tunable C_2 instead.

FIG. 30 shows six examples (a)-(f) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and six examples (h)-(m) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topologies of FIGS. 30f and 30m, the two tunable elements are

Fig. 30



above matching topologies with a tunable $\frac{1}{2}L_2$ instead.

FIG. 30 shows six examples (a)-(f) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and six examples (h)-(m) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topologies of FIGS. 30(a)-(f), the two tunable elements are capacitors, and for the topologies of FIGS. 30(h)-(m), the two tunable elements are one capacitor and one inductor.

Fig. 31

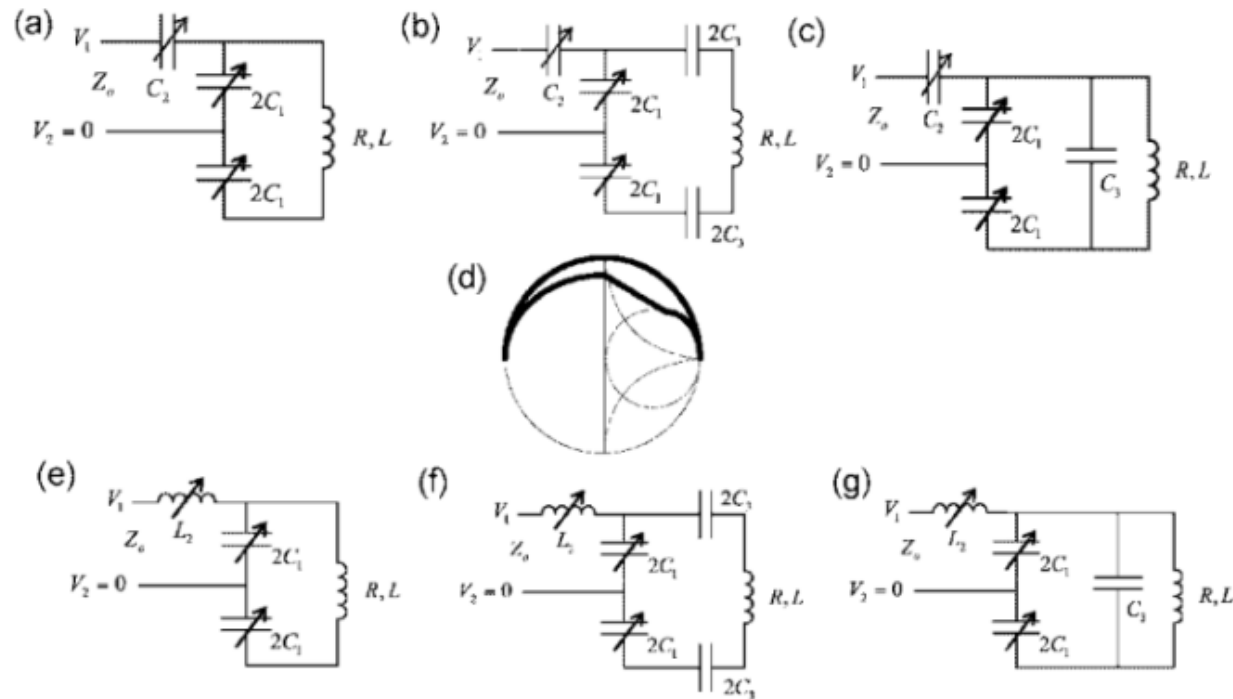


FIG. 31 shows three examples (a)-(c) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and three examples (e)-(g) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topolo-

Fig. 32

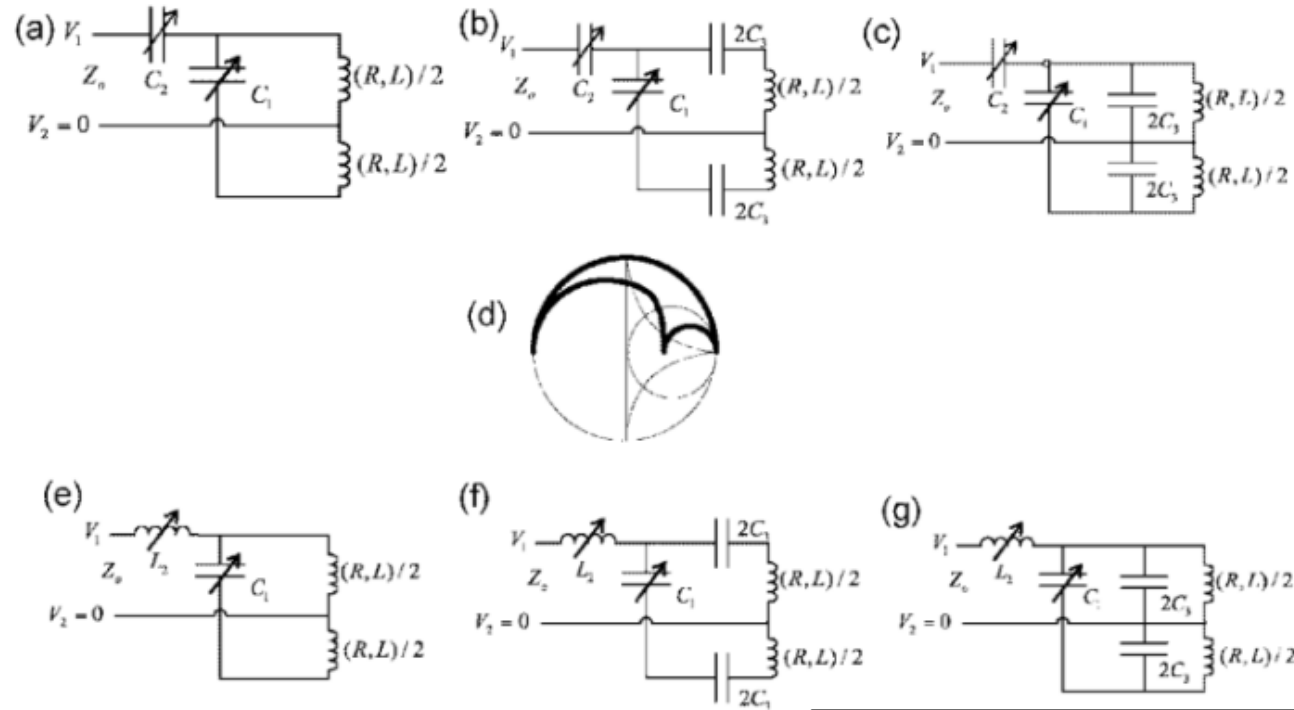


FIG. 32 shows three examples (a)-(c) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and three examples (e)-(g) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topolo-

Fig. 33

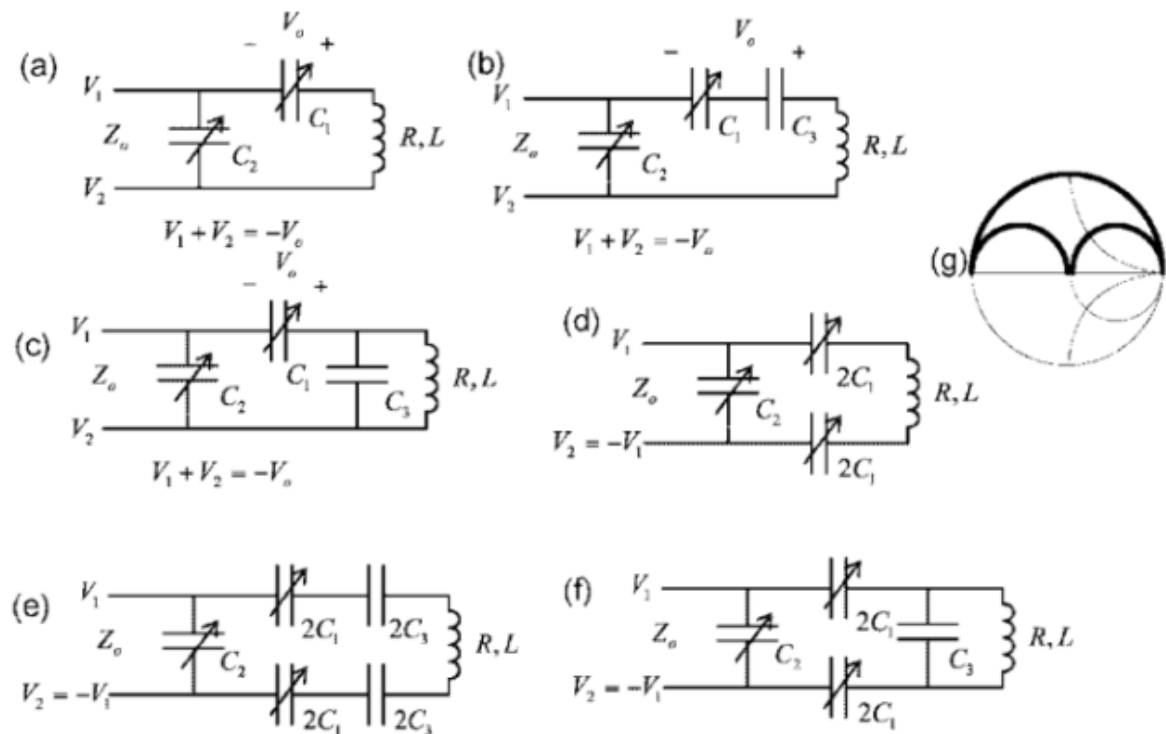


FIG. 33 shows six examples (a)-(f) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and six examples (h)-(m) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topolo-

Fig. 33

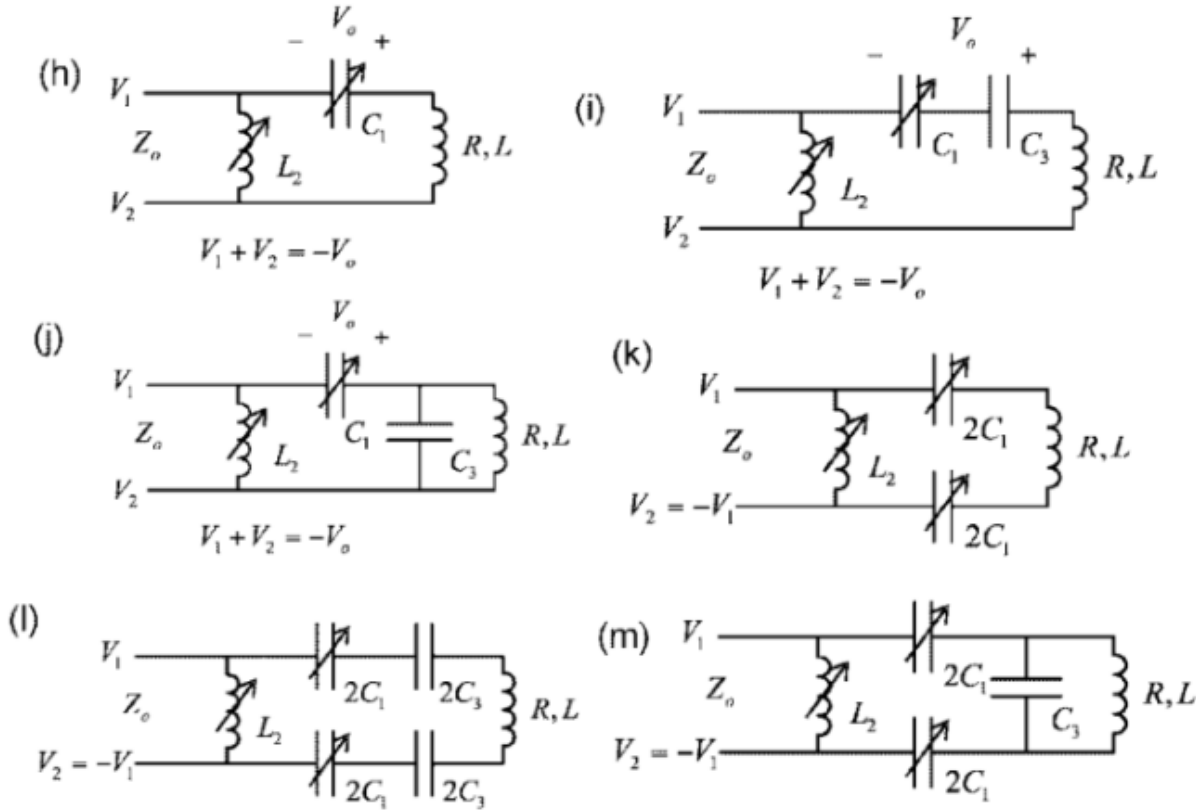


FIG. 33 shows six examples (a)-(f) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and six examples (h)-(m) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topolo-

Fig. 34

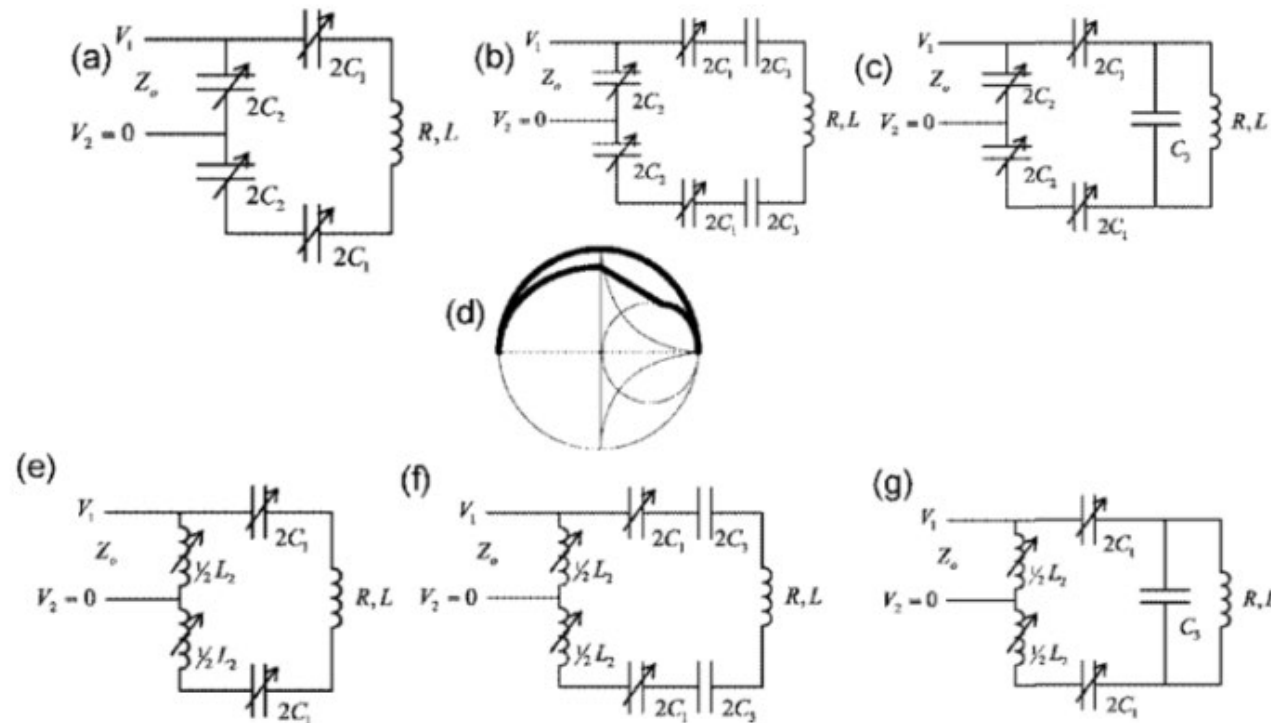
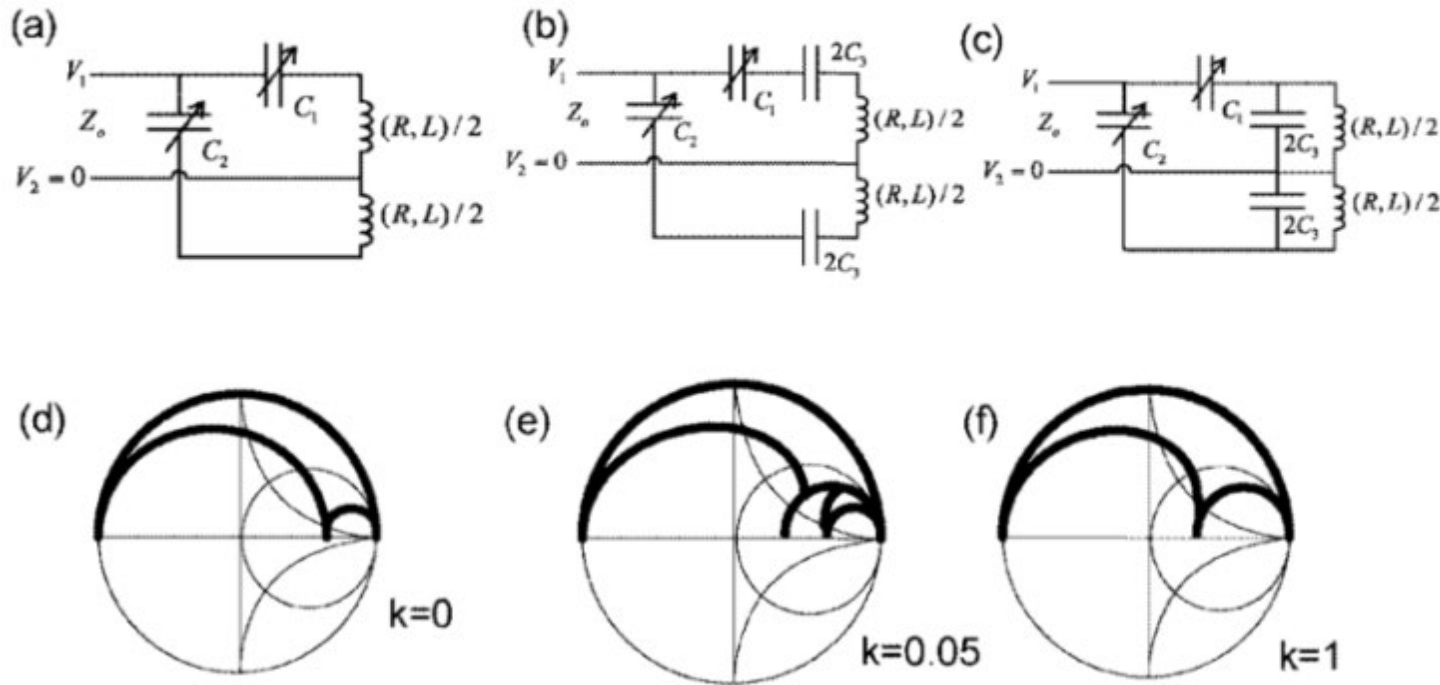


FIG. 34 shows three examples (a)-(c) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and three examples (e)-(g) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topolo-

Fig. 35



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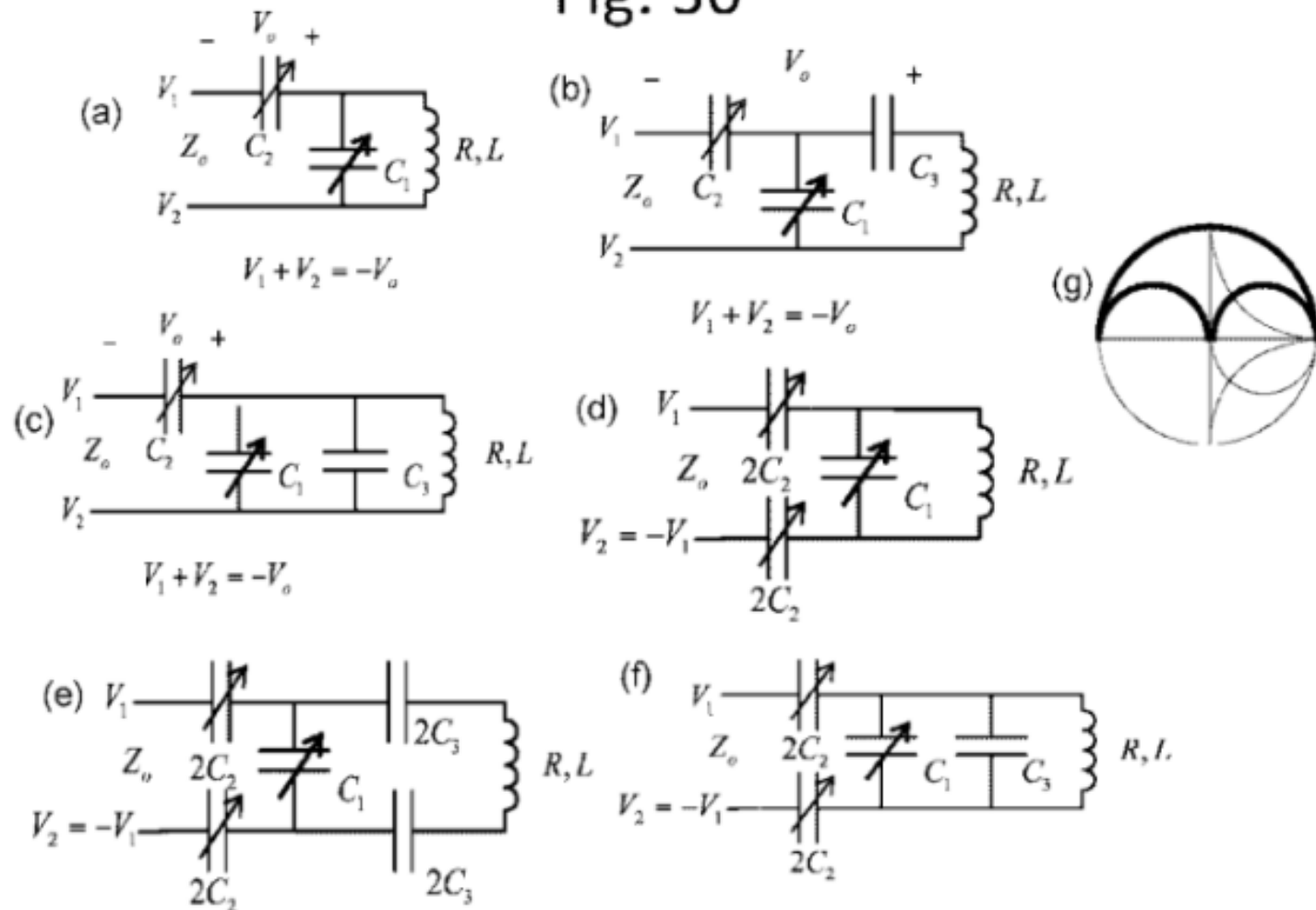
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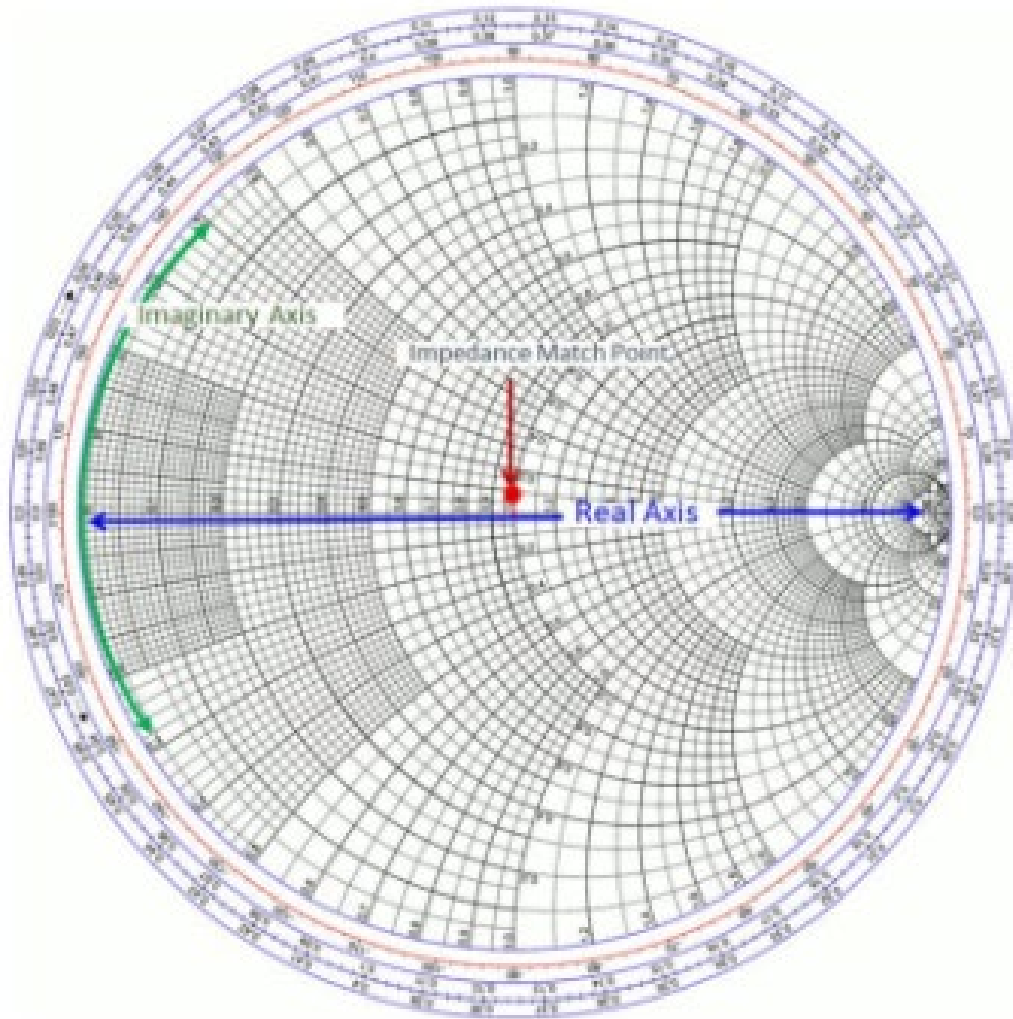
FIG. 35 shows three examples of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors. For the topologies of FIGS. 35, the ground termi-

This is further illustrated by the use of the Smith Charts in Figures 30-35 in the '719 Patent and explained by Dr. Horenstein ¶ 43:

“The horizontal axis represents the normalized real component of the impedance. The point of perfect match is achieved when the tuning trajectory arrives at the center of the circle.”

Fig. 30





Smith Chart

44. As a person of skill in the art of electromagnetics would have known, a Smith chart can be used to properly sequence the tuning of multiple variable capacitors in a network so as to arrive at an impedance match. (This iterative tuning process is described in detail in the '719 patent 52:39-65.) The pathway in bold on the Smith chart of Fig. 30(g) is traversed as the various capacitors in the network are, in turn, incrementally adjusted, following the curved axes of the Smith chart, until a perfect match at the center of the Smith chart is achieved. As a person of skill would have known, a circuit having two tunable reactances, e.g., capacitors, can establish an impedance match, and it also can be used to guarantee maximum power transfer from the source to the load.

Dr. Allen agrees that the '719 Patent discloses tuning the circuit requires multiple variable components: “This tuning can be done, for example, by connecting the inductive component to “networks of *variable capacitors*.” Allen Decl. (Exh. 1003) (citing '719 patent at 45:64-46:5, 46:37-44) (emphasis added).

In addition, Fig. 36 of the '719 patent does not disclose additional preferred embodiments of a resonator with a network of capacitors.

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Declaration in Support

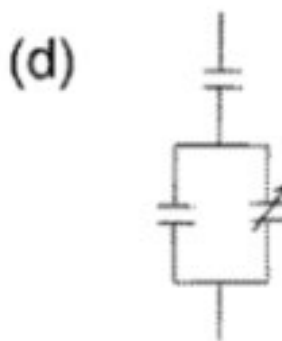
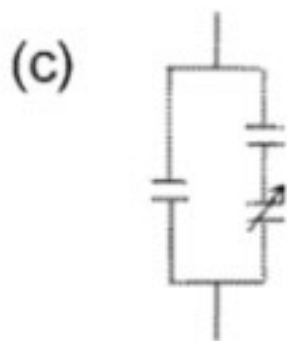
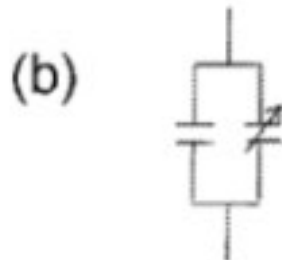
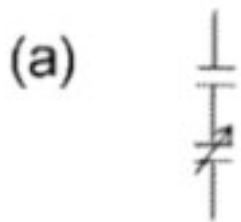
capacitance of the circuit “dynamically
external circuit impedance” may be neces
45:54-63. This tuning can be done, fo
component to “networks of variable capa
44 (explaining that the “topology of the ci
to an impedance, Z_0 , may include approp
and variable elements, so that the volt
components may be reduced and the desi
tuning resolution.”).

57. The '719 patent discloses th
“enclosed in an enclosure, container, sle
“almost any kind of material.” '719 pate
“[l]ow loss tangent materials such as Tef
be preferable for some applications.” '7
providing these examples, the '719 pate
may have a “negligible impact on the
materials with “moderate to high los
dissipative losses.” See '719 patent at 34
any definitive bounds for what constitutes

56. The '719 patent also explains that in applications where high Q resonators are subject to environmental variations, i.e., “where the low-loss inductive element or the external circuit, may exhibit variations,” tuning the

capacitance of the circuit “dynamically to match the inductive element to the external circuit impedance” may be necessary to preserve the high Q. '719 patent at 45:54-63. This tuning can be done, for example, by connecting the inductive component to “networks of variable capacitors.” '719 patent at 45:64-46:5, 46:37-44 (explaining that the “topology of the circuit matching a variable inductive element to an impedance, Z_0 , may include appropriate combinations and placements of fixed and variable elements, so that the voltage/current requirements for the variable components may be reduced and the desired tuning range may be covered with finer tuning resolution.”).

Fig. 36



- Instead, the figures in Fig. 36 are offered as alternatives to any of the single, variable capacitors in the preferred embodiment networks of Figs. 30-35, e.g., C1 and C2.
- Figs. 36(a) – (d) could potentially be used to replace one of the single, variable capacitors in the complete circuits that are disclosed as preferred embodiments in Figs. 30-35 with the accompanying Smith Charts for Figs. 30-35.
- The circuits of Figs. 36 show no inductors, no resistive loads, and, for that matter, no complete circuits.
- Additionally, the capacitors shown in Figs. 36 cannot perform any impedance matching, nor are they accompanied by any Smith Chart indicative of the two or more degrees of freedom to function as required by the circuits of Figs. 30-35.
- Thus, PO's construction of network of capacitors requiring two or more degrees of freedom does not exclude a preferred embodiment.

Pet. Reply quotes '719 Patent: “a network of capacitors, as used herein, may in general refer to any circuit topology including one or more capacitors.”

'719 patent 52:32-38.

But Petitioner:

- (1) failed to display the entire sentence; and**
- (2) failed to disclose that the sentence is in the same paragraph that begins with describing the circuits in Figs. 30(a) to Col. 52:16-20.**

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incorporate combinations of both fixed and variable elements, such that finer tuning resolution may be accomplished with the same variable elements.

Therefore, topologies using combinations of both fixed and variable elements may bring two kinds of advantages simultaneously: reduced voltage across, or current through, sensitive tuning components in the circuit and finer tuning resolution. Note that the maximum achievable tuning range may be related to the maximum reduction in voltage across, or current through, the tunable components in the circuit designs.

Element Topologies

A single variable circuit-element (as opposed to the network of elements discussed above) may be implemented by a topology using a combination of fixed and variable components, connected in series or in parallel, to achieve a reduction in the rating requirements of the variable components and a finer tuning resolution. This can be demonstrated mathematically by the fact that:

$$\frac{1}{X_{\text{series}}} = \frac{1}{X_{\text{fixed}} + X_{\text{variable}}}$$

$$\frac{1}{Y_{\text{parallel}}} = \frac{1}{Y_{\text{fixed}} + Y_{\text{variable}}}$$

where X_{series} is any element value (e.g. capacitance, inductance), X is voltage or current, and the "s" sign denotes the appropriate (series-addition or parallel-addition) combination of elements. Note that the subscript format for X_{series} is chosen to easily distinguish it from the radius of the area enclosed by a circular inductive element (e.g. x , x_c , etc.).

Furthermore, this principle may be used to implement a variable electric element of a certain type (e.g. a capacitance or inductance) by using a variable element of a different type, if the latter is combined appropriately with other fixed elements.

In conclusion, one may apply a topology optimization algorithm that decides on the required number, placement, type and values of fixed and variable elements with the required tunable range as an optimization constraint and the minimization of the currents and/or voltages on the variable elements as the optimization objective.

EXAMPLES

In the following schematics, we show different specific topology implementations for impedance matching to and resonator designs for a low-loss inductive element. In addition, we indicate for each topology: which of the principles described above are used, the equations giving the values of the variable elements that may be used to achieve the matching, and the range of the complex impedances that may be matched (using both inequalities and a Smith-chart description). For these examples, we assume that Z_0 is real, but an extension to a characteristic impedance with a non-zero imaginary part is straightforward, as it implies only a small adjustment in the required values of the components of the matching network. We will use the convention that the subscript, n , on a quantity implies normalization to (division by) Z_0 .

FIG. 29 shows two examples of a transformer-coupled impedance-matching circuit, where the two tunable elements are a capacitor and the mutual inductance between two inductive elements. If we define respectively X_1 and X_2 for FIG. 29(a) and X_1 and X_2 for FIG. 29(b), then the required values of the tunable elements are:

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above matching topologies with a tunable X_2 instead.

FIG. 30 shows six examples (a)-(f) of directly-coupled impedance-matching circuits, where the two tunable elements are capacitors, and six examples (h)-(m) of directly-coupled impedance-matching circuits, where the two tunable elements are one capacitor and one inductor. For the topolo-

in FIG. 28(d). It will be appreciated that a network of capacitors, as used herein, may in general refer to any circuit topology including one or more capacitors, including without limitation any of the circuits specifically disclosed herein using capacitors, or any other equivalent or different circuit structure(s), unless another meaning is explicitly provided or otherwise clear from the context.

Let us define, respectively, $Z = R + jX$ and $Z = R - jX$ for FIGS. 29(a) and (b).

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**Capacitor bank is defined separately from
“network of capacitors”**

impedance values required by the system design.” (*Id.*, 69:7-8; emphasis added)

51. As I now show, “
from “network of capacitors” and

52. The Wiley IEEE
capacitor bank A group of
parallel. (Wiley 92; emphasis

It would have been clear to a person of ordinary skill in the art that a series and/or parallel is a key feature of these classic electric circuits. A POSA would have known that capacitors could be connected in one of these series, parallel, or a combination thereof, just as a single capacitance C_{AB} of connection terminals A and B:
Capacitors Connected in Parallel

50. In contrast to the term “network of capacitors”, the alternate term

“capacitor bank” can also be found in the ’719 patent, as well as throughout Petitioner’s chosen prior art. Examples of its appearance in the ’719 patent include:

“The tunable elements may be **electrically switched capacitor banks**”(’719 Patent 57:56-57; emphasis added)

“**Switched capacitor banks** and other switched element banks may be used to assure the convergence to the operating frequencies and

impedance values required by the system design.” (*Id.*, 69:7-8; emphasis added)

impedance values required by the system design.” (*Id.*, 69:7-8; emphasis added)

51. As I now show, “capacitor bank” in the art has a very different meaning from “network of capacitors” as used in the ’719 patent.

52. The Wiley IEEE Dictionary defines “capacitor bank” as a group of capacitors connected in parallel. (Wiley 92; emphasis original)

It would have been clear to a person of skill that the connection in series and/or parallel is a key feature of a capacitor bank.

Below illustrate these classic connections that can be found in every textbook on electric circuits. A POSA would further have known that when capacitors are connected in one these series, parallel, or series/parallel connections, the net result is just a single capacitance C_{AB} of equivalent value as seen between the bank's connection terminals A and B:

Capacitors Connected in Parallel:

51. As I now show, “capacitor bank” in the art has a very different meaning from “network of capacitors” as used in the ’719 patent.

impedance values required by the system design.” (*Id.*, 69:7-8 added)

51. As I now show, “capacitor bank” in the art has a very different meaning from “network of capacitors” as used in the ’719 patent.

52. The Wiley IEEE Dictionary defines “capacitor bank” as **capacitor bank** A group of capacitors connected in series and/or parallel. (Wiley 92; emphasis original)

It would have been clear to a person of skill that the connection of the capacitors in series and/or parallel is a key feature of a capacitor bank. The two circuits shown below illustrate these classic connections that can be found in every textbook on electric circuits. A POSA would further have known that when capacitors are connected in one these series, parallel, or series/parallel connections, the net result is just a single capacitance C_{AB} of equivalent value as seen between the connection terminals A and B:

Capacitors Connected in Parallel:

52. The Wiley IEEE Dictionary defines “capacitor bank” as:

capacitor bank A group of capacitors connected in series and/or parallel. (Wiley 92; emphasis original)

It would have been clear to a person of skill that the connection of the capacitors in series and/or parallel is a key feature of a capacitor bank. The two circuits shown below illustrate these classic connections that can be found in every textbook on electric circuits. A POSA would further have known that when capacitors are connected in one these series, parallel, or series/parallel connections, the net result is just a single capacitance C_{AB} of equivalent value as seen between the bank's connection terminals A and B:

53. For the three capacitors connected in parallel between terminals A and B is given by:

$$C_{AB} = C_1 + C_2 + C_3 \text{ (parallel)}$$

54. For the three capacitors in series, the equivalent capacitance between terminals A and B is given by:

$$C_{AB} = (1/C_1 + 1/C_2 + 1/C_3)^{-1} \text{ (series)}$$

55. For the four capacitors in series/parallel, the equivalent capacitance between terminals A and B is given by:

$$C_{AB} = (1/C_1 + 1/C_3)^{-1} + (1/C_2 + 1/C_4)^{-1} \text{ (series)}$$

56. As these examples of capacitor bank (“a group of capacitors connected in series and/or parallel”) show, a capacitor bank is not the same thing as a “network of capacitors”, because the bank can represent just a single capacitance adding just one degree of freedom to the tuning process. In a capacitor bank, all capacitors share either the same voltage (for a parallel bank) or the same current (for a series bank), whereas in each of the capacitor networks of Fig. 30 (a) – (m), there is no common

⁴The examples of three or four capacitors here is arbitrary and chosen for illustration purposes.

56. As these examples of capacitor bank (“a group of capacitors connected in series and/or parallel”) show, a capacitor bank is not the same thing as a “network of capacitors”, because the bank can represent just a single capacitance adding just one degree of freedom to the tuning process. In a capacitor bank, all capacitors share

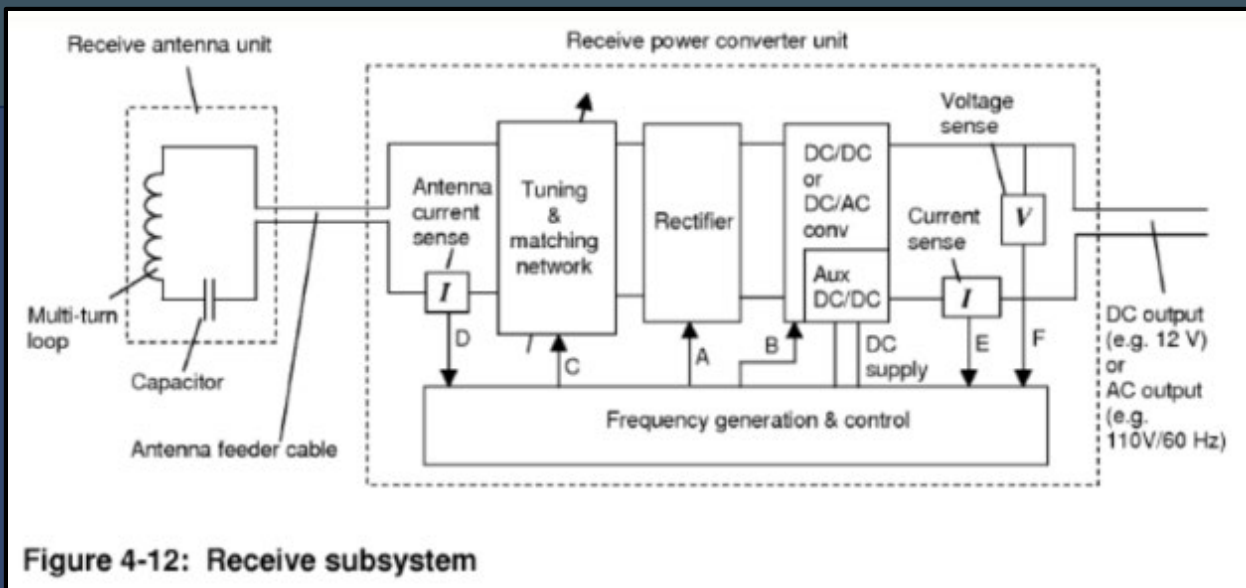
**Petitioner failed to meet its burden
to demonstrate that Cook-554 is Prior Art**

The elements of Cook-554 claim 17 have the following requirements:

(a) receive power via a resonant circuit...at a receive power level;

(b) convert the received power ... with a power converting circuit; and

(c) vary the impedance of the power converting circuit ... *based on the received power level*. Cook-554 claim 17 (emphasis added.)



- The received power of element (a) is the power received by the resonant circuit, i.e., the Receive Antenna Unit in Fig. 4-12. Horenstein Decl. at 95.
- The indicated power-converting circuit comprises the components within the central dotted box.
- The voltage sense V and current sense I (elements E and F) in Fig. 4-12 indeed yield a value of power that is delivered to the load. Cook Prov. at 31, Exh. 1006 pg. 043.
- The power delivered to the load is clearly not the power being received by the resonator as would be measured at the antenna feeder cable.

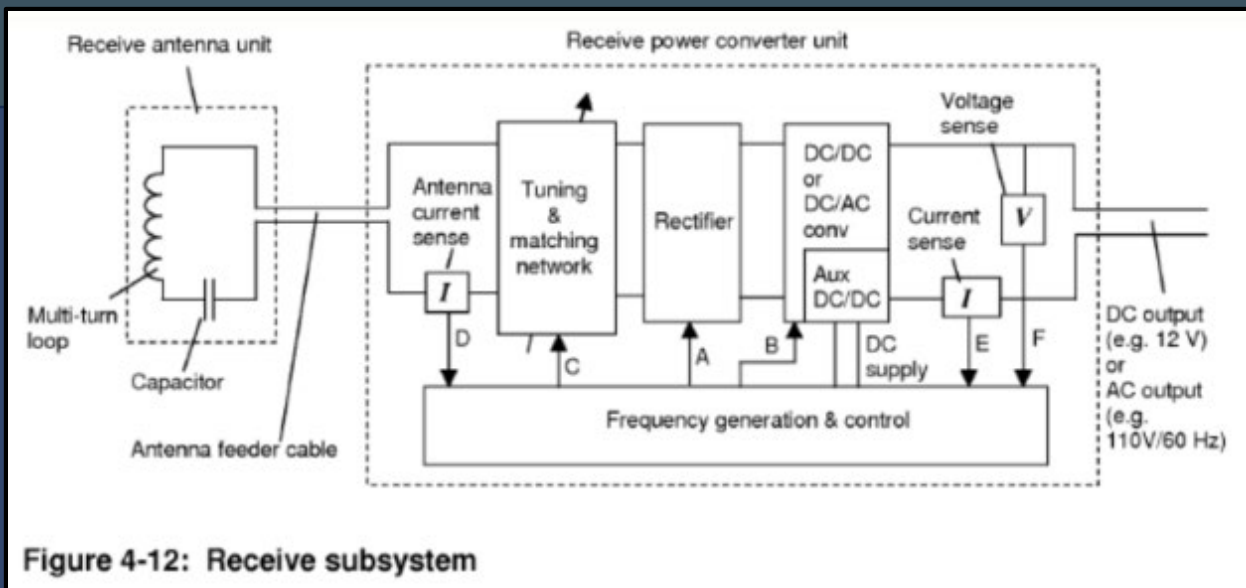


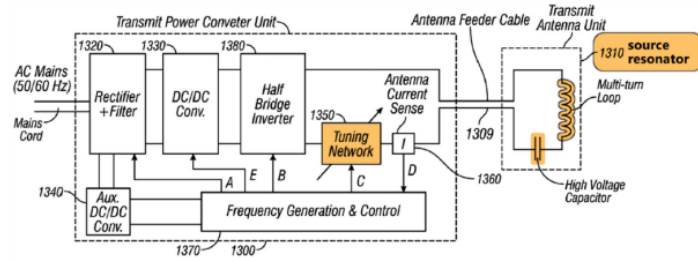
Figure 4-12: Receive subsystem

- The power received by the resonator is first converted by the Receive Power Converter Unit into a DC or AC output via a rectifier and DC/DC or DC/AC converter; this output power is then delivered to the load.
- The V and I sensors (E and F in Fig. 4-12) measure the power delivered to the load.
- Losses occur in the Receive Power Converter Unit. Cook Prov. at 5.51, Exh. 1006 pg. 060.
- Thus, the power delivered to the load, as measured by V and I, will be less than the power received by the resonator.

Independent Claim 17 Is Patentable Over Cook-554 (Petitioner's Ground 2)

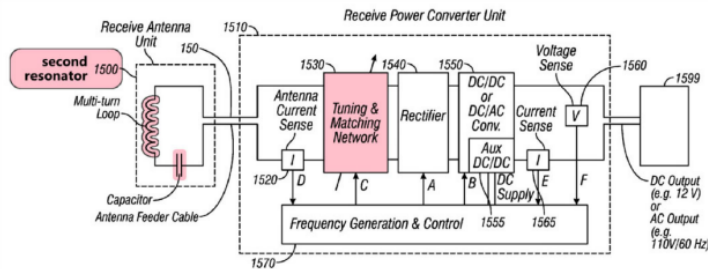
Petitioner alleges that the single capacitor bank in the tuning network of the transmit power converter unit, and the tuning and matching network of the receive power converter unit, is a network of capacitors. Pet. at 44-45.

transmit antenna unit corresponds to the source resonator, and that the receive antenna unit corresponds to the second resonator, as shown below.



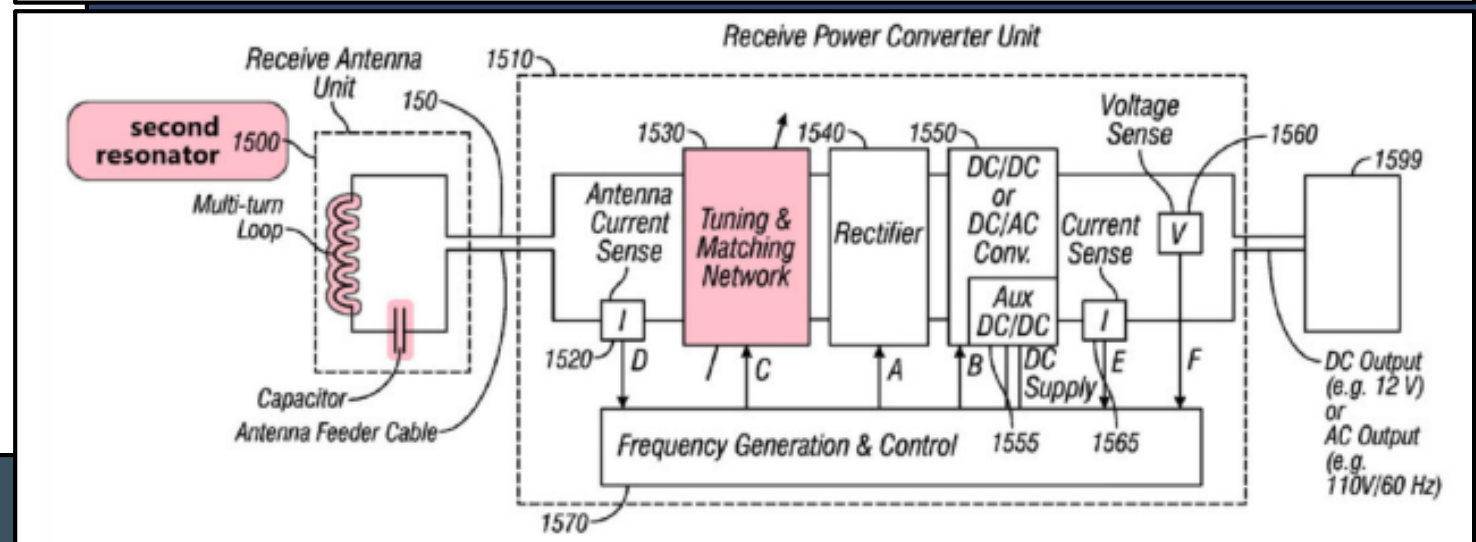
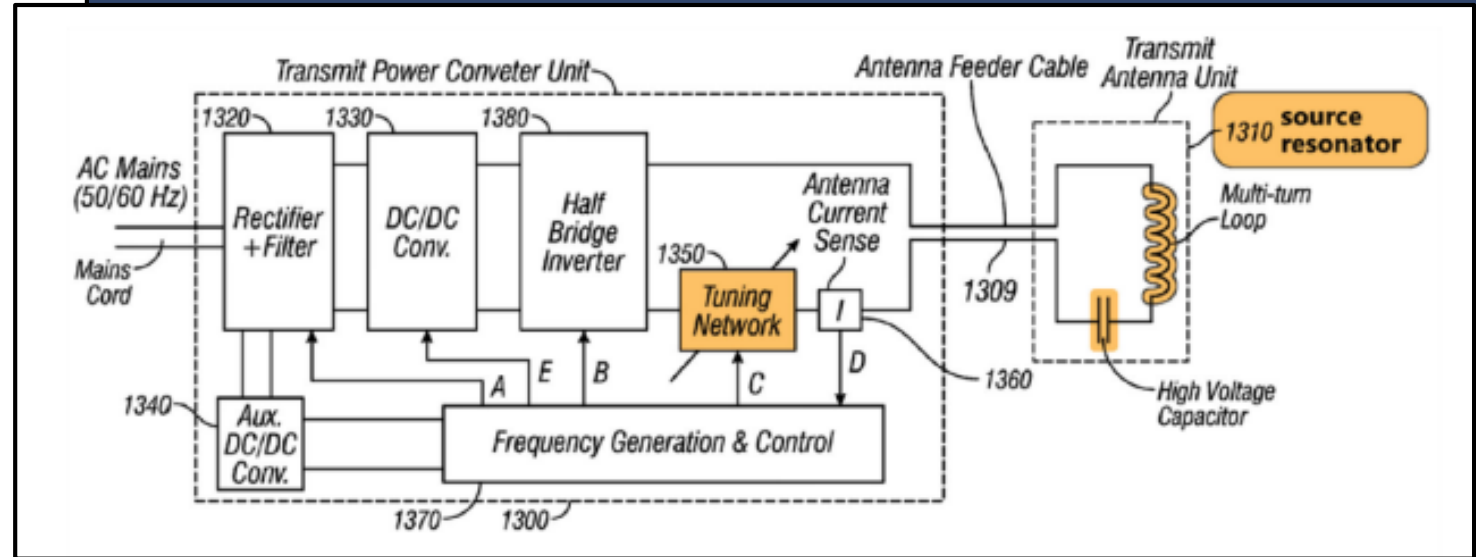
Pet. 44.

Similarly, Petitioner asserts that the receive antenna unit corresponds to the second resonator.



Id. 45.

- The tuning network is not a component part of the transmit or receive antenna units. Resp. at 52; Horenstein Decl. ¶ 122.



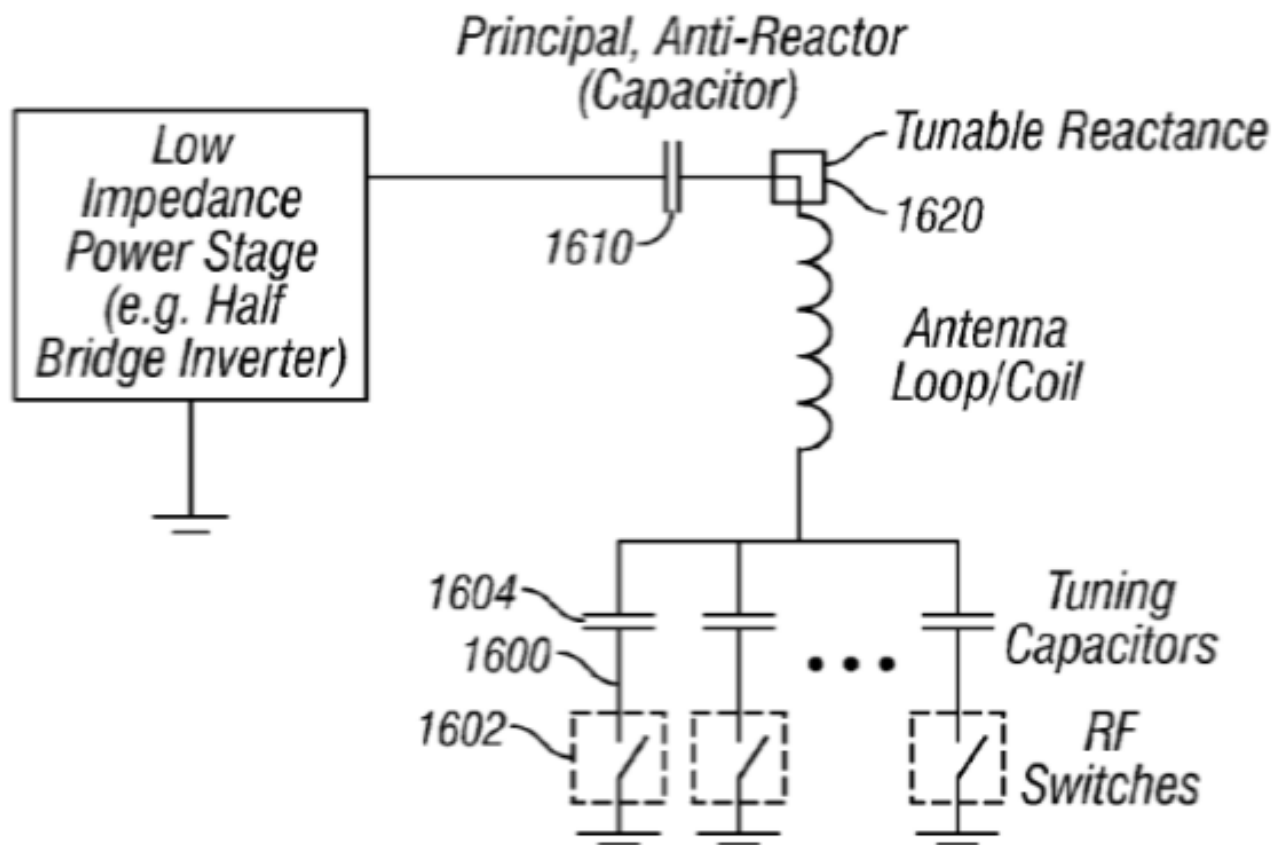


FIG. 16

The four elements in Fig. 16:

- are connected to the Power-Stage Bridge Inverter by a simple series connection
- all pass the same current from the Power-Stage Bridge Inverter and
- allow only adjustment of the resonant frequency
- do not adjust the load resistance presented to the power stage to a matching value

(Horenstein Decl. at 50 – 58 (Exh. 2011)).

function of a multi-reactance network.



FIG. 16

Cook-554 Fig. 16, annotated. (The common grounds at the bottom have been connected together in the figure on the right.)

- **Fig. 16 of Cook-554 only discloses a single capacitor bank**
- **Capacitors with RF switches that are opened or closed to adjust the effective capacitance of the system -- Cook-554 17:41-61**
- **The capacitor bank has only one degree of freedom. -- Horenstein ¶¶ 50-59; 119-120**

**Petitioner Did Not Meet Its Burden
To Show Independent Claim 17
Is Obvious Over Lee and Cook-523

(Petitioner's Ground 4)**

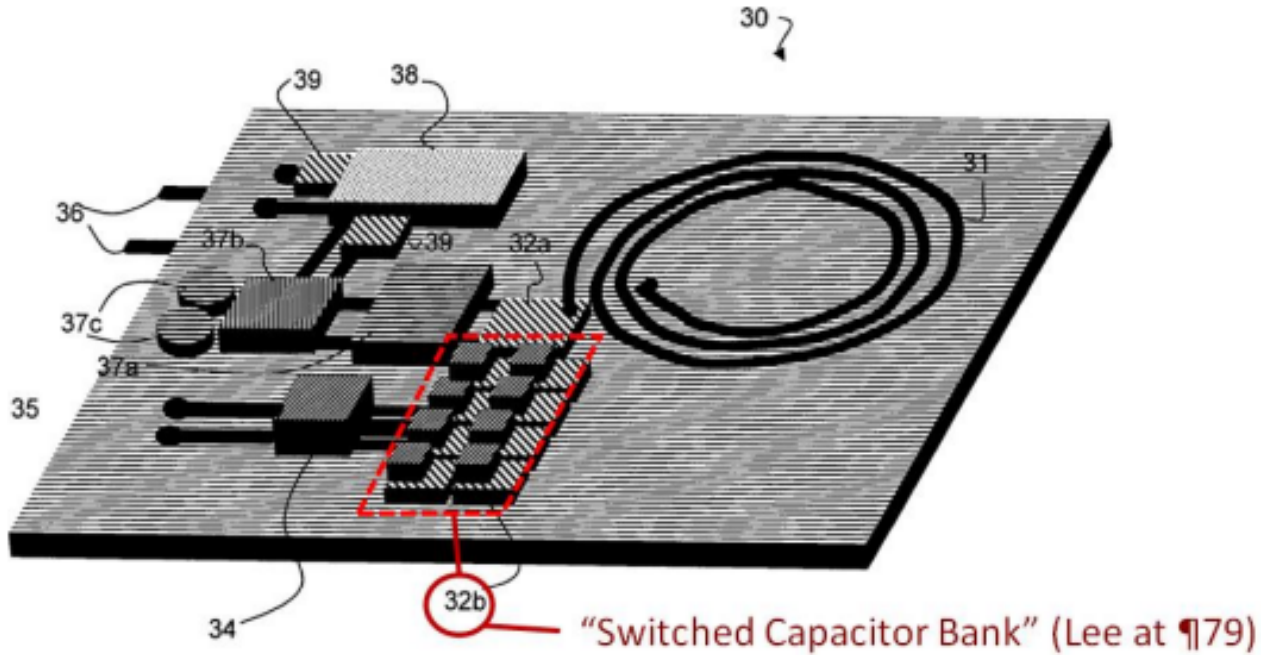
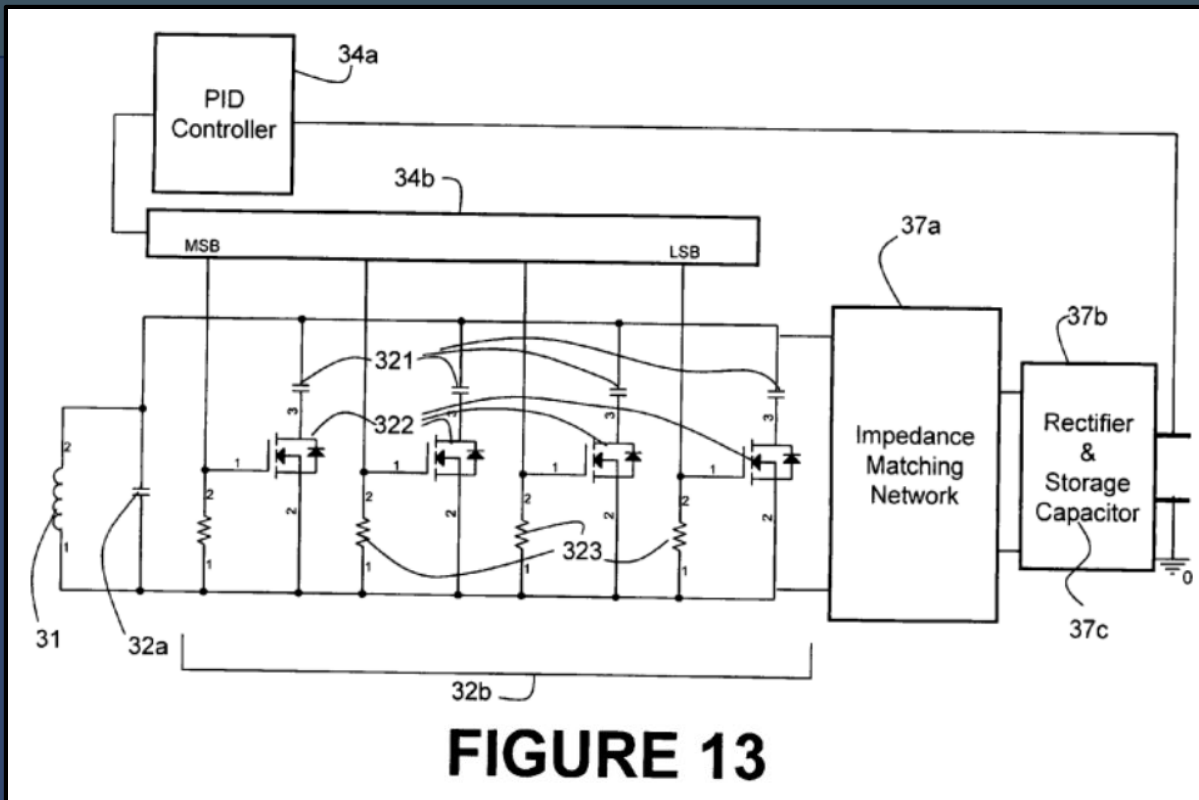


FIGURE 12

Lee Fig. 12, annotated

- Lee only discloses a single switched capacitor bank functioning as one variable capacitor. PO's Response (62-64); Horenstein Decl. ¶¶ 88-89.
- Functionally the same as the capacitor bank shown in Cook-554 Fig. 16. *Id.* at 91.
- The capacitor bank adjusts the resonant frequency. Lee [0078]; Pet.'s Reply at 29-30.



Lee does not disclose which electrical elements, if any, are inside the box labeled 37a in Figure 13, nor does Lee disclose the purpose or use of the box labeled 37a. Lee ¶ 75.

The entire paragraphs in Lee discussing Figures 12 and 13 only disclose adjusting the capacitance of the circuit using capacitor bank 32b (Lee ¶ 4, 23, 75, 78) in order to adjust the resonant frequency.

linear sections. The using printed circuit conditions, a plural reverse field region mere presence of a significant issue is magnetic field is an sign of the magneti portant. However, implies that there borders between the field regions. A second field nulls will negative magnetic other. Since the coils 21 and the second amount of magnetic coil 31, the current reduces the current.

[0071] Multi-phase both the field reverse. This can be seen in 271, 272, 273 of traveling wave natural array of coils FIG. 10 shows the excited by a long times, in which the evident.

[0072] A multi-phase similar in nature to array antenna. Ideal number, will produce close to a traveling usually limited to a N would entail the shifters. The minimum Theorem. The 4-phase clearly has an appearance wave. Due to the profile, the RMS (root sinusoidal. The calculated strength for the $\pm 22\%$. A more relevant is to use the average field over a small area. By choosing an appropriate physical dimension variation is reduced for a 6-phased drive RMS variation is a variation figure is among coil elements difficult and costly.

[0073] Applying a primary coil array along the diagonal sequence 491, 492 distribution that shows magnetic field excitation coils 21 drive two dimensional array

control the variable capacitor. The capacitance adjustment causes the resonant circuit of the secondary unit 30 to tune in to the RF driving frequency of the primary unit 20 until the voltage reaches the reference voltage value. The controller 34 can also compensate for any change in coupling or device load variation by tuning the resonant circuit in or out of the primary RF frequency through continuous output voltage and capacitance adjustment.

[0076] The ability of the secondary unit 30 to regulate output voltage is advantageous in many situations. A device to which the secondary unit 30 is attached requires regulated voltage to power it. Examples of such devices are mobile phones, MP3 players, cameras and camcorders, radios, portable game players, etc. Typically, such device is powered by a switched mode power supply whose output current are specifically designed for its use. A dedicated DC power supply is a major inconvenience for a user who may carry a multitude of electronic devices. In view of the present invention, the solution is to equip each device with a secondary unit 30 that can receive power from the primary unit 20 and regulate the output voltage to whatever the device needs. If the output voltage from the secondary unit 30 is unregulated, it may need a linear voltage regulator if the power device is small or a DC-DC converter if the power voltage regulation is required. Since the secondary unit 30 of the present invention can supply regulated voltage, the need to have a separate voltage regulator is obviated, making the conversion from the power supply to the contactless one of the present invention painless. With the addition of a DC current sense element, such as a series current sense resistor or mirrored sense resistor when MOSFETs are used in the bridge rectifier section 37b, it would be possible for the feedback controller 34 to control both the output current to behave like a lithium ion/polymer battery with little or no additional cost.

[0077] This specific embodiment of the secondary unit 30 can also be profitably employed to construct a power adapter for portable devices. Modern electronic devices are designed with a lot of built-in protection including over-voltage protection, under-voltage protection, over-current protection, etc. If such a device is connected to a variable voltage power supply, it would blow a fuse or the supply voltage exceeds a threshold. Once the supply voltage has the threshold, the device's power interface module will connect the device to the power unit to the power supply. During the operation, if the supply voltage spikes to a value that exceeds the threshold for over-voltage protection, the device's power interface module immediately disconnect the power from the power supply. Similarly, if the supply voltage dips to a value that is below a certain threshold, which may or may not be the same as the initial threshold, then the device also disconnect itself from the power supply, until the supply voltage returns to its normal range. Thus, it would be possible to program the feedback controller 34 of the secondary unit 30 to increase the regulated output voltage in steps, with a sufficient wait time to account for the initial delay before the power interface module of the device connects the device to

the secondary unit's output. The controller 34 of the secondary unit 30 monitors the device current to determine whether the connection has been made. When the controller has detected the rise in output current beyond a certain

reference voltage level that is high enough to turn the controller 34 on. Once the feedback controller 34 is turned on, it starts to regulate the voltage by comparing the voltage of the storage capacitor 37c and a reference voltage and takes the difference which is used as an error signal to

unregulated, it proportional, differential, and integral (PID) controller 34a

control the variable capacitor. The capacitance adjustment causes the resonant circuit of the secondary unit 30 to tune in to the RF driving frequency of the primary unit 20 until the voltage reaches the reference voltage value. The con-

of 2 of the smallest capacitance. So for example, if the smallest capacitance is 100 pF, then the other three capacitances are 200 pF, 400 pF and 800 pF. Each capacitor is in series with a MOSFET switch which can be turned on to enable the capacitor it is directly connected to, or to turn off to disable the capacitor. Since each MOSFET switch can be either ON, or OFF, the switched capacitor bank 32b can provide 24 or 16 different capacitance values which are more or less linearly distributed with values from 0 pF to 1,500 pF. The capacitance values are not precise because of the inherent variation of stock capacitors as well as the source drain capacitances of the MOSFETs. The source drain capacitance of the MOSFET is unimportant when the MOS-

- As noted in Lee, the switched capacitor bank 32b performs the function of an electronically controlled capacitor...” Lee ¶ 86.
- Thus in Lee, like Cook-554, a single, variable capacitor (in the form of a capacitor bank) maintains the resonant frequency.

- Lee does not disclose a second degree of freedom in order to match the resistance of the source of the wireless power transfer circuit to the resistance of the load, as disclosed and explained in detail in the '719 Patent and as required by Claim 17.
- Lee fails to mention, much less explain, the Smith Chart and its requirement for two degrees of freedom in order to tune the two variable elements to ensure resistance matching for a particular resonant circuit. Horenstein Decl. ¶¶ 45 – 49.
- Petitioner *and its technical expert* likewise failed to address the use of the Smith chart in illustrating the two-degrees-of-freedom tuning procedure disclosed in the '719 patent. Horenstein Decl. ¶ 44-57.
- Similarly, the Lee reference also never mentions the Smith Chart or the required two or more degrees of freedom.

- Petitioner misrepresents Dr. Horenstein's Deposition testimony by implying in a conclusory sentence in the Reply that Dr. Horenstein confirmed that Lee discloses a network of capacitors with two degrees of freedom. Reply at 30, citing --*Horenstein Tr. at 49: 19-24*.
- Indeed, the portion of Dr. Horenstein's testimony cited by Petitioner is not discussing Lee at all.
- Instead, in response to a question by counsel for Petitioner, Dr. Horenstein simply stated that impedance matching, as disclosed in the '719 Patent, requires two degrees of freedom. --*Horenstein Tr. 49:19-24*

1 and matching network is not connected directly to
2 what Cook has termed the receiver -- receive antenna
3 unit. So not directly connected to the receiver.
4 Figure 15.

5 By MR. PETERS:

6 Q. Do you dispute that the tuning and
7 network in Figure 15 performs an impedance
8 network for the multi-turn loop?

9 MR. LAWSON: Objection to form.

10 THE WITNESS: It performs impedance
11 matching so that the -- its input terminals
12 matched to the -- to its output terminals,
13 to the rectifier and then on to the DC -- to
14 or DC to AC converter, which is block 1515.

15 By MR. PETERS:

16 Q. So it performs impedance matching?

17 A. Between its left-hand input port and
18 right-hand output port.

19 Q. And I think we went over this earlier, but
20 it's your expert opinion that impedance matching
21 requires providing two degrees of freedom?

22 A. Generally it does. In the context of
23 impedance matching, as it's discussed in the '719
24 patent, it does.

25 Q. Does the '719 patent perform impedance

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Q. And I think we went over this earlier, but
it's your expert opinion that impedance matching
requires providing two degrees of freedom?

A. Generally it does. In the context of
impedance matching, as it's discussed in the '719
patent, it does.

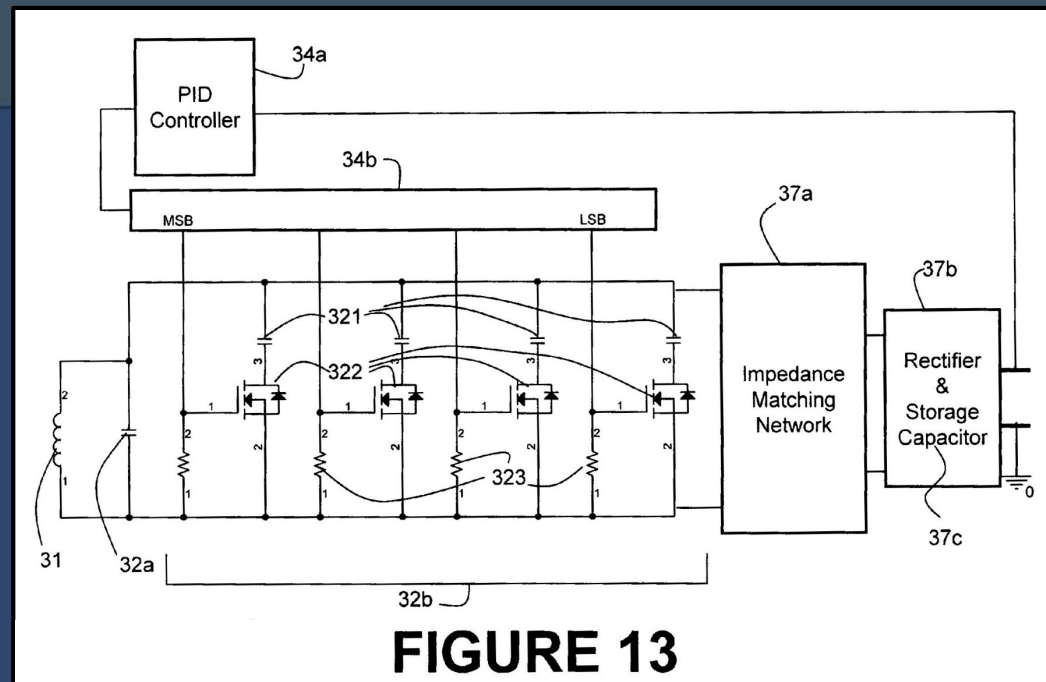


FIGURE 13

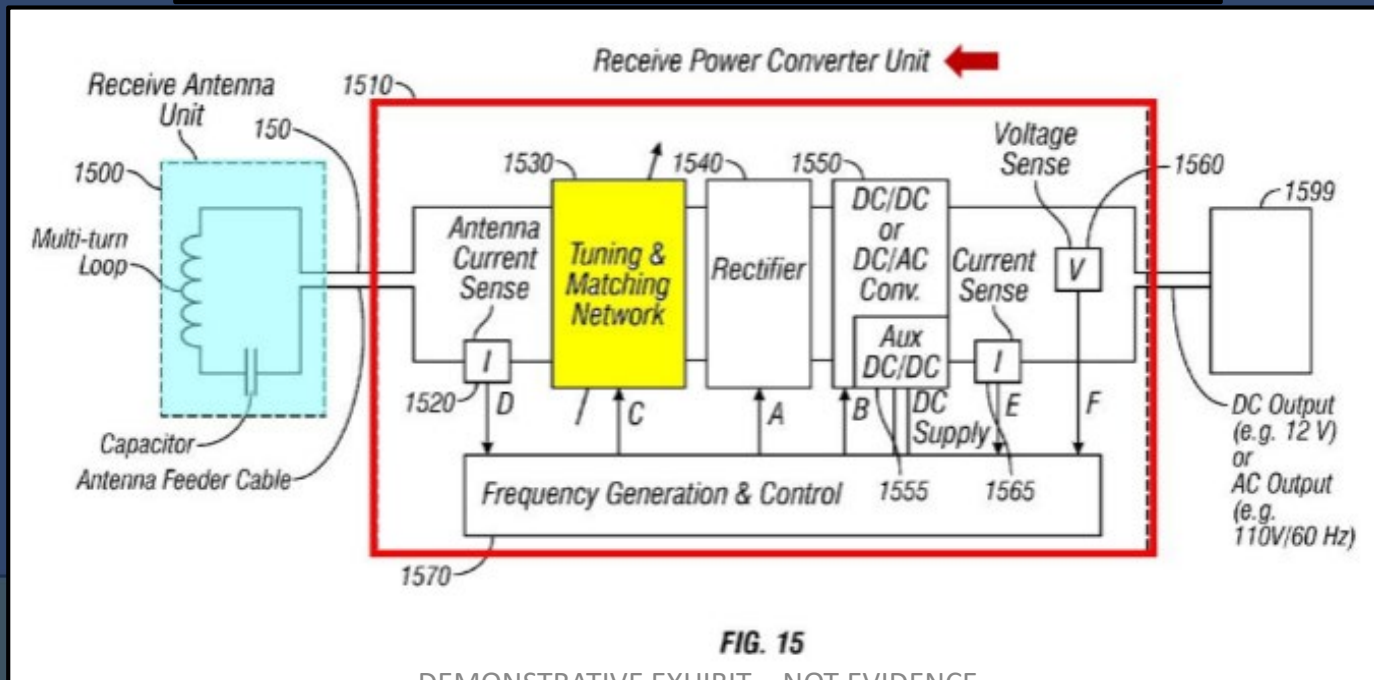


FIG. 15

CONCLUSION