(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 December 2010 (23.12.2010)

PCT

(10) International Publication Number
WO 2010/148199 A2

(51) International Patent Classification: *A61B 5/053* (2006.01)

(21) International Application Number: PCT/US2010/038991

(22) International Filing Date: 17 June 2010 (17.06.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/486,616 17 June 2009 (17.06.2009) US

(71) Applicant (*for all designated States except US*): **NUORTHO SURGICAL, INC.** [US/US]; 151 Martine Street, Fall River, MA 02723 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **MORGAN, Roy, E.** [US/US]; 401 Channing Way, Alemeda, CA 94502 (US). **AUGE, Wayne, K. II** [US/US]; 936 Vista Jemez Court, Santa Fe, NM 87505 (US).

(74) Agent: **VILVEN, Janeen**; Peacock Myers, P.C., P.O.Box 26927, Albuquerque, NM 87125-6927 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: ACTIVE CONVERSION OF A MONOPOLAR CIRCUIT TO A BIPOLAR CIRCUIT USING IMPEDANCE FEEDBACK BALANCING

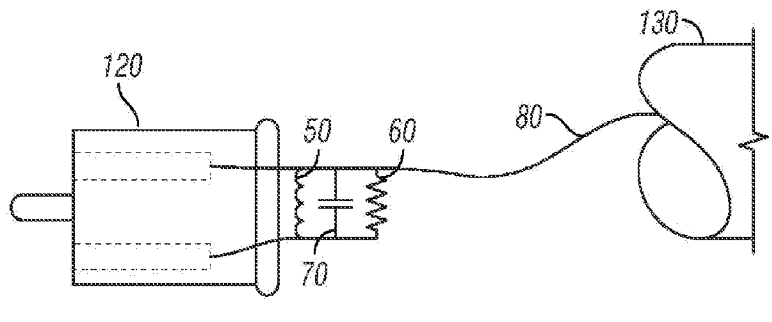

FIG. 3

(57) **Abstract**: Systems, devices, and methods for electrosurgery wherein a circuit bridge is created for a monopolar electrosurgical circuit that provides a matched impedance to load condition thereby joining the active (working) and return (reference) electrode leads into a single bipolar mode device.

WO 2010/148199 A2

INTERNATIONAL PATENT APPLICATION

ACTIVE CONVERSION OF A MONOPOLAR CIRCUIT TO A BIPOLAR CIRCUIT USING IMPEDANCE FEEDBACK BALANCING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Patent Application Serial No. 12/486,616 entitled "Active Conversion of a Monopolar Circuit to a Bipolar Circuit Using Impedance Feedback Balancing", to Roy E. Morgan and Wayne K. Augé, II, filed on June 17, 2009 and the specification and claims thereof are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

[0002] Embodiments of the present invention relate to the general field of electrosurgical generators that are used to power devices, such as instrument probes, developed for use in surgical and medical procedures.

Description of Related Art:

[0003] The use of electrosurgical instruments in various types of surgical procedures has become widespread and generally consists of a system whereby a treatment device probe is connected to an electrosurgical generator. The device probe delivers the energy from the electrosurgical generator to the tissue treatment site via electrodes to provide a therapeutic effect. Device probe and electrosurgical generator architecture have been developed for particular therapeutic needs, depending upon, for example, the goals of treatment, the tissue type to be treated, and the treatment environment. Most commonly, electrosurgical generators consist of either monopolar or bipolar configurations, or both, which have become well known in the art. Likewise, either monopolar or bipolar treatment device probes have been developed to connect to those types of electrosurgical generators via an electrosurgical generator output port, either monopolar or bipolar, respectively. Active (or working) and return (reference) electrodes then function in a variety of ways based upon, for example, configuration, architecture, and connection to the electrosurgical generator. In this manner, either a monopolar or bipolar output portal, or both, exists on the electrosurgical generator into which the device probe, either a monopolar or bipolar device respectively, is connected.

A monopolar device is connected to a monopolar output portal on the electrosurgical generator and, likewise, a bipolar device is connected to a bipolar output portal on the electrosurgical generator. Typically, feedback from the treatment site is then managed by way of the relevant monopolar or bipolar circuitry within the electrosurgical generator and between the device probe electrodes that are connected to the electrosurgical generator accordingly.

[0004] More generally, and to date, the electrosurgical industry has provided a wide variety of products geared toward this single-mode of operation from specific electrosurgical generator output portals (monopolar or bipolar). Within this design limitation, specific control mechanisms, circuitry, and software algorithms have been developed and applied to the management of the variable feedback that can be obtained from a single portal output for any given device. Since device probe geometries tend to be more fixed than variable with respect to monopolar or bipolar configuration, the electrical signature of a given device is commonly treated as a constant within the context of an overall surgical procedure; i.e. a monopolar or a bipolar device.

[0005] The direct result of this prior art has been to provide specific output portals for the most common types of electrosurgery; those being monopolar and bipolar. Each of these output portals is designed to provide specific controls that limit the amount of maximum current, voltage or time-based modulations of current and voltage in response to the variations in factors at the treatment site. The result is intended to control the overall output to the active (working) end of the attached device probe and keep its general state of operation within a specified “safe-range” to avoid excessive heat, current, or current density from forming within the surgical site or elsewhere within the patient at the time of treatment.

[0006] Such circuitry for this monopolar or bipolar configured output portals is contained within the physical confines of the electrosurgical generator enclosure itself, proximal to the connection of the device probe, and is coupled to an electronic and software controller that monitors said variables and continually checks their time-varying values against preset performance limits. When these performance limits are exceeded, the controlling algorithm forces a safety trip, thus shutting down the primary RF-power output to the working end of the attached device. The specifics of these predefined software controlled trip points is that they are based on the electro physical constraints electrosurgical generator manufacturers have placed on the output portals, which as previously discussed, are configuration specific (monopolar or bipolar). Thus, the physical spacing of primary components such as the active (working) and return (reference) electrodes plays a paramount role in what those specific characteristics are that govern said trip points for safety control.

[0007] The overall industry result from this configuration model is a trajectory of “silo” thinking for each specific electrosurgical output portal, meaning that devices have been optimized for either the monopolar output portal or bipolar output portal of electrosurgical generators. Traditional thinking of the prior art has been that there is no advantage in shrinking the physical space of a given portals output for a specific mode, meaning that a monopolar procedure that involves a separated ground pad, typically placed at a great distance from the surgical site, has been thought to need such separation to operate effectively and that such separation is exactly why the procedure has been named “mono” polar as the electrical poles are separated by such large relative distances that only a single pole is effectively at work within the surgical site. On the other end of the spectrum is the “bi” polar method of electrosurgery which has drawn its name from the physical basis of active (working) and return (reference) electrode proximities to one and other. Thus, to date industry has remained ensconced in fixed paradigm of one treatment device probe configuration per output port of the electrosurgical generator; i.e. monopolar device to monopolar output port and bipolar device to bipolar output port.

BRIEF SUMMARY OF THE INVENTION

[0008] An embodiment of the present invention relates to an electronic bridging circuit which includes one or more circuit components arranged in electrical communication with a primary radiofrequency active or reference/return electrode lead of a hand piece of an electrosurgical generator upon which lead a super-imposed rider wave signal is transmitted, the super-imposed wave signal normalized to a monopolar balanced state of feedback to the electrosurgical generator reference plate electrode monitoring circuit via the one or more circuit components; the one or more circuit components selected to affect the super-imposed wave signal by balancing the rider signal; and wherein monopolar outputs of the electrosurgical generator are converted to bipolar outputs compatible with the hand piece upon connection of hand piece with the generator. In the circuit, a plurality of the circuit components can be connected in a parallel configuration, a series configuration, or a combination thereof. The circuit components can include a capacitor, an inductor, a resistor or pluralities and/or combinations thereof. If a capacitor is provided, it can optionally have a value of about 1 picofarad to a value of about 1 microfarad, more preferably about 40 picofarads to a value of about 0.1 microfarad. Optionally, one or more of the components can be arranged in a bridge circuit.

[0009] An embodiment of the present invention also relates to an electrosurgical apparatus comprising a conventionally-shaped monopolar output universal plug for the delivery of primary RF electrical current, which comprises no more than two of the typical three conductors.

[0010] An embodiment of the present invention also relates to a method for converting a monopolar electrosurgical generator which outputs a power wave and a super-imposed rider wave for use in a bipolar electrosurgical configuration which method includes bridging leads connected to the monopolar electrosurgical generator with a bridging circuit having at least one balancing component, the balancing component selected such that the impedance encountered by the rider wave when traveling through a bipolar hand piece and the balancing component is substantially similar to the impedance encountered by the rider wave when a monopolar hand piece and return pad is connected to the electrosurgical generator. The balancing component can be disposed within the bipolar hand piece. The balancing component can comprise a plurality of components which can be active, resistive, or a combination thereof. The bipolar hand piece can be electrically connected to only one of the cut or coagulate outputs of the monopolar electrosurgical generator.

[0011] An embodiment of the present invention also relates to a method for using a monopolar output of an electrosurgical generator for a bipolar electrosurgical application which method includes connecting a plurality of active electrodes of a bipolar electrosurgical hand piece to an active electrode port of a monopolar electrosurgical generator; providing one or more components through which a reference signal passes, the one or more components selected such that the total impendence encountered by the reference signal is at least substantially similar to a total impedance which would be encountered by the reference signal if it were traveling through a functioning monopolar electrosurgical hand piece. At least one of the plurality of active electrodes can be connected to the active electrode port of the monopolar electrosurgical generator through a switch. Optionally, each of a plurality of the active electrodes can be connected to the active electrode port of the monopolar electrosurgical generator through respective switches. The plurality of active electrodes can be individually and/or simultaneously activated.

[0012] An embodiment of the present invention relates to an electrosurgical apparatus which includes a monopolar electrosurgical generator connected to a bipolar electrosurgical hand piece. The hand piece can operate in a cut only mode or in a coagulate only mode.

[0013] An embodiment of the present invention also relates to a bipolar electrosurgical hand piece connectable and operable with a monopolar electrosurgical generator.

[0014] In an alternative embodiment, the electrosurgical hand piece of each of the foregoing embodiments can be operable in-situ and optionally with a liquid environment about a tip of the hand piece.

[0015] Aspects, advantages and novel features, and further scope of applicability of embodiments of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those aspects and advantages of embodiments of the present invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0016] The accompanying drawings, which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating one or more preferred embodiments of the invention and are not to be construed as limiting the invention. In the drawings:

[0017] Fig. 1A is a drawing which illustrates the prior art traditional method of delivering monopolar high frequency electrical current to the human body during a treatment procedure;

[0018] Fig. 1B is a drawing which illustrates the circuit bridge according to one embodiment of the present invention for use with a traditional electrosurgical generator whereby the bridge is within the device and its connector to the electrosurgical generator creating a bipolar circuit based device connected to the monopolar electrosurgical generator;

[0019] Fig. 2A is a drawing which illustrates an alternative placement of the preferred embodiment of active bridge components within the electrosurgical circuit outside of the electrosurgical generator;

[0020] Fig. 2B is a drawing which illustrates an alternative embodiment depicting how the bridging circuit interacts with the return (reference) or sensing circuit;

[0021] Fig. 3 is a drawing which illustrates a preferred embodiment for the bridge circuit in which the connector terminal of the active (working) or return (reference) lead-wire is bridged with the necessary components for circuit matching;

[0022] Fig. 4 is a graphical representation of the characteristic impedance threshold limits and operational envelope of the preferred embodiment within existing safety envelopes of typical electrosurgical generators;

[0023] Fig. 5 is a drawing which schematically illustrates an embodiment of the present invention wherein a single active electrode is connected to a single switch;

[0024] Fig. 6 is a drawing illustrating a universal connector as can be modified in accordance with the teachings of one embodiment of the present invention;

[0025] Fig. 7 is a drawing which schematically illustrates an embodiment of the present invention wherein a plurality of electrodes are connected to a plurality of switches; and

[0026] Fig. 8 is a drawing which schematically illustrates an embodiment of the present invention wherein a plurality of active electrodes are connected to a single switch.

DETAILED DESCRIPTION OF THE INVENTION

[0027] In one embodiment, the present invention allows the general field of electrosurgery to use electrosurgical generators to power devices, such as instrument probes, developed for use in surgical and medical procedures.

[0028] More specifically, in one embodiment, the present invention relates to specific methods of connection of such devices to electrosurgical generators that provide active enhancement of output signal monitoring. Embodiments of the present invention also relate to specific management of circuit characterization when a single mode output from an electrosurgical generator is bridged to perform a circuit contraction in physical space.

[0029] The elements described herein relate generally to any electrosurgical generator that employs an active feedback monitoring algorithm designed to measure Voltage Standing Wave Ratio's (VSWR), total impedance change (ΔZ), current fluctuation threshold/change (ΔI), peak to peak voltage change or time-averaged voltage change (ΔV) and other similar manipulations of the variables of Ohm's Law as it applies to radio-frequency transmission circuits into loads of time-varying overall impedance.

[0030] Embodiments of the present invention are also useful to the general field of electrosurgery in which electrosurgical generators are used to power devices, such as instrument probes, developed for use in surgical procedures.

[0031] One or more embodiments of the present invention disclosed herein expands the functionality of the output ports of an electrosurgical generator through a bridging configuration that spatially contracts the heretofore separated independent poles of a monopolar system. Specifically, the bridging approach places the previously separated return (reference) electrode (commonly referred to as a return pad) in close proximity to the active (working) electrode through a reconfiguration of the connected device probe's circuitry. Additionally, passive and/or active electrical components are preferably employed in the completion of the bridge circuit to provide a rebalancing of the VSWR, Z_{tot}, I_{max}, V_{pp} or similar control variable that is typically contained and monitored within the electrosurgical generator to provide safety feedback trip points for primary electrosurgical power output shutdown. This rebalancing is termed BALUN. As a result, the new bridge components are positioned in a way so as to act as bridge circuit maximum or minimum limits to activation based on the nominal variable of Z_{tot} as measured between the output port of the electrosurgical generator and the active (working) end of the connected device probe. Furthermore, components used in the bridging circuit of the device may be selected to specifically mate with a specific type of electrosurgical generator and its corresponding control algorithm depending on the variable to which the specific generator is tuned.

[0032] The combination of the bridge circuit and passive/active components therein duplicating normal systemic control to the primary electrosurgical output power by modulating the reference signal to the electrosurgical generator monitoring circuit that enables early or delayed trip points dependent on the specific type and value of the components used in the bridging circuit. This added control creates the ability to connect lower energy devices to the electrosurgical generator that can be limited in their power capabilities below and within the spectrum of power output of the electrosurgical generator to which they are attached.

[0033] In some embodiments, the present invention can optionally be incorporated into an electrosurgical system that works in concert with specific instrumentation designed to take advantage of the bridge circuit configuration and reconfigured to work in a complementary manner from the electrosurgical generator output port to which it is attached. Simply put, this allows a) bipolar probe function from the monopolar output port of any given electrosurgical generator (termed the "primary" approach) and b) a reverse splitting of a bipolar output port into a monopolar output port or device is also enabled (termed the "reverse" approach). For the purposes of illustration, the primary approach will be discussed in more detail below with the understanding that the reverse approach will be subsequently obvious to those skilled in the art after studying this application.

[0034] With the primary approach the capability of monopolar output ports of electrosurgical generators is expanded and a new attached device functionality that has been designed in a bipolar configuration is provided. With the reverse approach, the capability of bipolar output ports of electrosurgical generators is expanded and a new attachment device functionality has been designed in a monopole configuration which is thus provided. With these advantages designed within the attached device to an electrosurgical generator, specific wave-form outputs, voltage, and current curves from the electrosurgical generator can now be applied in procedures from which they were previously excluded by definition, because of prior art's port-specific application. For example, in the reverse approach, existing monopolar devices are thus provided with the ability to use bipolar wave-forms at lower peak voltages and currents for procedures where tissue proximity requires greater care in managing the total current flow to prevent formation or delivery of excess localized energy.

[0035] Additionally, application of bridged signal circuitry to device instrumentation is not limited to "open" procedures, but can now also be applied to underwater environments that have previously been outside the application mode for some electrosurgical generators. Device configurations can now be specifically matched to procedures which are designed to utilize combined electrosurgical generator bridged output and instrument geometry. Both the low energy (tissue sparing) electrosurgical effects and higher energy (tissue ablation) effects can further be amplified through specific features or functions of the attached device and thereby improve the desired surgical outcome in relation to the amplified parameter.

[0036] Combinations of the above electrosurgical generator output ports and the use of a dynamically managed bridge circuit within the connected device become readily apparent for use within the gastro-intestinal system, urinary tract, thoracic cavity, cranial cavity, joints, wetted tissue, bone, and spinal column among others.

[0037] Fig. 1A illustrates the prior art's traditional method of delivering monopolar high frequency electrical current to the human body. The electrosurgical generator **40** is driven by AC-mains power and inductively coupled to the primary electrosurgical output power circuit **15**. The primary electrosurgical output power circuit is electrically coupled to the monopolar hand piece device probe **10** and delivers electrosurgical current to the surgical site when manually directed by the hand of the surgeon on the device activation switch. The electrosurgical current then passes through the conductive media of the human tissues **30**, whereupon it is typically routed by path of least resistance to the return electrode pad / plate **20** and returned to the electrosurgical generator return (reference) electrode via coupling cable **25**. In this manner the electrosurgical current is passed from one pole (the active or working) to the second pole (the return or reference) at frequencies that range from 400 kHz to 1GHz among others. Current passing through the human tissue zone **30** is not capable of being controlled to any extent by any portion of the electrosurgical system, except to start and stop the current flow itself. The dispersion and relative current density at any given point within the human tissues **30** is random and preferential to higher conductive tissues or electrical tissue reservoirs. As such, it is not uncommon for monopolar methods of electrosurgery to result in tissue burns within zone **30** resulting in tissue effects not associated with the intended surgical site. The invention disclosed herein overcomes the limitations of the fixed output port of an electrosurgical generator and the physical separation of the human tissue zone **30** required in the monopolar system by using balance/unbalance (BALUN) technology in the reference circuit bridge **25** to provide a new means of utilization for the monopolar electrosurgical generator in a bipolar fashion via the monopolar output port. This significantly decrease the risk of tissue burns or other unintended consequences of using monopolar system circuitry as established currently in prior art.

[0038] Fig.1B illustrates the circuit bridge of the present invention for use with a traditional electrosurgical generator whereby the bridge enables the ability to use a bipolar device in a monopolar output port of an electrosurgical generator. As depicted, the general method by which the overall electrosurgical circuit is governed is shown. In simple terms, the electrosurgical generator circuit is nominally represented by a typical high-frequency transmission line. It therefore follows that such a high frequency transmission line can be modeled effectively through the use of the characteristic impedance equation:

i. (Eq. 1) $$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$; where:

[0039] R= overall circuit transmission line resistance

[0040] G= overall circuit transmission line conductance

[0041] $j\omega$ = the phase component of the circuit transmission line's active response elements

[0042] L = overall circuit transmission line inductance

[0043] C= overall circuit transmission line capacitance

[0044] Since a typical electrosurgical generator transmission line consists of either closely spaced twisted-pair wires, straight-pair wires, or coaxial cable wires, the actual conductors of the overall circuit leads to a highly capacitive circuit orientation. Furthermore, the typical arrangement of the return electrode pad used universally in monopolar surgical configurations of the circuit forces an additional capacitive element if there is more than one electrical conductor used to provide the return pathway to the reference point. Dynamically, the variables with the greatest fluctuations intraoperativly when in use are a) the distance of the active (working) electrode to the surgical site, b) the conductivity of the interfacing media, c) the resistance of the active electrode (influenced by thermal properties; heat), and d) time-relative denaturation of tissue at the surgical site (related to conductivity of the interfacing media). Generally, the overall electrical parameters of those components of the system which are not immersed in the interfacing media at or near the surgical site tend to remain relatively constant by comparison. Thus, we can rewrite Eq. 1 in terms of those parameters that apply most prominently when operating the device to the characteristic impedance as:

(Eq. 2a) $$Z_0 = \sqrt{\frac{(R_0 + R_D + R_t) + j\omega L}{\left(k \cdot \frac{A}{d}\right) + j\omega C}}$$, where:

[0045] R_0= material resistance of the circuit (resistance per unit length)

[0046] R_D= resistance (change) at a specific distance from the surgical site (monopolar only)

[0047] R_t = resistance change due to thermal heating of the active electrode

[0048] k = conductivity of the specific interfacing media

[0049] A = microscopic surface area (geometric area× roughness factor) of the active electrode

[0050] d = distance between the active and return electrode

[0051] Note that the $\left(k \cdot \frac{A}{d}\right)$ term is one typically applied for the determination of media conductivity in a conductivity cell. The treatment site when wetted with interfacing media of an electrolyte kind is very much the same type of environment. As such, the conductivity parameters apply with the distance d being on the order of 1-2m. This simple fact, reveals how the connection between the active (working) and return (reference) electrodes is therefore governed mostly by the human tissues **30** (Fig. 1A) and not by the relatively small motions made by the surgeon during the act of treating the surgical site. The comparison is an order of magnitude in difference as the typical movement of the probe by the surgeon is on the order of 1 to 10cm as opposed to the distance between the active (working) and return (reference) electrode in a traditional system as in Fig. 1A. Furthermore, the components R_D and $\left(k \cdot \frac{A}{d}\right)$ effectively cancel each other out leaving the elements of the circuit that are most influential. A mark-up of the equation shows how these elements are cancelled:

¢ ¢

(Eq. 2b) $$Z_0 = \sqrt{\frac{(R_0 + R_D + R_t) + j\omega L}{\left(k \cdot \frac{A}{d}\right) + j\omega C}}$$

This reveals that in the general case, the thermal-resistive and capacitive properties govern in the surgical environment.

[0052] Fig. 1B illustrates how the circuit bridging component can be bridged from the active RF output circuit to the primary return circuit in order to establish a “matched” impedance of the circuit to the load when the monopolar mode electrosurgical generator output port is bridged into the bipolar mode of the device, resulting in the elimination of the traditional return pad. This simple elimination requires that the external circuit within the device configuration be matched anew to the electrosurgical generator sensing pattern such that it will operate according to the standard output curves prescribed by the electrosurgical generator. By combining the appropriate and independent amounts of active circuit elements to the bridge, the matched impedance can be achieved for a bipolar device to function normally from the monopolar outputs of a traditional monopolar electrosurgical generator. This now provides a way to power bipolar devices with power curves that have been traditionally reserved for monopolar devices alone. Many of the typical power output curves used in traditional monopolar electrosurgery have characteristics that are known to be of advantage for certain applications and tissue types, but lack safety in the monopolar delivery method in many instances, such as with tissue sparing treatments. The same curves when delivered via a bipolar device can now do so with a highly improved degree of safety by avoiding current flow through random parts of the human body to connect with a distant return pad. There are several ways in which such a bridging circuit can be achieved to provide a matching mechanism to the circuit for mating with any one of a large variety of existing traditionally monopolar electrosurgical generators available in the surgical marketplace.

[0053] For example, in the treatment of articular cartilage, the goals of removing damaged portions of that cartilage are often complicated by excess tissue necrosis of surrounding healthy cartilage cells. This chondrocyte collateral damage is very notable with current devices of the prior art as the ability to control energy deposition with a monopolar device is limited. The return sequence of the traditional circuit obviates the ability to limit current deposition in the surrounding healthy areas. By the application of the bridge circuit and associated balance/unbalance technology disclosed herein, a bipolar device can be configured to be powered by a monopolar electrosurgical generator. This advantage eliminates the safety risk of prior art systems for energy deposition to collateral tissue and also eliminates the need for a bipolar electrosurgical generator as a power source. Further, the large spectrum of power settings and other configuration variables within a monopolar electrosurgical generator can be now applied to bipolar devices for further treatment flexibility that is enhanced with the fine tuning of energy delivery.

[0054] In Fig. 1B, bridge elements **100** can include any one or a combination of the types of components shown, which include but are not limited to capacitance (capacitors), inductance (inductors), resistance (resistors), signal amplification (op-amps), over-current protection (fuses, links, etc.), and other circuit components known to those skilled in the art. For existing electrosurgical generators that provide a circuit sensing function to determine overall impedance through active (working) electrodes and return (reference) sensing signals parallel to the active output line, bridge components may be added between the active output line **15**, and the parallel sensing circuit and the return (reference) electrode line **25**. This parallel sensing circuit is most often implemented as a “rider” signal on one of the primary power lines; either output or return (reference) and is denoted as element **90**. This sensing circuit is typically filtered from the primary RF power signal and is used to determine the condition of the relative circuit impedance compared to the load impedance and is typically designed to “trip” when the two impedances become significantly imbalanced, indicating a fault condition in some part of the overall delivery circuit. In most cases such an imbalance is caused by a short or open circuit condition that evolves due to detachment of some element within the overall system such as, the return pad. Other fault conditions that can arise are averted by the present invention due to the elimination of the return pad and a provision of the electrical bridge that maintains the integrity of the sensing circuit and operability of built-in safety shut-down algorithm's within any ESU to which it is attached. The bridge circuit can be placed at any location between the output portal of the ESU and the electrosurgical hand piece distal tip.

[0055] As further depicted in Fig. **1B**, the method of creating the bridging circuit allows for a single device **10** (as labeled in Fig. 1A), to now utilize the output of a monopolar port from an electrosurgical generator and bridge the distance **110**, of the human tissues through which monopolar treatment current typically flows to the return pad. This joining of the active (working) **15** and return (reference) **25** electrodes in a single conductor has the benefit of expanding the use of the traditional electrosurgical generator consoles in ways that have been lacking until now. The pairing of the two primary conductors combined with the simultaneous elimination of the return pad is a net removal of active component influence from the overall electrosurgical generator system. The result is that in the bridging circuit, the same influence of active components must be restored in order to achieve a matched circuit into load condition.

[0056] As illustrated in Fig. 1B, the communication of the active components is not actually with the primary electrosurgical generator power output, but rather with a super-imposed "rider" signal that is typically used to monitor overall electrosurgical system conditions intra-operatively. This "rider" signal is typically conducted along the same conductors used for the primary electrosurgical power output but is graphically depicted as a separate conductor **90**, for clarity of understanding in separating a super-imposed electrical high-frequency signal from the underlying power output signal. While the physical connection of active components **100**, may be between the active (working) and return (reference) electrodes or pairs of either active (working) or return (reference) electrode leads, the values chosen for these components are not capable of exerting significant influence on the primary output waves of the high-power signal. The lower power "rider" wave however, is strongly influenced by these elements and as such is held in the matched state barring any significant changes at the working end of the bridged bipolar device **10**. Additionally, within the same device, several electrode pairs can be designed whereby each electrode pair has its own bridge circuit characteristics so that the device can operate in a multimodal fashion. The multimodal fashion can be of any number of configurations, such as having the electrode pairs activated with their own switch on the device handle or that each electrode pair is activated differently based upon its position on the device.

[0057] Fig. 2A illustrates an alternative placement of the preferred embodiment of active bridge components within the device electrosurgical circuit. In this embodiment, the bridge circuit elements **50, 60, 70** are preferably arranged in a parallel manner to provide a greater influence to the return (reference) electrode for each element of the circuit. In this manner, the bridge circuit is created from parallel elements and is completed proximal of the hand piece **10** but distal to the electrosurgical generator. This embodiment illustrates how the traditional return pad is now eliminated while maintaining the matched condition of the overall circuit to the load encountered within the surgical site. It also demonstrates the multimodal configurations that can be incorporated into the device design based upon varying bridge circuitry per electrode pairs.

[0058] Fig. 2B illustrates additional compositions and methods of use of an embodiment, wherein the interaction of the bridging circuit is directly with the theoretical sensing circuit line which provides for matching between the return (reference) line(s) to the electrosurgical generator output ports. The arrangement of bridge circuit **100** as shown can be in a parallel configuration, a series configuration, or any combinations thereof. While the physical connection of the components is preferably to the primary return (reference) or active (working) electrode lead lines, the effective communication of the bridging circuit is preferably with the “rider” frequency wave that is sent in a super-imposed manner along the same transmission lines, but measured via filtered sensing in an alternative test circuit to establish trip parameters for safe operation of the electrosurgical generator. Fig. 2B also demonstrates the multimodal configurations that can be incorporated into device design based upon varying bridge circuitry per electrode pairs.

[0059] Further detailed is the revised conductor set illustrating the joining of the monopolar active (working) and return (reference) electrodes and the complete elimination of the typical return pad **20** currently used in all monopolar procedures. The elimination of the human tissues bridge **30** (Fig. 1A) is also eliminated, thereby eliminating random energy propagations associated therewith. The super-imposed element of the “rider” frequency that is used to monitor overall electrosurgical circuit conditions intra-operatively is demonstrated. Active circuit elements **100** can be arranged in a multiplicity of methods such as but not limited to parallel, series, or blends thereof which yield preferential communication with the “rider” wave as opposed to the primary RF power wave due to specific values of the components designed for exactly that purpose.

[0060] Fig. 3 is a detailed illustration of the preferred embodiment for the bridge circuit in which the connector terminal of the active (working) or return (reference) lead-wire is bridged with the necessary components for circuit matching. For universal dual wire connector terminals in traditional monopolar electrosurgical consoles, the dual wires are often used to conduct high-frequency “rider” signals that are measured or monitored in fault detection circuits for open, short, or high impedance conditions that signal undesirable surgical conditions. This signal is bridged with active components **50**, **60**, **70** to provide a matched circuit within a single jacketed conductor **130**. Matching components can be placed at any point along the conducting pair to enhance or ameliorate the effects of linear resistance, capacitance, and/or inductance as the circuit may embody per unit length. Furthermore, such circuit components may be contained within the connector terminal itself to provide for both protection and structure for retention of such components.

[0061] Fig. 4 is a graphical representation of the characteristic impedance threshold limits and operational envelope of the preferred embodiment within existing safety envelopes of typical electrosurgical generators. With respect to increasing capacitance up to or beyond the matched load condition of curve **150**, there is no change in the point at which the electrosurgical generator sensing circuit will detect that the characteristic impedance of the overall output circuit has been exceeded. Threshold **140** is typically governed by a non-linear software algorithm that seeks to maintain a maximum voltage output, maximum current flow, at a minimum deviation from a user-selectable output value. Conditions where excessive capacitance is introduced into the circuit yields imbalanced curve **170** that will decrease the overall circuit characteristic impedance (ref. Eq. 2b) beyond the limit for any given user-selection of output. Similarly, in the theoretical case of complete elimination of all capacitance from the circuit, the overall characteristic impedance would approach zero. This is purely a theoretical condition as the existence of paired wires introduces a minimal amount of capacitance / resistance (impedance) that prevents the absolute zero condition from ever emerging. External modifications of parameters contained within Equation 2b, inevitably result in arrival at threshold points sooner than the matched condition and the matched condition represents the ideal arrival point at safety thresholds that do not modify electrosurgical generator output performance.

[0062] The bridging circuit operation is designed to provide an impedance matching equivalent circuit as seen by the output ports of a traditionally monopolar electrosurgical generator. Since no internal components of the electrosurgical generator are affected by this invention, the matching that the bridge circuit provides has no effect on the normal safety parameters of the electrosurgical generator and by definition forces the attached device containing the bridge circuit to operate within the safety envelope of the electrosurgical generator to which it is attached. This is clearly illustrated mathematically when the reduced version of equation 2b, shown as equation 3, is reviewed as shown below:

(Eq. 3) $$Z_0 = \sqrt{\frac{(R_0 + R_t) + c}{j\omega C}},$$ where c = a constant inductance.

[0063] As described in Fig. 4, the alterations of elements of this equation that alter the circuit characteristic impedance result in an imbalanced condition of the circuit that by definition creates conditions in which safety circuit shut-down of the attached device will occur at premature points relative to the optimal output of the electrosurgical generator. This has a dual advantage in that safety is maintained in unbalanced conditions, and simultaneously that the matched circuit state provides a peak output that is no greater than the electrosurgical generator is capable of under its ideal conditions at the output port as manufactured.

[0064] Accordingly, the use of a bridging circuit opens up new and more expansive uses for the power-outputs and associated wave-forms of those power outputs from monopolar electrosurgical generators that can now be employed in a bipolar manner, thus enabling broader treatment options for the wide variety of human tissues encountered in most surgical specialties. The bridge circuit for joining of monopolar outputs into a single bipolar device may be completed via multiple means, which include but are not limited to connector terminal bridging, conductor cable bridging with flexible circuit components, and bipolar hand-piece bridging with a variety of PCBA approaches.

[0065] Fig. 5 schematically illustrates an embodiment of the present invention wherein a conducting portion of bipolar electrosurgical probe **200** is electrically connected to switch **202** and wherein another conducting portion of bipolar electrosurgical probe **200** is electrically connected to component **204**. In this embodiment, component **204** most preferably bridges a plurality of connectors of the return cable connector **206**. Component **206** is most preferably selected to have a value such that a monopolar electrosurgical generator unit detects an impedance, when used with bipolar electrosurgical unit **200**, which impedance is substantially similar to that encountered when a monopolar electrosurgical probe is used with the generator. Accordingly, those skilled in the art, upon studying this application, will readily appreciate that component **206** can comprise an inductive value, a capacitive value, a resistive value, and/or combinations thereof, depending upon the generator to which bipolar electrosurgical probe **200** is connected. Optionally, component **206** can be a variably-adjustable component or plurality of variably-adjustable components such that a user can adjust the one or more components **206** to create an overall probe impedance which is substantially similar to that of a monopolar probe connected to the generator.

[0066] Traditional electrosurgical mono-polar devices use what is termed in the industry as a “Universal Connector” **300**, which is configured with 3-pole contacts **302** as illustrated in Fig. 6. The purpose of these connector poles is to provide dual functionality of cutting and coagulation at the distal tip of the working device. By design, wiring connected to each of the poles in the connector are routed to a collocation point where the individual wires are then bundled together through an insulating/protective jacket where they are further routed to the hand piece along a roughly 3-meter length of cabling. The circumstantial configuration of the cabling leads to several electrodynamic functions that must be compensated for when using a bridging-circuit approach in the conversion of a traditional mono-polar circuit to a bi-polar circuit. Of primary importance is that the bridging circuit contains the anticipated magnitude of impedance and that such impedance has the correct characteristic/type of impedance; meaning capacitive, inductive, and resistive or a combination thereof.

[0067] In one embodiment, the present invention comprises a conventionally-shaped universal connector which comprises only two of the typical three conductors. Accordingly, in one embodiment, the present invention comprises a conventionally-shaped universal connector which has only two conductors disposed therein and, of which, one conductor(s) are for the common (reference) conductor and the remaining conductor used is placed in either the coagulation conductor location or in the cutting conductor location. In an alternative embodiment, a conventional universal connector is provided with all three of the conductors, however, only two of the three conductors are electrically connected to the cabling leading to the hand piece.

[0068] As previously discussed, in an embodiment of the present invention, there is preferably the elimination of conductor comparably from that of a standard three conductor universal conductor **300** as the underlying functional power delivered to the hand piece from a single port of the electrosurgical unit is enabled to perform with improved control for use in both surgical functions of cutting and coagulation, thus providing surgical effect at lower energy output levels than heretofore contemplated by industry. Elimination of one of the conductors is useful since there exists, within the electrosurgical generator, reference ground planes that induce capacitive-coupling in wiring that contains the third functional pole and corresponding wire. These effects are known to those skilled in the art, and are typically referred to as “cross-talk” where unshielded wiring is routed in close proximity. The phenomenon is a function of the propagated electro-magnetic wave that is inadvertently “tuned” to an antenna of approximately 3-4 meters. Thus, a cable of the same length acts as an ideal “antenna” and receives these signals that subsequently generate spurious currents on the third pole and its corresponding wire. Spurious currents can have several detrimental effects when uncontrolled or ignored within the system of operation. In the case of the prior art, there exists the chance of control function triggering signals being overridden by antenna effect currents. Additionally, there exists a reverse condition, wherein the electrosurgical generator port that is not intended for use can, through capacitive coupling, conduct its output energy in a variable manner to the working end of the hand piece. This can result in a cutting level of energy output reaching the working end of a device when it is unintended. An improved method of achieving the desired output at the distal tip of the device is to remove the secondary higher energy conductor (i.e. the cutting conductor) thereby ensuring that no spurious currents are induced in an uncontrolled manner to the distal end of the device or to the electrosurgical generator that could destabilize operation.

[0069] In one embodiment, the present invention preferably uses only two of the typical three outputs of universal connector **300**. Accordingly, in one embodiment, the present invention uses only the common conductor and either the cutting output conductor or the coagulation output from a monopolar electrosurgical generator. Embodiments of the present invention eliminate the need for a dual function control mechanism through the advancement in understanding of distal tip electrode geometry and surface area relationships between the active and return electrode. This improvement provides for sufficient energy concentrations at the active electrode to be built up such that performing surgery across a broader range of power effect levels/functions is possible without the need of a different power output portal. Thus, the bridging circuit of the present invention also requires the elimination of at least one of the primary power output conductors of the universal connector to provide the preferred embodiment of lower energy level operations whilst simultaneously producing equivalent surgical effects to those devices of the prior art. It is through the use of and amplification of surgical effect in the lower energy bands of RF electrosurgical power output that tissue is thereby preserved and protected from exposure to excessive current or heat. The resulting surgical effect is the ability to perform traditional underwater surgery at power levels previously thought insufficient to perform surgical procedures from the coagulate only mode.

[0070] Given the above teaching, it should become clear to one of ordinary skill in the art that this method of use can be applied to the various modes of output from traditional electrosurgical generators resulting in yet further expansion of availability of power-output levels and wave-forms that have been limited to single mode operation heretofore. This expanded availability provides for greater functionality of the devices attached to sophisticated traditionally monopolar electrosurgical generators through broader arrays of energy availability to bipolar device modes that yield more controlled outcomes and greater predictability of those outcomes for most tissue types encountered in the surgical specialties.

[0071] The reverse approach as described above can similarly be designed for use in electrosurgical generators that use a bipolar output port that is to enable use of monopolar and bipolar devices to effect tissue treatment. The use of embodiments of the present invention as described herein provides the additional benefits of eliminating excessive equipment in the surgical suite and a reduction in required equipment space without significant added cost to the operative outcome of the electrosurgical approach. In addition, new high peak-to-peak voltage wave-forms, heretofore used only in monopolar methods, are thus also provided for bipolar systems. In addition, mixed-mode cutting and coagulating wave-forms previously relegated to monopolar systems are now also provided for bipolar systems in accordance with embodiments of the present invention.

[0072] In an embodiment of the present invention, as illustrated in Figs. 7 and 8, a plurality of active electrodes can optionally be provided which electrodes can optionally be connected to a single switch or to a plurality of switches such that each active electrode can be simultaneously or selectively activated.

[0073] Although the description above contains many specific examples, these should not be construed as limiting the scope of the invention but merely providing illustrations of some of the presently preferred embodiments of this invention. For example, monopolar to bipolar bridge circuitry can be combined or otherwise coupled, with additional power inputs to provide DC current sensing tools for either an integrated or stand-alone monitoring system of the treatment site characteristics.

[0074] Thus the scope of the invention should be determined by the appended claims and their legal equivalents, rather than narrowed by the specific illustrative examples given.

[0075] Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above are hereby incorporated by reference.

CLAIMS

What is claimed is:

1. An electronic bridging circuit comprising:

one or more circuit components arranged in electrical communication with a primary radiofrequency active or reference/return electrode lead of a hand piece of an electrosurgical generator upon which lead a super-imposed rider wave signal is transmitted, said super-imposed wave signal normalized to a monopolar balanced state of feedback to the electrosurgical generator reference plate electrode monitoring circuit via said one or more circuit components;

said one or more circuit components selected to affect said super-imposed wave signal by balancing said rider signal; and

wherein monopolar outputs of the electrosurgical generator are converted to bipolar outputs compatible with said hand piece upon connection of hand piece with the generator.

2. The circuit of claim 1 wherein a plurality of said circuit components are connected in a parallel configuration.

3. The circuit of claim 1 wherein a plurality of said circuit components are connected in a series configuration.

4. The circuit of claim 1 wherein one of said circuit components comprises a capacitor.

5. The circuit of claim 4 wherein at least one of said capacitors comprises a value of about 1 picofarad to a value of about 1 microfarad.

6. The circuit of claim 4 wherein at least one of said capacitors comprises a value of about 40 picofarads to a value of about 0.1 microfarad.

7. The circuit of claim 1 wherein one of said circuit components comprises an inductor.

8. The circuit of claim 1 wherein one of said circuit components comprises a resistor.

9. The circuit of claim 8 wherein said one or more components are arranged in a bridge circuit.

10. An electrosurgical apparatus comprising a conventionally-shaped monopolar output universal plug for the delivery of primary RF electrical current, which comprises no more than two of the typical three conductors.

11. A method for converting a monopolar electrosurgical generator which outputs a power wave and a super-imposed rider wave for use in a bipolar electrosurgical configuration comprising:

bridging leads connected to the monopolar electrosurgical generator with a bridging circuit comprising at least one balancing component,

the balancing component selected such that the impedance encountered by the rider wave when traveling through a bipolar hand piece, and

the balancing component is substantially similar to the impedance encountered by the rider wave when a monopolar hand piece and return pad is connected to the electrosurgical generator.

12. The method of claim 11 wherein the balancing component comprises a resistive component.

13. The method of claim 11 wherein the balancing component comprises a capacitive component.

14. The method of claim 11 wherein the balancing component comprises an inductive component.

15. The method of claim 11 wherein the balancing component is disposed within the bipolar hand piece.

16. The method of claim 11 wherein the balancing components comprise a plurality of components.

17. The method of claim 16 wherein said plurality of components comprises active and resistive components.

18. The method of claim 16 wherein at lease some of the balancing components are arranged in a parallel configuration.

19. The method of claim 16 wherein at lease some of the balancing components are arranged in a series configuration.

20. The method of claim 11 wherein the bipolar hand piece is electrically connected to only one of the cut or coagulate outputs of the monopolar electrosurgical generator.

21. A method for using a monopolar output of an electrosurgical generator for a bipolar electrosurgical application comprising:

connecting a plurality of active electrodes of a bipolar electrosurgical hand piece to an active electrode port of a monopolar electrosurgical generator;

providing one or more components through which a reference signal passes, the one or more components selected such that the total impendence encountered by the reference signal is at least substantially similar to a total impedance which would be encountered by the reference signal if it were traveling through a functioning monopolar electrosurgical hand piece.

22. The method of claim 21 wherein at least one of the plurality of active electrodes is connected to the active electrode port of the monopolar electrosurgical generator through a switch.

23. The method of claim 21 wherein each of a plurality of the active electrodes are connected to the active electrode port of the monopolar electrosurgical generator through respective switches.

24. The method of claim 21 wherein the plurality of active electrodes are individually activated.

25. The method of claim 24 wherein the plurality of active electrodes are simultaneously activated.

26. An electrosurgical apparatus comprising:

a monopolar electrosurgical generator connected to a bipolar electrosurgical hand piece.

27. The electrosurgical apparatus of claim 26 wherein said hand piece operates in a cut only mode.

28. The electrosurgical apparatus of claim 26 wherein said hand piece operates in a coagulate only mode.

29. A bipolar electrosurgical hand piece connectable and operable with a monopolar electrosurgical generator.

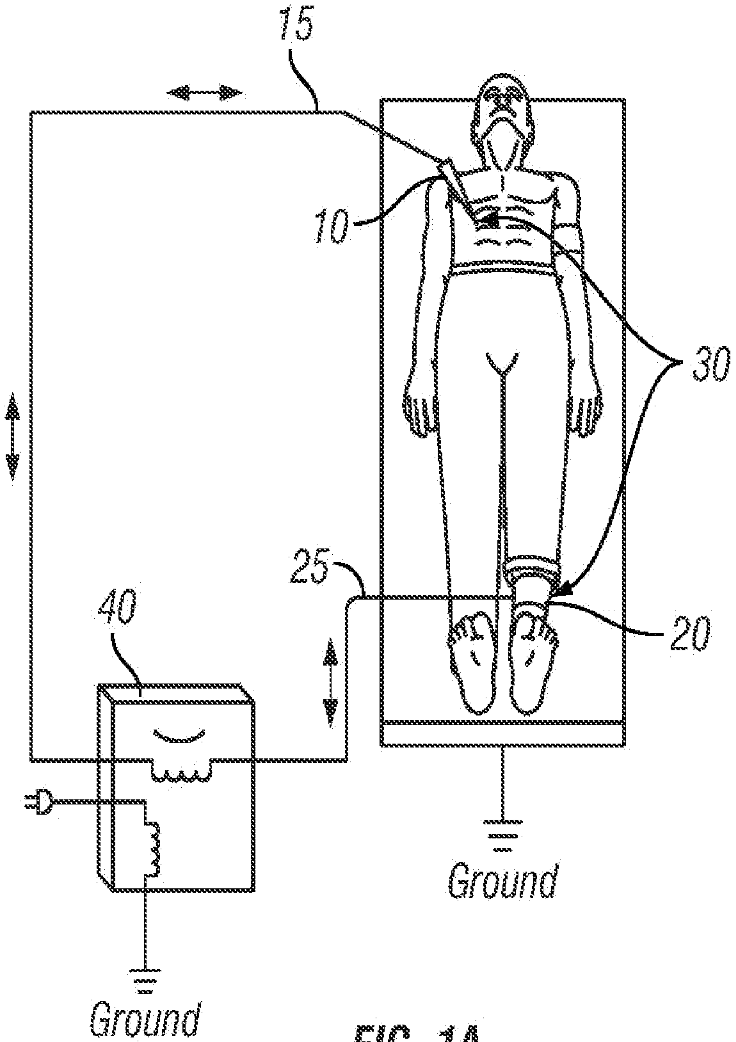

FIG. 1A
(Prior Art)

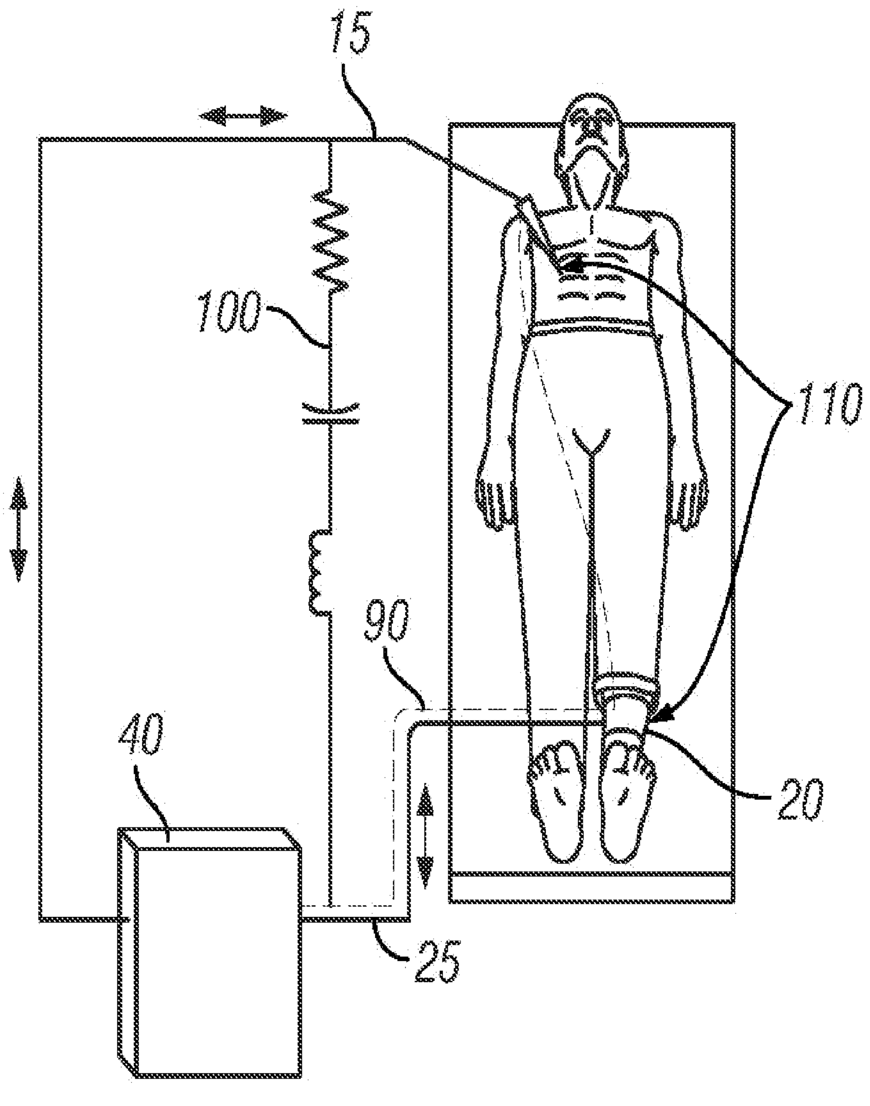

FIG. 1B

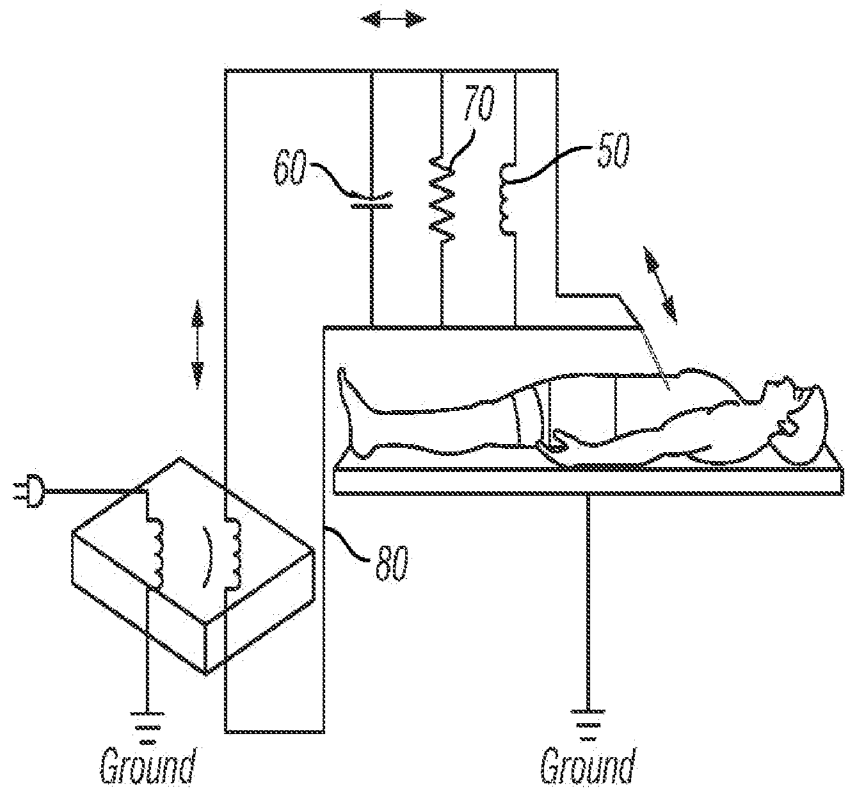

FIG. 2A

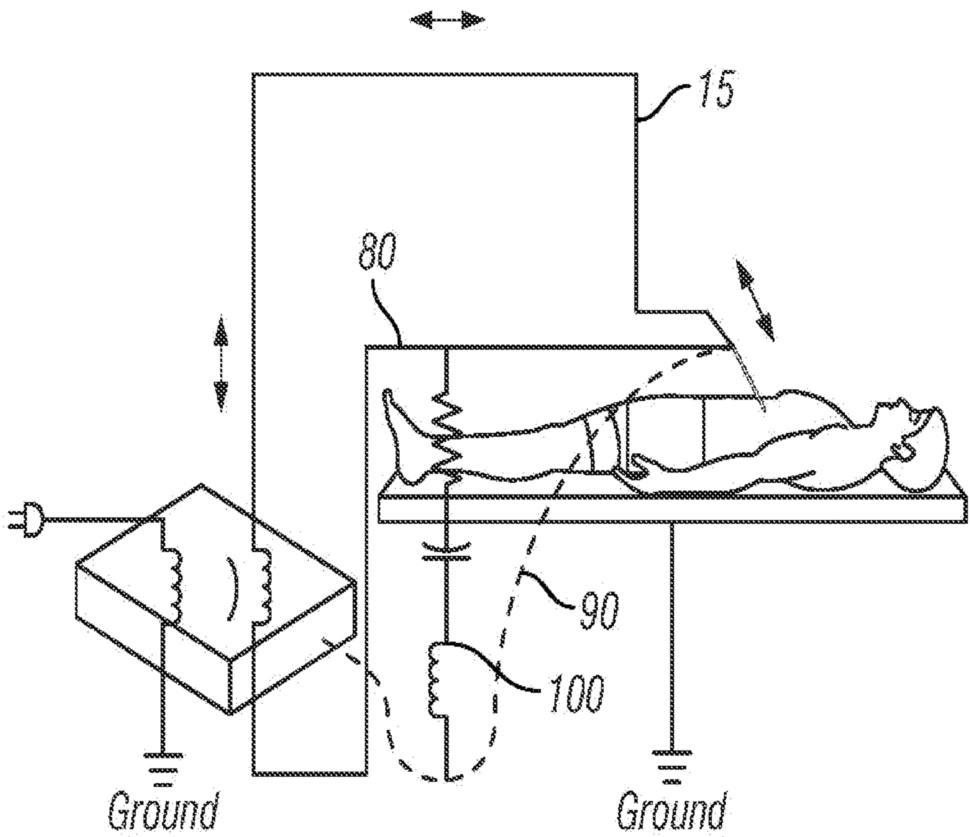

FIG. 2B

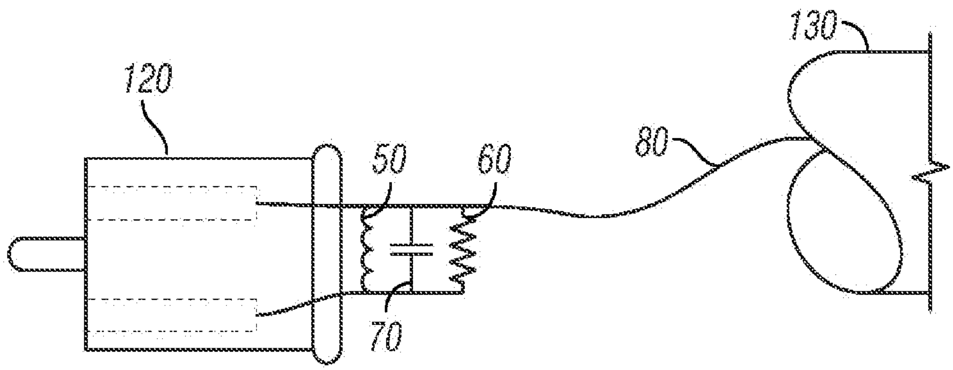

FIG. 3

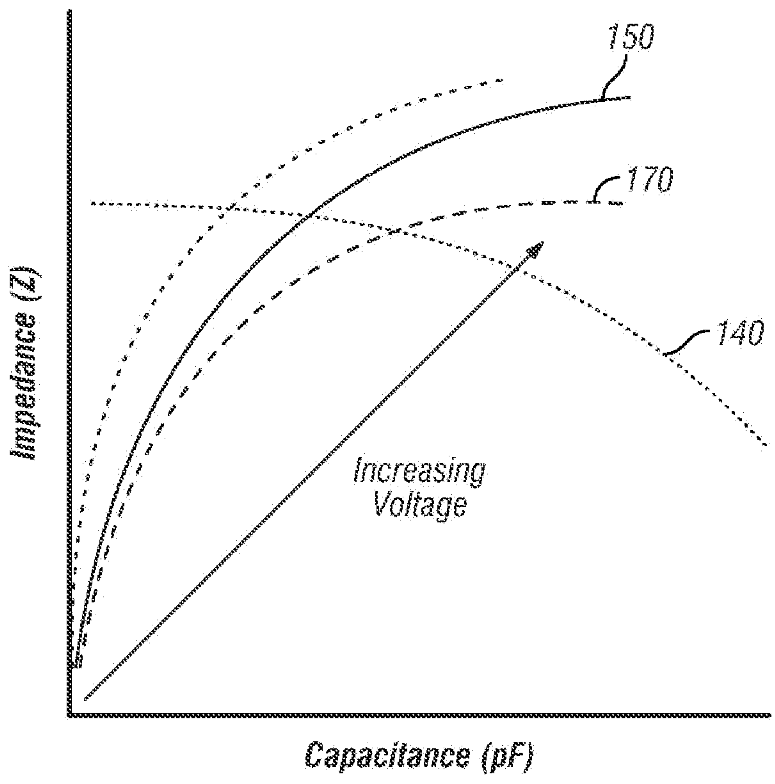

FIG. 4

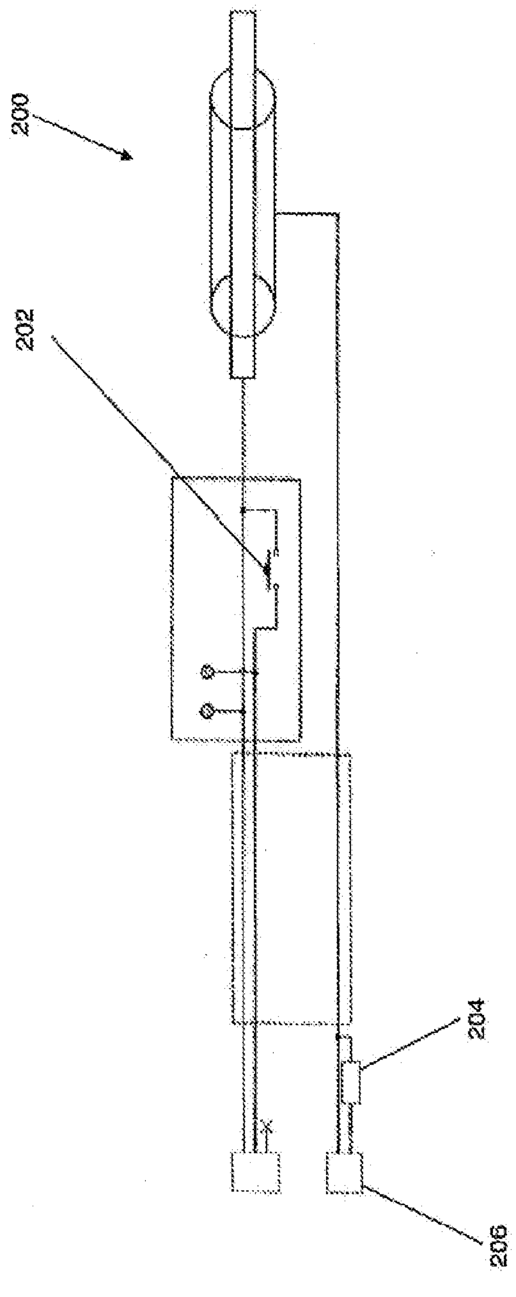

FIG. 5

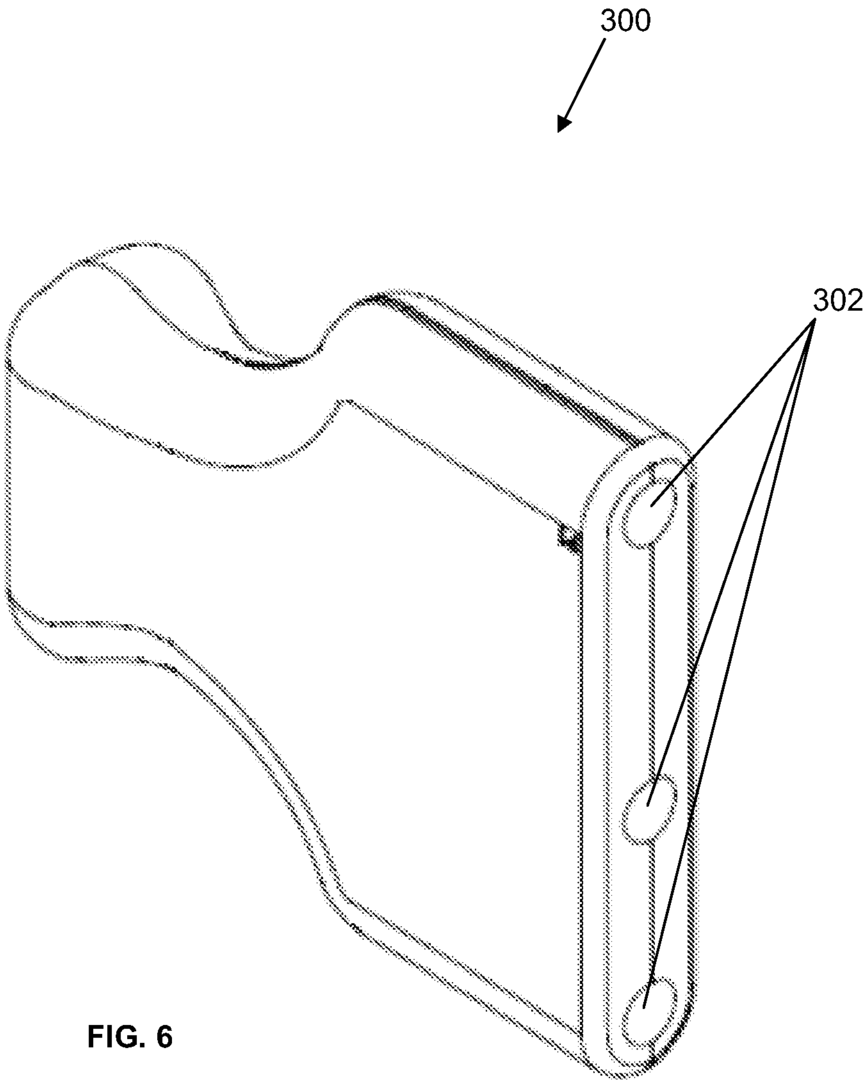

FIG. 6

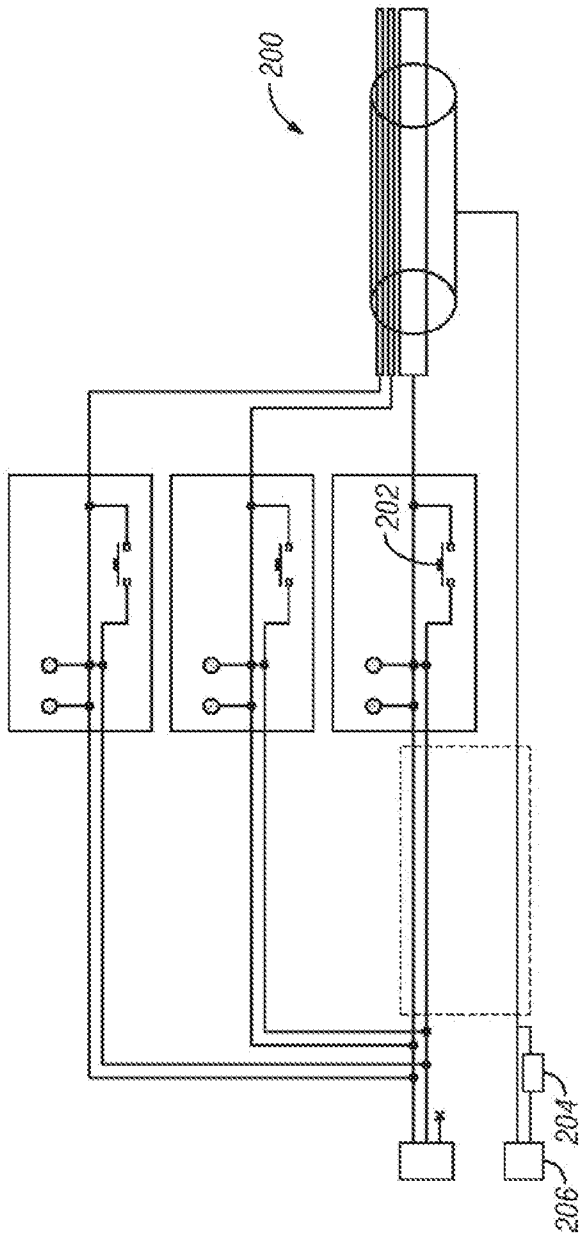

FIG. 7

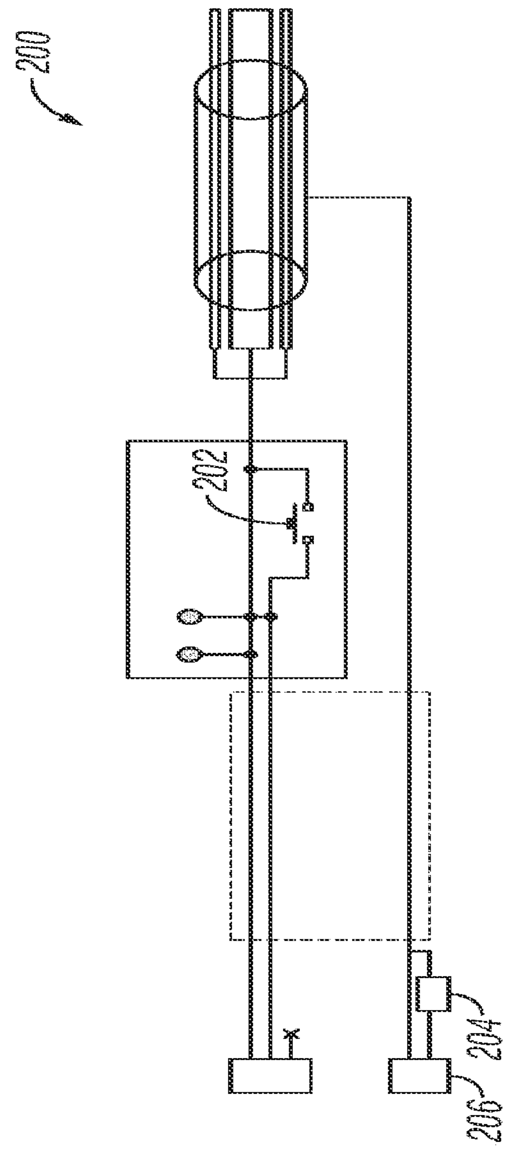

FIG. 8