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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 March 2002 (14.03.2002)

PCT

(10) International Publication Number
WO 02/19932 A1

(51) International Patent Classification[7]: A61B 18/12

(21) International Application Number: PCT/GB01/03939

(22) International Filing Date:
3 September 2001 (03.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0021799.2 5 September 2000 (05.09.2000) GB

(71) Applicant: **GYRUS MEDICAL LIMITED** [GB/GB]; Fortran Road, St. Mellons, Cardiff CF3 0LT (GB).

(72) Inventors: **GOBLE, Colin, Charles, Owen**; Park Close Lodge, Wick Lane, Englefield Green, Engham, Surrey TW20 0XE (GB). **GOBLE, Nigel, Mark**; East Court Farmhouse, Stype, Hungerford, Berkshire RG17 0RH (GB). **AMOAH, Francis**; 36 Greenfield Road, Whitchurch, Cardiff CF14 1TE (GB).

(74) Agents: **BLATCHFORD, William, Michael** et al.; Withers & Rogers, Goldings House, 2 Hays Lane, London SE1 2HW (GB).

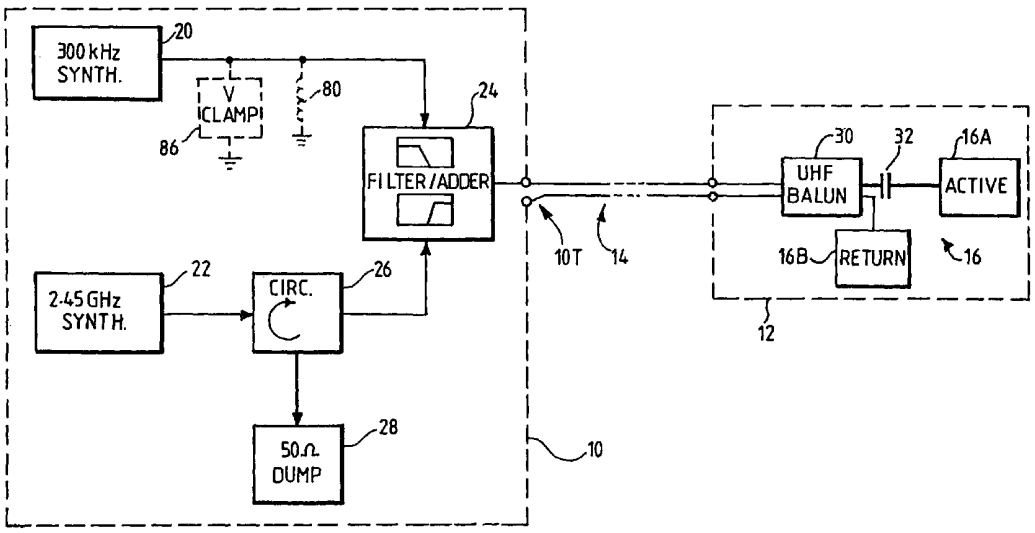
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ELECTROSURGERY SYSTEM



(57) Abstract: An electrosurgery system for electrosurgically cutting or vaporising living tissue comprises an electrosurgical generator (10) having a pair of output terminals and an electrosurgical instrument (12) containing an electrode assembly (16). The electrode assembly has at least one treatment electrode (16A) and an adjacent return electrode (16B). the generator and the assembly are arranged to deliver to the treatment and return electrodes radio frequency (r.f.) energy simultaneously at at least two frequencies, one of which is in a lower frequency range of from 50kHz to 50MHz and the other of which is greater than 300MHz. The r.f. current delivered at the lower frequency is limited in order to restrict dissipation of power in the tissue at that frequency and to permit tissue cutting or vaporisation using energy delivered at the higher frequency.

WO 02/19932 A1

Electrosurgery System

This invention relates to a radio frequency electrosurgery system and associated methods of operation.

It is known to use a needle or narrow rod electrode for cutting tissue in monopolar electrosurgery at frequencies in the range of 300kHz to 3MHz. An electrosurgical signal in this frequency range is applied to the electrode, and the electrical current path is completed by conduction through tissue to an earthing plate secured to the patient's body elsewhere. The voltage applied to the electrode must be sufficiently high to cause arcing and consequent thermal rupture so that tissue adjacent the needle is ablated or vaporised.

One problem with such a system is that the return path via the earthing plate can cause effects well beyond the treatment site. One of the objects of this invention is to provide for cutting or vaporisation of tissue without substantial effects of this kind.

According to a first aspect of this invention, an electrosurgery system for electrosurgically cutting or vaporising tissue comprises an electrosurgical generator and an electrode assembly having at least one treatment electrode and an adjacent return electrode, wherein the generator and the assembly are arranged to deliver to the treatment and return electrodes radio frequency (r.f.) energy simultaneously at at least two frequencies, one of which is in a lower frequency range of from 50kHz to 50MHz and the other of which is greater than 300MHz, the r.f. current delivered in the lower frequency range being limited such that the current-to-frequency ratio of energy delivered in the lower frequency range remains below a value of 17mA rms per 100kHz. In this way it is possible to strike an arc between the treatment electrode and the tissue to be treated using the r.f. energy in the lower frequency range, this arc providing a low impedance pathway for energy at a frequency greater than 300MHz to cause cell rupture and, as a result, cutting or vaporisation of the tissue. The return path for energy at the higher frequency is predominantly through the stray capacitance

between the tissue and the return electrode. This is particularly the case for current at the frequency greater than 300MHz. One of the effects of this is that tissue outside the treatment site is substantially unaffected.

Since the arc is established using low frequency energy, the components for generating and transmitting energy at the higher frequency, i.e. above 300MHz, may be designed solely to drive a low impedance. Furthermore, since coagulation of tissue generally requires high current, and the tissue presents a low impedance to the source, the electrode assembly may be constructed to provide UHF matching into a low impedance load, the system thereby providing efficient operation in both cutting/ vaporisation and coagulation modes using the single electrode assembly. Since the capacitive pathway from tissue to return electrode is of considerably lower impedance than at the lower frequency, high current can be delivered at UHF, the current density necessary for tissue treatment being confined to the treatment area. Tissue effects due to the low frequency energy are minimal due to the restriction of low frequency currents to low levels.

One of the ways of restricting low frequency current is to ensure that the source impedance at the operating frequency in the lower frequency range is comparatively high. The preferred system comprises a generator unit having a pair of r.f. output terminals, an instrument which includes a handpiece, a shaft mounted on the handpiece and the electrode assembly generally located at a distal end of the shaft, and a feeder cable arranged to connect the generator unit output terminals to the handpiece. The preferred lower frequency range is 100kHz to 5MHz. The high source impedance may be achieved by connecting a low value capacitor in series in the low frequency current path, e.g. between the feeder cable and the treatment electrode for restricting the current at the lower operating frequency such that the current-to-frequency ratio remains within the range referred to above. Preferably, the capacitor is located at the distal end of the shaft, immediately adjacent the treatment electrode. The instrument shaft may comprise a pair of supply conductors for delivering the r.f. energy to the electrode assembly, the capacitor being formed as the coaxial combination of a elongate inner conductor which is integrally formed with the treatment electrode, and a tubular outer conductor spaced from the inner conductor by a tubular heat resistant dielectric tube,

this tubular outer conductor being connected to one of the supply conductors of the shaft. Typically, in this case, the capacitor has a value of 5pF or less.

At UHF, the reactance of the capacitor is low and, therefore, has little effect on the transmission of UHF power to the treatment electrode.

The instrument shaft preferably includes a balun, advantageously mounted close to the electrode assembly. Such a balun, being configured to operate at the higher operating frequency serves to improve efficiency and to minimise tissue effects outside the treatment area.

It is also possible to raise the source impedance and hence limit the low frequency output current by arranging for the low frequency source in the generator unit to drive a resonant load, e.g. in the form of a shunt parallel resonant circuit with a Q in the region of 100 or greater. The parallel capacitance may be the capacitance of the feeder between the generator unit and the handpiece, while the parallel inductance, tuning the capacitance to the lower of the operating frequencies is preferably situated inside the generator unit and upstream of the stage performing combination of the high and low frequency signals. The resonant circuit allows voltages in excess of 700V to be generated, allowing formation of an arc between the treatment electrode and the tissue being treated. When the arc is struck or the treatment electrode touches tissue, the Q of the resonant circuit is reduced, and the output voltage collapses to prevent current delivery beyond the range specified above. The low frequency signal may be pulsed. This allows the driving impedance of the low frequency source into the resonant circuit to be reduced without exceeding the average current-to-frequency ratio. This in turn allows the rise time of the low frequency output voltage to be increased, despite the presence of the resonant circuit.

Whether the low frequency signal is continuous or pulsed, the maximum r.f. power delivered, continuously or during each r.f. burst, respectively, is preferably limited to 10W or less. The output voltage of the low frequency source may also be limited.

As a further alternative, the low frequency source impedance may be increased by inserting a series impedance such as a resistance in the low frequency output current path in a low frequency part of the generator unit.

According to another aspect of the invention, a method of operating an electrosurgical tissue cutting or vaporisation system which comprises an electrosurgical instrument having an active electrode and an adjacent return electrode, comprises supplying to the electrodes radio frequency (r.f.) energy simultaneously at at least two frequencies, one of which is in a lower frequency range of 50kHz to 50MHz and the other of which is greater than 300MHz, the current in the lower frequency range whilst the instrument is set to operate in a tissue cutting or vaporising mode being such that the current-to-frequency ratio of energy delivered in the lower frequency range remains below a value of 17mA rms per 100kHz.

According to yet a further aspect of the invention, a method of electrosurgically cutting or vaporising tissue using an electrosurgery system which comprises an electrosurgical generator and an electrode assembly having at least a treatment electrode and an adjacent return electrode, comprises bringing the treatment electrode to a position on or adjacent the tissue to be cut or vaporised, applying to the electrodes a first radio frequency (r.f.) signal component at at least one frequency in the range of from 50kHz to 50MHz to establish an arc between the treatment electrode and the tissue, and simultaneously applying to the electrodes a second r.f. signal component at at least one second frequency which is greater than 300MHz to cause a current at the second frequency to flow along the arc established by the first r.f. signal component, the level of the average current above 300MHz being at least an order of magnitude greater than the average current in the frequency range of from 50kHz to 50MHz during a cutting or vaporisation operation.

Preferably, the average current in the frequency range of from 50kHz to 50MHz is small enough to have no clinical effect or negligible total effect in the absence of the second r.f. signal component. A maximum value below 50mA is typical.

The invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a block diagram showing a electrosurgical system in accordance with the invention;

Figures 2A and 2B are perspective views of a UHF tissue vaporising instrument, Figure 2A being partly cut away;

Figures 3A and 3B are perspective views of a UHF tissue cutting instrument, Figure 3A being partly cut away;

Figure 4 is an equivalent circuit diagram of the instruments of Figures 2A, 2B, 3A and 3B;

Figure 5 is a low frequency load curve; and

Figures 6A and 6B are simplified circuit diagrams of the low frequency energy supply circuit in alternative electrosurgical systems in accordance with the invention.

The preferred embodiments of the present invention are applicable mainly to the performance of the laporscopic electrosurgery upon tissue in a gaseous environment (e.g. air) using a dual-electrode instrument having active and return electrodes situated at a distal end of an instrument shaft. The active electrode is applied either directly to the tissue or closely adjacent the tissue, while the return electrode is spaced from the tissue being treated where it is capacitively coupled to the tissue.

The apparatus described below, particularly the electrosurgical generator, has features in common with the apparatus described in our International Application No.WO 00/53112. The contents of this application is incorporated in the disclosure of the present application by reference.

Referring to Figure 1, an electrosurgical system in accordance with the invention comprises a dual-frequency generator unit 10 having output terminals 10C providing a radio frequency (r.f.) output to an electrosurgical instrument 12 via a flexible coaxial cable 14. The instrument 12 is in the form of a handpiece (not shown) with an instrument shaft having an electrode assembly 16 at its distal end, the assembly comprising the combination of an active or treatment electrode 16A and a return

electrode 16B. The construction of the electrode assembly will be described hereinafter. It will be appreciated that in some embodiments of the invention, all or part of the generator unit may be incorporated within the handpiece. Whether it is in the handpiece or separate, the generator may be activated by a switch in the handpiece or a foot switch separately connected to the generator unit 10. The mode of operation, e.g. between coagulation, cutting and vaporisation modes, is selected by controls also not shown in Figure 1.

The generator unit 10 contains separate 300kHz and 2.45GHz synthesisers 20, 22 the output signals of which are summed in adder 24 having low- and high-pass filters coupled to inputs arranged to receive the 300kHz and 2.45GHz signals respectively as shown. A circulator 26 connected in series between the 2.45GHz synthesiser 22 and the adder 24 serves to provide a 50ohm source impedance for synthesiser 22 under conditions of varying load impedance, with effective power being dissipated in a 50ohm reflective energy sink or dump 28, also connected to the circulator 26.

At the output of the adder 24, a composite signal consisting principally of the two frequency components at 300kHz and 2.45GHz is delivered to the output terminals 10T of the generator unit 10 and fed via a cable 14, which is typically in the region of 3m long, to the handheld instrument 12 and thereafter to the tissue under treatment. Both low and high frequency components are, consequently, fed via a single feeder structure to the electrodes 16A, 16B The instrument 12 also includes a UHF balun 30 for converting the high frequency (i.e. 2.45GHz or UHF) component from a single-ended signal, as present at the output terminals 10T of the generator unit 10, to a balanced signal at the active and return electrodes 16A and 16B. During operation of the system, r.f. energy is delivered by the generator unit 10 along the inner conductor of the feeder cable 14 via balun 30 to the active electrode 16A. The current then passes from active electrode 16A through the tissue being treated and via the capacitance between the tissue and the return electrode 16B, to the generator along the outer conductor of the feeder cable 14. Included in this current path is a current limiting capacitor 32 which raises the source impedance in respect of the low frequency (300kHz) component as seen at the electrodes. In the present embodiment, this capacitor has a value in the

region of 1.5pF and is located immediately adjacent the active electrode 16A at the distal end of the instrument shaft. In other embodiments it may be located elsewhere in the current path between the low frequency source 20 and the electrodes 16A, 16B, but the position at the distal end of the shaft is preferred to avoid the shunt capacitive loading of the instrument shaft and/or the feeder cable 14.

A distal end portion of the instrument shaft is shown in Figures 2A and 2B. Referring to these figures, shaft 12S takes the form of a rigid stainless steel tube mounted at its proximal end in a handpiece body (not shown). The shaft 12S constitutes a coaxial feed structure, with the stainless tube 12T acting as an outer supply conductor 12T. An inner wire 12W, insulated from the tube 12T via an insulating sleeve (not shown) forms an inner conductor. This inner conductor is tubular at the distal end of the shaft, where it is in the form of metallisation on a narrow ceramic tube 40, part of which is exposed beyond the distal end of outer conductor 12T, as shown as Figures 2A and 2B. Fixed within tube 40 is a central wire 42 the end of which, in this embodiment, is coiled to form an active electrode 16A suitable for tissue vaporisation. The ceramic material of tube 40 constitutes a low loss ceramic dielectric of a tubular capacitor formed by the metallisation on the tube 40 and the central wire 42. This capacitor has a value of about 1.5pF and, as such, represents a significant series impedance at the low operating frequency of 300kHz but at the upper frequency of 2.45GHz its impedance is comparable to or lower than the typical load impedance represented by the tissue under treatment and the capacitative return path.

Balun 30 takes the form of a conductive sleeve having an electrical length of $\lambda/4$ which is connected at its proximal end 30T to the outer supply conductor formed by tube 12T.

The return electrode 16B is in the form of a similar conductive sleeve, also connected at its proximal end 16B to the outer supply conductor. Both the balun 30 and the return conductor are quarter-wave resonant structures located on the distal end portion of the shaft 12S. The complete shaft and these sleeves are covered by an insulating layer which is not shown in Figures 2A and 2B.

An alternative configuration for the distal end of the shaft 12S is shown in Figures 3A and 3B. In this case, the current limiting capacitor (shown as element 32 in Figure 1) has an air dielectric, being formed by the combination of an axial conductive rod 46 and the inner metallisation 48 of a rigid insulative tube 50 which is also metallised on the outside to form the outer supply conductor 12TD of the shaft distal end portion. Inner rod 46 is held in its axial position by insulative spacers 52, 54. At its distal end, the inner rod 46 is connected to a wire electrode 16A which, in this case is somewhat smaller than the active electrode of the embodiment of Figures 2A and 2B, and is more suitable for tissue cutting. The rod 46 terminates at the proximal spacer 54 and the inner metallisation of tube 50 is connected to the inner supply conductor of a coaxial connector 60, while the outer metallisation on tube 50 is connected to the connector outer shield so that the shaft portion shown in Figures 3A and 3B may be connected to a proximal coaxial shaft portion, or directly to a handpiece body (neither shown). The balun 30 and the return electrode 16B are similarly constructed and connected as the equivalent components of the embodiments of Figures 2A and 2B and, again, the complete assembly is covered with an insulative coating, with the exception of electrode 16A.

As an aid to understanding the operation of the system, attention is directed to the equivalent circuit of Figure 4, the cutaway sleeve that is the quarter wave balun 30 being represented by a lumped inductor and capacitor combination connected to the outer supply conductor of the shaft 12S, here designated the "return" conductor 70. This balun matches inner and outer UHF currents. The return electrode sleeve 16B is also shown as a lumped resonant structure. This operates in a similar fashion to the balun but provides the predominant return path for r.f. energy at UHF, the resonant structure amplifying the return voltage due to its resonance at the upper operating frequency of 2.45GHz. The inductance of the return electrode sleeve 16B has a value such that it resonates with the combination of the stray return capacitance C_R and sleeve-to-shaft capacitance C_L at 2.45GHz. The return electrode is dimensioned accordingly.

It will be appreciated that the circuit elements due to the balun and return electrode sleeves 30, 16B are effectively invisible at the lower operating frequency. However, the current limiting capacitance 32 and the feeder capicitance C_C, which appears as a lumped capacitance at the lower frequency, have a significant effect. The value of capacitor 32 is typically 1.5pF, this value being appropriate for a lower operating frequency of about 300kHz. Alternative values having an equivalent series impedance may be selected for different lower operating frequencies. The effect of capacitor 32 is to limit the lower frequency current delivery to inconsequential values in terms of clinical effect.

When the system is used for tissue vaporisation, the active tissue 16A can become hot. In such circumstances, it is possible for thermionic rectification to occur, causing a charge build-up on any coupling capacitance such that intermittent contact with tissue subsequently causes alternate charging and discharging of the coupling capacitor. Positioning the capacitor 32 directly adjacent active electrode 16A allows it to remain small in value so that nerve stimulation due to thermionic rectification is virtually absent.

The capicitance C_C of the cable represents a low impedance source at the lower operating frequency and in this context coupling capacitor 32 has the advantage of reducing any high current discharge through an arc established between the active electrode tip 16A and the target tissue 72 due to the feeder capacitance C_C.

The raising of the source impedance at the lower operating frequency due to the coupling capacitor 32 is illustrated in the power/impedance load curve of Figure 5 which indicates maximum power occurring at about 250kilohms, the effective source impedance.

As mentioned above, the effect of the coupling capacitance 32 allows a high voltage low frequency signal to be applied across the electrodes 16A 16B without giving rise to corresponding currents at the lower frequency which have the potential to cause tissue effects both at the treatment site and at other sites on the patent's body, e.g. along

luminal structures such as blood vessels or adjacent an earthed structure such as an operating table. Accordingly, in a tissue cutting or vaporisation mode of the system, the 300kHz synthesiser 20 (Figure 1) can be activated to provide sufficient voltage across the electrodes 16A, 16B to cause arcing when the active electrode 16A is close to the target tissue 72. Simultaneous application of the 2.45GHz and 300kHz components to the tissue 72 allows UHF current to flow from the active electrode 16A along the arc to the tissue. Return currents of both components are coupled to the return electrode 16B by the stray tissue-to-electrode capacitance C_R. The current path provided by the arc constitutes a comparatively low impedance at UHF which means that the load impedance in the cutting or vaporisation mode is comparable to that in the coagulation mode. Accordingly, the same system may be used for both coagulation and cutting/vaporisation, taking advantage of the localisation of effect which can be achieved at UHF when driving impedances below 1 kilohm.

The level of voltage applied at the lower operating frequency to initiate an arc may be as low as 300V peak. A voltage in excess of 1000V peak may be used for tissue vaporisation. Once initiated, it is possible to sustain an arc with a voltage of less than 100V peak. The low impedance pathway created by the arc exists only for a very short time, but this is sufficient for coupling of UHF energy along the same pathway, high UHF currents being possible due to the considerably lower impedance of the return pathway at UHF. Should the active electrode 16A contact the target tissue 72, the applied voltage at the lower operating frequency will collapse so that a very small maximum current is delivered. Formation of the arc causes instantaneous discharge of the coupling capacitor 32 resulting in a very brief high current impulse which has a peak power much higher than the peak power available from the UHF source and which is capable of exciting the resonance of the resonant circuits represented by the return electrode 16B and balun 30 located at the distal end of the instrument shaft. These factors ensure that low frequency arcing provides a conductive pathway for the UHF component.

Vaporisation can be initiated in two ways. If the active electrode 16A is brought into close proximity with the tissue 72 such that the low frequency component initiates an

arc, the ionised pathway is then the preferred path for UHF current. Since the ionised pathway is extremely narrow at any instant, the subsequent delivery of UHF is with very high power density, which is capable of vaporising tissue. The ionised pathway moves towards the closest conduction point, with the result that all tissue within the arc strike distance of the active electrode 16A is vaporised. The second method of arc initiation is with the active electrode 16A already in contact with the tissue. Initially, the low frequency component is stalled by low impedance contact, but the delivery of UHF power through the low impedance contact results in tissue coagulation and desiccation. Desiccation proceeds when the electrode-to-tissue impedance rises sufficiently to allow a low frequency voltage gradient between the electrode and the tissue for creating the arc (the impedance at that point being greater than 50 kilohm.

The advantages of this method of operation are that all r.f. power is localised to the treatment zone, and the structure of the electrode assembly need be configured only for low impedance (high current) UHF power delivery. Such UHF power delivery may be optimised for tissue contact coagulation, cutting and vaporisation being achieved by addition of the low frequency component. Further advantages are the ability to use only low power low frequency drivers, much reduced radio frequency emissions due to the avoidance of currents through an earth return pad, and the ability to adjust the effect (e.g. between cutting and different degrees of vaporisation) by adjusting the low frequency peak voltage and the consequent arc striking distance. The ability to provide low frequency coupling by a comparatively small capacitance yields the advantage that stray return capacitance effects are negligible.

While some of the advantageous effects of situating the coupling capacitor in an electrode assembly may be lost, it is possible to achieve arc initiation with alternative capacitor positioning. For instance, the capacitor can be located in the handpiece body, i.e. at the proximal end of the instrument shaft, in which placed a capacitance value in the range of from 20pF to 100pF is appropriate. It is also possible to locate the capacitor in the generator unit. In this case, where a feeder cable is present, an appropriate capacitor value would be of the range of 300pF to 1nF.

Current limiting at the lower operating frequency may be achieved by alternative means. As an example, current limiting may be performed by the combination of low power delivery at the lower operating frequency in conjunction with resonant impedance transformation. The coupling capacitor 32 of the above-described embodiment may be omitted. Referring, then, to Figure 6A, the capacitance C_C of the feeder between the generator unit 10 and the active and return electrodes 16A, 16B is typically in the region of 300pF. This typically sets the low frequency source impedance as seen at the electrodes 16A, 16B to a value below 10 kilohms. At 300kHz, 300pF represents an impedance of 1.77 kilohms. To achieve similar steady state limiting as with the coupling capacitor embodiment described above, the impedance may be converted to a value above 100 kilohms, typically 250 kilohms, by use of a matching inductor 80 (see Figure 1 as well as Figure 6A) which forms a resonant circuit with the feeder capacitance C_C at the lower operating frequency, it being understood that in this case, capacitor 32 is omitted. At 300kHz, the value of the matching inductance required to match out the 300pF capacitance C_C of the feeder is about 800μH. The Q of the resonant circuit is preferably greater than 100 and typically greater than 140. This yields a source impedance of about 250kilohms and has a similar effect on current delivery as that produced by the coupling capacitor 32 of the previous embodiment. Power delivery at the lower operating frequency is limited to 20W or less, typically less than 5W, by a series impedance 84 in the low frequency part of the generator unit upstream of the combiner 24 (see Figure 1). Again, only a low power low frequency driver is necessary. Potentially, the peak energy associated with arc initiation is higher in this embodiment due to shunt capacitance C_C of the feeder being directly coupled to the electrodes 16A, 16B, with the result that the arc pathway has a lower impedance. To maintain the operating frequency of the lower frequency component at or near the resonant frequency of the combination of the cable capacitance CC and the inductance 80, the 300kHz synthesiser 20 is configured to track the resonance of the resonant circuit by self-tuning oscillation, as disclosed in GB2214430A, or by means of a closed loop control system using current and voltage phase relationships to alter frequency, as disclosed in EP0949886A. The contents of these applications are incorporated in the disclosure of the present application by reference. Other methods of achieving frequency tracking are known in the art.

The rapidity with which arc strikes can be initiated using the resonant circuit technique of lower frequency current limiting may be increased by modulating the 300kHz synthesiser output. For instance, if the output of this synthesiser is pulse modulated with a 50% duty cycle, the driving impedance of the r.f. source into the resonant network (inductor 80 and the feeder capacitance C_C) may be halved, since the average low frequency current compared with continuous delivery at the higher drive impedance is maintained. Consequently, the low frequency output voltage is correspondingly higher than required to initiate arcing, with the effect that an arcing voltage is reached more quickly. Limiting of the voltage may be performed by a voltage clamp shown in Figure 1 by element 86 using either zener diodes, varistors, or a variable active clamp such as well known in the art. The modulation duty cycle is preferably greater than 10% to reduce the likelihood of the maximum peak current reaching a value liable to cause the peak voltage developed between the patient and the ground to rise above 300V.

The series impedance 84 and resonating inductor 80 may be used in conjunction with the coupling capacitor in the electrode assembly, as shown in Figure 6B.

CLAIMS

1. An electrosurgery system for electrosurgically cutting or vaporising living tissue, comprising an electrosurgical generator and an electrode assembly having at least one treatment electrode and an adjacent return electrode, wherein the generator and the assembly are arranged to deliver to the treatment and return electrodes radio frequency (r.f.) energy simultaneously at at least two frequencies, one of which is in a lower frequency range of from 50kHz to 50MHz and the other of which is greater than 300MHz, the r.f. current delivered in the lower frequency range being limited such that the current-to-frequency ratio of energy delivered in the lower frequency range remains below a value of 17mA rms per 100kHz.

2. A system according to claim 1, arranged to deliver the said r.f. energy to the electrode assembly at both of the two frequencies along a single feeder between the generator and the electrodes.

3. A system according to claim 1, comprising a generator unit having a pair of r.f. output terminals, an electrosurgical instrument which includes a handpiece, a shaft mounted in the handpiece and the electrode assembly located at a distal end of the shaft, and a feeder cable arranged to connect the generator unit output terminals to the handpiece, wherein the instrument includes a current limiting capacitor connected in series between the feeder cable and the treatment electrode for limiting the current at the lower frequency to the said current range.

4. A system according to claim 3, wherein the capacitor is located at the distal end of the shaft.

5. A system according to claim 4, wherein the shaft comprises at least a pair of supply conductors for delivering the r.f. energy to the electrode assembly, and wherein the capacitor is formed as the coaxial combination of an elongate inner conductor, a tubular heat-resistant dielectric tube around the inner conductor, and a tubular outer conductor around the dielectric tube, one of the said inner and outer conductors of the

combination being connected to one of the supply conductors of the shaft and the other being connected to the treatment electrode.

6. A system according to claim 5, wherein the treatment electrode is monolithically integral with the capacitor inner conductor.

7. A system according to any of claims 3 to 6, wherein the capacitor has a value of 5pF or less.

8. A system according to claim 3, wherein the capacitor is located in the handpiece and has a value in the range of from 20pF to 100pF.

9. A system according to claim 1 or claim 2, comprising a generator unit having a pair of output terminals, an electrosurgical instrument which includes a handpiece, a shaft mounted in the handpiece, and the electrode assembly located at the distal end of the shaft, and a feeder cable arranged to connect the generator unit output terminals to the handpiece, wherein the system includes a low frequency source to generate r.f. energy in the said lower frequency range, and a current limiting impedance coupled in series between the low frequency source and the feeder cable.

10. A system according to claim 9, wherein the current limiting impedance is a capacitor the value of the which is in the range of from 300pF to 1nF.

11. A system according to any preceding claim, including a balun associated with the electrode assembly, the balun being configured to operate at the said frequency greater than 300MHz.

12. A system according to claim 1 or claim 2, having a handheld electrosurgical instrument which includes an elongate shaft mounted in the handpiece, and the electrode assembly located at a distal end of the shaft wherein:

the shaft comprises at least a pair of supply conductors forming a coaxial feeder structure for delivering electrosurgical r.f. energy from the generator to the electrode assembly;

the treatment electrode is electrically coupled to an inner supply conductor of the shaft;

the return electrode is electrically coupled to an outer supply conductor of the shaft and is set back from the treatment electrode;

the shaft carries a balun adjacent the electrode assembly, the balun being electrically coupled to the outer supply conductor; and

the shaft, the return electrode and the balun are covered in an insulative material.

13. A system according to claim 12, wherein the electrode assembly includes a current limiting capacitor in series between the inner supply conductor and the treatment electrode for limiting the current supplied to the electrodes at the lower frequency such that the said ratio remains within the said range.

14. A system according to claim 1, wherein the source impedance at the treatment electrode at an operating frequency in the lower frequency range is greater than 100 kilohm.

15. A system according to claim 1, wherein the current at an operating frequency in the lower frequency range is limited by means for increasing the source impedance at that frequency.

16. A system according to claim 15, wherein the current limiting means comprises a capacitance in series with the treatment electrode.

17. A system according to claim 16, wherein the current limiting means comprises a resonant impedance converter associated with an output of the generator.

18. A system according to claim 17, wherein the impedance converter comprises a parallel resonant circuit.

19. A system according to claim 17, including a coaxial feeder between the generator output and the electrode assembly, and wherein the impedance converter comprises an inductance associated with the generator output which resonates with the capacitance of the feeder at the operating frequency in the lower frequency range.

20. A system according to claim 19, wherein the generator is arranged such that the r.f. energy in the lower frequency range is pulse modulated.

21. A system according to claim 20, wherein the pulse duty cycle is at least 10%.

22. A system according to any preceding claim arranged such that the peak voltage in the lower frequency range when in a cutting/vaporisation mode is in excess of 500V.

23. A system according to any preceding claim, wherein the energy in the said lower frequency range is delivered at a frequency of 100kHz or higher.

24. A system according to any preceding claim, wherein the energy in the said lower frequency range is delivered at a frequency of 5MHz or below.

25. A system according to any preceding claim, wherein the r.f. current delivered in the lower frequency range remains below 50mA rms.

26. A method of operating an electrosurgical tissue cutting or vaporising system using an electrosurgical instrument having an active electrode and an adjacent return electrode, wherein the method comprises supplying to the electrodes radio frequency energy simultaneously at at least two frequencies, one of which is in a lower frequency range of 50kHz to 50MHz and the other of which is greater than 300MHz, the current in the lower frequency range whilst the instrument is set to operate in a tissue cutting or

vaporising mode being such that the current-to-frequency ratio of energy delivered in the lower frequency range remains below a value of 17mA rms per 100kHz.

27. A method according to claim 26, including maintaining the current-to-frequency ratio below the said value by driving the active electrode from a source impedance which is between 100kilohm and 500kilohm at the operating frequency in the lower frequency range.

28. A method according to claim 26 or claim 27, wherein the tissue cutting or vaporising mode is characterised by a peak voltage in the lower frequency range between 500V and 2000V.

29. A method of electrosurgically treating tissue using an electrosurgical instrument having an active electrode and an adjacent return electrode, comprising successively (a) cutting or vaporising tissue, and (b) coagulating tissue, wherein both steps (a) and (b) are performed by delivering radio frequency energy to the electrodes at a frequency greater than 300MHz, and wherein step (a) is characterised by simultaneously supplying r.f. energy at a frequency within a lower frequency range of from 50kHz to 50MHz, the r.m.s. current in the lower frequency range being limited to a value such that the current-to-frequency ratio of energy delivered in the lower frequency range remains below 17mA rms per 100kHz.

30. A method according to claim 29, wherein the r.f. energy delivered in the lower frequency range is pulsed, and the current-to-frequency ratio of energy delivered within each r.f. pulse burst in the lower frequency range remains below the said current-to-frequency ratio value.

31. A system according to claim 30, wherein the r.f. current in the lower frequency range during the pulse bursts remains below 50mA rms.

32. A method of electrosurgically cutting or vaporising tissue using an electrosurgery system which comprises an electrosurgical generator and an electrode

assembly having at least a treatment electrode and an adjacent return electrode, wherein the method comprises bringing the treatment electrode to a position on or adjacent the tissue to be cut or vaporised, applying to the electrodes a first radio frequency (r.f.) signal component at at least one frequency in the range of from 50kHz to 50MHz to establish an arc between the treatment electrode and the tissue, and simultaneously applying to the electrodes a second r.f. signal component at at least one second frequency which is greater than 300MHz to cause a current at the second frequency to flow along the arc established by the first r.f. signal component, the level of the average current above 300MHz being at least on order of magnitude greater than the average current in the frequency range of from 50kHz to 50MHz during a cutting or vaporisation operation.

33. A method according to claim 32, wherein the average current in the frequency range of from 50kHz to 50MHz is small enough to have no clinical effect or negligible clinical effect on the patient in the absence of the second r.f. signal component.

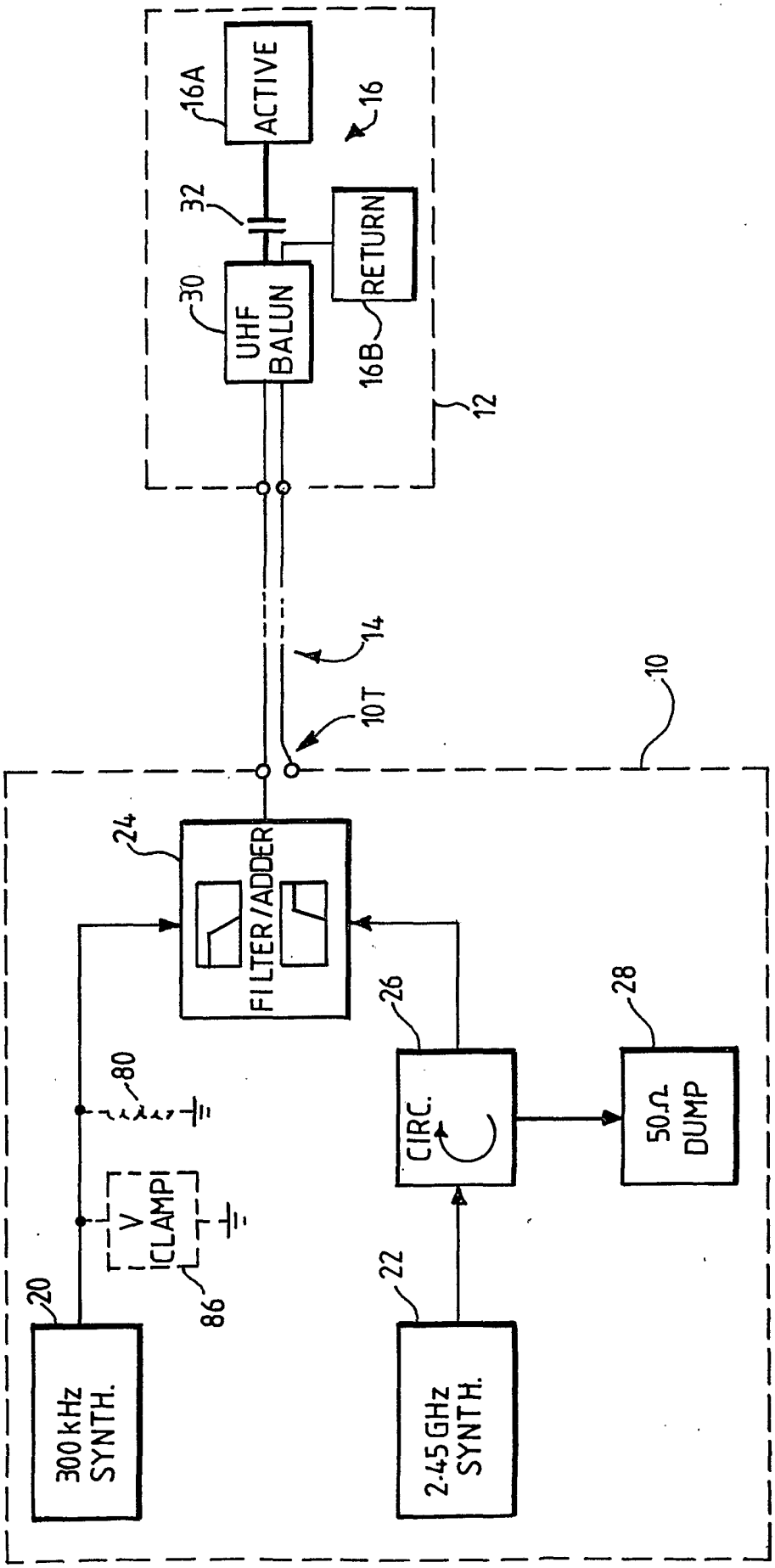

ACTIVE
16A
16
32
RETURN
30
UHF BALUN
16B
12
14
10T
10
24
FILTER/ADDER
26
28
80
CIRC.
50Ω DUMP
V
ICLAMPI
86
20
22
300kHz SYNTH.
2.45GHz SYNTH.

FIG.1

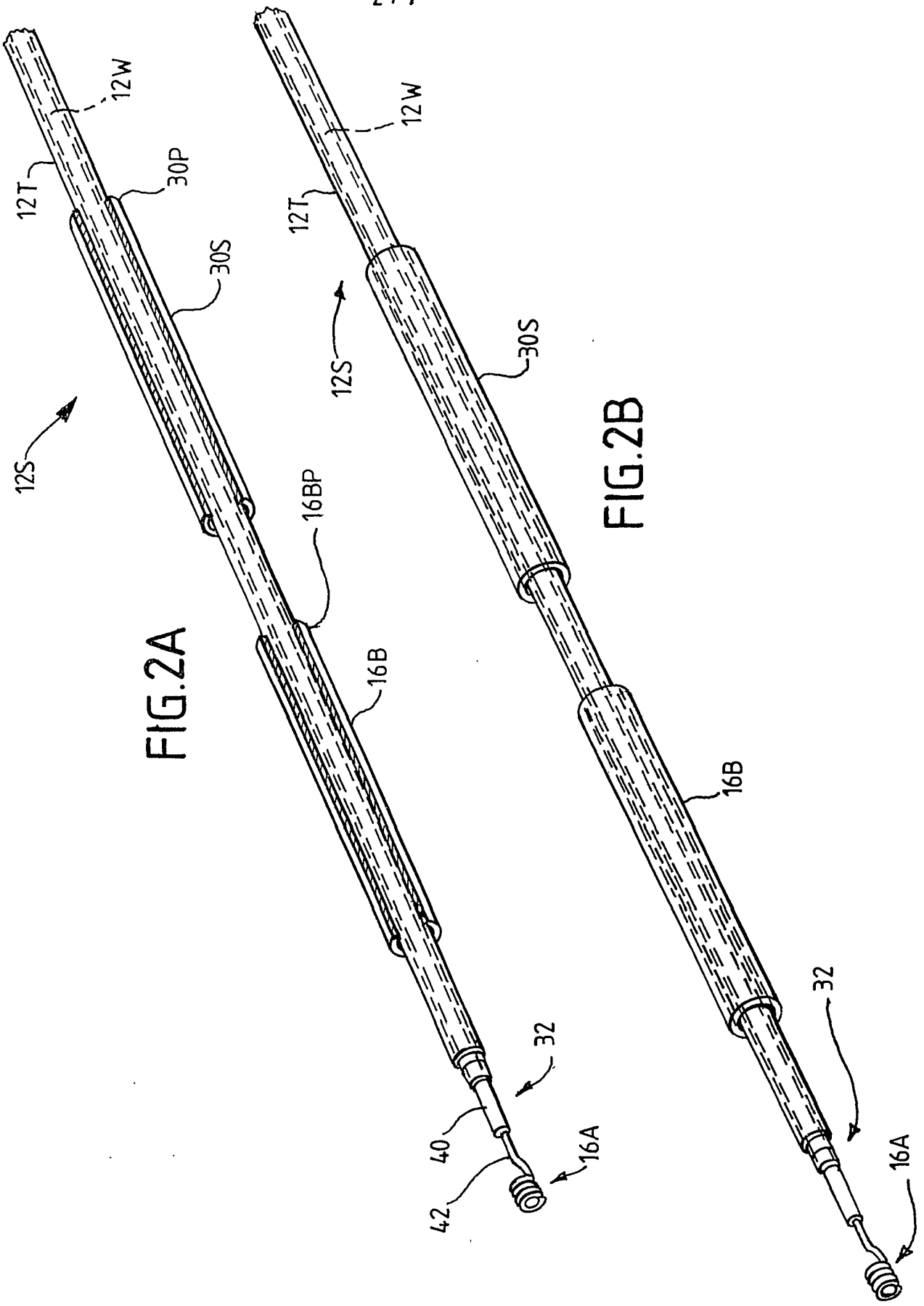

12W
12T
30P
30S
12S
16BP
16B
32
40
42
16A

FIG.2A

12W
12T
12S
30S
16B
32
16A

FIG.2B

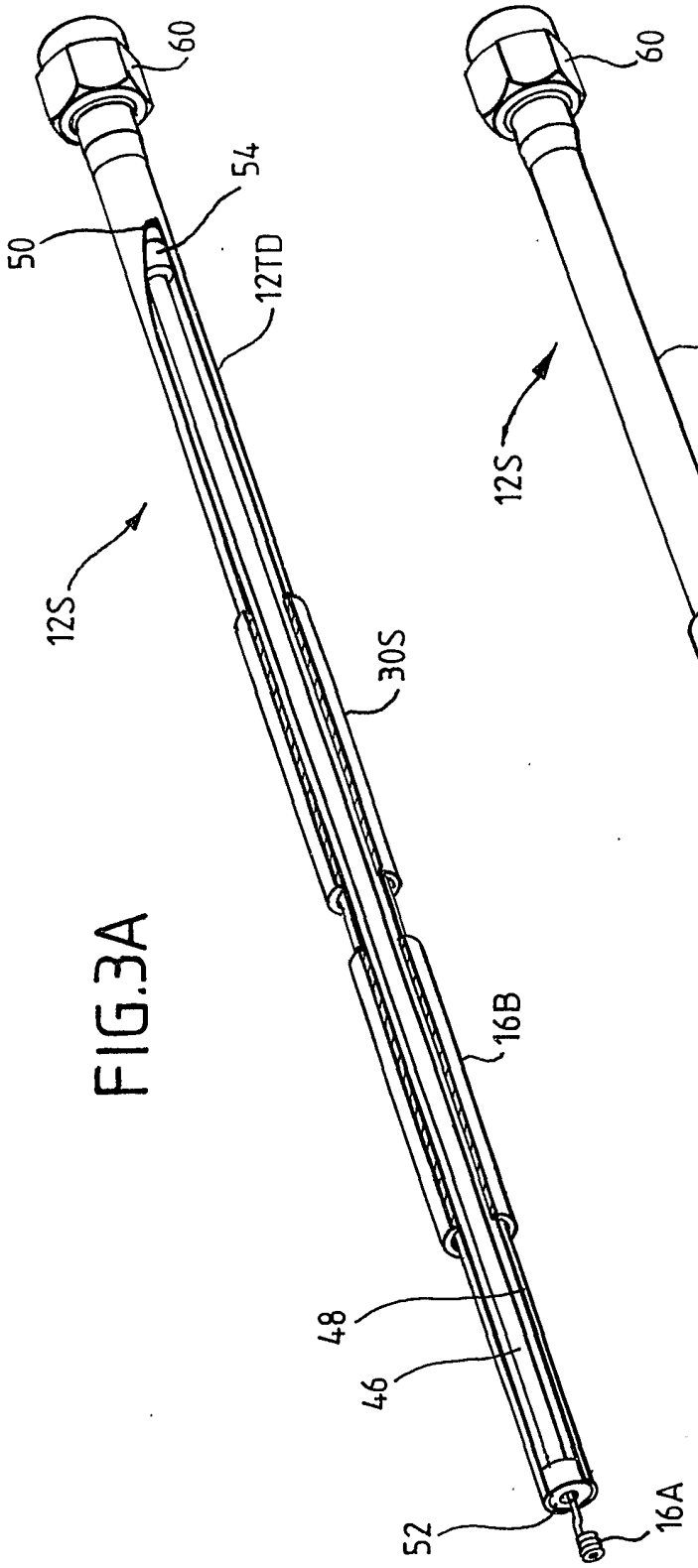


FIG.3A

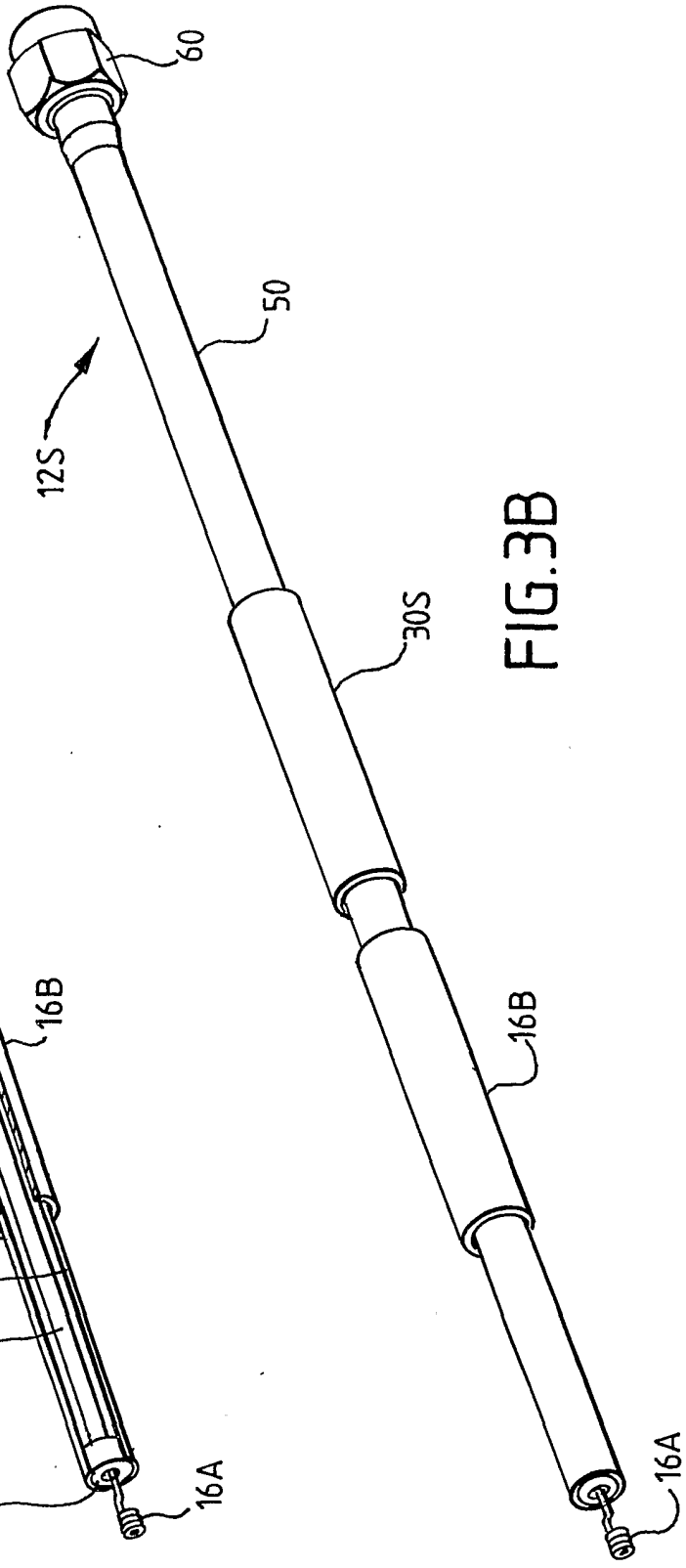


FIG.3B

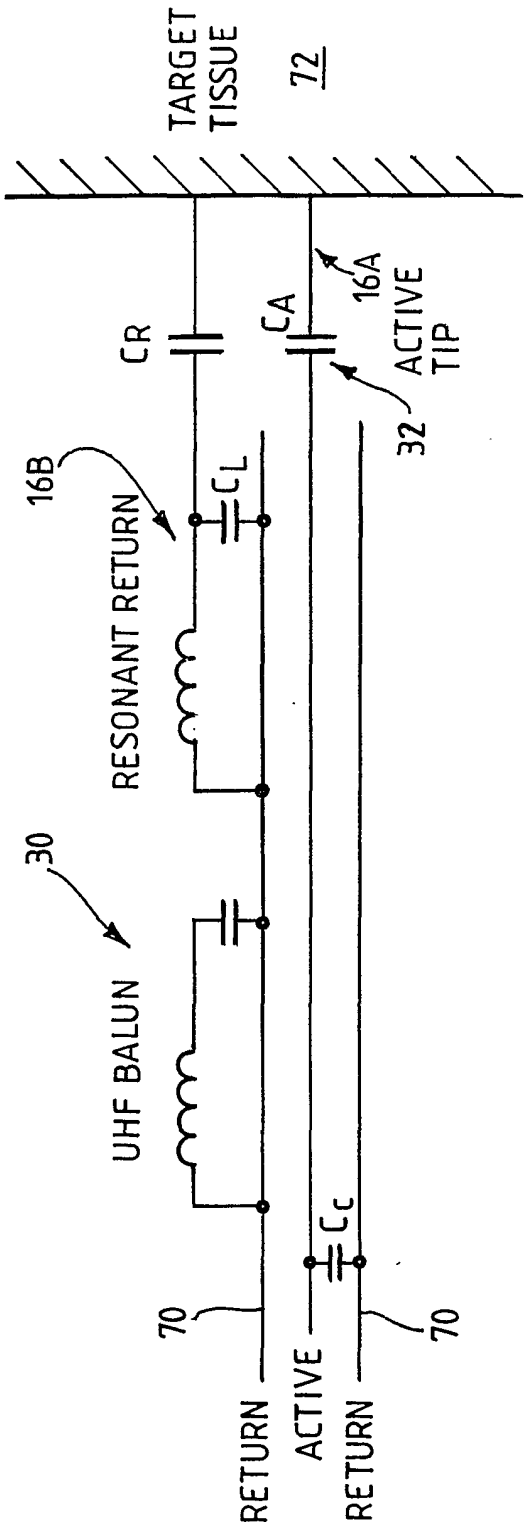

TARGET TISSUE
72
16A
ACTIVE TIP
32
C_A
C_R
16B
RESONANT RETURN
C_L
30
UHF BALUN
C_C
70
RETURN
ACTIVE
RETURN
70

FIG.4

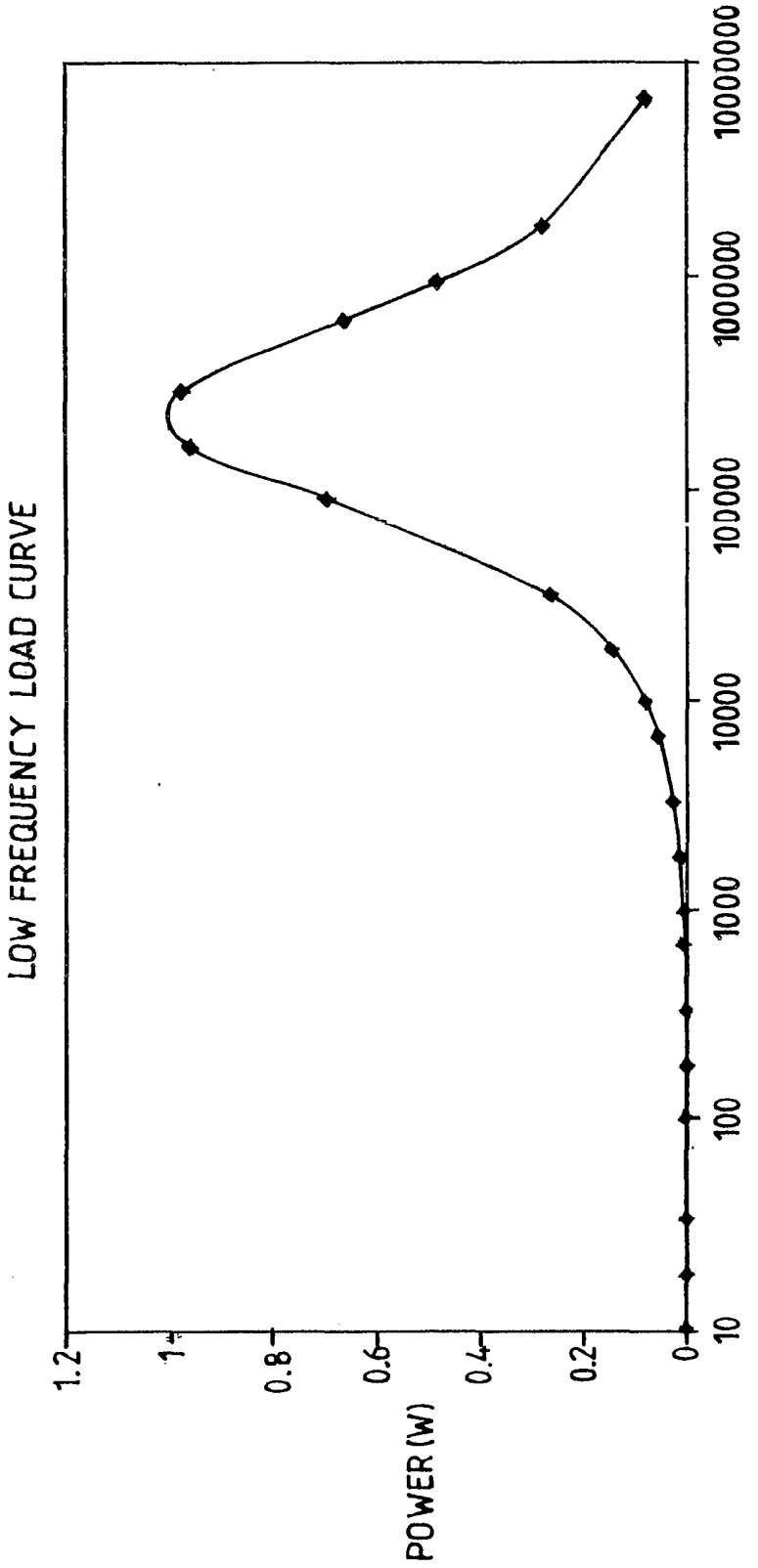

LOW FREQUENCY LOAD CURVE
POWER (W)
1.2
1
0.8
0.6
0.4
0.2
0
10
100
1000
10000
100000
1000000
10000000
IMPEDANCE (OHMS)

FIG.5

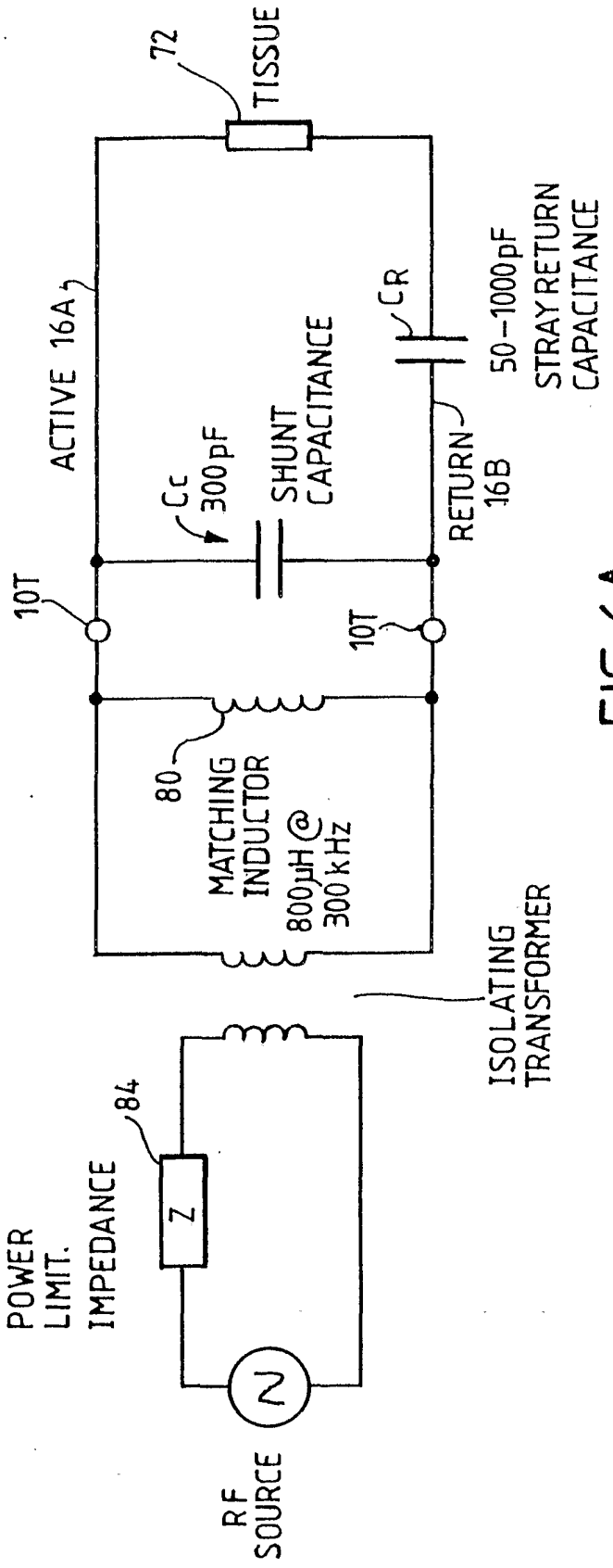

72
TISSUE
ACTIVE 16A
Cc
300pF
SHUNT
CAPACITANCE
CR
50–1000pF
STRAY RETURN
CAPACITANCE
RETURN
16B
10T
10T
80
MATCHING
INDUCTOR
800μH @
300kHz
ISOLATING
TRANSFORMER
84
POWER
LIMIT.
IMPEDANCE
Z
RF
SOURCE

FIG.6A

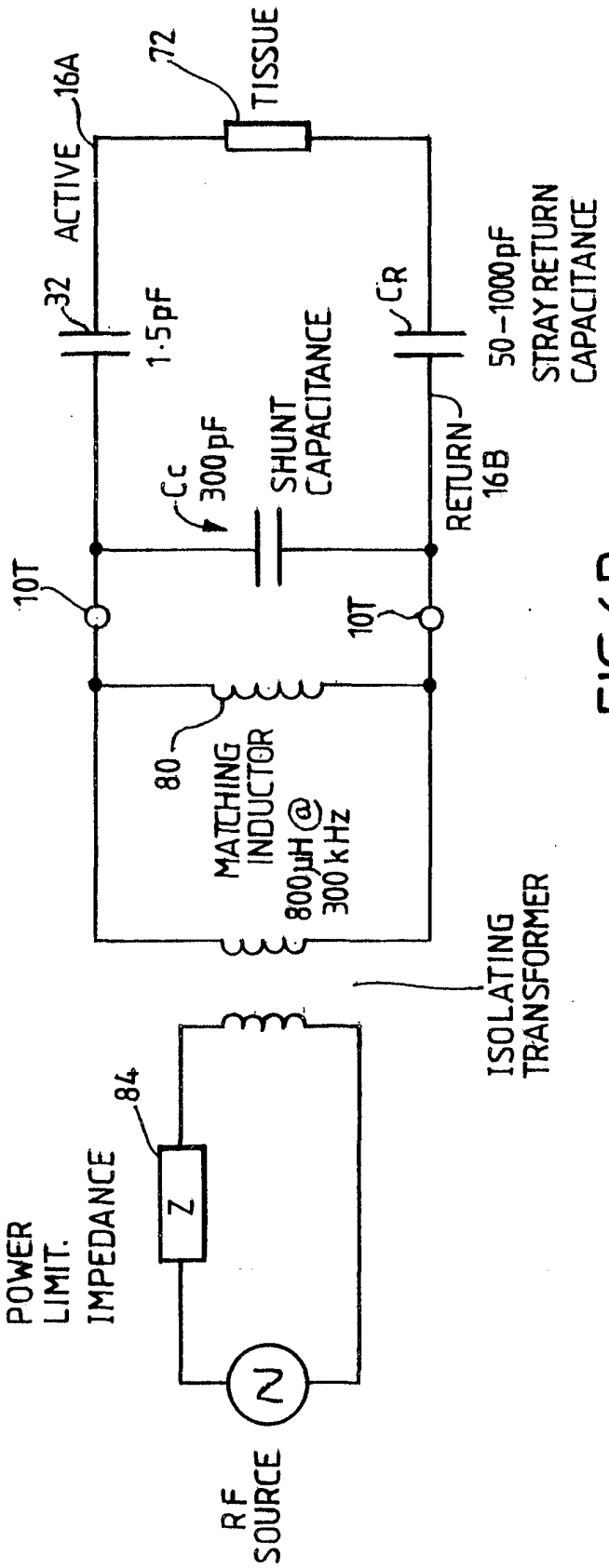

RF SOURCE
POWER LIMIT. IMPEDANCE
Z
84
ISOLATING TRANSFORMER
MATCHING INDUCTOR
800μH @ 300kHz
80
10T
10T
Cc 300pF
SHUNT CAPACITANCE
RETURN 16B
CR
50-1000pF STRAY RETURN CAPACITANCE
32
1·5pF
ACTIVE 16A
72
TISSUE

FIG.6B

INTERNATIONAL SEARCH REPORT

Inter ıal Application No
PCT/GB 01/03939

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B18/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 030 383 A (BENDEREV THEODORE V) 29 February 2000 (2000-02-29) column 6, line 45-49; figure 1 ---	1
A	US 5 484 400 A (LUNDQUIST INGEMAR H ET AL) 16 January 1996 (1996-01-16) see ref sign 40,30 fig 1 column 4, line 22-27 ---	1
A	WO 97 24074 A (WRUBLEWSKI THOMAS A ;CVINAR JOHN (US); TRAUB CRAIG (US); ISAACSON) 10 July 1997 (1997-07-10) see ref sign 102,104 fig 6 ---	1
P,A	US 6 264 650 B1 (ELLSBERRY MARIA B ET AL) 24 July 2001 (2001-07-24) figure 22 ---	1

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 October 2001	05/11/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Papone, F

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/GB 01/03939

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO 01 12089 A (SOMNUS MEDICAL TECH INC) 22 February 2001 (2001-02-22) figure 1	1

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 31

the cathegory of claim 31 is not clear, as it claims a system according to claim 30, claim 30 being a method claim

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte al Application No
PCT/GB 01/03939

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6030383 A	29-02-2000	US 5919189 A	06-07-1999
		US 6200022 B1	13-03-2001
		AU 3008197 A	09-12-1997
		EP 0904024 A1	31-03-1999
		JP 2000511077 T	29-08-2000
		WO 9743967 A1	27-11-1997
US 5484400 A	16-01-1996	US 5370675 A	06-12-1994
		US 5385544 A	31-01-1995
		AU 2196595 A	09-10-1995
		WO 9525472 A1	28-09-1995
		US 5542916 A	06-08-1996
		AT 132046 T	15-01-1996
		AU 671405 B2	22-08-1996
		AU 2047595 A	10-08-1995
		AU 657235 B2	02-03-1995
		AU 4999893 A	15-03-1994
		BR 9306893 A	08-12-1998
		CA 2121032 A1	03-03-1994
		CA 2226484 A1	03-03-1994
		DE 4305663 A1	17-02-1994
		DE 69301143 D1	08-02-1996
		DE 69325164 D1	08-07-1999
		DE 69325164 T2	25-05-2000
		EP 0611314 A1	24-08-1994
		EP 0629382 A1	21-12-1994
		EP 0893101 A2	27-01-1999
		ES 2084510 T3	01-05-1996
		ES 2134295 T3	01-10-1999
		FI 950584 A	04-04-1995
		FR 2694700 A1	18-02-1994
		GB 2269538 A ,B	16-02-1994
		IL 104647 A	31-12-1995
		JP 7503645 T	20-04-1995
		JP 3128242 B2	29-01-2001
		KR 273015 B1	01-12-2000
		MX 9304905 A1	29-04-1994
		NZ 255687 A	20-12-1996
		US 2001031941 A1	18-10-2001
		US 5421819 A	06-06-1995
		US 6022334 A	08-02-2000
		US 5435805 A	25-07-1995
		US 6102886 A	15-08-2000
		WO 9404220 A1	03-03-1994
		US 6241702 B1	05-06-2001
		US 5409453 A	25-04-1995
		US 5470308 A	28-11-1995
		US 5366490 A	22-11-1994
		US 5556377 A	17-09-1996
		US 5720718 A	24-02-1998
		US 5542915 A	06-08-1996
		US 5470309 A	28-11-1995
		US 5554110 A	10-09-1996
		US 5549644 A	27-08-1996
		US 6206847 B1	27-03-2001
		US 6129726 A	10-10-2000
WO 9724074 A	10-07-1997	AU 1569197 A	28-07-1997

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/GB 01/03939

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9724074 A		CA 2241215 A1	10-07-1997
		EP 0873087 A1	28-10-1998
		JP 2000502585 T	07-03-2000
		WO 9724074 A1	10-07-1997
US 6264650 B1	24-07-2001	US 6203542 B1	20-03-2001
		US 6159208 A	12-12-2000
		US 6063079 A	16-05-2000
		US 6109268 A	29-08-2000
		US 5697281 A	16-12-1997
		US 5902272 A	11-05-1999
		AU 5142900 A	12-12-2000
		WO 0071043 A1	30-11-2000
		US 2001029370 A1	11-10-2001
		US 2001032001 A1	18-10-2001
		AU 4650700 A	02-11-2000
		WO 0062698 A1	26-10-2000
		US 2001025176 A1	27-09-2001
		AU 1999099 A	05-07-1999
		EP 1039862 A1	04-10-2000
		WO 9930655 A1	24-06-1999
		AU 1194099 A	10-05-1999
		EP 1026996 A1	16-08-2000
		US 6190381 B1	20-02-2001
		US 6235020 B1	22-05-2001
		US 6142992 A	07-11-2000
		US 6053172 A	25-04-2000
		WO 9920185 A1	29-04-1999
		US 6086585 A	11-07-2000
		US 6296638 B1	02-10-2001
		US 6254600 B1	03-07-2001
		US 6238391 B1	29-05-2001
		US 6296636 B1	02-10-2001
		AU 706294 B2	10-06-1999
		AU 6026696 A	30-12-1996
		CA 2221330 A1	19-12-1996
		DE 29624229 U1	23-08-2001
		EP 1080682 A1	07-03-2001
		EP 0837647 A1	29-04-1998
		JP 2912023 B2	28-06-1999
		JP 10510745 T	20-10-1998
		US 6032674 A	07-03-2000
		WO 9639914 A1	19-12-1996
		US 6224592 B1	01-05-2001
		US 6066134 A	23-05-2000
		US 6179836 B1	30-01-2001
		US 5697882 A	16-12-1997
		US 5683366 A	04-11-1997
		US 6024733 A	15-02-2000
		US 5810764 A	22-09-1998
		US 5843019 A	01-12-1998
		US 5697536 A	16-12-1997
		US 5860951 A	19-01-1999
		US 5873855 A	23-02-1999
		US 2001020167 A1	06-09-2001
WO 0112089 A	22-02-2001	AU 7880600 A	13-03-2001
		WO 0112089 A1	22-02-2001