

CIRCUIT FOR RADIOFREQUENCY DEVICES APPLICABLE TO LIVING TISSUES AND DEVICE CONTAINING SAME

Description

Subject-matter of the invention

The present invention relates to a novel circuit for radiofrequency devices applicable to living tissues, which also includes devices for diathermy by conduction current of different types and electrosurgical scalpels which incorporate the circuit according to the present invention, said circuit having substantial features of novelty and inventive step allowing significant advantages to be obtained over what is known at present.

In particular, the circuit for diathermy devices by conduction and for electrosurgical scalpels according to the present invention allows the harmonics of a non-sinusoidal signal to be attenuated, allowing a sinusoidal signal to be obtained at the output of a high-efficiency amplifier in order to comply with electromagnetic compatibility (EMC) standards which are mandatory in practically all countries in the world.

As is known, EMC is the property by which an electronic appliance does not interfere with and is not interfered by other electronic appliances, when they are all operating correctly.

Background of the invention

Diathermy is the use of special electrical currents to raise the temperature of living tissue for therapeutic purposes. It is sometimes known as hyperthermy, particularly in the medical sector.

Equipment for diathermy by conduction current is very effective in many applications in the field of electromedicine and electroaesthetics. Electrosurgical scalpels are also sometimes referred to as diathermy appliances.

It is advantageous for diathermy equipment and electrosurgical scalpels to work with high-efficiency amplifiers (from the point of view of energy consumption), but in these circumstances they

usually emit multiple electromagnetic signals due fundamentally to parasitic elements which interfere with other electronic pieces of equipment.

These pieces of equipment for diathermy by conduction and electrosurgical scalpels usually function with sinusoidal signals like the one in Fig. 1. Fig. 2 shows the frequency spectrum of the signal of Fig. 1 using the Fourier transform which is another way of representing the signal in the frequency domain, the X axis showing the frequency and the Y axis showing the amplitude of the signal.

The increase of temperature of the living tissue by diathermy is obtained by transmitting energy to the tissue by two methods: by induced currents (electrodes not in contact with the tissue) or by conduction currents (electrodes in contact with the tissue).

In general, the signal frequency applied in the contactless connection method must be very much higher than the signal frequency applied in the contact connection method.

In diathermy by conduction two electrodes are contacted with the living tissue in such a way that a current flow occurs between the two electrodes and passes through the tissue that it encounters in its passage. The current flowing through the tissue causes the temperature to rise by the Joule effect, due to the electrical resistance of said tissue.

In equipment for diathermy by conduction the electrodes are connected by contact. There are two application methods: one is known as the capacitive method and the other as the resistive method.

The electrodes used in diathermy by conduction are normally asymmetric. In this case, and due to the current density, the greatest rise in temperature occurs in the tissue nearest the active electrode (the smaller one). In the capacitive method, the two electrodes are metal, but one of them has an insulating layer. In the resistive method, the two electrodes are metal with no insulation.

In electrosurgical equipment, such as electrosurgical scalpels, the current density is so high at the point of contact between the active electrode and the tissue that cutting, coagulation or fulguration of the tissue occurs.

It is very difficult to comply with EMC standards mentioned above when using this type of equipment. In fact, standard IEC 60601-2-2, which must be met by electroscaelpels, states that EMC tests must be carried out with the equipment connected, but with the output power at zero, since, at the time, it was accepted that it was very difficult to comply with EMC standards when the electroscaelpel is used for cutting, fulguration or coagulation, and since the equipment is used during a surgical operation for a relatively short time and the benefit to the patient is very high.

Equipment for diathermy by conduction operate in a similar way to an electroscaelpel, but with a much larger active electrode, so that the current density J in the contact area with the tissue is much lower, whereas the current I which flows through the tissue (of up to 3A effective R.M.S. value), the output voltage V (of up to 800 V of effective R.M.S. value) and the signal frequency (between 0.4 MHz and 3 MHz) are of approximately the same order of magnitude. From the EMC point of view, these voltages, currents and frequencies are relatively high, and make it very difficult to comply with the EMC standards in different countries. As there are no specific standards for this type of equipment, as there are for electroscaelpels, equipment for diathermy by conduction must meet the general EMC standard for medical equipment, EN 60601-1-2 in Europe. This states that EMC must be measured with the equipment in the worst possible condition, which is, at the maximum output power, unlike electroscaelpels which must be measured with the power at zero, which is a very much easier situation in which to meet the EMC requirements.

Any pure and periodic non-sinusoidal signal may be broken down into multiple sinusoidal signals known as harmonics (of differing frequency, amplitude and phase), which can be calculated from the Fourier transform of the periodic signal.

A method for minimising electromagnetic interference consists of the signal on which the amplifier works being pure sinusoidal, for example a class A amplifier, but in this case the maximum theoretical efficiency is 50 % with the consequent energy loss and heating of the equipment.

Some high-efficiency amplifiers such as those in class C, D, E or F, for example, may lead to theoretical efficiencies of up to 100 %. These amplifiers are based on generating a signal that ideally is squared (but may be trapezoidal or quasi-trapezoidal) or a pulse signal, and filtering the fundamental signal with the intention of achieving maximum attenuation of

undesired harmonics, normally with a second order *LC* filter, which may be serial or parallel, but no filter has been described in the prior art like the one described in this patent for this type of amplifier.

In practice, the efficiency of these amplifiers is less than the theoretical efficiency due to losses in the components and/or to non-matching of impedances.

Fig. 3 shows a squared signal. Fig. 4 shows that the frequency spectrum of said squared signal contains many other higher frequency signals (harmonics). These signals are undesired because they may connect to the network cable or because they may emit in the form of radiation through the patient's cables, which may more easily cause electromagnetic interference in other equipment.

Summary of the invention

Embodiments of the present invention relate to a circuit which seek to allow diathermy equipment to meet the EMC requirements of different countries more easily, particularly in radiated and conducted emission tests.

The circuit may be used in electrosurgical equipment and electroscalpels as well as in equipment for diathermy by conduction.

Embodiments of the present invention seek to attenuate undesired signals as far as possible, so that the equipment does not interfere with other electronic equipment when a generator of squared, trapezoidal, pulse or any other signal that contains harmonics is used as the main source of the signal.

The circuit consists of two resonant filters, one serial and the other parallel optionally separated by a transformer (which may have a turns ratio of 1:N, where N is a real number, which may be greater than unity if the fundamental signal of the input signal is to be amplified, or less than unity if the fundamental signal of the input signal is to be attenuated, or equal to unity if it is only to be isolated), which allow the fundamental signal of the input signal (a sinusoidal signal) to pass through, the circuit in its entirety attenuating the rest of the harmonics as the frequency thereof increases. This type of diathermy equipment usually has a condenser at its output, known as an anti-stimulus condenser to ensure that the non-

linear effects produced by high voltages (electric arcs) do not cause a demodulation that may generate low frequencies (which could cause fibrillation for example during a procedure using an electroscalpel, IEC 60601-2-2).

Said anti-stimulus condensers cause a fall in voltage and, to avoid this, provision is made to incorporate an inductance with a value such that, serially with the anti-stimulus condenser, the resonance frequency of the unit is the fundamental frequency of the input signal. An additional effect is thereby achieved, which is that the very high frequencies are attenuated due to said inductance, thus reducing the level of emissions radiated through the patient's cables.

According to an aspect of the present invention, there is provided a circuit for radiofrequency devices applicable to living tissues, which include devices for diathermy by conduction current with frequencies from 100kHz up to 10MHz of different types and electroscalpels, the circuit to supply the electrodes being characterised in that it comprises: a resonant serial filter consisting of an inductance L_{S1} and a capacitance C_{S1} a resonant parallel filter consisting of an inductance L_P and a capacitance C_P the resonant serial filter and the resonant parallel filter being synthonised to allow the fundamental signal of the input signal to pass through and which simultaneously attenuate exponentially the rest of the harmonics as the frequency of said harmonics increases, the resonant serial filter and parallel filters being separated by a transformer TRF with turn ratio 1:N, N being a real number wherein the output frequency is variable depending on the impedance of the electrode-plus-patient unit and the circuit and/or frequency can therefore be synthonised to match the impedances of the output circuit to the impedance of the electrode-plus-patient unit

These and other features will be better understood from the detailed description which follows, and from the accompanying drawings showing graphs of the signals normally used and an embodiment of the invention, given as a non-limiting example.

Description of the drawings

Fig. 1 shows an illustration of a sinusoidal signal (for example of 500 kHz, normalised at a unitary amplitude).

Fig. 2 shows the frequency spectrum of the signal of Fig. 1 using the Fourier transform, which is another way of representing Fig. 1, changing time (Fig. 1) for frequency on the X axis, the Y axis being the signal amplitude.

Fig. 3 shows a squared signal.

Fig. 4 shows the frequency spectrum of the signal of Fig. 3 using the Fourier transform. It can be seen that the squared signal contains other mixed signals at higher frequencies (harmonics) which may potentially cause interference. The X and Y axes have a logarithmic scale.

Fig. 5 shows a diagram of the circuit according to the invention, where 1 indicates the capacitive output (CAP) and 2 indicates the resistive output (RES).

In Fig. 6 it can be seen that at the output of the filter in the patient's resistance (R_{PAT}) the harmonics are substantially attenuated, as desired.

Detailed description

With reference to Fig. 5, the present invention comprises a circuit for equipment for diathermy by conduction consisting of two resonant filters, one serial and the other parallel, which are synthonised to allow the fundamental signal of the input signal which contains harmonics to pass through (this fundamental signal is a sinusoidal signal) and which exponentially attenuate the rest of the harmonics as the frequency of said harmonics increases.

The serial filter consists of the inductance L_{S1} and a capacitance C_{S1} , and offers very low impedance (in fact almost a short circuit) to the fundamental frequency of the input signal, and a high impedance to the rest of the harmonics of the input signal as the frequency thereof rises.

The parallel filter consists of the inductance L_P and a capacitance C_P , and offers very high impedance (in fact practically an open circuit) to the fundamental frequency of the input signal, and low impedance to the rest of the harmonics of the input signal as the frequency of said harmonics rises.

The fundamental signal of the signal with harmonics (a sinusoidal signal) will therefore pass with practically no attenuation to the output, whereas the resonant serial and parallel filters will increasingly attenuate the harmonics which cause interference as the frequency of said harmonics increases, thus facilitating compliance with the EMC standards.

A transformer TRF may optionally be inserted between the resonant serial filter consisting of L_{S1} and C_{S1} and the resonant parallel filter consisting of L_P and C_P , with a turn ratio of 1:N, where N is a real number which may be greater than unity if the fundamental signal of the input signal is to be amplified, or less than unity if the fundamental signal of the input signal is to be attenuated, or equal to unity if it is only to be isolated. The transformer may also be dispensed with.

The inductance of the resonant parallel filter L_P may be an independent inductance or the parasitic inductance of the secondary of the transformer TRF if present.

The proposed circuit is suitable for application to electrosurgical equipment such as electroscalpels, to equipment for diathermy by conduction with an insulated active metal electrode (capacitive mode, see Spanish patent 287 964 from the same applicant), to equipment for diathermy by conduction with a dual electrode: an insulated active metal electrode (capacitive mode) and with an active metal electrode (resistive mode, see Spanish patent 2 139 507 from the same applicant), and to equipment for diathermy by conduction with an active metal electrode. This type of equipment has a return or neutral electrode with a greater area than the active electrode. The circuit is also suitable for diathermy equipment such as that known as bipolar, in which both electrodes behave as active electrodes, are close to one another and are of similar size.

The equipment for diathermy by conduction described above usually has at its output a condenser C_{S2_CAP} (and C_{S2_RES} if the system has a resistive output, which is an active electrode without insulation), known as an anti-stimulus condenser to ensure that the electric arcs produced by high voltages do not cause low frequency currents through the demodulation effect. These low frequency currents ($f < 10$ kHz) may cause nerve stimulation or muscle contraction when the diathermy appliance is used.

The capacitance value of the anti-stimulus condenser is usually low (approximately a few nF), which causes a fall in voltage depending on its value (C_{S2_CAP} and/or C_{S2_RES}), and in the current I flowing through it.

A feature of the invention is that to avoid this fall in voltage, it is proposed to place an inductance (L_{S2_CAP} and/or L_{S2_RES}) serially with the anti-stimulus condenser (C_{S2_CAP} and/or C_{S2_RES} respectively) with a value such that it causes its resonance frequency to be equal to the fundamental frequency of the input signal. This causes the impedance of the network LC to be practically nil at the fundamental frequency of the input signal. Moreover, an additional effect is thereby achieved, in that the very high frequencies are attenuated due to said inductance (L_{S2_CAP} and/or L_{S2_RES}), thus reducing still further the level of emissions radiated through the patient's cables and through the network cable.

The values of the circuit components are independent of the output power. The values of each network LC of the circuit are a function of the work frequency corresponding to the formula (1)

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

To achieve maximum amplifier efficiency, the output frequency may vary depending on the impedance of the electrode-plus-patient unit, and therefore the circuit and/or frequency may be synchronised to match the impedances of the output circuit to the impedance of the electrode-plus-patient unit.

The typical frequency margin of the output signal for this type of equipment may be between 100 kHz and 10 MHz, so that no nerve stimulation occurs, and its value is not fundamental to the correct functionality of the circuit.

A practical embodiment, which is cited solely as a non-limiting example of the scope of the present invention, can be seen in Fig. 5. Fig. 6 shows how the high frequency harmonics have been attenuated when compared with the spectrum of the squared input signal (Fig. 4).

Clearly, the present invention will be applicable to radiofrequency equipment applicable to living tissues, such as equipment for diathermy by conduction: solely capacitive equipment (with an active metal electrode with an insulating layer), solely resistive equipment (with the active metal electrode), or capacitive and resistive equipment with the active electrode smaller than the passive electrode, bipolar equipment (with similar electrodes) and electroscalpels. In Fig. 5, 1 indicates the capacitive output (CAP) and 2 indicates the resistive output (RES).

It will be understood that the invention has been explained above simply as a non-limiting example and many variants may be introduced within the scope of the invention which is defined by the following claims.

Claims

1. Circuit for radiofrequency devices applicable to living tissues, which include devices for diathermy by conduction current with frequencies from 100kHz up to 10MHz of different types and electroscalpels, the circuit to supply the electrodes being characterised in that it comprises:
 - a resonant serial filter consisting of an inductance L_{S1} and a capacitance C_{S1}
 - a resonant parallel filter consisting of an inductance L_P and a capacitance C_P
 - the resonant serial filter and the resonant parallel filter being synthonised to allow the fundamental signal of the input signal to pass through and which simultaneously attenuate exponentially the rest of the harmonics as the frequency of said harmonics increases,
 - the resonant serial filter and parallel filters being separated by a transformer TRF with turn ratio 1:N, N being a real number
 - wherein the output frequency is variable depending on the impedance of the electrode-plus-patient unit and the circuit and/or frequency can therefore be synthonised to match the impedances of the output circuit to the impedance of the electrode-plus-patient unit
2. Circuit according to claim 1, wherein the inductance of the resonant parallel filter L_P is the parasitic inductance of the secondary of the transformer TRF.
3. Circuit according to claim 1, characterised in that the inductance of the resonant parallel filter L_P is an independent inductance.
4. Circuit according to anyone of claims 1 to 3, wherein there is an anti-stimulus condenser C_{S2_CAP} , C_{S2_RES} at each output, characterised in that an inductance L_{S2_CAP} , L_{S2_RES} is arranged serially with the condenser, the value of which is such that it produces resonance at the fundamental frequency of the input signal.
5. Circuit, according to anyone of claim 1 to 4, characterised in that the inductance L_{S1} and the capacity C_{S1} of the resonant serial filter offer a lower impedance to the fundamental frequency of the input signal and a higher impedance to the rest of the harmonics of the input signal.

6. Circuit, according to claim 5, characterised in that the inductance L_{S1} and the capacity C_{S1} of the resonant serial filter offer an impedance that is substantially a short circuit to the fundamental frequency of the input signal and high impedance to the rest of the harmonics of the input signal.
7. Circuit, according to anyone of claim 1 to 6, characterised in that the inductance L_P and the capacity C_P of the resonant parallel filter offer a higher impedance to the fundamental frequency of the input signal and a lower impedance to the rest of the harmonics of the input signal.
8. Circuit, according to claim 7, characterised in that the inductance L_P and the capacity C_P of the resonant parallel filter offer an impedance that is substantially an open circuit to the fundamental frequency of the input signal and low impedance to the rest of the harmonics of the input signal.
9. Diathermy device which comprises a circuit according to any one of claims 1 to 8.
10. Electroscaipel device which comprises a circuit according to any one of claims 1 to 8.

ABSTRACT

CIRCUIT FOR RADIOFREQUENCY DEVICES APPLICABLE TO LIVING TISSUES AND
DEVICE CONTAINING SAME

A circuit for radiofrequency devices applicable to living tissues and device containing same. The supply circuit for the electrodes comprises a series resonant filter and a parallel resonant filter, synthonized to admit the fundamental signal of the input signal and simultaneously and exponentially attenuate the remaining harmonics by increasing the frequency thereof, in such a way that the input signal with harmonics only passes the fundamental signal without attenuation to the output, while the harmonics causing interferences are increasingly attenuated as their frequency is raised.

FIG. 5