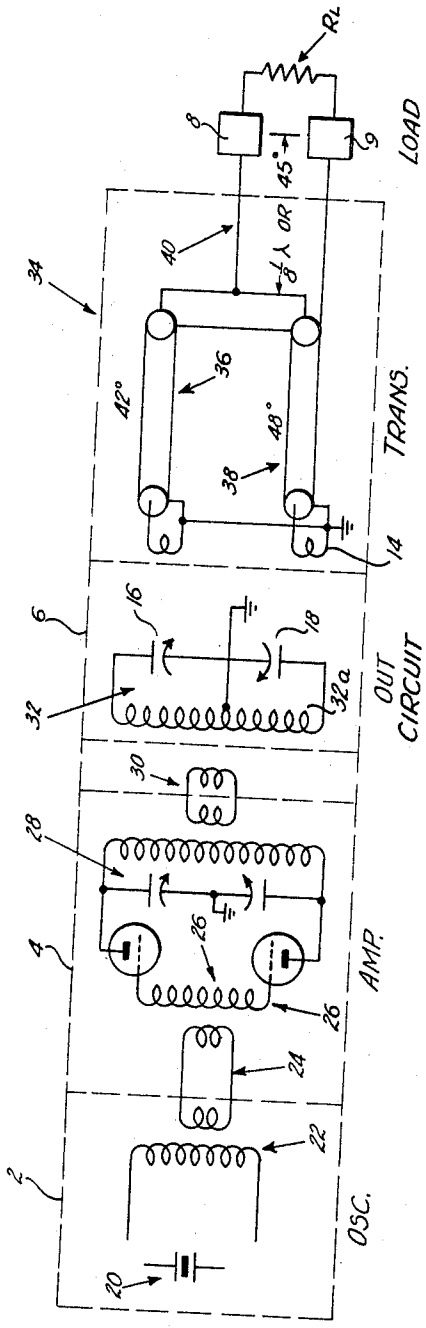
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LOAD COMPENSATING CIRCUIT FOR RADIO FREQUENCY GENERATORS

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LOAD COMPENSATING CIRCUIT FOR RADIO FREQUENCY GENERATORS

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ABSTRACT OF THE DISCLOSURE

A high frequency system which can be used for various purposes, such as diathermy treatment, destructive effect on insects, or the like, which comprises a high frequency source having a tuned output circuit, electrode means for applying radio frequency generated by the source to a load, and coupling means connecting the output circuit with the electrode means, wherein the coupling means includes reactive means for automatically electrically producing equal and opposite cancelling electrical effects in response to variations in the load to maintain resonance of the tuned output circuit.

This invention relates to radio frequency systems wherein radio frequency energy is used to create a particular effect such as heating in a given location between electrodes coupled in the system.

More specifically, the present invention is applicable to a radio frequency apparatus wherein a radio frequency field is created between two electrodes for purposes of providing a treatment, a given destructive effect or the like. While not limited to specific applications, the invention finds particular utility when applied to a radio frequency diathermy machine, or when applied to a device adapted to destroy undesired living creatures in a particular environment, such as boll weevils in grain.

As well known to those familiar with radio frequency apparatus, the output or dosage achieved with use of the apparatus can only be maintained constant when the load to which the output is fed remains constant. Moreover, as also well known, for best power or output control, it is desirable to have a tuned or resonant output circuit in the frequency generating section of the system. Where the load on the apparatus remains constant from the physical as well as the electrical standpoint, the output circuit can be pre-adjusted, i.e., tuned, in accordance with the operating frequency of the basic signal source, conventionally an oscillator, and with such adjustment, the energy transfer to the load can be established quite easily.

Where, however, the load includes an element which is physically and/or electrically variable, the problem of maintaining a proper match between the energy source or frequency generating section and the load becomes somewhat complicated.

To facilitate an understanding of the complications referred to above, it is helpful to initially consider the type of loads in question. Where the apparatus is used as a diathermy machine, for example, the patient has a particular part of his body subjected to the radio frequency energy in the field between the output electrodes of the apparatus. For a given position of the patient, the circuit can be adjusted to resonant conditions, but with any movement of the patient, there is a physical change in the load which reflects itself in the output circuit, and which accordingly requires compensating adjustment to maintain constant power, or in this instance, dosage.

Similarly, where the apparatus is used to destroy insects in a given environment, movement of the insects causes variations in the load from both the physical and electrical standpoints.

Even though the variations in question are comparatively small or minor, with any variations in the load, there is a variation in the power or energy delivered to the particular object undergoing treatment, whether beneficial or destructive, and the power or energy variation is undesirable. From the diathermy standpoint, the variations prevent the physician or operator from controlling the dosage as required, and from the destructive treatment standpoint, the variations are undesirable as improper energy transfer may have a destructive effect on the environment material such as the grain mentioned in the above exemplary discussion.

In recognition of the problems explained above, there have been prior suggestions as to how compensations might be made for variation in load experienced with a radio frequency apparatus of the above prescribed type. For example, where the apparatus is used for diathermy purposes, it has been suggested that a tuning element be incorporated to permit adjustment of either the output circuit or of a coupling network. With the former arrangement, an operator of the apparatus must have special skill and/or prolonged experience in order to maintain the required tuning. With the latter type of arrangement, mechanical components are utilized thus presenting comparatively slow response times and complexities in system operation.

Bearing the foregoing in mind, it will be understood that there is a need for an automatic compensating circuit or arrangement to be used with a radio frequency apparatus to automatically compensate for the normally encountered variations experienced in the load on such apparatus during the use thereof. In this regard, an effective solution requires a compensating arrangement which is simple in construction and which does not incorporate moving mechanical parts or the like.

The primary object of the present invention is to satisfy the aforesaid need, and provide a compensating arrangement for use with, or in combination with, a radio frequency apparatus of the aforesaid type, which compensating arrangement meets the stated test for an effective solution of the problem.

In more detail, it is an object of the present invention to provide electrical (electronic) means for automatically maintaining the output circuit of a radio frequency apparatus in resonant condition regardless of shifts in position or condition of the particular load to which the energy of the apparatus is being applied. In this regard, it is a further significant object of the present invention to provide such a means which does not require the use of any moving parts and which is simple in construction and dependable in operation.

The invention contemplates achieving the above objects through the use of a coupling means including transmission lines connected with the output electrode of a radio frequency apparatus of the aforesaid type. Specifically, it is an object of the invention to obtain automatic compensating adjustment by electrical means including transmission line sections which are so dimensioned and constructed as to reflect canceling variations in response to a change in the load on the apparatus.

It is known that when a tranmission line is short-circuited at the receiver, or when it is used with a resistance load less than the characteristic impedance so that the voltage distribution is of the short-circuit type, the power factor is inductive for lengths corresponding to less than the distance of the first voltage maximum, and thereafter alternates between capacitive and inductive at intervals of a quarter wavelength. Similarly, with an open-circuited receiver, or with a resistance load greater than the characteristic impedance so that the voltage distribution is of the open-circuit type, the power factor is capacitive for lengths less than the distance to the first voltage minimum. Thereafter, the power factor alternates between

capacitive and inductive at intervals of a quarter wavelength, exactly as in the short-circuited case.

In accordance with the invention, the above principles are applied in an output circuit or load coupling circuit of a radio frequency apparatus so that variations experienced with the load reflect themselves into transmission line sections which in turn react with respective off-setting or canceling inductive and capacitive changes that maintain resonant conditions even with shift or variation in the load.

Thus, in a more detailed sense, it is a basic object of the present invention to provide an automatic compensating means for use with a radio frequency apparatus, which automatic compensating means incorporates transmission lines adapted to react in opposite and canceling manners in response to load variations to thereby maintain resonant circuit conditions. Consistent with this object, it is a further object hereof to provide such an automatic compensating means wherein one transmission line path has an effective length less than one-fourth a wavelength, and wherein another transmission line path has an effective length greater than one-fourth a wavelength with the off-set in each line being at least substantially equidistantly off-set from one-fourth wavelength whereby reflected load changes manifest themselves as equal and inherently opposite inductive and capacitive variations which cancel one another.

Aside from the foregoing more basic objects, there are certain additional specific objects of the invention including the following: (a) the provision of a diathermy machine wherein the dosage can be accurately adjusted merely by varying the power output and without requiring continuous manual or mechanical compensating tuning with shifts in the load; (b) the provision of a radio frequency apparatus which is adapted to be used for destroying living objects such as insects which exist in a given material such as grain, without adversely affecting the given material; (c) the provision of an apparatus as prescribed in (b) wherein the apparatus is effective to kill living objects by imparting heat thereto without any appreciable heat generation in the surrounding material, such result being achieved by taking advantage of the differing moisture content of the living object and the material; (d) the provision of a radio frequency apparatus wherein reactive changes in the load characteristic are off-set through the use of transmission lines coupled between the load electrodes and an output transformer by dual secondary windings which operate with equal EMF and in the same phase; (e) the provision of such an apparatus wherein the transmission line paths are constructed with a common portion providing part of their effective length, and with separate portions providing different parts of their effective lengths to achieve the aforesaid more than one-fourth wavelength and less than one-fourth wavelength characteristics; and (f) the provision of such an apparatus which utilizes a conventional energy source such as a crystal controlled oscillator-voltage doubler-amplifier arrangement with a tuned output circuit.

The invention resides in the arrangement, combination and coupling of various components, and in the overall apparatus and method of operating the same. The invention will be better understood and objects other than those set forth above will become apparent, when consideration is given to the following detailed description. Such description makes reference to the annexed drawing.

The drawing presents a schematic representation of a high frequency energy source **10** which effectively comprises a conventional means for generating radio frequency signals or oscillations preferably of a single given frequency at any one time. To this end, the source **10** includes a conventional crystal controlled oscillator having a frequency doubler section forming the output network thereof. However, since this construction is well known, the drawing merely presents schematically the crystal **20** and the output winding **22** of such an arrangement, thus simplifying the drawing as well as the instant explanation.

The oscillator-doubler **2** is link coupled to the power amplifier generally designated by the numeral **4**. The coupling **24** is of conventional type, and feeds to the input winding of a schematically shown push-pull amplifier circuit **26**. The circuit **26** is a neutralized push-pull power amplifier stage also of conventional type, and has its plate tank circuit **28** link coupled, as by a standard coupling element **30**, with a tuned secondary output transformer circuit **32**.

The portions of the circuit described immediately above are well known, as indicated, and thus further discussion thereof appears unnecessary. The invention does not reside in the basic construction of the source **10**, but instead resides in the load compensating circuit to be described below, and in the combination of such circuit with a source such as described above. Thus, it will be understood that the combination with the described source is important, but that the source can be varied with arrangements still embodying the invention.

The output transformer circuit **32** is coupled to two electrodes **8** and **9** by the compensating means hereof, such compensating means being generally designated in the drawing by the numeral **34**. The electrodes **8** and **9** can be of any conventional type well known to those familiar with the art. The purpose of such electrodes is to induce a high frequency field in a given object or medium placed between the electrodes, the medium serving as the effective load. As already indicated, this medium may be part of a human body to be given a diathermy treatment for example, or it may be a body of grain having boll weevils therein, for example.

In any event, the medium provides a load which is schematically illustrated in the drawing and designated as R_L. The schematic representation of the load is made for sake of convenience and it will be appreciated that the same is representative of any desired treatment load whether the treatment is to be beneficial or destructive.

Understanding the above, attention can now be directed to the compensating means or means for maintaining the output circuit in tune with the load as the load characteristic varies. In the preferred embodiment, such compensating means includes a pair of secondary windings which are each wound with, or around the coil **32***a* of the output circuit and in the same direction so that their phases are equal. Also, such windings **12** and **14** are equally dimensioned (same number of turns preferably) so that they produce equal EMF outputs. The output of coils **12** and **14** feed to transmission line sections **36** and **38** and in turn through line section **40**. As indicated in the drawing, line section **36** is 42° in length at the operating (output) frequency of the source **10** and the transmission line section is 48° in length at such frequency. These lengths have been found to be particularly satisfactory and are used in accordance with the preferred embodiment hereof. However, the effective lengths can be varied within reasonable limits, with the important factor being that the overall length of each portion is maintained, in the manner explained below, so that two line paths exist which are equally and oppositely off-set respectively from a one-fourth wavelength (a 90° length).

The section **40** of the line, as also indicated in the drawing has an effective length of one-eighth wavelength and sections **36** and **38** are coupled in parallel at the output end and to section **40** which feeds at its output end to the respective electrodes **8** and **9**.

With the preferred construction described, the winding **12** is coupled to the load through 42° plus 45° or an 87° transmission line path (the line portion **40** being one-eighth wavelength which equals 45°). The winding **14**, on the other hand, is coupled to the load through 48° plus 45° or a 93° transmission line path. Since an effective one-fourth wavelength path equals a 90° line, the coupling path between winding **12** and the load is 3° less

than one-fourth wavelength and the coupling between winding **14** and the load is 3° more than one-fourth wavelength.

The coupling between the winding **12** and the load accordingly reflects an inductive variation with changes in the load and the coupling between winding **14** and the load reflects an equal capacitive variation with changes in the load. Since one path reflects the reactive change as capacitive and since the other path reflects the same reactive change as inductive, the reflections or reactive changes cancel one another. (Here the well known principle of the opposite reactive effects of inductances and capacitances is applied.)

In operation of the apparatus, the output circuit is adjusted to resonance by suitable adjustment of the conventional variable capacitors **16** and **18** which, as shown, form part of the resonant output transformer circuit **32**. This adjustment is made with the treatment load disposed between the electrodes. Once this initial adjustment is made, then with any variation in the load due to a change in physical position or characteristic thereof, there will be a reflected equal and opposite cancelling electrical effect as explained, and the system will remain tuned or in resonant condition.

It will be appreciated that the automatic compensation provided by the invention is achieved without the use of any mechanical adjustments and that the arrangement is highly simplified. The simplification afforded through the use of a transmission line having two sections of a length equally off-set from one-eighth wavelength and having one common section with a one-eighth wavelength length is an important factor from the economy standpoint as well as from the coupling standpoint, but two lines of the prescribed effective length could be used in place of the "common section" arrangement. Accordingly,

What is claimed is:

1. A high frequency system comprising a high frequency source having a tuned output circuit, electrode means for applying radio frequency generated by said source to a load, and coupling means connecting said output circuit with said electrode means, said coupling means comprising transmission line means having a first path coupling one of said electodes with said output circuit through a line path having an effective length of less than ¼ wavelength and having a second path coupling the other of said electrodes with said output circuit through a line path having an effective length greater than ¼ wavelength, said transmission line means comprising a pair of transmission line sections having effective lengths respectively greater and less than ⅛ wavelength and an additional transmission line section coupled with said pair of sections and having an effective length of ⅛ wavelength, whereby equal and opposite cancelling electrical effects are automatically electrically produced in response to variations in the load to maintain resonance of said tuned output circuit.

2. A high frequency system as defined in claim **1**, wherein said additional transmission line section is coupled in parallel with said pair of transmission line sections, whereby one section of said pair and said additional section form one line path and whereby the other section

of said pair and said additional section form the othe line path.

3. A high frequency system comprising a high frequency source having a tuned output circuit, said high frequency source comprising a crystal controlled oscillator means, a frequency doubling means coupled to the output of said oscillator means, and a power amplifier coupled to the output of said frequency doubler means for delivering high frequency oscillations to said output circuit, electrode means for applying radio frequency generated by said source to a load, and coupling means connecting said output circuit with said electrode means, said coupling means comprising transmission line means having a first path coupling one of said electrodes with said output circuit through a line path having an effective length of less than ¼ wavelength and having a second path coupling the other of said electrodes with said output circuit through a line path having an effective length greater than ¼ wavelength, whereby equal and opposite cancelling electrical effects are automatically electrically produced in response to variations in the load to maintain resonance of said tuned output circuit.

4. A high frequency system as defined in claim **3**, wherein said output circuit includes a coil and a pair of capacitance means coupled across respectively different sections of said coil, and wherein said transmission line means includes coil means inductively linked with said coil in said output circuit to transfer signals respectively to said first and second paths.

5. A high frequency system comprising a high frequency source having a tuned output circuit, electrode means for applying radio frequency generated by said source to a load, and coupling means connecting said output circuit with said electrode means, said coupling means comprising transmission line means having a first path coupling one of said electrodes with said output circuit through a line path having an effective length of less than ¼ wavelength and having a second path coupling the other of said electrodes with said output circuit through a line path having an effective length greater than ¼ wavelength, the difference between the effective lengths of said first and second paths being less than ¼ wavelength, whereby equal and opposite cancelling electrical effects are automatically produced in response to variations in the load to maintain resonance of said tuned output circuit.

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