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ENERGY RADIATION APPARATUS

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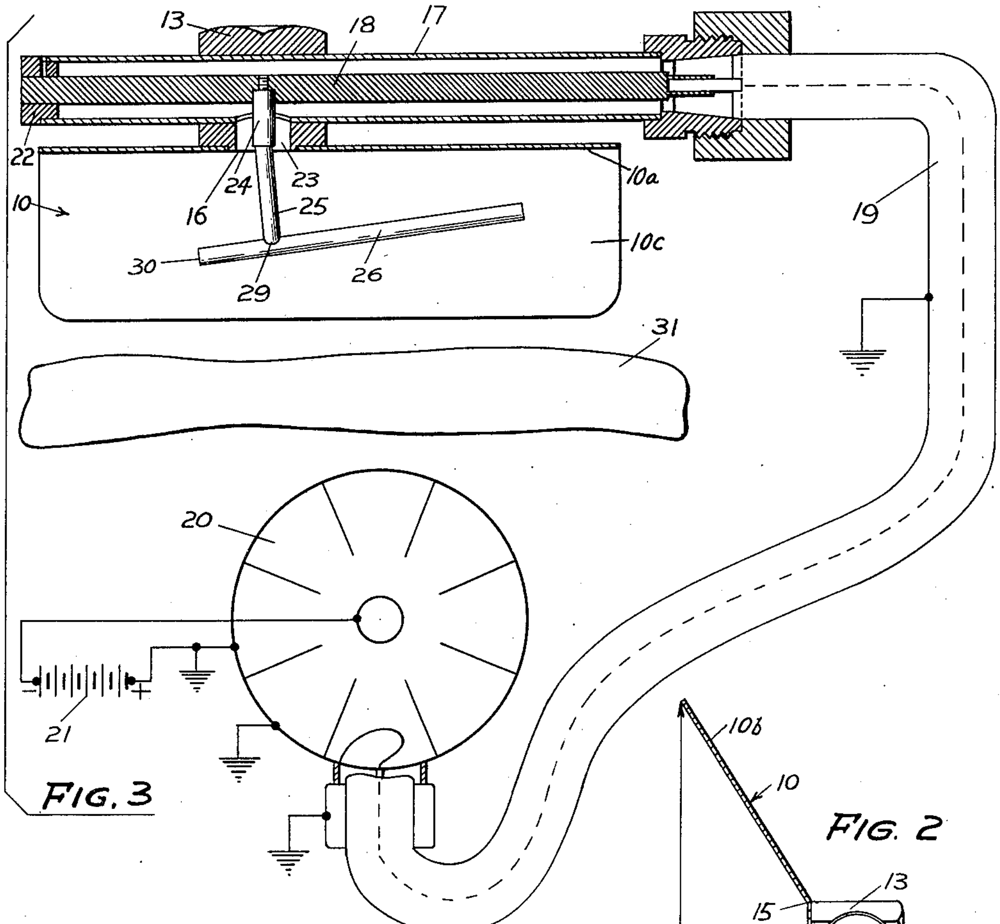

FIG. 3

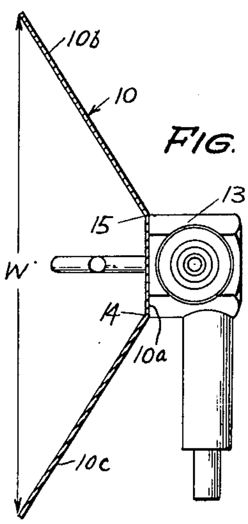

FIG. 2

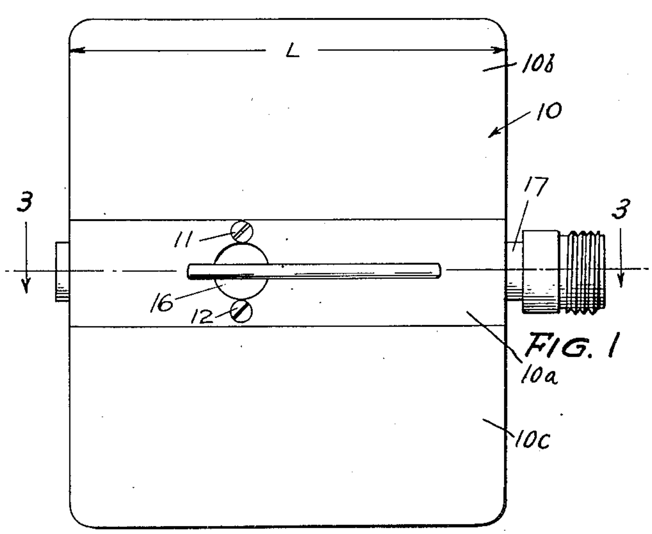

FIG. 1

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ENERGY RADIATION APPARATUS

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6 Claims. (Cl. 250—33.65)

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This invention relates to means for radiating electromagnetic energy of a microwave frequency and more particularly to such means adapted to produce a uniform pattern of radiation energy on or beneath the surface of an energy absorbing body which may be positioned very close, at a distance of a wavelength or less, from the radiating means.

The radiation device of this invention is particularly adapted to be used in therapeutic apparatus for radiating and focusing electromagnetic energy of a frequency within the range of 2300 to 3300 megacycles per second upon the surface of an energy absorbing body to be treated positioned at a distance of about a wavelength or less from the radiating means. In such apparatus it has been found desirable to provide a predetermined total impedance for the radiating means such as to produce a no-load standing wave ratio, hereinafter referred to as the standing wave ratio in air, of within the range of 1.2 to 1 and 1.6 to 1 in order to provide effective loaded impedance matching with an average body to be treated as more fully described in the copending patent application of Henry F. Argento, Serial No. 730,926, filed February 26, 1947. Under certain conditions of therapeutic application it is also desirable to provide a uniform pattern of energy on the surface or penetrating beneath the surface of an approximately flat object uniformly spaced over the entire area of the energy pattern from the radiating means.

It is an important object of this invention to provide a corner reflector type of radiating device for microwave electromagnetic energy which is so devised as to radiate a uniform pattern of energy that is devoid of strong energy areas or hot spots within the energy pattern and which will provide a predetermined shaped pattern of energy on a substantially flat surface of an energy absorbing body thus providing for even heating within the body over the entire area of the energy pattern so long as the surface of the body is uniformly spaced from the axial plane of the corner reflector.

It is also an object of this invention to provide a corner reflector and radiating device for microwave energy having novel means incorporated therein for obtaining a predetermined total impedance of the radiating means to the energy to be radiated such as to produce a desired standing wave ratio in air for the energy radiated, which standing wave ratio may be within the range of 1.2 to 1 and 1.6 to 1 in air.

It is a further object of this invention to provide a novel form of radiating device in which a combined corner reflector and radiating element is connected to one conductor of a transmission line containing the energy to be radiated and a novel form of radiating element is connected to the other conductor of the transmission line and uniquely positioned in predetermined relation to the combined corner reflector and radiating element such as to produce interaction and reflection between the radiations emanated by both radiating elements so that a predetermined pattern of energy of approximately the area of the reflector is radiated upon the flat surface of a body uniformly positioned at a distance of about a wavelength or less from the axial plane of the reflector.

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Additional objects and advantages of the invention will be apparent with reference to the following specification and drawing in which:

Fig. 1 is a top view of the radiation device of the invention;

Fig. 2 is an end elevation of the invention as seen from the coupling end of the matching stub and transmission line; and

Fig. 3 is a longitudinal section on the line 3—3 of Fig. 1 and also diagrammatically showing a magnetron source of electromagnetic energy together with a coaxial cable transmission line for connection to the radiation device.

Referring to the drawing, the radiation device of this invention is shown as particularly adapted for use in therapeutic apparatus wherein it is desired to radiate and focus electromagnetic energy of microwave frequency upon an energy absorbing body to be treated. Fig. 3 of the drawing shows the manner of positioning the radiation device of this invention to focus electromagnetic radiations upon a substantially flat surface such as a human chest illustrated.

The radiation device of this invention may hereinafter be referred to as a director and is comprised of a combined reflecting and radiating metal plate or element **10** and the radiating elements **25** and **26**. The reflector plate **10** is substantially rectangular in shape and is fastened by bolts **11** and **12** to a hexagonally shaped metal bushing or support **13**. The reflector element **10** includes a rectangular, central section **10***a* from the longer sides of which extend rectangular side sections **10***b* and **10***c* to provide obtuse interior corner angles at **14** and **15** and the magnitude of such corner angles may be suitably chosen as will be described hereinafter to obtain a predetermined width of radiated energy pattern which may preferably be determined to be substantially equal to the width W of the reflector element 10. The length L of the reflector element 10 may be selected in accordance with the frequency of electromagnetic energy to be radiated and may preferably be approximately .91 wavelength in length. The central section 10a of the reflector 10 is provided with an opening 16 through which may be extended a voltage feed line 24 to be hereinafter referred to.

Extending transversely through metal bushing 13 is a metal sleeve 17 enclosing an inner metal conductor 18 to thus form a combined transmission line and matching stub for energy supplied thereto from a coaxial cable 19 and magnetron oscillator 20. The magnetron oscillator 20 may be energized in any suitable manner from a source of direct current such as the battery 21 whose positive terminal is grounded together with the anode of the magnetron. The inner metal conductor 18 is supported in spaced concentric relation to the metal sleeve 17 by means of the shorting metal plug 22 fastened in the end of the one-quarter wave stub portion such that the metal plug is at a point of zero voltage field for the energy in the transmission line. An opening 23 is provided in the metal bushing 13 which may be of a diameter approximately equal to the internal diameter of the metal sleeve 17 and a voltage feed conductor 24 is fastened to the inner metal conductor 18 to extend through the opening 23. The dimensions of the voltage feed 24 and opening 23 are selected to match the dimensions in the transmission line consisting of the metal sleeve 17 and inner metal conductor 18 so that with the voltage feed 24 connected to the metal conductor 18 at a predetermined distance from the shorting plug 22, the field potential at the opening 16 in the reflector plate 10 will be substantially zero and the impedance to the energy in the line at that point will be approximately equal to the fifty ohm impedance of the transmission line. Other values of impedance for the transmission line may be selected, if desired, as should be readily understood.

Angularly extending from the voltage feed 24 in a plane perpendicular to the plane of the section 10a of the reflector plate 10 is the radiating element 25, the length of the element 25 being coordinated with the corner angles 14 and 15 of the combined reflector and radiating element 10 so that the corner reflector will be effective to produce a pattern of radiated energy substantially equal to its width W. It should be understood that the angles 14 and 15 of the corner reflector 10 or the length of the element 25 or both may be varied to obtain any desired width of energy pattern as is well known in the art. The length of the element 25 in the specific embodiment of the director may preferably be chosen to cooperate with an interior angle of 145 to 155 degrees for each of the corner angles 14 and 15 to produce a width of energy pattern equal to the width W of the reflector element 10.

Fastened to the free end of the element 25 is another radiating element 26 which may be described as substantially at right angles to the element 25. The element 26 is of a length equal to one-half wave-length of the energy to be radiated. It will be noted that the element 25 feeding energy to the element 26 is not connected thereto at the midpoint or point of zero field potential of the element 26 and that, therefore, a deliberate mismatching of impedance between the two elements 25 and 26 and to the energy to be radiated is obtained. This deliberate mismatching is a novel feature of the invention in order to obtain a predetermined total impedance for the director such as will provide a standing wave ratio within the range of 1.2 to 1 and 1.6 to 1 in air, which range of standing wave ratio is found to be desirable for use in therapeutic apparatus as more fully described in the copending application of Henry F. Argento previously referred to. The exact positioning of the juncture between the radiating element 26 and the element 25 is determined to be that point between its midpoint and one end at which the total impedance of the director as represented by the impedance of the element 25, the impedance of the element 26 and the impedance of the combined radiating and reflector element 10, is such as to give the desired standing wave ratio within the specified range. In the specific form of the invention being described, the element 25 is fastened to the element 26 at a point 29 approximately .29 wavelength from the end 30 which is effective to produce the desired standing wave ratio.

As is shown in the drawing, the element 26 is tilted somewhat from the horizontal and the element 25 is similarly tilted from the vertical. In other words, the axis of the radiating element 26 is not parallel to the plane of the section 10a of the combined reflector and radiating element 10 but is inclined from that plane by an angle which in the specific embodiment of the invention being described in approximately 7 degrees. The inclination angle or deviation for the element 26 from a plane parallel to the plane of the section 10a of the reflector 10 may preferably be selected to fall within a range of 6 to 10 degrees which under most conditions of operation will provide for a uniform spreading of the energy pattern along the length L of the combined reflector and radiating element 10 to an amount equal to or greater than the length L. Inclining the element 26 within the range specified results in an approximately uniform spreading of the energy pattern along the length L of the reflector 10. For any angle of inclination up to a maximum inclination angle the spread of radiation pattern along the length L is found to increase with the inclination angle. Beyond the maximum inclination angle of about 15 degrees the radiation pattern again starts to contract along the length L. For example, it has been observed that with the radiating element 26 in the horizontal plane, that is with no inclination angle and parallel to the plane of the section 10a of the reflector 10, the energy pattern produced in a flat body such as the chest, positioned at a uniform distance within a wavelength or less from the reflector plate 10, is substantially concentrated in a small area or hot spot coincident with the area in the vicinity of the voltage feed line 25. In order to obtain a uniform spreading of the energy pattern to have a length approximately equal to the length L of the reflector 10, the preferred embodiment of the invention provides for an angle of inclination for the radiating element 26 by an amount approximating 7 degrees from the plane of the section 10a of the reflector 10. It will be seen that juncture point 29 between the vertical element 25 and the horizontal element 26 is spaced from the shorter end 30 of the element 26 that is inclined away from the reflector plate 10. This location of the juncture 29 is necessary in order to assure the maximum spreading of the length of the radiation pattern along the maximum active length or longer end of the element 26 away from the vicinity of the voltage feed.

In using the director of this invention for therapeutic apparatus, it is found that when the plane of the reflector 10 is positioned parallel to the plane of a flat surfaced object to be treated, such as the human chest 31 shown in Fig. 3 of the drawing, a uniform pattern of heat having an area approximately equal to the area of the reflector plate 10 is produced on and in the body. It may be pointed out that the radiations produced by the director of this invention are believed to be the result of direct radiation from the elements 10, 25 and 26 together with radiations resulting from inter-action such as interference and reflection between the elements 10, 25 and 26 and that, therefore, the novel positioning of such elements with respect to each other as described in the foregoing results in the desirable uniform pattern of heat obtained.

It should be understood that the exact angles and dimensions specified for the particular form of the invention being described may be varied within reasonable limits to obtain the desired results when selecting various area sizes for the pattern of energy to be radiated in connection with selected frequencies of radiation energy. In the specific form of the invention, as described, the energy to be radiated was of a frequency of 2450 megacycles. It should also be understood that various other modifications will be apparent to those skilled in the art without departing from the spirit and scope of the appended claims.

What is claimed is:

1. Means for radiating electromagnetic energy comprising: a radiating and reflecting trough-like member; and a radiating rod supported in the concavity of said trough-like member, in a plane perpendicularly intersecting said trough-like member along a line lying in a plane including the longitudinal axis thereof, at an angle of from substantially 6° to substantially 10° to said axis.

2. Means for radiating electromagnetic energy comprising: a radiating and reflecting trough-like member including a central section, and a pair of side sections extending from said central section and forming therewith interior angles of from substantially 145° to substantially 155°; and a radiating rod supported in the concavity of said trough-like member, in a plane perpendicularly intersecting said trough-like member along a line lying in a plane including the longitudinal axis thereof, at an angle of from substantially 6° to substantially 10° to said axis.

3. Means for radiating electromagnetic energy comprising: a radiating and reflecting trough-like member; a radiating rod disposed in the concavity of said trough-like member; and means, extending into said trough-like member, and supporting said radiating rod in a plane perpendicularly intersecting said trough-like member along a line lying in a plane including the longitudinal axis thereof, at an angle of from substantially 6° to substantially 10° to said axis.

4. Means for radiating electromagnetic energy comprising: a radiating and reflecting trough-like member; a first radiating rod supported in the concavity of said trough-like member, and a second radiating rod, extending into said trough-like member, and supporting said first radiating rod in a plane perpendicularly intersecting said trough-like member along a line lying in a plane including the longitudinal axis thereof, at an angle of from substantially 6° to substantially 10° to said axis.

5. Means for radiating electromagnetic energy comprising: a radiating and reflecting trough-like member; a first radiating rod supported in the concavity of said trough-like member; and a second radiating rod, extending into said trough-like member, and supporting said first radiating rod in a plane perpendicularly intersecting said trough-like member along a line lying in a plane including the longitudinal axis thereof, at an angle of from substantially 6° to substantially 10° to said axis; said first radiating rod having a length of substantially .5λ, and the junction between said first and second radiating rods being subsantially .29λ from the end of said first radiating rod farthest removed from said trough-like member, where λ is the wavelength of the electromagnetic energy to be radiated.

6. Means for radiating electromagnetic energy comprising: a radiating and reflecting trough-like member including a central section, and a pair of side sections extending from said central section and forming therewith interior angles of from substantially 145° to substantially 155°; a first radiating rod supported in the concavity of said trough-like member; and a second radiating rod, extending into said trough-like member, and supporting said first radiating rod in a plane perpendicularly intersecting said trough-like member along a line lying in a plane including the longitudinal axis thereof, at an angle of from substantially 6° to substantially 10° to said axis; said first radiating rod having a length of substantially .5λ, and the junction between said first and second radiating rods being substantially .29λ from the end of said first radiating rod farthest removed from said trough-like member, where λ is the wavelength of the electromagnetic energy to be radiated.

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