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H. C. LINDAHL

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ENERGY RADIATION APPARATUS

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INVENTOR
HILMER C. LINDAHL
BY *Elmer J. Gorn*
ATTORNEY

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ENERGY RADIATION APPARATUS

Hilmer C. Lindahl, New York, N. Y., assignor to
Raytheon Manufacturing Company, Newton,
Mass., a corporation of Delaware

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This invention relates to means for radiating electromagnetic energy and more particularly to such means adapted to direct and focus beams of electromagnetic radiation energy upon an energy absorbing body to thus produce predetermined patterns of energy or heat in the body thus positioned within operating range of the directing means.

This application is a continuation of application, Serial No. 735,435, filed March 18, 1947 and now abandoned.

The energy directing and radiating means of this invention has particular utility in therapeutic deep heating apparatus of the kind disclosed and claimed in the copending patent applications of Percy L. Spencer, Serial No. 732,451, filed March 5, 1947, and Henry F. Argento, Serial No. 730,926, filed February 26, 1947, now Patent No. 2,567,757, granted September 11, 1951, wherein the use of electromagnetic radiations of a frequency in the microwave spectrum for the therapeutic deep heating of body tissues is described. As described in said copending patent applications, it is desirable to direct and focus the electromagnetic radiation energy of microwave frequency upon an energy absorbing body to thus produce predetermined patterns of heat energy at desired focused points in the body under treatment. In order to assure maximum effectiveness of energy transfer between the radiating apparatus and body, it is also desirable to properly match the impedance of the radiating element to the terminating impedance of an average body to be treated and the impedance of the radiation source. In the copending Argento application, it is disclosed that the correct impedance matching above described is obtained for most practical operating conditions when the total impedance of the director and radiating element is such as to produce a standing wave ratio in air of within the range of 1.2 to 1 and 1.6 to 1.

It is therefore, an important object of this invention to provide means comprising a stub radiating element and a hemispherical combined reflector and radiating element for radiating electromagnetic energy and for producing a circular pattern of heat as induced in a body by the radiated energy absorbed by the body positioned in front of the director at a distance of approximately a wavelength or less from the director opening, the circular pattern of heat having a diameter approximately equal to the maximum diameter of the director, thus providing for accurate focusing of the energy upon a body to

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be treated and avoiding wasteful misapplication of energy to parts of the body that are not intended to be treated.

It is another object of this invention to provide a combined directing and radiating apparatus which may be generically referred to as a director for properly focusing and directing radiated beams of electromagnetic energy to produce predetermined patterns of heat energy in a body to be treated positioned within the director's operating range and having novel means to obtain additional capacitive reactance and a total impedance for the director such as to produce any desired standing wave ratio in air which may preferably be within the range of 1.2 to 1 and 1.6 to 1.

It is yet another object of this invention to provide a radiation director comprising a radiating element combined with a reflecting element in such manner as to radiate and direct electromagnetic energy to predetermined areas of a body to be treated and for producing a circular pattern of heat energy in the body, the heat pattern having a relatively cold spot in a known position approximately at the center of the area such that, with proper manipulation and positioning of the director, irregular surfaces of a body such as an elbow or knee may be treated to produce even heating of the body at the same predetermined depth beneath the irregular surface of the body.

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

Fig. 1 is a view of the director in half-section along the axis of the matching stub and also showing diagrammatically a magnetron oscillator as a source of microwave electromagnetic energy;

Fig. 2 is a rear view of the director; and

Fig. 3 is a fragmentary section of a modified form of director.

Referring to Figs. 1 and 2 of the drawing, the combined radiating element and reflector of this invention, hereinafter termed a director, is shown to be connected with a source of microwave energy which may, for example, be a magnetron oscillator. While the director of this invention is particularly suited for use in therapeutic apparatus and will be described in connection with such apparatus, it will be understood that the invention is not limited to such usage.

The director 10 is comprised of the hemispherical combined reflector and radiating element 11 together with a bullet-shaped metal radiating

stub element 12. Under certain conditions it may be desirable to form the stub element 12 in an inverted conical shape or other form than bullet-shaped and also the reflector 11 may be formed with a parabolic or other shape if desired under certain conditions. The stub radiating element 12 is approximately one-quarter wavelength in length and is adapted to extend through an opening 13 of the hemispherical reflector and radiating element 11. It will be noted that, although the stub radiating element 12 does not contact the walls of the opening 13, it is, nevertheless, spaced very close thereto. Fastened by brazing, silver soldering or other suitable expedient to the rear of the hemispherical reflector and radiating element 11, which may hereafter be called the reflector 11, is a metal bushing 14 having a bore in alignment with the opening 13. Extending transversely through the metal bushing 14 and supported thereby is the metal sleeve 15, constituting the outer conductor of a matching stub element. Positioned concentrically within the matching stub sleeve 15 is an inner metal conductor 16 which is supported in the spaced concentric relation by the metal shorting plug 17 at the matching stub end. It should be understood that the metal plug 17 supporting the inner conductor 16 and connecting it to the outer metal sleeve 15 is located at a point of zero field potential with respect to the electromagnetic energy in the stub transmission line. It will now be seen that the stub radiating element 12 extending through the opening 13 is fastened at 12a to the inner metal conductor 16 of the matching stub 15 and supported thereby.

A coupling collar 18 is used to connect the matching stub sleeve 15 and inner conductor 16 to the outer and inner conductors, respectively, at one end of a coaxial cable 19. The other end of the coaxial cable 19 may be connected in a suitable manner to the anode and output loop of a magnetron oscillator 20 shown in diagrammatic form to be energized from a source of direct current 21 whose positive terminal may be grounded together with the anode of the magnetron. As shown in Fig. 2 of the drawing, the bushing 14 is also provided with a metal shaft or extension 22 by means of which the director may be fastened to a suitable support for positioning it in the desired relation to a body to be treated. The director 10 may, if desired, be provided with a protective cover 23 of Pliofilm or other suitable material which is transparent to the radiations produced but which will prevent body contact with the stub radiating element 12 and reflector 11, such as would cause accidental short circuit, arcing and severe burning.

It may be desirable to have a certain amount of reactance in the director 10 in order to provide a total impedance for the director such as will produce a standing wave ratio in air of within the range of 1.2 to 1 and 1.6 to 1 for the radiations emanated. The director of this invention is provided with the following described novel means of obtaining additional capacitive reactance such as to produce a total impedance to obtain the desired standing wave ratio in air. It will be noted that the stub radiating element 12 which is approximately one-quarter wavelength in length extends through the opening 13 along part of its active length, which part may preferably be $\frac{1}{6}$ or more of its total active length. The active length of the stub element 12 may be defined as the length along which the field of the applied electromagnetic energy is substantially

more than zero. Such part of the active length of the stub 12 is closely spaced to the opening 13 in the metal walls of the bushing 14, which bushing is electrically connected with the reflector 11.

As will be seen in Fig. 1 of the drawing, the spacing in the opening 13 is substantially less than the spacing between the inner conductor 16 and the outer sleeve 15 of the matching stub so that the close spacing thus afforded in the opening 13 along a portion of the active length of the stub 12 is, in effect, a line transformer providing added capacitive reactance to the energy in the system and giving a total impedance for the director element 10 such as to give the desired standing wave ratio. It should be understood that the length of the portion of active length for the stub 12 is determined by the desired amount of additional reactance necessary to obtain the desired standing-wave ratio. It is a particularly advantageous feature of this invention to provide for an additional capacitive reactance in the director as obtained in the above manner in order to properly match the director 10 to the flexible coaxial cable 19, which cable has a relatively large amount of inductive reactance to microwave frequencies of the electromagnetic energy which may be supplied to the cable. In the case of the therapeutic apparatus referred to, the frequencies used in the microwave spectrum may be within the range of 2300 to 3300 megacycles per second.

A somewhat modified form of the invention is shown in fragmentary section by Fig. 3 of the drawings and the same reference numerals are used to identify parts of the invention which are identical with the structure shown in Fig. 1 of the drawing. In the form of the invention shown at Fig. 3, the reflector element 11 is formed with the opening 13 drawn into an annular flangeway thus providing the wall surfaces 25. The matching sleeve 15 may then be silver soldered at 26 to the end of the flange 25 to provide a support for the reflector 11 from the matching sleeve 15. In this construction, it will be noted that the stub radiating element 12 extends through the opening 13 and that a portion of the active length of the stub element is in close proximity to the inner wall of the annular flange 25 of the reflecting element 11. Thus the added capacitive reactance for the director unit is obtained in the novel manner of this invention due to such close positioning of an active portion of the stub element 12 with the metal wall of the reflector 11.

Again referring to Figs. 1 and 2 of the drawing, it will be noted that the reflector element 11 may also be considered a radiating element since it is connected to one side of the transmission line represented by the outer metal sleeve 15 of the matching stub which is electrically connected to the outer conductor of the coaxial cable 19. In other words, the director 10 comprised of the reflector element 11 and stub radiating element 12 is, in effect, a modified form of a folded dipole antenna, although the combined reflector and radiator 11 is actually quite different from the usual di-pole element since it is hemispherical in contour. With the reflector element 11 connected as shown to one side of the transmission line containing the electromagnetic energy to be radiated, and with the metal bushing 14 also electrically connected to the reflector 11, it should be understood that the particular arrangement of the director in which the stub radiating element 12 passes through an opening 13 of the reflector 11 and in close proximity to the metal walls of the bushing 14 is effective as

a line transformer to provide additional capacitive reactance for the director 10 such that its total impedance will produce the desired standing wave ratio in air. The novel manner of obtaining additional capacitive reactance as described is not limited to the specific combination with a hemispherical reflector 11 as other shapes of a combined radiator and reflector could be used such as parabolic or cone shapes.

Considering Fig. 1 of the drawing, it will be seen that the stub radiating element 12 is positioned with its axis approximately parallel to the direction of travel for the radiations emanated. Such positioning of a stub radiating element 12 within a hemispherical, parabolic or similarly shaped combined reflector and radiator 11 produces a novel pattern of generated heat within an energy absorbing body positioned in front of the director opening at a distance of a wavelength or less. It should be pointed out that in using the director of this invention for therapeutic purposes it is found that the closer the body is positioned to the director 10, the greater is the heat produced in the body. The heat pattern produced by the director 10 is circular in area and corresponds approximately to the diameter of the opening of the reflector 11, which in one form of the invention may be 4 inches in diameter. Approximately in the center of such pattern of heat generated in a body positioned within the operating range of a wavelength or less from the director is also observed a relatively cold spot. The cold spot thus obtained in an energy absorbing body enables the director to be used for deep heat treatment of certain portions of a body having an irregular surface contour which may present portions of a body within the area of treatment at a shorter distance from the director than other portions within the area. For example, the human elbow shown in the drawing at 24 may be so positioned within operating range of the director 10 that its surface contour closest to the director is coincident with the colder spot in the heat pattern obtained from the director. Thus the same average amount of heating may be obtained over the entire area of treatment of the irregular surface contoured body such as the elbow positioned within operating range of the circular pattern of radiated energy.

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It should be understood that this invention is not limited to the specific embodiment described since equivalent constructions within the scope of the appended claims will occur to those skilled in the art.

What is claimed is:

1. Means for radiating electromagnetic energy comprising: a bushing having a transverse bore passing completely through said bushing and an axial bore passing partially therethrough and communicating with said transverse bore; a reflecting member mounted at one end of said bushing; a transmission line mounted in and passing completely through the transverse bore of said bushing; and a radiating stub member connected to said transmission line and projecting into said reflecting member through the axial bore of said bushing; said reflecting member comprising a portion of a sphere; and said stub projecting into said reflecting member a distance substantially equal to a quarter of the diameter of said sphere.

2. Means for radiating electromagnetic energy comprising: a bushing having a transverse bore passing completely through said bushing and an axial bore passing partially therethrough and communicating with said transverse bore; a reflecting member mounted at one end of said bushing; a coaxial transmission line mounted in and passing completely through the transverse bore of said bushing; and a radiating stub member threadedly connected to the central conductor of said transmission line and projecting into said reflecting member through the axial bore of said bushing; said reflecting member comprising a portion of a sphere; and said stub projecting into said reflecting member a distance substantially equal to a quarter of the diameter of said sphere.

HILMER C. LINDAHL.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,281,274	Dallenbach et al.	Apr. 28, 1942
2,446,982	Pound	Aug. 10, 1948
2,586,754	Wild	Feb. 19, 1952
2,586,827	Karlson	Feb. 26, 1952