Sept. 8, 1970 | K. FRITZ | 3,527,227

MICROWAVE ELECTRODES FOR MEDICAL THERAPY

Filed Sept. 19, 1966 | 2 Sheets-Sheet 1

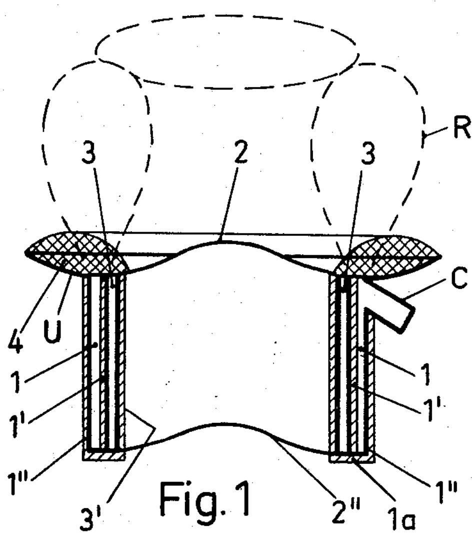

Fig. 1

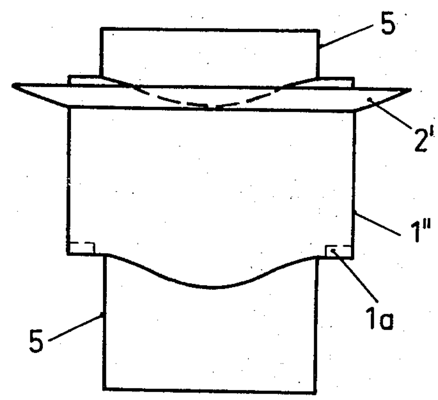

Fig. 2

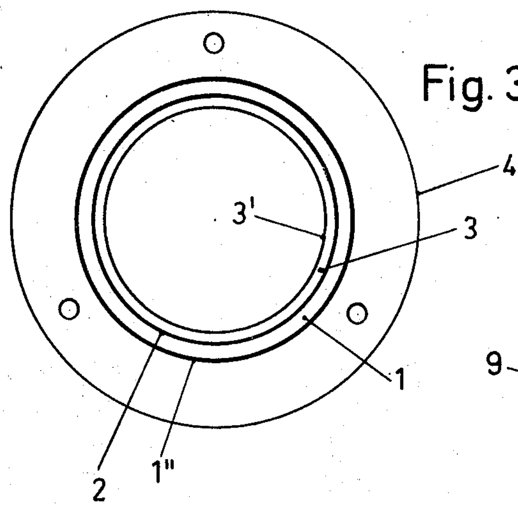

Fig. 3

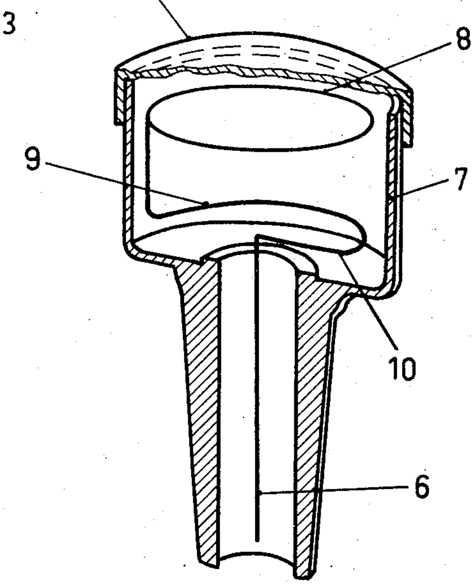

Fig. 4

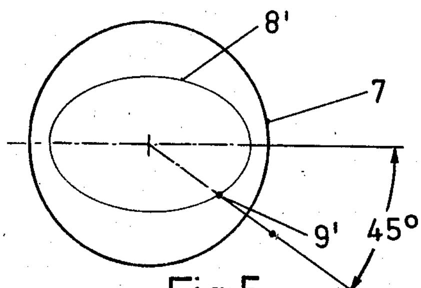

Fig. 5

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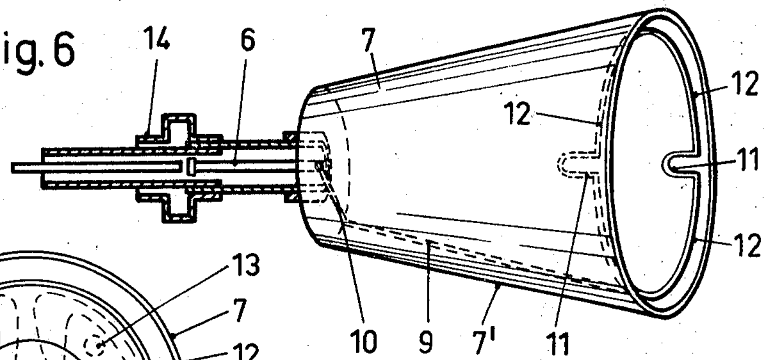
Fig. 6



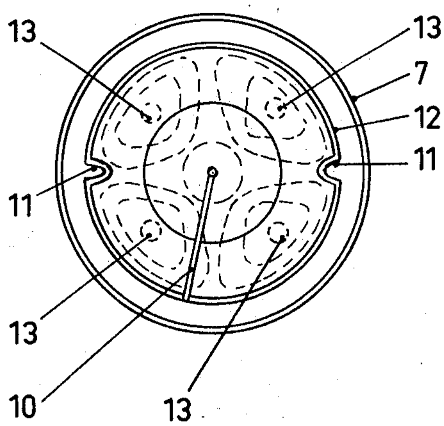


Fig. 7

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MICROWAVE ELECTRODES FOR MEDICAL THERAPY

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Int. Cl. A61n *00;* H05b *9/06*
U.S. Cl. 128—410 3 Claims

ABSTRACT OF THE DISCLOSURE

A radiator element, for example in form of a pair of concentric cylinders, a cylinder with a wire therein, is formed such that a slot effect is obtained; the slot is dimentioned and arranged to be out of resonance with a supply frequency, so that radiation from one slot region will be superimposed upon the radiation of another slot region, to provide a radiation pattern in a well defined region of the body, to which the radiator element is applied.

The present invention relates to electrodes, or antennas to radiate microwave energy for use in microwave therapy.

The electrodes, according to the present invention, consist of an envelope, or casing of conductive material which is formed with radiating slots. Radiation is emitted to the outside of the envelope through the slots, and can be beamed to a desired direction, for example towards a desired part of the human body, or to other objects to be treated, or irradiated with microwaves. The electrodes according to the invention enable the application of microwaves in the medical field because they permit the application of microwaves in various specific beam patterns to a well defined spot to be treated, so that no energy is lost, and stray energy can be avoided. Thus, a supply of microwave energy at about 10 watts, requiring apparatus which in the aggregate weights only about 1½ kg. is feasible, although equipment having an equal effect, and not being capable of presenting microwave energy in well defined regions may require total energy of from 100 to 150 watts, involving equipment weight of upwards of 12 kg.

It is an object of the present invention to provide antenna radiators for microwave frequency energy which are efficient, capable of directing energy in a predetermined pattern and location, and additionally of sufficient small size and light weight to be useful in medical applications.

Briefly, in accordance with the present invention, radiating slots or slot regions of special form and configuration are provided in antenna elements and dimensioned such that they are radiating out of phase, and out of frequency with respect to each other but in such a manner that the radiation from any one of the slots will add to that of any other, so that the total radiation diagram, representing the radiation effect as a whole will be as desired. The radiator element itself may have various forms; for example, a ring-shaped slot radiator with circular polarization may be provided, having a minimum of radiation in the axial direction which, when properly shielded, can be used to irradiate the sinus cavities surrounding the eye, leaving the eye however free of radiation.

Radiating slots, as such, are known and have been used heretofore with dimensions arranged to resonate at the frequency to be used. The narrow radiating slots, according to the present invention, are not in resonance with the radiation and produce a combined radiation pattern which, when viewed from a point outside of the radiation chamber, will be a composite of the radiation from each one of the slots, each one emitting radiation in a certain direction with a certain polarity, at a certain amplitude and phase. When a number of such slots are used, which have different directions of radiation, the effects of radiation of these slots with respect to the point outside of the chamber will add, so that a total radiation diagram representing the effect of the radiator as a whole can be obtained.

The structure, organization and operation of the invention will now be described more specifically in the following detailed description with reference to the accompanying drawings, in which:

FIG. 1 is a longitudinal, cross sectional view through a circular electrode in accordance with the present invention;

FIG. 2 is a side view of the electrode of FIG. 1, illustrating a modification;

FIG. 3 is a plan view of the electrode of FIG. 1;

FIG. 4 is a sectional, perspective view of a circular electrode illustrating another embodiment;

FIG. 5 is a schematic plan view of another embodiment;

FIG. 6 is a partly perspective, partly schematic view of another embodiment; and

FIG. 7 is a plan view of the electrode of FIG. 6, and indicating a radiation pattern.

Referring now to the drawings, and more particularly to FIGS. 1 and 2: electrodes **1′**, **1″**, cylindrical in shape, are separated by a gap forming a slot at the upper end in FIG. 1, and are closed, at the bottom, to provide a cavity in the form of a cylindrical ring therebetween. The effective axial length of the cavity is $\lambda/4$; the effective length is equal to the axial length, when the gap is an air gap, but may be reduced if the cavity is filled with a dielectric material. The upper opened rim of the cavity is curved to fit the contour of the object which is to be irradiated. FIG. 1 illustrates a curvature to fit over the human eye. The cavity has an outer metallic wall **1″**, with an upper open slot. A ring-like extension **2′** (FIG. 1) is provided to bear against the human body; extension **2′** may be covered with an elastic covering **4**, such as soft rubber or foamed plastic. A representative radiation diagram is indicated by dotted lines **R**; the radiation, as appears from the diagram, is in form of a ring, with no radiation emanating from the center. Excitation power to obtain the radiation is applied by connection to a coaxial cable at point C, as well known in the art. The polarization of the radiation will be circular. As each dipole element of the slot has a corresponding dipole element oscillating with the same amplitude, but opposite in phase, radiation along the central axis is a minimum. This minimum may, however, be distributed by reflections at the surface of the body to which the electrode is applied; if the eye is deeply set into the head, residual radiation may fall thereon. A second resonance chamber **3** formed by inner wall **1′** of the main resonance chamber **1**, and by a further cylindrical metallic element **3′** is coupled, by such residual radiation, to oscillate in a phase which will broaden and deepen the radiation diagram R, and effectively remove any axial components of radiation. FIG. 2 illustrates a slightly different version of the electrode of FIG. 1, and an improvement, in that within the inner cylinder **3′** is shown an elongated element **5**, slidable within cylindrical wall **3′**. Spacing from the cylindrical wall can be obtained by small dielectric elements, not shown, as well known in the art. The upper rim of wall **1′**, curved to fit the eye, is shown at **2**. The lower rim, illustrated at **2″**, is curved to conform to the contour of the upper rim **2** so that the axial length of the cavity between wall **1′** and wall **1″** is maintained. Element 5 (FIG. 2) additionally shields the eyeball from radiation.

The whole electrode may be made from aluminum, galvanized plastic or the like, and may be arranged with a handle to be hand-held and to be pressed against the region to be irradiated, for example against the head of a patient around the eye, by compression of resilient ring 2″, so that the eye may be opened freely. Since the lower end of the electrode unit may be open, that is only the cavity bounded by walls 1′, 1″ need be closed as shown at 1*a* (FIG. 1), the eye may be opened freely and the patient can look beyond the electrode. This point is of particular importance for the feeling of safety and security of the patient. It is also possible to fasten or secure the radiating electrode to a special belt or holding element, so that it can be secured to the head if radiation is to extend for an appreciable period of time.

FIG .4 illustrates another form of an electrode having a circular slot, to produce circular and linearly polarized radiation. This electrode contains a central supply wire **6**, to be connected to a coaxial cable as known in the art. Wire **6** is connected to a radiation wire **8**, of approximately circular outline, located within a cavity **7** which is cup-shaped, and forming a reflector. The circumferential length of wire **8** is preferably $2\times\lambda/2$; ring **8** is connected by means of a mechanically strong wire **9**, extending downwardly into the cup and then in a half-turn around the circumference to a radial spoke wire **10** and then to central conductor **6**, as shown in FIG. 4. The wire **9**, and the metallic wall together form an unsymmetrical Lecher system, having a fixed wave resistance. Wire **10** has a length of $\lambda/4$, and a coaxial cable formed of the metal extension of cup **7** and wire **6** has preferably the same resistance.

The system of FIG. 4 is adapted to radiate with two components, namely with two $\lambda/2$ dipoles, connected in parallel with a linear vector sum in linear polarization, and also at the same time as a homogeneous loaded ring in a ring-shaped field. The ring-shaped field exists between the wall and the antenna ring and is circularly polarized with a minimum of radiation in the central axis, similar to the embodiment of FIGS. 1 and 2. The edge of electrode **7** again may be padded, for example by means of foamed rubber **7′**, which may also be formed to extend across the entire electrode to seal the element against dirt or contamination, and as schematically indicated in FIG. 4.

The electrode wire **8** of FIG. 4 need not be circular; referring to FIG. 5, approximately the same amplitude of radiation for both circular and linear polarization can be obtained when the ring has preferably an elliptical shape, and connected to the central conductor **9** at a point about 45° with respect to the larger axis of the ellipse. Such a wire **8′**, connected at point **9′**, and the geometric relationship of the wire to the electrode cup **7** is illustrated in FIG. 5.

FIG. 6 illustrates another embodiment of an electrode in cup shape, utilizing similar principles as shown in FIG. 4. It permits a larger field to be applied to the human body, and thus can result in a larger area over which the blood circulation is to be improved by radiation. The total energy to be used will be the same as that in the electrode of FIG. 4. Referring now to FIG. 6, the radiating electrode, or antenna, contains a ring **12** twice the length of the ring **8** in FIG. 4, that is a length of four $\lambda/2$. By inserting small circumferential discontinuities, in the form of re-entrant, U-shaped bends **11**, ring **12** can cover a surface three times as large as the electrode of FIG. 4 having ring **8** therein. The wave length to be used with such an electrode can be about 12 cm. (S-band). The individual portions of this ring radiator

are oscillating in phase opposition, due to the double wave length wire; the radiation, thus, will be practically zero at any appreciable distance from the electrode, while close to the electrode, the radiation will have four distinct maxima **13**, as schematically illustrated in FIG. 7. The total energy of radiation, although the same as that of the electrode of FIG. 4, is now concentrated at the four spots **13**. As a result of the paths of nerves, muscles, and blood vessels in the human body, which extend in many various directions, and are interlaced, the human body does not react to the four maxima, spots **13**, separately, but rather reacts by a general rise of temperature in the entire region covered by electrode cup **7**. Blood cicula-tion is therefore increased over a larger area, the reaction of the body being as if the energy supplied would be three times as much as that of the energy of the electrode of FIG. 4; of course, the penetration of the energy will be shallow. Such shallow penetration is sufficient for most therapeutic use. The electrode permits application of microwave energy at minimum power level. Both the electrodes of FIG. 4 and FIG. 6 may be covered by a plastic, or other suitable material **7′** for ease of cleaning; in the alternative, paper or other disposable covers may be used. A conical handle, schematically illustrated in FIG. 4, may be arranged. A suitable impedance matching element **14**, shown in FIG. 6, may be incorporated in such a handle.

What is claimed is:

1. Therapeutic device to apply radiation to a human body comprising

- a radiator element formed by a cylindrical body open at one side, and cup shaped;
- a wire having a circular portion located within said cylindrical element, closely spaced from the wall therefrom, so that a gap is formed between said cylindrical element and said wire; and
- means supplying microwave energy at a predetermined frequency to said cylindrical element and said wire, said gap forming radiating slot regions dimensioned and arranged with respect to the microwave energy supplied to be out of resonance therewith to provide a defined radiation pattern at a desired region of the body.

2. Device as claimed in claim **1** wherein said wire, along its circumference, is formed with re-entrant bends to provide circumferential discontinuities, the total length of the wire at its circumferential direction being about twice the wave length at said predetermined frequency.

3. Device according to claim **1** wherein the wire within said cylindrical cup-shaped element is elliptical, said elliptical wire being connected to said supply of microwave frequency at a point angled 45° with respect to the longitudinal axis of the ellipse, whereby the electrode will radiate with linear and circular polarization.

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