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DIATHERMY APPLICATORS

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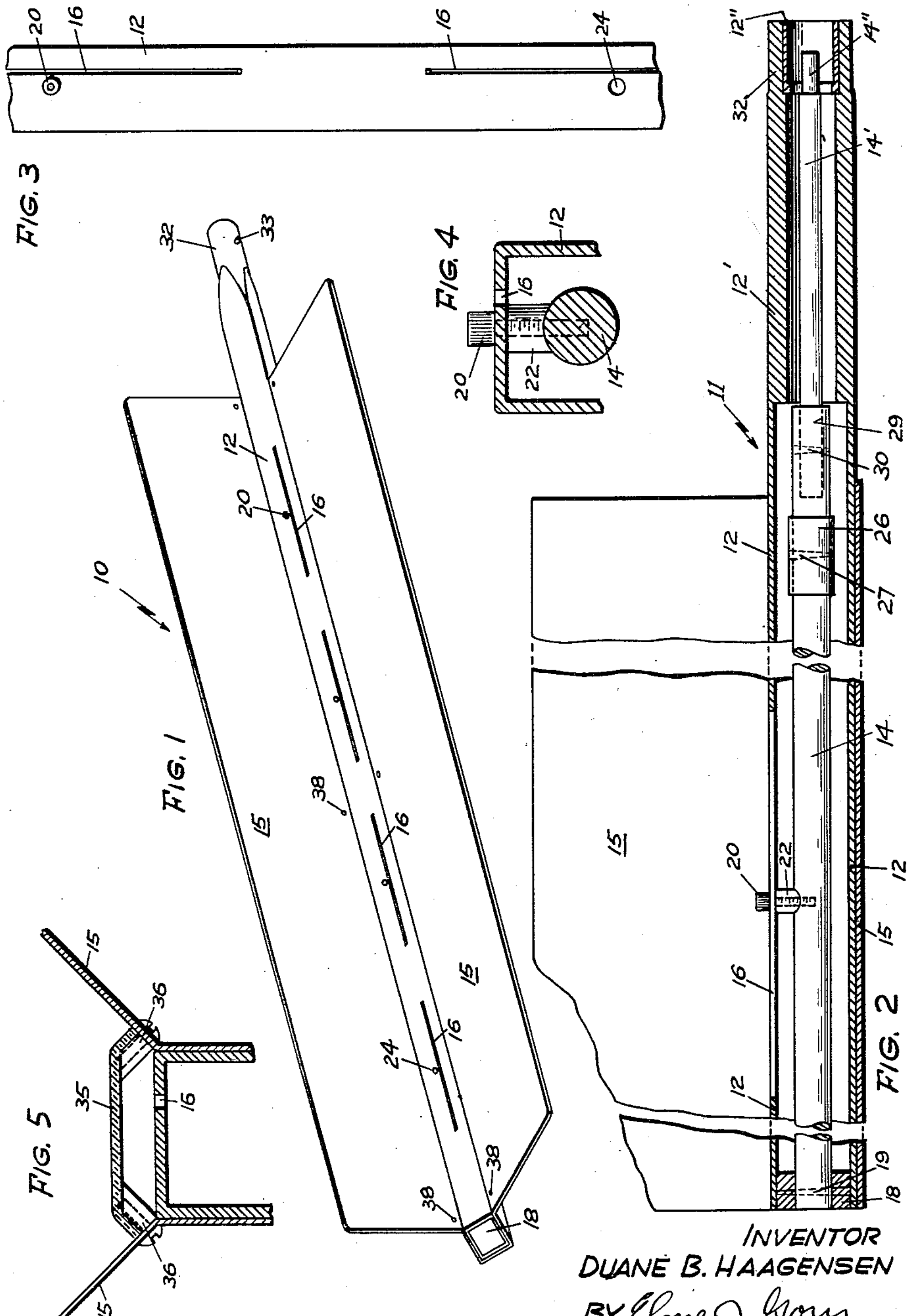

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DIATHERMY APPLICATORS

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This invention pertains to a diathermy applicator and, more particularly, pertains to a coaxial line antenna which is easy to fabricate and which is capable of producing a relatively uniform near field necessary for proper diathermy treatment of living tissue.

In the field of microwave diathermy it is desirable to produce uniform heating of the tissue placed in the vicinity of the energy radiating means. Uniformity of heating becomes increasingly difficult to achieve as the area of the tissue increases. Previous diathermy directors have been of limited effectiveness in treating tissue of large area such as the lumbar region or entire portions of the arm or leg because of this difficulty in obtaining a near field radiation pattern uniform over a wide area.

In accordance with this invention, a coaxial line slotted antenna is employed having a square outer conductor to which is connected a reflector element. A reflector element is used in order that the radiation from the antenna will not be omnidirectional but will be directed over a limited area. It has been found that the combined use of a slotted coaxial line with a square outer conductor and a reflector element for limiting the angle of radiation produces a relatively uniform near field radiation pattern over a substantial area with consequently uniform absorption of microwave energy and heating of the tissue.

The inner conductor of the coaxial line should be capable of being machined and assembled readily. The characteristic impedance of a coaxial line is inversely proportional to the square root of the capacitance of the line. By making the outer conductor of a coaxial line of square cross section having a width equal to the diameter of the circular outer conductor of a conventional coaxial line, the total capacitance between inner and outer conductor is decreased. In other words, for a given size line and a given characteristic impedance the inner conductor of a coaxial line having an outer conductor of rectangular cross section is greater than the inner conductor of the usual circular coaxial line; the machining of the inner conductor and the assembly of the inner conductor within the outer conductor is thereby facilitated.

Referring to the drawings:

Fig. 1 is an isometric view of an embodiment of the subject invention;

Fig. 2 is a diagrammatic representation, partly in section, of the embodiment shown in Fig. 1;

Fig. 3 is a fragmentary plan view of a portion of the antenna shown in Figs. 1 and 2;

Fig. 4 is a view illustrating certain details of mounting the inner conductor of the coaxial line antenna; and

Fig. 5 is a detail view showing the manner of securing a cover plate over the slotted face of the antenna.

The antenna 10 comprises a coaxial line 11 whose outer conductor 12 is of square cross section and whose inner conductor 14 is a cylindrical rod which, although shown as a solid rod, may be tubular. A substantially V-shaped reflector 15 is bent in the manner shown in Fig. 1 so as to surround three faces of outer conductor 12. The edges of the reflector in contact with conductor 12 are fastened

thereto, as by welding. The entire antenna, including reflector, is preferably made of a material of low density and high electrical conductivity, such as aluminum. The remaining face of conductor 12 contains a plurality of spaced narrow resonant slots 16 whose length, width and spacing will depend upon the microwave operating frequency and the type of radiation pattern desired. In one application, in which the operating frequency was approximately 2450 megacycles, each of the four slots was approximately 8.5 centimeters long and one millimeter wide and the spacing between centers of adjacent slots was approximately 12.6 centimeters or approximately one wave length. The slots are arranged with their longitudinal axes collinear and parallel to the longitudinal axis of the coaxial line. As shown in Fig. 3, the slots are displaced slightly from the center line of line 11; this displacement is a mechanical expedient to permit a good mechanical spacing of the inner and outer conductors.

A description of the manner of mounting inner conductor 14 within outer conductor 12 will now be given. A square plug 18 is mounted at one end of line 11 by means of a taper pin 19 which passes through a taper bore in conductor 14. This plug is of substantially the same dimensions as the inner dimensions of conductor 12 and serves not only as a support for inner conductor 14, but also to prevent the access of foreign matter into the line.

At intervals along the inner conductor equal to the spacing between transverse center lines of adjacent slots and arranged to line up with the center of each slot, a plurality of holes is bored and tapped to receive threaded pins 20. Between the inner surface of conductor 12 and the periphery of inner conductor 14 at each location of a tapped hole in conductor 14, a tubular collar or spacer 22 is inserted. As shown in Fig. 4, the bottom edge of spacer 22 is so shaped as to conform to the circular periphery of the inner conductor. A plurality of holes 24 is cut in the slotted face of the outer conductor 12 in alignment with the holes in conductor 14; holes 24 are located on the longitudinal center line of the slotted face 12 of line 11 and opposite the center of the corresponding slot, as shown in Fig. 3. Pins 20 are inserted through corresponding holes 24 and spacers 22 and screwed into the threaded holes of conductor 14 until the spacer 22 is firmly maintained in position. The head portion of each pin 20 is centered about the longitudinal center line of the slotted face of conductor 12 and opposite the center of the corresponding slot. Pins 20, in addition to supporting inner conductor 14 in proper spatial relationship with respect to outer conductor 12, also serve as probes for coupling energy from the lines to the corresponding slot.

At the end of coaxial line 11 remote from plug 18 an impedance matching section of gradually decreasing cross section is employed to match the coaxial line antenna to a power supply line. The section includes a choke 26 in the form of a tubular sleeve surrounding the main portion of inner conductor 14 and secured thereto by a taper pin 27. As shown in Fig. 2, an extension 14′ of inner conductor 14 is inserted in a recess 29 in one end of conductor 14 and held firmly in contact with the latter by one or more taper pins 30. An extension 14″ of the inner conductor is formed by machining down the end of conductor 14′ as shown in Fig. 2 and is of proper size for engagement with a standard coaxial line connector. Alternately, the extension 14″ could be connected to extension 14′ in the same manner that extension 14″ is connected to conductor 14.

Similarly, the internal periphery of outer conductor 12 is tapered in steps having a first reduced portion 12′ and a second reduced inserted portion 12″. As previously stated, the coaxial line 11 is preferably made of aluminum which is a soft material. In order to provide a good bearing surface when the end **32** of coaxial line is connected to a coaxial connector, the inserted portion **12"** comprises a cyindrical sleeve of a hard metal, such as brass, which is inserted in the end of the coaxial line as shown in Fig. 2. The end portion **32** of the coaxial line is machined round as shown in Fig. 1, so that connection may be made to a standard coaxial connector (not shown). Diametrically opposed guide pins **33** mounted on the periphery of the round end portion **32** of the outer conductor are adapted to fit into corresponding slots in the aforesaid coaxial connector.

Although theoretically unnecessary for proper and efficient operation, a thin cover strip **35** (see Fig. 5) of a material transparent to microwave energy, such as polystyrene, is mounted over the slotted face of the coaxial line. This cover strip prevents the entrance of dust and other foreign matter by way of the slots which would not only alter the dielectric constant of the coaxial line but alter the effective dimensions of the radiating slots and, consequently, affect the beam pattern. Cover strip **35** also protects the operator or patient from severe burns which would be received if contact were acidentally made with the high voltage existing across opposite edges of the slots. The cover strip is fastened to both sides of reflector **15** by means of screws **36** inserted in holes **38** in the reflector. The only restriction on the dimensions of the plastic cover strip is that it not be so thick as to alter the dielectric constant of the antenna. In practice, cover strip **35** is as long as the reflector and approximately one-sixteenth inch thick.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A microwave antenna comprising a coaxial line having a circular inner conductor and a rectangular outer conductor, one face of said outer conductor containing a single array of slots resonant at the operating frequency and spaced longitudinally along said line, means for supporting said inner conductor in fixed spatial relationship with respect to said outer conductor means included within said means for supporting for coupling energy from said line to said radiating slots, and reflector means attached to opposite edges of the slotted face of said outer conductor for restricting the angle of radiation from said antenna.

2. A microwave antenna comprising a coaxial line having a circular inner conductor and a rectangular outer conductor, one face of said outer conductor containing a single collinear array of spaced energy radiating slots resonant at the operating frequency and having their longitudinal axes parallel to and displaced from the central longitudinal axis of said line, means for supporting said inner conductor in fixed spatial relationship with respect to said outer conductor, means included within said means for supporting for coupling energy from said line to said radiating slots, and reflector means attached to oppostie edges of the slotted face of said outer conductor.

3. A microwave antenna comprising a coaxial line having a circular inner conductor and a rectangular outer conductor, one face of said outer conductor containing a single collinear array of slots spaced along the longitudinal axis of said line, means including a plurality of spaced pins securely attached to said inner and outer conductors for maintaining a fixed spatial relationship between said inner and outer conductors, said pins being positioned in energy-coupling relationship with said slots, and a reflector having a pair of angularly disposed plates attached to opposite longitudinal edges of the slotted face of said outer conductor.

4. A microwave antenna comprising a coaxial line having a circular inner conductor and a rectangular outer conductor, one face of said outer conductor containing a collinear array of slots spaced along the longitudinal axis of said line, a plurality of spaced pins having a head portion resting against the outer surface of said outer conductor and a threaded portion extending through said outer conductor into said inner conductor, said pins being positioned in energy-coupling relationship with said slots, and a reflector having a pair of angularly disposed plates attached to opposite edges of the slotted face of said outer conductor.

5. A microwave antenna comprising a coaxial line having a circular inner conductor and a rectangular outer conductor, one face of said outer conductor containing a collinear array of narrow slots resonant at the operating frequency and having their longitudinal axes parallel to and displaced from the central longitudinal axis of said line, a plurality of tubular spacers positioned between said inner and outer conductors, a plurality of spaced pins having a head portion resting against the outer surface of said outer conductor and a threaded portion extending through said outer conductor and said spacers into said inner conductor, said pins being positioned in energy-coupling relationship with said slots, and a reflector having a pair of angularly disposed plates attached to opposite edges of the sloted faces of said outer conductor.

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