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MICROWAVE CIRCUIT CONTROLS

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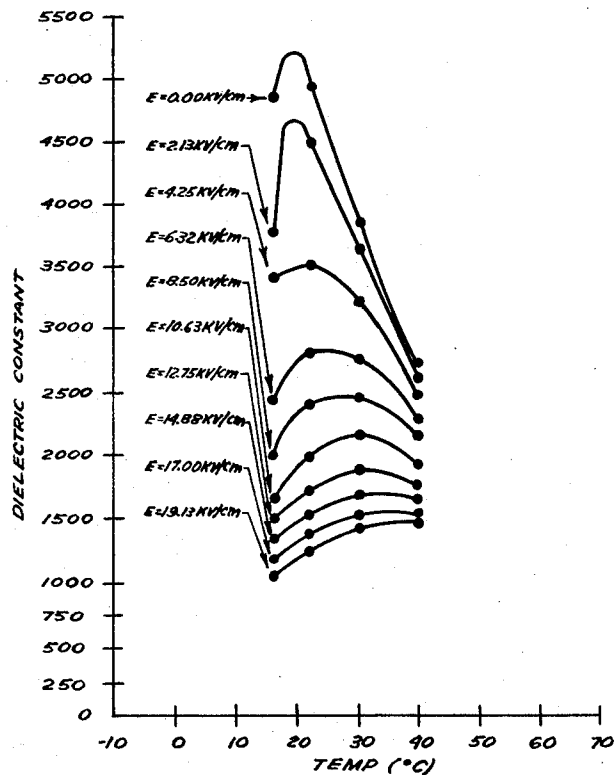
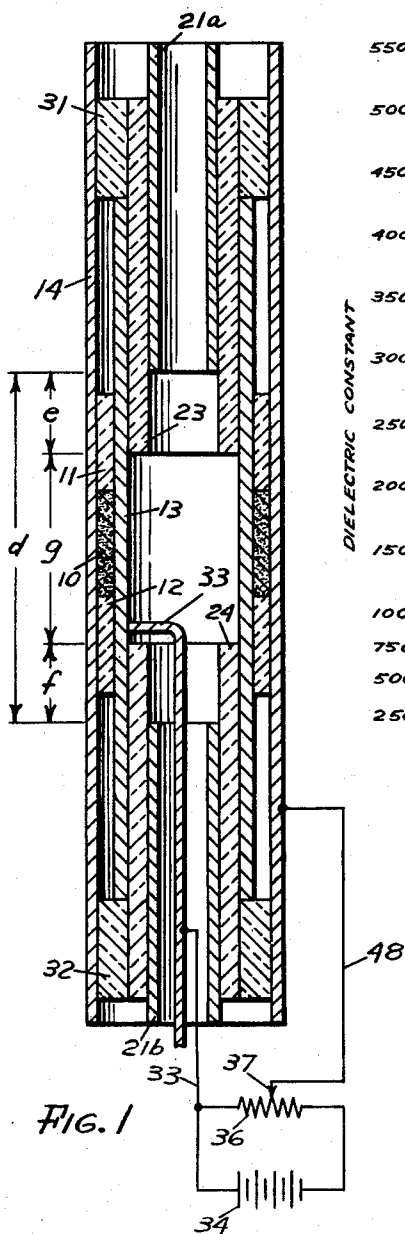


FIG. 2

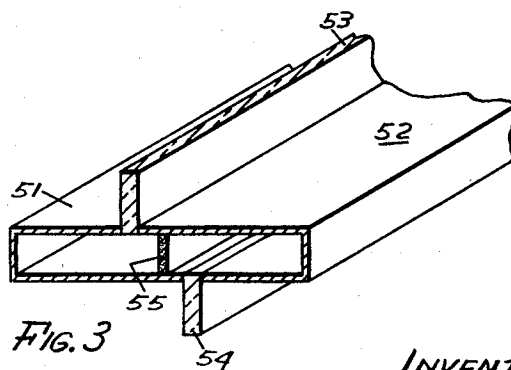


FIG. 3

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MICROWAVE CIRCUIT CONTROLS

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This invention relates to radiant energy, and particularly to the control of the transfer of radiant energy in microwave form, and to the composition and structure of component parts entering into the attainment of such energy transfer control.

The invention is characterized by the utilization of a frequency control method involving application of the principles of behavior of certain electric field-responsive materials as, for example, the titanates of barium and strontium, and utilizing such materials, particularly when mixed and sintered, to form a component part of a coaxial transmission line or wave guide, and to vary the electrical length of such energy conduit as desired, and thereby maintain a desired microwave frequency pattern. When the invention is so applied, it functions to vary the electrical length of the energy conduit by bringing about a regulated degree of change in the dielectric constant of the electric field-responsive component of the conduit structure, and it does so in a manner that does not require any change in the physical length of the conduit, or in the physical positioning thereof.

The invention also includes specific means for bringing about such regulated degree of change in the dielectric constant of the above-described field-sensitive control component of the transmission line structure. As illustrated herein, such means includes a source of high-voltage current, circuit connections for utilizing said current source to create an electric field embracing said field-sensitive control component, and means for varying the intensity of said electric field by varying the voltage applied through said circuit connections.

These and other characteristics and advantages of the invention will be better understood upon reference to the following description of the embodiment of the invention illustrated in the accompanying drawing wherein:

Fig. 1 is a longitudinal sectional view of a section of coaxial line embodying the invention;

Fig. 2 is a collection of curves showing the effect of voltage and temperature changes upon the dielectric constant of a tested control material at various voltage levels; and

Fig. 3 shows an embodiment of the invention in a wave guide structure.

Referring first to Fig. 1, the field-sensitive control material is shown in the form of a tubular element 10 sandwiched between abutting tubular pieces 11 and 12, with all three pieces being in nested relation to a pair of coaxially disposed tubes 13 and 14 of considerably longer extent, and constituting cooperating parts of the inner and outer sections of a coaxial transmission line for transfer of R.F. energy to or from a radiating or receiving antenna (not shown). The field-sensitive element 10 is preferably a molded and sintered mixture of titanates, such as barium and strontium titanates. When these are combined in a ratio of 73% BaTiO₃ to 27% SrTiO₃, the sintered product has the characteristic of changing its dielectric constant in accordance with electric field application in the manner indicated by the several curves shown

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in Fig. 2, when the voltage and temperature values are as shown. To obtain equivalent response at different temperature ranges (up to 140° C.) the 73-27 ratio would, of course, be varied accordingly.

The control element 10 is soldered or otherwise suitably bonded for intimate electrical energy exchange with respect to components 13 and 14 of the inner and outer coaxial line elements, respectively, while the abutting tubular sections 11 and 12 are each of a length corresponding to one-quarter wave length at the operating frequency (e.g. 3000 mc.) for which the system is designed. The material comprising these abutting sections 11 and 12 is preferably a ceramic substance of such dielectric qualities as to afford a good impedance match with the adjoining sections of the transmission line.

The central conductor, instead of being continuous within the coaxial line, is formed in two sections, 21a and 21b, separated by a distance "d" that is somewhat longer than, but embraces, the axial limits of the control element 10 and its abutting impedance-matching segments 11 and 12. Bridging the peripheral gaps between the central conductor sections, on the one hand, and the intermediate conductor section 13 on the other, are two sleeves, 23 and 24, of insulating material, such as "Teflon" or its equivalent, providing additional impedance matching as between the said conductor sections, and also providing surface insulation along the axial distances "e" and "f," respectively, where the conductors do not overlap.

The portion of conductor 13 lying between the facing ends of the insulating sleeves 23 and 24 constitutes a non-insulated coaxial line segment of "g" length, and of relatively larger inner diameter, as contrasted with the smaller diameter of line sections 21a and 21b. This increase in diameter at the region adjacent the voltage-sensitive material 10 has two major advantages: first, it reduces the magnitude of the voltage necessary to establish the desired strength of electric field embracing element 10, and secondly, it facilitates maintenance of a more uniform voltage gradient throughout the area embraced by the electric field.

To provide impedance matching between the two end sections 21a and 21b, on the one hand, and the center section 13 of the central conductor, on the other, quarter-wave length bushings 31 and 32 are inserted in the annular spaces adjacent the ends of conductor 13. These bushings 31 and 32 supplement the impedance matching provided by the outer end portions of the "Teflon" insulators 23 and 24, in that they compensate for the effect of the change in diameter of the outer portion of the line, at these axial positions.

Element 33 in Fig. 1 represents any suitable form of electrical connection between an external source of electric field-establishing voltage supply, on the one hand, and bridging section 13 of the inner coaxial line 21a—21b. Battery 34 may be such external source, and may have a capacity up to 5000 volts, with the actual applied voltage, at any stage in the operating cycle, being determined by suitable regulating means as, for example, the variable resistance unit 36, one of whose terminals is connected to line 33, while the movable junction 37 of said unit is in series with the outer conductor 14 of the coaxial line, and forms part of the return path 48 to the battery 34. Although not shown, it will be understood that the field-exciting circuit 34—33—13—10—14—48—36, controlling the dielectric characteristics of material 10, will include conventional quarter-wave length stub supports for the coaxial line structure illustrated, as a protection for said structure, in view of the high voltage drop across the conductors 33 and 48.

Fig. 3 shows the invention applied to a wave guide structure having a large width-to-height ratio to minimize the applied voltage requirements for a given strength of

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field excitation. The two halves 51, 52 of the wave guide include choke sections 53, 54 filled with "Teflon" or equivalent dielectric material for reciprocal insulation effect. A very thin strip of field-responsive material 55, similar to the material 10 of Fig. 1, is placed as shown, to form the separation of the wave guide into the said half-sections 51 and 52. The middle vertical plane is chosen as the plane of location for the strip 55 for the reason that this position marks the position of maximum electric field strength, (hence maximum dielectric constant sensitivity) in the fundamental mode of wave behavior. Alternatively, the entire wave guide could be filled with the sensitive material, but to do so would create difficulties in the matter of suitably insulating the top surface from the bottom surface, and in the matter of physically constructing a wave guide of correspondingly reduced dimensions.

The structure of Fig. 3 behaves exactly as that of Fig. 1, producing variation in the electrical length of the line as applied voltage is varied.

There is provided by this invention a transmission line capable of electrical length variation over a wide range without resort to moving parts, hence free of the physical difficulties that beset mechanically tuned structures. If desired, the voltage controlled by circuit 34—33 (which circuit is, of course, applicable to Fig. 3 analogously as to Fig. 1) may be automatic, as by connecting resistance element 36 into a circuit associated with a transmitter of controllable frequency, assuming that the line is of a length corresponding to an integral number of half-wave lengths, and is shorted at its ends, to produce a resonant cavity effect. If the resonant cavity thus produced is associated with a high-frequency transmitter tube, the control of the electrical length of the line; by the method and means herein described, will also serve as a control of the frequency generated by the tube. The transmitter tube may be of the magnetron or klystron variety, or it may be of any high frequency triode type.

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 high frequency transmission line comprising, in combination, an outer conductor, a first inner conductor, a pair of second inner conductors coaxially aligned but axially separated and having a diameter less than the diameter of said first inner conductor, insulating means

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positioned between said first inner conductor and said pair of said inner conductors, means including an electric field-responsive dielectric material disposed between said outer conductor and said first inner conductor in the region between said pair of axially separated second inner conductors, and means for controlling the strength of an electric field applied to said dielectric material, said last-named means comprising a variable voltage circuit connected between said first inner conductor and a source of energizing voltage.

2. A high frequency transmission line comprising, in combination, a first inner and an outer concentrically disposed conductor, a pair of coaxially aligned but axially separated second inner conductors disposed within said first inner conductor and having a diameter less than the diameter of said first inner conductor, an electric field-responsive dielectric material interposed between said first inner and said outer conductor in the region between said pair of axially separated second inner conductors, impedance matching means abutting said dielectric material, insulating means disposed between said pair of axially separated second inner conductors and said first inner conductor, and means for varying the dielectric constant of said material to control the electrical length of said line.

3. A high frequency transmission line comprising, in combination, a first inner and an outer concentrically disposed conductor, a pair of coaxially aligned but axially separated conductors disposed within said first inner conductor and having a diameter less than the diameter of said first inner conductor, an electric field-responsive dielectric material interposed between said first inner conductor and said outer conductor in the region between said pair of axially separated second inner conductors, impedance matching means abutting said dielectric material, insulating means disposed between said pair of axially separated second inner conductors and said first inner conductor, and means for establishing an electric field of variable effect upon said dielectric material to vary the dielectric characteristics thereof and thereby control the electrical length of said line.

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