Aug. 14, 1956 R. E. CHARLES 2,759,153

RADIO FREQUENCY ELECTRIC SWITCH

Filed June 22, 1950 3 Sheets-Sheet 1

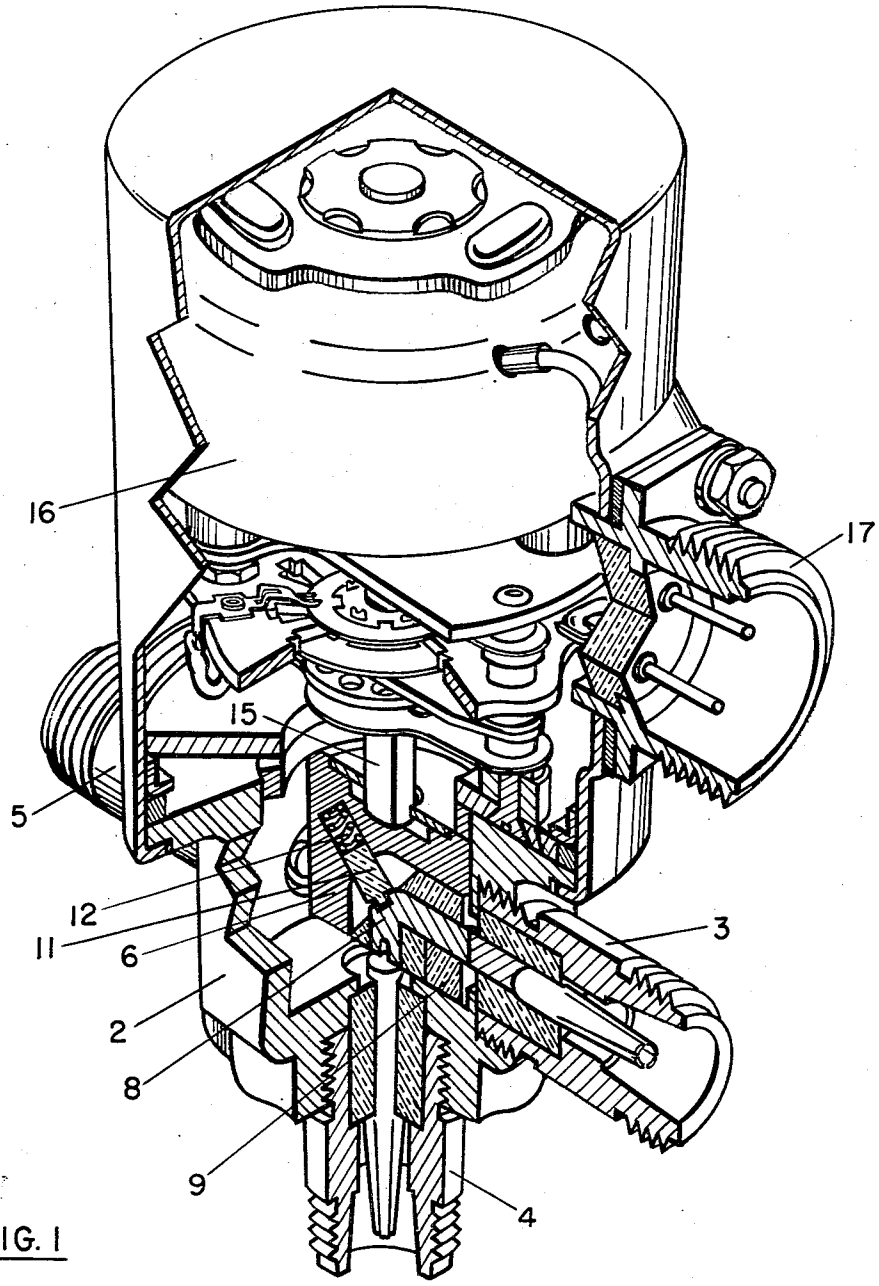


FIG. 1

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RADIO FREQUENCY ELECTRIC SWITCH

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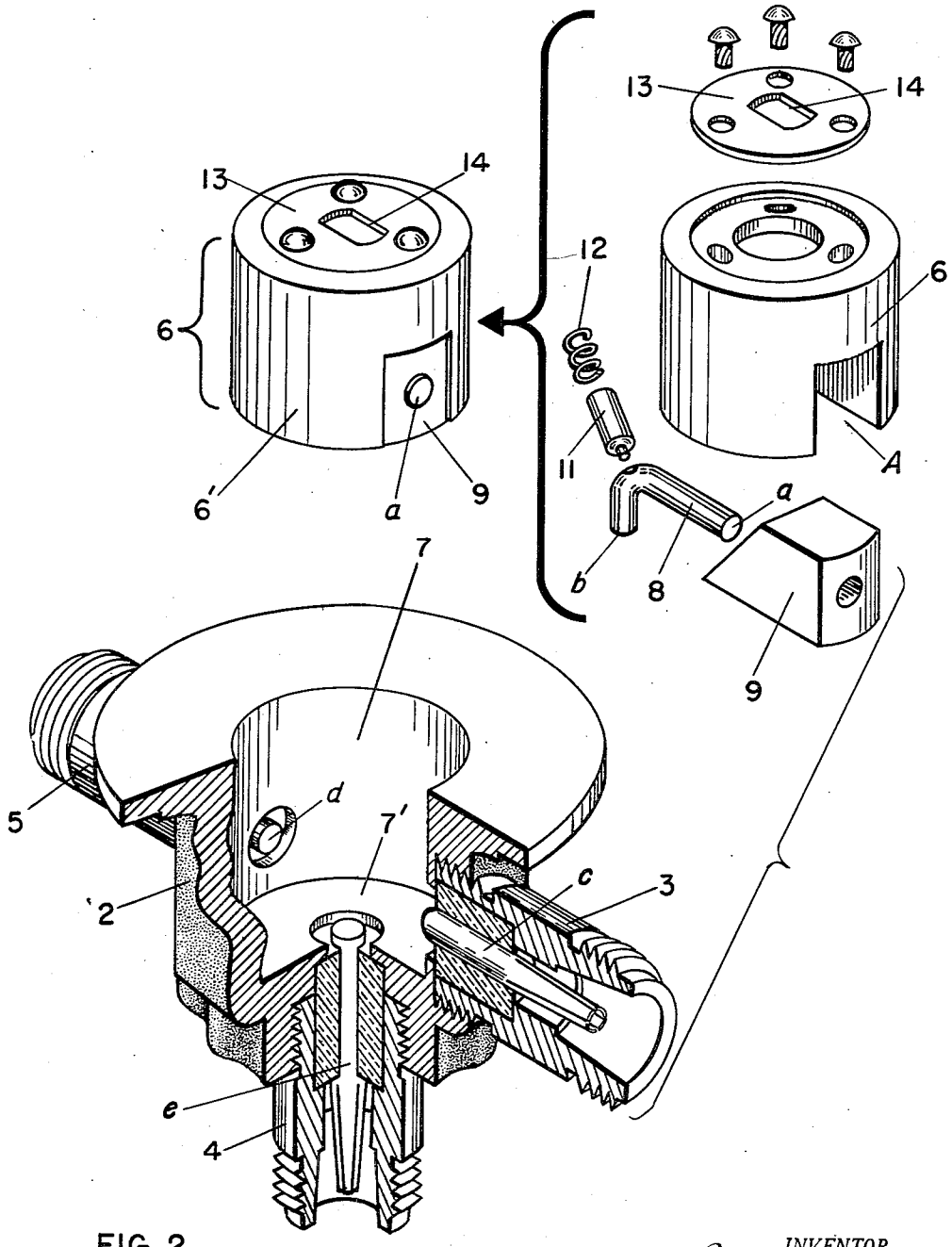


FIG. 2

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FIG. 5

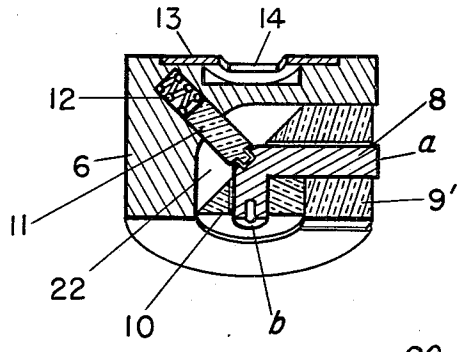


FIG. 7

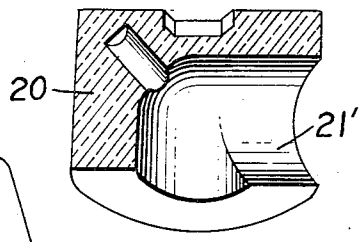


FIG. 4

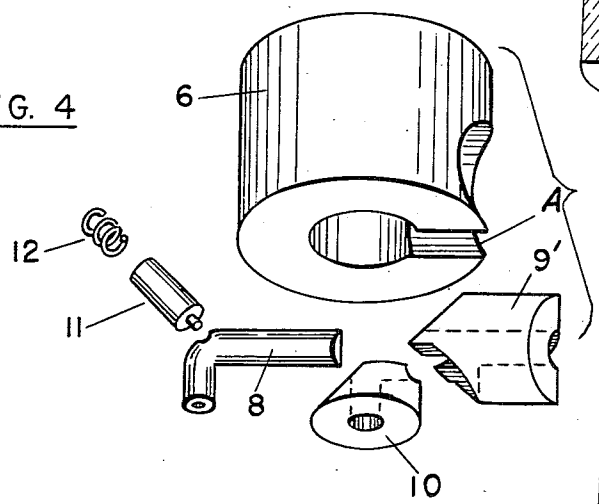


FIG. 6

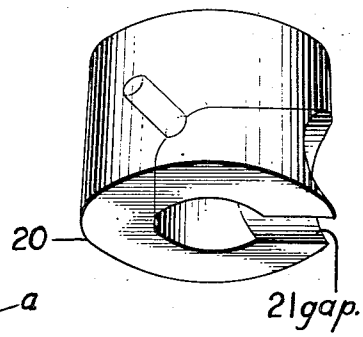
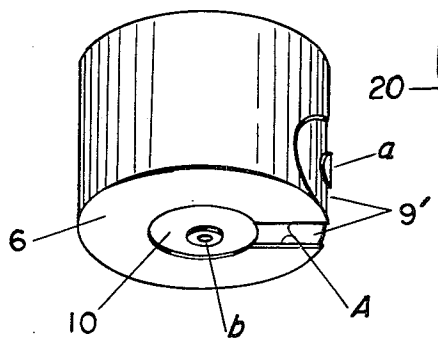


FIG. 3



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2,759,153

RADIO FREQUENCY ELECTRIC SWITCH

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Application June 22, 1950, Serial No. 169,698

10 Claims. (Cl. 333—7)

Switching in coaxial lines has heretofore been accomplished by using a movable switch member having the characteristics commonly present in round or circular coaxial lines and performing the switching operation by making and breaking the circuit at both the inner and outer conductors. Such a switching construction has been unsatisfactory for the reason that it introduces serious variations in the voltage standing wave ratio due to unpredictable variations in impedance created in the switch.

An ideal switch should have a reliable and absolute metal-to-metal bond through it to conduct the current carried by the outer conductor of the coaxial switch line. This condition has not been satisfied by any coaxial switch of which applicant has been able to learn.

Further requirements are that the impedance of the switch should be approximately equal to that of an equivalent section of the supply line, and the switch should not adversely affect the phase relationship of the current which it conducts.

In radio frequency circuits of this type carrying from, say, 100 to 10,000 megacycles, minor faults in the relation of the switch elements to each other, which would be utterly immaterial in low frequencies, can be so troublesome as to render the operation of the switch entirely unsatisfactory. Of lesser but substantial importance, is the fact that most coaxial switches designed for remote control require excessive power to operate them.

The present invention is especially concerned with the conditions above described and it aims to improve both the methods of coaxial switching and also the construction of coaxial switches with a view to approaching ideal conditions very closely.

The nature of the invention will be readily understood from the following description when read in connection with the accompanying drawings, and the novel features will be particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a perspective view of a power driven switch embodying features of this invention;

Fig. 2 is an exploded view of the switch unit per se;

Fig. 3 is a perspective view of a slightly different form of switch rotor adapted to be used in the switch body shown in Figs. 1 and 2;

Fig. 4 is an exploded view of the rotor shown in Fig. 3;

Fig. 5 is a vertical, sectional view through the axis of the latter rotor;

Fig. 6 is a perspective view of another rotor body made of plastic insulating material; and

Fig. 7 is a vertical, sectional view taken substantially through the axis of the rotor body shown in Fig. 6.

Preliminary to a detailed description of the constructions shown in the drawings, it may be pointed out that coaxial lines of both square and circular cross-sectional form are known and are in use. I have found that the principles of the square coaxial line can be used in the construction of a coaxial switch with very substantial advantages as compared to the circular forms of these switches heretofore used.

The present invention proceeds on this principle and provides a switch in which the movable element or rotor is made electrically and geometrically identical to square coaxial line construction. In such a switch the electromagnetic field is confined to the four sides of the square coaxial line. The electrical field is radial and the magnetic field is circular. Because of the longitudinal distribution of the surface current and charge in the conductors, the corresponding field distribution is referred to as "transverse electromagnetic" (abbreviated TEM) and is characterized by currents parallel to the axis. However, so long as the electromagnetic field is confined within a suitable coaxial metallic boundary it is permissible to construct the coaxial switch with one side independent of the other three sides. That is, the metallic boundary in any given cross-section need not necessarily be continuous. This permits a construction in which the switch body provides, in any switching position, a continuous conducting path for the current carried by the outer conductor of the coaxial line. But the circuit can be opened or closed simply by interrupting the continuity of the central conductor and restoring that continuity again.

Such a switch structure is illustrated in Figs. 1 and 2 in which the body of the switch is shown at **2**, preferably made of metal, and equiped with connector elements **3**, **4** and **5** by means of which the switch may be connected into one or more coaxial power supply lines as, for example, at **3** and **5**, and either may be connected to a branch line, as at **4**. These parts are all stationary and the switching operation is performed by means of some suitable movable element, preferably a rotor, the body of which is indicated at **6**.

In the form shown in these figures, the rotor body is made of metal and has the general form of a cylinder which fits snugly, but rotatably, in the rotor socket **7** in the body **2**. Extending through this body is a central conductor **8**, bent at right angles at an intermediate point in its length, and supported in an insulating block **9** which isolates it electrically from the body **6**. Thus, one of the terminal ends of the central conductor is exposed at *a*, Fig. 2, at a lateral surface of the rotor, while the other terminal end *b* is exposed at the lower axial end of the rotor. The former is positioned to make contact with either of the central conductors *c* or *d* of the connectors **3** and **5**, while the terminal *b* is adapted to make contact with the central conductor *e* of the connector **4**.

In order to improve the firmness of the contact between the rotor terminals and those of the connectors, an insulating plunger **11**, Fig. 1, is backed up by a spring **12** and bears against the central conductor **8** of the rotor at its bend or knee where the plunger pushes both end terminals of the central conductor outwardly into good contact with the corresponding conductors of the connectors **3** or **5** and the axial connector **4**. The part **8** has sufficient freedom of movement in the insulators **9** to permit this action.

For the purpose of operating the switch by power, a plate **13**, Fig. 2, is set into the upper end of the rotor body **6** and secured to it by screws, this plate being provided with a slot **14** to receive the lower end of an upright bar **15**, Fig. 1, which is driven by a small motor **16**. Power is supplied to it through a connector **17**.

A somewhat different form of rotor, better in some respects than that above described, is shown in Figs. 3, 4 and 5, and the parts corresponding to those illustrated in the latter figures are indicated by the same numerals. In this construction, the body **6** also is of metal and insulating members **9'** and **10** to take the place of the insulator **9**. They are of circular outline in transverse section and are shaped to fit together so that they effectually isolate the central conductor **8** from the metal body of the rotor.

It will be observed that whereas in prior art coaxial switches, the current has been interrupted at both the outer and inner conductors, in the switch devised by this invention the switch interrupts the current only at the inner conductor. While this cuts off the entire flow, it is a simpler construction and avoids the difficulties which always attend the making of a good contact at any point of current interruption. Here, the switch body **2** is used specifically for supporting the electric field, and the current path is maintained continuously through the switch body in all switching positions and does not have to be transmitted to the metallic body of the rotor. While some current of the outer circuit may flow through the rotor body, this element will, under these circumstances, act as a conductor for what may be referred to as a "shunt current," the main volume of current being carried by the switch body **2**.

One of the difficulties with prior art switches has been that the contact of the rotor body with the part of the switch body in which it rotates is never dependable, and this fact introduces variations in current flow which make the operation of these switches inferior. In the present construction, a gap is provided in the bottom surface of the rotor body **6**, as best shown at A in Figs. 2, 3 and 4, this gap being more or less filled by the insulator **9** or **9'**. This gap, however, is bridged electrically by the bottom **7'**, Fig. 2, of the socket **7** in which the rotor is mounted.

Consequently, current carried by the outer side of the coaxial line and coming in through the connector **3** finds a direct conducting path across the surface of the bottom **7'** where that surface is exposed at the gap A in the switches shown in Figs. 2, 3 and 4. This path for the outer current, in effect, short-circuits the longer path which the current could find if the gap A were not present, and it provides a path of low impedance, short in length, by which the current passes from the connector **3** to the connector **4** without going through the rotor. The same conditions exist, of course, when the rotor is positioned to conduct current between the connectors **4** and **5**. Also, because this path is independent of the rotor, its impedance is fixed and is not affected by the firmness or looseness of the contact between the metal body of the rotor and the encircling walls of the socket **7**.

To state the matter somewhat differently, the rotor is really a short section of a coaxial conductor with one side open at the gap A. As above pointed out, this is entirely permissible from a transmission standpoint. But, when the rotor is in its normal position in the socket **7**, then this open side is closed by the metallic bottom **7'** of the socket.

In this connection, it may also be pointed out that the conductor **8** should be centered in the insulator **9**, or in the combination of insulator pieces **9'** and **10**, and it should be positioned in substantially symmetrical relationship to the wall of the bore in which the insulator is mounted.

In some cases it may be found desirable to make the rotor body **6** of insulating material, and such a construction is shown in Figs. 6 and 7 where the rotor body is indicated at **20** as made of any one of the numerous plastics having good insulating properties and mechanical stability such, for example, as the Styrene compounds, Bakelite, Lucite, and others. As shown in Figs. 6 and 7, this body is designed to receive the central conductor **8**, shown in Fig. 5, together with its insulators **9'** and **10**, the plunger **11**, and the spring **12** which backs it up.

However, to provide the conductivity through this body which is afforded by those rotors shown in the other figures, its bore or cavity in which the insulating elements **9'** and **10** are mounted is silver-plated, or otherwise coated with conducting material, as indicated at **21'**. Such a rotor then functions in the same manner as does the rotor shown in Figs. 3, 4 and 5, and it is provided

with a gap **21**, like that shown at A in Figs. 3 and 4, which produces the same results above described.

The width of the gaps A or **21** above referred to need not be large. In a switch having a rotor an inch in diameter, a gap of from one-eighth to one-quarter of an inch in width functions satisfactorily, one of about three-sixteenths of an inch in width being preferred.

It should be observed that the insulators **9'** and **10** are so shaped as to leave an open-air space **22**, Fig. 5, in the bore of the rotor at the region adjacent to the knee of the conductor **8**. The plunger **11** extends through this space. It is here provided for the purpose of speeding up the electromagnetic wave around the longer path which it follows in making the turn around the bend of the conductor **8** so that the phase relationship of the electric field at the inner corner and the outside corner is not materially disturbed. That is the velocity of the electromagnetic wave in the dielectric media of the space **22** and the insulator **10** remains in approximately the same ratio so that the phase relationship of the electric field of the electromagnetic wave is maintained substantially unchanged.

As above indicated, an important advantage of this switch construction is the fact that it provides a fixed unbroken path for the current carried by the outer conductor of a coaxial line, which path is outside the rotor body. Part of this path is exposed at the gap or channel A at the lower end of the rotor. No current flow need go through the rotor body. The effect of this construction on the voltage standing wave ratio has been demonstrated. If this channel did not exist in the rotor, the resulting VSWR would be discontinuous with sharp peaks appearing irregularly and unpredictably across the radio frequency band, this effect being produced by poor contact between the rotor body and the switch body at the critical point of transmission of the electromagnetic wave, that is, at the meeting faces of the rotor and the switch body. The ideal switch should have an absolute metal-to-metal bond between the rotor and the switch body which, in this instance, forms the outer conductor. The channel A or **21** provided in the switches here disclosed is the nearest approach to this ideal condition because at the channel the bottom **7'** of the socket **7** forms the outer conductor for any current flowing through the switch. And that conductor is a metallic path, the continuity of which, with the adjacent connectors, is always maintained undisturbed. In this switch, the electromagnetic field pattern is confined to one switch channel only and that channel is isolated from all other channels.

An important practical advantage of this switch is that very little power is required to operate it by remote control. Also as will be obvious to those skilled in this art, the number and arrangement of the connectors with which the switch body is equipped necessarily will be varied to suit the requirements of individual situations. This construction, also, is equally applicable to wave guides and, consequently, the term "electric switch" as herein used, should be understood to include wave guides.

While I have herein shown and described a preferred embodiment of my invention, it will be evident that the invention is susceptible of embodiment in other forms without departing from the spirit or scope thereof.

Having thus described my invention, what I desire to claim as new is:

1. A radio frequency electric switch including a switch body having a metallic walled cylindrical socket therein, a plurality of radio frequency line connections in said switch body extending to the bottom surface of said socket at least one of said connections extending radially of said socket, a cylindrical switch rotor having a metallic walled radio frequency line cavity therein with a longitudinally extending open side along the bottom surface of said rotor arranged to connect two of said radio frequency line connections including at least one radially extending connection in one switch position, said rotor

being mounted in said socket and together with the metallic socket wall providing in said one switch position an enclosed radio frequency line with the metallic socket wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer peripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in said one position a radio frequency line of uniform impedance throughout its length with a continuous conducting path along the boundary of said line.

2. A radio frequency electric switch including a switch body having therein a metallic walled cylindrical socket having a plane bottom surface, a plurality of radio frequency line connections in said switch body extending to the plane bottom surface of said socket at least one of said connections extending axially of said socket and another extending radially of said socket, a cylindrical switch rotor having a longitudinally extending open sided metallic walled radio frequency line cavity with an open side along the bottom surface of said rotor arranged to connect a radially extending one of said radio frequency line connections with an axially extending one of said radio frequency line connections in one switch position, said rotor being mounted in said socket and together with the metallic socket bottom wall providing in said one switch position an enclosed radio frequency line with the metallic socket bottom wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer peripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in said one position a radio frequency line of uniform impedance throughout its length with a continuous conducting path along the boundary of said line.

3. A radio frequency electric switch including a switch body having a metallic walled socket therein, a plurality of radio frequency coaxial line connections in said switch body extending to said socket said connections having central conductor terminals exposed at said socket, at least one of said connections extending radially of said socket, a movable switch member having therein a longitudinally extending open sided metallic walled radio frequency cavity with an insulated coaxial central conductor therein arranged to connect two of said radio frequency coaxial line connections including at least one radially extending connection in one switch position, said member being mounted in said socket and together with the metallic socket wall providing in said one switch position a radio frequency coaxial line of uniform impedance with the metallic socket wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer peripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in one position a radio frequency coaxial line of uniform impedance throughout its length with a continuous conducting path along its boundary by said line.

4. A radio frequency electric switch as claimed in claim 1 in which the open sided metallic walled radio frequency line cavity is of rectangular cross sectional configuration.

5. A radio frequency electric switch including a switch body having therein a metallic walled cylindrical socket having a plane bottom surface, a plurality of radio frequency coaxial line connections in said switch body extending to the plane bottom surface of said socket, at least one of said connections extending axially of said socket and another extending radially of said socket, said connections having central conductor terminals exposed at said socket, a cylindrical switch rotor having therein a longitudinally extending open sided metallic walled radio frequency line cavity with an open side

along the bottom surface of said rotor arranged to connect a radially extending one of said central conductor terminals and an axially extending one of said central conductor terminals in one switch position, said rotor being mounted in said socket and together with the plane bottom surface of said socket providing in said one switch position an enclosed radio frequency coaxial line with the metallic bottom socket wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer peripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in said one switch position a radio frequency coaxial line of uniform impedance throughout its length with a continuous conducting path along the boundary of said line.

6. A radio frequency electric switch as claimed in claim 5 in which the open sided metallic walled radio frequency line cavity in said rotor is of rectangular cross sectional configuration with said rotor being mounted in said socket and together with the plane bottom surface of said socket providing in said one switch position a rectangular radio frequency line with the metallic socket wall forming a continuous unbroken side of the boundary of said line.

7. A radio frequency electric switch as claimed in claim 1 in which the metallic walled socket surface provides a closure for the exposed end of one of said radio frequency line connections in a second switch position wherein said one connection is not connected to said radio frequency line cavity.

8. A radio frequency electric switch having therein a metallic walled cylindrical socket having a plane bottom surface, a central axially extending radio frequency line connection extending to said plane bottom surface and a plurality of radially extending radio frequency line connections extending to the cylindrical walls of said socket at the plane bottom surface, a cylindrical switch rotor having a radially extending open sided metallic walled radio frequency line cavity arranged to connect a radially extending radio frequency line connection with said axially extending radio frequency line connection in one switch position, said rotor being mounted in said socket and together wth the metallic socket wall providing in said one switch position an enclosed radio frequency line with the metallic socket wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer peripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in said one position a radio frequency line of uniform impedance throughout its length with a continuous conducting path along the boundary of said line.

9. A radio frequency electric switch having therein a metallic walled cylindrical socket having a plane bottom surface, a central axially extending radio frequency line connection extending to said plane bottom surface, and a plurality of radially extending radio frequency line connections extending to the cylindrical walls of said socket at the plane bottom surface, said connections having central conductor terminals exposed at said socket, a cylindrical switch rotor having a radially extending open sided metallic walled radio frequency line cavity with a central conductor arranged to connect a radially extending radio frequency line connection with said axially extending radio frequency line connection in one switch position, said central conductor being bent at right angles and provided with one terminal exposed at the axial surface of the rotor and the other terminal exposed at the lateral surface of the rotor, said rotor being mounted in said socket and together with the metallic socket wall providing in said one switch position an enclosed radio frequency line with the metallic socket wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer pe-

ripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in said one position a radio frequency line of uniform impedance throughout its length with a continuous conducting path along the boundary of said line.

10. A radio frequency electric switch having therein a metallic walled cylindrical socket having a plane bottom surface, a central axially extending radio frequency line connection extending to said plane bottom surface, and a plurality of radially extending radio frequency line connections extending to the cylindrical walls of said socket at the plane bottom surface, said connections having central conductor terminals exposed at said socket, a cylindrical switch rotor having a radially extending open sided metallic walled radio frequency line cavity with a central conductor arranged to connect a radially extending radio frequency line connection with said axially extending radio frequency line connection in one switch position, said central conductor being bent at right angles and provided with one terminal exposed at the axial surface of the rotor and the other terminal exposed at the lateral surface of the rotor, means loosely mounting said conductor in said rotor, and resilient means mounted within said rotor acting on said central conductor to press both its terminal ends outwardly,

said rotor being mounted in said socket and together with the metallic socket wall providing in said one switch position an enclosed radio frequency line with the metallic socket wall forming a continuous unbroken longitudinal portion of the boundary of said line and with the outer peripheral edge of said cavity substantially flush throughout its entire length with said switch body in said one switch position so that said switch provides in said one position a radio frequency line of uniform impedance throughout its length with a continuous conducting path along the boundary of said line.

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