Dec. 21, 1954

R. E. CHARLES

2,697,767

COAXIAL SWITCH

Filed Dec. 18, 1950

2 Sheets-Sheet 1

Fig 1

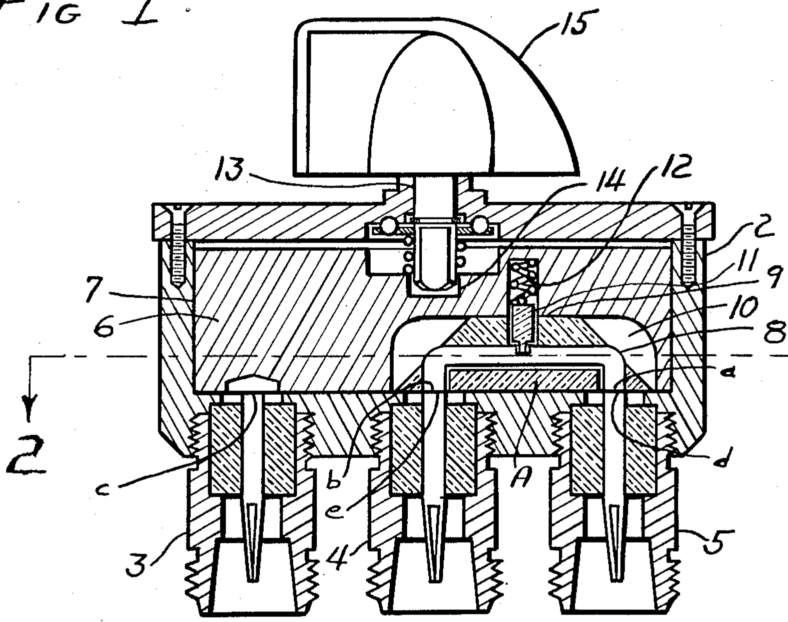
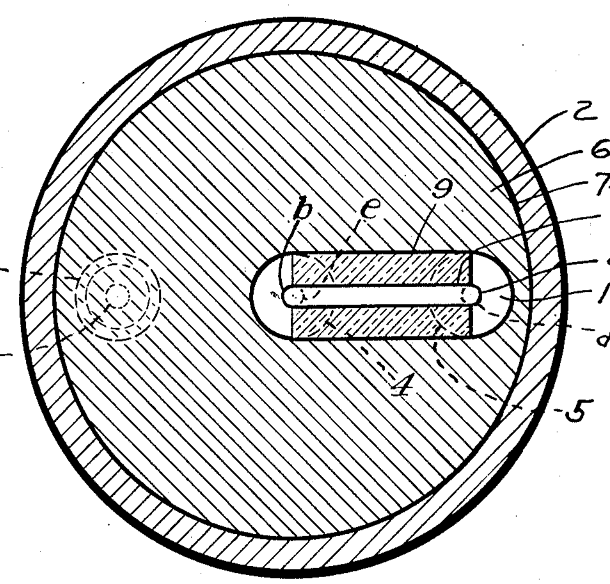


Fig 2



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2 Sheets-Sheet 2

Fig 4

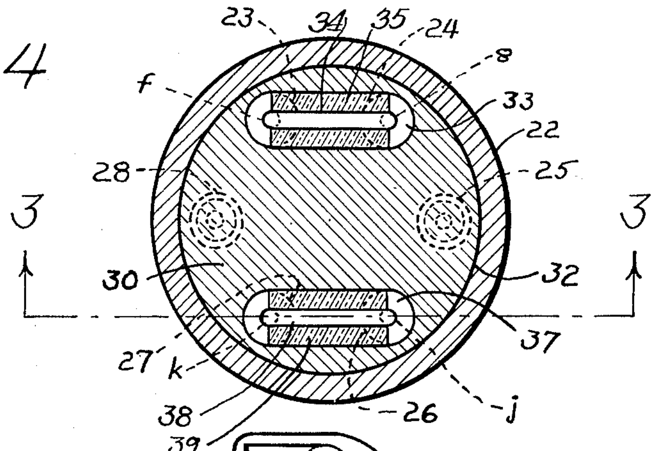


Fig 3

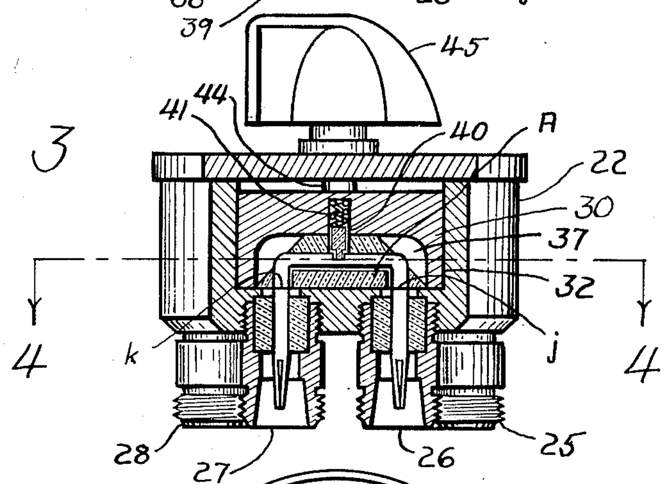
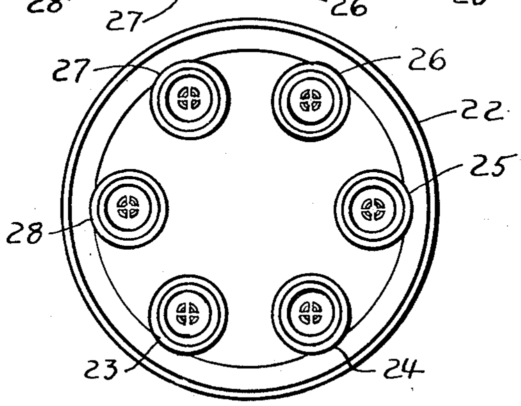


Fig 5



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COAXIAL SWITCH

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Application December 18, 1950, Serial No. 201,417

7 Claims. (Cl. 200—155)

Switching in coaxial lines has heretofore been accomplished by using a movable switch member having the electrical 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 in addition to suitable electrical characteristics 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. These conditions have 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 that 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, as well as to produce a switch of improved mechanical configuration.

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 an elevational view of a switch embodying features of this invention;

Fig. 2 is a cross-sectional view of the switch shown in Fig. 1;

Fig. 3 is an elevational view of a modified form of a switch embodying features of this invention;

Fig. 4 is a cross-sectional view of the switch shown in Fig. 3; and

Fig. 5 is a plan view of the switch shown in Fig. 3.

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.

2

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 equipped with connector elements **3**, **4** and **5** extending parallel to the axes of the switch and to each other by means of which the switch may be connected into one or more coaxial power supply lines in parallel alinement 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 twice at right angles at intermediate points 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. 1, at the lower surface of the rotor near the outer edge thereof, and the other terminal end *b* is exposed at the lower axial surface at the center 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 central portion between its bends or knees 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 insulator **9** to permit this action.

For the purpose of operating the switch, a shaft **13** is rotatably mounted in the upper portion of body **2**, said shaft **13** having a flattened lower end portion adapted to fit into a slot **14** centrally located in the upper surface of the rotor body **6**, so that rotation of shaft **13** will rotate rotor body **6**. A knob **15** may be mounted on the upper end of said shaft for operating the switch.

A somewhat modified form of switch, also having axial connectors, is shown in Figs. 3, 4 and 5, the particular arrangement shown being useful as a double pole double throw coaxial switch.

In this construction, in which the body of the switch is shown at **22**, preferably made of metal, and equipped with connector elements **23**, **24**, **25**, **26**, **27** and **28** disposed around the periphery of the lower surface of the body **22** and extending parallel to the axis of the switch and to each other by means of which a pair of coaxial power supply lines as, for example, at **24** and **27** may be connected to either one of two pairs of branch lines, as at **23** and **26** or **25** and **28**. 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 **30**.

In the form shown in Figs. 3, 4 and 5, the rotor body is made of metal and has the general form of a cylinder which fits snugly, but rotatably, in the rotor socket **32** in the body **22**. Extending through this body is a pair of central conductors, **34** and **38**, disposed in generally parallel relation on opposite sides of the rotor body, each conductor being bent twice at right angles at intermediate points in its length, said conductors **34** and **38** each being arranged to interconnect any two of the connectors **23**, **24**, **25**, **26**, **27** and **28**, and being supported on insulating blocks **35** and **39** which isolates them electrically from rotor body **30**. Thus each of the terminal ends of the central conductors is exposed at the lower surface of the rotor near the outer edge thereof. The terminal ends of each central conductor are positioned to make contact with any two adjacent connectors **23**, **24**, **25**, **26**, **27** and **28**, though other arrangements could be used if desired, for instance the terminal ends of a central conductor could be positioned to make contact with any two alternate connectors, **23**, **24**, **25**, **26**, **27** and **28**.

The conductors **34** and **38** are each provided with an insulating plunger **40** backed up by a spring **41** as shown in the construction of Figs. 1 and 2 and explained above.

Likewise, a shaft **44** rotatably mounted in body **22** is provided for rotating the rotor **30**, said shaft being retained in a hole at the center of the upper face of said rotor. A knob **45** is provided on the end of shaft **44** to enable the switch to be operated.

When the shaft **44** is rotated by knob **45**, the central conductors **34** and **38** are moved circumferentially successively to connect adjacent pairs of connectors. As illustrated, for instance, the end terminals *f* and *g* of conductor **34** are connected to connectors **23** and **24** respectively, interconnecting said connectors and forming one line of the coaxial pair, and the end terminals *j* and *k* of conductor **38** are connected to connectors **26** and **27** respectively interconnecting said connectors and forming the other line of the coaxial pair. If the switch is rotated clockwise, as shown in Fig. 4, end terminals *f* and *g* of conductor **34** will be connected to connectors **24** and **25** respectively and end terminals *j* and *k* of conductor **38** will be connected to connectors **27** and **28** respectively, the conductors **34** and **38** being moved circumferentially to their new position. Thus the coaxial pair at connectors **24** and **27** will be switched from connectors **23** and **26** to connectors **25** and **28**.

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 switches 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 on any point of current interruption. Here, the switch body **2** or **22** 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** or **22**.

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** or **30** as best shown in Figs. 1 and 3, this gap being more or less filled by the insulator **9**, **35** or **39**. This gap, however, is bridged electrically by the bottom of the socket **7** or **32** in which the rotor is mounted.

Consequently, current carried by the outer side of the coaxial line and coming in through a connector finds a direct conducting path across the surface of the bottom of the rotor cavity **7** or **32** where that surface is exposed at the gap A in the switch shown in Figs. 1 and 3. 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 between connectors without going through the rotor. 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** or **32**.

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, then this open side is closed by the metallic bottom of the socket.

In this connection, it may also be pointed out that the conductors **8**, **34** or **38** should be centered in the insulators **9**, **35** or **39** respectively, and 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 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. However, to confine the electromagnetic field to the waveguide and maintain coaxial configuration, the bore or cavity in which the insulating elements **9**, **35** or **39** are mounted should be silver-plated, or otherwise coated with conducting material. Such a rotor then functions in the same manner as does the rotor shown in Figs. 1, 2, 3, 4 and 5, and it is provided with a similar gap which produces the same results above described.

The width of the gaps A above referred to is the same as one side of the cross-section of a square sectional coaxial line.

It should be observed that the insulators **9**, **35** and **39** respectively are so shaped as to leave open-air spaces **10**, **33** and **37** respectively in the bore of the rotor at the region adjacent to the knee of the conductors **8**, **34** and **38** respectively. 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 bends of the conductors, **8**, **34** and **35** 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 spaces **10**, **33** and **37** and the insulators **9**, **35** and **39** 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 gap A provided in the switches here disclosed is the nearest approach to this ideal condition because at the channel formed by said gap A the bottom of the socket 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 due to the axial positioning of all connectors which enables them to be connected to a member of closely adjacent parallel coaxial lines, it may be fitted into a relatively small space.

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 preferred embodiments 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 therein a socket with a metallic surface, at least two radio frequency line connections in axially alined position in said switch body extending to said socket surface, and a movable switch member having a longitudinally extended open sided metallic walled radio frequency line cavity therein arranged to connect two of said radio frequency line connections in one switch position, said member being mounted in said socket and together with the metallic socket surface providing in said one switch position an enclosed radio frequency line of uniform impedance with the metallic socket surface 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 cylindrical socket having an axial metallic surface, at least two radio frequency line connections in said switch body extending axially of said socket to the axial surface of said socket, and a cylindrical switch rotor having a longitudinally extended open sided metallic walled radio frequency line cavity with an open side along the axial surface of said rotor arranged to connect two of said radio frequency line connections in one switch position, said rotor being mounted in said socket and together with the metallic socket axial surface providing in said one switch position an enclosed radio frequency line with the metallic socket surface 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 therein a socket with a metallic surface, at least two radio frequency coaxial line connections in axially alined position in said switch body extending to said socket surface, said connections having central conductor terminals exposed at said socket surface, and a movable switch member having a longitudinally extended open sided metallic walled radio frequency coaxial line cavity therein with an insulated coaxial central conductor therein bent twice with its ends exposed at said socket wall arranged to connect two of said radio frequency coaxial line central conductor terminals in one switch position, said member being mounted in said socket and together with the metallic socket surface providing in said one switch position a radio frequency coaxial line of uniform cross-sectional configuration throughout its length with the metallic socket surface 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 including a switch body having therein a cylindrical socket having an axial metallic surface, at least two radio frequency coaxial line connections in said switch body extending axially of said socket to the axial surface of said socket, said connections having central conductor terminals exposed at said socket axial surface, and a cylindrical switch rotor having therein a longitudinally extended open sided metallic walled radio frequency coaxial line cavity with an insulated central conductor therein bent twice with its ends exposed at said socket axial surface, said cavity having an open side along the axial surface of said rotor and said central conductor being arranged to connect two of said central conductor terminals in one switch position, said rotor being mounted in said socket and together with the axial surface of said socket providing in said one switch position an enclosed radio frequency coaxial line with the metallic socket surface 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.

5. A radio frequency electric switch as claimed in claim 4 in which the open sided metallic walled radio frequency coaxial line cavity in said rotor is of rectangular cross sectional configuration with said rotor being mounted in said socket and together with the axial surface of said socket providing in said one switch position a rectangular radio frequency line with the metallic socket surface forming a continuous unbroken side of the boundary of said line.

6. A radio frequency electric switch for coaxial lines including a switch body having therein a cylindrical socket having a plane axial metallic surface, at least two radio frequency coaxial line connections in said switch body extending axially to the plane axial socket surface thereof, said connections having central conductor terminals exposed at said socket axial surface, a cylindrical switch rotor having therein a radio frequency coaxial line cavity with an insulated central conductor therein arranged to connect two of said terminals in one switch position, said central conductor being bent twice at right angles with its terminals exposed at the plane axial surface of the 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 plane axial surface of said socket, providing in said one switch position a radio frequency coaxial line.

7. A radio frequency electric switch as claimed in claim 6 in which said central conductor insulating material is shaped to provide an air space in said rotor at the corners oppsite the bends in said central conductor.

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