Oct. 25, 1960 C. W. CONCELMAN 2,958,054

IMPEDANCE TERMINATED COAXIAL LINE SWITCH APPARATUS

Filed Nov. 24, 1958

Fig. 1.

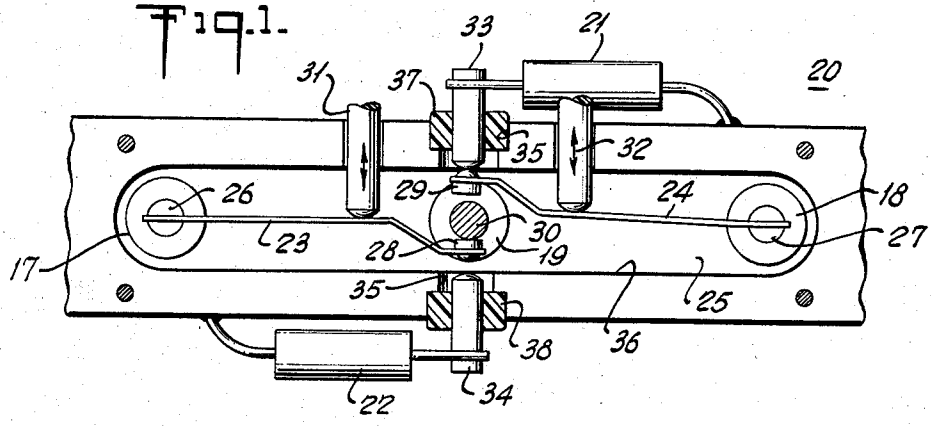


Fig. 2.

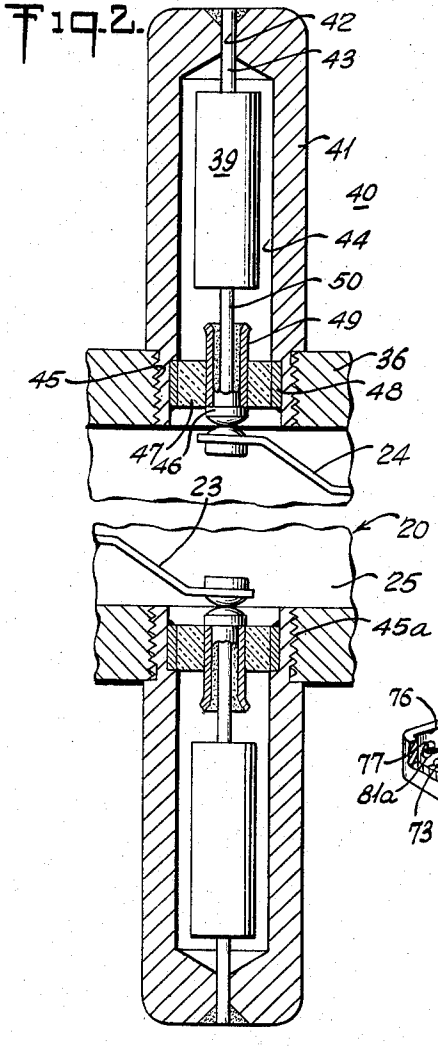


Fig. 3.

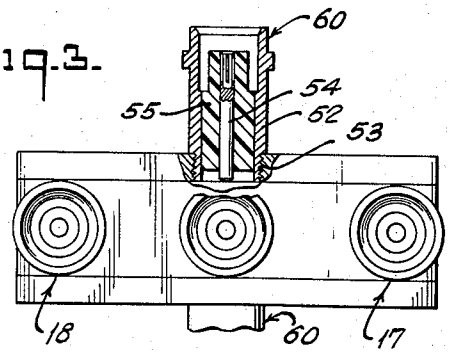
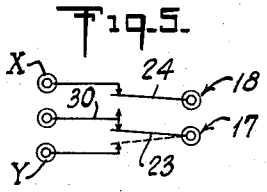


Fig. 5.



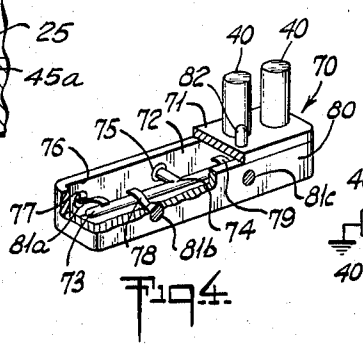
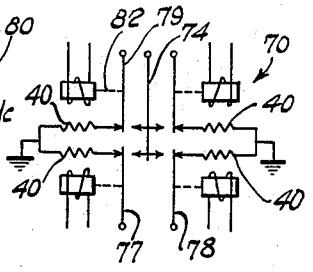


Fig. 4.

Fig. 6.



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IMPEDANCE TERMINATED COAXIAL LINE SWITCH APPARATUS

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3 Claims. (Cl. 333—7)

This invention relates to electrical switch relays, and more particularly, to switch relays adapted to connect independently and selectively a first high frequency coaxial transmission line to a plurality of high frequency coaxial transmission lines and wherein the unconnected lines of said plurality are resistor terminated by the switch relay.

This application is a continuation-in-part of co-pending application Serial No. 627,049, filed December 7, 1956, for Coaxial Line Switch Apparatus, in the name of Carl W. Concelman.

The instant invention contemplates relay switch apparatus affording improved cross-talk characteristics by minimizing the cross-talk over a wider band of frequency operation in comparison to the results heretofore achieved. As used herein, cross-talk means picking up a signal in the active transmission line circuit as a result of relatively imperfect electrical isolation of the inactive line from the active circuit. Prior art relay switches of the type contemplated herein are subject to cross-talk limitations, particularly so at the higher frequencies of the operating band. When the inactive part of the switch is open circuited, the end of the circuit becomes the highest voltage point of the standing wave. This high voltage develops a strong electric field near the switching components of the active circuit of the switch, and thus produces cross-talk. When the inactive part of the switch is shorted to ground, the end of such circuit becomes the highest current point of the standing wave. The high current develops a strong magnetic field within the switch chamber which may cause magnetic pick-up on the active circuit of the switch. In addition, the strong magnetic field sometimes makes it difficult to break the circuit during switching operations.

When the inactive part of the switch in accordance with this invention is terminated by a proper value of resistor, the standing wave is minimized; therefore, the high electric or high magnetic field is substantially eliminated.

It is, therefore, the main object of the instant invention to provide electrical switch relay apparatus providing means for interconnecting individually and selectively a first coaxial transmission line to any one of a plurality of coaxial transmission lines and affording improved, broad band operation with better cross-talk characteristics than heretofore achieved.

It is a further principal object of the instant invention to employ terminating resistive means of predetermined resistance integral with said switch apparatus wherein respective ones of the aforesaid plurality of lines are individually and alternately connected to the first of said lines while the other of said plurality of lines are automatically terminated with a correlated one of said resistive means during relay switch operation as one and then the other of the plurality of the lines are individually connected to the first of the lines.

It is a further object of the instant invention to provide transmission line matching means in the region of the switch relay chamber where the terminating resistive means is introduced for conductive connection with the switching arms of the relay to avoid impedance discontinuities thereat.

It is a further object of the instant invention to adapt the aforesaid terminating resistor means as a readily removable insert which may be attached to the relay switch such that impedance terminations of various value may be interchanged and/or replaced by coaxial line connectors to render such switch apparatus versatile in application and use.

It is still a further object of the instant invention to provide coaxial transmission line relay switches susceptible to economy of fabrication and simple in application and use for individually and selectively connecting and isolating alternate ones of coaxial line circuits in respect to active ones of such circuits while exhibiting improved cross-talk and broad band operation.

Other objects and advantages will become apparent from the following description taken in conjunction with the figures, in which:

Fig. 1 is a side elevational view partly in section of the interior of the switching chamber of an electrical relay switch in accordance with the practice of the invention;

Fig. 2 is a fragmentary elevational view and partly in section and illustrates the portion of a switch incorporating and attachable termination insert in accordance with the invention:

Fig. 3 is a fragmentary elevational view partly in section illustrating the switch wherein the resistor termination insert is replaced by a coaxial line connector in accordance with the invention;

Fig. 4 is a perspective view with cutaway portions illustrating a further application of the invention; and

Figs. 5 and 6 are schematic illustrations of the switch circuits illustrated by the other figures.

As noted hereinbefore situations arise where grounding of the switching arms introduces high standing wave ratios and associated reflections and thus prevents proper circuit operation whereas open circuiting of the inactive coaxial transmission line introduces cross-talk in the active line and thus interferes with its circuit performance. Fig. 1 illustrates a coaxial relay switch **20** wherein preselected impedances are integrally incorporated in relay switch **20** for the purpose of terminating alternative ones of the inactive circuits. Switch **20** has a pair of terminating resistors **21**, **22** of known resistance adapted to connect conductively with respective movable switch arms **23**, **24** during switch operation. Arms **23**, **24** extend longitudinally in an internal relay switch chamber **25** defined by the interior surfaces of the switch wall **36**. Each arm **23**, **24** has an end supported from a respective input inner conductor **26**, **27** of spaced coaxial connectors **17**, **18** at the opposite ends of chamber **25** to provide a rigid mechanical support for arms **23**, **24**. Conductors **26**, **27** project into chamber **25** and are continuations of con-

nectors 17, 18. Arms 23, 24 are made preferably of thin resilient material such as beryllium copper and have turned ends provided with contact points 28, 29 adapted for conductive contact with opposite portions of an output inner conductor 30. Output inner conductor 30 extends into chamber 25 and is a continuation of a center coaxial connector 19. The purpose of switch 20 is to connect the circuit coupled to connector 19 alternately with the circuits connected to connectors 17, 18.

The characteristic impedance of a coaxial cable is expressed approximately as follows (neglecting the resistance of the wire and the leakage conductance):

$$Z_c=\sqrt{\frac{L}{C}}$$

where

Z_c=Characteristic impedance,

where

L=Inductance per unit length, and
C=Capacitance per unit length.

Inductance L increases as the distance between the inner and the outer conductors increases, and capacitance C increases as the distance between the two conductors decreases; and also capacitance C is proportional to the dielectric constant of the medium (insulators, air, etc.) between the two conductors.

Whenever two coaxial devices are connected, it is desirable to match the characteristic impedances of both devices in order to minimize the reflecting wave energy which produces some standing wave on top of a traveling wave. Match is achieved by selecting a proper value of the dielectric constant and the distance between the two conductors to make the ratio of L and C approximately the same for the coupled devices.

The parameters of chamber 25 and arms 23, 24 are chosen to provide an impedance match with connectors 17, 18, 19 and associated coaxial line circuits connected thereto. In vertical cross-section, arms 23, 24 are relatively thin; whereas, in respect to the cross-sectional vertical and width dimensions, arms 23, 24 are proportioned and disposed in respect to the wall surfaces of chamber 25 to provide a favorable impedance for the coaxial section. Furthermore, it will be understood that the inner diameter of the outer conductors of connectors 17, 18, 19 are preferable approximately equal to the vertical cross-sectional dimension of chamber 25 to provide favorable impedance match. The outer conductors of connectors 17, 18 and 19 are conductively connected to chamber wall 36.

A pair of movable dielectric actuator pins 31, 32 are adapted for slidable inward and outward motion and extend through apertures in the walls of chamber 25. Pins 31, 32 are disposed to engage resilient arms 23, 24, respectively, and deflect same from an unstressed position as shown in Fig. 1 to a stressed position upon inward motion normal to the longitudinal axis of chamber 25.

A pair of opposed electrical conducting terminal members 33, 34 are held firmly and concentrically within stepped counterbores 35 at the opposed top and bottom chamber walls 36 by respective ones of a pair of insulated material bushings 37, 38. Members 33, 34 extend along a common axis substantially normal to the longitudinal axis of chamber 25. The inner ends of members 33, 34 preferably do not project inwardly into chamber 25 beyond the plane of the interior surface of chamber walls 36. The inner ends of members 33, 34 are disposed to provide conductive contact respectively with contact points 29, 28. Members 33, 34 are electrically isolated from chamber wall 36 and the outer ends of members 33, 34 extend externally of chamber 25 and are conductively connected to ends of respective terminating resistances 21, 22. The other ends of resistances 21, 22 are grounded to switch wall 36.

The diametrical sizes of members 33, 34, of stepped counter-bores 35 in conjunction with the dielectric of bushings 37, 38 are preferably selected to provide a workable impedance match. In addition, bushings 37, 38 are preferably made of glass or other dielectric material which can over a long period of use maintain members 33, 34 rigidly in position and thus withstand the switching action of arms 23, 24 as such arms make and break physical contact with respective members 34, 33 during switching operation.

Contact end 28 of arm 23 is downwardly turned and said arm is otherwise shaped and disposed when not stressed by pin 31 to maintain electrical contact with inner conductor 30. On the other hand, arm 24 is turned upwardly at its contact end 29 and is normally conductively contacting member 33 when not stressed by its actuator pin 32. Under deflecting stress, arm 23 will engage conducting member 34, and arm 24 engages inner conductor 30. Hence, it will be understood that contact points 28, 29 are adapted to effect conductive connection alternately to inner conductor 30 and opposed members 34, 33, respectively, as determined by the position of actuator pins 31, 32. It will be understood that actuating means (not shown) will be mounted externally on switch 20 to impart inward and allow outward motion to actuator pins 31, 32 as illustrated by the arrows. The resilient nature of arms 23, 24 act as a returning force upon removal of stress.

Various types of pulse circuits are used in computer and television applications where the operating frequency is low and where the circuit should be terminated in a resistive load for avoiding the problems described hereinbefore. For low frequency operation the embodiment shown in Fig. 1 provides satisfactory operation.

For frequency operation above 20 megacycles, the embodiment of Fig. 2 is preferable because at the higher frequencies, the open type of resistor terminations exhibit leakage from one resistor to another. For such high frequency applications, the termination should be a true coaxial load properly matched in impedance to that of the coupled circuit. The shield type of insert 40 illustrated in Fig. 2 achieves this object.

Since each relay 20 will normally include a pair of substantially identical inserts 40, only one will be described. Insert 40 has an outer housing 41 of suitable conducting material. Housing 41 has an opening 42 at one end through which a resistor lead 43 of a resistor 39 extends. Lead 43 is soldered to housing 41 at the end thereof. Housing 41 has a longitudinal interior bore 44 opened at its inner end. Resistor 39 is preferably a precision film resistor of known resistance and is coaxially supported in bore 44. The inner end of housing 41 is threaded at 45 to secure same to the open threaded wall portion 45*a* of relay 20 for removing or attaching insert 40 with respect to relay 20. Chamber wall 36 is provided with a pair of aligned and threaded open wall portions 45*a* along the top and bottom portions of wall 36 adjacent conductor 30. Bore 44 communicates with an open wall 45*a* when insert 40 is attachable to switch 20 as shown in Fig. 2.

Rigidity and proper coaxial relationship of an inner conductor member 46 of insert 40 is maintained by a dielectric and preferably glass bushing 47 bonded permanently to housing 41. Annular rings 48, 49 of suitable conducting material are soldered respectively to housing 41 and member 46 for the purpose of providing a suitable glass bonding material in the situation where the material used for housing 41 and member 46 does not provide desired bonding to glass. The other terminal lead 50 from resistor 39 is soldered to member 46. The dielectric of bushing 47 and the diametrical dimensions of member 46 and bore 44, or annular rings 48, 49 are selected to maintain a workable impedance match upon introducing insert 40 into relay 20 for a particular circuit of known characteristic impedance. It

will be understood that member **46** is substantially the equivalent of member **33** of the Fig. 1 embodiment and thus the inner end of insert **40** should be designed so that the inner of member **46** preferably does not project inwardly beyond the surface of wall **36**. The inner end of member **46** is designed to make conductive contact with a correlated switch arm during switching operation.

In Fig. 1, each switch arm **23**, **24** is adapted to alternate between conductor **30** and its respective terminating resistance during switching action so that as one arm contacts conductor **30**, the other arm of the pair is in resistor terminating position. This switching arrangement may be followed in the embodiment of Fig. 2. On the other hand, movable pins **31**, **32** and the relays for actuating said pins may be arranged on the switch body so that the switch arms **23**, **24** normally terminate with the respective resistors until the actuating means, the particular relay, is energized which causes a respective pin to move so that the engaged switch arm effects contact with conductor **30**. Fig. 2 illustrates the arrangement where the switch arms are normally in contact with the resistor inserts.

The foregoing arrangement increases the versatility and flexibility of switch **20**. A termination insert **40** may be easily removed and replaced by another either for the purpose of changing the value of the terminating resistance or for the purpose of replacing a defective insert. Frequently, during transmitter or receiver adjustments, it is desirable to feed into a dummy load rather than the antenna or normal load. The shielded coaxial insert **40** may be used for this purpose. Large resistors for high wattage dissipation may be required for transmitter applications. The embodiments of Fig. 2 provides the additional advantage in that resistor insert **40** may be replaced by a coaxial connector **60**, see Fig. 3. The inner end of connector **60** may be threaded at **53** to permit attachment to threaded opening **45***a* of chamber wall **36**. This provides added flexibility to the basic two-positioned switch for special types of electrical switching. Connector **60** is essentially an outer conductor **52** adapted for coupling to a coaxial transmission line. The inner end of connector **60** is provided with threads **53** and has an internal insulator bead **55** for supporting an inner conductor **54** coaxially within its outer conductor **52**. The inner end of inner conductor **54** is adapted to make and break contact with a correlated switch arm during its switching operation as noted hereinbefore.

Fig. 5 illustrates schematically the two-position switch illustrated in Figs. 1, 2 and 3. The symbols "X" and "Y" in Fig. 5 depict the individual resistive elements, such as shown in Fig. 1, or the resistive inserts as shown in Fig. 2, or a coaxial connector as shown in Fig. 3. The dashed line in this figure illustrates switch arm **23** when in its position to effect contact with conductive element **34**.

Fig. 4 illustrates another application of insert **40** wherein more than two inserts are used on a switch, such as switch body **70**. Switch **70** contemplates four switch arms and thus four inserts **40** threaded along an upper chamber wall or plate **71**. Two inserts **40** are shown because plate **71** is cutaway to illustrate the inside of switch chamber **72**. In this embodiment, a center conductor **73** is supported to extend parallel to the longitudinal axis of chamber **72**. Conductor **73** is supported by an inner conductor **74** of a center coaxial connector depicted at **75**. Connector **75** is joined to switch body **70** at a chamber side wall **76**. The four individual switch arms **77**—**79** (only three are shown in Fig. 4) extend into chamber **72** from opposite side walls **76**, **80** wherein each switch arm is substantially perpendicular to the longitudinal axis of chamber **72**. One end of each switch arm is conductively supported from an individual inner conductor of spaced coaxial connectors joined to side chamber walls **76**, **80** of switch body **70**. The spaced coaxial connectors are depicted as **81***a*, **81***b* and are alternately supported from opposite walls **76**, **80** for convenience of assembly of switch **70**. The free contact ends of the switch arms are adapted to contact respective resistor terminations **40** for their normal positions. The movable switch pins, one is shown at **82**, and the individual relays therefor, not shown, are arranged on switch body **70** so that upon energizing a particular relay, a correlated pin depresses a respective switch arm to effect contact of the depressed arm with center and inner conductors **73**, **74**. The circuit of Fig. 4 is shown schematically in Fig. 6.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electrical switch for connecting a first high frequency coaxial transmission line to a plurality of such transmission lines comprising, a switch body having a longitudinal internal chamber defined by interior conductive walls, first means supported by said body for connection to a first of said transmission lines and having an inner conductor extending into said chamber, a plurality of spaced means also supported by said body for connection to individual ones of said plurality of transmission lines and each having a respective inner conductor extending into said chamber, said first inner conductor projecting into said chamber intermediate said plurality of said respective inner conductors, a plurality of spaced deflectable conductive switch arms in said chamber, individual ones of said arms being supported by and joined to a correlated one of said plurality of said respective inner conductors, said arms extending substantially longitudinally from its correlated inner conductor to the first of said inner conductors, contact means on each arm for selective conductive contact with said first inner conductor, resistance means carried by said body externally of said chamber, conductive means having an end extending into said chamber juxtaposed the contact means of an individual one of said arms, insulator means for isolating said conductive means from said chamber walls, and means for deflecting said individual switch arm alternately from one to another of two positions to effect conductive contact with the juxtaposed end of said conductive means and said first inner conductor, said resistor means being conductively in series with said conductive means and said chamber walls, whereby the transmission line connected to said individual inner conductor is terminated by said resistor means when the switch arm supported by such individual inner conductor is deflected to make contact with said conductive means.

2. Apparatus as defined in claim 1 further including, a resistor means insert comprising, a housing of conductive material having a longitudinal interior bore, said bore having an open end, means on said housing adjacent its open end for removably joining said insert to said switch body, the open end of said housing bore being juxtaposed the contact means of said individual switch arm, said housing being conductively connected to said chamber walls, means for supporting said resistor means in said housing bore, said conductive means being supported in said housing bore adjacent its open end, said chamber walls having an opening aligned with said bore open end to accommodate conductive contact between the juxtaposed end of said conductive means and the contact means of said individual switch arm, said resistor means being conductively in series with said conductive means and said housing.

3. Apparatus as defined in claim 1 wherein said chamber walls including, opposed walls and end walls, said plurality of spaced means comprising a pair of such means each having a respective inner conductor extend-

ing into said chamber on opposite sides of said first inner conductor, said insulator means including a pair and individual ones of said insulator means being supported in a respective one of said opposed chamber walls, said conductive means including a pair and individual ones of said conductive means being supported in a respective one of said insulator means, said first inner conductor having opposed sides confronting respective ones of said opposite chamber walls, each switch arm extending substantially longitudinal from its respective inner conductor, and the contact means thereof projecting between the juxtaposed end of a respective one of said conductive means and a

respective one of the opposite sides of said first inner conductor, said resistor means being a pair and individual ones being conductively in series with a respective one of said conductive means and the chamber walls, whereby each arm alternates so that its contact means makes and breaks contact with the juxtaposed end of the correlated conductive means and said first inner conductor.

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