

July 19, 1960

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2,946,024

STRIP TRANSMISSION LINE SWITCH

Filed Nov. 25, 1958

2 Sheets-Sheet 1

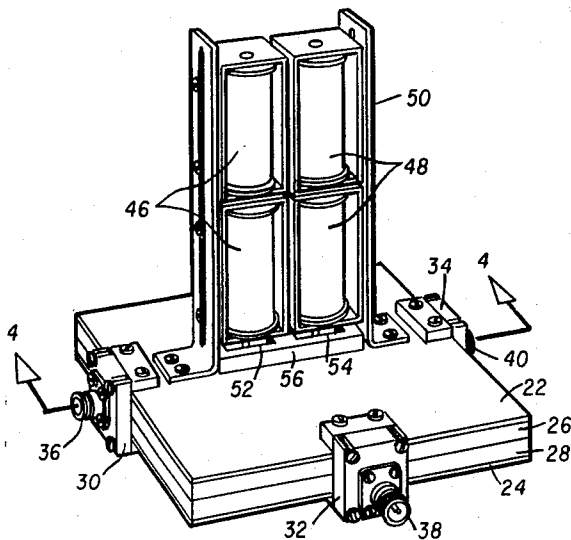


Fig 2

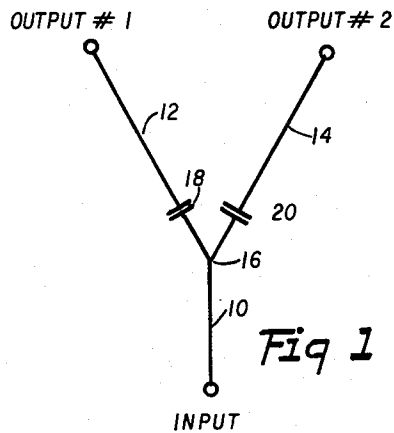


Fig 1

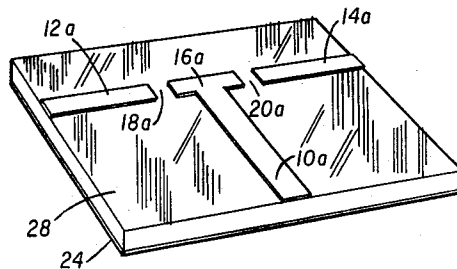


Fig 3

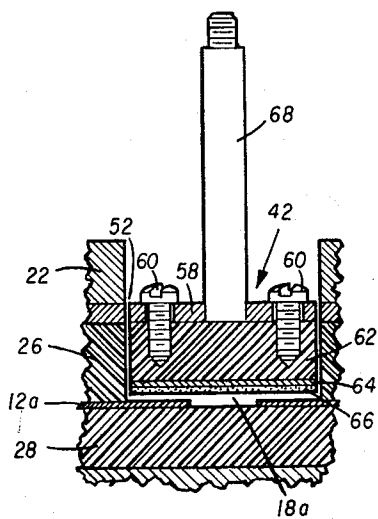


Fig 5

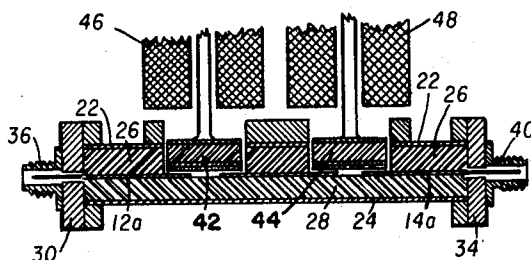


Fig 4

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2 Sheets-Sheet 2

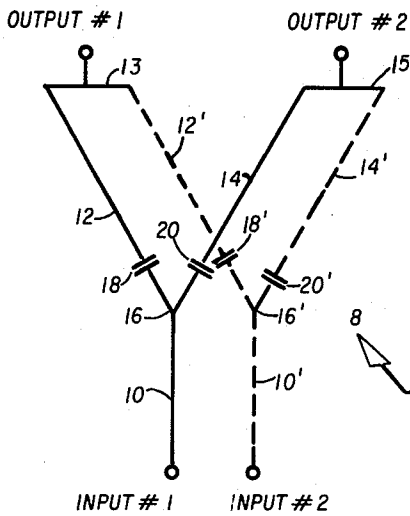


Fig. 6

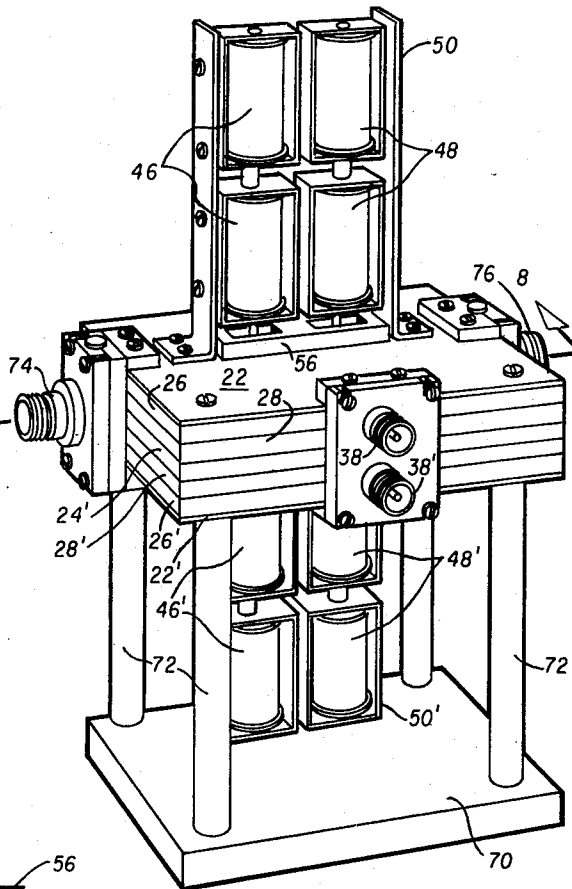


Fig. 7

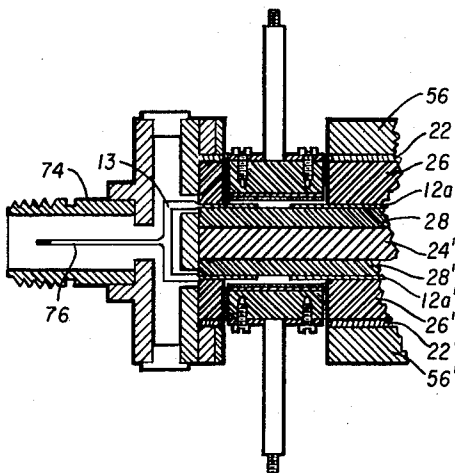


Fig. 8

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2,946,024

STRIP TRANSMISSION LINE SWITCH

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3 Claims. (Cl. 333—7)

This invention relates generally to radio frequency switches, and more particularly to a strip transmission line structure for selectively making and breaking a circuit between two or more coaxial transmission line sections.

In microwave electromagnetic energy transmission many occasions arise requiring the switching of energy from one transmission line to one of two other lines. In other applications it may be necessary to accept radio frequency power at two input terminals and transfer it along two separate paths to a possible choice of two outputs for each given path. It will be recognized that the first situation requires a single pole-double throw switch, and the second requires a double pole-double throw switch. In situations where switching of microwave energy at high power levels takes place, several difficulties occur with existing types of switching apparatus. One prior art method of accomplishing the foregoing switching functions involves the use of two individual commercially available single pole-double- or multi-throw switches coupled together at the respective outputs by radio frequency coaxial cables. Among the many disadvantages of such a switching arrangement are the following: metal-to-metal contact during the switching operation which greatly shortens switch life; the use of radio frequency cables between output connections presents phasing problems and increased insertion loss; large power consumption results from the heavy spring loading of the switching members; the switching arrangement results in a bulky package; and the arrangement is susceptible to increased insertion losses caused by misalignment or wear of the switching members after long periods of switch operation.

It is an object of the present invention to provide a radio frequency switch having no metal-to-metal contact of parts during the switching cycle.

Another object of the invention is to provide a non-contacting strip transmission line switch for selectively coupling microwave energy between transmission lines.

A further object of the present invention is to provide a radio frequency switch employing strip transmission line for selectively switching between an input terminal and two output terminals; i.e., a single pole-double throw radio frequency switch.

Still another object of the invention is to provide a switch employing strip transmission line arranged to accept radio frequency power at two input terminals and to selectively transfer this energy along two separate paths to a possible choice of two outputs for each given path; i.e., a double pole-double throw radio frequency switch.

Briefly, the single pole-double throw switch in accordance with the invention consists of a Y section of strip transmission line, the leg of the Y constituting the input, and the two arms of the Y providing two output terminals. Isolation between the two output terminals is obtained by providing a gap in the center conductor of the strip transmission line section in both of the arms. Selective closure of the gaps to permit transmission of

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energy along one or the other of the arms is afforded by means for capacitively coupling across the gaps. This is accomplished with a plate having the same width as the center conductor of the strip transmission line separated from the center conductor by a thin dielectric film. Controlled movement of the plate away from and toward the center conductor of the strip line opens and closes the transmission path.

The double pole-double throw switch in accordance with the invention consists of two Y strip line sections of the form just described, one mounted on top of the other. Corresponding output terminals of the two lines are electrically connected together in such a manner that reciprocity of impedance conditions exist at the gaps in the lines.

Other objects and features of this invention will be appreciated as the same becomes better understood by reference to the following description when considered in connection with the accompanying drawings, in which:

Fig. 1 is a schematic diagram of the single pole-double throw switch;

Fig. 2 is a perspective view of one form of single pole-double throw switch in accordance with the invention;

Fig. 3 is an isometric view of the lower half of the strip transmission line of Fig. 2, illustrating the arrangement of the center conductor;

Fig. 4 is an elevation cross-section view taken along line 4—4 of Fig. 2;

Fig. 5 is an enlarged view of one of the movable switching elements of Fig. 4;

Fig. 6 is a schematic representation of the double pole-double throw switch in accordance with the invention;

Fig. 7 is a perspective view of a strip transmission line double pole-double throw radio frequency switch; and

Fig. 8 is a partial elevation cross-section taken along line 8—8 of Fig. 7.

Referring now to Fig. 1, which is a schematic representation of a single pole-double throw switch, the switch consists basically of a Y section of transmission line which includes an input arm 10, and first and second output arms 12 and 14 joined to arm 10 at junction 16. Each of the output lines has an incremental section thereof removed so as to present an open circuit to radio frequency energy transmitted therealong from input arm 10, which open circuit may be selectively closed in accordance with the invention by capacitive coupling; hence, the representation of the switching means as capacitors 18 and 20. The distance from the junction 16 to the gaps in lines 12 and 14 is as short as possible in terms of wavelength at the frequencies for which the switch is intended. Assuming that the gap at 18 were closed, an open circuit gap at 20 introduces a mismatch and contributes an impedance component at junction 16, mainly capacitive reactance, the magnitude of which is a function of the electrical length from the junction to the gap. It is, of course, desirable that the open gap in one of the arms affect the closed gap in the other arm as little as possible, and the impedance contribution of the open gap can be minimized by locating it as closely as possible to the junction. A spacing between the gap and junction of

$$\frac{\lambda}{32}$$

has been found to be satisfactory, and while preferably shorter, the length was dictated by mechanical considerations. From what has been said, when the gap at 18 is closed (by means to be described) and the gap at 20 is open, the impedance at the junction 16 as seen from the input terminal is essentially the characteristic impedance of the transmission line, whereby power applied at the input terminal is conducted to output terminal No. 1

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with little reflection, and when the gap at 18 is open and the gap at 20 is closed power applied at the input is similarly conducted to output terminal No. 2.

The switch schematically illustrated in Fig. 1 may be implemented by a section of strip transmission line in the manner illustrated in Figs. 2, 3, 4 and 5. The strip transmission line is conveniently fabricated in the form shown in Fig. 2, wherein rectangular conductive plates 22 and 24, respectively bonded to dielectric slabs 26 and 28 constitute the ground planes of the strip transmission line. The center conductor of the strip transmission line is in the form of thin strips of conducting material bonded to the upper surface of the lower dielectric slab 28, as shown in Fig. 3. Instead of the Y configuration of Fig. 1, the center conductor is arranged as a T, having an input arm 10a and two output arms 12a and 14a extending in opposite directions from the junction 16a. At a short distance from the junction 16a, a short section is removed from each of arms 12a and 14a, which sections may be of the order of one-quarter inch in length, the gaps 18a and 20a thus formed being as close as possible to the junction 16a. The two slabs of dielectric material are firmly held in contact with each other by clamping assemblies 30, 32 and 34 which respectively include coaxial connectors 36, 38 and 40 for coupling radio frequency energy to and from the switch. The outer conductor of each of the couplers is electrically connected, through the clamping assembly, to both ground planes of the transmission line, and the inner conductors are respectively connected to corresponding termini of the inner conductor; that is, the inner conductor of coupler 36 is electrically connected to the outer end of arm 12a, the inner conductor of coupler 38 is connected to the outer end of arm 10a, and the inner conductor of coupler 40 is connected to the outer end of arm 14a. Satisfactory electrical connection between the inner conductor of the couplers and their respective sections of the inner conductor may be made by pressure contact alone, which method permits the ready disassembly of the switch. By way of example, the ground planes 22 and 24 may be fabricated of a suitable metal, such as brass, the dielectric slabs 26 and 28 may be formed of "Rexolite," a plastic material having a dielectric constant of about 2.55, and the inner conductor may be formed of copper foil.

Switching of energy applied to the input terminal between output coupler 36 and output coupler 40 is achieved by a pair of plungers 42 and 44 (Fig. 4) which are movable into and out of engagement with inner conductor sections 12a and 14a in the regions of gaps 18a and 20a, respectively. These plungers are movable in a direction perpendicular to the plane of the strip transmission line, and are conveniently actuated by solenoids 46 and 48 supported above the strip line on a suitable bracket 50. The plungers are of rectangular shape, having a width approximately equal to the width of strips 12a and 14a, and a length somewhat greater than the length of gaps 18a and 20a, and are movable in and out of rectangular openings 52 and 54 formed in upper ground plane 22 and dielectric slab 26. Guidance for the plungers, when they are out of engagement with the center conductor, is afforded by member 56 affixed to upper ground plate 22.

As best seen in Fig. 5, each of the plungers comprises a rectangular piece of metal 58 of a thickness equal to that of ground plane 22, to which is secured, as by nylon screws 60, a rectangular block 62 of dielectric material having substantially the same thickness and dielectric characteristics as dielectric slab 26. A thin conductive film 64, such as copper foil, is bonded to the underside of dielectric block 62, to which, in turn, is bonded a thin film of dielectric material 66. A suitable material for dielectric film 66 comprises 150 parts of titanium dioxide mixed with 100 parts of epoxy resin, and is applied to a thickness of approximately .001 inch. This dielectric film prevents metal-to-metal contact of the conductive plate 64 and the inner conductor 12a when the plunger is in its

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most downward position. The travel of the plunger, controlled by the rod 68 and its associated solenoid, is between an engaged position where the film 66 is in contact with inner conductor 12a to a disengaged position where the plunger is completely removed from the strip line; i.e., with the lower surface of the plunger substantially flush with the upper surface of ground plane 22.

The small spacing between conductive film 64 and the inner conductor 12a, when the plunger is engaged, provides a sufficiently high capacitance to lower the otherwise high reactance of the gap 18a to a value whereby the gap is essentially short circuited. Tests using the dielectric film described, whose dielectric constant is approximately 5.12, have indicated that there is insignificant mismatch at the gap when the plunger is engaged. Of course, when the plunger is disengaged there is insignificant capacitive coupling across the gap, with the result that it presents an open circuit. Thus, it will be apparent that when plunger 42 is down and plunger 44 is in the up position, power applied to the input coupling 38 will be transmitted to output coupling 36, and when the positions of the plungers is reversed, power appears at the output coupling 40.

Turning now to Figs. 6, 7 and 8, there is illustrated a double pole-double throw radio frequency switch consisting essentially of two switches of the form described in connection with Fig. 1 arranged back-to-back with the corresponding output connections of the two switches electrically connected together in such a manner that reciprocity of impedance conditions exist at the four gaps in the system. Referring to Fig. 6, and using the designations of Fig. 1, the switch shown in solid lines represents the structure of Fig. 2, and the switch shown in dotted lines, and on which primed corresponding reference numerals are used, represents another identical switch mounted beneath the first. Corresponding output terminals of the tube switches are connected together by transmission lines 13 and 15, the electrical and structural features of which will be described later. It will be apparent that power applied to input terminal No. 1 may be transmitted to either of the output terminals, and likewise power applied to input terminal No. 2 may be coupled to either of the output terminals. As explained in connection with Fig. 1, capacitors 18 and 20 represent the removable line sections, or plungers, in the upper line, and 18' and 20' represent similar elements in the second switch. When the plungers are actuated in proper sequence, reversal of output connections No. 1 and No. 2 is accomplished, the following being a typical sequence of operation. With radio frequency power fed into input terminals 1 and 2, and with the plungers disengaged at 18 and 20', radio frequency energy propagated toward junction 16 is transmitted to output terminal No. 2 because of the open circuit at 18. Similarly, energy applied to input terminal No. 2 is propagated to output terminal No. 1 because of the open circuit at 20'. Looking in to output terminal No. 2 with gap 20' open circuited, and gap 20 closed, the following impedance characteristics exist. Gap 20', being open circuited and relatively short, presents nearly an infinite impedance at output terminal No. 2, whereas gap 20, being a part of a continuous transmission line, presents at output terminal No. 2 the characteristic impedance of the transmission line. The combination of these two parallel impedances at the output terminal gives a resultant impedance which is very near that of the characteristic impedance of the transmission line. Accordingly, remembering the discussion of Fig. 1, the switch introduces very little mismatch whether looked at from the input terminals or from the output terminals.

Having described the single pole-double throw switch of Fig. 2 in considerable detail, the assembly of two such switches as shown in Fig. 7 need only be briefly described. To accommodate the solenoids 46' and 48' of the lower switch, the assembly may be mounted on a base 70 in-

cluding posts 72 of sufficient length to permit the assembly of bracket 50' between the switch assembly and the base. The strip transmission line portions of the two switches are identical with that shown in Fig. 2 with the exception that the ground plane 24 is common to the two strip lines, being designated in Fig. 7 as 24'. Two input terminals are provided, coupler 38 being connected to strip 10a of the upper switch, and coupler 38' being similarly connected to a comparable element in the lower switch. Thus, two independent input signals may be applied via individual cable connections to the switch. Two output terminals 74 and 76, corresponding to outputs No. 1 and No. 2 of Fig. 6, each connected to both strip transmission lines, are provided to couple energy from the switch. As best seen in the fragmentary cross-section view of Fig. 8, the outer conductor of coupling 74 is electrically connected to ground planes 22 and 22', and common ground plane 24', and the inner conductor 76 is connected by means of a short transmission line 13 to line sections 12a and 12a' of the two switches. Consequently, output power may be taken from coupling 74 whether propagated over the upper switch or the lower. Output coupling 76 is similarly connected to arms 14a and 14a' of the two switches. The opening and closing of the four arms of the switch may be programmed by suitable means (not shown) to achieve a desired switching of input signals applied to terminals 38 and 38' between output terminals 74 and 76. It will be recognized that the structure of Fig. 7 is a double pole-double throw switch for radio frequency power.

The switch construction according to Fig. 7 has been found to have an input voltage standing wave ratio under 1.4:1 over a bandwidth of more than an octave. Electrical path lengths between a single input and the two possible outputs have been found to vary less than two electrical degrees over a similar range of frequencies. At low duty cycles the switch is capable of handling a peak power level of 7 kilowatts, and an average power of the order of 50 watts has been coupled through the switch with no deterioration of the switching members.

From the foregoing it is seen that there is provided a switch having high peak power handling capabilities over a wide range of frequencies. Rapid switching may be achieved without expenditure of large amounts of switching power, and improved switch life is achieved by reason of the elimination of metal-to-metal contact during the switching cycle. The switching system is relatively compact, and is constructed as an integral unit with no interconnecting cables.

Having fully described a preferred embodiment of the invention, variations and modifications may now be suggested to those skilled in the art. For example, actuation of the plungers may be effected by means other than solenoids, for example, by a programmed cam arrangement, and the strip transmission line may take other configurations without departing from the spirit of the invention. It is the intention, therefore, that the invention be limited only by the appended claims.

What is claimed is:

1. A double pole-double throw strip transmission line switch comprising first, second and third flat metallic plates lying in spaced parallel planes, first and second branched metallic strips each having a trunk and two arms joined at a junction and respectively lying in planes between said first and second plates and between said second and third plates, and parallel thereto, and each equidistantly spaced from its corresponding flat plates by dielectric material, the trunks and arms of said two strips overlying each other, the arms of each of said strips having a short section removed therefrom at equal short distances from the junction to provide high impedance gaps to radio frequency energy applied to their respective trunks, said first and third plates and the dielectric material respectively spacing said first and third plates from said first and second strips having openings therein in register with said gaps, a plunger fitted in each of said openings for movement therein normal to said planes from a position to engage its corresponding section of flat strip to a position removed from the opening, each of said plungers comprising a block of dielectric material of a thickness substantially equal to the spacing between said first or third plate and its corresponding flat strip, a metallic plate of a thickness substantially equal to the thickness of said first and third plates secured to the outer surface of said block, a conductive film on the surface of the block confronting the gap and a film of dielectric material covering said conductive film, said plungers when said film of dielectric material is in contact with its corresponding flat strip being operative to close the gap to radio frequency energy, first and second separate input couplers respectively connected to the extremities of the trunks of said first and second flat strips, first and second transmission lines respectively connecting corresponding arms of said first and second strips together, and first and second output couplers respectively connected to said first and second transmission lines.

2. Apparatus in accordance with claim 1 wherein said openings are rectangular in shape and of a width approximately equal to the width of said strips and of a length slightly longer than the width of said gaps.

3. Apparatus in accordance with claim 1 including means for moving said plungers in and out of said openings to provide selective switching of energy applied to either of said input couplers to either of said output couplers.

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