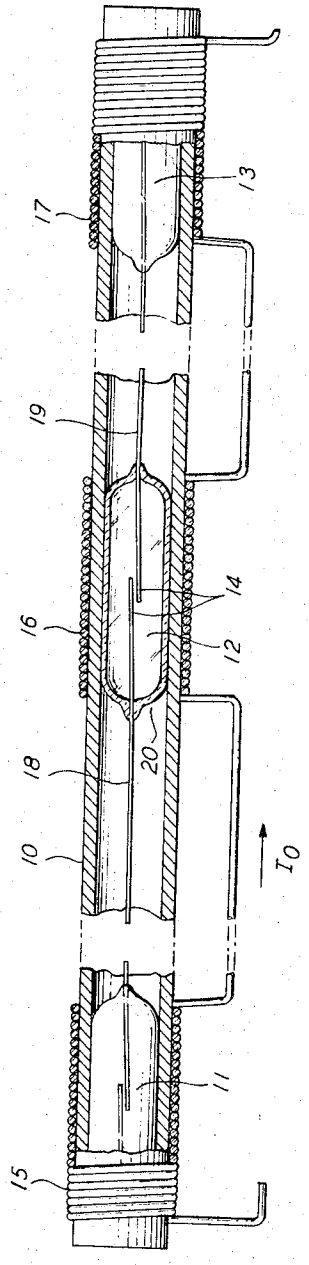
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COAXIAL CABLE SWITCH

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COAXIAL CABLE SWITCH

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This invention relates to coaxial cable switches.

One form of coaxial cable switch uses a reed switch in series with the center conductor of a cable. Although this is a relatively simple structure, the isolation provided when the switch is open is insufficient in some uses.

A switching arrangement that provides greater isolation in its open state appears in schematic form in the testing circuit of FIG. 4 of T. Slonczewski Patent No. 2,666,100. This arrangement comprises a pair of single-pole double-throw switches connected in series by a short length of coaxial cable. These switches are operable, in effect, to open the transmission path which is completed through the coaxial cable and insert a circuit under test in the path. As stated in the patent, the short length of cable reduces signal coupling via switch capacitances around the circuit under test.

A study of the Slonczewski arrangement has indicated that maximum isolation is produced when the intervening cable is one-quarter of the signal wavelength. Although the isolation thus provided is greater than that provided by the above-mentioned cable switch, this isolation is still insufficient for some applications. Furthermore, the over-all length of this arrangement places another limitation on its use.

An object of the present invention is to increase the isolation provided by coaxial cable switches.

Another object is to reduce the over-all length of relatively high isolation cable switches.

In accordance with the present invention, a coaxial cable switch having good open-circuit isolation and good closed-circuit conduction characteristics is provided by serially connecting at least three spaced switches in the center conductor of a coaxial line. A three-switch embodiment of the invention having an open-circuit isolation equal to the maximum possible with the two-switch Slonczewski arrangement, for example, is approximately one-twelfth the length of that arrangement. Furthermore, the open-circuit isolation of the three-switch embodiment may be increased by increasing the switch separations. For example, by doubling the separations the level of the leakage voltage is reduced by a factor of approximately eight. The interrelationships of switch separations, numbers of switches and isolations produced will be better appreciated from a study of the following description of a specific embodiment. Furthermore, other objects and features of the invention will become apparent from a study of the following description.

The drawing shows a three-switch embodiment of the invention. This embodiment includes an outer conductor **10** formed of tubularly-shaped non-magnetizable metal. Within outer conductor **10** are three spaced dry reed switches **11**, **12** and **13**. These reed switches are conventional and are described, for example, in "Recent Developments in Bell System Relays—Particularly Sealed Contact and Miniature Relays," by A. C. Keller, Bell System Technical Journal, January 1964, pp. 15–44. Each switch comprises (with reference to switch **12**) a pair of magnetic reeds **14** that are cantilever supported in a hermetically sealed glass envelope **20**. The free ends of the reeds overlap but in the absence of a magnetic field do not come into contact with one another. In the presence of a magnetic field, however, the free ends of the reeds pull into contact with one another to form a through circuit. Such

magnetic fields are produced by passing a current I_0 (by means not shown) through serially connected coils **15**, **16** and **17** which are wrapped around outer conductor **10** so that they surround switches **11**, **12** and **13**, respectively. Since the coils are connected in series, the switches are caused to operate simultaneously.

As stated above, switches **11**, **12** and **13** are spaced apart with respect to one another. In particular, switches **11** and **12** are interconnected by a coaxial line comprising a center conductor segment **18** and a segment of outer conductor **10**. Similarly, switches **12** and **13** are interconnected by a coaxial line comprising a center conductor segment **19** and a segment of outer conductor **10**.

The switch shown in the drawing may be inserted in a coaxial line, for example, by the use of conventional coaxial connectors. The switch also lends itself to the easy and compact construction of switching matrices by mounting a plurality of these switches as crosspoints between a pair of stripline printed circuit boards using, for example, conventional solder connections between the coaxial switches and the stripline structure.

The advantages of the present invention over the prior art may be better understood by considering the following discussion.

Applying conventional lumped constant analysis to a string of open switches (that is, serially connected switches with substantially zero transmission paths between them) produces the following conventional and well-known voltage divider expression:

$$\frac{V_{out}}{V_{in}}=\frac{\omega CR}{k+1} \tag{1}$$

where

ω=angular frequency,
C=open switch capacitance,
$k+1$=number of switches and
R=the load impedance.

In other words, each switch added to the string reduces the ratio by adding one to the denominator.

We have found that the above expression does not apply when coaxial cables are connected between the switches. In particular, for $(k+1)$ switches with k pieces of identical lossless coaxial cables interconnecting them, the following expression applies:

$$\left|\frac{V_{out}}{V_{in}}\right|=\frac{\omega CR}{A_k+(A-\omega CZ_0 \sin \beta d)\sum_{n=0}^{k-1}A^{k-1-n}A_n}$$

$$\left|\frac{V_{out}}{V_{in}}\right|\approx\frac{\omega CR}{\sum_{n=0}^{k}A^{k-n}A_n} \text{ for practical components} \tag{2}$$

where the values of A_n are given in the following table:

n	A_n
0	1
1	A
2	$2A^2-1$
3	$4A^3-3A$
.	.
.	.
.	.
k	$2AA_{k-1}-A_{k-2}$

and

$$A=\cos \beta d+\frac{\sin \beta d}{2\omega CZ_0} \text{ for lossless lines}$$

where:

$$\beta = \frac{\omega\sqrt{\epsilon_R \mu_R}}{c} \text{ (phase constant)}$$

ϵ_R=relative dielectric constant of coaxial cable,
μ_R=relative permeability constant of coaxial cable,
c=velocity of light,
d=distance between contacts from switch to switch,
Z_o=characteristic impedance of coaxial cable in ohms and

the remaining symbols have the same meanings as in Equation 1.

A better feeling for the results produced by the invention, and in particular the use of expression (2), may be gained by solving expression (2) for the value of d necessary in the illustrated embodiment to produce the same maximum isolation produced by the Slonczewski arrangement (that is, the value when a one-quarter wavelength cable is used in the Slonczewski arrangement). When this is done, d equals one-hundredths of a wavelength. Since two separations are present, the total switch length is $2d$ or two-hundredths of a wavelength. This is a substantial saving in lenght as it is less than one-twelfth that of the Slonczewski arrangement.

A still better feeling for the results produced by the invention may be obtained by doubling the above value of d and solving expression (2) for the new value of V_{out}/V_{in}. When this is done, it will be found that the new value is about one-eighth that of the old value. In other words, compared with the maximum isolation producible by the Slonczewski switch, the illustrated embodiment of the invention may be designed to produce eight times the isolation within one-sixth the length. These are substantial improvements in both isolation and length.

The invention has been disclosed and discussed in relation to a three-switch embodiment in which the switches are of the reed type. It should be understood that various other embodiments may be devised by those skilled in the art without departing from the spirit and scope of the invention. A study of expression (2) will disclose, for example, that for a fixed value of isolation, the over-all lengths of cable switches in accordance with the invention will decrease as the number of switches is increased. In use, there will be, of course, practical limitations to the number of switches that it is desirable to use. Furthermore, other types of switches may be used. Reed switches having a latching characteristic produced by the setting of remanent material may, for example, be used to eliminate the necessity of providing holding currents.

What is claimed is:

1. A coaxial cable switch comprising
an annular sheath of nonmagnetic electrically-conductive material,
a plurality of at least three switches mounted in said sheath with the contacts of each switch not in excess of one-quarter of a wavelength from the contacts of an adjacent switch,
a plurality of electrically-conductive members connected between said switches, respectively, to form a series combination, and
means for simultaneously operating all of said switches.

2. A coaxial switch in accordance with claim 1 in which said switches are magnetically responsive and said means for operating said switches comprises means for producing magnetic fields.

3. A coaxial switch in accordance with claim 2 in which said magnetically responsive switches are of the reed type and said magnetic field producing means comprises coil means surrounding the outer periphery of said sheath in the vicinity of each of said switches.

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