Jan. 3, 1967 R. ROBBINS ETAL 3,296,457

MATCHED SINGLE POLE SINGLE THROW DIODE MICROWAVE SWITCH

Filed Oct. 14, 1963 3 Sheets-Sheet 1

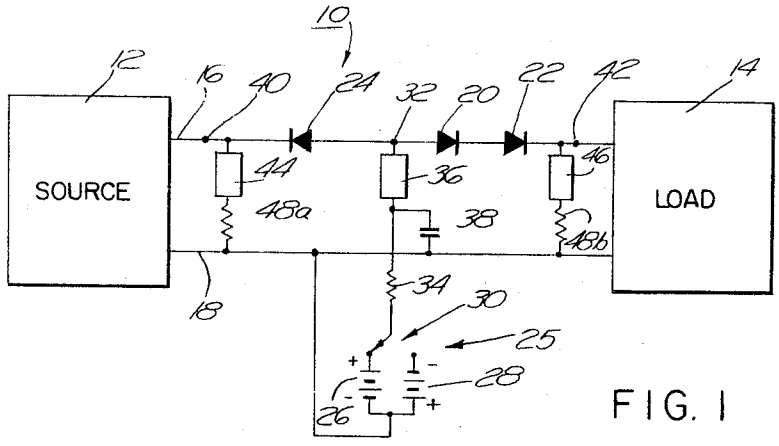


FIG. 1

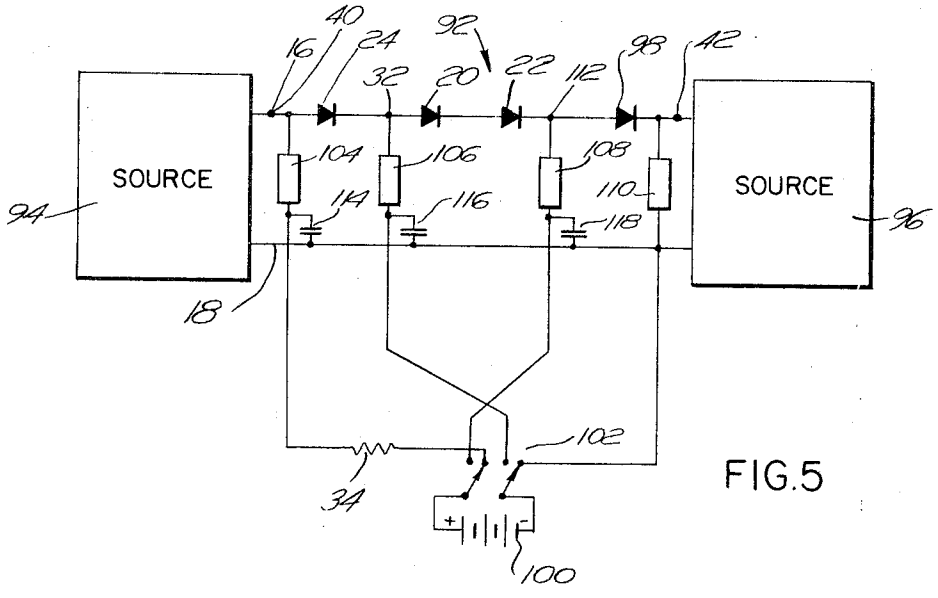


FIG.5

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MATCHED SINGLE POLE SINGLE THROW DIODE MICROWAVE SWITCH

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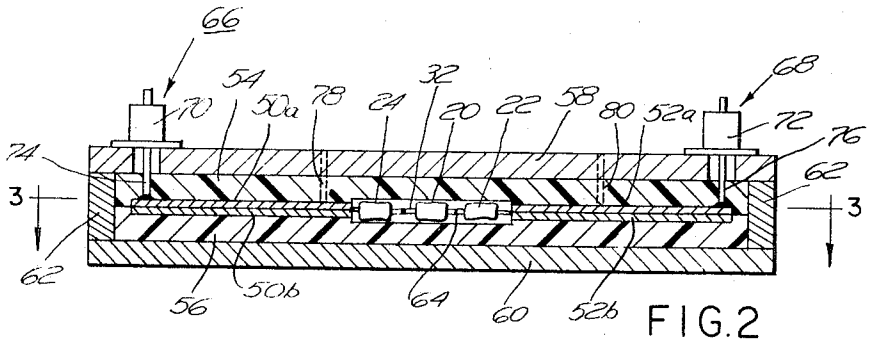


FIG.2

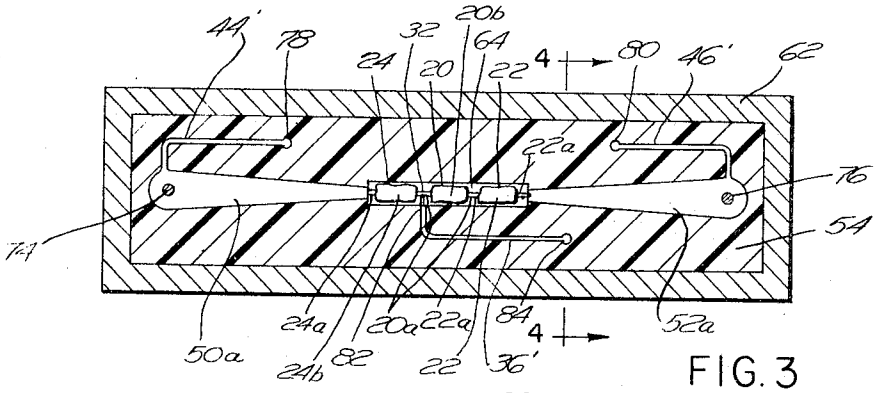


FIG. 3

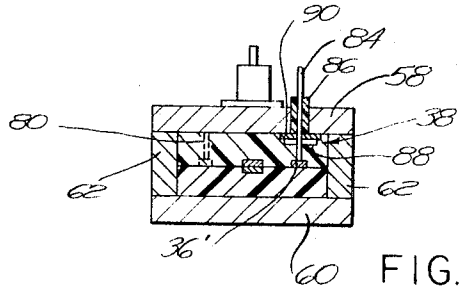


FIG. 4

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MATCHED SINGLE POLE SINGLE THROW DIODE MICROWAVE SWITCH

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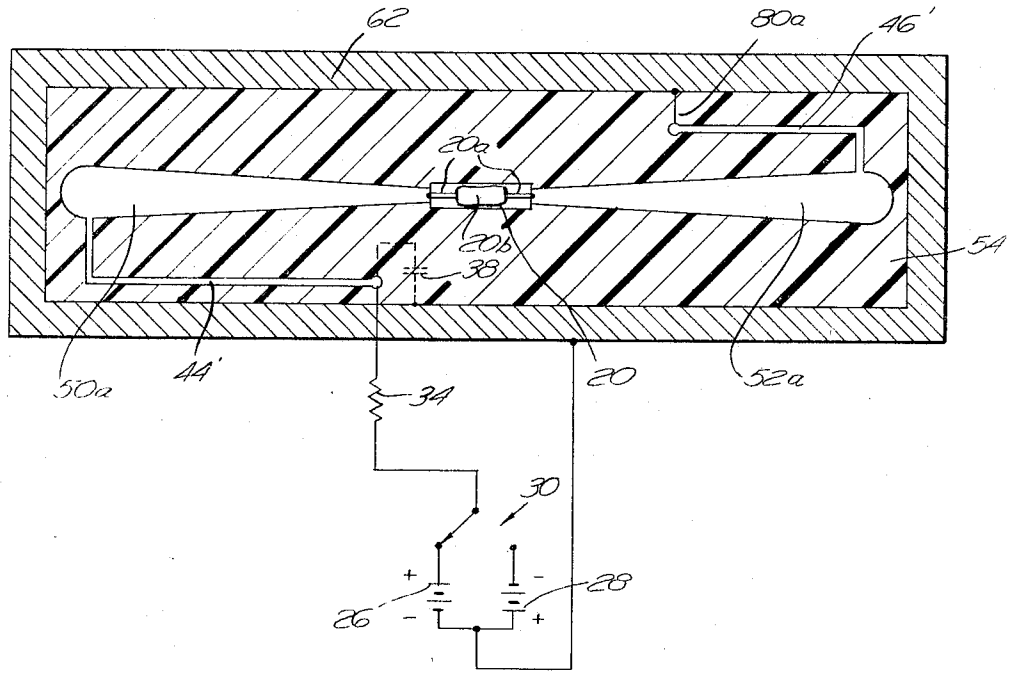


FIG. 6

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MATCHED SINGLE POLE SINGLE THROW DIODE MICROWAVE SWITCH

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Filed Oct. 14, 1963, Ser. No. 315,770
27 Claims. (Cl. 307—88.5)

This invention relates to an improved diode switch of the kind used to pass high frequency electromagnetic energy. More particularly, it relates to a diode type microwave switch providing a low standing-wave ratio in both the open and closed positions.

The use of the diodes as low power microwave switches offers a number of advantages over mechanical switches. In the first place, there are no movable switch contacts, with the attendant problem of noise due to poor connections. Furthermore, diode switches can be fabricated at a lower cost than comparable mechanical switches. They can be packaged in a smaller volume, and, in particular, they are readily incorporated in transmission lines used to convey high frequency energy. Also, they are easily controlled from remote locations, since the switching action is effected by means of direct current bias on the switching diodes.

A serious problem presented by a single-throw diode switch prior to the present invention is the relatively high voltage standing-wave ratio (VSWR) when the switch is open. When the switch is closed, it provides a matched impedance path to a properly matched load, and therefore, the VSWR is no problem. However, when the switch is open, thereby disconnecting the source from the load, it presents a high impedance termination for the transmission line to which it is connected; and the consequent impedance mismatch results in an undesirably high standing-wave ratio.

This problem is also encountered in multiple throw switches used in circuits in which energy travels in both directions. For example, if a switch is used to connect a single port at one end to any one of a number of ports at the other end, an energy source connected to the single port will be properly matched regardless of the switch position, assuming a suitable load connected to all of the ports at the other end of the switch. On the other hand, in prior switches an energy source connected to one of the ports at the second end of the switch will be properly matched only when that port is connected to the single port at the first end.

A further problem involving the use of diode switches concerns their frequency limitations. The upper frequency limits of prior diode switches are attained only at considerable cost and careful selection of the various components used in the switches. Even then the maximum frequency at which diode switches are practical has been substantially less than the level at which operation is desirable in many applications. This problem has manifested itself in the form of an unduly high standing-wave ratio at the input of the switch even when the switch is closed. While various schemes have been proposed to alleviate this problem, none have been commercially practicable, at least over a reasonably broad frequency range.

Accordingly, a principal object of the present invention is to provide an improved diode type switch having a relatively low standing-wave ratio when the switch is open. A more specific object of the invention is to provide a diode switch whose impedance provides a reasonably close match to the impedance of a transmission line when the switch is open.

Another object of the invention is to provide a switch of the above type which has a low insertion loss when the switch is closed to connect a source to a load.

It is also an object of the invention to provide a diode switch of the above character whose switching action can be readily controlled.

Another object of the invention is to provide a diode switch of the above type that provides high isolation when in the open condition.

Still another object is to provide a diode switch of the above type that has the above characteristics over a wide range of frequencies.

A further object is to provide a diode type switch having a low standing-wave ratio when the switch is closed. The switch should have this characteristic over a broad frequency range.

A further object is to provide a switch of the above type which occupies a small volume and can be incorporated in a strip transmission line.

Yet another object is to provide a switch of the above type which has a relatively low cost.

A still further object of the invention is to provide a switch of the above type which is bi-directional, in that it has the above characteristics for transmission of energy through it in either direction.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangements of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a schematic diagram of a switch incorporating the invention,

FIG. 2 is a longitudinal section of a strip transmission line unit embodying the switch of FIG. 1,

FIG. 3 is a second longitudinal section taken along line 3—3 of FIG. 2,

FIG. 4 is a transverse section taken along line 4—4 of FIG. 3,

FIG. 5 is a schematic diagram of a second switch incorporating the invention, and

FIG. 6 is a view, similar to that of FIG. 3 and partly in schematic form, of another switch embodying the invention.

In general, the invention makes use of a conventional high frequency switching diode, for example, a germanium diode such as type 1N277, connected in series in the transmission path controlled by the switch. A second diode, which may be termed an "absorption diode" for the purposes of the present invention, is inserted in series with the switching diode. This latter diode is of a type not used for high frequency switching purposes. Rather, it may be of a general purpose type. It is characterized by a low forward resistance together with a high reverse D.C. resistance. The low forward resistance is for the purpose of providing a low insertion loss when the switch conducts, while the high reverse resistance helps to provide the low standing-wave ratio which characterizes the switch. The requisite characteristic is generally found in silicon diodes, examples being types 1N457, 1N482 and 2N482B. The type 1N457 has a voltage drop of 1 volt with a forward current of 20 milliamperes and is suitable for many applications. In some cases, however, a lower forward resistance of the order of 5 to 10 ohms is preferable. As an example of the desired reverse characteristics, a D.C. resistance of 1

megohm with a reverse bias of 1 volt has been found suitable.

The switch is controlled in the same manner as previous diode switches by means of D.C. bias on the switching diode. In particular, passage of a forward current through the diode turns the switch "on" to provide a low impedance path for a high frequency signal through the diode. A reverse bias on the diode cuts off its conduction and interposes a high impedance from one end of the switch to the other.

The absorption diodes added by the present invention are biased in the forward direction along with the switching diode in order to provide the low insertion loss when the switch is "on." On the other hand, operation of the invention does not require that a reverse bias be applied to the absorption diode when the switch is open, inasmuch as the switching diode provides a sufficiently high impedance.

The invention also provides a substantial increase in the frequency range of the switch. We have found that the relatively large standing-wave ratio encountered in prior diode switches at high frequencies even with the switch closed is due largely to the reactances of the diode leads. We have also found that this problem can be essentially eliminated by using the leads as portions of a transmission line incorporating the switch. That is, the diodes are inserted in series in one of the conductors of a transmission line, and the transmission line conductors are arranged to provide a match between the characteristic impedance of the portion of the line incorporating the leads and the impedance of the remainder of the line.

This matching of impedances is readily accomplished by using a section of strip transmission line to house the diode. A line of this type comprises an "inner" conductor parallel to and spaced from at least one ground plane conductor. Preferably, the inner conductor is disposed between a pair of parallel ground plane conductors. The inner conductor is conveniently formed by use of etching techniques, and consequently, its width, one of the factors determining the characteristic impedance of the line, can be varied as desired. Thus, the inner conductor can be removed from a portion of the line, with the switch diode (or diodes) inserted in this portion. The leads of the diode then form a substitute for the removed inner conductor and thus cooperate with the ground plane conductors in the manner of a length of transmission line. At the ends of this portion of the line, i.e., at the points where the diode leads connect to the remaining inner conductor of the line, the latter conductor is provided with a width corresponding to a transmission line impedance matching that of the portion including the leads. From these points the width of the inner conductor can be tapered so as to provide a broad band impedance transformation resulting in any desired characteristic impedance at the ends of the switch.

Whereas practical diode switches have generally been limited to an upper frequency of about 3,000 megacycles, a switch incorporating our impedance matching technique has been operated at a frequency of 8,000 megacycles, with no significant increase in standing-wave ratio as compared with the previous limit.

As shown in FIG. 1 a switch **10** incorporating the invention is used to connect a source **12** to a load **14**. The switch **10**, which is incorporated in a transmission line comprising conductors **16** and **18**, includes a pair of switching diodes **20** and **22** in series in the conductor **16**, with an absorption diode **24** in series with the diodes **22** and **20**.

Illustratively, a bias supply **25** for the switch **10** includes a pair of batteries **26** and **28** selected by means of a switch **30**. One terminal of the bias supply is connected to the junction **32** between the diodes **20** and **24** by means of a current-limiting resistor **34** and a high frequency isolator **36**. A bypass capacitor **38** aids in providing isolation between the junction **32** and the power supply. The other terminal of the power supply is connected to terminals **40** and **42** of the switch **10** by way of the conductor **18** and isolators **44** and **46**. The isolators **36**, **44**, and **46** provide low resistance direct current paths between the various points on the conductor **16** and the respective terminals of the bias supply **25** while at the same time providing high impedances to high frequency energy and thus isolating such energy from the bias supply.

Where the isolators **36**, **44**, and **46** are connected across the transmission line as shown in FIG. 1, their impedances should be substantially greater than the characteristic impedance of the transmission line so as to shunt a negligible portion of the high frequency energy on the line. In their simplest form they may be merely fine wires having a diameter much smaller than the diameter of the wires used in the conductors **16** and **18**, and thus having a substantially greater inductance per unit length.

When the switch **30** is in the position illustrated, current from the battery **26** passes through the diodes **20**, **22** and **24** in the forward direction. Assuming that sufficient current (e.g., 20 milliamperes) passes through the diodes, they have low resistance and the switch **10** is therefore closed, connecting the source **12** to the load **14**. It should be noted that, in order to pass biasing current of the desired magnitude through the diodes **20** and **22** on the one hand and the diode **24** on the other hand, it may be advantageous to include a suitable resistor **48***a* or **48***b* in series with the isolator **44** or **46**, depending on the relative forward voltage-current characteristics of the diodes.

When the switch **30** is moved to its other position, the battery **28** is connected to apply a reverse bias to the diodes **20–24**. This greatly increases the impedance of the switching diodes **20** and **22**, thereby opening the switch **10** and isolating the source **12** from the load **14**. In prior diode switches, this would result in a large voltage standing-wave ratio along the transmission line **16–18** between the source **12** and the switch **10**.

However, with the inclusion of the diode **24** in the circuit, there is a remarkably low standing-wave ratio. For example, in one switch incorporating the invention, the following standing-wave ratios were measured at various frequencies:

Frequency (gc.s.):	Standing wave ratio
2.0	2.9
2.2	2.3
2.4	2.0
2.6	1.8
2.8	1.6
3.0	1.3

The switch was designed for operation at 3.0 gc.s., and it will be apparent that the standing-wave ratio with the switch open approximates the values which might be expected for a closed switch, i.e., biased for conduction. In fact, the standing-wave ratio at 3.0 gc.s. when the switch was open approximated a measured ratio of 1.1 when the switch was closed.

Nor does the presence of the diode **24** materially affect the insertion loss of the switch when it is closed, or "on." The insertion loss of the switch on which the above standing-wave ratio measurements were taken was found to range from 0.8 db to 1.3 db over an octave centered at 3.0 gc.s.

The exact mechanism by which the diode **24** minimizes reflection of energy from the switch **10** when the latter is open is unknown. In some manner this diode apparently absorbs incident energy and such absorption is unexpectedly a property of diodes having a high D.C. resistance when reverse bias is applied to them. However it should be noted that the diode **24** functions to minimize reflection even though no reverse bias is applied to it. That is, while the circuit of FIG. 1 shows both forward and reverse bias applied to the diode **24**, as well as to the diodes **20** and **22**, operation of the switch only requires

that the reverse bias be applied to the diodes **20** and **22**. The diode **24** then has zero reverse bias, in which condition it has the desired energy absorbing characteristic.

On the other hand, forward bias should be applied to the diode **24** when the switch is closed, i.e., conducting, in order to provide a low insertion loss. Thus, it will be apparent that the bias arrangement shown is merely illustrative of a number of different configurations which will provide bias conditions resulting in the superior characteristics of the switch.

While two switching diodes (**20** and **22**) have been shown in the drawing, it will be apparent that only one such diode is required for operation of the switch. However, two or more are generally preferred because of the increased isolation they provide between the terminals of the switch when it is open. It will be noted that for the purpose of the invention a plurality of switching diodes operate in the same manner as a single such diode. Therefore, the recitation of a single switching diode includes a plurality thereof.

As shown in FIGS. 2, 3 and 4, the preferred construction of the switch makes use of a compact section of strip transmission line incorporating the diodes **20**, **22** and **24**. Specifically, as seen in FIG. 2, inner-conducting strips **50***a*, **50***b*, **52***a* and **52***b* are bonded to insulators **54** and **56**. The insulators **54** and **56**, in turn, are disposed between top and bottom cover plates **58** and **60** which also serve as the outer or ground plane conductors of a strip transmission line section incorporating the inner strips **50** and **52**. The unit also includes an outer metallic enclosure **62** (best seen in FIG. 3) in electrical contact with the cover plates **58** and **60**.

As shown in FIGS. 2 and 3, the insulators **54** and **56** are provided with a recess **64** in which the diodes **20**, **22** and **24** are disposed. The diodes are connected in series with each other and also the conducting strips **50***b* and **52***b*, illustratively by soldering. The connection to the strips **50***a* and **52***a* also serves to connect the diodes to the strips **50***b* and **52***b* which are in register and in contact with the strips **50***b* and **52***b*.

Connections to the switch may be made by means of coaxial connectors shown in FIG. 2, and generally indicated at **66** and **68**, whose outer conductors **70** and **72** are connected to the cover plate **58**. The connectors also have inner conductors **74** and **76** extending through the cover plate **58** and suitably joined with the outer ends of the conducting strips **50***a* and **52***a* respectively.

As shown in FIG. 3, the isolators **36**, **44** and **46** preferably take the form of sections of strip transmission line incorporating conducting strips **36'**, **44'**, and **46'**. At one end, each of the strips **44'** and **46'** is integral with an inner conducting strip (**50***a* or **52***a*) at the juncture thereof with one of the connectors (**66** or **68**). The other ends of the strips **44'** and **46'** are attached to wires **78** and **80** which extend through the insulator **54** (FIG. 2) and are soldered to the cover plate **58**. The latter connection may conveniently be made by passing the wires **78** and **80** through holes in the plate **58** and then filling the holes with solder or other suitable material. Thus, the strips **44'** and **46'** provide direct connections between the strips **50** and **52**, and the other side of the tranmission line as embodied in the cover plates **58** and **60**.

At the same time they provide isolation at high frequencies. This isolation may be provided by either of two arrangements. In the first place, strips **44'** and **46'** are much narrower than the strips **50** and **52**. Therefore, the transmission lines of which they are the inner conductors have a substantially greater characteristic impedance than the transmission lines incorporating the strips **50** and **52**. Assuming reasonably close impedance matching of the switch to the devices connected by means of the connectors **66** and **68**, this means that division of power between the strips **50** and **52** on the one hand, and the strips **44'** and **46'** on the other hand, will, in general, result in diversion of only a negligible portion of power to the strips **44'** and **46'**. This mode of isolation assumes that the wires **78** and **80** provide sufficient resistance to terminate the lines incorporating the strips **44'** and **46'** with a reasonable approximation of their characteristic impedance. This will be the case if the conductors **78** and **80** include the respective resistors **48***a* and **48***b*, shown in FIG. 1.

Isolation also results when the conductors **78** and **80** have essentially zero impedance and the strips **44'** and **46'** are approximately one quarter wavelength long at the frequency of operation of the switch. In this case, a very high impedance is reflected to the junctures of these strips with strips **50** and **52**. While this mode of isolation is somewhat sensitive to frequency, we have found it to be effective over at least an octave.

The conducting strip **36'** is connected by means of a short wire **82** to the junction **32**. At its other end, the strip **36'** is connected to a wire **84** which, as best seen in FIG. 4, extends upwardly through a feed-through insulator **86** extending through the cover plate **58**. The wire **84** is externally connected to the bias supply **25** of FIG. 1.

The preferred construction of the by-pass capacitor **38** of FIG. 1 is shown in the detail of FIG. 4. It includes a disk **88** of metallic foil surrounding and connected to the wire **84**, together with an insulator **90** disposed between the disk **88** and the cover plate **58**. The area of the disk **88** and thickness of the insulator **90** are such as to provide a capacitance resulting in a negligible impedance at the frequency of operation of the switch. Thus, at this frequency there is, in essence, a direct connection between the wire **84** and the cover plate **58**. The conducting strip **36'** is preferably a quarter wavelength long at the frequency of operation and thus, it reflects a very high impedance back to the junction **32**, again resulting in isolation.

It will be noted that the conducting strips **50** and **52** are tapered, with their widths being greater at their outer ends and dinimishing in the direction of the diodes **20–24**. This taper serves to match the strip transmission line incorporating the strips **50** and **52** to the impedance of the coaxial cable used with the connectors **66** and **68** and also to the characteristic impedance of the leads of the diodes **20–24**.

That is, the leads of the diodes (FIGS. 2 and 3) serve as transmission line inner conductors. Thus, there is a characteristic impedance associated with them, and this can be determined for the purpose of providing an impedance match between them and the inner ends of the conducting strips **50** and **52** connected to the end leads **81** and **91**. The widths of the inner ends of the strips **50** and **52** are such as to match this impedance.

More specifically, when the diodes **20–24** are biased in the forward direction, almost the entire series reactance is in the form of the inductance of the leads **20***a* **22***a* and **24***a*. It appears that at high frequencies this reactance has a large value compared to the terminating impedances connected to the switch. This in itself serves to materially attenuate signals passed by the switch. Moreover, the lead inductances resonate with capacitances at various frequencies, thereby further degrading the impedance characteristics. These capacitances are believed to be mainly the capacitances between the body portions **20***b*, **22***b* and **24***b* of the diodes and the other side of the transmission line, i.e., the ground plane conductors. Thus, the inductances and capacitances serve as a low pass filter impairing the high frequency operation of the switch.

On the other hand, matching of the transmission line impedance at the inner ends of the strips **50** and **52** to the characteristic impedances of the portions containing the leads **20***a–24a* essentially eliminates the inductances of the leads at all frequencies of interest. This reduction in the effective series reactance also serves to reduce the effect of the shunt capacitances. If additional compensation is desired, the dielectric surrounding the diode bodies **20***b–24b* may be modified to provide a constant shunt capacitance along that portion of the line, and thus

further improve the independence of the switch characteristics from the frequency of the signals passed by the switch. The spacing between the diode bodies and the ground plane conductors (plates **58** and **60**) may also be modified to accomplish capacitance compensation.

However, we have found that, in general, matching of the lead impedances alone provides sufficient enhancement of the frequency characteristics. In particular, with this technique, diodes suitable for operation up to a limit of about 3000 megacycles have been successfully used in switches operating on 8,000 megacycle signals. Since this was the upper frequency limit of the test equipment, there is reason to believe that the upper frequency limit of the switch may have been even higher.

The strip transmission line construction of the switch is advantageous not only because of the small size of the entire package, but also because it greatly facilitates the matching of impedances. One of the parameters affecting characteristic impedance is the width of the inner conducting strips **50** and **52**: the impedance decreases as the width increases. Since the inner strips are readily formed and shaped by printed or etched circuit techniques, their widths are easily adjusted to any desired value. Moreover, it is a simple matter to taper the widths, as shown in FIGS. 2 and 3, so as to provide an impedance matching characteristic effective over a wide frequency range, rather than the relatively small bandwidth of conventional quarter-wavelength matching sections.

It will also be apparent from the foregoing description that the strip line construction provides a relatively low cost assembly, even with the improved performance of the switch.

Since the characteristic impedance of the transmission line portions using the leads **20***a*–**24***a* as inner conductors varies with the diameters of the leads, the leads should all have substantially the same diameter in order to avoid impedance discontinuities.

The impedance matching features of the invention is effective only when absorption diodes are used (FIGS. 1 and 5), but also in cases where they are not used. For example, as shown in FIG. 6, a switch may incorporate only the diode **20**, with the leads **20***a* connected to the impedance-matching inner conductor strips **50** and **52**. The tapered strips **50** and **52** operate, as described above, to effectively eliminate inductance of the leads **20***a* and thus extend the frequency range of the switch.

Because of the absence of an absorption diode, the switch illustrated in FIG. 6 is somewhat different from its counter part of FIGS. 1–4. Specifically, the biasing arrangement is modified by the elimination of the isolator **36'**. The end of the isolator **46'** is still connected to the ground plane system, by a wire **80***a*, shown schematically by the dash line. The outer end of the isolator **44'** is coupled to the ground plane system by the capacitor **38** in the manner shown in detail in FIG. 4. The current limiting resistor **34**, the batteries **26** and **28**, and the switch **30** operate in the same manner as in FIG. 1.

In FIG. 5, we have illustrated a switch **92** adapted for operation between sources **94** and **96**, which also serve as loads for each other. In an arrangement of this type, it is desirable that the switch **92** have bi-directional characteristics. That is, when it is open, it should provide a low standing-wave ratio for energy approaching from either direction. For this purpose it includes, in addition to the switching diodes **20** and **22** and the absorption diode **24**, a second absorption diode **98**, connected between the diode **22** and the terminal **42**. The diode **98** operates in the same manner for energy coming from a source **96** as the diode **24** does for energy delivered by the source **94**.

Bias for the switch **92** is illustratively provided by a battery **100** connected to the switch by means of a double-pole, double-throw switch **102** and isolators **104**, **106**, **108** and **110**. These isolators are similar to the isolators **36**, **44** and **46** (FIGS. 1–4). The isolator **110** is connected to both the conductors **16** and **18**. On the other hand, the isolators **104**–**108**, which are connected respectively to the conductor **16** at the terminal **40**, the junction **32**, and a second junction **112** between the diodes **22** and **98**, are not connected to the conductor **18**. Therefore, at the high frequencies passed by the switch **92**, connections are effectively made to the conductor **18** by means of by-pass capacitors **114**, **116** and **118**, similar to the capacitor **38** of FIGS. 1 and 4.

When the switch **102** is in the position illustrated in FIG. 5, current from the battery **100** passes through the diodes **24**, **20**, **22**, and **98** in their forward directions, and thus, the diodes present a low impedance for a connection between the sources **94** and **96**. On the other hand, when the switch **102** is reversed, a reverse bias is applied to the switching diodes **20** and **22**, thereby opening the switch **92** in the manner described above. It is noted that with the particular circuit illustrated in FIG. 5, no reverse bias is applied to the absorption diodes **24** and **98** when the switch is open. However, as noted above, these diodes still function as energy absorbers.

The switch **92** may be housed in the same manner as switch **10**, in a structure identical with that shown in FIGS. 2–4, with provision for the additional diode **98** and the additional isolater and by-pass capacitors.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are effiicently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contined in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

We claim:

1. A switch comprising:

(a) a transmission line section including first and second transmission line conductors,

(b) first and second diodes in series with each other in said first conductor,

(c) bias means connected to alternatively

(1) pass a forward current through said diodes, and

(2) apply a reverse potential to at least said second diode,

(d) said first diode being a general purpose silicon diode having low forward resistance and high reverse D.C. resistance, and

(e) said second diode being of a type having a high impedance at high frequencies when said reverse potential is applied thereto.

2. The combination defined in claim **1** in which said bias means is arranged to apply said reverse bias to said second diode without passing a forward current through said first diode.

3. The combination defined in claim **1** in which said second diode is of a type suitable for switching high frequency energy.

4. The combination defined in claim **1** in which said bias means includes:

(a) means for supplying said forward current and reverse potential, and

(b) high frequency isolation means connected between said supply means and said diodes, each of said isolation means including a section of transmission line arranged to present a high impedance at the frequency of operation of said switch to said transmission line section to which said diodes are connected.

5. A switch comprising:

(a) a transmission line section including first and second transmission line conductors,

(b) first, second and third diodes in series with each other in said first conductor, with said second diode connected between said first and third diodes,

(c) bias means connected to alternatively

(1) pass a forward current through said diodes, and

(2) apply a reverse potential to at least said second diode,

(d) said second diode being of a type having a high impedance at high frequencies when said reverse potential is applied thereto,

(e) said first and third diodes being general purpose silicon diodes having low forward resistance and high reverse D.C. resistance.

6. The combination defined in claim **5** in which said bias means is arranged to apply said reverse potential to said second diode without passing a forward current through said first and third diodes.

7. A strip transmission line switch for controlling a high frequency signal, said switch comprising:

(a) a pair of spaced-apart ground plane conductors,

(b) a strip line inner conductor having first and second ends,

(e) insulating means supporting said inner conductor between said ground plane conductors,

(d) at least one switching diode,

(e) at least one general purpose silicon diode having low forward resistance and high reverse D.C. resistance connected in series with said switching diode, the series combination of said diodes being in series in said inner conductor intermediate said ends thereof,

(f) a first bias conductor connected to receive a first switch operating potential, said first bias conductor

(1) being connected to the end of said switching diode intermediate said switching and general purpose silicon diodes, and

(2) extending from said inner conductor and between said ground plane conductors to a first point for a quarter-wavelength at the frequency of said high frequency signal,

(g) first conductive means

(1) connected to said first bias conductor at said first point,

(2) having a relatively small high frequency impedance to said ground plane conductors,

(3) whereby said first bias conductor presents a high impedance at its connection to said inner conductor,

(h) second and third bias conductors connected to receive a second operating potential and apply it to said inner conductor at the other ends of said diodes, and

(i) each of said second and third bias conductors presenting a relatively high impedance to high frequency signals on said inner conductor.

8. The switch defined in claim **7** in which

(a) said transmission line has first characteristic impedance at said ends,

(b) said diodes form with said ground plane conductors a transmission line section having an effective characteristic impedance different from said first impedances, and

(c) said strip line inner conductor has end sections between said diodes and said ends, said inner conductor and sections being tapered to provide impedance matching between said ends and said diodes.

9. The switch defined in claim **7** in which

(a) said first conductor forms a capacitor with at least one of said ground plane conductors, said capacitor having a low reactance at the frequency of said signal,

(b) each of said second and third bias conductors extends from said inner conductor and between said ground plane conductors to a connection point for a quarter-wavelength at the frequency of said high frequency signal, and

(c) second and third conductive means are connected respectively to said second and third bias conductors at said connection points, said second and third conductive means providing low impedances between said second and third bias conductors and at least one of said ground plane conductors at said signal frequency, whereby each of said second and third bias conductors presents a high impedance at its connection to said inner conductor.

10. A transmission line switch that provides a relatively low standing-wave ratio at a first terminal in both the open and closed conditions, said switch comprising:

(a) means forming first and second terminals,

(b) a transmission line

(1) comprising first, second and third serially-connected sections, and

(2) connected between said terminals with said first section connected to said first terminal and said third section connected to said second termnial,

(c) a general purpose silicon diode having low forward resistance and high reverse D.C. resistance,

(d) a switching diode in series with said general purpose silicon diode,

(e) the series combination of said diodes being connected in series with said transmission line in said second section thereof, with said general purpose silicon diode being intermediate said first section and said switching diode, and said second section being coextensive with said diodes and the leads thereof, and

(f) bias conductors connected with said transmission line,

(1) said bias conductors being arranged to apply a forward bias voltage to said diodes, and

(2) alternatively apply a reverse bias voltage to said switching diode without passing a forward current through said general purpose silicon diode,

(3) each bias conductor presenting a relatively high impedance to high frequency signals on said transmission line, thereby preventing transmission of substantial high frequency energy from said transmission line by way of said bias conductors.

11. The switch defined in claim **10** in which

(a) said transmission line comprises first and second transmission line conductors,

(b) said diodes are connected in series opposition in said first transmission line conductor,

(c) an end of a first bias conductor is connected to said first transmission line conductor intermediate said diodes, and

(d) second and third bias conductors are conducted together at one end and connected at their other ends to said first transmission line conductor in said first and third sections respectively,

(e) whereby said bias conductors are arranged to apply forward bias to both diodes and alternatively apply reverse bias to both diodes.

12. The switch defined in claim **11** in which said transmission line is a strip transmission line having

(a) a pair of ground plane conductors forming said second conductor, and

(b) a strip line inner conductor forming said first transmission line conductor in said first and third sections.

13. The switch defined in claim **12** in which

(a) said diodes include leads,

(b) leads of said diodes are connected with said inner conductor at the junctions thereof with said second section,

(c) said inner conductor being so shaped in said first

and third sections as to provide an impedance match between said first and second terminals and the characteristic impedance of the portions of said transmission line including said leads.

14. The switch defined in claim 10 in which
(a) said first terminal has a first characteristic impedance,
(b) said second transmission line section has a second characteristic impedance, and
(c) said first transmission line section matches said first characteristic impedance with said second impedance.

15. A transmission line switch that provides a relatively low standing-wave ratio at a first terminal in both the open and closed conditions, said switch comprising
(a) means forming first and second terminals,
(b) a transmission line comprising first and second conductors and having first, second and third serially-connected sections,
(c) said transmission line being connected between said terminals with said first section connected to said first terminal and said third section connected to said second terminal,
(d) a general purpose silicon diode having low forward resistance and high reverse D.C. resistance,
(e) a switching diode in series with said general purpose silicon diode,
(f) said diodes being connected to pass forward current in the same direction along said line,
(1) the series combination of said diodes being connected in series in said first conductor in said second section of said line, with said general purpose silicon diode being intermediate said first section and said switching diode, and
(g) first, second, and third bias conductors
(1) said first bias conductor being connected to said first transmission line conductor intermediate said diodes,
(2) said second bias conductor being connected to said first transmission line conductor in said first section,
(3) said third bias conductor being connected to said first transmission line conductor in said third section,
(4) so that a forward bias voltage applied between said second and third bias conductors forward biases both diodes, and a reverse bias voltage applied between said first and third bias conductors reverse biases only said switching diode,
(5) each bias conductor presenting a relatively high impedance to high frequency signals on said transmission line and thereby preventing substantial transfer of energy from said transmission line to said bias conductors.

16. The switch defined in claim 15 in which said transmission line is a strip transmission line having a pair of ground plane conductors forming said second conductor and a strip line inner conductor forming said first conductor.

17. A transmission line switch that provides a relatively low standing-wave ratio at its terminals in both the open and closed conditions, said switch comprising
(a) means forming first and second terminals,
(b) a transmission line comprising first and second conductors and having first, second and third serially-arranged sections,
(1) said transmission line being connected between said terminals with said first section connected to said first terminal and said third section connected to said second terminal,
(c) first and second general purpose silicon diodes having low forward resistance and high reversed D.C. resistance,
(d) a switching diode in series with and between said general purpose silicon diodes,
(1) the series combination of said diodes being connected in series in said first transmission line conductor in said second section of said line, and
(e) at least two bias conductors for receiving switch operating voltages, said bias conductors
(1) being connected to said first conductor,
(2) each presenting a relatively high impedance to high frequency signals on said transmission line,
(3) being arranged to apply a first operating voltage to forward bias said diodes, thereby closing said switch, and
(4) being arranged to apply a second operating voltage to reverse bias at least said switching diode without passing forward current through said first and second general purpose silicon diodes, thereby opening said switch.

18. The switch defined in claim 17 in which
(a) said transmission line is a strip transmission line having a pair of ground plane conductors forming said second conductor and a strip line inner conductor disposed between said ground plane conductors and forming said first conductor,
(b) said line has a first characteristic impedance at said first terminal,
(c) said second section of line is coextensive with said diodes and the leads thereof and has a second characteristic impedance, and
(d) said strip line inner conductor is shaped to match said first impedance to an impedance value intermediate said first and second impedances.

19. A switch comprising:
(a) a transmission line unit including first and second transmission line conductors,
(b) said transmission line unit including first, second and third serially-connected sections, said second section being between said first and third sections,
(c) a plurality of diodes in series with each other in said first conductor in said second section,
(d) said diodes having leads providing the connections between adjacent diodes and between said diodes and said first and third sections,
(e) bias means connected to alternatively
(1) pass a forward current through said diodes, and
(2) apply a reverse potential to at least a first one of said diodes,
(f) said first diode being of a type having a high impedance at high frequencies when said reverse potential is applied to it,
(g) at least a second diode of the general purpose silicon type having low forward resistance and high reverse D.C. resistance, said second diode being directly connected to said first sections being highly absorbent for high frequency energy when no forward current is passed through it, and
(h) said first and second transmission line sections providing impedance matches between the characteristic impedances at the ends thereof remote from said second section and the characteristic impedance of said second section.

20. The switch defined in claim 19 in which
(a) said leads cooperate with said second transmission line conductor as portions of a transmission line, and
(b) said first and third transmission line sections provide impedance matches between the ends thereof remote from said second section and the characteristic impedance of said portions including said leads.

21. The combination defined in claim 20 in which
(a) said transmission line is a strip transmission line comprising an inner conductor disposed between a pair of ground plane conductors,
(b) said inner conductor being said first transmission line conductor in said first and third sections, and said ground plane conductor being said second conductor.

22. A diode assembly for the processing of high frequency signals, said assembly comprising:
(a) a transmission line unit including first and second transmission line conductors,
(b) said transmission line unit comprising first, second and third serially-connected sections, said second section being between said first and third sections,
(c) at least a first diode in series in said first conductor in said second section,
(d) said diode having leads forming portions of said first conductor in said second section,
(e) diode leads connecting said second section with said first and third sections in said first conductor,
(f) said first transmission line conductor within said first and third sections having a configuration such as to provide impedance matches between the ends of said first and second sections remote from said second section and said transmission line portions including said leads.

23. The assembly defined in claim 22 including
(a) bias means for alternately biasing said first diode in the forward and reverse directions,
(b) said first diode being a high frequency switching diode.

24. The assembly defined in claim 22 in which
(a) said transmission line unit is a strip transmission line unit including a strip line inner conductor disposed between a pair of ground plane conductors,
(b) said inner conductor being said first transmission line conductor in said first and third sections, and said ground plane conductor being said second conductor.

25. The assembly defined in claim 24 in which
(a) each of said first and third sections has a characteristic impedance differing from that of said portions including said leads at the end of each section remote from said second section,
(b) said characteristic impedances of said first and third sections tapering from the values thereof at said remote ends to that of said portions so as to provide a substantial impedance match between said remote ends and said leads over a wide range of frequencies.

26. The assembly defined in claim 23 in which
(a) said transmission line unit is a strip transmission line unit including a strip line inner conductor disposed between a pair of ground plane conductors,
(b) said inner conductor being said first transmission line conductor in said first and third sections, and said ground plane conductor being said second conductor.

27. The assembly defined in claim 26 in which
(a) each of said first and third sections has a characteristic impedance differing from that of said portions including said leads at the end of each section remote from said second section.
(b) said characteristic impedances of said first and third sections tapering from the values thereof at said remote ends to that of said portions so as to provide a substantial impedance match between said remote ends and said leads over a wide range of frequencies.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,296,457 January 3, 1967

Robert Robbins et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 38, for "50a and 52a" read -- 50b and 52b --; line 39, for "50b and 52b" read -- 50a and 52a --; column 6, line 52, for "20a" read -- 20a, --; column 7, line 40, after "effective" insert -- not --; column 8, line 29, for "efficently" read -- efficiently --; line 32, for "contined" read -- contained --; column 9, line 24, for "(e)" read -- (c) --; column 11, line 72, for "reversed" read -- reverse --.

Signed and sealed this 7th day of November 1967.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
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