Dec. 8, 1970 H. J. PE PPIATT 3,546,633

ELECTRICALLY TUNABLE MICROWAVE BAND-STOP SWITCH

Filed Jan. 4, 1966 2 Sheets-Sheet 1

FIG. 1

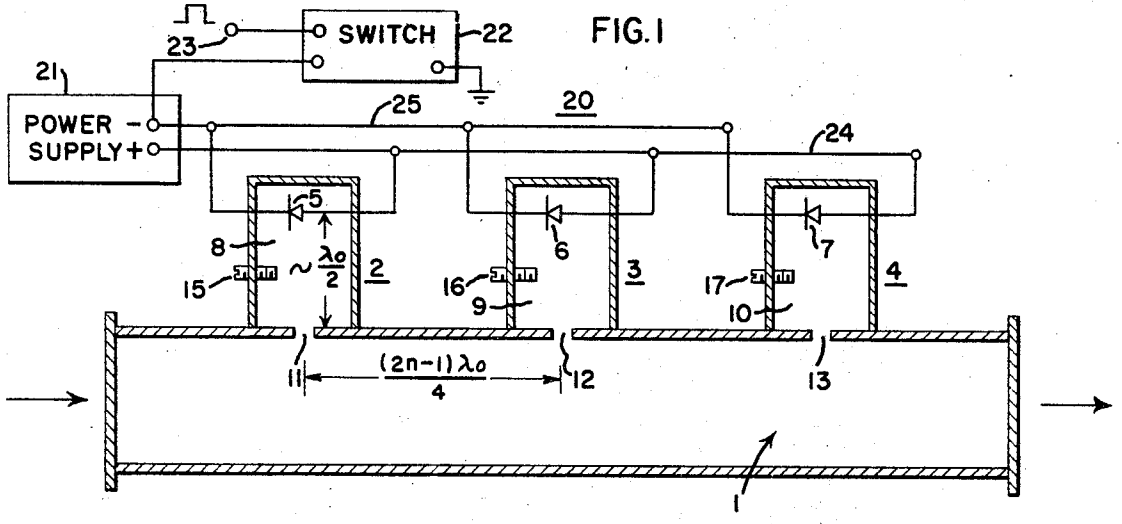


FIG. 2

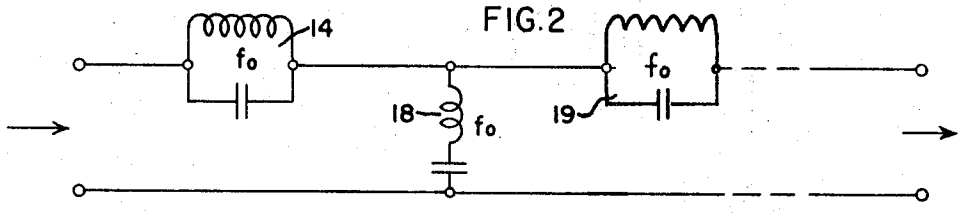
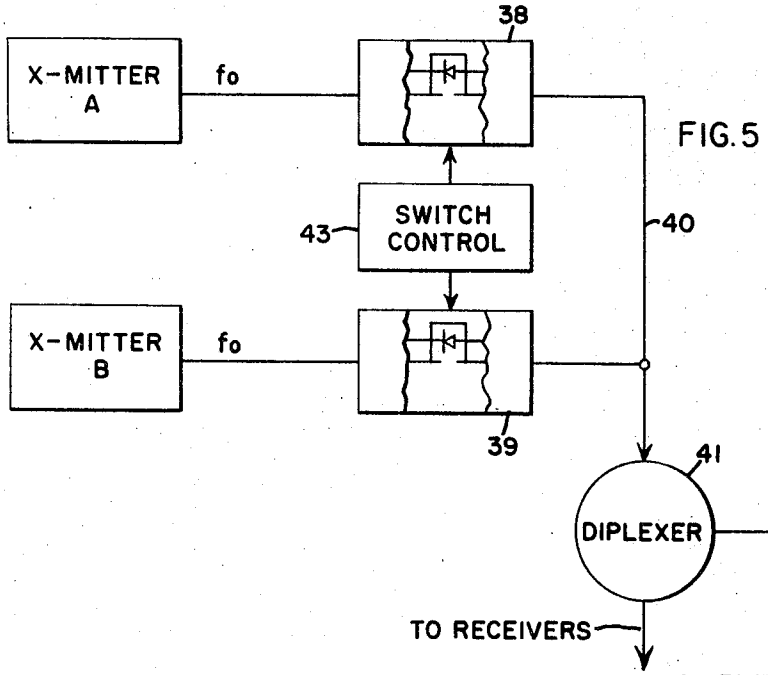


FIG. 5



INVENTOR:
HARRY J. PEPPIATT,
BY D. David Blumenfeld
HIS ATTORNEY.

ELECTRICALLY TUNABLE MICROWAVE BAND-STOP SWITCH

Filed Jan. 4, 1966 2 Sheets-Sheet 2

FIG.3

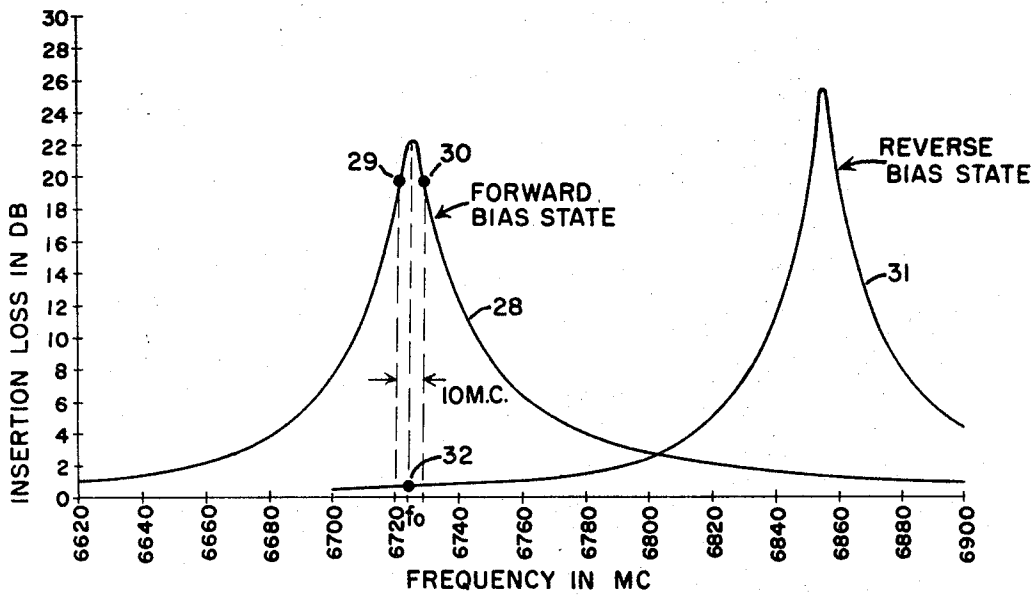
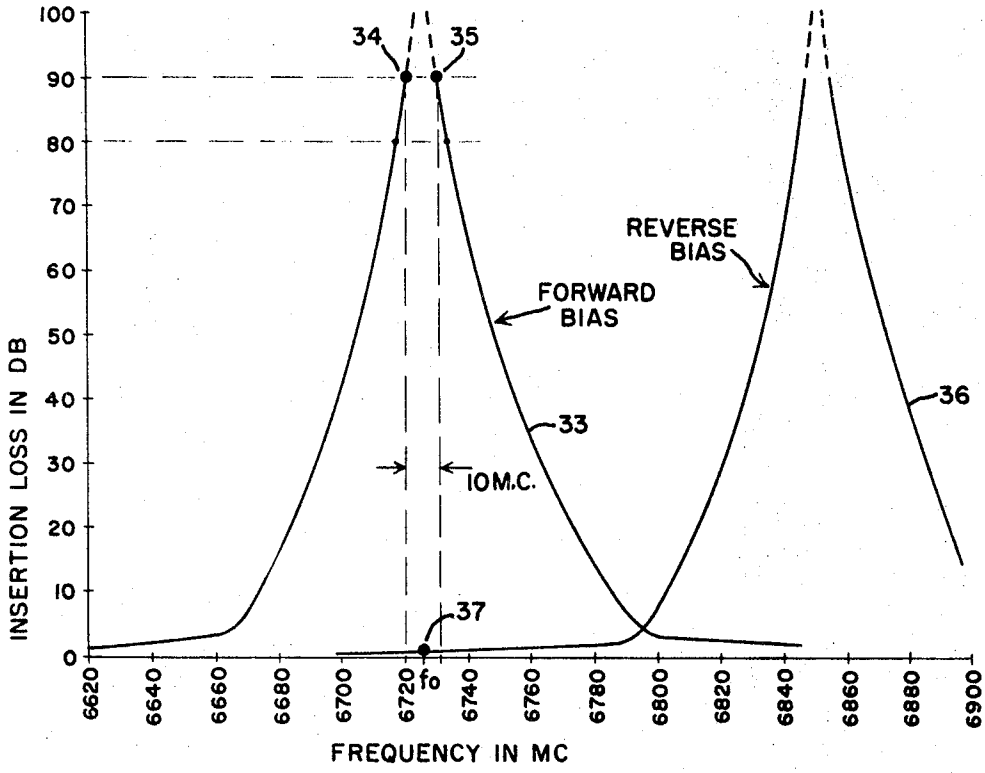


FIG.4



INVENTOR:
HARRY J. PEPPIATT,
BY J. David Blumenfeld
HIS ATTORNEY.

United States Patent Office 3,546,633 Patented Dec. 8, 1970

3,546,633

ELECTRICALLY TUNABLE MICROWAVE BAND-STOP SWITCH

Harry J. Peppiatt, Lynchburg, Va., assignor to General Electric Company, a corporation of New York

Continuation-in-part of application Ser. No. 414,596, Nov. 30, 1964. This application Jan. 4, 1966, Ser. No. 532,013

Int. Cl. H03h 7/10

U.S. Cl. 333—7 7 Claims

ABSTRACT OF THE DISCLOSURE

A narrowband waveguide switch is described which utilizes a plurality of resonators coupled to a main waveguide. Each of the resonators includes a switching diode which, when placed in the conducting state, controls the electrical length of the resonator in a manner such that the resonator acts as a band-stop switch terminating passage of the electromagnetic energy down the waveguide. The resonators are separated by an odd quarter wavelength of waveguide section to provide impedance transformations which enhance the attenuating characteristics of the switch.

This invention relates to an apparatus for controlling the propagation of electromagnetic energy and, more particularly, to a switch for electrically controlling the transmission of microwave energy along a wave guide. This is a continuation in part of my co-pending application, S.N. 414,596, filed Nov. 30, 1964 now abandoned.

There are presently available a variety of switching devices for controlling propagation of microwave energy along a wave guide or other transmission medium. One category of available microwave switches is the mechanical microwave switch which physically inserts movable vanes, spokes, or pins into the wave guide to control propagation. These, however, have many shortcomings as microwave switches. They require some sort of an actuating element and mechanical linkage to control movement of the vanes, etc., into and out of the wave guide. Consequently, the switches are usually bulky, complex, and costly. More importantly, however, mechanical switches, due to their size and inertia, are inherently slow in operation. Where rapid switching of microwave energy is required, as for example where a standby transmitter must be switched in because of a transmitter failure to prevent either interruption of communication or damage to the equipment, mechanical switches have proven to be simply too slow in operation to perform this function adequately.

Another class of microwave switches are those which, in one way or another, may be operated electrically. One species of electrically actuated microwave switches is the gaseous discharge switch. The gaseous switching devices are positioned in the wave guide, and the conductivity of the gas is controlled through an external power source and suitable electrodes, with the switching action being effected by short-circuiting the microwave energy, when the gas is ionized. While gaseous switches are in many ways a substantial improvement over mechanical switches, they also have limitations which circumscribe their usefulness. Since the switching mechanism is based upon a gaseous ionization process, the switching speed and the switching repetition rate are obviously limited by the ionization and deionization times of the gas. Furthermore, ionization is not instantaneous, and gaseous switches pass a short but intense "spike" of power at the start of the switching operation.

Still another class of electrically operated microwave switches are the so-called ferromagnetic switches which use a ferrite body and a controllable magnetic field as the

switching element. The magnetic field changes the permeability of the ferrite so that the impinging microwave energy is converted into waves of different polarization, the relative amplitudes of which are varied by the magnetic field to control propagation of the energy. Since the permeability of the ferrite, and thus the switching action, is based on the rise and collapse of a magnetic field, the speed of operation may be too slow for many applications.

In an attempt to avoid these limitations of size, complexity, and operating speed, solid-state devices, such as diodes, etc., have been proposed to perform this switching function. In a typical system of this type, the diode is located directly in a wave guide and is forward-biased into the conducting state whenever transmission of the electromagnetic energy down the wave guide is to be prevented. With forward-biase applied, the diode is driven into conduction and provides a very low impedance or short circuit across the wave guide. The impinging microwave signal is thus prevented from propagating along the guide and is substantially dissipated across the low impedance diode. While microwave switches of this type represent a definite improvement over mechanical, electromagnetic or gaseous switches in that the diode is small, may be electrically controlled, and is quite rapid in operation, it does have one serious limitation which severely restricts its usefulness. Its major shortcoming is that only low power signals can be switched. Since the diode must dissipate all of the impinging energy the amount of microwave energy, which can be switched, is limited to a fraction of a watt since, at greater power levels, the amount of power dissipated is sufficient to destroy the diode junction. Hence, a need exists for a simple, compact, electrically controlled microwave switch capable of handling substantial power levels.

It is, therefore, one of the primary objects of this invention to provide a microwave switching device which is small in size, simple in construction, rapid in operation, and capable of handling a large amount of power without damage to the switch.

A further object of this invention is to provide a high power microwave switching arrangement which can produce a high degree of isolation of the signal when the switch is actuated and has a very low insertion loss when the switch is not actuated.

Yet another object of this invention is to provide a high power microwave switch of the type utilizing electrically tunable resonant structures to control transmission of the microwave energy.

A still further object of this invention is to provide a microwave switching arrangement using one or more tunable resonant circuits of the band-stop or band-reject type which are electrically actuated to control transmission of the signal.

Other objects and advantages of the invention will become apparent as the description thereof proceeds.

The various advantages of the invention may be achieved in one form thereof by having a plurality of electrically tunable resonant structures positioned along a wave guide. Each of the resonant structures includes a diode which may be selectively reverse or forward-biased in order to control the electrical length and, hence, the resonant frequency of the structure. When the diode is forward-biased into the conducting state, it changes the resonant frequency of the resonant structure so that it acts as a high impedance in series with the wave guide, i.e., a band-stop filter, and prevents transmission of the incident microwave energy along the wave guide. The spacing between the resonant elements, if more than one is used, is kept at approximately an odd multiple quarter wave length of the signal center frequency. The odd multiple quarter wave length wave guide acts as an impedance transformer, and the high impedance resonant structures atfer the first are trans-

formed to low impedance series resonant shunt circuits, thereby enhancing the signal isolation effected by the switch. By using a plurality of resonant devices so spaced, the isolation provided by the plurality of resonant devices is substantially equal to the product of the isolation of the individual resonant circuits.

The novel features, which are characteristic of this invention, are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with other objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic illustration of the microwave switch constructed in accordance with the invention.

FIG. 2 shows an equivalent electric schematic diagram of the switch of FIG. 1.

FIG. 3 is a graphical representation of the operating characteristics of a single band-stop switching circuit constructed in accordance with the instant invention.

FIG. 4 is a graphic representation of the operating characteristics of a microwave switch including a plurality of band-stop switches separated by an odd quarter wave length.

FIG. 5 is a partial schematic diagram of a communication system utilizing a plurality of transmitters in which one of the transmitters is coupled to the radiating systems by means of the microwave switch of the instant invention.

FIG. 1 illustrates such a microwave switch for controlling propagation of electromagnetic energy along a transmission medium such as a wave guide. Microwave energy from a source, not shown, is propagated (from left to right as illustrated by the arrows) along wave guide **1** to a suitable utilization circuit, also not shown. Positioned along the wave guide is a microwave switching means consisting of a plurality of electrically tunable, band-stop filter switches **2**, **3**, and **4** which, as will be explained in detail later, isolate the microwave source and signal from the load.

Each of the band-stop filter switches includes a unidirectional conducting device, such as diodes **5–7**, positioned in resonators **8–10**. The conductivity of these diodes is varied between the conducting and nonconducting states to change the resonant frequency of the resonators thereby controlling transmission of the microwave energy down wave guide **1**. Resonators **8–10** are coupled to wave guide **1** by means of coupling slots **11–13**. The coupling slots may be either capacitive or inductive depending on their size and location in the "E" plane (or narrow cross-section) of the wave guide. With the switch actuated, resonators **8–10** are band-stop filters and prevent transmission of microwave energy in the selected band. In this state, the electrical length of the resonator is approximately a half wave length of the band-center frequency, f_0, i.e.,

$$\eta\frac{\lambda G_0}{2}$$

At this length, the admittance ($Y=G+jB$, where G is the conductance and jB the susceptance) of the resonators and their associated coupling slots is quite low. Since the resonators are coupled to the wave guide in the "E" plane the resonator admittances are in series with the wave guide and represent a very high impedance in series with the wave guide when the switch is actuated.

If coupling slots **11–13** are capacitive, the electrical length of the resonator in the switched condition is made to be slightly greater than a half wave length

$$l_1>\frac{\lambda G_0}{2}$$

so that the resonator represents an admittance having negative susceptance, $B=jK$ (i.e., inductive). The capacitive slots represent a positive susceptance. $B=+jK$, which cancels the negative susceptance of the resonator so that the resultant susceptance is zero $B_T=0$, and the resultant

admittance is a small conductance, $Y_T=G$ so that the equivalent electrical length of the total assembly, resonator, slot, etc. is

$$\frac{\lambda G_0}{2}$$

Thus, resonator **8** in the switched condition can be represented, as may be seen from FIG. 2, by a parallel tuned circuit **14** resonant at the center frequency f_0 of the microwave signal frequency band. Variable tuning screws **15–17** are provided for resonators **8–10** to provide additional tuning adjustment of the resonators in the switched condition so that the resonators and the coupling slots or irises present the proper impedance in the switched condition.

The individual resonant band-stop switches **2**, **3**, and **4** are separated by impedance transforming wave guide sections so that the high impedances of resonant cavities **9** effectively become a low impedance series resonant circuit **18** as shown in FIG. 2. To this end, the coupling slots **11**, **12**, **13** are separated from each other by an electrical length that is an odd multiple quarter wave length of the center frequency f_0 of the microwave signal frequency band,

$$\left(\frac{l_2=(2\eta-1)\lambda G_0}{4}\right)$$

This impedance transformation greatly enhances the signal isolation of which the switch is capable, with the total isolation of the switch being substantially equal to the product of the signal isolation provided by the individual band-stop switches.

As was briefly discussed before, diodes **5**, **6**, and **7**, positioned respectively in resonators **8–10**, perform the switching operation which changes the tuning of the resonators to convert them from band-stop switches in a band outside of the signal band so that they have substantially no effect on the microwave signal in wave guide **1**, to band-stop switches in the desired band to prevent further transmission of the energy. Diodes **5**, **6**, and **7** are preferably semiconductor junction diodes, the conducting states of which are electrically controlled to vary the electrical length of the resonators. Diodes **5**, **6**, and **7** are physically positioned in the resonators so that in the forward-biased or conducting state they present a short circuit across part of the resonator so that the electrical length of the resonators is changed sufficiently for it to be approximately a half wave length at the center frequency of the microwave signal frequency band

$$\eta\frac{\lambda G_0}{2}$$

At this electrical length, the resonators act as band-stop filters by inserting the transformed low impedance of resonator **9** in shunt between the high impedance resonators **8** and **10**. In the reverse-biased or nonconducting state, diodes **5**, **6**, and **7** are an open circuit. This changes the electrical length of the resonators and shifts the resonant frequency outside of the frequency band of the transmitted signal so that the resonators have substantially no effect on the transmitted signal. In other words, diodes **5**, **6**, and **7** provide a means for selectively tuning and detuning the resonators thereby controlling propagation of the microwave energy down the wave guide.

The conductive states of the diodes are controlled, either manually or automatically, by means of a suitable biasing circuit to provide electrical actuation of the switch. The biasing circuitry is shown generally at **20** and consists essentially of a switched DC source. The DC supply **21** has output terminals to which the diodes are connected and a switching device **22** which operates in response to an input control signal at terminal **23**. Switch **22**, as illustrated in FIG. 1, is simply a device for enabling the power supply and switching the polarities of the biasing voltages applied to the diodes. Thus, with a control signal applied to terminal **23**, the output of the DC supply has the polar-

ity shown in FIG. 1, and a positive voltage is applied to the anodes of diodes **5**, **6**, and **7** over supply bus **24**, and a negative voltage or ground is applied to the cathodes of the diodes over bus **25**. In the absence of an input signal to actuate switch **22**, the polarity of the output from DC supply **21** is reversed, and a negative voltage is applied to the anodes over bus **24** and a positive voltage over bus **25** so that the diodes are reverse-biased. It will be obvious, to those skilled in the art, that electrical control circuit **20** for the diodes may be actuated in any number of different ways, and that the arrangement illustrated in FIG. 1 is by no means limiting. For example, biasing of the diodes may be achieved manually or through any circuit arrangement for automatically changing the bias voltages in response to a condition, such as a fault on a system, etc., to a program controlled pulse.

The manner in which the multi-resonator microwave band-stop switch of FIG. 1 functions may perhaps be most easily understood by means of the schematic illustration of FIG. 2 which shows the equivalent electrical circuitry of the switching device illustrated in FIG. 1. Thus, with diode **5** biased into the conducting or forward direction, the electrical length of cavity resonator **8** is

$$\lambda G_0/2$$

The switch susceptances, which include the susceptance of the resonator, tuning screw **15**, and capacitive slot, cancel out so that the resultant susceptance is zero. Thus, the admittance of resonator **8** is a pure conductance of a very small value. Since capacitive coupling slot **11** is positioned in the "E" plane of the wave guide the admittance, which at f_0 is equal to a pure conductance, is connected in series with the waveguide. Resonator **8** may thus be represented by a series-connected parallel resonant circuit **14** resonant at the center frequency f_0 of the microwave signal. This high impedance isolates the microwave source and signal from the load and prevents further transmission of the signal.

A cavity resonator, such as the one illustrated at **8**, may typically provide approximately 20 to 25 db of signal attenuation or isolation. Since physically realizable resonators have a finite impedance rather than the theoretically infinite impedance of a parallel resonant circuit, complete isolation is, of course, not possible with a single resonator. In order to achieve greater than 20 or 25 db isolation possible with a single band-stop switch, additional resonators **9**, **10**, etc. are coupled to the waveguide **1** at odd multiples of a quarter wavelength from resonator **8**. The additional resonators **9** and **10**, etc., with diodes **6** and **7** forward-biased, also have an admittance at f_0 which is a pure conductance of a small value so that the impedance or resistance seen by the wave guide at the coupling slots **12** and **13** is very high and is the equivalent of a parallel resonant circuit in series with the wave guide. However, the electrical spacing of the coupling slots **12**, **13** of resonators **9** and **10** from the coupling slot **11** of resonator **8** and from each other is approximately an odd multiple of a quarter wavelength at the signal center frequency

$$f_0\left(\frac{\lambda G_0}{4}, \frac{3\lambda G_0}{4}, \frac{5\lambda G_0}{4}, \text{etc.}\right)$$

The wave guide section acts as an impedance transformer so that looking to the right from the resonator **8** the impedance of resonator **9** is transformed from a very high value to a very low value; in other words, the parallel resonant circuit representing resonator **9**, when viewed from resonator **8** and resonator **10**, is transformed to series resonant circuit **18** connected across the wave guide. This greatly enhances the isolation afforded by the switching arrangement. Assuming the parallel resonant circuit **14** in series with the waveguide has a very high but finite impedance Z at f_0, it is obvious that another parallel resonant circuit, having an impedance Z in series with **14**, only doubles the total impedance, i.e., Z_Z, and the attenuation and/or isolation is merely increased by 3 db. Thus, if the attenuation or isolation due to parallel resonant circuit **14** were 20 db, for example, the addition of a second parallel resonant circuit would merely increase the attenuation to 23 db, and so on, producing at best a small increase in the isolation. However, by the impedance transformation, the series resonant circuit **18** across the waveguide shunts the microwave signal not attenuated by network **14**. The microwave switch of the instant invention constitutes a plurality of such resonators electrically spaced by approximately an odd multiple of a quarter wavelength at f_0. By virtue of this spacing, alternate high impedances in series with the guide and low impedances in shunt with the guide are seen by the signal. In fact, as will be explained in detail presently in connection with FIGS. 3 and 4, the signal isolation, which can be achieved using n resonators, is approximately the product (or n times) of the attenuation of the individual resonators so that three resonators, each of which are individually capable of producing an isolation or attenuation of 20 db, produce a total attenuation of 60 db or more, whereas three resonators, without the impedance transforming sections, would, at most, produce an attenuation of 24 or 25 db.

FIG. 3 illustrates graphically, by means of curve **28**, the characteristic response of a single resonator band-stop filter switch. The signal frequency in megacycles is plotted along the abscissa and the insertion loss in db along the ordinate. Curve **28**, also identified by the legend "forward-bias state," illustrates the frequency response of the single resonator band-stop filter switch with the diode biased in the conducting or forward direction. The resonator was constructed to be resonant at 6725 megacycles with the diode forward-biased. It can be seen that at the center frequency of the band f_0=6725 mc. the insertion loss or attenuation of the signal is approximately 23 db. It can also be seen that for a bandwidth of approximately 10 megacycles centered about f_0, points **29** and **30** of curve **28**, the minimum attenuation of the switch is approximately 20 db. Curve **31**, labelled "reverse-bias state," illustrates the characteristic response of the single resonator band-stop filter switch with the diode reverse-biased into the nonconducting state. It can be seen that the resonant center frequency of the cavity is shifted to 6850 megacycles and out of the transmitted microwave signal band. In the desired 10 megacycle microwave band centered about the 6725 mc., point **32** of curve **21** shows that the insertion loss with the switch reverse-biased is only a fraction of a db. Thus, a band-stop switch, consisting of a single resonator, is capable, in the switched state, of providing from 20 to 23 db isolation and an insertion loss in the unswitched state of less than a db.

FIG. 4 illustrates the characteristic response of a band-stop switch of the type shown in FIG. 1 using four (4) resonators, each individually having the characteristic illustrated in FIG. 3. Curve **33** shows the characteristic response of the switch with the diodes in the four resonators forward-biased and in the conducting state, and curve **36** illustrates the response characteristics of the switch with the diodes reverse-biased. It can be seen from curve **33** that for a bandwidth of 10 megacycles centered about f_0=6725 mc. (points **34** and **35** on the curve), the signal attenuation is approximately 90 db; better than four times the isolation produced by single resonator band-stop switch in the same frequency band. It is apparent, therefore, that a band-stop microwave switch, using a plurality of electrically tunable band-stop filters each separated by an odd quarter wave length section, produces a signal attenuation or isolation which is at least equal to the product of the attenuation achieved by a single electrically controlled band-stop filter. This, of course, is highly desirable and is a great improvement over previously known microwave switches both in the degree of isolation afforded but also in the simplicity of the switch construction and the speed and effectiveness of its operation. It can also be seen from curve **36** of FIG. 4 that,

with the diodes reverse-biased so that the microwave signal is transmitted to the load, the insertion loss in the signal band (points **37** of curve **36**) is again less than a db.

By positioning the switching device as shown in FIG. 1 this offers an additional advantage in offering great flexibility in adjusting the impedance at the point of switching to the particular characteristics of the switching device. The power delivered to the load in the pass condition, and hence the power which the switch is capable of handling, is approximately equal to $\frac{1}{2}V_0I_s$, where V_0 is the voltage across the diode in the reverse-biased state and I_s is the current through the diode in the forward-biased state. V_0 and I_s have both D.C. and R.F. terms and in order to maximize the power that can be handled by the switch, the product, V_0I_s, must be maximized.

The maximum value of V_0I_s is determined by the safe thermal, voltage or current breakdown ratings of the switching device. This, in turn, is dependent on placing the diode at the proper position or impedance level in the circuit. The switch arrangement described here lends itself particularly to the solution of this difficulty for the impedance level at which the diode operates can be adjusted over a wide range of values by varying the distance between the switching diode and the end wall, a range of adjustment which makes it possible to match the requirements of many different available switching diode devices thereby optimizing the power handling capacity of the switch.

For a maximum impedance change (and hence a maximum frequency shift) between the conducting and non-conducting diode states, each diode is preferably spaced from the closed or shorted wall of its respective resonator by an electrical length that is an odd multiple of

$$\lambda G_0/4$$

This spacing may be varied considerably, as for example as much as plus or minus

$$\lambda G_0/8$$

depending upon the magnitude and characteristic (i.e., inductive or capacitive) of the impedance which the resonators are to present when the diodes are non-conducting. Thus, while a spacing of

$$\lambda G_0/4$$

may be ideal for many applications, other spacings may be used, depending upon operating conditions.

FIG. 5 illustrates partially in block diagram form one practical application of the microwave switching arrangement illustrated in FIGS. 1 and 2. It shows a communication system, with "hot" standby, which includes two transmitters operating simultaneously on the same frequency. Transmitters A and B operate on the same frequency and are continually energized to produce, for example, a 10 mc. output carrier signal centered at f_0. The transmitters are coupled through a pair of multi-elements band-stop filter switches **38** and **40** to common waveguide **40**, diplexer **41** and thence to a radiating element such as an antenna **42**. Switches **38** and **39** are controlled by a switch control element **43** which selectively maintains one of the two switches in the "On" condition and the other in the "Off" condition. The switch control **43** may be either manually operated or may be operative in response to some condition sensing device such as a sensing element for determining loss of the transmitted signal. Switch control element **43**, in one instance, forward-biases the diodes in switch **38**, thereby isolating transmitter A and its carrier signal from waveguide **40** while simultaneously reverse-biasing the diodes of switch **39**. The carrier signal from transmitter B passes through switch **39** to common wave guide **40**, diplexer **41** and antenna **42**. Upon the occurrence of some predetermined event, such as a failure of the transmitter or reduction of the power level for example, the switch control circuit, which may be of any suitable kind, is actuated. This removes reverse-bias from switch **39** and applies forward-bias, thereby isolating transmitter B from the common wave guide and the antenna. Simultaneously the diodes in switch **38** are reverse-biased, and the switch now passes the signal from transmitter A to wave guide **40** and to antenna **42**. Thus, by means of this simple multi-resonator band-stop switch arrangement, two or more transmitters may be easily diplexed to a single common wave guide or transmission medium and thence to a radiating element such as an antenna. Also, shown in FIG. 5 is the output from antenna **42** and diplexer **41** to one or more receivers, not shown, which may, in turn, contain band-stop switches of the type illustrated in connection with the transmitters.

It will be apparent now that a simple, inexpensive, rapid, and highly effective microwave switching arrangement has been described which produces a high degree of isolation by means of a simple but highly reliable structure.

Although a number of specific embodiments of the invention have been shown, it will, of course, be understood that the invention is not limited thereto since many modifications, both in the instrumentalities and circuit arrangement employed, may be made. It is contemplated by the appended claims to cover any such modifications which fall within the true scope and spirit of this invention.

I claim:

1. In a microwave switch, the combination comprising,

(a) a waveguide transmission path for microwave energy;

(b) a plurality of electrically tunable resonators positioned along said transmission path;

(c) a plurality of coupling apertures in said waveguide for coupling each of said resonators to said waveguide;

(d) switching means for changing the resonant frequency of said resonators so as to convert said resonators to band-stop filters in the switched state and thereby prevent transmission of said energy along said waveguide path, said switching means including:

(1) a solid-state element having two conductive states positioned in each of said resonators for varying the electrical length of said resonators, the electrical length of said resonators being such that each of said resonators acts as a high-impedance band-stop filter when said element is in one conductive state and the electrical length being such as to have substantially no effect on transmission of said energy when said element is in the other conductive state;

(2) electrical means for selectively switching said solid-state element into one or the other of the conductive states to control propagation of said microwave energy along said transmission path;

(e) and an impedance-transforming waveguide section having a length in the direction of energy propagation that is substantially equal to an odd multiple, including unity, of a quarter wavelength of said energy, and being positioned between each adjacent pair of said coupling apertures whereby said resonators in the switched state represent alternate high impedances in series with said transmission path and low impedances across said path to enhance attenuation of the microwave signals in the switched state.

2. In a microwave transmitting system, the combination comprising,

(a) a pair of continuously energized transmitters for generating microwave energy;

(b) a common waveguide and a radiating means coupled to said common waveguide;

(c) means for selectively coupling energy from one of said first and second transmitters to said common waveguide and to said radiating means, said coupling means including:

(1) first and second individual waveguides respectively coupled between said transmitters and said common waveguide;

(2) band-stop switch means associated with each of said individual waveguides, each of said band-stop switch means comprising a plurality of resonators coupled to a respective individual waveguide through coupling apertures, each of said resonators having diodes positioned therein for controlling the electrical length and thereby the resonant frequency of said resonators, said resonators being converted to band-stop filters in response to the conductive state of said diodes, each adjacent pair of apertures of each of said band-stop switch means being separated by impedance-transforming waveguide sections to enhance the attenuation of microwave energy when said diodes are in said conductive state;

(d) and switch control means for selectively biasing said diodes to bias said switch means associated with one of said individual waveguides so that the energy from one of said transmitters is attenuated and simultaneously to bias said switch means associated with the other waveguide so that energy from the other transmitter is coupled to said common waveguide, whereby only one of said continuously energized transmitters is operatively coupled to said common waveguide.

3. The microwave transmitting system of claim **2**, wherein said impedance-transforming waveguide sections are an odd multiple of a quarter wavelength long.

4. An improved microwave switch for selectively passing and blocking microwave energy of a selected frequency comprising:

(a) a waveguide section for providing a transmission path for microwave energy of a selected frequency;

(b) said waveguide section having a plurality of electrical coupling means at spaced intervals along said transmission path;

(c) each of said spaced intervals being substantially equal to an odd multiple, including unity, of a quarter wavelength at said selected frequency;

(d) a plurality of resonant cavities each having an input end and a shorted end spaced from said input end;

(e) a solid-state device respectively positioned in each of said cavities and spaced from said input end by a distance substantially equal to some multiple, including unity, of a half wavelength at said selected frequency;

(f) means respectively coupling the input end of each of said cavities to a respective one of said electrical coupling means;

(g) and means connected to each of said solid-state devices for selectively switching said solid-state devices into one conducting state so that said cavities present one electrical impedance at said selected frequency, and for selectively switching said solid-state devices into an opposite conducting state so that said cavities present a second electrical impedance at said selected frequency.

5. The improved microwave switch of claim **4** wherein each of said electrical coupling means comprises a coupling aperture in a wall of said waveguide section.

6. The improved microwave switch of claim **4** wherein each of said solid-state devices is spaced from said shorted end of its cavity by a distance approximately equal to some odd multiple, including unity, of a quarter wavelength at said selected frequency.

7. The improved microwave switch of claim **4** wherein each of said electrical coupling means comprises a coupling aperture in a wall of said waveguide section, and wherein each of said solid-state devices is spaced from said shorted end of its cavity by a distance approximately equal to some odd multiple, including unity, of a quarter wavelength at said selected frequency.

References Cited

UNITED STATES PATENTS

3,117,241	1/1964	Paynter et al.	333—7
3,164,792	1/1965	Georgiev et al.	333—73
3,179,816	4/1965	Hall et al.	333—7X
3,215,955	11/1965	Thomas et al.	333—7
3,245,014	4/1966	Plutchok et al.	333—97
3,278,868	10/1966	Kach	333—83
3,417,351	12/1968	Di Piazza	333—73

OTHER REFERENCES

"Microwave Semiconductor Switching Techniques," Garver et al., IRE Transactions on Microwave Theory and Techniques (volume MTT6), October 1958, No. 4 TK 7800 I 23; pages 378–381 relied upon.

HERMAN K. SAALBACH, Primary Examiner

C. BARAFF, Assistant Examiner

U.S. Cl. X.R.

333—73, 98