ABSTRACT: A switching device for tuning a hollow waveguide transmitting microwave signals, including a resonator comprising a section of the waveguide, a reed switch disposed in a normally open state interiorly of the resonator section, and a solenoid mounted exteriorly on the waveguide in proximity of the reed switch, the solenoid energized by a switching signal for providing a magnetic field to actuate the reed switch to a closed state to tune the resonator to a mid-frequency of a first preselected frequency band of microwave signals to reflect the latter signals in the waveguide; the solenoid deenergized in response to a discontinuance of the switching signal for terminating the magnetic field to permit the switch to return to the normally open state to tune the resonator to a mid-frequency of a second preselected frequency band of microwave signals different from the first preselected band of microwave signals to transmit the latter signals in the waveguide.
MICROWAVE SWITCHING DEVICE EMPLOYING A REED SWITCH ELEMENT

This invention relates to microwave signal transmission line including a swiching device of a mechanical type for controlling the transmission of microwave signals on the line and more particularly to such device comprising a reed switch.

Conventional mechanical type microwave switching devices, either manually or motor operated, have such faults as structural complexities, slow switching speeds, and expensive manufacturing costs.

In accordance with our prior invention described in the copending Japanese Pat. application No. 48316/67, the microwave switching device essentially consists of an auxiliary resonator section and a main resonator section. The present invention resides in an improvement in the prior invention in such a manner that the auxiliary resonator section is eliminated and the overall switching device is simplified, with the equivalent switching properties, performance, reliability and other advantages maintained.

A principal object of the invention is to provide improved tuning for a microwave resonator. Another object is to simplify the tuning of a microwave resonator.

A further object is to increase the speed of tuning a microwave resonator.

An additional feature is to improve the reliability of tuning a microwave resonator.

Still another object is to improve the speed of capability of tuning a waveguide resonator.

A still further object is to improve the operational economy of tuning a waveguide resonator.

A still additional object is to improve the manufacturing economy of tuning a waveguide resonator.

Advantages of the invention include simplicity of design, facile operation, low cost of maintenance.

In association with a hollow rectangular waveguide line for transmitting microwave signals, a specific embodiment of the present invention comprises a hollow waveguide resonator having one closed end and mounted on an outside surface of one wide wall of the waveguide line to provide a common wall between the resonator and the latter waveguide one wide wall in such manner that the latter wall includes an aperture for electromagnetically coupling the waveguide line and resonator, a reed switch mounted in the resonator and consisting of a hollow elongated dielectric tube, and two electric conductive reeds having overlapping and normally disengaged adjacent ends and positioned along a center axis of the tube; the reeds having other ends mounted in opposite closed ends of the tube and projecting outside thereof; the tube and reeds mounted in the resonator in such manner that the other reed ends are secured in opposite walls of the resonator and one other end of one reed projects outside the resonator as a further end portion which is encircled by an electric solenoid. A common center axis of the tube and reeds and a center axis of the waveguide line are parallel and lie in a vertical plane.

In the operation of the aforesaid described embodiment of the invention, the solenoid is energized by a switching signal to establish a magnetic field to activate the reeds to engage the overlapping ends thereof to tune the resonator to a mid-frequency of a first preselected frequency band of microwave signals for reflecting the latter signals on the waveguide transmission line, and the solenoid is deenergized in response to a discernance of the switching signal to terminate the magnetic field to permit the overlapping reed ends to return to the normal disengagement thereof to tune the resonator to a mid-frequency of a second preselected frequency band of microwave signals different from the first preselected frequency band microwave signals for transmitting the latter signals in the waveguide line.

One modification of the invention resides in a rectangular waveguide resonator formed on the inside of a rectangular waveguide transmission line and having a center axis of the reed switch displaced laterally from a center axis of the latter transmission line. Another modification concerns a coaxial conductor transmission line having a coaxial conductor resonator mounted thereon and including the two reeds forming the reed switch as the inner conductor of the coaxial conductor resonator. In an additional modification, two reed switches are positioned end-to-end as a segment of the inner conductor of the coaxial conductor transmission line to form two discrete side-by-side coaxial conductor resonators therein.

A feature of the invention is related to the high-speed capability of the reed switch having a switching time of less than one millisecond for tuning waveguide resonators.

The foregoing and other objects, features, and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a plan view partly in cross section of a microwave switching device according to this invention applied to a rectangular waveguide type band-rejecting microwave device;

FIG. 2 is a longitudinal sectional view of the device of FIG. 1 taken on the line a-a';

FIG. 3 is a cross-sectional view of the device of FIG. 1 taken on the line b-b';

FIG. 4 shows the attenuation vs. frequency characteristic curves of the microwave switching device shown in FIGS. 1, 2, and 3;

FIG. 5 is a plan view of another microwave switching device applied to a rectangular waveguide type band-pass filter;

FIG. 6 is a cross-sectional view of the device of FIG. 5 taken on the line c-c';

FIG. 7 shows the attenuation vs. frequency characteristic of the device shown in FIGS. 5 and 6;

FIG. 8 is a schematic circuit diagram illustrating a typical example of application of this invention; and

FIGS. 9, 10, and 11 are the cross-sectional views of other microwave switching devices applied to a coaxial transmission line.

It will be seen that the microwave switching device shown in FIGS. 1, 2, and 3 is composed of a rectangular waveguide 1, a cavity resonator 2, an aperture-defining element 3 between the waveguide and the cavity resonator, a sealed-in-glass reed switch 4 whose axis is disposed between the opposite walls of the rectangular cavity resonator 2, and a solenoid 5 surrounding a lead wire 7 of the reed switch 4 in the axial direction of said solenoid 5, which lead 7 is an extension of the reed 6.

In this embodiment, the opposite ends of the reed switch 4 are fixed by soldering to the opposite walls of the cavity resonator 2. The position at which the reed leads of the reed switch 4 are fixed is predetermined to a length of λ/2 (λ = guide wavelength of frequency f1) from a plane including the element 3 and the length of cavity resonator from the plane is preselected to (%λ) g.

In operation upon energizing, solenoid 5 to close the reeds 6, the cavity resonator is tuned to a resonance at frequency f1. Under the condition, therefore, the microwave centered at f1 and transmitted in the direction from A to B in the waveguide are reflected. Whereas, upon deenergizing the solenoid to open the reeds, the resonant frequency shifts from f1 to f2, thereby permitting microwaves centered at f2 to pass through the waveguide in the direction from A to B. Thus, the switching on and off of the reed switch 4 results in the switching of the microwaves transmitted in the direction from A to B.

It is not a necessary condition that the reed switch is disposed between the two opposite cavity walls so as to lie in a plane including the center axis of said waveguide as shown in FIG. 1. Instead, it may be disposed between two points on any two adjacent or opposite internal wall surfaces in any direction, provided the same degree of electric coupling can be secured.

In FIGS. 5 and 6 showing another embodiment of this invention, reference numeral 10 denotes a band-pass filter composed of a rectangular waveguide 1 and aperture-defining ele-
ment 3, numeral 4, 5, 6 and 7 are similar to those shown in FIGS. 1, 2 and 3.

Although the axis of the reed switch is laid in perpendicular to the top and bottom internal wall surfaces in this embodiment, it would be obvious that its axis may be terminated at any two suitable points respectively on the top and bottom internal wall surfaces.

Now, with this structure, the reed switch can be turned to either one of two states "make" and "break." Assuming that the resonant frequency of the band-pass filter is tuned to a frequency f₀ on closing of the contacts, it is caused to shift on opening of the contacts from f₁ to f₂ as characteristic shows in FIG. 7. Thus, the microwaves centered at f₂ and passed into the waveguide in the direction from C to D are reflected.

Although the present invention has been so far described as applied to rectangular-waveguide-type filters, it is similarly applicable to a coaxial line type microwave circuit. The reed switch is installed as a center conductor for the resonator with or without a short segment attached at each end of the reed switch. In such a configuration, a coaxial cavity resonator may be integrated in a coaxial line as a microwave transmission line in such a manner that the resonator is protrude from the coaxial line. When the type resonator comprises a coaxial type (FIG. 10), a clearance should be formed between one end of the reed switch and the center conductor of the axial coaxial line, in contrast with the case of the regular coaxial cavity resonators (FIG. 9) where the clearance is not needed. A solenoid for energizing the reed switch is disposed outside of the coaxial cavity resonator. Thus, the coaxial cavity resonator is externally coupled electrically or magnetically to the coaxial line.

Similarly this invention is applicable to the structure where the coaxial cavity resonator is inserted into the transmission line formed of the coaxial line (FIG. 11). In this case, the center conductor (reed switch) of the resonator serves as the center conductor of the coaxial line. Clearances are formed at both ends of the center conductor (reed switch) of the resonator, between itself and the center conductor of the coaxial line. A solenoid for energizing the reed switch is disposed surrounding the outside of the coaxial cavity resonator.

As will be apparent to those skilled in the art, any of the above-mentioned embodiments is rarely used as a single element in practical applications. They are used in most cases in multiple stages in which a plurality of similar switching devices are connected in cascade.

Among a variety of applications that are conceivable as to the present microwave switch device, a typical example is illustrated in FIG. 8 in block form. In this FIG., the present microwave switching devices S₁ and S₂ constitute a complete switching device in the two arms of a T-branch composed of a waveguide, or a coaxial line (or stripline). This circuit operates as a complete switching device in such a way that when either of the switches S₁ and S₂ is opened the other is closed. This will enable the switching device in FIG. 8 to selectively transmit the microwaves centered at the respective frequencies f₁ and f₂ to the branch a.

While the principles of this invention have been described above in connection with specific embodiments thereof, it is to be clearly understood that they are described by way of examples and not as a limitation to the scope of this invention.

We claim:
1. A switching device for tuning a waveguide transmitting microwave signal, comprising in combination:
   a hollow rectangular waveguide constituting said waveguide for transmitting said microwave signals therein;
   a hollow rectangular waveguide resonator having one closed end and perpendicularly mounted on one side of said hollow waveguide to provide a common wall section between said hollow waveguide one wide side and an open end of said resonator, said section having an aperture for electric coupling said hollow waveguide and said resonator;
   a reed switch including two conductive reeds disposed lengthwise on a common center axis and having overlapping and normally disengaged adjacent ends, said reeds positioned between opposite wide walls of said resonator and having other ends respectively secured in said respective latter walls, one of said reeds having a further portion of said other end thereof projecting outside said resonator wide wall in which said last-mentioned other end is secured; and
   energizing means coupled to said one reed other end further portion and responsive to an application of a switching voltage thereto to establish a magnetic field to actuate said reeds to engage said overlapping adjacent ends therefrom to tune said resonator to a midfrequency of a first preselected frequency band of microwave signals for reflecting said last-mentioned signals in said hollow waveguide; said energizing means being energized in response to a discontinuance of said switching voltage to terminate said magnetic field to allow said reed overlapping adjacent ends to return to said normal disengagement thereof to tune said resonator to a midfrequency of a second preselected frequency band of microwave signals different from said first preselected frequency band microwave signals for transmitting said last-mentioned signals in said hollow waveguide.
2. The switching device according to claim 1 in which said common center axis of said reed reeds and a center axis of said hollow waveguide lie in one plane.
3. The switching device according to claim 1 in which said reed switch includes a dielectric tube for housing said reeds in such manner that said other ends of said reeds are secured in closed opposite ends of said tube to extend outside thereof, said center axis of said reeds is disposed on a center axis of said tube, and said center axes of said reeds, tube and hollow waveguide lie in one plane.
4. The switching device according to claim 1 in which an inside surface of said resonator closed end is positioned three-quarter wavelength from an inside surface of said hollow waveguide one wide side; one wavelength being equal to a waveguide wavelength of said midfrequency of said first preselected frequency band microwave signals.
5. The switching device according to claim 1 in which a center axis of said reeds is disposed a distance of one-half wavelength from an inside surface of said hollow waveguide one wide side; and an inside surface of said resonator closed end is disposed a distance of three-quarter wavelength from an inside surface of said hollow waveguide one wide side; one wavelength being equal to a waveguide wavelength of said midfrequency of said first preselected frequency band microwave signals.
6. The switching device according to claim 1 in which said common center axis of said reeds is perpendicularly disposed between said opposite wide walls of said resonator.
7. The switching device according to claim 6 in which said center axis of said reeds is disposed a distance of one-half wavelength from an inside surface of said hollow waveguide one wide side; one wavelength being equal to a waveguide wavelength of said midfrequency of said first preselected frequency band microwave signals.
8. A switching device for tuning a waveguide transmitting microwave signals, comprising in combination:
   a hollow rectangular waveguide constituting said waveguide for transmitting said signals;
   a cavity resonator provided inside said hollow waveguide and having two spaced apertures aligned on a center axis of said hollow waveguide to form a filter;
   a reed switch including two conductive reeds extending lengthwise on a common center axis and having overlapping and normally disengaged adjacent ends; said reeds disposed in said filter between opposite wide sides of said waveguide and having other ends respectively secured in said respective latter sides; one of said reeds having a further portion of said other end thereof projecting out-
side said hollow waveguide wide side in which said last-mentioned other end is secured; and
energizing means coupled to said one reed other end further portion and activated by a switching voltage applied thereto to establish a magnetic field to actuate said reeds to engage said overlapping adjacent ends thereof to tune said filter to a midfrequency of a first preselected frequency band of microwave signals for transmitting said last-mentioned signals in said hollow waveguide; said energizing means deactivated in response to a discontinuance of said switching voltage to terminate said magnetic field to allow said reed overlapping adjacent ends to return to said normal disengagement thereof to tune said filter to a midfrequency of a second preselected frequency band of microwave signals different from said first preselected frequency band microwave signals for reflecting said last-mentioned signals in said hollow waveguide.

9. The switching device according to claim 8 in which said common center axis of said reeds is disposed perpendicularly relative to said wide sides of said hollow waveguide.

10. The switching device according to claim 9 in which said reed switch includes a dielectric tube for housing said reeds in such manner that said center axis of said reeds and a center axis of said tube are coincident and said other ends of said reeds are secured in closed opposite ends of said tube to extend outside thereof.

11. The switching device according to claim 9 in which said common axis of said reeds is further disposed in a preselected position relative to a center axis of said hollow waveguide;

12. The switching device according to claim 11 in which said common center axis of said reeds is further disposed in said preselected position which is in a lateral direction relative to said hollow waveguide center axis.

13. A switching device for tuning a waveguide transmitting microwave signals, comprising in combination:

a hollow rectangular waveguide constituting said waveguide for transmitting said signals;

a cavity resonator provided inside said hollow waveguide and having two spaced apertures aligned on a center axis of said hollow waveguide to form a filter;

a reed switch including:

a dielectric tube having closed opposite ends and two conductive reeds extending lengthwise on a common center axis and having overlapping and normally disengaged adjacent ends; said reeds disposed inside said tube in such manner that said reed common center axis and a center axis of said tube are coincident and other ends of said reeds are secured in said respective tube closed opposite ends to extend outside thereof; said last-mentioned tube and reeds disposed inside said filter in such position that said coincident axes of said reeds and tube are perpendicular to opposite wide sides of said waveguide filter and said extended other ends of said reeds are secured in said respective last-mentioned opposite wide sides; one of said reeds having a further portion of said other end thereof projecting outside said waveguide filter wide side in which said last-mentioned other end is secured; said coincident axes of said tube and reeds laterally displaced from a center axis of said waveguide filter; and
solenoïd means encircling said one reed other end further portion and activated by a switching voltage applied thereto to establish a magnetic field to actuate said reeds to engage said overlapping adjacent ends thereof to tune said filter to a midfrequency of a first preselected frequency band of microwave signals for transmitting said last-mentioned signals in said hollow waveguide; said solenoïd means deactivated in response to a discontinuance of said switching voltage to terminate said magnetic field to allow said reed overlapping adjacent ends to return to said normal disengagement thereof to tune said filter to a midfrequency of a second preselected frequency band of microwave signals different from said first preselected frequency band microwave signals for reflecting said last-mentioned signals in said hollow waveguide.