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MICROWAVE BROADBAND SWITCHING ASSEMBLY

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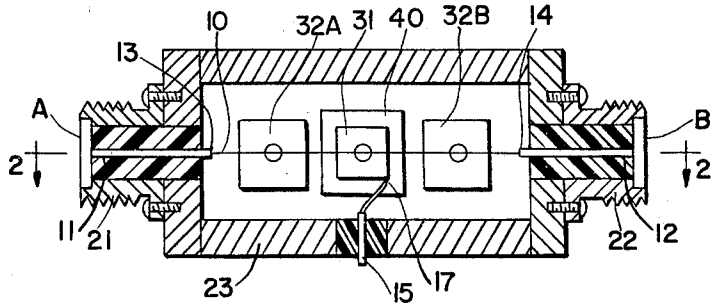


FIG. 1

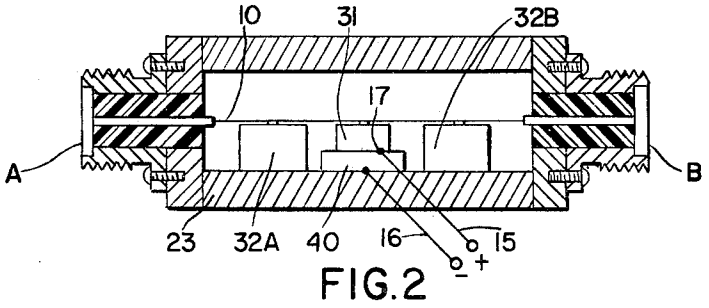


FIG.2

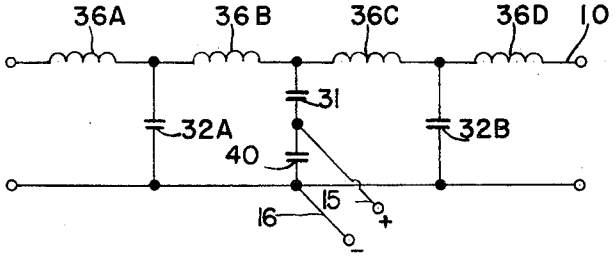


FIG.3

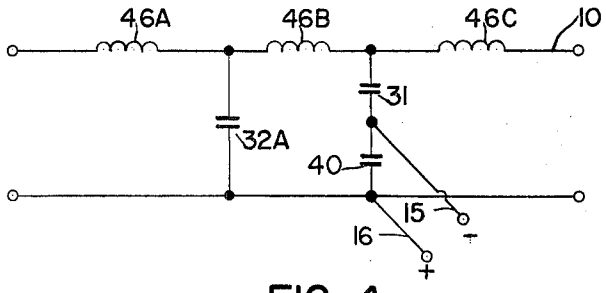


FIG. 4

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MICROWAVE BROADBAND SWITCHING ASSEMBLY

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ABSTRACT OF THE DISCLOSURE

A broadband microwave switch includes a pair of coaxial terminals, an outer conductor defining a cavity and an inner conductor extending through the cavity and capacitively coupling the coaxial terminals to one another. Within the cavity, a plurality of diode chips have one terminal connected to this inner conductor. At least one of these diode chips is capactively insulated at the other terminal from the outer conductor. The remaining diode chips have their other terminals respectively connected to the outer conductor. A conducting wire extends through and is insulated from the outer conductor and into the cavity connecting with the terminal of the diode chip which is capacitively insulated from the outer conductor to allow a bias signal to be supplied to the diode chips. Portions of the inner conductor within the cavity coact with the outer conductor to define substantially inductive transmission line segments. The substantially inductive segments coact with the effective capacitance of the nonconducting diode chips to define a substantially reflectionless filter circuit.

Background of the invention

The present invention relates in general to microwave switches and more particularly concerns a novel broadband microwave switch of high electrical performance, small physical form which is easy and inexpensive to fabricate in large and small quantities while maintaining a high degree of repeatability in electrical performance.

One well known type of diode switch comprises an inner conductor within a cavity which is capacitively coupled to the coaxial terminals and having cartridge or encased type diodes connected thereto. Cartridge crystals require a crystal holder and elaborate spring mechanisms to create proper contact between the crystal and the inner conductor. Moreover these large crystals need elaborate biasing methods introducing further fabrication problems and usually unwanted reflections at microwave frequencies. While these techniques have not foreclosed satisfactory diode switch operation, they do introduce mechanical and electrical problems which are disadvantageous. The mechanical structures heretofore known are not only complex, but also present considerable problems in connection with R–F impedance matching, particularly when broad bandwidths are desired.

These problems are caused mainly by the relatively large size of the crystals and their inherent mismatch with respect to the standard impedances found in the microwave field (i.e. 50 ohms).

It is an important object of the invention to overcome limitations of the prior art and provide a broadband diode switch of relatively small size that is adapted for utilization of standard miniature diode chips. It is another object to provide a relatively simple method of low relection bias insertion.

A further object of this invention is to provide a broadband diode switch of relatively low SWR which is susceptible of sealed or unsealed operation.

A further object of this invention is to provide a broadband diode switch of relatively low insertion loss and yet achieving high isolation when bias is applied.

Another object of this invention is to provide a broadband diode switch adaptable to use of a variety of diode chips.

A further object of this invention is to provide a broadband diode switch incorporating bias carrying means within the circuit.

Another object of the invention is to achieve one or more of the preceding objects while keeping costs relatively low.

Summary of the invention

According to the invention, two coaxial outer terminals are connected to an outer conductor defining a cavity. The signal conductors inside each of the coaxial outer terminals are capacitively coupled to an inner conductor extending through the cavity. A plurality of diode chips are inside the cavity. One of these diode chips has one terminal connected to the inner conductor extending through the cavity and the other terminal connected to a capacitor insulating the diode chip from the outer conductor. The remaining diode chips have one terminal connected to the inner conductor extending through the cavity and the remaining terminals respectively connected to the outer conductor defining the cavity. Bias is supplied by means of a conducting wire extending through and insulated from the wall of the cavity defining outer conductor. This wire extends into the cavity and is connected to the diode chip which is capacitively insulated from the outer conductor at the terminal which is connected to the capacitor. Portions of the inner conductor within the cavity coact with the outer conductor to define substantially inductive transmission line segments. The substantially inductive segments coact with the effective capacitance of the nonconducting diode chips to define a substantially reflectionless filter circuit.

In a modification of the present invention, there are only two diode chips, one being capacitively insulated from the outer conductor; the other having one terminal directly connected to the outer conductor. The remaining terminals of both diode chips are connected to the inner conductor extending through the cavity which is capacitively coupled to the signal conductors in each of the coaxial outer terminals. Bias is supplied in the same manner as above to the diode chip being capacitively insulated from the outer conductor at the terminal connected to the capacitor.

These and other objects and advantages of the present invention will be more clearly understood when considered in conjunction with the accompanying drawings in which:

Brief description of the drawings

FIG. 1 is a longitudinal sectional view of the broadband diode switch having two coaxial terminals according to the invention;

FIG. 2 is a sectional view through section line 2—2 of FIG. 1;

FIG. 3 is a schematic circuit diagram of the embodiment of FIGS. 1 and 2; and

FIG. 4 is a schematic circuit diagram of a modification of the invention.

Detailed description of the preferred embodiments

Corresponding reference symbols will be used throughout the drawings to indicate corresponding elements where applicable.

With reference now to the drawings and more particularly to FIG. 1 thereof, there is shown a longitudinal sectional view of the embodiment of the invention in which the two coaxial terminals A and B of the microwave

switch are diagrammatically represented. Signal conductors **11** and **12** of coaxial terminals A and B, respectively, are capacitively coupled to inner conductor **10** extending through the cavity at points **13** and **14**, respectively. The capacitance at points **13** and **14** between inner conductor **10** and signal conductors **11** and **12** presents a low impedance at the microwave frequencies of interest, and a high impedance at the biasing signal frequency.

Casing **23** defines the outer conductor for inner conductor **10** and also intercouples the reference terminals **21** and **22** of coaxial terminals A and B respectively. Capacitive insulator **40** is attached by one terminal to the floor of the cavity formed by outer conductor casing **23**. Diode chip **31** is placed upon and connected to the remaining terminal of capacitor insulator **40** and has its remaining terminal connected to inner conductor **10** extending through the cavity. Dode chips **32A** and **32B** are connected to the floor of the cavity formed by outer conductor casing **23** and have their remaining terminals respectively connected to the inner conductor **10** extending through the cavity. Conductor **15** is a thin conducting wire extending through and insulated from the wall of outer conductor casing **23** into the cavity and connects to the terminal of diode chip **31** which is attached to the capacitive insulator **40**.

FIG. 2 is a sectional view through the embodiment of FIG. 1 better illustrating the relationship among capacitive insulator **40**, the floor of the cavity formed by outer conductor casing **23**, diode chip **31**, and diode chips **32A** and **32B**, and inner conductor **10** extending through the cavity. This view shows how conducting wire **15** attaches to the junction of capacitive insulator **40** and diode chip **31** at point **17**. Conductor **16** is attached to casing **23** so that when a potential difference occurs between conductors **15** and **16**, a bias signal is developed across the diode chips.

FIG. 3 is a schematic circuit diagram of the embodiment of FIGS. 1 and 2 illustrating the diode chips in their nonconducting states as substantially capacitive elements and further showing how diode chips **31** and **32A** are in series combination with respect to a bias signal supplied across conductors **15** and **16**, as are diode chips **31** and **32B**. The diode chips may be arranged so that the polarization of the diode chips allows each series combination to conduct when a positive bias signal is supplied to conductors **15**. When the diode chips are in their conducting mode, as caused by the positive bias signal being applied to conductor **15**, diode chips **32A** and **32B** are virtual short circuits to the R-F frequencies, thereby causing virtually no signal to pass through the device.

Conductor **10** may be considered as a plurality of serially-connected substantially inductive distributed parameter transmission line elements, represented by inductors **36A**, **36B**, **36C** and **36D** in FIG. 3. The values of the respective inductors are chosen so that, upon coacting with the shunt-connected substantially capacitive nonconducting diode chips **31**, **32A** and **32B**, a substantially reflectionless low pass filter circuit is created.

FIG. 4 is a schematic circuit diagram of a modification of the invention in which only two diode chips, **31** and **32A**, are used. The diode chips are arranged, as in FIG. 3, in series with respect to a bias signal applied to conductors **15** and **16**, but they may be reversed in polarity thereby requiring a negative bias signal to be applied to conductor **15** if the diode chips are to conduct.

Again the diode chips in their nonconducting states are represented as substantially capacitive elements. The capacitors coact with the substantially inductive segments of the inner conductor **46A**, **46B** and **46C** forming a substantially reflectionless low pass filter circuit.

In a specific embodiment of the invention 50 ohm type axial terminals were used with an outer conductor casing of Kovar material, 0.557 inch long. The cavity formed within the outer conductor was 0.337 by 0.150 inch. 200 pf. capacitors were used as coupling capacitors connecting the inner conductor to the signal conductors of the connectors. 0.005 inch by 0.001 inch ribbon was used as the inner conductor within the cavity. A 200 pf. capacitor was used to insulate one diode chip from the outer conductor. Three Si PIN diode chips were used within the cavity. The diode chips required a bias current of 50 ma. positive in order to switch the diodes to their conducting states. The diode switch operated over a frequency range of 0.5 to 12.4 gHz. with an insertion loss of 2.0 db and 2.0 maximum SWR. When the diode chips were switched to their conducting states an isolation of 70 db was achieved.

An important feature of the invention is the adaptability of the structure to accommodating terminals at different locations. FIG. 1 shows terminals being brought out at opposite points of the longitudinal axis of the diode switch. But the invention operates equally well with the terminals in space quadrature or at other suitable angles.

Another important feature of the invention is the adaptability of the diode switch to accommodating various types of diode chips. Varactors, PIN diodes or any other unilaterally conducting device may be used depending upon the particular design criteria (modulation levels, switching speed, power handling capability or other constraints). Different types of diode chips may be intermingled within the switch itself. The proper values for the substantially inductive conductors may be calculated knowing the capacitance of the nonconducting diode chips, thus creating a substantially reflectionless filter circuit.

Another important feature of the invention is the freedom of the frequency response of the switch from perturbations caused by the bias insertion structure. The bias is applied within the circuit at a point essentially maintained at R-F ground potential, effectively isolating the bias carrying circuits from the R-F transmission portion of the circuit.

The invention is illustrated with a rectangular cavity formed by the outer casing. The cavity can be cylindrical or in any other suitable shape. The diode switch may also be constructed of two parallel plates forming a transmission line with the diode chips and insulating capacitor being mounted on one or both of the plates. The diode switch may be constructed in microstrip or any other TEM waveguide configuration.

The diode chips may be mounted within the cavity with such polarity as to conduct when either positive or negative D–C bias is applied.

The terminals of the invention may be coaxial, as illustrated above, lug terminals, or any type of terminals to allow convenient use of the invention.

Other modifications and uses of and departures from the specific embodiments described herein may be practiced by those skilled in the art without departing from the inventive concepts. Consequently, the invention is to be construed as limited solely by the spirit and scope of the appended claims.

What is claimed is:

1. A broadband microwave switch comprising:

means defining first and second terminal pairs,

first conducting means defining a cavity and normally maintained at a reference potential intercoupling reference ones of each of said terminal pairs,

each of said terminal pairs having a signal terminal,

second conducting means within said cavity for intercoupling said signal terminals,

means defining a plurality of diode chips,

a first of said diode chips having a first terminal connected to said second conducting means within said cavity and a second terminal connected to means insulating said diode chip from said first conducting means and coacting therewith to define capacitive means,

the remainder of said diode chips having one terminal connected to said second conducting means within

said cavity and the other terminal connected to said first conducting means,

and means defining a conducting lead extending through said first conducting means defining said cavity and insulatedly separated therefrom and into said cavity connecting to said first diode chip at said second terminal for carrying a biasing signal.

2. A broadband microwave switch in accordance with claim **1** having three of said diode chips wherein said first diode chip is interposed between the remaining two diode chips.

3. A broadband microwave switch in accordance with claim **1** having two of said diode chips.

4. A broadband microwave switch according to claim **1** wherein said second conducting means includes inductive means coacting with the effective capacitance of said diode chips in their nonconducting states to define a substantially reflectionless filter circuit.

5. A broadband microwave switch according to claim **1** wherein said capacitive means comprises means for maintaining said second terminal of said first diode chip essentially at R-F ground potential.

6. A broadband microwave switch according to claim **1** and further comprising capacitive means intercoupling said second conducting means with said signal terminals.

7. A broadband microwave switch according to claim **5** wherein said second conducting means includes inductive means coacting with the effective capacitance of said diode chips in their nonconducting states to define a substantially reflectionless filter circuit.

8. A broadband microwave switch according to claim **7** and further comprising capacitive means intercoupling said second conducting means with said signal terminals.

9. A broadband microwave switch according to claim **8** comprising three of said diode chips wherein said first diode chip is interposed between the remainder of said diode chips.

10. A broadband microwave switch according to claim **8** comprising two of said diode chips.

11. A broadband microwave switch according to claim **9** wherein said inductive means includes means serially interposed between said diode chips.

12. A broadband microwave switch according to claim **10** wherein said inductive means includes means serially interposed between said diode chips.

References Cited

UNITED STATES PATENTS

3,337,820	8/1967	Harper	307—320 X
3,417,351	12/1968	Piazza	333—73

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