ABSTRACT: A series biasing circuit includes a three terminal filter circuit within an outer conductor defining a cavity. The filter circuit has two signal terminals extending through and insulated from the wall of the cavity and common terminals connected to the cavity. A conducting wire extends through and is insulated from the outer conductor and into the cavity and connects to the filter circuit at a point which is capacitively insulated from the outer conductor. Portions of the inner conductors coact with the outer conductor within the cavity to define substantially inductive transmission line segments. These substantially inductive segments coact with substantially capacitive elements to define a substantially reflectionless filter circuit.
MICROWAVE SERIES SWITCH BIASING CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates in general to series biasing circuits and more particularly concerns a novel broadband series biasing circuit of high electrical performance and small physical form which is relatively easy and inexpensive to fabricate in large and small quantities with uniformly high quality.

Most methods of biasing in microwave circuits locate the biasing circuit in the microwave package itself. While this technique has not foreclosed satisfactory biasing, it does introduce fabrication, electrical and mechanical problems.

Also switching elements, such as crystals, normally require a return for crystal current to the conductor casing, usually maintained at ground or reference potential. The mechanical structure for such networks is not only complex, but also presents considerable problems in RF impedance matching.

Where the biasing circuitry or the return for the switchable elements cannot be located within the microwave package, because of mechanical or electrical constraints, a series biasing circuit is needed. Prior art series biasing circuits have a number of disadvantages. The mechanical structures have been relatively large and complex, presenting considerable problems in packaging and in RF impedance matching. Also, the bandwidth of these packages has been inherently small, thereby limiting the bandwidth of the operating microwave system as a whole.

Accordingly, it is an important object of this invention to provide a series biasing circuit which is substantially reflectionless over a relatively broad band of frequencies.

It is another object of the invention to provide a series biasing circuit in accordance with the preceding object which provides a return for crystal current.

It is another object of the invention to provide a series biasing circuit in accordance with the preceding object which may still function effectively as a filter for other purposes.

It is another object of the invention to provide a series biasing circuit capable of handling relatively large quantities of RF and bias power while introducing relatively little reflection in microwave frequencies of interest.

It is another object of the invention to provide a series biasing circuit susceptible to sealed or unsealed operation which is relatively easy and inexpensive to fabricate in large and small quantities with uniformly high quality.

SUMMARY OF THE INVENTION

According to the invention, a substantially reflectionless filter circuit, comprising substantially reactive series and shunt elements, having three terminals is placed within an outer conductor defining a cavity, so that its series signal terminals extend beyond the outer conductor defining the cavity and are insulated therefrom. The remaining terminal of the filter circuit is connected within the cavity to the outer conductor. A conducting wire extends through and is insulated from the outer conductor and into the cavity and connects to the substrate reflectionless filter circuit at a point which is capacitively insulated from the outer conductor. Within the cavity, portions of the inner conductors coact with the outer conductor forming substantially inductive transmission line segments. Substantially capacitive elements included within the cavity coact with the substantially inductive segments to comprise an essentially reactive biasing network. A first substantially capacitive element within the cavity serially connects the signal terminals of the circuit. The first substantially capacitive element is interposed between substantially inductive transmission line segments, thus creating a high pass filter configuration. The substantially inductive transmission line segments connect with the outer conductor by second substantially capacitive elements. The second substantially capacitive elements are chosen so that substantially all of the RF signal is passed through to ground while the bias signal is effectively blocked.

Numerous other features, objects and advantages of the invention will become apparent from the following specification when read in connection with the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal section view of a preferred embodiment of the invention;

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

FIG. 3 is a schematic diagram of a preferred embodiment of the invention in series with an element to be biased and

FIG. 4 is the dual of the circuit of FIG. 3 and represents another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference now to the drawings and more particularly to FIG. 1 thereof, there is shown a longitudinal sectional view of a preferred embodiment of the invention in which the series terminals 10 and 12 of the substantially reflectionless filter circuit are diagrammatically represented.

Outer conductor casing 20 defines a cavity for the substantially reflectionless filter circuit. Conductors 11 and 13 respectively connect to signal terminals 10 and 12 and extend through, and are insulated from casing 20, and into the cavity connecting to opposite terminals of series capacitor 30. Capacitor 30 is insulated from outer conductor casing 20 by insulating means 31. Within the cavity, conductors 15 and 17 respectively connect conductors 11 and 13 to terminals of capacitors 32 and 34 respectively. Capacitors 32 and 34 have their remaining terminals connected to outer conductor casing 20. Conductor 19 extends through and is insulated from outer conductor casing 20 and into the cavity connecting with capacitor 34 at a terminal capacitively insulated from outer conductor casing 20. Conductors 15 and 17 coat with outer conductor 20 to define substantially inductive transmission line segments.

FIG. 2 is a sectional view through the embodiment of FIG. 1 better illustrating the relationship among capacitor 30, insulator 31 and conductors 11 and 13 and casing 20.

With reference now to FIG. 3, there is shown a schematic circuit diagram of the embodiment of FIGS. 1 and 2 showing the series and shunt legs, biased elements, for example, a diode network 45, in series and the bias source 50. Capacitor 30 is connected in series with conductors 11 and 13 and terminals 10 and 12. The shunt legs comprise a series combination of inductive and capacitive elements, conductor 15 acting as an inductive element and capacitor 32 as a capacitive element in one leg and conductor 17 acting as an inductive element and capacitor 34 as a capacitive element in the other leg. The shunt legs are connected to conductors 11 and 13, respectively, and are both attached to casing 20 at the other end to define a common terminal. Conductor 18 also is connected to casing 20. Conductor 19 connects to the shunt leg at a point A capacitively insulated from the common terminal and supplies the bias input to the circuit to be switched. Bias is supplied by bias source 50 across conductors 18 and 19. The combination of diodes 40 and 41 is connected in series with the circuit and form the biased network 45.

Referring to FIG. 4 there is shown the dual of the filter circuit of FIG. 3. It is known that if it is desired to obtain the driving point admittance having the same characteristic on an admittance basis as the impedance of the known circuit, it is only necessary to make the following changes:

1. Change each capacitor having a value C in farads to an inductor having the same inductance L numerically in henries;

2. Change each inductance having a value L in inductance to a capacitor having the same numerical value C in farads;

3. Change series-connected elements to shunt-connected elements; and

This is accomplished in a circuit of FIG. 4. Thus, the filter circuit consists of serially connected parallel combinations of C and L with conductors 11 and 13 and terminals 10 and 12. Inductive element L comprises the shunt leg which is connected at one end between the parallel combination of the series reactive elements to terminal 40 and has its other end connected to the common terminal 20. Again bias is supplied at a point A capacitively insulated from outer conductor 20 by conductor 19. This may be accomplished by inserting an RF bypass capacitor C in series with inductive element L.

Having described the embodiment and the physical arrangement of the circuit components, it is appropriate to consider the techniques and design criteria used. The schematic circuit diagram FIG. 3 illustrates a series m-derived high pass filter in m-section form in series with a diode network and a bias source. The filter is designed to present a substantially matched impedance to the biased RF circuit over the frequency range of interest. The schematic circuit diagram of FIG. 4 shows another shunt m-derived high pass filter of T-section form. The components of this filter circuit are also chosen to present a substantially matched impedance to the biased RF circuit.

The capacitors in the shunt legs of the embodiment of FIG. 3 of the invention may be chosen so that substantially all of the signal frequency is passed to the outer conductor casing while effectively blocking the bias signal at that point. Thus the substantially inductive transmission line sections may be maintained substantially at RF ground potential rendering the biasing circuit virtually independent of the bias signal network. Consequently, the RF signal passing through the circuit will be virtually independent of the configuration and variations of the bias insertion network.

The inductance value of the substantially inductive transmission line segments may be calculated from the well-known equation:

\[ L = \frac{\pi}{\omega} \times Z_0 \times \tan \beta l \]

where the capacitors in the shunt legs are effective short circuits to RF frequencies and \( \beta = 2\pi f / \lambda \) and \( l \) is the length of the conductor. It is preferred that, in the range of operation, the length of the inductive segment be substantially less than the wavelength, preferably approximately a quarter wavelength at the highest frequency of interest. Then:

\[ X_L = L \cdot \omega Z_0 = \frac{Z_0}{\lambda} \sqrt{\frac{\omega L}{Z_0}} \]

where \( \lambda \) is the velocity of propagation of the electromagnetic wave. Thus, \( L \approx \frac{Z_0}{\sqrt{\omega}} \).

The appropriate values of the respective capacitances and inductances may then be derived using filter circuit formulas.

In a specific embodiment of the invention, 50 ohm type coaxial terminals were used with an outer conductor casing of Kovar material 0.100 inch thick. The cavity formed within the outer conductor was 0.100 by 0.250 inch. 0.001 by 0.003 inch wire was used for the series inner conductors of the series m-derived m-section high pass filter within the cavity. A 1 pf capacitor was used in the series leg of the filter circuit. 0.001 inch diameter wire was used to create substantially inductive elements of the shunt legs and 30 pf capacitors were also used in the shunt legs to create substantially capacitively reactive elements. 0.001 inch diameter wire was used within the cavity for supplying the bias signal to the circuit and extended through and was insulated from the casing to an axial terminal outside the cavity.

The series biasing circuit operated over a frequency range of 1.0 to 12 GHz with a maximum of SWR of 2.0. The device has an insertion loss of 0.5 db over that range and the maximum power rating of 10 watts.

An important feature of the invention is the adaptability of the structure to accommodating different types of coaxial terminals at different locations. FIG. 1 shows signal terminals being brought out in opposite points on longitudinal axis of the biasing circuit but the invention operates equally well with the signal terminals and space quadrature of at other suitable angles.

FIG. 3 shows the series biasing circuit in series with a diode network. The biasing circuit may be used to bias any type of diode, diode circuit or other network which requires a bias signal.

The invention is illustrated with rectangular cavity formed by the outer conductor casing. The cavity may be cylindrical or any other suitable shape. The series biasing circuit may also be constructed of two parallel plates forming a transmission line with the filter circuit being mounted on one or both of the plates. The invention may also be constructed in microstrip or any other TEM waveguide configuration.

Other modifications and uses of and departures from the specific embodiment as 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 embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques herein disclosed and limited solely by the spirit and scope of the appended claims.

What I claim is:

1. A broadband series biasing circuit operative over a predetermined microwave frequency range comprising, means defining first and second terminal pairs each having a signal terminal and a reference terminal, first conducting means defining a cavity and normally maintained at a reference potential intercoupling reference ones of each of said terminal pairs, means wherein said cavity defining a substantially reflection less high pass filter circuit that is one of \( w \) and \( T \) networks formed of substantially inductive and substantially capacitive elements intercoupling said signal terminals and having a biasing substantially capacitive element having one terminal contacting said first conducting means and its other terminal in series with a first substantially inductive element that is a lead connected to at least one other capacitive element connected to the junction of a second inductive element and said first signal terminal, said substantially reflectionless high pass filter circuit presenting a substantially constant predetermined impedance to said first and second terminal pairs over said predetermined microwave frequency range, and means defining a biasing signal terminal extending through and insulatedly separated from said first conducting means and connected to said other terminal, said reflectionless high pass filter circuit comprising means for establishing an RF path between the signal terminals of said first and second terminal pairs and a conductive path for carrying a DC bias potential between said biasing signal terminal and at least one of said signal terminals, said signal terminals extending through and insulatedly separated from said first conducting means,

2. A broadband series biasing circuit in accordance with claim 1 wherein said substantially reflectionless high pass filter circuit is a \( w \) network having said one other substantially capacitive element intercoupling said signal terminals, a first series circuit comprising said second substantially inductive element and a third substantially capacitive element intercoupling one of said signal terminals with said first conducting means and a second series circuit comprising said first substantially inductive element and said biasing substantially capacitive element intercoupling the other of said signal terminals with said first conducting means,

3. A broadband series biasing circuit in accordance with claim 1 wherein said substantially reflectionless filter circuit is a \( T \) network having a first parallel circuit comprising said second substantially inductive element and said one other substantially capacitive element in series with a second parallel circuit comprising a third substantially inductive element and a third substantially capacitive element intercoupling said signal terminals and a series circuit comprising said first substantially inductive element and said biasing substantially capacitive element intercoupling the junction of said first and second parallel circuits with said first conducting means.
5. A broadband biasing circuit in accordance with claim 3 wherein conductors insulatedly separated from said first conducting means comprise said substantially inductive elements and coact with said first conducting means to define transmission line segments corresponding substantially to a quarter wavelength at a predetermined highest frequency of interest in said predetermined microwave frequency range has been inserted.

6. A broadband biasing circuit in accordance with claim 4 and further comprising unilaterally conducting means to be biased intercoupling at least one of said signal terminals DC coupled to said biasing signal terminal with said first conducting means.

7. A broadband biasing circuit in accordance with claim 5 and further comprising unilaterally conducting means to be biased intercoupling at least one of said signal terminals DC coupled to said biasing signal terminal with said first conducting means.

8. A broadband biasing circuit in accordance with claim 6 and further comprising a source of biasing potential intercoupling said biasing signal terminal with said first conducting means.

9. A broadband biasing circuit in accordance with claim 7 and further comprising a source of a biasing potential intercoupling said biasing signal terminal with said first conducting means.