

[54] RF REJECTION FILTER
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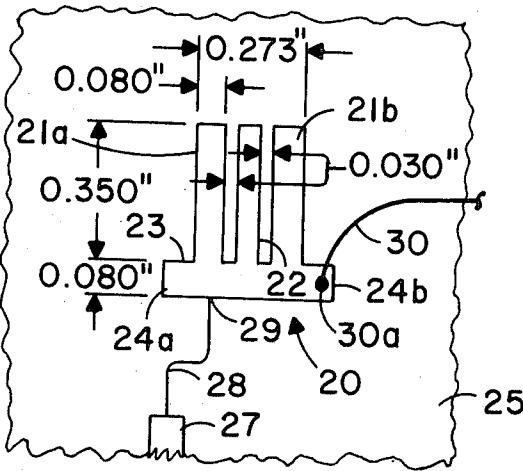
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321/69

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[57] ABSTRACT
An RF suppression filter using several quarter RF wavelength long strips in parallel that are open-ended to form an RF ground at their common tie-points in the form of a section of conductive line. This base line is extended to terminations at each end to a length beyond the respective outside stubs that enables all stubs to recognize the same electrical reference plane and yet to a length that is short relative to any RF wavelength encountered within the operational bandwidth for the filter.

10 Claims, 10 Drawing Figures



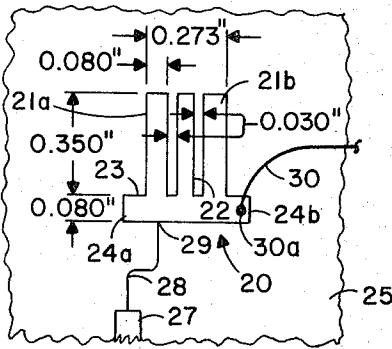


FIG. 1

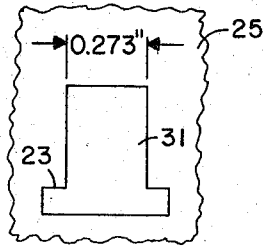


FIG. 3

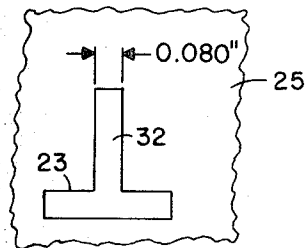


FIG. 4

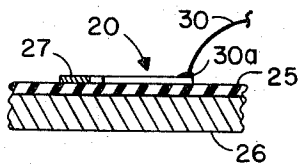


FIG. 2

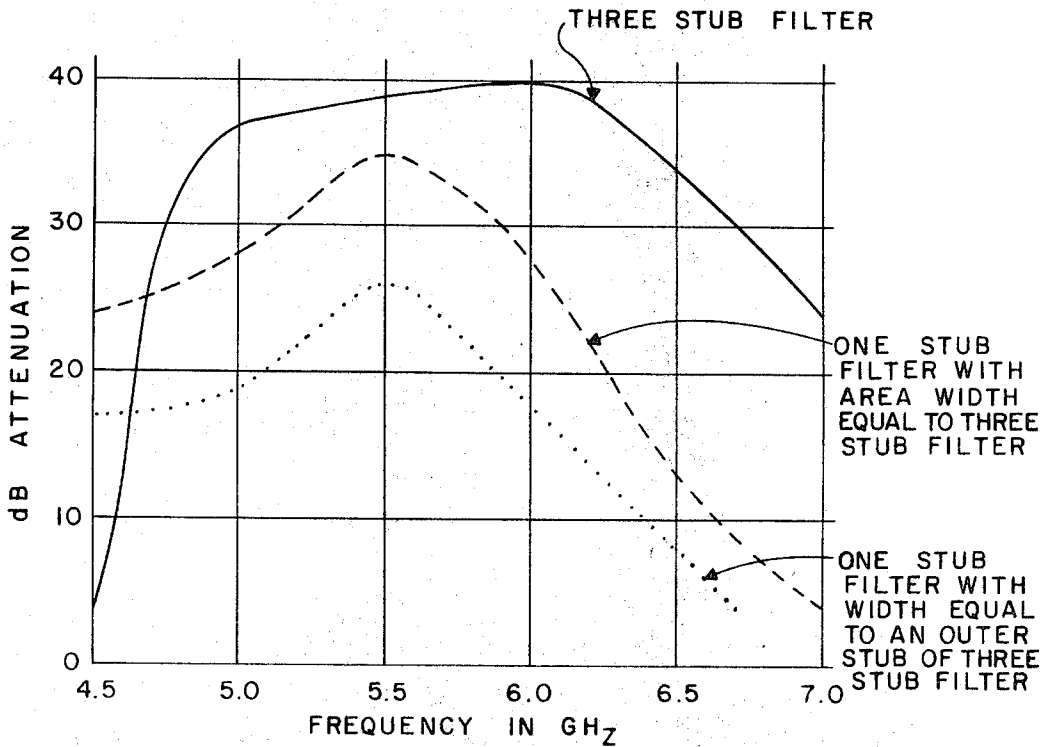
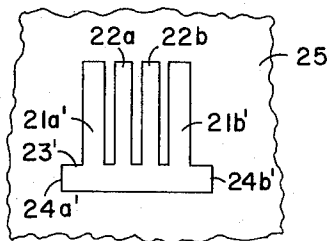
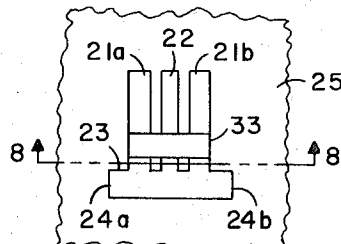
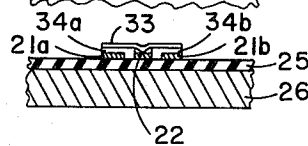
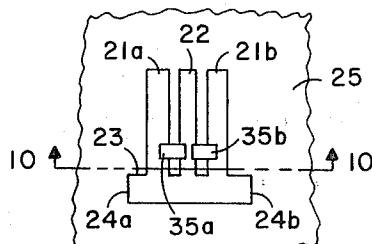
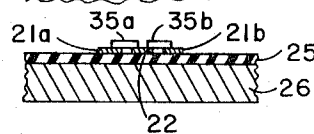


FIG. 5

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RF REJECTION FILTER

This invention relates in general to RF filters, and in particular, to a microwave RF rejection filter with several quarter wavelength open ended strips extended from a length of conductive line to recognize the same electrical reference plane and with the filter supported in substantially uniform capacitively coupled relation to an electrically conductive ground plane.

With microstrip and stripline microwave planar circuits signal transition requirements are many times imposed wherein signal connections must be made to conductors not containing RF signals that may be present in portions of the related microwave circuitry. Such non-RF lines may carry dc currents that may be called upon to either power semiconductor devices or for removal of low frequency output signal currents from such semi-conductors and further, intermediate frequencies (IF) may be the product output of, for example, a microwave mixer circuit as in the product output path from mixer diodes of a microwave frequency mixer having a microwave local oscillator input and a microwave RF signal input. In any event, whatever the particular signals of interest may be, it is necessary to provide a path for their transmission that does not disturb the microwave circuit either by loss of microwave energy or by an undesired change in impedance of the microwave line or circuit elements. Furthermore, there are some applications where it is important to provide a low impedance over a band of frequencies on a microwave conductor itself. Obviously, these particular applications require a very low impedance circuit structure through the RF frequency band of operation involved. Such a low impedance circuit structure may be used in combination with a quarter wavelength high impedance transmission line to present a very high impedance in operational effect in parallel with the RF conductor. Circuit analysis has demonstrated, using transmission line theory, that such a high impedance compared to the characteristic impedance of the RF line, will extract a negligible portion of the RF power in the RF microwave circuitry and causes only a negligible change in RF line impedance. Practically speaking, an ohmic value resistive connection to the RF line is achieved without any significant disturbance of the RF line. In some instances where a low RF impedance is desired in parallel with an RF transmission line, the rejection filter may be attached directly to the RF line.

One approach that has been used to attain such a low RF impedance has been to use a single low impedance open-ended transmission line stub with the lower the impedance of the stub the lower the output impedance becomes. However, this approach simply has not attained the degree of low impedance desired such as to adequately provide the RF rejection factor required. Further, such previously used approach has at times led to, with the large width of low impedance stub employed, other transmission modes to be excited thereby defeating the desired function of an RF rejection filter.

It is, therefore, a principal object of this invention to provide a filter connected to microwave RF circuitry and to low frequency or dc circuitry capable of insuring substantially zero RF signal content in the low frequency or DC circuitry.

Another object with such an RF rejection filter is to insure clean RF free IF signal output from a microwave RF signal mixer circuit.

A further object with such an RF rejection filter is to insure minimal disturbance of microwave circuitry either by loss of microwave energy or by an undesired change in impedance of a microwave line or circuit elements.

Features of the invention useful in accomplishing the above objects include, in a microwave RF rejection filter, several quarter RF wavelength long strips in parallel open-ended to form an RF ground at their common tie point conductive line interconnective base. This interconnective base conductive line is extended to terminations at each end at such length beyond the respective outside stubs as to enable all stubs to recognize the same electrical reference plane and yet to a length that is short relative to any RF wavelength encountered

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within the operational bandwidth for the filter. The filter is supported in substantially uniform spaced capacitively coupled relation to an electrically conductive ground plane in order to attain, substantially, an RF signal short to ground through the desired bandwidth range of operation. It is a multi-stub RF rejection filter where optimum performance is attained when the impedance and hence the propagation velocity is approximately the same for all of the several stubs. This is with cross coupling between closely spaced parallel stubs requiring that the inside middle stub, or stubs if the filter is more than a three stub filter, are more narrow than the outer stubs in order that all have essentially the same electrical RF signal length. Thus, the contribution of each filter stub is maximized in effectively lowering the RF output impedance of the composite filter with an even mode type coupling and the adjacent stubs at essentially the same potential. It should be noted, that while some measure of correction for the deficiencies being dealt with may be accomplished by changing length of individual stubs as, for example, by shortening a middle stub of a three equal width stub filter, it is particularly desirable to have equal stub lengths for layout purposes among other reasons.

A specific embodiment representing what is presently regarded as the best mode of carrying out the invention is illustrated in the accompanying drawings.

In the drawings:

FIG. 1 represents a top plan view of applicant's microwave RF rejection filter in a three stub substrate bond mounted microcircuitry microstrip board configuration;

FIG. 2, a partial cut away and sectioned view of such microstrip board microwave circuitry;

FIG. 3, a top plan view of a one stub filter with area width equal to that of the three stub filter of FIG. 1;

FIG. 4, a top plan view of a one stub filter with width equal to that of an outer stub of the three stub filter of FIG. 1;

FIG. 5, a family of curves illustrating insertion loss (in db) to frequency performance for the three stub RF rejection filter of FIG. 1, the one stub filter of FIG. 3, and the one stub filter of FIG. 4;

FIG. 6, a top plan view of a four stub RF rejection filter;

FIG. 7, a top plan view of a three stub RF rejection filter with additional capacitance provided between the center stub and the two outside stubs;

FIG. 8, a partial cut away and sectioned view along line 8—8 of the microstrip board filter of FIG. 7, with additional capacity structure detail shown;

FIG. 9, a top plan view of a three stub RF rejection filter with an alternate approach providing additional capacitance between the center stub and the two outside stubs; and

FIG. 10, a partial cut away and sectioned view along line 10—10 of the microstrip board filter of FIG. 9 with additional capacity structure detail shown.

Referring to the drawings:

With the RF rejection filter 20, of FIGS. 1 and 2, the filter 20 is shown to be a three stub filter with the outer stubs 21a and 21b being of greater width and parallel, in closely equally spaced relation, to center stub 22. This is with the three stubs 21a, 21b and 22 extended from a section of conductive line 23 extended to end terminations 24a and 24b all bonded to a dielectric material layer 25. The dielectric layer 25 is in turn bonded to a metal ground plane plate 26. Please note that in various units of the RF rejection filter 20, of FIG. 1, the filter has been produced in microstrip circuitry form bonded to a relatively low dielectric constant dielectric polyolefin having approximately a 2.3 to 2.5 dielectric constant and approximately 0.026 inches thick and with the microstrip circuitry forming the filter 20 being one ounce (0.0014 inch thick) copper bonded to the upper surface of the dielectric material 25.

An RF rejection filter such as shown in FIG. 1 with the dimensions indicated thereon has been employed very effectively in the IF output of a microstrip mixer circuit (not shown) with an IF connection from the RF open end of an IF

signal combiner stub 27 through an RF signal quarter wavelength long RF high impedance line 28 to a connective junction 29 with the base of conductive line section 23. Further, a jumper lead line 30 extends from soldered connective junction 30a on the base conductive line section 23 to IF utilizing circuitry (not shown). It is important that the high impedance line 28 junction 29 with conductive line section 23 and the connective junction 30a of line 30 therewith have spacing therebetween preferably equal to or greater than the spacing between the centers of the two outermost filter stubs 21a and 21b. Still further, it has been found advantageous to locate the junction 29 of line 28 with the line section 23 close to alignment with the center line of stub 21a and jumper lead line 30 junction 30a with the conductive line section 23 being located in close proximity to the line termination end 24b. This is with the RF rejection filter 20, or what may be referred to by many as an RF suppression filter, having the conductive line section 23 base thereof serving as a pad for the soldered connection 30a thereto of line 30 with a large enough area presented thereby to avoid delamination when the IF bus lead 30 is soldered to the microstrip board. One might suggest that a solid pad of copper could be used; however, this is not suitable since it would look like a resonant section at the higher frequencies. With the individual stub strips of the rejection filter 20, of FIG. 1, a filter configuration is provided advantageously avoiding undesired resonance otherwise encountered with such a large copper area. The RF rejection filter, of FIG. 1, with RF signal input fed to termination end 24a and output sensed from termination end 24b of the conductive line section 23, is particularly useful through the 5 to 6.5 GHz bandwidth range with a db attenuation to frequency operational characteristic curve as shown by the solid curve of FIG. 5, as compared with the less desirable db attenuation characteristics attained as represented by the dashed line of FIG. 5 for the one stub 31 filter of FIG. 3 with an area width equal to the three stub filter width of FIG. 1. The wide stub 31 of the one stub filter of the FIG. 3 embodiment extends from a conductive line section 23 base of substantially the same size and dimensions of the corresponding line section 23 on the FIG. 1 embodiment and other dimensions lengthwise of the stub 31 much the same as with the filter stubs in the embodiment of FIG. 1. The operational results attained, as represented by the dotted line in FIG. 5, were provided with a one stub 32 filter as shown in FIG. 4 with the one stub 32 having the same width as the wider outer stubs of the FIG. 1 embodiment and other dimensions thereof substantially the same as with the embodiment of FIG. 1. Please note further that with both the embodiments and FIGS. 3 and 4, as prior art expediciencies, the filters were microstrip conductive copper metal bonded to a dielectric material layer 25 of microstrip board substantially the same as with the embodiment of FIG. 1. With the prior art single stub RF filter devices of FIGS. 3 and 4 and with the additional embodiments of FIGS. 6 through 10, portions duplicating those of the embodiment of FIG. 1 are given the same number and, where a component or section is substantially the same, it is given a primed number as a matter of convenience.

With reference again to the embodiment of FIG. 1, the stub or strip 22 in the middle is narrower than the outside stub strips 21a and 21b in order that the impedance of all the strip stubs be substantially the same with their propagation velocity substantially the same. This is with all the strips 21a, 21b, and 22 made substantially a quarter of the RF signal wavelength long and to reinforce each other with impedance being

$$Z_0 = \sqrt{\frac{L}{C}}$$

where Z_0 is the characteristic impedance, L the inductance per unit length, and C the capacity per unit length. Thus, there is an interdependent relationship between inductance and capacitance wherein the middle strip stub of a three stub filter appears to have greater capacitance to ground if all of the strip stubs were of the same width and of the same length since the outer adjacent strip stubs affect the value of the center strip

stub. This cross effect is countered by making the inside strip narrower to thereby increase the inductance of that strip and simultaneously reducing its capacity to ground and thereby simultaneously increasing the impedance of the strip stub in order that the impedance of all the strip stubs may be made to be substantially equal.

Referring again to the db attenuation to frequency operational curves of FIG. 5 for the embodiment of FIG. 1 and the prior art devices of FIGS. 3 and 4, a measurement of insertion loss is provided on a comparison basis between these three filters. It is seen that applicant's three stub RF rejection filter of FIG. 1 provides almost 40 db attenuation over approximately a 20 percent bandwidth and is, advantageously, deeper and broader than the results obtained with the other two filters. Throughout substantially all of the operational bandwidth involved, the broad stub filter of FIG. 3 does not provide as good attenuation as with the three stub filter of FIG. 1; however, the filter of FIG. 3 is considerably more effective than the narrower one stub filter of FIG. 4. Thus, it appears that applicant's three stub filter, that is illustrated in microstrip form, attains a total loss and bandwidth generally exceeding other known filters occupying comparable areas. Since it is quite desirable in many instances to effectively reject microwave energy from conductors that do not carry microwave signals but that are joined to microwave conductors, the subject filter, in the form that is shown in FIG. 1, or for that matter in other forms such as shown, for example, in FIG. 6 that is a four stub version, are quite suitable for microwave integrated circuits in planar configuration with circuit size and space being a primary consideration. Please note that while the various embodiments of the filter are shown in microstrip configurations, the various embodiments presented could be adapted to stripline construction in a manner that would be readily apparent to those skilled in the art or, alternatively, the filter forms could be supported in uniformly spaced capacitively coupled relation to an electrically conductive surface that, although generally planar, could with a further modification thereof be curved with the filter form being correspondingly curved in mating relation thereto.

With these improved multi-stub filters, it is important that the propagation velocity of the individual stubs in the filter be so chosen that the total loss in db attenuation be a balanced joint contribution from the several stubs of a filter. Should the individual filter stub propagation velocities depart from the desired optimum relationship therebetween, narrow frequency bands will in many instances appear within the useful frequency operation bandwidth range where insertion loss becomes very low, thereby reducing the effectiveness of the filter in such low insertion loss regions generally identified as pips. Please note that this deficiency may be corrected in many instances by altering the length of individual stubs, but it should be realized again that it is highly desirable to keep stub lengths identical for layout purposes among other reasons. With the embodiment of FIG. 6, which is a four stub embodiment, the two middle stubs 22a and 22b are made more narrow than the outermost stubs 21a' and 21b' in accord with the same operational characteristics controlling the narrowing of the center stub 22 in the FIG. 1 embodiment with, in the embodiment of FIG. 6, the conductive line section 23' being again extended beyond the outermost edges of the outer stubs 21a' and 21b' to terminations 24a' and 24b' so extended that all of the stubs see substantially the same electrical signal reference plane.

The problem of pips within the usable frequency range of a filter is a problem that may be remedied in many instances by adding capacity between the inner and outer stubs of applicant's new RF rejection filters with the addition of capacity required being relatively low, generally less than 5 picofarads. In the embodiment of FIGS. 7 and 8, the conductive metal pattern of the three stub filter shape on microstrip 25 is substantially the same as in FIG. 1 with additional interstub capacity attained through use of a strip of metal 33 bonded to and extending over intermediate dielectric material layers 34a

and 34b, and overlying all the stubs, and with the conductive metal strip 33 deformed down and bonded to the center stub 22, as by conventional means in the middle. Obviously, RF signal rejection characteristic testing may be employed to determine the location of pips and the optimum placement of, although location along the stubs is usually not critical, and value of capacitance to be provided by a strip 33 with such additional pip countering structure as shown.

In the embodiment of FIGS. 9 and 10, wherein the three stub microstrip copper planar circuit form is the same as with the embodiment of FIG. 1, the capacitance added is provided by two chip capacitors 35a and 35b, of known construction, with the opposite plate terminals thereof fixed in contact with, respectively, the center stub 22 and respective outer stubs 21a and 21b.

With reference in general to applicant's new multi-stub RF rejection filters, please note again that it is necessary to provide a section of conductive line, that each outer open-ended stub is joined to, enabling all the individual stubs to recognize substantially the same electrical reference plane. In order that this may be accomplished, the common line section must be extended to end terminations beyond the outside stubs by a length that is short compared to any RF signal wavelength within the operation bandwidth for the filter and, generally, at least as long beyond the outer stubs as the widest stub width dimension. The common line section should also be approximately as wide as the width of the outermost filter stubs. Further, the greater the number of stubs employed generally results in an increase in the insertion loss of the filter and a lowering of the filter output impedance. Even so, a practical limit for most usage has been found to be the three stub version as a good basic design adequately satisfying operational requirements usually imposed. Still further, while an increased separation of stubs may provide a lower possible impedance, as a practical matter, a separation of approximately 0.1 wavelength therebetween has proven to be quite useful, with a practical operational design being defined as an RF rejection filter giving reasonably low impedance over approximately a 20 percent bandwidth that, as related to some other filters, is relatively compact.

Whereas this invention is here illustrated and described with respect to several specific embodiments hereof, it should be realized that various changes may be made without departing from the essential contributions to the art made by the teachings hereof.

I claim:

1. In a microwave RF rejection filter, a filter form supported in substantially uniformly spaced capacitively coupled relation to the surface of an electrically conductive material coextensive through the area of the filter form; said filter form including several open-ended stubs spaced in mutual capacitive and

inductive cross coupled relation; electrical reference plane means interconnecting said several open-ended stubs; said electrical reference plane means being a section of conductive line extended to terminations at each end at a length beyond adjacent outer stubs that is short relative to RF signal wavelengths within the operational bandwidth for the filter, said stubs being substantially a quarter of an RF wavelength long in their extension from said electrical reference plane means to the stub outer open ends, filter form signal connective means; and with area of filter form middle stubbing varied from area of outer stubs for all filter form stubs to be substantially the same effective operational electrical length and attain substantially equal impedance and substantially equal propagation velocity in all of the stubs of the filter form, all of said stubs being of substantially equal length in extension from said electrical reference plane means to the stub outer open ends and with a middle stub being narrower than the width of individual outer stubs, said several stubs being in substantially uniformly spaced parallel relation with spacing between said stubs of approximately 0.1 RF signal wavelength.

2. The microwave RF rejection filter of claim 1, wherein said RF rejection filter is a three stub filter.

3. The microwave RF rejection filter of claim 1, wherein said RF rejection filter is a four stub filter.

4. The microwave RF rejection filter of claim 1, wherein the terminations of said conductive line are extended approximately a sixteenth of an RF wavelength beyond the adjacent outer stubs.

5. The microwave RF rejection filter of claim 1, also including supplemental capacitive means capacitively interconnecting a middle stub to outer stubs.

6. The microwave RF rejection filter of claim 5, with the value of said supplemental capacitive means through each capacitive coupling thereof is at a value less than 5 picofarads.

7. The microwave RF rejection filter of claim 5, with said supplemental capacitive means being in the form of a conductive material band extended over all three stubs of a three stub filter, supported in spaced insulated relation to the outer stubs and bonded to the middle stub.

8. The microwave RF rejection filter of claim 1, with said supplemental capacitive means being in the form of capacitor chips each capacitively interconnecting two adjacent stubs.

9. The microwave RF rejection filter of claim 1, wherein said filter form is substantially in planar form and the surface of said electrically conductive material is a planar surface in substantially equally spaced parallel relation to said filter form.

10. The microwave RF rejection filter of claim 9, wherein said microwave RF rejection filter is in the form of microwave microstrip circuitry on microstrip board.

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