United States Patent

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[54] MICROWAVE NARROW BAND-PASS FILTER
3 Claims, 4 Drawing Figs.

[52] U.S. Cl. ..... 333/73 W, 333/83 R, 333/98 R
[51] Int. Cl. H03h 7/10, H01p 7/06, H03h 7/08
[50] Field of Search ..... 333/73, 76, 83, 84, 72, 98; 324/77—81; 325/452, 477, 490, 3, 39—40, 63, 432

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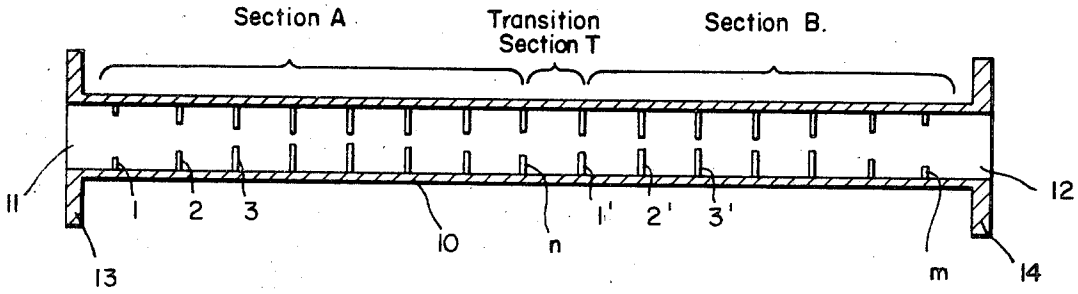
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ABSTRACT: A very narrow band-pass microwave filter is described. Narrow bandwidth operation with low passband insertion loss is achieved by utilizing a cascaded combination of two band-pass filters coincidentally tuned in a unique manner. By providing independent adjustment of the two constituent filters of the cascaded combination arbitrarily narrow passband can be obtained over the operating frequency range.



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SHEET 1 OF 2

Fig. 1.

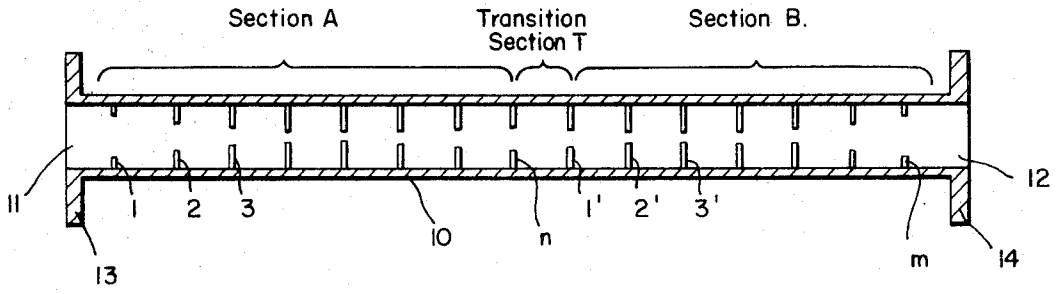
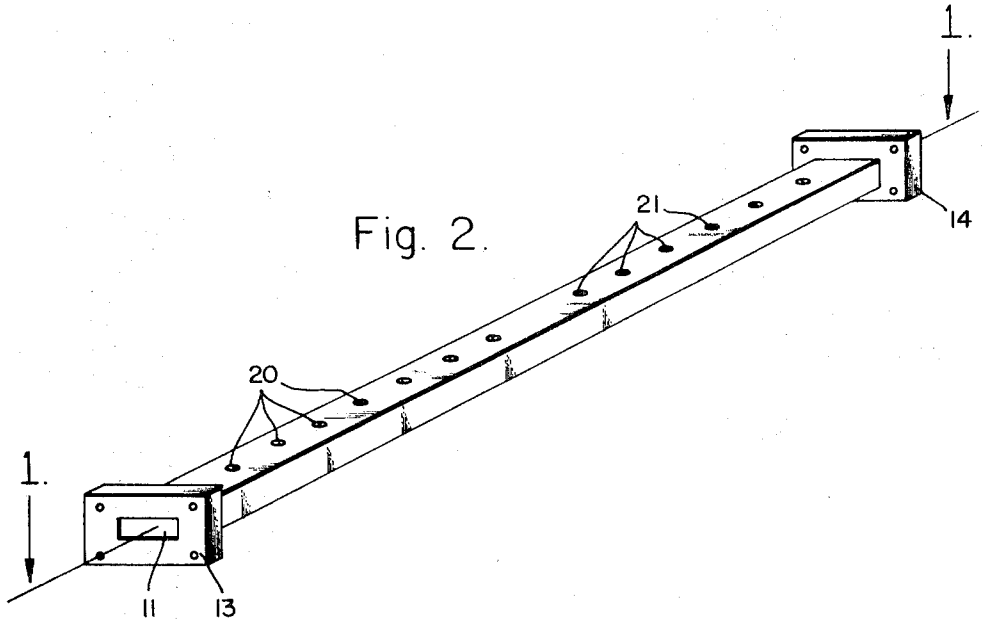


Fig. 2.



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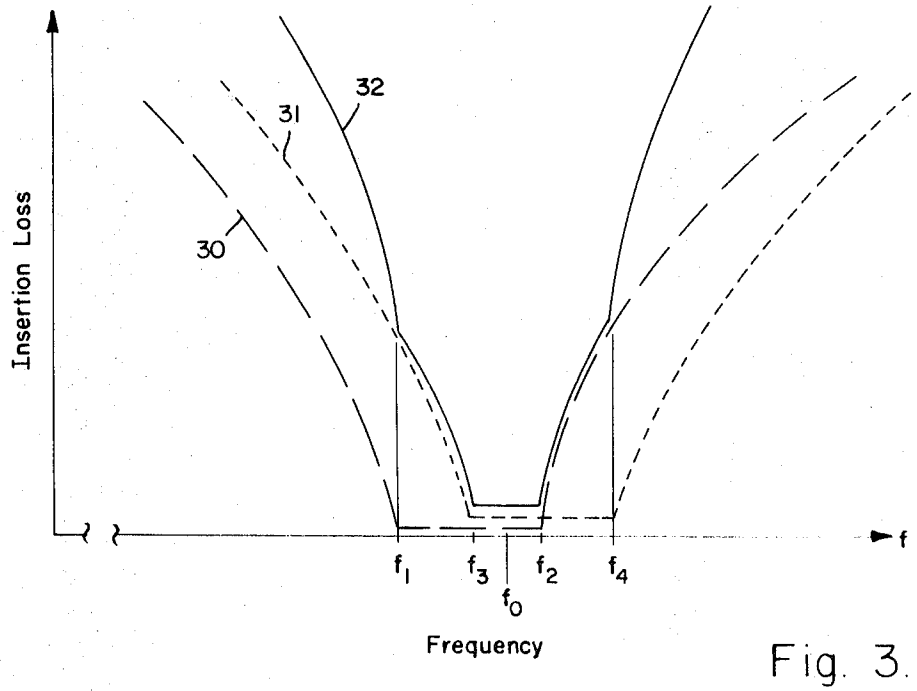

Insertion Loss
32
31
30
f
f_1
f_3
f_0
f_2
f_4
Frequency

Fig. 3.

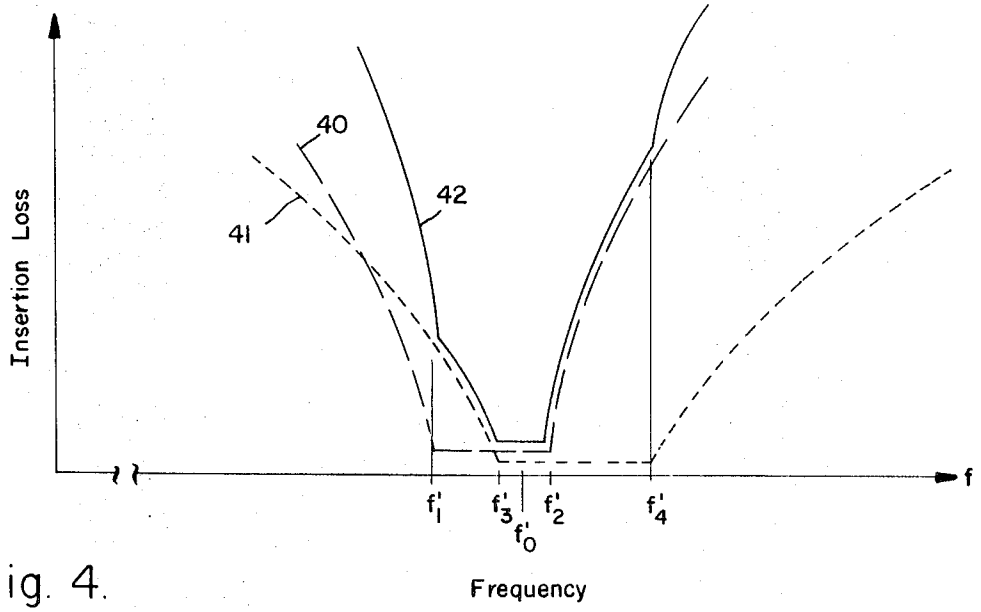

Insertion Loss
40
41
42
f
f'_1
f'_3
f'_0
f'_2
f'_4
Frequency

Fig. 4.

MICROWAVE NARROW BAND-PASS FILTER

FIELD OF THE INVENTION

This invention relates to microwave filters, and more specifically to narrow-band microwave band-pass filters.

DESCRIPTION OF THE PRIOR ART

One of the more common passive circuit components found in microwave systems is the microwave filter. Since the groundwork was laid in the mid-1930's, countless man-hours of design and development effort have been expended on the improvement of microwave filters. Apart from mode-selection filters, which are a subject unto themselves, microwave filters can be generally described as: (1) highpass, (2) lowpass, (3) band-elimination, and (4) band-pass.

The deal band-pass filter has an input port and an output port and a transmission characteristic such that frequency components lying within a predetermined band of frequencies, termed the passband, are transmitted through the filter without loss, whereas frequency components above and below the passband are totally rejected. In practice, however, the ideal filter cannot be realized, but only approximated.

In the design of practical microwave band-pass filters, many competing and often mutually exclusive requirements must be considered. For example, low weight and small size may often be sacrificed for high-power performance. Similarly, small size and structural simplicity may be sacrificed for very steep rolloff characteristics. By the same token, narrow bandwidth microwave band-pass filters generally in use are characterized by a relatively high passband insertion loss.

It is a general object of the present invention to provide a narrow-band microwave band-pass filter having improved passband insertion loss.

It has long been known that microwave filters can be coupled in cascade to realize a composite filter structure having characteristics which are not readily obtainable with a single filter structure alone. For example, narrow bandwidth band-pass filters have been proposed which comprise, in cascade, a low-pass filter and a high-pass filter having cutoff frequencies which correspond to the lower and upper passband frequencies, respectively. In general, however, the rolloff characteristics of such structures are not as steep as are often desired.

It has also been proposed to employ in cascade with a conventional band-pass filter a pair of band-elimination filters, each tuned to one side of the passband. Whereas such a structure is capable of providing a very steep cutoff characteristic, it can do so only at the expense of increased cost, complexity and relatively high passband insertion loss.

Accordingly, it is another object of the present invention to provide an improved narrow-band microwave band-pass filter having low passband insertion loss and relatively steep rolloff characteristics.

It is yet another object of the present invention to provide a microwave band-pass filter having adjustable passband center frequency, bandwidth and rolloff characteristics.

SUMMARY OF THE INVENTION

In accordance with the principle so the present invention these objects are accomplished with a microwave filter structure comprising two cascaded sections. Each of the constituent filter sections has a band-pass characteristic which is individually adjustable. The passbands of the sections are adjusted so that a portion of the passband of each section overlaps a portion of the other by an amount corresponding to the desired passband of the composite filter.

In a preferred embodiment, each of the sections comprises a length of conductively bounded waveguide containing a plurality of coupled cavities. Each section is preferably designed for a substantially flat passband with low passband insertion loss. Although the passband of each constituent section can be relatively wide, the passband of the composite filter can be arbitrarily narrow. That is, unlike prior art "stagger tuning," wherein two relatively narrow-band filters are tuned to produce a wide band-pass characteristic, the present invention utilizes two relatively wideband filter sections which provide a band-pass characteristic which is much narrower than either section alone.

BRIEF DESCRIPTION OF THE DRAWINGS

The above mentioned and other features and objects of the present invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a cross-sectional view of a preferred embodiment of the present invention;

FIG. 2 is a pictorial view of the embodiment of FIG. 1;

FIG. 3 is a graphical representation of the insertion loss response characteristics of the embodiment of FIG. 1; and

FIG. 4 is a graphical representation of an alternative response characteristic illustrative of the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring more specifically to the drawings, FIG. 1 is a cross-sectional view of a preferred embodiment of the present invention. In FIG. 1 a section of conductively bounded rectangular waveguide **10** is provided with an input port **11** and an output port **12**. Coupling flanges **13** and **14** disposed at the input and output ports, respectively, facilitate connection to external microwave circuit components with which the filter is sued.

Between input port **11** and output port **12** waveguide section **10** is divided into two separate sections indicated as section A and secton B, separated by a matching or transition section T. In section A a group of conductive irises **1**, **2**, **3**—*n* serve to divide waveguide section A into a first plurality of coupled microwave cavities. A similar group of irises **1'**, **2'**, **3'**—*m* also serves to divide section B into a second plurality of microwave cavities.

Although irises **1**, **2**, **3**—*n* and **1'**, **2'**, **3'**—*m* are sown in FIG. 1 as symmetrical inductive irises, it is understood that this is intended solely for the purpose of illustration. Other forms of irises or cavity coupling schemes known in the art can be utilized to realize the coupled cavity filter sections A and B of the embodiment of FIG. 1.

In general, the design of microwave band-pass filters utilizing a plurality of coupled cavities is well known in the art. One conventional approach, which is widely used, can be found in an article entitled "Direct-Coupled-Resonator Filters" by S. B. Cohn, Proceedings of the I.R.E., Vol. 45, No. 2, Feb. 1957, pp. 187—196. Each of the section A and B can be designed individually in accordance wit the technique outlined in the above article in the manner to be explained in greater detail hereinbelow.

In the pictorial view of FIG. 2, each of the coupled cavities of Sections A and B are shown as being provided with tuning screws **20** and **21**, respectively. Tuning screws **20** and **21** are included for the purpose of allowing fine adjustment of the coupled cavities of Sections A and B as is well known in the art.

In the practical design of microwave filters, the designer generally begins with a set of design specifications which must be met. For example, the band-pass may be specified as well as the minimum allowable attenuation at some frequency above and below the upper and lower band-pass frequencies, respectively. A minimum insertion loss in the passband may also be specified for design purposes. In addition, source impedance, load impedance, size, weight, etc., may be specified.

A band-pass filter designed in accordance with the prior art procedure described in the above-mentioned article exhibits a power loss at the center of the passband which is given approximately by the formula:

$$\text{Loss} \approx C\frac{\omega_0}{\omega_h - \omega_l}\sum_{k=1}^{p}\frac{g_k}{Q_k} \text{ (in db)} \quad (1)$$

where C is a constant ω_0, ω_1 and ω_h represents the center frequency, and lower and upper passband frequencies, respectively. And where g_k and Q_k are of the conductance and unloaded Q of the kth element of a p element filter, respectively.

In keeping with the design of the present invention, however, a narrow-band filter is realized by the use of the cascaded combination of two much wider passband filter sections, the response curves of which overlap. By way of example, if each section A and B is designed for a passband four times as wide as the passband ($\omega_h - \omega_l$) then the loss for each section becomes smaller, although not precisely in the same ratio because of slight changes in the other parameters in equation (1). However, assuming that the loss for each section does become proportionately less; it is seen that the total loss for the composite filter is the additive combination of those of sections A and B or approximately one-half that of the prior art design.

The design procedure of the present invention can be more clearly understood with reference to the response characteristics depicted in the graph of FIG. 3. In FIG. 3, the insertion loss of filter sections A and B of FIG. 1 are shown by dashed curve 30 and dotted curve 31, respectively. The insertion loss passband characteristic of filter section A extends between a first frequency f_1 and a second frequency f_2. The insertion loss passband characteristic of filter section B, on the other hand, extends between a third frequency f_3 and a fourth frequency f_4. The overlap between curves 30 and 31 (i.e., f_2–f_3) represents the overall passband of the composite filter.

The solid curve 32 represents the insertion loss band-pass characteristic of the overall filter of FIGS. 1 and 2 and corresponds to the sum of the insertion loss of individual sections A and B. The passband of the composite filter, as mentioned above, extends between frequency f_3 and f_2. The rolloff or steepness of the response characteristic 32 above and below the passband increases rapidly at frequencies below f_1 and above f_4, a feature which is quite desireable in many applications.

In FIG. 3, the response characteristic 32 is substantially symmetrical about the center frequency f_o of the passband. Unsymmetrical response characteristics can also be easily obtained in accordance with the principles of the present invention. An unsymmetrical characteristic typical of the infinite variety of unsymmetrical response characteristics which can be obtained is shown in the graphical representation of FIG. 4.

In FIG. 4, the insertion loss response characteristic of section A is indicated by dashed line 40. The passband of section A extends between a first frequency f'_1 and a second frequency f'_2. The passband of section B extends between a third frequency f'_3 and fourth frequency f'_4. As seen from FIG. 4, the rolloff of the response of section B is much more rapid than that of section A with the result being an unsymmetrical overall response curve 42 of the composite filter.

From FIG. 4 it is apparent that if the desired overall response characteristic is such that the rolloff is to be greater at one or the other side of the passband it can be easily achieved. With filters designed by the prior art techniques, however, the rolloff response is generally symmetrical and the filter is designed so that the requirement is met for the steepest side of the passband. In this manner the less steep side of the passband will also be met but at the expense of overdesign.

The overall response characteristics of filters in accordance with the present invention can be easily adjusted by adjustment of the passband of either section A, section B, or both sections simultaneously. Referring once again to the response characteristic of FIG. 3, if it is desired to reduce the bandwidth of the overall characteristic curve 32, three alternatives

are possible. The response of section A indicated by curve 30 can be shifted to a lower frequency or that the section B indicated by curve 31 can be shifted to a higher frequency. Furthermore, if the center frequency f_o of the desired passband characteristic is to remain unchanged, both the response of sections A and B can be simultaneously shifted lower and higher, by a corresponding amount.

The response curve of the filter sections A and B can be shifted over a limited frequency range by the use of tuning screws 20 and 21, respectively. The range over which the filter is adjustable is determined largely by the broader of the two bandwidths of either section A or section B. The maximum bandwidth, of the composite filter, on the other hand, is primarily determined by the narrower of the two bandwidths of section A or B.

Thus, by merely shifting the response of section A or section B higher or lower, the insertion loss of the overall response characteristic remains substantially unchanged and an arbitrary narrow passband can thereby be achieved. Furthermore, by utilizing filter sections of differing rolloff, such as indicated in FIG. 4, arbitrary slopes on one or both sides of the passband can be obtained.

An experimental embodiment similar to that depicted in FIGS. 1 and 2 was constructed and tested. The experimental embodiment was designed for center frequency of approximately 7,200 MHz. This embodiment utilized of standard WR (112) rectangular waveguide having inside dimensions of 1.122 ×0.497 inches. Section A consisted of a seven element coupled-cavity filter designed to give 0.01 db. ripple Chebyshev response over a 200 MHz. bandwidth. Section B comprised a six element coupled-cavity filter design to yield a 0.01 db. ripple Chebyshev response over a 200 MHz. bandwidth. The two sections were joined by a transition section having a length corresponding approximately to the average length of the constituent cavities of sections A and B.

The experimental filter was adjusted to provide a 1db. bandpass of from 12.5 MHz. to 200 MHz. and an insertion loss of 0.8 db. at the center frequency of approximately 7,200 MHz.

In all cases it is understood that the above-described embodiments are merely illustrative of but a small number of the many possible specific embodiments which can represent applications of the principles of the present invention. Numerous and varied other arrangements including those using differing constituent filter types and design types can be readily devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the present invention.

What I claim is:

1. A narrow-band band-pass filter comprising, in combination:
   - a first coupled-cavity resonator filter section having a substantially flat band-pass response over a first frequency range;
   - a second coupled-cavity filter section having a substantially flat band-pass response over a second frequency range;
   - said first and second frequency ranges being coextensive over a third frequency range, said third frequency range being substantially less than either said first or second frequency ranges; and
   - means for electromagnetically coupling said first and second filter sections in cascade between an input port and an output port.

2. The band-pass filter according to claim 1 wherein said coupling means comprises a waveguide matching section.

3. The band-pass filter according to claim 2 wherein said matching section has a length substantially equal to the average length of the cavities of said first and second filter sections.