DUAL CAVITY BANDPASS FILTER

Filed Sept. 19, 1967 2 Sheets-Sheet 1

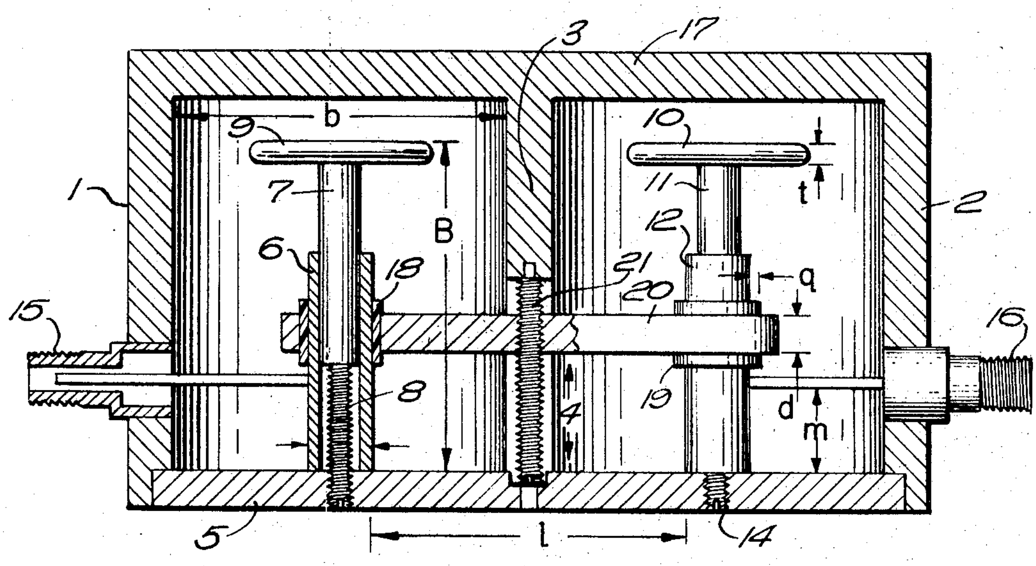

FIG. 1

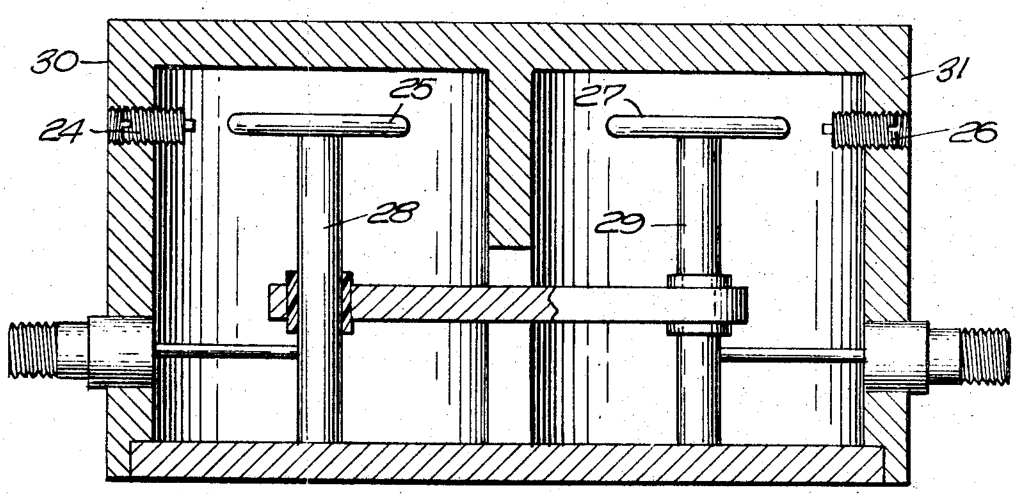

FIG. 2

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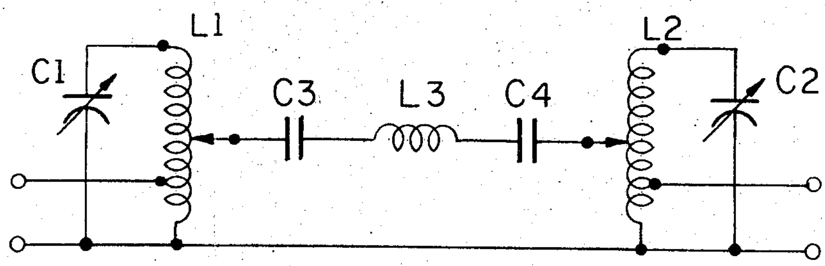

FIG. 3

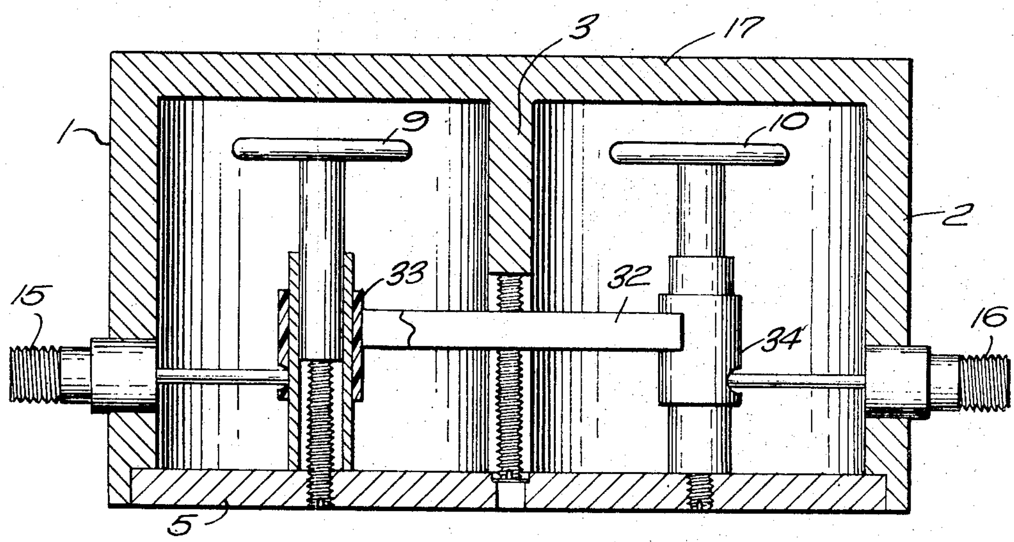

FIG. 4

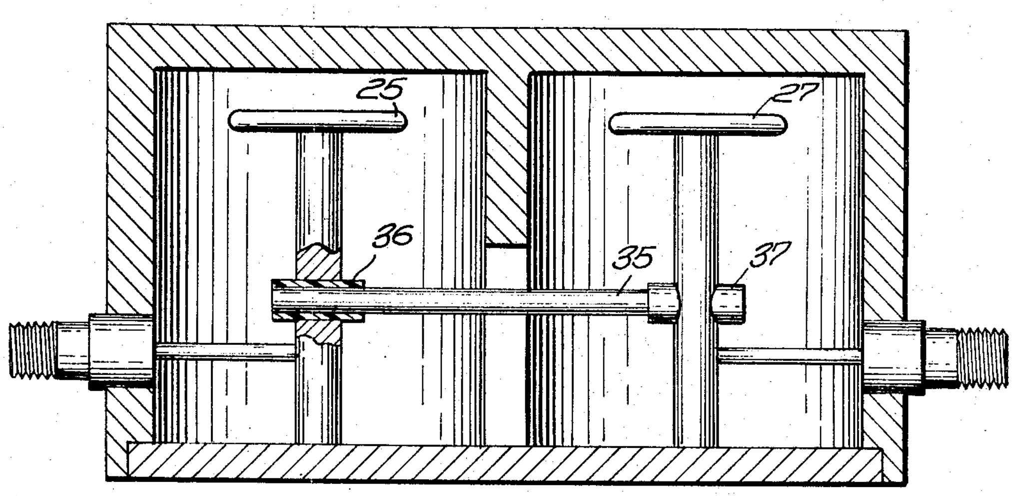

FIG. 5

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3,516,030

Patented June 2, 1970

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3,516,030

DUAL CAVITY BANDPASS FILTER

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Filed Sept. 19, 1967, Ser. No. 668,810

Int. Cl. H03h 7/10, 9/00

U.S. Cl. 333—73 2 Claims

ABSTRACT OF THE DISCLOSURE

This invention concerns apparatus for filtering electromagnetic wave energy according to the frequency of its vibrations and more particularly relates to a bandpass filter employing dual resonant cavities.

Bandpass filters are devices which transmit electromagnetic waves whose frequencies lie within a continuous region (i.e., the band) of the electromagnetic spectrum of frequencies and reject those waves whose frequencies are outside the band. In the ideal bandpass filter, the electromagnetic energy whose frequencies are within the band proceeds through the filter without attenuation whereas the energy at all other frequencies is totally prevented from passing through the filter.

It is well known that filters can be constructed of lumped elements, that is, of elements such as coils and condensers, whose reactance is principally of one kind, that is, whose reactance is principally inductive or capacitive. At higher frequencies, filters are constructed of resonators formed by semi-lumped elements or from elements whose capacitance and inductance are distributed, such as coaxial line resonators, strip transmission line resonators, or waveguide resonators. Hollow waveguide or cavity resonators usually provide the best unloaded Q's and, therefore, are used for filters where low insertion loss and a bandwidth in the microwave region are desired. However, waveguide resonators have the disadvantage of being bulky. It is the principal object of the invention to provide a filter employing cavity resonators, that is, materially less bulky than waveguide resonator filters of conventional construction.

The invention resides in a pair of cavity resonators that are arranged side by side and are coupled together by a series resonant configuration through their common wall. Each cavity is provided with a post that is positioned longitudinally within the cavity and is attached at one end to the cavity's end wall. The free end of the post has a flat face which confronts the opposite end of the cavity to produce a condition of resonance within the cavity. In one embodiment of the invention, the longitudinal posts are adjustable in length to permit tuning of the cavities. In another embodiment the length of the posts are fixed and tuning screws are provided in each cavity. A marked fore-shortening of each cavity is brought about by attaching to the free end of the post a disc which is materially larger in diameter than the diameter of the post. By coupling to a selected point along the length of the post in one resonator, the input impedance can be matched to the impedance of the signal source. Similarly, the output impedance of the filter can be matched to the impedance of the output circuit by coupling to a selected point on the post in the other cavity.

The invention, both as to its construction and manner of operation can be better understood from the following exposition when considered in conjunction with the accompanying drawings, in which:

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

FIG. 2 is a sectional view of an embodiment of the invention in which the length of the posts are fixed and tuning screws are provided in the cavities; and the coupling between cavities is fixed;

FIG. 3 depicts a lumped element equivalent of the invention;

FIG. 4 is an enlarged view of a portion of the invention and depicts a second embodiment of the coupling arrangement between the cavities;

FIG. 5 is a sectional view of the invention and depicts a third embodiment of the coupling arrangement between the cavities.

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Referring now to FIG. 1, there is shown a pair of similar hollow cylindrical cavity resonators **1** and **2** connected side to side and having a common wall **3**. The common wall has an opening or iris **4** in it. The opposite end of resonator **1** is closed by a plate **5** having a sleeve **6** extending into the cylinder along the cylinder's longitudinal axis. A post **7**, having a screw-threaded shaft **8** mating with threads in the end plate **5**, or in sleeve **6**, extends through the sleeve and has a disc **9** attached to its free end. The other end of post **7** is slotted and as the shaft is engaged with the threads of the end plate **5**, by turning the shaft, the post can be advanced in to the cavity or withdrawn from it. A source of trouble in the filter can result from the failure of the post to maintain a good electrical connection with sleeve in which it slides. It is preferred, therefore, to construct the sleeve **6** with fingers which grip the post and yet permit the post to move to and fro in the sleeve. The fingers may be formed by slotting the free end of the sleeve and deforming the fingers inwardly so that they are spread by the insertion of the post.

In cavity **2**, is a similar disc **10** that is attached to the free end of the post **11** which is slidably mounted in a sleeve **12** attached to end plate **5**. The plate **5** closes off the end of resonator **2** and the plate is provided with threads **14** which engage the threaded shaft of post **11** and permit that post to be advanced into or retracted from the cavity.

To provide signal coupling into and out of the filter; the outer conductor of a coaxial connector **15** is secured to the wall of resonator **1** and the center conductor is connected to the sleeve **6** at a distance *m* from end plate **5**. Similarly, a second coaxial connector **16** is secured to the wall of resonator **2** and sleeve **12**.

FIG. 3 is a diagrammatic representation of the lumped constant equivalent of FIG. 1 embodiment. Cavity resonator **1** is represented by inductance L_1 and capacitance C_1, cavity resonator **2** is represented by inductance L_2 and capacitance C_2, and the coupling between the resonators is represented by capacitance C_3, C_4 and inductance L_3. A considerable part of the inductance L_1 resides in the sleeve **6** and post **7** and the capacitance C_1 if formed by the capacity between disc **9** and the end wall **17**. Similarly, for cavity resonator **2**, a part of inductance L_2 resides in the sleeve **12** and post **11**, and the capacitance C_2 is formed, by the capacity between the end wall **17** and disc **10**.

C_3 is formed by the capacitance between the sleeve **6** and the rod **20**, C_4 is formed by the capacitance between sleeve **12** and rod **20**. A considerable part of the inductance L_3 resides in the rod **20**. C_3, C_4, and L_3 form a series resonant condition to couple the desired signal from cavity **1** to cavity **2**. Rod **20** passes through an opening **4** from cavity **1** to cavity **2**. If the length B of post **7** is altered, the inductance L_1 will be altered and the resultant change in position of disc **9** will cause capacitance C_1 to change. The resonant frequency of cavity **1** can be tuned by adjusting the length B of post **7**. Similarly, the resonant frequency of cavity **2** can be tuned by adjusting the length of post **11**. Dielectric material **18** and **19** insulate and position rod **20**. A nonmetallic screw **21** allows rod **20** to be positioned along sleeves **6** and **12** to change the amount of coupling between cavities **1** and **2**. The dimensions *d* and *l* of rod **20** determine the inductance, L_3 and with dielectric **18** and **19** of thickness *q* determine the capacitance of C_3 and C_4.

Discs **9** and **10** should be of sufficient thickness *t* so as to be rigid despite the thermal and electrical stresses set up in those members. Beyond the requirement of rigidity, the disc thickness can be increased to enhance somewhat the capacitance that is a parameter of the resonant cavity.

It is assumed that both cavity resonators, **1** and **2** are tuned to the same frequency, although it is evident that those resonators may be tuned to resonate at different frequencies, if such operation were required. The length B of the post in the FIG. 1 embodiment is approximately equal to $\lambda/8$ where λ is the wavelength in free space of a wave vibrating at the mid-band frequency of the filter.

The characteristic impedance of the cavities can be assumed to be given by

$$z_0=\frac{138}{\sqrt{\epsilon}}\log 10\frac{b}{a}$$

where

b is the internal diameter of the cavity
a is the external diameter of sleeve **6**
ϵ is the relative dielectric constant of the medium in the cavity.

Because the length B of the post in the cavity is inductive, the post is equivalent to the winding of a transformer. The distance *m*, measured from the end plate to a point on the post or on the sleeve, determines the input impedance of the cavity **1**. Similarly, the distance measured between corresponding points in cavity **2** determines the output impedance of that cavity. Since the dual coupled cavities form a symmetrical device, the input signal may be impressed upon either connector **15** or **16** and the output of the filter is obtained from the other connector. The impedance of most coaxial connectors has been standardized at 50 ohms and when such standard connectors are employed, the distance *m* is selected so that the center conductor is connected to give the best impedance match.

FIG. 2 depicts an embodiment of the invention in which the posts **28** and **29** are fixed in length rather than being of adjustable length as in the FIG. 1 embodiment. To permit tuning of the cavity resonators **30** and **31**, a tuning screw is provided in each resonator. The tuning screw **24** is located in the wall of resonator **30** in a position where it is adjacent to disc **25**. Similarly, the tuning screw **26** in the wall of resonator **31** is in a position where the screw is adjacent to disc **27**. By adjustment of screw **24**, the cavity resonator **30** can be tuned and by adjustment of screw **26** the other resonator can be tuned. However, the tuning of one resonator affects the other so that each cavity cannot be tuned completely independently of the other. In other respect, the embodiment of FIG. 2 is similar in construction to the FIG. 1 embodiment.

In the embodiments of FIGS. 1 and 2, the longitudinal axial length of the resonators has been markedly foreshortened by employing discs on the free ends of the posts. Where an increase in the bulk of the dual cavity filter can be tolerated, posts **28** and **29** can be used without end plates. The elimination of the end plates necessarily requires a cavity of greater length to maintain the same resonant frequency. The cavity is equivalent to an open circuited quarter wave resonant line and therefore the cavity, without the end plates, is approximately a quarter wavelength at the mean wavelength of the filter.

FIG. 4 depicts a modification of the invention which permits a greater range of adjustment in the coupling between the two cavities. The insulative sleeves **33**, **34** of the FIG. 4 embodiment correspond to the sleeves **18** and **19** of the FIG. 1 embodiment except that the sleeves **33**, **34** cover a larger longitudinal extent of the posts. The ends of the coupling rod **32** partially encircle the sleeves **33**, **34** and are able to slide along those sleeves when the screw is turned to raise or lower the coupling rod. As the sleeves extend below the points where the input and output connections tap onto the posts, apertures are provided in the sleeves through which the connections to the posts are made. The ends of rod **32**, because they do not completely encircle the sleeves, permit the rod to be lowered without interference from the input and output connections.

FIG. 5 depicts a further embodiment of the invention in which the coupling rod **35** is fixed in position. Each of the posts has a transverse aperture lined with an insulative sleeve **36** or **37**. The coupling rod bridges the distance between the two posts and has its ends disposed in he sleeves **36**, **37**.

Because variations in embodiments of the invention are possible in the light of the foregoing teaching, it is intended that the invention not be limited to the details of construction and arrangement of parts specifically described or illustrated. Rather, it is intended that the scope of the invention be delimited by the appended claims and encompass such structures as do not in essence depart from the invention there defined.

What is claimed is:

1. A band pass filter comprising a pair of resonant cavities disposed side by side and having between them a common wall, the common wall having an aperture extending between the two cavities, each cavity being terminated by an end wall, each end wall having a conductive post protruding therefrom into the cavity, each post having a flat surface at its free end, confronting the opposite end wall of the cavity, the posts in the two cavities being parallel, means for coupling a signal into one cavity, means for extracting a signal from the other cavity, a conductive coupling rod extending through the aperture in the common wall transversely to the parallel posts, the ends of the coupling rod being proximate to the posts to capacitively couple the rod to the posts, dielectric members interposed between the ends of the coupling rod and the adjacent posts, and the coupling rod being of a length which in conjunction with its capacitive coupling provides a low impedance path between the cavities for signals in the filter's pass band.

2. The invention according to claim **1**, further including means for moving the coupling rod to cause the ends of that rod to be shifted longitudinally along the posts.

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U.S. Cl. X.R.

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