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Scheiner

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[54] **LOW LOSS HIGH-Q FILTER**

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[52] **U.S. Cl.** ..... **333/73 W,** 333/83 R, 333/98 R

[51] **Int. Cl.** **H01p 7/06**

[58] **Field of Search** .... 333/73 R, 73 W, 83 R, 98 R

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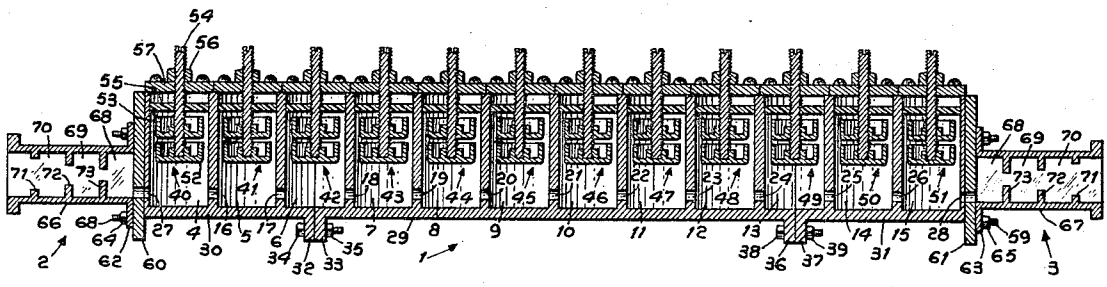
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[57] **ABSTRACT**

A low loss high-Q filter is disclosed herein having a restricted bandpass of 7.25–7.75 GHz with an in-band insertion loss of 0.5db, an out-of-band rejection greater than 80db and negligible spurious responses in-band. This is accomplished by providing two types of directly coupled variable resonators. The first type of variable resonators includes a series of twelve right circular cylindrical cavity resonators directly coupled in series with each other. Two of the second type of variable resonators are provided with each of these second type of variable resonators being directly coupled to opposite ends of the series coupled cylindrical resonators. Each of these second type of variable resonators include three directly coupled rectangular waveguide cavity resonators.

18 Claims, 3 Drawing Figures



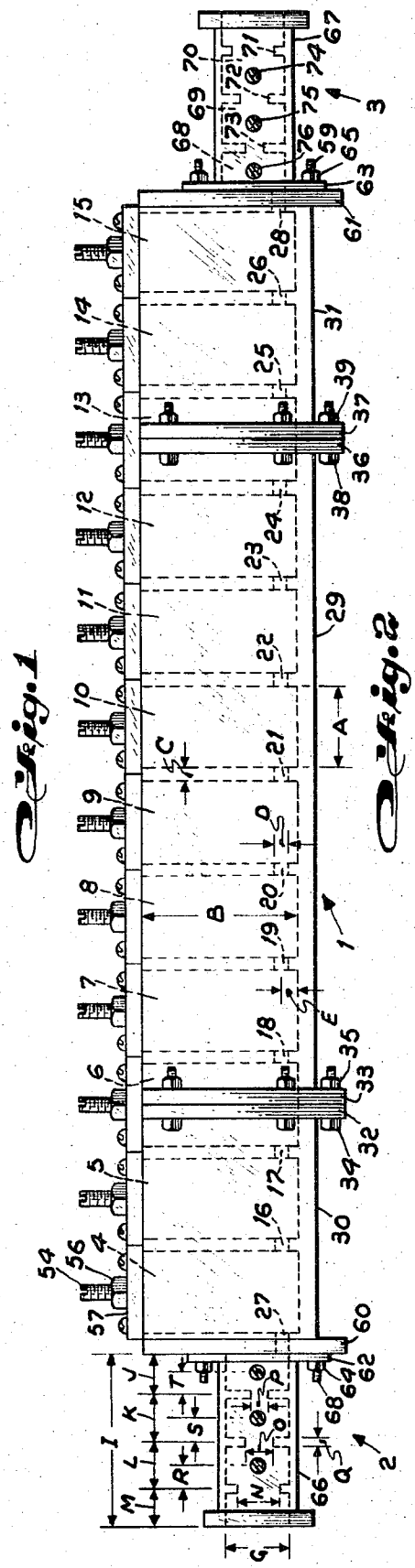


Fig. 1

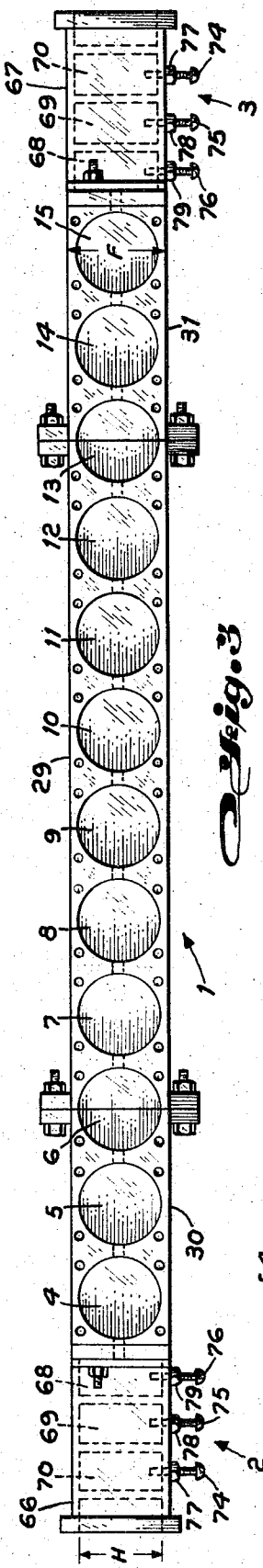


Fig. 2

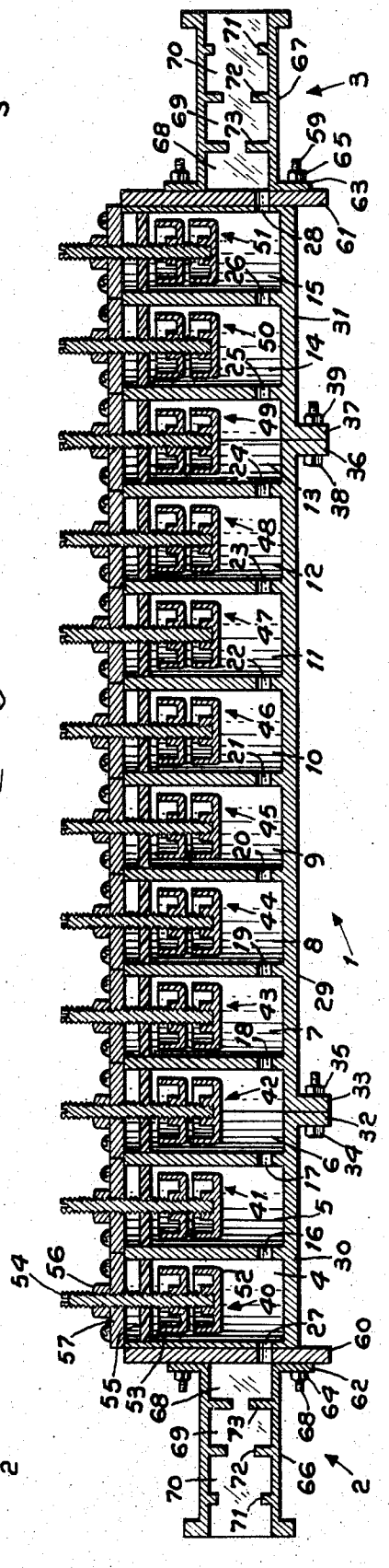


Fig. 3

LOW LOSS HIGH-Q FILTER

BACKGROUND OF THE INVENTION

This invention relates to a low loss high-Q filter and more particularly to such a filter that can be employed in communication systems as the receiver preselector filter.

Adjacent frequency bands have often been used in communication systems for simultaneous transmission and reception of intelligence. The commonality of design afforded by this choice of system is obvious, however, duplex operation has become more difficult as a result of imrovements in power amplifiers and receivers. Transmitters producing **10** kilowatts in a frequency band adjacent to the operating band of a low noise receiver impose stringent requirements on the receiver preselector filter. The preselector filter must reject the transmitted energy to prevent degradation of the receiver and at the same time be sufficiently low loss so that the contribution to the system temperature is minimal. The figure of merit used to evaluate the performance of a communication terminal is the system gain vs. the temperature ratio. An increase in temperature of a receiver obviously reduces the figure of merit, but the insertion loss of the preselector filter has a dual effect (1) it reduces gain and (2) increases noise temperature. An increase in temperature is approximately 7° for each 0.1db (decibel) increase in insertion loss where the total insertion loss is less than 1.0db and, conversely, every 0.1db improvement obtained in the preselector filter is equivalent to a 7° improvement in the receiver for the same combined noise temperature.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a preselector low loss high-Q filter which can satisfy the requirements imposed by present day communication systems.

Another object of the present invention is to provide a preselector high-Q filter that will provide a lower in-band loss than conventional waveguide filters.

Still another object of the present invention is to provide a low loss high-Q preselector filter that can meet the requirements of present day communication systems and can be readily manufactured.

A feature of the present invention is the provision of a low loss high-Q filter comprising: a plurality of right circular cylindrical cavity resonators; a first plurality of rectangular waveguide cavity resonators connected to one end of the cylindrical resonators; a second plurality of rectangular waveguide cavity resonators connected to the other end of the cylindrical resonators; first means for direct coupling of the cylindrical resonators in series and for direct coupling to the first and second waveguide resonators; and second means for direct coupling of each of the first and second plurality of waveguide resonators in series.

BRIEF DESCRIPTION OF THE DRAWING

Above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawing, in which:

FIG. **1** is a side elevational view of a low loss high-Q filter in accordance with the principles of the present invention with the tuning arrangements of the right circular cylindrical cavity resonators omitted for clarity;

FIG. **2** is a top view of the low loss high-Q filter of FIG. **1** with the tops of the right circular cylindrical cavity resonators removed; and

FIG. **3** is a longitudinal cross sectional view of the low loss high-Q filter of FIG. **1.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following description an actual reduction to practice of the low loss high-Q filter of the present invention will be described. The filter of the reduction to practice had the following characteristics: a passband of 7.25 – 7.75 GHz (gigahertz), an in-band insertion loss of 0.5 db, a passband standing wave ratio of 1.2, a Q in the order of 10,000 as indicated by the measured passband insertion loss and an out-of-band rejection greater than 80db. The various dimensions that are given hereinbelow are for this actually reduced to practice filter. However, it should be noted that the low loss high-Q filter of this invention may be dimensioned to have other passbands, in-band insertion losses, values of Q, passband standing wave ratios and out-of-band rejection characteristics.

Referring to FIGS. **1, 2** and **3,** there is illustrated therein a reduction to practice of a low loss high-Q filter in accordance with the principles of the present invention. The filter of the reduction to practice of the present invention is an eighteen pole, 0.01db ripple, Chebyshev filter including a central filter section **1** having formed therein a first type of variable cavity resonators and two identical end filter sections **2** and **3** having formed therein a second type of variable cavity resonators. Filter section **2** is directly coupled to one of the end cavity resonators of filter section **1** and filter section **3** is directly coupled to the other of the end cavity resonators of filter section **1.**

Filter section **1** includes twelve right circular cylindrical cavity resonators **4–15** with each of these cylindrical resonators being directly coupled to each other by means of circular apertures **16–26** disposed adjacent the bottom of each of cylindrical resonators **4–15.** Resonator **4** is provided with a circular aperture **27** to provide direct coupling to filter section **2** while resonator **15** is provided with a circular aperture **28** to provide direct coupling to filter section **3.** Each of the apertures **16–28** are at right angles with respect to the longitudinal axis of each of cylindrical resonators **4–15** and extend through the cylindrical wall of these cylindrical resonators.

It should be noted from the illustration that filter section **1** is actually formed in three parts, a central part **29** and two identical end parts **30** and **31.** The central part **29** includes six whole cylindrical resonators **7–12,** a half of cylindrical resonator **6** and a half of cylindrical resonator **13.** End part **30** includes therein whole cylindrical resonators **4** and **5** and end part **31** includes therein whole cylindrical resonators **14** and **15.** End part **30** includes the other half of resonator **6** while end part **31** includes the other half of cylindrical resonator **13.** The parts **29–31** are appropriately connected together to form filter section **1** such as by providing flanges **32** and **33** to connect end part **30** to central part **29** by employing a suitable fastener, such as bolts **34** and nuts **35.** Similarly, flanges **36** and **37** are provided

on parts **29** and **31**, respectively, which are suitably fastened together, for instance, by bolts **38** and nuts **39**.

Each of the resonators **4–15** include therein a tuning arrangement such as a choke coupled double bucket plunger **40–51**. Each of these plungers **40–51** include two buckets **52** and **53** tapped to receive tuning bolt **54**. Buckets **52** and **53** are dimensioned and spaced from the inner cylindrical surface of the cylindrical resonators an amount appropriate for the passband frequency involved. Each of the plunger units **40–51** include a plastic disc **55** which is tapped to receive tuning screw **54**. Disc **55** contacts the inner surface of each of the cylindrical resonators to enable the plunger units **40–51** to be smoothly guided up and down the cylindrical resonators coaxial of the longitudinal axis of these cylindrical resonators. A locking nut **56** is provided in association with the tuning bolt **54** and the top **57** to lock the plunger units **40–51** in the position that properly tunes the associated cylindrical resonator. Each of the tuning plungers **40–51** have the same construction and relationship to their associated cylindrical cavity and, therefore, each of these plunger units will not be described separately.

For the reduction to practice, each of the cylindrical resonators **4–15** had a diameter A equal to 1.300 inches and a depth B equal to 2.875 inches. The spacing C between adjacent cylindrical resonators was equal to 0.062 inches. Each of the circular coupling apertures **16–28** had a diameter D equal to 0.555 inches with the center of these coupling apertures being disposed a distance E equal to 0.410 inches from the bottom surface of each of the cylindrical resonators. The width F of the block in which the cylindrical resonators are formed was equal to 1.500 inches.

Each of the filter sections **2** and **3** are identical as mentioned hereinabove and are secured to the ends of filter section **1** by means of bolts **58** and **59** and nuts **64** and **65**. Bolts **58** and **59** are secured to flanges **60** and **61** and extending through apertures in flanges **62** and **63**.

Each of the filter sections **2** and **3** are formed from a rectangular waveguide having inner dimensions of $G \times H$ which is equal to 1.252×0.628 inches. Each of the waveguide sections **66** and **67** include therein three rectangular waveguide resonators **68, 69** and **70** with irises **71, 72** and **73** defining the rectangular waveguide cavity resonators and providing the direct coupling between these resonators. Capacitive tuning bolts **74, 75** and **76** tune the associated rectangular waveguide resonators **68, 69** and **70**. Nuts **77, 78** and **79** are locking nuts for capacitive tuning bolts **74, 75** and **76**, respectively.

In the actual reduction to practice, waveguides **66** and **67** had a length I equal to 3.313 inches while resonator **68** had a length J equal to 0.915 inches, resonator **69** had a length K equal to 0.935 inches and resonator **70** had a length L equal to 0.838 inches. The distance M between iris **71** and the output of the waveguide **66** had a value equal to 0.625 inches. Iris **71** had an iris opening N equal to 0.506 inches, iris **72** had an iris opening O equal to 0.281 inches and iris **73** had an iris opening P equal to 0.236 inches. These dimensions given for the iris openings are symmetrical with the longitudinal center line of the waveguides **66** and **67**. Each of the iris vanes forming the iris openings have a width Q equal to 0.032 inches. The capacitive tuning bolt **74** was spaced from the center line of iris **71** an R equal to 0.419 inches, capacitive tuning bolt **75** was spaced from the center line of iris **72** an amount S equal to 0.467 inches and capacitive tuning bolt **76** was spaced from the center line of iris **73** an amount T equal to 0.473 inches.

Again in accordance with the reduction to practice described herein the waveguides **66** and **67** were copper rectangular waveguides while the cylindrical resonators **4–15** were formed in a block of aluminum. When the aluminum filter section **1** and the copper waveguides **66–67** were fastened together and tested it was found that the filter had an in-band insertion loss of 1.0 db. This insertion loss was not the insertion loss required and, therefore, the filter was disassembled and the aluminum material forming filter section **1** had the inner surfaces of the cylindrical resonators **4–15** silver plated. The filter was then assembled and again tested and it was discovered that the filter now had the desired in-band insertion loss of 0.5 db.

The low loss high-Q filter described with respect to FIGS. **1, 2** and **3** was built by selecting for filter section **1** a resonator building block of the right circular cylindrical type, first, because of the higher Q available with this type of resonator as compared with the standard waveguide resonator and, secondly, for ease of fabrication as compared with an elliptical or spherical resonator. The filter in accordance with the principles of the present invention uses two different resonators directly coupled within the same filter structure in which internal coupling values are satisfied to provide the desired in-band response and out-of-band rejection and, thus, provides an efficient preselector filter for a receiver that can be employed in present-day communication systems.

While I have described above the principles of my invention in connection with specific apparatus it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A low loss high-Q filter comprising:

a plurality of right circular cylindrical cavity resonators;

a first plurality of rectangular waveguide cavity resonators connected to one end of said cylindrical resonators;

a second plurality of rectangular waveguide cavity resonators connected to the other end of said cylindrical resonators;

first means for direct coupling of said cylindrical resonators in series and for direct coupling to said first and second waveguide resonators; and

second means for direct coupling of each of said first and second plurality of waveguide resonators in series;

each of said cylindrical resonators having a longitudinal axis and each of said cylindrical resonators being oriented with respect to each other so that each of said longitudinal axes are parallel with respect to each other;

said first means including

a plurality of circular apertures, each of said plurality of apertures being disposed adjacent the bottom of an associated one of said cylindrical resonator, at right angles to said longitudinal axis of

said associated one of said cylindrical resonators and to extend through the cylindrical wall of said associated one of said cylindrical resonators to provide direct coupling between adjacent ones of said cylindrical resonators, and

a pair of circular apertures, one of said pair of circular apertures being disposed adjacent the bottom of a first of said cylindrical resonators, at right angles to said longitudinal axis of said first of said cylindrical resonators and to extend through the cylindrical wall of said first of said cylindrical resonators to provide direct coupling to said first plurality of waveguide resonators, and the other of said pair of circular apertures being disposed adjacent the bottom of a last of said cylindrical resonators, at right angles to said longitudinal axis of said last of said cylindrical resonators and to extend through the cylindrical wall of said last of said cylindrical resonators to provide direct coupling to said second plurality of waveguide resonators.

2. A filter according to claim **1,** wherein each of said first and second plurality of waveguide resonators are iris coupled.

3. A filter according to claim **1,** wherein said cylindrical resonators are formed in an aluminum block and the inner surfaces of said cylindrical resonators are silver plated.

4. A filter according to claim **2,** further including a plurality of tuning means, each of said plurality of tuning means being disposed in a different one of said cylindrical resonators coaxial of said longitudinal axis.

5. A filter according to claim **2,** further including a plurality of tuning means, each of said tuning means being disposed in a different one of said first and second plurality of waveguide resonators.

6. A filter according to claim **2,** wherein each of said irises are oriented at right angles with respect to said longitudinal axes.

7. A filter according to claim **2,** further including a first plurality of tuning means, each of said first plurality of tuning means being disposed in a different one of said cylindrical resonators coaxial of said longitudinal axis; and

a second plurality of tuning means, each of said second plurality of tuning means being disposed in a different one of said first and second plurality of waveguide resonators.

8. A filter according to claim **4,** wherein each of said plurality of tuning means includes a choke coupled double plunger.

9. A filter according to claim **5,** wherein each of said plurality of tuning means includes a capacitive tuning screw.

10. A filter according to claim **7,** wherein each of said first plurality of tuning means includes a choke coupled double plunger; and each of said second plurality of tuning means includes a capacitive tuning screw.

11. A filter according to claim **10,** wherein said cylindrical resonators are formed in an aluminum block and the inner surfaces of said cylindrical resonators are silver plated.

12. A filter according to claim **11,** wherein said first and second waveguide resonators are formed in a rectangular copper waveguide.

13. A filter according to claim **3,** wherein said first and second waveguide resonators are formed in a rectangular copper waveguide.

14. A filter according to claim **13,** wherein each of said first and second plurality of waveguide resonators are iris coupled.

15. A filter according to claim **14,** wherein each of said irises are oriented at right angles with respect to said longitudinal axes.

16. A low loss high-Q filter comprising:

a plurality of right circular cylindrical cavity resonators;

a first plurality of rectangular waveguide cavity resonators connected to one end of said cylindrical resonators;

a second plurality of rectangular waveguide cavity resonators connected to the other end of said cylindrical resonators;

first means for direct coupling of said cylindrical resonators in series and for direct coupling to said first and second waveguide resonators; and

second means for direct coupling of each of said first and second plurality of waveguide resonators in series;

said filter being an eighteen pole, 0.01 decibel ripple, Chebyshev filter with said cylindrical resonators equal to 12 and each of said first and second waveguide resonators equal to 3.

17. A filter according to claim **16,** wherein each of said cylindrical resonators are formed in an aluminum block and the inner surfaces of said cylindrical resonators are silver plated; and said first and second waveguide resonators are formed in a rectangular copper waveguide.

18. A filter according to claim **17,** wherein said aluminum block includes two end portions and a central portion, said end portion and said central portion being joinable to form said twelve cylindrical resonators,

each of said end portions having two and a half cylindrical resonators of said 12 cylindrical resonators, and

said central portion having a first half cylindrical resonator of said twelve cylindrical resonators to join with said half cylindrical resonator of one of said end portion to form a full cylindrical resonator of said 12 resonators, a second half cylindrical resonator of said 12 cylindrical resonator to join with said half cylindrical resonator of the other of said end portion to form a full cylindrical resonator of said twelve cylindrical resonators and six full cylindrical resonators of said twelve cylindrical resonators disposed in series between said first and second half cylindrical resonator.

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