

July 25, 1939.

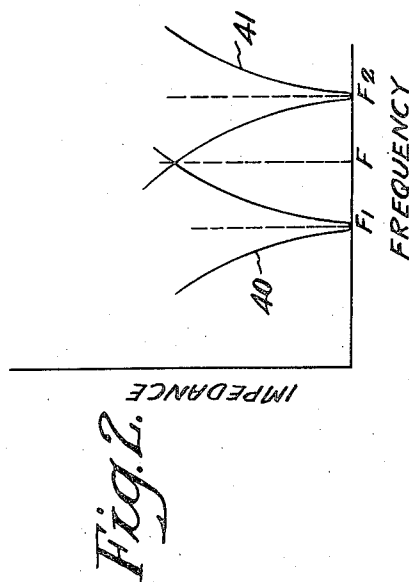
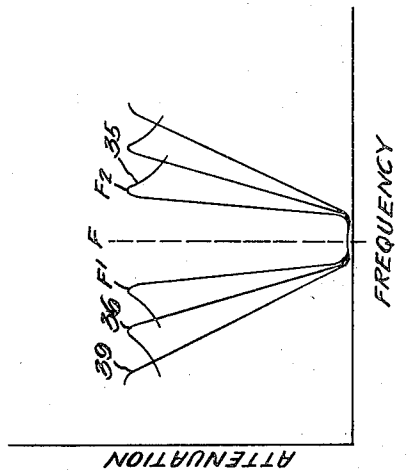
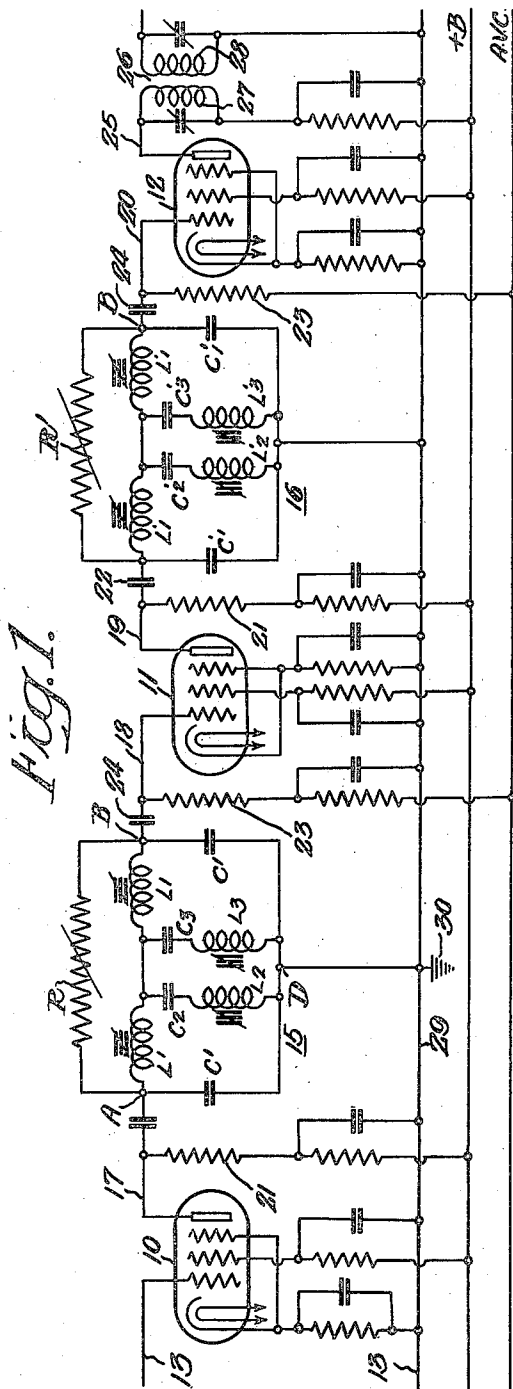
V. D. LANDON

2,167,079

BAND PASS FILTER

Filed Nov. 28, 1936

2 Sheets-Sheet 1



33

Inventor
Vernon D. Landon
[Signature]
Attorney

July 25, 1939.

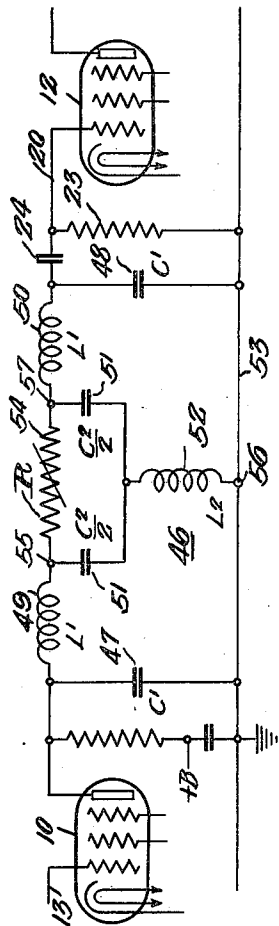
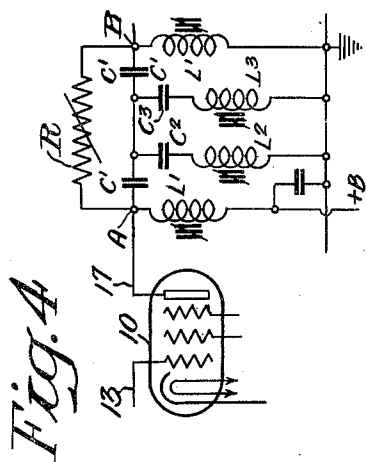
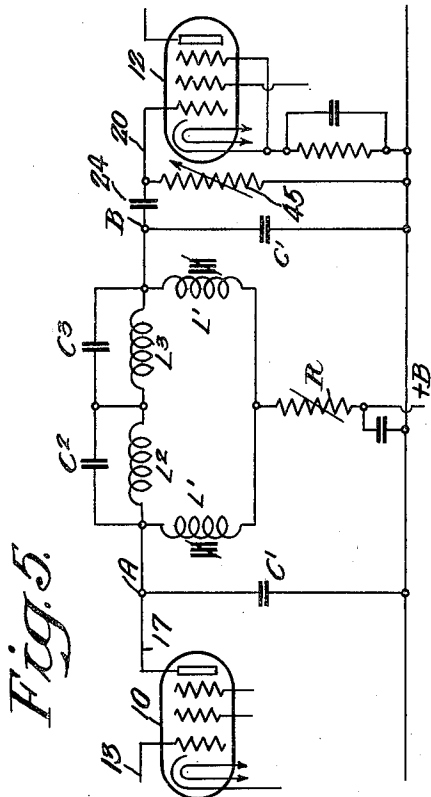
V. D. LANDON

2,167,079

BAND PASS FILTER

Filed Nov. 28, 1936

2 Sheets-Sheet 2



25

Inventor

Vernon H. Landon

Attorney

UNITED STATES PATENT OFFICE

2,167,079

BAND PASS FILTER

Vernon D. Landon, Haddonfield, N. J., assignor
to Radio Corporation of America, a corpora-
tion of Delaware

Application November 28, 1936, Serial No. 113,157

13 Claims. (Cl. 178-44)

The present invention relates to band pass filters for high frequency radio signaling circuits and the like, such as are found in radio frequency and intermediate frequency amplifiers of radio receiving systems.

The invention relates more particularly to intermediate or constant frequency amplifiers, and has for its object to provide an improved band pass filter network which may provide two points of signal attenuation adjacent to the pass band of the filter, to provide sharp cut-off of undesired signals and to provide a relatively high input and output impedance, whereby the filter is adapted to be used as an interstage coupling means in connection with high gain, high impedance amplifier tubes.

In one of its aspects, the invention contemplates an improvement upon the circuits shown in patents to Mason 1,967,249 and 1,967,250 to obviate the necessity for utilizing a crystal as the filter means, whereby the cost of the filter is reduced.

A form of band pass filter to which the invention is readily adapted is that known as an M-derived band pass filter with mid-shunt termination.

It is an object of the present invention to provide means for compensating the positive resistance in the attenuating circuits by a single circuit element connected between two points on the filter network and to improve the input and output impedance of a filter network of the character above referred to.

It is a further object of the present invention to provide a high impedance band pass filter, with the same attenuation and cut-off characteristics as a dissipationless filter, without using crystal filter elements therein.

It is a still further object of the present invention to provide a practical circuit for obtaining infinite attenuation at a plurality of rejection frequencies in a band pass coupling network in connection with high gain amplifier tubes, without resorting to complicated means for effecting resistance cancellation therein.

The invention will be understood from the following description, when considered in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings,

Figure 1 is a schematic circuit diagram of a portion of a high frequency or intermediate frequency amplifier embodying the invention,

Figures 2 and 3 are curves illustrating certain

operating characteristics of the system shown in Fig. 1, and

Figures 4, 5 and 6 are schematic circuit diagrams of modifications of the invention shown in Fig. 1.

Referring to Fig. 1, a plurality of high gain screen grid amplifier tubes 10, 11 and 12 are connected in cascade relation to provide a multi-stage amplifier, having input leads 13 and output leads 14. The amplifier tubes are coupled, in accordance with the invention, by means of filter networks indicated generally at 15 and 16, the former being interposed between an output circuit 17 and an input circuit 18 of the first and second stage tubes 10 and 11, respectively. The second filter network 16 provides coupling means for the output circuit 19 of the second stage tube 11 and the input circuit 20 of the third stage tube 12. Suitable output coupling means 21 and 22 are provided for the output circuits 17 and 19 and similar coupling means 23 and 24 are provided for the input circuits 18 and 20.

Coupling with the output circuit 25 of the tube 12 is provided by a tuned transformer 26 having a tuned primary winding 27, and a tuned secondary winding 28. This provides a pair of coupled tuned circuits following the filter networks in the signal amplifier circuit.

Each of the filter networks is of the T type comprising series inductances L_1 and L_1 , forming with shunt capacitors C_1 and C_1 , and providing a predetermined band width, with cut-off frequencies at either end of the band as is well known. The low potential side of the circuit is indicated by a terminal D through which the capacitors C_1 and C_1 are connected to the ground lead 29 and chassis ground 30 of the amplifier.

The capacities represented by C_1 and C_1 may in part be supplied by fixed or variable capacitors and may also be provided by the internal tube capacities connected therewith. With high inductance elements, these provide relatively high input and output impedances for the filter network in connection with the tubes.

Filter networks of this character are referred to in the patent to Zobel 1,538,964 issued May 26, 1925 and are also referred to in the patent to Bode 2,002,216, issued May 21, 1935. The bridged-T type of network shown includes equal inductances L_1 and L_1 and the capacitors C_1 and C_1 in shunt rather than in series whereby the impedance of the network at the input terminal A and the output terminal B is raised to a value suitable for use between high impedance amplifier devices of the type shown at 10 and 11.

Furthermore, the shunt circuit or stem of the T network comprises two tuned series resonant circuits comprising capacitors C_2 and C_3 and series inductances L_2 and L_3 . These are provided by inductors having variable magnetite core tuning as indicated, whereby the resonance frequency of the circuit is variable in conjunction with fixed capacitors at C_2 and C_3 . The inductances L_1 and L_2 preferably are also provided by variable magnetite cores as indicated. Adjustable core inductances are known and extensively used, and as shown, may be of any suitable type. In the filter network shown, the use of variable inductance devices, particularly with magnetite cores, not only permits variable tuning to an accurate frequency response, with permanent adjustment, but permits the inductance of such devices to be relatively high as is desirable to permit the use of series tuning capacitors having relatively low capacity.

It will be noted that two series tuned circuits connected in parallel provide the stem of the T network. These circuits are tuned to differing frequencies, on opposite sides of the pass band. That is, each is tuned to a frequency adjacent to and outside the pass band, for attenuating signals adjacent in frequency to the cut-off frequency of the filter network at each end of the pass band. They are, therefore, dissipative reactances in the stem of the T structure of the network.

It has been found that a high degree of attenuation may be provided by this arrangement and that the resistance of the attenuation circuits may both be cancelled by the single resistor means R connected between the input terminal A and the output terminal B of the filter network, thus eliminating the necessity for an additional stage for attenuating both sides of the pass band as has heretofore been considered necessary.

The two meshes L_1-C_1 are each tuned to the mean frequency of the pass band. The mesh L_2-C_2 is tuned to one attenuation peak outside the pass band, and L_3-C_3 is tuned to the other attenuation peak. For example, as indicated at F_1 and F_2 in Figs. 2 and 3 the mean band pass frequency is indicated at F . Considering L_2-C_2 and L_3-C_3 in parallel, it will be seen that there are two frequencies at which the impedance of the stem of the T network may assume the proper value for infinite attenuation. The response characteristic is indicated by the curve 35 in Fig. 3.

It should be noted that this performance curve has high attenuation immediately on either side of the pass band but that the attenuation is reduced at frequencies farther removed from the pass band. Accordingly, in order to obtain a nearer approach to an ideal response curve, the filter section or network 16 is provided between the amplifier tubes 11 and 12. This is the same as the filter section or network 15 and corresponding elements are similarly designated. The filter network 16 may be tuned in the same manner but for attenuation at peaks farther removed from the pass band. In Fig. 3 the response characteristic of the filter 16 is indicated by the curve 36.

The coupled tuned circuits provided in conjunction with the transformer 26 provides further attenuation at a greater distance from the attenuation peaks of the filters, as indicated by the curve 39 in Fig. 3, whereby interference adjacent to and over a range of frequencies some-

what widely removed from the pass band is effectively prevented through the cooperation of the two filter sections and the tuned coupled circuits in conjunction with the coupling transformer 25.

In this network, the T-network between points A and B causes a voltage at B, 180° out of phase at the rejection frequencies, which voltage is cancelled by a voltage drop through the resistor R at the point B. This is accomplished with a pair of dissipative resonant circuits in an M-derived band pass filter, with but one resistor between points A and B.

In these circuits C_2-L_2 provide a low impedance at the frequency F_1 , while the circuit C_3-L_3 provides a low impedance at F_2 . The parallel combination resonates at the frequency F , as shown in Fig. 2, thereby preventing attenuation at the mean frequency of the pass band. With the resistor R properly adjusted, the attenuation at the frequencies F_1 and F_2 is made substantially infinite. The response characteristic of the rejector circuit C_2-L_2 is indicated by the curve 40 and that of the circuit C_3-L_3 is indicated by the curve 41 in Fig. 2.

In Figs. 1 and 4 the proper value for R is given by the formula

$$R = \frac{\omega^2 L_1^2}{R_2}$$

in which R_2 is the effective series resistance of L_2C_2 or L_3C_3 at resonance. In Fig. 5 the proper value for R is given by the formula

$$R = R_2 \frac{L_1^2}{L_2^2}$$

in which R_2 is the effective series resistance of L_2C_2 or L_3C_3 at resonance. In Fig. 6 the proper value for R is given by the formula $R=4R_2$, in which R_2 is the effective series resistance of L_2C_2 at resonance. In any case, R is properly adjusted when the effective resistance of the rejector circuits is reduced to substantially zero or minimum value.

In the filter circuits 15 and 16 it will be noted that the terminal resistance and the points of application and utilization of the signal are paralleled by the terminal capacitors C_1 and C_1 . This change from series to parallel resonant circuits in the input and output elements of the filter network accomplishes a desired increase in impedance level, and the circuits terminate in shunt capacity as is desirable. Therefore, these circuits are particularly well adapted as coupling units between high gain amplifier tubes, as shown. While these circuits are not considered to be conventional, it has been found that they operate to provide the desired response curve, particularly when the circuits L_1C_1 are slightly detuned from the mean pass band frequency to obtain a flat transmission in the pass band, as indicated by the curve 35 in Fig. 3.

Referring now to the circuits shown in Figs. 4 and 5, in case that the plate requirements are relatively heavy, the input and output circuit elements L_1C_1 may be interchanged as indicated, to provide the inductance elements L_1 in shunt across the filter circuit and, since these elements are of relatively high inductance, the high impedance input characteristic of the filter is maintained.

For the purpose of readily comparing the circuits of Figs. 1, 4 and 5, the same reference characters are applied to like parts throughout. In this arrangement it will be seen that the induct-

ance L_1 at the input circuit is in series with the anode circuit 17 of the tube 10 in Fig. 5 and the inductance in the input side of the network of Fig. 4 is in a similar position to convey the plate current in lieu of a resistor or other coupling device.

In Fig. 5 the filter circuit is further modified to provide the rejector circuits C_2L_2 and C_3L_3 in series in the filter network, while the compensating resistor R is connected in the low potential side of the filter network in series with both inductances or inductors L_1 . This circuit, like that of Fig. 4, has the advantage that one of the inductors is arranged to carry the plate current of the tube to which the network is coupled. Furthermore, this circuit permits the tube capacity to be used as part of the filter input capacity, whereas in Fig. 4 the filter does not call for a terminal shunt capacity. Therefore the circuit of Fig. 4 is useful only when the filter capacity C_1 , for example, is less than the tube capacity by a relatively wide margin. This is a bridged T structure in which the arms are similar reactances, as in Fig. 1, but with the bridging impedance provided by one or more dissipative parallel resonant circuits, while the resistance R is located in the stem of the T structure.

Viewed in one way, the dissipation in the parallel resonant circuit or circuits may be said to be substantially nullified when R is of sufficient resistance to provide a voltage equal to the impedance drop in the rejector circuits at the rejection frequency.

In conjunction with the method of detuning one or more of the circuits L_1C_1 to provide a flat transmission in the pass band, it is desirable also to concentrate at one end of the filter network the damping or resistance by means of a single terminal resistor such as the resistor 45 in Fig. 5. This may be adjusted until the proper amount of damping is obtained and this is determined by the fact that the shoulders of the pass band frequency characteristic have less tendency to droop when the terminal resistance is concentrated at one end of the filter network.

Likewise in the circuit of Fig. 1, the resistors 21 and 23 are preferably widely different in value, 23 being high and providing substantially no load, whereby the loading of the filter is at one end and provided by the resistor 21.

Referring now to Fig. 6, a filter network 46 is shown in which the rejector circuit of Fig. 1 is modified to form a bridged T structure within the T structure of the filter network which includes the input shunt capacity 47 as C_1 , and series inductance 49 as L_1 at the input end, and the output series inductance 50 as L_1 and the shunt capacity 48 as C_1 at the output end. The rejector circuit comprises a dissipative reactance in the stem of the T having the capacitor sections 51 as

$$\frac{C_2}{2}$$

in each arm of the T and providing reactances of opposite sign. The bridging impedance is the resistor 54 having approximately four times the resistance of the stem reactor 52.

If the capacitors 51 are each made equal to one half of the capacity C_2 of Figs. 1, 4 and 5, and the inductor 52 made equal to the inductor L_2 , the filter network is then effective to attenuate one side of the pass band, for example, at the frequency F_1 of Fig. 3, while the resistance of the rejection circuit including the inductor 52

is effectively reduced to permit attenuation at the frequency F_1 to be substantially infinite.

In Fig. 6 the infinite attenuation occurring at the resonant frequency of L_2C_2 can be easily understood through the following explanation. Assuming for the moment that L_1 (50) is open circuited, the current in the two halves of C_2 are substantially equal because the impedance $4R_2$ is small compared to the reactance of C_2 . Hence the current in $4R_2$ is one-half the current in R_2 (the resistance of L_2).

The power dissipated in $4R_2$ is

$$\left(\frac{I}{2}\right)^2 4R_2 \text{ equals } I^2 R_2$$

The power dissipated in R_2 is $I^2 R_2$.

The total power dissipated is $2I^2 R_2$.

Hence the effective impedance to ground from point 55 is $2R_2$.

The input voltage equals $I2R_2$. The voltage drop across $4R_2$ equals

$$\frac{I}{2} 4R_2 \text{ equals } 2IR_2$$

The voltage drop across $4R_2$ being equal to the input voltage, the point 57 is at ground potential. Reconnecting coil L_1 (50) has no effect since the voltage applied to it is zero.

Since the currents in the two halves of C_2 are not exactly equal the exact frequency of infinite attenuation is slightly removed from the resonant frequency of L_2C_2 .

From the foregoing description it will be seen that advantage may be taken of the use of band pass filters in high frequency amplifiers, particularly intermediate frequency amplifiers as coupling units between high impedance circuits and that a plurality of rejection frequency points may be introduced into the response characteristic of the amplifier by providing a suitable number of filter coupled amplifier stages, with or without the simple addition of a pair of tuned coupled circuits to extend the attenuation range on each side of the band pass characteristic.

The filter networks shown and described have the advantage that they may be terminated by unequal resistances with one resistance lumped at either end of the filter thereby to compensate for undesirable peaks in the response characteristic and to provide a substantially flat response over the pass range of the filter.

Furthermore, the filter networks shown and described have the advantage that a plurality of rejection circuits may be neutralized as to their resistance whereby a high degree of attenuation is attained by the use of a single resistor in the circuit arranged in an opposite branch to the filter branch containing the rejector circuits.

I claim as my invention:

1. In a band pass signal filter network having at least two branches, the combination of a pair of dissipative resonant circuits in one branch of the network providing two frequency points of high signal attenuation on opposite sides of the pass band of the filter, and a single resistor having substantially no frequency characteristic connected in another branch of the network to improve the attenuation at both of said frequency points, said resistor having a resistance value such that the effective resistance of each of said resonant circuits is thereby reduced to a minimum value.

2. In a band pass signal filter network having at least two branches, the combination of a pair of dissipative resonant circuits in one branch of

the network providing two frequency points of high signal attenuation on opposite sides of the pass band of the filter; a single resistor having substantially no frequency characteristic connected in another branch of the network to improve the attenuation at both of said frequency points; and means connected in said network providing effective damping of the band pass circuits thereof, said last named means comprising terminal resistors having widely unequal values providing for concentrating said damping at one end of the filter, said damping being adjusted for a substantially flat band pass response characteristic.

3. In a band pass filter, the combination of a bridged-T structure including dissipative reactance elements in at least one of the branches thereof, means in another of said branches for compensating the resistance of said reactance elements at predetermined rejection frequencies, and means providing terminal resistances in said filter, unequal to a degree at which the response characteristic in the pass band is substantially flat, said last named means comprising terminal resistors and high impedance terminal circuits for said filter, said resistors having widely unequal values whereby the damping is concentrated at one end of the filter.

4. In a multi-stage signal amplifier, the combination of a plurality of amplifier tubes arranged in cascade relation to each other to provide a signal amplifying channel, and means providing an inter-stage coupling device between at least two of said amplifier tubes, comprising an M-derived band pass signal filter having at least two branches, a pair of dissipative resonant circuits in one branch of the network tuned to two differing rejection frequencies, a single resistor connected in another branch of the network to compensate the resistance of said resonant circuits jointly whereby substantially infinite attenuation is provided by said circuits, and means for extending the width of the rejection frequency band comprising a pair of tuned coupled circuits interposed in the signal amplifying channel and tuned to the mean frequency of the pass band of said channel.

5. In an M-derived band pass signal filter, the combination of means providing two points of high attenuation on opposite sides of the pass band of the filter, said first named means comprising two parallel resonant rejector circuits tuned to differing frequencies on either side of the pass band of the filter and said rejector circuits being in series with each other to provide in combination the series elements of a π structure of dissipative reactive elements, and a resistor common to the ground return circuits of both legs of the π structure, whereby the attenuation is increased at the resonant frequency of each rejector circuit.

6. In a multi-stage high frequency signal amplifier comprising a plurality of electric discharge amplifier devices, the combination of a plurality of M-derived band pass filters connected between said devices as interstage coupling means therefor, one of said filters having at least two branches, a pair of dissipative resonant circuits in one branch of said filter providing high attenuation on opposite sides of the pass band of said filter, a resistor connection in another branch of the filter providing cancellation for the resistance of said circuits jointly, and means providing unequal resistance termination for said filter.

7. In a multi-stage high frequency signal amplifier comprising electric discharge tubes, the combination of a plurality of band pass filters connected between said tubes as interstage coupling means therefor, one of said filters including means providing two frequency points of high attenuation on opposite sides of the pass band of the filter, said means comprising two series tuned rejector circuits in parallel with each other as the stem of a T structure of dissipative reactive elements, and a resistor bridging the arms of the T structure for applying a compensating voltage across the arms of the T structure, whereby the attenuation is increased at the resonant frequency of each rejector circuit.

8. A band pass filter comprising in combination, means providing a rejector circuit having a bridged-T structure having two arms and a stem, a dissipative reactance in the stem of the T structure, means for causing the arms of the T to be reactive and equal to each other, and of such a reactance value when used in parallel as to resonate with the stem of the T to a rejection frequency, and means providing a bridging impedance for the T structure having a resistance of substantially four times the resistance of the resonant circuit provided by the stem of the T and two reactive arms.

9. An intermediate frequency amplifier for a superheterodyne receiver comprising in combination, a plurality of high gain electric discharge tube amplifier stages, a band pass filter network in at least one of said stages, said filter network having at least two branches, a pair of dissipative resonant circuits in one branch of the network providing two frequency points of high signal attenuation on opposite sides of the pass band of the filter, means in another branch of the network for compensating the resistance of said resonant circuits thereby to render the attenuation therein substantially infinite, and means including the internal capacities of the tubes of the amplifier providing shunt input and output capacities for said filter.

10. An intermediate frequency amplifier for a superheterodyne receiver as defined in claim 9 further characterized by the fact that the terminal resistances of said filter network is provided at one end of the filter network by a coupling impedance in one of the tube circuits.

11. An intermediate frequency amplifier for a superheterodyne receiver as defined in claim 9 further characterized by the fact that a second band pass filter is included in a second amplifier stage as the coupling means therefor, said band pass filter having rejection circuits tuned to differing rejection frequencies from the first filter thereby to widen the attenuation band on opposite sides of the pass band of the amplifier.

12. An intermediate frequency amplifier for a superheterodyne receiver as defined in claim 9 further characterized by the fact that a second band pass filter is included in a second amplifier stage as the coupling means therefor, said band pass filter having rejection circuits tuned to differing rejection frequencies from the first filter thereby to widen the attenuation band on opposite sides of the pass band of the amplifier, and that a pair of tuned coupled circuits is included in the amplifying channel in cooperation with said filters to provide a further extension of the attenuation range on opposite sides of the pass range of the amplifier.

13. A filter system comprising in combination, means providing a rejector circuit comprising a

bridged-T structure having two arms and a stem, a dissipative reactance in the stem of the T structure, means for causing the arms of the T to be reactive and equal to each other, and
5 of such a reactance value when used in parallel as to resonate with the stem of the T to a rejection frequency, means providing a bridging impedance for the T structure having a resistance of substantially four times the resistance of the resonant circuit provided by the stem of the T and two reactive arms, and means providing acceptor circuits at the input and output ends of
5 said rejector circuit.

VERNON D. LANDON.