May 5, 1942. N. M. RUST ET AL 2,281,621

BAND PASS FILTER

Filed April 30, 1941

Fig. 1

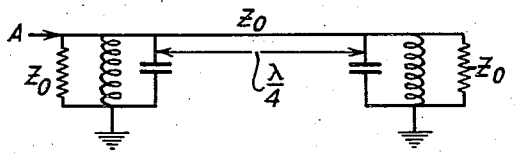


Fig. 2

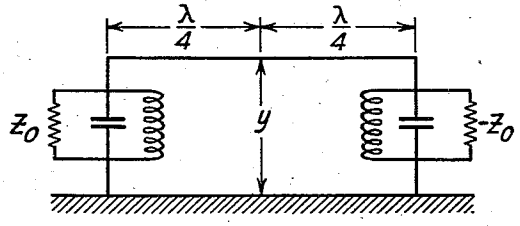


Fig. 3

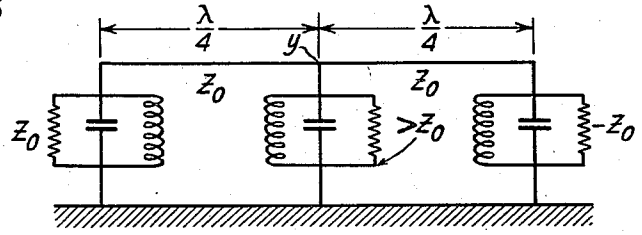


Fig. 4

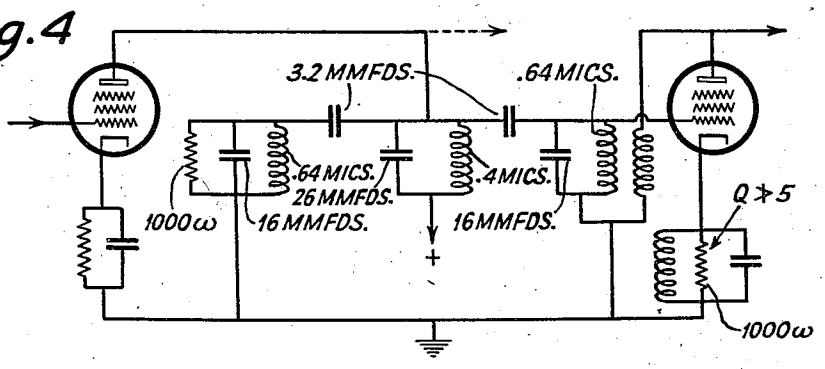
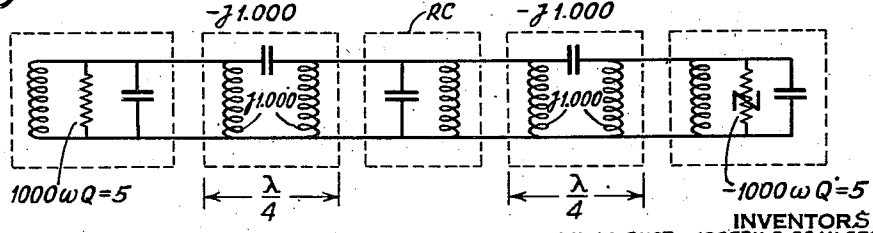


Fig. 5



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BAND-PASS FILTER

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Application April 30, 1941, Serial No. 391,205
In Great Britain October 5, 1939

7 Claims. (Cl. 179—171)

This invention relates to band-pass filters and has for its object to provide improved filters which are comparatively flexible in design and will facilitate the production of wide band amplifiers of high gain and large signal-to-noise ratio, or narrow band amplifiers of great selectivity and with a flat topped response curve such as will give a good signal-to-noise ratio. Though not limited to its application thereto the primary applications of the invention are to television amplifiers, and to intermediate frequency amplifiers for broadcast and like receivers.

The present invention may be regarded as a development or variation of the invention contained in our co-pending application Serial No. 359,182, filed October 1, 1940. According to this said invention a band-pass filter effect is obtained by superimposing upon the frequency-impedance characteristics of one network, the frequency-impedance characteristic of at least one further network which is coupled to the first in such manner that the impedance elements in the second network are, in effect, reversed. In other words, there are employed, in accordance with the invention contained in the specification of the above application, two networks coupled together in such manner that the second network acts as though it were directly included in and as part of the first network but with its impedance elements reversed. The expression "reversed" as employed in this connection is used to mean inversion and sign reversal of an impedance as set out in the said specification. In the various arrangements described in the co-pending application referred to negative impedances of a value comparable to positive impedances and varying in the same manner as the frequency is varied, are used to produce an impedance which is substantially constant over a band of frequencies and is of a higher value than the original positive impedance to be operated upon. In other words, negative resistance effects are used to compensate positive resistance effects, and negative reactance effects to compensate positive reactance effects. In these arrangements both negative effects are produced by valve circuits.

The present invention differs from the previous invention above referred to in that, although pure negative resistance produced by a valve arrangement is still used to cancel positive resistance, the cancellation of reactive effects is produced by a quarter wave line action. The present invention offers the advantage of being rather more practical and economical for narrow band working, e. g. for handling ultra short wave television carriers and sidebands.

According to the present invention a band pass filter comprises at least two tuned circuits including similar reactive elements and in one of which the effective parallel resistance is positive and in the other of which the effective parallel resistance is negative the said two tuned circuits being connected together by means of a quarter wave line and the values of the resistances in each case being equal to that of the characteristic impedance of the said line.

The invention is illustrated in and explained in connection with the drawing accompanying the specification, in which Fig. 1 represents a circuit which will serve to explain the principles underlying the invention, Figs. 2 and 3 are modifications of an embodiment of the invention, Fig. 4 is a practical circuit arrangement embodying the invention, and Fig. 5 represents the electrical equivalent of the circuit shown in Fig. 4.

In order that the invention may be the better understood there will first be given a brief and simplified description of the phenomena upon which the invention is based.

Consider first a circuit as shown in Figure 1 which is an explanatory diagrammatic figure. In this circuit a quarter wave line (conventionally indicated by the dimension $\lambda/4$, λ being the wave length) is terminated by impedance networks which are similar as regards reactive properties but whose resistive components are equal and opposite. In other words, the equivalent shunt resistance is positive in one impedance network and negative in the other. Each, moreover, is numerically equal to the characteristic impedance Z_0 of the line.

In accordance with the well known properties of a quarter wave line the impedance looking into the line with the near end termination disconnected is Z_0 at the in-tune frequency, but at frequencies off-tune, this impedance behaves as the inverse of that terminating the far end of the line. Thus a parallel resonance circuit will appear as a series resonant circuit of approximately the same Q as that of the parallel resonant circuit and its reactance will change in the opposite direction and at approximately the same rate over a small band of frequency near resonance.

The change in reactance (or rather susceptance) of a circuit shunting the near end will therefore be cancelled by that of a similar circuit at the far end over a frequency band near resonance. At frequencies further from resonance, the susceptance changes differ and no longer cancel completely.

If the resistive component of one terminating impedance be negative, it will produce a negative admittance at the other end of the line, which will cancel the positive admittance of the circuit shunting that end, giving (theoretically) zero admittance, i. e. infinite impedance at and near the in-tune frequency. The line admittance will change an increasing amount with increasing departure from this in-tune frequency and cancellation will no longer be complete.

Measurements taken at point A (to earth) would reveal that at the tune frequency of the circuits the negative and positive resistance effects would cancel and the impedance would be very high (theoretically it would be infinite). About the tune frequency for a small frequency band the impedance would remain resistive owing to the quarter wave reactance cancellation, but the net value would drop, owing to the negative resistance component thrown over by the quarter wave line varying. Finally as the divergence from tune increased, the reactance cancellation would not hold further, and the net impedance would not only further decrease in value but also swing in phase angle. A useful but limited compensation effect with an increase of impedance would be obtained, therefore, the limitation being imposed firstly by incomplete resistance cancellation, and secondly by incomplete reactance cancellation.

With an arrangement as shown in Figure 2 the reactance swings (with frequency variation) in the two tuned circuits are identical, but the resistance effects are of opposite sign. The combined result is therefore a cancellation of resistance effects and a summation of the reversed reactance effects thrown over by the quarter wave lines. A parallel tuned circuit of relatively high Q value shunting the junction of the two lines as in Figure 3, gives reactance swings of opposite sign to those thrown over by the quarter wave lines, and, (over a small band of frequencies) produces reactance cancellation, the resistance component of this circuit stabilising the circuit over all.

Actually the susceptance thrown over by the two lines increases uniformly at first with change of frequency from resonance, then more slowly and finally decreases. If the initial susceptance change of the center circuit be made slightly less than the initial susceptance change of the lines, at some frequency off-tune, the susceptance of the center circuit will equal that of the lines and exact cancellation will take place. This arrangement will then give a treble humped response curve, viz., one hump at the tune frequency F_0 and two at the frequencies F_1 and F_2 of susceptance cancellation, spaced logarithmically equidistance from F_0. Outside F_1 and F_2 the curve drops sharply because the susceptance of the middle circuit increases much more rapidly than that of the lines, and compensation is increasingly reduced.

The resistance component remains unchanged (expressed as a parallel resistance) since the only resistance that changes is that of the lines, each of which changes to the same amount and cancel one another out. Between F_1 and F_2 the impedance is substantially constant and is raised very considerably by the action of the negative impedance.

In practice the required conditions can be obtained with simple circuits, as shown in Figure 4.

In Figure 4 actual values are indicated by way of example.

The circuit illustrated in Figure 4 is designed to give at 50 megacycles with a band width substantially flat of ± 2 megacycles, a stage gain of the order of 50 with television pentodes. It will be seen that the anode circuit load of the first valve has a condenser of 26 mmfds. and the grid load of the output valve one of 16 mmfds.—in both cases these can be realised with valve and wiring stray capacities. The arrangement of cathode impedance in the output valve limits the negative impedance applied by the back coupling to $\propto$ 1,000 ohms, or more logically, the negative admittance applied cannot exceed 1/1000 or .001 ohm.

As will be seen from Figure 5, the coupling system between the circuits is equivalent to quarter wave lines. In this figure the quarter wave lines are conventionally indicated as $\lambda/4$ and the reactance correction circuit is indicated as RC.

The shunt inductance of the quarter wave line systems are, of course, lumped in with the tuning coils of the tuned circuits, just as the valve and wiring stray capacities are lumped in with the condensers.

What we claim is:

1. A band pass filter circuit comprising at least two tuned circuits including similar reactive elements and in one of which the effective parallel resistance is positive and in the other of which the effective parallel resistance is negative, the said two tuned circuits being connected together by means of a quarter wave line and the values of the resistances in each case being equal to that of the characteristic impedance of the said line.

2. A filter in accordance with claim 1 wherein the two tuned circuits are connected together by two quarter wave lines in series, there being connected across the filter at the junction of the two lines a parallel tuned circuit of relatively high Q value.

3. A filter circuit comprising a valve having a tuned anode circuit, a parallel tuned circuit having a positive effective parallel resistance connected to said anode circuit over one quarter wave line and a further parallel tuned circuit having a negative effective parallel resistance connected to said anode circuit over a second quarter wave length line.

4. A filter circuit as claimed in claim 3 wherein the said further tuned circuit is connected to the grid of an output valve.

5. A filter circuit as claimed in claim 3 wherein the said further tuned circuit is connected to the grid of an output valve and there is included in the cathode leg of said output valve a resistance of value equal to said positive effective resistance of the first parallel tuned circuit and wherein the anode of said output valve is coupled back to the inductance of said further tuned circuit.

6. A filter circuit as claimed in claim 3 wherein the said further tuned circuit is connected to the grid of an output valve and wherein the capacitances of said parallel tuned circuits are constituted, at least in parts, by the capacities of the valves and wiring.

7. A filter circuit as claimed in claim 3 wherein the said further tuned circuit is connected to the grid of an output valve and wherein the inductances of the quarter wave line are constituted by the inductances of the tuned circuits.

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