

Feb. 13, 1934.

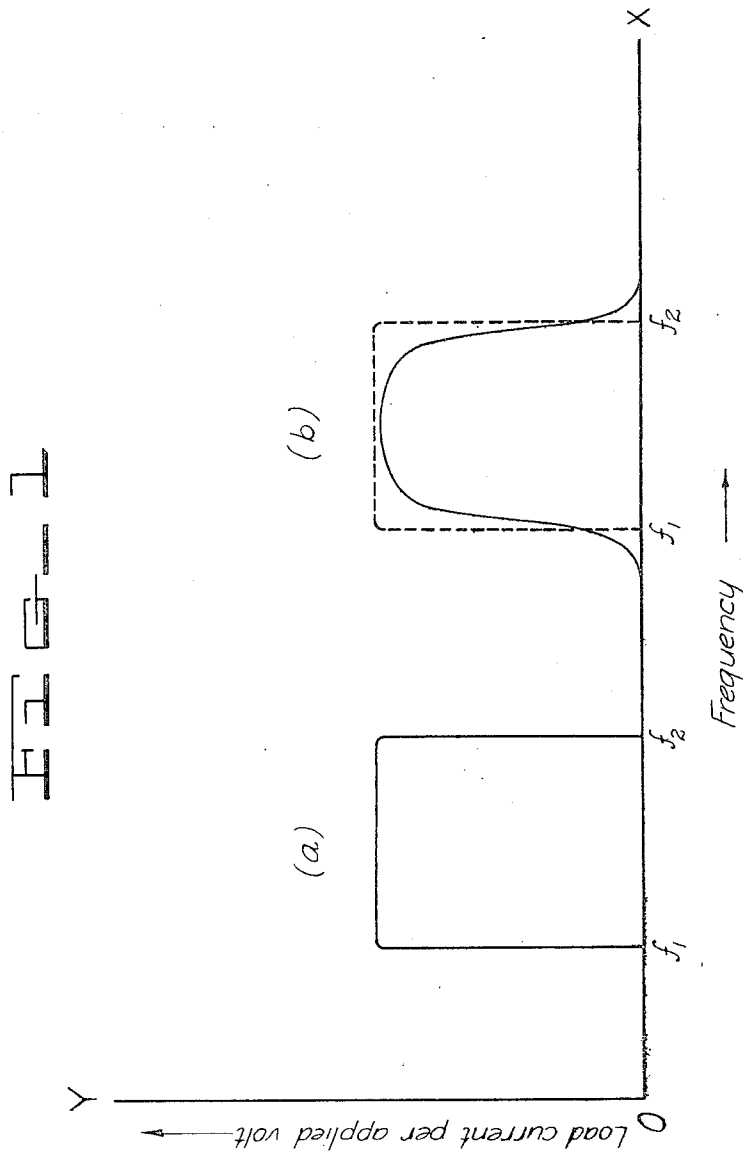
R. D. DUNCAN, JR

1,946,574

FILTER SYSTEM

Filed Nov. 15, 1930

3 Sheets-Sheet 1



INVENTOR

Robert D. Duncan, Jr.

BY

Wm. J. Herdman
ATTORNEY

Feb. 13, 1934.

R. D. DUNCAN, JR

1,946,574

FILTER SYSTEM

Filed Nov. 15, 1930

3 Sheets-Sheet 2

FIG. 2

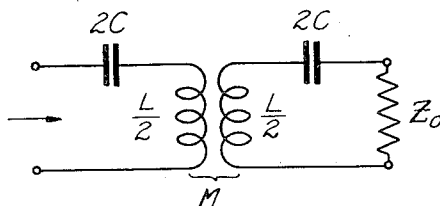


FIG. 3

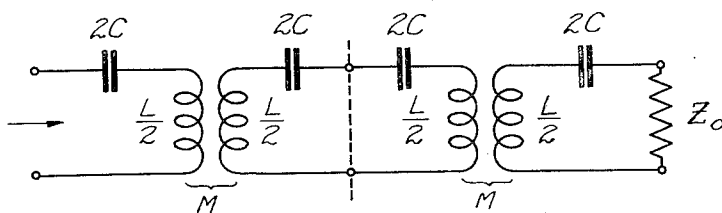


FIG. 4

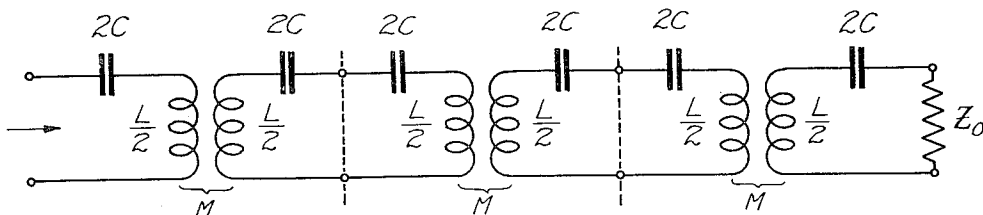
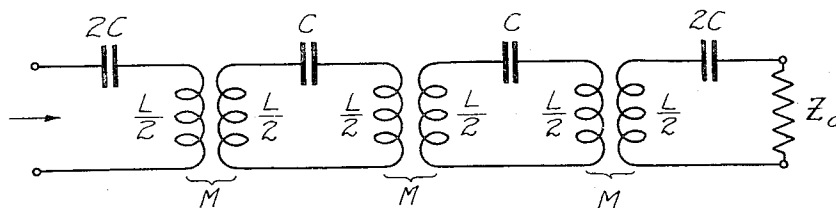


FIG. 5



INVENTOR

Robert D. Duncan, Jr.

BY

Wm. J. Herdman
ATTORNEY

Feb. 13, 1934.

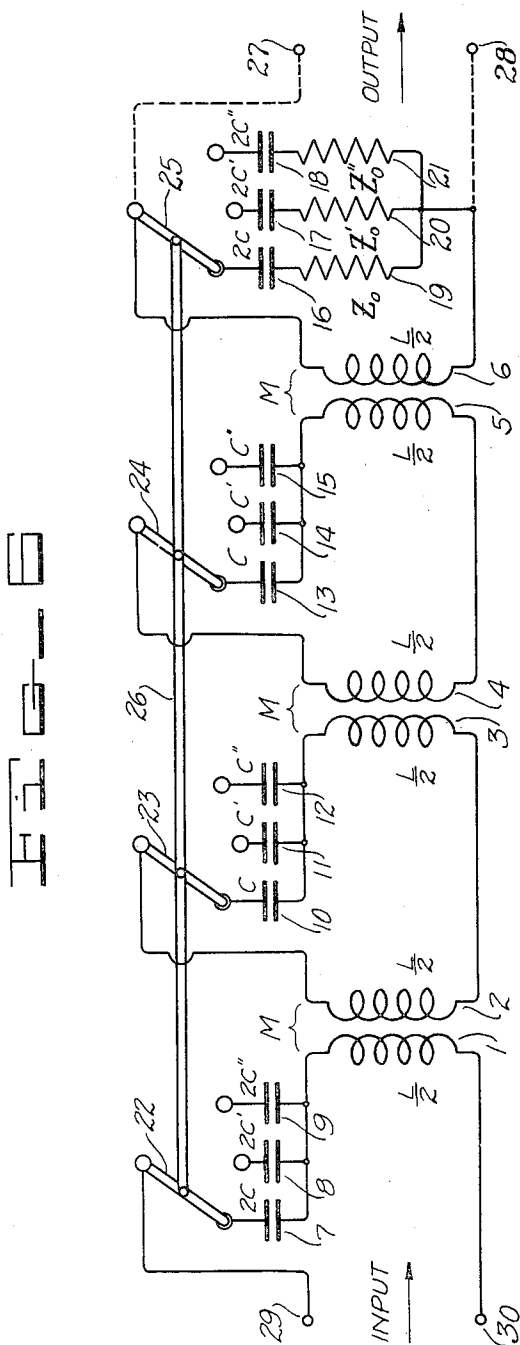
R. D. DUNCAN, JR

1,946,574

FILTER SYSTEM

Filed Nov. 15, 1930

3 Sheets-Sheet 3



INVENTOR

Robert D. Duncan, Jr.

BY

Wm. J. Herdman

ATTORNEY

UNITED STATES PATENT OFFICE

1,946,574

FILTER SYSTEM

Robert D. Duncan, Jr., East Orange, N. J., assignor to Wired Radio, Inc., New York, N. Y., a corporation of Delaware

Application November 15, 1930
Serial No. 495,823

2 Claims. (Cl. 178-44)

My invention pertains in general to electric filters and specifically relates to electric filters of the band pass type.

To produce an electrical organization which is selectively responsive to any one of several predetermined frequency bands, it is necessary to provide either several filter systems, each of which is individually responsive to one of the desired frequency bands, or else one filter system in which the circuit constants can be altered. The use of several filter systems involves multiplication of electrical elements which results in bulky and expensive construction. To incorporate several filter systems in an electrical organization in which space limitation is an important consideration, such as in radio receiving equipment, is obviously a difficult if not impractical design problem. It is also undesirable, from an electrical standpoint, to use several filters since the inductances and capacitances comprising the filter networks must be so disposed that there will be no coupling between the various elements. To produce a single filter system in which the circuit constants can be altered to shift the unattenuated frequency band along the frequency spectrum can, therefore, be considered a more desirable procedure.

One of the objects of my invention consists in providing a network adapted to produce substantially no attenuation of currents or voltages within a selected frequency band and extremely high attenuation at all other frequencies.

Another object comprises producing a filter system in which the circuit constants can be simply and conveniently altered to render the filter selectively responsive to one of several predetermined frequency bands.

A further object consists in providing a band pass filter system in which the value of the capacitance and the value of the terminating impedance are altered by predetermined amounts, while maintaining a constant value for inductance, whereby the frequency band, of predetermined width, to which the filter system is responsive, is shifted along the frequency spectrum.

A further object of my invention comprises producing a filter system in which different predetermined values of circuit constants are selected by switching means.

I accomplish the above desirable objects in a novel filter system having variable values of capacitance and terminating impedance.

In the drawings which accompany and form a part of this specification:

Fig. 1 is a graphical representation of the transmission characteristics of an ideal and an actual band pass filter.

Figs. 2-5 diagrammatically represent the theoretical evolution of one form of filter system.

Fig. 6 diagrammatically represents an electrical organization incorporating a form of filter evolved in Figs. 2-5 and which comprises one embodiment of my invention.

In a theoretical filter system without losses the ratio of current input to current output, over the unattenuated frequency band, and with the proper value of terminating impedance, will be unity, while the ratio outside of the unattenuated frequency band will be infinity. This will be seen by reference to transmission curve "a" of Fig. 1, in which the current output per volt is plotted against frequency f_1 and f_2 being the cut off frequencies. The difference of the cut off frequencies, $f_2 - f_1$, therefore represents the unattenuated or band pass frequency range.

In reality, any filter will have losses due to resistance of the circuit elements. The effect of circuit resistance on the theoretical transmission curve is shown in curve "b" of Fig. 1, in which the ordinates of the curve are not constant over the unattenuated band, but vary somewhat. Outside of the unattenuated band, the ordinates fall rapidly to zero, but the ratio of input to output current is not infinity as with the theoretically perfect structure. Although circuit losses result in a lowering of the amplitudes over the unattenuated frequency band, for purposes of practical design, the departure in form of curve "b" from curve "a" can be disregarded.

As before stated, the condition of Fig. 1 for transmission over the unattenuated frequency band for a finite filter system exists only when the filter system has the proper terminating impedance. Since a finite filter system is a section of an infinite system, the terminating impedance of the former is the input impedance of an infinite system. This is usually referred to as the "iterative impedance". The iterative impedance varies with the frequency and the proper terminating impedance of a finite filter system should equal the iterative impedance for every frequency within the band pass or unattenuated range. In practice this is not usually obtainable and a finite filter is generally terminated with an impedance equal to the iterative impedance at a predetermined frequency within the band pass range. For the filter structures of Figs. 2 and 5 inclusive it may be shown that the "nominal" value of the iterative impedance Z_0 for the tuning frequency of the circuits is

$$Z_0 = \frac{K}{2} \sqrt{\frac{L}{C}}$$

where K is the coefficient of coupling and is equal to

$$\frac{M}{2L}$$

In order to shift the unattenuated frequency band $f_2 - f_1$ along the frequency spectrum, or

along the axis OX, of Fig. 1, it is necessary to alter the values of the inductances or capacitances forming the system. For reasons of simplicity, cheapness in construction, to avoid tapped inductances, et cetera, it has been found that this frequency shift can be effectively accomplished, as hereinafter pointed out, by altering the capacitance values of the filter system without altering the inductance values.

According to the present embodiment of my invention I contemplate varying the value of the capacitance C of the filter system and maintaining the value of the inductance

$$\frac{L}{2}$$

constant.

Since, in the above equation for Z_0 , the value of the terminating impedance Z_0 varies inversely as the one-half power of the value of the capacitance C, it will be evident that inasmuch as the frequency shift is brought about by change of the value of C, the value of the terminating Z_0 must also be proportionately changed. According to the filter system of my invention, I have therefore provided means to simultaneously alter the value of the capacitance and the value of the terminating impedance by predetermined amounts so that the filter system can be made selectively responsive to one of several predetermined frequency bands.

For the purpose of the present description, I have arbitrarily illustrated one embodiment of my invention in which a network having inductively coupled circuits is employed. However, any band pass network having inductance, capacitance, and a terminating impedance can be equally well employed without departing from the intended scope of my invention.

In Fig. 2, I have shown a network comprising a single mesh of a band pass filter having inductively coupled circuits and a terminating impedance of the proper value.

Fig. 3 represents a filter system of the same type, but comprising two meshes. Fig. 4 represents the same type of filter, but comprising three meshes, which, I have found, gives satisfactory results. In actual practice, it is unnecessary to have two capacitances in the middle circuits, since the same values can be obtained by providing a circuit as shown in Fig. 5 which is electrically equivalent to Fig. 4.

In Fig. 6, I have shown a filter system electrically equivalent to the representation of Fig. 5 and Fig. 4, but in which means are provided to vary the values of the circuit constants by predetermined amounts in accordance with the system of my invention.

Inductance 1 is electromagnetically coupled to inductance 2. Inductance 3 is coupled to inductance 4, while inductance 5 is coupled to inductance 6. Capacitance 7, 8, and 9 are connected to the inductance 1 as shown. Capacitances 10, 11, and 12 are similarly connected to inductance 3, while capacitances 13, 14, and 15 are connected to inductance 5. The capacitances 16, 17, and 18 are connected in series with the impedances 19, 20, and 21, respectively, which are commonly connected to one side of the inductance 6 as shown. The relation of the values of the capacitances and the values of the inductances is indicated, in Fig 6, by the values C and

$$\frac{L}{2}$$

It will be evident, then, that the values of the capacitances of the two middle circuits represented by C will be half the value of the capacitances respectively represented by 2C. The derivation of these relative values has been previously pointed out.

The capacitances in each of the four groups of three have a different value, and each of the impedances 19, 20, and 21 has a different value. For example, the capacitances 7, 10, 13, and 16, and the impedance 19, are all of related values to form, in combination with the inductances, a filter system responsive to a definite frequency band. The capacitances 8, 11, 14, and 17, and the impedance 20 form a filter system having different circuit constants and which is responsive to a different frequency band, while the capacitances 9, 12, 15, and 18, and the impedance 21, form a band pass filter having still different circuit constants and which is responsive to another frequency band.

It is evident, then, that by any of the foregoing substitutions of related values of capacitances and terminating impedances, the filter system as an entirety can be made selectively responsive to any one of three predetermined frequency bands of predetermined widths. It is to be understood that the number of groups of capacitances and resistances can be varied to make the filter system responsive to a different number of frequency bands, if desired.

Switches 22, 23, 24, and 25 are disposed within the circuit, as shown, and are mechanically connected by an insulating bar 26 so that a related group of capacitances and a proper terminating resistance can be simultaneously selected in a convenient manner. However, the exact nature of the switching mechanism is not a part of my present invention.

The filter system of my invention is primarily, although not exclusively, intended for operation with devices which are voltage actuated, such as a space discharge detector or amplifier. To operate into such a device, the output terminals 27 and 28 are connected, as shown by dotted lines, across the inductance 6 to obtain the advantage of the additive voltage step-up across the terminating resistance and the capacitance in series therewith. In this arrangement, the output voltage will be greater than the voltage applied at the input terminals 29 and 30.

It will now be obvious that I have produced a novel band pass filter system which can be made selectively responsive to any one of a group of frequency bands of predetermined width by altering the value of the circuit constants by predetermined amounts. The system of altering the value of the capacitance and the value of the terminating impedance in the filter network, while maintaining the inductance value constant, offers many advantages. I have found in experiments that the filter system constructed according to my invention is very efficient from an electrical standpoint, and is extremely simple and compact. Although I have shown a preferred embodiment of my invention, it is, of course, to be understood that many changes and modifications will readily occur to those skilled in the art, but which will not depart from the intended scope of my invention. I do not, therefore, desire to limit myself to the foregoing except insofar as may be pointed out in the appended claims.

What I claim as new and original and desire to secure by Letters Patent of the United States is:

1. A filter system comprising, a circuit composed of a constant value of inductance, a plurality of capacitances of different values and a plurality of terminating impedances of different values, each of said capacitances when associated with said inductance and a selected terminating impedance rendering said circuit responsive to a definite frequency band and means for selectively utilizing said capacitances and terminating impedances in combination with said inductance to shift the position of said frequency band along the frequency spectrum.
2. A filter system comprising, a network having a constant value of inductance and a plurality of predetermined values of capacitances, switching means adapted to select any one of said effective values of capacitance, a plurality of terminating impedances for said network and switching means adapted to act simultaneously with said first mentioned switching means to select any one of said impedances to cooperate with a selected value of capacitance whereby the frequency response of said network may be shifted along the frequency spectrum.

ROBERT D. DUNCAN, JR.

15	90
20	95
25	100
30	105
35	110
40	115
45	120
50	125
55	130
60	135
65	140
70	145
75	150