

Nov. 12, 1935.

W. VAN B. ROBERTS

2,020,377

BAND PASS CIRCUIT

Filed Oct. 17, 1930

4 Sheets-Sheet 1

Fig. 1

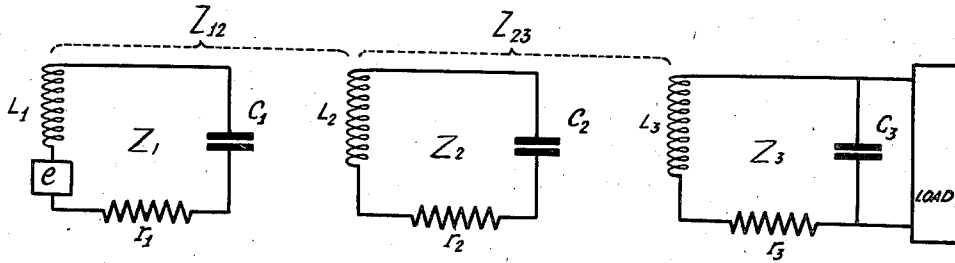
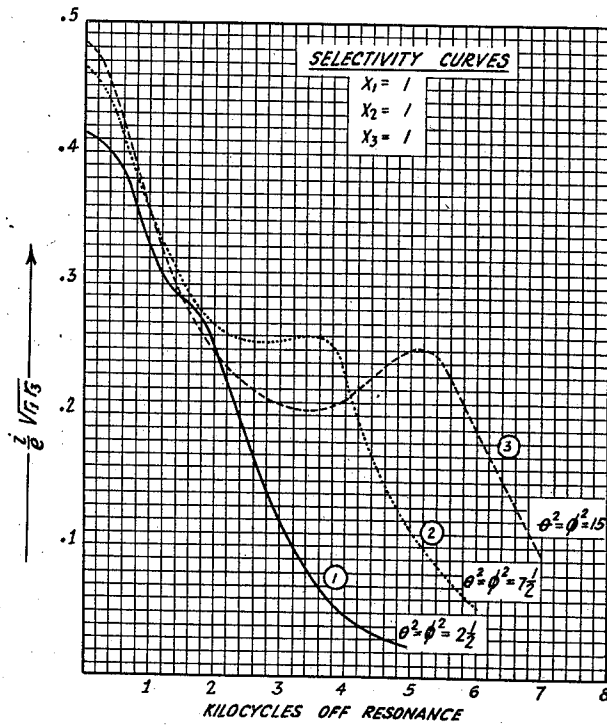


Fig. 2



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Fig. 6

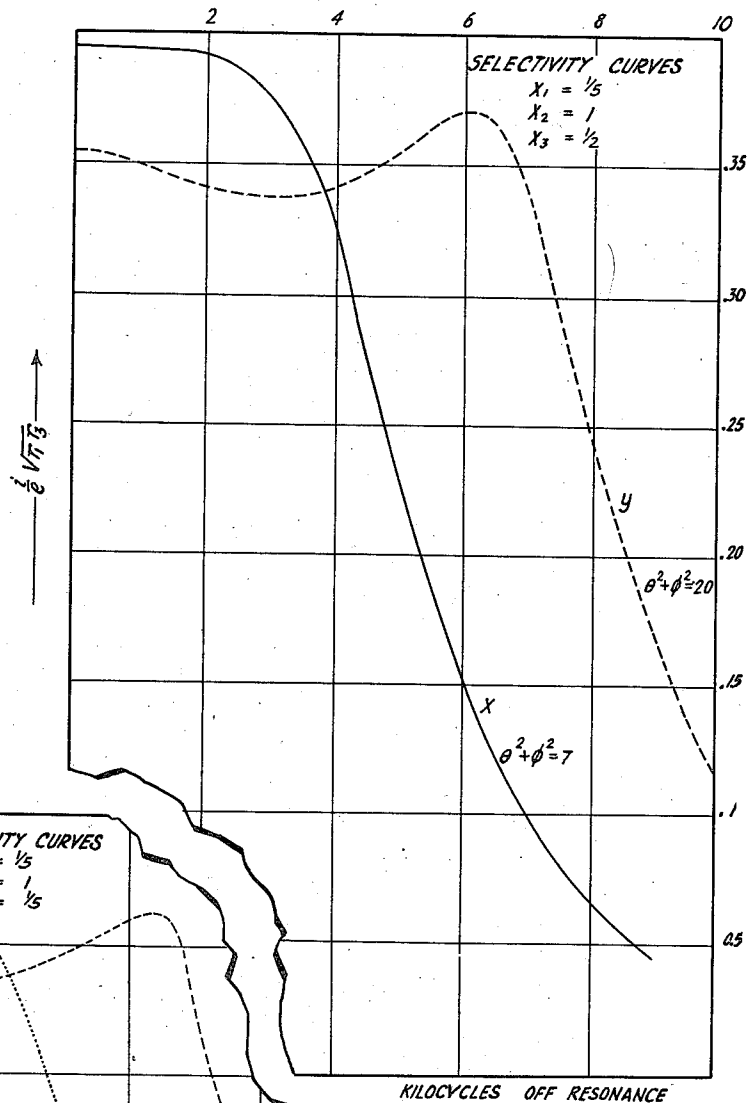
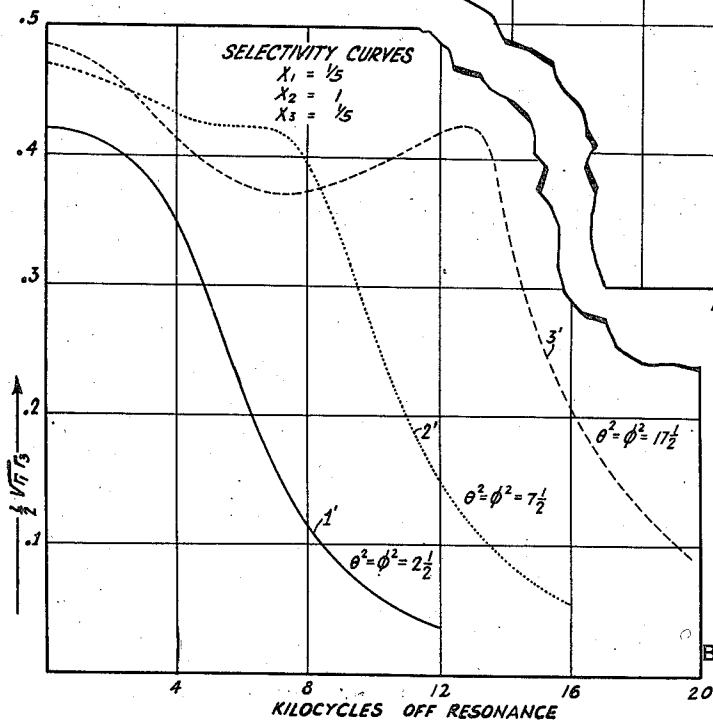


Fig. 3



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Fig. 5

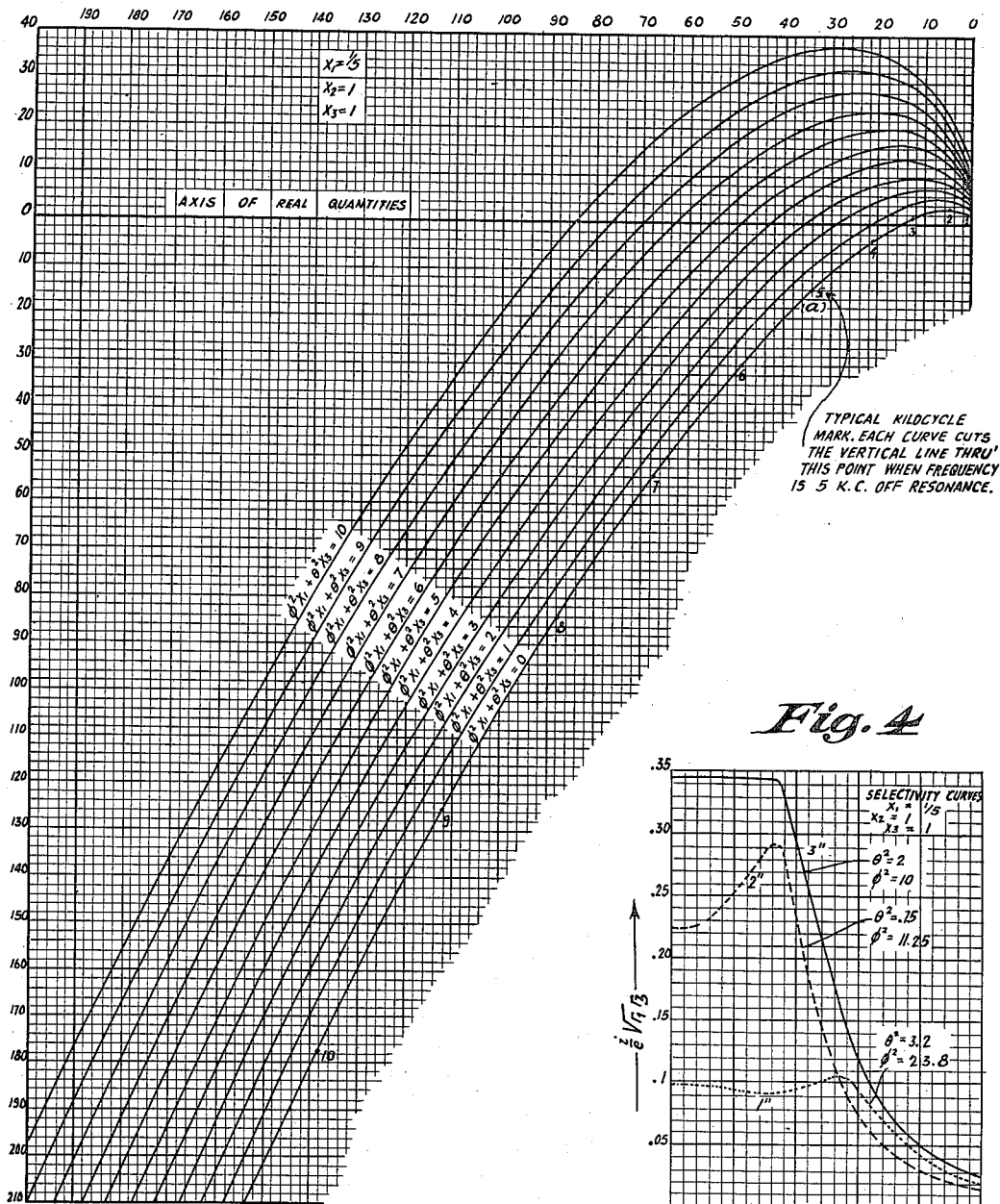
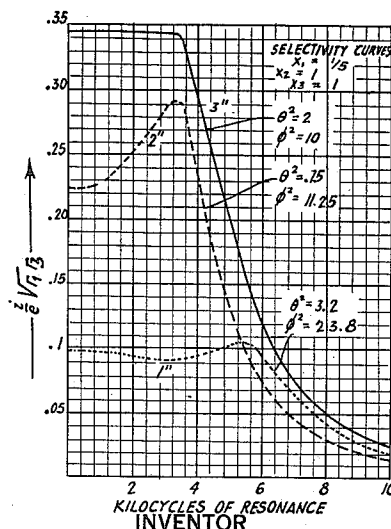


Fig. 4



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Fig. 7

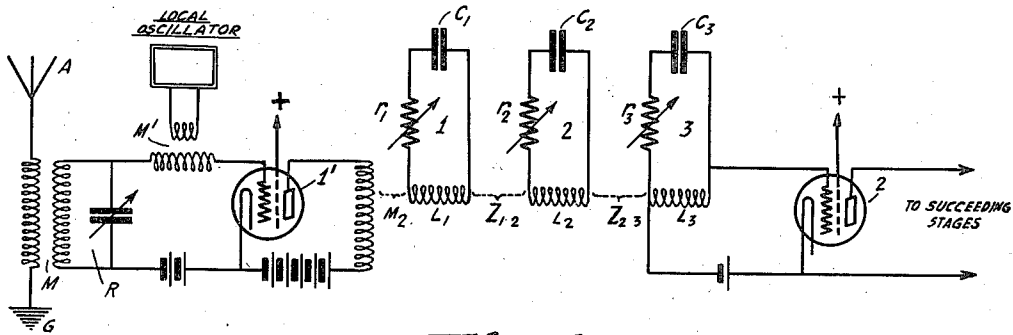
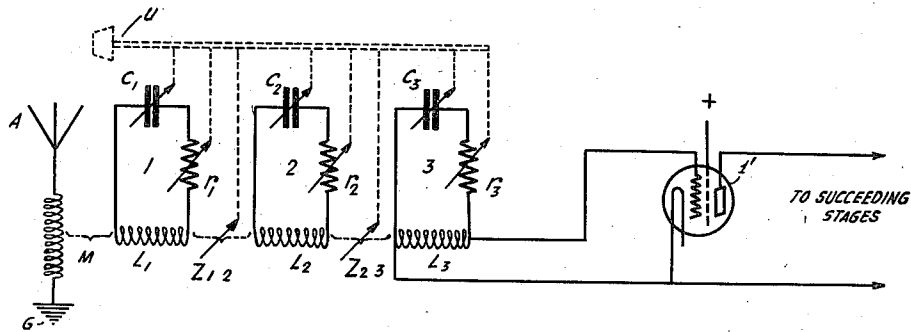


Fig. 8



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UNITED STATES PATENT OFFICE

2,020,377

BAND PASS CIRCUIT

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Application October 17, 1930, Serial No. 489,273

13 Claims. (Cl. 178—44)

My present invention relates to electric wave transmission systems, and more particularly to novel methods of, and means for, transmitting electric waves through band pass networks.

One of the main objects of the present invention is to provide an improved selecting system capable of selecting a band of frequencies.

Another important object of the invention is to provide a wave filter construction capable of approximating, in its operating characteristics, various desired selectivity characteristics.

Another object is to provide a wave filter system adapted for use in a high frequency signalling circuit, whose characteristics over a band of frequencies is more nearly flat than has been possible with previously known types of filters.

Still another object is to provide for use in a radio receiver a filter for selecting a given channel, or band, from the range of broadcast frequencies in such a way that frequencies within the band, but near its limits, are more efficiently transmitted than frequencies in the central portion of the band.

A still further object of the invention is to provide a filter network, for use with a radio receiver, which selects a band of frequencies wherein those frequencies lying near the edges of the bands are the most efficiently transmitted, while those lying near the center of the band are next most efficiently transmitted, and those lying between the middle and the edges are the least efficiently transmitted, whereby the high and low audio frequencies resulting from detection will be accentuated with respect to the intermediate audio frequencies so as to compensate for the tendency of audio amplifying and reproducing systems to operate most efficiently at the intermediate audio frequencies.

And still other objects of the invention are to improve generally the efficiency of band pass transmission networks, and to particularly provide band-pass wave filters, and circuits including such filters, which are not only reliable and flexible in operation, but economically assembled.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings,

Fig. 1 is a graphical analysis of a well known type of electric wave filter,

Fig. 2 shows selectivity curves for the filter of Fig. 1, according to present design,

Fig. 3 shows selectivity curves for the same filter, according to another design of prior art,

Fig. 4 shows selectivity curves for the same filter, according to the invention,

Fig. 5 shows a graphical analysis for securing the curves of Fig. 4,

Fig. 6 shows other selectivity curves, according to the invention,

Fig. 7 diagrammatically shows a superheterodyne receiver circuit embodying the invention,

Fig. 8 shows the invention applied to a broadcast receiver of the non-heterodyne type.

Referring to the accompanying drawings in which like characters of reference indicate the same parts in the different figures, the invention will best be understood after an analysis of the performance of the component circuits of the well known type of filter shown in Fig. 1. Let Z_1 be the circuit impedance of circuit 1, Z_2 that of circuit 2, Z_3 that of circuit 3. Let Z_{12} be the mutual impedance between circuits 1 and 2, and Z_{23} the mutual impedance between circuits 2 and 3. All these are complex quantities. It can be easily shown that the current i in circuit 3 produced by voltage e in circuit 1 is given by

$$i = \frac{e Z_{12} Z_{23}}{Z_1 Z_2 Z_3 - Z_3 Z_{12}^2 - Z_1 Z_{23}^2} \quad (1)$$

Suppose now that the three circuits each including inductance L , capacitance C and resistance r , are tuned to the same frequency F . Consider circuit 1 for the moment. The reactance or imaginary part of Z_1 at frequency $F + f_x$ is

$$2\pi(F + f_x)L_1 - \frac{1}{2\pi(F + f_x)C_1}$$

If, however,

$$\left(\frac{f_x}{F}\right) < 1,$$

this may be expanded into the form

$$2\pi FL_1 + 2\pi fL_1 - \frac{1}{2\pi FC_1} \left(1 - \frac{f_x}{F} + \frac{f_x^2}{F^2} - \frac{f_x^3}{F^3} + \dots\right)$$

and if

$$\frac{f_x^2}{F^2}$$

is negligible in comparison with

$$\frac{f_s}{F}$$

as it is if

$$\frac{f_s}{F} < \frac{1}{100},$$

this becomes simply $4\pi f_x L_1$. Therefore,

$$Z_1 = r_1 + j4\pi f_x L_1,$$

and similar expressions may be derived for Z_2 and Z_3 .

Now, let f_x be the number of kilocycles above resonance, and let $4f_x L_1 = x_1 f_x r_1$, which defines x_1 as the number of ohms reactance of the whole of circuit 1 per ohm resistance of the circuit per kilocycle off resonance. The value of x_1 is, of course,

$$\frac{4L_1 \times 1000}{r_1},$$

x_2 and x_3 being similarly defined. Finally, let $-Z_{12}^2 = \theta^2 r_1 r_2$ and $-Z_{23}^2 = \phi^2 r_2 r_3$, and $z_1 = 1 + jx_1 f$; $z_2 = 1 + jx_2 f$; $z_3 = 1 + jx_3 f$. It follows from the

$$\theta^2 = \frac{-Z_{12}^2}{r_1 r_2} \text{ and } \phi^2 = \frac{-Z_{23}^2}{r_2 r_3}.$$

Substituting these new letters into the equation for the current, we have

$$i = \frac{e}{\sqrt{r_1 r_3}} \times \frac{\theta \phi}{z_1 z_2 z_3 + \phi^2 z_1 + \theta^2 z_3}, \quad (2)$$

which holds very accurately in the vicinity of resonance.

In the above Equation (2) the symbols $z_1 z_2 z_3$ designate the circuit impedances of the three circuits respectively divided by the respective circuit resistances. That is,

$$z_1 = \frac{Z_1}{r_1}$$

etc. Then, z_1 etc., may be defined in words as the circuit impedance per ohm of circuit resistance. The above Equation (2) for the current (i) is derived from the Equation (1) as follows: Substituting in the Equation (1)

$$\sqrt{-\theta^2 r_1 r_2} \text{ for } Z_{12} \text{ and } \sqrt{-\phi^2 r_2 r_3} \text{ for } Z_{23},$$

we get

$$i = \frac{e j \theta \sqrt{r_1 r_2} j \phi \sqrt{r_2 r_3}}{Z_1 Z_2 Z_3 + Z_1 \phi^2 r_2 r_3 + Z_3 \theta^2 r_1 r_2}.$$

Substituting,

$$\begin{aligned} r_1 z_1 &\text{ for } Z_1 \\ r_2 z_2 &\text{ for } Z_2 \\ r_3 z_3 &\text{ for } Z_3 \end{aligned}$$

$$i = \frac{-e \theta \phi r_2 \sqrt{r_1 r_3}}{r_1 r_2 r_3 z_1 z_2 z_3 + r_1 r_2 r_3 z_1 \phi^2 + r_1 r_2 r_3 z_3 \theta^2}.$$

From this is obtained the Equation (2). The negative sign has been dropped from the latter as phase is of no interest.

Consider, now, the function

$$\begin{aligned} z_1 z_2 z_3 + \phi^2 z_1 + \theta^2 z_3. \text{ Its real part} \\ = 1 - (X_1 X_2 + X_1 X_3 + X_2 X_3) f^2 + (\theta^2 + \phi^2). \end{aligned}$$

Its imaginary part=

$$(x_1 + x_2 + x_3) f - x_1 x_2 x_3 f^3 + (\phi^2 x_1 + \theta^2 x_3) f.$$

It can, now, be seen that if $x_1 = x_3$, both the real and imaginary parts are functions of the quantity $(\theta^2 + \phi^2)$. That is, altering the separate values of θ and ϕ has no effect, unless the value of

$(\theta^2 + \phi^2)$ is thereby altered. Hence, only a single family of curves will be produced by putting various values of $(\theta^2 + \phi^2)$ into the plot of the locus of $z_1 z_2 z_3 + \phi^2 z_1 + \theta^2 z_3$, as f starts from zero and increases.

Now, the selectivity curve, that is, the shape of the curve of i plotted against f , depends upon the shape of the locus of $Z_1 Z_2 Z_3 + \phi^2 Z_1 + \theta^2 Z_3$, and if only a single family of such loci can be produced by varying the single available parameter $(\theta^2 + \phi^2)$, it will not be possible to obtain much variety in the selectivity curve by varying this parameter. The main object of this invention is attained by making x_1 and x_3 sufficiently different so that a double infinity of curves can be obtained by varying θ and ϕ individually. By this means, I have been able to obtain a wide variety of desirable selectivity curves.

Figs. 2, 3, 4 and 6 illustrate respectively selectivity curves from the graphical analysis of circuits that are first identical; second, with end circuits identical; third, with two adjacent circuits identical; and fourth, with all circuits different. These differences, it will be understood, refer to the values of the x 's and not to the resonant frequency.

The curves of these figures are secured in the same way. Specifically, the graphical analysis employed in Fig. 5 to secure the selectivity curves of Fig. 4, will be explained. First, the values of x_1 , x_2 , and x_3 , written at the top of Fig. 5 are substituted in the expressions for the real and imaginary parts of $z_1 z_2 z_3 + \phi^2 z_1 + \theta^2 z_3$. With θ and ϕ both assumed to be zero one curve is plotted in the complex plane by plotting the value of $z_1 z_2 z_3$ for various values of f , and drawing a smooth curve through these points. The origin is the intersection of the real axis with the right hand edge of the ruled portion of the paper. The resulting curve is the lowest of the curves on each of the graphical analyses, and curve (a) in Fig. 5.

Next, an arbitrary value of $(\phi^2 x_1 + \theta^2 x_3)$ is assumed, and the ordinates at each point on the first curve are increased by $(\phi^2 x_1 + \theta^2 x_3) f$, and a smooth curve drawn through the resulting points. By assuming various values for $(\phi^2 x_1 + \theta^2 x_3)$, as shown in Fig. 5, a number of curves are obtained and an analysis is completed. In order to save labor the various curves are not displaced in the positive direction along the real axis, as would be the case if the curves were all to be used with the same point as origin. I think it is easier to shift the point used as origin to the left along the real axis by an equal amount, which of course comes to the same thing.

Where $x_1 = x_2 = x_3$ we have a condition usually found in a chain of tuned circuits (where the circuits are similar in power factor) Fig. 2 shows three selectivity curves obtained from a graphical analysis not shown for simplicity. The particular choice of the values of x 's does not lessen the generality of the analysis, as will be shown later.

In using the graphical analysis for Fig. 2 to calculate the selectivity curves, shown therein, it is necessary to use as origin for any given curve a point on the real axis having the same number written beneath it as the value of $(\theta^2 + \phi^2)$ which is marked on the curve. It is equally apparent, if a pair of dividers is used to observe the variation in radius vector of these curves, that an account of the limitation as to choice of origin for each curve, the resulting selectivity curves obtainable are limited to such shapes as illustrated in curves 1, 2 and 3.

The shapes change from that of curve 1 to that of curve 3 as the value assumed for $(\theta^2 + \phi^2)$ increases. Only if $(\theta^2 + \phi^2) > 12$ are there three maxima as shown in curve 3. Furthermore, it is not feasible to obtain a selectivity curve with the middle maximum lower than the other two.

In Fig. 3, there are shown three selectivity curves obtained from a graphical analysis when designing the wave filter in accordance with the principles of Campbell. In this case the addition of proper terminating resistances results in making $x_1 = x_3 = 1/5$. The value of x_2 is taken as unity, and it is believed that in actual practice it would not be possible to obtain an inductance for the middle circuit, more free of resistance than indicated by this value.

Using the constants of a filter designed in close accordance with the formulae given by Zobel at the top of page 42 of the Bell System Technical Journal for January, 1923, the performance of this filter for any values of the shunt inductances can be determined from a graphical analysis (not shown). When this is done, however, due to the limitations imposed upon the choice of origin for each curve, as explained heretofore, the possible selectivity curves are limited to shapes such as shown in curves 1', 2' and 3' in Fig. 3. Thus, it will be appreciated that the teachings of the present filter art do not lead to the best results in the case of three coupled tuned circuits.

Now, Figs. 4 and 5 are based upon the assumption that $x_1 = 1/5$, $x_2 = x_3 = 1$. In this case, the separate values of θ and ϕ independently affect the nature of the selectivity curve so that when using the graphical analysis of Fig. 5, any point on the real axis may be used as origin in connection with any curve. This produces a double infinity of different selectivity curves, and allows attaining such desirable shapes, and such a variety of shapes, as indicated in curves 1'', 2'', 3'' in Fig. 4 and x, y in Fig. 6.

Fig. 5 is used as follows: Having chosen a point on the real axis and one of the family of curves to use in connection with this point as origin, we have available two equations. The position of the origin determines the value of $(\theta^2 + \phi^2)$. The legend on the curve used gives the value of $(\phi^2 x_1 + \theta^2 x_3)$. Since x_1 and x_3 are fixed for all curves on the chart, the separate values of θ and ϕ are easily deduced from these two equations, and are the values that must be incorporated in the construction of the filter to give the selectivity curve that is plotted by the use of the particular origin and curve chosen. With a pair of dividers, it is easy to pick out a combination of origin and curve that will give almost any desired result.

The selectivity curves of Fig. 6 are based upon the values $x_1 = 1/5$, $x_2 = 1$, $x_3 = 1/2$, obtained from a graphical analysis (not shown) but obtained and used in exactly the same fashion as Fig. 5. To be sure of getting all possible selectivity curves, more analyses may be made for various combinations of values of x_1 and x_3 . It is not necessary to use for x_2 any other value than unity in any of the charts because the variety of results depends upon varying the relative values of the x 's, and all possible combinations of relative values may be obtained with one of the quantities fixed at an arbitrary value which for convenience I have chosen as unity.

By inspection of the expressions for the real and imaginary parts of the functions plotted in the various charts, it is easily seen that dividing the values of all x 's by 2 will not change the shape

of the curves at all, but will merely double the value of f , marked at each point on the curves. Thus, if a selectivity curve has been obtained which has the desired shape, but is, for example, only one-third as wide as desired, all that is necessary is to divide the values of all the x 's by 3, and the width of the band will be thereby tripled. Only positive values of f have been considered but this all that is necessary as the selectivity curve is symmetrical.

It will, thus be seen that there has been disclosed a novel method of obtaining a selectivity curve approximating a given arbitrary shape which consists in making the power factors (ratio of resistance to reactance) of the end circuits of a three circuit filter different from each other, whereby a double infinity of possible selectivity curves is produced to choose from, in contrast to a single family of curves resulting from equality of power factors of the end circuits.

It should be noted that the present invention requires that x_1 and x_3 be different. But from the definition of x_1 and x_3 it is obvious that this requires that the ratio

$$\frac{L_1}{r_1}$$

be different from the ratio

$$\frac{L_3}{r_3}$$

It has been shown heretofore that

$$x_1 = \frac{4\pi L_1(1000)}{r_1}$$

and

$$x_3 = \frac{4\pi L_3(1000)}{r_3};$$

it would therefore be obviously impossible for x_1 to differ from x_3 without

$$\frac{L_1}{r_1}$$

differing from

$$\frac{L_3}{r_3},$$

and vice versa. But this again is tantamount to saying that the power factors

$$\frac{r_1}{\omega L_1} \text{ and } \frac{r_3}{\omega L_3}$$

are different. The term power factor is chosen to explain the conditions of the invention because the expression "power factor of a coil" is in common use and well known to those skilled in the art.

In Fig. 7, there is shown a circuit of the well known superheterodyne type embodying the transmission network utilizing the principles of the invention.

This circuit comprises a signal collecting means which is constituted by the usual grounded antenna circuit A, G, and which energy collecting circuit is coupled, as at M, to the input circuit of any desired type of frequency changing arrangement generally denoted by the reference numeral 1'. This frequency changing device may include a resonant input circuit R, connected in the usual and well known manner to the input electrode of an electron discharge device, preferably of the screen grid type, and upon the control electrode of which device is impressed oscillations produced by a local oscillator, through a coupling M1.

As is well known in the art, and consequently does not require needless repetition in this application, the frequency changer device can be preceded by a plurality of tuned radio frequency amplification stages, and, furthermore, the adjusting devices of the various tuned stages may be uni-controlled in any well known manner.

The beat frequency, in the output circuit of the changer 1, is impressed upon circuit 1 of the transmission net-work, described heretofore, through a coupling M₂. The transmission network comprises circuits 1, 2 and 3, circuits 1 and 2 being coupled by the mutual inductance between coils L₁ and L₂, and which coupling is denoted by the symbol Z₁₂ as heretofore employed. In the same manner the circuits 2 and 3 are coupled by the mutual inductance of coils L₂ and L₃, and this coupling is denoted by the symbol Z₂₃. The capacities in each of the circuits 1, 2 and 3 are denoted respectively by the symbols C₁, C₂, C₃. Each of these circuits also includes a resistance r₁, r₂, and r₃, each of these resistances being made adjustable so that the characteristics (the power factors as expressed in detail heretofore) of the circuits may be regulated in accordance with the principles enunciated heretofore.

The input electrodes of a second electron discharge device 2 are connected across the terminals of inductance L₃, and the output electrodes of this device, the device preferably being of the screen grid type, are connected to any succeeding stages of intermediate frequency amplification. It will be readily understood that the three circuits 1, 2 and 3 are all tuned to the same frequency, which frequency is the intermediate, or beat frequency, impressed upon circuit 1 from the output circuit of the device 1 and impressed upon the input electrodes of the first stage of intermediate frequency amplification 2. The stages succeeding the device 2, may include another detector stage, subsequent audio stages and a loud speaker, as is well known to those skilled in the superheterodyne art.

By interposing a transmission network between the frequency changer device and the intermediate frequency amplifier of a superheterodyne, which transmission network is designed so that the power factors of the end circuits 1 and 3 are different from each other, there is secured a considerable number of advantages. In the first place, it will be appreciated, from a consideration of Figs. 4 and 6, as compared with Figs. 2 and 3, that selectivity curves can be produced having a flatness of top impossible to produce by methods known to the prior art to date. Furthermore, the use of such a network in association with the intermediate frequency amplifier facilitates the design of a superheterodyne receiver having not only optimum selectivity, but quality comparable to any type of tuned radio frequency receiver. Again, it allows deficiencies in the audio amplifier and loud speaker to be compensated for by intensifying or reducing the transmission efficiency in almost any way required, as explained in connection with Fig. 6.

In Fig. 8, there is shown a receiver circuit which embodies the present invention in the form of a continuously tunable filter circuit employed between a grounded antenna circuit A, G and the input electrodes of an electron discharge device 1', which device is preferably of the screen grid type. Here, again, the transmission network consists of three circuits 1, 2 and 3, each of the circuits embodying an inductance, resistance and capacitance, denoted by symbols similar to those

employed in Fig. 7. However, in this use of the invention the capacities are adjustable, the resistances also being made adjustable, and the couplings between the inductances of circuits 1 and 2, 2 and 3, also being adjustable. For a reason to be explained in detail below, the adjustable elements of the circuits 1, 2 and 3 are all simultaneously and similarly varied by a uni-control mechanism U.

It will be appreciated that the output circuit of the device 1' may be connected to any succeeding number of untuned radio frequency amplification stages, and subsequent detector and audio frequency amplifier stages, or that the stages succeeding the device 1' may include further tuned radio frequency amplification stages, the variable capacities, or other tuning means thereof, of which are coupled to the uni-control means U for simultaneous and similar control of all the tuning elements. Obviously, when the characteristics of circuits 1, 2 and 3 are designed according to the principles enunciated heretofore, it is possible to transmit the same band of frequencies throughout the broadcast range with a perfectly flat top, as clearly shown by curve 3'', in Fig. 4. In this way, a band pass receiver may be designed which possesses characteristics impossible of attainment by present known methods. Of course, the tunable band pass unit 1, 2 and 3 may be disposed between device 1' and a subsequent electron discharge device, both units in that case being uni-controlled.

The width of band selected depends upon the values of θ and ϕ and, also, upon the circuit resistances if the inductances are fixed. But, for a given coil, the resistance varies with frequency. Hence, if it is desired to keep band width substantially the same whether the filter is tuned to high or low frequency the resistances must be kept constant by adding a variable amount, or θ and ϕ must be arranged to vary with frequency, also. As the resistance increases with increasing frequency, θ and ϕ must vary in such a way as would cause a narrowing of the band with increasing frequency if the resistances did not vary. Such variations in θ and ϕ can be pre-arranged mechanically, or by means of suitably proportioned compound couplings as the mutual impedances, as explained in my co-pending application Serial No. 133,283.

It is to be noted that in all cases where different values of the r 's are required, the differences can be obtained not only by making the resistances different, but also by keeping the resistances the same and changing the inductance of our circuit, or by a combination of both methods. In the case of Fig. 5, for example, to make $x_1 = \frac{1}{2}$, it would be preferable to use as small a value of r_1 as possible, as the current is thereby increased, the diminished value of X_1 being obtained by decreasing L₁. It is pointed out that the couplings Z₁₂ and Z₂₃ in Fig. 8 may be varied simultaneously independently of the control of the capacities C₁, C₂, C₃. In such a case, it should be noted that the coupling control would comprise an effective tone control adjustment, since the coupling control would vary the type of selectivity curve, and hence the relative amounts of high and low frequencies in the final output.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described but

that many modifications in the circuit arrangements, as well as in the apparatus employed, may be made without departing from the scope of my invention as set forth in the appended claims.

5 What I claim is:

1. In combination, a source of intermediate frequency energy, an amplifier, and a network connected between said source and amplifier consisting of three coupled oscillation circuits, all the circuits being tuned to the intermediate frequency, the ratios of resistance to inductance in the end circuits being sufficiently different and the couplings between the circuits being of such relative values that the energy is transmitted in a substantially uniform manner from the source to the amplifier.

2. A high frequency transmission network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the frequency of the energy to be transmitted, a passive mutual impedance element coupling the first and second circuit and a second passive mutual impedance element coupling the second and third circuit, the ratio of resistance to inductance in the first circuit being substantially different from the corresponding ratio in the third circuit, the values of said couplings and the ratios of resistance to inductance in the three circuits being such as to give a desired frequency transmission characteristic substantially different from that possible of attainment with said ratios the same in the first and third circuits.

3. A high frequency transmission network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the frequency of the energy to be transmitted, a passive mutual impedance element coupling the first and second circuit and a second passive mutual impedance element coupling the second and third circuit, the ratio of resistance to inductance in the first circuit being substantially different and less than the corresponding ratio in the third circuit, the values of said couplings and the ratios of resistance to inductance in the three circuits being such as to give a desired frequency transmission characteristic substantially different from that possible of attainment with said ratios the same in the first and third circuits.

4. A high frequency transmission network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the frequency of the energy to be transmitted, a passive mutual impedance element coupling the first and second circuit and a second passive mutual impedance element coupling the second and third circuit, the ratio of resistance to inductance in the first circuit being substantially different and less than the corresponding ratio in the third circuit, the values of said couplings being sufficiently different and the ratios of resistance to inductance in the three circuits being such as to give a desired frequency transmission characteristic having a substantially flat top substantially different from that possible of attainment with said ratios the same in the first and third circuits.

5. A high frequency transmission network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the frequency of the energy to be transmitted, a passive mutual impedance element coupling the first and second circuit and a second passive mutual impedance element coupling the second and third circuit, the ratio of resistance to in-

ductance in the first circuit being substantially different and less than the corresponding ratio in the third circuit, the values of said couplings being such that the said first is greater than the said second and the ratios of resistance to inductance in the three circuits being such as to give a desired frequency transmission characteristic having a triple hump wherein the center hump does not exceed the outer two in height.

6. In combination, in a superheterodyne receiver, a source of intermediate frequency energy, an amplifier, and a network connected between said source and amplifier, said network having a resonance curve characteristic which has a substantially flat top over a band of modulation frequencies equal to the modulation band of a received signal, said network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the operating intermediate frequency, a passive mutual impedance element coupling the first and second circuits and a second passive mutual impedance element coupling the second and third circuits, the ratio of resistance to inductance in the first circuit being substantially different and less than the corresponding ratio in the third circuit, the values of said couplings and the ratio of resistance to inductance in the three circuits being such as to impart said characteristic to said network.

7. In combination, in a superheterodyne receiver, a source of intermediate frequency energy, an amplifier, and a network connected between said source and amplifier, said network having a resonance curve characteristic which has a substantially flat top over a band of modulation frequencies equal to the modulation band of a received signal, said network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the operating intermediate frequency, a passive mutual impedance element coupling the first and second circuits and a second passive mutual impedance element coupling the second and third circuits, the ratio of resistance to inductance in the first circuit being substantially different and less than the corresponding ratio in the third circuit, the values of said couplings and the ratio of resistance to inductance in the three circuits being such as to impart said characteristic to said network, and means for varying the resistance of said network for regulating the said transmission characteristic of the network.

8. A high frequency transmission network consisting of three cascaded resonant circuits, each of said circuits being individually tuned to the frequency of the energy to be transmitted, a passive mutual impedance element coupling the first and second circuits and a second passive mutual impedance element coupling the second and third circuits, said cascaded circuits having respectively x_1 , x_2 and x_3 as values of reactance per ohm resistance per kilocycle off resonance, the value x_1 being substantially different from the value x_3 whereby a different frequency characteristic results from each different combination of individual values of θ and ϕ , θ and ϕ both being greater than unity, θ being defined as the ratio of mutual impedance between the said first and second circuits to the square root of the product of the resistance of the first and second circuits, and ϕ being defined as the ratio of the mutual impedance between the second and third circuits to the square root of the product of the resistance of the second and third circuits.

9. In a transmission network as defined in claim 8, the value x_1 being substantially less than the value x_3 and θ being very much less than ϕ whereby a double hump characteristic is imparted to said network.

10. In a network as defined in claim 8, the value x_3 being less than the value x_1 and ϕ being very much less than θ .

11. In a transmission network as defined in claim 8, wherein the values x_1 and x_2 are substantially equal, the value x_3 differing severalfold from the values x_1 and x_2 , and wherein θ is greater than ϕ , and both θ and ϕ are greater than unity.

12. In a transmission system the combination with two tuned circuits each including adjustable

resistance, and magnetic coupling between said circuits, of means for simultaneously adjusting the coupling between said circuits and the effective magnitudes of the said resistances.

13. In a carrier wave receiver, a plurality of cascaded stages and couplings between adjacent stages, the coupling between one pair of adjacent amplifiers comprising a pair of circuits tuned to the frequency of a desired signal, reactance coupling said circuits to each other, adjustable resistances in each of said circuits, and means for adjusting the effective magnitudes of the said resistances and of said coupling reactance.

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