Aug. 22, 1944. G. L. FREDENDALL 2,356,308

WIDE BAND AMPLIFIER

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FIG. 1.

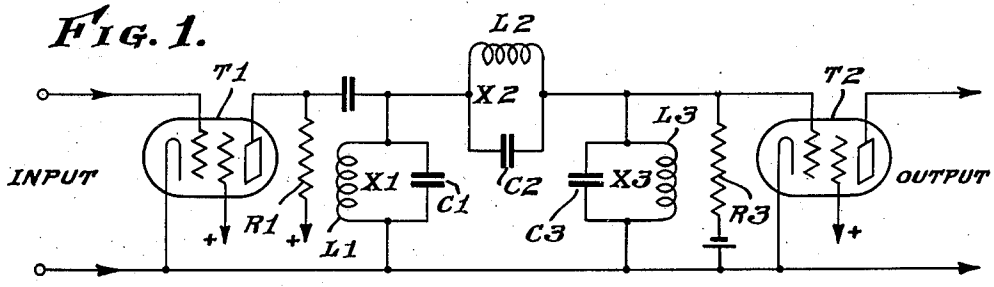


FIG. 2.

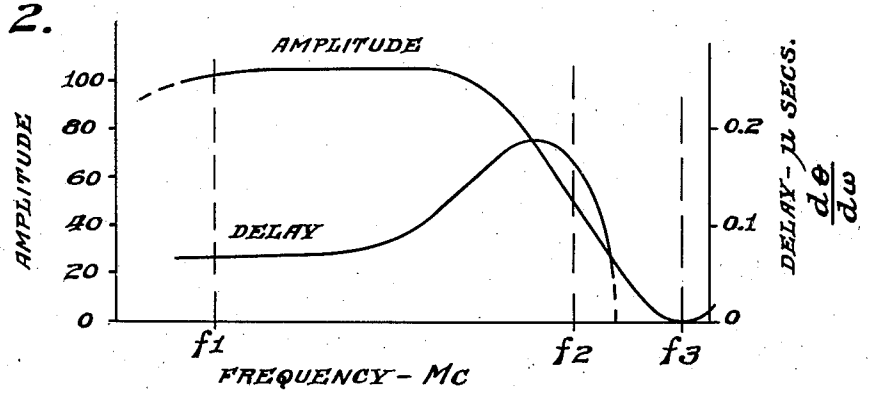
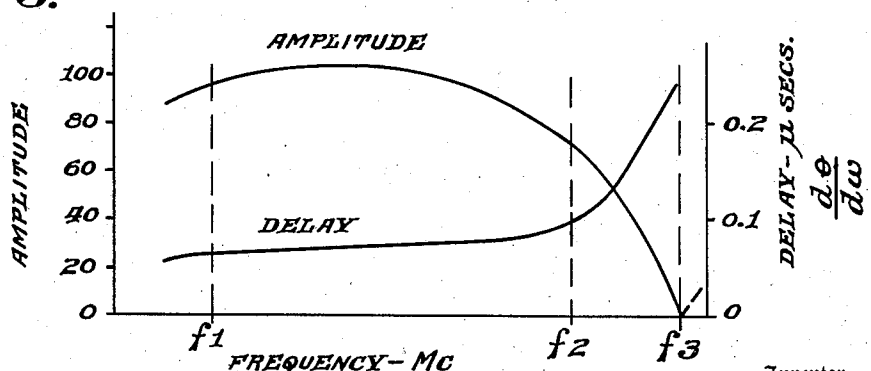


FIG. 3.



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FIG. 4.

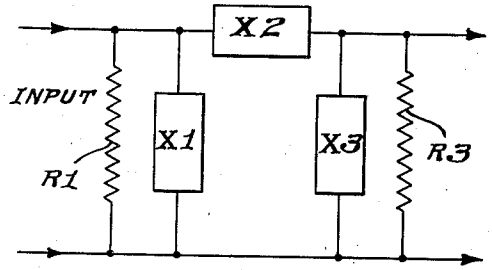


FIG. 5.

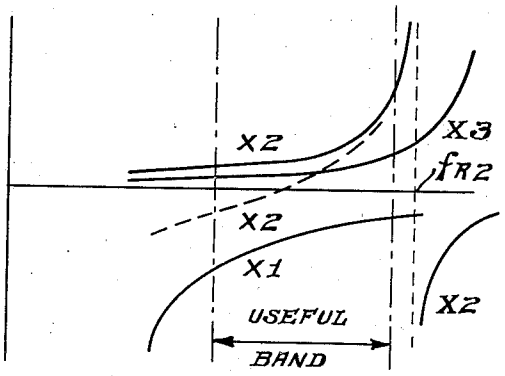


FIG. 6.

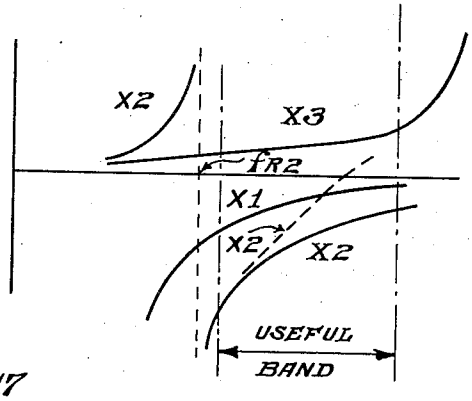
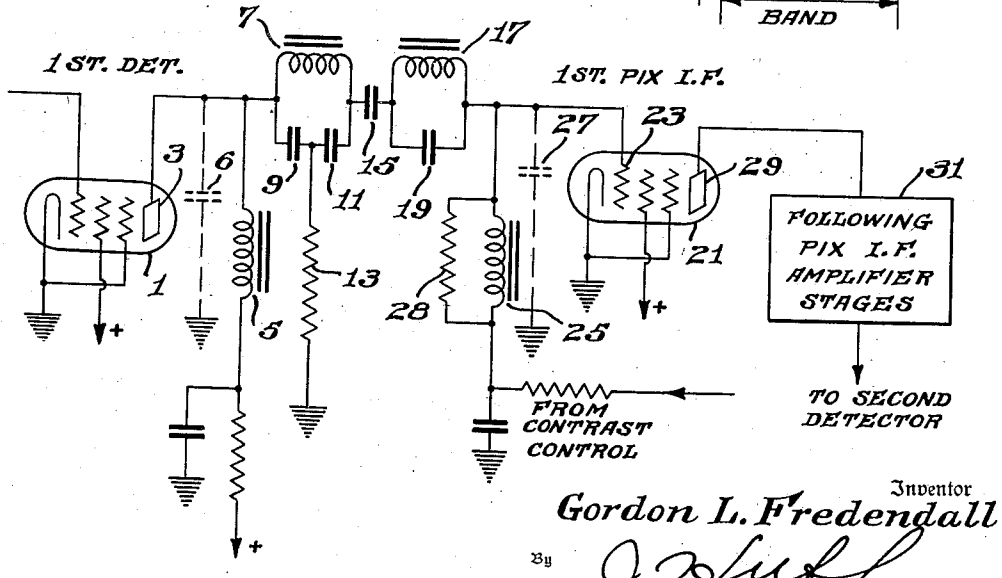


FIG. 7.



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Patented Aug. 22, 1944 2,356,308

UNITED STATES PATENT OFFICE

2,356,308

WIDE BAND AMPLIFIER

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Application January 31, 1941, Serial No. 376,877

5 Claims. (Cl. 178—44)

This invention relates to amplifying systems and, more particularly, to an improved amplifier coupling network having substantially uniform phase delay over a useful pass band.

In systems wherein it is necessary to transmit an extremely wide band of frequencies, it is of primary importance that the amplifiers used therein transmit their signals substantially free from phase distortion. It is well recognized that, in wide band amplifiers such as those required for use in television, in contradistinction to audio frequency amplifying systems, the phase relation between the input and output of the various frequency components present in the video signals must be regularly maintained because any relative phase displacements between these components results in a loss of definition in the reproduced picture. In this connection, it is exceedingly important that the midfrequency components have their initial phase relation with respect to higher frequency components free from any variation or deviation.

Any phase displacement between these two sets of components destroys the sharpness of detail inasmuch as the frequency components do not coincide in proper spacial relation with the background so that, instead of a sharp and clear image, a fuzzy image is reproduced.

It is common knowledge that the video signal is conveyed through the video frequency and intermediate frequency amplifier of a television system as the envelopes of the radio frequency and intermediate frequency signals. Phase distortion of the envelope results when the overall phase characteristics of the radio frequency and intermediate frequency amplifiers is not a uniformly straight line.

It has heretofore been proposed to provide a wide pass band amplifier by the provision of a plurality of parallel resonant peaking circuits, each of which are tuned to a different frequency wherein the combination will provide a reasonably flat frequency response over a relatively wide range of frequencies. Such an amplifier is shown and described in the Vreeland Patent 1,730,987, of October 8, 1929.

In the reception of television signals with an associated and adjacent band of sound signals, it is not only necessary to provide a reasonably wide pass band for the reception of the video signals, but it is also necessary to include in the intermediate amplifier circuit a rejector circuit which prevents the passage of sound signals through the video system.

Furthermore, it is particularly desirable to reduce the width of the band occupied by the transmission of video signals and this may be satisfactorily accomplished by the partial elimination of one of the side bands of the transmitter carrier frequency.

In shaping the pass band response of the intermediate frequency amplifier, it is necessary to consider both the width of the pass band and the rejection of adjacent signals. In the copending application of G. L. Grundmann, Serial No. 258,990, filed February 28, 1939, now Patent No. 2,261,803, granted November 4, 1941, it has been proposed to include rejector circuits for eliminating both the associated sound wave channel and the sound channel of the television transmitter occupying the adjacent band. Shaping of the resultant pass band with peaking circuits resonant within the pass band has also been proposed, such as to provide a reasonably flat response to the total pass band of useful frequencies. The peaking circuits may be of the shunt parallel tuned circuit type.

In each of the circuits, hitherto proposed, in which it has been desired to provide a band pass filter in combination with parallel resonant rejector circuits and parallel resonant peaking circuits, the resonant frequency of all the peaking circuits is within the desired pass band. Such is obviously the most satisfactory solution when it is desired to obtain a substantially uniform amplitude response throughout the pass band.

As is well known, dissymmetry of the transmission band characteristic of a radio receiver about the normal or mean frequency value produces a relative phase shift of the modulation side bands. In order to overcome the distortion which is likely to follow changes in phase shift relative to frequency, it has been proposed to introduce a complementary dissymmetry in phase distortion in the video amplifier. Such a method and means is shown and described in Foster Patent No. 2,093,556.

According to the present invention, substantially uniform time delay throughout the entire pass band is obtained by providing a signal transmission system which includes a rejector circuit having a resonant frequency adjacent the desired pass band and a plurality of peaking circuits at least one of which has a resonant frequency adjacent the frequency to which the rejector circuit is responsive and more remote from the pass band than the resonant frequency of the rejector circuit.

The primary object of this invention is to improve the phase characteristics in band pass amplifiers.

Another object of this invention is to obtain nominally infinite attenuation in a signal transmission system, together with improved phase characteristics.

Other and incidental objects of the invention will be apparent to those skilled in the art from a reading of the following specification considered in connection with the accompanying drawings, in which

Figure 1 is a schematic circuit diagram showing one form of this invention;

Figures 2 and 3 are explanatory curves relating to the operation of this invention;

Figure 4 is a schematic diagram of another form of the invention;

Figures 5 and 6 are explanatory curves relating to the operation of the system of Figure 4; and

Figure 7 illustrates the use of one form of this invention in combination with a television receiver.

Figure 1 shows certain stages of a television receiver designed for vestigial side band transmisison. Thus, an input signal of intermediate frequency is applied to a vacuum tube T1 whose output is coupled to a network including a parallel connected parallel tuned circuit or peaking circuit including inductance L1 and capacity C1. There is serially connected a second tuned circuit or rejector circuit including a parallel connected inductance L2 and capacity C2. A second parallel tuned circuit or peaking circuit connected in parallel with the output of the tube T1 includes inductances L3 and C3. The network circuit is terminated in resistance R3 and its output is applied to the input of tube T2 whose output is applied to the succeeding intermediate frequency amplifier stage.

By selecting suitable values for the elements of such a coupling circuit, it is possible to obtain a substantially uniform amplitude response over the entire band of signals to be passed by the intermediate frequency amplifier, as indicated by the amplitude curve of Fig. 2. Such practical conventional circuits used as the interstage coupling means usually exhibit undesirably long and unequal time delays in the region f_2 to f_3. This unequal time delay period is illustrated by the delay curve of Fig. 2.

By time delay is meant the rate of change of the phase angle with angular frequency.

$$\text{Delay}=\frac{d\theta}{d\omega}$$

where θ is the phase shift angle and ω is $2\pi f$.

The curves in Fig. 2 illustrate the type of amplitude and time delay characteristic obtained for the circuit of Fig. 1 for the values of circuit elements shown in Table I below:

TABLE I

Cut-off at f_1 and f_2

$$C3=C1=\frac{1}{(\omega_2-\omega_1)R}\sqrt{1-\frac{f_2^2-f_1^2}{f_3^2-f_1^2}}$$

$$C2=\frac{f_2^2-f_1^2}{f_3^2-f_2^2}\left(\frac{C1}{2}\right)$$

$$L3=L1=\frac{1}{\omega_1^2 C1}$$

$$L2=\frac{1}{\omega_3^2 C2}$$

$$R3=R1=\frac{1}{(\omega_2-\omega_1)C1}\sqrt{1-\frac{f_2^2-f_1^2}{f_3^2-f_1^2}}$$

f_1=9.25 mc.
f_2=12.75 mc.
f_3=14.25 mc. (freq. of ∞ attenuation)

Such unequal delay as shown by the delay curve in Fig. 2 causes blurring of abrupt transitions between contrasting shades in a television picture.

By so choosing the circuit constants, such, for example, as given in Table II, it may be seen that a distinctly different relation between the resonant frequencies of the parallel combinations of inductance and capacity exists, namely,

$$f_{R1}<f_{R2}<f_{R3}$$

instead of the relation $f_{R1}=f_{R3}<f_{R2}$ which exists in Table I.

TABLE II

$$f_{R1}=\frac{1}{2\pi\sqrt{L1C1}}$$

$$f_{R2}=\frac{1}{2\pi\sqrt{L_2C_2}}$$

$$f_{R3}=\frac{1}{2\pi\sqrt{L3C3}}$$

R1=R2=1500 ohms
L1=35 μh.
L2=2.1 μh.
L3=6.45 μh.
C1=19 μμfd.
C2=60 μμfd.
C3=16 μμfd.

Figure 3 shows amplitude and time delay characteristics of the circuit shown in Figure 1 using circuit constants given with such a relation as shown in Table II. A comparison of Figures 2 and 3 indicates appreciable improvement in time delay charactersitics. Such improvement results when the signs of X2 and X3 are the same for frequency lying below the resonant frequency of Z2 or, in other words, when f_{R2} lies between f_{R1} and f_{R3}. The values of X1, X2 and X3 were chosen for a specific application, but it is not intended to limit this invention to such values. The parallel circuits X1 and X3 may be interchanged without affecting the results.

The amplitude characteristic for such values as shown in Table II and illustrated in Fig. 3 is not flat under any substantial portion of the useful frequency band. It may be said that an improved time delay characteristic was obtained at the expense of flat amplitude response. In the design of a cascade amplifier or of television intermediate frequency circuits, such an amplitude characteristic as shown in Figure 3 may be compensated by other interstage coupling filters.

The principle in accordance with this invention is capable of application to the generalized type of network shown in Figure 4, where R1 is the input resistance, X1 is the input impedance, X2 is the series impedance, and R3 is the output resistance with the reactance X3 connected in parallel thereto.

If it be assumed that X2 provides infinite attenuation at f_{R2} and has the reactive component shown in Figure 5, then, either X1 or X3, but not both, will have the same sign as X2 throughout the region of the useful pass band near f_{R2}. X2 may take the course shown by the full line or the dotted line in Figure 5. If X2 follows the dotted line, then X2, among other possibilities, may consist of two parallel tuned circuits in series. One parallel circuit will resonate at f_{R2}; the other parallel circuit will resonate below the useful band. The reactance X3 is shown as positive and the X1 as negative. The signs of these reactances may be interchanged. The filters shown in Figure 4 may have terminating resistance at both ends or at only one end.

Figure 6 shows the behavior of the reactances in Figure 4 when the frequency of infinite atten-

uation is near the lower end of the useful pass band. In this case, the signs of the reactances X3 and X1 may be interchanged.

In Figure 7, there is shown a practical application of this form of coupling circuit to first stage of intermediate frequency amplification in a television receiver of the superheterodyne type.

Tube 1 is a first detector whose anode 3 is supplied with a positive potential through an inductance 5. The inductance of 5 and the distributed capacity of 6 of tube 1 form a tuned peaking circuit. The anode 3 is also connected to a series rejector circuit composed of inductance 7 and capacities 9 and 11 serially connected. Between condensers 9 and 11 a resistance 13 is connected to ground. A coupling condenser 15 connects first rejector circuit with a second rejector circuit including inductance 17 and capacity 19. R13 is a balancing resistance for the purpose of increasing the rejection at the point of high signal attenuation over a value which would obtain if losses in the rejector circuit including inductance 7 and capacitors 9 and 11 were not balanced. The tube 21 is the first stage of the picture intermediate frequency amplifier and its control electrode 23 is connected to the second rejector circuit including the inductance 17 and condenser 19. The control electrode 23 also has connected in parallel therewith an inductance 25 which, taken in connection with the input capacity of the tube 21 represented by the capacity 27, forms a parallel tuned circuit or peaking circuit. Resistance 28 is connected in shunt with the output such as resistor R3 in Figure 4. A control electrode 23 of the first intermediate amplifier stage is connected to the contrast control such that the contrast of images may be manually controlled. The output signal from the tube 21 is passed from the anode 29 to the following picture intermediate frequency amplifier stages 31.

In the operation of the circuit shown in Figure 7, the peaking circuit including inductance 5 and capacity 6 is given value such as, for example, shown in Table II as L1 and C1 so that its resonant frequency is the one near f_1 in Fig. 3. The values of the elements of the series rejector circuit including inductance 7 and the condensers 9 and 11 are chosen such that the resonant frequency of the rejector circuit is below f_1 in order to reject the associated sound which is transmitted in a sound channel adjacent to the video channel shown in Figure 3.

The values of the elements of the rejector circuit including inductances 17 and 19 are chosen such as, for example, given by Table II for L2 and C2 such that its resonant frequency occurs at f_3 which is the sound channel of the adjacent television broadcast band.

The values of the elements of the peaking circuit including inductance 25 and capacity 27 are selected in accordance with the values of L3 and C3 of Table II such that its resonant frequency is in the vicinity of f_2 shown in Figure 3. It will be seen that the resonant frequency of the peaking circuit including inductances 25 and 27 is outside the video band. This produces substantially uniform time delay over the useful video band as shown in Figure 3.

While several systems for carrying this invention into effect have been indicated and described, it will be apparent to one skilled in the art that this invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of this invention as set forth in the appended claims.

I claim as my invention:

1. In a signal transmission system, a band pass filter having an improved phase delay characteristic comprising a plurality of filter circuits in combination, each circuit comprising inductance and capacity connected in parallel, one of said circuits being a serially connected rejector circuit with a resonant frequency chosen adjacent to said pass band, another of said filter circuits serving as a parallel connected peaking circuit whose resonant frequency is lower than the resonant frequency of said rejector circuit, and still another of said filter circuits serving as a second parallel connected peaking circuit whose resonant frequency is higher than the resonant frequency of said rejector circuit.

2. The system as defined in claim 1 wherein the input and output terminals of said band pass filter are each connected to a space discharge device, and wherein the capacity element of each of said peaking circuits is provided by the inherent capacity of said discharge devices.

3. In a signal transmission system, a band pass filter having an improved phase delay characteristic comprising a plurality of filter circuits in combination located progressively in said systems, each circuit comprising inductance and capacity connected in parallel, one of said circuits being a serially connected rejector circuit with a resonant frequency chosen adjacent to said pass band, another of said filter circuits connected ahead of said rejector circuit and serving as a parallel connected peaking circuit whose resonant frequency is lower than the resonant frequency of said rejector circuit, and still another of said filter circuits following said rejector circuit and serving as a second parallel connected peaking circuit whose resonant frequency is higher than the resonant frequency of said rejection circuit.

4. In a signal transmission system, a band pass filter including the combination of a serially connected parallel resonant rejector circuit whose resonant frequency is above the upper frequency limit of said pass band, a second serially connected parallel resonant rejector circuit adjacent said first rejector circuit in said filter whose resonant frequency is below the lower frequency limit of said pass band, a parallel connected parallel resonant peaking circuit preceding said rejector circuits whose resonant frequency is within and near the lower frequency limit of said pass band, and a second parallel connected parallel resonant peaking circuit following said rejector circuits whose resonant frequency is above the resonant frequency of said first-mentioned rejector circuit.

5. In a band pass amplifier including a plurality of discharge devices, a parallel resonant rejector circuit connected in series with said discharge devices and whose resonant frequency is above the upper frequency limit of said pass band, a peaking circuit comprising an inductance and the inherent capacity of one of said discharge devices whose resonant frequency is within said pass band, and a second peaking circuit another of said discharge devices comprising an inductance and the inherent capacity of one of said discharge devices whose resonant frequency is above the resonant frequency of said rejector circuit.

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