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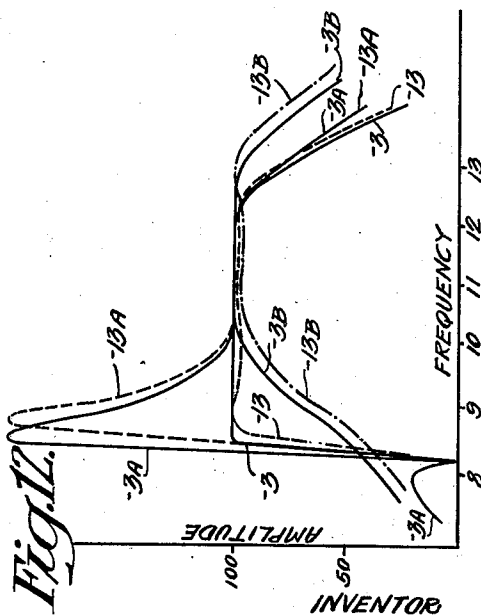
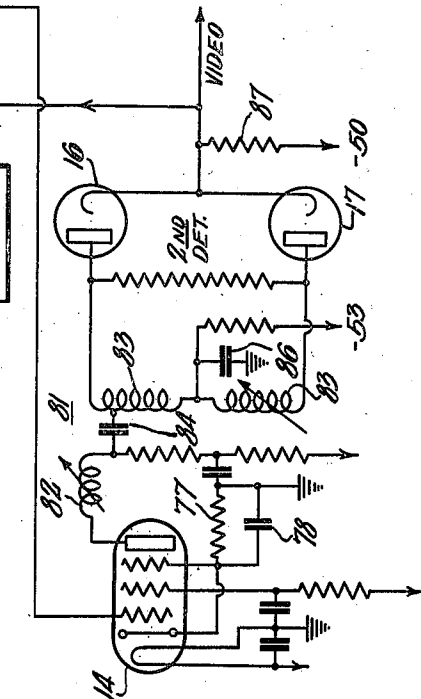
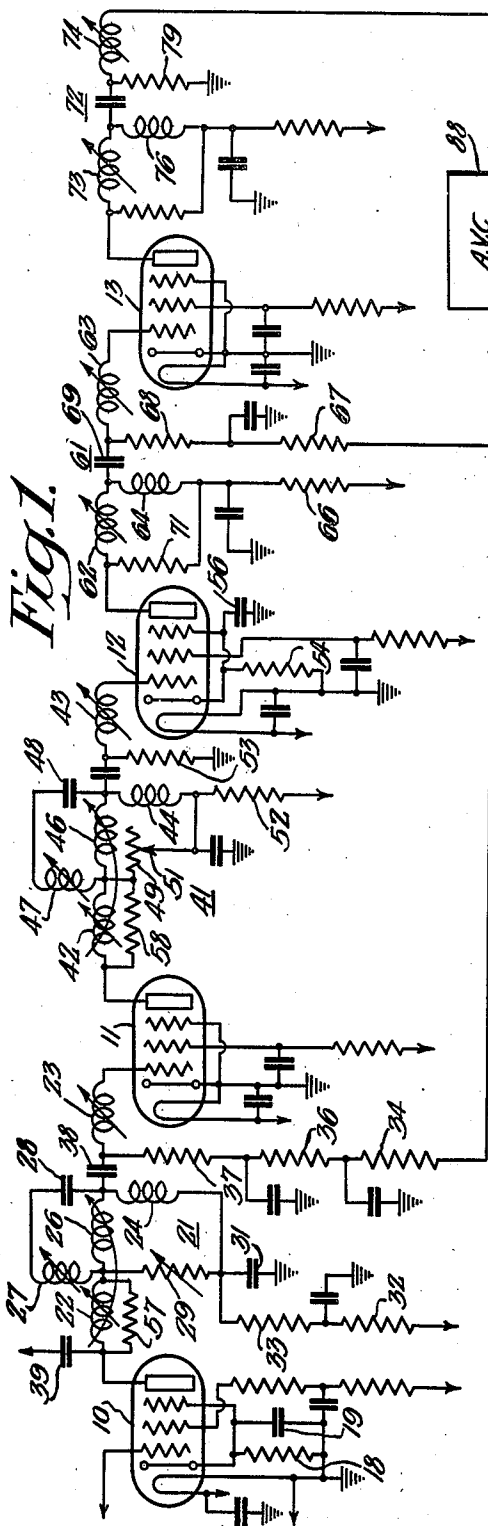
G. L. GRUNDMANN

2,261,803

WIDE BAND AMPLIFIER

Filed Feb. 28, 1939

2 Sheets-Sheet 1



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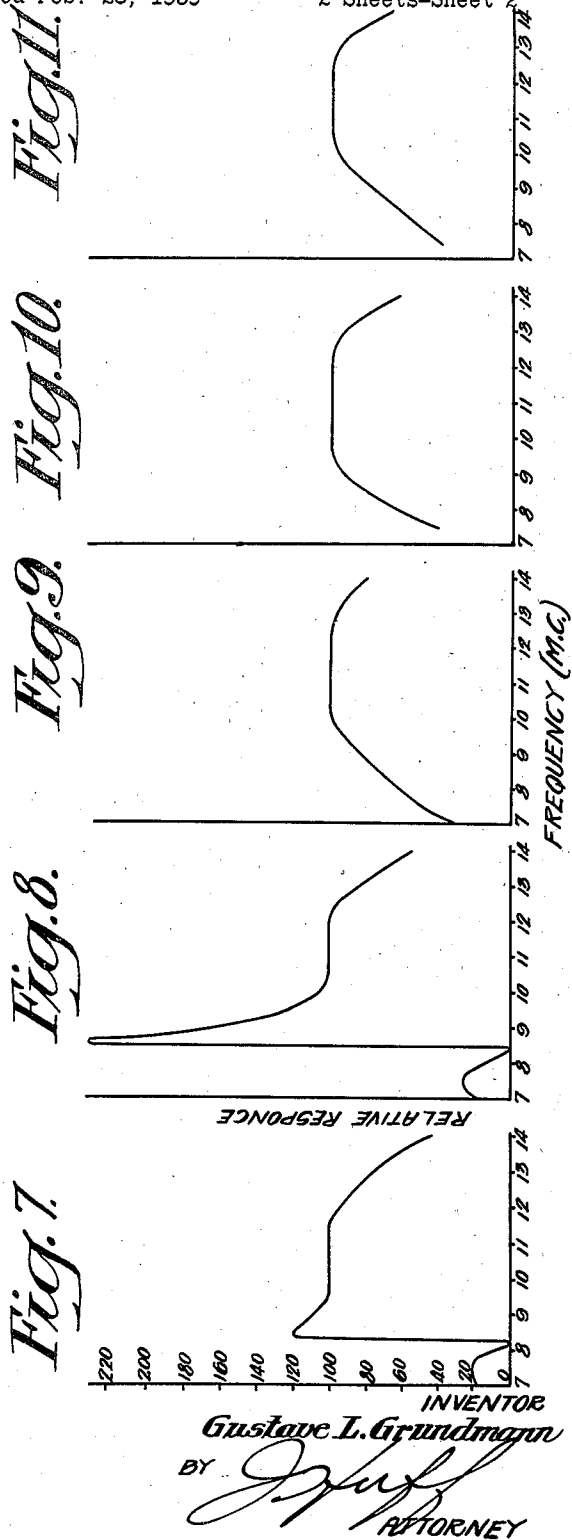
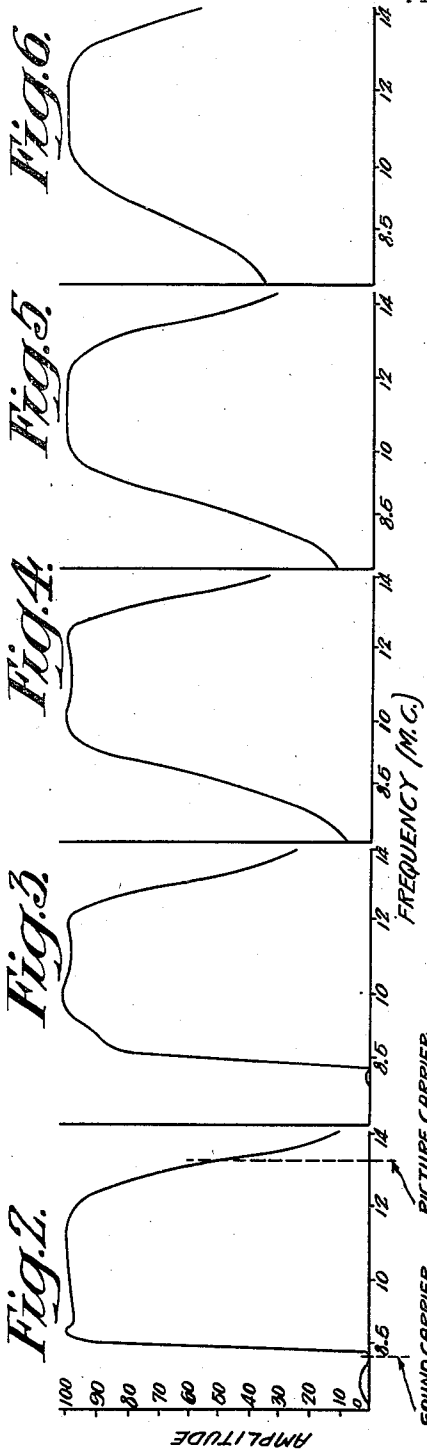
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,261,803

WIDE BAND AMPLIFIER

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Application February 28, 1939, Serial No. 258,990

8 Claims. (Cl. 179—171)

My invention relates to wide band amplifiers and particularly to intermediate frequency amplifiers for television receivers or the like.

One of the more difficult problems in designing a high frequency, wide band amplifier is to obtain an amplifier of sufficient gain per stage which also has a pass band of sufficient width. For example, by employing coupled tuned circuits and sufficient damping, the pass band can be made very wide but the gain is low.

An object of my invention is to provide an improved amplifier having a wide pass band and also having a comparatively high gain without employing an excessive number of stages.

A further object of my invention is to provide an improved amplifier in which the pass band is not shifted an undesirable amount by the application of a varying automatic volume control voltage.

In practicing my invention I utilize a plurality of amplifier stages having unlike selectivity or pass band characteristics, one or more stages having less than the required response near one end of the amplifier pass band and another stage including a tuned rejector circuit which is so adjusted with respect to its associated network that this stage has a highly peaked selectivity curve near the said one end of the amplifier pass band whereby a substantially flat overall frequency response over a wide frequency band is obtained. At the same time this widening of the pass band is not obtained at the expense of amplifier gain.

Shifting of the amplifier pass band as a result of changes in A. V. C. bias is avoided by applying this bias to one or more stages which include a rejection circuit and to one or more stages which contain no rejection circuit but which have primary and secondary circuits unequally loaded. A certain change in A. V. C. bias will shift the peak of the response curve for a stage of the first type toward one end of the pass band and will simultaneously cause the response curve for a stage of the second type to "tilt" in the proper direction to maintain the overall response flat. Any shift of the pass band toward the high frequency end or low frequency end of the frequency spectrum is negligible.

The invention will be better understood from the following description taken in connection with the accompanying drawings in which

Figure 1 is a circuit diagram of a portion of a television receiver embodying my invention;

Figures 2 to 6 are curves showing the selectivity characteristic for different portions of the amplifier shown in Fig. 1;

Figures 7 to 11 are curves showing the selectivity characteristics for individual amplifier stages of the circuit shown in Fig. 1; and

Figure 12 is a group of curves showing the effect of an automatic volume control bias on the amplifier of Fig. 1.

Referring to Fig. 1, the first detector of a television receiver of the superheterodyne type is indicated at 10. The intermediate frequency signal appearing in the output of the first detector 10 is amplified by intermediate frequency amplifier tubes 11, 12, 13 and 14 and the amplified output is supplied to a suitable second detector, such as a push-pull detector, comprising diodes 16 and 17. The first detector tube and the intermediate frequency amplifier tubes may be pentodes of the usual type having indirectly heated cathodes.

The first detector may be provided with a certain amount of self-bias by means of a cathode resistor 18 and a shunting condenser 19.

The first detector 10 is coupled to the first intermediate frequency amplifier stage through a coupling network 21 which comprises two coupled tuned circuits, one of which includes a rejector circuit. The coupling network illustrated is designed in accordance with the teachings of my Patent No. 2,207,796, issued July 16, 1940, and assigned to the Radio Corporation of America, in which the said network is claimed. As explained in this patent, the network 21 includes a rejector circuit of the bridged-T type.

The coupling network 21 comprises a tunable primary coil 22, a tunable secondary coil 23, and a coupling coil 24, the primary and secondary circuits being tuned by the output and input capacities of the tubes 10 and 11, respectively, and the coupling coil 24, which is common to the two tuned circuits providing the proper amount of coupling to provide the desired band pass characteristic.

The primary circuit includes a rejector circuit consisting of a coil 26 in series with the primary and secondary coils, the coil 26 being shunted by a coil 27 and a condenser 28 in series whereby the rejector circuit 26, 27, 28 may be tuned to parallel resonance at the frequency to be rejected. As taught in my above-mentioned patent coupling between the coils 22 and 26 is provided, the coupling being such as to provide a negative mutual inductance whereby a resistor 29 may be connected from the junction point of coils 22 and 26 through a blocking condenser 31 to ground to form a rejector circuit of the bridged-T type. By giving the resistor 29 the proper value of resistance, the effect of the resistance necessarily present in the parallel resonant circuits 26, 27 and 28 may be balanced out to provide infinite rejection at the unwanted frequency.

Plate voltage is supplied to the detector tube 10 through suitable filter resistors 32 and 33 and through the resistor 29 and primary coil 22. A suitable automatic volume control biasing voltage is supplied through filter resistors 34 and 36 and through a grid resistor 37 and the secondary coil 23 to the control grid of the amplifier

tube 11. Plate voltage is kept off the control grid of the tube 11 by means of a blocking condenser 38. It may be noted that where sound accompanies the picture the sound signal may be taken off the plate of the first detector through a blocking condenser 39. As will be pointed out hereinafter, the coupling network 21 is so designed that it has a peaked response close to one end of the desired I. F. amplifier pass band. In the example being described, this peaked response is at the low frequency end of the I. F. amplifier pass band. Also, the rejection circuit in this example is tuned to reject the sound accompanying the picture signal to be amplified and therefore is tuned to the sound signal frequency which is on the low side of the amplifier pass band.

The first I. F. amplifier stage comprises the amplifier tube 11 and the coupling network 41. The network 41 is designed in the same way as the network 21 except that it is designed to provide a very highly peaked response at the low frequency end of the pass band, this being where the following amplifier stages are lacking in the desired response in the particular amplifier under consideration.

The coupling network 41 comprises a primary coil 42, a secondary coil 43, a coupling coil 44 and a rejection circuit consisting of a coil 45 shunted by a coil 47 and a condenser 48. The effect of the resistance of the parallel resonant circuit 46; 47, 48 is balanced out by means of a resistor 49. The amount of balancing resistance included in the circuit may be varied by adjusting the tap 51.

Plate voltage is supplied to the tube 11 through a filter resistor 52, coupling coil 44 and the coils 46 and 42. A suitable bias is applied to the control grid of the amplifier tube 12 through a grid resistor 53 by means of a self-biasing cathode resistor 54 having in shunt thereto a condenser 56.

At this point it may be noted that in each of the networks 21 and 41 the peaked response at the low frequency end of the pass band is obtained by making the circuit from the tube plate to ground series resonant at the frequency where the peaked response is desired. In the network 21 this peaked response is held down to a comparatively small value by means of the grid resistor 37 connected across the coupling coil 24 and by means of other resistance in the circuit. In the network 41, however, this resonant peak is allowed to rise to a very high value by providing less damping in the circuit. For example, the coupling coil 44 is shunted by a resistor 53 having greater resistance than the grid resistor 37 in the preceding network. Damping resistors 57 and 58 are employed to provide the flat portion of each selectivity curve. Without these resistors the selectivity curves would be double peaked.

The character of the response curves for the above described networks will be seen by referring to Figs. 7 and 8, Fig. 7 showing the response curve for the network 21 and Fig. 8 showing the highly peaked response curve for the first I. F. amplifier stage.

The second I. F. amplifier stage comprises the amplifier tube 12 and a coupling network 61. The network 61, which does not include a rejection circuit, is of the type described and claimed in Patent No. 2,199,604, issued May 7, 1940, to H. C. Allen and G. L. Grundmann and assigned to the Radio Corporation of America. It comprises a tuned primary circuit which includes a primary coil 62 and a tuned secondary

circuit which includes a secondary coil 63, the primary and secondary circuits being coupled by means of an inductance coil 64 which is common to the two circuits. The primary and secondary circuits are so coupled and tuned as to give the desired band pass characteristic, the response curve for the network 61 being shown in Fig. 9.

Plate voltage for the tube 12 is supplied through a filter resistor 66 and through the coils 64 and 62 to the plate electrode. An automatic volume control biasing voltage is supplied to the control grid of the tube 13 through a filter resistor 67, a grid resistor 68 and the secondary coil 63. In this coupling network, as in the other coupling networks of the amplifier, suitable filter condensers are associated in the usual manner with the filter resistors. The usual blocking condenser 69 is provided for keeping plate voltage off the grid of the tube 13. Preferably, a certain amount of damping is provided in the form of a resistor 71 connected across the coils 62 and 64 which damps the primary circuit more than the secondary circuit, as will be explained hereinafter.

By so designing the coupling network 61 that the gain over the greater part of the pass range is held at a comparatively high level, the network has a characteristic, as shown in Fig. 9, such that the gain falls off rather rapidly at the low frequency end, whereby in the region of 8.5 megacycles the gain is down to only about 70% of the desired value.

The third I. F. amplifier stage comprises the tube 13 and a coupling network 72. The coupling network 72 is similar to the network 61 and, as shown in Fig. 10, has a frequency response which is down a substantial amount from the desired value at the low frequency end of the desired pass range for the amplifier.

The coupling network 72 comprises a primary coil 73, a secondary coil 74 and a coupling coil 76. As in the preceding stage, the primary and secondary circuits are so tuned and coupled as to provide an amplifier stage of the band pass characteristic.

The amplifier tube 14 is provided with a suitable value of self-bias by means of a cathode resistor 77 and a shunting condenser 78, this bias being applied to the control grid of tube 14 through a grid resistor 79.

The fourth and last I. F. amplifier stage comprises the tube 14 and a coupling network 81 which feeds into the second detector. In the particular circuit being described by way of example the network 81 is of the type described and claimed in Patent No. 2,157,170, issued May 9, 1939, to G. L. Grundmann and H. C. Allen and assigned to the Radio Corporation of America.

The network 81 comprises a tunable primary coil 82 and a secondary coil 83 which is trapped at its midpoint and which has opposite ends connected to the plates of the diodes 16 and 17. The secondary coil 83 is tuned by means of the capacity of the diodes 16 and 17 and by means of an adjustable magnetic core or the like in the coil 83 to approximately the midpoint frequency of the desired pass band.

The primary coil 82 is coupled through a portion of the secondary coil 83 by means of a coupling or blocking condenser 84. Thus, there is formed a primary circuit which also may be tuned to approximately the mid-frequency of the desired pass band. This primary circuit may be traced from the plate of tube 14 through the coil 82, the condenser 84 and through a section of the

coil 83 to the mid-point tap of coil 83 and from therethrough a filter condenser 86 to ground. The coupling between the tuned primary circuit and the tuned secondary circuit is provided by that portion of the coil 83 which is common to the two tuned circuits. These circuits are so tuned and coupled as to provide the band pass characteristic shown by the response curve of Fig. 11.

The output signal of the second detector appears across the output resistor 87 and is supplied to a suitable video amplifier not shown. As is well understood in the art, there appears across the resistor 87 a signal component which is a measure of the average carrier amplitude and which, therefore, may be utilized to provide automatic volume control. In accordance with well known practice, I connect the input circuit of a suitable automatic volume control amplifier, indicated by the block 88, to the cathode end of the output circuit of the A. V. C. circuit 88 a negative biasing voltage which varies in accordance with the amplitude of incoming signals.

By referring to Figs. 2 to 6, it will be seen that by causing a coupling network such as network 41 which includes a rejector circuit to resonate in the proper manner, I have increased the band width of an amplifier without sacrificing amplifier gain. Fig. 2 shows the overall selectivity curve for the amplifier. This is the selectivity of the amplifier from the grid of the first detector tube 10 to the plates of the diodes 16 and 17. It will be seen that the amplifier response holds up at the low frequency end to a frequency very close to that of the sound signal which is to be rejected. Fig. 3 is the selectivity curve for the four I. F. amplifier stages, that is, it is an overall response curve with the first detector coupling network 21 omitted. It will be noted that this curve falls off slightly at the low frequency end, this lack in response being compensated in the complete amplifier by the peaking at the low frequency end provided by the network 21 as illustrated in Fig. 7.

Fig. 4 shows the over-all frequency response for the second, third and fourth I. F. amplifier stages. It will be seen that these stages between 8.5 and 10 megacycles are below the desired response. Obviously, the low frequency response has been brought up to the desired value by means of the compensating networks 21 and 41, mainly by the network 41 which has the very high peak at the low frequency end of the pass band as shown in Fig. 8. It will be understood that any desired percentage of the total desired compensation may be provided by each of the networks 21 and 41.

Fig. 5 shows the frequency response for the third and fourth I. F. amplifier stages in cascade, while Fig. 6 shows the frequency response for the fourth stage alone.

From the foregoing, it will be apparent that the gain of the second, third and fourth amplifier stages was held up to a reasonable value by making no attempt to obtain the desired response in these amplifier stages over the entire pass band. Yet, by combining these amplifier stages in cascade with a suitably designed amplifier stage of the type having a rejector circuit with a portion of the network properly resonated, the desired wide band response at the desired gain is attained with a minimum number of stages.

In designing a compensating network such as network 41, there are at least three requirements to be met in selecting capacity and inductance values for the network as follows:

1. The network must be properly coupled and

tuned to function as a filter having the desired pass band.

2. The rejector circuit must be tuned to the frequency of the signal to be rejected.

3. The circuit must be series-resonant from the tube plate to ground at or near the desired cut-off frequency adjacent to the signal being rejected. In the circuit illustrated, it is series-resonant at a frequency just above the rejection frequency.

It will be apparent that these several requirements are interdependent. The proper design may be obtained by treating the circuit as a pair of coupled circuits having the desired band width and connected in a T network such as the one shown at 61. The effective primary, secondary and coupling inductances may be obtained from filter theory. It now remains to modify the magnitude of the primary inductance to some value such that the insertion of the series rejector will permit the primary to have the previously determined effective inductance at midband. The selection of values to be used in the series rejector circuit must make this circuit resonate at the desired rejection frequency and is somewhat governed by practical considerations, such as limits in tuning range provided by 27 and manufacturing tolerances of capacity 28.

It now remains to be seen whether the resulting network is series resonant from the plate electrode (of tube 11, for example) to ground at the frequency where the high peak of the selectivity curve is desired. If it resonates at the wrong frequency, the L. C. ratio of the rejector circuit must be changed. By cut and try with the use of visual line-up equipment, the circuit can readily be made to resonate in the desired manner at the proper frequency to give the desired compensation.

If desired, the circuit values may be calculated by means of simultaneous equations but the procedure outlined above is more satisfactory in practice due to lack of information as to the exact values of distributed capacity of the various circuit elements.

My invention is not limited to the use of compensation at the low frequency end of the pass band. For example, it may be desirable to provide rejection at the high frequency end of the pass band in order to reject the sound signal of a television transmitter on an adjacent channel as described and claimed in my Patent No. 2,217,839, issued October 15, 1940. In this patent capacity coupling is employed and the rejection circuit is tuned to a frequency just above the pass band. By resonating the circuit from plate to ground at or near the high frequency cut-off and providing insufficient damping to hold down the resonant peak, this peak may be allowed to rise to a value high enough to compensate for lack of high frequency response in other amplifier stages.

Specifically, there may be substituted for the network 61, by way of example, a network designed to provide rejection on the high side of the pass band as described in my above-mentioned Patent 2,217,839 and designed also to have a resonant peak at or near the cut-off point at the high frequency end of the pass band to compensate for lack of high frequency response in other amplifier stages.

In cases where the television receiver is to be operated with the picture carrier frequency half way down on the selectivity curve as indicated in Fig. 2, and where rejection on the high side

of the pass band is desired, the above-mentioned network of my Patent 2,217,839 may be substituted for one or more of the coupling networks 61 and 72 without employing compensation. That is, the network giving rejection on the high side is designed to have a substantially flat response at the high frequency end of the pass band but, by properly resonating the circuit, the gain is held up in the region of the high frequency cut-off and the cut-off is sharpened.

As previously indicated the receiver for which the selectivity curves of Figs. 2 to 6 are drawn is designed for operation with the picture carrier frequency half way down on the selectivity curve as shown in Fig. 2 and indicated by the legend and the dotted line. A comparison of the curves in Figs. 2 to 6 shows that the side of the selectivity curve on which the picture carrier frequency falls has been given the desired shape and steepness by a proper adjustment of the two amplifier stages which include rejector circuits. Specifically, it will be noted that the picture carrier frequency falls at substantially the same point on the curves of Figs. 4, 5 and 6. That is, at about 90 percent response; that it falls on the curve in Fig. 3 at about 75 percent full response; and that it falls on the curve in Fig. 2 at the desired point of 50 percent response. Thus, the shaping of the picture carrier frequency side of the selectivity curve obviously is accomplished primarily in the I. F. amplifier stages 21 and 41 which include the rejector circuits.

Referring now to the design of my amplifier with respect to the automatic volume control action, it will be noted that the A. V. C. voltage is applied to the control grid of tube 11 and to the control grid of tube 13. Thus a change in A. V. C. bias will change the selectivity characteristics of networks 21 and 61 because of changes in the input capacities of tubes 11 and 13 as is well understood in the art.

I have discovered that this change in selectivity for a network of the character of network 21 is as represented by the curves marked —3A and —13A in Fig. 12. As shown, a change in A. V. C. bias from —3 volts to —13 volts causes the resonant peak of the curve to shift slightly towards the high frequency end of the pass band. The selectivity curve, it will be noted, shifts only at the low frequency end of the pass band.

Considering the network 61, since the primary circuit is loaded more than the secondary circuit an increase in A. V. C. bias will cause the selectivity curve to tilt down at the low frequency end of the pass band. Thus the curve for network 61 when there is an A. V. C. bias of —3 volts is indicated at —3B. An increase in A. V. C. bias to —13 volts causes the curve to take the position indicated at —13B.

For the condition of —3 volts bias the overall response of networks 21 and 61 is shown by the curve marked —3. The overall selectivity after the A. V. C. bias has increased to —13 volts is shown by the dotted line curve marked —13.

It will be apparent that there has been negligible shift of the selectivity characteristic at the high frequency end of the pass band and only a slight shift at the low frequency end. Such a shift at the low frequency end is not objectionable whereas it might be objectionable at the high frequency end since it is preferred to have the picture carrier located exactly half way down on the curve as indicated in Fig. 2.

The fact that a selectivity curve may be tilted in the desired direction with changes of A. V. C.

bias by properly loading the coupling network has been explained in Patent No. 2,185,879, issued January 2, 1940, to H. C. Allen and assigned to the Radio Corporation of America. In this Allen patent there is claimed the feature of loading successive stages differently to make the curve of one stage tilt up at one end at the same time the curve of another stage tilts down at this end, whereby the overall response remains flat. In the instant application, substantially the same result is obtained by utilizing the shift of a resonant peak in one stage in combination with the tilting of a curve in another stage.

Attention is called to the fact that in place of the specific rejector circuits shown in networks 21 and 41, there may be substituted in either network either an ordinary parallel resonant circuit having no means for balancing out the effect of resistance or there may be employed the type of bridged-T network which does not contain negative mutual inductance, this latter type being described in my above-mentioned Patent No. 2,207,796. Any of these networks having series resonance from the amplifier tube plate to ground to give a peak in the selectivity curve for compensation has the characteristic illustrated in Fig. 12. That is, only the peaked portion of the curve shifts with A. V. C. bias whereby it may be employed in cascade with a network such as 61 for maintaining a suitable overall response.

I claim as my invention:

1. In combination, an amplifier stage having a certain pass range and cut-off point, a second amplifier stage connected in cascade with said first-mentioned stage and having therein a rejector circuit which resonates at a frequency outside said pass band but close to said cut-off frequency for the purpose of removing an undesired signal at said frequency, said first-mentioned stage being designed for maximum gain over the greater part of the pass band at the expense of gain near said cut-off point, and said second-mentioned stage being designed to have a response curve with a resonant peak within said pass band and close to said cut-off point whereby the overall response of said two stages is made at least to approximate a flat-topped curve over all of said pass range.

2. An amplifier comprising a plurality of amplifier stages connected in cascade, said amplifier being designed to have an overall band pass characteristic and including at least one stage which is deficient in gain at one end of said pass band, said amplifier also including an amplifier stage which has therein a rejector circuit which resonates at a frequency outside of and adjacent to said one end of the pass band for the purpose of removing an undesired signal at said frequency, said last-mentioned stage being so designed as to have a selectivity curve having a resonant peak within and at said end of the pass band whereby the overall response of said amplifier at said end of the pass band is increased and made more nearly flat.

3. In combination, an amplifier stage having a certain pass band and cut-off point, said stage being designed for maximum gain over the greater part of the pass band at the expense of gain near said cut-off point, a second amplifier stage connected in cascade with said first-mentioned stage, said second-mentioned stage being of the type comprising a tuned primary circuit and a tuned secondary circuit coupled by a reactance unit common to said tuned circuits, said primary

circuit including a parallel resonant rejector circuit in series with said reactance unit and tuned to a frequency outside said pass band and adjacent to said cut-off point, said second-mentioned stage being designed to have a response curve with a resonant peak within said pass band and close to said cut-off point whereby the overall response of said two stages is made more nearly flat than the response of said first stage.

4. In combination, an amplifier stage having a certain pass range and cut-off point, said stage comprising a coupling network, an amplifier tube having input electrodes connected to said network, a second amplifier stage connected in cascade with said first-mentioned stage and including a coupling network having therein a rejector circuit which resonates at a frequency outside said pass band but close to said cut-off frequency, a second amplifier tube having input electrodes connected to said second network, said first-mentioned stage being designed for maximum gain over the greater part of the pass band at the expense of gain near said cut-off point, said second-mentioned stage being designed to have a response curve with a resonant peak within said pass band and close to said cut-off point whereby the overall response of said two stages is made at least to approximate a flat-topped curve over all of said pass range, means for applying an automatic volume control voltage to said tubes, and means for so loading the network of said first-mentioned stage that a change in A. V. C. bias causes its selectivity curve to tilt in a direction to compensate for a simultaneous shift in the resonant peak of said second stage whereby there is avoided any large shift in the frequency spectrum of the overall selectivity curve of said two stages with changes in A. V. C. bias.

5. An amplifier comprising a plurality of amplifier stages connected in cascade, said amplifier being designed to have an overall band pass characteristic and including at least one stage which is deficient in gain at one end of said pass band, said one stage comprising a coupling network, an amplifier tube having input electrodes connected to said network, said amplifier also including an amplifier stage which has a coupling network in which there is a rejector circuit which resonates at a frequency adjacent to said one end of the pass band, said last-mentioned stage being so designed as to have a selectivity curve having a resonant peak at said end of the pass band whereby the overall response of said amplifier at said end of the pass band is increased and made more nearly flat, a second amplifier tube having input electrodes connected to said second network, means for supplying automatic volume control bias to said tubes, and means for causing the selectivity curve for the first-mentioned stage to tilt in the proper direction in response to an increase in A. V. C. bias to compensate for a simultaneous shift in said resonant peak whereby the overall selectivity characteristic of said stages remains substantially unchanged.

6. In combination, an amplifier stage having a certain pass band and cut-off point, said stage including two coupled tuned circuits and being designed for maximum gain over the greater part of the pass band at the expense of gain near said cut-off point, one of said tuned circuits

being a primary circuit and the other being a secondary circuit, a second amplifier stage connected in cascade with said first-mentioned stage, said second-mentioned stage being of the type comprising a tuned primary circuit and a tuned secondary circuit coupled by a reactance unit common to said tuned circuits, said primary circuit including a parallel resonant rejector circuit in series with said reactance unit and tuned to a frequency outside said pass band and adjacent to said cut-off point, said second-mentioned stage being designed to have a response curve with a resonant peak within said pass band and close to said cut-off point whereby the overall response of said two stages is made more nearly flat than the response of said first stage, an amplifier tube having input electrodes connected to the coupled tuned circuits of said first stage, a second amplifier tube having input electrodes connected to the secondary circuit of said second stage, means for applying an automatic volume control bias to said tubes, and means for loading the primary circuit of the first-mentioned stage more than the secondary circuit coupled thereto.

7. In a television receiver of the superheterodyne type including an intermediate frequency amplifier which has a certain selectivity characteristic having a certain cut-off point at one side thereof and on the other side of which the carrier of the received signal is to be located substantially fifty percent down, and in which the said amplifier includes a plurality of cascaded amplifier stages, one of which includes a rejector circuit which resonates for rejection of an undesired signal having a frequency outside of the amplifier pass range but close to said cut-off point, the method of lining-up said amplifier to produce a selectivity characteristic having the desired slope on the said other side which comprises adjusting certain of said stages to give approximately one hundred percent response at said carrier frequency and adjusting at least one of the stages including a rejector circuit to so reduce the overall amplifier response that it is substantially fifty percent at said carrier frequency.

8. A television receiver of the superheterodyne type comprising an intermediate frequency amplifier which includes a plurality of cascaded amplifier stages, said amplifier having a certain pass range and cut-off point as represented by a frequency response curve, said curve having a certain slope on the side opposite said cut-off point, the frequency response curve for certain of said amplifier stages being substantially flat up to and including the carrier frequency of the signal to be received, at least one other amplifier stage including a rejector circuit tuned to provide rejection of an undesired signal at a frequency close to said cut-off point but outside said pass band, said last amplifier stage being adjusted to have a substantially flat response over a certain frequency range and to have a response at said carrier frequency which is substantially less than the response in the region of said flat response, and such that the overall frequency response characteristic of said amplifier at the carrier frequency is substantially fifty percent of the maximum frequency response.

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