

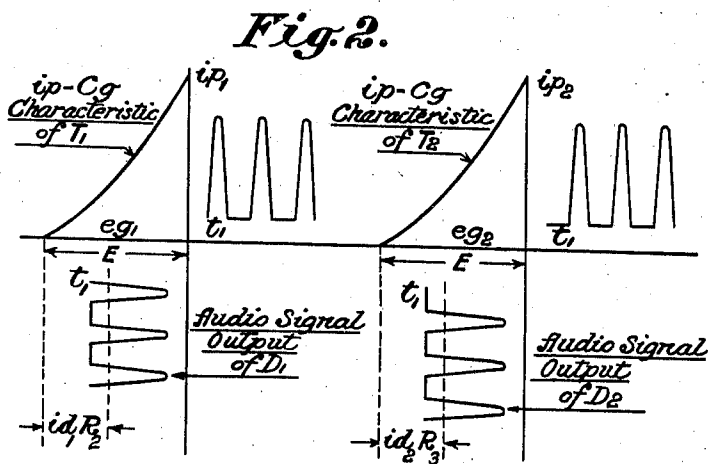
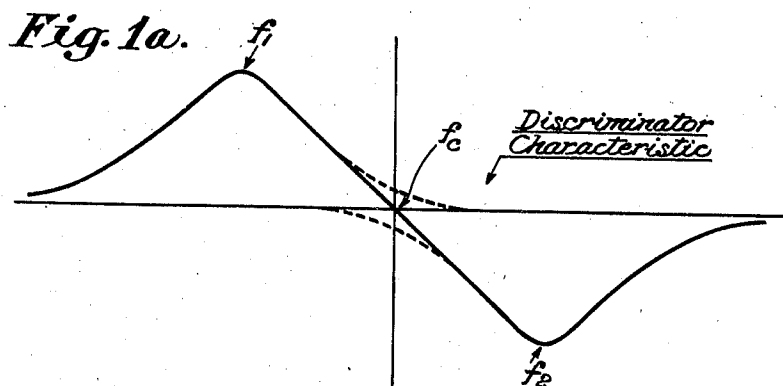
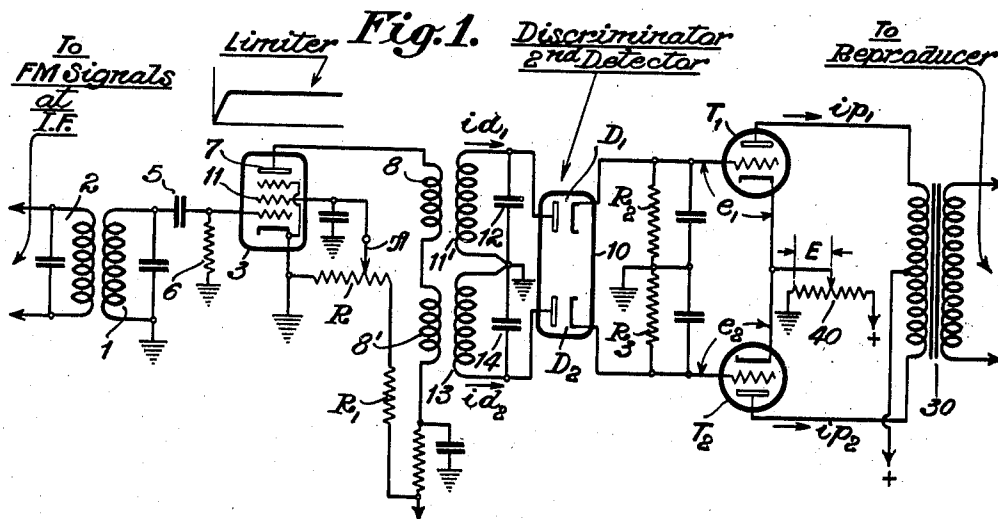
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DETECTED FREQUENCY MODULATED WAVE AMPLIFIER

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## UNITED STATES PATENT OFFICE

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DETECTED FREQUENCY MODULATED  
WAVE AMPLIFIERJohn A. Rankin, Port Washington, N. Y., assign-  
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My present invention relates to amplifiers for detected frequency modulated waves, and more particularly to push-pull amplifiers of the class B type adapted for amplifying detected frequency modulated carrier waves.

One of the main objects of my present invention is to provide a push-pull amplifier of the class B type for amplifying the modulation voltage output of a frequency modulation receiver detector; the amplifier, by virtue of its being biased at, or beyond, cut-off in the absence of signals, being very economical of plate current, and being adapted to eliminate noise reproduction in the absence of signals.

Another important object of this invention is to provide in a frequency modulation receiver of the type provided with an adjustable limiter and a detector, a push-pull amplifier of the class B type which is directly coupled to the detector output resistors; the amplifier operating as a class A amplifier to provide linear signal amplification, but operating as a class B amplifier in the absence of signals thereby insuring freedom from noise effects usually secured when operating highly sensitive frequency modulation receivers in the absence of signals.

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 a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit diagram of an arrangement embodying the invention.

Fig. 1a is the discriminator characteristic of the detector network,

Fig. 2 graphically presents the operation of the circuit of Fig. 1.

Referring now to Fig. 1, wherein is shown that portion of a frequency modulation receiver essential to a proper understanding of the invention, it is to be understood that the receiver is of the superheterodyne type. It may be adapted to receive signals in the 43 to 50 megacycle range, the presently assigned frequency modulation band. It is not believed necessary to describe the circuit details of the receiving system prior to the limiter stage. Those skilled in the art are fully aware of the manner of supplying to the input circuit the frequency modulated carrier waves whose center frequency is at an intermediate frequency. The latter may have a value, for example of 2 to 4 megacycles. The modulation signals appear on the carrier waves, of course, as a frequency variation of the carrier frequency. The amplitude of the modulation frequencies cor-

responds to the extent of deviation of the carrier frequency, whereas the modulation frequencies determine the rate of deviation of the carrier frequency.

The specific type of limiter has been described and claimed in application Serial No. 359,330 filed October 2, 1940, by Dudley E. Foster and John A. Rankin, Patent No. 2,266,541, December 16, 1941. In that application it is pointed out that adjustment of the tap A along the bleeder resistor R results in volume control action. The circuit 2, tuned to the intermediate frequency value, may be considered as located in the plate circuit of the last intermediate amplifier tube. The circuit 1 is reactively coupled to circuit 2, and is, also, tuned to the center frequency ( $f_c$ ) of the intermediate frequency energy. The limiter stage functions to insure the transmission to the second detector of solely frequency modulated carrier waves, no amplitude modulation effects being transmitted. It is well recognized that passage of the frequency modulated carrier waves through the prior resonant circuits, noise impulses and fading effects produce a variation in amplitude of the frequency modulated carrier waves.

The limiter stage itself may comprise a tube 3, which may be a pentode of the 6SJ7 type, the signal grid thereof being coupled to the high potential side of the input circuit 1 by a coupling condenser 5. The grid leak resistor 6 connects the grid end of condenser 5 to the grounded cathode. The plate 7 of the limiter tube is connected to a source of positive potential through the primary windings 8 and 8'. Each of the windings may, of course, be shunted by condensers so as to resonate each of them to the operating intermediate frequency value. The screen grid electrode 11 of the limiter tube is connected to a predetermined point on the voltage supply bleeder R. The latter comprises a plurality of resistor sections arranged in series between the plate potential supply terminal and the grounded cathode. The bleeder sections consist of a potentiometer R—A which is adjustable, and a section R<sub>1</sub> of constant magnitude. The screen grid is by-passed to ground for intermediate frequency currents, and there is applied to the screen grid electrode a positive potential which is of a predetermined magnitude.

When the magnitude of one portion of the resistor R is decreased, then the magnitude of the remainder thereof is increased. Hence, it will be seen that the potentiometer arm A connects the screen lead to the bleeder R so as to vary the magnitudes of the sections thereof in inverse senses. The primary function of the limiter tube is to act in the manner of an amplifier which is very easily overloaded. That is, grid current is caused to flow and plate current saturation is produced on one half of the signal cycle,

and plate current cut-off is created on the other half of the cycle. As stated before, the essential purpose of the tube is to wipe out all amplitude variations present in the output of the preceding network, and to pass on to the following discriminator a constant amplitude-variable frequency signal.

Above the limiter tube in Fig. 1 there is shown a typical signal input-signal output characteristic of a limiter. As shown in the aforesaid application, the effective threshold value is varied as the screen voltage is changed. For example, the limiting action of the stage varies as the limiter screen potential is changed from plus 10 to plus 150 volts. As the screen potential is increased the signal output level at the limiter output circuit is similarly increased, and the effective threshold point is also increased. In a limiter of the screen grid type the plate current cut-off value is largely dependent on the screen potential, and, hence, the detector output for a given deviation is a function of the limiter screen potential. Consequently, the adjustment of screen potential in the limiter tube may be used to control the output from the following detector while at the same time maintaining the limiting action unimpaired. It is not believed necessary to describe the function of the limiter in any further detail, further reference being made to the aforesaid application.

The following discriminator-second detector network may comprise any well known type of circuit. In Fig. 1a there is shown the typical characteristic curve of such a network. Those skilled in the art are fully acquainted with the various types of networks that may be employed between the audio amplifier stage and the limiter output circuit. It is sufficient for the purpose of the present application to point out that the discriminator-detector network may follow, if desired, the teachings disclosed by S. W. Seeley in U. S. Patent 2,121,103 granted June 21, 1938. In this type of circuit there is produced across opposed load resistors of a pair of diode rectifiers rectified voltages in polarity opposition. To preserve simplicity of disclosure there is specifically shown in Fig. 1 the type of discriminator-detector network wherein there is used a pair of diode rectifiers having input circuits oppositely and equally mistuned with respect to the center frequency of the frequency modulated carrier waves.

Thus, the numeral 10 denotes a double diode tube, say of the 6H6 type, which has housed therein the elements of a pair of diode rectifiers. One of the diodes  $D_1$  has its anode connected to ground through the coil 11 of its tuned input circuit, the coil 11 being shunted by condenser 12. The input circuit 11—12 is fixedly resonated to the frequency  $f_1$  which is located a predetermined frequency value to one side of the center frequency value. The diode  $D_2$  has its anode connected to ground through the coil 13 of its input circuit, the coil being shunted by condenser 14. The input circuit 13—14 is resonated to the frequency  $f_2$  which is located on the opposite side of the center frequency. It will be understood that both these mistuned frequencies are displaced by equal frequency values. The primary winding 8 is reactively coupled to coil 11, while winding 8' is reactively coupled to the coil 13. The arrow located above input circuit 11—12 shows the current flow through diode  $D_1$  and is designated by the reference letters  $i_{d_1}$ . Similarly,

the current flowing through the second diode is indicated below circuit 13—14 which is designated by reference letters  $i_{d_2}$ .

The cathodes of the two diodes are connected together through the series load resistors  $R_2$  and  $R_3$ , and the junction of these two resistors being established at ground potential. Each of these resistors is shunted by a condenser for the purpose of by-passing the carrier frequency currents to ground. As is well known to those skilled in the art, across each of the load resistors  $R_2$  and  $R_3$  there is developed modulation voltage which corresponds to the modulation signals originally imposed on the carrier wave at the transmitter. It is not believed necessary to explain this in detail since those skilled in the art are fully aware of the manner in which this type of discriminator-detector network functions. In general, it may be stated that when the frequency of the applied intermediate frequency energy has an instantaneous value equal to the center frequency, then no modulation voltage whatever is developed across either of resistors  $R_2$  and  $R_3$ . However, when the instantaneous frequency of the modulated carrier waves applied to the input circuits 11—12 and 13—14 deviates towards the resonant frequencies of either of these input circuits, there will be built up across the respective load resistors  $R_2$  and  $R_3$  rectified voltage.

Since the junction of resistors  $R_2$  and  $R_3$  is at ground potential, the cathode ends of each of these load resistors may be directly connected to the control grids of a pair of push-pull connected audio amplifier tubes. Thus, the audio amplifier  $T_1$  has its control grid connected directly to the cathode end of resistor  $R_2$ , while the control grid of amplifier  $T_2$  is connected to the cathode end of resistor  $R_3$ . The cathodes of both audio tubes are connected in common to a desired point on bleeder resistor 40. The bias applied to the grids of  $T_1$  and  $T_2$  is indicated by the letter E. The modulation voltages applied to the grids of tubes  $T_1$  and  $T_2$  are indicated by the symbols  $e_1$  and  $e_2$  respectively. The plate current flowing through the tube  $T_1$  is indicated by the arrow designated  $i_{p_1}$ , and the plate current flowing through tube  $T_2$  is indicated by the arrow designated  $i_{p_2}$ . The plates of the audio amplifier tubes are connected to the opposite ends of the primary winding of the audio output transformer 30, the positive potential supply lead being connected to a mid-tap on the primary winding. The bleeder resistor 40 may be connected to the plate supply. The secondary winding of transformer winding 30 will, of course, be coupled to one or more audio amplifier stages and/or the final audio reproducer of any well known type.

In Fig. 2 there are shown various curves for graphically explaining the functioning of the present invention. The bias E is made sufficiently high so as to insure operation of tubes  $T_1$  and  $T_2$  as a class B push-pull amplifier. In other words, in the absence of signals the audio tubes are biased to, or beyond, plate current cut-off. In Fig. 2 there is shown the plate current-grid voltage characteristic of tube  $T_1$ , as well as the similar characteristic of the tube  $T_2$ . It will be observed that both of these characteristics are substantially wholly in the negative region, and that the audio amplifiers arranged in push-pull relation do not draw grid current. Since the value of E is such that it biases each of the tubes to the cut-off value, the push-pull stage is a linear amplifier for signals. That is, the signals are amplified without distortion, and yet is very

economical of plate supply current. The output of a pair of frequency modulation diode rectifiers is ample to drive a pair of audio amplifier tubes arranged as an over-biased amplifier where grid current does not flow. By means of the present invention there is provided a distortionless push-pull audio amplifier of the over-biased type in combination with a limiter, wherein the limiter screen potential may be varied to control the volume output of the receiver. A saving in components results from using the present arrangement in that no coupling condensers are necessary between the detector cathodes and the audio input grids. Furthermore, it is only necessary to use a single volume control means, that is to say the screen potential adjusting device, whereas in most circuits of similar arrangement there is utilized a dual volume control device. Again, in frequency modulation receivers there occurs a high noise output when no signals are received. This is due to the high sensitivity of the system. By using the present invention the noise output is eliminated because the tubes  $T_1$  and  $T_2$  are biased to, or beyond, cut-off for no-signal input.

Referring again to Fig. 2, the bias  $E$  is bucked out in part by the diode currents  $i_{d1}$  and  $i_{d2}$  flowing through the load resistors  $R_1$  and  $R_2$  respectively. Due to the half sine wave output of each half of a frequency modulation detector with sine wave modulation the output stage may be biased to cut-off and still remain functioning as a linear amplifier. The signal wave applied to each of the grids of tubes  $T_1$  and  $T_2$  is shown in Fig. 2. The important thing to note in Fig. 2 is that the tubes  $T_1$  and  $T_2$  draw plate current at different times. This is illustrated by noting that the time for the grid signal waves and  $i_p$  waves start at  $t_1$ . For the first half cycle the tube  $T_1$  has a half positive sine wave pulse applied to its grid and a half sine wave pulse of plate current flows, while tube  $T_2$  has no audio grid signal or output through the first half cycle. During the second half cycle  $T_1$  receives no audio grid signal and hence no output, but the grid signal of tube  $T_2$  has a half sine wave pulse as is the plate current. It is to be noted that while the dotted portions of the characteristic of Fig. 1a are actually secured in operation, distortion introduced thereby on the negative half cycles of the audio waves is ineffective since tubes  $T_1$  and  $T_2$  are biased to cut-off.

Where it is desired to use this arrangement of driving a push-pull audio amplifier, but utilizing coupling condensers in the connection between the cathode of each diode and the corresponding audio input grid, it is necessary to utilize the grid leak resistor connection between each of the audio grids and ground. In that type of circuit a lower value of bias will be necessary because the drops across  $R_1$  and  $R_2$  no longer subtract from  $E$ . It is, also, to be understood that tubes  $T_1$  and  $T_2$  may be either triodes, pentodes or beam power output tubes.

While I have indicated and described a system 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 organization shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. In combination with a frequency modulation detector of the opposed diode type having

an input circuit upon which is impressed frequency modulated carrier waves, an output circuit for said detector comprising a pair of load resistors arranged in series relation and having the junction thereof at a relatively fixed potential, a pair of modulation voltage amplifier tubes arranged in push-pull relation, means directly connecting the input electrodes of the amplifiers without coupling reactances to respectively different points on said load resistors which are at different potentials with respect to said fixed potential point, and means for negatively biasing said input electrodes substantially to amplifier space current cut-off points in the absence of received modulated waves, said biasing means being chosen to locate the plate current-input electrode voltage characteristic of each amplifier substantially wholly in the negative region whereby the amplifiers do not draw input electrode current throughout operation thereof.

2. In combination with a frequency modulation detector of the type comprising a pair of rectifiers having opposed resistors in polarity opposition, means for establishing the mid-point of said resistors at a relatively fixed potential, and a class B push-pull audio amplifier having the signal grids thereof directly connected, and without the interposition of any coupling condensers, to respective ends of said load resistors which are on opposite sides of said fixed potential point and the signal grid voltage-plate current characteristic of each of the push-pull amplifier tubes being substantially wholly located in the negative region to prevent grid current flow during audio amplification.

3. In combination a frequency modulation detector having an input circuit upon which is impressed frequency modulated carrier waves, an output circuit for said detector comprising a pair of load resistors arranged in series relation and having the junction thereof at a desired potential, a pair of amplifier tubes arranged in push-pull relation, means directly connecting the input electrodes of the amplifiers to respectively different points on said load resistors which are at different potentials with respect to said desired potential point and without the interposition of any coupling condensers, and means for negatively biasing said input electrodes to amplifier space current cut-off points whereby said amplifier tubes operate with linear amplification for signals but prevent noise reproduction in the absence of signals, said biasing means being chosen to locate the plate current-input electrode voltage characteristic of each amplifier substantially wholly in the negative region whereby the amplifiers do not draw input electrode current throughout operation thereof.

4. In combination with a frequency modulation detector of the type comprising a pair of diode rectifiers having opposed resistors in polarity opposition, means for establishing the mid-point of said resistors at a relatively fixed potential, and a class B push-pull audio amplifier having the signal grids thereof directly connected to respective ends of said load resistors which are on opposite sides of said fixed potential point and without the interposition of coupling condensers, the grid voltage-plate current characteristic of each audio amplifier tube being located in the negative region to prevent grid current flow thereby to permit said class B amplifier to be driven by said diode rectifiers.

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