

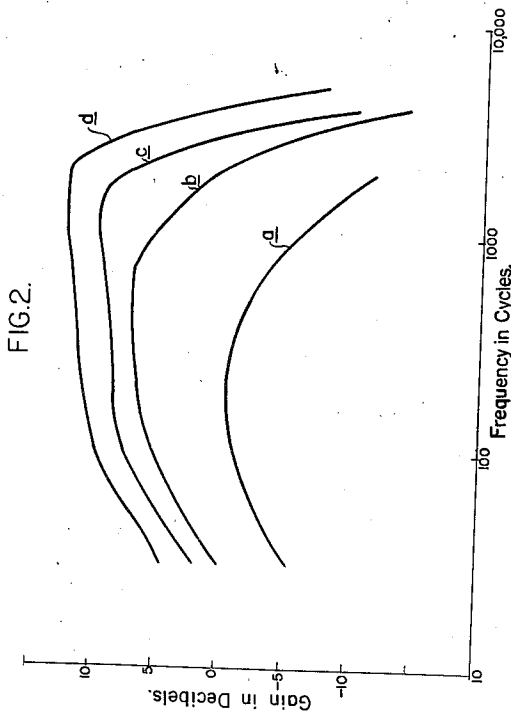
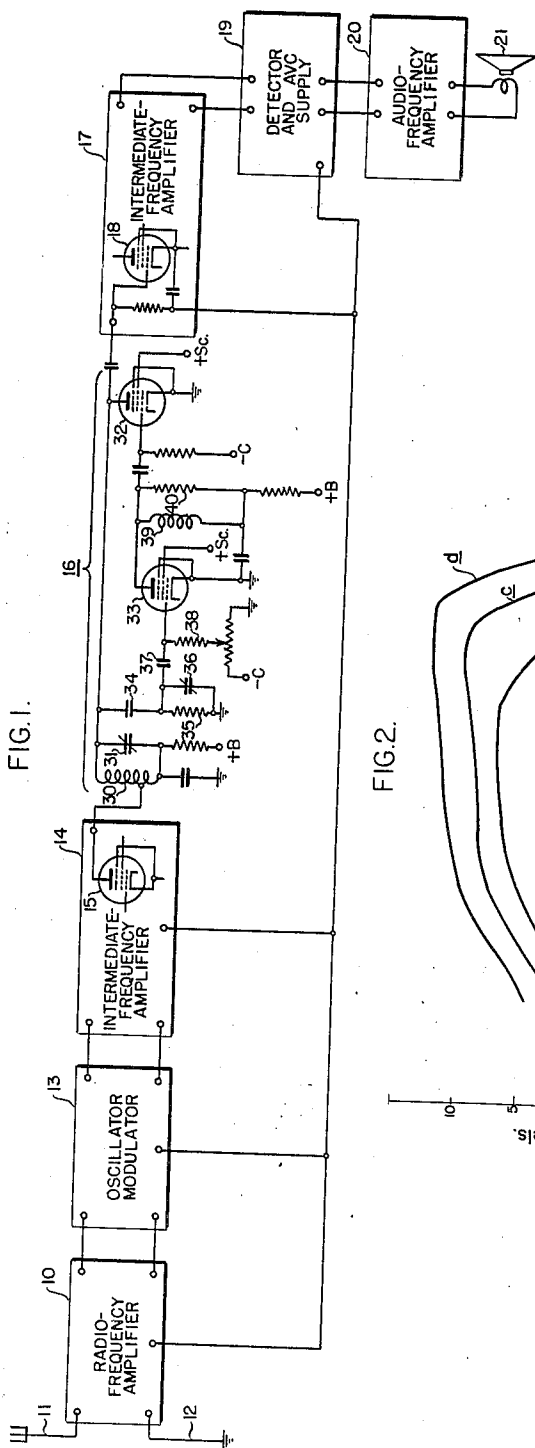
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BAND-PASS SELECTOR SYSTEM

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BAND-PASS SELECTOR SYSTEM

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This invention relates to band-pass selector systems and more particularly to such systems in which the width of the frequency band transmitted by the system is adjustable. While band-pass selector systems constructed in accordance with the present invention are of general utility, they are particularly suitable for use in the intermediate-frequency channel of modulated-carrier signal receivers of the superheterodyne type for controlling the selectivity and fidelity of the response of the receiver.

Band-pass selector systems of conventional design usually comprise a pair of resonant circuits tuned to the same or different frequencies and suitably coupled inductively, capacitively, or by a combination of these individual couplings. The desired response of this type of selector system is substantially uniform over a band of frequencies in the vicinity of the mean resonant frequency of the selector, while signal components of all other frequencies are sharply discriminated against and attenuated to a substantial degree by the selector. In general, the width of a frequency band passed by such a selector system may be varied by adjusting the coupling between the two circuits, by adjusting the resonant frequencies of the two circuits relative to each other, or by a combination of these two adjustments. Selector systems of the type described generally utilize coupling systems which are nondirective in nature; that is, either circuit may be the input circuit and the other the output circuit without substantially affecting the characteristics of the system. Such a system is to be contrasted with the type of selector utilizing vacuum tube coupling in one or both directions between the input and the output circuits, wherein one or both of the couplings are primarily unidirective.

Band-pass selector systems, wherein the nondirective form of coupling is utilized, are, in general, open to the criticism that only mechanical or relatively complicated nonmechanical expedients are known for adjusting the width of the frequency band to be transmitted. Band-pass selector systems employing unidirective couplings in the forward and backward directions between the tuned circuits, however, require a separate vacuum tube or the equivalent in each of the forward and backward coupling paths. All of the above-mentioned band-pass selectors, moreover, require two resonant circuits and also require some form of additional control arrangement if utilized in a modulated-carrier signal receiver.

It is an object of the present invention, therefore, to provide an improved band-pass selector system of simple arrangement in which one or more of the above-mentioned disadvantages of prior art systems are eliminated.

It is another object of the invention to provide an improved band-pass selector system requiring only one tuned circuit in the signal-translating channel with which it is associated.

It is another object of the invention to provide an improved band-pass selector system in which the width of the pass band inherently increases with the amplitude of the signal input to the selector, the selector comprising no external or additional control circuits.

In accordance with the invention, an improved band-pass selector comprises a modulated-carrier signal-translating stage including a single tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated by the stage. A feed-back circuit is provided for the tuned circuit which includes a device having a nonlinear transfer characteristic between its input and output terminals. Means are provided for applying to the input terminals of the feed-back circuit a voltage varying in accordance with the instantaneous amplitude of the voltage across the tuned circuit; further means are provided for applying the output current of the feed-back circuit to the tuned circuit to vary the voltage across the tuned circuit; and additional means are provided for substantially eliminating regeneration and degeneration through the feed-back path at the carrier frequency of the system, the arrangement being effective to vary the effective selectivity of the stage in accordance with the amplitude of the signal input thereto.

In a preferred embodiment of the invention, the device utilized in the feed-back circuit is a vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to the tube. Also, in accordance with a preferred embodiment of the invention, an auxiliary amplifier is included in the feed-back circuit in cascade with the above-mentioned nonlinear device.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring now more particularly to the drawing, Fig. 1 is a circuit diagram, partially schematic, of an embodiment of the invention as incorporated in the intermediate-frequency channel of a superheterodyne receiver, while Fig. 2 is a graph illustrating certain of the operating characteristics of the circuit of Fig. 1.

Referring now more particularly to Fig. 1 of the drawing, there is shown a circuit diagram partly schematic, of the improved band-pass selector system of the invention embodied in a modulated-carrier receiver of the superheterodyne

type for controlling the selectivity of the intermediate-frequency channel of the receiver. Briefly described, the receiver of Fig. 1 comprises a radio-frequency amplifier 10, having input terminals connected to an antenna 11 and ground 12 and output terminals coupled to a frequency changer or oscillator-modulator 13. Connected in cascade with the output circuit of frequency changer 13, in the order named, are an intermediate-frequency amplifier 14 of one or more stages and comprising a vacuum tube 15, a variable band-pass selector system 16, an intermediate-frequency amplifier 17 of one or more stages including a vacuum tube 18, a detector and automatic amplification control unit 19, an audio-frequency amplifier 20, and a sound reproducer 21. The bias potential derived from automatic amplification control source 19 may be applied to one or more of the stages including radio-frequency amplifier 10, the modulator included in frequency changer 13, and intermediate-frequency amplifiers 14 and 17. It will be understood that only the portions of the circuits of tubes 15 and 18 pertinent to the present invention are shown, and that these tubes include the additional conventional circuits necessary for their operation as vacuum-tube amplifiers in a manner which is well understood in the art.

Considering first the operation of the receiver as a whole, without regard to the details of the band-pass selector of the invention, per se, a desired received signal is selected and amplified in radio-frequency amplifier 10 and is converted to a modulated intermediate-frequency signal by frequency changer 13. The signal as thus converted is further amplified in intermediate-frequency amplifier 14, further selected by band-pass selector 16, amplified by intermediate-frequency amplifier 17 and detected by detector 19, thereby producing the audio-frequency modulation components which are, in turn, amplified by the audio-frequency amplifier 20 and reproduced by the sound reproducer 21. The amplification of the received signal is subject to automatic control by the control-bias potential derived from source 19, according to the manner well understood in the art, to maintain the signal input to detector 19 within a relatively narrow range for a wide range of received signal intensities.

Referring now more particularly to the details of the band-pass selector system of this invention, that is, the band-pass selector 16 coupled between the intermediate-frequency amplifiers 14 and 17, the selector 16 comprises a parallel-tuned circuit, having a high Q and including an inductance 30 and a condenser 31, normally resonant in the vicinity of the frequency of the carrier wave to be translated, and a feed-back circuit for tuned circuit 30, 31 including a device having a nonlinear transfer characteristic. The non-linear device may comprise a vacuum tube 32 having its output circuit connected directly across tuned circuit 30, 31 and, in order to provide the required amplitude of signal input thereto, having its input circuit coupled to tuned circuit 30, 31 through a vacuum-tube amplifier 33. In order substantially to eliminate regeneration and degeneration through the feed-back path at the carrier frequency of the system at all signal levels, there is provided a network for effecting a 90-degree phase shift at the carrier frequency of the system between the signal derived from tuned circuit 30, 31 and the signal applied to the input circuit of vacuum tube 32, this network including

a condenser 34 connected in series with a parallel-connected resistor 35 and adjustably-fixed condenser 36 across tuned circuit 30, 31, and a parallel-connected inductance 39 and resistor 40 in the output circuit of tube 33. As used in this specification, the term "regeneration" is used in a broad sense to include both positive and negative regeneration. The signal voltage across parallel-connected resistor 35 and condenser 36 is applied to the input circuit of tube 33 through a coupling condenser 37 and a grid-leak resistor 38. A suitable bias is provided for the input circuit of tube 33 from a source -C, as indicated.

In considering the operation of the circuit described above, it will be seen that tuned circuit 30, 31 takes the place of the conventional band-pass selector including an intermediate-frequency transformer as a coupling device between intermediate-frequency amplifier tubes 15 and 18. The output current i_0 of any vacuum tube may be represented by the equation:

$$i_0 = A + A_1 e + A_2 e^2 + A_3 e^3 + \dots \quad (1)$$

where A, A_1 , A_2 , A_3 , etc., are coefficients depending on the particular tube utilized, and e is the input voltage of the tube. The operation of the present invention depends upon the fact that vacuum tube 32 has a nonlinear transconductance characteristic or an output current characteristic having a substantial cubic term, which means that the coefficient A_3 in Equation 1 has a substantial value relative to the other coefficients. The input voltage of tube 33, derived from tuned circuit 30, 31, is amplified in tube 33 and applied to the input terminals of tube 32, and shifted in phase 90 degrees with respect to the voltage across the tuned circuit. A nonlinear reactance is then supplied by the control tube 32 to tuned circuit 30, 31. If tube 32 has a substantially nonlinear characteristic under the circuit conditions described above, the effective selectivity of the tuned circuit 30, 31 is changed by the feed-back voltages and the effective selectivity of the circuit 16 depends on the amplitude of the output voltage of intermediate-frequency amplifier 14.

The term A of Equation 1 represents a direct current component. The term $A_1 e$ is a component at the carrier frequency which, with the 90-degree phase shift provided between tuned circuit 30, 31 and the input electrodes of tube 32, causes the tube 32 to reflect a fixed reactance independent of the signal input to the system into tuned circuit 30, 31. The effect of this component may, therefore, be eliminated by adjusting condenser 31 to provide the desired resonant frequency for tuned circuit 30, 31. The term $A_2 e^2$ is a component which may be resolved into a direct current and a current at double the signal frequency. Neither of these components influences the effective signal voltage across tuned circuit 30, 31.

The term $A_3 e^3$ may be resolved into currents at the original carrier frequency, at three times this frequency, and into sidebands of both of these frequencies. The carrier and sidebands at three times the original carrier frequency may be neglected since these components introduce no appreciable voltage into the tuned circuit 30, 31. The remaining current components of $A_3 e^3$ are at frequencies near the resonant frequency of the circuit 30, 31 and, when combined with the currents introduced from tube 15, determine the voltage components which exist at the same frequencies across the circuit 30, 31.

The phase relations of the currents from the

tubes 15 and 32 are such that, for the arrangement shown in Fig. 1, the carrier and upper sideband voltages across the tuned circuit 30, 31 are materially reduced by feedback, while the lower sideband voltage is either reduced to a lesser extent or is increased. The tendency for the lower sideband voltage to increase is confined to those sideband frequencies for which, because of the phase relations between the currents from the tubes 15 and 32, the circuit is positively regenerative. All of these effects increase as the input signal is increased since they depend on the cube of the voltage applied to the input of the nonlinear tube 32.

The usual modulated-carrier input signal comprises a carrier-wave component with two sidebands displaced equally and oppositely from the carrier-wave component of the signal. In most prior art band-pass selector systems, the arrangement is such as to affect both sidebands symmetrically with respect to the carrier-wave component of the signal. The arrangement of the present invention, however, has an asymmetrical effect upon the sidebands of the translated signal. It is, therefore, impractical to consider the selectivity characteristic of tuned circuit 30, 31 in the conventional manner. However, the over-all frequency-response characteristic of the system, as determined in the audio-frequency portion of the receiver, is also a measure of the effective selectivity of tuned circuit 30, 31. Such characteristics are shown in Fig. 2 in which curves *a*, *b*, *c*, and *d* represents the audio-frequency response characteristics of the receiver for different values of signal input to the selector system 16, such values progressively increasing from curve *a* to curve *d*. It is thus seen that, as the signal input to selector system 16 increases, the effective width of the pass band of selector 30, 31 also inherently increases. A mathematical analysis of the circuit of Fig. 1 indicates that the distortion components introduced by this type of selector system are small and this conclusion is borne out in practice, there being normally no distortion which is detachable by the human ear.

It will be understood that the tuned circuit of the invention may be utilized in combination with additional tuned circuits provided the nonlinear tube is connected only to the tuned circuit of the invention. Also it will be understood that a network for providing a phase shift of 90 degrees in the direction opposite that provided between tuned circuit 30, 31 and the input circuit of tube 32 may be utilized in place of the network illustrated in the drawing.

The following circuit values are given as illustrative of one embodiment of the invention:

Tube 32—Type 6J7
Tube 33—Type 6K7

Mean intermediate frequency kilocycles	150
Condenser 34—micro-microfarads	5
Resistor 35—ohms	10,000
Inductance 39—millihenries	4.5
Resistor 40—ohms	8,000
C bias voltage for tubes 32 and 33—volts	4.5
Signal input to selector 16 for curve <i>a</i> of Fig. 2—volts R. M. S.	0.022
Signal input to selector 16 for curve <i>b</i> of Fig. 2—volts R. M. S.	0.22
Signal input to selector 16 for curve <i>c</i> of Fig. 2—volts R. M. S.	0.45
Signal input to selector 16 for curve <i>d</i> of Fig. 2—volts R. M. S.	1.02

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit for said tuned circuit including a device having a nonlinear transfer characteristic and having input and output terminals, means for applying to said input terminals a voltage varying in accordance with the instantaneous amplitude of the voltage across said tuned circuit, means for applying the output current of said device to said tuned circuit to vary the voltage thereacross, and means for substantially eliminating regeneration and degeneration through said feed-back path at said carrier frequency, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

2. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output terminals, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, means for applying to said input terminals a voltage varying in accordance with the instantaneous amplitude of the voltage across said tuned circuit, means for applying the output current of said tube to said tuned circuit to vary the voltage thereacross, and means for substantially eliminating regeneration through said feed-back circuit at said carrier frequency, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

3. A modulated-carrier signal-translating stage comprising, a single tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output terminals, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, means for applying to said input terminals a voltage varying in accordance with the instantaneous amplitude of the voltage across said tuned circuit, means for applying the output current of said tube to said tuned circuit to vary the voltage thereacross, and means for substantially eliminating regeneration through said feed-back circuit at said carrier frequency, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

4. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output terminals, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, means for applying to said input terminals a voltage varying in accordance with the instantaneous amplitude of the voltage across said tuned circuit, means for applying the output current of said tube to said tuned circuit to vary the voltage thereacross, and means for substantially eliminating regeneration through said feed-back circuit at said carrier frequency, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

age to said tube over its normal operating range, means for applying to said input terminals a voltage varying in accordance with the amplitude of the voltage across said tuned circuit and 90 degrees displaced therefrom, and means for applying the output current of said vacuum tube to said tuned circuit to vary the voltage thereacross, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

5. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output terminals, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, means for applying to said input terminals a voltage varying in accordance with the amplitude of the voltage across said tuned circuit and 90 degrees displaced therefrom, said feed-back circuit being substantially less frequency-selective than said tuned circuit, and means for applying the output current of said vacuum tube to said tuned circuit to vary the voltage thereacross, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

6. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output terminals, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, means comprising a vacuum-tube amplifier for applying to said input terminals a voltage varying in accordance with the instantaneous amplitude of the voltage across said tuned circuit, means for applying the output current of said vacuum tube to said tuned circuit to vary the voltage thereacross, and means for substantially

eliminating regeneration through said feed-back circuit at said carrier frequency, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

7. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output terminals, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, means comprising a vacuum-tube amplifier for applying to said input terminals a voltage varying in accordance with the instantaneous amplitude of the voltage across said tuned circuit, said vacuum-tube amplifier having a substantially linear transconductance characteristic over its normal operating range, and means for substantially eliminating regeneration through said feed-back circuit at said carrier frequency, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

8. A modulated-carrier signal-translating stage comprising, a tuned circuit normally resonant in the vicinity of the frequency of the carrier wave to be translated, a feed-back circuit including a vacuum tube having input and output electrodes, said vacuum tube having an output current characteristic with a substantial component varying as the cube of the input voltage to said tube over its normal operating range, a network having a 90-degree phase shift at the frequency of said carrier, said input electrodes being coupled across said tuned circuit through said network and said output terminals being coupled directly across said tuned circuit, whereby the output current of said tube is effective to vary the voltage across said tuned circuit, thereby to vary the effective selectivity of said stage in accordance with the amplitude of the signal input thereto.

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