Oct. 8, 1940. J. F. FARRINGTON 2,216,998

BAND-PASS SELECTOR SYSTEM

Filed April 27, 1938

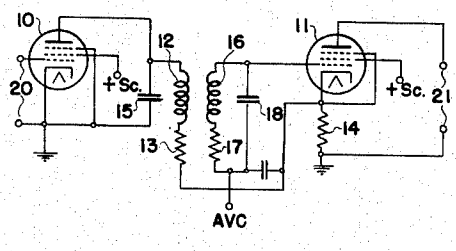


FIG.1.

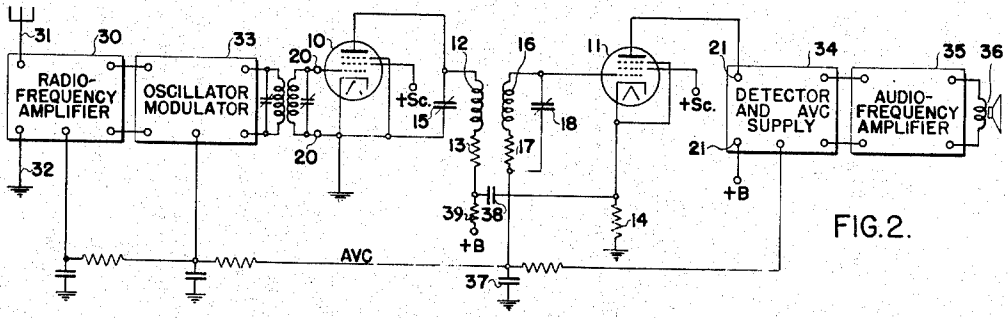


FIG.2.

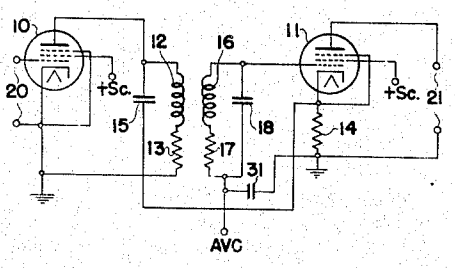


FIG.3.

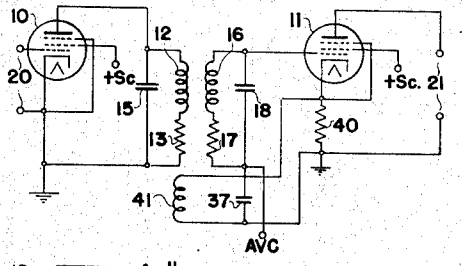


FIG.4.

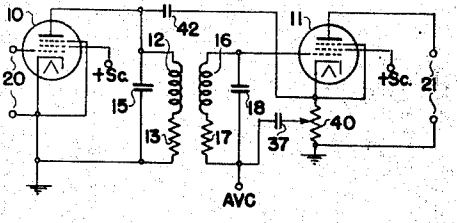


FIG.5.

INVENTOR
JOHN F. FARRINGTON
BY Laurence B. Dodds
ATTORNEY

Patented Oct. 8, 1940

2,216,998

UNITED STATES PATENT OFFICE

2,216,998

BAND-PASS SELECTOR SYSTEM

John F. Farrington, Flushing, N. Y., assignor to Hazeltine Corporation, a corporation of Delaware

Application April 27, 1938, Serial No. 204,528

17 Claims. (Cl. 179—171)

This invention relates to band-pass selector systems and, more particularly, to such systems in which the width of the frequency band transmitted through 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 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 responsiveness of this type of selector system is substantially constant 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 are attenuated to a substantial degree by the selector. In general, the width of the frequency band passed by such a system may be varied either by changing the coupling between the two circuits or by adjusting the resonant frequencies of the two circuits relative to each other. The couplings referred to are nondirective in nature; that is, either circuit may be made 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 each direction between the input and output circuits, wherein each of the couplings is primarily unidirective. Such a system is described and claimed in the copending application of Harold M. Lewis, Serial No. 70,172, filed March 21, 1936.

Band-pass selectors 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. Further, the conventional type of coupling referred to is inherently incapable of producing amplification of the transmitted signal components. Band-pass selector circuits employing unidirective couplings in the forward and backward directions between tuned terminal circuits, however, require a separate vacuum tube, or the equivalent, in each of the forward and backward coupling paths. Band-pass selectors are known in which the total coupling between the tuned terminal circuits is provided by a combination of directive and non-directive couplings. Such an arrangement is disclosed and claimed in United States Letters Patent No. 2,033,330, granted March 10, 1936, on the application of Leslie F. Curtis. That patent discloses an arrangement having inductive coupling between two tuned circuits in the signal-translating channel of a signal receiver and also having an additional directive coupling in the backward direction through a tube in the signal-translating channel preceding the tuned circuits.

It is an object of the present invention, therefore, to provide an improved band-pass selector system of simple arrangement in which the total coupling between the input and output circuits of the system is partially directive and partially nondirective and which is capable of uniformly translating a desired band of frequencies with sharp discrimination against all other frequencies.

It is another object of the invention to provide an improved band-pass selector system which is capable of amplifying in the coupling path the signal components transmitted through the system.

It is a further object of the invention to provide an improved band-pass selector system of the type described which is readily adjustable to vary the width of the frequency band transmitted by the system.

More particularly, it is an object of the invention to provide an improved band-pass selector system of the type described in which the width of the frequency band passed by the system may be varied by adjusting the value of a biasing potential applied to a control electrode of a vacuum tube connected in the signal-translating channel of the system at a point in the channel succeeding the coupled tuned circuits.

In accordance with the invention, a signal-translating channel comprises a band-pass selector system for passing a band of frequencies. The selector includes input and output tuned circuits resonant at frequencies within the band and mutual reactance means coupling the circuits, as well as unidirective coupling means coupling the circuits in the backward direction. The unidirective coupling means comprises a vacuum tube having input and output electrodes and an output circuit coupled to the output electrodes, while means are provided for impressing at least a portion of the voltage across one of the tuned circuits between the input electrodes. Means are also provided for deriving a voltage from the output circuit of the tube, having a phase substan-

tially independent of the impedance of the output circuit, and for coupling the derived voltage effectively in series in the other of the tuned circuits. The last-named coupling means are substantially less frequency-selective than the tuned circuits and co-operate with the tuned circuits to provide a coupling reaction between the tuned circuits which is regenerative at frequencies within the vicinity of the resonant frequencies and decreasingly regenerative at frequencies above and below the resonant frequency. To secure a unidirective form of coupling, an element having a directive transconductance, such as a vacuum tube, is thus included in the backward coupling means. In the preferred embodiments of the invention, this vacuum tube is included in the signal-translating channel at a point succeeding said tuned circuits. With this form of coupling between the circuits, the backward coupling may be varied at will by varying the value of transconductance of the directive coupling element, for example, with a control grid-biasing potential, to adjust the band-pass characteristic symmetrically with respect to the mean resonant frequency of the system. The response characteristics obtained are somewhat like those procured by symmetrically detuning a pair of loosely coupled tuned circuits as described in the paper entitled "High fidelity receivers with expanding selectors" by Wheeler and Johnson, published in "Proceedings of I. R. E.," June, 1935, at pp. 594–609. Further, in accordance with the invention, means may be provided whereby the grid-cathode capacitance of the vacuum tube comprising the directive coupling means may be held constant as the control grid-bias potential is changed to control the selective properties of the system. This prevents detuning of the output circuit of the selector and enables symmetrical expansion of the band-pass characteristic of the selector to be procured.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawing, in which Fig. 1 is a circuit diagram of an embodiment of the invention; Fig. 2 is a circuit diagram, partially schematic, of a radio broadcast receiver of the superheterodyne type employing a band-pass selector constructed in accordance with the invention; while Figs. 3–5, inclusive, illustrate different embodiments of the invention.

Referring now more particularly to Fig. 1 of the drawing, there is shown a band-pass selector comprising a tuned primary circuit coupled to the output electrodes of a vacuum tube 10 and a tuned secondary circuit coupled to the input electrodes of a second vacuum tube 11. The primary circuit comprises series-connected inductance 12, resistor 13 representing the inherent resistance of inductance 12, and resistor 14 across which is connected the tuning condenser 15. The secondary circuit comprises series-connected inductance 16 and resistor 17 representing the resistance of inductance 16, across which is connected a tuning condenser 18. Inductance 12 is inductively coupled to inductance 16, providing a mutual reactance means coupling the input and output tuned circuits. A load circuit (not shown) is provided for the output circuit of vacuum tube 11 and may be connected between the output terminals 21. Input terminals 20 are connected to the input circuit of tube 10.

In explaining the operation of the circuit of Fig. 1, it is assumed that both of the tuned circuits comprising the selector are resonant at the same frequency. Reference is made to the fact that, in the usual intermediate-frequency transformer having nondirective inductive coupling between the windings thereof, the primary current induces a voltage E_{12} in series with the secondary circuit. This secondary induced voltage causes a secondary current to flow which reacts on the primary circuit, inducing a counter voltage E_{21} in series with the primary circuit. This counter voltage has a marked effect on the magnitude and phase characteristics of the primary current as a function of frequency. The primary-current response curve exhibits a double peak at coefficients of coupling even less than optimum, because E_{21} represents a voltage that decreases rapidly on either side of the common resonant frequency of the primary and secondary circuits. This double-peaked primary current is masked in its effect on the secondary current at less than optimum coupling by the selectivity characteristics of the secondary circuit. However, at couplings greater than optimum, the secondary current characteristic also becomes double-peaked, although never to such a marked degree as the primary-current characteristic. When the circuits are overcoupled by mutual inductance, it is possible to procure a sharp overall response characteristic and wipe out the loss in transfer efficiency through the selector at the resonant frequency by introducing in series with the primary circuit a feed-back voltage of opposite phase to the counter voltage E_{21}. The resistor 14 in the cathode circuit of tube 11 of Fig. 1 provides such feed-back voltage when the mutual inductance between coils 12 and 16 is poled properly. This auxiliary feed-back voltage is proportional to the mutual conductance of amplifier tube 11. Consequently, by controlling the grid bias of this amplifier, the response characteristic of the selector may be varied from a condition of efficient signal transfer and high selectivity to one of lower signal transfer and broad selectivity. In the circuit of Fig. 1, amplifier tube 11 succeeds selector 12, 15, 16, 18 in the signal-translating channel of the system and is utilized to perform the dual function of providing the usual amplification and of providing the feed-back voltage in the primary circuit varying in accordance with its mutual conductance. Insofar as the band-pass characteristics of the selector are concerned, the circuit of Fig. 1, taking into account the transconductance of vacuum tube 11, gives response characteristics as if there were an effective coefficient of coupling k_{eff} between windings 12 and 16 of

$$k_{eff}=\sqrt{\frac{M^2-g_mR_kL_2M}{L_1L_2}}$$

where

M=the mutual inductance of windings 12 and 16.

g_m=the change in cathode current produced by unit change in control grid voltage.

R_k=resistance of resistor 14.

L_1=the self-inductance of winding 12.

L_2=the self-inductance of winding 16.

A suitable variable selector design is obtained by making M sufficiently large to obtain the desired maximum band width or peak separation

when the transconductance of tube 11 approaches zero and solving for R_k by setting $k_{eff}=0$. The resonance characteristic of the selector of the invention for $k_{eff}=0$ is the same as would be obtained if the tuned circuits 12,15 and 16,18 were in different stages of the system. The desired average power factor P_0 is obtained by selecting suitable values for coil resistances 13 and 17.

It will be understood that the vacuum tube 11 comprises a unidirective coupling means coupling the input and output tuned circuits in the backward direction and that the voltage derived from the ouput circuit of tube 11, which is fed back to the tuned circuit 12,15, has a phase substantially independent of the impedance of the output circuit of tube 11. It will also be understood that the directive coupling path comprising the transconductance of vacuum tube 11 and resistor 14 is substantially less frequency-selective than the tuned circuits 12,15 and 16,18 and that the directive coupling path co-operates with the tuned circuits to provide a coupling reaction therebetween which is regenerative at frequencies in the vicinity of the mean resonant frequency of the system and which is decreasingly regenerative at frequencies above and below said mean resonant frequency, in a manner more fully described in the above-mentioned Lewis application.

Fig. 2 is a circuit diagram, partially schematic, of the improved band-pass selector system, embodied in a broadcast receiver of the superheterodyne type, for controlling the selectivity of the intermediate-frequency channel of the receiver. Briefly described, the receiver comprises a radio-frequency amplifier 30 having input terminals connected to an antenna 31 and ground 32 and output terminals coupled to a frequency changer or oscillator-modulator 33. Connected in cascade with the output circuit of frequency changer unit 33, in the order named, are an intermediate-frequency amplifier comprising vacuum tube 10, a variable-band-pass selector system and intermediate-frequency amplifier comprising inductances 12 and 16 and vacuum tube 11, a detector and automatic amplification control unit 34, an audio-frequency amplifier 35, and a sound reproducer 36. The bias potential derived from the automatic amplification control source 34 may be applied to one or more of the stages of radio-frequency amplifier 30, the modulator included in frequency changer unit 33 and one or both of the intermediate-frequency amplifiers 10 and 11.

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 30 and is converted to a modulated intermediate-frequency signal by frequency changer 33. The signal as thus converted is further amplified in intermediate-frequency amplifiers 10 and 11 and detected by detector 34, thereby producing the audio frequencies of modulation which are, in turn, amplified by the audio-frequency amplifier 35 and reproduced by the sound reproducer 36. The amplification of the received signal is subject to automatic control by the control-bias potential derived from source 34 according to the manner well understood in the art.

Referring now more particularly to the details of the band-pass selector system constructed in accordance with this invention, the system comprises a band-pass selector and amplifier coupled between terminals 20 and terminals 21. The band-pass selector of Fig. 2 is similar in many respects to the band-pass selector of Fig. 1 and similar circuit elements have been given identical reference numerals. The band-pass selector of Fig. 2 differs from that of Fig. 1 only in the connection of the return lead of the grid circuit of vacuum tube 11 which, in the circuit of Fig. 2, is connected to ground through a blocking condenser 37 rather than directly to the cathode of tube 11 as in the circuit of Fig. 1. A decoupling resistor 39 is provided in the output circuit of tube 10.

The operation of the circuit of Fig. 2 is similar to that of Fig. 1 except that a desirable effect is secured, as is explained hereinafter in more detail, due to the fact that resistor 14 is included in the input circuit of tube 11.

The circuit of Fig. 3 is similar to the embodiment of the invention disclosed in Fig. 2, the primary difference being that the resistor 14 is included in the capacitive leg of tuned circuit 12,15 rather than in the inductive leg, as in Fig. 2. The circuit of Fig. 3 gives the same performance as the circuit of Fig. 2 provided the polarity of the coupling between inductances 12 and 16 is positive rather than negative as in the case of the couplings between the corresponding inductances of Fig. 2.

In the circuits of Figs. 1, 2, and 3 the effect of feed-back resistance 14 in lowering the effective Q ($\omega L/r$) of the primary circuit comprising inductance 12 and condenser 15 can be lessened to some extent by increasing the self-inductance of inductances 12 and 16 as well as the ratio of the inductance of winding 16 with respect to that of winding 12 within the limits of practicability.

In the embodiment of the invention disclosed in Figs. 4 and 5, the effect of the cathode feed-back resistor of the control tube 11 can be made negligible by employing an impedance transformation. Referring particularly to the circuit of Fig. 4, the selector is generally similar to that of the preceding figures and similar circuit elements have been given identical reference numerals. The cathode feedback resistor included in the output circuit of the control tube 11 has been given the reference numeral 40 to indicate that it is of a different order of magnitude than the cathode-resistor utilized in the circuits of Figs. 1, 2, and 3. The voltage across the cathode-resistor 40 is coupled into the primary tuned circuit comprising condenser 15 and inductance 12 by means of an auxiliary inductance 41 connected across resistor 40 and inductively coupled to inductance 12. The circuit is so proportioned that

$$\omega_0 L = SNR_k \text{ and } \omega_0 M_a = SR_k$$

where

ω_0=mean resonant angular frequency of the selector.

M_a=mutual inductance between windings 12 and 41.

N=any number greater than unity.

S=any number greater than 10.

NR_k=resistance of feed-back resistor 40.

L=self-inductance of winding 41.

The circuit of Fig. 5 is generally similar to the circuit of Fig. 4, the small capacitance 42 serving the same purpose as the mutual inductance between windings 12 and 41 of Fig. 4. Both circuits serve to introduce an impedance transformation

that minimizes the losses in the primary circuit. The circuit is so proportioned that

$$C_1 = NC_a$$

where

C_1=sum of the capacitances of condensers 16 and 42.

C_a=capacitance of condenser 42.

The value of N selected in either Fig. 4 or Fig. 5 has an identical effect on the performance of each circuit. In practice, NR_k, which is the value of resistor 40 of Figs. 4 and 5, is ordinarily made large enough to serve as a self-bias resistor for tube 11, which requires a resistance of around 250 to 350 ohms. R_k, which is the value of resistor 14 in Figs. 1, 2, and 3, is of the order of 20 ohms, thus making N about 15. Therefore, the resistance coupled into the primary circuit through the mutual inductance between inductance 12 and 41 of Fig. 4 or through the capacitive coupling of condenser 42 of Fig. 5 is only one to two ohms.

When the grid lead of tube 11 of the above circuit is returned to the cathode, as in the embodiment of Fig. 1, the performance of the system may, in certain applications, be impaired by the presence of inherent capacitance between the grid of tube 11 and ground. This capacitance causes an increase in the resonant frequency of the secondary circuit 16, 18 as the transconductance of control tube 11 is decreased. Inasmuch as any variation of the control tube input capacitance with transconductance shifts the secondary resonant frequency in the same direction, the response curve may become asymmetrical at low values of transconductance. However, with the grid return lead connected to ground, as shown in the embodiments of Figs. 2, 3, 4, and 5, the circuit is stabilized even when the input capacitance of vacuum tube 11 varies with variations of the transconductance of tube 11. This is true because the grid and cathode circuits of vacuum tube 11 in these embodiments of the invention complete a compensating circuit. A resistance component and a reactance component are thus reflected into circuit 16, 18 due to feedback from the voltage developed across the resistor which is common to the input and output circuits of tube 11. The resistance component is negative. The capacitance component is made up of two terms, one term of which is independent of frequency but which increases as the value of transconductance g_m of tube 11 decreases, and the other term of which is a function of frequency. The circuit is so proportioned that the second term is appreciably smaller than the first term. This can be done by returning screen and suppressor grids of tube 11 to ground rather than to its cathode. The circuit is then proportioned so that the desired compensation is secured. In case over-compensation for input capacitance variation with transconductance results from a particular circuit design, the grid return lead may be connected to a tap on resistor 14 or resistor 40, as shown in Fig. 5, to obtain exact frequency compensation. In case under-compensation results from a particular circuit design, the condenser 18 alone may be returned to a tap on resistor 40. It can be demonstrated mathmatically that the magnitude of the frequency shift, due to variation in transconductance of the control for a given value of cathode resistance, may be increased by directly inserting a portion of the cathode resistance in series with the capacitance branch 18 of the secondary circuit. As illustrative of a particular embodiment of the invention, the following circuit constants are given for an embodiment of the invention of the type disclosed in Fig. 3 in which the mean resonant frequency of the system is 450 kilocycles:

Tube 10	Type 6A8
Tube 11	Type 6K7
Inductance 12	0.52 millihenrys
Q of primary circuit 12, 15	115
Inductance 16	0.466 millihenrys
Q of secondary circuit 16, 18	115
Mutual inductance between windings 12 and 16	18 microhenrys
Resistor 14	20 ohms
Inductance in anode circuit of tube 11	0.6 millihenrys

As illustrative of another embodiment of the invention in a system having a mean frequency of 450 kilocycles, the following circuit constants are given for an embodiment of the circuit of Fig. 5:

Tube 10	Type 6A8
Tube 11	Type 6K7
Inductance 12	0.52 millihenrys
Q of primary circuit 12, 15	115
Inductance 16	0.466 millihenrys
Q of secondary circuit 16, 18	115
Resistor 40	250 ohms
Condenser 42	30 micro-microfarads
Inductance in the anode circuit of tube 11	0.6 millihenrys

In each of the foregoing examples, the tube 10 is specified as a pentagrid converter tube of the type 6A8 and an embodiment utilizing a tube of this type is suitable for use as an oscillator-modulator, for instance, as the oscillator-modulator 33 of the receiver of Fig. 2. However, tube 10 may be a conventional pentode, as illustrated in the drawing, if the tube is to be utilized as an intermediate-frequency amplifier in a radio receiver, as shown in Fig. 2.

It will be understood that operating potentials, together with suitable blocking condensers to restrict the flow of direct currents to the tube circuits, are provided for the circuits of Figs. 1, 3, 4, and 5 in a conventional manner.

While there have been described what are at present considered to be the preferred embodiments 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 signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having input and output electrodes and an output circuit coupled to said output electrodes, means for impressing at least a portion of the voltage across one of said tuned circuits between said input electrodes, and means for deriving a voltage from the output circuit of said tube having a phase substantially independent of the impedance of said output circuit and

for coupling said derived voltage effectively in series in the other of said tuned circuits, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of the resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

2. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having a variable transconductance and having input and output electrodes and an output circuit coupled to said output electrodes, means for impressing at least a portion of the voltage across one of said tuned circuits between said input electrodes, and means for deriving a voltage from the output circuit of said tube having a phase substantially independent of the impedance of said output circuit and for coupling said derived voltage effectively in series in the other of said tuned circuits, means for varying said transconductance to vary the effective coupling between said circuits, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

3. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having input and output electrodes and an output circuit coupled to said output electrodes, means for impressing at least a portion of the voltage across said output tuned circuit between said input electrodes, and means for deriving a voltage from the output circuit of said tube having a phase substantially independent of the impedance of said output circuit and for coupling said derived voltage effectively in series in said input circuit, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of the resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

4. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having input and output electrodes and an impedance coupled between said output electrodes, said input electrodes being effectively coupled directly across at least a portion of said output tuned circuit, means for deriving a voltage from the output circuit of said tube having a phase substantially independent of said impedance and for effectively coupling said voltage in series in said input tuned circuit, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

5. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having variable transconductance and having input and output electrodes and an impedance coupled between said output electrodes, said input electrodes being effectively coupled directly across at least a portion of said output tuned circuit, means for deriving a voltage from the output circuit of said tube having a phase substantially independent of said impedance and for effectively coupling said voltage in series in said input tuned circuit, means for varying said transconductance to vary the effective coupling between said circuits, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

6. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a repeater in said signal channel having input and output electrodes, said input electrodes being coupled to said output circuit, an impedance in the load circuit of said vacuum tube, and a circuit for deriving from said load circuit a voltage having a phase substantially independent of said impedance and for coupling said voltage into said input circuit, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of the resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

7. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said selector comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum-tube repeater in said channel at a point succeeding said tuned circuits and having input

and output electrodes, said input electrodes being coupled to said output circuit, a cathode-resistor for said vacuum tube, and a circuit for coupling at least a portion of the voltage developed across said resistor to said input circuit, said coupling means being substantially less frequency-selective than said input and output circuits and co-operating with said circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

8. A signal-translating channel including a band-pass selector system for passing a band of frequencies, said selector system comprising input and output circuits resonant at frequencies within said band, means comprising mutual reactance coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective means comprising a vacuum-tube repeater in said channel having input electrodes coupled to said output circuit, and a cathode-resistor for said vacuum tube, said resistor being effectively coupled in series in said input circuit, said coupling means being substantially less frequency-selective than said input and output circuits and co-operating with said input and output circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

9. A signal-translating channel including a band-pass selector system for passing a band of frequencies, said system comprising input and output circuits resonant at frequencies within said band, said input circuit comprising a capacitance leg, means comprising positive mutual inductance coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum-tube repeater in said channel having input electrodes coupled to said output circuit, and a cathode-resistor for said vacuum tube, said resistor being effectively coupled in series in said capacitance leg, said coupling means being substantially less frequency-selective than said input and output circuits and co-operating with said input and output circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

10. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said system comprising input and output circuits resonant at frequencies within said band, means comprising mutual reactance coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum-tube repeater having a variable transconductance in said channel at a point succeeding said tuned circuits and having input electrodes coupled to said output circuit, a cathode-biasing resistor for said vacuum tube, said resistor being effectively coupled in series in said input circuit and in the input circuit of said tube, and means for varying said transconductance, said coupling means being substantially less frequency-selective than said input and output circuits and co-operating with said input and output circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and and decreasingly regenerative at frequencies above and below said resonant frequencies.

11. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said system comprising input and output circuits resonant at frequencies within said band, means comprising mutual reactance coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube in said channel having input electrodes coupled to said output circuit, a cathode-biasing resistor for said vacuum tube, and impedance transforming means for coupling at least a portion of the voltage across said resistor into said input circuit, said coupling means being substantially less frequency-selective than said input and output circuits and co-operating with said input and output circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

12. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said system comprising input and output circuits resonant at frequencies within said band, means comprising mutual reactance coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum-tube repeater in said channel having input electrodes coupled to said output circuit, a cathode-biasing resistor for said vacuum tube, and means comprising an inductance inductively coupled to said input circuit for coupling at least a portion of the voltage across said resistor into said input circuit, said coupling means being substantially less frequency-selective than said input and output tuned circuits and co-operating with said circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

13. A signal-translating channel comprising a band-pass selector system for passing a band of frequencies, said system comprising input and output circuits resonant at frequencies within said band, means comprising mutual reactance coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube in said channel having input electrodes coupled to said output circuit, a cathode-biasing resistor for said vacuum tube, and means comprising a condenser effectively coupled to said input circuit for coupling at least a portion of the voltage across said resistor to said input circuit, said coupling means being substantially less frequency-selective than said input and output circuits and co-operating with said circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

14. A band-pass selector system for passing a band of frequencies comprising input and output tuned circuits resonant at frequencies within said

band, coupling means coupling said circuits in one direction, unidirective coupling means coupling said circuits in the other direction, said unidirective coupling means comprising a vacuum tube having variable transconductance and having input electrodes coupled to one of said circuits and output electrodes coupled to the other of said circuits, means for adjusting said transconductance to vary the coupling between said circuits, and means for substantially eliminating variations in the input capacitance of said vacuum tube with variations in its transconductance, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

15. A band-pass selector system for passing a band of frequencies comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance coupling means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having a variable transconductance and having input electrodes coupled to said output circuit and output electrodes coupled to said input circuit, a cathode-biasing resistor for said vacuum tube, means for varying said transconductance to vary the effective coupling between said circuits, means comprising said cathode-resistor for preventing a variation in the input capacitance of said tube with variations in said transconductance, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said circuits which is regenerative at frequencies within the vicinity of said resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

16. A band-pass selector system for passing a band of frequencies comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having a variable transconductance and having input electrodes coupled to said output circuit and output electrodes coupled to said input circuit, a cathode-biasing resistor for said vacuum tube, means for varying said transconductance to vary the effective coupling between said circuits, means comprising an adjustable portion of said cathode-resistor for preventing a variation in the input capacitance of said tube with variations in said transconductance, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of the resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

17. A band-pass selector system for passing a band of frequencies comprising input and output tuned circuits resonant at frequencies within said band, mutual reactance coupling means coupling said circuits, unidirective coupling means coupling said circuits in the backward direction, said unidirective coupling means comprising a vacuum tube having a variable transconductance and having input electrodes coupled to said output circuit and output electrodes coupled to said input circuit, a cathode-biasing resistor for said vacuum tube, means for varying said transconductance to vary the effective coupling between said circuits, means comprising said cathode-resistor for effecting a variation in the input capacitance of said tube with variations in said transconductance, the value of said resistor being a compromise between the value required for cathode biasing, band width adjusting and eliminating variation in the input capacitance of said tube with transconductance, said coupling means being substantially less frequency-selective than said tuned circuits and co-operating with said tuned circuits to provide a coupling reaction between said tuned circuits which is regenerative at frequencies within the vicinity of the resonant frequencies and decreasingly regenerative at frequencies above and below said resonant frequencies.

JOHN F. FARRINGTON.