

June 3, 1941.

J. PLEBANSKI

2,244,259

ELECTRIC TRANSMISSION NETWORK

Filed Nov. 7, 1938

2 Sheets-Sheet 1

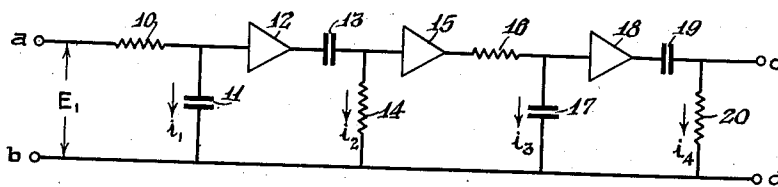


Fig. 1

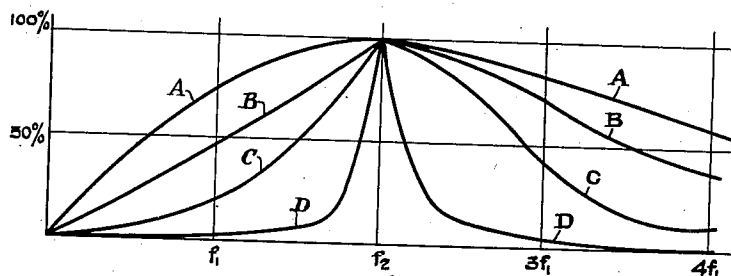


Fig. 2

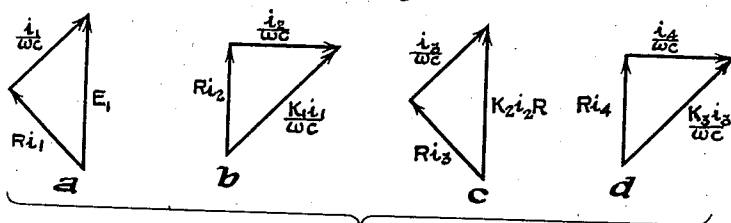


Fig. 3

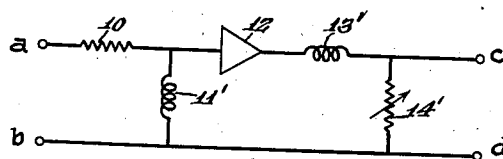


Fig. 4

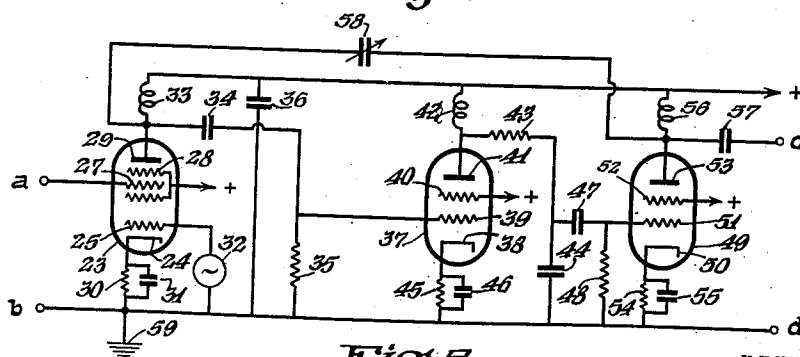


Fig. 5

INVENTOR.

BY

Jozef Plebanski

Att. Pleb.

ATTORNEY.

June 3, 1941.

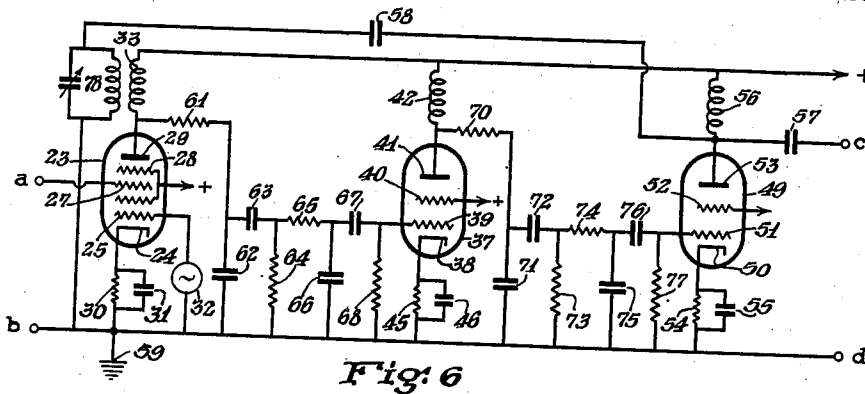
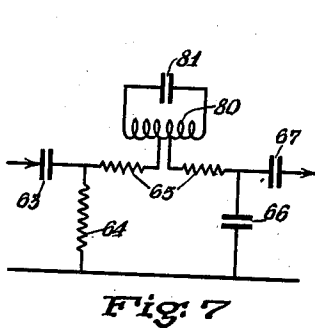
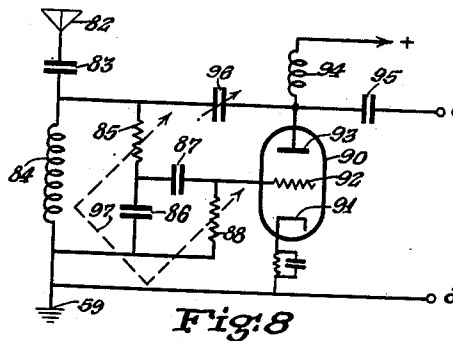
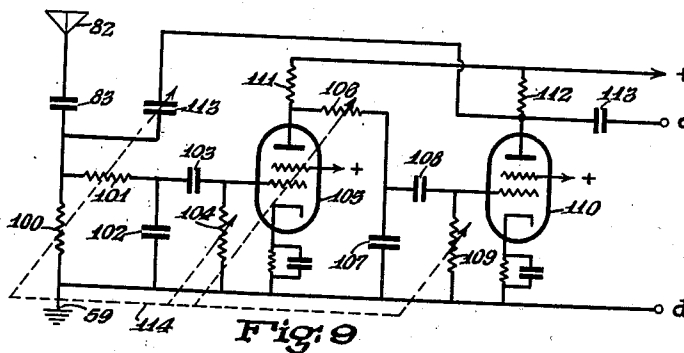
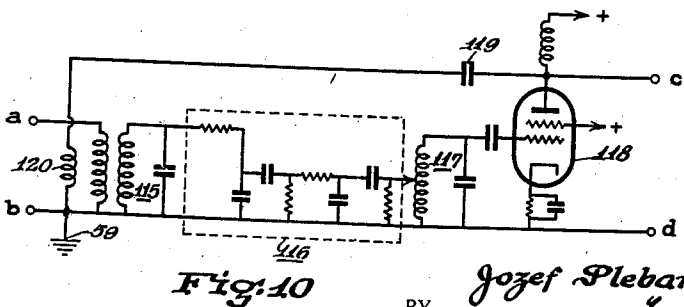
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,244,259

ELECTRIC TRANSMISSION NETWORK

Jozef Plebanski, Warsaw, Mokotow, Poland, assignor to Radio Patents Corporation, a corporation of New York

Application November 7, 1933, Serial No. 239,235
In Poland December 31, 1937

7 Claims. (Cl. 178—44)

The present invention relates to means for and a method of translating electric wave energy comprising a plurality of components of different frequencies such as an audio frequency or any other signalling frequency band.

An object of the invention is to provide a frequency discriminating or selective network more particularly of the band-pass type comprising solely ohmic impedances and reactive impedances of like type such as either condensers or induction coils as compared with the conventional selective circuits or filters comprising both capacitative and inductive reactance elements.

A more specific object is to provide a frequency discriminating network or filter having a maximum or "resonance" frequency and being comprised solely of ohmic resistances and capacity elements.

Another object is to provide a filter or frequency discriminating network having a "resonance" or maximum response frequency and comprising solely ohmic resistances and inductive reactance elements.

A further object is to provide a filter or translation circuit for electric wave energy having a band-pass characteristic with sharp cut-off characteristics and comprised solely of ohmic resistances and either capacitative or inductive reactance elements.

A still further object is to provide a frequency discriminating network or filter whose electrical characteristics such as its band width or "resonance" frequency may be controlled in an easy and efficient manner by adjusting one or more of the filter elements.

A further object is to provide a multiple section filter or network of the band-pass type which may be adjusted or tuned in a simple manner to a desired frequency or band of frequencies.

The above and further objects as well as aspects of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of this specification and wherein:

Figure 1 shows a multi-section "tunable" filter network according to the invention and comprised solely of ohmic resistances and capacity elements.

Figure 2 is a graph showing a set of response curves explanatory of the function and novel effects obtained with a system according to Figure 1.

Figure 3 shows a set of vector diagrams being further explanatory of the function and operation of Figure 1.

Figure 4 illustrates a similar filter to Figure 1 embodying inductive reactances and means for adjusting its maximum frequency.

Figure 5 is a diagram showing a three-stage amplifier with intercoupling networks or filter sections interposed between the amplifying stages to obtain a band-pass effect in accordance with the invention.

Figure 6 is a modified diagram of a band-pass amplifier of the type according to the invention.

Figure 7 is a partial diagram illustrating an improvement of the filter network embodied in Figure 6.

Figure 8 illustrates a further embodiment of an adjustable or tunable filter of the type according to the invention embodied in a radio receiver.

Figure 9 illustrates a modification of Figure 8.

Figure 10 shows a combination of a filter network according to the invention with standard resonant circuits known in the art.

Similar reference characters identify similar parts throughout the different views of the drawings.

Referring more particularly to Figure 1, there is shown a diagram of a multi-section filter or four pole network having a pair of input terminals, *a*, *b* and a pair of output terminals *c*, *d*. The filter in the example illustrated comprises four sections, each section consisting of a series combination of an ohmic resistance and a capacity element, and amplifiers or uni-lateral conducting devices interposed between the successive filter sections. According to the diagram shown, there is shunted across the input terminals, *a*, *b* a resistance 10 in series with a capacity 11 thereby causing a current *i*₁ through this series circuit by an impressed potential *E*₁ which may be an audio frequency, intermediate or radio frequency potential and comprise an extended band of component frequencies. The capacitive voltage drop produced across the condenser 11 is impressed upon the input of an amplifier schematically shown at 12 and the amplified output current *i*₂ passed through a similar series section comprising a condenser 13 and a resistance 14 in series. The potential drop produced across the resistance 14 is in turn impressed upon the input of a further amplifier 15 and the amplified current *i*₃ passed through the next filter section comprising a resistance 16 and a condenser 17 in series. The capacitive potential drop across the condenser 17 is in turn applied to the input of a third amplifier 18 having condenser 19 and resistance 20 forming a further series section inserted in its output circuit. The ohmic

resistance drop produced by the output current i_4 across resistance 20 may be applied through the output terminals, c, d to a further filter section or to a utilization circuit as may be desired, depending on existing requirements.

By using a system or filter of this type comprising a plurality of series sections each consisting of a resistance and a reactive impedance such as a condenser, as shown in the example, and by alternately impressing the reactive and ohmic potential drops from one section upon the next succeeding section preferably through individual amplifiers interposed between the sections, frequency response or "resonance" curves are obtained having a shape as shown in Figure 2. In the latter the abscissae represent in a known manner the frequency of the impressed input potential E_1 while the ordinates represent the response such as the output current i_4 or potential drop across 20 for equal amplitudes of the input potentials. As is seen the response curves have a definite maximum or "resonance" frequency determined by the constants of the filter elements and defined more sharply as the number of the sections is increased. Thus, curve A in Figure 2 corresponds to a two-section filter, while curves B, C, and D correspond to filters having a successively increased number of series sections connected in the manner described.

In a preferred form of filter or network of the type shown in Figure 1, all ohmic resistances 10, 14, 16, 20 and the capacities 11, 13, 17, 19 are equal in which case it is found by theoretical analysis that the response or potential drop at the output of the n th section will be as follows:

$$i_n R = \frac{ER^{\frac{n}{2}}}{(wC)^{\frac{n}{2}} \sqrt{R^2 + \frac{1}{w^2 C^2}}}$$

wherein R represents the resistance, C the capacity for all sections and w is the frequency of the impressed potential in radians per second.

It is obvious from the above that such a "tuned" circuit can be used in place of the usual resonant or filter networks. As is further understood similar conditions will prevail if the condensers in Figure 1 are replaced by induction coils. Maximum response or "resonance" is obtained when the ohmic and reactive potential drops in each section are equal to each other that is for

$$\frac{1}{wC} = R$$

in case of a resistance capacity network or $wL = R$ in case of a resistance inductance network from which the resonance frequency is obtained as follows:

$$w = \frac{1}{RC} \text{ or } \frac{R}{L}$$

Referring to Figure 3 there are shown the vector diagrams for the resonance frequency. According to diagram 3a the input potential E_1 is equal to the vectorial sum of the resistive voltage drop Ri_1 (resistance 10) and the capacitive voltage drop

$$\frac{i_1}{wC}$$

(capacity 11) both voltage drops being in phase quadrature relative to each other. Since both impedances are equal to each other in the "resonance" condition under consideration the re-

sistive voltage drop leads the impressed potential by 45° while the capacitive voltage drop lags the impressed potential by the same phase angle. In Figure 3b there is shown the vector diagram for the second section wherein

$$\frac{K_1 i_1}{wC}$$

represents the amplified capacitive voltage derived from the condenser 11 through the amplifier 12. This amplified voltage in turn is equal to the vectorial sum of the resistive drop Ri_2 (resistance 14) and the capacitive drop

$$\frac{i_2}{wC}$$

(capacity 12) the former leading and the latter lagging the amplified voltage

$$\frac{K_1 i_1}{wC}$$

Figure 3 shows the diagram for the third section comprising the amplified voltage $K_2 i_2 R$ derived from the drop across resistance 14 through the amplifier 15. This output voltage in turn is equal to the vectorial sum of the resistive drop Ri_3 (resistance 16) and the capacitive drop

$$\frac{i_3}{wC}$$

(capacity 17) the former leading and the latter lagging the voltage $K_2 i_2 R$. Finally, in the fourth section as shown in Figure 3d, the amplified output voltage

$$\frac{K_3 i_3}{wC}$$

derived from the capacitive drop across capacity 17 through amplifier 18 is equal to the vectorial sum of the resistive or output potential drop Ri_4 across resistance 20 and the capacitive potential drop

$$\frac{i_4}{wC}$$

(capacity 19). Similar conditions prevail if the resistive and reactive impedances of the several sections are unequal, that is if the frequency differs from the "resonance" or maximum frequency. In either case, it is seen that the phase of the impressed voltage is rotated in one section by a certain angle in one direction and in the reversed direction by the same angle in the succeeding section in such a manner that by employing an even number of sections the output voltage (Ri_4 in the example described) will be in phase with the impressed voltage (E_1) or in phase opposition in considering the reversals by 180° if using discharge amplifiers such as three electrode electron tubes of known type. This characteristic is of importance if it is desirable to employ positive or negative feedback from the output of a section at a higher oscillation level to a point of the amplifier at a lower oscillation level.

Referring to Figure 4, there is shown a two section filter or network similar to Figure 1 and comprising induction coils 11' and 13' in place of condensers. There is further shown in this figure a variable resistance 14' by means of which the maximum or resonance frequency may be adjusted as will be obvious from the above. The greater the resistance, the lower will be the frequency as is understood from the foregoing relationship. This constitutes an important feature of the invention in that it is possible in this manner to adjust the entire filter by varying one or

more elements thereof. For "tuning" purposes it is desirable to employ ganged elements for simultaneously adjusting all of the filter sections in a manner as is customary with the usual tuning systems in multi-stage amplifiers, as will be described in greater detail hereafter. It will be obvious that the amplifiers interposed between the filter sections may be omitted or any other type of uni-lateral conducting devices may be employed in place of amplifiers between one section and the preceding section of the filter.

Referring to Figure 5 there is shown a three stage vacuum tube amplifier in the example illustrated an intermediate frequency amplifier for use in a superheterodyne receiving system. It is to be understood, however, that an intermediate frequency amplifier is shown for illustrating purpose only and that the circuit and improvements described may be employed with equal advantage in any other type of amplifying or translation system. Referring more particularly to the exemplification illustrated, wave energy such as high frequency or intermediate frequency signals which may be derived from an antenna, transmission line, etc., are impressed through input terminals *a, b* across the grid 27 and cathode 24 of an electronic mixer tube 23 or frequency changer of known construction and comprising a local oscillation grid 25, a screen grid 28 surrounding the signal input grid 27 and an anode 29. Item 30 is a resistance shunted by a by-pass condenser 31 and arranged in the cathode-to-ground (59) lead of the tube to provide suitable grid biasing potential in a manner well known in the art. Local oscillations of different frequency produced by a generator 32 are impressed upon the grid 25, whereby in a known manner signals of intermediate frequency equal to the difference between the frequency of the input signals applied through *a, b* and the frequency of the local oscillations produced by the generator 32 are generated in the output circuit of the tube. In place of a separate generator or local oscillator 32 a further positive grid may be provided with an oscillating circuit connected thereto and to the grid 25 in a known manner. The anode 29 is connected to a high tension supply source indicated by the + sign through a suitable coupling impedance such as an induction coil 33 in the example shown. By proper design of the impedance 33 potential variations at intermediate frequency are produced at the anode and impressed upon the grid of an amplifier tube 37 through a first series section comprising a condenser 34 and resistance 35 shunting the anode cathode path of the tube 23. The resistive voltage drop generated across the resistance 35 is impressed across the grid 39 and cathode 38 of the amplifier 37, the latter comprising further a screen grid 40 and anode 41. Item 36 is a large by-passing condenser between the high potential terminal and ground. Item 42 is a coupling impedance connected between the anode 41 and the + terminal of the high tension source to produce amplified potential variations at the anode 41. The latter are impressed upon a second series filter section comprising a resistance 43 and a condenser 44. Items 45 and 46 are a resistance-capacity shunt combination placed between the cathode 38 and ground to provide suitable grid biasing potential for the tube 37. The capacitive voltage drop produced across the condenser 44 is impressed across the grid 51 and cathode 50 of a third amplifying tube 49 by means of a coupling condenser 47 and grid

leak 48. The tube 49 comprises further a screen grid 52 and anode 53. A resistance-capacity shunt combination 54 and 55 is inserted in its cathode-to-ground lead to provide proper grid bias. The anode 53 is connected to the high tension source through a coupling inductance 56 to produce potential variations to be impressed to an output or utilization circuit connected to terminals *c, d* through a coupling condenser 57.

As is seen from the foregoing the amplifier described constitutes a two-section filter of the type according to Figure 1 the first section being comprised of condenser 34 in series with resistance 35 and the second section comprising resistance 43 and condenser 44.

A "tunable" or adjustable circuit of the type according to the invention, while resembling in many respects the conventional oscillatory or resonance circuits having both inductance and capacity, differs however from the latter in that no magnification of the signal potentials takes place due to the natural resonance or oscillating characteristics of the circuit. This disadvantage, however, can be substantially minimized or eliminated by employing feedback or regeneration from a point at a higher oscillation level to a point at a lower oscillation level of the amplifier. Such a feedback path is shown in Figure 5 connected between the anode of tube 49 and the anode of tube 23 or input of the first filter section 34, 35 and including an adjustable condenser 58 for controlling the amount of feedback or regeneration. It is to be pointed out that in this case of direct feedback, that is without the use of a feedback transformer the feedback potential should be derived from the output of a stage of even order, i. e., the 2nd, 4th, 6th, etc., stage so as to be in phase with the potential at the point reacted upon, that is the potential at the anode 29 of tube 23 in the example illustrated. This requirement is also necessary in view of the fact that the phase of the signal voltage is alternately advanced and retarded in the successive series sections constituting the filter system as described hereinabove. Thus by deriving the feedback potential from the output of a stage of even order, that is the 2nd, 4th, 6th, etc., stage, the phase rotation effected through the filter sections is compensated thereby ensuring a positive feedback or regeneration.

Referring to Figure 6, there is shown an amplifier with a modified filter arrangement compared with the previous illustrations. The filter networks embodied as shown in Figure 6 differ from the previous arrangements such as Figure 1 in that the amplifiers or uni-lateral conducting devices between the successive sections are omitted thereby obtaining a plurality of low-pass, high-pass sections directly connected in tandem. Filters of this type have a somewhat broader, or less sharply pronounced response characteristic compared with the previous arrangements, however a greater cut-off or discriminating effect may be obtained by additional features and improvements incorporated in the system shown by Figure 6. According to the latter, the potential variations at intermediate frequency produced at the anode 29 of the mixer valves 23 are impressed upon a multiple section filter having a first section comprising a resistance 61 in series with a capacity 62. The capacity 62 is shunted by a second section comprising a capacity 63 in series with a resistance 64. This second section is in turn shunted by a third section comprising a resistance 65 in series with a capacity 66. The

latter is in turn shunted by a fourth section of the filter comprising a capacity 67 and resistance 68 in series. The resistive voltage developed across the resistance 68 is impressed across the grid-cathode path of the second amplifying tube 37 in a manner similar to the preceding circuit. The potential variations at the anode 41 of the tube 39 are impressed upon a similar multi-section filter including a first section comprised of a resistance 70 in series with the condenser 71. The latter is shunted by a second filter section comprised of a condenser 72 in series with a resistance 73, the latter being in turn shunted by a resistance 74 and a condenser 75 forming a third section of the filter. The fourth section comprises a condenser 76 and resistance 77 being connected across condenser 75 in a manner substantially similar to the filter preceding the tube 37. The resistive voltage developed across the resistance 77 is impressed across the grid-cathode 50 path of the third amplifying tube 49 in a manner similar to the preceding circuit. A system of this type has a comparatively flat frequency characteristic and in order to improve the sharpness of the band or frequency cut-off there is provided a feedback path connected between the anode 53 of the third amplifying stage 49 and the anode circuit 33 of the first or mixer tube 23 which forms the input to the filters 61-68. This feedback path differs from the feedback path in Figure 5 in that it includes a tuned circuit of standard design 78 comprising a capacity shunted by an inductance, the latter being arranged in inductive relation with the coupling inductance 33 in the anode circuit of tube 23. In this manner, a band-pass characteristic with improved cut-off effects is obtained for a multi-stage amplifier such as an intermediate frequency amplifier which has the advantage over the known multistage selective amplifiers that only a single tuned circuit is required, thus eliminating substantially the problems of adjustment and alignment of the several stages and other drawbacks of the conventional circuits.

A further means for improving the cut-off effect or sharpness of a resistance-capacity filter of the type shown in Figure 6 consists in the provision of an anti-resonant or parallel tuned circuit in series with one or more of the filter elements such as shown in the partial diagram according to Figure 7. In the latter, a parallel tuned circuit comprising an inductance 80 shunted by a condenser 81 is connected to the resistance 65 to act as an absorption circuit for frequencies equal to its resonance frequency which is chosen to be equal or near to the desired cut-off frequency of the filter. In the example shown a portion of the inductance 80 is serially inserted in the center of the resistance 65. Two such circuits may be associated with the filters 61-68 and 70-77, respectively, one of which circuits is tuned to the lower cut-off frequency and the other is tuned to the higher cut-off frequency of a desired frequency response band to be passed by the amplifier or filter system. As is understood, the tuned circuit 80, 81 may also be inserted in series with one of the shunt paths (resistance 64) of the filter and tuned to a frequency near or equal to the cut-off frequency of the filter but within the band to be transmitted.

Referring to Figure 8 there is shown a radio receiving system having embodied therein an adjustable filter network according to the invention as a tuning element. The circuit shown

comprises an antenna 82 connected to ground through a coupling condenser 83 and input inductance 84. The inductance 84 is shunted by the first section of the adjustable filter comprising a resistance 85 in series with a condenser 86. The latter is in turn shunted by a second filter section comprising a condenser 87 in series with resistance 88. The potential drop developed across the resistance 88 is impressed upon the grid-cathode path of an amplifying tube 90 comprising a cathode 91, grid 92, and anode 93, and forming the input stage of the receiver. The anode 93 is connected to the + terminal of a high tension source through a coupling inductance 94 on one hand and to the terminal c through a coupling condenser 95 on the other hand. The terminals c, d, may be connected to a second stage of amplification or any other utilization or output circuit as may be desired. There is further shown a variable feedback condenser 96 placed between the anode 93 and the upper end of the input inductance 84. The resistances 85 and 88 are variable and connected through a common adjusting element indicated at 97 to provide uni-control for "tuning" the receiver to a desired signal frequency.

Referring to Figure 9, there is shown a modified receiving system comprising resistance and capacity elements only. An input impedance 100 in series with the antenna circuit is shunted by the first section of an input filter comprising a resistance 101 in series with a capacity 102. The latter is shunted by the second filter section comprised of a capacity 103 in series with a resistance 104. The voltage drop developed across the latter is impressed across the grid-cathode path of a first amplifying tube 105. The latter has a coupling resistance 111 placed between its anode and the high potential supply source. The potential variations developed at the anode of the tube 105 are transmitted to a second amplifier 110 through a filter network having a first section comprised of a resistance 106 in series with a condenser 107 and a second section connected across the condenser 107 and comprised of a condenser 108 in series with a resistance 109. Resistance 109 is connected across the grid-cathode path of the amplifier 110, the latter having a coupling resistance 112 inserted between its anode and the high potential source and coupling condenser 113 placed between the anode and terminal c. Feedback potential is applied from the anode of tube 110 through a variable condenser 113 to the junction between resistances 100 and 101, i. e. the input to the first section of the input filter network connected to the antenna circuit. Resistances 101, 103, 106, 109 as well as the variable feedback condenser are shown connected or ganged through a common adjusting element schematically indicated at 114 whereby with the proper design of the condenser 113 and the resistance elements uni-control may be effected in a simple and sufficient manner to adjust the entire receiver to a desired frequency.

Referring to Figure 10, there is shown a combination of conventional tuning circuits comprising both capacity and inductance with an aperiodic network or filter of the type according to the invention. In the arrangement shown input potentials which may be derived from an antenna transmission line or any other source are impressed from terminals a, b inductively upon a parallel tuned circuit 115. The latter is in turn connected to a filter network 116 of the type shown by the invention the output of which is

applied to a further tuned circuit 117 serving to control amplifying tube 118. Amplified output currents are fed back through a condenser 119 and feedback coil 120 upon the input circuit 115.

In place of direct feedback or regeneration it may be desirable to employ a negative feedback, as is the case in Figure 8, to obtain certain advantages such as reduction of noise or distortions, etc. If an inverse or negative feedback is desired the feedback potential should be derived from the output of the 1st, 3rd, 5th stage unless a transformer is provided in the feedback path as shown in Figure 6. Furthermore, it is necessary in order to obtain the proper phase relation that an even number of filter sections is provided between successive stages such as shown in Figure 6 in order to compensate for the phase rotation effected by the several sections of the filters as will be understood from the above.

It will be evident from the foregoing that the invention is not limited to the specific arrangement of parts and elements of steps disclosed herein for illustration but that the novel underlying idea and principle of the invention are susceptible of numerous modifications and variations coming within the broader scope and spirit of the invention as defined in the appended claims. The specification and drawings are to be regarded in an illustrative rather than a limiting sense.

I claim:

1. In a system for translating signal wave energy comprising a band of component frequencies, a plurality of amplifying valves connected in cascade, inter-coupling valve networks each comprising an ohmic resistance and a reactance of the same kind in series, said resistance and reactance being designed to have equal impedance for the center frequency of the band to be translated, an input circuit coupled to the first valve and an output circuit coupled to the last valve, means for deriving input voltages for successive amplifying stages alternately from the ohmic and reactive potential drop produced by the respective networks, and means for feeding back potential from the output of a valve stage of higher order to the coupling network of a preceding valve stage of even lower order.

2. In a system for translating signal wave energy comprising a band of component frequencies, a plurality of amplifying valves connected in cascade, intercoupling valve networks each comprising an ohmic resistance and a condenser in series, the reactance of the condenser and resistance of each network being equal for the center frequency of the band being translated, an input circuit coupled to the first valve and an output circuit coupled to the last valve, means for deriving input voltages for successive amplifying stages alternately from the ohmic and capacitative potential drop produced by the respective networks, and means for feeding back potential from the output of a valve stage of higher order to the coupling network of a preceding valve stage of even lower order.

3. In a system for translating signal wave energy comprising a band of component frequencies, a plurality of amplifying valves connected in cascade, intercoupling valve networks each comprising an ohmic resistance and a condenser in series, the reactance of the condensers and resistance of each network being equal for the center frequency of the band being translated, an input circuit coupled to the first valve and an output circuit coupled to the last valve, means for de-

riying input voltages for successive amplifying stages alternately from the ohmic and capacitative potential drop produced by the respective networks, a feedback circuit from the output of a valve stage of higher order to the coupling network of a preceding valve stage of even lower order, and a resonant circuit tuned to the center frequency of the band being translated inserted in said feedback circuit.

4. In a system for translating electric wave energy comprising an extended band of component frequencies, a main amplifying wave path comprising a plurality of networks each constituted by an ohmic resistance and a reactance of the same kind in series, the reactance and the ohmic resistance of each network being substantially equal for the center frequency of the band to be translated, means for alternately impressing reactive and resistive voltage drop from one network upon the succeeding network, a feedback path from a point of higher oscillation level to a point of lower oscillation level of said main wave path, and resonant impedance means inserted in said feedback path to sharpen the frequency response characteristic of said wave path.

5. In a system for translating electric wave energy comprising an extended band of component frequencies, a main amplifying wave path comprising a plurality of networks each constituted by an ohmic resistance and a reactance of the same kind in series, the reactance and the ohmic resistance of each network being substantially equal for the center frequency of the band to be translated, means for alternately impressing reactive and resistive voltage drop from one network upon the succeeding network, a feedback path from a point of higher oscillation level to a point of lower oscillation level of said main wave path, and a parallel tuned circuit resonant to the center frequency of the wave band to be translated inserted in said feedback path.

6. In a system for translating electric wave energy comprising an extended band of component frequencies, a main amplifying wave path comprising a plurality of networks each constituted by an ohmic resistance and a condenser in series, the reactance of the condenser and the ohmic resistance of each network being substantially equal for the center frequency of the band to be translated, means for alternately impressing capacitative and resistive voltage drop from one network upon the succeeding network, a feedback path from a point of higher oscillation level to a point of lower oscillation level of said main wave path, and resonant impedance means inserted in said feedback path to sharpen the frequency response characteristic of said wave path.

7. In a system for translating electric wave energy comprising an extended band of component frequencies, a main amplifying wave path comprising a plurality of networks each constituted by an ohmic resistance and a condenser in series, the reactance of the condenser and the ohmic resistance of each network being substantially equal for the center frequency of the band to be translated, means for alternately impressing capacitative and resistive voltage drop from one network to the succeeding network, a feedback path from a point of higher oscillation level to a point of lower oscillation level of said main wave path, and a parallel tuned circuit resonant to the center frequency of the wave band to be translated inserted in said feedback path.

JOZEF PLEBANSKI.