July 19, 1938. N. M. RUST 2,124,212

RADIO RECEIVER

Filed Dec. 12, 1936 2 Sheets-Sheet 1

Fig. 1

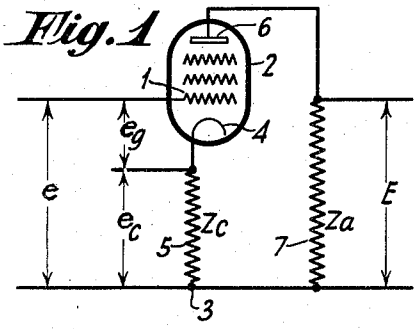


Fig. 2

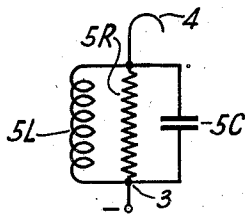


Fig. 3

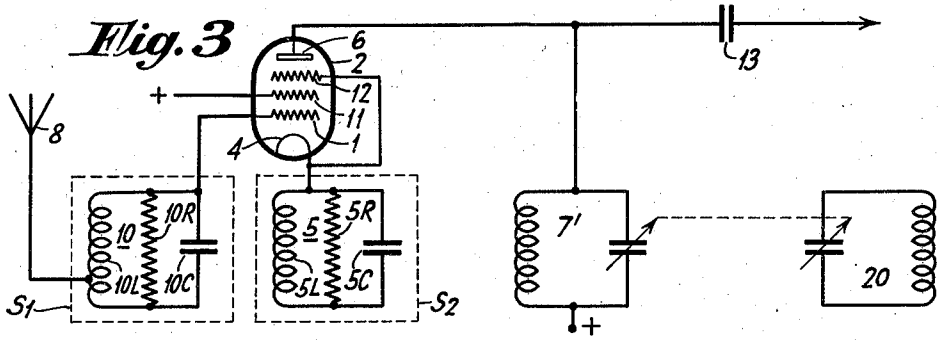


Fig. 4

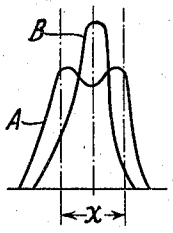


Fig. 5

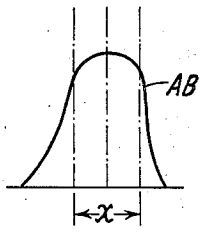


Fig. 6

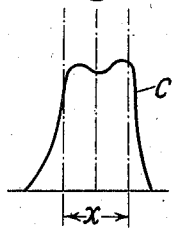


Fig. 7

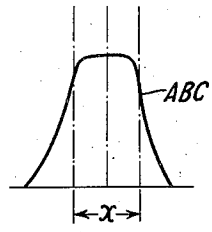


Fig. 10

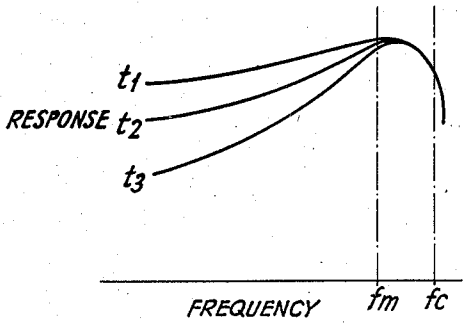
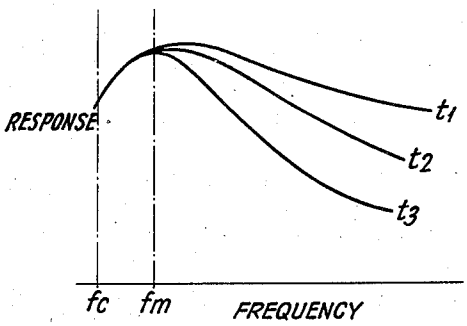


Fig. 12



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July 19, 1938. N. M. RUST 2,124,212

RADIO RECEIVER

Filed Dec. 12, 1936 2 Sheets-Sheet 2

Fig. 8

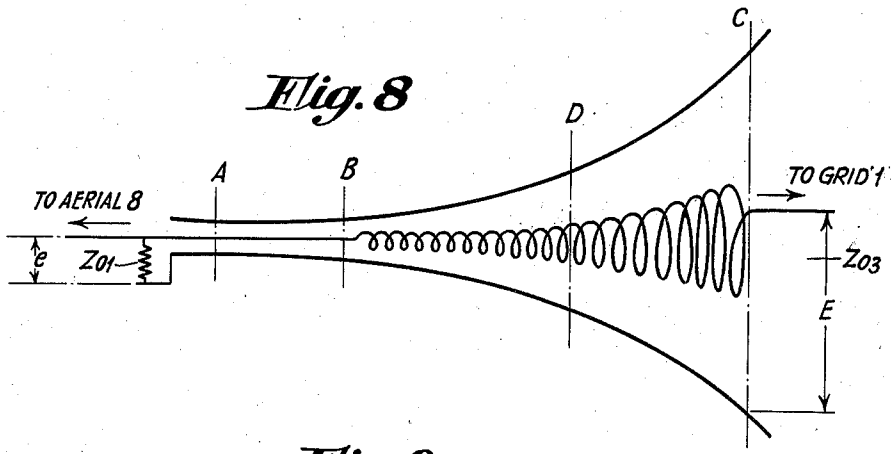


Fig. 9

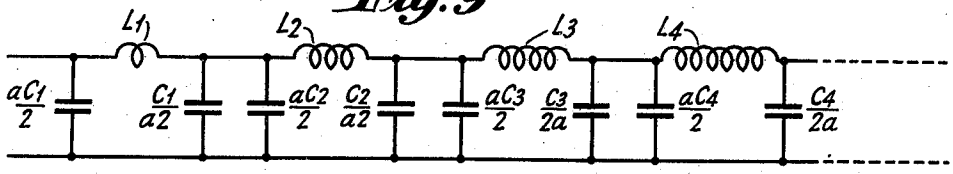


Fig. 13

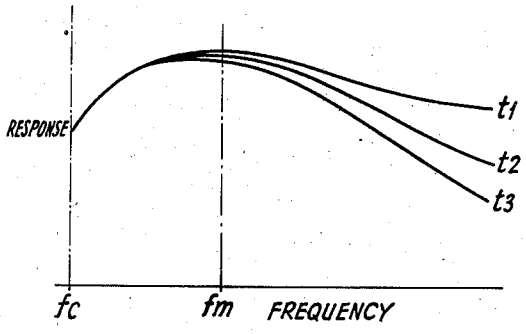


Fig. 11

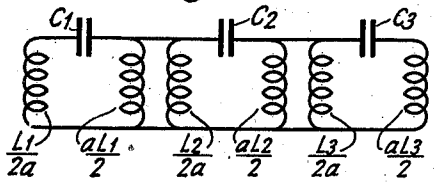


Fig. 15

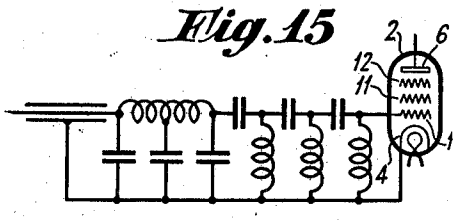
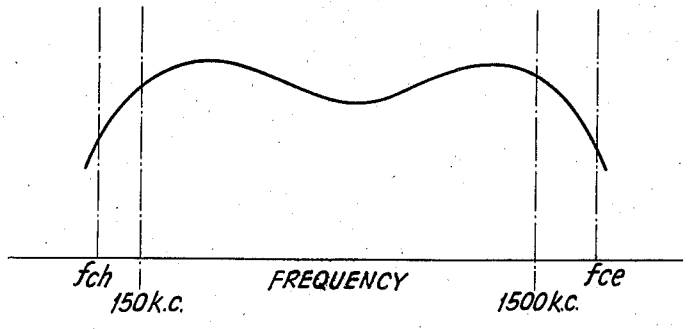


Fig. 14



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UNITED STATES PATENT OFFICE

2,124,212

RADIO RECEIVER

Noël Meyer Rust, Chelmsford, England, assignor to Radio Corporation of America, a corporation of Delaware

Application December 12, 1936, Serial No. 115,475
In Great Britain December 10, 1935

6 Claims. (Cl. 250—20)

This invention relates to radio and like receivers and more particularly to thermionic valve circuit arrangements for coupling a radio receiving aerial to the remainder of the receiver.

The usual present day practice in broadcast radio receivers is to connect or couple the receiving aerial to a tunable circuit which feeds into the first valve of the receiver, this tunable circuit being as a rule gang controlled with the other tunable circuits of the receiver.

A difficulty met with in such arrangements is that the aerial causes loss of sharpness of tuning in the tunable circuit to which it is coupled or connected, while furthermore, it is always necessary to resort to a compromise in the adjustment of the coupling condition between the aerial and the said tunable circuit so as to avoid disturbing the "ganging" of the tuning controls, and also to avoid unduly damping the first tunable circuit. Moreover, the adjustment which should be adopted for best results when one receiving aerial is coupled or connected to the receiver will not be the same as that for best results if a different aerial is connected or coupled to the receiver, and in practice, therefore, it is necessary to provide an aerial "trimmer" condenser to allow the receiving set to be adjusted to suit the various different aerials which may be encountered with in practice. Another important disadvantage met with in the usual known arrangement is that cross modulation effects tend to appear—particularly when it is sought to receive a relatively weak station operating on a wave length adjacent that of a more powerful station.

The object of the present invention is to provide improved arrangements wherein the above defects and disadvantages are substantially reduced or eliminated. More specifically the invention seeks to provide arrangements wherein cross modulation effects are largely reduced or eliminated; wherein disturbance of "ganging" by an aerial is avoided; wherein the aerial does not adversely affect the tuning of the first sharply tuned circuit of the receiver; and wherein it is not necessary to provide any "trimmer" condenser, or the like, for enabling the receiver to be suited to different receiving aerials.

According to the main feature of this invention the first sharply tuned circuit of a radio or like receiver is preceded by a coupling thermionic valve having a semi-aperiodic input circuit and this valve is arranged to be subjected to negative reaction applied in semi-aperiodic manner. The term "semi-aperiodic" is employed in this specification to mean the obtaining of aperiodic or approximately aperiodic action only over a predetermined frequency range—normally the tuning range. The term "negative reaction" is employed in this specification to mean reaction applied in such manner that energy derived from an output circuit is employed to diminish input potentials.

Preferably in carrying out this invention the reaction is obtained by means of a semi-aperiodic impedance network in the cathode circuit of the coupling valve having the semi-aperiodic input circuit.

In some cases, more especially where the source of signals to be received (for example an aerial) is remote from the receiver proper and is connected thereto through a high frequency cable, the coupling valve, instead of having an input circuit constituted by an ordinary semi-aperiodic circuit, may be fed through a tapered line or a network equivalent thereto.

In the drawings accompanying the specification, Fig. 1 is a portion of an amplifier circuit serving to explain the invention,

Fig. 2 shows a cathode circuit embodying a part of the invention,

Fig. 3 shows a receiving circuit according to the invention utilizing a coupling tube between the aerial and the receiver proper, impedance networks such as shown in Fig. 2 being connected to the cathode and to the control grid,

Figs. 4–7 are frequency characteristic curves obtained with a superheterodyne circuit of which Fig. 3 is a part,

Fig. 8 is an alternative circuit for coupling the aerial to the coupling tube,

Fig. 9 is a network equivalent to that of Fig. 8,

Fig. 10 shows the response curve obtained with the circuit of Fig. 9,

Fig. 11 is a network that may be used in place of that shown in Fig. 9 and made up of high pass sections.

Figs. 12 and 13 show the response curves obtained with the circuit of Fig. 11,

Fig. 15 is an input network combining elements from both Figs. 9 and 11, and

Fig. 14 is the response curve obtained with the circuit of Fig. 15.

In order that the invention may be the better understood, consider the relations which exist in a valve in which negative reaction is obtained by means of an impedance in the cathode circuit thereof. Referring to Fig. 1 suppose a signal voltage e be applied between the control grid 1 of a valve 2 (e. g. as shown a pentode) and a point 3 which is connected to the cathode 4 through a cathode impedance 5 of value Z_c the said point 3 being also connected to the anode 6 through an anode impedance 7 of value Z_a from which output voltage (E) is taken. (For the purpose of simplicity anode and grid potential sources are ignored). Suppose the valve be of high internal impedance i. e. of high impedance relative to the impedance Z_a. Let u be the voltage magnification constant of the valve; ρ the internal impedance of the valve;

g the mutual conductance of the valve; e_g the voltage applied between the control grid 1 and the cathode end of the impedance 5; e_c the voltage across the cathode impedance 5; i_a the anode current, and e_a the instantaneous anode voltage. Then, of course,

$$u=\frac{de_a}{de_g}$$

(i_a being constant) and

$$g=\frac{u}{\rho}$$

(the mutual conductance) =

$$\frac{di_a}{de_g}$$

Since the valve is of high impedance it may be assumed that

$$ue_g\frac{Z_a}{Z_a+\rho}=ue_g\frac{Z_a}{\rho}=e_ggZ_a$$

The following relations then exist:—

$$E=e_ggZ_a$$

$$e_c=e_ggZ_c$$

$$e=e_g(1+gZ_c)$$

Therefore

$$\frac{E}{e}=\frac{gZ_a}{1+gZ_c}$$

or

$$E=e\cdot\frac{gZ_a}{1+gZ_c}$$

In other words, the input signals applied between the control grid and the end of impedance 5 remote from the cathode are reduced by the counter volts applied across the said impedance 5 so that the voltage effectively acting on the grid 1 due to the signal may actually be very much less than the input voltage e. It is roughly true that the cross modulating effect of a strong signal on a weak signal when both signals are applied to the grid of the same valve, is dependent mostly on the amplitude of the grid swing produced by the strong signal and only to a very small extent upon the anode loading conditions so that cross modulation effects cannot be prevented by sharply tuning the anode circuit to offer low impedance to strong unwanted signals. If, therefore, cross modulation is to be reduced the grid swing must be restricted at the grid of the valve most liable to introduce it—even at the expense of amplification. Although at first sight such reduction of grid swing could be obtained by feeding the grid through a potentiometer, this expedient has the serious disadvantage that, although the input signal is reduced, valve "noise" is not reduced.

In carrying out this invention the cross modulation effects are reduced by reducing the effective input by negative reaction coupling or feedback induced by a cathode impedance. It is possible by adopting this expedient to reduce the noise level to a very low amount, and there is the added advantage that the negative reaction not only reduces a stabilizing action upon the stage to which it is applied but also indirectly upon the receiving system as a whole.

The obtaining of negative reaction by means of a cathode impedance is, of course, known per se; for example it has been applied to low frequency circuits and also—though with less success—to high frequency circuits. In known arrangements wherein negative reaction by means of a resistance in the cathode lead has been applied to high frequency circuits, a limitation has been found to be set by the effective cathode-earth capacity which acts as a by-pass. Where indirectly heated cathode valves are employed this capacity is mostly made up of the capacity between the cathode itself and the heater, and in practice, in known high frequency circuits as just described, this capacity has been such as to limit the resistance value which can be employed in the feedback impedance to about 800 ohms. Consider the effect of this limitation in the case of a valve for which g=1 milliampere per volt. Then taking Z_c as 800 ohms and inserting these values in the formula

$$\frac{E}{e}=\frac{gZ_a}{1+gZ_c}$$

it will be seen that the counter voltage will be only .8 of the actual voltage. To obtain any improvement in diminution of cross modulation effects it is necessary to increase the value of Z_c, and in carrying out this invention as applied to a known circuit as shown in Fig. 1 the impedance 5 which in the said known circuit is a simple resistance is constituted by a semi-aperiodic system. This system is preferably as shown in the accompanying Fig. 2, i. e. it comprises an inductance 5L, a resistance 5R and a capacity 5C all in shunt with one another, the inductance and capacity resonating together at a frequency at about the middle of the desired tuning range and the resistance being of such value as to provide an approximately flat topped impedance-frequency curve for the said tuning range. For example where the invention is applied to a radio receiver designed to tune from 200 to 550 metres, the inductance 5L and capacity 5C may be so chosen as to give resonance at about 300 metres, the resistance 5R being so chosen that the Q value for the whole network consituting Z_c is less than 1 so that over the tuning range the impedance Z_c will only alter by about ±30% and with a relatively low phase shift. An inductance value of about 2000 microhenries, a capacity value of about 12.5 micromicrofarads, and a resistance value of about 12,500 ohms are suitable for this numerical example. The capacity 5C, of course, includes (and in some cases may even be wholly constituted by) the effective self-capacity between the cathode of the valve and earth, that is to say the self-capacity of the coil 5L plus any stray capacity. The best arrangement is that in which the inductance of 5L is made as big as possible and tunes mainly with its own self-capacity and stray capacity, any actual physical condenser provided at 5C being merely a trimmer condenser for fine tuning adjustment. For the wave length range considered (200–550 metres) Z_c is approximately equal to 10,000 ohms. It will be seen that the ratio of counter voltage to actual voltage is now 10 so that the actual grid voltage will be only 1/11th of the applied input voltage.

If a negative reaction arrangement with a cathode impedance as above described were employed alone, the valve having an ordinary aperiodic input circuit constituted, for example by a simple resistance, there would still be the disadvantage that cross modulation effects could occur due to strong signals outside the tuning range i. e. at frequencies at which the impedance Z_c is so low that the value g Z_c is not large compared with unity. For example if, taking the specific figures above given, there were a strong input signal on a wave length of 1500 metres Z_c

would, for this frequency, only be about 250 ohms and g Z_c only about .26 so that the back coupling effect would hardly reduce the applied input voltage at all.

In carrying out this invention this difficulty is avoided by constituting the input circuit of the valve by another semi-aperiodic circuit of the same nature as the semi-aperiodic cathode impedance, the aerial being preferably "tapped down" upon this semi-aperiodic input circuit so that the aerial impedance is properly matched. The first sharply tuned circuit of the receiver is an ordinary parallel tuned circuit in the anode circuit of the coupling valve, and it will be obvious that this tuned circuit may be directly ganged for uni-control with the other circuits of the receiver without considering the aerial at all.

A preferred aerial coupling network in accordance with this invention is shown in the accompanying Fig. 3. Here the aerial **8** is connected to a tapping point low down upon an inductance **10L** which is connected between the control grid **1** of a high impedance coupling valve **2** (e. g. as shown a high frequency pentode) and earth. The inductance **10L** is shunted by a resistance **10R** and also by a capacity **10C** so that the grid circuit of the coupling valve is constituted by a semi-aperiodic network generally designated **10** having a substantially constant response for the intended tuning range, the response falling away outside this range. The cathode **4** of the coupling valve—which may be indirectly heated—is connected to earth through another semi-aperiodic network generally designated **5** and consisting of an inductance **5L** shunted by a resistance **5R** and by a capacity **5C**, the dimensioning of this semi-aperiodic network **5** being substantially the same as that of the semi-aperiodic grid circuit network **10**. The screen grid **11** of the valve is positively biased, as in the usual way, and the suppressor grid **12** thereof is connected to the cathode also as in the usual way. The anode **6** of the valve is coupled, for example, through a condenser **13** to the next stage (not shown) of the receiver and is also connected through a sharply tuned parallel tuning circuit **7'** (constituting the first sharply tuned circuit of the receiver) to a source of anode potential (not shown). The tuning reactance in this tuned circuit **7'** (e. g. a variable condenser) is gang controlled with the tuned reactance or reactances of the other variably tunable circuits of the receiver such as circuit **20**. Preferably, though not necessarily, the circuits **10** and **5** are screened; for example, as shown, they may be mounted in separate screening boxes **S1**, **S2**.

With the arrangement of Fig. 3 the input volts applied to the coupling valve from the aerial are, within the tuning range, reduced due to the negative back coupling, and as respects frequencies outside the tuning range (where the cathode impedance due to network **5** becomes reduced and accordingly the back coupling effect is also reduced) the applied input voltage from the aerial is reduced owing to the drop in impedance of the semi-aperiodic grid circuit **10**. With similar semi-aperiodic circuits at **10** and **5** it is possible to maintain the ratio of the net voltage applied between grid **1** and cathode **4** of the coupling valve **2** to the actual voltage supplied from the aerial at a roughly constant quantity both as respects frequencies in the tuning range and outside it.

It is preferred to make the parallel tuned circuit **7'** in the anode circuit of the coupling valve as sharply tuned as possible and to follow it with a radio frequency band pass circuit. The aerial coupling arrangement with the sharply tuned anode circuit and the succeeding band pass circuit may be arranged to give, in combination, side band cut off effects which may be corrected for in subsequent stages of the receiver—e. g. in the case of a superheterodyne receiver, in the intermediate frequency stages. Thus by following the sharply tuned circuit in the anode circuit of the coupling valve with a radio frequency band pass circuit of the "double hump" characteristic type (i. e. one with two "humps" joined by a "dip" in the middle of the band pass) and by utilizing an intermediate frequency band pass amplifier with a similar "double hump" type of characteristic a substantially flat topped over-all characteristic can be obtained. This is graphically shown in the accompanying Figs. 4, 5, 6 and 7 where curves A and B in Fig. 4 are respectively band pass and sharply tuned high frequency characteristics; the curve A B of Fig. 5 is the resultant; the curve C of Fig. 6 is the intermediate frequency band pass characteristic; and the curve ABC of Fig. 7 is the overall resultant characteristic. In Figs. 4, 5, 6 and 7, x represents the required band pass range. Substantially constant selectivity circuits of the variable inductance type, wherein tuning is obtained by movement of a portion of the core of a ferro-magnetically cored inductance or inductances (the core being, for example, of the material known in England under the registered trademark "Ferrocart") may advantageously be employed for the tuning circuit in the anode circuit of the coupling valve and for a "double hump" radio frequency band pass circuit succeeding said tuned circuit. Although in carrying out this invention a high degree of immunity from cross modulation effects can be obtained, quite a reasonable amplification can also be obtained in the coupling valve by the use of a coupling valve of high impedance with a sharply tuned circuit included in its anode circuit. By employing good quality coils the value of Z_a at resonance may be made as high as 200,000 ohms and with $g=1$ and $Z_c=10{,}000$ an amplification of 18.2 is obtained from the coupling valve. Similarly the aerial input efficiency can readily be made higher than would be the case were a purely aperiodic grid circuit employed.

If desired, the semi-aperiodic grid circuit may be so designed in a manner known per se that its response instead of being constant or approximately constant over the tuning range, rises, or alternatively falls somewhat with increase in wave length. This may be of advantage in some cases since it may assist in the obtaining of a desired over-all frequency-sensitivity curve for the receiver as a whole, e. g. to compensate for an undesired shape of characterisic presented by some other stage of the receiver.

Though not limited to its application thereto the invention is particularly advantageous when the coupling valve is a so-called "electron beam" valve, that is to say, a valve such as is described in the British Patent Specification No. 403,973, wherein the electron discharge partakes more of the nature of the discharge in a cathode ray tube than of the discharge in an ordinary thermionic valve as at present in common use.

In some cases, especially where the source of signals to be received is remote from the receiver proper, the coupling valve grid may be fed through a tapered line or equivalent network; for example the circuit **10** of Fig. 3 may be re-

placed by a tapered line or equivalent network. Where the receiving aerial is connected to a remote receiver through a high frequency cable there arises the problem of how to transform the relatively low impedance conditions of the cable to the high input impedance conditions of the valve while still retaining effective action over a considerable wave length range. The use of a tapered line or equivalent network, suitably designed, goes far towards solving the problem. The accompanying Figure 8 shows a suitable design of tapered line. Here the tapered line consists of a central conductor of spiro-helical form of simultaneously increasing diameter and closer pitch centrally positioned in a bell like outer sheath. The tapered line extends from B to C, the length A B representing a high frequency cable of normal constants of inductance L1 per unit length and capacity C1 per unit length. The input impedance to the cable is represented by the resistance Z_{01} the input voltage being e. As indicated in Fig. 8 the characteristic impedance changes gradually over the length of the tapered line. If L1, C1, be respectively the inductance and capacity per unit length at B; L2 C2 the corresponding quantities at D; and L3 C3 the corresponding quantities at C; then at B the impedance

$$Z_{01}=\sqrt{\frac{L1}{C1}}$$

at D the impedance

$$Z_{02}=\sqrt{\frac{L2}{C2}}$$

and at C the impedance

$$Z_{03}=\sqrt{\frac{L3}{C3}}$$

Z_{03} represents the characteristic impedance looking into the end at C and, by the choice of a correct terminating impedance correct matching of impedance is obviously obtainable. Further there is a voltage step up effect for the ratio E/e (E is the output voltage) is equal to

$$\sqrt{\frac{Z_{03}}{Z_{01}}}$$

An actual tapered line as shown in Fig. 8 is difficult to design and construct but an equivalent network made up of a number of sections as shown in the accompanying Fig. 9 may be used. Fig. 9 shows what is really an artificial tapered line. In this figure the inductances in the successive sections increase and the capacities decrease, in a definite ratio as indicated on the figure, where L1, L2, L3 . . . are the inductances and the capacities are of the values marked.

$$\frac{L2}{L1}=\frac{L3}{L2}=\frac{L4}{L3}=$$

the taper factor (t)

$$\frac{C1}{C2}=\frac{C2}{C3}=\frac{C3}{C4}$$

Or, more generally expressed

$$t=\frac{Ln}{Ln-1}\frac{Cn-1}{Cn}$$

The larger the number of sections the smaller will be the taper factor t. Now

$$L1C1=L2C2=L3C3=\ldots\ LnCn$$

and this product will define a cut-off frequency in ordinary filter technique. The tapered artificial line differs from an ordinary filter in that adjacent sections can only be made to match each other at one frequency. The larger the taper factor the larger will be the "mismatch" at a frequency other than the matching frequency and hence the larger will be the reflection loss. The factor a (see Fig. 9) is a function of the ratio of the matching frequency to the cut-off frequency. Thus the performance of the artificial taper line, owing to intersection "mis-matching" effects, can approach the ideal only if t approaches unity; hence, for level response conditions, the ratio of output to input impedance

$$\left(\frac{Z_{on}}{Z_{01}}\right)$$

must be small if a small number of sections is to suffice. For a large value of

$$\frac{Z_{on}}{Z_{01}}$$

the number of sections (n) must be large.

In practice the cut-off frequency may be chosen above the highest frequency in the band to be passed and the sections may be designed to match at this frequency. The number of sections is then chosen from consideration of the requirements of (1) input impedance to the coupling valve (2) taper factor (3) and actual value of the final inductance Ln in relation to the highest frequency in the band (Ln must not be such as to resonate anywhere near this highest frequency); in conjunction with the fact that the value

$$\frac{Cn}{Za}$$

must not be less than the value given by stray capacities, grid capacity to earth, wiring capacity to earth . . . and so forth. With suitable design, overall response curves of the general nature shown in the accompanying Fig. 10 will be obtained. In this figure response is plotted along the ordinate line and frequency along the abscissa line. $t1$ $t2$ $t3$ are progressively larger values of taper factor; fm is the matching frequency; and fc the cut-off frequency. Thus a practical compromise may be reached which will give a reasonable step-up ratio where it is most required with a permissible drop in response at the lower frequencies.

By employing an artificial taper line made up of high pass sections—for example, as shown in the accompanying Fig. 11 and designing on the same principle, a step-up ratio combined with a high pass effect is obtainable. Typical response curves for a filter as shown in Fig. 11 are represented in the accompanying Fig. 12 in which the references correspond to those of Fig. 10. For the line of Fig. 11

$$\frac{C1}{C2}=\frac{C2}{C3}=\frac{Cn-1}{Cn}=t$$

(the taper factor) =

$$\frac{L2}{L1}=\frac{L3}{L2}=\frac{Ln}{Ln-1}$$

By selecting fm further away from fc the general shape of the response curve becomes as shown in the accompanying Fig. 13. The combination of a curve such as the curve $t2$ of Fig. 13 with a curve such as the curve $t2$ of Fig. 10 produces an overall curve such as that shown in the accompanying Fig. 14 and the accompanying Fig. 15 shows a double artificial taper line (consisting obviously of a low pass portion succeeded by a high pass portion) whereby a curve such as that of Fig. 14 is obtainable. In practice, as is indicated in Fig. 14 a satisfactory aperiodic action is

obtainable over a range such as that extending from 150 kc. to 1500 kc.

Having described my invention, what I claim as novel and desire to secure by Letters Patent is:

1. A receiving system comprising a coupling tube which constitutes the first tube of the system, a relatively highly damped resonant circuit connected between the input grid electrode and the cathode of said tube, a similar circuit connected to the cathode of said tube and included in a path common to both the grid-cathode circuit and the anode-cathode circuit, and a resonant circuit which constitutes the first variably tuned circuit of the system connected between the anode and cathode of said coupling tube.

2. A receiving system according to claim 1 wherein said relatively highly damped resonant circuits each comprises an inductance, a resistance and a capacity all connected in parallel.

3. A receiving system according to claim 1 wherein said relatively highly damped resonant circuits each comprises an inductance, a resistance and a capacity all connected in parallel and an antenna circuit having a connection to an intermediate point on the inductance included in the relatively highly damped resonant circuit constituting the coupling tube input circuit.

4. A receiving system comprising a coupling tube which constitutes the first tube of the system, a relatively highly damped resonant circuit connected to the input grid electrode and the cathode of said tube, said circuit comprising an inductance, a resistance and a capacity all in parallel, said inductance and capacity resonating with one another at a frequency at about the middle of the desired tuning range and said resistance being of such value as to provide an approximately flat topped impedance-frequency curve for said tuning range, a second relatively highly damped resonant circuit connected to the cathode of said tube and included in a path common to both the grid-cathode circuit and the anode-cathode circuit, and a variably tuned circuit connected between the anode and cathode of said coupling tube.

5. In a receiving system, a plurality of tunable circuits, the variable condensers of which are ganged for unicontrol, an antenna, and means interposed between said antenna and the first of the tunable circuits for preventing a change in antenna constants from disturbing the tracking of the gang condensers, said means comprising a vacuum tube which is provided in a path common to its grid-cathode and anode cathode circuits with a network for producing degeneration, a similar network connected between the grid and cathode of said tube, and a direct connection from the antenna to said last named network.

6. A receiving system of the superheterodyne type, comprising a coupling tube which constitutes the first tube of the system, a relatively highly damped resonant circuit connected between the input grid electrode and cathode of said tube, a similar circuit connected to the cathode of said tube and included in a path common to both the grid-cathode circuit and the anode-cathode circuit, said circuits of the coupling tube being designed to give a double humped band pass curve, a resonant circuit which constitutes the first variably tuned circuit of the system connected between the anode and cathode of said coupling tube, said anode resonant circuit being sharply tuned to give a response characteristic with a peak between the two above humps, and an intermediate frequency amplifier also designed to give a double humped characteristic, the three characteristics combining to give a substantially flat-topped band pass curve.

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