PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 1

Fig. 1.

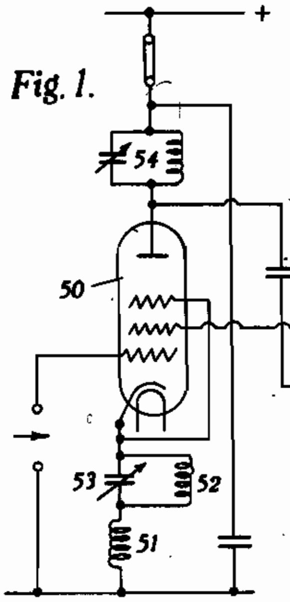


Fig. 2.

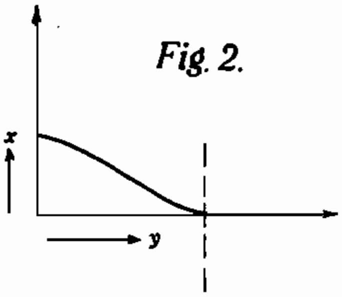


Fig. 3.

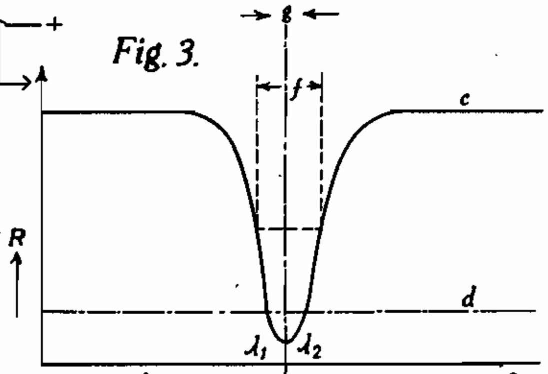


Fig. 4.

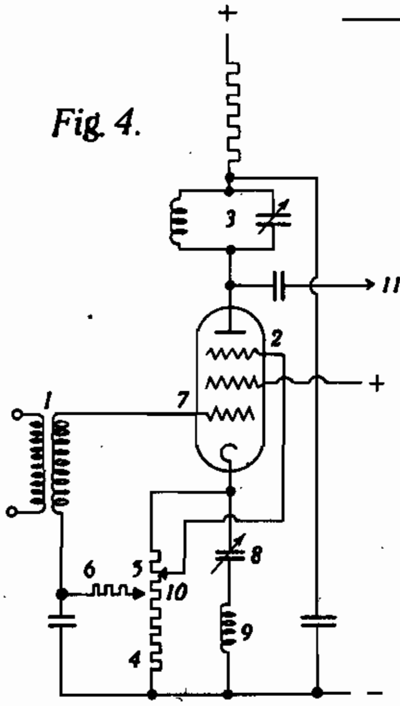
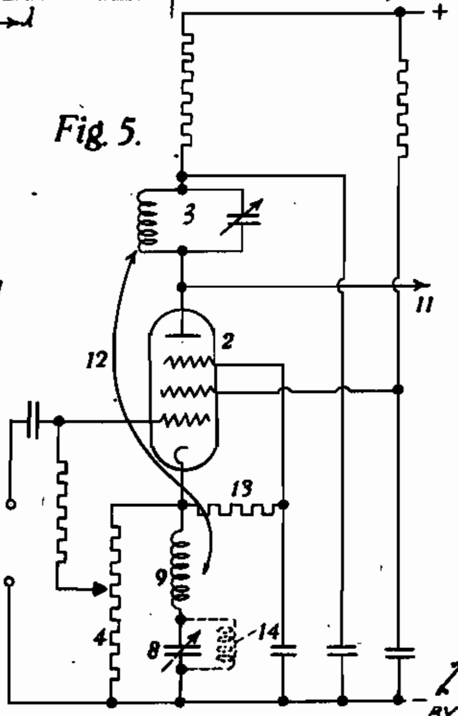


Fig. 5.



INVENTOR
L de Kramolin
BY
Stone Boyden Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 2

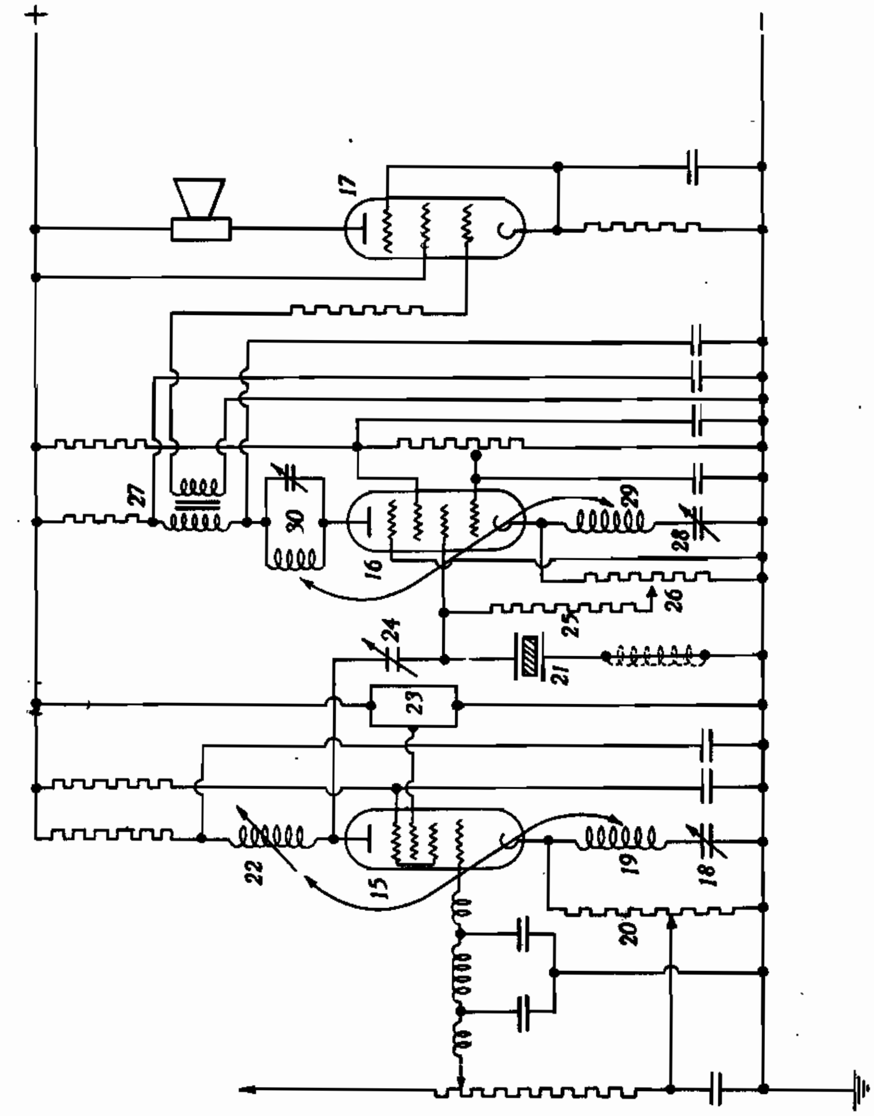


Fig. 6.

INVENTOR
L. de Kramolin
BY
Stone Boyden & Mack
ATTORNEYS

PUBLISHED L. DE KRAMOLIN **Serial No.**
MAY 25, 1943. SELECTIVITY APPARATUS **181,087**
BY A. P. C. Filed Dec. 22, 1937 12 Sheets-Sheet 3

Fig.6.

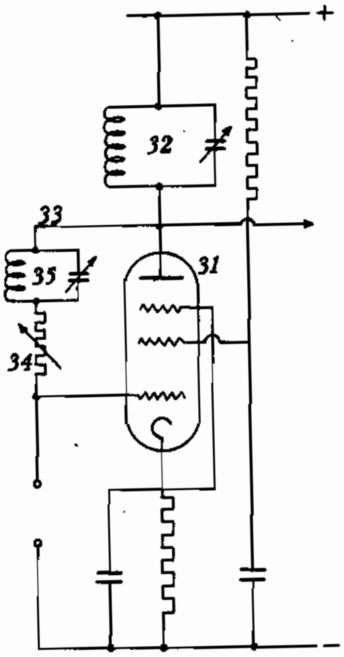


Fig.7.

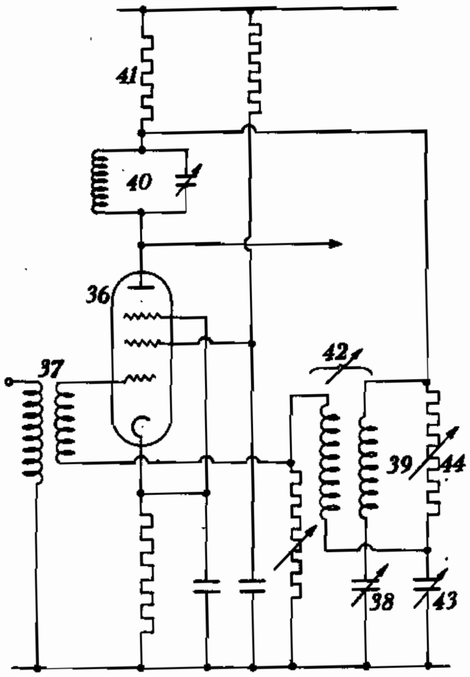
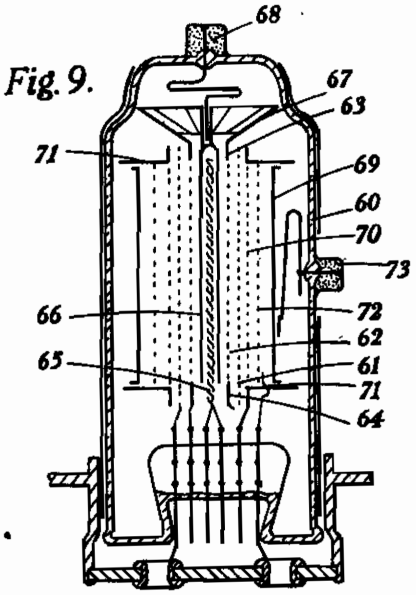


Fig.9.



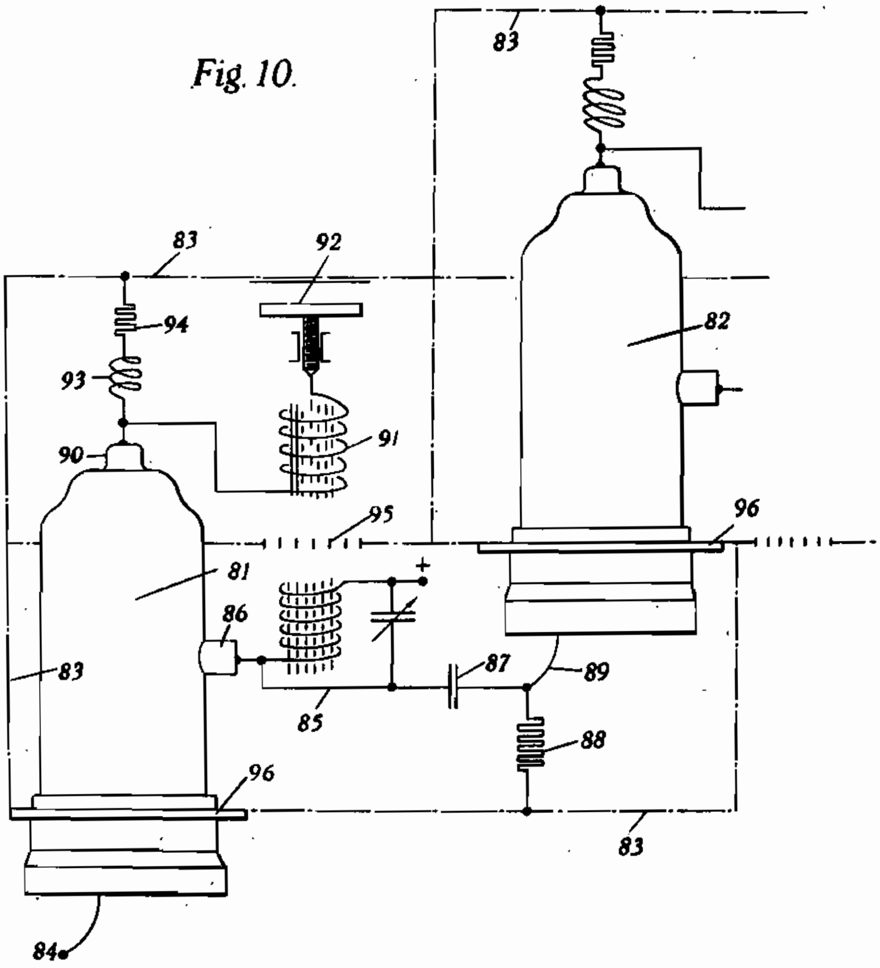
INVENTOR
L. de Kramolin
BY
Stone Boyden Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 4

Fig. 10.



INVENTOR
L. de Kramolin
BY

ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 5

Fig. 11.

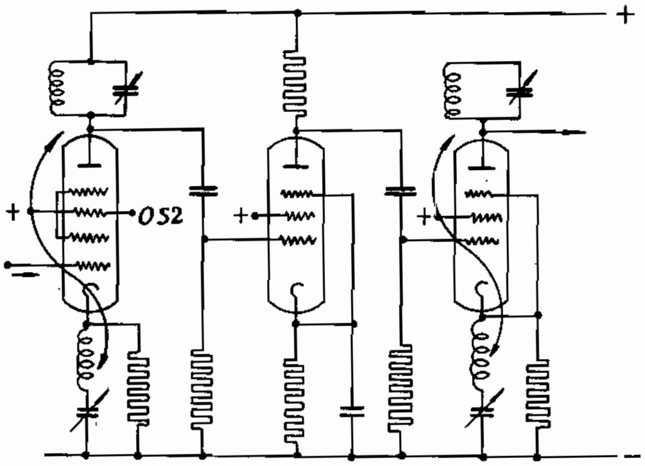


Fig. 12.

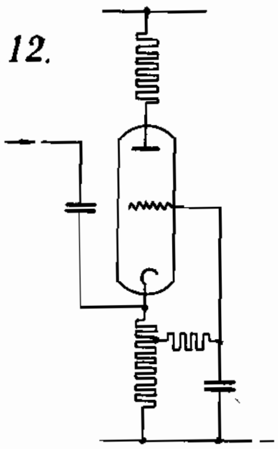
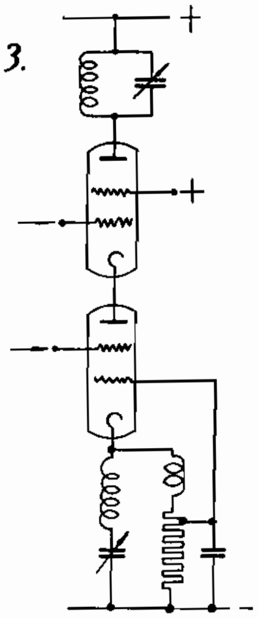


Fig. 13.



INVENTOR
L. de Kramolin
BY
Stone Boyden & Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 6

Fig. 8.

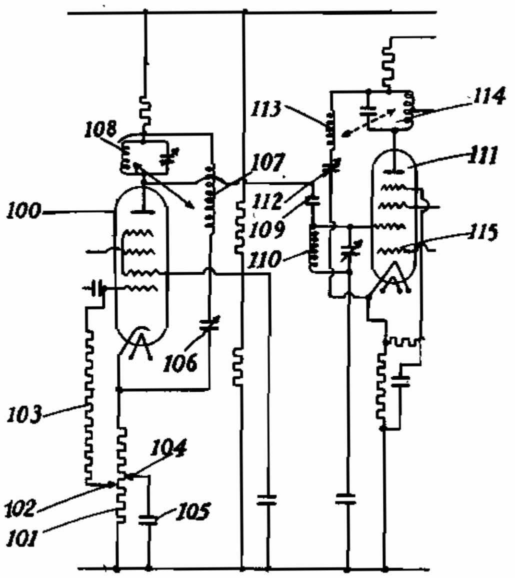


Fig. 9.

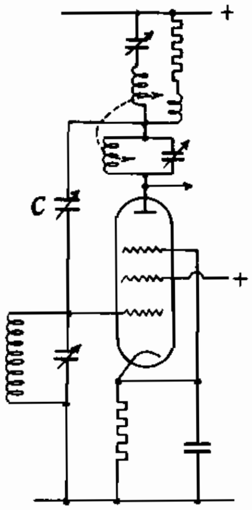
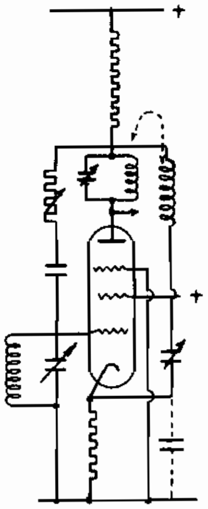


Fig. 10.



INVENTOR
L. de Kramolin
BY
Stone Boyden & Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets–Sheet 7

Fig. 17.

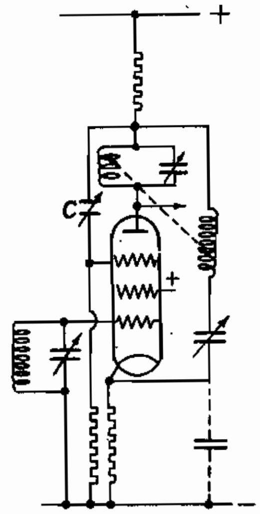


Fig. 19.

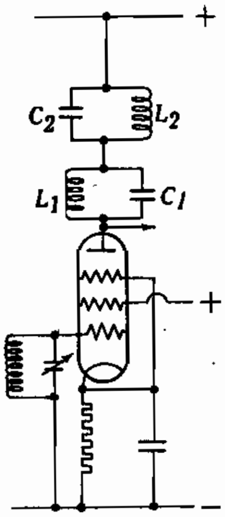
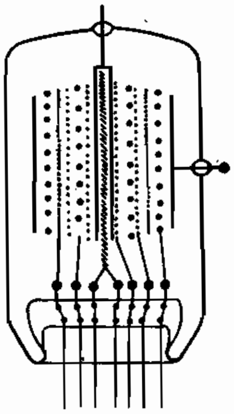


Fig. 18.



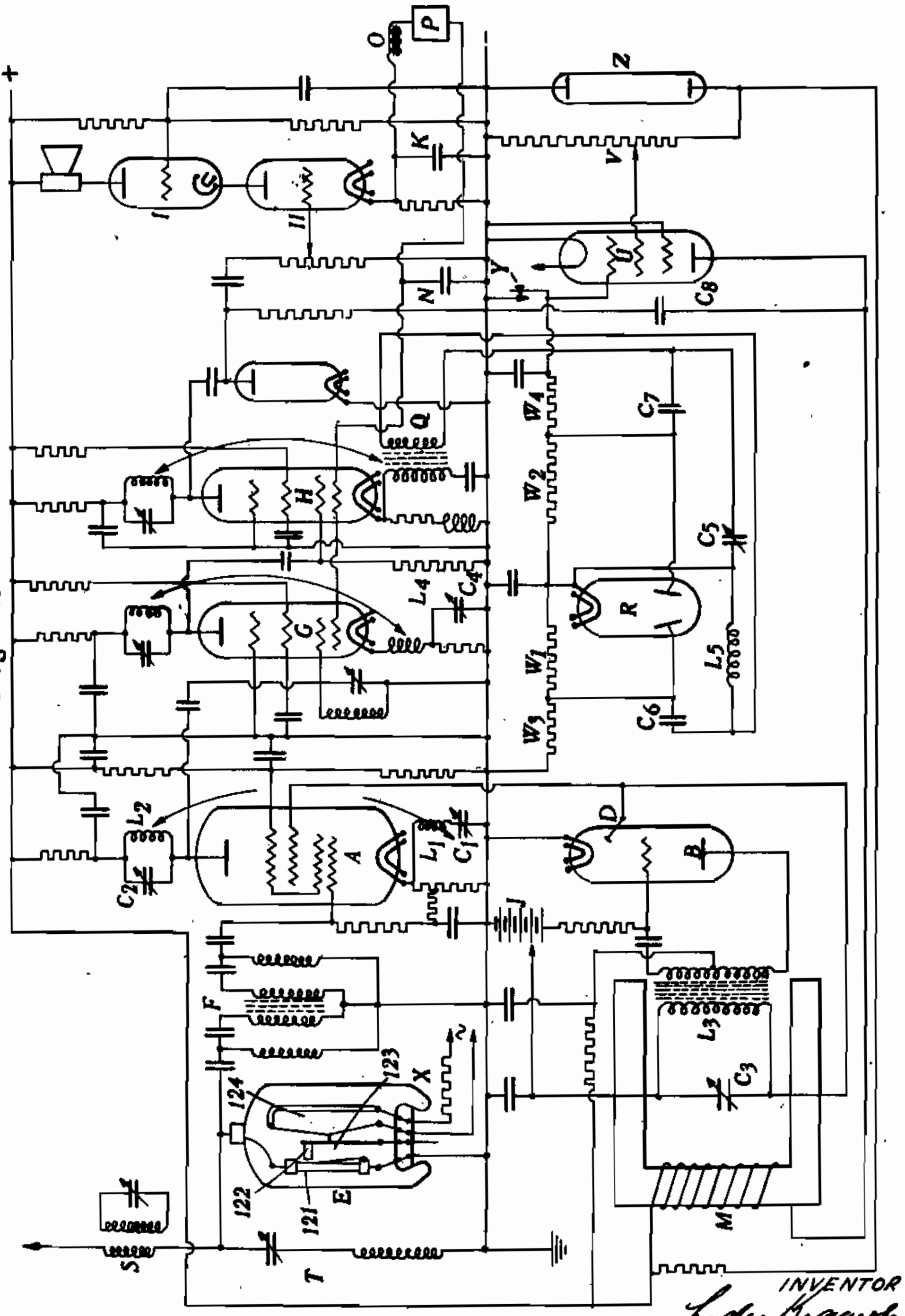
INVENTOR
L. de Kramolin
BY
Stone Boyden & Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 8

Fig. 20.



INVENTOR
L. de Kramolin
BY
Stone Boyden & Mack
ATTORNEYS

Fig. 21.

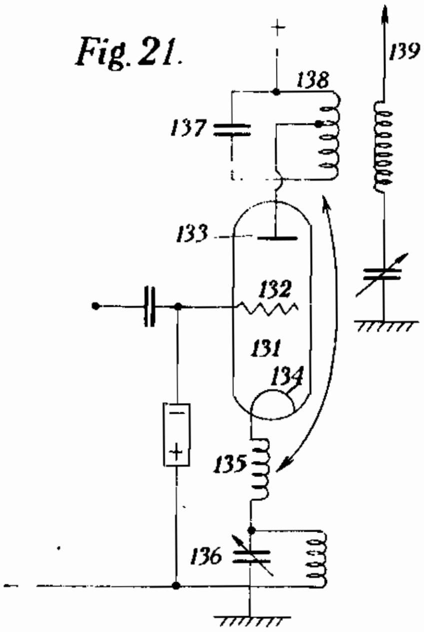
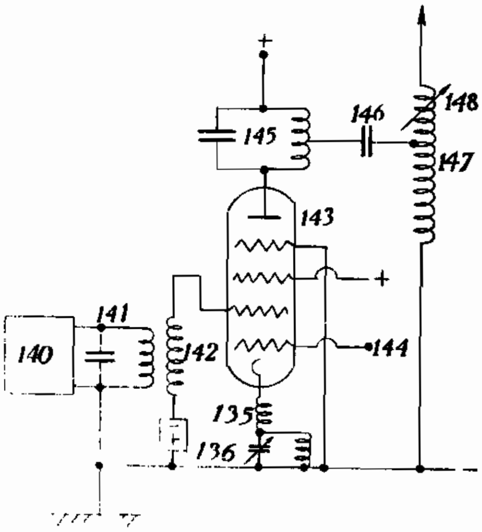


Fig. 22.



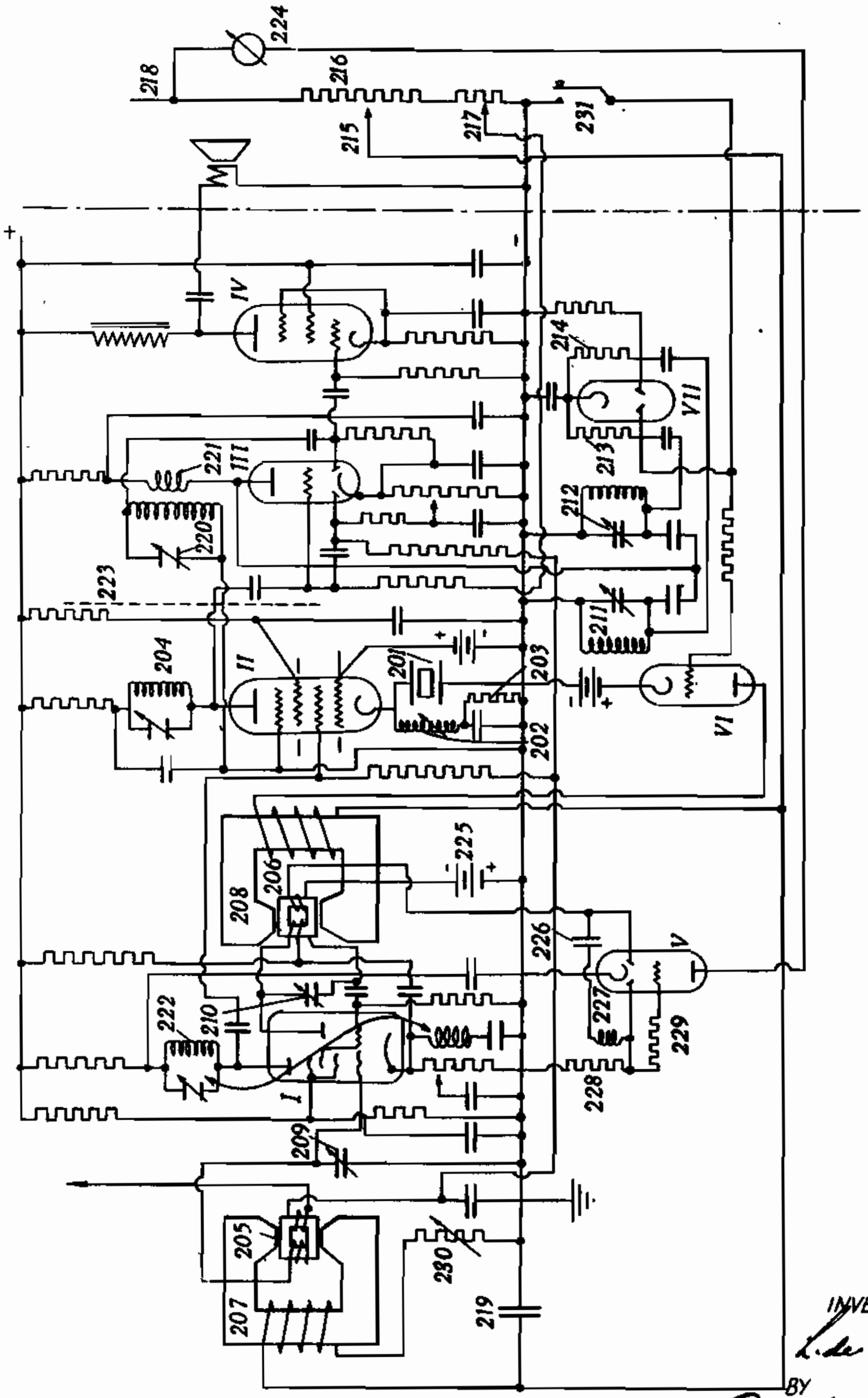
INVENTOR
L. de Kramolin
BY
Stone Boyden Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 10

Fig. 11.



INVENTOR
L. de Kramolin
BY
Stone, Boyden & Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 11

Fig. 12.

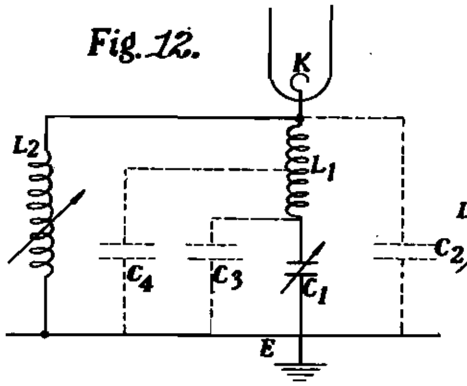


Fig. 13

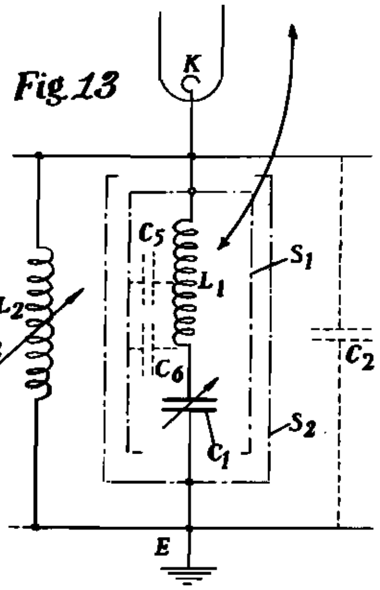


Fig. 14.

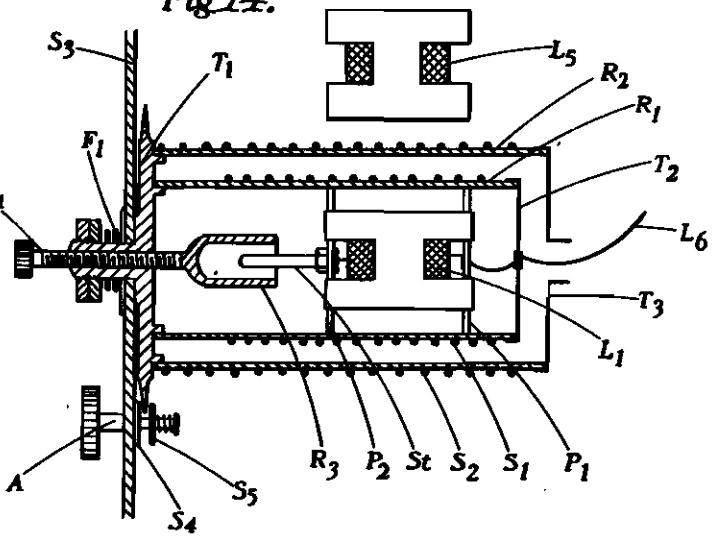
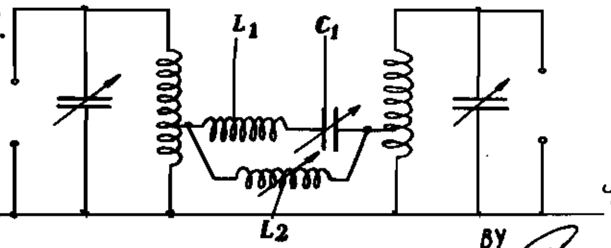


Fig. 27.



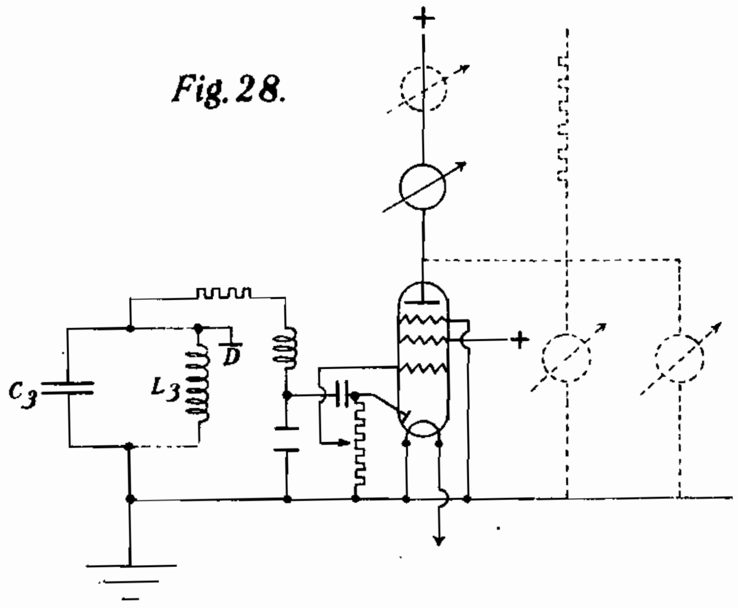
INVENTOR
L. de Kramolin
BY
Stone Boyden & Mack
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

L. DE KRAMOLIN
SELECTIVITY APPARATUS
Filed Dec. 22, 1937

Serial No.
181,087
12 Sheets-Sheet 12

Fig. 28.



INVENTOR
L. de Kramolin
BY

Published May 25, 1943

Serial No. 181,087

ALIEN PROPERTY CUSTODIAN

SELECTIVITY APPARATUS

Ladislas de Kramolin, Berlin-Kladow, Germany;
vested in the Alien Property Custodian

Application filed December 22, 1937

The present invention relates to selectivity arrangements for oscillatory circuits and particularly for radio receiving and transmitting circuits.

In general, the selective qualities of a set which are obtainable with oscillatory circuits are dependent upon the determinative portions of these circuits alone, so that normally it is not possible to obtain with tuning circuits which are composed of given capacities and inductances, and with the losses peculiar to these determinative portions, a greater separating sharpness than approximately corresponds to the half-value width (Halbwertsbreite) of such a circuit, the separating sharpness being intended to mean here the interval between two channels to be separated.

If, therefore, the half-value width of an oscillatory circuit amounts to 10 kilocycles, it is therefore not possible to obtain the result, by any desired number of such circuits in an arrangement, that it allows of separating channels from one another, the interval of which is less than 10 kilocycles.

According to the present invention, use is made of counter-coupling or negative feed-back channels in amplifying arrangements, which counter-coupling channels contain filter means dependent upon frequency, that is, for instance, oscillatory circuits or combinations of such oscillatory circuits (band filters or limiting filters or the like), whereby selective structures can be produced which are not subject to the above limitations.

The circuits inserted in the counter-coupling channels may be series or parallel resonant circuits or combinations of both types, and the counter-coupling channels may either lie in the anode circuits or equivalent circuits themselves, in which they are arranged either in the anode or cathode supply leads of the amplifier units, or they may lie in the supply leads to individual or several control or auxiliary electrodes, the essential fact always residing in that they serve as means for obtaining a selective counter-coupling.

In order that the invention may be more clearly understood, various embodiments will be described with reference to the accompanying drawings.

If an amplifier according to Fig. 1 is constructed, for instance, with a pentode **50** in the well-known connection with a tuned anode circuit **54**, and if at first the constructional elements in the cathode lead, namely, the inductances **51**, the choke **52** and the condenser **53** are imagined to be replaced by a normal variable resistance, the following can be observed:—

No consideration will be given in the first place to the production of the grid bias for the input grid, but it is assumed that, by means of a constant favourable grid bias produced in some manner, the valve operates on the steepest part of the characteristic which can be controlled by the input voltage to be amplified. If, now, the resistance imagined in the cathode lead is given the value zero, the highest amplification is given by the other determining portions of the circuit. If the resistance is slowly increased, commencing from zero, a diagram results which is illustrated in an approximate manner in Fig. 2. In this curve the value x represents the particular amplification which corresponds to a resistance value y of the variable resistance imagined in the cathode lead. The curve shows that, on gradually increasing the resistance, the amplification decreases, since, of course, with increasing resistance, the counter-voltage becoming effective at the input grid of the tube continuously increases. The input circuit of the tube, which is inserted at the place indicated by the arrow between the grid supply lead and negative pole may, in this case, be constructed in any desired way: It may be a question of a coupling coil which is substantially aperiodic for the frequencies to be amplified, a transformer tuned to the frequencies to be amplified, or an ohmic resistance or the like.

As the curve in Fig. 2 shows, at a certain limiting value of y, x has become equal to zero, that is, even with a further increase of y no further substantial change takes place in the arrangement. The actual operations probably show small deviations from the curve shown due to stray capacities, since however, especially with tubes having a high amplification factor and great steepness, only small resonance values suffice to obtain in the curve the value of y indicated by the chain-dotted section line, the parallel capacities do not falsify the conditions set forth, to any great extent.

Therefore, the law exists that amplification occurs below a certain value of y, but no further amplification occurs above a certain value of y.

The network formed by the constructional elements **51**, **52** and **53** now corresponds to a series resonant circuit, since the choke coil **52** connected in parallel with the condenser **53** is to have such a high inductance that it acts merely as a capacitive resistance for the frequencies to be considered here, while, on the other hand, it allows the anode direct current necessary for the working of the tube to reach the cathode.

Curve C in Fig. 3 shows the resistance of the combination **51**, **52**, **53** which is effective at different frequencies, the abscissae indicating wave-lengths and the ordinates resistances.

Commencing from small wave-length values, the combination has a certain, rather considerable reactance of capacitive nature. On approaching the resonance frequency, the capacitive resistance gradually falls until reaching the resonance frequency. At this resonance frequency, the capacitive resistance has completely disappeared and the arrangement has a minimum effective resistance. On further increase of the wave-length, the effective resistance of the combination increases again, in which case at increasing wave-length it now has an inductive character.

For the consideration to be undertaken here in the first instance, it is not important whether the resistance is purely ohmic capacitive or inductive, but only the potential drop occurring due to the resistance is of interest. If we now consider the curve *c* in Fig. 3, it is found, as was not otherwise to be expected, that it is a question here substantially of an inversely recorded resonance curve, the resonance sharpness, that is, the obtainable flank steepness, half-value width etc. being given by the loss resistance of the circuits employed, in other words, by the circuit quality. Therefore, under normal conditions, only a definite selectively determined by the half-value width of the resonance curve can be obtained with these given constructional elements.

This is important, in particular, in short-wave sets and, therefore, also in superheterodyne receivers with a short-wave intermediate frequency part, since if, for example, owing to the obtainable circuit quality at a definite frequency, a half-value width of 15 kilocycles is given, even no greater selectivity can be obtained by series connection of any desired number of such circuits in amplifiers and the like that is, for instance, no stations can be separated which have a mutual frequency interval of 10 kilocycles.

If, however, the determinative portions of the circuit, on the one hand, and the determinative portions of a tube arrangement according to Fig. 1 are so chosen that the limiting value of the resistance *y* as represented in Fig. 2 by the chain-dotted line is illustrated by the chain-dotted line *d* as entered in Fig. 3, the following results; since an amplification, of course, only occurs at all if the resistance in the cathode circuit is, for instance, less than the value *d*, then on passing through the wave-length spectrum (see Fig. 3) no amplification occurs at all if, commencing at the minimum wave length, advancement is made up to the value λ_1. Only commencing from the value λ_1 does amplification begin, which increases, reaches its maximum amount at the resonance value of the circuit, and then falls again until the wave length λ_2 is reached, whereas after exceeding this wave-length value, all amplification again ceases.

Whereas there is obtained by the determinative portions of the circuit a resonance curve which has a half-value width *f*, the width of the whole range, within which an amplification takes place, is characterised only by the wave-range *g* in Fig. 3.

It is therefore seen that by this means it is possible, with the aid of a circuit which in itself would not render possible any separation of transmitters of a certain frequency interval, even in the case of several cascade circuits, to construct an amplifier which has a greater separating sharpness.

Since, especially at high frequencies, stray capacities may introduce errors, it is important to work with tubes having a relatively high "Durchgriff" and high steepness. On the other hand, it is also desirable that the tubes shall have a high internal resistance, in order that even with good tuning circuits, **54** in the anode circuit of the arrangement (Fig. 1), no excessive current intensity drop occurs near the resonance position.

For the production of the effect just described, exponential tubes may also be employed, but it may be very desirable to use tubes which have a sharp lower bend in their characteristic, for which reason preferably indirectly-heated tubes are employed in such cases. It is also desirable in these cases to use cathodes of the smallest possible emission work, or other cathodes, in which as small as possible a control of the Maxwell speed distribution is existent.

In order to make the current drop in the tube small and thus also the effective counter-coupling at the input grid in the case of anode circuit coupling to the next amplifying stage or other circuits, it may also be desirable to connect ohmic resistances in series with the circuit **54**. Of course, when coupling subsequent circuits, however, no restriction is made to the tuned anode circuit coupling, but, for coupling, tuned or non-tuned transformers and all other possibilities of coupling well-known per se of periodic or aperiodic nature may be employed.

Instead of a simple series resonant circuit after the fashion of Fig. 1, there may also be inserted in the cathode lead a plurality of circuits or networks, filters or the like, which produce a larger number of channels due to the effects illustrated by Figs. 2 and 3, or, alternatively, band or limiting filters may be used in the cathode supply lead, whereby the frequency ranges approximately determined by these filters then undergo a sharper separation than by the filter means alone.

The arrangement therefore serves quite generally to increase the flank steepness and to increase the obtainable selectivity with any frequency-differentiating or any other filter means.

Instead of working at the lower bend, it is also possible to work at the upper bend of an amplifying arrangement; instead of tubes, any other amplifiers may be used accordingly.

Similarly as by the use of series resonances in the cathode circuit the conditions set forth are produced, it may be desirable for obtaining complementary conditions to provide parallel resonant circuits in the cathode lead, in which case, when working at the lower or upper bend, corresponding phenomena result.

Selective conditions with regard to frequency and amplitudes may also be produced if the work is done within a limited range between the lower and upper bend, which will then be over-controlled on exceeding certain amplitudes.

A further possibility of use of the arrangement described with reference to Figs. 2 and 3 resides also in the following. It is known particularly in normal three-electrode tubes that it is difficult to obtain, say, in a receiving circuit designed with the assistance of the well-known Huth-Kuhn oscillating circuit, an approximately constant back-coupling in internal capacity or an auxiliary capacity connected in parallel therewith, over a large frequency range. Since, in the curve diagram of Fig. 3, the effective resistances towards one side are capacitive and towards the other side are inductive, then by such an arrangement of tuning means in the cathode circuit, frequency dependencies of the anode circuit can be compensated upon adequate arrangement and, thus, constant back-coupling effects can be obtained.

Further modifications of the invention are shown in Figs. 4–8.

Fig. 4 shows an arrangement in which **1** is the input transformer of a pentode **2**. The amplified output arises in the tuned anode circuit **3**. In the cathode supply lead, a resistance **4** is inserted, from which the grid bias for the control grid **7** can be derived through a slider **5** and decoupling resistance **6**.

For the oscillations reaching the control grid **7** through the transformer **1**, the resistance **4** constitutes a counter-coupling arrangement. By this means, therefore, in contradistinction to a back-coupling, amplification-reducing voltages are introduced.

An exception exists only for such oscillations to which the series resonant circuit **8**, **9** is tuned, since for these oscillations the resistance **4** is practically short-circuited.

By tuning the circuit **3**, on the one hand, and the circuit **8**, **9**, on the other to a certain receiving frequency, the result can be obtained that, independently of possible selection means which are already existent in the grid circuit of the tube **2**, an increased tuning sharpness arises as compared with an arrangement in which only a tuned anode circuit is provided.

This increased tuning sharpness is not only attributable to the fact that, in addition to the tuning means of the circuit **3**, still further means are provided in the anode circuit, but owing to the use of the series resonant circuit in the cathode supply, an increase of selectivity going beyond this pure total effect occurs.

This, as well as the sensitivity of the arrangement can be considerably increased if a regulatable back-coupling is introduced, which can be obtained in a simple manner, for example, by applying a variable voltage to the grid **2** by means of a further slider **10**. The more the slider **10** approaches the cathode, the stronger the back-coupling becomes. In this manner, a very sensitive adjustment of the arrangement can be found.

With a permanently adjusted back-coupling, the selectivity and sensitivity of the arrangement can also be increased still further by repeated re-tuning of the circuits **3**, on the one hand, and **8**, **9**, on the other.

This appears to be attributable to the fact that by small variations of the condenser **8** the phase position existing in the anode circuit is varied and thus the arrangement can be adjusted to most favourable conditions.

Since very slight variations of the capacity **8** are already accompanied by very material alterations of the selectivity and sensitivity, a variation in the series resonant circuit **8**, **9** or a displacement of the slider **10** in any apparatus, particularly in a receiving set, may also be used for selectivity or sensitivity regulation.

On manual adjustment, in this case, the three variables, namely, the resistance **10**, the inductance **9** or the condenser **8** may be operated.

The arrangement appears to have a substantially greater importance, however, for an automatic sensitivity or selectivity regulation, since, as has been mentioned, small variations in this circuit already produce considerable effects, so that, with the aid of small control voltages, by means of control tubes, by means of condensers dependent upon voltage (for instance, piezo-electric arrangements) or by means of inductances dependent upon voltage or current (e. g. premagnetising arrangements of iron-containing coils) the required small variations of the capacity, inductance or resistance in this circuit can be produced.

In this case, several arrangements according to Fig. 4 may be combined in a cascade amplifier, which also applies to the arrangements to be further described.

It is precisely in highly-selective sets that this arrangement may be of importance because it allows of obtaining very high selectivity figures with a relatively small number of tubes without large amplification losses.

If, in a normally tuned cascade amplifier, two tubes are coupled together, then normally two tuned circuits are provided, namely, a tuned anode circuit, which is connected to the anode of a preceding tube and a tuned grid circuit, which is connected to the grid of the next succeeding tube.

Apart from the cases in which this arrangement serves to obtain a resonance curve flattened at the top, which, moreover, can be obtained by suitable determination of the dimensions also in an arrangement according to Fig. 4, such devices mainly have the purpose of increasing the selectivity by the use of two circuits instead of an ordinary anode circuit coupling.

This selectivity increase, however, is obtained at the cost of a very considerable amplification loss, since even with optimum coupling of the two circuits, of course, only 50% of the voltage can be transferred to the grid of the succeeding amplifying tube, which would otherwise be existent in the ease of ordinary coupling of two successive amplifier stages by a single tuned anode circuit.

If, however, the procedure according to Fig. 4 is adopted, the lead **11** may be directly connected to the grid of the next succeeding tube, so that, therefore, the full amplification is existent as in the case of a normal coupling by tuned anode circuits, but nevertheless owing to the two existing tuning circuits between the tube **2** and the succeeding amplifying tube, namely, owing to the circuit **3**, on the one hand, and the circuit **8**, **9**, on the other, not only the selectivity otherwise obtainable with two circuits exists, but an even higher separating sharpness.

Therefore, in this way, desired selectivities can be obtained without the amplification losses occurring with the ordinary use of coupled circuits, in which case, of course, the arrangement described here may be combined with the use well-known per se of coupled circuits, that is, special tuned circuits in the grid circuits.

It is precisely in the superheterodyne receivers frequently employed at the present day, having a very small number of amplifying tubes, that the arrangement described is advantageous, since it is not necessary to increase the number of tubes in order to be able to increase the number of oscillatory circuits employed, and greater selectivity without amplification loss can be obtained in the case of an equal number of tubes.

A three-tube superheterodyne set would, for instance, be constructed substantially as follows according to present-day principles: The anode circuit of the mixing tube would be tuned to the intermediate frequency and coupled to a further tuned oscillatory circuit, which is connected to the grid of the succeeding intermediate-frequency pentode. The anode circuit of this pentode is also tuned and transfers a voltage to a diode with a succeeding loud-speaker tube. Therefore, altogether three intermediate-frequency circuits are provided.

With the same tube equipment the set can be constructed on the basis of the present application as follows. The mixing tube receives a tuned anode circuit as well as a series resonant circuit in the cathode lead, which circuit is tuned to the intermediate frequency. The tuned anode circuit is coupled to a tuned input grid circuit, which is connected to the intermediate-frequency pentode. This intermediate-frequency pentode has again a tuned anode circuit and a series resonant circuit in the cathode lead. However, let the set be unaltered. With the same number of tubes, five tuned circuits are then provided instead of three tuned circuits, without having to involve the additional amplification losses when using further coupled circuits.

In addition, the series circuit existing in the cathode circuit supply lead of the mixing tube acts for all frequencies which do not correspond to the intermediate frequency as a negative back-coupling in linearising manner, so that the purpose of the multiplicative mixing often employed at the present day can be achieved to an increased extent in the mixing tube. Moreover, the series resonant circuit in the cathode supply lead of the high-frequency pentode, owing to introduction of a certain degree of back-coupling, allows of removing the damping of the anode circuit of this tube, so that the damping caused by the diode path in this circuit can be eliminated, so that this circuit also provides a high selectivity and sensitivity.

If it is desired to obtain band filter effects, that is, for instance, resonance curves which have at the apex a depression or a rectangular flattening, this can be produced by corresponding adjustment of the values of 8, 9 and 10 or equivalent measures (for instance in arrangements where the counter-coupling is obtained not by a resistance **10** but by capacitive or inductive counter-coupling means well-known per se).

A depression in the resonance curve arises entirely by itself if the dynamic resistance of the circuit **3** becomes so great that it is no longer negligible as compared with the internal resistance of the tube **2**.

By the use of tubes which, during operation, permit a variation of their alternating current resistance, it is easily possible in this way to alter the resonance curve form and thus to introduce a variable selectivity.

Since such a variation of the tube resistance, for instance in tubes which are constructed as exponential tubes, is possible by mere bias variation at the control grid or any auxiliary grid, this method is also particularly suitable for automatic selectivity or other regulating arrangements. In particular, this applies to multi-stage arrangements.

As has already been set forth above, by small successive after-regulation of the condenser in the circuit **3** and of the condenser **2**, and possibly also of the slider **10**, the sensitivity and separating sharpness of an arrangement according to Fig. 4 can be made extremely high. Finally, however, there is, of course, a limit at which the arrangement then goes into self-oscillation.

Shortly before reaching this limit, the arrangement is still very stable with regard to voltage fluctuations of the tube feeding currents, but relatively low high-frequency voltages as well as sudden current impulses in any lead situated in the vicinity cause a commencement of natural oscillations.

For example, the anode voltage of the arrangement can be increased by 100% by gradual upward regulation, without the arrangement commencing to oscillate, whereas a cutting-in and out of an incandescent lamp provided at the experimental table can effect the initiation of natural oscillations, evidently by impulsive excitation of the tuned oscillatory circuits.

This sensitivity of the arrangement brought to a highly-sensitive condition, in relation to substantially excessive high-frequency voltages, can be considerably reduced if an exponential tube is employed as the amplifying tube.

Since, as is shown in Fig. 4, a variable back-coupling can be introduced by a tapping **10** at the resistance **4** and this back-coupling, particularly if the resistance **4** is not bridged over by a series circuit **8**, **9**, is independent of frequency to a great extent, such an arrangement may also be employed after the fashion of a multi-vibrator. In such a case, it may then be preferable to interchange the function of the input grid **7** and of the collecting grid **2** or to take care in some other manner that the voltage derived by the slider **10** reaches a grid with greater steepness than the steepness acting at the input grid.

Instead of a single grid connected to the resistance **4** (collecting grid in Fig. 4), several grids may also be connected by means of regulatable sliders or otherwise to this resistance, so that negative and positive back-coupling voltages are supplied to them.

By difference or sum effects between such different grids which are adjustable preferably in voltage amplitude by means of sliders or the like, quite high sensitivities can be obtained, since the tube can be brought to quite an unstable condition by successive after-regulation of these different grid voltages. The different grids in this case must not be at the cathode direct current potential, but the direct current bias of the grids may be adjusted independently of its alternating current voltage by the use of coupling resistances and condensers, as is shown for the collecting grid of Fig. 5.

For perfectly aperiodic back-couplings, aperiodically-acting resistances are preferably used also in the anode circuit and possibly in the input circuit.

While, in an arrangement according to Fig. 4, the back-coupling may be devised in such a manner that it has an amplifying effect on different frequencies, which may be advantageous, for instance, in a mixing tube for superheterodyne receivers, particularly when using aperiodic input circuits, it may be desired for other cases not to derive the back-coupling from an aperiodically-acting member, such as the resistance **4**, but, on the contrary, to limit the back-coupling action only to a desired frequency or a desired frequency band.

Such an arrangement is diagrammatically illustrated in Fig. 5. Since the series resonant circuit **8**, **9** has a small resistance only for the oscillations to which it is tuned, it is clear that a back-coupling which is effective between the series resonant circuit 8, 9 and the tuned anode circuit 3 will be effective only for the natural frequency of these circuits. It increases the selectivity further and increases the sensitivity for the tuning frequencies. The back-coupling, in this case, may be effected both inductively and capacitively.

In Fig. 5, an inductive back-coupling is illustrated by the curved arrow 12. Whereas, as described in the arrangements corresponding to Fig. 4, maximum sensitivities can be obtained by successive re-tuning of the circuits 3 or 8, 9, arrangements according to Fig. 5 and similar thereto (that is, in particular, those which work with tuned back-coupling) are extremely stable in tuning at all occurring degrees of coupling between the coil 9 and circuit 3. In this case, extremely high selectivities can be obtained at somewhat reduced sensitivity.

Since the collecting grid 2, if it is directly connected to the cathode can cause, with adequate collecting-grid steepness, such a strong back-coupling that the tube 3 oscillates, it may be preferable to introduce an additional counter-coupling for the back-coupling adjustment between the coil 9 and the inductance of 3.

In addition, however, the collecting grid 2 may also be directly led to the negative pole of the anode voltage. This may cause a general reduction of amplification by the negative bias of the collecting grid which then arises.

If such an effect is feared, or if for other reasons a too strongly negatively biased collecting grid is not desired, then according to Fig. 5, the collecting grid can be brought to earth potential as regards alternating current by means of a high-ohmic de-coupling resistance 13 and decoupling condenser 14, while it is at cathode potential or at some other desired potential as regards direct current.

In particular, if the internal resistances of the tubes 2 are not very great, it is desirable, for obtaining maximum selectivity in the circuits 3, to make the ratio of capacity to the inductance large, that is, larger than usual.

Furthermore, it is desirable, in the arrangements discussed here, to make the ratio of capacity to the inductance in the series resonant circuits 8, 9 very small, that is, in contradistinction to the anode circuits 3, to make the capacity 8 very small and to make the inductance 9 large, without this, however, positively having to be the case.

In particular, in the modification of the inventive idea as illustrated by Fig. 5, with a back-coupling having a tuned action, it is unnecessary, owing to the high selectivity obtainable in any case and owing to the great stability of the back-coupling obtainable between the two tuning circuits, to use circuits which are constructed particularly low in losses.

It has been found, on the contrary, that excellent separating sharpnesses can also be obtained in very cheaply constructed circuits. In this case the back-coupling by no means has to be critically adjusted. With a medium back-coupling adjustment, which already produces a very high separating sharpness, the stability towards voltage variations is so great that even an anode voltage increase from 200 to 500 volts does not effect any self-oscillation. Even at anode voltage variation between 100 and 500 volts, no perceptible de-tunings occur in the circuits.

However, it is by no means necessary for the construction of arrangements according to Fig. 4 or Fig. 5, to use only pentodes or other screen-grid tubes, but very useful selectivities and amplifications can also be obtained even with triodes in this manner. By means of the stable back-coupling, the damping produced by small tube resistance in the directly or inductively-coupled anode oscillatory circuit can also be compensated in this case.

This is a circuit which is noteworthy, also because it allows of using two tuning circuits in a triode without self-oscillation occurring owing to the anode-grid capacity, as would be the case when using tuned anode and grid circuits.

If a tuned circuit is likewise connected to the input grid of a tube, which is provided, for instance, according to Fig. 4 or Fig. 5, with two tuned circuits in the anode and cathode supply lead, then undesired coupling phenomena may occasionally arise owing to the capacity between the input grid, which is usually situated nearest to the cathode, and the cathode itself. In such cases, it may be preferable not to choose as input grid a grid situated adjacent the cathode, but to arrange between the cathode and input grid one or more auxiliary grids. For instance, a space-charge grid may be provided between the cathode and input grid.

In order to supply the cathode emission current to the tube system and in order to produce as uniform a resistance as possible for the frequencies which differ from the natural frequency of the oscillatory circuits, the series combination 8, 9 in the constructional examples shown is bridged over by a resistance 4, which determines the degree of the negative back-coupling for the frequencies which are not desired. However, this resistance may also be omitted, in which case a choke coil is preferably connected in parallel with the condenser 8, as is shown in dotted lines in Fig. 5.

The arrangement shown in Fig. 5, as has already been mentioned, is so constant in the back-coupling adjustment, that a rather extensive removal of damping, particularly if an additional screening grid is provided between the input grid and cathode, is possible even with the existence of several stages connected in cascade.

As has already been mentioned when discussing Fig. 4, special effects can be obtained by de-tuning the series resonant circuit 8, 9 with respect to the anode circuit 3, so that, therefore, different resonant frequencies are provided for these two circuits. Also, instead of series resonant circuits in the cathode supply lead for for the purpose of obtaining selective counter-coupling in the anode circuit, parallel circuits may be provided alone or in addition to the series resonances, in order to suppress particularly undesirable oscillations, as may be desirable, for instance, in mixing arrangements of superheterodyne receivers. Also, instead of simple resonant circuits, networks which are more complicated may be provided on the cathode or anode side, and which have not a single but several preferred frequencies or frequency ranges, or suppress or pass broader frequency ranges.

Indirectly-heated or other equi-potential cathodes are particularly suitable for the cathodes, but directly-heated cathodes may also be employed. In this case, the tuning coil 9 and the choke coil connected in parallel with the condenser 8 are then preferably made from the cathode supply leads. To this end, there can be made from these two heated leads a cable of two twisted conductors insulated from one another, from which the said coils are wound. Any parallel resistances **4** need then be connected only on one side direct to the cathode, since, in comparison with these high-ohmic resistances, the cathode resistance is negligible. Of course, however, also a connection at the real or electrical centre of the cathode could be effected.

A further constructional example of the idea of the invention is shown in Figure 6. Here, there is shown a possible application to a so-called "single-span" superhet receiver, that is, a superheterodyne receiver in which the tuning is effected merely by the variation of the oscillator oscillation, whereas the input circuit is aperiodic, since the disturbing oscillations are removed by the use of a fixed filter in the input circuit and by employing a relatively high intermediate frequency.

By this, however, it is not intended to mean, for instance, that the features shown would not also be advisable in ordinary superheterodyne receivers or other sets.

The tube **15** is a mixing hexode, the tube **16** a pentode which acts as intermediate frequency amplifier and audion, and the tube **17** the loudspeaker tube. In the cathode supply lead of the tube **15** there is provided a series resonant circuit **18**, **19**, which is tuned to the intermediate frequency.

This has the selectivity-increasing effect for this frequency and, in addition, has the advantage that for the other frequencies, owing to the negative back-coupling which arises, a linearisation occurs, the magnitude of which can be adjusted by variation of the resistance **20**. From the resistance **20**, moreover, the most favourable grid bias for the input grid of a mixing tube is derived by means of a slider.

Owing to this linearising effect, cross-modulation is avoided to a great extent for all the oscillations which reach the input grid of the tube, so that, therefore, even when using a somewhat curved tube characteristic, as may be desirable for volume control purposes, the advantages of a purely multiplicative mixing are existent to the highest degree.

Since a quartz crystal **21** is coupled to the anode circuit of the mixing tube, the tuned anode circuit **22** is very poor in capacity, that is, is only designed as a tunable choke. By back-coupling the coils **19** and **22**, an increase or reduction in sensitivity (according to the direction of coupling) as well as a regulation of selectivity can again be effected.

If the tube **15** is constructed as an exponential tube, then a volume control can be effected in a very effective manner by means of the slider at the resistance **20**.

The tuning is effected, as has already been mentioned, merely by adjustment of the oscillation frequency of the oscillator **23**. For the purpose of a most favourable coupling adjustment, the small coupling capacity **24** is made variable.

The tube **16** contains likewise a series resonant circuit **28**, **29** in the cathode lead, as well as a tuned anode circuit **30** in the anode lead.

The grid bias is derived through a high-ohmic resistance **25** from the counter-coupling **25** from the counter-coupling resistance **26**. The crystal **21** as well as the remaining tuned circuits are adjusted to the intermediate frequency.

By coupling the coils **29** and **30**, a back-coupling can be introduced in the tube **16**. In certain circumstances, the circuit **30** may, in this case, be replaced by a simple back-coupling coil. The crystal **21** therefore acts as an additional tuning member as well as an audion blocking condenser.

Between the crystal and the negative bus-bar, the variable inductance shown in dotted lines may be inserted. This inductance may be adjusted with the capacity of the crystal **21** to series resonance for the frequency to be received or an adjacent, particularly lower frequency, and may then have the following action:

Since the resonance curve of the coupling inductance **22** is relatively broad, then in spite of the selective properties of the crystal, a number of indesirable oscillations would eventually reach the input grid of the tube **16**. If a series resonance path is produced by the inductance shown in dotted lines, between the grid and earth for these frequencies reproduced, after amplification, by the choke coil **22**, then the grid is practically short-circuited for these frequencies. Only with the narrow frequency band to which the crystal responds is the series frequency disturbed and thus the input grid of the tube **16** excited.

Therefore, in the tube **16**, both an amplification of the intermediate frequency and an audion effect occur and the low-frequency currents obtained are supplied through a transformer **27** to the final tube **17**.

In the Figures hitherto described, direct or alternating current resistances inserted in the cathode lead have always been shown as counter-coupling means.

Figure 7 shows another form of construction of a counter-coupling which has similar effects. Here, in a tube **31** which has, in a manner well-known per se, a tuned anode circuit **32**, a connection **33** from the anode to the grid is provided.

Since, as is well-known, the anode voltage is displaced 180° in phase with respect to the grid voltage, then by suitable return of a part of the anode voltage to the grid, a counter-coupling can be obtained. By varying the resistance **34**, the level of this returned voltage can be favourably adjusted. If this resistance is so adjusted that the voltage impressed from the anode circuit upon the grid is equal to the input voltage reaching the grid, then no amplification occurs at all, since the two voltages having, as mentioned, a phase displacement of 180°, neutralise one another.

If, in addition to the resistance **34**, a tuned circuit **35** is provided, then since this tuning circuit constitutes a high resistance for its natural frequency, only a small counter-voltage will be transmitted at this natural frequency to the input grid and, therefore, this frequency is amplified. It is therefore seen that owing to the circuit **35** a further means of selection is provided, which can be used independently or together with other tuning circuits as, for instance, the circuit **32**, for separating desired frequencies.

In tubes with a very high amplification factor, the resonance resistance of the circuit **35** may not be sufficient in certain circumstances. It can be then increased by a suitable back-coupling arrangement, or altenatively, several circuits **35** may be connected in series.

A further constructional example of the inventive idea is illustrated in Fig. 8. As has already been mentioned, it is necessary for the obtaining of the highest possible selectivity that the counter-coupling shall be made as strong as possible for all undesirable frequencies. However, in arrangements, for instance, according to the constructional examples shown in **Figs. 4** and **5**, this means that the resistance **4** is made high and that also the resistance **8, 9** is to be very high for all frequencies, with the exception of the resonant frequencies.

This resistance, however, becomes greater, the smaller the capacity and the greater the inductance of this circuit can be made for a given wave-length.

Since it is essential that for this purpose all stray capacities shall be reduced if possible, for which reason also the corresponding cathodes are to have the smallest possible capacity with respect to their heating body or other apparatus parts, it is also preferably to make the coils **9, 19, 29** or the like as small as possible in order to make them poor in capacity. Since, in this case, however, the mutual spacing between the turns must not be reduced too much for the same reason, a small copper cross-section and thus a relatively high effective resistance of the coils, of course, results.

In order apparently to reduce this effective resistance which, of course, is also maintained in the case of resonance and which acts for the resonance frequency as a counter-coupling, the use of back-coupling has already been recommended, which, however, is not irremissible.

The construction example in **Figure 8** shows a possibility of completely avoiding the occurrence of a counter-coupling even without back-coupling for the case of resonance.

36 is an amplifying tube, to which input voltages are supplied through the transformer **37**. To the anode of the tube **36**, for instance, a tuned anode circuit **40** is again connected. The amplified currents are kept away from the anode voltage source by the de-coupling resistance **41** and pass through a blocking condenser to a network, from which the counter-coupling voltages or back-coupling voltages can be derived.

In the present case, a counter-coupling is to be effected again for all frequencies with the exception of a desired frequency.

The above-mentioned network is so arranged that for the desired frequency even without the use of an additional damping-reducing back-coupling, no counter-coupling voltages can arise at the input grid.

For this purpose, in the first instance, the series combination **38, 39** is again tuned to the desired frequency. Then, by means of the variable coupling **42**, an adjustment is effected at which for undesired frequencies an adequate counter-voltage arises at the input grid of **36**. By the tuning of the condenser **43** and adjustment of the resistance **44**, there can then be found upon subsequent correction at the condenser **38** a position at which absolutely no counter-voltage arises for the desired frequency at the input grid.

If, instead of the filtering-out of a certain frequency from a frequency mixture of undesirable frequencies, the suppression of an undesirable frequency in a larger frequency mixture is aimed at, then in all the arrangements described here this can be achieved by providing a parallel resonant circuit at the points where a series resonant circuit is provided, while, on the other hand, at those points where a parallel resonant circuit is provided, this is replaced by a series resonant circuit.

A very material advantage of such arrangements for increasing selectivity resides in the fact that the two main functions hitherto carried out in a resonance amplifier by the coupling oscillatory circuits or the like can be separated and, thus, more favourable results can be obtained.

In a resonance amplifier working, for instance, with tuned anode circuits as coupling means, the case was hitherto such that the tuned anode circuit determined both the obtainable amplification and the selectivity of the particular stage. It was, therefore, necessary to effect a compromise. Thus, for instance, if importance was attached to very high selectivity, the ratio of capacity to inductance in this oscillatory circuit had to be kept at a certain value, which could not be reduced. The higher the inductance of this circuit, the higher is the obtainable amplification in general.

The highest dynamic resistance results (if no excessive damping is provided), as is wellknown, if the oscillatory circuit merely consists of the natural capacity of a coil and the inductance of this coil. However, since in such a case the selection is usually insufficient, the high amplification which is possible in such an arrangement generally could not be utilised.

Since it has now been found that by arranging a tuned counter-coupling channel and, in particular, by means of a series resonance circuit, which may be arranged at any point between the anode and cathode, preferably between the cathode and the negative pole of the anode voltage source, a very substantial increase of the inductance can be otbained, much greater latitude is obtained in the choice of the values for the anode circuit serving as coupling member.

In such a resonance amplifier, which was tuned to 1600 kilocycles and constitutes the intermediate frequency amplifier of a "single-span" superhet receiver, it was found, for example, that the half-value width, which was obtained by means of a series resonant circuit situated between the cathode and negative anode voltage pole, was so much less, than the half-value width obtainable with a normal anode tuning circuit alone, that this tuned anode circuit in practice hardly contributed to the obtaining of the tuning sharpness.

Therefore, without renunciation of separating sharpness, this anode tuning circuit could be varied at will (on the condition that the internal resistance of the tube is still large in relation to the dynamic resistance of the anode tuning circuit, a condition which is generally fulfilled in normal high-frequency pentodes) without the tuning sharpness substantially determined only by the cathode series resonant circuit varying, and, therefore, when choosing a very small capacity and very high inductance, it is possible to obtain for this anode tuning circuit amplifications with good selective properties of the amplifier, which are not obtainable with normally-constructed amplifiers.

The assumption for the best possible outputs is definitely that certain conditions are fulfilled which are generally to be fulfilled with normal tubes.

In the constructional examples discussed with reference to **Figs. 9 to 13**, it is assumed in this case that the tuned back-coupling or counter-coupling channel is formed by a series resonant circuit inserted between the cathodes and negative anode voltage source; if, instead of this tuned coupling channel, a different channel is chosen, the constructional examples described here for series resonance in the cathode supply lead are to be suitably modified.

When using tubes usual in commerce, it has been found that, in the first instance, the capacity between the input grid and the cathode is very undesirable, particularly if a tuning circuit is connected to the input grid. By the use of a neutralising arrangement, the effect of this undesirable capacity may be removed.

The neutralisation may, inter alia, be so formed that the tuned grid circuit produces, either by purely inductive means in a coupling coil, or by additionally winding a few turns on the earthed side of a grid inductance after the fashion of a spare transformer, a counter-voltage, which now acts through a neutralising condenser upon the cathode, or, alternatively, in a similar manner, a neutralising voltage may be produced by the coil of the series resonant circuit lying in the cathode, the neutralising voltage so obtained then acting through a neutralising condenser, a so-called "Neutroton", upon the control grid.

In addition to this cathode-control grid capacity, however, the anode-cathode capacity is also very undesirable. Since a series resonant circuit is situated in the supply lead to the cathode according to the above, an undesirable coupling or counter-coupling easily arises between the anode of the tube and cathode, if appreciable capacities are effective between these two electrodes.

This becomes particularly disturbing again when an oscillatory circuit is connected not only to the anode of the tube, but also to the control grid, as is usual in tuned series amplifiers. Since the grid oscillatory circuit in spite of neutralisation with respect to the cathode usually still has a residual coupling to the cathode circuit and since, on the other hand, owing to the capacitive or other stray coupling which exists between the cathode and anode the anode circuit is also coupled to the cathode circuit, the maximum amplification usually cannot be stably utilised, since in this way energy returns through the cathode circuit to the grid circuit and the arrangement then commences to oscillate.

A large part of these detrimental couplings arises within the tube, namely, in the base and in the pinch, and it is therefore desirable also to neutralise or, in order to obtain best results (when using the series resonant circuit in the cathode supply lead, otherwise, as already mentioned, variations must be suitably effected) to use a tube construction according to Fig. 9.

This tube **60** is constructed, for instance, as a pentode with the one difference that between the control grid **61** and the cathode an electrode **62** constructed as a screen-grid is also provided, which by application to weakly positive potential with respect to the cathode can simultaneously exert the steepness-increasing effect of a space-charge grid.

This grid **62** terminates at both ends in solid tubular extensions **63**, **64**, which extend beyond the ends of the other electrodes. The tubular extension **64** also protects the parts of the filament **65** which are situated outside the cathode **66**, so that no disturbing influence of the amplifying operation can be caused by them, while the tubular extension **63** preferably merges into a conical part **67**. This conical part extends, if possible, up to the glass wall of the tube, in order to provide an effective screening of the cathode supply pole **68** arranged at the upper end of the tube envelope, from the other tube electrodes. Since the conical part **67** of the space charge screen-grid **62** (but a space charge effect at this grid may also be renounced, in which case it can then be more weakly or more strongly negatively biased), if it were to extend close to the glass wall and were to consist of massive metal, might easily present difficulties in de-gassing, then in the constructional example of Fig. 9 there is attached to the conical metal part, which only has about 5 mm. projection with respect to the grid diameter, a conical extension of metallised mica slotted in sector fashion. This metallised mica cone has a screening effect similarly as if it were to consist of massive metal; since, however, on thorough heating with high-frequency eddy currents owing to the high resistance of the thin metal layer or other conductive layer on the mica, the latter is not heated to a very high temperature, then no breaking of the envelope dome owing to contact with the screen can arise.

The grid **62** is followed, reckoned as next from the cathode **66**, by the actual control grid **61**. This control grid receives its supply, contrary to present-day practice, through the pinch. Since the control grid is generally connected in any case to an oscillatory circuit, the capacity existing between the control grid and the other electrodes in the pinch, which are earthed as regards high frequency, only enters the arrangements as additional oscillatory circuit capacity and is therefore harmless.

The cathode **66**, on the contrary, is to have, according to the above, as small a capacity as possible both with respect to the control grid and with respect to the anode **69** and, moreover, as small a capacity as possible with respect to any other electrodes. Therefore, as shown in the constructional example of Fig. 9, an outgoing lead **68** at the top of the tube envelope is advisable. Moreover, it is advisable to make the distance between the cathode body **66** and filament **65** as large as possible in order to keep the cathode capacity low with respect to earth, since it is thereby possible to give the cathode series resonant circuit a very small tuning capacity and thus high selectivity. The cathode may also be made rather short in order to achieve this object; the deficiency in steepness possibly resulting in this case can be removed again by the action of the space-charge grid **62**.

As third electrode from the outside, the well-known screen electrode **70** follows, which is generally at positive potential and which is extended at the top and bottom again by plate-shaped members **71** for improving the screening of the electrodes from one another. In order to bring the plate-shaped members again close to the glass wall or to the screening coating provided inside and/or outside on the glass wall, metallised mica plates or mica plates coated with thin foil, for instance, resistance material, may be used.

Reckoned as the last grid from the cathode, a collecting grid **72** then follows, which in turn is surrounded by the anode **69**.

Instead of the pentode-like tube described here, hexode, septode or octode-like tube structures may also be employed.

Moreover, it may be preferable to use instead of a pentode-like arrangement, a mere screen-grid tube arrangement, in which the collecting grid is omitted. In particular, it is preferable to work, according to the principles of the well-known Harries tube, with a critical, fairly large distance between the anode and the screen-grid, Thereby, the anode-earth capacity is considerably reduced and, therefore, a still higher L—C ratio may be given to the coupling oscillatory circuit to be connected to the anode, which inter alia acts favourably for the obtainable amplification.

A construction according to electron-optical aspects also furnishes, inter alia, advantages, particularly in this respect. The anode **69** has a special lead-out terminal **73** direct through the glass wall. As is shown, the tube **60** is cylindrically shaped with the exception of the constriction of the dome envelope, so that the construction with the screening plates extending close up to the tube wall can be introduced from the bottom into the tube.

The fused seam between the plate and envelope therefore lies further outside, which stipulates a large diameter of the tube base. However, in the present case, this is not undesirable, since the tube base is preferably made of metal or is metallised and forms an additional covering of the holes serving for receiving the tube, in the screening boxes of the amplifier, as is apparent from Fig. 10.

If the tubes are introduced from the bottom into the screening boxes, then the screening boxes must have a recess for the passage of the lateral anode terminal **73**. This passage is then closed by the tube base when the tube is introduced.

Also otherwise, the larger tube base is not undesirable owing to the larger distances between the individual feed wires and the good insulation etc. thereby possible.

In order to assemble the tube in a simple way in spite of the two envelope contacts, the supply leads to these two contacts are made resilient, the dome contact having a resilient pin, which engages in a sleeve-shaped continuation of the cathode body, while there is fixed to the anode a resilient contact tongue, which comes into connection with the lateral contact point at the envelope when the system is inserted in the envelope in the manufacturing operation.

Since, in practice, usually vacuum tubes or tubes filled with inert gases will be in question, danger to the contact by oxidation need not be feared. Frequently, however, it may happen that, owing to the heating of the metal parts which is necessary for the expulsion of the gas, the elasticity decreases and then the contact becomes unsafe. It is then necessary to produce the resilient parts in such a manner that even when using ductile material, the resiliency is maintained, or provision should be made for a subsequent permanent connection of the parts making contact in the envelope.

To produce such a permanent connection the following method has proved highly successful. Those two parts which are to be connected together are made of a material which has a relatively high melting point. The two contacting parts or at least one of the two is then coated at least at the point of contact, with a material which has a lower melting point and then, after assembly of the tube, that is, preferably in the de-gassing operation, in which the metal parts of the tube are highly heated by electron or ion bombardment or by thorough heating by means of high frequency eddy currents, the contacting parts are so highly heated that the material of low melting point, which surrounds one or both parts at the point of contact or is applied to the point of contact, fuses, whereby the two parts to be connected are then connected by a kind of soldering process. This method can be quite commonly employed in the construction of tubes or the like.

It has proved particularly successful in the present case in fixing the anodes to the lateral fused-in portions already previously arranged in the envelope. The anode was made in this case, for instance, from nickel wire network and the end of the lateral anode supply wire fused into the envelope also consisted of nickel. The nickel wire end, which was about ½ millimetre thick, was covered with fine silver wire (about 0.2 mm) and was mechanically biased in such a manner that the wire end resiliently pressed on the anode body approximately over a distance of 2 to 3 mms. On thoroughly heating the anode with high-frequency eddy currents, the silver then melted and connected the anode gauze with the supply wire by hard soldering. If, in the case of the connection, it is not a question of bodies which can be conveniently heated up like an anode from outside by high frequency, it is advisable to effect the point of connection at a small metal plate or metal ring or metal bow specially provided for this purpose, which can be heated up from outside by induction currents.

Although in the present case the use of this method was chiefly described for lateral fused-in portions at the tube envelope, the method can accordingly be applied to all other cases in which the making of a durable connection in vacuo is important, that is, also in the case of the connection of the cathode lead-in arranged centrally on the envelope dome.

The getter pill is preferably arranged between the upper screen of the cathode screen-grid and the upper screening plate of the anode screen-grid. On vapourising the getter, the result is then obtained that, firstly, these two screening plates are metallised, which is desired according to the above and renders it superfluous to use already metallised mica in the assembly, whereas, on the other hand, since this space is screened on all sides against the remaining electrodes and the holding wires, the result is obtained that no getter deposit can form on insulators and glass parts at places where it might be detrimental for the operation of the tube.

The constructional elements mutually supporting the individual grids, as, for instance, holding parts of mica, ceramic material or the like, are not shown for the sake of clearness; these parts may, however, be constructed in such a manner that e. g. between the anode and cathode screening plate, between which the getter is supposed to be situated, all the other grid holding wires or the like are covered by the said insulators; if a deposit forms here on the insulator, this deposit may merely connect together the cathode and anode screening plate. By means of a current impulse between the two corresponding electrodes, the conductive bridge which possibly forms may then be interrupted. Any remaining weak "creeping" current path, however, is harmless, since both electrodes only carry direct current potentials and are earthed as regards high frequency or alternating current.

Fig. 10 shows a diagrammatic section from a suitable arrangement for the construction of such a series amplifier. In this figure, only the high-frequency circuits situated between two tubes are shown, but, of course, such an amplifier may be provided with almost any number of stages and, therefore, the arrangement shown in Fig. 10 must be imagined to be continued to the right or left in the sheet of drawings in this case.

81 and **82** in this case are tubes which are constructed after the fashion of Fig. 9. **83** are the metal walls or metallised walls of screening boxes. The voltage to be amplified is supplied to the grid supply lead **84**. The tuned anode circuit **85** is connected to the anode terminal **86** of the first tube and is connected in a manner well-known per se through a coupling condenser **87** and a leakage resistance **88** to the grid supply lead **89** of the next tube. The cathode supply lead **90** of the first circuit is connected to the earthed mass of the screening boxes **83**, which is connected to the negative anode voltage pole, through a series resonant circuit which consists of an inductance **91** and a capacity **92**.

Since the cathode lead **90** only has a low capacity with respect to other apparatus or tube parts owing to the particular construction of the tube, the regulatable capacity **92**, which is tuned together with the coil to the frequency to be amplified, may be made rather small, without there being produced by the effect of the stray capacity of **90**, a parallel resistance to the series combination **91**, **92** which constitutes for the frequencies departing somewhat from the resonance frequency a smaller resistance than this series combination itself, so that the latter becomes ineffective.

Of course, there may be cases where, even if the capacitive leakage resistance, owing to stray capacities, becomes relatively small with respect to the resistance of the series circuit in the non-resonance condition, an adequate selectivity increase by the series circuit is nevertheless obtained. Generally, however, the difference of the resistance effective between the cathode and mass may be as large as possible between the resonance condition and non-resonance condition, in order to produce resonance properties which are as pronounced as possible.

When choosing the tuning values, and also in all other cases in the art, a compromise is necessary. The smaller the capacity **92** becomes, the greater is the resistance of the circuit **91**, **92** for non-resonance frequencies. On the other hand, however, a further increase of the resistance **91**, **92** for non-resonance frequencies has no longer any great purpose if there is produced by the stray capacities from the cathode contact **90** to other parts of the tube or of the apparatus a parallel resistance which is considerably less than the resistance of the combination **91**, **92**.

The losses in the coil **91** also increase with progressive reduction of **92**, and since these losses also appear in the resonance condition as effective resistances, the desirable large difference between the resonance resistance and non-resonance resistance is thereby reduced. Moreover, the obtainable amplification per stage is reduced by the effective resistance remaining in the resonance case as an ohmic counter-coupling resistance. Where, therefore, a residual counter-coupling for the purpose of the linearisation of the amplifier characteristic is not desired, as, for instance, in mixing tubes in superheterodyne receivers and the like, the reduction of the capacity will therefore only be taken so far that only a small value results in the case of resonance as effective resistance of the complete circuit.

In 1,600 kilocycle-amplifiers, for example, a form of capacity **92** which is illustrated in Fig. 10 has proved successful. At a threaded spindle which runs in a threaded bearing insulated against the screening boxes **83** there is provided a plane, circular plate of about 30 millimeters diameter, which can be moved towards or away from the screening wall for the purpose of tuning. For safeguarding against short-circuits, the casing wall may be protected at the point situated opposite the condenser, by an insulating coating, as indicated by a line in the drawing.

The choke **93** and the resistance **94** are connected in parallel with the series combination **91**, **92**. The resistance provides for the production of the required grid bias, whereas the choke **93** within the frequency range coming into question is to represent a high high-frequency resistance, so that the effectiveness of the combination **91**, **92**, is not reduced by the parallel resistance being too small. The fact that by means of such a choke, resonance positions within more remote frequency ranges can possibly be produced, is usually insignificant, since more remote frequency ranges can be adequately weakened by the tuned anode circuits **85** of such an amplifier.

As is apparent from the diagrammatic circuit diagrams, it may be preferable to couple the coils of the oscillatory circuit **85** and the cathode coils **91**, which coupling, according to the sense of coupling, may act as a stabilising counter-coupling or as a damping-reducing back-coupling. If, for instance, a very high frequency is amplified, then in spite of the most careful screening measures, the internal tube capacities may suffice to cause a tendency to oscillation even with, in particular, multi-stage amplification. In this case, with the said coils, a stabilisation can be obtained by means of a certain counter-coupling, so that here the coupling serves as a method of neutralisation. On the other hand, however, by means of a back-coupling effect between the anode and cathode circuit, a very considerable amplification increase and selectivity increase can be obtained.

The desired adjustment of the mutual coupling of the two coils can be obtained in a manner well-known per se by making one of the two coils rotatable. If the desired sense of coupling is fixed, the two coils may also be firmly arranged and only the opening **95** in the screening wall separating the two coils may be more or less constricted by a screening flap and thereby the action of the two coils on one another may be regulated.

Since, with the high amplification generally occurring here, most careful screening is important, a grid of parallel wires or the like which is indicated by short transverse lines is provided in the opening **95**, which grid, particularly with an arrangement of these parallel wires which is insulated on at least one side, makes it possible to prevent in practice an electrical action of the two coils and corresponding circuit parts on one another, while an inductive mutual influencing takes place.

The tubes **81** and **82** are inserted from below in the corresponding screening boxes. Therefore, in the circular opening serving for receiving the tubes, recesses are provided in at least one screening wall for the passage of the anode terminals **86**. If the tubes are insulated, these passages are covered by the base flanges **96**.

If specially constructed tubes according to Figs. 9 and 10 are not used, the subject of the application can, of course, also be carried out, but the obtainable advantages are fewer. If, while using ordinary commercial tubes, it is desired to derive the full advantages which the subject of the application offers, this can be done in various ways.

One possibility is illustrated in Fig. 11. Between two tubes, which, according to this invention, work with an additional coupling channel, in the present case with a series resonance provided in the cathode lead as a counter-coupling, in which case the series resonant circuits of the cathode lead may be inductively coupled with the tuning circuits provided in the anode lead, an aperiodically-coupled tube is provided.

In the constructional example of Fig. 11, the first tube is imagined to be a mixing tube and therefore has, in addition to the input grid and the screen-grid, a grid to which the oscillator voltage is applied. This, however, is immaterial; therefore, in a tube amplifier, the first and third tube could also be uniformly constructed.

Between the first and third tubes, an aperiodically-acting tube is inserted, in the present constructional example a pentode. Since pentodes or even only screen-grid tubes are on the market, in which the anode has a special connecting terminal provided on the envelope, it is possible by means of the circuit connection shown in the drawing, of a pentode or of an ordinary screen-grid tube, to obtain the result that the anode circuit of the first tube is not coupled to the cathode circuit of the third tube through a grid-capacity, since, of course, the grid of the third tube is connected to the anode of the second tube and the anode of the second tube is screened from the input grid of this tube and thus from the anode circuit of the first tube by a screen-grid.

The capacitive coupling between the anode circuit and cathode circuit of the first tube on the one hand and of the third tube on the other is definitely maintained if these two tubes have no special outgoing anode supply leads. These capacities, which are mainly existent in the tube bases, can be removed, however, by an inductive counter-coupling (see arrows) to the extent desired. Since, in general, a back-coupling effect in the individual stages is desired, a complete neutralisation by counter-coupling will generally not be effected.

Since the central tube, particularly at higher frequencies, does not contribute much to the amplification, it is desirable to limit the expenditure for this as much as possible.

Fig. 12 shows an example of how cheap single-grid tubes can be used for this purpose, in which case, to obtain the best effects, it is desirable that the anode supply lead shall be specially led out of the envelope. The output voltage of the first tube in Fig. 11 is applied here to a high resistance lying in the cathode lead.

A favourable grid bias for the screen-grid connected as regards high frequency to the negative pole of the anode voltage and thus to earth is produced by a branch resistance. This is necessary, as the cathode resistance must be high in order not excessively to damp the preceding anode circuit (a certain damping is not detrimental, since it can be compensated by back-coupling in the first tube).

Since, due to this high cathode resistance, the high negative grid bias which would be produced by directly connecting the grid with the negative pole of the anode voltage source, would lock the tube, the arrangement shown in Fig. 12 is chosen, which allows of choosing the grid bias independently of the potential drop in the cathode resistance. From the anode of the three-electrode-tube, the output voltage is again passed on to the third tube of Fig. 11. The grid of the three-electrode tube connected to earth as regards high frequency effects the desired screening between the output circuit of the first tube and the input circuit of the third tube in Fig. 11.

A further embodiment employing tubes usual in commerce is shown in Fig. 13. Here, two tubes are connected in series, in which case, as has already been mentioned in British Specification No. 415,079, attention should be paid to the fact that by the cathode heating of the upper tube, no appreciable leakage to other apparatus parts or to earth takes place. This can be done, as described in the said prior application, by heating the cathode with transformers poor in capacity arranged near to the cathode, or, alternatively, by indirect heating of the upper tube as poor in capacity as possible, as well as by any other kind (photo-emission, secondary emission, virtual cathodes or the like) which allows of producing an emission without an excessive detrimental leakage.

Both tubes in Fig. 13 therefore act practically similarly to a tube with a correspondingly high number of grids. The lower tube may be a three-electrode tube, in which case the control grid is connected as regards high frequency to earth. The nature of the grid-bias variation as shown or some other similar arrangement at this grid may be used for volume control, particularly if one of the two tubes or tube systems is constructed as an exponential tube.

In the cathode supply lead of the tube, furthermore, the series resonant circuit is provided. The anode supply lead is again separately led out of the tube if possible.

The input voltage is then applied to the control grid of the upper tube, while the anode of the upper tube is screened against this control grid by a screen-grid kept at a positive potential. The desired screening between the control grid and anode is then produced again by the last-mentioned screen-grid, whereas by means of the control grid which is earthed as regards high-frequency in the lower tube, a screening between the upper control grid acting as input grid and the series resonant circuit situated in the lower cathode supply lead is obtained.

Instead of the upper tube, the lower tube may also be provided with two control electrodes; the upper tube may then be a single-grid tube. This case is illustrated by the second grid shown in dotted lines in the lower tube.

In the case of Fig. 13, the additional expenditure of a special tube is also necessary for the decoupling; however, since both tube systems fully amplify here, an advantage exists over the arrangements shown in Figs. 11 and 12 with aperiodically-acting coupling tubes, which may be desired in many cases.

In the description of Figs. 9 and 10, it has already been pointed out that it is advantageous to avoid as far as possible the capacity between the cathode and the cathode heater. This requirement can be complied with by means which bring the cathode to emission in a different manner. There may be mentioned here photo-emission, thermal emission by radiation, secondary emission or virtual cathodes, etc.

A further means consists in reversing the usual practice and inserting the coupling resistances, which connect together the individual stages of an amplifier, that is, in the present case, for example, the tuned anode circuits, in the cathode lead, and transferring the series resonant circuits into the anode lead. In this case it may be preferable to earth also the anode side instead of the cathode side of the amplifier.

Since the anodes, of course, do not necessitate any heating leads, then, particularly if care is also taken by the other construction of the amplifier (for instance, after the fashion of the Harries tube) that the capacity of the anode to screening electrodes etc. remains small, the condition of the existence of minimum leakage capacities at the series resonant circuits which is sometimes desirable as already explained above, can be produced. Moreover, particularly when using tubes customary in commerce, an undesirable coupling between circuits can often be avoided by the coupling circuits in the case of successive amplifying stages lying alternately in the cathode supply lead and anode supply lead, while series resonant circuits also lie alternately in the cathode and anode supply lead of the individual stages.

In the case of octodes, hexodes and septodes etc. it is often possible, merely by an alteration in the arrangement of the base or of the leads led directly out of the envelope, to produce the screening desirable in the case of the present application, without introducing further additional electrodes and without coming into conflict with the usual mode of operation and the fields of application of these tubes.

In order not to obtain any detrimental couplings through the heating leads at the voltage sensitivity of the cathodes which is existent in the case of maximum utilisation of the advantages of the subject of the invention, it may be preferable to arrange the heating leads in such a manner that all the heating leads, while screened from the individual tubes, are led to a common connecting point, at which the leads are connected through large condensers to earth or chassis. Possibly, special de-coupling means may be provided in the supply leads of the individual heaters to this common connection to the source of heating voltage.

The screen, of course, need only extend so far as the heating leads must be passed through non-corresponding screening spaces.

Since the series resonant circuits provided in the cathode leads are bridged over either by choke coils or resistances, the values of which are determined by the degree of the counter-coupling desired in the case of non-resonance and, therefore, there may arise in the resistances a potential drop which does not coincide with the desired grid biases, care should be taken that the grid bias can be derived from these resistances independently by tappings or the like, as is shown in Fig. 12. If variable grid bias is desired, the grid bias is therefore to be variable independently of the value of the resistances lying in the cathode supply lead.

If, for certain reasons, the arrangements of Figs. 11, 12 and 13 or similar arrangements are preferred to the arrangements of Fig. 9 or 10 or the like, it may be preferable to combine the tube systems serving for de-coupling or screening (central tube of Fig. 11 or tube of Fig. 12) with a preceding or succeeding tube system to form a multiple tube. The same applies to the two systems of Fig. 13.

Instead of two tube systems, of course, a larger number of tubes according to Fig. 13 may also be connected together.

Among other advantages, only small stray capacities exist in multiple-tube structures.

If there exists between two circuits, for instance a cathode series resonant circuit and an anode tuning circuit, a coupling which is unfavourable for the amplifying operation in the whole amplifier, while the anode circuit in itself still shows an undesirable broad tuning, it may be preferable to produce a neutralisation by counter-coupling between the series circuit and the anode circuit, and to eliminate the damping of the anode circuit by additional damping-eliminating means, for instance, a back-coupling, on the collecting grid from the anode circuit. Therefore, in this case, too small a damping at one point is compensated, whereas at another point too great a damping is reduced in the same tube.

Hexodes or the like are still more favourable than pentodes for such cases, since the third grid, reckoned from the cathode, that is, the second control grid of a hexode is more suitable than the collecting grid.

Other counter-coupling channels may just as well be advantageous, of course, under altered circumstances. Thus, for instance, a counter-coupling through the second control grid of an hexode may be advantageous. Likewise, such counter-coupling arrangements may be inserted in the screen-grid leads.

In the case of very sensitive arrangements, it may be important to screen the cathodes against the filament by additional metal envelopes or grids earthed or brought as regards high-frequency to earth potential.

If, as has already been mentioned above, tubes according to Fig. 9 or the like are constructed, then the space-charge grids serving as screen or intermediately positioned grids may be used for modulation purposes or the like, since such functions of additional grids, of course, generally do not prevent the latter from acting simultaneously as screen.

Therefore, for instance, in transmitting amplifiers, such auxiliary grids may be used at the same time for modulation purposes as well as in intermediate-frequency receiving arrangements.

As has already been mentioned, an arrangement in which tuning means substantially according to Fig. 10 are provided in the cathode and also in the input and output circuit has the great advantage that there is a material selectivity increase with respect to the simple anode circuit coupling.

For many cases, so-called band-filter couplings are known, in which therefore at least two resonant circuits are provided between the output side of a tube and the input side of a next succeeding tube. Such amplifiers, however, have the drawback as compared with simple anode circuit coupling, that in the best case only 50% of the total amplification otherwise possible can be obtained, while this limitation does not exist in the present arrangement.

However, the other advantages of the band-filter coupling can also be obtained with the subject of this invention, for instance, an almost optional broadening of the resonance curve, without the flank steepness being highly affected in this case. This can be achieved in itself by employing in the counter-coupling channels, that is, for instance in the cathode supply lead or in supply leads to a screen grid, instead of the simple series resonant circuits, chain conductors, such as coupled circuits or the like.

However, such effects can also be obtained with the simple arrangements according to Fig. 10, if the circuits are somewhat detuned with regard to one another within one or more stages. In particular, at very high frequencies, say, in the amplification of broad bands for television purposes, such arrangements are very useful owing to the high obtainable band widths at relatively good total amplification both as straight amplifiers and also as intermediate-frequency amplifiers.

When working with superheterodyne receivers of high intermediate frequency, that is, in particular, "single-span" superhets, it has also been found that it is particularly important to provide good screening of the individual electrodes from one another in the mixing tube.

Thus, for example, the practice generally carried out at the present day, of separately leading out only the control grid in the envelope in a mixing hexode or mixing octode is usually not sufficient. Since, in such receivers, particularly on the reception of long waves, the oscillator frequency shows only quite small (10% and less) detunings with respect to the intermediate frequency, instability easily occurs on the reception of long waves owing to accompanying phenomena or the like. This instability appears to arise inter alia through the base capacities between the control grids, to which the oscillator frequency is supplied, and the anode circuits, which, of course, are tuned to the intermediate frequency.

This detrimental influence is manifested particularly if, as described above in various constructional examples, the cathode circuit is also tuned. Therefore owing to the base constructions or the capacities present therein, an influencing between the oscillator circuit and tuned intermediate frequency circuits or the like inserted in the anode or cathode lead can then particularly easily arise, which has the unfavourable result of a whistling tendency, whistling points etc., especially on the reception of long waves.

Therefore, according to the present application, as is shown in a constructional example in Figs. 9 and 10, care is to be taken that the control grid, anode and cathode are screened against one another as well as possible and separately led out, a separate lead-out of that control grid to which the oscillator voltage is applied being provided in the case of mixing tubes. One of the outgoing leads to be separated, however, for instance, as shown in Figs. 9 and 10 for control grids, may be led out of the envelope together with the screen-grid leads.

A further constructional example of the present invention applied to a mixing tube and intermediate frequency amplifier of a "single-span" superheterodyne receiver is shown in Fig. 14.

In this example, the resistance **101** connecting the cathode of the mixing tube **100** with the negative anode voltage lead serves for counter-coupling. By means of a slider **102** which connects the grid-leak resistance **103** to any desired point of this cathode resistance, the most favourable grid bias of the mixing tube can be adjusted; with the slider **104** shown opposite, which is connected to an earthed condenser **105**, the degree of counter-coupling can be adjusted to the desired resistance.

This counter-coupling has a double effect. On the one hand, it acts in a linearising manner with regard to the frequencies reaching the input grid of the mixing tube and, furthermore, it acts through the agency of the series resonant circuit **106**, **107** connecting the cathode to the tuned anode circuit **100**, to increase the selectivity. This series resonant circuit, as is indicated by the dotted arrow, may be adjustably coupled with the tuned anode circuit.

By the arrangement of the series resonant circuit as shown here, which acts to increase the selectivity, two larger condensers are saved, namely, on one hand, the bridge-over condenser usually arranged between the cathode and earth and, furthermore, the de-coupling condenser leading from the anode de-coupling resistance to the earth lead. Thereby, the additional filter effect which otherwise arises owing to these decoupling condensers and which contributes to the smoothing of the anode current is removed, but since, of course, the counter-coupling is effective also for the alternating current component possibly contained in the anode voltage, such superimposed alternating voltages are considerably less harmful here than in normal arrangements.

Since this is chiefly obtained owing to the absence of the cathode resistance bridge-over condenser, the teaching results therefrom, also is normally constructed high-frequency amplifiers, to choose such an arrangement acting as counter-coupling also for low-frequency disturbances. In a normal high-frequency amplifier, therefore, the bridge-over condensers of the cathode resistance producing the grid bias or of another cathode resistance would intentionally have to be chosen so small, contrary to the former practice, that they are probably sufficient to pass approximately without resistance the high-frequency voltages between the cathode and earth which are to be amplified but that, on the other hand, they are so small that they still constitute a very high resistance for low-frequency disturbing voltages contained in the anode supply current and, therefore, act here as counter-coupling resistance.

This means, as compared with the use of larger cathode condensers of often one or even more micro-farads as is customary at the present day, not only a substantial economy but also a considerable reduction of the alternating current hum and similar disturbances.

The anode tuning circuit **108** of the mixing tube is then coupled through a small capacity **109** to the input tuning circuit **110** of the intermediate-frequency amplifier tube **111**. The coupling between both tuning circuits is to be so loose that no broadening of the resonance curve occurs since at these high frequencies the necessary selectivity is not obtained otherwise. Also with the tube **111** a series resonant circuit **112**, **113** connecting the anode circuit **114** with the cathode is provided, which acts to increase the selectivity.

Since the series resonant circuit **112**, **113** couples the cathode to the anode circuit, then owing to the control-grid-cathode capacity through this series resonant circuit, a coupling between the grid circuit and anode circuit may result, which would then cause an instability of the amplifier. In order to remove this, there is inserted between the cathode and control grid an auxiliary grid **115** which has a screening effect between these two electrodes. Since, with the series resonant circuits serving for increasing selectivity, it may lead to difficulties if also the anode current of the oscillator tube flows through the cathode resistance of the mixing tube, as may be the case with combined oscillator and mixing tubes (for example, type ACH **1**) frequently used at the present day, it is preferable either to use a separate oscillator tube or to transmit the oscillator oscillation inductively to the mixing tube grid.

In order to avoid the undesirable coupling which may arise between the anode and input circuit of the tube 111 owing to the cathode control-grid capacity, without being constrained to employ a separate tube with a screened cathode, a circuit according to Fig. 15 may be advisable. Here, the series resonant circuit is placed between the anode tuning circuit and the positive pole of the anode voltage source. The counter-coupling is effected here by a special condenser C, which only requires a low capacity. In order to supply voltage to the anode, the series resonant circuit in the anode supply lead must be bridged over by a resistance which acts as decoupling resistance. A choke connected in parallel with the series circuit condenser could also serve this purpose. However, since the abovementioned resistance would be connected in parallel with the input circuit of the tube and, therefore, has a damping and selectivity-worsening effect, it is preferable to connect a choke with the resistance, as is shown in Fig. 15. The series circuit and tuned anode circuit may again be coupled together, as is indicated by the arrow, in which case by adjustment and possible reversal of polarity of the coupling, care may be taken that a removal of damping increasing the selectivity, but no self-oscillation, occurs.

Fig. 16 shows a further possibility of connection. The series resonant circuit is connected here again between the upper anode circuit connection and the cathode. The counter-coupling channel contains, in addition to a condenser, a variable high-ohmic resistance, which serves for adjusting the counter-coupling. The anode circuit and series circuit may then again be coupled together. The cathode may be bridged over with respect to earth by a condenser, which is indicated by the dotted line in the drawing.

Since, as has already been discussed in reference to Fig. 15, a connection of the input circuit with the anode circuit through a condenser C may cause an additional damping of the input circuit, since the resistance serving for supplying the anode current is connected in parallel with this circuit through the condenser C (in an arrangement according to Fig. 16, neutralisation may also be effected by a coupling condenser connected according to Fig. 15, if this neutralising condenser has an approximately equal capacity to the anode grid capacity) the circuit according to Fig. 17 has proved to be useful, where the counter-coupling channel is effected through the capacity C not on the input grid but on another grid, in the present case on the collecting grid of a pentode. Instead of the collecting grid of the pentode, a second control grid may also be employed in the case of a hexode, octode or the like; possibly the screen-grid of a screen-grid tube is also already sufficient. Here also the cathode may again be bridged over by a condenser with respect to earth.

If, for screening of the input grid against the cathode, an additional grid arranged between the cathode and the control grid is employed, as in the tube 111 of Fig. 14, then it is desirable, in order to obtain adequate steepnesses, to bias this grid positively as a space-charge grid. In this case, however, certain difficulties arise. If the "Durchgriff" of this cathode-screen is made small enough to obtain a very effective screening, then this cathode screen, if it acts as a space-charge grid, must itself pass an amount of current which is very large in proportion, in order to obtain a desirable high control-grid steepness in the tube. If, however, the "Durchgriff" of this space-charge grid is made large enough, in which case desirably high steepness can be obtained at the control gride without inconveniently high space-charge grid current, the screening effect is small.

It has therefore proved to be preferable to separate the screening effect and the space-charge grid effect and to arrange directly in front of the cathole a pure screen-grid which is approximately at cathode potential or negative potential and which undertakes the prevention of capacitive coupling between the cathode and control grid; then, outside this grid, an actual space-charge grid with a relatively high "Durchgriff", whereby the necessary steepness is produced at the control grid without the space-charge grid having to receive disproportionally high currents and then to arrange the actual control grid on the outside of this space-charge grid.

A normal pentode would then have to be converted into a seven-electrode tube as shown in Fig. 8.

The leading-out of the cathode and anode is preferably effected directly at the glass envelope, whilst the remaining feeds are normally effected in the pinch of the tube.

The arrangements shown here, however, although they were only indicated for high-frequency amplification are suitable for mixing circuits (in which case preferably at least one grid should also be provided for the introduction of the oscillator voltage) and for all other purposes.

A further interesting use of the series resonant circuit is shown in Fig. 19. Here, a normal pentode amplifier stage is shown, in which instead of a single anode tuning circuit, two such tuning circuits are provided. In this case, care is taken that the two circuits are de-tuned by a small amount with respect to one another and with respect to the frequency to be amplified. The capacity C_1 with the inductance L_2 then forms one series resonant circuit, whilst the capacity C_2 with the inductance L_1 forms a second series resonant circuit. These two series resonant circuits effect for frequencies which are displaced to quite a small extent in both directions with respect to the frequency to be amplified, channels of low resistance. The result is thereby obtained that the resonance curve of the amplifier in both directions has a very step fall or rise whereby the selectivity of such an arrangement is greatly increased. This circuit is also particularly advantageous in the so-called "single-span" superhets, where very high selectivity is important owing to the high intermediate frequency generally used.

Fig. 20 shows a complete circuit arrangement of a single-span superheterodyne receiver embodying the selectivity arrangements according to this invention.

At the tube A, the series resonant circuit is formed by the coil L_1 and the capacity C_1, while L_2, C_2 constitutes the normal anode tuning circuit. The circuit L_1, C_1 forms a counter-coupling channel, since, of course, it constitutes a considerable resistance for all impulses which do not arrive with its natural frequency, and therefore, for such impulses, like any other resistance inserted in the cathode supply of an amplifier and not bridged-over by condensers or the like, acts as a counter-coupling resistance. However, since the circuit L_1, C_1, of course, cannot be constructed without resistance, a certain resistance also remains for the resonant frequency, namely, the effective resistance of the circuit, and has a counter-coupling effect. This residual resistance deteriorating the resonance properties can be removed by a back-coupling, for instance, between the coils L_1, L_2, which, however, also offers other advantages as regards selectivity and sensitivity.

If this circuit is constructed in a tube which, as is the case, for example, in the intermediate-frequency part of a superheterodyne receiver, generally is to fulfil no other functions than the amplification of this one frequency, this arrangement can be fully utilised.

If, however, it is used in circuits in which an amplified tube or other amplifier unit has to fulfil several functions simultaneously, as is the case, for example, in a mixing tube in a superheterodyne receiver, ineonveniences may arise, which may be removed as follows:

As long as the back-coupling L_1, L_2 is not fully utilised, nothing particularly disadvantageous is manifested in a superheterodyne receiver. If, however, it is endeavoured to turn to account the advantages of this coupling to a higher degree by more critical adjustment, an instability is manifested on traversing the receiving wave-range. Investigations have shown that it is attributable to the influence of the second control grid, at which, as is well known, the locally generated auxiliary oscillations are applied. The amplitude of the superheterodyne has not the same magnitude at each oscillation of a traversed wave range and the amplitudes of different magnitude cause a variation of the mean voltage effective at this grid or of the resultant bias of this grid, whereby the steepness in the tube A and, thus, the effect of the back-coupling between L_1 and L_2 is varied.

An attempt, instead of the automatic grid bias production by blocking condensers and grid leak resistances, as is usually employed in the generator of a superhet, to produce a fixed grid bias, for instance by means of cathode resistance or by means of a tapping at a special voltage divider of the anode voltage has a partial success, but is not satisfactory in all cases.

An arrangement which, on the contrary, produces a complete stability even at a very critical adjustment is shown in the form of construction given by way of example in Fig. 20. The oscillator tube B has here a diode path D, which is connected in parallel with the oscillator oscillatory circuit L_3, C_3 and is negatively biased by a battery J. Instead of the battery J, the bias may also be derived in any well-known manner, that is, for instance, by means of a voltage divider from the anode voltage, by special rectification and filtering from an auxiliary winding of the mains transformer or by cathode resistances, also from the mains or other source of anode voltage, or in the case of tubes heated by direct current, also from a source of heating voltage.

The biased diode path D, which could also be replaced by some other biased rectifier, for instance, a "Westector", or by some other current or voltage-limiting arrangement, has the effect that the amplitudes of the circuit L_3, C_3 cannot be increased above the value determined by the diode bias. For this purpose, however, it is desirable to keep the internal resistance of the diode path as small as possible. Likewise, it is desirable to choose the grid bias at the tube B greater than at the diode D. This requirement which is not absolutely necessary, may, however, be fulfilled also by corresponding choice of the transformation ratio at the coil L_3 with respect to its primary winding or similar measures.

In the present constructional example, the core of the coil L_3 is arranged between the poles of an additional magnet M, which enables both the automatic tuning and the remote tuning of the set.

In order to cover as wide a tuning range as possible with a given controlling output at the magnet, it is preferable to give the high-frequency core of the coil L_3 a permeability which is relatively very high for high-frequency cores. This may be achieved inter alia by increasing, under otherwise equal circumstances, the compression pressure in the production of the core, by reducing the thickness of the insulating layers separating the individual core particles, or by somewhat increasing the core-particle size with respect to normal high-frequency coils, although the last-mentioned possibility must not be exaggerated owing to the rapidly increasing damping losses. The use of starting materials of very high permeability, as, for instance, iron-nickel alloys, is also advisable for the same reason both for the magnet and for the core material.

Moreover, the use of these materials for the core and also for the magnet has the further great advantage that these materials are extremely poor in remanence, whereby the calibration error which otherwise frequently arises in magnetic tuning is reduced. It is, however, essential to employ both for the core and for the magnet, materials which have very small coercive force.

As has already been mentioned above, it is a question in the described receiving set of a so-called "single-span" superhet. Instead of sharply tuned preselection circuit coupled to the oscillator circuit mechanically or otherwise, there will therefore be used either, in general, only permanently tuned filters or, insofar as variable circuits are employed, only broadly-tuned circuits, in which an exact observance of synchronism is not important.

In the constructional example of Fig. 20, F is the filter which consists of three T-members. In this case, the inductance of the middle T-member is sub-divided into a primary and secondary winding, which is preferably arranged on a high-frequency mass core. By the sub-division of an alternating current resistance in a filter member, for instance, by sub-division of the mean inductance, it is possible to obtain a favourable matching of the output values of the antenna circuit to the input values of the first tube. Since it is important in superheterodyne receivers and particularly in those with aperiodic input circuits, to avoid as far as possible over-control of the mixing tube, which could produce undesirable combination oscillations by rectifier or modulation action, it is advisable to effect the volume control in the input, even in spite of the use of the negative back-coupling shown here, by cathode resistances, which has a linearising action.

Since, however, in the constructional example of Fig. 20, which shows a set adapted to be remotely operated, a simple regulatable high-ohmic resistance or high-ohmic potentiometer cannot be used, but a remotely-controllable variable high-ohmic resistance must be used.

In the example given, a tube E is used as input resistance, in which a pure ohmic resistance **121** is used for the regulation. This ohmic resistance is provided with a spring **122**, which can be so pressed against the resistance **121** through a lever fixed to a stronger leaf spring **123**, that it completely bridges-over the resistance. At heavier or lower pressure exerted by the spring **123**, a larger or smaller part of the spring **122** is caused to roll off at the resistance **121**, so that the effective value of the resistance **121** is regulatable by the spring pressure **123**. The pressure of the spring **123** is determined by a filament **124**, which expands more or less on heating and thus, by regulation of its heating current, allows of regulating the effective value of the resistance **121**. Instead of a filament **124** there may also be used for resistance regulation in any desired manner a bimetallic strip, which can be electrically heated, possibly, such a bi-metallic strip may be used directly instead of the spring **122**.

The regulation of the resistance in the tube E is effected at the operating post by a regulating resistance.

Furthermore, there are also provided in the input circuit a rejector circuit S and an acceptor circuit T. These serve for blocking-out a local transmitter and for preventing the penetration of the intermediate frequency into the input circuit. S and T may also exchange the functions just described. Furthermore, with the existence of several local transmitters, several circuits S or T may also be provided.

The tube A or its anode circuit is coupled with the grid circuit of the tube G by a small condenser, such as a Neutrodon.

It has already been mentioned that the diode path D may also be replaced by a "Westector" or the like; however, it is also to be pointed out that when connecting up such a voltage limiter, an increase in the volume, that is, an increase of the amplifying effect of the tube A is obtained. This volume increase can be particularly observed in a mixing tube of the type of the well-known tube ACH1, is a biased "Westector" is connected in a normal manner to the generator circuit connected to the triode part of this tube.

Instead of connecting the diode or an equivalent element which, as has already been described, is to have as small as possible an internal resistance, to the inductance L_3, the connection, as is shown in Fig. 20 in dotted lines, could also be made to the primary winding of this iron core.

In the tube G there takes place a further amplification and a further selectivity increase, particularly owing to the action of the cathode series resonant circuit L_4, C_4. A choke with a series-connected resistance is connected in parallel with the condenser C4. The resistance serves for producing the grid bias and the choke for keeping high frequency from this resistance. The tube G is provided with three separated lead-in wires, the cathode preferably being separately led out at the top of the envelope or in some other manner at the envelope; likewise, the anode or the grid receives a separate lead at the envelope, while the last of the high-frequency-carrying electrodes, that is, either the remaining control grid or the remaining anode can be led out through the pinch together with the electrodes which are at a fixed potential as regards high frequency. Of course, the cathode could also be led out of the pinch in the normal way and then the grid and anode can be separately led out at the envelope; since, however, it has proved to be preferable to make the capacity of the cathode with respect to earth and other apparatus parts as small as possible, it is sometimes desirable, particularly in the case of amplification of shorter wave-lengths, to lead out the cathode separately in order not to increase still further the capacity which is unavoidable in any case owing to the heater.

On amplification of particularly short-wave currents, it may be preferable specially to dimension the indirectly-heated cathodes substantially in such a manner that the cathodes receive a greater diameter and a smaller length than usual, whereby the capacity between the heater and the cathode itself can be reduced. The linearity of the characteristic which falls owing to the larger cathode diameter under otherwise equal circumstances forms no great drawbacks in the case of use in the intermediate-frequency part of a superheterodyne receiver.

For the rest, however, it is also possible, particularly when amplifying short-wave currents, to supply the cathode heater through the coil of the series resonant circuit. In such a case, the conductor of the coil L_4 would then consist of at least two individual conductors insulated from one another, which may be twisted together. These individual conductors carry the heating current in opposite directions, while they are traversed by the high-frequency currents in the same direction. In this way, iron-containing inductances may also be employed, even with relatively high heating currents, instead of L_4, without modulation phenomena occurring owing to the heating current, since the heating currents, owing to the bifilar effect of the winding, do not result in any magnetisation of the core of L_4.

When using high-frequency strands, different sets of the strands may be used for the supply and return of the heating current. If three sets of high-frequency strands are provided, the third set may be used for earthing of the cathode envelope in the manner of low-frequency, while the other two sets supply the heating input to the filament and remove same. With directly heated tubes, for instance battery tubes, of course, two conductors or sets of conductors are sufficient.

As has already been described, by coupling between L_4 and the corresponding anode circuit inductance, an additional selectivity and sensitivity increase in the case of back-coupling, or a band broadening (selectivity regulation) in the case of counter-coupling can be obtained.

Since a coupling between the anode circuit of the tube G and L_4 would also cause a coupling between the anode circuit of the tube G and the grid circuit of the same tube by capacity between the cathode and control grid, still a further screening grid is provided between these two last-mentioned electrodes. Since, furthermore, for the selectivity-increasing effect of the series resonant circuit lying in the cathode supply lead, the greatest possible steepness of the tube is desired, this additional screening grid is brought to a positive potential with respect to the cathode and acts as space-charge grid, which, however, is not absolutely necessary.

If the "Durchgriff" through this space-charge grid is small, as is, of course, desirable for the purposes of a very effective increase of steepness and screening of the control grid from the cathode, then a large emission current is absorbed by this positive grid. Since it is not rational to derive this large emission current, which in a constructed model with a very low Durchgriff through the space-charge grid amounts to a value up to 20 milli-amperes, directly from the anode voltage source, since otherwise a large portion of output in series resistance must be neutralised, which not only unnecessarily loads the anode current source, but, what is important, for instance, particularly in mains sets, also very heavily pre-loads the filter means associated with anode voltage and thus necessitates more expensive filter means, it is advisable in such a case to derive the space-charge grid current from a point before the anode side of the filter means, particularly before the anode current mains choke. There may then be connected directly behind the rectifier tube a resistance which produces the necessary potential drop, in order to reduce the anode voltage, which of course amounts normally to several hundred volts, to an amount of about 10 to 20 volts.

Since rather high resistances are necessary for the reduction of this voltage resistance and since on the other hand, at voltages of only 10 to 20 volts, very cheap electrolytic condensers can be used without danger, as is usual, for instance, for bridging the cathode resistance, the filtering produced by this resistance and the said condensers is usually already sufficient. If necessary, two or more of such resistance capacity members may be connected in series in order to produce a higher degree of filtering.

If no particular safety precautions are provided, it is advisable in such a case, however, to heat the rectifier tube indirectly, in order to prevent excessive voltages from arising, on heating the tube cathodes, at the electrolytic condensers of the space-charge grids. If economy in current consumption is important, the space-charge grid voltage may be derived from a separate rectifier. In this case also, the expenditure on additional filter means is not very great, since for very small means at the low voltages employed, high capacities in the form of electrolytic condensers are available, so that as further filter means, possibly resistances suffice, but at least only very small inductance are required. In such a case, the rectifier tubes which supply the anode tube may possibly be provided with an additional auxiliary electrode possibly arranged at a smaller distance from the cathode.

In the constructional example of Fig. 20, however, there is used for the feeding of the space-charge grids of the intermediate-frequency tubes G and H another method which can be carried out entirely without additional expenditure of energy for the feeding of the space-charge grids. Here, the potential drop is used, which in any case is necessary in order to bring the cathode of the loudspeaker tube to a higher potential by the grid bias of this tube.

Modern loudspeaker tubes require, as is well-known, rather high anode currents. Thus, for example, the well-known speaker pentodes, type **AL4**, works with an anode current of 36 to 40 milli-amperes, to which the screen-grid current is added, so that in the cathode resistance producing the grid bias, a current of about 45 milli-amperes flows. Since the space-charge grids of the tubes G and H, as already mentioned, may each have 10 to 20 milli-amperes current absorption and since, furthermore, their voltage may be about 4 to 10 volts positive with respect to the cathode, then by suitably dimensioning, the grid bias of the final tube on the one hand, and the space-charge grid voltage and space-charge grid current of the high-frequency tubes, on the other, the output otherwise to be neutralised in the cathode resistance of the final tube may be advantageously utilised here for the feeding of the space-charge grids. The bridging-over condenser K, which is existent in any case, together with a further condenser N preferably also constructed as an electrolytic condenser, and a decoupling resistance or a decoupling inductance O take care that the low frequency from the cathode circuit of the final tube is kept away from the space-charge grids. If necessary, the space-charge grids of the two tubes G and H may also be coupled with one another.

If at P a potentiometer or other voltage regulator is inserted, then by means of the space-charge grid voltage, an additional regulation of the amplification or back-coupling in the tubes G and H may be effected, which, since a volume control by the tube E is already existent, can either be utilised on replacement of the manually operated potentiometer P by an automatic arrangement, for automatic volume control or, alternatively, by variation of the back-coupling in the circuits of the tubes G and H, may also be utilised for manual or automatic band width regulation. For the rest, of course, the tubes G and H may, however, also be used, particularly on suitable construction of their control electrodes, as normal exponential tubes (hexodes) for a manual or automatic regulation at the control grids.

The alternating voltage amplified by the tube G is transferred through a blocking condenser to the grid of the following amplifier tube H. The arrangement at the tube H corresponds substantially to that of the tube G. Only the series circuit in the cathode supply lead is coupled here through a transformer. The cathode is at first connected for direct current again to the negative anode voltage pole through a resistance producing the grid bias, and a choke constituting a high resistance for the high frequency to be amplified.

Connected in parallel with this branch is the primary of a high-frequency transformer Q in series with a condenser, which "blocks" the direct current, so that the resistance connected in the parallel branch for grid bias production is not short-circuited. On the secondary side there is connected to the transformer the series resonant circuit L_5, C_5, which is again so tuned that it constitutes as high a resistance as possible for all frequencies with the exception of the resonant frequency (intermediate frequency of the receiver).

Of course, the condenser C_5 must not be so small and the inductance L_5 must not be made so large that the stray capacities already constitute an essential short-circuit path to the resistance formed by the series resonant circuit in the non-resonance case, since otherwise the purely ohmic resistance of the circuit L_5 C_5 existing in the resonance case is unnecessarily increased.

The transformer Q is so dimensioned that the conditions existing in the circuit L_5, C_5 are transferred almost without alteration to the cathode circuit. It is preferable to dimension the inductance L_5 or the condenser C_5 for low voltages, since then the stray capacities, of course, are negligible in their action, and to produce the required high-ohmic action in the non-resonance case merely by transformer matching with the aid of the winding ratio at the transformer Q in the cathode circuit of the tube H.

This is advisable, however, only if the circuit L_6, C_5, exactly as has been described in the case of the tube G, is used only for the purposes of the selectivity increase or sensitivity increase.

In the case of the tube H, however, the series resonant circuit L_6, C_5 together with the rectifier tube R is also used for automatic tuning control. Since high voltages are desired for this case at the circuit L_6, C_5, the series resonant circuit itself is to be used here with a small capacity and large inductance.

In itself, for example, when using "Westectors" or the like rectifiers, it would be possible to obtain the regulating voltage by rectification also directly at a series resonant circuit inserted in the cathode supply lead of a tube. If, however, a normal diode is employed, then in this case the cathode-filament capacity may be disturbing and then it may be advisable to excite the series circuit through a transformer, in order that the resting potential of the circuit L_6, C_5 can be chosen at will. The increased losses caused by the transformer coupling can be compensated to the desired degree by a back-coupling indicated, for instance, by the double arrow shown in dotted lines.

However, even if, as is shown in the Figure by way of example, the series resonant circuit is not directly connected in the cathode supply lead, but is connected thereto by transformer, particularly attention should be paid to the capacitive conditions, since already small irregularities may disturb the clearness of the resonance position. The centre of the series resonant circuit, that is, the point of connection between L_6 and C_5 is connected to the diode cathode, which in turn may be earthed for high frequency through a condenser.

Since the parallel capacity to the series circuit inter alia is not to be too large for the reasons set forth above, relatively small condensers C_6 and C_7 are provided for the coupling of the diode path. Since these small condensers, moreover, are connected in series with one another with respect to the series circuit, the disturbances by these condensers may be kept small.

If resonance exists between the intermediate frequency coming into action at the circuit L_6, C_5 and the natural frequency of the circuit, then at L_6 and C_5 equal voltages arise and the resistances W_1 and W_2 are therefore traversed by equal but oppositely directed currents. Since, in the present case, an increased time constant is no drawback and the circuit L_6, C_5 is to be loaded as little as possible, the resistances W_1 and W_2 are preferably chosen as very high-ohmic resistances.

Since the centre of the series resonant circuit is at earth potential as regards high frequency and the difference of the voltage values at the resistances W_1 and W_2 is to be employed for controlling the tube U, that is, must be conducted outwards, then further resistances W_3 and W_4 are provided, which in the manner of high frequency, preserve the symmetry of the circuit L_6, C_5 with respect to earth or the other apparatus parts, but, on the other hand, allow of supplying the difference of the voltages at W_1 and W_2 to the grid of the tube U.

Preferably, the tube U receives a negative bias which, in a manner well-known per se, can be produced by any method known according to the state of the art, from the heavy current supply feeding the apparatus. No particular negative grid bias is, however, shown for the tube U.

In the anode circuit of the tube U, the winding of the magnet M is provided, which by pre-magnetisation of the corresponding high-frequency core allows of influencing the inductance of the coil L_3. If a frequency now impinges on the circuit L_6, C_5, which departs from the theoretical frequency, then, according as to whether the wave length is greater or smaller than the theoretical frequency, a different voltage will arise at C_5 or L_6 and, therefore, the control grid of the tube will be more or less negatively biased. By this means, a smaller or greater anode current is driven through the winding M and thereby the frequency of the oscillator circuit is decreased or increased until the theoretical frequency is practically again existent in the circuit L_6, C_5.

The small residual remanence still existing for the magnet M and the core of the coil L_3 has the effect, in this case, on favourable dimensioning of the amplification factor of the tube U and of the other elements, that by this automatic sharp-tuning arrangement, a very complete correction of tuning errors is effected.

In addition to the automatic tuning correction, however, the magnet M serves simultaneously for the remote operation of the set. To this end, the screen-grid voltage of the tube U is made variable by the potentiometer V. The potentiometer V in this case should be imagined to be arranged at the place of operation, in the same way as the regulating resistance X used for the volume control. These circuit elements were not arranged separately from the corresponding tubes merely for the sake of clearness.

In order, when operating the potentiometer V, to prevent a drawing phenomenon of the tuning which is caused by the action of the automatic sharp tuning, a switch Y is provided which short-circuits the automatic tuning device when the potentiometer V is operated. The elements V and Y may be positively connected together, so that an operation of the potentiometer automatically puts the automatic tuning correction means out of action.

In order to make the tuning or tuning indication at the potentiometer V independent of possible fluctuations of the current sources, a glow discharge stabiliser Z is provided, from which the screen-grid voltage of the tube U is derived. The tube U is so dimensioned that by traversing the resistance of V with the current tap, the entire wave-range of the receiver can be utilised.

The cathode circuit of the tube H is therefore utilised here with the aid of the series resonant circuit not only for the obtaining of a selectivity increase, but also for the purposes of an automatic tuning correction.

As already mentioned above, it may be preferable for the purpose of economy of space-charge grid current, to divide the function of the first grid employed in the tubes G and H, which grid at the same time causes the screening between the control grid and cathode and a space-charge removal, and to provide a separate space-charge grid and cathode screen-grid. In this case, the separate space charge grid can then be particularly advantageously employed as an auxiliary anode for a direct current amplification, while the particular cathode screen-grid can be used as a control grid of the direct current regulating operation. The two grids can easily be kept at zero potential as regards alternating current by blocking condensers and other de-coupling means, so that then such a tube performs two functions without being constrained in any way to concessions and compromises, which are otherwise necessary in reflex circuits.

The low-frequency voltages produced at the last-discussed diode are now supplied in the loudspeaker tube or in the loudspeaker tube unit (according to whether the two tube systems I and II are arranged in a common tube envelope or not), which consists of two systems connected in series. Such series-connected systems have, as has also already been set forth in a prior application of the present Applicant, similar characteristics to screen-grid tubes or pentodes, in which case, however, the series-connected tube systems present the advantage that it is unnecessary to arrange a particular collecting grid in order to remove secondary emissions of the upper grid acting as screen-grid and in which case, furthermore, practically a negligibly small output is received by the upper grid, whereas, as is well-known, the output consumption of the screen-grids of normal multi-grid tubes may be very considerable.

These advantages result in extremely high rectilinearity of the characteristics and, thus, slight distortions, as can hardly be achieved in pentodes.

The present invention can also provide advantages for transmitters or transmitter amplifiers.

It has been found that a substantial progressive advantage when using such circuits in a transmitter is the immunisation from higher harmonics. It is well-known to use additional filter circuits for the filtering-out of higher harmonics in transmitter circuits. For this purpose, chiefly parallel circuits have hitherto been employed. According to the present application, one or more series circuits are to be employed for the achievement of the said object. Fig. 21 shows a construction by way of example in a self-excited transmitter. **131** is the tube of the transmitter with the control grid **132**, the anode **133** and the cathode **134**. In the cathode supply lead a series resonant circuit is inserted, which consists of the coil **135** and the condenser **136**. In parallel with the condenser **136** a choke coil is provided which serves for supplying the direct current.

The tuned anode circuit **137**, **138** serves for coupling to the radiating antenna **139**. The back-coupling for generating the oscillator oscillation can be carried out in any desired manner. In the present constructional example, a back-coupling between the coils **135** and **138** is used for oscillation generation. This has the advantage that the grid **132** remains at a steady potential as regards high-frequency, and any modulation currents can be supplied to this grid without regard to any high-frequency voltage. However, all other well-known methods of modulation may also be employed.

In Fig. 22, the arrangement of the series resonant circuit **135**, **136** in a transmitting amplifier is shown in a further constructional example. The oscillator produces here an oscillation in the oscillatory circuit **141** which, through the coil **142**, transfers the oscillation to the control grid of the tube **143**. The tube **143** is essentially a high-frequency transmitting pentode but, moreover, has an additional grid **144**, which effects a screening of the control grid connected to the coil **142**, against the cathode.

This screening grid **144** is not absolutely necessary, but is preferable. It may receive according to the dimensioning and the construction of the tube, a positive voltage, in which case it simultaneously exerts a space-charge grid effect, or the grid **144** may have cathode potential, or it may have a negative potential with respect to the cathode.

The grid **144** or a further auxiliary grid arranged at this point or elsewhere may be used for impressing a modulation. In addition to the grid **144**, a second grid would then be provided between the cathode and control grid.

From the antenna circuit **145** the amplified oscillation is then transmitted to the antenna circuit **147** through a coupling condenser **146**. The antenna may be adjusted by a variometer **146** to exact resonance with the transmitted oscillation. Since here also the series resonant circuit **135**, **136** again produces a strong counter-coupling at all oscillations which do not coincide with the natural wave of the series resonant circuit, all the disturbing oscillations, but particularly for instance, overtones, which might disturb, are separated out, and therefore the effect is obtained which otherwise is obtained by special filter means for suppressing harmonic oscillations, without appreciable losses having to be involved, since the circuit **135**, **136** constitutes for the desired useful oscillation a practically negligible resistance, which corresponds only to the effective resistance of this circuit, which resistance is to be kept small.

Since a quartz crystal electrically corresponds to a series resonant circuit, that is, a circuit having very small capacity, then according to a feature of the invention, the series resonant circuit is constituted by a quartz crystal.

Fig. 23 shows a constructional example of this idea of the invention. The idea of the invention is illustrated here in a remotely-controlled set, the control quartz being situated in the cathode circuit of the tube II. The quartz itself with its holder is denoted here by **201**. Since the static capacity of the quartz with its holder would constitute a parallel path for the undesirable oscillations, this parallel capacity is tuned out by a coil **202**, which is preferably made variable. The tuning-out has the effect that the static capacity of the quartz and of the support as well as the remaining stray capacities together with the coil **202** form an oscillatory circuit, which is tuned to the oscillations to be received. Connected in series with the coil **202** is the resistance **203**, bridged over by a parallel condenser, which resistance serves for producing the grid bias. This resistance **203**, it is true, damps the oscillatory circuit **201**, **202**, but this is not detrimental in the present case, since the oscillatory circuit **201**, **202** of course is to serve for tuning out undesirable frequencies. Its resonance curve becomes so broad owing to the resistance **203**, that for all frequencies which are at all still amplified by the anode circuit **204** of the arrangement, an effective blocking in the cathode lead is produced, which is only interrupted by the narrow frequency band, which the quartz crystal **201** passes. Since the selectivity of the quartz crystal is extremely great, that is, the band which is passed by it is only very narrow, an extremely selective receiving set can be produced in this manner.

If the reception of speech or music is to be provided for, which, as is well-known, requires a certain band width for its transmission, then in principle two methods can be used: either the intermediate frequency of the receiving set may be placed so high that also the frequency band passed by the quartz is broad enough to reproduce speech and music well, or by the damping of the quartz, a broadening of the band passed is effected.

This damping can be effected either by enclosing the quartz in pressure gas or in a liquid which consumes a part of the oscillating energy by friction losses, which can be effected, for example, by enclosing the quartz in small ampules, or the quartz may be electrically damped. For the purpose of the electrical damping, resistances may be connected in series or in parallel with the quartz, these resistances being either effective resistances or reactances. As reactances, preferably series or parallel resonant circuits are employed which are connected either in parallel or in series with the quartz and which may be suitably back-coupled or counter-coupled with the corresponding anode or other circuit of the amplifier. It is then possible, by varying the coupling or by varying the tuning of such circuits, to vary the quartz damping or the band width passed, so that a set with variable band width is then obtained in a simple manner.

In itself, the method described here is, of course, applicable to any type of receiver. However, since the quartz, of course, only permits a variation of the received wave-length on quite a small scale, it is necessary to insert the quartz in a circuit which, in operation, does not vary its tuning even on the reception of different transmissions. From this results the preferable use of the superheterodyne principle.

In Fig. 23, therefore, the apparatus is constructed as a superheterodyne receiver, it being a question here of a superheterodyne receiver with remote tuning by the influencing of premagnetisable coils, but it is to be readily understood that any other type of superheterodyne receiver may also be employed.

The input circuit of the superheterodyne receiver consists of the coil **205** to which the antenna circuit is also coupled at a tapping, as well as the rotary condenser **209**, which serves for the adjustment of the wave-range as well as for the approximate establishment of synchronism between the input circuit and oscillator circuit. The oscillator circuit is formed from the coils on the core **206** and the condenser **210**. The cores **205** and **206** consist of a Ferrocart-like material, it being, however, preferable to give these in a manner described above, a somewhat higher permeability than is otherwise usual for high-frequency cores. The cores are situated between the poles of two magnets **207** and **208**, the magnetism of which can be varied by a regulatable magnetising direct current for the purpose of the tuning of the set. The receiver is arranged in a manner well-known per se, with the aid of the diode VII and the circuits **211** and **212**, which are somewhat detuned in opposite directions with respect to the intermediate frequency, for an automatic tuning correction. The difference voltage arising at the resistances **213** and **214** issued in a manner well-known per se for the regulation of the automatic correction of the tuning, this difference voltage being effective at the grid of the auxiliary tube VI.

In the anode circuit of the tube VI, the exciting windings of the two magnets **207** and **208** are inserted in parallel connection. The anode voltage for the tube VI may be derived at the operating post through the slide **215** from the resistance **216** which therefore acts as potentiometer. The resistance **216** is connected, on one hand, through a smaller resistance **217** to the negative pole of the anode voltage source, while, on the other hand, it is connected through the lead **218** to the positive pole.

A certain difficulty in a remotely-tuned set resides in obtaining a suitable and cheap arrangment for remote volume-control. In itself, it would be obvious to provide for the high-frequency amplifying tubes, that is, in this case, for the tubes I and II, an exponential characteristic, and to effect the volume control by means of a more or less strong bias. However, this is difficult to carry out when the set, as is frequently required in modern sets, is to be provided with an automatic volume control, for which then the said two tubes are employed while utilising an exponential characteristic.

In the present case, therefore, for this purpose, the tube III is employed which is a duo-diode-triode, that is, a tube which is relatively cheap and, owing to the simultaneously existing two diode paths, can be employed both for automatic volume control and for demodulation. The control grid of this tube is connected here through a blocking ocndenser direct to the oscillatory circuit **204**. The oscillatory circuit **220** is inductively coupled to the anode circuit of the tube III by means of the coupling coil **221**, and in normal tubes, for instance, a coupling ratio of 1:5 to 1:10 is advisable.

Between the two circuits **204** and **220**, an electrostatic screen **223** is provided, which may consist, for instance, of a number of parallel earthed wires arranged close to one another and has the effect that the two circuits **220** and **204** can be inductively coupled together, without appreciably influencing one another capacitively.

In this way, a neutralisation of the capacitive coupling within the tube III, which, of course, is not a screen-grid tube, can be obtained, in which case this neutralisation must only be taken so far that an adequate elimination of damping is effected in the circuits **204** and **220** in order to compensate for the damping produced at these two circuits by the connected diode paths. This damping compensation serves here primarily for obtaining a large amplification, since, of course, provision is made for an adequate selectivity by means of the quartz crystal **201** and the tuning circuits **204**, **220** and **222** do not have to produce the main selectivity, which is already achieved by the crystal **201**, but merely provide for the remote selectivity. In dimensioning these circuits, therefore, an extremely small capacitive resistance and a very large inductive resistance can also be used, so that a very large dynamic resistance and thus a high amplification results.

Should the amplification be affected by excessive damping of the circuit **222**, then here a remedy may be provided by back-coupling this circuit with the series resonant circuit in the cathode, as is indicated by the curved arrow, while the circuits **220** and **204** are, of course, undamped by mutual coupling.

By means of the resistance **217** at the operating post and the corresponding slider, the bias for the tube III may be made negative to such an extent that practically no more sound comes through, whereas, on the other hand, by reduction of the negative bias, the back-coupling condition can be reached, that is, the set can be adjusted to maximum volume and sensitivity.

In order to make the automatic volume control independent of the adjustment of the volume at the operating post, the diode is connected for the volume control direct to the circuit **204**.

In order that the back-coupling between the circuit **222** and the corresponding cathode circuit shall not be influenced by variations of the oscillator voltage, the oscillator voltage is limited by a diode in the tube V. This is effected by negatively biasing the particular diode path by means of a biasing battery **225** or other source of bias, that is, no damping of the circuit whatsoever is caused, as long as the oscillator voltage does not exceed the bias. If, however, the amount of the bias is reached, then from this point onwards the diode path acts practically as a short-circuit and thus prevents a further increase of the voltage, so that the oscillator voltage is kept constant over the entire range.

The second diode path of the tube V is also connected to the oscillator voltage through a relatively large blocking condenser **226** and a choke coil **227**. The choke **227**, with respect to which the capacitive resistance of the condenser **226** is negligible. forms together with the capacity of the corresponding diode path a member dependent upon frequency, so that at the corresponding diode path a voltage is effective which is merely dependent on the frequency of the oscillator. This voltage is rectified and produces at the resistance **228** a direct current voltage, which acts through the resistance **229** on the grid of the tube V and therefore controls the anode current of the tube V in accordance with the oscillator frequency, so that the instrument **224**, which measures the current of the tube V, can be calibrated in frequencies.

It has already been mentioned above that it is preferable for the dimensioning of the series resonant circuit, which is to be situated in a counter-coupling channel, that is, for instance, in the supply to the cathode of an amplifying tube, to make the capacity of this circuit as small as possible in order to obtain as small a band width as possible.

As mentioned above, however, in amplifiers, for example those which work according to the principle of grid control, any desired reduction of the tuning capacity of the series resonant circuit lying in the cathode supply, or of a corresponding four-pole, which may then, of course, consist of a larger number of capacities and inductances, is not possible because the stray capacities themselves already become equally large particularly at a certain minimum value of the tuning capacity, and then a reduction of the tuning capacity can practically bring no further advantages.

In Fig. 12, the conditions which arise, in particular, at very small tuning capacities C_1, are pictorially illustrated. E is here the common earth lead or an equivalent zero lead of the apparatus and K the cathode, in the supply of which the said tuning circuit is to lie. L_1 is the tuning inductance.

It is now found that, in the first instance, two kinds of stray capacities are existent, firstly, the capacity C_2 shown in dotted lines, which therefore primarily constitutes the stray capacity between the cathode and that end of the coil L_1 which is connected to the cathode, with respect to earth, and, furthermore, the stray capacities C_3 and C_4. If the stray capacity C_2 becomes rather large this means that, in addition to the path through L_1 and C_1, a further parallel path to the cathode is existent, and it is apparent that the selective properties of the circuit L_1, C_1 must become ineffective if the parallel path C_2 receives such a small resistance in relation to the resistance provided by the actual tuning elements themselves, that this last-mentioned resistance is useless for the operation of the apparatus.

This drawback may then be obviated, as has already been mentioned above if there is connected in parallel with the capacity C_2 a coil L_2, preferably a variometer, and the inductance of this variometer L_2 is varied until this coil together with the stray capacities is tuned to the desired frequencies.

Since the selectivity of the arrangement is already roughly produced by the usual anode circuit or grid circuit tuning means and the tuning of the stray capacity C_2 and the coil L_2 is effected to the same frequencies as those of the said selection means, the following case is then given: By the said tuning means on the anode or control-grid side, only a certain frequency band is, in general, conducted to the arrangement, and substantially the same frequency band is tuned out again by the counter-coupling resistance, which is formed by the tuning means C_2, L_2, so that, if only this capacity C_2 and L_2 were provided, practically nothing at all is amplified.

It is seen that the pass range of the amplifier is now exclusively determined by the tuning of L_1, C_1, and it should be assumed that no difference whatever exists any longer in making C_1 as small as may be desired. This is no true, however, owing to the stray capacities C_4 and particularly C_3.

These two last-mentioned stray capacities lie in parallel with the actual tuning capacity C_1, and it is obvious that therefore the tuning capacity C_1 can never be made smaller than the value which is determined by the capacities C_4 and particularly C_3. Practical experiments have shown that the smallest effective value of C_1 which can be obtained in this manner lies at approximately 2–4 cms. capacity. These values are just sufficient to obtain in a tube with sufficient steepness, even at 1600 kilocycles, band widths which lie at about 10 kilocycles or even less. The adequate steepness may also be obtained, regardless of the fact that the geometrical arrangement of a normal tube is correspondingly chosen, by utilising a space-charge grid effect, as has also already been described.

However, cases may arise where it is undesirable to use tubes of such high steepness and, moreover, it would also be desirable to reduce the band widths materially, since then the possibilities arise of obtaining in the short-wave range substantially more favourable selectivities than hitherto. This may also be valuable for the ranges in longer waves, since, for instance, an apparatus according to the so-called "single-span" superhet principle can then be constructed, which receives a very high intermediate frequency and yet is sufficiently selective.

It is shown in Fig. 25 how this can be carried out. This figure corresponds substantially to the arrangement of Fig. 24, except that a screen S_1 is also provided over the tuning circuit L_1, C_1 or at least over the coil L_1. This screen is shown in chain-dotted lines, whereby it is to be indicated that it is not made of solid material, but that for many cases, particularly when the coil L_1 is to couple to some other coil, it is preferable to make it of a wire network of parallel wires or the like, so that an electrostatic screening takes place, but an inductive coupling with another coil is possible.

If this screen S_1 were now connected to earth potential, the conditions would not be improved but worsened, since, of course, the stray capacity of the coil L_1 towards earth is then further increased. The screen S_1 is therefore kept at cathode potential, as indicated in the drawing. All stray lines of force which issue from the coil L_1 and would otherwise discharge on the earth lead E are then intercepted by the screen S_1 and, therefore, an increased capacity of the coil L_1 towards the cathode side develops, which, however, as is to be shown in the following, is not detrimental for the present purpose.

Seen from the cathode side, the two stray capacities C_5 and C_6, which correspond to the first-mentioned stray capacities C_3 and C_4, now no longer lie in parallel with the condenser C_1 but in series with this condenser. Since, however, a series connection of condensers, as is well-known, always has a smaller capacity than the smallest individual capacity of the series circuit, it is now possible to adjust any small capacities with the condenser C_1. With respect to the inductance of the coil L_1, the stray capacities C_5 and C_6 cause an apparent inductance increase, which can be compensated by suitable dimensioning of the coil L_1.

Since, as has already been previously pointed out, it is absolutely necessary that the screening should be as complete as possible between the individual circuits whilst the coil L_1 shall be capable of coupling, for the purpose of the neutralisation of existent residual couplings or for obtaining a removal of damping or the like, to the anode circuit coil or grid-circuit coil, the difficulty arises that owing to the screen S_1, which is, of course, at cathode potential, a capacitive coupling could arise towards a further coil, with which the coil L_1 is to be coupled. In order to avoid this, a further earthed screen S_2 is arranged at some distance from the screen S_1. By the two screens S_1, S_2 or by the mutual capacity of these two screens, which, if it becomes very disturbing, can of course be reduced by arranging the two screens at a somewhat greater distance from one another, no drawback is generally obtained, because the capacity of the two screens S_1, S_2 to one another is, of course, only connected in parallel with the stray capacity C_2 which exists in any case, and can be tuned out by corresponding adjustment of the variometer.

The variometer L_2 may, in this case, be of a very simple construction. Usually, ordinary honeycomb winding coils which are variable in their relative position are sufficient. Therefore, for example, a fixed coil may be provided, with respect to which a second coil may be moved, towards or away from it, by means of a spindle or the like. The two coils constituting the variometer L_2 need not be of particularly damping-free construction, since it may be favourable, if the band tuned out by the tuning means L_2, C_2 is rather broad, whereby the tuning is then little critical.

As great a dynamic resistance of the tuning circuit C_2, L_2 as possible is also unnecessary, since a dynamic resistance of 10 to 20,000 ohms is already sufficient to suppress amplification practically completely.

On the other hand, a large damping again has the advantage that possibly a particular subsequent correction of the tuning at the coil L_2 or at a small tuning condenser connected in parallel with the capacity C_2 is no longer necessary. For this reason, it may be preferable to wind the coil or the coils L_2 from very thin or resistance wire, in which case then this high resistance or this relatively high resistance of the coils L_2 presents the additional advantage that it can be used for producing a certain direct current potential drop, which produces the grid bias of the control grid with respect to the cathode K.

An example of a constructional arrangement of the individual parts in an arrangement according to Fig. 25 is given by Fig. 26. L_1 is here again the tuning winding of the series resonant circuit, which in the present constructional example is arranged on a double-T-shaped coil of high-frequency iron. Such a high-frequency iron may be, for instance, the well-known H-core made of "sirufer." The iron core of the coil L_1 projects through corresponding recesses in the two plates P_1 and P_2 in such a manner that thereby the coil core undergoes a firm support within a Bakelite tube R_1. The Bakelite tubes R_1 and R_2 are fixed to corresponding recesses of a metal plate T_1. The metal plate T_1 has a tubular extension which projects through the screen S_3, which is earthed and may represent the screening wall of some screening box or the like. By means of a spring F_1, the plate T_1 is pressed against the screening wall in such a manner that it can be rotated about the tubular member passing through the screening wall S_3.

Between the two friciton discs S_4 and S_5, which are resiliently pressed together, the tapered edge of the plate T_1 is gripped in such a manner that, by rotation of the driving wheel A, the whole body containing the tuning core with winding L_1 can be rotated about its axis, whereby a variable coupling can be obtained between the coil L_1 and the coil L_5, which may belong to the anode circuit or any other circuit of the receiver.

One end of the coil L_1 is connected to the plate T_2, which in turn is connected by a screened lead L_6 to the cathode. The other supply lead to the coil L_1 terminates at the pin St. This pin forms together with the metal tube R_3, which is fixed to the drive Tr_1 a capacity which corresponds to the capacity C_1 in Figs. 24 and 25 and can be varied in its value by more or less screwing-in of the drive Tr_1.

The tube R_1 carries at its outer side a wire spiral S_1 which preferably has a medium pitch. The winding preferably has a free end and is connected also to the plate T_2 and one feeding end of the coil L_1 or through the lead L_6 to the cathode of the tube, and corresponds to the screen S_1 in Fig. 25. The large pitch of the coil S_1 prevents it having an appreciable inductance. If, however, the whole apparatus is intended for the reception of rather short waves, or if it is a question of short-wave transmitting apparatus in which the inductance also of a coil of large pitch could already lie within the resonance position of other constructional elements, then it may be advisable to provide, instead of a coil, only individual wire rings on the tube R_1, which may possibly be slotted and all electrically connected together by a transverse lead and connected to the plate T_2.

Likewise, the tube R_2 also carries a wire coil S_2 which is constructed substantially in accordance with the wire coil S_1, but is electrically connected to the plate T_1 instead of T_2.

If desired, a quartz stage in a cathode circuit may be combined with cathode circuits in other amplifier stages, which are constructed in accordance with the above details, since the advantage of a cumulatively-acting selectivity increase is then obtained, without necessitating several exactly equal quartzes which as is well-known, can only be manufactured with extreme difficulty.

This can also be used for the construction of the well-known quartz filters, in which therefore several circuits are coupled together by a quartz acting as series circuit. As is well-known, a variation of the band width in such quartz filters is possible by varying series or parallel resistances or varying the tuning of the coupled circuits. The advantage just mentioned then exists, however, that the selectivity figure of a single quartz stage is no longer sufficient and several such stages would have to be provided for obtaining the required high selectivity. However, this is again difficult because exactly equally tuned quartzes can only be made with great difficulty. A remedy may be provided here also by means of an arrangement according to the application.

One stage of a quartz filter with a normal oscillating quartz may be designed again as coupling member of the two circuits, which are usually tuned circuits, and the remaining stages of the whole amplifier are then provided with series resonant circuits instead of quartzes, said series resonant circuits being designed after the fashion of the arrangements described in Figs. 24, 25 and 26.

If it is a question of relatively large band widths, which are to be transmitted, then the use of an ordinary series resonant circuit as coupling member between the individual circuits of the filters or as coupling member between two tuning circuits of the filters is possibly sufficient; if, however, small band widths are to be obtained, then the parallel capacities according to Fig. 24 and possibly also other stray capacities according to Fig. 25 must be tuned out.

As has already been pointed out on several occasions, the arrangements described here are not restricted to receiving circuits, but can of course also be applied to transmitters of any circuit owing to thin selectivity-increasing effect.

In transmitters, in particular, the removal of the higher harmonics by such means will often be very desirable.

Fig. 27 shows such a filter in simplest construction, the same references as in Figs. 24, 25 and 26 having been used for the coupling member between the two main circuits constituting the filter.

As has already been mentioned, the obtainable band width depends not only upon the choice of the capacities C_1 in Figs. 24, 25 and 26, but also upon the steepness of the tube employed. If, therefore, at a given adjustment of the oscillating circuit in the cathode supply lead, for instance, a band width of about 5 kilocycles is obtained, if the tubes have full steepness, then, of course, on regulating down the steepness, for instance, by means of an automatic volume control, which may then be effected by more or less large negative grid bias at the control grid or at another negative grid, or, alternatively, which may be effected by variation of the positive bias, say, at the space-charge grid, simultaneously also the band width is regulated. If the instantaneous steepness is small, then the band width is automatically increased. This effect arises when, by means of the automatic volume control, in the case of the existence of loud signals, the sensitivity is regulated back. It is therefore found that, here, without substantial additional means, a very effective automatic band width regulation can be achieved if only one automatic volume control is provided.

The selectivity curve of the receiver or of the amplifier (if the latter is not arranged in a receiver but in a transmitter or the like) may, moreover, be varied at will. It has already been stated that instead of a simple circuit, four-poles, which consist of a larger number of circuits, may be employed. In addition to this method, there is moreover yet another, simpler, method of obtaining, for instance, a resonance curve flattened at its peak.

If, by choice of the anode circuit and the tube data, the result is obtained that in the case of resonance the tube or the anode coupling resistance is over-matched, the following remarkable phenomenon occurs: As long as the anode circuit resistance is small as compared with the internal resistance of the tube, the steepness of the tube at different frequencies may be assumed as constant, independently of the anode circuit. If, however, owing to the fact that the resistance of the anode circuit is made very high for the desired frequency, which can be achieved, for instance, by back-coupling of the anode circuit and/or by making the capacity of the anode circuit small in proportion to the inductance and, furthermore, by making the internal resistance of the tube also relatively small, the result is obtained that in the case of resonance the anode circuit coupling resistance becomes large in proportion to the internal resistance of the tube, then in the case of resonance a considerable reduction of the effective steepness occurs, that is, the statically measured steepness is reduced by change-over to a dynamic steepness of substantially lower value. However, since, on the other hand, as has been pointed out, the steepness of the selectivity curve caused by the series resonant circuit or the like in the cathode lead is dependent upon the tube steepness, that is, upon the effective tube steepness, it follows from this that at the flanks of the curves, that is, at points which depart to some extent from the resonance value, a great steepness will exist, whereas directly at the resonance point, at which the dynamic steepness of the tube is small owing to the high anode resistance, the steepness of the resonance curve is flattened, which then results in a characteristic of the nature of a band filter. In this case, these values may be adjusted at will by varying the bias at the control grids or even by varying the positive voltage at the space-charge grid or by some other voltage variation.

Since the tube has at least two grids, at which such voltage variations may cause deformations of the resonance curve, a grid, for instance, the control grid, which may undergo a formation after the fashion of an exponential tube, may serve for automatic selectively regulation, whereas, for example, the voltage variation at the space-charge grid may cause a manual selectivity variation. For the correct working of such an automatic or manual selectivity regulation, it is desirable that the band width of the selection means connected on the anode side shall be substantially broader than that of the selection means arranged in the cathode supply lead.

Since, moreover, in most cases, an additional back-coupling is provided between the circuit in the cathode supply lead and, for instance, the anode circuit, the first-mentioned effect can be further extended and increased by a variation of the voltage at these grids. If the instantaneous steepness of the tube is great, then a strong back-coupling action also occurs, which still further increases the resistance of the anode circuit, whereas with tubes regulated down, the anode circuit of the tube is also reduced in its resistance by the reduced back-coupling. It is seen that, therefore, this action may be utilised both as an increase of the regulating capacity for the volume control and for assisting the automatic selectivity regulation.

If, in the constructional examples hitherto discussed, screened cathodes were usually mentioned, this is a consequence of the arrangement of the counter-coupling oscillatory circuits in the cathode supply lead. If these counter-coupling circuits are not provided in the cathode supply lead, that is, if special counter-coupling channels are arranged, which lead to special control grids, then these particular control grids themselves must be screened from the other grids and from the other tube parts by screening electrodes; therefore, all that has been said for the cathode construction can then be applied accordingly to these other electrodes.

On the other hand, if the cathode capacity C_2, that is, the stray capacity in Figs. 24 to 26 is tuned out by an auxiliary inductance L_2 or the like, the cathode itself may be constructed with somewhat higher capacity than is otherwise expedient, since, of course, an increase of the stray capacities is no longer so dangerous. Therefore, in this case, the separate leading-out of the cathode supply lead at the envelope itself may be disregarded, and the cathode may be led out as usual through the pinch. But, of course, in spite of this, if the oscillatory circuit is provided in the cathode supply lead, a sufficient screening against the other electrodes must be used. For the purpose of pure regulation, as is usual, for instance, in hexodes, there may also be provided in the tubes further grids for supplying regulating voltages, which may then simultaneously take over the function of screen-grids.

As has already been previously pointed out the screening of the cathode is necessary chiefly when, as is usual in a cascade amplifier, the grid circuit and the anode circuit as well as the circuits used in the cathode for increasing selectivity are tuned to the same frequency. If, however, the frequency to which the grid circuit of a tube is tuned is not identical with the frequency to be amplified, as may be the case, for example, in the mixing tube circuits of the superheterodyne arrangement, in which case, of course, the grid circuit of the mixing tube is tuned to the frequency to be received but not to the intermediate frequency to be amplified, this screening may in some cases be dispensed with.

In this case, however, another peculiarity is to be observed. In particular, in those mixing tubes which, moreover, contain a triode system for the production of the local oscillator oscillation, but also in the other ordinary mixing tubes according to the multi-grid system, a certain capacity exists between the cathode and that grid at which the oscillator oscillations arise or are applied. However, since the cathode, in the circuits discussed here, usually does not have earth potential, but is at high-frequency potential owing to the oscillatory circuit situated in the cathode supply, then through this capacity disturbances are easily initiated between the grids carrying the oscillator oscillation and the cathode, which disturbances are manifested as undesirable accompanying phenomena. These phenomena act particularly detrimentally when the tuning circuit located in the cathode supply, that is, for example, the series circuit L_1, C_1 is back-coupled with the corresponding anode circuit which in itself, of course, causes an increase of the amplification and selectivity.

In this case, on adjusting the oscillator oscillation, which is necessary, of course, when tuning transmitters or receivers, a self-oscillation of the circuits may suddenly be caused. To avoid this, either the electrodes carrying an oscillator voltage, particularly the oscillator grids, are to be screened against the cathode, or the detrimental capacity must be compensated by a neutralising circuit. The neutralisation can be carried out, for example, in such a manner that opposite the cathode point, still further windings are provided on a coil body, which is connected on one side to the cathode itself, and there is derived from these additional turns a neutralising voltage which is also connected through a regulatable neutralising capacity to the cathode.

Since, in this case, no particular adjustment of a neutralising point is necessary, the screening of these electrodes from the cathode by the arrangement of additional screens and screen-grids is still more favourable. These screen-grids, if it is expedient for the process of amplification in the tube, may reecive a positive potential in order to act in this way as a space charge grid or actual screen-grid.

They are to be earthed as regards alternating current by the arrangement of capacities. In this way, usually, the detrimental base capacities cannot be removed and, therefore, in such cases, it is also expedient to lead out these grids separately at the tube envelope.

Reference will now be made to the particular circumstances, the consideration of which is important, if it is desired to utilise counter-coupling channels for the obtaining of selective properties. In particular, this applies in the use of tuning means, as, for instance, series resonant circuits in the cathode supply lead of amplifying tubes.

When, in the present application, however, amplifier tubes were mentioned, this expression is by no means intended to cover here only the incandescent cathode vacuum amplifiers most customary at the present day, but is to be applied accordingly to all other types of amplifiers; in particular, all amplifiers based, for instance, on the principle of electron multiplication as well as gas or vapour-filled amplifiers are also to be covered thereby. An arrangement, which in the present case, for instance, is preferably arranged in the cathode supply lead, does not necessarily have to be provided in such a case also in the cathode supply lead.

As will be shown further below, e. g. when using tuning circuits, say series resonant circuits, in the cathode supply lead of a pentode-like tube or multi-grid tube constructed in some other manner, particular advantages result owing to the fact that this circuit is traversed by the sum of all the emission currents which pass to the main anodes and also to the auxiliary electrodes. Therefore, on suitable application of the subject of the invention to electron multipliers, it may be preferable in such a case to arrange a similarly-acting circuit not in the cathode supply lead, which, of course, in this case, carries the lowest current intensity, but in the circuit of the last anode or in a circuit which is traversed by the currents of individual or a number of auxiliary anodes, which already carry greater currents.

Returning to the case of an amplifying tube constructed according to the aspects usual at the present day, if we observe the effects arising owing to a series resonant circuit which is inserted in the cathode supply lead, the following is to be observed. If the tube employed is a triode, then a relative voltage variation between the cathode and control grid, no matter how this voltage variation occurs, will result under otherwise equal conditions in equal controlling actions. Therefore, in such a case, if at first the simplified assumption is made that the voltage difference between the cathode and anode is kept constant, it is immaterial whether the cathode potential is kept constant and the control grid potential is varied by a certain amount, or whether the control grid potential is kept constant and the cathode potential is varied by the same amount with respect to the control grid potential.

If, on the contrary, we consider, for example, a pentode in usual connection, it is by no means material whether merely the potential of the control grid is varied with the cathode kept constant or whether the control grid potential is kept constant and the cathode potential is varied by the same amount.

Whereas in the case of the cathode kept constant there arises merely owing to the variation of the control grid potential a controlling action which was hitherto generally utilised for amplifying purposes, there arises, on the contrary, if the control grid potential is kept constant and the cathode voltage is varied by the same amount, a considerably greater control action which is explained by the fact that also the other electrodes of the tube, for instance, the screen-grid and collecting grid also exert in such a case an additional controlling action, since, of course, they are kept at fixed potential already by the use of the well-known circuits.

Therefore, if the cathode alters its potential, for instance, by 1 volt, then not only a relative voltage variation of 1 volt occurs between the cathode and control grid, but at the same time there also occurs an equally large voltage variation, controlling in the same sense, between the cathode and screen-grid and cathode and collecting grid, so that the total alteration of the emission current of the cathode at an alteration of the cathode potential by the same amount is much larger than if only the control grid is altered while the cathode is kept constant.

Since the selectivity-increasing effects of a tuning circuit arranged in the cathode supply lead, for instance, a series resonant circuit are due to the fact that, owing to the potential drop occurring in the cathode supply lead, the cathode carries out voltage fluctuations relatively to the other electrodes of the tube, it is seen that when using multi-grid tubes, the effects of such a circuit can be extremely increased.

It is furthermore known that with the aid of the principle of the space-charge grid tube by the production of virtual cathodes, which can be brought near to the controlling cathodes, extreme steepnesses can be obtained. Such a case of a control of a virtual cathode exists, however, e. g. in a normal pentode already with some approximation, if the cathode potential is varied relatively to the potential of the other electrodes. Between the screen-grid and collecting grid, a potential threshold develops which may act as virtual cathode, particularly on favourable dimensioning of the tube. Now, if the voltages at these electrodes are suitably chosen, the result can be obtained that on varying the cathode potential by two such successive auxiliary electrodes with a high potential difference, quite considerable additional steepnesses with regard to the control by cathode potential fluctuations can be achieved. In this case, for example, the collecting grid or other electrodes may perhaps be connected with the cathode.

It is therefore particularly preferable, in arrangements which work with negative back-coupling for the purpose of increasing selectivity and particularly with negative back-coupling by tuning means in the cathode supply lead (or accordingly in the anode or auxiliary electrode supply lead, for instance, in electron multipliers) to use tubes which have potential thresholds after the fashion of those existing between the screen-grid and the collecting grid of a pentode, in which case it is favourable that, as e. g. in an hexode or octode, several such potentiometer thresholds follow one after the other and it is furthermore favourable in such a case to adjust the voltages between these successive electrodes in such a manner that virtual cathodes forming high steepnesses are formed with cathode potential fluctuations.

What is said here for multi-grid discharge vessels also equally applies to such discharge vessels or discharge system arrangements in which a plurality of discharge vessels or discharge systems are employed in series connection (see, for example, tube I and tube II in Fig. 20) in order to obtain similar effects as in multi-grid tubes.

In the above, different types of counter-coupling have been shown, but it is to be pointed out that the existing possibilities are not exhausted thereby and that according to the particular problem which happens to arise, it may be preferable to choose any other type of counter-coupling instead of that shown, in which case by selection means inserted in the counter-coupling channel, either desired frequencies may be selected from a frequency mixture or undesirable frequencies in a frequency mixture may be suppressed.

Fig. 23 shows an alternative arrangement employing ammeters or voltmeters for giving indication of the adjusted frequency in magnetically tuned receivers. The circuit L3 C3 and the diode D correspond to those shown in Fig. 20.

LADISLAS DE KRAMOLIN.