

Feb. 11, 1941.

D. KOFFYBERG

2,231,389

TUNABLE OSCILLATORY CIRCUITS

Filed Sept. 27, 1939

2 Sheets-Sheet 1

Fig. 1

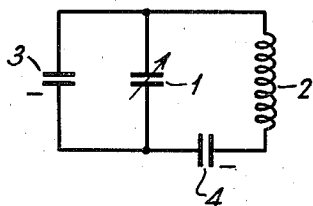


Fig. 3

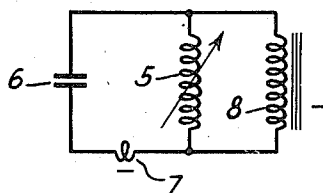


Fig. 2

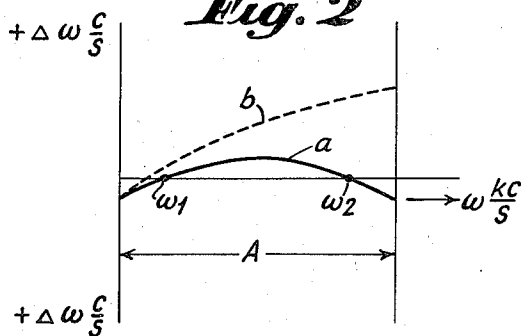
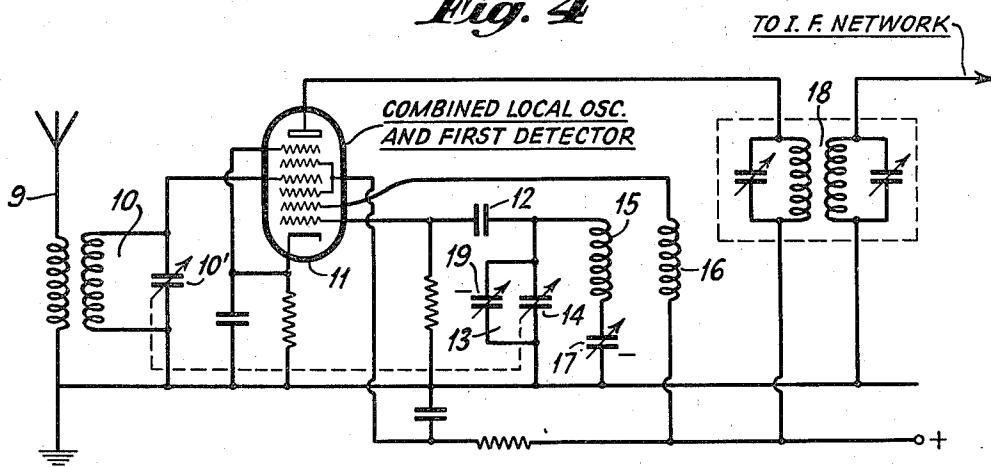


Fig. 4



BY

INVENTOR.
DIEDERIK KOFFYBERG

J. H. Swer
ATTORNEY.

Feb. 11, 1941.

D. KOFFYBERG

2,231,389

TUNABLE OSCILLATORY CIRCUITS

Filed Sept. 27, 1939

2 Sheets-Sheet 2

Fig. 5

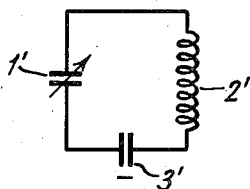


Fig. 6

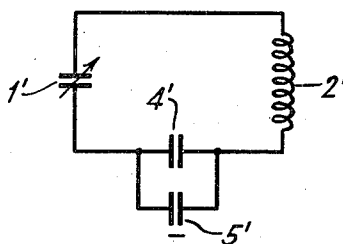


Fig. 7

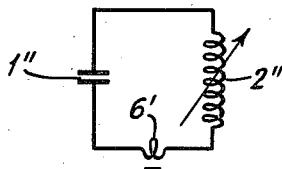
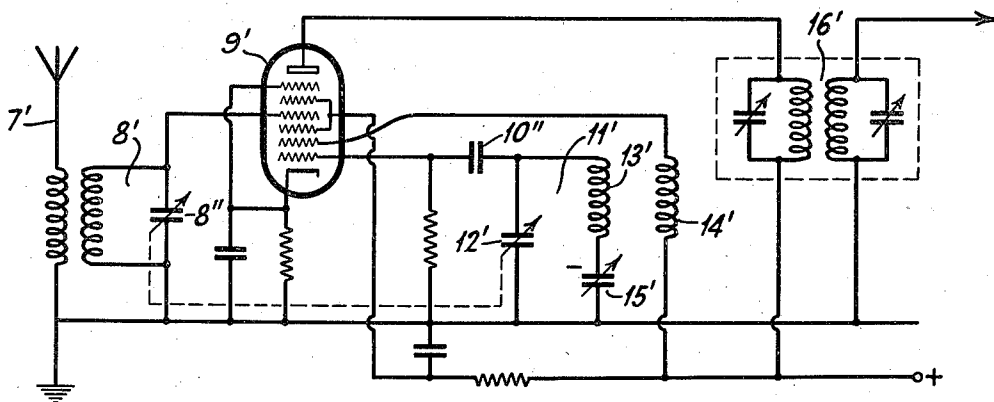


Fig. 8



INVENTOR.
DIEDERIK KOFFYBERG

BY

H. S. Brown
ATTORNEY.

UNITED STATES PATENT OFFICE

2,231,389

TUNABLE OSCILLATORY CIRCUITS

Diederik Koffyberg, Eindhoven, Netherlands, assignor to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, a corporation of the Netherlands

Application September 27, 1939, Serial No. 296,726
In Germany May 8, 1939

5 Claims. (Cl. 250—40)

The present invention relates to a circuit arrangement for the amplification or production of high frequency oscillations, and more particularly to a radio receiving circuit arrangement including a tunable oscillatory circuit.

As is well known, the natural frequency of an oscillatory circuit generally decreases with increasing temperature, because both the capacity and the inductivity of the oscillatory circuit and of the elements associated therewith increase with increasing temperature, or, to put it another way, have a positive temperature coefficient of electric resistance. This often annoying temperature dependency of an oscillatory circuit can be reduced or suppressed in a well known manner; for instance, by connecting a fixed condenser, whose capacity has an opposite and consequently as a rule a negative temperature coefficient, in parallel with the oscillatory circuit. If, however, the oscillatory circuit is tunable, this known circuit for decreasing the natural temperature dependency of an oscillatory circuit allows complete compensation of temperature dependency only for a single frequency of the tuning range. For higher frequencies there occurs over-compensation, whereas for lower frequencies the natural temperature dependency of the oscillatory circuit is only decreased, but not eliminated. The said expedient does not permit the natural temperature dependency of the oscillatory circuit to be reduced throughout the tuning range in a not even approximately regular manner.

The present invention permits the natural temperature dependency of a tunable oscillatory circuit to be reduced in a much more favorable manner. According to the invention there is connected in parallel with, and in series with, the adjustable reactance for tuning the oscillatory circuit in each instance an additional reactance, which additional reactances have the same character as the adjustable reactance and whose temperature dependency is directed in opposition to that of the adjustable reactance. The size and the temperature dependency of each of the additional reactances are preferably so chosen that the natural frequency of the oscillatory circuit is independent of the temperature for one of the higher frequencies and for one of the lower frequencies of the tuning range.

In a heterodyne receiving circuit arrangement, including an oscillatory circuit and a second oscillatory circuit detuned with respect to the former, each of which oscillatory circuits can be tuned by means of an adjustable condenser and with which for equalization of the oscillatory cir-

cuit of the oscillator an additional condenser is connected in parallel with its tuning condenser, whereas for keeping constant the difference in natural frequency of both oscillatory circuits a further additional condenser is connected in series with the last mentioned tuning condenser, the two additional condensers receive, according to a further feature of the invention, a temperature dependency directed in opposition to that of the tuning condenser of the oscillatory circuit of the oscillator.

The invention will be more clearly understood by reference to the accompanying drawings representing, by way of example, some embodiments thereof. In the drawings, Figs. 1 and 3 represent oscillatory circuits according to the invention; Fig. 2 represents a graph of the temperature dependency of two oscillatory circuits, Fig. 4 shows a heterodyne receiving circuit arrangement according to the invention, Figs. 5, 6, and 7 show respectively different simplified embodiments, and Fig. 8 shows a system similar to Fig. 4 embodying a simplified modification of the invention.

Fig. 1 shows a tunable oscillatory circuit comprising an adjustable condenser 1 and a fixed coil 2. As has already been stated the capacity of tuning condenser 1 and the inductance of coil 2 generally increase with increasing temperature. For reducing the temperature dependency of the oscillatory circuit involved thereby a condenser 3 is connected in parallel with the tuning condenser, and a condenser 4 is connected in series with the tuning condenser. Each of the condensers 3 and 4 has a capacity which decreases with increasing temperature or in other words a negative temperature coefficient. In the drawing the negative temperature coefficient is designated by a negative sign.

Of course, condensers 3 and 4 may be various types of condensers having a negative temperature coefficient. For this purpose, use may, for instance, be made either of condensers known per se having a dielectric whose dielectric constant decreases with increasing temperature or condensers whose electrodes are adjustable relatively to one another and, by means of a bi-metal strip or the like, are moved with respect to one another with an increase in temperature so that the capacity decreases. The capacity of condenser 3 is preferably chosen smaller than the minimum capacity of the tuning condenser, and this for limiting as little as possible the tuning range which can be attained by means of tuning condenser 1. If limitation of the tuning range which can be secured by means of tuning con-

condenser 1 is not desirable the capacity of condenser 4 is to be chosen materially higher than the maximum capacity of the tuning condenser.

The influence of temperature dependency on the additional condenser 3 is greater as the capacity of tuning condenser 1 is smaller and will consequently be greater as the adjusted natural frequency of the oscillatory circuit is higher. When the capacity of condenser 3 is small with respect to the maximum capacity of the tuning condenser the influence of temperature dependency of condenser 3 to low frequencies of the tuning range will only be comparatively very small. The influence of temperature dependency of the additional condenser 4 is greater in contradistinction to that of condenser 3 as the capacity of the adjustable condenser 1 is higher, and will consequently be greater as the adjusted natural frequency of the oscillatory circuit is lower.

Since the temperature dependency of condenser 3 strongly responds to high frequencies, but the temperature dependency of condenser 4 strongly responds to low frequencies of the tuning range it is possible to choose the size and temperature dependency of these condensers so that for one of the higher frequencies and for one of the lower frequencies of the tuning range the natural frequency of the oscillatory circuit is independent of the ambient temperature. As a result thereof the remaining temperature dependency of the oscillatory circuit is only very small throughout the tuning range.

The temperature dependency of the oscillatory circuit then available appears from the graph represented in Fig. 2. The abscissa-axis has plotted on it in kilocycles/second the natural frequency ω of the oscillatory circuit (tuning range A), the variation $\Delta\omega$ of the natural frequency occurring at a definite temperature variation of say 1°C . being plotted in cycles/second on the ordinate axis. The solid curve *a* indicates the natural frequency variation of the oscillatory circuit when using the circuit according to the invention. Therefrom it appears that in regard to the natural frequency the oscillatory circuit is independent of the temperature for the frequencies ω_1 and ω_2 . For comparison the natural frequency is indicated by a dotted curve *b* when using exclusively the condenser 3 connected in parallel with tuning condenser 1. As appears therefrom the use of the invention yields a very material improvement in regard to temperature dependency of the oscillatory circuit.

When for tuning the oscillatory circuit a coil with adjustable inductance is used, two additional coils having a negative temperature coefficient must be used in order to compensate for the natural temperature dependency of the oscillatory circuit according to the invention. As is well known a negative temperature coefficient of a coil consisting of several turns may, for instance, be obtained by such mechanical attachment of the coil that due to an increase in temperature its axial length becomes comparatively much greater. Similarly an iron-cored coil may be used with which the permeability of the core decreases with increasing temperature. In the circuit shown in Fig. 3 the oscillatory circuit consists of a fixed condenser 6 and an adjustable coil 5. A preferably small coil 7 having a negative temperature coefficient is connected in series with the tuning coil 5. Furthermore, a preferably large coil 8 having a negative temperature coefficient is connected in parallel with the tuning coil. The coil 8, which is preferably larger

than the maximum size of the tuning coil, has an iron core whose permeability decreases with increasing temperature.

It is to be noted that coil 7 responds most strongly to high frequencies, whereas coil 8 responds most strongly to low frequencies of the tuning range. Otherwise, the effect of the two additional coils 7 and 8 is similar to that of both additional condensers 3 and 4 shown in Fig. 1. The additional reactances of the tunable oscillatory circuit, which are used according to the invention, may be used for reducing the natural temperature dependency of the oscillatory circuit, and, in addition, for other purposes as will be set out, for instance, by reference to Fig. 4.

Fig. 4 represents a heterodyne receiving circuit of a well known type. The high frequency voltages taken from an antenna 9 are supplied to an input oscillatory circuit 10 which can be tuned by means of an adjustable condenser 10' and is connected to the fourth control grid of a mixing tube 11. The first control grid of the mixing tube is coupled with an oscillatory circuit 13 by means of a grid condenser 12. This oscillatory circuit can be tuned by means of an adjustable condenser 14 which is adjusted in common with the tuning condenser 10' of the input circuit 10. The coil 15 of the oscillatory circuit 13 is coupled in such a manner with a coil 16 interposed in the circuit of the second grid of the mixing tube that local oscillations are produced.

As is well known it is often required for maintenance of a substantially constant frequency difference between the signal input circuit and the oscillatory circuit of the local oscillator to connect a small condenser 19, which may be adjustable if desired, in parallel with the tuning condenser 14. Furthermore, it is necessary to displace the frequency of the input oscillatory circuit 10 and the oscillatory circuit 13 by an amount corresponding to the desired intermediate frequency. The intermediate frequency, to which the intermediate frequency bandpass filter 18 interposed in the anode circuit of mixing tube 11 is tuned, being invariable the frequency difference of the two oscillatory circuits 10 and 13 must be kept as constant as possible. As is well known this constant frequency difference is secured by providing an additional condenser 17 in series with condenser 14 and coil 15 of the oscillatory circuit 13.

According to the invention the disturbing natural temperature dependency of oscillatory circuit 13 is eliminated by giving condensers 17 and 19 a negative temperature coefficient. Since, as will be appreciated, in the example shown in Fig. 4 the value of the capacity of both condensers 17 and 19 generally cannot be chosen in accordance with the temperature dependency, it is, of course, necessary for securing the desired effect in regard to elimination of the disturbing temperature dependency of the oscillatory circuit to choose the temperature dependency of each of the condensers 17 and 19 accordingly. Sometimes it may be advantageous, for instance if the size of condenser 19 can be determined only very inexactly beforehand and consequently its influence on the temperature dependency of the oscillatory circuit neither can be exactly determined beforehand, to connect in parallel with tuning condenser 14 a condenser having a fixed capacity but an adjustable temperature coefficient. In this case the oscillatory circuits 10 and 13 can be balanced by means of condenser 19, whereupon the temperature dependency of oscillatory circuit 13 can be re-

adjusted by means of the condenser with adjustable temperature coefficient.

Fig. 5 shows a tunable oscillatory circuit constituted by an adjustable condenser 1' and a fixed coil 2'. As already mentioned, the capacity of the condenser 1' and the inductance of the coil 2' generally increase at an increase in temperature. To reduce the resulting dependency on temperature of the oscillatory circuit, the adjustable condenser 1' according to the invention has an additional condenser 3' connected in series with it, whose capacity decreases at an increase in temperature or, to say it briefly, exhibits a negative temperature coefficient. In Fig. 5, the negative temperature coefficient of this condenser has been denoted by a negative sign. For the condenser 3' use may, of course, be made of different kinds of condensers with a negative temperature coefficient. To this end, use may be made, for example, of the condensers known per se having a dielectric, whose dielectric constant decreases at an increase of temperature, or of condensers whose electrodes are arranged so as to be movable with respect to one another and, at an increase in temperature, are mutually displaced by means of a bi-metallic strip or the like in such manner that the capacity decreases.

The capacity of the condenser 3 is preferably greater than the maximum capacity of the tuning condenser. Particularly in this case it may be advantageous with a view to saving cost to use the arrangement shown in Fig. 6, in which the additional impedance used is constituted by the parallel connection of two condensers 4' and 5' of different size, instead of a single condenser with a negative temperature coefficient. The larger condenser 4' may in this case exhibit a slightly positive temperature coefficient, whereas the smaller condenser 5' exhibits so strong a negative temperature coefficient that the total capacity of the parallel-connected condensers 4' and 5' exhibit the negative temperature coefficient required to compensate the natural dependency on temperature of the oscillatory circuit.

If for tuning the oscillatory circuit use is made of a coil, the inductance of which is adjustable the additional reactance used for compensating the dependency on temperature must be preferably a very small coil 6' as is shown in Fig. 7. As is well known, a negative temperature coefficient of a coil constituted by a few turns may be obtained, for example, by such a mechanical construction of the coil that an increase in temperature results in a comparatively great increase of its axial length. Use may alternatively be made of a coil provided with an iron core, in which the permeability of the core decreases at an increase in temperature.

The additional reactance of the tunable oscillatory circuit used according to the invention may be used to reduce the dependency on temperature of the oscillatory circuit and, in addition, for other purposes, as will be explained more fully, by way of example, by reference to Fig. 8. Fig. 8 shows a superheterodyne receiving arrangement of the kind known per se. The high frequency voltages derived from an aerial 7' are supplied to an input oscillatory circuit 8' which can be tuned by means of an adjustable condenser 8'' and is connected to the fourth control grid of a mixing tube 9'. The first control grid of the mixing tube is connected to an oscillatory circuit 11' by means of a grid condenser 10''. This oscillatory circuit may be tuned by an adjustable condenser 12' which is adjusted in common with the tuning condenser

of the input circuit. A coil 13' of the oscillatory circuit 11' is coupled to a coil 14' interposed in the circuit of the second grid of the mixing tube, in such manner that oscillations are produced.

As is well known, it is necessary that the input oscillatory circuit 8' and the oscillatory circuit 11' of the oscillator should be displaced in frequency by an amount corresponding to the desired intermediate frequency. Since the intermediate frequency, to which the intermediate frequency band-filter 16' interposed in the anode circuit of the mixing tube 9' is tuned, is invariable, the difference in natural frequency between the two oscillatory circuits 8' and 11' must be maintained as constant as possible. This can be achieved, as is well known, by providing an additional condenser 15' in series with the condenser 12' and the coil 13' of the oscillatory circuit 11.

According to the invention, a reduction of the natural dependency on temperature of the oscillatory circuit 11' is now obtained by giving the condenser 15' a negative temperature coefficient. In view of the choice of the additional reactance it should still be noted that a complete compensation of the natural dependency on temperature of the oscillatory circuit due to the measure according to the invention can only be obtained for a single frequency of the tuning range, and that the detuning produced due to fluctuations of the ambient temperature is generally most disturbing for the higher frequencies of the tuning range.

What is claimed is:

1. In a high frequency oscillatory circuit comprising a pair of reactances of opposite sign, means for adjusting the magnitude of one of said reactances thereby to adjust the frequency of the circuit over a wide range of frequencies, a third reactance in shunt with said adjustable reactance, a fourth reactance in series with both said pair of reactances, said third and fourth reactances being of the same sign as said adjustable reactance, and said third and fourth reactances each having temperature coefficients of the opposite sign to said adjustable reactance.

2. In a high frequency oscillatory circuit comprising a pair of reactances of opposite sign, means for adjusting the magnitude of one of said reactances thereby to adjust the frequency of the circuit over a wide range of frequencies, a third reactance in shunt with said adjustable reactance, a fourth reactance in series with both said pair of reactances, said third and fourth reactances being of the same sign as said adjustable reactance, and said third and fourth reactances each having temperature coefficients of the opposite sign to said adjustable reactance, and the magnitudes of said third and fourth reactances being so related that the oscillatory circuit frequency is independent of temperature for one of the higher frequencies and for one of the lower frequencies of said range.

3. In a high frequency oscillatory circuit comprising a pair of reactances of opposite sign, means for adjusting the magnitude of one of said reactances thereby to adjust the frequency of the circuit over a wide range of frequencies, a third reactance in shunt with said adjustable reactance, a fourth reactance in series with both said pair of reactances, said third and fourth reactances being of the same sign as said adjustable reactance, and said third and fourth reactances each having temperature coefficients of the opposite sign to said adjustable reactance, and said adjustable reactance being a condenser having a positive temperature coefficient.

4. In a high frequency oscillatory circuit comprising a pair of reactances of opposite sign, means for adjusting the magnitude of one of said reactances thereby to adjust the frequency of the circuit over a wide range of frequencies, a third reactance in shunt with said adjustable reactance, a fourth reactance in series with both said pair of reactances, said third and fourth reactances being of the same sign as said adjustable reactance, and said third and fourth reactances each having temperature coefficients of the opposite sign to said adjustable reactance, said adjustable reactance being a coil having a positive temperature coefficient.
5. In a high frequency oscillatory circuit comprising a pair of reactances of opposite sign, means for adjusting the magnitude of one of said reactances thereby to adjust the frequency of the circuit over a wide range of frequencies, a third reactance in shunt with said adjustable reactance, a fourth reactance in series with both said pair of reactances, said third and fourth reactances being of the same sign as said adjustable reactance, and said third and fourth reactances each having temperature coefficients of the opposite sign to said adjustable reactance, said third reactance having a magnitude larger than the maximum value of the adjustable reactance, and the fourth reactance having a value smaller than the minimum value of the adjustable reactance.

DIEDERIK KOFFYBERG.