

April 11, 1939.

N. M. RUST

2,154,076

FILTER CIRCUITS

Filed March 9, 1936

2 Sheets-Sheet 1

Fig. 1

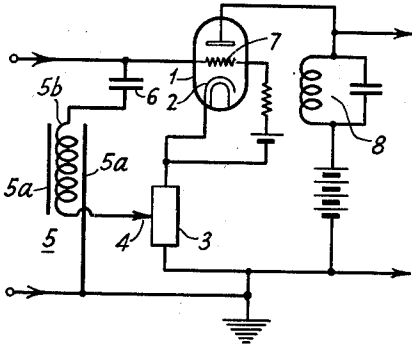


Fig. 2

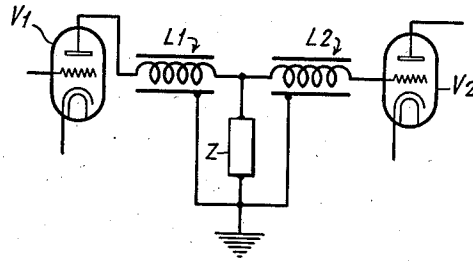


Fig. 5

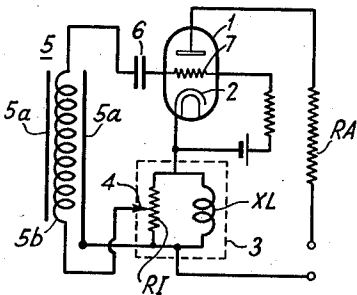


Fig. 3

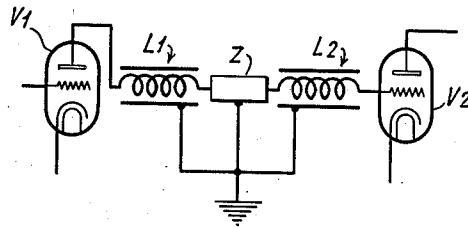


Fig. 6

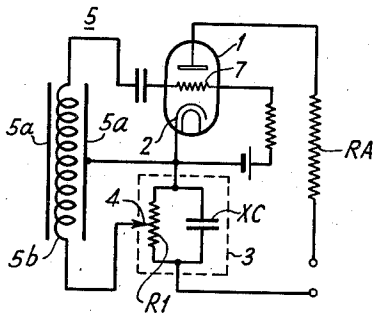
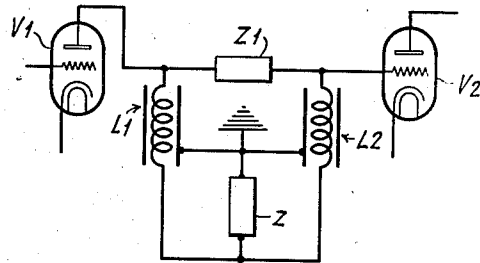


Fig. 4



INVENTOR.
NOEL MEYER RUST

BY

H. S. Brown
ATTORNEY.

April 11, 1939.

N. M. RUST

2,154,076

FILTER CIRCUITS

Filed March 9, 1936

2 Sheets-Sheet 2

Fig. 7

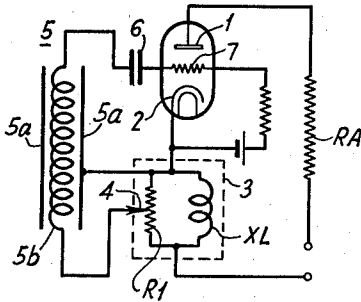


Fig. 8

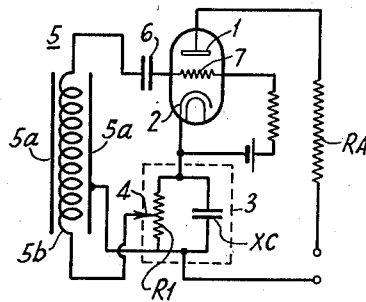


Fig. 9

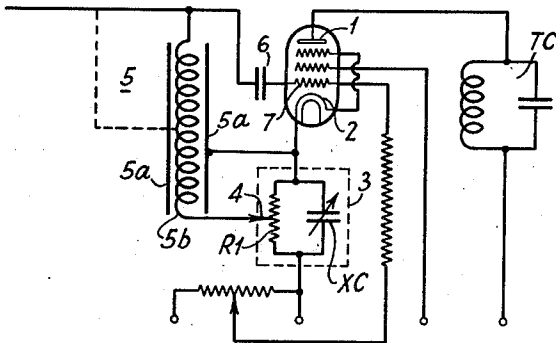


Fig. 10

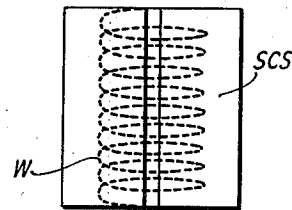
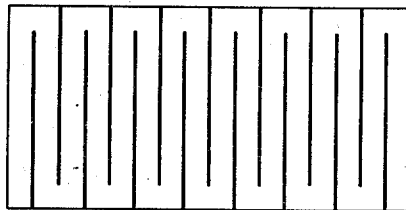


Fig. 11



INVENTOR.
NOEL MEYER RUST

BY

H. B. Brown
ATTORNEY.

UNITED STATES PATENT OFFICE

2,154,076

FILTER CIRCUITS

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

Application March 9, 1936, Serial No. 67,770
In Great Britain March 16, 1935

4 Claims. (Cl. 178-44)

This invention relates to radio and other high frequency circuit arrangements and to electrical filters for use in radio and other high frequency circuit arrangements.

In many radio and similar circuit arrangements and in electrical filters, it is required to connect together two points in a circuit through an electrical resonant device which will present high impedance at one end and low impedance at the other; and, according to this invention, such a resonant device is constituted by a quarter wavelength artificial line or by an artificial line of electrical length equal to one or more whole wavelengths plus or minus a quarter wavelength.

Artificial lines for use in carrying out this invention may, where adjustment or variability of the line is required, be artificial lines in accordance with the invention described in copending application Serial No. 69,098, filed March 16, 1936, by R. F. O'Neill et al., but where adjustment or variability of the line is not required, the said artificial line may be constituted as shown in the accompanying Fig. 10 by a coil W positioned within a split conductive screen SCS so that the screen provides the major portion of the distributed capacity of the coil, the coil inductance plus the distributed capacity together providing the artificial line effect. If desired, a ferromagnetic core may be provided within the coil. Preferably the screen has not merely a single slit but has a large plurality of parallel slits, adjacent slits starting at opposite tubular ends of the screen but stopping short of the opposite end. Such a screen is shown in developed view in the accompanying Fig. 11, and may be made mechanically firm by means of paper stuck on outside and/or inside the screen and covering the slits.

An important application of the invention is to feed back or reaction thermionic valve arrangements wherein feed back or reaction control is required.

In practice, it is a difficult matter to effect variable reaction or feed back, more particularly where very high frequencies are in question, without sacrifice of efficiency, convenience, simplicity of operation, or stability, and the present invention may be utilized to provide an improved variable reaction arrangement in which these difficulties are avoided.

The invention is illustrated in and further explained in connection with the accompanying drawings, wherein:

Figs. 1 to 9, inclusive, show various embodiments of the invention, and

Figs. 10 and 11 show features of the artificial line which may be used with the invention.

Referring to Fig. 1, which shows diagrammatically one form of improved variable reaction thermionic valve amplifier circuit arrangement in accordance with this invention, the amplifier

valve 1, which is shown as a triode but may be any other convenient form of valve, has its cathode 2 connected to earth or to some other point of fixed alternating current potential through a low impedance 3 of, for example, ten to twenty ohms in value. A variable tapping point 4 upon this impedance is connected to one end of a quarter wavelength artificial line 5 and the other end of the line is connected through a suitable condenser 6 to the grid 7 of the valve, the signals to be amplified being applied direct to this grid. An artificial line in accordance with the invention contained in the copending application, supra, or an invariable artificial line as hereinbefore described, is preferably employed and the screen member 5a of the line is connected to earth. One end of the coil 5b of the line is connected to the tap 4 and the other end of the coil 5b is connected through the condenser 6 to the grid 7. The anode circuit of the valve may contain the usual tuned circuit 8 or it may contain another quarter wavelength artificial line. The impedance 3 should be such as to provide a 90° phase shift to the current entering the line so that, with the phase shift through the line—the action of which is to swing the phase through 90° both as regards current and voltage—the total phase change due both to the quarter wave line and the cathode coupling impedance 3, is such that the resultant voltage applied to the grid 7 from the line is in phase with the signal voltage which is directly applied between the grid 7 and earth.

It will be seen that with this arrangement by virtue of that property of a quarter wavelength artificial line by which it presents high impedance at its open end and low impedance at its short circuited end, the required impedance conditions are obtained, namely high impedance at the grid of the valve and low impedance at the cathode end. Because the artificial line has a voltage multiplying effect any feed back potentials from the impedance which is between the cathode of the valve and earth will be amplified before reaching the grid.

Another application of the invention is to band pass filters or band pass coupling circuits. For example, in Fig. 2 is shown a band pass coupling arrangement in accordance with this invention and comprising two quarter wave artificial lines L1, L2 in series with one another, the free end of one artificial line being connected to the anode of the first valve V1 and the free end of the other artificial line being connected to the grid of the second valve V2 to be coupled together by the filter. The junction point of the two artificial lines is connected to earth through a suitable impedance Z, as well known per se in filter and band pass coupling circuit practice. The two screens of the two artificial lines are

earthed as shown, and accordingly by virtue of the property of an artificial line to present a high impedance at its open end and a low impedance at its short circuit end, the required impedance relations are obtained, namely high impedance facing towards the anode of the first valve V1 and the grid of the second valve V2 and low impedance at the junction point of the two series connected artificial lines L1, L2. If desired, separate wires may extend from the low impedance terminals of the lines to separate polarizing batteries.

In a modified band pass filter, in accordance with this invention and illustrated in Fig. 3, two quarter wave artificial lines L1, L2 in series are again employed, but the artificial lines are not directly connected but are put in series through a suitable impedance network Z, as known per se in band pass filter practice, a central point upon this network being earthed and the screens of the artificial lines being also earthed as represented in Fig. 3.

In yet a third form of band pass coupling arrangement, in accordance with this invention and illustrated in Fig. 4, the band pass coupling arrangement of Fig. 2 is modified by providing a further impedance network Z1 directly between the anode of the first valve and the grid of the second. In this case the impedance network so connected should be of high impedance and the impedance network Z, which is between earth and the junction point of the two series connected quarter wave artificial lines L1, L2, should be of low impedance.

Detailed description of the impedance networks embodied in the band pass coupling circuits above described is thought to be unnecessary as the said coupling arrangements are, from the general filter point of view, known per se, and the said networks are designed in accordance with well known principles, the novelty of the present invention, as applied to these filters, consisting in the substitution of the quarter wave artificial lines for what would, in hitherto known filters of equivalent general arrangement, be tuned circuits.

It was pointed out in connection with Fig. 1 that the impedance 3 should be such as to produce a 90° phase shift to the current entering the line so that, with the phase shift through the line—the action of which is to swing the phase through 90° both as regards current and voltage—the total phase change due both to the quarter wave line and the cathode coupling impedance 3, is such that the resultant voltage applied to the grid 7 from the line is in phase with the signal voltage which is directly applied between the grid 7 and earth. Experiment has shown that there are two convenient ways of obtaining the correct phase relationship as applied to

$$\frac{\lambda}{4}, \frac{5\lambda}{4}, \frac{9\lambda}{4} \dots \left(n\lambda + \frac{\lambda}{4}\right)$$

reaction effects (where λ is the wavelength and n is any whole number) and similarly two convenient ways of obtaining the correct phase relationship as applied to

$$\frac{3\lambda}{4}, \frac{7\lambda}{4}, \frac{11\lambda}{4} \dots \left(n\lambda - \frac{\lambda}{4}\right)$$

reaction effects. For the sake of simplicity, circuits for the

$$\frac{\lambda}{4}$$

reaction condition will first be described and, again for the sake of simplicity, it will be assumed that the anode loading is purely resistive—i. e. complications due to a (possibly) mistuned anode circuit will be ignored.

Figs. 5 and 6 illustrate two arrangements for the

$$\frac{\lambda}{4}$$

reaction condition. Fig. 5 shows a circuit as represented in Fig. 1 but in Fig. 5 the impedance 3 (the apparatus within the dotted rectangle marked 3 in Fig. 5) is shown in detail and the anode load is represented by a resistance RA. The impedance 3 comprises an inductance XL shunted by a resistance R' on which the tap 4 is made. In Fig. 6 the impedance 3 comprises a condenser XC shunted by a resistance R' on which the tap 4 is made.

In these arrangements, if XL or XC, as the case may be, is small relative to the sum of RA plus the internal resistance of the valve, the total anode current will not be appreciably changed either as regards amplitude or phase, from what would obtain were the impedance 3 omitted. The line, which is a quarter wavelength long, may be regarded as resistive load connected at one end to the tap 4 upon the impedance 3 which is traversed by the anode current. On these assumptions it may be shown that the reaction voltage applied by the line 5 to the grid is in phase with the input voltage directly applied thereto—the required condition for correct reaction. This applies both to the inductive case (Fig. 5) and the capacity case (Fig. 6). It will be noted that the difference between the methods of connection of the line in Figs. 5 and 6 is that in the former case the line is between tap 4 and the end of impedance 3 remote from the cathode, whereas in the capacity case (Fig. 6) the line is between tap 4 and the cathode end of impedance 3.

The arrangements of Figs. 5 and 6 apply when the line is $\frac{1}{4} \lambda$ long or

$$n\lambda + \frac{\lambda}{4} \text{ long}$$

Figs. 7 and 8 are figures corresponding respectively to Figs. 5 and 6 and show the methods of connection when the line is

$$n\lambda - \frac{\lambda}{4} \text{ long}$$

Corresponding references are used throughout Figs. 5 to 8 and it will be noted that for the inductive case of Fig. 7 the same method of line connection is used as for the capacity case of Fig. 6 and similarly the same method is used for the capacity case of Fig. 8 as for the inductive case of Fig. 5. This, of course, is because Figs. 5 and 6 are concerned with

$$\frac{\lambda}{4} \text{ or } \left(n\lambda + \frac{\lambda}{4}\right) \text{ lines}$$

while Figs. 7 and 8 are concerned with

$$\left(n\lambda - \frac{\lambda}{4}\right) \text{ lines}$$

and the phase shift produced by lines with which Figs. 5 and 6 are concerned differs by 180° from the phase shift produced by lines with which Figs. 7 and 8 are concerned.

In Figs 5 to 8 the anode load is resistance RA. If, however, an accurately tuned circuit (tuned to the frequency corresponding to the wavelength

condition selected) be substituted for the resistance RA, it is found that a smaller cathode impedance 3 can be used for the same degree of reaction while furthermore, variation of the tap 4 produces substantially no alteration of the frequency at which the whole arrangement exhibits maximum gain. Such variation is in practice produced if the anode load be a resistance RA.

It will also be appreciated that where RA is substituted by a tuned circuit it is possible, by mistuning the said circuit, or by otherwise suitably adjusting its tuning, to obtain results other than those given above for Figs. 5 to 8. For example, when using a circuit as above given for the

$$\frac{\lambda}{4} \text{ and } n\lambda + \frac{\lambda}{4} \text{ cases}$$

but with RA replaced by a tuned circuit, it is possible, by tuning the anode circuit to a frequency corresponding to a wavelength of

$$n\lambda - \frac{\lambda}{4}$$

to obtain proper reaction at that frequency. Similarly a circuit as above given for the

$$n\lambda - \frac{\lambda}{4}$$

case may be caused to operate satisfactorily at a frequency corresponding to a wavelength of

$$n\lambda + \frac{\lambda}{4}$$

by substituting for RA a tuned circuit resonant for the selected wavelength

$$n\lambda + \frac{\lambda}{4}$$

Again, by substituting for RA a tuned circuit suitably mistuned one way or the other, it is possible to make arrangements as shown in Figs. 5 and 6 operate for a wavelength

$$n\lambda - \frac{\lambda}{4}$$

and similarly to make arrangements as shown in Figs. 7 and 8 operate for a wavelength

$$\frac{\lambda}{4} \text{ or } n\lambda + \frac{\lambda}{4}$$

Operation obtained by such mistuning and tuning arrangements is, however, apt to be jerky and unstable and is not, therefore, preferred.

Although in Figs. 5 to 8 triodes are illustrated, other forms of valve may be used, and, indeed, multi-grid valves—notably high frequency pentodes—are to be preferred partly because of the more nearly resistive input impedance obtained and partly because of the higher grid input impedance obtained.

A typical intermediate frequency stage embodying the invention and suitable for use in a superheterodyne receiver is shown in Fig. 9. Except that this stage includes a pentode instead of a triode and that a tuned circuit TC is substituted for the resistance RA, Fig. 9 is like Fig. 8 and as similar references are used in both these figures detailed description of Fig. 9 is thought unneces-

sary. XC is shown as variable and for a case where the line 5 is

$$\frac{\lambda}{4}$$

at 330 kc., XC may be variable between about .02 and 1 mfd. R' may be about 50 w. and the circuit TC may consist of an inductance of about 1100 microhenries shunted by a condenser of about .00021 mfd. The input from the preceding frequency changer stage (not shown) may be applied to the grid 7 as shown, or the input lead may be tapped down on the coil 5b, as indicated in dotted lines, or an inductively coupled input may be used according to which is most convenient.

It is to be understood that the various reaction arrangements illustrated and described are not limited to their application to cases where the reaction is insufficient for self-oscillation for, obviously, by increasing the reaction beyond this point, the invention may be utilized to provide improved oscillators.

What is claimed is:

1. Band pass filter comprising two artificial lines of lumped impedance arranged in series, each artificial line being an odd multiple of one-quarter wavelength long, an impedance connected to the junction point of said lines, the free ends of said lines presenting high impedance, whereby said filter transfers a band of frequencies efficiently from one free end to the other, each of said artificial lines being composed of a coil within a metallic shield, said shield being connected to a point of fixed alternating current potential.

2. Band pass filter comprising two artificial lines of lumped impedance arranged in series, each of said lines being electrically one-quarter wavelength long, an impedance connected between the junction point of said lines and a point of fixed alternating current potential, the free ends of said lines presenting high impedance, whereby said filter transfers a band of frequencies efficiently from one free end to the other, each of said artificial lines being composed of a coil within a metallic shield, said shield being connected to a point of fixed alternating current potential.

3. Band pass filter comprising two artificial lines of lumped impedance arranged in series, each of said lines being electrically one-quarter wavelength long, an impedance connected between and in series with said lines, the free ends of said lines presenting high impedance, whereby said filter transfers a band of frequencies efficiently from one free end to the other, each of said artificial lines being composed of a coil within a metallic shield, said shield being connected to a point of fixed alternating current potential.

4. Band pass filter comprising two artificial lines of lumped impedance arranged in series, each of said lines being electrically one-quarter wavelength long, an impedance connected between the junction point of said lines and a point of fixed alternating current potential, and a high impedance connected across the other ends of said lines, whereby said filter transfers a band of frequencies efficiently, each of said artificial lines being composed of a coil within a metallic shield, said shield being connected to a point of fixed alternating current potential.

NOËL MEYER RUST.