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CIRCUIT FOR THE AMPLIFICATION OF ULTRA-HIGH FREQUENCIES

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Fig. 1

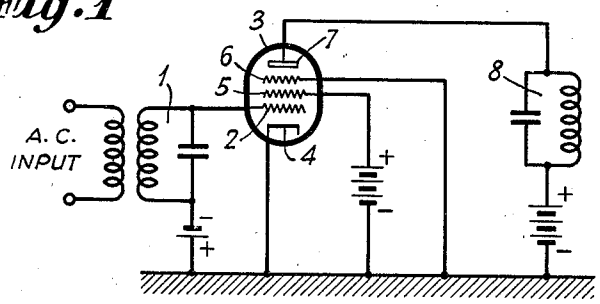
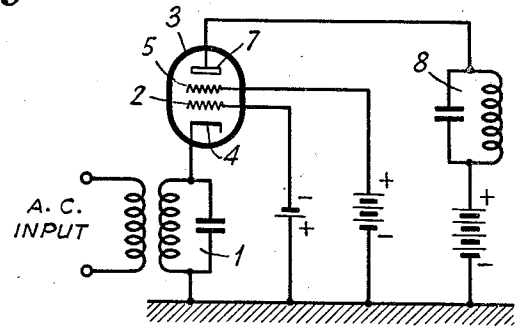


Fig. 2



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CIRCUIT FOR THE AMPLIFICATION OF ULTRA-HIGH FREQUENCIES

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2 Claims. (Cl. 179—171)

This invention is concerned with a circuit organization adapted to amplify ultra-high frequencies. The same may be used for frequency ranges or bands in which the electron transit time inside the tube is comparable to the frequency of the oscillation to be amplified, that is to say, especially for frequencies of more than 100 mega-cycles (ultra-short waves and decimeter waves).

In the accompanying drawing Fig. 1 shows a conventional amplifier circuit utilizing a pentode tube, and Fig. 2 discloses an amplifier circuit embodying the present invention.

In conventional circuit organizations such as Fig. 1 used for the amplification of alternating potentials by means of electron tubes, the alternating potential to be amplified is fed to a lead brought to a grid interposed in the discharge path. The alternating potential to be amplified, for instance, by way of inductive coupling means, is fed to the oscillatory circuit 1 which is connected between the grounded cathode 4 and control grid 2 of the pentode 3. The cathode 4, the screen grid 5 and the suppressor grid 6 are directly grounded or grounded by way of direct current sources of voltage supply. The alternating voltage impressed upon the control grid results in a flow of alternating current to the anode or plate 7 and thus an amplified alternating voltage in the oscillatory circuit 8 which is included in the plate lead. Now, as has been demonstrated by more recent research (see the article by H. Rothe entitled "The behavior of electron tubes for high frequencies," published in No. 9, April 1, 1937, pp. 33–65 of Die Telefunkenroehre), the control action brought upon the electron current by the control grid where high frequencies are concerned is not free from dissipation even when the control grid is negatively biased so that it can not be struck by electrons. For the electrons flying through the openings of the control grid by influence action cause an alternating current to flow in the control grid. However, this current does not present exactly a 90-degree angle lead in reference to the grid alternating potential; indeed, because of the finite transit time of the electrons from the cathode to the control grid surface, it may show an angle of lead less than 90 degrees or even lag behind the grid alternating voltage. However, this means that in the control grid circuit there flows a real alternating current component, and this means dissipation of power and thus damping in the associated oscillation circuits. The imaginary component of the influence current moreover means an increase in the effective capacity of the control grid. The real component of the said current grows in proportion to ω^2 (where ω is the cyclic frequency or frequency in radians). As a result, a limitation is soon imposed upon the chances of amplification by standard tubes and conventional circuit organizations as the frequency is raised. In practice, it has been ascertained that for frequencies approximately above 300-megacycles amplification with conventional tubes with circuit arrangements of the kind shown in Fig. 1 is no longer feasible.

Now, it is true that there is a chance to utilize the inversion properties of the electron stream, for as soon as the influence A. C. shows a lag in relation to the grid alternating potential of over 90 degrees, the real component of the influence A. C. becomes negative. In this region of inversion de-attenuation or regeneration in the associated oscillation circuits takes place so that, also inside this frequency range, amplification would be feasible with a circuit arrangement of the kind shown in Fig. 1. But quite apart from the fact that this inversion occurs practically only for ultra-high frequencies, it is to be noted that the control grid in the circuit organization of Fig. 1, moreover, presents such a high capacitance with respect to the two adjacent electrodes, being at ground potential (cathode and screen grid), that for these high frequencies an effective tuning of the grid circuit would be hardly feasible.

In addition to the circuit scheme shown in Fig. 1, an arrangement for electron tubes comprising a grid electrode between the heated filament and the plate has been disclosed in the prior art (see U. S. Pat. No. 1,896,534) in which the grid electrode is earthed, while the filament leads contain coupling coils which supply the filament with the alternating potentials to be controlled. Also known in the earlier art are mixer tube circuit arrangements, in which the heterodyne (or locally generated) oscillation is fed to the filament circuit. What was guiding in this scheme was the desire to save and dispense with a distinct grid for the introduction of the control alternating potential. As shall be shown further below, these circuit organizations operating with a controlled filament potential have an unsatisfactory behavior in the customary broadcast waves, and there was nothing to indicate that the situation would be any different in the case of ultra-short waves.

Now, according to the invention, in the opera-

tion of a circuit organization adapted for the amplification or generation of alternating potentials of ultra-high frequency, the RF potential to be amplified is introduced in the cathode lead and the grid or grids are grounded for RF, while the tube is operated in such a way that it works within the inversion region.

Referring to the exemplified embodiment of the invention shown in Fig. 2, and preserving the same reference numerals for identical or similar parts as in the scheme of Fig. 1, this circuit organization differs from Fig. 1 in so far as the input circuit 1, which is fed with the alternating potential to be amplified, is included in the cathode supply lead rather than in the lead brought to the control grid, while the control grid 2 and the screen grid 5 are grounded directly and with the interposition of the requisite D. C. source of voltage supply. Hence, these two grids, if their leads be designed so that they are practically free from inductance, present no alternating potential to ground. For reasons to be discussed more fully further below, only a tetrode is to be used in this embodiment; in other words, the screen is followed directly by the anode 4 whose lead includes the oscillatory circuit 8 across which the amplified alternating potential is developed.

So far as the control of the electron current is concerned, it should, fundamentally speaking, be immaterial whether the alternating potential is fed to the control grid or to the filament. In either instance, the effective potential of the control grid surfaces has an alternating component with respect to the filament, and this results in an A. C. component in the electron current. However, looked at from the viewpoint of the power required for the control action, there are very basic distinctions between the two arrangements. Examining first the situation where very low frequencies are dealt with, it will be understood that the influence current flowing to the various electrodes as a result of electron motion and the displacement currents caused as a result of inter-electrode cold capacitances do not yet play any part at all as compared with the electron currents. Now, since no electrons are able to reach the control grid 2, provided it is impressed with a negative biasing voltage with respect to the cathode, it follows that for such low frequencies the control action is actually free from dissipation in a circuit organization as shown in Fig. 1. However, in the circuit scheme of the kind shown in Fig. 2, for low frequencies, a rather appreciable power is dissipated for the control action, for, as will be noted, the whole A. C. component of the electron current flows through the oscillatory circuit 1. The resistance, which is in parallel relation to the oscillatory circuit 1, is equal to the "diode resistance" of the discharge arrangement, in other words, it is equal to the A. C. resistance measured between the cathode and the combination of all other electrodes of this discharge tube. For normal amplifier purposes, in the case of medium frequencies (broadcast waves), as will thus be seen, this circuit arrangement shown in Fig. 2 is unfavorable.

However, where ultra-high frequencies are concerned, the conditions become wholly different. For instance, as demonstrated on page 40 of the Rothe article hereinbefore cited, the resistance of a diode path assumes a negative value as soon as the transit time t of the electrons from the filament to the plate of the diode becomes equal to the period; in other words, as soon as the transit time angle $\theta=\omega t$ assumes a value ranging between 2π and 3π. Inside this inversion range, as will thus be noted, amplification would very readily be feasible; in fact, by virtue of the negative resistance of the discharge path, there is even obtained de-attenuation (regeneration) in the associated oscillation circuit 1. By choosing accurate values for the resistance of the oscillatory circuit it will be an easy matter to make conditions so that de-attenuation or regeneration will not result in self-oscillation.

However, the circuit organization of Fig. 2, inside this region of inversion, offers still further advantages over the circuit scheme in Fig. 1. For while in the case of the latter, the input capacity is governed by the static capacity of the control grid in relation to the cathode and the screen grid, to which is added a positive dynamic capacity, it will be seen that the input capacity in the case of a circuit organization of Fig. 2 is given only by the capacity of the filament with respect to the control grid, and this capacity also comprises a static and a dynamic capacity component. However, in the case of an arrangement as shown in Fig. 2, the latter is always negative. Hence, even the static input capacity in the arrangement of Fig. 2 is substantially lower than in the arrangement of Fig. 1 (in practice, it is less than one-half); but in actual operation it is still further diminished by the negative dynamic capacity.

The tubes, where used in a circuit scheme of the kind shown in Fig. 2, may moreover be made substantially simpler and their dimensions may be chosen so as to facilitate manufacture. For while in an arrangement of the circuit as in Fig. 1 the distance between the various electrodes must be made as small as possible to the end of securing shorter transit times and thus a lower input damping, the aim when working within the inversion range, on the contrary, is just to make the transit times greater. Thus there result essentially greater distances between the various electrodes, which makes for greater ease and convenience of manufacture, and also a lower cold capacitance between the cathode and the control grid. However, there is a still further advantage; the tubes required for a circuit arrangement as shown in Fig. 2 require only two grids. Practical experience has shown that, where high frequencies are dealt with, as far as feasible two grounded grid electrodes must be interposed between the electrodes with RF potentials to the end of preventing all risks of the displacement currents flowing to these grounded electrodes occasioning a coupling relation between such RF carrying electrodes. Hence, in a circuit organization as shown in Fig. 1, it will always be found imperative in practice to use a pentode, even where for reasons of secondary emission no suppressor grid would be needed. However, in the circuit scheme shown in Fig. 2 in which only the cathode and the plate are at RF potential, a tetrode type of tube suffices.

In the case of tubes which are incorporated in a circuit scheme as in Fig. 2, it is the partial or componental capacity C_{ak} between the plate and the filament that is decisive in reference to the coupling between the RF electrodes rather than the capacity component C_{ga} between control grid and plate; and capacitance C_{ak} should be made as low as feasible, that is to say, it should be less than 10^{-2} mmf. Tubes of this kind, consequently, should be of a wholly different con-

struction. The electrodes designed to shield the capacitance component C_{ak} must be kept at ground potential. They may be connected directly with the control grid or else the screen grid. As is also known attention must be paid in this connection so that the capacitance component $C_{ga}<C_{gk}$, and that the capacitance component $C_{sGk}<C_{sGa}$, where C_{sGk} and C_{sGa} the capacitance between the screen grid and the filament and the plate, respectively.

The energy required for the heating of the cathode (either directly or indirectly), in the circuit scheme Fig. 2, must be conducted by way of the oscillation circuit I, the oscillation coil, for instance consisting of several stranded conductors or a hollow conductor in the interior of which the heating current leads are accommodated.

A few words must be said respecting the diode resistance inside the inversion region. Recent research has demonstrated that the electron speed must be comparatively high, that is, it must range between around 15 and 30 v. in order that the inversion properties may be brought out more clearly. Thus, if, for instance, within the first inversion range (where transit time angle $\theta=2\pi$ to 3π) of a diode the diode resistance is to become negative, then the filament and the plate must be spaced so far apart that, for a plate potential between 15 and 30 v. the transit time angle will just lie between 2π and 3π. If the plate potential for this angle is smaller, then the inversion effect is blurred or indistinct for then the electron transit time because of differences in the initial speeds of the electrons, is no longer unequivocal. While it may happen in such instances that the diode resistance inside the inversion range assumes a very high positive value or even becomes slightly negative, it will no longer attain the theoretical value.

What I claim is:

1. In a circuit for the amplification of ultra-high frequency oscillations, the combination of an electron discharge tube provided with a cathode, an anode and first and second grids interposed between cathode and anode in the order named, means for applying the oscillations to be amplified between cathode and ground, an output circuit including a source of potential connected between anode and ground, and means for maintaining said grids at radio frequency ground potential, the operating potentials of the several tube electrodes and their respective spacings being so chosen that the tube operates in the region where the real component of the current of the first grid assumes a negative value.

2. In a circuit according to the invention defined in claim 1, wherein the first grid is maintained at a negative potential and the second grid is maintained at a positive potential.

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