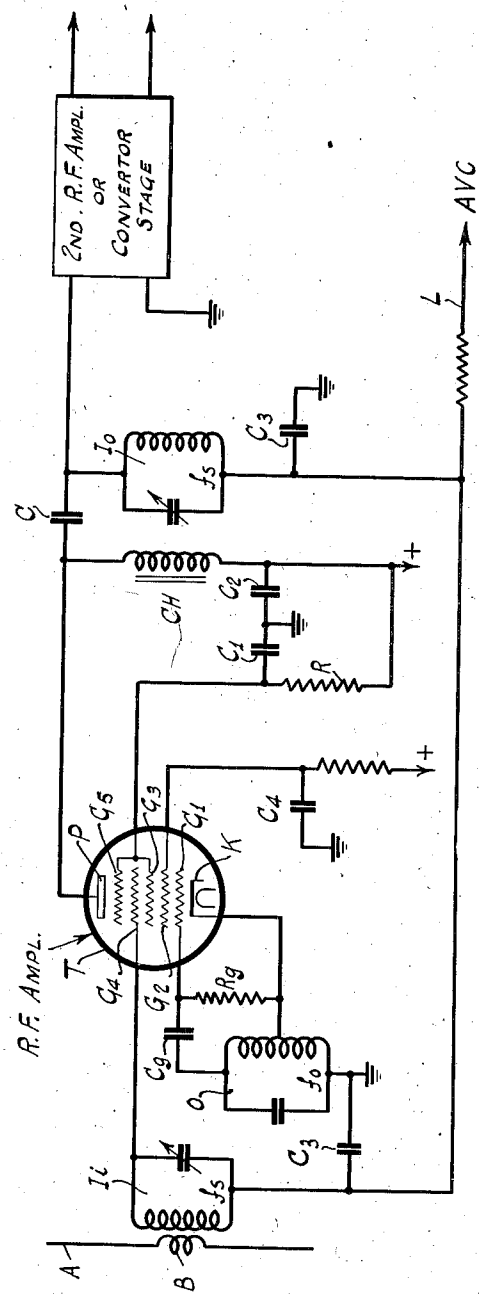
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ULTRA-HIGH-FREQUENCY AMPLIFIER

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ULTRA-HIGH-FREQUENCY AMPLIFIER

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This invention relates generally to ultra-high-frequency amplifiers for operation at such high frequencies that the conductance of the input circuit of the amplifier is an appreciable factor in determining the response characteristic of the stage.

It is well known that circuits using conventional pentode tubes, while having satisfactory performance at low and medium-high frequencies, have certain drawbacks at frequencies in excess of about 10 mc. For example, such tubes exhibit a low positive input conductance as a result of transit time losses and the effect of which is to load the tuned circuit connected to the signal grid of the tube. The input loading is made manifest by a decrease in the gain and selectivity of the circuit.

According to the invention the input loading of the tube employed in an amplifier circuit is not only reduced, but by a proper choice of operating conditions is made negative in sign.

It is therefore an object of the invention to provide an improved ultra-high-frequency amplifier stage, the response of which is not substantially limited by the input conductance of the tube included in the stage.

Another object is to provide a pentagrid- or oscillator-converter to function as an RF amplifier of frequencies above about 10 mc. in order to obtain high antenna circuit gain and selectivity and in which the input loading is effectively reduced or even made negative.

A further object is to operate a pentagrid- or oscillator-converter as an RF amplifier in a manner such that at frequencies above about 10 mc. its performance is far superior to that obtainable with the conventional pentode tube.

In superheterodyne receivers the use of an oscillator-converter tube and circuit is known to produce an input conductance which may be negative thereby effectively reducing losses in the circuit connected to the input terminals of the oscillator-converter.

According to the present invention, however, we make use of the above phenomenon by employing a converter-oscillator as the radio frequency amplifier in an ultra-high frequency receiver to obtain greater gain and selectivity in the first tuned circuit. The oscillator portion of the tube need not be tuned and may be at some frequency sufficiently removed from the signal and I. F. frequencies so as not to introduce spurious responses.

The novel features characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and mode of operation together with further objects and advantages thereof will best be understood by reference to the following description taken in connection with the accompanying drawing in which the single figure illustrates an ultra-high frequency amplifier embodying the invention.

Referring to the circuit shown in the drawing, T is a tube known as a pentagrid-converter and is provided with a cathode K, successive grids G_1 - - - to G_5 and a plate electrode P. The tube T may be of the type presently known as the "6A8," although other types such as the "6K8" and "6SA7" may also be successfully used.

Signal frequencies from a suitable source such as the antenna A which may be a dipole or other type are transferred through the coupling coil B to the tunable input circuit I_1 which is connected to the signal input grid G_4.

The output circuit I_o is resonant to the same signal frequency f_s as the input circuit I_1 and is connected through the coupling condenser C to the plate P. Positive potential is supplied to the plate through a choke coil CH and to the screen grids G_3, G_5 by way of the resistance R. Suitable condensers C_1 and C_2 for by-passing radio frequencies to ground are connected to the screen grids and to the plate. The signal control grid G_4 is supplied with a bias derived from an A. V. C. source through the conductor L, and if desired a fixed or other bias may be employed. The output of the amplifier may be coupled to a second similar R. F. amplifier or else to a converter stage of conventional design, bias to the signal control grid of the second amplifier or converter being similarly supplied. The condensers C_3 serve to provide a radio frequency path for the signal frequencies in the tunable circuits I_1 and I_o.

The cathode K, first or oscillator grid G_1 and second or oscillator anode-grid G_2 constitute the oscillator section of the tube. The oscillator which for the purpose of illustration is shown to be of the Hartley type comprises a fixed-tuned circuit O resonant to the oscillator frequency f_o. It will be understood of course that other forms of oscillators may be used equally as well without departing from the invention. The oscillator grid G_1 is connected through the grid condenser C_g to the high potential side of the circuit O. The cathode K is tapped to an intermediate point on the coil of the circuit O. The grid resistor R_g is connected between the oscillator grid G_1 and cathode, the combination of C_g and R_g providing suitable operating bias for the grid G_1.

The G_2 serves as the oscillator anode and with respect to high frequencies is connected to ground through the condenser C_4. As heretofore stated the oscillator section of the tube is adjusted to oscillate at some frequency remote from the signal and I. F. frequencies. Unlike the local oscillator in superheterodyne receivers, the frequency of the oscillator circuit above described is not varied with tuning, but rather it is adjusted to a fixed value, preferably outside the frequency range of the received signals. Its only purpose is its effect in the production of negative input conductance, the theory of which will now be described.

The space current between G_2 and G_3 is relatively independent of the bias on the signal grid, G_4, due to the interposed screen, G_3. That is to say the sum of the currents in the plate P and the screens G_3 and G_5 is relatively constant. The electrons passing through G_3 will be subject to the influence of G_4, and at some high negative bias on G_4 will be completely prevented from passing through this grid, resulting in plate-current cut-off as in the ordinary triode. However, as the negative bias on G_4 is decreased from some high value the plate current will not increase linearly because the supply of electrons getting through G_3 is limited.

This limitation is brought about as follows: The potential of the oscillator grid G_1 and the anode-grid G_2 exert the primary influence in determining how many electrons shall be available for the plate. The grid G_3 by virtue of its potential and its position will draw some value of current, which current will be relatively independent of the potential of G_4, with the remainder of the current passing to the plate. Therefore, by a proper choice of potentials for G_2 and G_3 there will be a scarcity of electrons on the G_4 side of G_3 for some range of potentials on G_4 (low values of negative bias). This deficiency of electrons will cause the I_p vs. E_{G_4} characteristic to flatten out at low negative bias values on G_4.

Then, with electrode potentials selected to cause an electron deficiency in the G_3—G_4 space over a certain range of bias values on G_4, we may say to a first approximation that the current passing through G_3 is constant with respect to the potential of G_4 over that restricted range of operation. Expressing this in the form of an equation we have,

$$I = kpv \approx \text{a constant}$$

where,

p=charge per unit volume, (negative)
v=velocity of electrons in that volume
k=a constant

Now, if the signal grid potential G_4 increases, the velocity v of the electrons in the space between G_3 and G_4 will increase, and the charge p will decrease. This decrease in charge in the G_3—G_4 space will cause electrons to flow into the signal grid, or current to flow out. Thus, an increase in potential of the signal grid is accompanied by a change of opposite sense in the current in that electrode, which condition is the criterion for negative conductance.

The electrons moving in the space G_4—G_5 during the increase in potential of the signal grid will suffer a decrease in velocity, which will be accompanied by an increase of unit charge in this region. The increase in charge in this space will cause electrons to flow out of the signal grid, or current to flow in. Thus, the electrons in this region contribute a positive component to the input conductance.

The net input conductance of the tube will depend in sign and in magnitude upon the relative importance of the two effects operating simultaneously within the signal-grid-screen space. The average potential of the signal grid will affect the distribution of electrons within the signal-grid-screen space, and the average potential of the oscillator-grid will determine the number of electrons passing through the screen. Therefore, the bias on the oscillator grid and that on the signal grid will both affect the magnitude of the input conductance. However, the oscillator frequency has no effect upon the magnitude of the input conductance.

For purpose of comparison there is given in the following table the values of input conductance at specified frequencies of the 6A8 and 6J7, converter and pentode tubes, respectively.

	6A8	6J7
Anode volts	250	250
Screen volts:		
G_3–G_5 of 6A8	100	
G_2 of 6J7		100
Signal grid bias	−3	−3
Osc. grid voltage (G_2 of 6A8)[1]	250	
Input conductance at 5 mc ..... umhos	+.25	+2.75
Input conductance at 10 mc ..... do	−2.0	+8.0
Input conductance at 20 mc ..... do	−14.0	+26.0

[1] Supplied through 20,000 ohm dropping resistor.

While we have shown and described a preferred embodiment of our invention, it will be understood that modifications and changes may be made without departing from the spirit and scope of our invention, as will be understood by those skilled in the art.

What we claim is:

1. A high frequency amplifier circuit comprising a tube provided with a cathode, a plurality of grid electrodes and an anode, an input circuit resonant to a desired signal frequency connected to one of the grids, said input circuit having appreciable conductance at the operating frequency, means connected to certain of the tube electrodes constituting a generator of oscillations at a frequency remote from the signal frequency for reducing said input conductance, and an output circuit resonant to the signal frequency connected to the anode.

2. A high frequency amplifier circuit comprising a tube provided with a cathode, a plurality of grid electrodes and an anode, an input circuit resonant to a desired signal frequency connected to one of the grids, said input circuit having appreciable conductance at the operating frequency, circuits connecting the cathode and certain of the other grids constituting a generator of oscillations at a frequency remote from the signal frequency for reducing said input conductance, and an output circuit resonant to the signal frequency for reducing said input

3. A high frequency amplifier circuit comprising a tube provided with a cathode, a plurality of grid electrodes and an anode, a resonant input circuit tunable through a range of desired signal frequencies connected to one of the grids, said input circuit having appreciable conductance at the operating frequency, circuits connecting the cathode and certain of the other grids constituting a generator of oscillations at a fixed frequency remote from the signal frequency for reducing said input conductance, and a resonant output circuit tunable through said

range of signal frequencies connected to the anode.

4. A circuit for the amplification of frequencies above about 10 megacycles comprising a tube having at least a cathode, signal control grid and an anode, input and output circuits resonant to the same frequency connected respectively to the signal grid and anode, and means for preventing loading of the input circuit by operating the tube with a negative input conductance, said means comprising a plurality of additional electrodes within the tube and circuit elements connected thereto for producing oscillations at a frequency sufficiently removed from the signal frequencies to be amplified so as not to introduce spurious response in the output circuit.

5. A circuit for the amplification of ultra-high frequencies, above about 10 megacycles, comprising a tube having at least a cathode, an oscillator control grid, an oscillator anode-grid, a screen grid, a signal control grid and an output anode arranged in the order named, input and output resonant circuits tunable to the same signal frequency connected respectively to the signal control grid and anode, and means for preventing loading of the input circuit by operating the tube with a negative input conductance, said means comprising circuit elements connected to the oscillator control grid and anode-grid for producing oscillations at a frequency sufficiently removed from the received signal frequency so as not to introduce spurious response in the output circuit.

6. An ultra-high frequency amplifier for frequencies above about 10 megacycles comprising a tube having at least a cathode, an oscillator control grid, an oscillator anode-grid, a screen grid, signal control grid and an output anode arranged in the order named, input and output circuits resonant to the same frequency connected respectively to the signal control grid and anode, circuit elements connected to the oscillator control grid, anode-grid and cathode for producing oscillations at a frequency outside the range of the received signal frequencies, the potentials on the oscillator anode-grid and the screen grid being so chosen that the space charge between the signal control grid and the screen grid is such that an increase in signal grid potential is accompanied by a change of opposite sense in the signal grid current, whereby the tube input conductance assumes a negative value.

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