July 30, 1940. J. F. FARRINGTON 2,209,394

SIGNAL TRANSLATING STAGE

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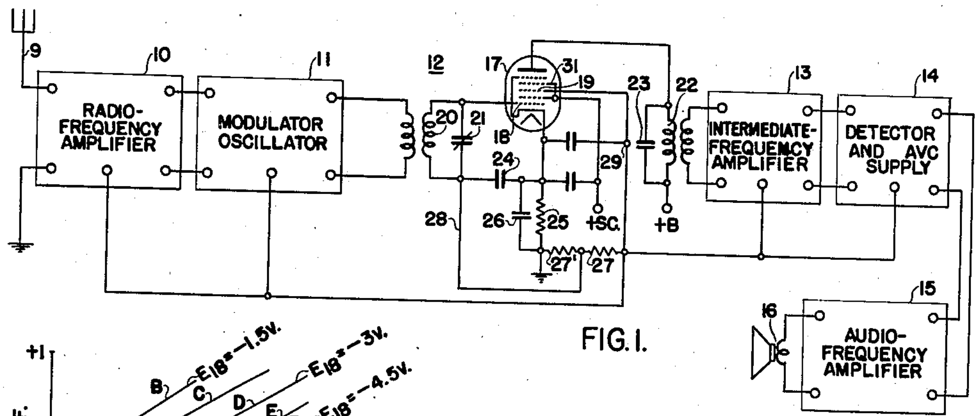


FIG. 1.

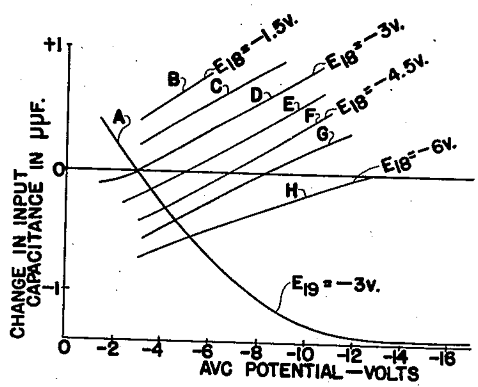


FIG. 2.

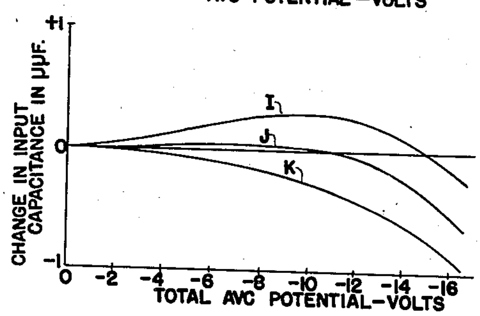


FIG. 3.

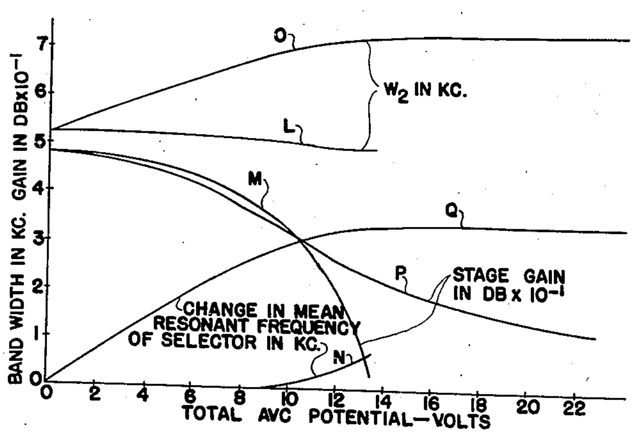


FIG. 4.

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## SIGNAL-TRANSLATING STAGE

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6 Claims. (Cl. 179—171)

This invention relates to a signal-translating stage including a vacuum tube and, particularly, to such a stage including means for preventing changes in the effective input capacitance of the vacuum tube included in such a stage which result from control of the transconductance of the tube by a variable-bias potential. While the invention is of general application, it is of particular utility in high-frequency selector amplifiers, especially those having resonant input circuits in which the tuning capacitance is comparable in magnitude with the input capacitance of the tube.

In a high-frequency signal-translating stage in which there is included a vacuum-tube amplifier coupling a pair of tuned circuits, it is common to apply an adjustable-bias potential to the control grid to adjust the gain of the stage. When the stage is controlled in this manner, an appreciable change in the effective input capacitance of the tube occurs. The change in input capacitance may exceed 1.5 micro-microfarads in some cases. This change in input capacitance causes detuning of the associated tuned circuit, the amount of detuning depending on the tuning capacitance of the tuned circuit. Thus, if a 75 micro-microfarad tuning condenser is used, a 1% change in the resonant frequency of the tuned input circuit may take place as a consequence of varying the grid-bias voltage to obtain substantial gain control action. If the input and output tuned circuits are fairly selective circuits, for example, circuits having a Q of the order of 100, this detuning will materially broaden and shift the frequency-response characteristic of the selector-amplifier system.

An object of the invention is to provide a vacuum-tube signal-translating stage in which the input capacitance of the tube is substantially unaffected by the application of a variable potential to an electrode of the tube to control its transconductance.

An additional object of the invention is to provide a high-frequency signal-translating stage having a tuned input circuit, the resonant frequency of which is not substantially altered by the application of a variable-bias potential to the input circuit of a vacuum tube included in the stage.

In accordance with the invention, a signal-translating stage including a vacuum tube comprises a source of electrons, a control electrode adjacent the source of electrons, a second electrode beyond the control electrode, and one or more additional electrodes beyond the second electrode. Means are provided for applying an adjustable negative-bias potential to the control electrode to vary the transconductance of the tube; for applying a positive-bias potential to the second electrode; and for applying a negative-bias potential to one of the additional electrodes. Means are further provided for adjusting the bias potential of the said one of said additional electrodes simultaneously with, and in the same sense as, that of the control electrode, the variations of the adjustable potentials being proportioned to maintain substantially constant the input capacitance of the control electrode throughout a wide range of adjustment of the transconductance of the tube.

In accordance with a specific feature of the invention, there is provided in a modulated-carrier signal-translating apparatus including an automatic amplification control, a translating stage comprising a vacuum tube having a cathode, grid, anode, and an additional electrode interposed between the grid and the anode. A resistance voltage divider is directly connected to the amplification control and means are provided for controlling the transconductance of the tube including means for deriving from the voltage divider a first variable negative-bias potential and applying it to the above-mentioned grid and a second variable negative-bias potential and applying it to the above-mentioned additional electrode. The variable negative-bias potentials are so proportioned as to maintain the capacitance of the grid-cathode circuit substantially constant while effecting a substantial variation in the transconductance of the tube.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Fig. 1 of the drawing is a circuit diagram, partly schematic, illustrating an embodiment of the invention in the intermediate-frequency channel of a modulated-carrier signal receiver of the superheterodyne type; and Figs. 2, 3, and 4 illustrate certain operating characteristics of the system of Fig. 1.

Referring now to Fig. 1 of the drawing, there is shown a circuit diagram of a modulated-carrier signal receiver of the superheterodyne type embodying the invention in which certain conventional portions are indicated schematically since, per se, they form no part of the invention. This receiver comprises, in cascade, an antenna circuit 9, a radio-frequency selector and amplifier 10 of one or more stages, a frequency changer or oscillator-modulator 11, an intermediate-frequency amplifier stage 12, an intermediate-frequency amplifier 13 of one or more stages, a detector and A. V. C. supply 14, an audio-frequency amplifier 15 of one or more stages, and a loud-speaker 16. An automatic amplification control potential derived from the A. V. C. supply 14 is applied to the tubes of a desired number of the preceding stages of the receiver in a conventional manner.

Neglecting for the moment the operation of the parts of the system involving the present invention, the system described above includes the features of a conventional superheterodyne receiver. The operation of such receiver being well understood in the art, a detailed explanation thereof is deemed unnecessary. Briefly, however, a desired modulated-carrier signal intercepted by antenna 9 is selectively amplified in radio-frequency amplifier 10 and converted in frequency changer 11 to an intermediate-frequency modulated-carrier signal. This signal is selectively amplified by intermediate-frequency selector and amplifier 12, intermediate-frequency amplifier 13, and translated therefrom to the detector and A. V. C. supply 14 where the audio frequencies of modulation and the automatic amplification control-bias potentials are derived. The audio frequencies of modulation are amplified in audio-frequency amplifier 15 and reproduced by loud-speaker 16 in a conventional manner. The input to detector 14 is maintained within a relatively narrow range for a wide range of received signal intensities by the application of an automatic amplification control potential to one or more stages of radio-frequency amplifier 10, oscillator-modulator 11, intermediate-frequency amplifier selector 12, and one or more stages of intermediate-frequency amplifier 13, in a conventional manner.

Coming now to the parts of the arrangement involving the present invention, the intermediate-frequency amplifier 12 comprises a tuned input circuit 20, 21 coupled to a tuned output circuit 22, 23 through a multielectrode vacuum tube 17, the output circuit 22, 23 being coupled to the input circuit of the intermediate-frequency amplifier 13. Vacuum tube 17 includes a cathode, a grid 18, an anode, and an additional electrode 19 interposed between the grid 18 and the anode. The A. V. C. supply 14 is provided with a load circuit including a resistance voltage divider including resistors 27 and 27', the bias voltage developed across the resistor 27' being applied to the inner control grid 18 of tube 17 and the total bias voltage being applied to the outer control grid 19 of tube 17, these bias voltages being proportioned to maintain the grid-cathode capacitance of tube 17 substantially constant while effecting a substantial variation of the transconductance of the tube. A cathode-biasing resistor 25 shunted by by-pass condenser 26 is provided for the tube 17. Operating potentials are applied to the tube in a conventional manner from the terminals indicated as +B and +Sc.

The input capacitance of tube 17 is maintained substantially constant with variations of the automatic amplification control potentials applied to grids 18 and 19 to vary the gain of the stage by proper adjustment of the relative magnitudes of the control potentials.

In order to illustrate the principle of the invention, reference is had to Fig. 2 which shows the capacitance change measured at the input grid of a 6L7 tube, which is a type of tube which may be used as tube 17 in the circuit of Fig. 1, as a function of the negative-bias voltages on the input grid 18 and the injector grid 19. Curve A shows that the input capacitance of the tube diminishes as the negative-bias voltage on the signal or input grid 18 is increased. In obtaining this curve, an input signal of 450 kilocycles was applied to the tube, and a constant potential of −3 volts was applied to the injector grid 19. Curves B to H show that the input capacitance increases with increased negative-bias potential on the injector grid 19. In each of these curves, the voltage of grid 18 is maintained constant at the value indicated. An inspection of curves B to H shows that, over a limited range of variation of the bias voltage upon the signal grid 18, the input capacitance can be held exactly constant by applying to the grid 19 a bias voltage varying in a particular manner with respect to the bias voltage on grid 18. The relative variations of the grid-bias potentials are such that they supplement one another in controlling the mutual conductance of the tube, increasing negative biases on the two grids cumulatively reducing the mutual conductance. The proper bias potentials for grid 19, as the bias voltage on grid 18 is varied, are obtained by drawing a horizontal line through curves B—H, inclusive, and applying a potential to grid 18 determined by its intersections of curves B—H, inclusive, at the same time that a bias is applied to grid 19 corresponding to the value shown on the abscissae at the point of intersection.

For this particular tube, the ratio of the potentials required on grids 18 and 19 to avoid variation of the input capacitance is not constant. However, the desired variable ratio of potentials can be approximated by the use of a fixed ratio of control voltages and the addition of a variable-bias voltage derived from a cathode-biasing resistor. The curves of Fig. 3 illustrate what can be accomplished by this procedure using a cathode resistor of 200 ohms. Input capacitance characteristics of the selector-amplifier circuit 12 without the load circuit 22, 23 and with a 450 kilocycle input to tuned circuit 20, 21 resulted in the curves shown in Fig. 3. Curve I was obtained using an A. V. C. ratio of 1:3 on the input grid 18 and the injector grid 19, respectively, curve J was obtained using an A. V. C. ratio of 2:5, and curve K was obtained using an A. V. C. ratio of 1:2. It is seen that, using a 2:5 ratio of A. V. C. potential on the grids, the input capacitance is held substantially constant over the major portion of the A. V. C. range, as indicated by curve J, Fig. 3. For contrast, attention is directed again to curve A of Fig. 2 which shows a marked change of input capacitance of the tube when its mutual conductance is controlled in the conventional manner. By the use of the invention, therefore, the selector circuits may be designed with much higher L/C ratios to give correspondingly higher gain for a given permissible variation of the selector characteristics.

Fig. 4 illustrates the characteristics of the selector-amplifier circuit 12 in a receiver having an intermediate frequency of 450 kilocycles and using a 2:5 ratio of A. V. C. potential applied to the grids 18 and 19, respectively. Curve L shows the frequency band width at half amplitude ($W_2$) of the signal output of the selector amplifier 12; curve M shows the gain of the stage; and curve N shows the shift in the mean resonant frequency of the selector-amplifier system, all with respect to A. V. C. potential. It will be noted that substantial variation in the gain of the amplifier is obtained without material change in the characteristics of the selector system. By way of contrast, curves O, P, and Q show the corresponding characteristics of the selector amplifier when operated in the conventional manner with A. V. C. applied to the signal grid 18 only. It will be noted that a very material change in the band width and a substantial shift of the mid-band frequency of the selector occur as a result of detuning of the input circuit of the amplifier by variation of the input capacitance of the vacuum tube.

The following circuit constants were used in obtaining the data for the curves L, M, and N of Fig. 4 and are illustrative of a specific application of the invention:

| | |
|---|---|
| Intermediate frequency ........kilocycles.. | 450 |
| Inductances 20 and 22........millihenry.. | 1.2 |
| Condensers 21 and 23 micro-microfarads.. | 104 |
| Q of tuned circuit 20, 21 and 22,23........ | 100 |
| Resistor 25........................ohms.. | 200 |
| Resistor 27..........................do.... | 50,000 |
| Resistor 27'.........................do.... | 33,000 |
| Tube 17.................................. | 6L7 |

While applicant does not desire to be restricted to any particular theory of operation, it is believed that the characteristics described above may be explained as follows: under normal operating conditions, the signal grid 18 and the injector grid 19 are maintained negative and the screen grid and anode are held at positive potentials with respect to the cathode. Electrons pass from the cathode through the grid 18 to the anode. Since grid 18 is negative, the grid wires are surrounded by zero potential electron sheaths through which electrons cannot pass to the grid although they can pass through the spaces between the sheaths to the positively charged electrodes beyond. The zero potential sheaths surrounding the grid wires are, in effect, connected to the cathode through the low resistance electron stream. Therefore, the space between the grid 18 and the zero potential grid sheaths may be regarded as constituting a capacitance directly in the input circuit of the tube. When the grid is only slightly negative, the zero potential sheaths are contracted close to the grid wires and the capacitance between the sheaths and the grid is large. When the potential becomes more negative, the zero potential sheaths expand away from the grid wires and diminish the input capacitance. Under this condition, changing the potential of any electrode between the input grid and the anode in a manner to increase the electron density in the space surrounding the grid forces the zero potential sheaths to contract toward the grid wires. Such control may be effected by appropriate variation of the potential on grid 19. With proper adjustments of the inner and outer grid potentials, the effective position of the zero potential sheaths with respect to the input grid wires may be maintained unaltered and, consequently, the grid-cathode capacitance can be maintained substantially constant as the grid biases are varied to vary the mutual conductance of the vacuum tube.

While there have been described what are at present considered to be preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a modulated-carrier signal-translating apparatus including an automatic amplification control, a translating stage comprising a vacuum tube having a cathode, grid, anode, and an additional electrode interposed between said grid and anode, a resistance voltage divider directly connected to the automatic amplification control of the system, means for controlling the transconductance of said tube including means for deriving from said voltage divider a first variable negative-bias potential and applying it to said grid and a second variable negative-bias potential and applying it to said additional electrode, said variable negative-bias potentials being proportioned to maintain the capacitance of said grid-cathode circuit substantially constant while effecting a substantial variation in the transconductance of said tube.

2. In a modulated-carrier signal-translating apparatus including an automatic amplification control, a translating stage comprising a vacuum tube having a cathode, anode, and two additional electrodes, a resistance voltage divider directly connected to the automatic amplification control of the system, means for controlling the transconductance of said tube comprising means for deriving a variable negative-bias potential from said voltage divider and applying it to one of said additional electrodes, thereby tending to vary the effective capacitance between one of said additional electrodes and said cathode, and means for deriving a second negative-bias potential from said voltage divider and applying it to the other of said additional electrodes to compensate said tendency.

3. In a modulated-carrier signal-translating apparatus including an automatic amplification control, a translating stage comprising a vacuum tube having a cathode, grid, anode, and an additional electrode interposed between said grid and anode, a resistance voltage divider coupled to the automatic amplification control of the system, means for controlling the transconductance of said tube including means for deriving from said voltage divider a first variable-bias potential and applying it to one of said grids and a second variable-bias potential and applying it to said additional electrode, said bias potentials having a fixed ratio, means including a cathode-biasing resistor for obtaining an additional variable-bias potential common to said grid and said additional electrode and controllable by said variable-bias potentials, said additional variable-bias potential and said variable-bias potentials co-operating to maintain substantially constant the grid-cathode capacitance of said tube while effecting a substantial change in the transconductance of said tube.

4. A signal-translating stage including a vacuum tube comprising, a source of electrons, a control electrode adjacent said source of electrons, a second electrode beyond said control electrode, one or more additional electrodes beyond said second electrode, means for applying an adjustable negative-bias potential to said control electrode to vary the transconductance of said tube, means for applying a positive-bias potential to said second electrode, means for applying a negative-bias potential to one of said additional elec-

trodes, and means for adjusting the bias potential of one of said additional electrodes simultaneously with and in the same sense as that of said control electrode, the variations of said adjustable potentials being proportioned to maintain substantially constant the input capacitance of said control electrode throughout a wide range of adjustment of the transconductance of said tube.

5. A signal-translating stage including a vacuum tube comprising, a cathode, a control electrode adjacent said cathode, a second electrode beyond said control electrode, one or more additional electrodes beyond said second electrode, means for applying an adjustable negative-bias potential to said control electrode to vary the transconductance of said tube, means for applying a positive-bias potential to said second electrode, means for applying a negative-bias potential to one of said additional electrodes, and means for adjusting the bias potential of one of said additional electrodes simultaneously with and in the same sense as that of said control electrode, the variations of said adjustable bias potentials being proportioned to maintain substantially constant the capacitance between said control electrode and said cathode throughout a wide range of adjustment of the transconductance of said tube.

6. In a modulated-carrier signal-translating apparatus including an automatic amplification control, a signal-translating stage including a vacuum tube comprising a source of electrons, a control electrode adjacent said source of electrons, a second electrode beyond said control electrode, one or more additional electrodes beyond said second electrode, means for deriving from said automatic amplification control a varying negative-bias potential and applying it to said control electrode to vary the transconductance of said tube, means for applying a positive-bias potential to said second electrode, and means for deriving from said automatic amplification control a second varying negative-bias potential and applying it to one of said additional electrodes simultaneously with and in the same sense as that to said control electrode, said varying bias potentials being proportioned to maintain substantially constant the input capacitance of said control electrode throughout a wide range of adjustment of the transconductance of said tube.

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