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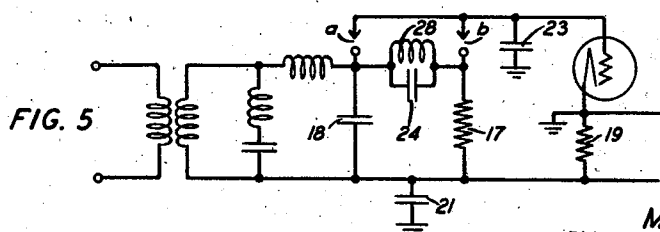
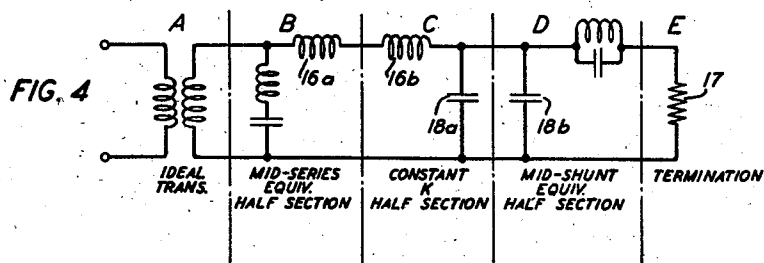
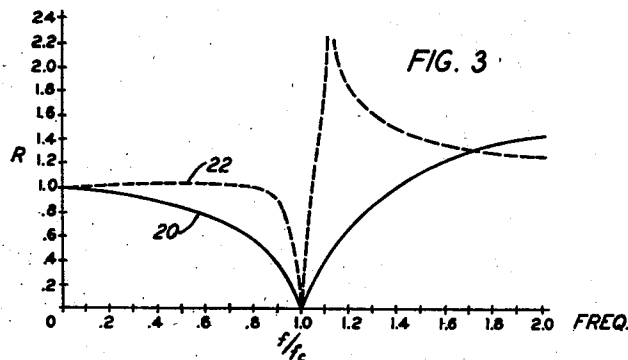
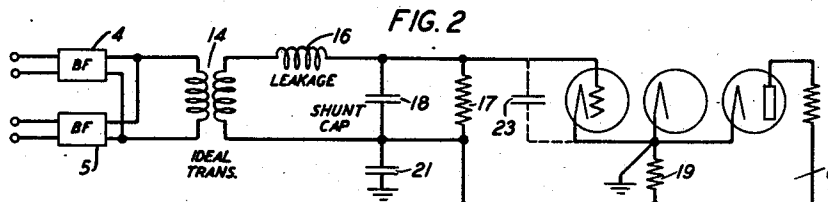
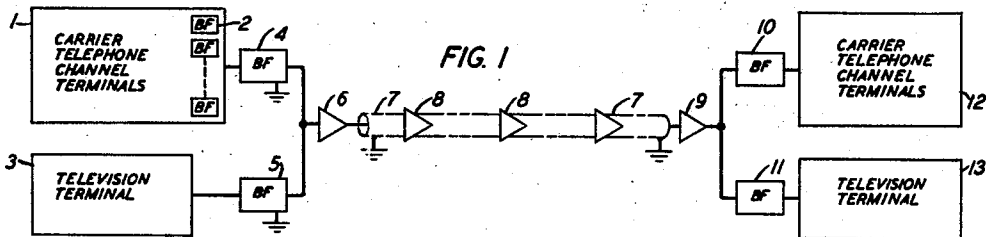
M. E. CAMPBELL

2,356,446

AMPLIFIER CIRCUIT

Filed April 16, 1942

2 Sheets-Sheet 1



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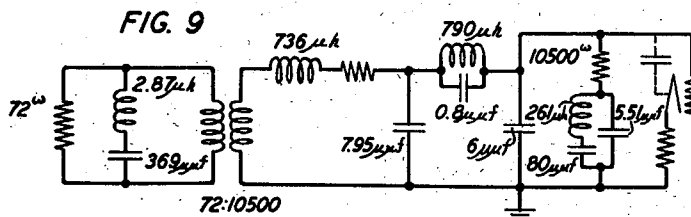
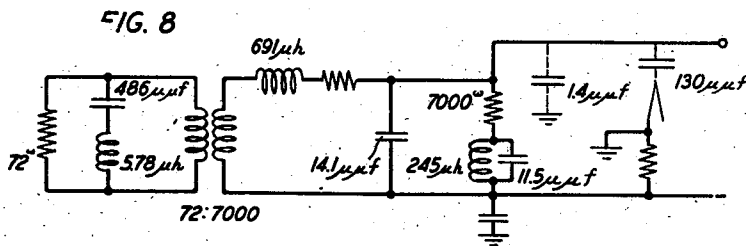
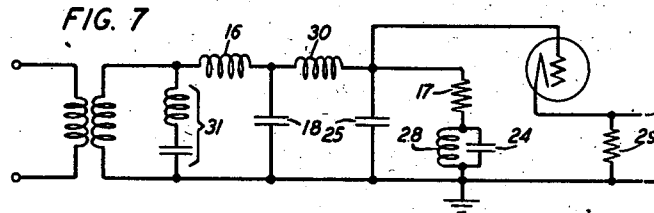
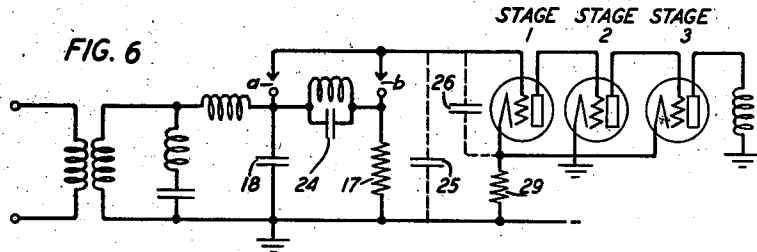
M. E. CAMPBELL

2,356,446

AMPLIFIER CIRCUIT

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,356,446

AMPLIFIER CIRCUIT

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3 Claims. (Cl. 179-171)

The present invention relates to coupling circuits for coupling a vacuum tube amplifier to a terminal input or output circuit to secure efficient transfer of waves of a broad band of frequencies. A typical, though not limiting, use for such a circuit is instanced by a multiplex carrier telephone system having a terminal amplifier common to all of the channels and included between the channel terminals and the line.

The general object of the invention is to secure increased efficiency and improved broad band performance in a coupling circuit of the general type mentioned.

A related object is to improve the signal-to-noise ratio.

The nature and objects of the invention will appear more fully from the following detailed description with reference to the attached drawings in which:

Fig. 1 is a block schematic diagram of an overall system to which the invention is especially applicable;

Fig. 2 shows a prior art type repeater and input circuit therefor;

Fig. 3 shows graphs to be referred to in the description;

Figs. 4 to 9, inclusive, are schematic circuit diagrams of coupling circuits in accordance with the invention for coupling a line to the input or output of a repeater.

The particular embodiment of the invention that is to be specifically disclosed herein is in a broad band system of the type indicated in outline in Fig. 1, in which the carrier terminal 1 at the transmitting station comprises a plurality of carrier telephone transmitting channels ending in selective filters 2 facing the multiplex line 7. A television terminal is also indicated at 3 which may be used simultaneously with the telephone channels or alternatively with respect to the telephone channels. Broad band filters 4 and 5 serve to separate the ranges employed for the two types of transmission.

Whether both types of transmission are used at once or whether only the carrier telephone channels or only the television terminal are provided, the input to the amplifier 6 is from one or several filters 2, 4 or 5, as the case may be. These filters are in practice designed to work into a resistive circuit and it is necessary for best performance to provide an input coupling into the amplifier 6 that presents a resistive impedance into which these filters may work of the same value at all frequencies in the transmission band.

Amplifier 6 is shown working into a coaxial line 7 having intermediate repeaters 8 spaced along it and leading eventually to a common output amplifier 9 which may be similar in design to amplifier 6. A similar problem arises here also, of providing a resistive impedance termination facing the receiving end filters 10, 11 or the individual channel filters in the carrier telephone terminal 12. The television receiving terminal is at 13.

It is desirable to use a transformer in the coupling circuit in order to transform the impedances to obtain a match between the nominally 72-ohm circuit represented by the terminal circuits and the grid or plate impedance of the amplifier, which may be, e. g., 7,000 ohms. If a transformer alone were used together with the usual terminating resistance, the network would appear as in Fig. 2 representing the input coupling case. The terminating resistance is 17. This figure shows the equivalent impedance diagram where the ideal transformer is shown at 14, the leakage inductance at 16 and the shunt capacity at 18. Such a circuit has the configuration of a low-pass filter and would give a very poor impedance as shown by the curve 20 of Fig. 3. The resistance is seen to fall off gradually over the transmission range so that if very much of the available band were used, the resistance would vary widely over the band. It is noted that in this figure the amplifier 6 is shown as a three-stage stabilized feedback amplifier of the series feedback type, the feedback impedance being at 19. The cathodes are at ground potential and the capacity to ground, 21, of the input coupling circuit appears effectively in shunt to the feedback impedance. The grid to cathode capacity is shown at 23 which in this case is also the grid to ground capacity.

In accordance with one feature of the invention, the coupling circuit is made to have a more nearly constant resistance over the band by building out the circuit to the form shown in Fig. 4, which can be broken down into five parts A, B, C, D and E. The A part is the ideal transformer, B is a half section of an M-derived mid-series equivalent filter, this section including coil 16a which represents a part of the leakage inductance 16 of Fig. 2. C represents a half-section constant-K filter made up of the remainder of the leakage inductance 16b and part of the shunt capacity 18a. D is a half-section M-derived mid-shunt equivalent filter including the remainder of the shunt capacity 18b. E is the terminating resistance 17. This

network has a characteristic of the type given by the dotted curve 22 of Fig. 3.

In general, the distributed capacity of the transformer is limiting and hence to keep the filter elements 16 and 18 in the proper relationship 16 is padded out.

While this network has a more nearly uniform, high resistance characteristic over a relatively wide band, the problem arises of how to take best advantage of this characteristic in connecting it to an amplifier input or output, especially a stabilized feedback amplifier. (Stabilized feedback amplifiers are shown in numerous prior art patents; see for example Bode 2,123,178, July 12, 1938.) It is desired to obtain maximum signal voltage on the grid (or out of the plate) and the most favorable loop gain and phase shift characteristic for the amplifier. Fig. 5 designates two alternative points of connection of the grid, to either *a* or *b*. Point *a* is the more advantageous point to which to make connection. It not only is a point of maximum signal voltage so far as the network itself is concerned but the disposition of the parasitic capacities is more favorable from the feedback standpoint in the case of the *a* connection. Regarding the feedback impedance 19 as a source of voltage that is to be applied to the grid, the parasitic capacity 21 is directly in shunt across 19 and this cannot be avoided with this type of circuit. Following on from there, with the *a* connection the capacity 18 is in parallel with the branch comprising resistance 17 and capacity 24 in series (at very high frequencies where this effect is important the inductance 28 can be disregarded). These two parallel branches (18 and 17, 24) join at *a* leading to the grid, with parasitic capacity 23 shunted across to the ground return side of the circuit just traced. The fed back voltage reaching the grid is, therefore, principally determined in the asymptotic frequency region by the potentiometer effect of the capacities 18 and 23. With connection to *b*, it will be seen that the fed back voltage at extreme high frequencies is determined by the potentiometer effect of capacities 18 and 24 in series as one potential dividing impedance and capacity 23 as the other and that the voltage reaching the grid is smaller in this case. This same reasoning is applicable to the output transformer circuit also.

The limit of loop gain of the amplifier in the useful band is determined by the asymptotic gain and phase margin, so that by increasing the feedback voltage reaching the grid at extreme high frequencies, the loop gain in the band is similarly increased.

The feedback circuit shown in Fig. 5 is of the series type. Fig. 6 shows for illustrative purposes another known type of feedback amplifier using cathode impedance feedback in which the cathodes of stages 1 and 3 are connected together and through a feedback impedance 29 to ground, the cathode of stage 2 being grounded. In this type of circuit the high side of the input and output transformers are grounded so that the capacity 21 of Fig. 5 is absent. In this circuit, connection to terminal *b* gives a poor termination for the input coupling network since it causes capacity 25 to appear directly in shunt across the terminating resistance 17. Connection of the grid to terminal *a* places capacity 25 across capacity 18 or in effect incorporates it into capacity 18 so that it can be taken entirely into account in the network design. Connection at *a* also results in better transmission of

the fed back voltage to the grid for the reasons given in connection with Fig. 5.

The fact that capacity 25 appears next to the tube, while capacity 18 is associated with the transformer, makes it possible to keep these two capacities separate by inserting a series inductance between them, thus making possible a higher transformer step-up with the same parasitic elements. This is illustrated in Fig. 7 where inductance 30 is connected between capacities 18 and 25. If inductance 30 has parasitic capacity the network can be M-derived (using a different value of *M* than used above) to include such a capacity in the design. In this figure the position of resistance 17 and coil and condenser 28, 24 have been interchanged in order to place the latter elements nearer to ground, since the parasitic capacity of the resistor 17 can be held small and that of 28 can be made part of the capacity 24.

In an actual design, the shunt 31 must be transferred to the low side since it cannot physically be connected between the ideal transformer and its leakage inductance 16. In so transferring it, its impedance is reduced in the ratio of the impedance transformation ratio of the transformer. The actual configuration of an input or output coupling circuit used by applicant in a 60-kilocycle to 2-megacycle amplifier is given in Fig. 8 with the circuit constants marked on it. This is of the type of network shown in Figs. 4 and 5. A similar diagram for the type of input coupling shown in Fig. 7 is given in Fig. 9. The capacity inductance shunt across the low impedance side of the transformer is in practice "trimmed" or made variable to correct for manufacturing irregularities. In this latter figure the 80 μ f. condenser was inserted in series with the coil 28 (see Fig. 7) to improve the attenuation and phase characteristic of the amplifier at its low frequency cut-off region, this in combination with the terminating resistance equalizing the transformer impedance so as to extend the range to lower frequencies. This was put in for use especially in systems in which television is to be transmitted, using frequencies extending downward in the frequency scale close to zero. The inclusion of this capacity for this purpose is being shown for completeness of disclosure but in and of itself it forms no part of the present invention.

What is claimed is:

1. In combination, a stabilized feedback broad band amplifier having cathode, grid and anode elements, a feedback impedance having one end connected to the cathode and its opposite end adapted for connection to an amplifier grid terminal and to an amplifier anode terminal, to provide a feedback path for said amplifier, a coupling circuit for coupling said amplifier to a terminal circuit having a highly resistive impedance, said circuit comprising a non-unity ratio transformer the leakage inductance and shunt capacity of which together form inherently a low-pass filter section, a first M-derived filter section including as an element a portion of said leakage inductance, and a second M-derived filter section connected in said circuit, facing said shunt capacity, for flattening the response characteristic of the circuit up to near the cut-off frequency, a terminating resistance for said second M-derived filter section, and connections from the terminals of said second M-derived section facing said shunt capacity to, respectively, the said opposite end of said feedback

impedance and one of the two said amplifier terminals.

2. A circuit for coupling a stabilized feedback amplifier to a highly resistive low impedance circuit including a two-winding non-unity ratio transformer having its low impedance side connected to said circuit and its high impedance side connected to said feedback amplifier, said coupling circuit comprising together with said transformer a mid-series equivalent M-derived half section of filter, a half-section constant-K filter, a mid-series equivalent M-derived half section of filter and a terminating impedance in the order named, the connection from said coupling circuit to said amplifier being made at the junction between said two last-mentioned half sections of filter.

3. The combination of a broad band filter hav-

ing a highly resistive terminal impedance over said band, a stabilized feedback amplifier having a grid terminal, an anode terminal and a feedback terminal, said amplifier having a cathode and a feedback impedance connected between said cathode and said feedback terminal, and a coupling circuit having an impedance transforming transformer with its low impedance side connected to said filter, said transformer being built out to provide on its high impedance side an equivalent half-section M-derived filter, in tandem with other equivalent half-filter sections and a terminating resistance, and connections from the junction points of two of said half sections to, respectively, one of said two first-mentioned terminals of said amplifier, and said feedback terminal.

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