

Oct. 28, 1941.

A. L. STILLWELL

2,260,493

AMPLIFIER

Filed Nov. 1, 1940

FIG. 1

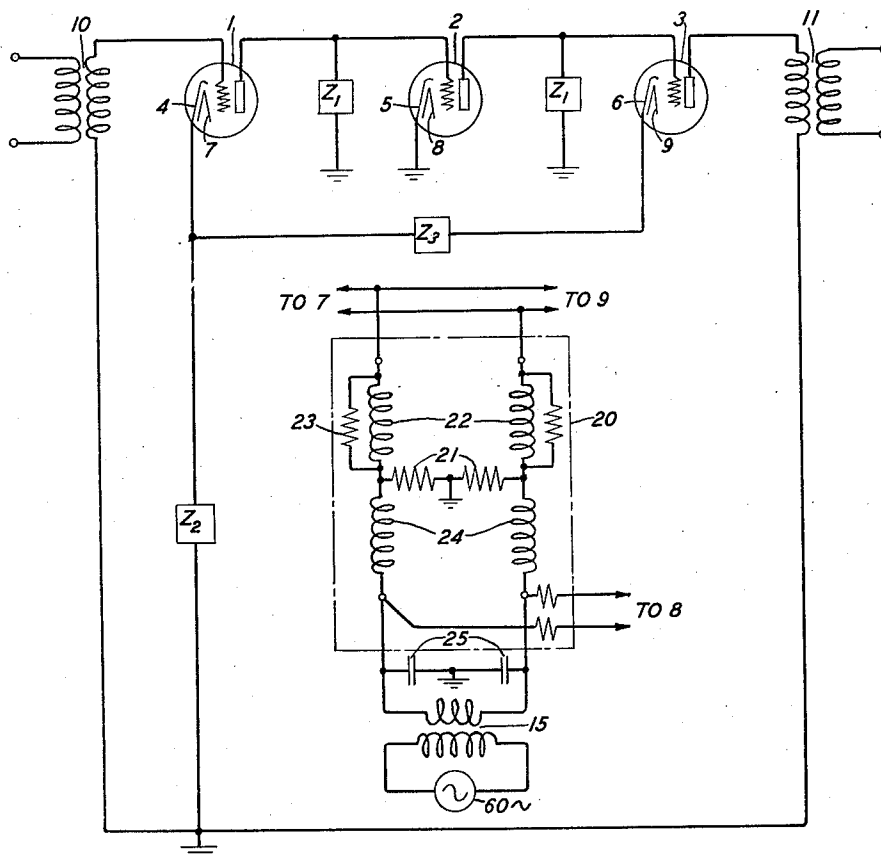


FIG. 2

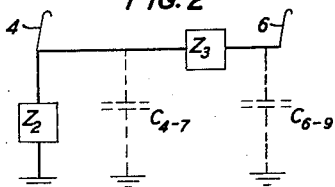
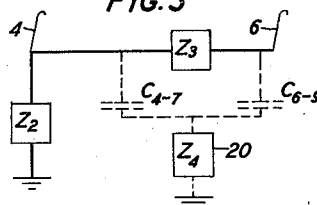


FIG. 3



INVENTOR
A. L. STILLWELL
BY
N. S. Ewing
ATTORNEY

UNITED STATES PATENT OFFICE

2,260,493

AMPLIFIER

Albert L. Stillwell, Westfield, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application November 1, 1940, Serial No. 363,803

5 Claims. (Cl 179—171)

This invention relates to electric wave amplification and more particularly to electric wave amplifiers comprising amplifying discharge devices having indirectly heated cathodes.

In certain types of electric wave amplifiers proposed heretofore the cathode in one or more of the amplifying tubes employed is maintained at a potential that for frequencies to be amplified is other than ground potential. If in such case the tubes are of the so-called heater type comprising a heater element within the envelope of the tube and in proximity to the cathode, the capacitance that inherently exists between the cathode and its heater may deleteriously affect the operation of the amplifier. Thus, in a negative feedback amplifier of the cathode feedback type as disclosed for example in United States Patent No. 2,227,048, issued December 31, 1940 to J. M. West (application Serial No. 218,300, filed July 9, 1938) where a plurality of the cathodes are connected to the high potential side of the beta circuit, the cathode-to-heater capacitances appear as a shunt across the beta circuit, the heater supply being effectively at ground potential for signal currents. Inasmuch as capacitance across the mu-beta circuit of a feedback amplifier definitely fixes a limit on the design and performance of the amplifier, the cathode-to-heater capacitances mentioned will often be found highly undesirable.

A principal object of the present invention is to minimize the effect of cathode-to-heater capacitance on the performance of amplifiers of the kind described.

In accordance with a preferred embodiment of the invention, the foregoing object and others that will appear hereinafter are achieved by associating with the cathode heater circuits, impedance elements or networks of such character and disposed in such relation to the deleterious capacitance that the latter, although not reduced in magnitude, is effectively isolated from the signaling circuit. The nature of the invention will appear more fully from the following description of the preferred embodiment illustrated in the accompanying drawing. In the drawing,

Fig. 1 illustrates schematically a three-stage negative feedback amplifier embodying the invention in preferred form; and

Figs. 2 and 3 are simplified equivalent circuit diagrams to which reference will be made in the course of the description of Fig. 1.

The amplifier depicted in Fig. 1 is a three-stage negative feedback amplifier of the cathode feedback type as disclosed more fully in the patent

to West cited hereinabove. As will be apparent to those skilled in the art many details not essential to an understanding of the present invention have been omitted, and for such details reference may be made to the West patent. The specific amplifier shown comprises three tubes 1, 2 and 3, connected in tandem by coupling impedances Z_1 , and the amplifier as a whole is adapted for connection to an external circuit by means of input transformer 10 and output transformer 11. The cathode 5 of the intermediate amplifier tube 2 is connected to ground. Cathodes 4 and 6 of tubes 1 and 3, respectively, are connected together to one terminal of an impedance network Z_2 , the other terminal of which is connected to ground. The anode circuits of tubes 1 and 3 are completed to their respective cathodes 4 and 6 through the common impedance element Z_2 , and the resultant voltage appearing across the latter is applied through the secondary winding of input transformer 10 to the control grid of tube 1 to effect gain-reducing feedback.

The impedance Z_2 will be recognized as being a feedback coupling impedance connected across a beta or feedback circuit. An impedance Z_3 may be inserted in the lead to cathode 6 to provide additional local feedback for tube 3. It may be supposed for specific example that the amplifier of Fig. 1 is so proportioned as to be adapted for the amplification of multiplex carrier telephone or carrier television signals ranging in frequency from 60 kilocycles to 3 or 4 thousand kilocycles per second.

Cathodes 4, 5 and 6 are associated with respective cathode heaters 7, 8 and 9 which are connected directly or indirectly to a 60-cycle or other suitable heating current source. Cathode heater 8 is indicated as being connected in the usual manner to the secondary winding of a power supply transformer 15. Cathode heaters 7 and 9 on the other hand are indicated as being connected to the power supply transformer through an impedance network 20, the nature and purpose of which will appear presently. The transformer end of a cathode heater circuit is almost always, if not quite invariably, at ground potential in so far as radio frequency currents are concerned. Often the mid-point of the heater transformer secondary winding is directly grounded; sometimes as in Fig. 1 the transformer secondary terminals are capacitively shunted to ground; and in any case the mass and stray capacitances of the power transformer effectively provide ground for high frequency currents. If cathode heaters 7 and 9 were connected in the

usual manner to the heater current source, that is, directly as heater 8 is connected, it is evident that the capacitance C_{4-7} between cathode 4 and heater 7 would directly connect cathode 4 capacitively to ground and that the heater-to-cathode capacitance C_{6-9} in tube 3 would similarly capacitively connect cathode 6 to ground.

In the circumstances assumed, the two cathode-to-heater capacitances are related to the feedback impedance elements in the manner shown diagrammatically in Fig. 2. That is, capacitance C_{4-7} constitutes a direct shunt across the beta circuit coupling impedance Z_2 and capacitance C_{6-9} effectively shunts the series combination of impedances Z_2 and Z_3 . Inasmuch as impedance Z_2 would ordinarily be of small magnitude as compared with impedance Z_3 , the capacitance C_{6-9} has the principal effect of capacitively shunting impedance Z_3 . The shunting capacitance in each case introduces an inherent limitation on the design and performance of the amplifier. The shunting of impedance Z_3 which is assumed to be of high impedance, moreover, makes more critical the proportioning of the internal elements thereof inasmuch as the total capacitance across Z_3 would ordinarily be strictly limited. It may be noted that the capacitances indicated are respectively proportional in size to the number of amplifier tubes operated in multiple, and that if local feedback in the last stage were dispensed with, all of the capacitances would be lumped across the beta circuit impedance Z_2 .

The undesirable condition indicated in Fig. 2 is avoided and other advantages are secured in accordance with the invention by interposing between cathode heaters 7 and 9 and the grounded or effectively grounded end of the heater circuit a network 20 that offers high longitudinal impedance to the flow of current in the upper portion of the frequency range, that is, high impedance at all frequencies for which the cathode-to-heater capacitive reactance would be significant. The specific network shown is of H configuration, the shunt arm of which comprises two series connected resistors 21 grounded at their junction. The two series arms adjacent the heaters comprise each a series inductance 22 shunted by a resistor 23. The two series arms adjacent the transformer 15 comprise series inductances 24.

In a particular case in practice resistors 21 were 1000 ohms each; elements 22, 100 microhenries each; resistors 23, 6000 ohms; and elements 24, 1 millihenry each. The several resistors provide damping to suppress possible resonance effects particularly in the event of a short-circuit between a cathode and its heater. Inductances 22 offer high impedance at the upper frequency end of the feedback range where the shunting effect of C_{4-7} and C_{6-9} tends to limit the asymptotic feedback. Inductances 24 are comparatively large and offer high impedance at all frequencies within the signaling band for which cathode-to-heater short circuit would importantly affect the external gain. Bearing in mind that the impedance Z_2 may be of the order of one hundred ohms over the signaling band, it will be understood that the network 20 interposes in the heater lead a longitudinal impedance that is many times as large as Z_2 at all significant frequencies. The impedance offered by network 20 to the flow of heating current is practically negligible. To avoid series resonating of inductances 24 and the stray capacitance of the power

transformer, at least within the signal frequency range, the stray capacitance is augmented by the large parallel capacitance afforded by bypass condensers 25.

Fig. 3 shows in diagrammatic form the changes brought about by the insertion of the longitudinal impedance Z_4 of network 20. It will be seen that the capacitance C_{4-7} no longer directly shunts the beta circuit impedance Z_2 , for the high impedance Z_4 is now interposed in the shunting connection. Capacitance C_{6-9} is similarly isolated from shunting effect on impedance Z_2 . With respect to its shunting effect on local feedback impedance Z_3 , capacitance C_{6-9} is now connected in series with capacitance C_{4-7} across impedance Z_3 , the effective shunting capacitance thereby being substantially reduced. In this way the asymptotic performance of the feedback path can be materially improved and hence also the feedback in the band.

A feature of the invention is the protection it affords against complete disability of the amplifier in the event of an accidental short circuit arising between a cathode, such as 4 or 6, and its associated heater. From Fig. 2 it is evident that if the capacitance C_{4-7} were converted into a conductive short circuit, as by contacting of cathode 4 and heater 7, the beta circuit of the amplifier would be directly short-circuited by the fault. Fig. 3 shows on the other hand that with an arrangement in accordance with the invention, short-circuiting of capacitance C_{4-7} would still leave a high impedance Z_4 in the shunting connection and the operation of the amplifier would be not substantially affected. Similar remarks may be made with reference to impedance Z_3 and the possible short-circuit of capacitance C_{6-9} .

Although the present invention has been described principally with reference to the illustrated preferred embodiment, it will be evident to those skilled in the art that the invention is susceptible of application in other forms within the spirit and scope of the appended claims.

What is claimed is:

1. A signal amplifier of the cathode feedback type comprising amplifier tubes of the cathode heater type, a heating current source connected to the heaters of said tubes, the cathode of at least one of said tubes being maintained at high potential for signal frequency, and an impedance network interposed in the heating current leads associated with the said cathodes that are maintained at high potential for signal frequency, said network introducing high longitudinal impedance to ground for at least signal frequencies in the upper portion of the signal frequency range.

2. A signal amplifier of the cathode feedback type comprising at least three stages of amplification connected for cathode feedback operation, a signal amplifier tube of the cathode heater type in each of said stages, a local feedback impedance element in the cathode lead of the tube in the third of said stages, an alternating current source connected to the cathode heaters of all of said tubes, and an impedance network interposed between the first and last stage heaters and the point of connection of the second stage heater to said source, said network offering low impedance to the heating current and relatively high impedance to signal frequencies.

3. An electric wave amplifier of the feedback type employing heater type tubes, said amplifier having a beta circuit such that at least one of

the cathodes of said tubes is maintained off ground potential for all frequencies in the frequency range to be amplified, and means in the heater lead associated with said cathode offering substantial longitudinal impedance to all frequencies in the amplified range, whereby said beta circuit is protected against disability in the event of a short circuit between said cathodes and their associated heaters.

4. An electric wave amplifier of the feedback type, said amplifier having a beta circuit and comprising heater type tubes, the cathode of at least one of said tubes being connected to a point in said beta circuit of high potential relative to ground for frequencies to be amplified, whereby the capacitance between the said cathode and its associated heater tends to shunt said beta circuit,

and means in the heating current circuit to said heater introducing such impedance that the shunting effect of said capacitance is substantially reduced.

5. An electric wave amplifier for the amplification of high frequency signals, comprising signal amplifier tubes of the cathode heater type, at least one of said cathodes being connected to ground only through an impedance that is high at least for frequencies in the upper portion of the signaling frequency band whereby cathode-to-heater-to-ground capacitance tends to reduce the said impedance, and impedance means in the heater circuit associated with said cathode for increasing the impedance to ground for said signal frequencies.

ALBERT L. STILLWELL.