

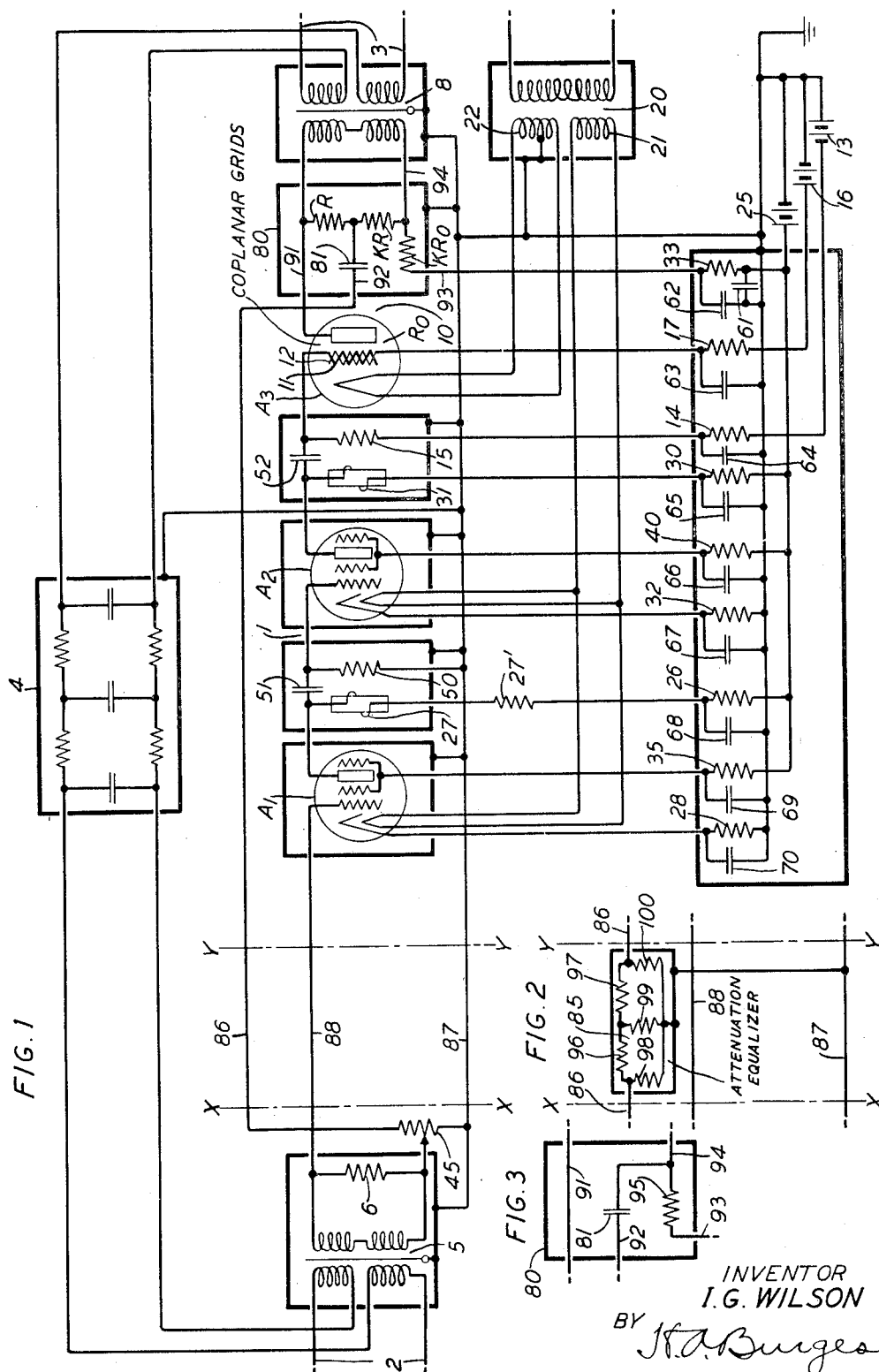
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ELECTRIC WAVE AMPLIFYING SYSTEM

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ELECTRIC WAVE AMPLIFYING SYSTEM

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This invention relates to electric wave translating systems, as for example, wave amplifying systems or wave amplifying and attenuation equalizing systems employing feed-back vacuum tube amplifiers.

A representative object of the invention is to control transmission efficiency in such systems, as for instance to vary their gain or adjust their gain-frequency characteristics by controlling the feed-back.

In a representative specific aspect the invention is a negative feed-back vacuum tube amplifier of the general type disclosed in the application of H. S. Black, Serial No. 439,205, filed March 26, 1930 for Wave translation systems (or corresponding British Patent 371,887), or in the application of H. S. Black, Serial No. 298,155, filed August 8, 1928 for Wave translation systems (or corresponding British Patent 317,005), or in the application of H. S. Black, Serial No. 606,871, filed on even date herewith for Wave translation systems. In accordance with the present invention waves are fed back from a voltage dividing potentiometer forming a portion of the output circuit serially through the incoming circuit and a grid-cathode space path in the first stage of the amplifier. If desired, an attenuation equalizer is connected in the output circuit between the anode-cathode space path of the last stage of the amplifier and the potentiometer, to control the gain-frequency characteristic of the amplifier in the general manner disclosed in the second and third of the above mentioned Black applications.

Changing the setting of the potentiometer is a simple method of changing the amount of feed-back and consequently changing the amplifier gain. Moreover, the serial relation referred to above prevents the feed-back action from unduly lowering the impedance that the amplifier presents to the incoming circuit and facilitates maintaining that impedance constant. Further, the above described means for varying the gain facilitates avoiding change of the impedances between which the attenuation equalizer is connected. It is desirable to design the equalizer to work between given impedances, and change of those impedances would, in some cases, change the gain-frequency characteristics of the equalizer.

Other objects and aspects of the invention will be apparent from the following description and claims.

In the drawing, Fig. 1 is a circuit diagram of

an amplifying system embodying one form of the invention; and

Figs. 2 and 3 show modifications which may be made in the system of Fig. 1.

In the amplifying system of Fig. 1, an amplifier 1 comprising vacuum tubes A₁, A₂ and A₃ in cascade connection amplifies waves received over incoming line or circuit 2 and transmits the amplified waves to outgoing line or circuit 3. The circuits 2 and 3 may be, for example, sections of a multiplex carrier telephone cable circuit, the amplifier 1 amplifying simultaneously the waves of a number of carrier telephone channels and/or carrier telegraph channels, extending over a frequency range from 8 kilocycles to 100 kilocycles for instance.

A direct current by-pass set 4 comprising a network of series resistance arms and shunt capacitance arms by-passes direct current, for example, direct current telegraph signals, past the amplifier.

The incoming circuit 2 terminates in a transformer 5 shunted on its secondary side by a resistance 6 of the order of 70,000 ohms, for example. The resistance 6 assists in terminating the circuit 2 in the proper value of impedance to reduce reflection.

The output circuit of the amplifier is connected to the outgoing or load circuit 3, which comprises amplifier output transformer 8, through a Wheatstone bridge 10. The space discharge path resistance R₀ of the last stage of the amplifier is one ratio arm of the bridge, and the circuit 3 is the output diagonal of the bridge. The four ratio arms of the bridge are designated by their resistance or impedance values R₀, KR₀, KR and R, where R may be a resistance and K a constant, or where R₀, KR₀, KR, R and K may be complex quantities or quantities of any suitable values as long as

$$\frac{R}{KR} = \frac{R_0}{KR_0}$$

Tubes A₁ and A₂ may be, for instance screen grid, indirectly heated cathode tubes of high amplification factor, or so called high mu tubes, for example, the Western Electric Company type 259-A tubes. Tube A₃ may be, for example, a coplanar grid tube of the type disclosed by H. A. Pidgeon and J. O. McNally in their Patent 1,923,686, August 22, 1933, or in their Patent 1,920,274, August 1, 1933, or in their paper published in the Proceedings of the Institute of Radio Engineers, vol. 18, pages 226-293, February, 1930. Such a tube has two grids 11 and 12, each active

elementary area on either grid being close to a corresponding active area on the other grid and being at substantially the same location as that corresponding area with respect to the cathode and the anode or plate. By way of example, each grid may have its lateral wires lie in the same surface, for instance the same plane or cylindrical surface, as the lateral wires of the other grid and alternate with them. The tube may have the flat type electrode structure disclosed in the above mentioned Patents 1,923,686 and 1,920,274 and paper by Pidgeon and McNally. Such electrode structure affords large electrode surfaces between which electrons may flow, with relatively small inter-electrode spacing and is thus well adapted for large power output. As brought out by the above mentioned disclosures of Pidgeon and McNally, a vacuum tube having a space-charge grid in coplanar relation with a control grid is especially adapted for operation as a power tube by employing a high value of control grid negative biasing potential and a control grid input voltage wave of large amplitude (i. e., a large grid swing) and a high positive biasing voltage on the space-charge grid. The tube A₃ may be operated in this manner with grid 11 serving as a control grid receiving the signal voltage transmitted from tube A₂ and maintained at negative potential by a negative biasing voltage applied from battery 13 through resistances 14 and 15 and with grid 12 serving as a space-charge grid maintained at positive potential by a positive biasing voltage applied from battery 16 through resistance 17. This tube may be a Western Electric Company type 281—A coplanar grid tube, for example.

The filaments of the three tubes are heated from a filament voltage supply transformer 20, which has a secondary winding 21 supplying voltage to the heater elements of tubes A₁ and A₂ in parallel, and has a secondary winding 22 supplying voltage to the filamentary cathode of tube A₃.

Battery 25 supplies the plate potentials and the screen grid potentials for the amplifier. The space current for tube A₁ flows from the positive pole of the battery through resistance 26, resistance 27, inductance 27, tube A₁ and resistance 28 to the grounded pole of the battery. Resistance 27' tends to maintain the low frequency gain. This resistance may have a value of 4000 ohms, for example.

The space current for tube A₂ flows through resistance 30, inductance 31, tube A₂ and resistance 32; and the space current for tube A₃ flows through resistance 33, resistance KR₀, thence in parallel through a path including resistances KR and R in series and a path including the primary winding of output transformer 8, and thence through tube A₃ to the filamentary cathode of the tube, and thence through the halves of winding 22 to ground.

The potentials for the screen grids of tubes A₁ and A₂ are supplied from battery 25 through resistances 35 and 40, respectively.

The voltage drop across resistance 28 supplies negative biasing potential for the grid of tube A₁ through the portion of potentiometer 45 between ground and the adjustable contact of the potentiometer and thence through resistance 6 and the secondary winding of input transformer 5 in parallel.

The voltage drop across resistance 32 supplies negative biasing voltage for the grid of tube A₂ through resistance 50.

Tubes A₁ and A₂ are coupled through condenser 51; and tubes A₂ and A₃ are coupled through condenser 52. Each of these condensers may have a capacity of the order of 0.25 mf., for example.

Each of condensers 61 and 62, which are two condensers connected respectively from the high potential and low potential ends of resistance 33 to ground, serves as a filter condenser, in connection with its associated resistance, for suppressing noise and reducing undesired feed-back and singing tendencies, as does also each of the condensers 63 to 70, which are eight condensers respectively associated with resistances 17, 14, 30, 40, 32, 26, 35 and 28. Each of these ten condensers 61 to 70 may have a capacity of the order of 0.75 mf., for example. These ten condensers and these eight resistances may be potted in a metallic shielding case or can as shown, of copper for instance, forming a resistance condenser group to be mounted as a unit, for example, on a metallic mounting plate (not shown), which in turn may be mounted on a relay rack and on which all of the apparatus shown in the drawing may also be mounted but from which the shielding can may be electrically insulated if desired. The input transformer 5 and the resistance 6 similarly may be potted in a shielding can as shown. The by-pass set 4, the output transformer 8 and the filament heating transformer 20 similarly may be potted, each in a separate shielding can as shown. Similarly, the interstage coupling elements 27, 50 and 51 may be mounted as a unit in a shielding can, as shown, as may likewise the interstage coupling elements 15, 31 and 52. The tubes A₁ and A₂ are also shown in shields, but these are removable metallic covers, which may fit over the tubes and be removably attached to the mounting panel (not shown) referred to above, so that the tubes will be readily accessible. A shielding can 80 is also shown for the ratio arms KR₀, KR and R, and with them may be potted a condenser 81, of 0.1 mf., for example, through which the (entire) resistance of potentiometer 45 is connected in the output circuit of the amplifier.

Alternating current in the output circuit of the amplifier flows through a circuit extending from the plate of tube A₃ through that tube to the filament of the tube, which is grounded through the two halves of winding 22, and from ground to the junction point of KR and R through two parallel paths, one comprising the entire resistance of potentiometer 45 and the condenser 81 in serial relation and the other comprising condenser 62, KR₀ and KR all three in serial relation, and from that junction point through R back to the plate of tube A₃. The outgoing circuit 3 forms one diagonal of the bridge 10.

The incoming circuit 2, the variable portion of the amplifier output circuit included between the adjustable contact of potentiometer 45 and ground, and the grid-cathode space path in tube A₁ are all connected in serial relation (through condenser 70). Similarly, the amplifier anode-cathode space path in tube A₃ is connected in serial relation with the incoming circuit 2 and the amplifier grid-cathode space path in tube A₁, a circuit in which these three elements are in serial relation extending from the anode of tube A₃ through resistance R, condenser 81, a variable portion of the resistance of potentiometer 45 to the adjustable contact of the potentiometer, incoming circuit 2, the amplifier grid-cathode space path in tube A₁, condenser 70

to ground, the two halves of winding 22 to the filament of tube A₃, and the amplifier anode-cathode space path of tube A₃ back to the anode of tube A₁.

5 In the direct current by-pass set 4 the four resistances shown may have equal values, for example, 500 ohms; and the condenser capacities may be, for instance, of the order of 1 mf. for each of the end condensers and 4 mf. for the intermediate condenser.

10 Resistances 14, 15, 17, 26, 28, 30, 32, 33, 35, 40 and 50 may be respectively 2000 ohms, 100,000 ohms, 100 ohms, 250 ohms, 400 ohms, 250 ohms, 600 ohms, 83 ohms, 180,000 ohms, 80,000 ohms and 2 megohms, for example; and inductances 27 and 31 may be respectively .077 henry and 2 henries.

To avoid danger of singing, the phase shift in a single trip around the feed-back loop circuit of the amplifier may be made to differ from zero and from 360 degrees and every integral multiple thereof for every frequency for which there is a gain in a single trip around the loop. It is desirable in attaining this end to yet have the amplification in a single trip around the loop large (much greater than unity) in the utilized frequency range, since then, as brought out in the above mentioned applications of H. S. Black, the distortion reduction effected by the negative feed-back is large (assuming propagation around the loop does not discriminate between signal and products due to non-linear response). Therefore the amplifier should be carefully designed with reference to the phase shifts and gains around the loop circuit at all frequencies. Since the phase shifts and attenuations introduced by the interstage coupling circuits, the feed-back path through condenser 81 and the distributed capacity in the amplifying system, for instance, are of importance and should be carefully controlled, a number of appropriate circuit constants have been given above to facilitate practice of the invention. However, values given are merely illustrative and the invention is not limited thereby.

In the utilized frequency range the amplification from the grid of the first tube to the plate of the last tube is sufficiently large to obtain the desired large amplification (in a single trip) around the loop with a large amplification reduction in the feed-back path from the plate of the last tube to the grid of the first tube. As brought out in the above mentioned applications of H. S. Black, with this condition the amplification of the amplifier and the gain, which is a measure of the absolute value of the amplification, can be large (much greater than unity) at the same time that the distortion reduction by the feed-back is large.

60 By varying the position of the adjustable contact of potentiometer 45 the amount of negative feed-back in the system can be increased or decreased to respectively decrease or increase the gain of the system. Accomplishing the change of gain by changing the amount of feed-back tends to maintain high and constant the ratio of signal power to resistance noise power delivered to the outgoing circuit 3. The serial relation of the high internal grid-cathode impedance of the tube A₁ with the incoming circuit and the potentiometer 45 tends to reduce the effect of change of the potentiometer setting upon the impedance which the amplifier system presents to the incoming circuit 2 and reduce the degree to which the impedance of the incoming

circuit 2 affects the amount of feed-back to the grid and cathode of the tube A₁.

Fig. 2 shows between lines X—X and Y—Y a circuit which may be substituted for the portion of Fig. 2 between the lines X—X and Y—Y to include a reactive network forming an attenuation equalizer 85 in the feed-back path of the amplifying system. Conductors 86, 87 and 88 are the same in Fig. 2 as in Fig. 1, except that in Fig. 2 the equalizer 85 may have one or more impedances constituting one or more series arms conventionally shown as generalized impedances 96 and 97 connected in conductor 86 and one or more impedances constituting one or more shunt arms conventionally shown as generalized impedances 98, 99 and 100 connected between conductors 86 and 87. The equalizer may be of any suitable type, as for example, any of the types disclosed in the above mentioned applications of H. S. Black, one of which types comprises in tandem relation, basic and building-out equalizers and a regulating equalizer adjustable for giving gain changes having a desired variation with frequency. The regulating equalizer may be either manually or automatically adjustable. The equalizer 85 may be incased in a shield as shown, similar to the shields referred to above.

As explained in the second and third of the above mentioned applications of H. S. Black, the greater the loss that the attenuation equalizer 85 introduces in the feed-backpath at any frequency, the less will be the amount of negative or gain-reducing feed-back at that frequency, and consequently the greater will be the amplifier gain at that frequency.

The equalizer 85 may be of a type designed to work between given impedances and therefore it is desirable that the impedances which it faces be substantially constant so that it will have the desired loss-frequency characteristics. The serial relation of the high internal grid-cathode path in tube A₁ and the incoming circuit 2, with respect to the potentiometer 45, reduces variation that change in the potentiometer setting tends to produce in the impedance presented by the potentiometer to the equalizer.

Fig. 3 shows in shielding casing 80 a circuit which may be substituted for the portion of the circuit of Fig. 2 in casing 80 in the latter figure when it is desired to omit the bridge 10, either with the equalizer in circuit or not. Conductors 91, 92, 93 and 94 and condenser 81 are the same in Fig. 3 as in Fig. 1. With the substitution just mentioned, unidirectional space current for tube A₃ flows from conductor 93 through resistance 95 of Fig. 3, conductor 94, primary winding of output transformer 8, and conductor 91 to the plate of tube A₃, the remainder of this space current circuit being as in Fig. 1; and alternating current in the output circuit flows through a circuit extending from the plate of tube A₃ through that tube to the filament of the tube, which is grounded through the two halves of winding 22, and from ground to the junction point of resistance 95 and condenser 81 through two parallel paths, one comprising the entire resistance of potentiometer 45 and the condenser 81 in serial relation and the other comprising condenser 62 and resistance 95 in serial relation, and from that junction point through the outgoing circuit 3 (i. e., through the primary winding of output transformer 8) back to the plate of tube A₃.

What is claimed is:

1. A wave transmission system comprising a vacuum tube device having a grid-cathode path, 150

an incoming circuit for supplying to said device waves to be transmitted thereby, a feedback path for said device, a transmission control network in said feedback path having transmission characteristics dependent upon the impedance termination of the network, a voltage dividing potentiometer terminating said network and having adjustable connection to said incoming circuit, and means connecting said incoming circuit in serial relation with said grid-cathode path and a variable portion of said potentiometer.

2. A wave transmission system comprising a vacuum tube device having a grid, cathode means, an anode, a grid-cathode space path and an anode-cathode space path, an incoming circuit for supplying waves to said device to be transmitted thereby, an outgoing circuit for said device, a voltage dividing potentiometer resistance with ad-

justable connection to said incoming circuit, an attenuation equalizer network connected between said outgoing circuit and said potentiometer resistance and connecting a portion of said potentiometer resistance, said incoming circuit, said grid-cathode space path, said anode-cathode space path and said outgoing circuit in serial relation in the order named, means for supplying unidirectional biasing potential to said grid through a portion of said potentiometer resistance and through said incoming circuit, and means for supplying unidirectional potential to said anode through said outgoing circuit, said equalizer comprising a reactive network of series and shunt arms and having attenuation frequency characteristics dependent upon the impedances which it faces.

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