July 23, 1929. V. M. GRAHAM 1,721,992

RADIO SIGNALING SYSTEM

Filed Sept. 16, 1925

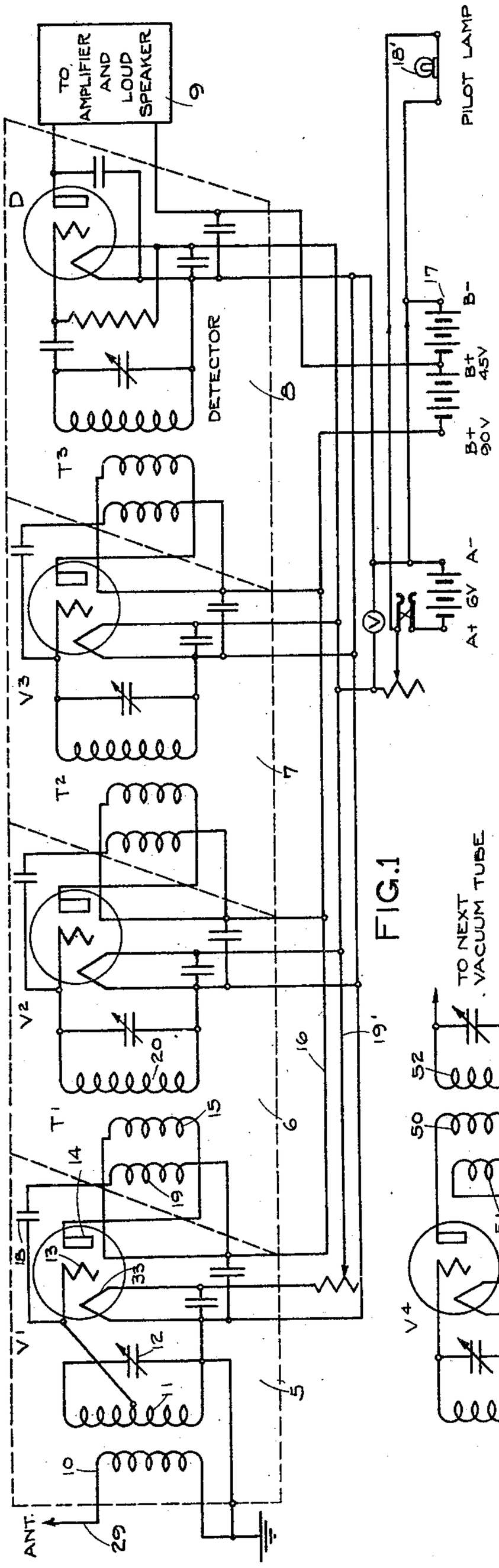

FIG. 1

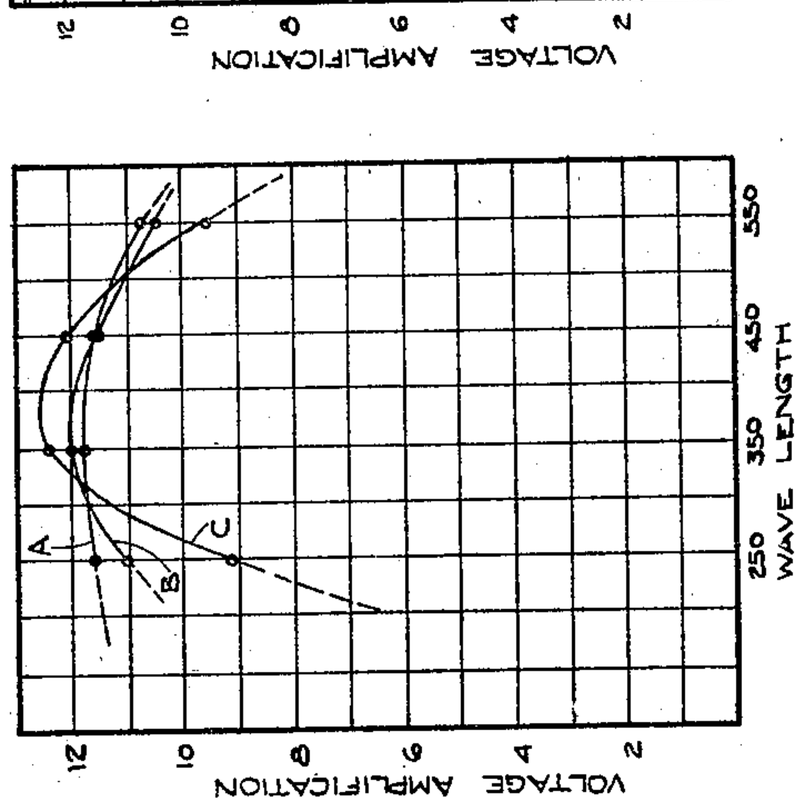

FIG. 2

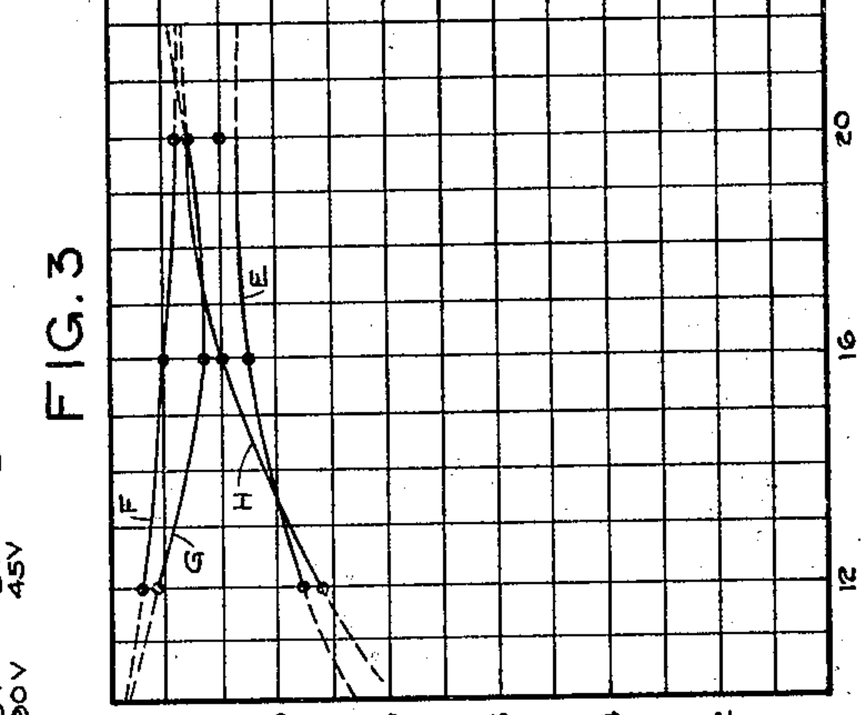

FIG. 3

FIG. 6

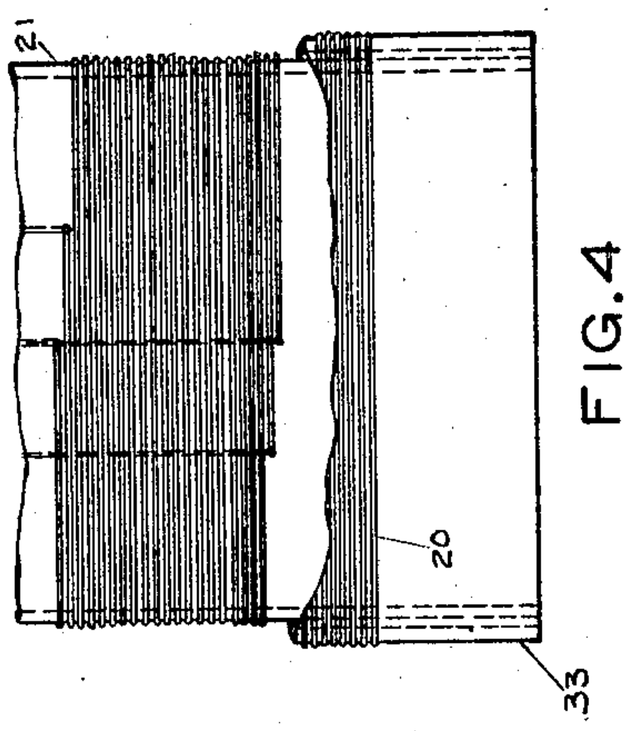

FIG. 4

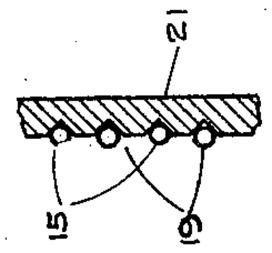

FIG. 5

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UNITED STATES PATENT OFFICE.

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RADIO SIGNALING SYSTEM.

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This invention relates to amplifiers and more particularly to multi-stage amplifiers employing an electron discharge tube in each stage.

In multi-stage amplifiers having electron tubes, especially those employed for amplifying radio-frequency currents, it is customary to couple the output circuit of one electron tube to the input circuit of a second electron tube, by means of an air-core transformer. It has been recognized in such radio-frequency amplifiers especially those in which each of the stages are tuned to the frequency of the incoming signal, that it is desirable to have a high degree of voltage amplification, resulting from the design of the transformer. In the past, such multi-stage radio-frequency amplifiers have not amplified all portions of the frequency range to an equal amount, in other words these amplifiers are less efficient at certain portions of the frequency range, than at others. In one type of radio-frequency amplifiers, which has proven especially satisfactory, it is customary to provide a neutralizing winding in addition to the primary and secondary windings of the transformers, which when incorporated with a neutralizing condenser in the circuits of a stage, serves to prevent regeneration by eliminating capacity coupling between the input and output circuits of such a stage.

The present invention resides in the method of coupling two or more stages of a multi-stage radio-frequency amplifier, wherein the voltage amplification is rendered more nearly uniform throughout a determined frequency range; more specifically, this invention resides in the arrangement of the primary and neutralizing windings of a radio-frequency transformer, as well as the spacing between the turns of these windings, so that the frequency characteristic of the radio-frequency transformer may be regulated in part by this variation to introduce loss in the tuned input circuit.

The invention further consists in controlling the frequency characteristics of a radio-frequency transformer by introducing a dielectric loss into the tuned input circuit with which it is associated.

Referring to the drawings, Fig. 1 represents a multi-stage tuned radio-frequency receiving set. Fig. 2 is a chart showing the effects on the voltage amplification at various wave lengths of varying the spacing between the primary and neutralizing windings of a transformer. Fig. 3 is a chart having various graphs showing the voltage amplification plotted as a function of turns per inch of the primary and neutralizing coils at several different wave lengths. Fig. 4 is a portion of a radio-frequency transformer showing a primary, secondary and neutralizing winding, and Fig. 5 is a sectional portion of an insulating tube provided with properly spaced grooves, in which the primary and neutralizing windings are wound. Fig. 6 shows a modified form of the invention.

Referring to the drawings, Fig. 1 represents three units of tuned radio-frequency amplification, in which the units are designated 5, 6 and 7, respectively. The amplified signal energy of these radio-frequency units is rectified in a detector 8 and the rectified signals may be amplified and translated into sound by a loud speaker unit 9.

This receiver is provided with an antenna 29, which includes the primary winding 10 of a radio-frequency transformer of the air-core type, having a secondary winding 11. A variable condenser 12 is connected across the terminals of this transformer to provide a tuned input circuit for the electron discharge tube V^1. An intermediate point on the secondary winding 11 is connected to the grid 13 of this tube, while the lower terminal of this winding is connected to one side of the heating system of the filament 33 of this same tube. The output circuit of this tube is connected from its plate 14 through the primary winding 15 of a radio-frequency transformer T^1, thence through the conductor 16, the B battery 17, pilot lamp 18′, and the conductor 19 to the heating circuit of the filament 13. As is well known there is an undesirable coupling between the input circuit and the output circuit or plate circuit of an electron discharge tube, due to the inherent capacity existing between its elements such as the grid 13 and plate 14. This capacity coupling may be eliminated by providing a neutralizing condenser 18 and a neutralizing winding 19′, so arranged as to apply a capacity current to the grid 13, equal and opposite to that which would normally be applied to the grid through the mentioned inherent capacity. The secondary winding 20 of the transformer is included in the input circuit of a second

electron discharge device V^2 also provided with a neutralizing condenser and neutralizing winding as in the case of the first mentioned device. This device is coupled to the third stage of radio-frequency amplification, by means of a transformer T^2, similar in structure and arrangement to that shown at T^1. The third unit of radio-frequency amplifier, including the well known electron discharge tube V^3, is coupled to the detector tube D, by means of a radio-frequency transformer T^3, similar to the transformers T^1 and T^2. The output circuit of the detector D is coupled to an amplifier and loud speaker system, designated 9, which may be of any well known structure and arrangement.

The several units of the receiver of Fig. 1, are shielded by means of metallic compartments formed preferably of sheet copper enclosing the transformer, the condenser and tube of each unit to prevent electromagnetic or other coupling between the various units as is indicated by dotted lines in Fig. 1.

For purposes of this description an electron tube with its input circuit and its output circuit is referred to as a stage and a plurality of these stages arranged in cascade constitute a multi-stage amplifier.

Each of the transformers T^1, T^2 and T^3 consists of a primary winding 15 and a neutralizing winding 19′ which are parallel wound on a tube of insulating material 21, and a secondary winding 20 wound on a second tube 33 of insulating material arranged to closely encircle the first tube. As indicated in Fig. 5, the tube 21 has grooves spaced a strictly accurate predetermined distance apart, in which grooves the primary and neutralizing windings are wound. It will be noted that these turns are alternately positioned on the insulating tube and may be applied by winding the wires of the two coils simultaneously.

The frequency characteristic of radio-frequency transformers such as are used in a tuned radio-frequency amplifier may be regulated in part by varying the loss in the tuned input circuit of each of the stages. It has been discovered that this loss is most effective when present as a dielectric loss and it may be obtained by reflecting into the circuit of the secondary winding of the transformer, the dielectric loss between the alternately wound turns of the primary and the neutralizing winding of the transformer, just referred to.

In order to indicate the effect of varying the spacing between the several turns of the primary and neutralizing windings, reference is made to Fig. 2, wherein the graphs A, B and C indicate the relation between voltage amplification and wave length when all of the determining factors are constant except the number of turns per inch. In deriving these graphs, the primary windings of the transformers consist of 24 turns of #29 double silk covered wire on an insulating tubing having an outside diameter of two and one-half inches and the neutralizing windings consisted of 25 turns of #29 double silk covered wire wound parallel with the primary winding on the same tubing, while the secondary windings consisted of 63 turns of #20 enamelled wire on a tubing of two and three-fourths on its outside diameter.

The transformer represented by graph A had its primary winding and its neutralizing winding each wound with 20 turns per inch, and the transformer represented by graph B had these windings wound with 16 turns per inch, while the transformer represented by graph C was wound with 12 turns per inch in each of these windings.

Fig. 3 shows graphs indicating the variation of the voltage amplification of a tuned radio-frequency transformer at resonance with respect to the spacing of the number of primary turns per inch with the same number of primary, neutralizing and secondary turns, that is, with a primary winding consisting of 24 turns of #29 double silk covered wire on tubing of two and one-half inches in diameter and a neutralizing winding consisting of 25 turns of #29 double silk covered wire, parallel wound with the primary winding on the same tubing, while the secondary winding consists of 63 turns of #20 enamelled wire on tubing of two and three-fourths inches on its outer diameter, having 23 turns per inch. In this figure, curve E represents a wave length of 250 meters, curve F a wave length of 350 meters, curve G a wave length of 450 meters and curve H a wave length of 550 meters.

In Fig. 6 there is illustrated a modified form of the invention, in which a single amplifier stage with other associated circuits shows the relation of the invention to a multi-stage amplifier.

In a radio receiver of the type in which tuned circuits, and means for balancing against undesirable couplings other than the neutrodyne arrangement of Fig. 1 are employed, it is desirable to control the amplification, so that more uniform amplification is obtained over the whole frequency range, and so that the amplification can be reduced at the higher frequencies to render the receivers stable against oscillations.

In the case of the receiver of Fig. 1, the capacity between the neutralizing winding, such as 19′ and the primary winding, such as 15 furnishes a dielectric loss, which serves to straighten out the frequency characteristics of the amplifier. In other types of radio-frequency amplifiers, such as shown in Fig. 6, where a neutralizing winding such as previously described is not used, the frequency characteristic curve will be very steep, sloping upward at the higher frequencies. In

order to flatten this characteristic, that is, to obtain uniform amplification, it is necessary to add dielectric loss to the transformer, since it is insufficient merely to make the primary winding of high distributed capacity, because the voltage is not of sufficient amplitude and because the effectiveness of the dielectric loss varies as the square of the applied voltage.

With a view of increasing the voltage that it is possible to apply in addition to the distributed capacity of the primary winding, it is necessary to take advantage of the transformer action. Thus in addition to the primary winding 50 in the output circuit of the vacuum tube V^4, an auxiliary coil 51 is provided, which is wound parallel to the primary winding with a one to one ratio of turns. The lower end of the coil 51 is left unconnected, while the other end is attached to the terminal of the primary winding, which is connected to the positive pole of the B battery. It will be noted that in this arrangement the point of the highest self-induced potential of the primary coil 50, that is the upper terminal, is opposite the low potential or upper terminal of the coil 51 and that the terminal of the primary coil having low self-induced potential is opposite to the terminal of the coil 51, which is of high induced potential. From this, it will be seen that the potential differences between the two windings throughout their whole length is practically equal to the self-induced potential across the primary coil. This arrangement provides a much greater dielectric loss than is otherwise possible, owing to the large amount of capacity between the two windings and further due to the high potential applied.

This dielectric loss may be reflected into the secondary coil 52 of the transformer to provide uniform amplification over a wide predetermined range of frequencies.

What I claim is:

1. In a multi-stage tuned radio-frequency amplifier, having an electron discharge device in each stage provided with an input circuit and an output circuit, a transformer with a primary winding and a secondary winding for coupling the output circuit of one stage to the input circuit of a second stage, and means for neutralizing capacity coupling between the input circuit and the output circuit of each stage including a neutralizing winding, the method of producing amplification over a wide range of frequencies, which consists in employing such spacing between the turns of the primary and neutralizing windings as to introduce predetermined loss into the input circuit which loss varies with the frequency.

2. In an amplifier, two electron discharge tubes, each having filament, grid and plate electrodes, with inherent capacity existing there-between, an input circuit connected between the grid and filament of each electron discharge tube, an output circuit including a plate and filament, a transformer having a primary winding in the output circuit of the first electron discharge tube and a secondary winding in the input circuit of said second electron discharge tube to couple said last mentioned circuits together, a neutralizing winding and a neutralizing capacity connected between the grid and filament of said first electron discharge tube, and a common tubular support on which said primary and neutralizing windings are alternately wound with uniform predetermined spacing between their turns to introduce a predetermined loss into the input circuit of said second electron discharge tube, which loss varies with the signal frequency.

3. In an amplifier, two electron discharge tubes each having filament, grid and plate electrodes with inherent capacity existing there-between, an input circuit connected between the grid and filament of each electron discharge tube, an output circuit including each plate and filament, a transformer having a primary winding in the output circuit of the first electron discharge tube and a secondary winding in the input circuit of said second electron discharge tube to couple said last mentioned circuits together, a neutralizing winding and a neutralizing capacity connected in circuit between the grid and filament of said first electron discharge tube, and a common tubular support with grooves spaced a predetermined distance apart, said primary and neutralizing windings being alternately wound in the grooves of said support to introduce a predetermined loss into the input circuit of said second electron discharge tube, which loss varies with the signal frequency.

In witness whereof, I hereunto subscribe my name this 10th day of September, A. D. 1925.

VIRGIL M. GRAHAM.