

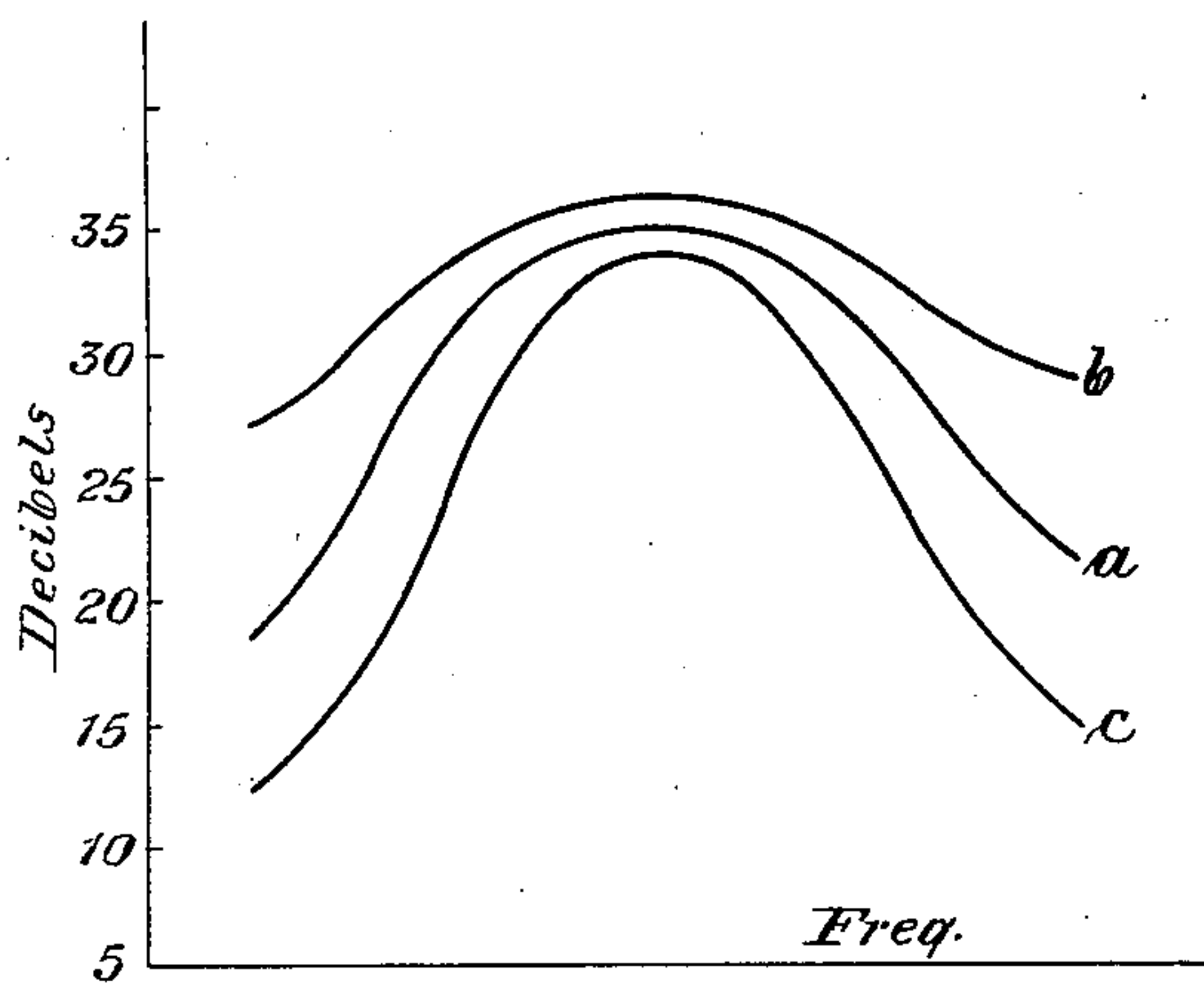
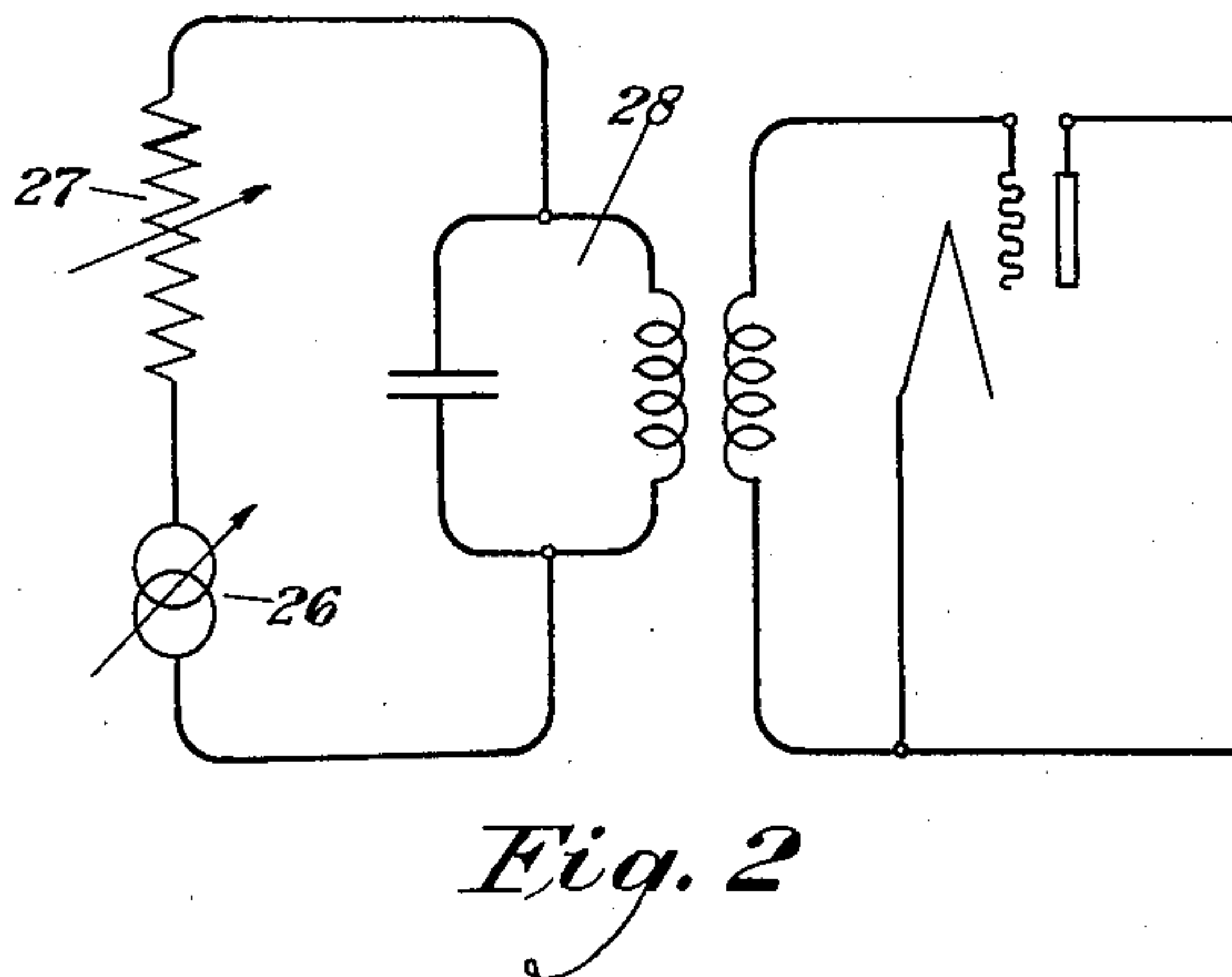
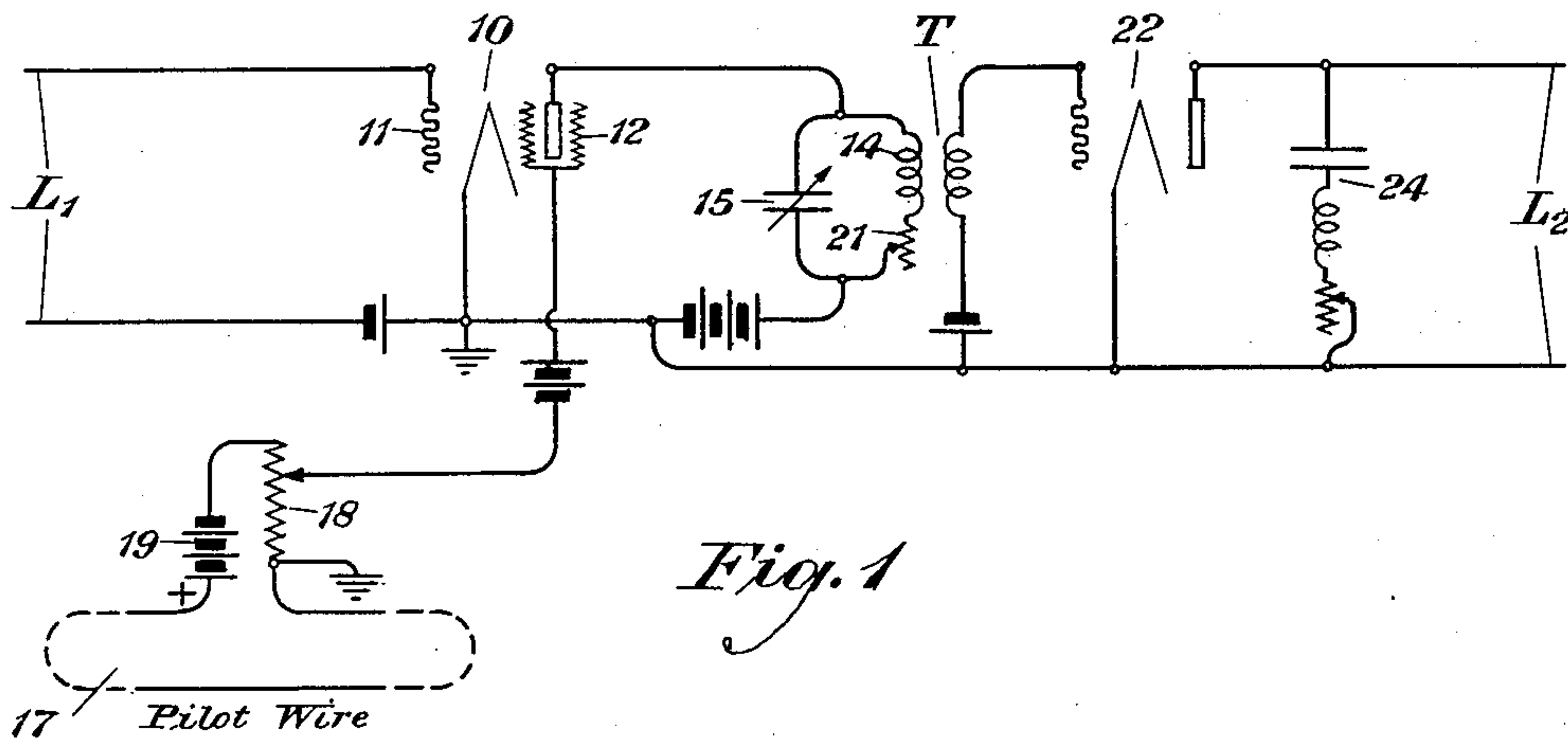
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TRANSMISSION REGULATOR CIRCUITS

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TRANSMISSION REGULATOR
CIRCUITS

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5 Claims. (Cl. 178-44)

This invention relates to transmission circuits, and more particularly to the regulation of transmission circuits in which a pilot wire is used as a part of such regulating system. Its purpose is to provide suitable means for compensating for changes in gain or loss experienced by signal currents flowing in such circuits. A further purpose is to provide such compensation, but in a manner so that the amount of compensation is in accordance with a desired function of the frequency. Still another purpose is to combine the particular properties of a vacuum tube such as a variable mu tube with an impedance which is itself a function of the frequency, and such a function of the frequency that when combined with variations in the mu of a tube and the internal impedance thereof, the overall gain is itself a function of the frequency in a manner desired.

The invention may be described briefly as follows: A pilot wire has associated with it a suitable circuit, such as the necessary portions of a Wheatstone bridge, to deliver an E. M. F. which varies in accordance with the change of resistance of the pilot wire. This E. M. F. is applied to a grid of an amplifier tube which receives the incoming signal from a transmission line for amplification. One type of tube which may be used is the so-called variable mu tube in which the amplification factor and the internal resistance depend on the biasing voltage of a grid. If the E. M. F. delivered by the pilot wire and its associated circuit is applied to a grid of the tube its amplification factor, and therefore gain, is varied accordingly. Such circuits are disclosed in various patents, such for instance as that to Dutton 1,849,141, March 15, 1932 and that to Corderman 1,871,959, August 16, 1932.

The gain in such circuits as disclosed in the two patents cited above is independent, or substantially independent, of the frequency so that the frequency characteristic of the transmission line, with its gain control and other repeaters, is the same whether the gain introduced by the repeater is at one value or another. In many cases I find it desirable to arrange the circuit in such a manner as to alter the frequency characteristic when the gain is changed. I find this particularly advantageous, for example, if such devices are used in regulating repeaters in connection with automatic pilot wire regulators of the kind described in the patents cited above. My invention consists in introducing such modification in frequency characteristic when the gain is changed, by adding reactances to the load impedance of the tube so that the load impedance,

and consequently the gain change due to changing the tube impedance, is different at different frequencies. This is accomplished in part by choosing a tube for the gain control portion of the circuit which not only has a variable mu but especially a variable internal plate impedance, both of these varying in accordance with the bias of a grid of the tube.

The invention will be better understood by reference to the following specification and accompanying drawing, in which Figure 1 shows a circuit embodying my invention; Fig. 2 is a diagrammatic sketch to illustrate the principles involved in my invention; and Fig. 3 shows characteristics of circuits to be used.

Referring more particularly to Fig. 1, there is shown an incoming line L_1 and an outgoing line L_2 at a repeater point. The repeater consists of a plurality of stages of vacuum tube amplifiers, in this case shown as two stages, the first of which is used for gain control as well as amplification and the second of which makes up such additional amplification as is desired at this repeater point. The first tube 10 may be variable mu type of tube, the mu or amplification factor depending upon the bias of a grid element. In this particular case the tube is shown as having four elements, the one element 11 being the control grid and the element 12 being a screen grid. The control grid may be one of non-uniform grid mesh or spacing. Such a tube when properly designed has the characteristic that its amplification factor is modified by the bias of the screen grid 12, and at the same time the internal impedance of the tube is modified. In general, when the grid 12 is made more positive the amplification factor is decreased and the internal impedance is decreased, and I make use of these particular characteristics in carrying out my invention.

Although in Fig. 1 is shown a four-electrode variable mu tube with the mu and impedance controlled by variations in the potential of grid 12, it is evident that other types of tubes may be used and that the control may be obtained by variations in the potential of any of the electrodes, such for example as by variations in the potential of the control grid or the plate, provided such variations change the impedance of the tube.

The output circuit of the tube 10 is shown as consisting of an inductance 14 and condenser 15 in parallel, the coil 14 at the same time acting as the primary of a transformer T the secondary of which is associated with the input circuit of

the amplifier tube 22. Suitable plate and biasing voltages are supplied for each of the elements to bring them to the voltages desired for normal operation of the tubes.

5 In the event that the circuit is used to control the transmission gain over a plurality of lines, such as L_1 , by means of a pilot wire 17, then the potential of the grid 12 is controlled by an E. M. F. delivered from the pilot wire circuit. In this particular figure the pilot wire 17 is shown as having in series with it a resistance 18 and a battery 19. Current from the battery flows through the pilot wire and the resistance 18, and the potential drop across the resistance 18 is applied to the grid 12 in the manner shown. If, now, the resistance of the pilot wire changes due to changes in temperature, then the potential drop across the resistance 18 also changes, and the potential of the grid 12 is accordingly modified. In case the resistance of the pilot wire rises, it is desired that the gain of the tube 10 shall be increased, that is, the potential of the grid 12 shall be made more positive. This may be accomplished in the circuit of Fig. 1 by having the battery 19 poled as indicated. The increase of potential of the grid 12 accomplishes two things—namely, it decreases the amplification factor and it decreases the internal impedance, but generally in such amounts as to increase the effective gain of the tube 10. If the load circuit of the tube 10 were non-reactive, that is, independent of frequency, then the gain introduced by the tube 10 would be the same for all frequencies. In my invention, however, I desire to depart from this condition for reasons set forth above, and I do this by making the load circuit reactive, as indicated at 14 and 15. This circuit, being a parallel tuned circuit, has its maximum impedance at the frequency for which the circuit is tuned, and the impedance falls off for both higher and lower frequencies. The steepness at which this impedance falls off can be controlled by the resistance of the circuit, here shown at 21.

45 The operation of the circuit is seen in a simpler way by reference to Fig. 2, in which there is shown a source of alternating voltage 26 corresponding to the equivalent voltage set up in the output circuit of the tube 10 by an alternating voltage on the grid 11. The magnitude of the voltage 26 will depend on the μ of the tube, that is, upon the potential of the grid 12. In series with 26 is shown a variable impedance 27 which corresponds to the internal plate resistance of the tube 10, the value of this internal impedance being dependent on the potential of the grid 12. In series with 26 and 27 is shown the anti-resonant circuit 28 corresponding to the circuit 14 and 15 of Fig. 1. The behavior of the circuit 1 will be similar in every respect to that of the circuit 2.

An understanding of the invention is still further given by reference to Fig. 3, in which the gain of an amplifier plotted in decibels is shown as ordinate and the frequency is shown as abscissa. The effective gain of the tube can be expressed by the relation

$$\mu = \mu_0 \frac{Z_e}{Z_e + Z_i}$$

70 where μ_0 is the amplification factor of the tube under any given set of conditions, Z_e is the external impedance of the circuit and Z_i is the internal impedance of the tube. The effective

amplification can thus be altered either by modifying μ_0 or by modifying the fraction

$$\frac{Z_e}{Z_e + Z_i}$$

80 In my invention both of these are modified to bring about the desired results. For a given value of μ_0 the circuit will have maximum gain at the frequency for which the circuit 14—15 is anti-resonant, for at this frequency Z_e has a large value compared to which Z_i is quite small. At other frequencies the impedance factor becomes smaller, so that the gain as a function of frequency might be represented by the curve *a* of Fig. 3. If, now, we consider μ_0 as being constant and the internal impedance decreases due to more positive grid, then the effective gain is increased less at the tuning frequency than at other frequencies as indicated by curve *b*. On the other hand, if the grid becomes less positive the internal impedance increases and the loss is less at the tuning frequency than elsewhere, as indicated by curve *c*. In case μ_0 is not constant the curves *b* and *c* will be moved parallel to themselves in a vertical direction. It is this characteristic of the tube 10 and its immediately associated circuits that I wish to attain.

While this circuit arrangement may be used in a variety of places, I would give as an illustration that of a telephone line with a signal covering the speech range of frequencies. In general, the loss of such a line increases as the frequency goes up, and it will be desirable that at the repeater station such differences in loss should be compensated for, and this may be done if the overall characteristic of the repeater station is complementary to the line characteristic. In addition, however, the line may be of a type in which the variation of gain, as temperature changes, is greater for high frequencies than for low frequencies, and it is in this connection especially that my invention finds applicability, in the manner described in greater detail in connection with Fig. 3. The tuning frequency would be chosen so any desired portion of the characteristic comes into use.

It will be understood that while the load circuit of the tube 10 is shown as an anti-resonant circuit, it may be desirable to use other types of reactive networks which might take on quite a complicated form in order to yield the frequency characteristic which is desired. Also, in the introduction of such a network to give the desired difference in gain variation at different parts of the frequency spectrum, an undue distortion of the voice current might be introduced. This can be overcome by inserting at some suitable part of the circuit, such as in the output circuit of the tube 22, a network 24 which is complementary to the network in the output of the tube 10. In the circuit of Fig. 1, for instance, where the one circuit is a parallel tuned circuit, the other is shown as a series tuned circuit, again with a series resistance to adjust the sharpness of the tuning of the circuit 24.

140 The operation of the network 14, 15 in introducing transmission loss is dependent on the internal impedance of the tube 10, and is different for different frequencies. The same may be said of network 24 with respect to the tube 22, and the object of the invention is to give the system from 10 to 24 such a transmission characteristic that it compensates for the changes in transmission characteristics of the line section L_1 to give an overall characteristic which remains constant.

Since the transmission characteristic of the line section L₁ shows an increased loss as the temperature rises, it is necessary to increase the gain from 10 to 24. Further, since the increased loss, that is, the change in transmission characteristic, is a function of frequency as well as temperature, it becomes important to make the gain from 10 to 24 also a function of frequency in the reverse or complementary manner, thus maintaining an overall constant characteristic. At all temperatures the tube 10 and network 14, 15 would possess frequency discrimination of some sort and this is not desirable, for at some temperature, say the average temperature, the section has presumably been adjusted by equalizing networks, etc., to a satisfactory condition. The frequency discrimination or distortion from 14, 15 should, therefore, be balanced out at that temperature. This is accomplished by the network 24, which is of such character that at a certain pilot wire temperature, that is, a certain biasing of grid 12, the network 14, 15, along with the network 24, are complementary and just compensate each other so far as frequency is concerned. With the circuit shown in Figure 1 the behavior of 22 and 24 remains substantially constant but the frequency discrimination of 10, taken with 14, 15, changes with temperature and is so designed as to change inversely as the change in frequency discrimination of the line itself, thus maintaining an overall unchanged characteristic at all temperatures.

It will be apparent that many other variations may be made in this circuit and that it will find application in numerous places other than the one given for illustrative purposes, all without departing from the spirit of this invention.

What is claimed is:

1. In a gain control circuit, a vacuum tube amplifier having a grid, the amplification and the internal impedance of the tube being dependent on the biasing voltage on this grid, and an impedance which is a function of frequency in the output of the vacuum tube, the characteristic of the last mentioned impedance being such that with change of the bias on this grid the gain of the tube is altered, and altered by different amounts for different frequencies and means for controlling the said grid bias in accordance with the required gain.

2. In a transmission line, a repeater station, a pilot wire gain control system associated therewith including a pilot wire and a connected circuit which are adapted to deliver an electromotive force in accordance with changes in pilot wire resistance, a vacuum tube amplifier asso-

ciated with the transmission line, the tube having an amplification factor and an internal impedance depending on its biasing voltage, means for biasing the tube in accordance with the pilot wire electromotive force, and an impedance element in the output circuit of the tube, the impedance of said element being a function of the frequency of the current therethrough and having a range of substantially different preassigned values corresponding to the useful frequencies on the transmission line such that the overall gain of the tube is a function of the frequencies mentioned within said range in a preassigned manner.

3. The combination of claim 2 characterized by the fact that the amplifier thereof feeds into another amplifier to give the necessary overall gain for the repeater station, and further characterized by the fact that the impedance load of the succeeding amplifier is such as to compensate at one temperature for frequency discrimination due to the gain control tube.

4. In a transmission line subject to changes in transmission loss with temperature, these changes being a function of frequency, a repeater station, a pilot wire gain control system associated therewith including a pilot wire and a connected circuit which are adapted to deliver an electromotive force in accordance with changes in the pilot wire resistance, an amplifier associated with the transmission line, the amplifier having a grid and having an amplification factor and an internal impedance depending on a biasing voltage on said grid, means for biasing the said amplifier grid in accordance with the pilot wire electromotive force, and networks associated with the amplifier and cooperating with the variable internal impedance to compensate for the variations in transmission loss at different frequencies.

5. In a gain control circuit, a gain control vacuum tube amplifier having a grid, the amplification and the internal impedance of the tube being dependent on the biasing voltage on said grid, an impedance which is a function of frequency in the output of the vacuum tube, the characteristic of the last mentioned impedance being such that with change of bias on said grid the gain of said tube is altered and altered by different amounts for different frequencies, a second impedance associated with the control circuit and of such characteristic as to compensate at one gain level for frequency discrimination due to the gain control tube, and means for controlling the grid bias of said control tube in accordance with the required gain.

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