Sept. 29, 1925. 1,555,037

J. S. STONE

RESISTANCE AMPLIFIER

Filed Oct. 4, 1921

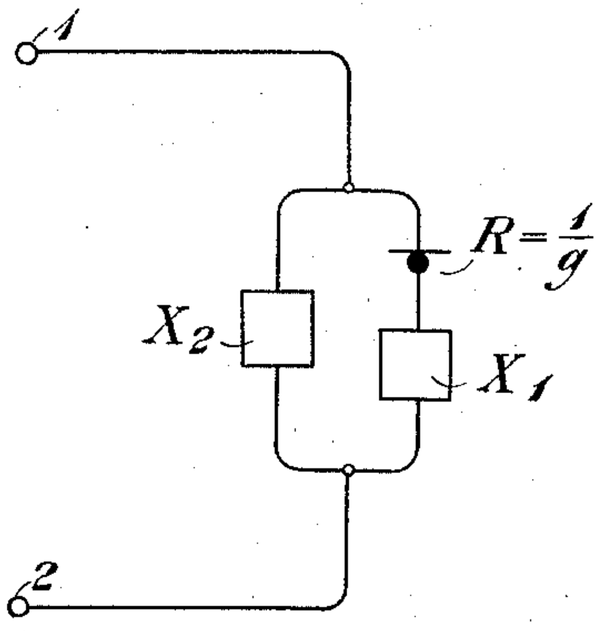

Fig. 1

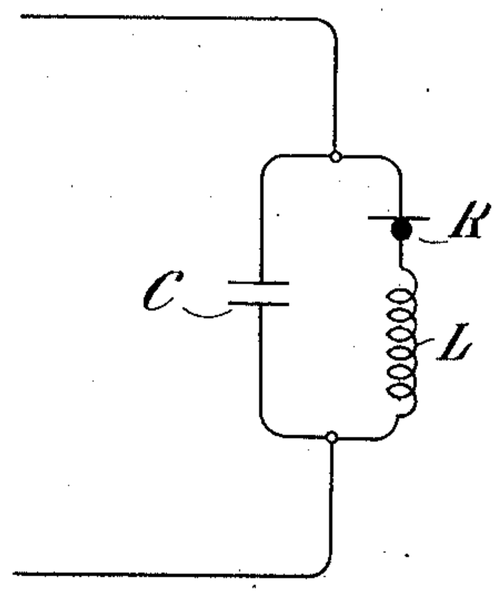

Fig. 2

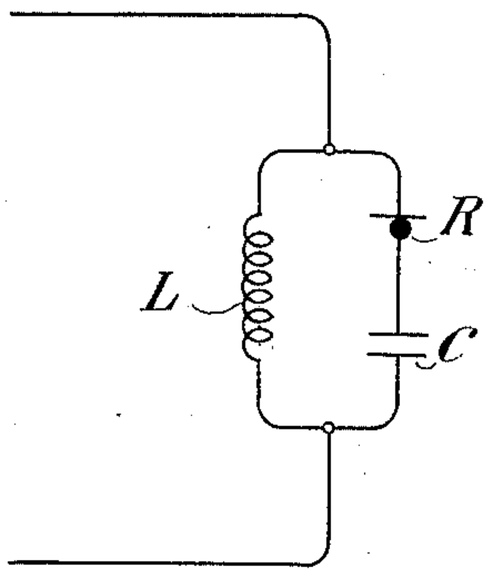

Fig. 3

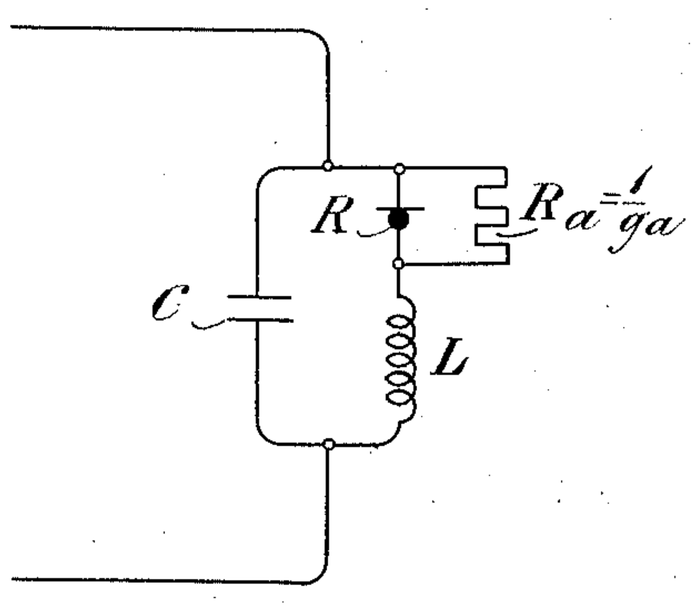

Fig. 4

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UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF SAN DIEGO, CALIFORNIA, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

RESISTANCE AMPLIFIER.

Application filed October 4, 1921. Serial No. 505,351.

To all whom it may concern:

Be it known that I, JOHN STONE STONE, residing at San Diego, in the county of San Diego and State of California, have invented certain Improvements in Resistance Amplifiers, of which the following is a specification.

This invention relates to methods and means for amplifying resistances, and in particular is adapted for use in cases where a telephone transmitter of the microphone type is to be used in a circuit in which the apparent resistance of the transmitter, or the impedance which it offers in the circuit, should be larger than the actual ohmic resistance of the transmitter. That is, the invention is a method and means for magnifying or amplifying a resistance.

It occurs in certain circuits, such as high frequency circuits, that the impedances involved are quite high and in case any apparatus, such as a telephone transmitter or a telephone receiver, is to be used therein, high efficiency requires that the impedance offered by said apparatus be of about the same magnitude as the remainder of the circuit with which it is associated. In general, however, the resistance of a telephone transmitter is quite low and is not, therefore, well adapted for use in such circuits.

Heretofore it has been common to increase the apparent resistance of the transmitter or receiver or other element by placing it in the secondary of a step-down transformer, but the transformers are never perfect and offer a certain leakage reactance, depending upon the frequency of the oscillations in the circuit. This leakage reactance can, in part at least, be neutralized by a series condenser in the primary or the secondary of the transformer, but since the leakage reactance is itself a function of the resistance of the element, such neutralization can never be completely effective, and the primary circuit of the transformer cannot be maintained in resonance for a given frequency when the resistance is varied, as is the case where the resistance is a telephone transmitter.

My invention will be better understood by reference to the accompanying drawing, taken in connection with the specification. In this drawing, Figure 1 is a generalized circuit showing connections which will give the desired results, and Figs. 2, 3 and 4 are specific forms of circuits.

In case the resistance element is a microphone transmitter of resistance R or conductance g an increase of pressure on the diaphragm results in a decrease of resistance or an increase of conductance, and for small changes, the increase in conductance is approximately proportional to the increase in pressure, so that its conductance at any pressure is given by

$$g=g_0p$$

where g_0 is the conductance at unit pressure and p is the instantaneous value of the pressure. In case the pressure on the diaphragm is varied in accordance with a sine function, there will be the relation

$$g=g_0(p_0+p_1 \sin \omega t).$$

An analytical consideration of the circuit of Fig. 1 will be of assistance in understanding the invention, in which figure R is a resistance such as a telephone transmitter, and X_1 is a reactance in series with R, while X_2 is a reactance in shunt to R and X_1. In the case of the circuit of Fig. 1, Fig. 2 and Fig. 3, the admittance y as viewed from outside the loop circuit, will be given by

$$y=\frac{1}{R\pm jX_1}+\frac{1}{\mp jX_2}$$

where

$$j=\sqrt{-1}.$$

Therefore

$$y=\frac{RX_2\pm j\,(X_1(X_1-X_2)+R^2)}{X_2(X_1^2+R^2)}$$

If X_1 and X_2 each be made equal to s, then

$$y=\frac{R}{s^2}\frac{1}{\sqrt{1+\frac{R^2}{s^2}}}e^{j\tan^{-1}\pm\frac{R}{s}}$$

If $\frac{s}{R}$ be made large compared to unity, y becomes sensibly a pure conductance

$$g'=\frac{R}{s^2}\equiv\frac{1}{s^2g}\text{ and }R'\equiv\frac{1}{g'}=\frac{s^2}{R'}$$

where R′ is the apparent resistance of the transmitter. From this last equation it is seen that under the imposed conditions of

$$X_1=X_2=s\text{ and }sg\text{ or }\frac{s}{R}$$

large compared to unity the resistance of the transmitter has been multiplied by

$$\frac{s^2}{R^2}.$$

In the case of Fig. 2, $X_1=L\omega$ and $X_2=\frac{1}{C\omega}$ while in case of Fig. 3, $X_1=\frac{1}{C\omega}$ and $X_2=L\omega$ whence in either case $s^2=\frac{L}{C}$.

The condition $X_1=X_2$ is realized by making $LC\omega^2=1$. When therefore sg is large compared to unity and $CL\omega^2=1$.

$$g'=\frac{1}{s^2g}=\frac{1}{s^2g_0p_0}\left[1-\frac{p_1}{p_0}\sin\omega t+\left(\frac{p_1}{p_0}\sin\omega t\right)^2\text{------}\right]\quad(2)$$

If $\frac{p_1}{p_0}$ is small compared to unity

$$g'=\frac{1}{s^2g_0p_0}\left(1-\frac{p_1}{p_0}\sin\omega t\right)\quad(3)$$

If $\frac{p_1}{p_0}$ is not sufficiently small the higher power terms in equation (2) will cause distortion. This may be reduced by the suitable use of resistance and part of my invention consists in such use. This is shown in Fig. 4, where a reistance R_a of conductance g_a is connected in shunt to R. In such case the quantity g in equation (2) is to be replaced by (g_a+g) and it becomes

$$g'=\frac{1}{s^2(g_a+g)}=\frac{1}{s^2(g_a+g_0p_0+g_0p_1\sin\omega t)}\quad(4)$$

If now g_a is made sufficiently large so that

$$\frac{g_0p_1}{g_a+g_0p_0}$$

is small compared to unity, equation (4) becomes

$$g'=\frac{1}{s^2(g_a+g_0p_0)}\left(1-\frac{g_0p_1}{g_a+g_0p_0}\sin\omega t\right)\quad(5)$$

and thus substantially distortionless transmission is obtained.

From the foregoing it will be seen that by placing the transmitter or other resistance element in a resonant loop circuit the apparent resistance of the element will be magnified by the factor $(1+s^2g^2)$ and that distortion may be diminished by placing a second resistance in shunt to the resistance to be magnified. It will further be seen that placing a resistance shunt about a telephone transmitter will improve the quality of the transmission whether or not the transmitter be placed in the resonant loop circuit, and that when it is so placed in a resonant loop circuit the greater the amplification the less distortion will there be.

What is claimed is:

1. The method of reducing the distortion in a telephone transmitter which consists in connecting a resistance in shunt to said transmitter.

2. A circuit adapted to carry an alternating current and containing a resistance element, means for amplifying the apparent resistance of the element comprising a series inductive reactance and a shunt capacity reactance and a resistance in shunt to the said element to correct for distortion.

3. A circuit adapted to amplify the resistance of an element for alternating current of a certain desired frequency, said circuit comprising a resonant loop circuit in which the ratio of inductance to capacity is relatively large, the resistance element being connected in series in one side of said loop circuit, and a second resistance connected in shunt to said resistance element whereby the complete circuit has an increased resistance at the desired frequency and is substantially free from distortion with variation of the resistance of said element.

4. In combination in a network, a resistance of variable value, a shunt resistance associated therewith and of constant magnitude considerably greater than any value attained by the said variable resistance, and means comprising reactance elements to increase the resistance of the network considerably above that of the said two resistances in parallel.

5. In combination, a telephone transmitter, a reactance in series therewith, an opposite reactance in parallel with said series combination and a relatively large constant resistance shunting the said transmitter whereby the resistance of the combination is increased over that of the said transmitter

and is more constant than that of the said transmitter.

6. In combination, a variable resistance and a shunt resistance of substantially greater magnitude and constant value, a reactance in series to said resistances in parallel and an opposite reactance in parallel with the entire foregoing combination whereby the resistance of the entire combination is greater than of said variable resistance and more nearly constant.

In testimony whereof, I have signed my name to this specification this 26th day of September, 1921.

JOHN STONE STONE.