Sept. 22, 1936. T. NAKASHIMA ET AL 2,055,156

AMPLIFYING SYSTEM FOR TELEVISION

Filed Nov. 8, 1932 2 Sheets-Sheet 1

Fig. 1.

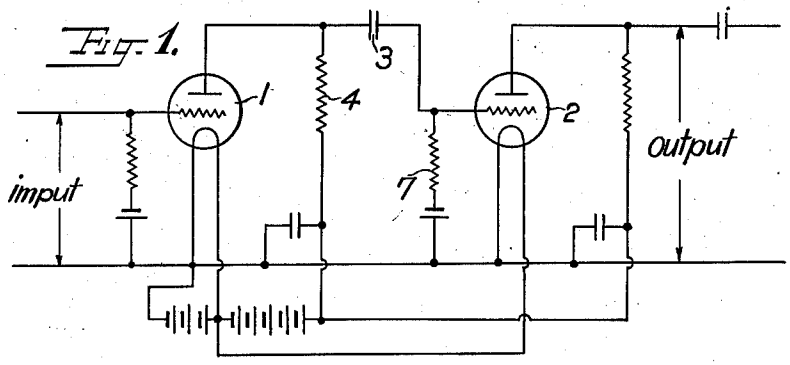


Fig. 2.

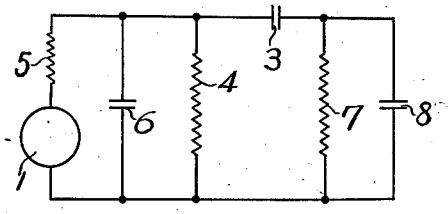
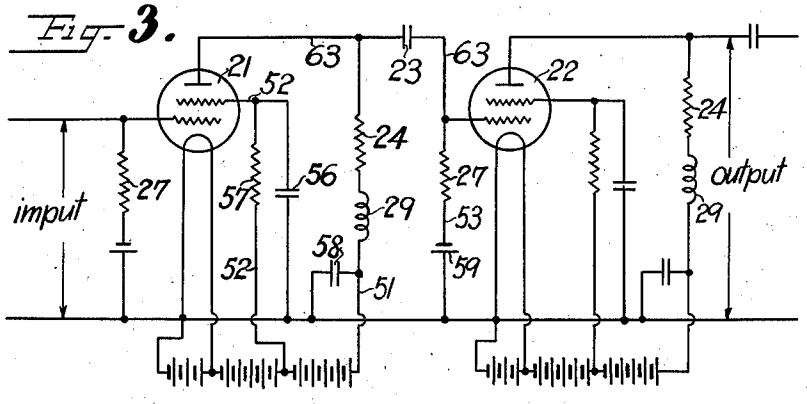


Fig. 3.



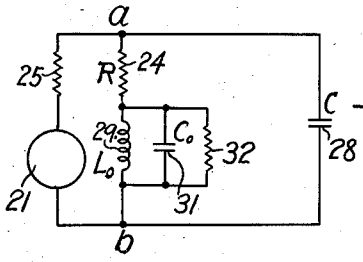


Fig. 4.

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Fig. 5.

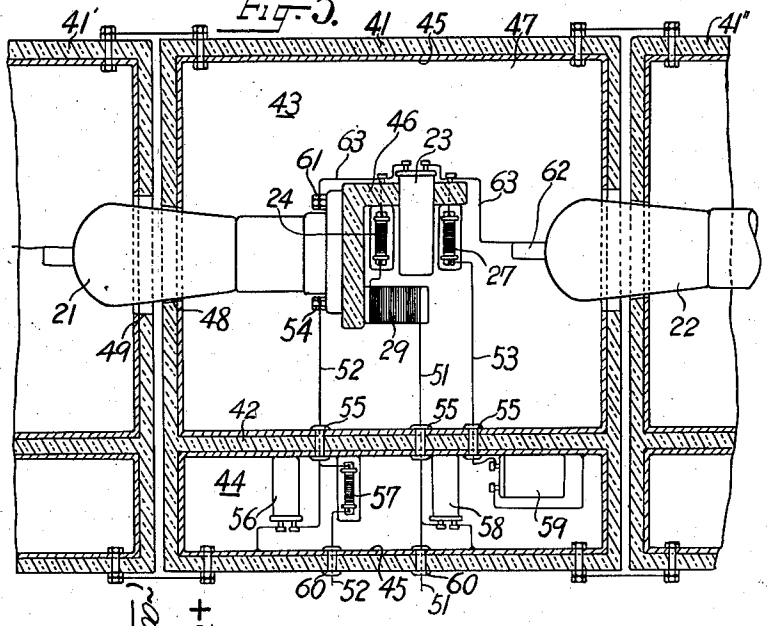


Fig. 6.

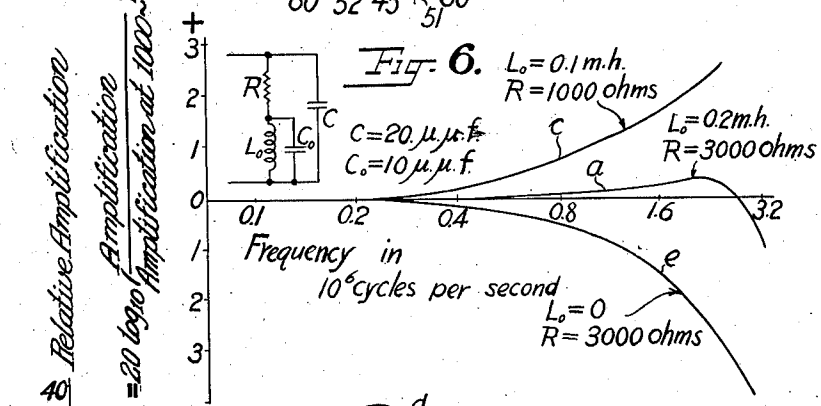
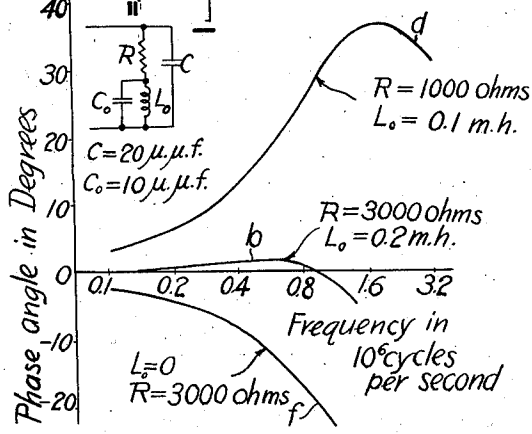


Fig. 7.



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2,055,156

AMPLIFYING SYSTEM FOR TELEVISION

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Application November 8, 1932, Serial No. 641,706
In Japan January 2, 1932

4 Claims. (Cl. 179—171)

Our invention relates to improvements in amplifying systems and more particularly to improvements in systems for amplifying photo-electric current in television transmitting systems.

One object of our invention is to provide means for amplifying image current or photo-electric current in television transmitting systems at substantially a constant degree throughout the wide frequency range from about ten cycles to several hundred thousand cycles, say 250,000 cycles or over, per second.

Another object of our invention is to provide amplifying apparatus with extremely low distributed static capacity.

A further object of our invention is to provide means for compensating for image-current deviation at the upper or high-frequency region of the frequency range.

A further object of our invention is to provide means for compensating for the lowering amplification characteristic at the upper region of the frequency range.

A still further object of our invention is to provide a system for amplifying a current whose frequency varies from about ten cycles to several hundred thousand cycles per second at substantially a constant degree of amplification.

Other objects and features of our invention will be apparent from the appended claims and the following description in connection with the accompanying drawings, wherein:

Fig. 1 shows the usual capacity-coupled resistance amplifier system for radio telephony.

Fig. 2 shows an equivalent circuit of one stage of the system shown in Fig. 1.

Fig. 3 is a diagrammatic illustration of one embodiment of our invention.

Fig. 4 shows an equivalent circuit of one stage of the system shown in Fig. 3.

Fig. 5 shows diagrammatically, partly in section, a preferred construction and arrangement of an amplifying apparatus according to our invention provided with means for minimizing the distributed capacity.

Figs. 6 and 7 are curves showing amplification characteristics and phase characteristics, respectively, of our improved system.

In the system for televising moving pictures or other moving objects, it is desirable to use a large number of view-elements, or picture-elements, say ten thousand or above, in order to secure a clear reproduction of televised views, and if such a large number of view-elements are used, the modulating current variation takes place at a rate corresponding to a frequency which varies from about ten cycles to several hundred thousand cycles per second according to the rate of change of the darkness of successive view-elements swept by a scanning light-beam.

Referring to Fig. 1, the system shown comprises a triode amplifier tube 1 whose grid circuit is connected to a source of current to be amplified, not shown, and the plate circuit of which is coupled to the grid circuit of a similar amplifier tube 2 of the succeeding stage, through a coupling condenser 3. The plate circuit of the tube 2 is coupled to a succeeding amplifier or a modulator, not shown, in the usual manner.

The plate circuit of the amplifier tube 1 includes a coupling resistance 4 in series, and the potential difference across the resistance is applied to the grid electrode of the second tube 2.

As far as the frequency range under consideration is concerned, an equivalent circuit for the tube 1 and its associated parts may be drawn as shown in Fig. 2, wherein 5 represents the internal resistance of the tube 1, and 6 the static capacity of the tube 1 together with wirings therefor. 7 shows the grid resistance and 8 the effective static capacity of tube 2 and its wiring.

According to our invention, in order to obtain an adequately constant degree of amplification at the low frequency region of the frequency range, including 10 cycles per second, the reactance due to the coupling condenser 3 at such low frequency should be negligible in comparison with the grid resistance 7. For example, if the condenser 3 has a capacity of 0.1 microfarad, the resistance 7 should be more than 1.5 megohms.

On the other hand, in order to obtain constant amplification characteristic at the upper region of the frequency range, including several hundred thousand cycles per second, the resistance 4 should be negligible in comparison with the reactance due to the capacities 6 and 8 at such high frequency. However, the reduction in the value of resistance 4 causes a reduction in the degree of amplification, and in order to obtain as high as possible a degree of amplification, it is proposed to reduce the capacities 6 and 8, thus permitting the use of a relatively high resistance 4. A preferred construction suitable for such reduction in the capacities is shown in Fig. 5, and will be described hereinafter.

With the above arrangement, we obtain a substantially constant degree of amplification throughout the whole frequency range from about ten to several hundred thousand cycles

per second, but we have found that, at the upper region of the frequency range, some phase displacement of the output current from the input and a lowering of the degree of amplification occurs, whereby the received image will be blurred. In order to prevent such change of amplification, we propose to use a self-inductance coil in series with the resistance **4**.

Referring to Fig. 3, tetrode tubes **21** and **22** are utilized as amplifiers. While we show only two such tubes, it will be understood that this is merely by way of example and there is no limitation as to the number of amplifier tubes utilized. Tetrode tubes have no feed-back action, and have a relatively high coefficient of amplification. The plate circuit of each tube includes a repeating resistance **24** corresponding to resistance **4** of Figure 1 and a self-inductance coil **29**, respectively, and the succeeding two stages are coupled with each other through a coupling condenser **23**. The grid circuit of each tube includes a grid resistance **27** corresponding to **7** of Figure 1.

As far as the upper portion of the frequency range in question is concerned, an equivalent circuit may be drawn as shown in Fig. 4, in which **25** represents the internal resistance of the first amplifier tube **21**, and **28** the static capacity of the whole circuit, the capacity **28** corresponding to the sum of the capacities **6** and **8** of Fig. 2. The inductance coil **29** has distributed capacity **31** and resistance **32** which represents all the energy losses within the coil **29**. As will readily be understood, the self-inductance **29** affects the whole circuit in the reverse sense to the capacity **28**.

Assuming that R represents the resistance value of the resistor **24**, L_0 the self-inductance of the coil **29**, C_0 the capacity **31**, C the capacity **28**, ω_0 the angular velocity of the natural frequency of the coil **29**, and ω the angular velocity of the frequency of amplified current, and also that the resistance **32** is infinite or there is no energy loss within the coil **29**, as is permissible for the frequency range under question, the imaginary component of the resultant impedance Z of the circuit between the two points *a* and *b* shown in Fig. 4 is

$$jX=j\omega L_0\left[1-\frac{\omega^2}{\omega_0^2}\left(1+\frac{C}{C_0}\right)\right]-j\omega CR^2\left(1-\frac{\omega^2}{\omega_0^2}\right)^2 \quad (1)$$

For any frequency of amplified current within the frequency range under question, the ratio ω/ω_0 may be equal to or smaller than 0.4, and

$$\left(\frac{\omega}{\omega_0}\right)^4$$

may be neglected, and the imaginary component will be represented by

$$jX=j\omega L_0\left[1-\left(\frac{\omega}{\omega_0}\right)^2\left(1+\frac{C}{C_0}\right)\right]-j\omega CR^2\left[1-2\left(\frac{\omega}{\omega_0}\right)^2\right] \quad (2)$$

We can make the ratio C/C_0 unity, by connecting additional capacitance in parallel with the coil **29**, and

$$jX=j\omega L_0\left[1-2\left(\frac{\omega}{\omega_0}\right)^2\right]-j\omega CR^2\left[1-2\left(\frac{\omega}{\omega_0}\right)^2\right] \quad (3)$$

For the purpose of the present invention to prevent any phase displacement of amplified current, the imaginary component *jX* should be preferably zero, and we obtain a condition as follows:—

$$\omega L_0\left[1-2\left(\frac{\omega}{\omega_0}\right)^2\right]=\omega CR^2\left[1-2\left(\frac{\omega}{\omega_0}\right)^2\right]$$

$$\therefore L_0=CR^2 \quad (4)$$

This condition is an ideal one, and in practicing our invention, it is to be understood that the ratio C/C_0 may be other than unity, and there may be a slight energy loss within the coil **29**, without departing from the spirit of the invention.

If K is a factor representing the deviation, $L_0=CR^2\times K$, then

when $C/C_0=0.5$, $K=0.89$
when $C/C_0=1$, $K=1$
when $C/C_0=2$, $K=1.11$
when $C/C_0=3$, $K=1.88$
when $C/C_0=4$, $K=3.40$

L_0 is, therefore, as nearly equal to CR^2 ($L_0=CR^2$) as C/C_0 differs from 0.5 to 2, provided that an error of about 10% is permissible. For the purpose of applicant's invention C is nearly equal to C_0 when C/C_0 is from 0.5 to 2. In Figs. 6 and 7 curves *a* and *b* show that the deviation of amplification and the phase displacement is negligible for the frequencies below about 0.6 mega-cycles with $C/C_0=2$.

In Fig. 6 the ordinate is scaled in transmission units, taking amplification degree at 1000 cycles as unity. As is well known, from about five hundred to several thousand cycles, i. e., at a frequency which is so low that static capacities of amplifier tubes, etc., have no effect, but is so high that coupling capacity and grid resistance have no effect, the amplification degree is constant. This constant amplification degree A_0 is taken as a standard, and if A is the amplification degree at any high frequency, A/A_0 shows the percentage variation of amplification degree from the standard A_0 for varying frequencies. Such an expression of relative amplification is a common practice (see "Experimental Television Transmitting Apparatus" by R. D. Kell, Proceedings of the Institute of Radio Engineering, Dec. 1933, vol. 21, No. 12, p. 1688).

It is also a common practice to show amplification degree in decibels N_{db},

$$N_{db}=20\log_{10}\left(\frac{V_2}{V_1}\right)$$

where V_1 is the input voltage and V_2 is the output voltage of an amplifier. (See Transmission Networks and Wave Filters, by T. E. Shea, p. 47.)

We use decibels

$$20\log_{10}\left(\frac{A}{A_0}\right)$$

as the scale of the ordinate in Fig. 6 instead of

$$\frac{A}{A_0}$$

For the standard amplification degree A_0, the zero line is utilized and the deviation can be shown by positive or negative value depending whether the deviation is above or below the standard.

In a practical design of our improved system, UY—224 tubes are used for amplifiers **21** and **22** and the capacity C will be about 20 micro-micro-farads. The amplification-factor and phase-displacement characteristics are shown in Figs. 6 and 7, respectively.

If the Equation (4) is satisfied for the UY—224 tubes, L_0 becomes 0.18 millihenry. When we use

a resistor with R of 3000 ohms and a self-inductance coil with L_0 of 0.2 millihenry having distributed capacity of 10 micro-microfarads, capacity C being 20 micro-micro-farads we obtain characteristic curves *a* and *b* in Figs. 6 and 7, respectively in which the Equation 4 is approximated.

Our invention further includes a compensator for the drop and the phase displacement of the output voltage of photo-electric current, which are inevitable at high frequencies, due to static capacity of photo-electric-cell circuit, to scanning operation where the scanning light-beam has an appreciable cross-sectional area, and to static capacity of modulator tubes, etc. Such a compensator may be used in cascade connection with amplifiers, and a generally flat amplifying characteristic can be obtained for the whole amplifier circuit.

Our compensator has generally a construction similar to our amplifier exemplified in Fig. 3, but it must be so designed or adjusted that the undesirable effects of the above-mentioned static capacities and scanning operation are neutralized, in other words, the compensator should have over-compensation characteristics at high frequencies, as compared to the case when it is used as a pure amplifier. For this purpose, the resistance R must be further lowered, say to 1000 ohms, and, at the same time, the inductance L_0 must also be further lowered, e. g., to 0.1 millihenry. By such a reduction in the resistance value, it may happen that the absolute amplification is necessarily reduced and consequently material amplification is not effected at lower frequencies, but material amplification is obtained at least at higher frequencies due to the raising characteristic of amplification which is caused by the increase in the effect of inductance L_0 at high frequencies. The curves *c* and *d* in Figs. 6 and 7, respectively, show the over-compensation characteristics of our compensator as above-specified, and these characteristic curves *c* and *d* have substantially similar shapes but opposite sense to the corresponding characteristic curves, not shown but similar to *e* and *f*, respectively, of the drop and the phase displacement of the output voltage of photo-cell current, due to static capacity of photo-electric-cell circuit, to scanning operation where the scanning light-beam has an appreciable cross-sectional area, and to static capacity of modulator tubes, etc., and it will now be obvious that the drop and the phase displacement are adequately compensated for by the compensator according to our invention.

In Fig. 5 is shown a preferred construction and arrangement of our improved amplifying apparatus in which distributed capacity is reduced to a minimum. The apparatus comprises a cabinet **41** of insulating material, and having a partition **42** therein forming two compartments or enclosures **43** and **44**. Each compartment is shielded by metallic plates such as copper plate **45** forming a static and magnetic shield.

Within the upper compartment **43** is provided a shelf **46** of insulating material at the centre portion of the compartment and secured to and supported from one wall **47** of the cabinet. The shelf carries thereon the amplifier tube **21**, repeating resistance **24**, self-inductance coil **29**, coupling condenser **23**, and grid resistance **27** for the next amplifier tube **22**.

The tube **21** extends laterally from the shelf **46** into the upper compartment of the preceding cabinet **41'** for the preceding amplification stage, through openings **48** and **49** provided in the corresponding side walls of the cabinets, and substantially half the length of the tube **21** lies within each of the cabinets **41** and **41'**.

The tube **22** and its associated parts are similarly arranged in the next cabinet **41''**.

Wires **51**, **52**, and **53**, respectively from the coil **29**, the screen grid terminal **54** of the tube **21**, and the resistance **27**, extend downward, through insulating bushings **55** mounted in the partition **42**, into the lower compartment **44**. Within the compartment **44** are disposed a screen grid bypass condenser **56**, a screen grid resistance **57**, a plate bypass condenser **58**, and a grid bias battery **59**. The condensers **56** and **58**, and the battery **59** are connected between the respective wires **52**, **51** and **53**, and the grounded lining **45** of the lower compartment **44**, while the wires **52** and **51** extend through insulating bushings **60** in the bottom wall of the cabinet and are respectively connected to energizing sources outside the cabinet.

The filament terminals, not shown in Fig. 5, are connected to the energizing source outside the cabinet by means of wires, not shown, which extend through the back wall **47** of the cabinet. The coupling condenser **23** is connected between the plate terminal **61** of the tube **21** and the control grid terminal **62** of the succeeding tube **22**, by wires **63**.

Since the parts **23**, **24**, **27** and **29** are centrally disposed with respect to the grounded lining **45** of the upper compartment **43**, and since the connecting wires **51**, **52**, **53** and **63** are of minimum length by proper arrangement of the parts, the distributed capacity of the parts and wiring is obviously minimized.

The capacity is the element at the high frequency end, that causes the drop in amplification. Assuming that the amplification resistance is constant, and that an inductance is put in to balance the capacity, the relative rate of amplification will necessarily be reduced when the inductance is reduced. However, if the amplification resistance is reduced to one third, the lower limit of high frequency, at which the capacity begins to affect the amplification, is increased to about three times, in other words, the effect of the capacity on the amplification at any high frequency will be reduced to one third by the above-mentioned reduction in the resistance. In Fig. 6, the curve *c* is shown within the frequency range in which the capacity does not substantially affect the amplification by the above reasons.

Thus, within the frequency range corresponding to Fig. 6, the relative rate of amplification can be determined by the relative amount of the inductance and resistance.

It must also be noted that, the effect of inductance at any high frequency becomes about three times conspicous when the resistance is reduced to one third, and consequently, the relative rate of amplification is not necessarily reduced by any reduction in inductance only. The curve *c* represents the case when the amplification is determined by the relative amount of resistance and inductance and shows the raising characteristic due to the effect of inductance.

While we have described particular means for practising our invention, it will be recognized that this is only by way of illustration of general principles and that our invention is not limited to that particular means, but various

changes, modifications and alterations may be made without departing from the spirit and scope of the invention as defined in the appended claims.

We claim as our invention:—

1. In an amplification system for television in which the number of view elements is more than five thousand, the combination with two vacuum tubes, each having an anode, a cathode, a grid and a grid shield, a resistor connected between said anode and said cathode of one of said tubes, and a condenser connected between the anode of said one of the vacuum tubes and the grid of the other of said vacuum tubes, of means for reducing the capacity of said tubes and connections thereof to such a low value that the resistance of said resistor is negligible in comparison to the reactance of said capacity at the high frequencies corresponding to said number of view elements, and a self-inductance coil connected in series circuit relation with said resistor, whose self-inductance L_0 is nearly equal to CR^2 where C is the capacity of the whole circuit and R the resistance of said resistor.

2. In an amplification system for television in which the number of view elements is more than five thousand, the combination with two vacuum tubes, each having an anode, a cathode, a grid and a grid shield, a resistor connected between said anode and said cathode of one of said tubes, and a condenser connected between the anode of said one of the vacuum tubes and the grid of the other of said vacuum tubes, of a self-inductance coil connected in series circuit relation with said resistor, the ratio of the angular velocity of the frequency of the current amplified by said system to that of the natural frequency of said self-inductance coil being less than 0.4 and the capacity existing along said coil being nearly equal to the capacity C of the whole circuit at the high frequencies corresponding to said number of view elements, and the self-inductance of said coil being nearly equal to CR^2 where R is the resistance of said resistor.

3. In a television system in which the number of view-elements is more than five thousand, and in which the scanning operation is effected by use of a light-beam having an appreciable cross-sectional area, and appreciable static capacity is inevitable due to photo-electric-cell circuit, modulator tubes etc., a compensator for the drop and the phase displacement of the output voltage of photo-electric current at high frequencies due to said scanning operation and static capacity, comprising two vacuum tubes, each having an anode, a cathode, a grid and a grid shield, a resistor connected between said anode and said cathode of one of said tubes, and a condenser connected between the anode of said one of vacuum tubes and the grid of the other of said vacuum tubes, means for reducing the capacity of said tubes and connections thereof to such a low value that the resistance of said resistor is negligible in comparison to the reactance of said capacity at the high frequencies corresponding to said number of view elements, and a self-inductance coil connected in series circuit relation with said resistor, whose self-inductance L_0 is larger than CR^2 where C is the capacity of the whole circuit and R the resistance of said resistor, L_0 and R being respectively of such low value that said drop and phase displacement are compensated for.

4. In a television system in which the number of view-elements is more than five thousand, and in which the scanning operation is effected by use of a light-beam having an appreciable cross-sectional area, and appreciable static capacity is inevitable due to photo-electric-cell circuit, modulator tubes etc., a compensator for the drop and the phase displacement of the output voltage of photo-electric current at high frequencies due to said scanning operation and static capacity, comprising two vacuum tubes, each having an anode, a cathode, a grid and a grid shield, a resistor connected between said anode and said cathode of one of said tubes, and a condenser connected between the anode of said one of vacuum tubes and the grid of the other of said vacuum tubes, a self-inductance coil connected in series circuit relation with said resistor, the ratio of the angular velocity of the frequency of the photo-electric current to that of the natural frequency of said self-inductance coil being less than 0.4 and the capacity existing along said coil being nearly equal to the capacity C of the whole circuit at the high frequencies corresponding to said number of view elements, the self inductance L_0 of said coil being larger than CR^2 where R is the resistance of said resistor, and L_0 and R being respectively of such low value that said drop and phase displacement are compensated for.

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