March 21, 1939. A. V. BEDFORD 2,151,072

TELEVISION TRANSMITTER

Filed April 25, 1935 2 Sheets-Sheet 1

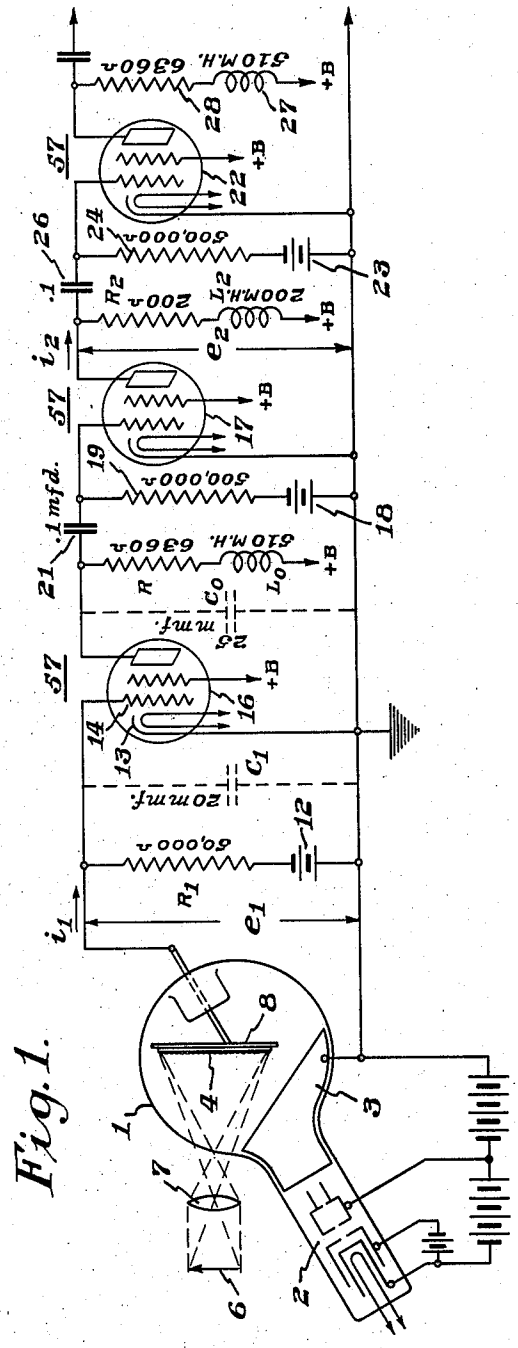


Fig. 1.

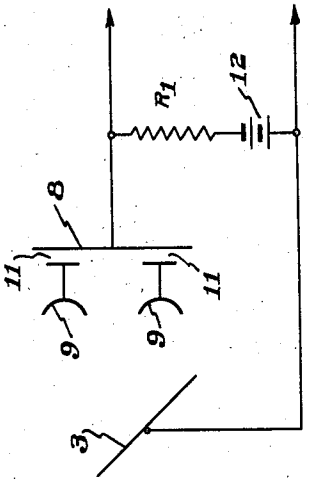


Fig. 2.

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Fig. 3.

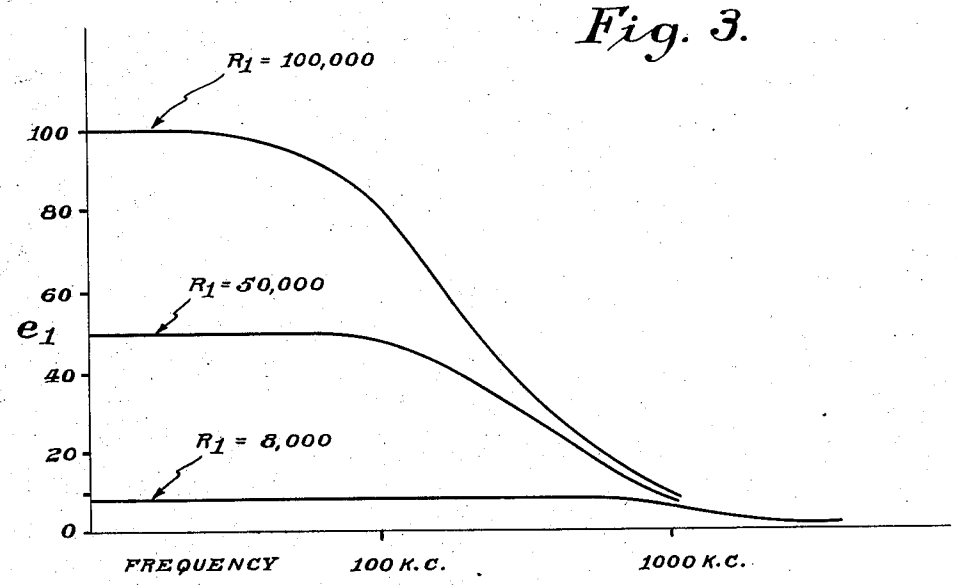
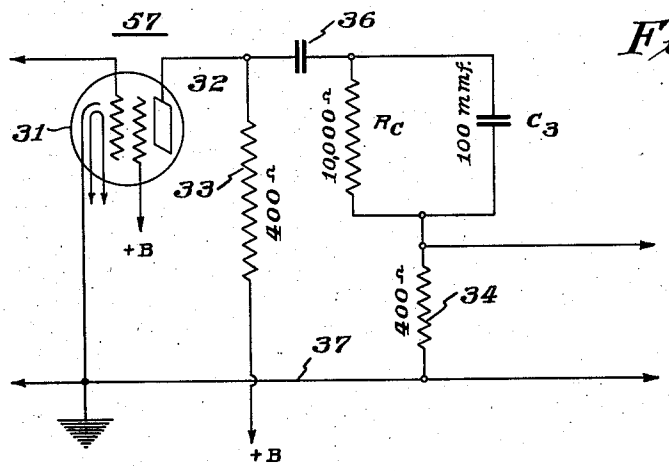


Fig. 4.



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Patented Mar. 21, 1939

2,151,072

UNITED STATES PATENT OFFICE

2,151,072

TELEVISION TRANSMITTER

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Application April 25, 1935, Serial No. 18,136

6 Claims. (Cl. 179—171)

My invention relates to television transmitters and particularly to transmitters of the type employing cathode ray transmitter tubes.

Prior to my invention it was standard transmitter practice to so design the output circuit of the cathode ray tube that the frequency response curve of the tube was flat. The picture signal was then fed into an amplifier designed to have a flat frequency-response characteristic whereby the signal appearing in the amplifier output was a true representation of the conditions of light and shade of the picture.

In order to make the frequency response curve of the cathode ray tube flat, it was necessary to give the output resistor of the cathode ray tube an impedance value approximately equal to or less than the impedance of the capacity in shunt to the cathode ray tube output circuit at the highest frequency to be amplified. Since the internal impedance of the preferred type of cathode ray tube is very high, usually at least ¼ megohm, such a circuit design resulted in very inefficient operation of the cathode ray tube whereby a large amount of picture signal amplification was required. Consequently, the resulting picture signal at the receiver was unsatisfactory because of the undue amplification of stray fields, tube hiss, tube microphonics, thermal agitation, etc.

An object of my invention, therefore, is to provide an improved picture transmitting circuit for supplying substantially undistorted picture signals from a high impedance light-sensitive device.

A further object of my invention is to provide an improved cathode ray tube circuit for transmitting pictures.

A further object of my invention is to provide a method of and means for reducing noise in signals supplied from a high impedance light-sensitive device.

A still further object of my invention is to provide a method of and means for reducing "noise" in picture signals obtained from a cathode ray tube of the type in which a light-sensitive mosaic is scanned by the cathode ray.

In a preferred embodiment of my invention I employ a cathode ray transmitter tube of the type which comprises a light-sensitive mosaic upon which is formed an optical image of the picture to be transmitted. Picture signals are produced by scanning the mosaic by an electron beam. The output circuit of the cathode ray tube is coupled to the input circuit of an amplifier through an output resistor which is given a resistance value considerably higher than the impedance of the capacity in shunt to the output circuit at the highest frequency to be transmitted.

As a result of using this comparatively high output resistance, the lower frequency components of the picture signals are amplified much more than they would be by the circuit formerly employed which was designed to have a substantially flat frequency response characteristic. The highest frequency components of the picture signals are amplified approximately the same amount as when employing the former circuit design.

It will be apparent that the lower frequency components of the picture signal will require a comparatively small amount of amplification and, since it is in this frequency range that most of the noise appears, the result is that the noises are not amplified to an objectionable degree.

The building up of the low frequency response in the cathode ray tube output circuit follows a definite law and, as a result, it is possible to design an amplifier having a complementary characteristic whereby the over-all frequency-response curve is made substantially flat. In the preferred embodiment of my invention this complementary characteristic is obtained in one amplifier stage while the other amplifier stages are adjusted individually to have a flat frequency response characteristic.

Other objects, features and advantages of my invention will appear from the following description when taken in connection with the accompanying drawings, in which

Figure 1 is a circuit diagram of a preferred embodiment of my invention,

Fig. 2 is a schematic diagram which is referred to in explaining the theory of operation of the cathode ray tube shown in Fig. 1,

Fig. 3 is a group of curves which are referred to in explaining the invention, and

Fig. 4 is a circuit diagram of a frequency compensating circuit which may be employed in place of the compensating circuit shown in Fig. 1.

Referring to Fig. 1, the transmitter circuit comprises a cathode ray tube 1 consisting of an evacuated envelope having an electron gun 2 therein for producing a beam of electrons, a second anode 3 and a mosaic 4 of light sensitive elements. An optical image of the picture to be transmitted, indicated at 6, is projected upon the mosaic 4 by means of a suitable lens system indicated at 7. This forms on the mosaic what may be referred to as an electrical image of the picture, whereby picture signals representative of the conditions of light and shade of the picture are produced as the mosaic is scanned by the electron beam. The beam is caused to scan the mosaic 4 by means of deflecting plates or coils (not shown).

The mosaic may be made in different ways as explained in the article by V. K. Zworykin appearing in the Proceedings of the Institute of

Radio Engineers for January, 1934, pages 16 to 32, this article giving a more detailed description of a cathode ray tube of this type. The mosaic consists of a great number of light sensitive elements which are insulated from each other and which are also insulated from a metallic signal plate 8 upon which they are mounted.

The circuit for the photoelectric cell portion of the cathode ray tube 1 will be more readily understood by referring to Fig. 2. In this figure parts corresponding to those in Fig. 1 are indicated by the same reference numerals. Only two of the many light sensitive elements are represented in this diagram, these elements being identified by the reference numeral 9. The capacity of each light sensitive element 9 to the signal plate 8 is represented by small condensers 11. It will be apparent that the light sensitive elements 9 act as the cathode of photoelectric cells and that the second anode 3 acts as an anode common to the large number of cathodes.

Referring to both Fig. 1 and Fig. 2, the signal plate 8 is connected through a resistor R_1 and a biasing battery 12 to the second anode 3 and to ground.

The resistor R_1 and the biasing battery 12 are connected across the cathode 13 and grid 14 of an amplifier tube 16 which, in the particular embodiment being described, is a screen grid tube of the 57 type. In this particular circuit the combined capacity of the signal plate and leads to ground and of the control grid to ground, that is, the total capacity appearing across electrodes 8 and 3, is 20 micro-microfarads, this capacity being indicated at C_1.

If the circuit were designed to give a flat frequency-response curve at the input circuit of the amplifier tube 16, as was the practice prior to my invention, the resistor R_1 would be given a value of about 8000 ohms. This would be determined by making its value equal to the capacitive reactance of the cathode ray tube output circuit at the highest frequency to be amplified, this reactance being equal to

$$\frac{1}{2\pi f C_1}=8000 \text{ ohms}$$

where the highest frequency is 1000 k. c.

By referring to the curves in Fig. 3, it will be seen that when the resistor R_1 is given this value the frequency response characteristic of the circuit feeding into the first amplifier tube 16 is substantially flat.

In accordance with my invention, I make the value of the resistor R_1 much higher than is permissible if a flat frequency response characteristic is to be obtained at the input of tube 16. In the specific circuit being described, R_1 has been given a value of 50,000 ohms. By referring to Fig. 3 it will be seen that when R_1 is given this value the amplification of the lower frequency components of a picture signal is approximately six times the amplification which would be obtained when employing the lower resistance value. It will also be noted that at the higher frequencies the amplification falls off rather rapidly. If desired, still higher amplification may be obtained by giving the resistor R_1 a still higher resistance value as will be evident by referring to the upper curve in Fig. 3 which shows the frequency-response characteristic for the output circuit of the cathode ray tube when R_1 has been given a value of 100,000 ohms.

For the purpose of illustration, only three amplifier stages are shown in the picture amplifier. The first stage and the third stage are so designed that their individual frequency-response curves are flat. The second stage is so designed in accordance with my invention that it amplifies the high frequencies more than the low frequencies and compensates for the falling frequency-response characteristic of the cathode ray tube output circuit caused by the use of a resistor R_1 having high impedance. As will be understood from a detailed explanation of the circuit given later in the specification, the output or load impedance of the second stage is made so low that this stage provides little if any amplification of picture signals, the other amplifier stages being depended upon to give the necessary amplification.

The output circuit of the first amplifier tube 16 includes a peaking coil L_0 and a plate resistor R. The input circuit of the second amplifier tube 17 includes a biasing battery 18 and a grid resistor 19. The output circuit of the first tube is coupled to the input circuit of the second tube through a coupling condenser 21. It will be noted that the peaking coil L_0 has a value of 510 microhenrys and that the plate resistor R has a value of 6360 ohms, these values being the proper ones to give the first amplifier stage a flat frequency response characteristic up to 1000 k. c. where the capacity across the output electrodes of the tube 16, indicated at C_0, is 25 mmf.

The output circuit of the second or compensating tube 17 includes an inductance coil L_2 and a plate resistor R_2. It will be noted that the load impedance of the tube 17 is made very low, the plate resistor R_2 having a value of only 200 ohms whereby the shunting effect of distributed capacity in the plate circuit is negligible. The inductance of the coil L_2 is determined by equations which will be referred to hereinafter.

The third amplifier stage comprises an amplifier tube 22 having an input circuit which includes a biasing battery 23 and a grid resistor 24. The output circuit of the second amplifier stage is coupled to the input circuit of the third amplifier stage through a coupling condenser 26.

The output circuit of the tube 22 includes an inductance coil 27 and a plate resistor 28, these impedance units having proper values to give the third amplifier stage a flat frequency response characteristic just as in the case of the first amplifier stage.

The invention will be better understood by referring to the following equations, in which vectorial values are used:

If e_1 is the alternating-current voltage impressed upon the input circuit of the first amplifier tube 16, i_1 the alternating current supplied from the signal plate 8, z the impedance of the output circuit of the cathode ray tube, R_1 the resistance of the resistor R_1, and C_1 the capacity indicated at C_1, then

$$e_1=i_1 z=i_1\frac{1}{1/R_1+j2\pi f C_1} \qquad (I)$$

If e_2 is the alternating current voltage appearing across the output electrodes of the second tube 17, i_2 the alternating current appearing in plate circuit of this tube, R_2 the resistance of resistor R_2, and L_2 the inductance of the coil L_2, then

$$e_2=i_2(R_2+j2\pi f L_2) \qquad (II)$$

It will be noted that in Equation (II) the capacity across the output circuit of the tube 17 is ignored but this is permissible because the im-

pedance of the load circuit is made very low. In both of the above equations,

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

and f=frequency in cycles per second.

If we assume that the first amplifier stage has been given a linear frequency-response characteristic, then

$$i_2=Ke_1 \qquad \text{(III)}$$

where K is a constant, since the load impedance of the compensating tube **17** is negligible compared with its internal or plate impedance, and since the coupling circuit between tube **16** and tube **17** has a linear response.

Substituting in Equation (III) the value of e_1 from Equation (I) we get

$$i_2=Ki_1\frac{1}{1/R_1+j2\pi fC_1} \qquad \text{(IV)}$$

Substituting the above value of i_2 is Equation (II) we get

$$e_2=Ki_1\frac{1}{1/R_1+j2\pi fC_1}(R_2+j2\pi fL_2)=$$

$$Ki_1\frac{R_2+j2\pi fL_2}{1/R_1+j2\pi fC_1} \qquad \text{(V)}$$

If

$$\frac{R_2}{1/R_1}=\frac{L_2}{C_1}$$

then $e_2=K_1i_1$ where K_1 is a constant. If $e_2=K_1i_1$, an undistorted picture signal is impressed upon the input circuit of the last amplifier **22**. This follows since i_1 is substantially independent of the load across the cathode ray tube, the load impedance being low compared with the tube impedance.

That $e_2=K_1i_1$ under the conditions assumed, may be proved as follows:

By the above assumption

$$R_2=\frac{L_2}{C_1R_1}$$

Substituting in equation (V,)

$$e_2=Ki_1\frac{\frac{L_2}{C_1R_1}+j2\pi fL_2}{1/R_1+j2\pi fC_1}$$

Clearing the equation of the j term,

$$e_2=Ki_1\frac{\frac{L_2}{C_1R_1}+j2\pi fL_2}{1/R_1+j2\pi fC_1}\cdot\frac{1/R_1-j2\pi fC_1}{1/R_1-j2\pi fC_1}$$

$$=Ki_1\left[\frac{\frac{L_2}{C_1R_1^2}-\frac{j2\pi fC_1L_2}{C_1R_1}+\frac{j2\pi fL_2}{R_1}+(2\pi f)^2L_2C_1}{\frac{1}{R_1^2}+(2\pi fC_1)^2}\right]$$

$$=Ki_1\left[\frac{\frac{L_2}{C_1R_1^2}+(2\pi f)^2L_2C_1}{\frac{1}{R_1^2}+(2\pi fC_1)^2}\right]$$

$$=Ki_1\left[\frac{L_2\left(\frac{1}{C_1R_1^2}+\frac{(2\pi fC_1)^2}{C_1}\right)}{\frac{1}{R_1^2}+(2\pi fC_1)^2}\right]$$

$$=Ki_1\frac{L_2}{C_1}\left[\frac{\frac{1}{R_1^2}+(2\pi fC_1)^2}{\frac{1}{R_1^2}+(2\pi fC_1)^2}\right]=K_1i_1$$

where

$$K_1=K\frac{L_2}{C_1}$$

With the values of R_1, C_1, and R_2 indicated in Fig. 1, we may calculate the required value of L_2 as follows:

$$L_2=C_1\frac{R_2}{1/R_1}=C_1R_1R_2$$

$$=20\times10^{-12}\times50{,}000\times200$$
$$=200\times10^{-6}$$
$$=200 \text{ microhenrys}$$

In determining the proper value of L_2, the value of R_1 is determined by considerations previously explained, the value of C_1 is fixed by the structure of the cathode ray tube and the first amplifier tube, and the value of R_2 is determined by selecting a value that will make substantially negligible the effect of the capacity across the output electrodes of the amplifier tube **17** at the highest frequency to be amplified.

As previously stated, the first and third amplifier stages should have a substantially flat frequency response characteristic. If peaking coils are used as illustrated, this characteristic may be obtained by making the plate resistor R equal to the reactance of the distributed capacity C_0 across the output circuit of the amplifier tube **16** at the highest frequency f_0 to be amplified, and by making the reactance of the peaking coil L_0 equal to ½ the reactance of the distributed capacity at the said frequency. That is,

$$R=\frac{1}{2\pi f_0C_0}$$

and

$$2\pi f_0L_0=\tfrac{1}{2}\left(\frac{1}{2\pi f_0C_0}\right)$$

or

$$L_0=\frac{1}{8\pi^2f_0^2C_0}$$

The above method of calculating the plate resistor and peaking coil values is based upon the assumption that the plate impedance is very high compared with the load impedance, this being true if the tube is of the screen grid type.

While the individual amplifier stages associated with the compensating stage should be given flat frequency-response curves for best results, reasonably good results in some cases may be obtained by adjusting the amplifier stages as a group to obtain an overall frequency-response curve which is approximately flat.

It will be apparent that in accordance with my invention the cathode ray tube works into a load circuit which is predominately capacitive over the greater part of the frequency range of the transmitter. This is shown by the falling characteristic of the upper curves in Fig. 3. The resistor R_1 is required only as a grid leak.

Attention is directed to the fact that the picture signals are amplified sufficiently before they are impressed upon the compensating stage to prevent the signal voltage from falling to a value lower than its input value at any point in the circuit. In other words, the overall gain at any point in the amplifier for any frequency in the amplifier frequency range should not be less than one. Otherwise, the ratio of signal to noise will drop to a value which is too low and the quality of the picture will be impaired.

In the circuit illustrated, which is designed to pass frequencies up to 1000 k. c., the gain in the first stage is about 7.5 while the gain in the second stage or compensating stage is about 0.24 at the lowest frequency. Therefore, at the lowest frequency, the overall gain of the two stages is $7.5\times.24=1.8$.

In practice, it is generally desirable to employ

two or more amplifier stages preceding the compensating stage, each having a flat frequency-response curve, in place of the single stage 16 shown in Fig. 1. If 57 type tubes are used and the amplifier is to pass frequencies up to 1500 k. c., at least two amplifier stages should precede the compensating stage.

By designing a circuit in accordance with my invention, the signal to noise ratio is maintained at a high value as compared with that obtainable in previous picture transmitters. As a result, I can obtain a good picture instead of a very poor one.

A compensating network of the type described comprising an inductance coil and a resistor is the preferred one to use in practicing my invention since maximum gain is obtained in the compensating stage by its use. However, a capacity-resistance network, such as shown in Fig. 4, may be substituted therefor and a marked reduction in noise obtained as compared with the noise in the output of circuits previously employed.

Referring to Fig. 4, the compensating stage comprises a screen grid vacuum tube **31** which has a positive potential applied to its plate **32** through a low impedance resistor **33**. The resistance of resistor **33** is made so low that the effect of the distributed capacity in the output circuit of the tube **31** is negligible. A network consisting of a high impedance resistor R_c shunted by a condenser C_3 in series with a low impedance resistor **34** is connected across the output electrodes of the tube **31** through a coupling condenser **36** and a conductor **37**. If circuit values of the order indicated on the drawings are employed, the compensating stage will have a frequency-response characteristic complementary to that of the cathode ray tube output circuit.

It can be shown that the network of Fig. 4 gives proper compensation if there is the following relation between circuit elements.

$$\frac{R_c}{R_1}=\frac{C_1}{C_3}$$

Then if R_c is given a value of 10,000 ohms

$$C_3=\frac{R_1C_1}{R_c}=\frac{50{,}000\times 20 \text{ mmf.}}{10{,}000}=100 \text{ mmf.}$$

From the foregoing description it will be apparent that various modifications may be made in my invention without departing from the spirit and scope thereof, and I desire, therefore, that only such limitations shall be placed thereon as are necessitated by the prior art and set forth in the appended claims.

I claim as my invention:

1. In a system for amplifying picture signals covering a wide frequency band, in combination, a photoelectric cell device having output electrodes and having high internal impedance, an amplifier comprising at least one amplifying stage having an output circuit and a compensating stage having an input circuit, said input circuit being coupled to said output circuit, and means for coupling said photoelectric cell device to said amplifier stage through a circuit which, because of distributed capacity, is predominately capacitive over at least eighty percent of the range of frequencies to be amplified, the resistance of said circuit being effectively connected across said electrodes and at the lowest frequency in said range being at least ten times as great as the capacity reastance of said circuit effectively in shunt to said electrodes at the highest frequency to be amplified whereby the picture signal output from said device at the low frequency end of said band is large compared with noise at said low frequency end produced in the portion of said system immediately following said device thereby giving a good signal to noise ratio in the output of said system, said amplifying stage having a substantially flat frequency-response characteristic over said range, and said compensating stage having a frequency-response characteristic which is complementary to that of said photoelectric cell device.

2. In combination, a light sensitive device having high internal impedance and having output electrodes, an electric discharge tube having an input circuit and an output circuit, a grid leak resistor included in said input circuit, said output electrodes being connected to said input circuit whereby said resistor is in series with said internal impedance, a compensating electric discharge tube of the screen grid type having a control grid, a cathode and a plate, means for impressing signals appearing in said output circuit upon said control grid and said cathode, a plate resistor and an inductor in series, means for applying voltage to said plate through said plate resistor and said inductor, and a utilization circuit connected across said plate resistor and said inductor, said resistors and said inductor having the relation

$$R_1R_2=\frac{L_2}{C_1}$$

where

R_1=the resistance of said grid leak resistor,
R_2=the resistance of said plate resistor,
L_2=the inductance of said inductor, and
C_1=the capacity effectively in shunt to said output electrodes.

3. The invention according to claim 2 characterized in that the value R_2 is small compared with the plate impedance of said compensating tube.

4. In a picture transmitter system wherein picture signals are produced covering a certain frequency range and wherein there is more noise from certain sources at the low frequency end of said range than at the high frequency end thereof, the combination of a photoelectric cell device of the high vacuum type having high internal impedance and having output electrodes, an amplifier tube having input electrodes, a loading network which couples said output electrodes to said input electrodes, said network having an effective resistance R_1 and a shunt capacity C_1, R_1 at the lowest frequency to be amplified being at least ten times the capacity reactance of said network at the highest frequency to be amplified, a compensating circuit having a frequency response characteristic which is complementary to that of said photo-electric cell device, and means for supplying the output of said amplifier tube to said compensating circuit, said certain sources being located between said photo-electric cell device and said compensating network, the resistance of resistor R_1 being so high that said picture signals at the low frequency end of said range where the noise from said certain sources appears are held at a substantially higher amplitude level than the amplitude of noise from said sources whereby the signal to noise ratio is maintained comparatively high at the low frequency end of said range.

5. In combination, a light-sensitive device having high internal impedance and having output electrodes, an electric discharge tube having an

input circuit and an output circuit, a loading network which couples said output electrodes to said input circuit, said network having an effective resistance R_1 which is in series with said internal impedance and having a shunt capacity C_1, a compensating electric discharge tube of the screen grid type having a control grid, a cathode and plate, means for impressing signals appearing in said output circuit upon said control grid and said cathode, a compensating circuit including a resistor and an inductor in series connected to have signals impressed thereacross from said screen grid tube, and a utilization circuit connected across said resistor and said inductor, said resistor and said inductor having the relation

$$R_1R_2=\frac{L_2}{C_1}$$

where

R_1=said network resistance,

R_2=resistance of said compensating circuit resistor,

L_2=the inductance of said inductor and

C_1=the capacity effectively in shunt to said output electrodes.

6. In a system for amplifying picture signals covering a wide frequency band, in combination, a photoelectric cell device of a high vacuum type having high internal impedance and having output electrodes, an amplifier tube having input electrodes, a loading network which couples said output electrodes to said input electrodes, said network having an effective resistance and a shunt capacity, said effective resistance being so large as compared with the capacity reactance of said network at the highest frequency to be amplified that said network presents a capacitive reactance over the upper 80 percent. of the frequency band to be amplified whereby the picture signal output from said device at the low frequency end of said band is large compared with noise at said low frequency end produced in the portion of said system immediately following said device thereby giving a good signal to noise ratio in the output of said system, a compensating circuit having a frequency response characteristic which is complementary to that of said photoelectric cell device, and means for supplying the output of said amplifier tube to said compensating circuit.

ALDA V. BEDFORD.