Feb. 2, 1943. A. V. BEDFORD 2,309,744

TELEVISION SYSTEM

Filed Sept. 7, 1940 2 Sheets-Sheet 1

FIG. 1.

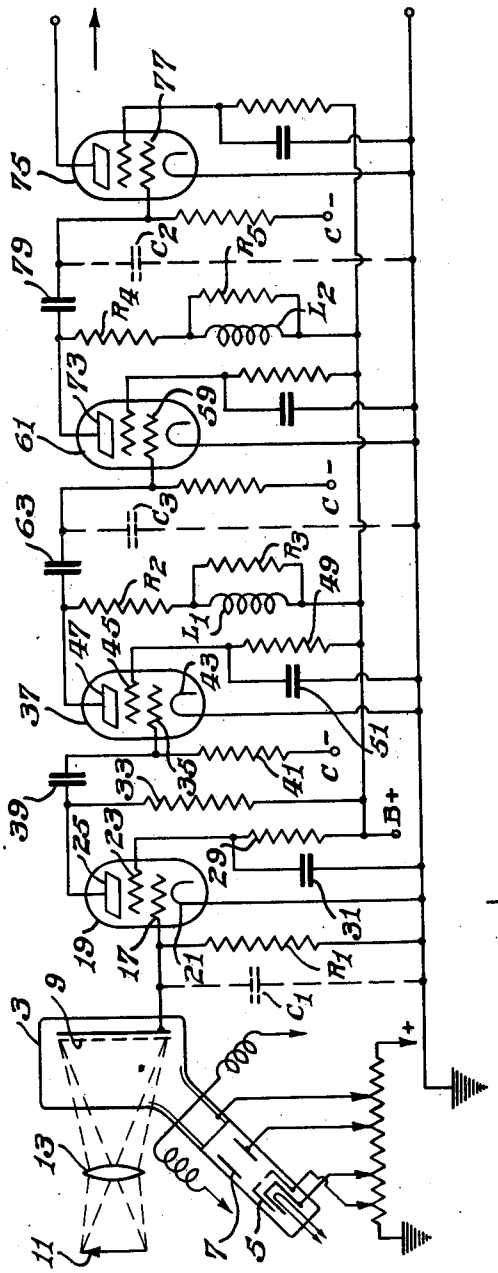
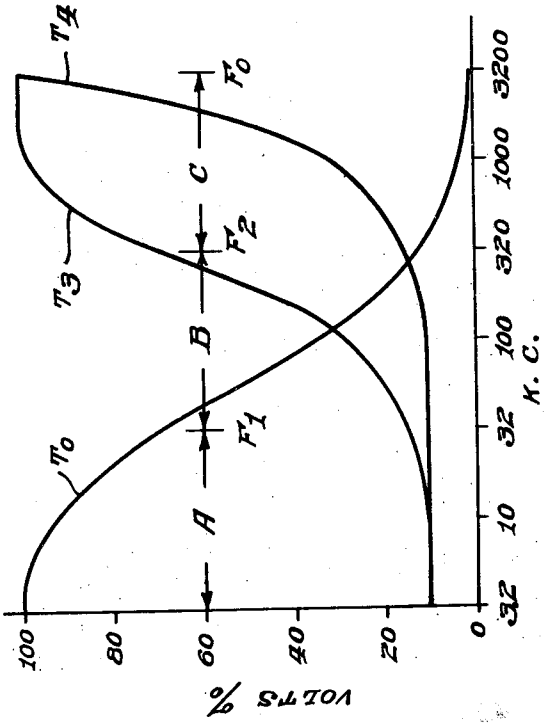


FIG. 2.



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FIG. 3.

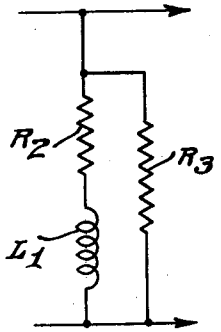


FIG. 4.

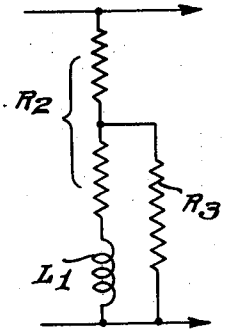


FIG. 5.

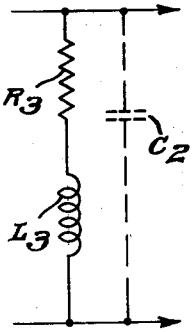


FIG. 6.

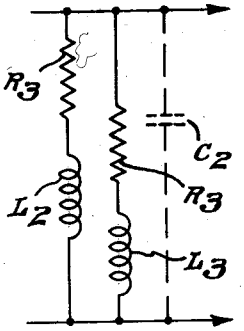


FIG. 7.

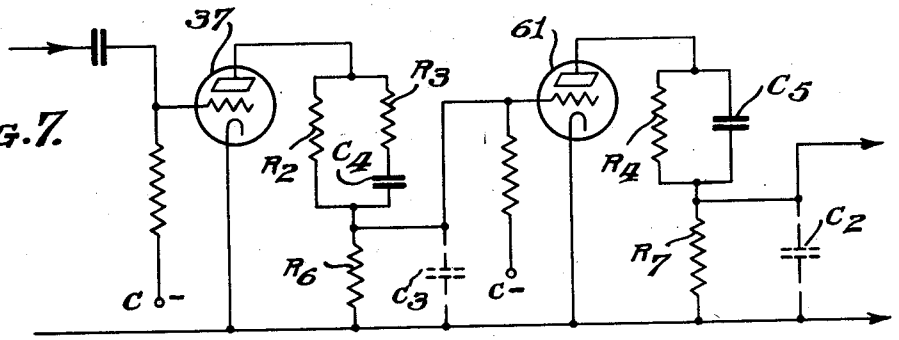
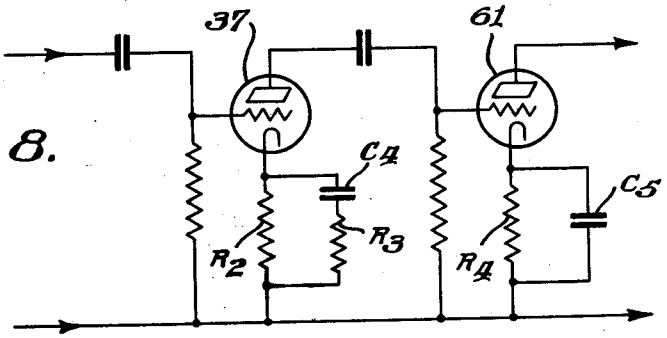


FIG. 8.



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UNITED STATES PATENT OFFICE

2,309,744

TELEVISION SYSTEM

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Application September 7, 1940, Serial No. 355,797

4 Claims. (Cl. 178—7.2)

This invention relates to television transmitters and more particularly to transmitters of the type employing cathode ray tubes.

Television signaling systems are adapted to provide images of high definition over a relatively wide band of signaling frequencies. It is well known that thermionic amplifying tubes, their associated circuits, and cathode ray transmitter tubes experience a falling off in response at high frequencies due to the fact that the interelectrode and interelement capacity is of sufficient magnitude to provide relatively low impedance over the upper range of the required frequency band. One method of overcoming this decreased efficiency in the television system is to design the output circuit of the cathode ray transmitter tube so that the response of the transmitter tube is substantially flat over the useful band of frequencies. This has been accomplished by providing a low value load resistance for the transmitting tube so that the distributed capacity in the transmitter tube would have little effect on the response characteristic in the useful band. Picture signal from the transmitter tube was then fed into an amplifier designed to have a flat frequency response whereby the signal appearing at the output of the amplifier was a true representation of the conditions of light and shade of the picture. The use of a low valued load resistance in the output circuit of the transmitting tube reduces its output considerably, thus requiring a large amount of amplification which consequently introduces a large amount of extraneous noise and thereby deleteriously affecting the resultant transmitted image.

In order to obtain low noise to signal ratio from a high impedance wide band low output device, such as a cathode ray transmitter tube, it is advantageous to operate the device into a load which has high shunt resistance compared to the shunt capacity reactance due to the stray and distributed capacity of the tube and circuit. At the highest useful frequency the output resistor may well be one hundred or more times as high in value as the shunting capacitive reactance. In the arrangement of my previous Patent No. 2,151,072, the loss in response at high frequency resulting from a transmitter tube provided with a relatively high load resistance was equalized by an inductance connected in series with a low-valued plate resistor in a subsequent amplifier stage.

In order that the effect of the interelectrode capacitance may be negligible, the reactance of the inductance at the highest useful frequency must be small compared to that of the interelectrode capacity. The value of the load resistance will be only one hundredth of the reactance of the inductance, say 10 ohms, and hence will be so small that at low frequency the signal on the control electrode of the falling amplifier stage will be so small that the low frequency interference due to unsteady power supply of the amplifier tubes may be objectionable.

This difficulty is greatly reduced by equalizing for the falling frequency characteristic in two or more amplifier stages, thus allowing greater low frequency gain in each of the amplifier stages since the high frequency gain is limited by the interelectrode capacitance.

Two or more identical stages in cascade cannot be made to provide equalization, according to the correct law, to compensate for a single input circuit. This is evident when it is considered that for all except the very low frequencies, the input signal to the amplifier from the cathode ray transmitter tube varies inversely as frequency. A single stage may be designed to provide gain which varies directly as frequency over a similar range, however, if two stages having similar frequency response characteristics were used the gain would vary as the square of frequency which would not correctly compensate for the falling-off characteristic of the cathode-ray transmitter tube. Two amplifier stages in which each provides gain varying in accordance with the square root of frequency would be satisfactory but no simple circuit is now available to provide such a characteristic.

According to this invention, two or more equalizing circuits have different rising frequency characteristics and are connected in cascade so that one provides gain substantially proportional to frequency for a first part of the useful frequency band and the other or others provide substantially uniform gain for that first part of the useful frequency band but provides gain proportional to the frequency for other parts of the useful frequency band. The response characteristic of the several circuits are also complementary at the transition points between different parts of the frequency band.

The principal object of this invention is to provide a television system having a uniform response over a large range of frequencies.

Another object of this invention is to provide an amplifier which will compensate for the attenuation at high frequency due to the

stray capacity of a transmitter tube and its associated circuits.

A still further object of this invention is to provide a multi-stage wide-band amplifier whose frequency response is substantially flat over the lower portion of the band and increases proportional to frequency over the higher portion of the band.

Other and incidental objects of this invention will be apparent to those skilled in the art from the following specification considered in connection with the accompanying drawings in which

Figure 1 is a circuit diagram showing one form of this invention,

Figure 2 is a graph illustrating the operation of this invention, and

Figures 3, 4, 5, 6, 7 and 8 are modifications of this invention.

Referring now in more detail to Fig. 1, the amplifier circuit comprises a cathode ray transmitter tube 1 having an evacuated envelope 3 and electron gun 5 therein for producing a beam of electrons, a second anode 7 and a mosaic 9 of electron-emissive elements. An optical image of the scene 11 to be transmitted is projected upon the mosaic 9 by means of a suitable lens system 13. An electrical representation of the optical image is formed on the mosaic so that when the mosaic is scanned by the electron beam from gun 5 it produces picture signals representative of the optical image 11. The beam is caused to scan the mosaic 9 by means of deflecting coils 15 or any other suitable deflecting means.

A further and more complete description of the cathode ray transmitter tube may be found in an article by V. K. Zworykin appearing in the Proceedings of the Institute of Radio Engineers for January 1934, pages 16 to 32.

The train of picture signals is transmitted to the control electrode 17 of the amplifier tube 19 having a cathode 21, an auxiliary electrode 23 and an anode 25. The grid leak resistor R_1 maintains the control electrode 17 at a suitable bias potential. The distributed capacity of the picture tube is indicated by the broken line shown by capacity C_1. The auxiliary electrode is supplied with positive potential through resistance 29 and bypass condenser 31. The anode 25 is supplied with positive potential through resistor 33 and the amplified signal is impressed upon the control electrode 35 of the next amplifier tube 37 through coupling condenser 39. Suitable bias potential is applied to control electrode 35 through resistor 41. Tube 37 contains cathode 43, auxiliary electrode 45 and anode 47. The positive potential for auxiliary electrode 45 is supplied through resistor 49 and bypass condenser 51.

A frequency compensating circuit composed of resistances R_2, R_3 and inductance L_1 is connected to the anode circuit of discharge device 37. The modified signal from anode 47 is impressed upon the control electrode 59 of tube 61 through coupling condenser 63. Capacity C_3 represents the interelectrode capacity of the tubes 37, 61 and their associated circuits. A second frequency compensating circuit comprising the resistances R_4, R_5 and inductance L_2 is connected to the circuit of the anode 73 of tube 61. The signal from the anode 73 is then amplified in tube 75 by transmitting it to control electrode 77 through coupling condenser 79. The interelectrode capacity of tube 75 is shown by capacity C_2.

The anode circuit of tube 37 and the anode circuit of tube 61 may be adjusted to compensate for the high frequency losses in the transmitter tube output circuit resulting from high resistance R_1 and capacity C_1, by making:

$$R_1 = X_{C1} = 1/(2\pi f C_1) \text{ at } f_1 \quad (1)$$

$$X_{L1} = 2\pi f_1 L_1 = R_2 \text{ at } f_1 \quad (2)$$

$$R_3 = X_{L1} = 2\pi f_2 L_1 \text{ at } f_2 \quad (3)$$

$$X_{L2} = 2\pi f_2 L_2 = R_4 \text{ at } f_2 \quad (4)$$

where

f_0=maximum frequency utilized (for example, 3,000,000 C. P. S.)

f_1=a lower transition frequency (for example, 30,000 C. P. S.) and

f_2=a much higher transition frequency (for example, 300,000 C. P. S.).

Referring now to Fig. 2, T_0, T_3 and T_4, respectively, show the response characteristic curve of the three anode circuits of the three discharge devices 3 (picture transmitter tube), 37 and 61.

If the falling off in frequency response of the transmitter tube was to be compensated for in one stage of amplification, the anode circuit of the compensating stage would contain an inductance whose value is governed by the following equation:

$$L_1 = R_2 R_1 C_1 \quad (5)$$

where

L_1=the inductance in the anode circuit,

R_2=the series resistance in the anode circuit,

R_1=the load resistance of the transmitter tube, and

C_1=distributed capacity of the picture transmitter tube and associated circuit in order for the output voltage of the amplifier stage to be uniformly proportional to the current of the picture tube. If the falling-off in frequency-response characteristic of the picture tube is to be compensated for in a single stage, the valve R_2 will necessarily be so low that the irregularities in the power supply voltage will be appreciable by comparison with the picture signal.

It is apparent that Equations 1 and 2 define L_1 to have the same value as was given in Equation 5 for the one amplifier stage frequency response characteristic equalizer. F_1 defines the frequency at which the voltage across L_1 has become equal to that across R_2 and the voltage across L_1 exceeds the voltage across R_2 for all higher frequencies. Hence F_1 may be called the "coming-in" transition frequency for L_1. R_3 has little effect at this frequency because the reactance of L_1 is relatively low with respect to R_3. If R_3 and C_3 were not present, this circuit would provide correct equalization. At F_2 the "going-out" transition frequency of L_1, the value of X_{L1} reaches R_3 so that L_1 and R_3 are equally responsible for the amplification of the stage comprising tube 37.

The voltage across R_2 is almost negligible at frequency F_2. R_3 and R_2 are given such a value that C_3 will not appreciably load the circuit at the maximum frequency of the useful band. At the same transition frequency F_2, the voltage across L_2 in the plate circuit of discharge device 61 becomes equal to the voltage across R_4. Above this frequency the voltage across L_2 continues to rise and assumes the task of compensating for the continued fall of high frequency response of the picture transmitter tube 1.

For the purpose of this illustration, we may consider the curve T_0 to be substantially flat in

region A (that is, up to F_1) and that it falls inversely as the frequency in regions B and C. Curve T_3 is substantially flat in regions A and C and rises proportional to frequency in region B. Curve T_4 is substantially flat in regions A and B and rises proportional to frequency in region C.

A third equalizing stage of amplification could be added to extend the range further by shunting L_2 by a resistor equal to X_{L2} at F_0, making F_0 a transition frequency. The third network would be added elsewhere as in anode circuit of tube 75. It would consist of a resistor in series with an inductance having a reactance equal to the resistor at frequency F_0. The maximum compensated frequency would then become equal to F_0.

More equalizing stages could be added by either extending the band or by spacing the transition frequencies closer in the band. It must be observed that the "coming-in" transition frequency of each stage is the same as the "going-out" transition frequency of the stage adjacent on the low frequency side in the frequency band.

It will be noticed that according to one form of this invention regardless of how many stages of compensation there may be, the inductance shunting resistor will be omitted in the compensating stage having the highest transition frequency. It is, however, satisfactory to use the inductance-shunting resistor in each stage providing the "going-out" transition frequency of the stage, having the highest coming in transition frequency, is at the upper limit of the desired band.

Referring now to Fig. 3, if the various transition frequencies F_1, F_2 and F_0 are not as much as several octaves apart in frequency, the resistor in series with the inductance becomes comparable with the resistor shunting the inductance. If this obtains, it is important whether the resistor R_3 shunts the inductance L_1 alone or shunts the series resistor R_2 also, as shown in Fig. 3. The "coming-in" transition frequency of L_1, for example, then is effected by R_3 as well as by R_2. Similarly, the "going-out" transition frequency is affected by R_2 also instead of by R_3 alone, as indicated by Equations 3 and 4. A slight revision of values of R_2, R_3 and L_1 can be made to reduce the error involved though in many applications no revision will be needed.

Referring now to Fig. 4, R_3 may be tapped into R_2 and in some cases the need for revision of resistance values may be eliminated. In this form of the invention R_3 shunts only part of R_2.

Turning now to Fig. 5, it is well known that such a circuit is essentially a resistance R_3 up to a frequency of one half or more of F_R, where:

$$F_R=1/(2\pi\sqrt{LC}) \quad (6)$$

$$K=2\pi F_R CR=1.51 \quad (7)$$

$$R=K/(2\pi F_R C) \quad (8)$$

This circuit is commonly used for a coupling impedance between the stages for a uniform response video signal amplifier.

It was shown in Fig. 3 that, according to one form of this invention, both the series resistance R_2 and inductance L_1 are shunted by a resistance R_3. However, no account was taken of the unavoidable stray capacitance. Fig. 5 specifically takes into account the unavoidable stray capacity C_2 of the circuit and tube electrodes. We know that, in order to provide a circuit which presents a resistive load to a definite range of frequencies and in which there is included a capacity such as C_2, it is necessary to include in the shunt resistance circuit an inductance such as L_3 in Fig. 6; therefore, the elements R_3, L_3 and C_2 in effect combine to produce a resistive load across the channel, thus resulting in a circuit, the equivalent of which is shown in Fig. 3.

Fig. 7 shows still another embodiment of this invention in which a compensated circuit comprising condensers and resistances is used. The capacities and resistances are of such a value that the corresponding stages produce response curves similar to curves t_3 and t_4 shown in Fig. 2. One compensating circuit comprises resistance R_2 in series with resistance R_6 and series circuit comprising resistance R_3 and capacitor C_4 connected in parallel with resistance R_2. Another compensating stage including tube 61, which has the highest "coming-in" transition frequency of all the compensating stages, is provided with a resistance R_4 in series with resistance R_7 in its anode circuit, resistance R_4 having a condenser C_5 shunted therewith.

A better understanding of the operation of Fig. 7 will be had with reference to Fig. 2. F_1 defines the frequency at which the admittance of C_4 has become equal to that of R_2, and the admittance of C_4 is more than that of R_2 for all higher frequencies. R_3 has little effect at this frequency because the reactance of C_4 is relatively high with respect to R_3. Hence F_1 may be called the "coming-in" transition frequency for C_4. At F_2, the "going-out" transition frequency of C_4, the value of X_{C4}, (the reactance of C_4) reaches R_3, so that the admittances of C_4 and of R_3 are equally responsible for the amplification of the stage comprising tube 37. At frequencies above F_2, C_4 has little effect because X_{C4} is relatively low with respect to R_3.

R_2 and R_6 are given such a value that C_3 will not appreciably load the circuit at the maximum frequency of the useful band. At the same transition frequency F_2, the admittance of C_5 in the anode circuit of discharge device 61 becomes equal to the admittance of R_4. Above this frequency, the current through C_5 continues to increase, thus assuming the task of compensating for the continued fall of high frequency response of the picture transmitter tube.

Referring now to Fig. 8, there is shown another embodiment of this invention in which the compensating circuit of each of the amplification stages is provided for in the cathode circuit of the discharge devices. Discharge device 37 has in its cathode circuit a series resistance R_2 shunted by a series circuit comprising capacity C_4 and resistance R_3. At least one of the stages, that is, the stage compensating for that highest part of the useful frequency range, is provided with a cathode resistor R_4 and a shunt condenser C_5.

By using resistance in the cathode circuit of a discharge device, it is possible to introduce enough negative feedback in the circiut to control the response characteristics of a tube. By including in the cathode circuit a circuit whose impedance changes with frequency it is possible to change the frequency response of an amplifier. By referring again to Fig. 2, the operation of the circuit shown in Fig. 8 may be more readily understood. F_1 defines the frequency at which the admittance of C_4 has become equal to that of R_2, and admittance of C_4 is less than the admittance of R_2 for all higher frequencies. Hence, F_1 is called the "coming-in" transition frequency for the amplifying stage comprising discharge device 37 and its associated circuit. R_3 has little effect

at this frequency because the reactance of C_4 is relatively high with respect to R_3. At F_2, the "going-out" transition frequency of the stage comprising tube 37, the value of X_{C4} reaches R_3, so that C_4 and R_3 are equally responsible for the amplification of the stage comprising tube 37. At frequencies above F_2, C_4 has little effect because X_{C4} is relatively low with respect to R_3.

At the same transition frequency F_2, the voltage across C_5 in the cathode circuit of the discharge device 61 becomes equal to the voltage across R_4. Above this frequency, the admittance of C_5 continues to increase and assumes the task of compensating for the continued fall of high frequency response of the picture transmitter tube.

While several systems for carrying this invention into effect have been indicated and described, it will be apparent to one skilled in the art that this invention is by no means to be limited by the particular organization shown and described but that many modifications thereof will be made without departing from the scope of this invention as set forth in the appended claims.

I claim as my invention:

1. In combination with a cathode ray pickup tube for generating picture signals occupying a wide frequency band, said tube having high internal impedance and having output terminals that have unavoidable capacity therebetween, an output resistor connected between said terminals, an amplifier including a first vacuum tube having input electrodes connected across said resistor, said resistor having such high resistance that the frequency response characteristic at said input electrodes falls with increase in frequency, said amplifier comprising a plurality of amplifier stages connected in cascade, one of said stages including a frequency correcting network which gives to said one stage a frequency response characteristic which has a rising response with increase in frequency over a band of intermediate frequencies in said wide band and which has a substantially flat response over the rest of said wide band, and another of said stages including a frequency correcting network which gives to said other stage a frequency response characteristic which has a rising response with increase in frequency over a band of frequencies at the high frequency end of said wide band and which has a substantially flat response over the rest of said wide band, the overall frequency response characteristic of said two stages with frequency correcting networks being substantially complementary to the frequency response characteristic at said input electrodes.

2. In combination with a cathode ray pickup tube for generating picture signals occupying a wide frequency band, said tube having high internal impedance and having output terminals that have unavoidable capacity therebetween, an output resistor connected between said terminals, an amplifier including a first vacuum tube having input electrodes connected across said resistor, said resistor having such high resistance that the frequency response characteristic at said input electrodes falls with increase in frequency, said amplifier comprising a plurality of amplifier stages connected in cascade, one of said stages including a frequency correcting network which gives to said one stage a frequency response characteristic which has a rising response with increase in frequency over a band of intermediate frequencies in said wide band and which has a substantially flat response over the rest of said wide band, and another of said stages including a frequency correcting network which gives to said other stage a frequency response characteristic which has a rising response with increase in frequency over a band of frequencies toward the high frequency end of said wide band and which has a substantially flat response over the rest of said wide band, the rising frequency response characteristic of each of said stages with frequency correcting networks being substantially complementary to the frequency response characteristic at said input electrodes for corresponding bands of frequencies.

3. A frequency compensating television signal transmission circuit having a frequency response characteristic which rises in response to frequency throughout its entire pass band and comprising in combination a plurality of amplifier stages each having a frequency response characteristic which does not vary with frequency except wherein the response characteristic rises in response to frequency over a portion of said band other than that portion of said band in which each of the other of said stages have rising frequency characteristics, and wherein said portions make up the entire band.

4. A frequency response compensating television signal transmission circuit having a frequency response characteristic which rises substantially proportional to frequency over a relatively wide frequency range comprising in combination a plurality of signal amplifying stages each of which has a frequency response characteristic which is substantially flat except wherein the response characteristic rises substantially proportional to frequency over a different portion of said frequency range and wherein said portions make up substantially the entire frequency range.

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