DUAL PULSED-PILOT-CARRIER ALC FOR TEMPERATURE AND COLOR STABILITY OF CATV SIGNALS

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Introduction and Summary

Automatic level control is required in any CATV system of appreciable length, due to changes in cable attenuation with temperature. Temperature-sensing and single-and dual-CW-pilot-carrier control are discussed, and compared with pulsed or modulated pilot carrier control methods. Pulsed or modulated pilot carrier control is found to be superior, and gives much more stable output levels as amplifier circuitry is subjected to extremes of temperature. Also, Color-Beat interference between pilot carrier and video carrier is eliminated through use of a synchronized pulse generator in the head-end.

Basic Considerations

A problem which is basic to all cable transmission systems is the variation of cable attenuation with temperature. This variation with temperature is primarily due to the temperature coefficient of resistance of the cable center conductor. Most cable used in CATV systems employ a copper center conductor and an aluminum or copper outer conductor. The surface conducting area of the inner conductor is much less than that of the outer conductor; consequently most of the cable loss is due to the inner conductor resistance (current flows essentially on the surface due to skin effect). So the temperature coefficient of resistance of the inner conductor primarily determines the over-all cable attenuation variation with temperature.

For copper the loss at any temperature T (centigrade) is:

(Eq. 1) $$\text{Loss at temperature } T \text{ (decibels)} = A_{20} \left[1 + .0019\,(T-20) \right]$$

A_{20} = cable loss at 20°C. and given frequency

In a 20-dB span of cable the attenuation will then vary .038 dB per degree C. In terms of degrees Fahrenheit, this variation is approximately .001 dB per dB per degree. Thus, for a temperature variation of 0°F. to 100°F. and a 20 dB span of cable, the attenuation change will be +2 dB. When it is considered that a trunk system can have cable spans of several hundred dB (with a 10 dB attenuation variation per 100 dB for a 100°F. temperature variation) it is obvious that a means of stabilizing levels must be found. Otherwise signals will overload amplifiers in cold weather and will drop into the noise level in hot weather.

Temperature-Sensing Level Control

The problem of level variation with temperature has been minimized in some amplifiers by employing compensating devices in the amplifier. A temperature sensitive resistance in the amplifier has been used to reduce the amplifier gain as the temperature is reduced and thereby at least partially compensates for the decrease in cable loss. There are three factors which limit the precision of this form of open loop temperature compensation. First, it is virtually impossible to insure that the temperature compensation which has been designed into the amplifier will match that of the cable with the necessary precision. Second, the average cable temperature may differ from that of the amplifier. This occurs, for example, on a hot summer day, when the CATV amplifier is shaded by a building or a tree. Third, level errors are cumulative; each amplifier does not correct for the errors in output level of the preceding amplifiers. Cascadibility of amplifiers using this type of "Automatic Level Control" is severely limited.

Composite AGC

Many amplifiers, mostly the earlier tube-type, utilized a broadband composite AM detector to sense total energy (all channels) transmitted through the amplifier. The output of this detector was used to bias amplifier tubes or drive an attenuator to change gain of the amplifier to maintain an essentially constant output. These amplifiers work reasonably well, and many are still in use today. However, precision level control, needed for very long cascades, cannot be achieved over the band because of the constant changes in energy content of the individual signals, and because certain signals are not always present. Precision control of amplifier response also presents a problem in these systems.

C-W-Pilot-Carrier Level Control With Single Detector

Another technique now widely employed is to apply stable signals to the trunk line at the head-end, and then use closed-loop control in each amplifier to hold the levels of these signals constant. Frequencies of 73.5, 116, 165, 225 MHz and others have been employed by different equipment manufacturers. Small narrow-band amplifiers (receivers) in the trunk line units provide an automatic-level-control voltage which is used to vary the gain and slope of the broadband trunkline amplifier. This control voltage is derived by rectifying the pilot carrier.

As the cable temperature drops, and the cable loss decreases, the pilot-carrier level input to the amplifier increases. This increase is amplified and rectified by the pilot-carrier amplifier. This rectified voltage is applied to a voltage-controlled attenuator in the trunk amplifier which reduces the gain of the trunk amplifier. Pilot-carrier level control acts to maintain a constant level of the pilot-carrier at the trunk amplifier output under all conditions. This method of control is therefore essentially independent of temperature differentials between the cable and the amplifier. Further, each amplifier tends to correct for any error in the output of the previous amplifier.

The loss of a given length of coaxial cable varies as the square root of frequency. A cable with 20 dB loss on channel 13 will have only 10.4 dB loss on channel 2 (20 dB $x\sqrt{\frac{54}{211}}$ = 10.4 dB). From equation 1 it is found that for this cable length, the attenuation of channel 13 will vary by 2 dB but the attenuation of channel 2 will vary only by 1.04 dB as the temperature varies from 0°F. to 100°F. This points up a major problem in the AGC of CATV amplifiers: if a single pilot carrier is employed at midband for AGC, only the midband will be held by a <u>closed loop</u> system, the high and low frequencies can only receive a compromise (non-closed-loop) correction, which will always be subject to differences in cable and amplifiers. These small differences can be cumulative, on long cable runs. This correction, usually called "tilt-compensation" is often accomplished by applying the same control voltage also to a varicap in one or more of the amplifier stages, so that channel 13 gain is changed approximately twice as much as channel 2 gain.

When a single pilot carrier is employed for ALC in a system, it is desirable to employ the highest practical frequency. This is true for the following general reasons: (1) A high-frequency signal undergoes a greater level variation for a given temperature variation and therefore, the ALC circuits receive a greater change on which to operate. (2) A single pilot system will typically provide 1/2 dB amplifier level stability at the pilot frequency over the full range temperature. With only a high-frequency pilot, at the high end of the channel the pilot signal may be held constant to within 1/2 dB. With high frequency pilot control the low frequency (channel 2) gain will vary by approximately 1/2 dB for each 1 dB of ALC at the high end for correct cable compensation. If the ALC of a given amplifier is 1/2 dB due to temperature instabilities on the high end (channel 13), it is typically only 1/4 dB off on the low band. Conversely, with a low frequency pilot, at the low end of the band each 1 dB variation in gain produced by the ALC at low band must produce a 2 dB variation at high band to provide compensation of the cable. If the ALC provides the same stabilization as above, within 1/2 dB, at the low frequency pilot, the high band levels may be off by 1 dB. Thus, for a 1/2 dB pilot ALC stability, a high-frequency pilot will typically allow a maximum variation of 1/2 dB while a low-frequency pilot might allow a 1 dB maximum variation.

The most practical ALC method is to employ two pilot carriers, one at high band and one at low band. Any tilt variations caused by cable characteristics, amplifier characteristics, or passive-device characteristics will be automatically corrected by the dual-pilot-carrier amplifier, which is normally placed at every 4th to 6th station, with single-pilot-carrier (tilt compensated) amplifiers in between.

Selection of Pilot Carrier Frequencies

The frequencies of these carriers should be relatively close to the TV carriers but not spaced so as to interfere with the TV signals, or to allow TV signals to affect the operation of the pilot carrier and receiver.

In a conventional, standard 12 channel system the following frequencies are available: (1) below 54 MHz (channel 2); (2) between channels 4 and 5 (a band from 72 to 76 MHz is available between these channels); between the FM band and channel 7 (108 to 174 MHz); (3) above channel 13 (above 216 MHz).

In more-than-12-channel systems, the frequencies available for pilot carriers are dependent upon the system type. For mid-band systems which carry additional channels in the frequency range of 108 to 174 MHz, the following ranges are available: (1) below 54 MHz; (2) between channels 4 and 5; (3) above 216 MHz. For systems which apply additional channels above 216 MHz (1) frequencies below 54 MHz are available; (2) the band between channels 4 and 5; (3) the range between 108 and 174 MHz; (4) above the highest-frequency carrier.

The frequencies below 54 MHz and the range between channels 4 and 5 are available for a low frequency pilot carrier in all systems. For 12-channel systems and 20-channel mid-band systems a high pilot carrier above 216 MHz is optimum and for 20-channel high-band systems the high pilot should be above 270 MHz. On the basis of these considerations the following pilot frequencies are desirable:

	Standard 12-Channel System	20-Channel Midband	20-Channel High Band
Low Pilot	73.5 MHz	73.5 MHz	73.5 MHz
High Pilot	225 MHz	225 MHz	225 MHz

A low pilot of 73.5 MHz is chosen first because it provides better ALC stability than a pilot carrier below 54 MHz. Most existing amplifiers do not extend below 50 MHz in frequency response, and this low-frequency range is now being used for 2-way transmission. Further, 73.5 MHz has been widely employed by several manufacturers, and problems associated with this frequency have been solved (this will be discussed later). A pilot carrier at 225 MHz is field-proven and is again selected for systems with frequencies below 216 MHz. For high band systems with frequencies up to 270 MHz, somewhat better ALC stability is obtained if the pilot carrier is moved nearer the top of the band (between 270 and 280 MHz for example).

Pilot Carrier/Video Color Interference

The problem which has occurred in the field with a 73.5 MHz CW pilot carrier has been due to a beat product between the 73.5 MHz and the channel 5 picture carrier. This third-order beat occurs in the TV receiver tuner and is usually apparent only in color TV receivers which have poorer third order intermodulation performance. Sensitivity adjustment in the color-carrier circuit also has some effect. These receivers usually have solid state RF stages and mixers. The relationships between carriers are as follows:

(a) Channel 5 Video Carrier = 77.25 MHz

(b) Major spectral component at channel 5 video = ±N (.015750) MHz
where N = any integer

(c) Third order beat = $2 F_1 - F_2$

(d) $2F_1 - F_2 = 2[77.25 \pm N(.015750)] - 73.5$

$= 81.00 \pm 2N(.015750)$

(e) Ch. 5 color carrier = 80.829545 (not-offset)

(f) For N = -5; $2F_1 - F_2 = 81.000 - 10(.015750)$ (or if pilot-carrier is off by approximately 150 kc)

$= 80.842500$

Thus the products (f above) fall within 15 kC of the color subcarrier (e). This spurious signal asynchronously aids or retards the resultant phasor formed with the color subcarrier and produces a color-bar pattern on the TV screen.

This interference problem is eliminated by using a pulsed pilot carrier at 73.5 MHz which is synchronized to the horizontal blanking pulses of channel 5 (patented). The 73.5-MHz carrier is applied for only 3 microseconds during the horizontal blanking interval of ch. 5. A block diagram of this synchronized RF pulse generator is shown in Figure 1.

Use of a pulsed pilot carrier negligibly affects the ALC circuits of the trunk amplifiers. Since the RF pilot is on for only 3 microseconds and is off for 60 microseconds, the ALC detector in the trunk amplifier requires a rapid rise time (less than 3 microseconds) and a long fall time (greater than 60 microseconds) to assure efficient operation on the pulse. This requires only a minor modification, if any, on most existing trunkline amplifiers.

Trunk-Amplifier ALC Circuit Considerations

We have seen that a pulsed pilot carrier is required at 73.5 MHz, and that a CW pilot may be employed at 225 MHz.

Consider now the conventional ALC circuitry employed in trunk amplifiers, as shown in the block diagram of Figure 2. The trunkline input is amplified by the trunk amplifier and is applied to a power splitter. The power splitter passes most of this signal to the line output but provides a low level output (typically 20 dB below the line output) to the band pass filter. This filter is typically a 2-resonator type with a band pass of approximately 1 MHz in a 73.5 MHz pilot amplifier and 2.5 MHz in a 225 MHz pilot amplifier. Insertion loss is typically 8 dB.

For a 73.5-MHz pilot the input level to the band pass amplifier is approximately 0 dB mV and because the detector requires a 1 volt input the RF gain of this bandpass amplifier must be high, typically 60 dB.

The dc output from the detector is applied to a dc amplifier and this amplifier in turn drives the ALC attenuator of the trunk amplifier to provide closed-loop gain control. For dual-pilot carrier control, an identical second loop supplies a voltage to drive a frequency-sensitive-device such as a varicap.

High RF gain in the ALC amplifier in this method is required to minimize temperature drift in the dc output of the detector. The dc voltage drop across a conducting germanium semiconductor diode is typically .3 volts but this drop decreases by approximately 2 millivolts per degree centigrade. If, for example, the detector of figure 2 receives a 0.5 volt peak RF signal, the rectified output will be only .2 volt due to the diode drop. If the temperature drops by 50°C. then the output voltage will decrease to (.2 - .002 x 50 = 0.1 volt). This in itself will cause a 6 dB ALC instability, which is intolerable and difficult to compensate. This effect is minimized by applying a large signal to the diode. Thus with 1 volt (rms) applied to the detector, a dc voltage of typically 1.1 volts dc is developed. This decreases to 1.0 volts for a 50°C. temperature decrease (1.1 - .002 x 50 = 1.0). This causes an ALC instability (of only 1 dB) which can be further reduced by compensation. The requirement of a high RF level must be met whenever a highly-stable detected dc voltage is needed. This means that a high-gain bandpass amplifier like that of Figure 2 must be incorporated in the trunk amplifier. Unless this amplifier is carefully bypassed and shielded, leakage of its signal can produce peaks in the response of the trunk amplifier. If the preselector is not carefully aligned, adjacent TV signals can also affect ALC levels. If the preselector is not temperature stable, its loss will also vary with temperature, and further affect ALC levels.

Pulsed Pilot Carrier ALC with Double Detector

We now consider an ALC system which is used with a pulsed pilot carrier. This system offers advantages of simplicity, excellent performance and flexibility. Use of this circuit requires a pulsed RF pilot carrier. Both 73.5-MHz and 225-MHz pulsed pilot carrier are easily provided. The ALC circuit of Figure 2 may be employed in the trunk amplifiers with only minor modifications for either a CW pilot or a pulse pilot carrier.

The pulsed pilot ALC system is presented in Figure 3. A portion of the trunkline output is applied through a power splitter to the ALC section. Note that this signal is applied to an isolation amplifier which precedes the bandpass filter. This isolation amplifier provides a broad band matched input impedance. When the low level output of the power splitter of the conventional ALC of Figure 2 is applied to the bandpass filter, a small ripple, on the order of .05 dB, is produced in the over-all trunk amplifier response. This dip or valley is due to the input impedance characteristic of this filter. For frequencies above and below its bandpass it is a high impedance. For frequencies within its bandpass, it is a low impedance and although hardly apparent with one amplifier, a ripple of 0.5 dB or more can occur at the pilot frequency when ten or more amplifiers are cascaded, causing the pilot-carrier level to drop off accordingly. The broadband, matched isolation amplifier of Figure 3 minimizes this problem.

Output of the bandpass filter is applied to the low-level RF detector. The output of this detector is AC-coupled to the high-gain video amplifier. The isolation amplifier has a gain of typically 15 dB; hence the signal applied to the RF detector is only 15 dBmV.

Based on the previous analysis of detector performance with temperature, it would appear that very unstable detector performance will be obtained. This is not the case because this RF detector provides an AC (pulse) output rather than DC. It has been found that a detector will deliver a very constant AC output over a wide temperature range even with low RF input levels, although the DC output will under these conditions vary widely. This is made apparent by the curves of Figure 4, which show that the volt-amp diode characteristic translates vertically as temperature is increased but the slope at any given input voltage is essentially unchanged. At a CW pilot level Vp, the DC voltage output of the detector increases by ΔV as the temperature increases from 0°F. With a pulsed pilot the <u>peak</u> to <u>peak</u> pulse amplitude is virtually unchanged as temperature increases from 0°F. to 100°F. It is from this peak-to-peak pulse that the ALC circuit of Figure 3 operates.

The AC output from the low-level RF detector of Figure 3 is a pulse which is stable with temperature. This low-level pulse is AC coupled to a high-gain video amplifier which provides 70 dB gain. This 70 dB gain is easily obtained in a single integrated circuit package; 70 dB of video gain, in the range of 15 to 200 KHz can be obtained with smaller, less expensive circuitry than can the 60 dB of RF gain of Figure 2 (73.5 or 225 MHz). Output from the video amplifier consists of video pulses with typical peak-to-peak amplitudes of 2 volts. These high-level pulses are applied to a peak detector which provides a temperature-stable dc output voltage to the dc amplifier which in turn drives the trunk amplifier attenuator and/or varicap to provide closed-loop gain and slope control of the amplifier.

The arrangement of Figure 3 has several advantages over the conventional circuit of Figure 2 in addition to elimination of color beat in Channel 5:

(1) The unit of Figure 3 can be made physically smaller because 70 dB of video gain can be obtained in a single integrated circuit. The 60 dB of RF gain in Figure 2 requires much more space because of the inherent coupling problems at VHF, and the fact that this gain cannot be obtained in a single integrated circuit. (2) The configuration of Figure 3 is less costly than that of Figure 2. (3) The pilot carrier frequency can be easily changed. The circuitry of Figure 3 following the bandpass filter is always the same regardless of the pilot carrier frequency. The only elements of 3 which change with pilot carrier frequency are those of the bandpass filter which can be easily modified to operate at any pilot frequency. The circuit configuration of Figure 2 requires that both the bandpass filter and bandpass amplifier be modified for major pilot carrier frequency changes.

Trunk Amplifier ALC Stability

Initially, the trunk amplifier output stability will be considered for the pilot carriers. Then, stability over the total operating frequency range will be considered, since true "level control" is accomplished only when all levels remain stable.

The output level of an ALC trunk amplifier is a function of two parameters. One of these is the absolute temperature stability of the ALC system, which is essentially independent of the input signal level and is only a function of temperature. The other is the closed loop ALC gain. These relationships may be assumed linear for small signal changes. Consider the following relationship:[1]

(Eq. 2) $$\Delta E_o \text{ (dB)} = \frac{\Delta E_{in} \text{ (dB)}}{1 + G} + K \Delta T$$

where ΔE_o = dB change in output trunk level at the pilot frequency

ΔE_{in} = dB change in the trunk input level

ΔT = temperature change, °F

K = an ALC stability constant with dimensions of dB per degree F^o

G = ALC gain constant

$= G_1 G_2 G_2$

where $G_1 = \dfrac{\text{voltage change at final detector output}}{\text{dB change in trunk amp output}} = \dfrac{\text{volts}}{\text{dB}}$

G_2 = D.C. gain of amplifier following final detector

$$G_3 = \frac{\text{dB change of attenuator in trunk amplifier}}{\text{voltage change of ALC}} \qquad \frac{\text{dB}}{\text{volt}}$$

In designing a trunk amplifier ALC system the variations in output level (ΔE_o) can be made very small for given variations in amplifier input (ΔE_{in}) by making the gain constant (G) arbitrarily large. This may be done by having a high dc amplifier gain (G_2) a high RF or video gain (G_1), or a very sensitive ALC attenuator, G_3. Good design requires a balance and optimum distribution of these gains. For the level variations encountered at the input of a trunk amplifier (± 4 dB or less), the gain constant can be easily made sufficiently large so that a ± 4 dB input variation produces only ± .1 dB output variation. Thus the first term of equation 2 does not represent a major design problem, and CATV amplifiers have been available with very high gain constants to hold output variations within very small limits, at constant ambient temperatures.

If the input level to an ALC controlled trunk amplifier is held constant, and the amplifier environment is varied from typically -40°F. to +140°F., it will be found that the output level of many CATV trunk amplifiers will significantly vary. The ALC system can handle input variation (G is high) but is basically temperature unstable (K is high), and the output level will be held only as constant as the ALC gain remains constant.

To hold the trunk amplifier output constant to 1 dB requires individual amplifiers and filters to be stable to a fraction of a dB over a wide temperature range. And when the temperature coefficient of semiconductors and economically-feasible passive components are considered, these are extremely tight limits. The most practical solution is to produce a design in which the various temperature coefficients cancel each other.

If, for example, the isolation amplifier gain of Figure 3 rises by .25 dB, the bandpass filter insertion loss increases by .25 dB, the low level RF detector and video amplifier gains increase by .5 dB for a temperature change of -30 to +150°F., then the trunk level will vary by .5 dB (+.25 - .25 +.5) and with additional small compensatory elements, this variation can be further decreased.

Unfortunately, the temperature coefficients of the elements of the ALC circuits of trunk amplifiers are not all the same. Thus, in 100 IC video amplifiers, 80 may have a gain characteristic which increases an average of 1 dB as the temperature changes from -30 to +150°F.; 15 may have a gain characteristic which increases by only .5 dB over this temperature range; and 5 may have a gain characteristic which <u>decreases</u> by a .5 dB over this range.

The mean and variances of the statistical distribution of the temperature coefficients of the ALC system must be considered in ALC design. The over-all system noise figure and cross modulation characteristics vs. temperature are primarily determined by the mean ALC characteristics. Thus, if in a 20-amplifier system the output of all amplifiers but 1 increase by .5 dB as temperature increases, and in only one amplifier the output increases by 2 dB, the over-all system cross modulation will increase by 1 dB (2 x .5) and will be negligibly affected by a 2 dB rise in one amplifier (assuming the amplifier remains in a well-behaved X-mod range).

The final factors to be considered are the effects of temperature variation upon the insertion loss and tuning of the pilot carrier bandpass filters of Figures 2 and 3. These filters employ high-Q tuned circuits which are very lightly loaded to provide narrow bandwidth and high rejection to the TV carriers. As a result of the high Q and narrow bandwidth, small variations in L and C can detune the filters. These variations can be caused by both temperature changes and high humidity.

Humidity can be a significant problem in a sealed trunk amplifier if, for example, the amplifier is opened on a warm humid day and then closed. The air in the amplifier now contains significant water vapor. The passive tuning elements (capacitors and inductors) generate no heat. As outside temperature drops, the warm humid air in the trunk amplifier around these components deposits moisture droplets on them when the dew point is reached and these moisture droplets significantly lower Q and vary capacitance in this VHF range.

Tests performed on numerous glass, air, and ceramic trimmers demonstrated this to be a very significant problem, and the best solution was found to be to use sealed fixed capacitors and tune the circuits by varying the inductance.

The inductors employed in these filters are air wound with heavy wire and as temperature rises this wire expands slightly and this expansion increases the inductance slightly. This effect is neutralized by employing sealed tuning capacitors with a slight negative coefficient of capacitance (typically 15 parts per million per degree C.) The capacitance decreases slightly as the inductance increases, and negligible detuning occurs.

The final temperature effect is a slight decrease in Q of the filters as coil resistance increases at higher temperature. This produces a slight increase in insertion loss, which is compensated in the video amplifier.

Level Control at Frequencies Other Than Pilot-Carrier

At frequencies other than those of the pilot carriers, the output level at frequencies other than the pilot carriers is determined partially by the temperature coefficients of frequency response of the trunk amplifier. With a single 73.5-MHz pilot carrier in an ideally-tilted amplifier, and a 0.5 dB ALC stability, the stability at 216 MHz is approximately 1 dB. It was shown earlier that use of a high-frequency pilot reduces the error, which is further reduced with dual pilot control.
A stable temperature characteristic over the full band requires a temperature-stable basic trunk amplifier response in addition to a temperature-stable ALC system.

Temperature Variations in Trunk System Performance

Consider first a perfect trunk ALC system in which the output of all amplifiers is held absolutely constant. With 20 dB spacing between amplifiers the levels below are obtained (full tilt system with 20 dB (cable) spacing on channel 13 at 60°F.):

TABLE 1 - "Perfect" ALC Stability

	Output Level		Input Level	
Temperature	Ch. 2	Ch. 13	Ch. 2	Ch. 13
- 30°F	25 dBmV	+35 dBmV	+15.9 dBmV	+16.8
+ 60°F	+25	+35	+15 dBmV	+15 dBmV
+130°F	25	+35	+14.3	+13.6

TABLE 2 - Cable Characteristics

	Cable Loss	
Temperature	Ch. 2	Ch. 13
- 30°F	9.1 dB	18.2 dB
+ 60°F	10. dB	20.0 dB
+130°F	10.7	21.4 dB

From the output levels of Table 1 we can say that there will be no change in the system cross modulation as temperature is varied (based upon the practical assumption that system cross modulation (X mod) = $K_1 + 2\Delta E_o$ (dBmV). From the input levels of Table 1 we see that the system noise on channel 13 will decrease by 1.8 dB as the temperature drops from

+60°F. to -30°F. Conversely as the temperature increases from +60°F. to 130°F. the system noise rises by 1.4 dB.

The "Perfect" ALC system described by Table 1 is characterized in equation 2 by the two constants G and K. For perfect ALC, G = 00 and K = 0. We next consider a less perfect system in which G = 00 and K = -.01 dB per F°. This system is characterized by Table 3 below.

TABLE 3 - System Levels for K = -.01, G = 00

Temperature	Output Level		Input Level	
	Ch. 2	Ch. 13	Ch. 2	Ch. 13
- 30°F.	+25.9 dBmV	+35.9 dBmV	+16.8	+17.7
+ 60°F.	+25	+35	15	15
+130°F.	+24.3	+34.3	+13.6	+12.9

From this table we see that at the low system temperature over-all cross modulation increases by 1.8 dB but noise figure drops by 1.8 dB (Ch. 13). At high temperature system cross modulation drops by 1.4 dB but system noise figure increases by 1.4 dB (at Ch. 13).

Table 4 below shows system levels for a stability constant of +.01 dB /F°.

Table 4 - System Levels for K = +.01, G = 00

Temperature	Output Level		Input Level	
	Ch. 2	Ch. 13	Ch. 2	Ch. 13
+ 30°F	24.3	34.3	15.2	16.1
+ 60°F	25	35	15	15
+130°F	25.9	35.9	15.2	14.5

Table 5 below summarizes the performance of the systems of Tables 1, 3, and 4.

System	Change in System Noise Figure		Change in System Cross Mod.	
	Ch. 2	Ch. 13	Ch. 2	Ch. 13
K = 0	- .9/+ .7	-1.8/+1.4	0/0	0/0
K = -.01	-1.8/+1.4	-2.7/+2.1	+1.8/-1.4	+1.8/-1.4
K = +.01	- .2/- .2	-1.1/+ .5	-1.4/+1.8	-1.4/+1.8

Parameter at -30°F./Parameter at +130°F.

From Table 5 it is apparent that ALC instabilities cause variations in system cross modulation, and the variation in cross modulation is independent of the drift direction (i.e. K = +.01 or .01). However, it is seen that the system noise figure changes less over the temperature range for K = +.01, that is, if the amplifier output level increases with cable attenuation.

We conclude that the ALC system should allow minimum output level variation and the statistical mean output of a group of amplifiers should be slightly positive for increasing temperature.

Conclusion

Use of dual-pulsed-pilot-carrier ALC control in CATV transmission system amplifiers provides greatly increased stability in the system, besides eliminating interference between the pilot carrier and TV channels. Careful design, test, and selection of components, with temperature compensation, provide for output level stability at all temperatures.

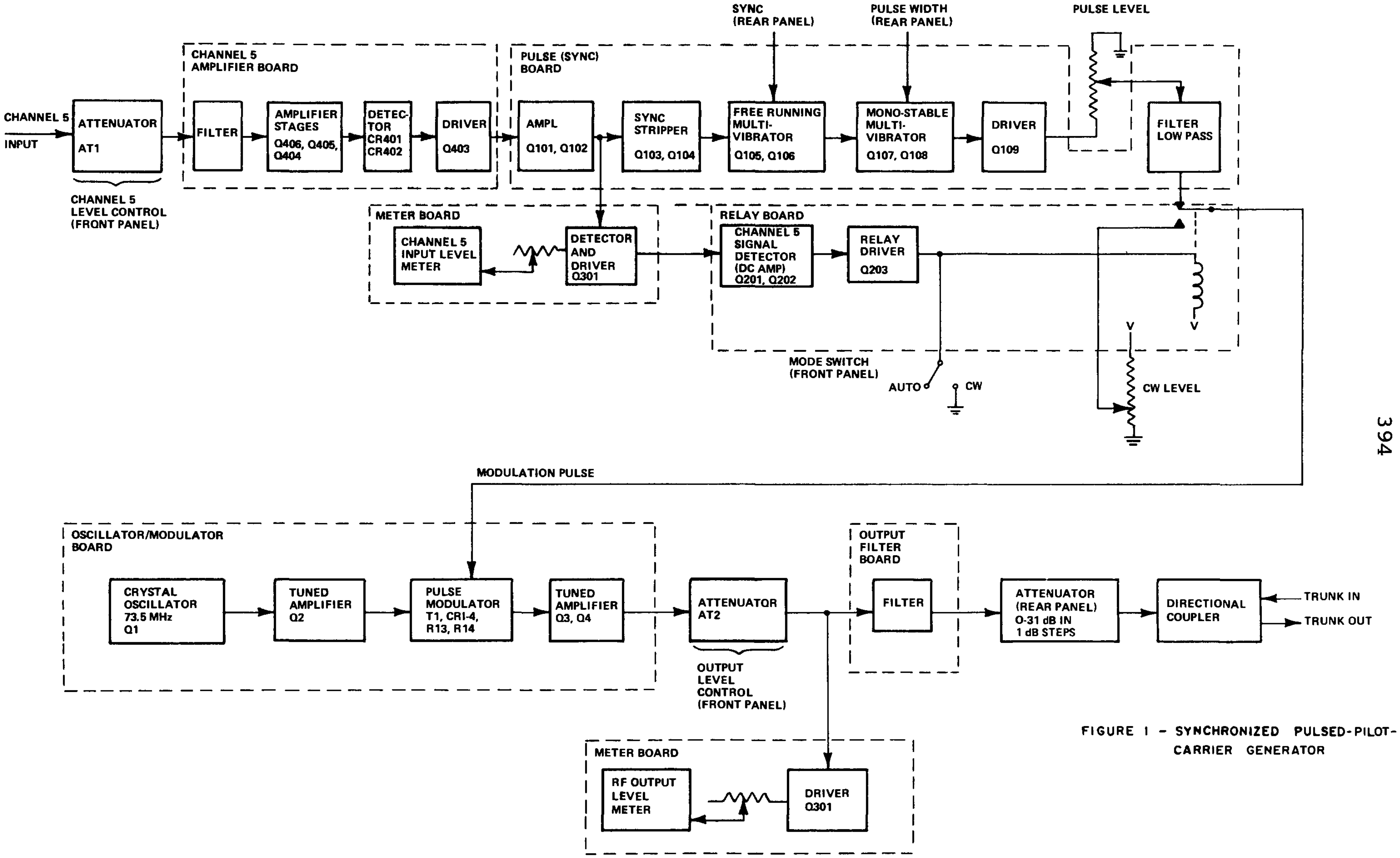

FIGURE 1 - SYNCHRONIZED PULSED-PILOT-CARRIER GENERATOR

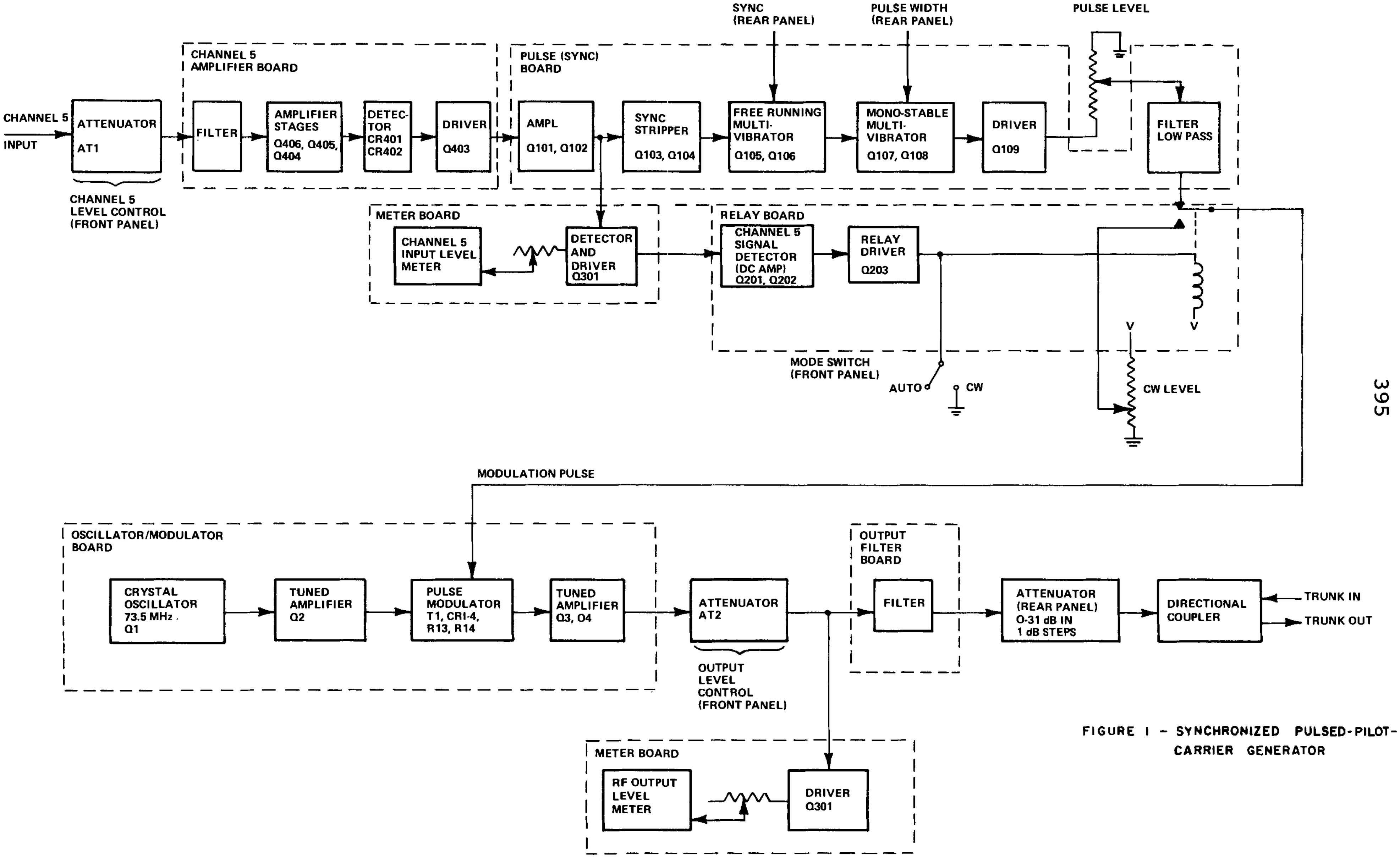

FIGURE I - SYNCHRONIZED PULSED-PILOT-CARRIER GENERATOR

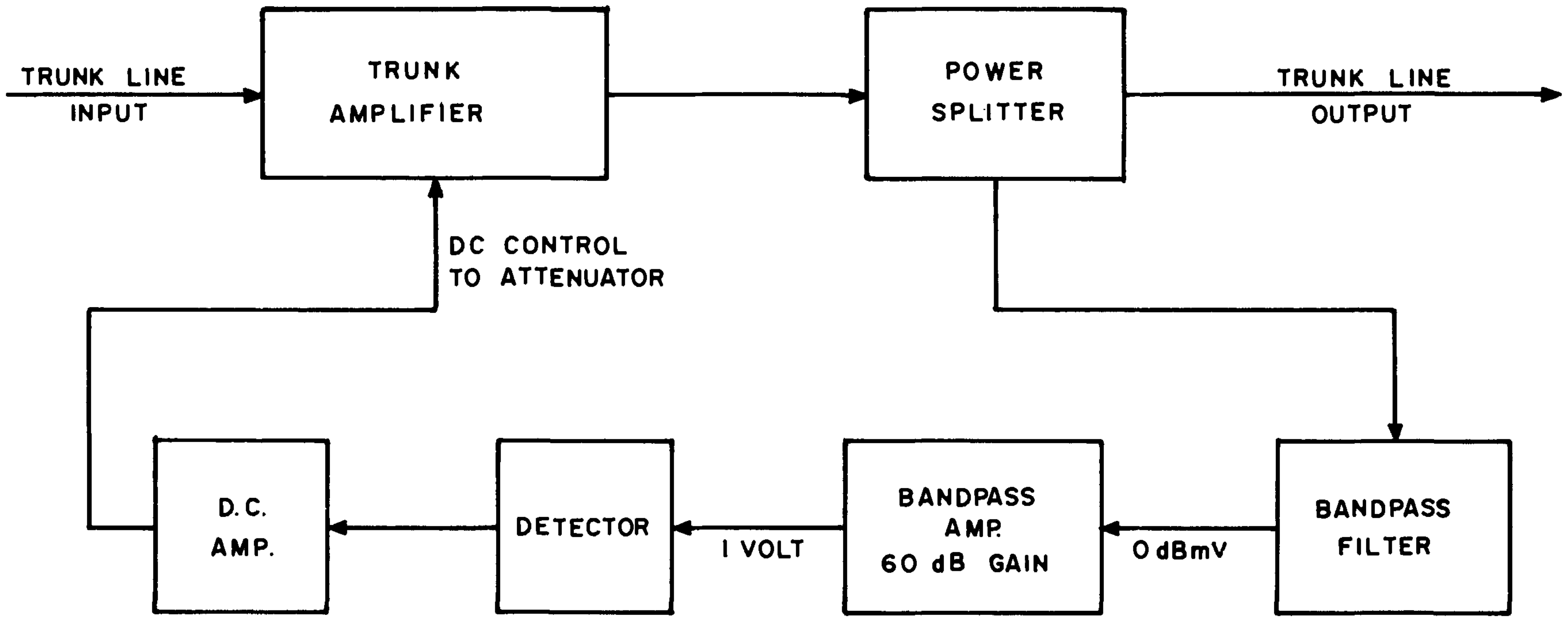

FIGURE 2 - CONVENTIONAL CW-PILOT-CARRIER TRUNK AMPLIFIER ALC

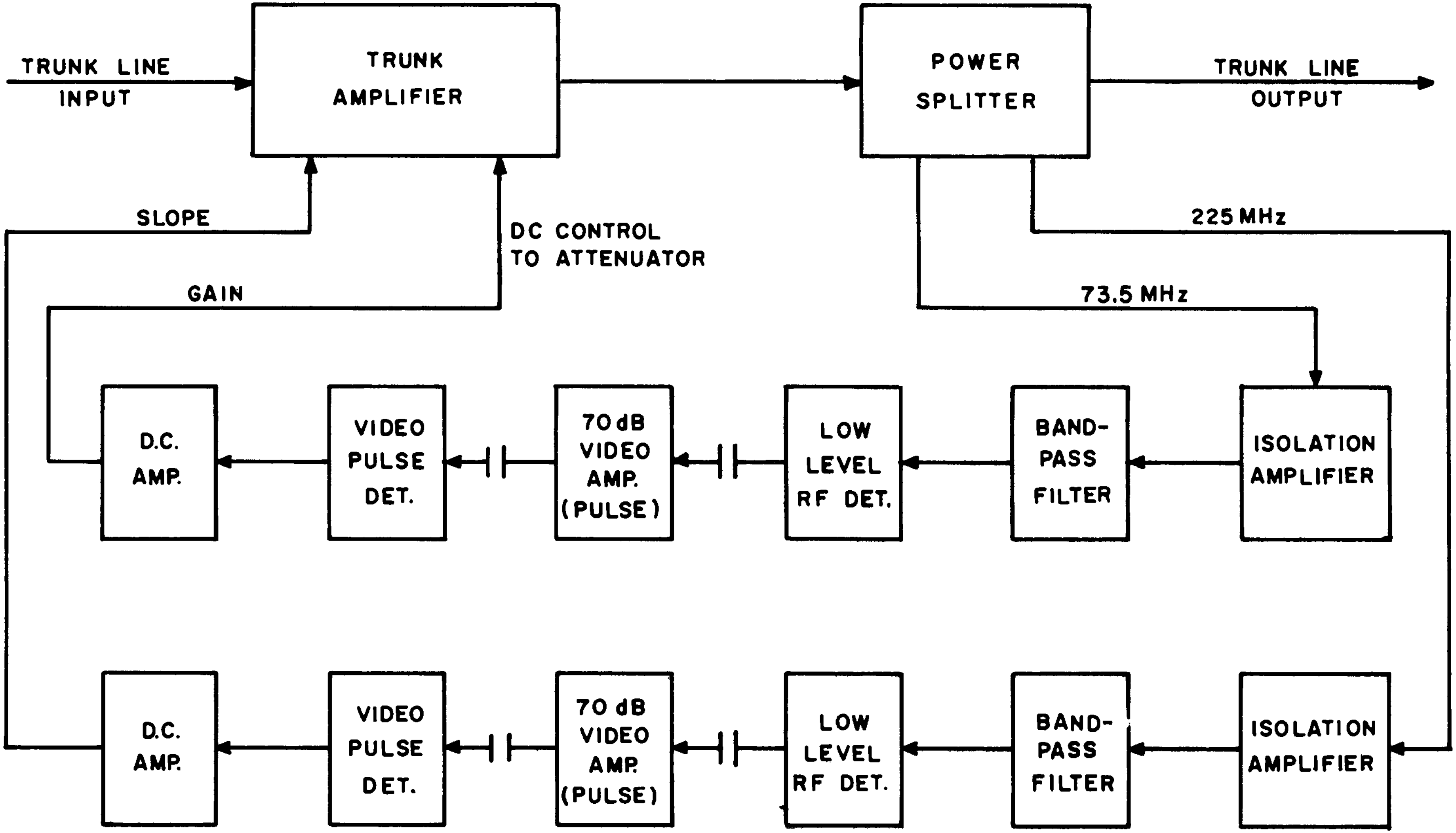

FIGURE 3 – PULSED-PILOT-CARRIER ALC

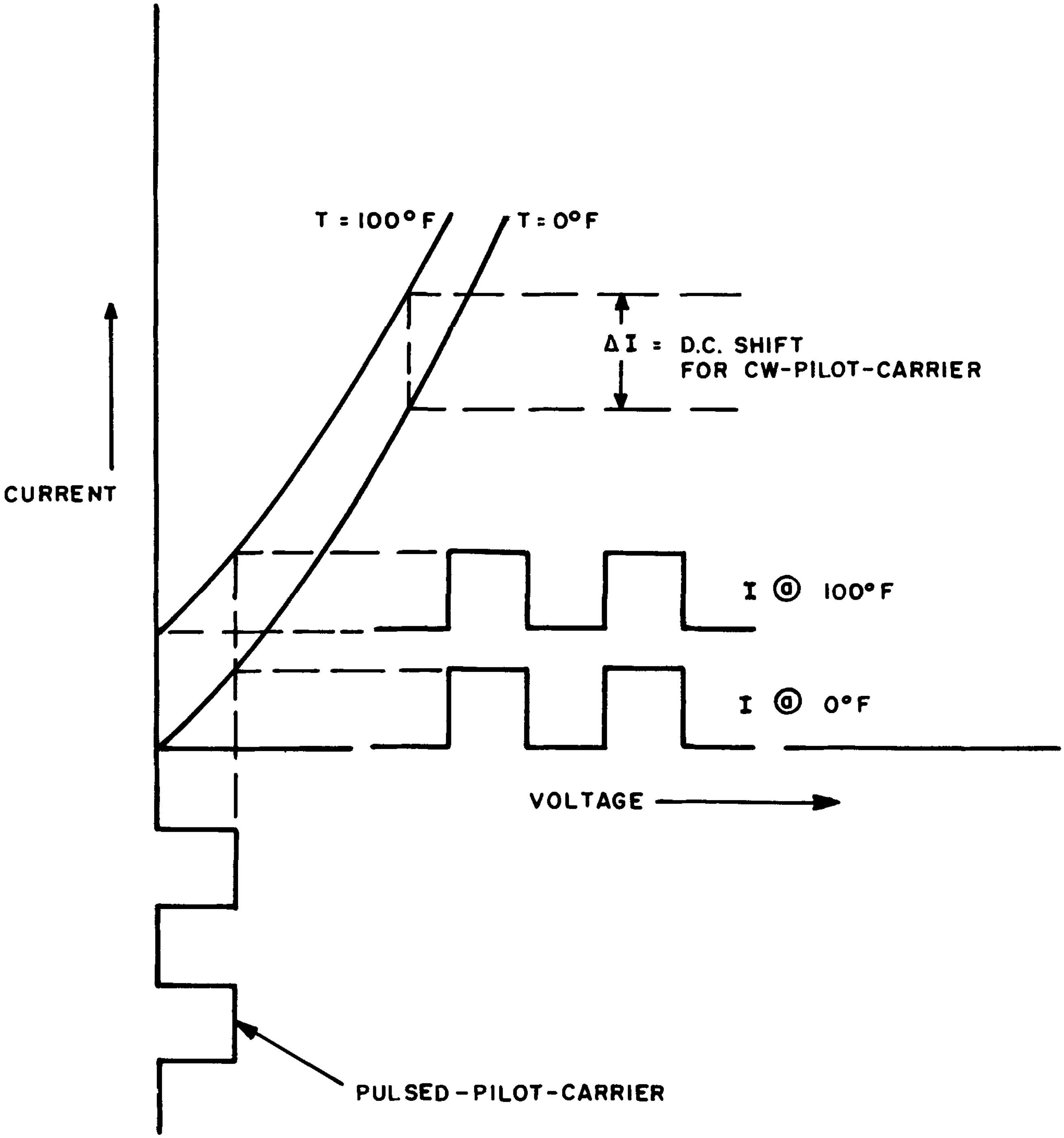

FIGURE 4 – DIODE DETECTOR CHARACTERISTICS

References:

(1) Victor, W. K., and M. H. Brockman. "The Application of Linear Servo Theory to the Design of AGC Loops". Proceedings of the IRE, Vol. 48, February, 1960, pp. 234-238.

Referring to the last equation on page 236 of this article, if we let $t \to \infty$, the steady-state expression for change in receiver (amplifier) attenuation $a^*(t)$ dbv $= \dfrac{\Delta a_{db}}{1+\frac{1}{G}} = \dfrac{G\Delta a_{db}}{1+G} = \dfrac{G\Delta E_{in}}{1+G}$

(Δa_{db} in the change in input signal level $= \Delta E_{in}$)

$\Delta E_{out} = \Delta E_{in} - a^*(t)_{db}$ in dB, for small signal levels, and, substituting for $a^*(t)_{db}$

$$\Delta E_{out} = \Delta E_{in} - \frac{G\,\Delta E_{in}}{1+G}$$

$$= \frac{\Delta E_{in}\,(1+G-G)}{1+G} = \frac{\Delta E_{in}}{1+G} \qquad \text{(dB)}$$

To which we add an arbitrary temperature-variable factor $K\Delta T$ to represent output level changes caused by temperature instability of the AGC Loop:

$$\Delta E_{out} = \frac{\Delta E_{in}}{1+G} + K\Delta T \qquad \text{dB}$$