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CHARACTERISTICS OF COMPANDORS FOR TELEPHONY

ITU-T Recommendation G.162

Superseded by a more recent version

(Extract from the *Blue Book*)

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NOTES

1 ITU-T Recommendation G.162 was published in Fascicle III.1 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation G.162

CHARACTERISTICS OF COMPANDORS FOR TELEPHONY

(Geneva, 1964; amended at Mar del Plata, 1968)

These characteristics are applicable to compandors of modern design for use either on very long international circuits or on national and international circuits of moderate length.

Some of the clauses given below specify the joint characteristics of a compressor and an expander in the same direction of transmission of a 4-wire circuit. The characteristics specified in this way can be obtained more easily if the compressors and expanders are of similar design; in certain cases close cooperation between Administrations may be necessary.

It should also be noted that the equipement produced so far for circuits of moderate length may be completely satisfactory for those circuits and yet not quite meet the clauses of this Recommendation.

1 Definition and value of the unaffected level

The unaffected level is the absolute level, at a point of zero relative level on the line between the compressor and the expander of a signal at 800 Hz, which remains unchanged whether the circuit is operated with the compressor or not. The unaffected level is defined in this way in order not to impose any particular values of relative level at the input to the compressor or the output of the expander.

The unaffected level should be, in principle, 0 dBm0. Nevertheless, to make allowances for the increase in mean power introduced by the compressor, and to avoid the risk of increasing the intermodulation noise and the overload which might result, the unaffected level may, in some cases, be reduced by perhaps as much as 5 dB. However, this reduction of unaffected level entails a diminution of the improvement in signal-to-noise ratio provided by the compandor. This possible reduction should be made by direct agreement between the Administrations concerned. No reduction is necessary, in general, for systems with less than 60 channels.

Note - The increase in the mean power in the transmitted band determined by the compressor in the telephone channel depends on the value of the unaffected level, the attack and recovery times, the distribution of the speech volumes and the mean power level of transmitted speech. When 0 dBm0 is adopted for the unaffected' level, it appears that the effective increase in the mean power level is of the order of 2 or 3 dB.

2 Ratio of compression and expansion

2.1 *Definition and preferred value of the* **ratio of compression**

The ratio compression of a compressor is defined by the formula:

$$\alpha = \frac{n_e - n_{e0}}{n_s - n_{s0}}$$

where:

n_e is the input level;

n_{e0} is the input level corresponding to 0 dBm0;

n_s is the output level;

n_{s0} is the output level corresponding to an input level of n_{e0}.

The preferred value of α is 2, though lower values are permissible, provided sufficient noise improvement is obtained. The value shall not exceed 2.5 for any level of input signal and at any temperature between + 10 °C and + 40 °C.

2.2 *Definition and preferred value of the* **ratio of expansion**

The ratio of expansion of an expander is defined by the formula:

$$\beta = \frac{n'_s - n'_{s0}}{n'_e - n'_{e0}}$$

where:

n'_e is the input level;

n'_{e0} is the input level corresponding to 0 dBm0;

n'_s is the output level;

n'_{s0} is the output level corresponding to an input level of n'_{e0}.

The preferred value of ß is 2, though lower values are permissible, provided sufficient noise improvement is obtained. The value shall not exceed 2.5 for any level of input signal and at any temperature between + 10°C and +40°C.

2.3 *Range of level*

The range of level over which the recommended value of α and ß should apply should extend at least:

from + 5 to - 45 dBm0 at the input of the compressor, and

from + 5 to - 50 dBm0 at the nominal output of the expander.

2.4 *Variation of compressor gain*

The level at the output of the compressor, measured at 800 Hz, for an input level of 0 dBm0, should not vary from its nominal value by more than ± 0.5 dB for a temperature range of + 10°C to + 40°C and a deviation of the supply voltage of ± 5% from its nominal value.

2.5 *Variation of expander gain*

The level at the output of the expander, measured at 800 Hz for an input level of 0 dBm0, should not vary from its nominal value by more than ± 1 dB for a temperature range of + 10 °C and + 40 °C and a deviation of the supply voltage of ± 5% from its nominal value.

Note - It is desirable, especially for compandors intended for very long circuits, to set stricter limits than the values of +0.5 dB and ± 1 dB given under § 2.4 and § 2.5; +0.25 dB and +0.5 dB respectively are preferable.

2.6 *Conditions for stability*

The insertion of a compandor shall not appreciably reduce the margin of stability. To ensure this, for the combination of an expander and a compressor on the same 4-wire circuit and at a given station, the error of the output level of the compressor with respect to any value of expander input level shall not exceed + 0.5 dB. This error is referred to the level obtained at the compressor output when the input level is 0 dBm0. This limit shall be observed at all frequencies between 200 and 4000 Hz within the temperature range + 10°C to + 40°C. No negative limit is specified for the error. In this test an attenuator shall be inserted between the expander and the compressor, the value of which is to be set in accordance with the following Note 1.

Note 1 - This Note concerns the influence of a compandor on the loop gain of a 4-wire circuit and on the margin of stability.

In examining this problem, a connection was considered made up of three 4-wire circuits, *AB, BC* and *CD,* which link the terminal stations *A* and *D* (at which the terminating sets are located) through the intermediate stations *B* and *C.* It is assumed that the circuit *BC* is equipped with compandors. It is desired to determine the tolerances for the gain of the combination of expander and compressor at *C* in order to limit the reduction in the margin of stability caused by their insertion. To facilitate study of this question it is assumed that, in normal use, the expander output and compressor input are points of the same relative level.

The following expression then gives the loss between the output of the expander at *C* and the input of the compressor at *C:*

$$a_s = a_0 + a_r + a_x + a_y$$

where

a_0 is the nominal transmission loss of the chain of circuits between the 2-wire terminals at *A* and *D*;

a_r is the balance return loss at the terminating set at *D*;

a_x is the departure of transmission loss of channel *CD* from its nominal value;

a_y is the departure of transmission loss of channel *DC* from its nominal value.

The two latter values may be positive or negative.

It may be concluded that, in order that the measurement of the gain of the combination of an expander and a compressor at the same station may satisfactorily determine the total effect on the margin of stability, the following conditions must be observed:

The expander must be connected to the compressor via an attenuator, the loss of which should cover the entire range of values for a_s which actually occur when there is a risk of instability. To take account of all practical conditions, it would probably be necessary to consider a very wide range.

However, considering only the important example of a terminal compandor and zero balance return loss, then $a_s = a_0$ and this is the value which is generally recommended for the loss of the attenuator between expander and compressor in this test.

Nevertheless, when it is possible to determine the exact values of a_r, a_x and a_y, corresponding to the most probable condition of instability, the exact value of a_s can be specified.

It has been assumed that the expander output and the compressor input are normally points of the same relative level. If this is not the case, and if the relative level at the expander output is a_c dB higher than the relative level at the compressor input, the loss in the attenuator should be increased by a_c (which may be positive or negative).

Note 2 - Cross-connection between the control circuits of the compressor and expander may have advantages from the point of view of circuit echoes; hence, its use should be allowed. On the other hand its use, which has some disadvantages from the point of view of signalling-to-voice break-in, will certainly be confined to exceptional cases. In consequence, there seems no need for any special recommendations on the subject.

2.7 *Tolerances on the output levels of the combination of compressor and expander in the same direction of transmission of a 4-wire circuit*

The compressor and expander are connected in tandem. A loss (or gain) is inserted between the compressor output and expander input equal to the nominal loss (or gain) between these points in the actual circuit in which they will be used. Figure 1/G.162 shows, as a function of level of 800-Hz input signal to the compressor, the permissible limits of difference between expander output level and compressor input level. (Positive values indicate that the expander output level exceeds the compressor input level.)

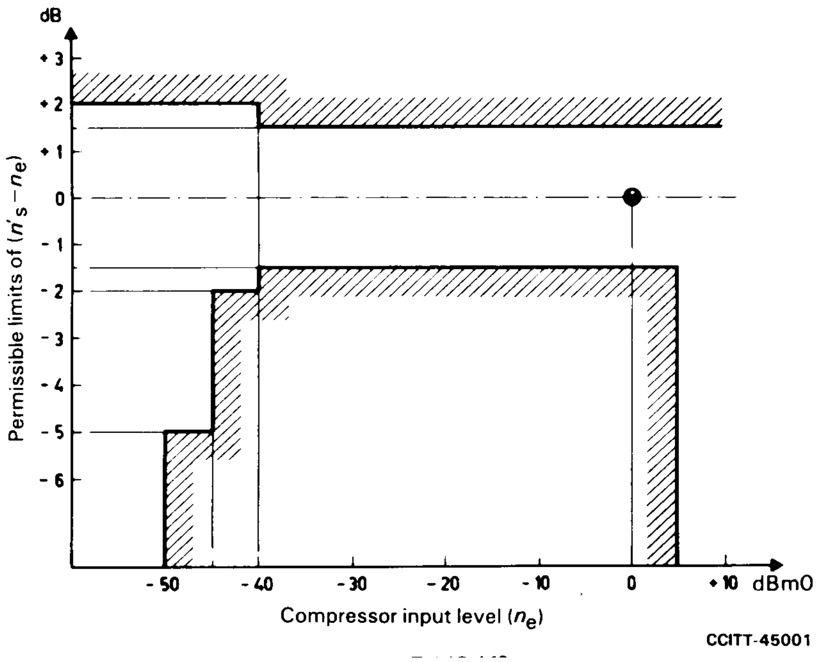

FIGURE 1/G.162

The limits shall be observed at all combinations of temperature of compressor and temperature of expander in the range + 10°C to + 40°C. They shall also be observed when the test is repeated with the loss (or gain) between the compressor and expander increased or decreased by 2 dB.

Note - The change of gain (or loss) of 2 dB mentioned in § 2.7 above is equal to twice the standard deviation of transmission loss recommended as an objective for international circuits routed on single group links in Recommendation G.151, § 3.

3 Impedances and return loss

The nominal value of the input and output impedances of both compressor and expander should be 600 ohms (nonreactive).

The return loss with respect to the nominal impedance of the input and the output of both the compressor and the expander should be no less than 14 dB over the frequency range 300 to 3400 Hz and for any measurement level between + 5 and - 45 dBm0 at the compressor input or the expander output.

4 Operating characteristics at various frequencies

4.1 *Frequency characteristic with control circuit clamped*

The control circuit is said to be clamped when the control current (or voltage) derived by rectification of the signal is replaced by a constant direct current (or voltage) supplied from an external source. For purposes here, the value of this current (or voltage) should be equal to the value of the control current (or voltage) obtained when the input signal is 0 dBm0 at 800 Hz.

For the compressor and the expander taken separately, the variations of loss or gain with frequency should be contained within the limits of a diagram that can be deduced from Figure 1/G.132 by dividing the tolerance shown by 8, the measurement being made with a constant input level corresponding to a level of 0 dBm0.

These limits should be observed over the temperature range + 10° C and + 40° C.

4.2 *Frequency characteristic with control circuit operating normally*

The limits given in § 4.1 should be observed for the compressor when the control circuit is operating normally, the measurement being made with a constant input level corresponding to a level of 0 dBm0.

For the expander, under the same conditions of measurement, the limits can be deduced from Figure 1/G.132 by dividing the tolerances shown by 4.

These limits should be observed over the temperature range + 10° C to + 40° C.

5 Nonlinear distortion

5.1 *Harmonic distortion*

Harmonic distortion, measured with an 800-Hz sine wave at a level of 0 dBm0, should not exceed 4% for the compressor and the expander taken separately.

Note - Even in an ideal compressor, high output peaks will occur when the signal level is suddenly raised. The most severe case seems to be that of voice-frequency signalling, although the effect can also occur during speech. It may be desirable, in exceptional cases, to fit the compressor with an amplitude limiter to avoid disturbance due to transients during voice-frequency signalling.

5.2 *Intermodulation tests*

It is necessary to add a measurement of intermodulation to the measurements of harmonic distortion whenever compandors are intended for international circuits (regardless of the signalling system used), as well as in all cases where they are provided for national circuits over which multi-frequency signalling, or data transmission using similar types of signals, is envisaged.

The intermodulation products of concern to the operation of multi-frequency telephone signalling receivers are those of the third order, of type $(2f_1 - f_2)$ and $(2f_2 - f_1)$ where f_1 and f_2 are two signalling frequencies.

Two signals at frequencies 900 Hz and 1020 Hz are recommended for these tests.

Two test conditions should be considered: the first, where each of the signals at f_1 and f_2 is at a level of - 5 dBm0 and the second, where they are each at a level of - 15 dBm0. These levels are to be understood to be at the input to the compressor or at the output of the expander (uncompressed levels).

The limits for the intermodulation products are defined as the difference between the level of either of the signals at frequencies f_1 or f_2 and the level of either of the intermodulation products at frequencies $(2f_1 - f_2)$ or $(2f_2 - f_1)$.

A value for this difference which seems adequate for the requirements of multi-frequency telephone signalling (including end-to-end signalling over three circuits in tandem, each equipped with a compandor) is 26 dB for the compressor and the expander separately.

Note 1 - These values seem suitable for Signalling System No. 5, which will be used on some long international circuits.

Note 2 - It is inadvisable to make measurements on a compressor plus expander in tandem, because the individual intermodulation levels of the compressor and of the expander might be quite high, although much less intermodulation is given in tandem measurements since the characteristics of compressor and expander may be closely complementary. The compensation encountered in tandem measurements on compressor and expander may not be encountered in practice, either because there may be phase distortion in the line or because the compressor and expander at the two ends of the line may be less closely complementary than the compressor and expander measured in tandem.

Hence the measurements have to be performed separately for the compressor and the expander. The two signals at frequencies f_1 and f_2 must be applied simultaneously, and the levels at the output of the compressor or expander measured selectively.

6 Noise voltages

The effective value of the sum of all noise voltages referred to a zero relative level point, the input and the output being terminated with resistances of 600 ohms, shall be less than or equal to the following values:

- at the output of the compressor: (10 mV unweighted - 38 dBm0)

  (7 mV weighted - 41 dBm0p)

- at the output of the expander: (0.5 mV weighted - 84 dBm0p)

It is not considered useful to specify a value of unweighted noise voltage for the expander.

7 Transient response

The overall transient response of the combination of a compressor and expander which are to be used in the same direction of transmission of a 4-wire circuit fitted with compandors shall be checked as follows:

The compressor and expander are connected in tandem, the appropriate loss (or gain) being inserted between them as in § 2.7.

A 12-dB step signal at a frequency of 2000 Hz is applied to the input of the compressor, the actual values being a change from - 16 to - 4 dBm0 for attack, and from - 4 to - 16 dBm0 for recovery. The envelope of the expander output is observed. The overshoot (positive or negative), after an upward 12-dB step expressed as a percentage of the final steady-state voltage, is a measure of the overall transient distortion of the compressor-expander combination for attack. The overshoot (positive or negative) after a downward 12 dB step, expressed as a percentage of the final steady-state voltage is a measure of the overall transient distortion of the compressor-expander combination for recovery. For both these quantities the permissible limits shall be ± 20%. These limits shall be observed for the same conditions of temperature and of variation of loss (or gain) between compressor and expander as for the test in § 2.7.

In addition, the attack and recovery times of the compressor alone shall be measured as follows:

Using the same 12-dB steps as above for attack and recovery respectively, the attack time is defined as the time between the instant when the sudden change is applied and the instant when the output voltage envelope reaches a value equal to 1.5 times its steady-state value. The recovery time is defined as the time between the instant when the sudden change is applied and the instant when the output voltage envelope reaches a value equal to 0.75 times its steady-state value.

The permissible limits shall be not greater than:

- 5 ms for attack,
- 22.5 ms for recovery.

The following additional test shall be used to check the effect of the compandor on certain signalling systems which may be sensitive to envelope distortion immediately following the sudden application of a sinusoidal signal.

The overall transient response of the combination of a compressor and expander which are to be used in the same direction of transmission on a 4-wire circuit is measured with an "infinite" upward input step, i.e. with a signal applied after a period with no input.

The level of the signal to be applied is - 5 dBm0.

Provided the measurement is effected with an interval of at least 50 ms between the pulses, the limits shown by an unbroken line in Figure 2/G.162 should be observed for the overshoot of the final voltage V_1; in most cases an attempt should be made if possible to observe the narrower limits, indicated in the figure by a broken line.

These limits shall be observed for the same conditions of temperature loss (or gain) between compressor and expander as for the tests with 12-dB steps.

Note 1 - The tests of transient distortion described involve the measurement of the overshoot or undershoot of the envelope of the applied sinusoidal signal. It may happen that, due to small unbalances in the variable loss device, very-low-frequency components of the control current appear at the output. These are not a modulation of the signal frequency, but they produce an unsymmetrical waveform and render it difficult to determine the overshoot or undershoot of the envelope. While it is undesirable that these low-frequency components should be so large as to increase significantly the risk of overload of the line equipment, they are of no importance for speech transmission and will not affect tuned signalling receivers. However, it is desirable to consider whether these components may affect the guard circuits of some signalling receivers. If so, it may be necessary to specify a maximum value for these components and to include an appropriate test in this Recommendation.

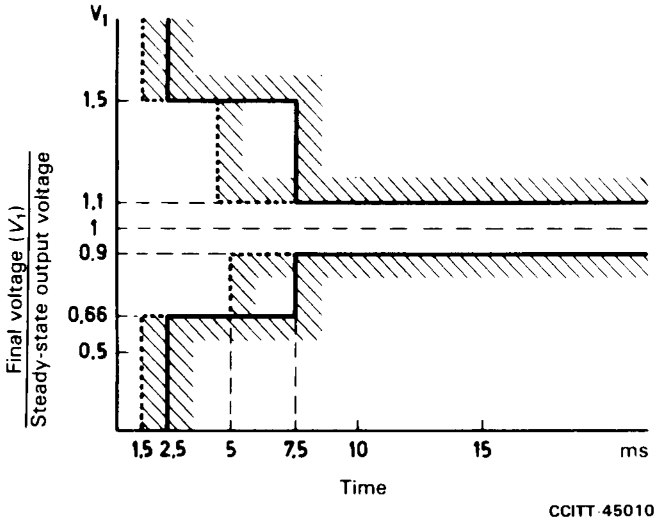

FIGURE 2/G.162

To simplify the measurement of the true envelope amplitude in the presence of these unbalance components, it is admissible and convenient to insert at the input to the measuring oscillograph a high-pass filter having a cut-off frequency of about 300 Hz. However, a filter which is effective in removing unbalance components may itself introduce additional transient distortion in the signal envelope. To avoid this difficulty, the following method of calculation may be adopted which does not require a filter.

If at any instant the amplitude of the envelope in a positive direction is + E_1 and in the negative direction is - E_2 then the two-envelope amplitude is given by

$$\frac{1}{2}\left[\,(+E_1) - (-E_2)\,\right] \equiv \frac{1}{2}\left[\,|E_1| + |E_2|\,\right]$$

and the unbalance component is given by

$$\frac{1}{2}\left[\,(+E_1) + (-E_2)\,\right] \equiv \frac{1}{2}\left[\,|E_1| - |E_2|\,\right]$$

This method is not only simple and free of the transient distortion problem which occurs with a filter, but it also provides direct information on the unbalance which, as indicated above, may be important.

Note 2 - The time constants of the expander control circuit should in principle be equal to those of the compressor control circuit so as to avoid any overshoot (positive or negative) in the transient response.

Note 3 - If an Administration prefers to use a direct method of measuring expander attack and recovery times, the following might be adopted:

To define the attack and recovery times of the expander, a sudden change in level from -8 to -2 dBm0 should be applied to its input for measurement of the attack time, and from -2 to -8 dBm0 for measurement of the recovery time. The attack time is represented by the time between the moment when the abrupt variation is applied and the moment when the output voltage reaches a value *x* times its final value. The recovery time is represented by the time between the moment when the abrupt variation is applied and the moment when output voltage reaches a value *y* times its final value. The times thus measured should lie between the same limits as those shown for the compressor. Bearing in mind detailed differences in the construction of the various compandors now in use, specific figures for *x* and *y* cannot be given. Hence, each Administration will have to determine the correct values of *x* and *y* for the type of compandor concerned.

For an ideal expander, 0.57 and 1.51 are valid for *x* and *y;* by way of example, the Italian Administration has found 0.65 for *x* and 1.35 for *y* for a certain type of construction.

Some Administrations have said that it might be preferable to specify fixed values of *x* and *y*, for all types of expander, leaving Administrations free to choose the limit values for attack and recovery times according to the different types of expander. Values of 0.75 and 1.5 are proposed for *x* and *y* in this method of measurement.

Note 4 - The "infinite" step transient response measurements refer to a compressor-expander combination connected in tandem; moreover, several Administrations have investigated the possibility of meeting the limits shown in the Figure 2/G.162, even for a chain of three compandors in tandem, by bringing also the channel modulating and demodulating equipment into the connection. This modem equipment may cause an undesirable transient phenomenon in the step at the expander output; this phenomenon, and the intermodulation of the third order associated with it, may influence the multi-frequency signalling.