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CHARACTERISTICS OF SYLLABIC COMPANDORS FOR TELEPHONY ON HIGH CAPACITY LONG DISTANCE SYSTEMS

ITU-T Recommendation G.166

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation G.166 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.

CHARACTERISTICS OF SYLLABIC COMPANDORS FOR TELEPHONY ON HIGH CAPACITY LONG DISTANCE SYSTEMS

(Malaga- Torremolinos, 1986; amended at Melbourne, 1988)

Compandors adhering to Recommendation G.162, *Yellow Book,* were intended for use in small capacity network systems and their use in large capacity network long-distance systems is not recommended. Compandors adhering to this Recommendation are intended for use in large capacity long-distance systems. Their use on small capacity network systems is optional. They are not intended for use in subscriber applications such as mobile communication systems.

1 General

1.1 Syllabic compandors are devices in which gain variations occur at a rate comparable to the syllabic rate of speech. A compandor consists of a combination of a compressor at one point in a communication path, for reducing the amplitude range of signals followed by an expander at another point for a complementary increase in the amplitude range. The compandor enhances the subjective speech performance primarily due to two actions. The compressor increases the average speech level of weaker signals prior to entering a communication path where increased noise is expected to be encountered. The expander, in returning the speech signal to its original dynamic range provides a subjective enhancement to the communication path by attenuating the noise perceived by the listening party during silences. For a further description of compandor operation see Annex A.

1.2 This Recommendation does not specify the detector characteristics, e.g., peak, r.m.s. or average.

The performance recommended may not be sufficient to ensure compatibility between compandors conforming to this Recommendation but which are of different design. Before using compressors and expanders of different design origins at opposite ends of the same circuit, Administrations should test them for compatibility. The tests should take account of the sensitivity of compandor performance to the characteristics of the test signal.

1.3 The use of a number of syllabic compandors on circuits carried on the same FDM carrier may result in a changed load being presented to the FDM system. The FDM system operating parameters could, therefore, require appropriate adjustment as a function of the load.

1.4 It should be noted that the subjective enhancement which occurs on speech, when syllabic compandors are used, does not apply to transmission of non-speech signals which may experience a signal-to-noise degradation on syllabic compandored circuits.

1.5 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. Application rules for syllabic compandors address this issue.

2 Definitions

2.1 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.

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 must be adjusted taking into account the capacity of the system. (See Reference [1], Chapter II, Annex 4, for detailed discussion of this adjustment.)

2.2 ratio of compression

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

$$\alpha = \frac{L_{1\,CIN} - L_{2\,CIN}}{L_{1\,COUT} - L_{2\,COUT}}$$

where

$L_{1\,CIN}$ and $L_{2\,CIN}$ are any two different compressor input levels within the compressor operating range.

$L_{1\,COUT}$ and $L_{2\,COUT}$ are the compressor output levels corresponding to input levels $L_{1\,CIN}$ and $L_{2\,CIN}$ respectively.

2.3 ratio of expansion

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

$$\beta = \frac{L_{1\,EOUT} - L_{2\,EOUT}}{L_{1\,EIN} - L_{2\,EIN}}$$

where

$L_{1\,EIN}$ and $L_{2\,EIN}$ are any two different expander input levels within the expander operating range.

$L_{1\,EOUT}$ and $L_{2\,EOUT}$ are the expander output levels corresponding to input levels $L_{1\,EIN}$ and $L_{2\,EIN}$ respectively.

3 Characteristics of syllabic compandors

3.1 *Unaffected level*

A nominal value of -10 dBm0 for the unaffected level is recommended for high capacity systems. However, Administrations are free to mutually negotiate a different unaffected level to allow optimal loading of their transmission systems. Such variation is expected to be in the range -10 to -24 dBm0. The loading effects of pilot tones should be considered.

3.2 *Ratio of compression* α

The compandor compression ration α should be 2 over the range of level specified in § 3.4 and over the temperature range + 10 °C to + 40 °C. The difference between the measured level and the calculated level at the output of the compressor assuming a value of exactly 2 should not exceed ± 0.25 dB.

3.3 *Ratio of expansion* β

The compandor expansion ratio β should be 2 over the range of level specified in § 3.4 and over the temperature range + 10 °C to + 40 °C. The difference between the measured level and the calculated level at the output of the expander assuming a value of exactly 2 should not exceed ± 0.4 dB.

3.4 *Range of level*

Under study

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

from + 5 to - 60 dBm0 at the input of the compressor, and

from + 5 to - 65 dBm0 at the nominal output of the expander.

3.5 *Variation of compressor gain*

The level at the output of the compressor, measured at 800 Hz, for an input level equal to the unaffected level, should not vary from its nominal value by more than ± 0.25 dB for a temperature range of + 10 °C to +40 °C and a deviation of the supply voltage of ± 5% from its nominal value.

3.6 *Variation of expander gain*

The level at the output of the expander, measured at 800 Hz for an input level equal to the unaffected level, 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.

3.7 *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.166 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.)

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 and the measurement corrected by ± 4.0 dB, assuming a β of 2.00.

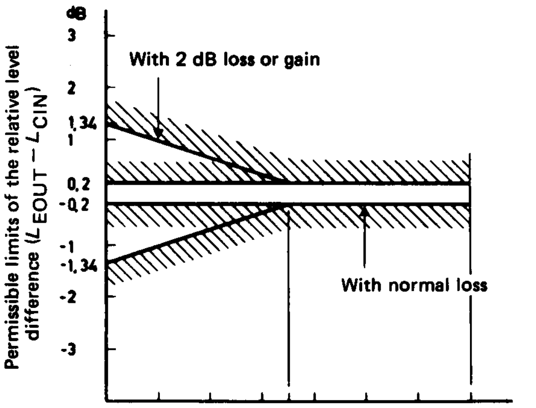


FIGURE 1/G.166

Tolerances on the output levels of the combination of compressor and expander

3.8 *Conditions for stability*

See descriptions given in § 2.6 of Recommendation G.162, Volume III of the *Yellow Book,* ITU, Geneva, 1981, § 2 of Recommendation G.143, *Red Book,* and Reference [1].

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 § 3.7 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.

4 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 20 dB over the frequency range 300 to 3400 Hz and for any measurement level between + 5 and - 60 dBm0 at the compressor input or the expander output.

5 Operating characteristics at various frequencies

5.1 *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 set to the unaffected level.

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 the unaffected level.

5.2 *Frequency characteristic with control circuit operating normally*

The limits given in § 5.1 should be observed for the compressor when the control circuit is operating normally, the measurement being made with a constant input level corresponding to the unaffected level.

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.

6 Nonlinear distortion

6.1 *Harmonic distortion*

The total harmonic distortion, measured with an 800 Hz sine wave at the unaffected level, should not exceed 0.5% 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.

6.2 *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 32 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.

7 Noise

The effective value of the sum of all noise 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: - 45 dBm0p
- at the output of the expander: - 80 dBm0p.

8 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 § 3.7.

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 § 3.7.

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:

- 3 ms minimum, 5 ms maximum for the attack time, and
- 13.5 ms minimum, 22.5 maximum for the recovery time.

ANNEX A

(to Recommendation G.166)

Compandor enhancement characteristics

The improvement which the compandor makes available is based on the fact that interference is most objectionable during quiet speech or pauses, but is masked by relatively loud speech. While it will not be necessary, therefore, to alter the performance of the system for speech signals at a high level, an improvement has to be provided when the signal level is low. This noise reduction can be arranged by introducing loss at the receiving end of the circuit during periods when the signal is faint or absent. The loss so introduced will affect the noise or crosstalk which has crept in along the route, so that the interference is reduced by the amount of this loss. However, the desired signals are also affected, and in order that the speech level finally received shall be unchanged by the insertion of the compandor, an equal amount of gain has to be introduced at the sending end. The overall equivalent of the circuit is thereby kept constant, and also the low level signals are raised above the background of interference on the line.

The above-mentioned condition must not, however, be allowed to persist when high-level signals have to be transmitted, or overloading could occur in the line amplifiers along the route. The function of the compandors is to introduce the required amounts of gain and loss automatically in just such a way that the overall circuit equivalent remains unchanged irrespective of the speech level, while the signal-to-noise ratio is increased for low-level signals. This is shown schematically in the level diagram of Figure A-1/G.166. For one particular level, called the *unaffected* level *X*, the use of the compandor at no point introduces gain or loss, and the signal passes at an unchanged level throughout the system, as shown by (1), (2), (3).

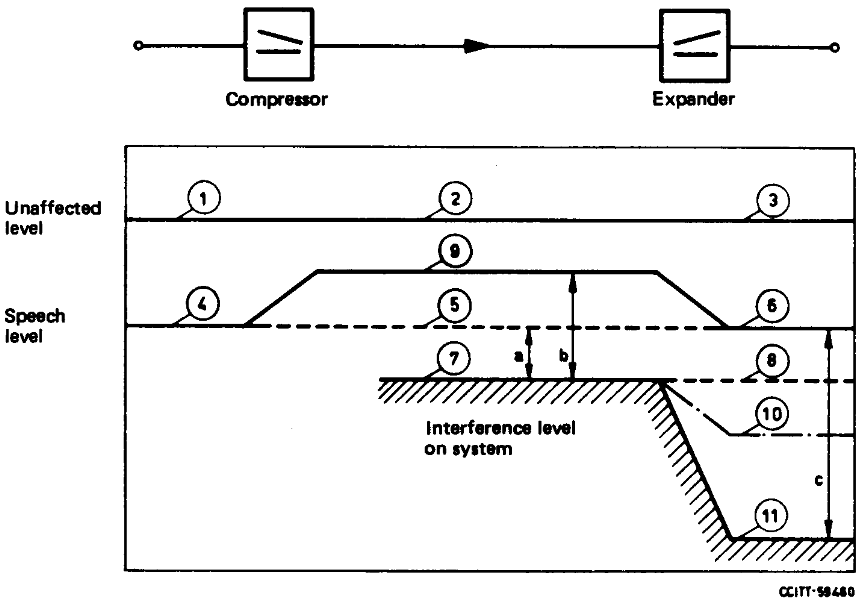
Any given level of speech (4) would also normally (i.e. without compandors) pass at an unchanged level through the system as shown at (4), (5), (6). If we suppose that the level of interference on the system (noise, crosstalk, etc.) is that shown by (7), the signal/interference ratio is then given by *a*, and the interference level appearing at the output is that shown by (8), during both speech and pauses.

By the introduction of the compandor, however, the incoming speech level (4) is raised to (9), thereby giving a signal/interference ratio within the system of *b*. The level of the speech is restored to (6) at the receiving end, and the corresponding interference level *during speech* is shown at (10). However, as stated earlier, of even greater significance is the interference level during pauses, which is that shown at (11). Thus the effective ratio between speech signals and interference heard *during pauses* has the value shown by *c*.

The part of the compandor at the sending end is called the compressor, because the range of levels of the incoming speech signals is compressed. The unaffected level recommended by the CCITT for high capacity systems is - 10 dBm0. However, Administrations may mutually negotiate a different unaffected level to permit optimal loading of their transmission systems. The unaffected level is expected to range from - 10 to - 24 dBm0. The selected unaffected level will affect the mean power per channel.

The part of the compandor at the receiving end is called the expander, and the same level remains unchanged.

It will be seen from the foregoing that, when compandors are required, one compandor has to be inserted at each end of the telephone circuit in the voice-frequency 4-wire path, with the compressor in the sending channel and the expander in the receiving channel.



All levels are referred to a point of zero relative level.
Full lines show system performance with compandors; dashed lines without.
a Signal/interference without compandor.
b Increased signal/interference obtained during speech due to use of compressor.
c Ratio between speech and interference heard during pauses, due to use of entire compandor. For a theoretical 2:1:2 compandor, this has a value 2 *b*.

FIGURE A-1/G.166

Level chart for transmission system with compandors

Reference

[1] CCITT Manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.