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**GENERAL CHARACTERISTICS
OF INTERNATIONAL TELEPHONE CONNECTIONS
AND INTERNATIONAL TELEPHONE CIRCUITS**

ECHO CANCELLERS

ITU-T Recommendation G.165

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation G.165 was revised by the ITU-T Study Group XV (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

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

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Recommendation G.165

ECHO CANCELLERS

(Geneva, 1980; amended at Malaga-Torremolinos, 1984;
at Melbourne, 1988 and at Helsinki, 1993)

1 General

1.1 Echo cancellers are voice operated devices placed in the 4-wire portion of a circuit (which may be an individual circuit path or a path carrying a multiplexed signal) and are used for reducing the echo by subtracting an estimated echo from the circuit echo. They may be characterized by whether the transmission path or the subtraction of the echo is by analogue or digital means (see Figures 1, 2 and 3).

1.2 This Recommendation is applicable to the design of echo cancellers using digital or analogue techniques, and intended for use in an international circuit. Echo cancellers designed to this Recommendation will be compatible with each other and with echo suppressors designed in accordance with Recommendation G.164. Compatibility is defined in 1.4/G.164. Freedom is permitted in design details not covered by the requirements.

Echo cancellers may be used for purposes other than network echo control on international or mobile telephony circuits, e.g. in active 2-wire/4-wire hybrids or 2-wire repeaters, but this Recommendation does not apply to such echo cancellers.

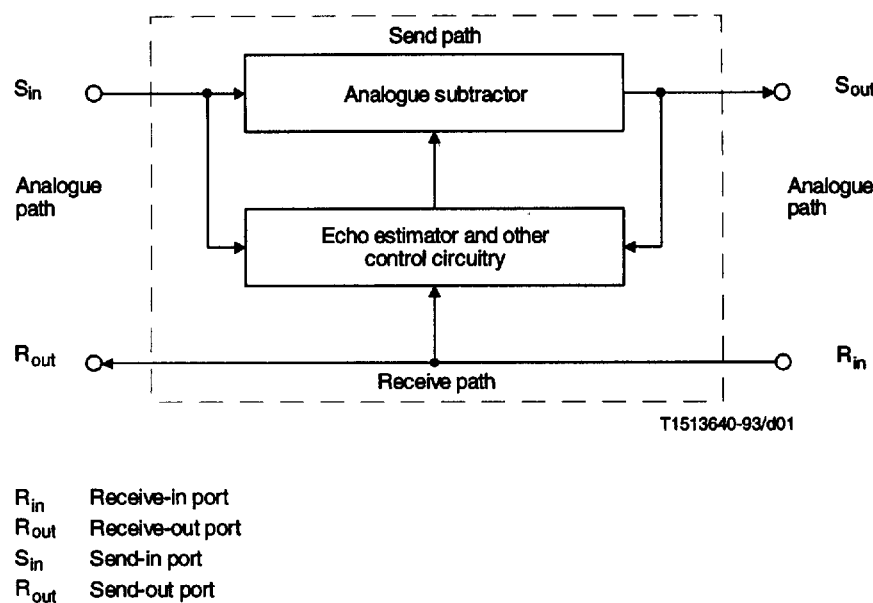
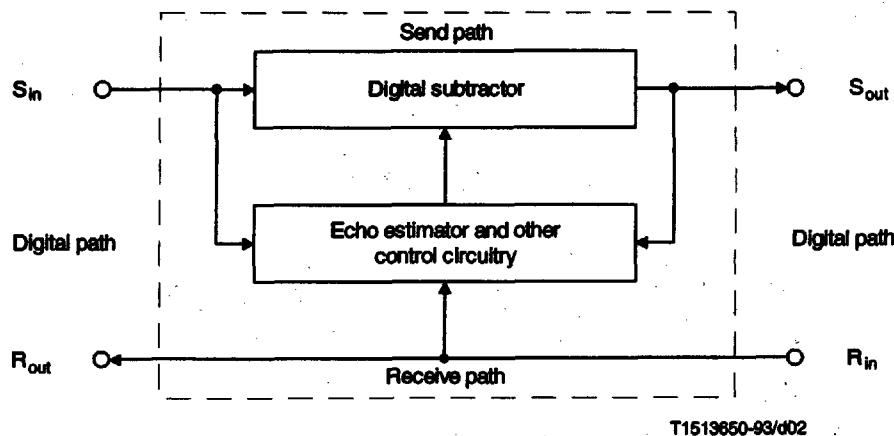


FIGURE 1/G.165

Type A echo canceller



NOTE – Functionally, a type C digital echo canceller (DEC) interfaces at 64 kbit/s. However, 24 or 30 digital echo cancellers for example may be combined corresponding to the primary digital hierarchy levels of 1544 kbit/s or 2048 kbit/s, respectively.

FIGURE 2/G.165
Type C echo canceller

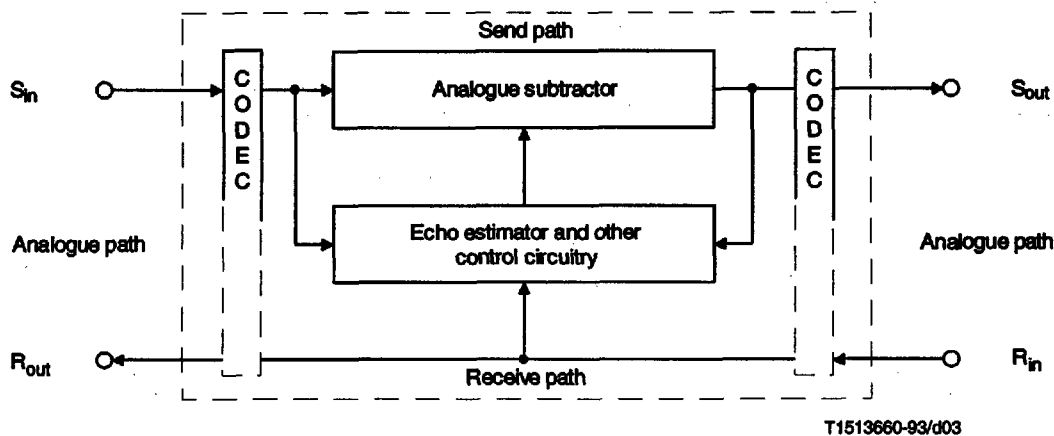


FIGURE 3/G.165
Type D echo canceller

1.3 The tests in this Recommendation focus on band-limited noise performance. Echo cancellers passing these tests may nevertheless perform poorly on speech. It is recommended that designers and/or users of echo cancellers ensure adequate speech performance as recommended in 3.4.2.

Furthermore, network echo cancellers must perform adequately on many non-speech signals as well, e.g. voice-band data, and that performance is not dealt with at all in this Recommendation. Tests have shown that not all echo cancellers passing the tests in clause 3 are guaranteed to perform correctly on voice-band data traffic, in particular on Group 3 facsimile signals. Additional tests to address this problem are under study but it is recommended that designers and/or users of echo cancellers ensure adequate voice-band data performance in addition to passing tests in clause 3.

2 Definitions relating to echo cancellers¹⁾

In the definition and text, L will refer to the relative power level of a signal, expressed in dBm0 and A will refer to the attenuation or loss of a signal path expressed in dB.

2.1 echo canceller

F: annuleur d'écho

S: compensador de eco; cancelador de eco

A voice operated device placed in the 4-wire portion of a circuit and used for reducing near-end echo present on the send path by subtracting an estimation of that echo from the near-end echo (see Figure 4).

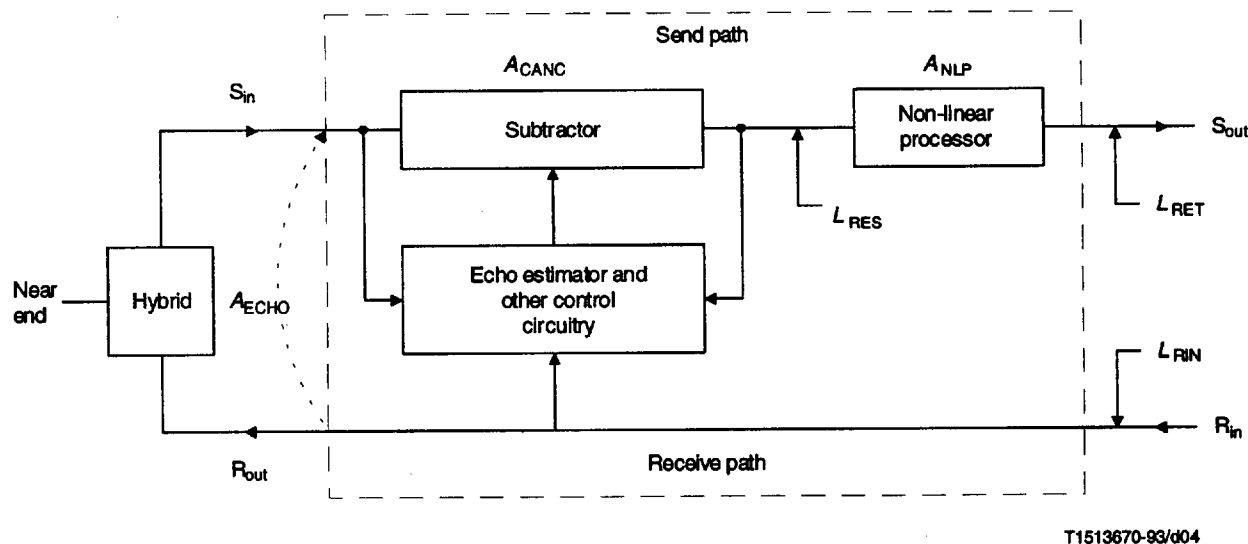


FIGURE 4/G.165
Echo canceller

2.2 echo loss (A_{ECHO})

F: affaiblissement d'écho (A_{ECHO})

S: atenuación del eco (A_{ECHO})

The attenuation of a signal from the receive-out port (R_{out}) to the send-in port (S_{in}) of an echo canceller, due to transmission and hybrid loss, i.e. the loss in the (near-end) echo path.

NOTE – This definition does not strictly adhere to the echo loss definition given in 2.2/G.122 which applies to loss of the a - t - b path viewed from the virtual switching point of the international circuit. The echo canceller may be located closer to the echo reflection point.

2.3 pure delay (t_r)

F: retard pur (t_r)

S: retardo puro (t_r)

The delay from the R_{out} port to the S_{in} port due to the delays inherent in the (near end) echo path transmission facilities. In this case, the transit time directly across the hybrid is assumed to be zero.

¹⁾ These definitions assume that non linearities are not present in the (near-end) echo path and that the signal at S_{in} is purely echo.

2.4 (near-end) echo path or end delay (t_d)

F: retard de trajet d'écho (proche), ou retard d'extrémité (t_d)

S: retardo de trayecto de eco (cercano); o retardo de extremo (t_d)

The sum of pure delay (t_r) and dispersion time is the time required to accommodate the band-limiting, multiple reflection, and hybrid transit effects. This is illustrated in Figure 5. It should be noted that this definition assumes a single echo path. If there are multiple echo paths, the overall echo path delay is the maximum of the individual echo path delays. Since dispersion time varies with different national networks, echo canceller echo path delay capacity is given per this definition. With 8 kHz sampling and an FIR (finite impulse response) version of echo canceller, the number of taps an echo canceller has for a given t_d in msec is 8 times t_d .

2.5 cancellation (A_{CANC})

F: annulation (A_{CANC})

S: compensación; cancelación (A_{CANC})

The attenuation of the echo signal as it passes through the send path of an echo canceller. This definition specifically excludes any nonlinear processing on the output of the canceller to provide for further attenuation.

2.6 residual echo level (L_{RES})

F: niveau d'écho résiduel (L_{RES})

S: nivel de eco residual (L_{RES})

The level of the echo signal which remains at the send-out port of an operating echo canceller after imperfect cancellation of the circuit echo. It is related to the receive-in signal L_{Rin} by

$$L_{RES} = L_{Rin} - A_{ECHO} - A_{CANC}$$

Any nonlinear processing is not included.

2.7 nonlinear processor (NLP)

F: processeur non linéaire (NLP)

S: procesador no lineal (NLP)

A device having a defined suppression threshold level and in which:

- signals having a level detected as being below the threshold are suppressed, and
- signals having a level detected as being above the threshold are passed although the signal may be distorted.

NOTES

- The precise operation of a nonlinear processor depends upon the detection and control algorithm used.
- An example of a nonlinear processor is an analogue centre clipper in which all signal levels below a defined threshold are forced to some minimum value.

2.8 nonlinear processing loss (A_{NLP})

F: affaiblissement par traitement non linéaire (A_{NLP})

S: atenuación por procesamiento (o tratamiento) no lineal (A_{NLP})

Additional attenuation of residual echo level by a nonlinear processor placed in the send path of an echo canceller.

NOTE – Strictly, the attenuation of a nonlinear process cannot be characterized by a loss in dB. However, for purposes of illustration and discussion of echo canceller operation, the careful use of A_{NLP} is helpful.

2.9 returned echo level (L_{RET})

F: niveau de retour d'écho (L_{RET})

S: nivel del eco devuelto (L_{RET})

The level of the signal at the send-out port of an operating echo canceller which will be returned to the talker. The attenuation of a nonlinear processor is included, if one is normally present. L_{RET} is related to L_{Rin} by

$$L_{RET} = L_{Rin} - (A_{ECHO} + A_{CANC} + A_{NLP})$$

If nonlinear processing is not present, note that $L_{RES} = L_{RET}$.

2.10 combined loss (A_{COM})

F: affaiblissement combiné (A_{COM})

S: atenuación combinada (A_{COM})

The sum of echo loss, cancellation loss and nonlinear processing loss (if present). This loss relates L_{Rin} to L_{RET} by:

$$L_{RET} = L_{Rin} - A_{COM}, \text{ where } A_{COM} = A_{ECHO} + A_{CANC} + A_{NLP}$$

2.11 convergence

F: convergence

S: convergencia

The process of developing a model of the echo path which will be used in the echo estimator to produce the estimate of the circuit echo.

2.12 convergence time

F: temps de convergence

S: tiempo de convergencia

For a defined echo path, the interval between the instant a defined test signal is applied to the receive-in port of an echo canceller with the estimated echo path impulse response initially set to zero, and the instant the returned echo level at the send-out port reaches a defined level.

2.13 leak time

F: temps de fuite

S: tiempo de fuga

The interval between the instant a test signal is removed from the receive-in port of a fully-converged echo canceller and the instant the echo path model in the echo canceller changes such that, when a test signal is reapplied to R_{in} with the convergence circuitry inhibited, the returned echo is at a defined level.

This definition refers to echo cancellers employing, for example, leaky integrators in the convergence circuitry.

3 Characteristics of echo cancellers

3.1 General

This Recommendation is applicable to the design of echo cancellers. The echo cancellers are assumed to be "half" echo cancellers, i.e. those in which cancellation takes place only in the send path due to signals present in the receive path.

3.2 Purpose, operation and environment

Echo, in any 2-wire or combination 2- and 4-wire telephone circuit, is caused by impedance mismatches. An echo canceller can be used to reduce this echo to tolerable levels.

The echo present at the send-in port of an echo canceller is a distorted and delayed replica of the incoming speech from the far end, i.e. the echo is the incoming speech as modified by the echo path. The echo path is commonly described by its impulse response (see Figure 5). This response of a typical echo path shows a pure delay t_r , due to the delays inherent in the echo path transmission facilities, and a dispersed signal due to band limiting and multiple reflections. The sum of these is the echo path delay, t_d . The values of delay and dispersion will vary depending on the properties of the echo paths, e.g. they may vary for different national networks. Note that the echo path can still include more than one source of echo; many network configurations exist in which multiple 2-wire to 4-wire conversions exist in the end path of an echo canceller.

It is assumed that the echo paths are basically linear and not continuously varying²⁾, e.g. have no phase roll (see Recommendation G.164). The performance of the echo canceller is critically dependent on the linearity of the echo path between R_{out} and S_{in} (see Figure 4). A signal with peak clipping, presented at R_{in} , will cause minimal degradation in canceller performance. This is because the identical peak clipped signal is presented to both the echo estimator and the real echo path. If peak clipping occurs in either only the branch to the echo estimator or only in the real echo path, the difference in the two signals will cause the canceller performance to degrade. This is because the linear processing used in the canceller cannot develop a model to accurately represent the non-linearity introduced by peak clipping.

The echo path may include both analogue and digital links. The digital links introduce a peak clipping level defined in Recommendation G.711 as the level of the peak of a +3.1 dBm0 sine wave. Application of the clipping level to the R_{in} signal prior to the location of the internal branch point to the echo estimator will minimize the degradation of canceller performance for high level signals.

In addition, the loss of the echo path in dB (see 2.2) is likely to be such that the minimum loss from R_{out} to S_{in} of the echo canceller will be equal to the difference between relative levels at these two ports plus 6 dB. Echo cancellers designed to this Recommendation will perform properly for echo loss (A_{ECHO}) of 6 dB or greater. For (A_{ECHO}) less than 6 dB they may still work but with degraded performance. It is not possible to quantify this degraded performance.

An echo canceller must be able to synthesize a replica of the echo path impulse response. Many echo cancellers model the echo path using a sampled data representation, the sampling being at the Nyquist rate (8000 Hz). Such an echo canceller, to function properly, must have sufficient storage capacity for the required number of samples³⁾. Typically, too few storage locations will prevent adequate synthesis of all echo paths; too many storage locations will create undesirable additional noise due to the unused locations which, because of estimation noise, are generally not zero. It should be recognized that an echo canceller introduces an additional parallel echo path. If the impulse response of the echo path model is sufficiently different from the echo path impulse response, the total returned echo may be larger than that due to the echo path only.

The echo paths change as the echo canceller is used in successive connections. When speech first arrives at R_{in} , the echo canceller must adapt or converge to the new echo path, and it is desirable that this be fairly rapid, e.g. about one-half second. Also the residual echo should be small regardless of the level of the receive speech and the characteristics of the echo path. Some Administrations feel that a slightly higher residual echo level may be permitted provided it is further reduced using a small amount of nonlinear processing (see 5).

- 2) Echo cancellers designed specifically for echo paths which are nonlinear and/or time variant are likely to be much more complex than those not so designed. It is felt that insufficient information exists to include such echo cancellers in this Recommendation. Echo cancellers conforming to this Recommendation are adaptive and will cope with slowly varying echo paths when only a receive signal is present.
- 3) Echo cancellers having storage capacities of 8 ms to 64 ms have been successfully demonstrated. Maximum echo path delay t_d , in the network in which the canceller will be used will determine the required storage capacity.