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STANDARDIZATION SECTOR
OF ITU

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TRANSMISSION SYSTEMS AND MEDIA

GENERAL CHARACTERISTICS OF INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

TRANSMISSION ASPECTS OF UNBALANCE ABOUT EARTH

ITU-T Recommendation G.117

(Previously "CCITT Recommendation")

FOREWORD

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

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation G.117 was revised by ITU-T Study Group 12 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 6th of February 1996.

NOTE

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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CONTENTS

SUMMARY

In many applications, the balance performance of equipment is crucial in order to ensure a satisfactory suppression of unwanted signals from the normal transmission path. This Recommendation gives guidance of suitable measurement methods for evaluating different effects of unbalance.

TRANSMISSION ASPECTS OF UNBALANCE ABOUT EARTH

(Geneva, 1980; amended at Malaga-Torremolinos, 1984 and Melbourne, 1988;
revised in 1996)

1 Objective

This Recommendation gives a comprehensive set of prescriptive measurements of various balance parameters for one-port and two-port networks. These are intended for use either in the field or in the factory with relatively simple test apparatus (e.g. standard transmission oscillators, level measuring sets), and a special test bridge. Measuring arrangements for assessing the degree of unbalance are covered in Recommendation O.9 [1], which are consistent with this Recommendation.

The definitions and methods are so devised that the results obtained from separately-measured (or specified) items of equipment (e.g. feeding-bridges, cable pairs, audio inputs to channel translating equipment, etc.) can be meaningfully combined though not necessarily by simple decibel addition. This allows the performance of a tandem connection of such items to be predicted or at least, bounds determined for that performance. Performance in this sense means those features affected by unbalanced conditions, e.g. level of impulsive noise, sensitivity to longitudinal exposure, crosstalk ratios, etc.

2 Principles of the scheme of nomenclature

Many different terms have been used throughout the literature concerning unbalance about earth, some conflicting, or in other respects inadequate. The descriptive titles of the quantities given in this Recommendation are based on the following principles which have been adopted:

a) Mode *conversion*, e.g. a poor (unbalanced) termination will develop an unwanted transverse signal when excited by a longitudinal signal. The measure of this effect is here termed *longitudinal conversion ratio*, and when expressed in transmission units *Longitudinal Conversion Loss*, or LCL.

b) When a two-port is involved where for example an excitation at one port produces a signal at the other port, then the designation will include the word *transfer*, for example *longitudinal conversion transfer ratio* and the corresponding *loss*, LCTL.

c) The impedance of the longitudinal path presented by a test object is a key parameter. The term *longitudinal impedance ratio* and the corresponding decibel expression, *longitudinal impedance loss,* are used to characterize the particular measurement defined.

d) Active devices which are sources of signals (e.g. an oscillator, the output port of an amplifier) are additionally characterized by the amount of unwanted longitudinal signal that is present in the output. The key word *output* is now included, to give *longitudinal output voltage,* and the corresponding *longitudinal output level.* When such unwanted signals are expressed as a proportion of the wanted (transverse) signal the key phrase is *output signal balance ratio,* the decibel expression of which is *output signal balance.*

e) Devices which continuously respond to signals (e.g. level-measuring sets, the input port of an amplifier) and which can in principle respond to unwanted longitudinal signals by reason of internal mechanisms (i.e. even if their input impedances were perfectly balanced) are characterized by measures containing the words *input interference.* These measures are *input longitudinal interference ratio* and the corresponding decibel expression *input longitudinal interference loss.* The long-established and well-defined *common-mode rejection ratio* is maintained. The term *sensitivity coefficient* is avoided, since this is widely used in the Directives [2] and the work of Study Group 5 with a rather specialized meaning.

f) When a two-port network is involved, the input and output signals may not be the same, for example, they may have different levels, frequencies (FDM modems) or structure (PCM multiplex equipments). These aspects should be taken into account when formulating proposals for the item under test.

g) In the case of receiving devices in which the operation is not a linear continuous function of the level of the input signal (e.g. a group-delay measuring set or a data modem) the key principle is the *threshold* level of the interference; this is the level at or above which an unacceptable amount of degradation of performance or misoperation occurs. Thus *longitudinal interference threshold voltage* and the corresponding *levels* are obtained.

3 Summary of the descriptive terms used

3.1 One-port networks

a) transverse reflexion factor (transverse return loss: TRL);

b) transverse conversion ratio (loss: TCL);

c) longitudinal conversion ratio (loss: LCL);

d) longitudinal impedance ratio (loss: LIL);

e) transverse output voltage (level: TOL);

f) longitudinal output voltage (level: LOL).

Voltages e) and f) are unwanted signals uncorrelated to the wanted signals.

3.2 Two-port networks

3.2.1 Separate measurement

For each port taken separately the one-port measures:

a) transverse reflexion factors (transverse return losses: TRL);

b) transverse conversion ratio (loss: TCL);

c) longitudinal conversion ratios (losses: LCL);

d) longitudinal impedance ratios (losses: LIL);

e) transverse output voltage (levels: TOL);

f) longitudinal output voltage (levels: LOL).

3.2.2 Measurement combined

In addition, the following transfer parameters are for each of the two directions of transmission:

a) transverse transfer ratios (losses: TTL);

b) transverse conversion transfer ratios (losses: TCTL);

c) longitudinal transfer ratios (losses: LTL);

d) longitudinal conversion transfer ratios (losses: LCTL).

3.3 Signal generating devices

– Output signal balance ratio (losses: OSB).

This is in addition to the six one-port measures listed in 3.1.

3.4 Signal receiving devices

a) Input longitudinal interference ratio (loss: ILIL).

b) Longitudinal interference threshold voltage (level).

These are in addition to the six one-port measures listed in 3.1. If the wanted signal is longitudinal (e.g. as in a signalling system) and the interfering voltage transverse, replace the word *longitudinal* with *transverse* in the descriptive terms.

4 Definitions and measuring techniques based on idealized measuring arrangements

The illustrated definitions in this clause assume ideal test bridges (with lossless infinite-inductance centre-tapped coils), zero impedance voltage generators and infinite-impedance voltmeters.

An important aspect of this set of mutually consistent measurements is that the test bridge provides simultaneously defined reference terminations of Z ohms for the transverse paths, and $Z/4$ ohms for the longitudinal paths. From this starting point, the performance of cascaded items, each measured in the prescribed fashion, can be calculated. This takes account of the fact that the cascaded items do not, in general, exhibit the reference impedances provided by the test conditions.

It simplifies the mathematical treatment if the reference impedance is non-reactive and this also accords with the important objective of being able to use readily-available transmission test-apparatus to obtain field and factory measurement results.

The ideal test bridge configuration used in the following pages is shown in Figure 1.

Note, however, that this test bridge configuration, with transversal impedance Z and longitudinal impedance $Z/4$, in general does not represent conditions met in practice. Thus, some care is needed when translating measured unbalance parameters into useful unbalance information for practical cases. This applies in particular for the commonly used parameter LCL, Longitudinal Conversion Loss. This is discussed in more detail in Annex A.

The transverse and longitudinal sources E_T and E_L are activated as required by the particular measurement being made. In Figure 6, neither source is active, and the bridge then provides only passive terminations of Z and $Z/4$.

NOTE – It would have been in keeping with traditional transmission theory for the parameters to be defined in terms of half the open-circuit e.m.f. However, to harmonize with Recommendation O.9, this Recommendation defines some parameters in terms of V_{T1}. If the input impedance of the device under test is nominally equal to the driving device, then the two methods are equivalent.

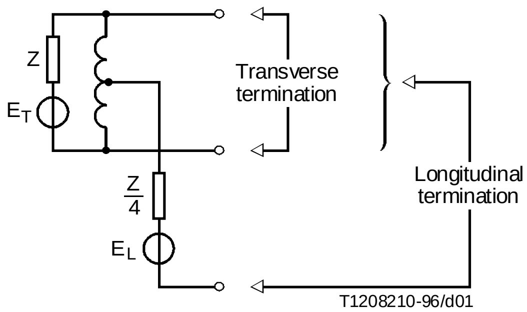
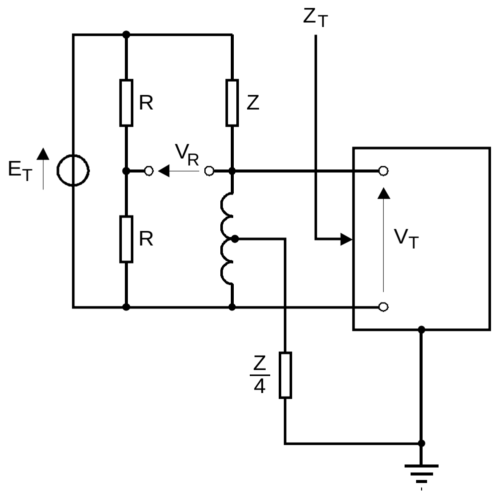


FIGURE 1/G.117

4.1 One-port networks

4.1.1 **Transverse reflexion factor (return loss)** (see Figure 2)



$$\text{Transverse reflexion factor } \rho = \frac{Z - Z_T}{Z + Z_T} = \frac{\text{reflected voltage}}{\text{forward voltage}} = \frac{2V_R}{E_T}$$

and

$$\text{Transverse Return Loss (TRL)} = 20 \log_{10} \left| \frac{1}{\rho} \right| = 20 \log_{10} \left| \frac{E_T}{2V_R} \right| \text{ dB}$$

NOTES

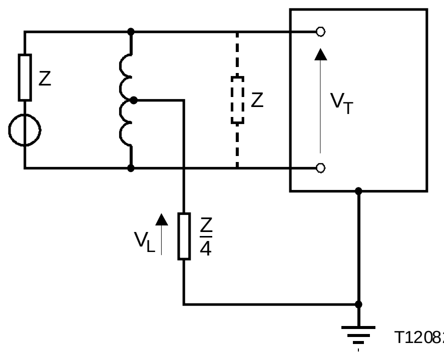
1 The value of R is (theoretically) irrelevant. The potential divider across the zero-impedance generator is only needed to derive half the generator voltage, which is numerically equal to the forward voltage needed for the definition.

2 Conventional return-loss measuring bridges do not terminate the longitudinal path with $Z/4$. This is unimportant when the return loss is some 20 dB or so less than the longitudinal conversion loss of the test object. In this case the reflected power is substantially greater than the power diverted to the longitudinal path, and there is negligible error.

3 If Z_T is known then clearly $\rho = 1 - \frac{2V_T}{E_T}$ is not needed. If V_T is measured ρ can be calculated from the expression $\rho = 1 - \frac{2V_T}{E_T}$, which is however somewhat inconvenient for high values of return loss.

FIGURE 2/G.117

4.1.2 **Transverse conversion ratio (loss)** (see Figure 3)



Transverse conversion ratio, $k = \frac{V_L}{V_T}$

and

Transverse Conversion Loss (TLC) $= 20 \log_{10} \left| \frac{1}{k} \right| = 20 \log_{10} \left| \frac{V_T}{V_L} \right|$ dB

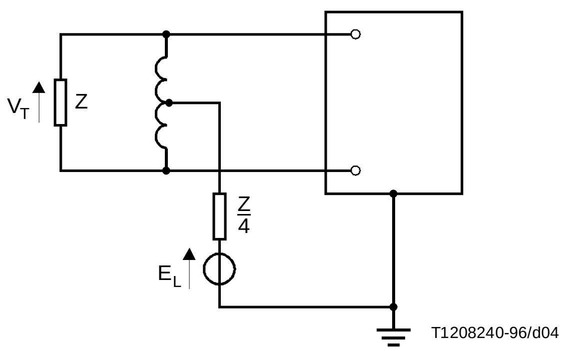
NOTES

1 In the case where the network is linear passive and bilateral, the transverse Conversion Loss (TCL) is equal to half the longitudinal conversion ratio *c*. However, this relationship is not true for other network arrangements.

2 The dotted component is needed for a two-terminal device which, when in use, only bridges the transmission circuit and will not be explicitly referred to again.

FIGURE 3/G.117

4.1.3 **Longitudinal conversion ratio (loss)** (see Figure 4)



Longitudinal conversion ratio, $c = \frac{V_T}{E_L}$

and

Longitudinal Conversion Loss (LCL) $= 20 \log_{10} \left| \frac{1}{c} \right| = 20 \log_{10} \left| \frac{E_L}{V_T} \right|$ dB

NOTES

1 This measure is variously referred to in other Recommendations as:

a) Longitudinal balance.

b) Degree of unbalance.

c) Unbalance.

d) Degree of longitudinal balance.

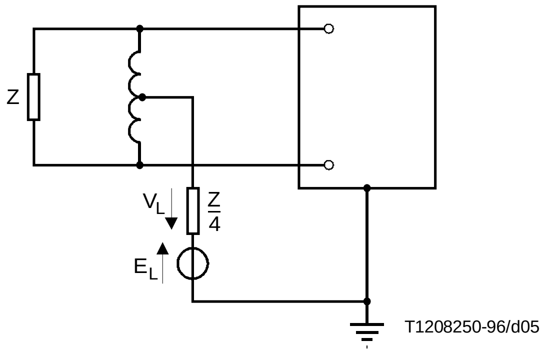
e) Signal balance ratio.

f) Impedance unbalanced to earth.

2 The longitudinal conversion ratio is applicable to any one-port, even to those which are sources of signals (e.g.: oscillateur output terminals). In such cases the transverse voltage V_T must be measured selectively if it is required to measure this loss in respect of a signal generator in operation.

FIGURE 4/G.117

4.1.4 **Longitudinal impedance ratio (loss)** (see Figure 5)



$$\text{Longitudinal impedance ratio, } q = \frac{E_L}{V_L}$$

and

$$\text{Longitudinal Impedance Loss (LIL)} = 20 \log_{10} \left| q \right| = 20 \log_{10} \left| \frac{E_L}{V_L} \right| \text{ dB}$$

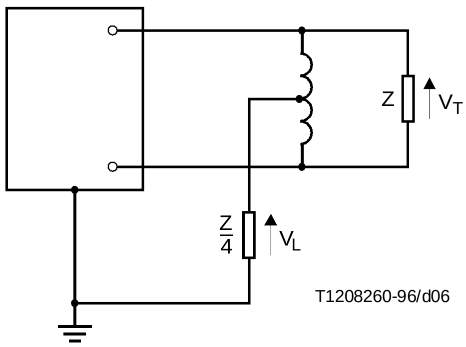
NOTES

1 This is an additional measure that is needed if the performance of a cascade of items is to be predicted.

2 In the case of test-objects which are virtually earth free (e.g.: double-insulated, portable test apparatus with no deliberate connection to earth) the value of V_L will be very small and the corresponding ratio (and loss) will be very large. In such cases the coupling introduced between longitudinal and transverse paths will be very small and the effect is not important.

FIGURE 5/G.117

4.1.5 **Transverse and longitudinal output voltages (levels)** (see Figure 6)



$$\text{Transverse output voltage} = V_T$$

$$\text{Transverse Output Level (TOL)} = 20 \log_{10} \left| \frac{V_T}{1 \text{ volt}} \right| \text{ dBV}$$

$$\text{Longitudinal output voltage} = V_L$$

$$\text{Longitudinal output level (LOL)} = 20 \log_{10} \left| \frac{V_L}{1 \text{ volt}} \right| \text{ dBV}$$

NOTES

1 These measures relate to unwanted signals uncorrelated to the wanted signal. For exemple, a.d.c. signaling system in the longitudinal path may deliver unwanted transverse signals. Similarly the output of an amplifier may deliver an unwanted longitudinal “hum” signal, or a cable pair may deliver unwanted longitudinal signals arising from induction or radiation.

2 Other reference voltages than 1 volt may be used, for example 0.775 V for 1 mW at 600 Ω (with the designation dB [3]).

FIGURE 6/G.117

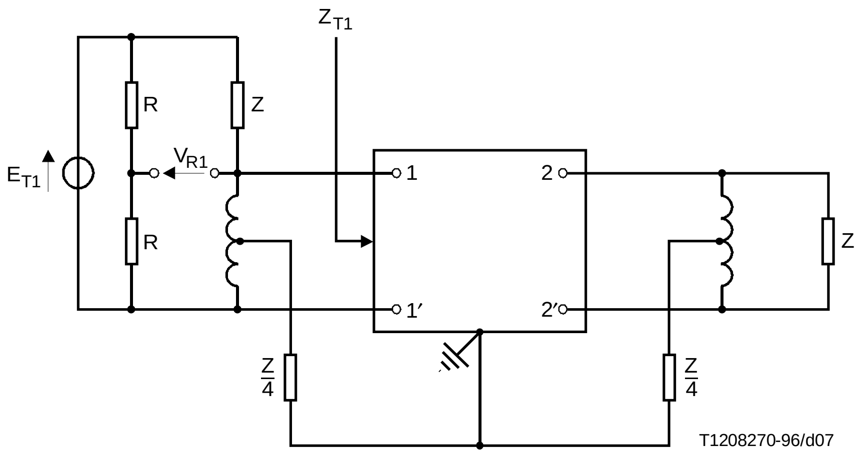
4.2 Two-port networks

These follow similar principles to those defined for one-port networks but now signals can be transferred from one port to the other. The two ports are distinguished by the subscripts 1/1′ for one end and 2/2′ for the other. There are two types of measurements:

- those in which the excitation and response are at the same side of the network; these are as already defined for a one-port but will carry a single subscript 1/1′ or 2/2′ as appropriate;

- those in which the excitation and response are at opposite sides of the network. The designation will contain the word transfer and the symbol two subscripts, the order of which indicates the direction of transmission.

4.2.1 **Transverse reflexion factors (return losses)** (see Figure 7)



Transverse reflexion factor at port 1/1 = $\rho_1 = \frac{Z - Z_{T1}}{Z + Z_{T1}} = \frac{2V_{R1}}{E_{T1}}$

and

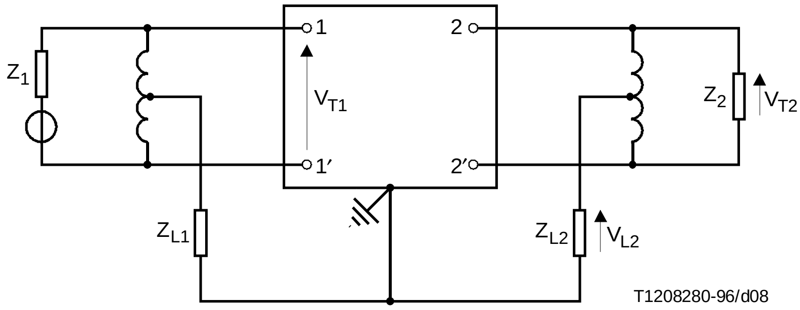
Transverse Return Loss at port 1/1′ (TRL_1) = $20 \log_{10} \left| \frac{1}{\rho_1} \right| = 20 \log_{10} \left| \frac{E_{T1}}{2V_{R1}} \right|$ dB.

and similarly for port 2/2′ (TRL_2)

NOTE – Z_{T1} is the impedance presented by port 1/1′ when port 2/2′ is terminated with a test-bridge as shown.

FIGURE 7/G.117

4.2.2 **Transverse transfer ratios (losses) and conversion transfer ratios (losses)** (see Figure 8)



$$\text{Transverse transfer ratio 1 to 2} = g_{12} = \frac{V_{T2}}{V_{T1}}$$

and

$$\text{Transverse Transfer Loss 1 to 2 } (TTL_{12}) = 20 \log_{10} \left| \frac{1}{g_{12}} \right| = 20 \log_{10} \left| \frac{V_{T1}}{V_{T2}} \right| \text{ dB}$$

$$\text{Transverse conversion transfer ratio 1 to 2} = t_{12} = \frac{V_{L2}}{V_{T1}}$$

and

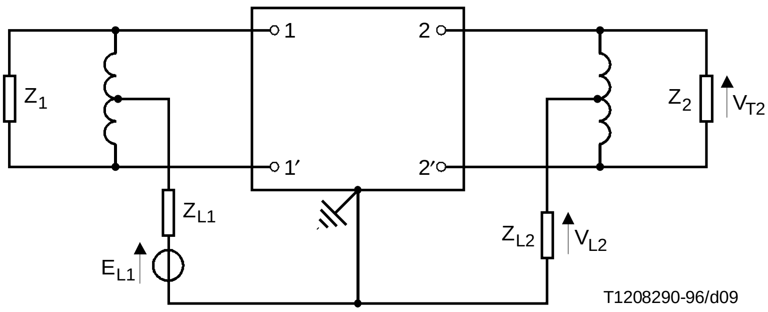
$$\text{Transverse Conversion Transfer Loss 1 to 2 } (TCTL_{12}) = 20 \log_{10} \left| \frac{1}{t_{12}} \right| = 20 \log_{10} \left| \frac{V_{T1}}{V_{L2}} \right| \text{ dB}$$

Interchanging 1 and 2 gives the definition for the transfer ratios TCTL for the other direction of transmission.

NOTE – Z_1 and Z_2 are the terminating impedances connected to the input and/or output port respectively of the item under test. Z_1 and Z_2 are generally within ± 25 percent of the nominal impedance of the port to which they are connected. If measurements are made via high-impedance input ports, an additional impedance Z_1 should be connected to the input port 1/1. The longitudinal impedances Z_{L1} , and Z_{L2} are nominally equal to $Z_1/4$ and $Z_2/4$ respectively. Different values, however, may be used. This may be necessary to more properly simulate operating conditions of the time under test. In such cases the value of Z_{L1} or Z_{L2} shall be specified by the Recommendation covering the item under test.

FIGURE 8/G.117

4.2.3 Longitudinal transfer ratios (losses) and conversion transfer ratios (losses) (see Figure 9)



$$\text{Longitudinal transfer ratio 1 to 2} = m_{12} = \frac{V_{L2}}{E_{L1}}$$

and

$$\text{Longitudinal Transfert Loss 1 to 2 (LTL}_{12}\text{)} = 20 \log_{10} \left| \frac{1}{m_{12}} \right| = 20 \log_{10} \left| \frac{E_{L1}}{V_{L2}} \right| \text{ dB}$$

$$\text{Longitudinal conversion transfer ratio 1 to 2} = h_{12} = \frac{V_{T2}}{E_{L1}}$$

and

$$\text{Longitudinal Conversion Transfer Loss 1 to 2 (LCTL}_{12}\text{)} = 20 \log_{10} \left| \frac{1}{h_{12}} \right| = 20 \log_{10} \left| \frac{E_{L1}}{V_{T2}} \right| \text{ dB}$$

Interchanging ports 1/1′ and 2/2′ gives the definition for the transfer ratios and losses LTL_{21} and $LCTL_{21}$ for the other direction of transmission.

NOTES

1 This measure is referred to in other Recommendations as *impedance imbalance to earth.*

2 It would have been more in keeping with traditional transmission theory if these quantities were defined in terms of *half* the open-circuit e.m.f. However, the ITU-T Recommendations concerning balance parameters involving a longitudinal excitation are already in terms of the open-circuit e.m.f. It is not thought useful to introduce a 6-dB “discrepancy” between existing practice and these new definitions.

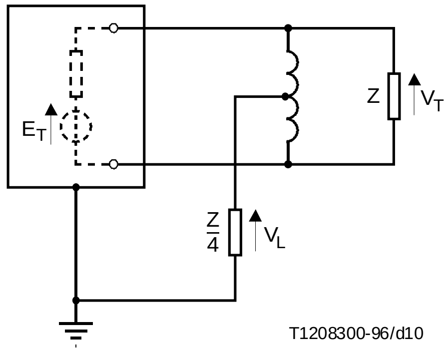
3 Z_1 et Z_2 are the impedances connected in parallel to the input and/or output port respectively of the item under test. Z_1 and Z_2 are generally within ± 25 percent of the nominal impedance of the port to which they are connected. If measurements are made via high-impedance input ports, an additional impedance Z_1 should be connected between ports 1/1′. The longitudinal impedances Z_{L1}, and Z_{L2} are nominally equal to $Z_1/4$ or $Z_2/4$ respectively. Different values, however, may be used. This may be necessary to properly simulate operating conditions of the item under test. In such cases the value Z_{L1} and/or Z_{L2} shall be specified by the Recommendation covering the item under test.

FIGURE 9/G.117

4.3 Signal generating devices

In addition to the six one-port measures already defined, an additional measure is required to control the amount of unwanted signal correlated with the wanted signal delivered by the device to the circuit it is connected to. This special measure is the output signal balance ratio (loss).

4.3.1 **Output signal balance ratio (loss)** (see Figure 10)



Output signal balance ratio, $b = \frac{V_L}{V_T}$

and

Output signal balance loss (OSB) = $20 \log_{10} \left| \frac{1}{b} \right| = 20 \log_{10} \left| \frac{V_T}{V_L} \right|$ dB

NOTES

1 This measure is a generalized version of the quantities referred to as the unbalance of output e.m.f.

2 This measure is also related in a somewhat indirect and complicated fashion to the sensitivity coefficients for electromagnetic and electrostatic induction defined in [2], if the cable pair is considered as a simultaneous source of a transverse signal correlated with the induced longitudinal voltages.

3 The test object itself provides the source of signal. Hence a separate generator is not required.

4 The definition relates particularly to generators of transverse signals (e.g.: transmission oscillators) but can be readily extended to cover the case of a longitudinal signal generator (e.g.: a low-frequency signalling system using the earthed-phantom). In this case the ratio could be inverted so that the decibel expression remains positive.

5 The other quantities (return loss, longitudinal conversion lost, longitudinal impedance loss and the uncorrelated transverse and longitudinal output voltages) must be measured selectively in order that their values in working conditions be obtained.

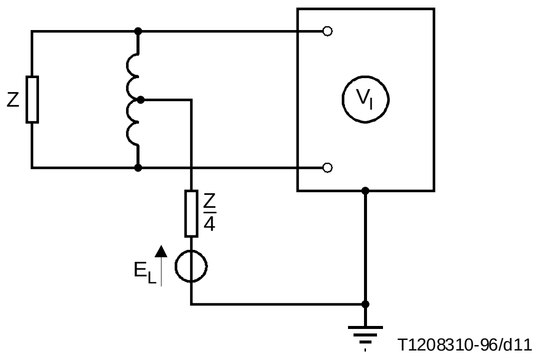
FIGURE 10/G.117

4.4 Signal receiving devices

In addition to the six one-port measures already defined, additional measures are required for signal receiving devices to control their sensitivity to unwanted signals. Two cases are important. Firstly, there are receiving devices in which the response is a linear, continuous function of the wanted signal level, e.g. the indication of a level-measuring set. In this case unwanted signals give rise to *inaccuracy.*

In the other kind of receiver such as data modems, group-delay distortion measuring sets, signalling receivers, unwanted signals cause errors or *misoperation.* Two additional measures are defined.

4.4.1 Input longitudinal interference ratio (loss) (see Figure 11)



$$\text{Input longitudinal interference ratio} = s = \frac{V_I}{E_L}$$

and

$$\text{Input longitudinal interference loss} = 20 \log_{10} \left| \frac{1}{s} \right| = 20 \log_{10} \left| \frac{E_L}{V_I} \right| \text{ dB}$$

in which V_I is the voltage indicated by the measuring set being tested.

NOTES

1 This is a generalized version of the quantities referred to as the receiver signal balance ratio (Recommendation O.41 [4]).

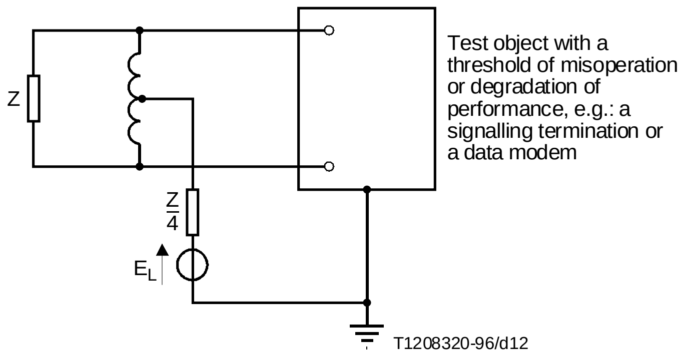
2 The measuring instrument itself provides one of the voltages required by the definition.

3 This measure is related to the well-known *common-mode rejection ratio* but not in any simple fashion. In particular it is not 6 dB different. This is because when the longitudinal rejection ratio is measured, the input transverse terminals are short-circuited and there is no transverse signal to generate any additional longitudinal signal via the unbalance of the input impedance.

4 The concept could be extended to cover receivers which respond linearly to longitudinal signals, and here it is transverse signals that interfere. The designation would then be input *transverse* interference ratio (loss) with a correspondingly different circuit arrangement.

FIGURE 11/G.117

4.4.2 **Longitudinal interference threshold voltage (level)** (see Figure 12)



Longitudinal interference threshold voltage = E_L

and

$$\text{Longitudinal interference threshold level} = 20 \log_{10} \left| \frac{E_L}{1 \text{ volt}} \right| \text{ dBV}$$

in which E_L is the voltage at which misoperation of the test device just occurs

NOTES

1 Other reference voltages than 1 volt may be used, for example, 0.775 V for 1 mW into 600 Ω (with the designation dB [3])).

2 "Misoperation" or the amount of degradation of performance would have to be defined. For a data modem it might have to be in terms of error ratio.

3 The threshold voltage may be specified as an rms value, or as an impulsive voltage as measured by an impulsive counter, or in terms of its waveshape (e.g.: square, triangular).

4 The concept could be extended to cover unwanted transverse signals affecting the operation of longitudinal receivers, with appropriate changes to the testing circuit and designation.

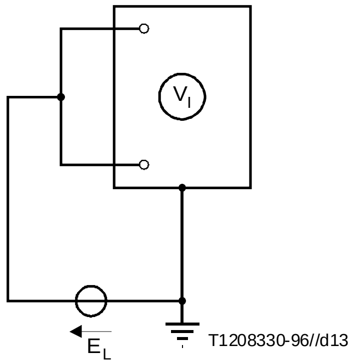
FIGURE 12/G.117

5 Other measurement definitions

5.1 Common-mode rejection ratio

This is another quantity that is appropriate to signal receivers and is measured in accordance with the principle shown in Figure 13, the input terminals being short-circuited and then energized together.

It is clear that this measure is similar to the input longitudinal interference ratio but since there is no transverse signal (by reason of the short circuit) no longitudinal/transverse conversion mechanism within the test-object is excited. In general, there is no simple relationship between the two measures, as can be seen from the generalized measuring instrument illustrated in Figure 14, in which the input impedance is unbalanced and the gain ratios of the two halves of the differential amplifier are also slightly different. Provided the value for ε is as in Figure 14 and Δ << 1, the various balance parameters are as indicated. This assumes the common mode rejection ratio is not twice the input longitudinal interference ratio, i.e. there is not a 6-dB difference between their decibel values.



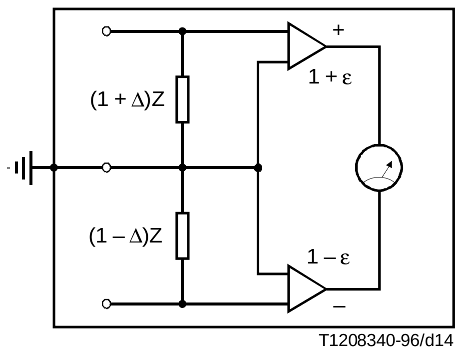
$$\text{Common-mode rejection ratio} = \left|\frac{E_L}{V_I}\right|$$

and

$$\text{Common-mode rejection} = 20 \log_{10}\left|\frac{E_L}{V_I}\right| \text{ dB}$$

NOTE – V_I is the voltage indicated by the measuring set being tested.

FIGURE 13/G.117



$$\text{Common mode rejection ratio} = 2\varepsilon$$

$$\text{Input longitudinal interference ratio} = \varepsilon + \frac{\Delta}{2} \quad (\varepsilon, \Delta \ll 1)$$

$$\text{Longitudinal impedance ratio} = 0.5 \quad (\Delta \ll 1)$$

$$\text{Longitudinal conversion ratio} = \frac{\Delta}{2} \quad (\Delta \ll 1)$$

FIGURE 14/G.117

A measuring set in which there is both a passive unbalance and an internal active unbalance

Annex A

Aspects of conversion from longitudinal to transversal signals at analogue ports in some practical cases

(This annex forms an integral part of this Recommendation)

A.1 Introduction

Cables for telecommunication purposes sometimes have to pass areas that have strong, disturbing electromagnetic fields which may cause significant longitudinal signals along the cables. For voiceband telephone signals, the established technique is to use well-balanced cables and equipment so that the conversion from longitudinal to transversal signals is sufficiently suppressed. In general, the cables have a much higher degree of balance than what is obtainable for terminal equipment. The governing factor is then the properties of the terminal equipment, i.e. the balance to Earth of that port which is connected to the cable.

The balancing properties of an equipment port can be expressed in many ways. The most commonly used parameter appears to be the "Longitudinal Conversion Loss", LCL. The general definition of LCL is given in clause 2 which in principle applies to all cases. However, in *equipment specifications,* LCL most often is understood to be a value which is obtained in a specific measuring setup according to Figure 4, where the transverse terminating impedance Z is made 600 ohms resistive and the longitudinal source impedance $Z/4$ thus is 150 ohms resistive.

The advantage of this latter definition is that LCL is obtained in a well-defined manner and that this LCL value gives a general indication of how well the port is balanced to Earth. However, the configuration in Figure 4 does not correspond too well with a realistic representation of actual, practical cases:

1) The transverse terminating impedance nowadays is not always 600 ohms resistive but can be a complex, nominal impedance as given for instance in Recommendation Q.552.

2) The longitudinal source impedance is resistive only in exceptional cases but rather like a high capacitance.

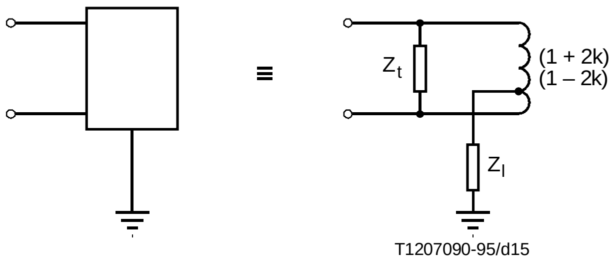
Thus, when a more accurate analysis of the actual longitudinal-to-transversal conversion is needed, either a special test setup, simulating actual conditions, has to be used and/or a more detailed circuit analysis has to be performed. In what follows, such an analysis will be made in order to illustrate the difference between a measured LCL and the actual conversion LCL.

To distinguish the cases, the Longitudinal Conversion Loss measured in the 600/150 ohms test bridge will be designated LCL_m, and the Longitudinal Conversion Loss in the actual circuit LCL_c.

A.2 Calculation of the longitudinal conversion loss

The unbalance properties of an equipment port or a network port can be described in many ways by equivalent circuits. The one shown in Figure A.1, employing an ideal choke with a tap, will be used here because it leads to simple expressions. (The factor k is a measure of the degree of unbalance.)

This equivalent circuit type can be used both for the circuit (cable or the test bridge), that introduces the longitudinal voltage, and for the terminating equipment, as Figure A.2 depicts. (Note that the cable and the test bridge are supposed to be perfectly balanced.)



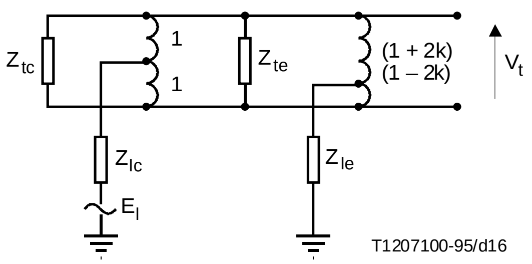
Z_t Transverse impedance

Z_l Longitudinal impedance

k Transverse Conversion Factor

FIGURE A.1/G.117

Equivalent circuit for the unbalance-to-earth at a port



Z_{te}, Z_{le} transverse resp. longitudinal impedance of the equipment

Z_{tc}, Z_{lc} transverse resp. longitudinal impedance of the cable or the test bridge

FIGURE A.2/G.117

Equivalent circuit for conversion of the longitudinal voltage E_l to the transversal voltage V_t

Using the equivalent circuit, the following expression for the Longitudinal Conversion Loss LCL_C in the general case is derived:

$$LCL_c = 20 \cdot \lg \left| \frac{1}{k} \left\{ (Z_{lc} + Z_{le}) \cdot \left(\frac{1}{Z_{tc}} + \frac{1}{Z_{te}} \right) + k^2 \right\} \right| \quad \text{dB} \qquad \text{(A-1)}$$

Note that this equation is valid for all values of k, i.e. even if the port would be totally unbalanced. However, in general, the terminating equipment is reasonably well-balanced, i.e. k is small, so that equation A-1 can be simplified to:

$$LCL_c = 20 \cdot \lg \left| \frac{1}{k} \left(Z_{lc} + Z_{le} \right) \cdot \left(\frac{1}{Z_{tc}} + \frac{1}{Z_{te}} \right) \right| \quad \text{dB} \qquad \text{(A-2)}$$

In the measuring setup for the longitudinal conversion loss we have:

$$Z_{lc} = 150 \text{ ohms}; \qquad Z_{tc} = 600 \text{ ohms}; \qquad \text{(A-3)}$$

so that:

$$LCL_m = 20 \cdot \lg \left| \frac{1}{k} (150 + Z_{le}) \cdot \left(\frac{1}{600} + \frac{1}{Z_{te}} \right) \right| \quad \text{dB} \qquad \text{(A-4)}$$

A.3 The difference between LCL_c and LCL_m in a practical case – two examples

The disturbing circuit is assumed to be a subscriber cable, perfectly balanced, and the terminating equipment the input analogue port of a digital exchange. The terminal equipment has a slight unbalance to Earth.

The equipment transversal impedance Z_{te} is complex, and can be represented by a resistance of 275 ohms and a parallel combination of a resistance of 780 ohms and a capacitance of 150 nF. This impedance is a sufficiently close match to the input transversal impedance of the cable circuit so that $Z_{tc} = Z_{te}$.

The equipment longitudinal impedance Z_{le} is assumed to be 300 ohms resistive.

In the first example the cable is terminated by a telephone set with a very high longitudinal impedance to Earth. Then the circuit, i.e. the cable, input longitudinal impedance Z_{lc} can be represented by a capacitance C_s in series with a small resistance. Here C_s = 500 nF and R_s = 75 ohms are chosen values as being typical for a subscriber line.

In the second example the subscriber line is terminated by an equipment, perfectly balanced, but with a very low longitudinal impedance to Earth. Then Z_{lc} can be considered as a pure resistance, three times higher than in the first case, i.e. Z_{lc} = 225 ohms.

The difference (LCL_c – LCL_m) for the two cases is shown in Figures A.3 and A.4 respectively.

The first example: high longitudinal impedance to Earth at the far end.

The second example: low longitudinal impedance to Earth at the far end.

A.4 Additional Insight into Longitudinal Conversion Loss

A more complete analysis of LCL differences between actual longitudinal conversion loss circuits and longitudinal conversion loss test sets has been done. Two conclusions are noteworthy:

1) The real difference between the test set and the actual longitudinal conversion loss is rather independent of the terminal input impedance and therefore this analysis applies to virtually all reasonable exchange input impedances including 600 ohms and 900 ohms + 2.16 μF.

2) The difference between the actual longitudinal conversion loss and the longitudinal conversion loss as measured by the test set is compensated for by the lower LCL limits at lower frequencies as noted in Recommendation Q.553. Recommendation Q.553 requires a minimum of 40 dB LCL from 300 Hz to 600 Hz and 46 dB of LCL from 600 Hz to 3400 Hz.

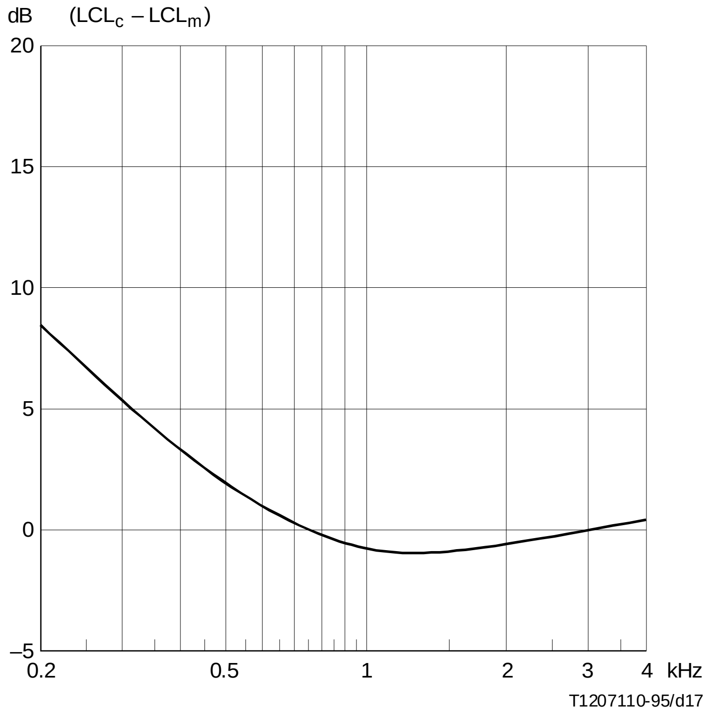


FIGURE A.3/G.117

Difference between actual longitudinal conversion loss LCL_c and LCL_m, measured in the standard test bridge

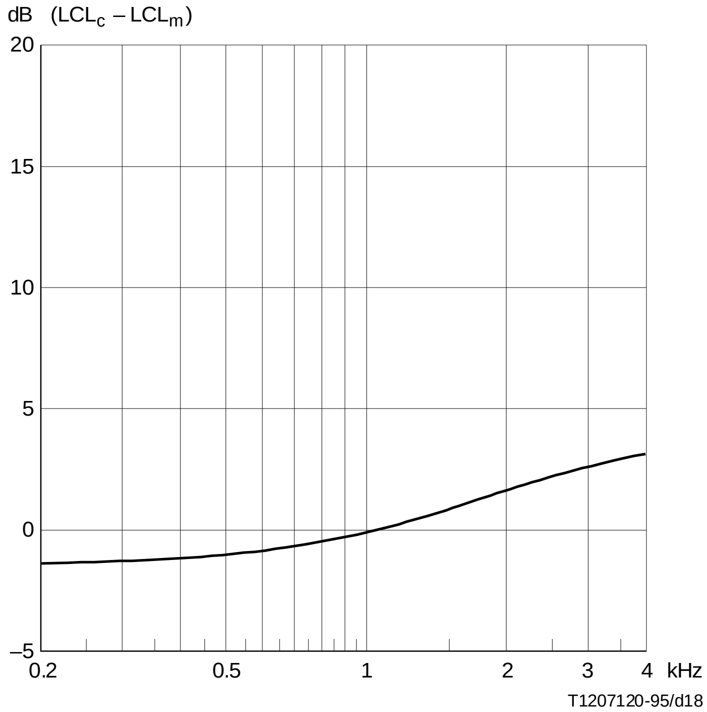


FIGURE A.4/G.117

Difference between actual longitudinal conversion loss LCL_c and LCL_m, measured in the standard test bridge

References

[1] CCITT Recommendation O.9 (1988), *Measuring arrangements to assess the degree of unbalance about earth*.

[2] CCITT *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified ralways lines*, ITU, Geneva, 1990.

[3] ITU-R Recommendation V.574 (1990), *Use of the decibel and the neper in telecommunications*.

[4] ITU-T Recommendation O.41 (1994), *Psophometer for use on telephone-type circuits*.