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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

International telephone connections and circuits –
Transmission planning and the E-model

The use of the decibel and of relative levels in speechband telecommunications

Recommendation ITU-T G.100.1

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
Transmission planning and the E-model	G.100–G.109
General Recommendations on the transmission quality for an entire international telephone connection	G.110–G.119
General characteristics of national systems forming part of international connections	G.120–G.129
General characteristics of the 4-wire chain formed by the international circuits and national extension circuits	G.130–G.139
General characteristics of the 4-wire chain of international circuits; international transit	G.140–G.149
General characteristics of international telephone circuits and national extension circuits	G.150–G.159
Apparatus associated with long-distance telephone circuits	G.160–G.169
Transmission plan aspects of special circuits and connections using the international telephone connection network	G.170–G.179
Protection and restoration of transmission systems	G.180–G.189
Software tools for transmission systems	G.190–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T G.100.1

The use of the decibel and of relative levels in speechband telecommunications

Summary

Recommendation ITU-T G.100.1 provides the definition for different logarithmic power level measurement units in current use in telecommunication systems. This Recommendation also provides the relationship amongst those units and usage examples. The text herein is a merger of information that has been previously dispersed over several publications and supersedes the contents of: Recommendation ITU-T B.12, Annex A of Recommendation ITU-T G.100, Annex A of Recommendation ITU-T G.101, Annex B of Recommendation ITU-T Q.551, and clause 3.8 of Recommendation ITU-T G.101.

History

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* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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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Table of Contents

		Page
1	Scope.....	1
2	References.....	1
3	Definitions	2
	3.1 Terms defined elsewhere	2
	3.2 Terms defined in this Recommendation.....	2
4	Abbreviations and acronyms	2
5	Conventions	2
6	Fundamentals about dB	2
	6.1 Loss and gain.....	3
	6.2 The letter "p" in "dBmp" and "dBm0p"	5
	6.3 Correction factors	5
	6.4 Signal-to-noise ratio	7
	6.5 Sound pressure level.....	7
7	The use of a reference signal	7
8	Relationships between the units "dBm", "dBr" and "dBm0"	9
	8.1 General	9
	8.2 The unit "dB"	10
	8.3 The unit "dBm"	10
	8.4 The unit "dBr"	11
	8.5 The unit "dBm0"	12
	8.6 The relationship between dBm, dBr and dBm0	13
	8.7 The unit "dBov"	13
	8.8 Relationship between overload (dBov) and maximum levels (dBm0)	14
9	The concept of "relative levels"	15
	9.1 General principles.....	15
	9.2 Circuits and connections.....	16
	9.3 The speech signal and the dynamic range of the voice channel.....	17
	9.4 Relative level designations for a digital path	20
	9.5 Relative levels in equipment design, specification and testing	21
	9.6 Relative levels in transmission planning and maintenance	24
	Appendix I – The neper	27
	I.1 Introduction	27
	I.2 Definition of the neper.....	27
	I.3 Use of the decibel and of the neper	27
	Bibliography.....	28



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Recommendation ITU-T G.100.1

The use of the decibel and of relative levels in speechband telecommunications

1 Scope

In transmission engineering, most often it would be rather impractical to characterize the magnitude of signals directly by a numerical value in volts or watts. Instead, a logarithmic measure is used, expressed in "dB", to characterize the signal magnitude in relation to some chosen reference value. Designations commonly used are "power level difference", "voltage level difference", etc., all expressed in "dB". A level difference from a standard situation is described simply as "level". Loss and gain are also measured in "dB".

The term "relative levels" has been a very useful term in transmission planning for the last 40 years and is expected to be so in the future. However, the public switched telephone networks have changed considerably in these years. Especially with the introduction of digital exchanges which causes some uncertainty concerning the application of relative levels and necessitates some changes in the traditional way of applying relative levels. In this Recommendation, relative levels and associated terms are explained and examples are shown to clarify these concepts.

Guidance on the use of decibels in the field of sound transmission and radio frequencies can be found in [ITU-R V.574-4].

Notations for expressing the reference of a level can be found in Part 5 of [IEC 60027-3].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.111] Recommendation ITU-T G.111 (1993), *Loudness ratings (LRs) in an international connection.*
- [ITU-T G.121] Recommendation ITU-T G.121 (1993), *Loudness ratings (LRs) of national systems.*
- [ITU-T G.223] Recommendation ITU-T G.223 (1988), *Assumptions for the calculation of noise on hypothetical reference circuits for telephony.*
- [ITU-T G.711] Recommendation ITU-T G.711 (1988), *Pulse code modulation (PCM) of voice frequencies.*
- [ITU-T G.712] Recommendation ITU-T G.712 (2001), *Transmission performance characteristics of pulse code modulation channels.*
- [ITU-T G.722] Recommendation ITU-T G.722 (2012), *7 kHz audio-coding within 64 kbit/s.*
- [ITU-T O.41] Recommendation ITU-T O.41 (1994), *Psophometer for use on telephone-type circuits.*
- [ITU-T P.56] Recommendation ITU-T P.56 (2011), *Objective measurement of active speech level.*

[ITU-T P.79]	Recommendation ITU-T P.79 (2007), <i>Calculation of loudness ratings for telephone sets.</i>
[ITU-R V.574-4]	Recommendation ITU-R V.574-4 (2000), <i>Use of the decibel and the neper in telecommunications.</i>
[IEC 60027-3]	IEC 60027-3:2002, <i>Letter symbols to be used in electrical technology – Part 3: Logarithmic and related quantities, and their units.</i>
[IEC 60651]	IEC 60651:1979, <i>Sound level meters.</i>

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CLR	Circuit Loudness Rating
DRS	Digital Reference Sequence
FDM	Frequency Division Multiplexing
LR	Loudness Rating
MNRU	Modulated Noise Reference Unit
PBX	Private Branch exchange
PCM	Pulse Code Modulation
RLR	Receive Loudness Rating
RMS	Root Mean Square
SPL	Sound Pressure Level
SLR	Send Loudness Rating
TRP	Transmission Reference Point

5 Conventions

None.

6 Fundamentals about dB

The *bel* (symbol B) expresses *the ratio of two powers* by the decimal logarithm of this ratio. This unit is not often used, having been replaced by the *decibel* (symbol dB), which is one-tenth of a bel.

The decibel may be used to express the ratio of two *field quantities*, such as voltage, current, sound pressure, electric field, charge velocity or density, the square of which in linear systems is proportional to power. To obtain the same numerical value as a power ratio, the logarithm of the field quantity ratio is multiplied by the factor 20, assuming that the impedances are equal.

The relationship between a current or voltage ratio and that of the corresponding power ratio is impedance dependent. Use of the decibel when the impedances are not equal is not appropriate unless adequate information is given concerning the impedances involved.

The "dB" is a very practical unit which can be used in many different applications.

Comparing two signal powers P_1 mVA and P_2 mVA, P_1 is said to be at an L dB higher (power) level than P_2 , where

$$L = 10 \cdot \log \frac{P_1}{P_2} \text{ [dB]} \quad (6-1)$$

Comparing two voltages, V_1 volts and V_2 volts, V_1 is said to be at an L dB higher (voltage) level than V_2 , where

$$L = 20 \cdot \log \frac{V_1}{V_2} \text{ [dB]} \quad (6-2)$$

Note that "power" depends on the square of "voltage", hence the coefficient 10 in equation (6-1) and the coefficient 20 in equation (6-2).

Equation (6-2) is also used for quantities other than volts, for instance, currents, acoustic pressure, etc. Note that the term (V_1/V_2) must be a dimensionless quantity. This is automatically fulfilled when V_1 and V_2 represent two amplitudes of the same kind. Otherwise, V_1 and V_2 must each be referred to specific reference values of the proper dimension. (For instance, the send sensitivity of a telephone set is described as the relationship between the input pressure in Pascal and the output voltage in volts, expressed as "dB rel. 1V/Pa".)

6.1 Loss and gain

The unit dB is also used to characterize loss or gain (of power or voltage) in a system.

Figure 1 shows how a voltage loss may be defined and calculated. The voltage loss is equal to the voltage level difference between port a) and port b).

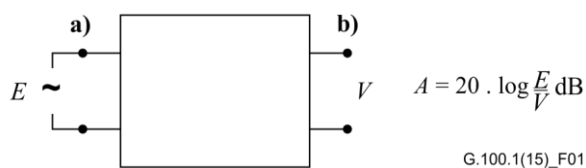


Figure 1 – Example of voltage loss from port a) to port b)

A special case is the return loss A_r which gives a measure of the mismatch between two impedances Z_1 and Z_2 . (A_r can be described as the voltage loss between the incident and the reflected signal at the point of mismatch.) The expression for A_r is:

$$A_r = 20 \cdot \log \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{ [dB]} \quad (6-3)$$

For passive, reciprocal two-ports (like analogue, passive filters) it has been found practical to base the loss concept on the power level difference between the so-called apparent powers at the input and the output of the two-port. (It can be shown that for such types of circuits this definition of loss results in the same loss for both directions of transmission.)

Figure 2 depicts the configuration.

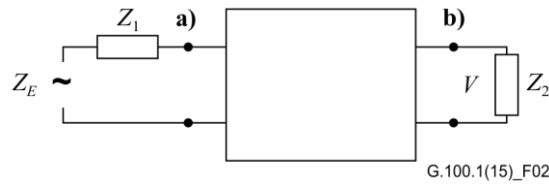


Figure 2 – Example for apparent power loss calculation

Note that the signal generator in Figure 2 produces a single-frequency tone.

The reference apparent power P_1 from the generator is defined to be obtained when the load is equal to the generator impedance Z_1 . With the designation P_2 for the output apparent power we get:

$$P_1 = \frac{E^2}{|Z_1|} \quad P_2 = \frac{V^2}{|Z_2|} \quad (6-4)$$

Thus, the (apparent power) loss is:

$$A = 10 \cdot \log \frac{P_1}{P_2} \text{ [dB]} = 20 \cdot \log \sqrt{\frac{|Z_1|}{|Z_2|}} \cdot \frac{E}{V} \text{ [dB]} \quad (6-5)$$

However, in telephone networks the transmission chain consists of cascaded units which contain amplifiers and 4-wire loops which are non-reciprocal and therefore the loss concept in equation (6-5) needs some modification in order to remain practical.

As long as the impedances Z_1 and Z_2 are real and constant with frequency, equation (6-5) is still used as a definition of loss. "Apparent power" (expressed in mVA) is in this case equal to "active power" (expressed in mW).

When one or both of the impedances are complex and varying with frequency, the transfer of "apparent power" at different frequencies is not an adequate measure of circuit performance. One of the reasons why is that the active components in the chain react on input voltage, not on apparent power.

Therefore, a circuit in accordance with Figure 2 is defined as having a flat frequency response when

$$20 \cdot \log \frac{E}{V} = \text{constant} \quad (6-6)$$

irrespective of how the (given) impedances Z_1 and Z_2 vary with frequency.

To retain the coupling to the power concept, the nominal loss A_0 is defined as the apparent power loss at a reference frequency $F_0 = 1020 \text{ Hz}$ as follows:

$$A_0 = 20 \cdot \log \frac{E(F_0)}{V(F_0)} \sqrt{\frac{|Z_2(F_0)|}{|Z_1(F_0)|}} \text{ [dB]} \quad (6-7)$$

Thus, the frequency-dependent loss of a circuit in accordance with Figure 2 is defined as:

$$A(f) = 20 \cdot \log \frac{E(f)}{V(f)} \sqrt{\frac{|Z_2(F_0)|}{|Z_1(F_0)|}} \text{ [dB]} \quad (6-8)$$

The losses of cascaded units can be added to get the total overall loss of the chain provided the impedance mismatching at the interconnection points is reasonably small.

NOTE 1 – These loss definitions also apply for electro-acoustic parameters, such as telephone set sensitivities. In this case, however, for the send characteristics the input voltage in volts is divided by the output sound

pressure in Pascal and vice versa for the receive characteristics. (Corrections are to be applied if the nominal impedance is not 600 ohms.)

NOTE 2 – The concept of apparent power at a frequency different from the reference frequency of 1020 Hz is irrelevant.

NOTE 3 – The receive characteristic of a telephone set is usually rather flat with frequency within the transmitted speech band. The send characteristic often has a pronounced pre-emphasis at the high end of the frequency band.

6.2 The letter "p" in "dBmp" and "dBm0p"

The additional small letter "p" is derived from the French word "ponderé" for "weighted" and means that the considered value is a noise level, measured by a psophometer with a special noise weighting filter included as described in [ITU-T O.41].

6.3 Correction factors

Depending on the type of test instruments, auxiliary equipment and test objects, sometimes correction factors need to be used, to either adjust the correct test signal level, or to obtain the correct test result. This mainly occurs in conjunction with capacitive complex impedances.

In practice, test instruments may be used with input/output impedances of only 600 Ω resistive and consequently send levels or displayed results referred to 1 mW. To provide the correct termination of test objects with complex impedances, auxiliary devices called "impedance converters" are used. The principle of such an impedance converter is shown in Figure 3 in the application for sending and in Figure 4 for receiving.

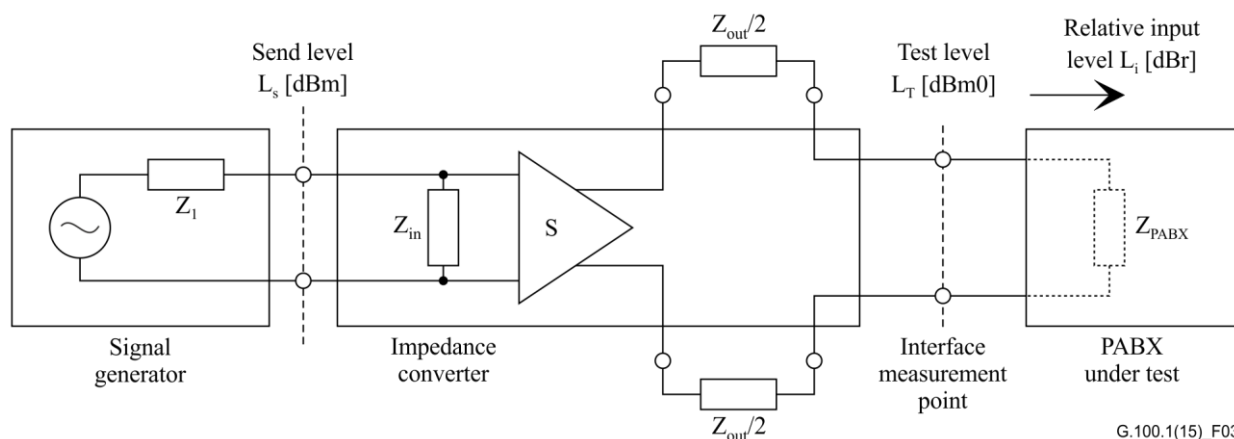


Figure 3 – Impedance converter in the sending path

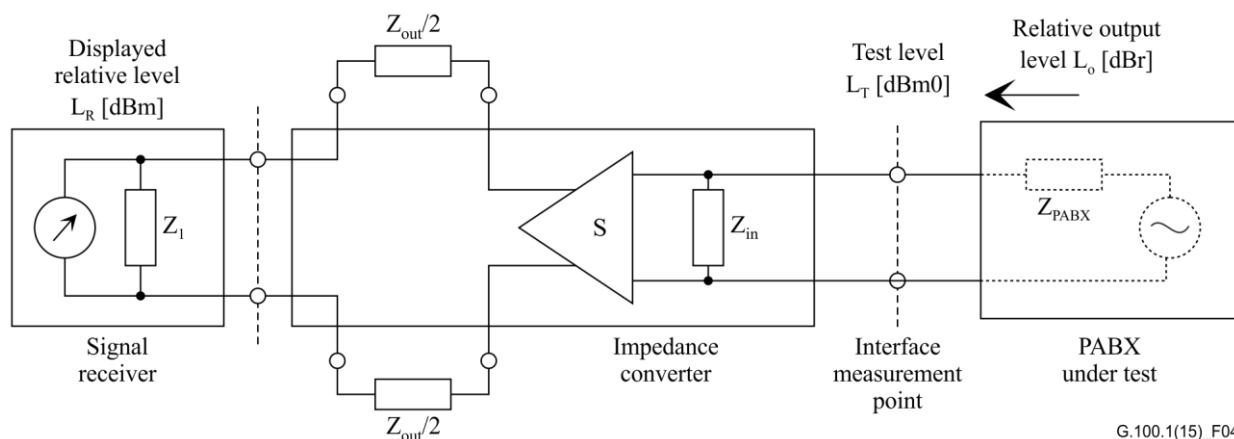


Figure 4 – Impedance converter in the receive path