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Technical regulations concerning international railway telephone circuits

Prescriptions techniques relatives aux communications téléphoniques ferroviaires internationales
Technische Vorschriften für internationale Eisenbahn-Fernsprechverbindungen

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Summary

This leaflet defines the elements used for international telephone communications and the rules to be observed in establishing international circuits. The technical characteristics of the analogue and digital transmission systems constituting these circuits are also specified. Reference is further made to specifications relating to line systems, such as the overhead line, cables and directional radio links. Finally, the maintenance procedures to be applied are dealt with.

NB : this leaflet forms part of a set, including:

- *UIC Leaflet 750*,

- *UIC Leaflet 753-2*.

There is also a reference, in point 2.3.4, to *UIC Leaflet 911-4* "Standard provisions for modems and transmission lines used in data links with a binary throughput of 600 to 9 600 bits/s".

1 - General

Preliminary note

This text is based largely on ITU-T (see List of abbreviations - page 33) regulations, and references are to the most recent edition of the ITU-T Recommendations. It specifies and summarizes the main regulations with which international railway telephone connection circuits must comply, using the units defined in Appendix A - page 31.

Some of these regulations are mandatory. Operating aspects are dealt with in *UIC Leaflet 750* (see Bibliography - page 34).

1.1 - Definitions

1.1.1 - International railway circuits

The following shall be considered as international telephone circuits:

1. Inter-railway circuits proper, i.e. international telephone circuits affording direct connections between the telephone systems of any two countries and suitable for international railway telephone transit calls.

   Lines connecting stations directly adjacent to frontiers, and which are only used for local purposes, are not therefore taken into account here.

2. Railway internal 4-wire circuits affording direct communication with the main exchanges of inter-railway circuits, which are used for establishing international transit calls between two non-adjacent countries.

1.1.2 - National circuits

National circuits are those which do not fall into either of the above categories. They include extension circuits, local circuits, and user lines.

1.1.3 - International exchanges

International circuits are those terminating at main exchanges of inter-railway circuits. When considered from the point of view of international connections, such exchanges can be either of a terminal or transit nature. In the case of the latter, they must be designed for connecting international circuits.

1.1.4 - International connections

International connections are established through the equipment linking together the two subscriber stations belonging to different networks and having access to international circuits.

It includes therefore the two subscriber stations, a chain of international and national circuits, and the relevant switch gear (manual or automatic).

1.2 - International railway telephone service

International railway telephone connections cannot be set up except by agreement with the railways and observance of certain technical specifications given in this leaflet. These specifications could prove inadequate in the event of the system of circuits becoming too complex. It may then prove worthwhile to provide very-long-distance direct inter-railway circuits.

A data base established by the responsible panel of experts is kept updated by the UIC on the basis of information furnished by the Railways. This data is accessible from the Internet at the UIC Site under the following address http://ernst.uic.asso.fr/.

2 - Technical regulations concerning transmission

2.1 - General features of an end-to-end international connection

2.1.1 - Reference equivalent

2.1.1.1 - In any international railway telephone connection, the reference equivalent between two users (telephones included) is not strictly limited, since the number of sections that can be connected end-to-end in the international chain is unlimited.

2.1.1.2 - However, in practice, the reference equivalent of the international chain should not exceed 3 dB with the result that the total reference equivalent for the longest international connection should not exceed 36 dB, taking into account the directives given below (21 dB + 3 dB + 12 dB).

O **2.1.1.3 -** The reference equivalent of the national transmitting system (counted from the telephone to the original international circuit as defined in point 1.1.1 - page 2) must not exceed 21 dB (telephone included).

O **2.1.1.4 -** The reference equivalent of the national receiving system (counted from the ends of the international circuit to the telephone) shall not exceed 12 dB (telephone included).

2.1.1.5 - The equivalent should in theory have the same value for both directions of transmission.

2.1.1.6 - Figure 1 below gives an example of the distribution of equivalents for an end-to-end international connection.

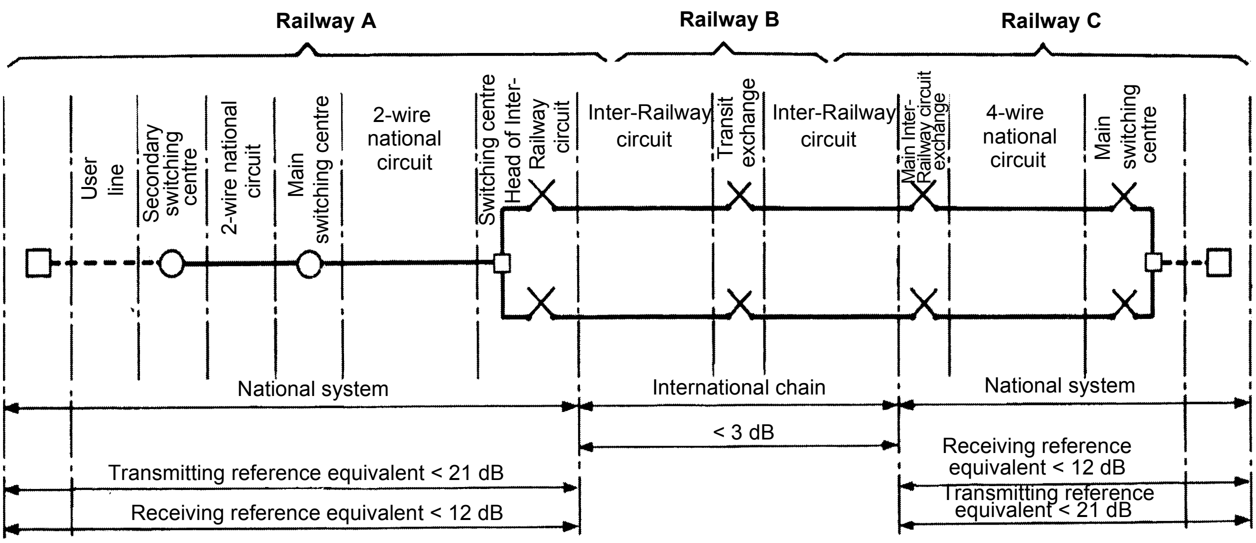

Fig. 1 - International telephone circuits - Example of distribution of equivalents

2.1.2 - Articulation indices

2.1.2.1 - The transmitting and receiving reference equivalents for user telephone sets in international connections are not fixed. The values fixed for the national system in point 2.1.1 - page 4 should be observed.

2.1.2.2 - The response curve of the user telephone set should be as even as possible with a slight rise near the high frequencies (e.g. 2 dB per octave). The difference between the limit values should not be greater than 10 dB (in the 300 to 3 400 Hz range).

2.1.3 - Phase delay

O **2.1.3.1 -** To cut down echo effects, phase delay between two users in an end-to-end international connection should be limited to:

- 150 ms where possible,
- 400 ms in all cases, with echo suppressors,

measured at a frequency of about 800 Hz.

O **2.1.3.2 -** To achieve this, phase delay on each of the national transmitting or receiving systems must not exceed 18 ms and phase delay on the international circuit must not exceed 25 ms.

2.1.3.3 - Only high-speed transmission circuits should be used as international circuits and, preferably, digital multiplex system links.

2.1.4 - Envelope delay distortion

To allow "Telematics" applications at lower average speeds, the envelope delay distortion must come within the template shown in Figure 2 below.

Nota : "Telematics" applications are data processing functions that use subscriber telephone lines.

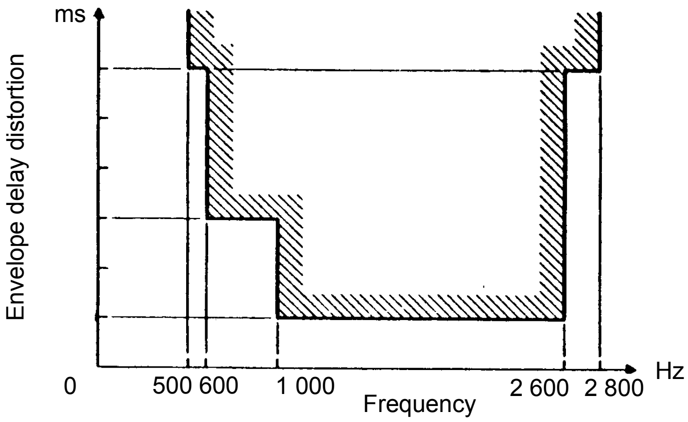

Fig. 2 - Template of envelope delay distortion in relation to the minimum value for an end-to-end international circuit

2.2 - General characteristics of the international circuit chain and national extension circuits

2.2.1 - Types of circuit and interconnection of circuits

O **2.2.1.1 -** The arrangement known as the 4-wire system shall be used for international circuits.

O **2.2.1.2 -** 4-wire connections must be used for junctions between two international circuits.

2.2.1.3 - The 4-wire interconnections should be carried out by direct connection of the transmitting and receiving lines. In actual fact, although indirect connection by means of differential transformers is in theory equivalent to a direct connection, this latter expedient should be avoided since unbalance is likely to result from abnormal conditions, and have undesirable effects upon the signals.

O **2.2.1.4 -** The junction between an international circuit and a 4-wire national extension circuit shall be done by means of the 4-wire connection.

2.2.2 - Permissible equivalents for national circuits

The minimum equivalent for national circuits shall be arrived at by calculating:

- the minimum value of the permissible equivalent from the point of view of echo (in respect of the person speaking);
- the minimum value of the permissible equivalent from the point of view of stability (risk of singing point oscillations).

The higher of the two values is the relevant figure.

The maximum equivalent of national circuits shall be based on the values laid down in point 2.1.1 - page 4, and on the equivalent values for transmission and reception of the telephones used.

2.2.3 - Echo effects

O **2.2.3.1 -** The minimum permissible values for attenuation of echo currents at 800 Hz are given in Figure 3 - page 7 below. The curves only apply to circuits without echo suppressors only, this being the normal case on the railways.

2.2.3.2 - Echo currents result from unavoidable imperfections in impedance matching between circuits, terminating sets, amplifiers, etc. The magnitude of the echo can be calculated by taking into account the return loss at the terminating sets and, at the distant end, the gains encountered in the circuits, and the propagation time on the various sections of line used. This calculation, which is not usually necessary when multiplex equipment interconnected with 4-wire circuits is used, is carried out in accordance with the method recommended by the ITU-T (*Recommendation G.131,* see Bibliographie - page 34).

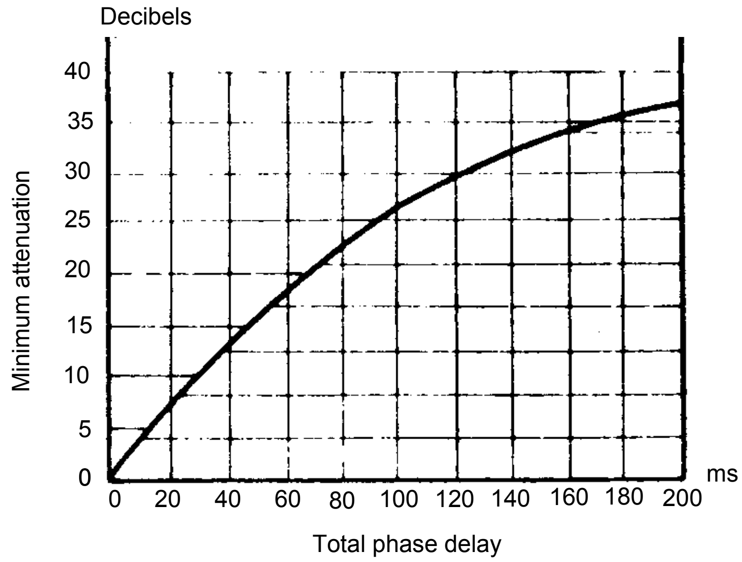

Fig. 3 - Curve giving the minimum permitted echo attenuation value for circuits without echo suppressors in relation to total phase delay on echo current paths

2.2.4 - Transmission stability

O **2.2.4.1 -** The stability of the chain of national and international circuits between the two local exchanges, when these are insulated, must be at least 3 dB.

2.2.4.2 - To enable this condition to be fulfilled, a minimum value should be fixed for attenuation, measured at the international exchange in which the international circuit between the national transmitting and receiving extension system ends. This value should be equal to or higher than (6+n) dB, "n" being the number of 4-wire circuits in the national chain. The 2-wire circuit terminals must be insulated while the measurement is being carried out.

2.2.4.3 - The calculation shall be made according to the method recommended by the ITU-T (*Recommendation G.131*).

2.2.4.4 - As the equivalent variation increases with the number of circuits, it should be kept to a minimum by carrying out maintenance at carefully selected intervals.

O **2.2.4.5 -** A limit value of ±1 dB shall be observed for the deviation in time of each international circuit in relation to the rated value.

2.2.5 - Cross-talk between the different circuit chains

2.2.5.1 - The cross-talk ratio between the two 4-wire circuit chains shall be limited by the following conditions laid down for each element in the chain:

O **2.2.5.2 -** The far or near-end cross-talk measured between two 4-wire circuits shall not be less than 58 dB.

O **2.2.5.3 -** The cross-talk ratio between the two connections established in an international exchange shall not be less than 70 dB.

2.2.6 - Cross-talk between the outward and return channels of a 4-wire circuit chain

2.2.6.1 - The cross-talk ratio between outward and return channels of a 4-wire circuit shall be limited by the following conditions laid down for each element in the chain:

O **2.2.6.2 -** The near-end cross-talk ratio measured between the two transmission directions of a 4-wire circuit shall be at least 43 dB.

O **2.2.6.3 -** The cross-talk ratio between the two connections which constitute the outward and return channels of a 4-wire circuit path in an international exchange must not be less than 60 dB.

2.2.7 - Circuit impedance

O **2.2.7.1 -** All circuits leading to the same exchange must possess the same rated impedance value at the switches, both for 2-wire and 4-wire circuits. This rated value must be 600 Ω.

2.2.7.2 - The return-current coefficient should remain below 0,10.

2.2.8 - Envelope delay distortion

Envelope delay distortion in the circuit chain is determined by observing the condition laid down in point 2.1.4 - page 5 for each circuit in the chain. In this way, it is hoped that the lower mean data transmission speeds (e.g. 1 200 bits per second) will function correctly.

2.3 - International circuits

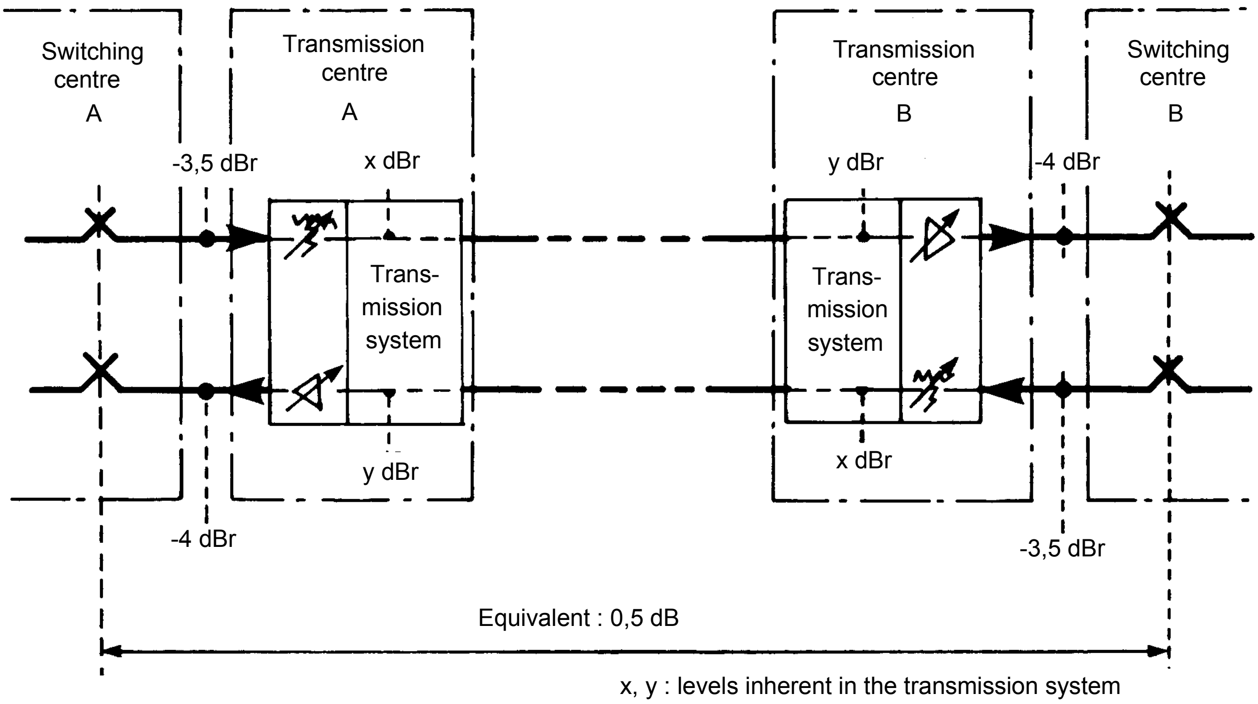

Fig. 4 - International telephone circuits -
Example of distribution of levels for an international circuit

2.3.1 - Nominal equivalent

O **2.3.1.1 -** International circuits should have an equivalent of +0,5 dB between their 4-wire terminals. The relative levels at the ends of each international circuit have been fixed at:

- 3,5 dBr at the transmitting end,
- 4,0 dBr at the receiving end.

If required, attenuation pads may be used for this purpose in terminal apparatus.

O **2.3.1.2 -** The interconnection, at a transit end, of two 4-wire circuits must be carried out in such a way that the equivalent of the chain made up of these two interconnected circuits possesses almost the same nominal standard value as the equivalent of a single circuit.

2.3.1.3 - This equivalent is measured under the same conditions as for a single circuit: it must take into account the insertion loss of the transit switching equipment, as well as any line simulator included in the chain of international circuits.

2.3.1.4 - Equipment effecting the changeover from 4 to 2 wires at the input to the national network forms part of the national network.

O **2.3.1.5 -** All the above equivalents must incorporate the attenuation of the telephone exchanges crossed, which implies that a circuit within a network regulated at 0 dB equivalent must observe the nominal equivalent and will therefore be suitable for use as an international circuit as defined in point 1.1.1, paragraph 2 - page 2.

NB : Precautions must be taken when building time exchanges, which theoretically can produce gains.

2.3.2 - Useful frequency bands and attenuation distortion

NB : For circuits built with new materials

International circuits to be installed must have useful frequencies ranging from 300 to 3 400 Hz minimum. The deviation with frequency of the terminal service equivalent should also not exceed the limits given in Figure 5 below.

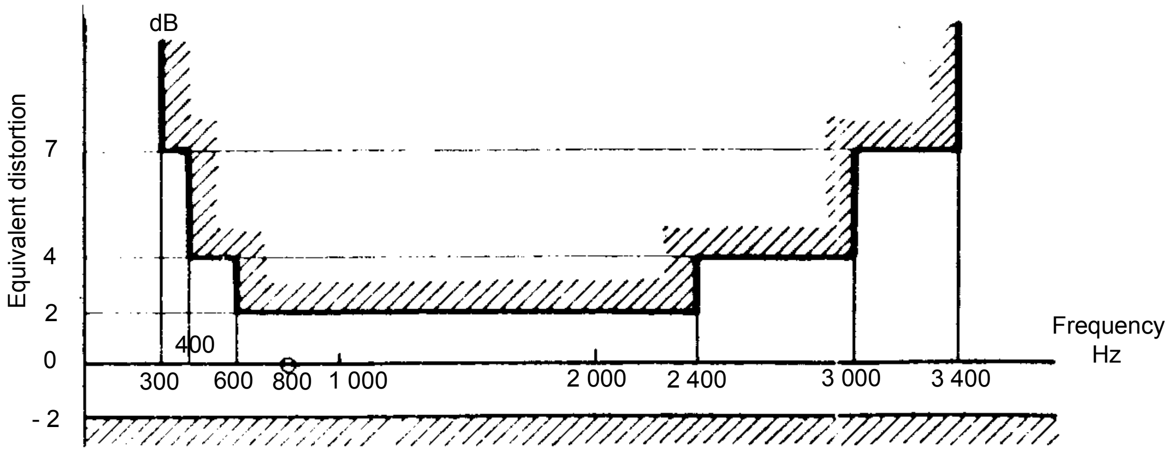

Fig. 5 - Template of equivalent distortion with frequency in an end-to-end international circuit

2.3.3 - Circuit noise

As recommended by the ITU-T, it is desirable for total noise not to exceed in any one hour the mean value of 10 000 pWop, over a 2 500 km circuit, which corresponds to a psophometric electromotive force of about 3 mV at the end of the circuit (relative level point: -4 dBr).

This power limit can be amply met with digital multiplex systems (see point 3.3 - page 16), for which the noise level is practically independent of the length of the line.

It should also be easy to meet with European circuits using analogue multiplex equipment (see point 3.2 - page 12), on cables, for which noise can even be reduced to:

[4 000 (terminals and exchanges) + 4 Lkm] pWop according to length.

However, this limit cannot be met with analogue multiplex systems on overhead lines except by limiting the length of the line.

Noise on this type of line can be evaluated at

(4 000 + 8 Lkm) pWop

2.3.4 - Envelope delay distortion

The delay distortion with frequency should be within the limits shown in the template in *UIC Leaflet 911-4* (see Bibliography - page 34).

2.3.5 - Downtime or power switching time

Every attempt should be made to provide a permanent service by reducing downtime for maintenance to a minimum and installing continuous power supply systems.

2.4 - National circuits

O ### 2.4.1 - Nominal equivalent

2.4.1.1 - The nominal equivalent of the national circuit chain must be the same for both transmission directions. This implies the use of symmetrical terminating sets.

2.4.1.2 - The maximum nominal attenuation available for circuits and switches in the national chain follows directly from the technical regulations defined in point 2.1 - page 4.

2.4.2 - Useful frequency bands

For all new circuits to be established, it is recommended that the 300 - 3 400 Hz bandwidth be the useful frequency bandwidth, as is the case with international circuits.

2.4.3 - Circuit noise

2.4.3.1 - The quality of communication is related particularly to the signal/noise ratio, which depends on transmission power and any attenuation on the lines, also on the quality of the telephone at the receiving end.

2.4.3.2 - The signal/noise ratios which must be observed at the receiving end are as follows:

O **2.4.3.2.1 -** For 100% of the time S/N ≥ 5 dB

2.4.3.2.2 - For 95% of the time (over any 1/4 hour)

- mandatory: S/N ≥ 10 dB
- recommended: S/N ≥ 20 dB

2.4.3.3 - In simple terms, it follows from this, bearing in mind normal attenuation and quality of reception, that psophometric electromotive forces (whatever their origin) measured at the subscriber's telephone set, must comply with the following rules:

O **2.4.3.3.1 -** For 100% of the time e ≤ 5 mV

2.4.3.3.2 - For 95% of the time (over any 1/4 hour)

- mandatory: e ≤ 3 mV
- recommended: e ≤ 1 mV (value set by the ITU-T).

2.4.4 - Envelope delay distortion

The delay distortion with frequency should lie within the limits shown in the template in *UIC Leaflet 911-4*.

3 - Technical regulations concerning equipment

3.1 - Homogeneity

3.1.1 - Number of sections in a circuit

As an international circuit is normally very long, it will not always be possible to build it in a homogeneous manner over the whole distance. However every attempt should be made to ensure that it is as homogeneous as possible, and using multiplex systems is one way of achieving this.

If the use of different types of section in a circuit proves unavoidable, the maximum number of sections of a different type on any international circuit should be limited to 3.

Two audio-frequency or multiplex circuits with directly interconnected sending and receiving channels should of course be regarded as one section, provided the regulations in points 2.1.3, 2.1.4, 2.2.1 to 2.2.6, 2.2.8 and 2.3.1 to 2.3.4 are observed.

O 3.1.2 - Junctions between the different sections of a circuit

Since international links are built 4-wire, the junctions between the different sections must also be 4-wire.

3.2 - Analogue multiplex systems

NB : These systems are also called "Carrier current systems" or "Shared-frequency multiplex - SFM".

Analogue multiplex systems have become obsolete. They have been replaced by the digital systems described in point 3.3 - page 16.

The regulations given below apply to analogue multiplex systems used in international connections, whichever chain they belong to.

3.2.1 - General regulations

3.2.1.1 - Stability of virtual carrier frequencies

O **3.2.1.1.1 -** The stability of virtual carrier frequencies must be such that, between an audio-frequency applied at the origin of a circuit and the corresponding frequency at the other end, the maximum deviation is ±2 Hz, whatever the nature of the circuit, i.e. whether there be intermediate modulations and demodulations or not.

NB : This condition also allows data transmission (see UIC Leaflet 911-4).

3.2.1.1.2 - For this to occur, the stability of the carrier current generators must be in the order of 10^{-6}. The same should be true of the pilot current generators, so that the link can be correctly monitored.

O 3.2.1.2 - Linear cross-talk

3.2.1.2.1 - The near-end cross-talk ratio between the two transmission directions, at frequencies used for all pilot or other carrier system measurement waves, must be at least equal to 40 dB.

3.2.1.2.2 - For the terminal equipment alone, the cross-talk ratio (corresponding to the intelligible cross-talk only) measured between two carrier channels of a basic group must not be less than 65 dB.

3.2.1.3 - Circuit noise (including non-linear cross-talk)

Calculations relating to circuit noise for carrier system building projects are based on the concept of "psophometric power", which is normally measured in relation to a weighted network as defined in ITU-T *Recommendations G.223 and G.227* (see Bibliography - page 34).

It is recommended that the average psophometric power for noise on any given channel should not exceed:

(4 000 + 4 Lkm) pWop for cable multiplex circuits,

(4 000 + 8 Lkm) pWop for overhead line multiplex circuits,

with a maximum of 10 000 pWop. These values were fixed on the assumption that the nominal mean signal power during the busy hours was -15 dBmo.

3.2.1.4 - Pilot frequencies

O **3.2.1.4.1 -** Each system to be installed in the future shall have an automatic gain-regulation device, controlled by at least one line regulation pilot per transmission direction for lines borne by cables and two pilots of different frequencies for each transmission direction in the case of overhead lines.

3.2.1.4.2 - The railways concerned shall agree on the frequency spectrum transmitted to the line and the choice of pilot frequencies to be used.

3.2.1.4.3 - If agreement cannot be reached, the two Railways shall adopt one of the following procedures:

- consider the frontier amplification exchange where two different systems are interconnected as the end of a line regulation section, that is to say, stop each country's pilot at the frontier and generate the pilots adopted by the other country and which must be reintroduced into the line beyond the frontier;

- choose the pilots in the two systems which have exactly the same relative positions with regard to the exchange for the group of telephone channels transmitted on the line and the same relative levels. The pilots can then be transferred by the same process as the primary groups.

3.2.1.4.4 - It is also desirable that, when self-regulating amplifiers are used, an alarm signal should be given when the amplitude of the input pilot deviates more than ±4 dB from its nominal value.

3.2.1.4.5 - In addition, it is desirable that an alarm signal be set off at the origin of the system if the amplitude of the pilot varies by more than ±0,5 dB.

3.2.1.5 - Frequencies transmitted on the line

For equipment to be installed in the future, it is recommended that virtual carrier frequencies be spaced at 4 kHz intervals in the basic group.

3.2.1.6 - Signalling

O **3.2.1.6.1 -** For international circuits, bilateral agreements shall be reached regarding one of the following four systems:

- zero-frequency out-of-band signalling,
- high-frequency out-of-band signalling,
- 2 280 Hz single speech frequency signalling,
- double speech frequency signalling.

3.2.1.6.2 - If the latter two systems are used, they must comply with ITU-T (*Recommendation G.224*, see Bibliography - page 34).

3.2.2 - Analogue terminal equipment

3.2.2.1 - Uniformity of characteristics

3.2.2.1.1 - To obtain total compatibility between terminal equipment, the two sets should preferably be ordered from the same firm.

O **3.2.2.1.2 -** If, for various reasons, the two Railways cannot order from the same firm, they should agree on a choice of system and draw up joint specifications for invitations to tender, giving all the technical details so that the terminal installations operate in perfect harmony.

3.2.2.1.3 - An attempt should also be made to obtain a joint guarantee from the two tenderers on the correct functioning of the link.

3.2.2.2 - Carrier leak transmitted on the line

The absolute power level of carrier leak transmitted on the line shall in no case exceed the values given below:

- for one transmission direction and on one channel: -26 dBmo;
- for all the channels in the system and for each transmission direction separately: -20 dBmo.

In the case of overhead line transmission where it is desirable to take precautions against the risk of conversations exchanged on the line being captured by an ordinary radio-receiver set, carrier leak must be reduced even further.

3.2.2.3 - Variation with frequency of the equivalent of a sending and receiving equipment pair (AF - AF)

When looping the sending and receiving equipment of one terminal, the equivalent variation with frequency should not exceed the limits given in the graph in Figure 6 - page 15.

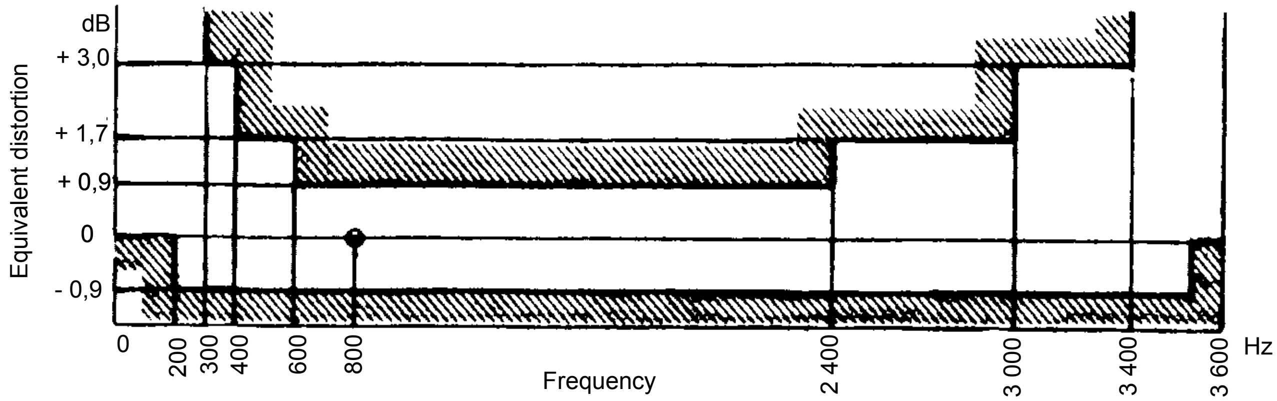

Fig. 6 - Template of equivalent distortion with frequency in channel transmitting and receiving equipment on a single 12-channel terminal looped on itself

3.2.2.4 - Variation with frequency of the terminal sending equipment output level (AF - HF)

In order to avoid arguments between railways in charge of terminal equipment at either end of a carrier circuit, it might be advisable to have a graph indicating the permitted limits for variation (with frequency) of the relative power output level of the terminal equipment.

The graph shown in Figure 7 below shall be used for this purpose. It applies to each terminal equipment output channel of a multiplex system.

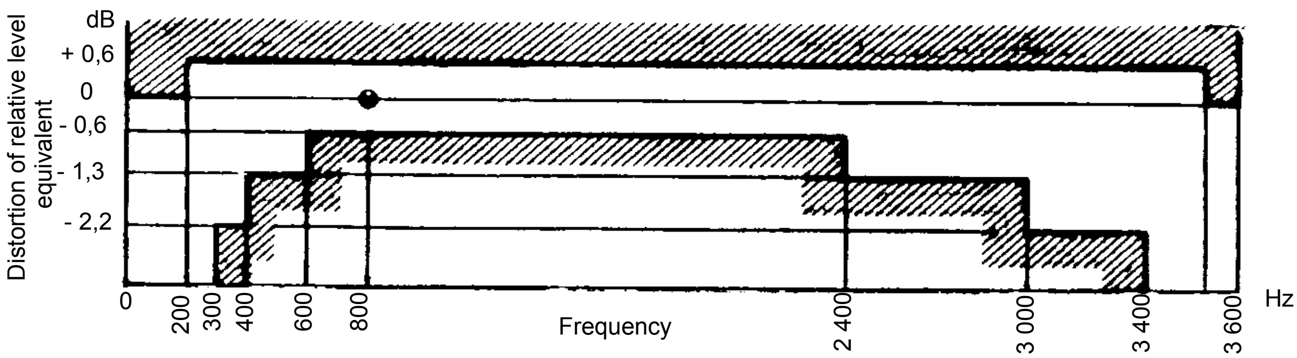

Fig. 7 - Template of distortion of relative power level, with frequency, measured at any terminal equipment channel output in a 12-channel terminal

3.2.2.5 - Cross-talk

The cross-talk ratio between two different channels of a multiplex system, measured in a terminal station, should not be less than 65 dB.

3.2.2.6 - Return-current coefficient

Since circuits should have a nominal impedance of 600 Ω (see point 2.2.7 - page 8), it is recommended that multiplex equipment presents the same impedance on the telephone exchange side with the same tolerance.

Also, on the line side, it is advisable to limit the return-current coefficient at the ends of an amplification section so that the reflected near-end cross-talk does not contribute excessively to the total far-end cross-talk.

Tolerances are given in ITU-T *Recommendation G.322, Point 1.5* (see Bibliography - page 34).

3.2.3 - Intermediate analogue repeaters

3.2.3.1 - Harmonic distortion

O **3.2.3.1.1 -** The harmonic distortion of a repeater shall not exceed the limit values given below:

- when a power input level of 1 mWo is applied to the entry of a telephone channel, 2nd order harmonic distortion attenuation shall be equal to or greater than 70 dB; 3rd order harmonic distortion attenuation shall be at least equal to 80 dB.

3.2.3.1.2 - For cable circuits, it is recommended that these values be increased to 79 dB and 92 dB respectively.

3.2.3.2 - Cross-talk ratio

The cross-talk ratio between two repeaters in the same station shall not be less than 80 dB.

This value applies to the equipment as a whole, including the input and output transformer.

3.2.3.3 - Impedance

The same impedance values should be adopted as for the terminal stations with the same tolerances.

3.3 - Digital multiplex systems

3.3.1 - General

Digital multiplex systems, sometimes called "impulse and coding modulation systems" (ICM) or "time division multiplex" (TDM) have been standardised by the ITU-T in the form of:

- a "primary" system, with 30 useful channels (*Recommendations G.703/G.704*, see Bibliography - page 34), which could possibly be divided into subgroups for separate applications;

- higher order plesiochronous multiplex systems (PDH) with 8 Mbit/s (120 channels), 34 Mbit/s (480 channels) and 140 Mbit/s (1 960 channels);

- higher order synchronous multiplex systems (SDH) with 155 Mbit/s (STM1), 622 Mbit/s (STM4) and 2,5 Gbit/s (STM16) (*Recommendations G.707, G.708, G.709*, see Bibliography - page 34).

3.3.2 - General technical regulations

Primary multiplexing equipment shall contain 30 useful channels and operate at 2 048 kbit/s. It must comply with ITU-T *Recommendation G.732, Vol. 111.2* (see Bibliography - page 34).

3.3.3 - Extreme end terminal equipment

Quality characteristics of channels at audio frequencies shall comply with ITU-T *Recommendation G.712* (see Bibliography - page 34).

3.3.3.1 - Quantification noise

This shall be measured preferably according to ITU-T method 1 and should be above the template shown in Figure 8 below.

NB : ITU-T method 1 consists in the transmission of a noise band instead of a single frequency (method 2).

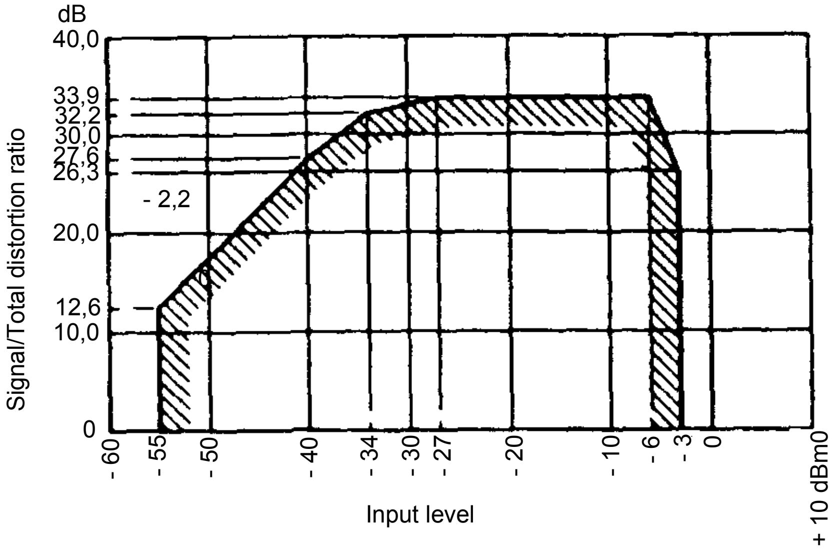

Fig. 8 - Template of signal/total distortion ratio with input level (method 1) for an ICM channel

The measuring apparatus should comply with ITU-T *Recommendation O.131* (see Bibliography - page 34).

3.3.3.2 - Noise on an idle channel

No frequency (e.g. frequency of sampling), measured selectively, should exceed -50 dBmo and the psophometric noise should be less than -65 dBmop.

3.3.3.3 - Attenuation distortion

The attenuation variation for each channel with frequency, in relation to 800 Hz, should remain within the limits of the template in Figure 9 - page 18.

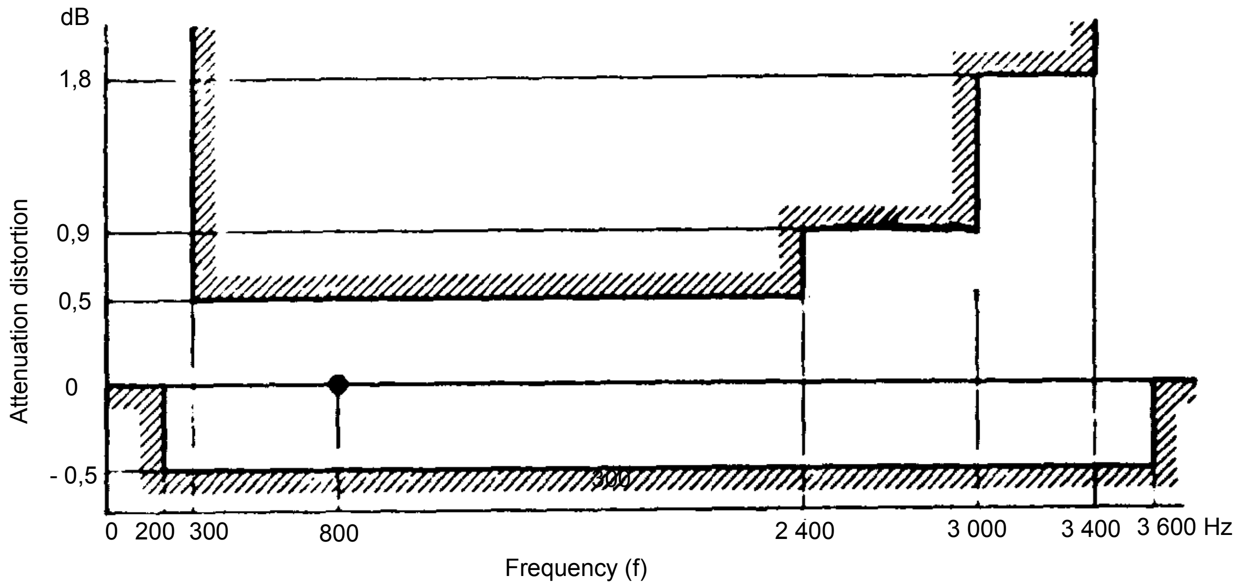

Fig. 9 - Template of attenuation distortion with frequency for an ICM channel

3.3.3.4 - Interchannel cross-talk

Cross-talk between the channels in a set of multiplexing equipment, measured with a sinusoidal signal in the 700-1 100 Hz frequency range (but not a sub-multiple of the sampling frequency), should be better than 65 dB.

3.3.3.5 - Go-to-return cross-talk

This cross-talk should be better than 60 dB for all frequencies in the passing band transmitted at 0 dBmo.

3.3.4 - Line terminating equipment

This equipment ensures that digital transmission links are possible using copper lines, optical fibres or directional radio links. The following distinctions are made:

- LTN (line terminating equipment) for a copper quad providing remote power feeding and remote monitoring of regenerative repeaters (RR) installed every 1 830 m;

- OLTN (optical line terminating equipment) using fibre optics (one fibre per direction of transmission);

- xDSL-type equipment (ETSI Standards, TS 101.135), which, by converting digital signal codes (CAP, 2B1Q), enables the spans between regeneration points (around 7 km) to be increased with copper cables. This equipment should allow remote power feeding of at least one RR (regenerative repeater) and the far terminal, or two RRs with the far terminal supplied locally.

3.4 - 4-wire AF repeaters

3.4.1 - Gain

The repeater should produce a gain of at least 24 dB, measured at the frequency of 800 Hz.

The gain produced by a repeater (alone or in association with an attenuation distortion corrector) must vary with the frequency, in order to compensate sufficiently for the distortion introduced by the line into the useful frequency bandwidth (300 to 3 400 Hz).

The gain must be independently adjustable for each transmission direction, in steps of no more than 1 dB. The curves representing the gain according to frequency must be parallel for all adjustments of repeater gain in the frequency bands transmitted.

3.4.2 - Impedance and return-current coefficient

Since circuits should have a nominal impedance of 600 Ω (see point 2.2.7 - page 8), it is recommended that the repeaters present the same impedance on the telephone exchange side, with the same tolerance.

On the line side, the impedance of the repeater (excluding the line transformers) shall be approximately equal to that of the circuit on which the repeater is assumed to operate (seen through the line transformers) so that at any of the useful frequencies the return-current coefficient module is at least 0,4 for repeater input impedance and 0,6 for output impedance.

3.4.3 - Harmonic distortion coefficient

The total harmonic distortion coefficient shall not exceed 5% for a frequency of 800 Hz for a maximum power of 20 mW, the repeater output being connected to a 600 Ω resistor.

3.4.4 - Permitted variation (with frequency) for the relative power output level at a frontier repeater station

This variation for a 4-wire circuit transmitting frequencies in the 300-3 400 Hz band, must be within the template given in Figure 10 - page 20.

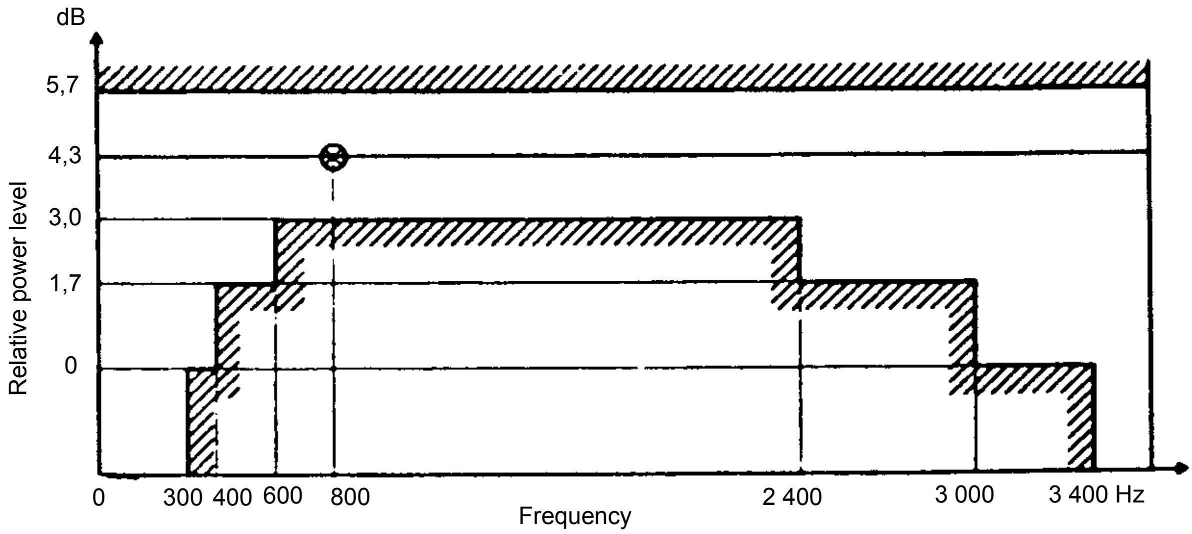

Fig. 10 - Template of relative power output level against frequency at a frontier repeater station, frontier side, for an international audio frequency circuit

3.4.5 - Cross-talk

Cross-talk attenuation measured between the exit terminals of any two repeaters shall be at least 74 dB including the cabling of the amplification exchange.

4 - Technical regulations concerning lines

4.1 - General

The establishment of international links does not require the standardisation of lines, as very different types of lines can meet the performance levels laid down and described in points 1 - page 2 and 2 - page 4 above. The aim of this paragraph is not therefore to make any one kind of line mandatory, but simply to indicate which types could be used.

4.2 - Overhead lines (metallic conductors)

NB : The reliability and quality obtained with this sort of line are inferior to those obtained with cables. It is therefore not advisable to build international circuits on overhead lines.

If, however, there is no alternative, the following rules shall be observed:

4.2.1 - Mechanical properties

O **4.2.1.1 -** For international telephone lines, only conductors with a diameter of 2,5 mm or more shall be used.

4.2.1.2 - The diameter must be increased to 3 mm for lines exposed to strong winds or crossing mountain areas where frost and snow may cause substantial damage.

4.2.1.3 - Conductors must be made of copper alloys of a type that will ensure the highest possible mechanical strength, while at the same time meeting the conditions laid down for attenuation.

4.2.1.4 - The stability of the line of pylons must as far as possible be greater than the strongest storm, wind, frost and snow forces.

4.2.2 - Joints

O **4.2.2.1 -** All joints on overhead lines must be made in such a way that they do not introduce any variable resistance.

4.2.2.2 - In any amplification section of an overhead line or in a section between a repeater and the nearest terminal station, the difference in resistance of the two conductors of any pair, measured in direct current, shall not exceed 2 Ω.

O 4.2.3 - Impedance regularity

4.2.3.1 - In any one amplification section or in a section between an exchange and the next terminal exchange, the metal, the diameter of the conductors and the distance between the conductors in an international telephone circuit must always remain the same to ensure satisfactory homogeneity.

4.2.3.2 - The sections of overhead lines must be built with sufficient regularity and maintained with sufficient care (frequent measurements, preventive maintenance, etc.), to ensure that the regularity attenuation has at least the same value as the equivalent of the circuit.

4.2.4 - Attenuation-frequency characteristics

If one wishes to operate several multiplex systems working in the same frequency range in the same air space, the "attenuation frequency" characteristic must resemble a regular curve as closely as possible. On a new line built for analogue multiplex 12-channel working and one phantom circuit, deviations from the regular curve can be kept within ±2 dB in any amplification section in the entire useful frequency band.

4.2.5 - Cross-talk and the effects of heavy current lines (catenaries in particular)

4.2.5.1 - To limit disturbance, international telephone circuits must be equipped with rotary devices or crossings. For multiplex systems, it is advisable to adopt groups with a rotary step of not more than 250 metres.

O **4.2.5.2 -** As far as dangers associated with heavy current lines are concerned, telephone circuits must satisfy the conditions laid down in "Directives concerning the protection of telecommunications lines against the harmful effects of electric lines", published by the ITU-T.

4.2.5.3 - As for problems of operation, an international circuit built on overhead lines must comply with point 2.3.3 - page 10 of this leaflet.

4.2.6 - Circuit insulation

O **4.2.6.1 -** The insulation of each wire in relation to the earth should not fall below the value 1 MΩ x km.

4.2.6.2 - For overhead lines crossing industrial areas, where the value would be difficult to maintain in rainy weather, it is advisable to use insulated wire.

4.2.6.3 - Lines shall be equipped at least at their ends with protective devices (lightning arresters) against external overvoltage.

4.2.7 - Intermediate cable sections

On overhead lines operated with multiplex circuits, underground sections must be avoided as far as possible.

Where these are unavoidable (e.g. certain tunnels, watercourse crossings with mobile bridges, etc.), it is advisable to harmonise the overhead line and cable by using transformer circuits which harmonise impedance in the range of frequencies used in carrier current and let the direct current through. This allows any reflection which may occur to be reduced and leaves the possibility of measuring insulation resistance over the whole circuit.

4.2.8 - Lead-in cables

O **4.2.8.1 -** The length of the lead-in cables at the ends of the circuit shall be kept to the strict minimum.

4.2.8.2 - If long lead-in cables cannot be avoided, then the system of transformer circuits described in the previous article shall be adopted.

4.2.9 - Disconnection points

O **4.2.9.1 -** Circuits carried by overhead lines must be equipped with disconnection points so that faults can be accurately located.

4.2.9.2 - Since disconnection points can themselves give rise to faults, they should be kept to the minimum acceptable from the point of view of local requirements. However they should not be more than 200 km apart.

4.2.9.3 - It is also advisable to establish a disconnection point in each of the two frontier stations.

4.2.9.4 - Long-length cables should be avoided in areas where open wire circuits cross a disconnection point.

4.3 - Cable circuits

4.3.1 - Protection of cables

4.3.1.1 - Protection against humidity

This is provided by the metal sheath of the cable (usually lead or aluminium) which is absolutely water-tight. All the connection parts (sleeves, splice boxes, Pupin boxes, etc.) are also water-tight, since the sheath is usually welded at these points.

NB : If an aluminium sheath is used, it should itself be protected from corrosion by a polyethylene sheath for example.

4.3.1.2 - Mechanical protection

When this is considered necessary, one or more steel strips should be wound round the sheath to protect the cable. In order to prevent rapid deterioration of the strips through oxidation, an external covering (bitumen, polypropylene tarred cord, plastic oversheath, etc.) should be used.

In addition, external protective devices, e.g. conduits or special markings can be used, taking special account of likely risks from track work.

4.3.1.3 - Electrical protection against the effects of alternating-current electrification systems

O **4.3.1.3.1 -** As far as dangers arising from high-voltage lines are concerned, telephone circuits must satisfy the conditions laid down in the "Directives concerning the protection of telecommunications lines against the harmful effects of electric lines", published by the ITU-T.

4.3.1.3.2 - For operational problems, points 1.1.3 - page 2 and 2.4.3 - page 11 should be consulted.

4.3.1.3.3 - Protection is afforded both by the metal sheath and the steel strips.

4.3.1.3.4 - The metal sheath, especially when made of aluminium, which has a lower specific resistance than lead, allows a substantial flow of equalizing current. To ensure this flow, the cable sheath must be earthed with a measured impedance of less than one ohm at all levels. Two methods can be used to obtain this result depending on the type of cable covering:

- if the strips are covered with an insulating sheath, they can be earthed very easily in the area of connection boxes, using a low resistance earthing system;

- by putting the strips in direct contact with the soil with the help of semi-conductor surfacing products (classical compound) and ensuring the continuity of the strips, the sheath and the mass of the connection boxes. Extra earthing systems may be required in rocky ground.

4.3.1.3.5 - The sheath-ground and conductor-ground circuits are coupled together magnetically by the strips, thus providing substantial equalization.

4.3.1.3.6 - The reducing factor obtained with the cables at electric traction current frequency should never be greater than 0,5 for an inductive field of 100 V/km.

NB : The reducing factor is the ratio between the e.m.f. induced on the wire concerned and the e.m.f. that would be induced on an unprotected wire in the same geometrical position.

NB : A cable with an aluminium sheath of average capacity allows a reducing factor of about 0,1 at 50 Hz and about 0,2 at 16 2/3 Hz.

An even better reducing factor is thus obtained at audio frequencies allowing better resistance to noise produced by electric traction.

4.3.1.4 - Electrical protection against the effects of direct-current electrification systems

The cable sheath and strips may well deteriorate as a result of electrolytic corrosion at points where the cable would be electropositive in relation to the surrounding soil.

This effect can be avoided:

- either, if the cable is not insulated from the soil, by installing protective devices (cathodic protection, electrical discharging, etc.), at critical points (e.g. near traction sub-stations),

- or, preferably, by preventing traction current from travelling along the sheath and the strips. This can be achieved by using an oversheath or by winding plastic material round the cable to insulate it from the soil.

If required, insulating joints may even be used every 10 km or so to break the continuity of the sheath and strips.

The reducing factor of the cable itself should not be neglected. It should then be considered at audio frequencies. This can be an efficient way of abating electric traction noise.

4.3.2 - Circuits for multiplex systems

R **4.3.2.1 - Composition of cables to be laid**

For cables to be laid towards frontiers or across frontiers and likely to be used in the future for inter-railway circuits, it is advisable to have one or more multiplex installations to be agreed among the Railways concerned.

4.3.2.2 - Types of lines

4.3.2.2.1 - Given the wide range of lines that can be used, it is impossible to make any recommendations. At the most it can be stated that they fall into three broad categories:

- symmetrical pairs,
- coaxial pairs,
- optical fibres.

4.3.2.2.2 - However, since the characteristics of optical fibres are better than the characteristics of coaxial pairs (noise immunity, spacing between two regenerations, better transmission capacity), it is recommended that fibre optics should be used in all new cables for digital multiplex systems.

4.3.2.2.3 - Symmetrical pairs have wire diameters varying between 0,8 and 1,4 mm and a line capacity varying between 25 and 40 nF/km. Those used by the railways can carry:

- analogue systems, with a capacity of between 10 and 120 channels and an amplification interval of between 3,6 and 30 km (according to the number of channels and the characteristics of the pair),
- digital systems, with a capacity of 30-120 channels and a regeneration interval varying from 1,8 to 4 km, according to the type of pair and capacity.

4.3.2.2.4 - Coaxial pairs are also of varying types from 0,7/2,9 mm pairs to 2,6/9,5 mm pairs. Those used by the railways can carry:

- analogue systems with a capacity of 120-960 channels and an amplification interval of between 4 and 12 km, according to the type of pair and number of channels;
- digital systems, with a capacity of between 120 and 1 920 channels and regeneration intervals varying from 3 to 12 km according to the type of pair and the capacity.

4.3.2.2.5 - Optical fibres support digital systems (voice/data/image applications).

4.3.2.2.6 - There are two types of optical fibres:

1. multi-mode optical fibres: these have a diameter of 50/125 micrometers and are reserved for short-distance links (5 km maximum) for local applications. They are used for 850 and 1 310 nanometer wavelengths;

2. single-mode optical fibres with a diameter of 9/125 micrometers (core and cladding diameter respectively).

   This type of fibre with 1 310 and 1 550 nanometer wavelengths is used for distances between 5 and 150 km, depending on the connections used. 1 310 nanometer wavelengths are reserved for distances below 50 km.

NB : ITU-T *Recommendations G.652* and *G.655* describe several types of existing single-mode fibre. The use of Type G.655 is not warranted by the distances and throughputs required.

4.3.2.3 - Selection criteria for multiplex systems and carrier systems

4.3.2.3.1 - The choice of multiplex system and corresponding line should be examined on the basis of the total number of channels to be installed, the required reliability (which will affect the minimum amplification or regeneration interval permissible, the organisation of correction maintenance and the unit capacity of the systems) as well as the total cost of the line and multiplex equipment (terminals and line).

NB : for example, it might prove more practical to have in one cable three 120-channel systems and to divide the circuits of each application between them, rather than one single 360-channel system, which may bring about a total interruption of the connections if a repeater breaks down.

4.3.2.3.2 - Railways would be well advised to follow ITU-T standards for both the line and the multiplex system.

O **4.3.2.3.3 -** If the proposed link crosses a frontier, the study should be carried out by the railways concerned and result not only in the choice of an ITU-T standardised system but also in a common line, at least for the amplification or regeneration section crossing the frontier.

R **4.3.2.3.4 -** It is advisable for the railway with the amplification exchange nearest the frontier to adopt the same type of line and, if possible, the same type of cable as the neighbouring railway.

4.3.3 - Audio-frequency circuits (AF)

Preliminary note: the use of such circuits on international routes is not recommended (see point 2.1.3 - page 5).

However, if there is no alternative but to use them, the regulations for international circuits given in points 2.3.1, 2.3.2, 2.3.3 and 2.3.5 should be observed and the following provisions complied with.

4.3.3.1 - Uniformity of the main characteristics

O **4.3.3.1.1 -** The two neighbouring railways shall agree on the definition of cables to be laid so that the characteristics of the amplification section crossing the frontier are as homogeneous as possible.

R **4.3.3.1.2 -** To achieve this, the two railways should either order the whole amplification section from the same supplier, or the railway with the amplification exchange nearest the frontier should adopt the same type of AF line and if possible the same type of cable as the neighbouring railway, including the load characteristics, so that there is de facto coordination between the two companies working on either side of the border.

4.3.3.2 - Characteristics of lines for AF circuits

Type of cable. The Railways concerned shall agree on:

- the capacity of the cable (number of pairs or quads),
- the type of stranding (pair, starquad, or quad with combinable pairs),
- the type of insulation (paper, polyethylene),
- the diameter and type of conductors,

NB : The use of copper conductors less than 0,8 mm in diameter is discouraged.

- the effective, real and phantom capacity,

- the pupinisation interval and cable marking, observing this interval on the amplification section,

NB : There are no plans to build international circuits on non-loaded pairs.

- the type and characteristics of the loading coils.

These parameters and the permitted tolerances for each shall be determined so that, for each audio-frequency amplification section, the following characteristics are complied with:

- Impedance balancing

  On each audio-frequency amplification section, the circuit regularity attenuation shall be at least 27 dB.

- Attenuation

  Attenuation of an amplification section measured at a frequency of 800 Hz should not be allowed to exceed 21 dB.

- Cross-talk

  On an amplification section, the far or near-end cross-talk ratio, measured between two circuits (with the same or two different quads), must be at least 65 dB.

- Noise

  In order to comply with point 2.3.3 - page 10, the psophometric noise power measured at the end of a circuit on an amplification section should not exceed -60 dBmp.

To reach this result, one should take into consideration:

- the reducing factor of the cable at audiofrequencies along electrified railway lines (both direct and alternating current);

- the imbalances in real capacity to the earth in the cable which must be reduced as much as possible over the whole amplification section during connections. In this respect the following maximum values are recommended after balancing (values in picofarads for a load section):

	99% of values	**80% of values**
real imbalance of sheath	350	200
phantom imbalance of sheath	450	300

- possibly the imbalances caused by terminal installations. ITU-T *Recommendation K.10* gives limit values for dissymmetry.

4.4 - Micro-wave links

4.4.1 - General

For micro-wave link transmission, the noise criterion is particularly important, because the radio-field may be very greatly affected by meteorological conditions, the combination of multiple paths and problems concerning the long-term stability of the transmission-receiving equipment.

Also, the establishment of a link of this kind may in certain countries present a problem in respect of the allocation of radio frequencies. Given the wide range of frequency bands that can be used and the different national regulations, it is not possible to recommend any particular type of equipment.

On the other hand micro-wave links have the advantage of being easy to implement compared with cables for point-to-point links, and are unaffected by civil engineering work.

4.4.2 - Use

According to CCIR *Recommendation 393/1* (International Radio Consultative Committee - a predecessor organization of the ITU-T), non-weighted noise levels of 10^6 pW with an integration time of 5 ms can occur on multiplex micro-wave links at a zero relative level point at certain periods.

These periods should not represent more than 0,01% of the time in any given month, or more than 0,1% of the time during any given hour.

This means that the link can be expected to become inoperable for periods of time up to 3,6 s. This disadvantage exists for links with an aerial and single radio frequency and can be avoided by using a wide range of space and/or frequencies.

International micro-wave links should therefore be installed only in a "diversity" arrangement, after problems of radio and electricity regulations have been resolved.

5 - Maintenance of inter-Railway circuits

o 5.1 - Diagram

For each link, the Railways concerned shall by joint agreement produce a diagram containing all the technical information required for maintenance, i.e. the nature of each section, the levels at each end point and at each section termination point, as well as the nominal impedance at these points and normal noise voltage values.

o 5.2 - Main exchange

For each link, one of the terminal exchanges of the link shall be designated as the main exchange and given the task of organising preventive and corrective maintenance in collaboration with other exchanges belonging to each of the Railways concerned.

o 5.3 - Periodic tests and measurements

5.3.1 - General

Transmission measurements must be carried out periodically.

5.3.2 - Definition of operations; periodicity

The terminal and intermediate exchanges shall be equipped with the appropriate measuring equipment for this purpose. The operations to be carried out are the following:

5.3.2.1 - Daily

- a signalling test and a conversation test,
- for overhead lines, measurement of insulation and resistance of loops.

5.3.2.2 - Monthly

- measurement of the equivalent at 800 Hz at terminal points. However, this measurement may be carried out every two months only, by agreement between the Railways
- for overhead lines, a check on equality of resistance in the two wires of each pair.

5.3.2.3 - Half-yearly

- measurement of the frequency and level of the signalling current at terminal exchanges,
- measurement of impulse distortion

5.3.2.4 - Annually (in Spring or Autumn)

- measurement of the equivalent at different frequencies (300 - 400 - 600 - 800 - 1 400 - 2 000 - 2 400 - 3 000 - 3 400 Hz) over the whole of the link and on each of the constituent sections,
- measurement of cross-talk,
- measurement of background noise (psophometric electromotive force).

Also, in the case of multiplex equipment:

- For analogue systems:

  - measurement of the high-frequency output level in exchanges,
  - measurement of carrier frequencies at terminal exchanges,
  - measurement of frequency deviation,
  - measurement of the pilot level at all exchanges.

- For digital systems :

  - measurement of quantification noise,
  - measurement of the frequency margin of regenerators and of the link as a whole.

For cable circuits, it is advisable to set up a permanent insulation monitoring device.

5.3.3 - Implementation of operations

All operations shall be carried out in compliance with the relevant ITU-T Recommendations.

If, on a fraction of an international circuit, maintenance is carried out by a telecommunications operator or the Post Office, a special agreement shall be drawn up between the Railways concerned.

Appendix A - Definitions of concepts and units

Reference equivalent

This is a comparison by telephonometric measurement between the telephone system under study and a standard system.

The system used as a standard is NOSFER (see List of abbreviations - page 33) which is housed in the ITU-T's laboratories or another system standardised in relation to NOSFER.

The comparison is made using standardised lines of variable attenuation, whereby the measurements recorded can be converted into decibels.

Either the whole system or one of the three main parts (transmitter, line, receiver) can be compared.

Absolute power level

This is the logarithmic ratio of a power P_1 to the reference power 1 mW. It is expressed in dBm.

Power level (dBm) = $10 \log_{10} P_1$

(with P_1 in mW)

Relative power level

This is, at a point X in a circuit, the logarithmic relationship of the power P_X at this point to the corresponding power P_0 at a point 0 chosen as reference. It is expressed in dBr.

(The origin of the circuit or the complete chain is often chosen as reference point 0).

$$\text{Relative power level} = 10 \log_{10} \frac{P_X}{P_0}$$

The relative level expresses the difference between the absolute power levels measured at point X and point 0.

Absolute power level in relation to relative level zero

This is the absolute power level of a signal, which, after being measured at a point in the circuit where the relative level is known, is corrected so as to be related to relative level zero. It is expressed in dBmo.

For example, a pilot wave measuring -58 dBm at a relative power level of -33 dBr is said to measure - 25 dBmo.

Absolute psophometric power level in relation to relative level zero

This is the same notion as above, but the absolute power level is measured through a psophometric telephone filter defined by the ITU-T. It is expressed in dBmop.

Hatching coefficient

This is a ratio. It expresses the fraction of energy reflected (in relation to the total energy that could be transmitted) at a point in a circuit as a result of the lack of matching impedance at this point.

If Z_1 and Z_2 are the real impedances in the circuits before and after the point considered, the matching coefficient equals:

$$C\ adp = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

List of abbreviations

NOSFER	Basic new system of determining reference equivalents
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector

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