5i’

INDEX OF TRANSMISSION PERFORMANCE RECOMMENDATIONS

(See Note)

7 *Non-linear distortion*

7.1 Non-linear distortion G.151

7.2 Amplitude limitation (peak limiting) G.232

7.3 Quantization distortion G.113, 712, 713, 714, 733, 792

8 *Transient impairments*

8.1 Impulse noise G.113

8.2 Phase hits G.113

8.3 Gain hits G.113

8.4 Drop-outs G.113

9 *Special circuits*

9.1 Private networks G.171

9.2 Conference connections G.172

Note — This index provides a partial list of Recommendations pertaining to transmission performance. It is not a complete index of all performance Recommendations, and reference should be made to the Series P Recommendations for information regarding transmission quality.

H.T. [1T1]

TABLES SUMMARIZING THE RECOMMENDATIONS CONCERNING |
LINE TRANSMISSION

TABLE 1

Summary of main characteristics specified by the CCITT for international telephone circuits

| ua)

and international connections

(This very condensed table is not a Recommendation,
and reference should be made to the complete Recommendations)

For an international circuit (1)		
For a complete connection or for its parts (2)		
Loudness ratings For the connection and for the national systems G.111, § 1; G.121	G.111, § 2	
Nominal 4-wire (transmission plan, see G.101) 0.0 dB G.101 — Digital 0.5 dB G.101 — Analogue Echo effects (G.131, § 2) Four-wire chain national circuits: G.101, § 2.2, G.121, G.122		
Transmission stability Balance return loss of national network (G.122)	G.131, § 1	
Attenuation/frequency distortion G.151, § 1; Figure 1/G.151 Objective for 12 circuits (Figure 1/G.132) For data: see H.12		
Group delay (*t*) For the connection (G.114) *t* | 50 ms, without reservation *t* | 00 ms, acceptable with conditions For data: see H.12	G.114	
Phase distortion (from the group delay *t*) *t* m — *t* m i		

n | 0 ms | ub) *t* M — *t* m i n | 5 ms | ub) (G.133) } For the 4-wire chain (G.133) *t* m — *t* m i n | 0 ms *t* M — *t* m i n | 0 ms For each national 4-wire chain: (G.133) *t* m — *t* m i n | 5 ms *t* M — *t* m i n | .5 ms }	{	

{
Variation of overall loss with time
}
Mean deviation from nominal
| (+- | .5 dB
Std. dev | dB or 1.5 dB
(G.151, § 3)
}
Extension circuits: as (1) (G.151)
For data: see H.12
}
	{
	
	{	

{
Linear crosstalk between different circuits (near- or far-end crosstalk ratio ?63)
}
?63 ≥" | 5 dB (G.151, § 4, Notes 1 and 3)
}
Extension circuits: as (1) (G.151)
}
	{
	
	{	

{
Near-end crosstalk ratio between the two directions of transmission
}
Ordinary circuits: ≥" | 3 dB
(G.151, § 4)
With speech concentrator: ≥" | 8 dB
With echo suppressor: ≥" | 5 dB
(G.151, § 4) (Note 4)
}
Extension circuits: as (1) (G.151)
}
	{
	
	{	

TABLE 1 *(concluded)*

For an international circuit (1) } For a complete connection or for its parts (2) }	{ {	
Circuit noise	See Table 1 | fIbis	

{
VF impedance of the channel translating equipment
}
Nominal value 600 ohms
(G.232, § 11.2)
}
		{

{
Frequency difference at two ends of a carrier circuit
}
	| Hz (G.135, G.225)	G.135, G.225

Power at zero relative level point {	Telephony, mean power in busy hour 18 channels 15 µW 7.5 µW 11.25 µW	Speech currents, etc. | 12 channels or less 35 µW
Maximum power for data transmission over circuits in the switched		

m = nominal minimum frequency effectively transmitted.

M = nominal maximum frequency effectively transmitted.

min = frequency corresponding to minimum group-delay time.

a) Unless otherwise indicated, circuits for voice-frequency telegraphy or phototelegraphy have the same characteristics.

[b] These values apply to the chain of international circuits.

[c] Calculation target value or conventional value for a hypothetical reference circuit.

[d] This Recommendation contains restrictions of use. See also Recommendation H.34.

Tableau [2T1], p.2

SUMMARY TABLES
TABLE 1 | fIbis
{
Summary of noise objectives specified by the CCITT and the CCIR
for telephone circuits
(This very condensed table is not a Recommendation,
and reference should be made to the complete Recommendations)
}

{ Types of systems General objectives Cable | ua) or radio-relay link Single-hop satellite link Submarine cable | ua) All systems }					
{ Telephone circuits considered | ub) } National 4-wire extension circuits and international circuits from 250 to 2500 km } Circuits | uc) from 2500 to about 25 | 00 km } Circuits from 7500 to about 15 | 00 km } Circuits from 2500 to about 25 | 00 km } Chain of six international circuits }	{ Circuits of 5000 km { { {	{			
Recommendations of the CCITT G.152 G.212 | ud) G.222 G.226 }	{ G.215	G.153		G.153	G.
Recommendations of the CCIR	391, 392 393, 395 396, 397			352 353	
{ Hypothetical reference circuit (HRC) or typical circuit considered } HRC of 2500 km | ue) or similar real circuit } Circuit of 5000 km | ue) } Circuit of 7500 km | ue) } Basic HRC of at least 7500 km } Chain of more than 25 | 00 km }	{ { { {	Chain of about 25 | 00 km	{		

<table>
<tr><td>Recommended objectives</td><td>{</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Unweighted power
% of the month during which 10^6 pW (5 ms) can be exceeded
}</td><td>{</td><td>0.1</td><td></td><td>0.3 | uf)</td><td>0.3 | uf)</td><td></td><td></td></tr>
</table>

Tableau [1T2] A L’ITALIENNE, p.3

{
TABLE 1 | fIbis (concluded)
}

{		Up to 2500 km	More than 2500 km			
G.123						
CCIR Recommendations	395	395	395	395	395	396; 392
{ Total length *L* in km of the longline FDM carrier systems in the national chain }						HRC of 2500 km |
{ (4000 + 4*L*) pW or (7000 + 2*L*) pW | uh) }						

Tableau [2T2] A L'ITALIENNE, p.4

H.T. [3T2]

a) For these systems, it is sufficient to check that the objectives for the hourly mean is attained.

b) Special objectives for telegraphy are indicated in Recommendations G.143, G.153 and G.442. Objectives for data transmission are shown in Recommendations G.143 and G.153.

c) For some very large countries, refer to Recommendation G.222, § 3.

d) See, in this Recommendation, the details of the hypothetical reference circuits to be considered.

e) The objectives for line noise, in the same column, are proportional to the length in the case of shorter lengths.

f) Provisionally.

g) Objective 3 pW/km for the worst circuits; if a real circuit has more than 40 | 00 pW, it should be be equipped with a compandor.

h) For planning purposes.

i) Except in extremely unfavourable climatic conditions.

General comment — All the values mentioned in this table refer to a point of zero relative level of a telephone circuit set up on the system under consideration (of the first circuit, for the chain). Furthermore (G.123), the psophometric e.m.f. of noise induced by power lines should not exceed 1 mV at the ‘‘line’’ terminals of the subscriber’s station. The mean value of the busy-hour noise power through a 4-wire national exchange:
| 00 pWp. Limits of unweighted noise through exchange: 100 | 00 pW.

H.T. [T3]

SUMMARY TABLES

TABLE 2

Summary of main characteristics specified by the CCITT for carrier terminal equipments

(This very condensed table is not a Recommendation, and reference should be made to the complete Recommendations)

	{	3-channel (G.361)	12-channel (G.232)
{ Level of carrier leak on the line: } { a) within the 60-108 kHz band } — per channel — per group | ua) { b) outside the 60-108 kHz band }	—26 dBm0 —20 dBm0 —50 dBm0	—17.**5** dBm0 —14.5 dBm0	—26 dBm0 —20 dBm0 —50 dBm0
{ Attenuation/frequency distortion }	Figures 1/G.232 and 2/G.232		
Group delay	Table 1/G.232		
Non-linear distortion	Figure 3/G.232		
Amplitude limiting	Definition (G.232, § 8)		
Crosstalk ratio ≥" | 5 dB for intelligible crosstalk (G.232, § 9) ≥" | 0 dB for unintelligible crosstalk between adjacent channels (G.232, § 9) }	{		
{ Near-end crosstalk ratio (A) between HF points } ≥" | 7 dB without echo suppressors (G.232, § 9) ≥" | 2 dB with echo suppressors (G.232, § 9) }	{		
{ Near-end crosstalk ratio (X) between audio points } ≥" | 3 dB without echo suppressors (G.232, § 9) ≥" | 8 dB with echo suppressors (G.232, § 9) }	{		
Relative levels G.232, § 11; Table 2/G.232 }	{		
Impedance	600 ?73 (G.232, § 12)		
{ Protection and suppression of pilots }	G.232, § 13		

a) When part of the group is transmitted over open-wire lines (see Recommendation G.232, § 5.1).

Note — See Recommendations G.234 and G.235 for 8-channel and 16-channel equipments, respectively.

Tableau [3T2] A L'ITALIENNE, p.5

H.T. [T3]
SUMMARY TABLES
TABLE 2
Summary of main characteristics specified by the CCITT for carrier terminal equipments
(This very condensed table is not a Recommendation,

and reference should be made to the complete Recommendations)

	{	3-channel (G.361)	12-channel (G.232)
{ Level of carrier leak on the line: } { a) within the 60-108 kHz band } — per channel — per group | ua) { b) outside the 60-108 kHz band }	—26 dBm0 —20 dBm0 —50 dBm0	—17.**5** dBm0 —14.5 dBm0	—26 dBm0 —20 dBm0 —50 dBm0
{ Attenuation/frequency distortion }	Figures 1/G.232 and 2/G.232		
Group delay	Table 1/G.232		
Non-linear distortion	Figure 3/G.232		
Amplitude limiting	Definition (G.232, § 8)		
Crosstalk ratio ≥" | 5 dB for intelligible crosstalk (G.232, § 9) ≥" | 0 dB for unintelligible crosstalk between adjacent channels (G.232, § 9) }	{		
{ Near-end crosstalk ratio (A) between HF points } ≥" | 7 dB without echo suppressors (G.232, § 9) ≥" | 2 dB with echo suppressors (G.232, § 9) }	{		
{ Near-end crosstalk ratio (X) between audio points } ≥" | 3 dB without echo suppressors (G.232, § 9) ≥" | 8 dB with echo suppressors (G.232, § 9) }	{		
Relative levels G.232, § 11; Table 2/G.232 }	{		
Impedance	600 ?73 (G.232, § 12)		
{ Protection and suppression of pilots }	G.232, § 13		

a) When part of the group is transmitted over open-wire lines (see Recommendation G.232, § 5.1).

Note — See Recommendations G.234 and G.235 for 8-channel and 16-channel equipments, respectively.

Tableau [T3], p.6

H.T. [T4]

TABLE 3

Summary of main characteristics specified by the CCITT for groups and supergroups

(This very condensed table is not a Recommendation,

and reference should be made to the complete Recommendations)

	Group	Supergroup	
{ Ratio between wanted component and the following components, defined in G.242, § 1.2: }	at 84 kHz (G.242) (dB)	at 412 kHz (G.242) (dB)	
{ — intelligible crosstalk | ua) }	70	70	
{ — unintelligible crosstalk | ua) }	70	70	
— possible crosstalk	35	35	
{ — harmful out-of-band }	40	40	
{ — harmless out-of-band }	17	17	
{ Additional suppression to safeguard pilot frequencies (G.243) }		{ at least 40 dB at 308 kHz ± | | z at least 20 dB at 308 and 556 kHz ± | 0 Hz (relative to 412 kHz value) }	
{ Additional suppression to safeguard additional measuring frequencies (G.243) }		{ at least 20 dB at 308 and 556 kHz ± | 0 Hz at least 15 dB at 308 and 556 kHz ± | 0 Hz (relative to 412 kHz) (see also Figure 1/G.243) }	
{ Range of insertion loss over the passband for through-connection equipments }	{ ± | dB relative to 84 kHz (G.242) }	{ ± | dB relative to 412 kHz | dB for SG 1 and 3 (G.242) }	
{ Range of insertion loss over 10 | (deC and 40 | (deC for through-connection equipments }	{ ± | dB to 84 kHz relative to the insertion loss at 25 | (deC (G.242) }	{ ± | dB at 412 kHz relative to the insertion loss at 25 | (deC (G.242) }	
Pilot frequency for (G.241) Absolute power level at zero relative level point (for tolerances, see G.241)	Frequency (kHz) | ub)	Accuracy (Hz)	{

(dBm0) }			

{
—
Basic group B | uc)
}
	84.080 84.140 104.080	± | ± | ± |	—20 —25 —2

— Basic supergroup	411.860 411.920 547.920	± | ± | ± |	—25 —20 —2

a) For telephony (G.242).

b) See Recommendation G.241 for use of these frequencies.

c) Also applies to 8-channel groups (G.234).

Tableau [T4], p.7

H.T. [T5]

TABLE 3 | fIbis

Summary of main characteristics specified by the CCITT
for mastergroups,
supermastergroups and
15-supergroup assembly

	Mastergroup	Supermastergroup	15-supergroup a
{ Ratio between wanted component and the following components defined in G.242, § 1.2 }	at 1552 kHz (G.242) (dB)	at 11 | 96 kHz (G.242) (dB)	at 1552 kHz (G.2
{ — intelligible crosstalk | ua) }	70	70	70
{ — unintelligible crosstalk | ua) }	70	70	70
— possible crosstalk	35	35	35
{ — harmful out-of-band }	40	40	40
{ — harmless out-of-band }	17	17	17
{ Variation of insertion loss in passband of through-connection equipment } { ±1 dB with respect to value at 1552 kHz (G.242) } { ±1.5 dB with respect to value at 11 | 96 kHz ±1 dB in each mastergroup (G.242) } { ±1.5 dB with respect to value at 1552 kHz ±1 dB in each supergroup (G.242) }			
{ Variation of insertion loss between 10 | (deC and 40 | (deC of through-connection equipment } { ±1 dB at 1552 kHz relative to insertion loss at 25 | (deC (G.242) } { ±1 dB at 11 | 96 kHz relative to insertion loss at 25 | (deC (G.242) } { ±1 dB at 1552 kHz relative to insertion loss at 25 | (deC (G.242) }			
{ Relative levels at distribution frames (G.233) }	(dBr)	(dBr)	(dBr)
— transmit	—36	—33	—33
— receive	—23	—25	—25 or —
{ Return loss at modulator input (G.233) }	(dB) ≥" | 0	(dB) ≥" | 0	(dB) ≥"
{			

Mastergroup, supermastergroup or 15-supergroup assembly pilots (G.241) in: } Level (for tolerances, see G.241) (dBm0) }	Frequency (kHz)	Frequency (Hz)	{
— basic mastergroup — basic supermastergroup { — basic 15-supergroup assembly }	1 | 52 11 | 96 1 | 52	± 2 ±10 ± 2	—20 —20 —20

a) For telephony (G.242).

Tableau [T5], p.8

H.T. [T6]

TABLE 4

Summary of characteristics specified by the CCITT for carrier systems
on open-wire lines

(This very condensed table is not a Recommendation,
and reference should be made to the complete Recommendations)

	Systems acting on each pair 3-circuit systems 12-circuit systems	{	

Line frequencies
— for a single system
Figure 1/G.361; (see also G.361 §§ 1.1, 2.1, 2.2)
}
Figure 1/G.311 or
Figure 2/G.311
}
{
—
for several systems on the same route
}
See Figure 3/G.311
and Figure 4/G.311 for examples
}
	{
	Figure 1/G.314
	
	Figure 1/G.361
		{
		
		[G.314, c)]
			{
			
			{

Pilots — frequency 16.110 and 31.110 kHz or 17.800 kHz | ua) (G.361, § 1.3) } — level	{ [G.314, d)] —15 dBm0	(G.311, § 5)	—20 dBm0 | ub)

{
Terminal equipment and intermediate repeater output. Relative level per channel at 800-Hz equivalent
frequency
}
| 7 dBr (G.361, § 1.2)
}
| 7 dBr ±1 dBr
(terminal equipment)
| 7 dBr ±2 dBr
(intermediate repeater equipment)
(G.311,
§ 3)
}
	{
	| 7 dBr [G.314, b)]
		{	

{
Frequency accuracy of pilot and carrier frequency generators
}
2.5×10^{D}lF261^{5}
(G.361, §§ 1.3 and 1.8)
}
1×10^{D}lF261^{5}
[G.314, d)]
}
5×10^{D}lF261^{6}
(G.311, § 6)
}
	{
	
	{
	
	{		

a) Used only by agreement between Administrations.

[b] Provisional Recommendation.

[c] For text of this Recommendation, see *Orange Book* , Volume III-1, Geneva, 1976.

Tableau [T6], p.9

H.T. [T7]

TABLE 5

Summary of characteristics specified by the CCITT for carrier systems on symmetric-pair cables

| ua)

(This very condensed table is not a Recommendation,

and

reference should be made to the complete Recommendations)

	System			
	1, 2 or 3 groups	4 groups	5 groups	2 supergroups
Line frequencies Figure 2*b*)/G.322 Scheme 1 Scheme 1 | fIbis | ub) } Figure 2*c*)/G.322 Scheme 2 Scheme 2 | fIbis | ub) } Figure 4/G.322 Schemes 3 and 4 Scheme 3 | fIbis | ub) }	Figure 2*a*)/G.322 { {	{		

{
Relative level at repeater output | uc) (low-gain systems) (G.322, § 2.2.1)
}
	—11 dBr	—14 dBr	—14 dBr	—14 dBr

{
Relative level at repeater output | uc) (valve-type systems) [G.324, B, b)] | ud)
}
— nominal value
— tol´erance
	+4.5 dBr
	± | dB
		+1.75 dBr
		± | dB
			+1.75 dBr
			± | dB
				+1.75 dBr
				± | dB

{
Return loss of repeater and line impedances [G.322, § 1.5)]
}
| .15
$\sqrt{\frac{fIf}{fI f_{max}}}$
or
}
| .15
$\sqrt{\frac{fIf}{fI f_{max}}}$
or
}
| .15
$\sqrt{\frac{fIf}{fI f_{max}}}$
or
| .10 (paper-insulated cables)
}
| .15
[Formula Deleted]
or
| .17 (cable types II | fIbis and III | fIbis
| ub)
G.611)
}
	{
	{
	{
	| .25
		| .10	{	

Tableau [T7], p.10

H.T. [1T8]

TABLE 6

Summary of characteristics specified by the CCITT for carrier systems on 2.6/9.5-mm coaxial cables

(This very condensed table is not a Recommendation, and reference should be made to the complete Recommendations.)

System

2.6 MHz | ua) (1) 4 MHz (2) 12 MHz (3) 60 MHz (4)

Line frequencies {
Figure 1/G.337 | ud) and
Figure 1/G.338 | ud)
} {
Figure 1/G.338 | ud) and Figure 3/G.332
} {
Figure 1/G.332 to Figure 4/G.332
} {
Figure 1/G.333 and Figure 2/G.333

}

Pilot frequencies
{
—
line-regulating pilots
} **{**
60 kHz ± 1 Hz or
308 kHz ± 3 Hz
2604 kHz ± 30 Hz
[G.337 | ud), A, b)]
} **{**
60 kHz ± 1 Hz or
308 kHz ± 3 Hz
4092 kHz ± 40 Hz and see
G.338 | ud), b) 1)
} **{**
4287 kHz ± 49.2 Hz for valve-type systems
[G.339 | ud), b) 1)]
12 | 35 kHz ± 124.3 Hz transistorized
systems (G.332, § 2.1)
} **{**
4287 kHz ± 42.9 Hz
12 | 35 kHz
± 124.3 Hz
22 | 72 kHz
± 223.7 Hz
40 | 20 kHz
± 409.2 Hz
(G.333, § 2.1)
}
{
—
auxiliary line-regulating pilots
} **[G.337 | ud), A, b)]** **[G.338 | ud), b) 1)]** **{**
308 kHz ± 3 Hz and
12 | 35 kHz
± 124.3 Hz for valve-type systems [G.339 | ud)
b) 1)]
308 kHz ± 3 Hz and
4287 kHz ± 42.9 Hz for transistorized
systems
(G.332, § 2.1)
}

Frequency comparison pilots
— national **as (2)** **{**
60 or 308 kHz,
1800 kHz | ub)
[G.338 | ud), b) 2)]
} **{**
300 or 308 kHz (G.332, § 2.2)

}				
— international	as (2)	{		
1800 kHz [G.338 | ud), b) 2)]				
}	{			
308 and 1800 kHz 300 kHz | ub) 808 kHz | ub)’ and 1552 kHz | ub) (G.332, § 2.2)				
}	{			
4200 or 8316 kHz (G.333, § 2.2) }				

{
Additional measuring frequencies
}
(G.332, § 2.3) and [G.339 | ud), b) 3)]
}
	[G.337 | ud), A, c)]
	(G.333, § 2.3)
		[G.338 | ud), b) 4)]	{	

{
Level of line-regulating pilots and additional measuring frequencies
}				

— adjustment value	as (2)	{		
— 10 dBm0 ± 0.5 dB [G.338 | ud), b)]				
}	{			
— 10 dBm0 ± 0.5 dB [G.332, b) 1)]				
}	as (2)	{		
— 1.2 Nm0 for some systems [G.338 | ud), b)]				
}	{			
— 1.2 Nm0 for valve-type systems [G.339 | ud), b)] }				
— error in the level	as (3)	as (3)	{	
±0.1 dB (G.332, § 2.1)				
}	as (3)			
— variation with time	as (3)	as (3)	{	
± 0.3 dB (G.332, § 2.1)				
}	as (3)			

Tableau [1T8], p.11

H.T. [2T8]
TABLE 6 *(Concluded)*

	System			
	2.6 MHz | ua) (1)	4 MHz (2)	12 MHz (3)	60 MHz (4)
{ Impedance match between repeaters and line *N* (as defined in G.332, § 3) } *N* ≥" 40 dB for *f* < 300 kHz [G.338 | ud), e)] *N* ≥" 45 dB for *f* > 300 kHz [G.338 | ud), e)] } *N* ≥" 48 dB for 300 *f* 5564 kHz [valve-type systems G.339 | ud), e)] *N* ≥" 48 dB for *f* = 300 kHz and *N* ≥" 55 dB for *f* ≥" 800 kHz (transistorized systems G.332, § 5) } *N* = 65 dB | uc) (G.333, § 5) }	{ { {			
Relative level on line [G.332, f)] and [G.339 | ud), f) }	(G.333, § 6)	{		

a) Use of the 6-MHz system for telephony is specified otherwise (see G.337 | ud), B).

b) Only used by agreement between Administrations.

c) The value of 65 dB is valid for telephone transmission.

d) For the text of Recommendations G.337, G.338 and G.339, see *Orange Book* , Volume III-1, Geneva, 1976.

TABLE 7
Summary of characteristics specified by the CCITT for carrier systems on 1.2/4.4-mm coaxial cables

(This very condensed table is not a Recommendation, and reference should be made to the complete Recommendations.)

	Systems			
	1.3 MHz	4 MHz	6 MHz	12
Line frequencies	Figure 1/G.341	{ Schemes 1 and 2 of Figure 1/G.343 }	{ Schemes 1, 2 and 3 of Figure 1/G.344	

} (G.345)

{
Pilot frequencies
—
line-regulating pilots
1364 kHz ± 13.6 Hz
(G.341, § 2.1)
See G.343, § 2.1 and Scheme 1
[G.338, b) | uc) 1];
Scheme 2
(G.332. § 2.1)
308 kHz ± 3 Hz (G.344)
—
auxiliary line-regulating pilots
60 kHz ± 1 Hz or 308 kHz ± 3 Hz (G.341, § 2.1)
4287 kHz
± 42.8 Hz | ua)
(G.343, § 2.1)
4287 kHz
± 42.8 Hz | ub) 6200 kHz
± 62 Hz (G.344, § 2.1)
}

{
The provisions of this Recommendation are those appearing in Recommendation G.332 (see the preceding Table 6), with the exception of the matching
—
frequency comparison pilots
60 kHz or 308 kHz (G.341, § 2.2)
Scheme 1
[G.338 | uc), b) 2)] and Scheme 2 (G.332, § 2.2)
Schemes 1 and 2 [G.338 | uc), b) 2)]
Scheme 3
(G.332,
§ 2.2)
}

{
Additional measuring frequencies
} (G.341, § 2.3) (G.343, § 2.3) (G.344, § 2.3)
{
Level of line-regulating pilots and additional measuring frequencies
}
— adjustment value {
—10 dBm0 or
—1.2 Nm0 for some systems
(G.341, § 2)
} —10 dBm0 (G.343, § 2) —10 dBm0 (G.344, § 2)
— tolerances (G.343, § 2) (G.344, § 2)

{
Impedance match between repeaters and line
} {
N
≥" | 4 dB for a 6-km repeater section
N
≥" | 2 dB for an 8-km repeater section (G.341, § 5)
} {
N
≥" | 0 dB for

f = 60 kHz *N* ≥"	7 dB for *f* ≥"	00 kHz (4-km repeater section G.343, § 5) } *N* ≥"	0 dB for *f* ≥"	00 kHz *N* = 50 dB for *f* = 60 kHz (3-km repeater section, G.344, § 5) } *N* = 63 dB for a 2-km repeater section (G.345) }	{ {			
{ Relative levels on line and interconnection } —9 dBr at 4028 kHz or —8.5 dBr at 4287 kHz (G.343, § 6) }	(G.341, § 6) —17 dBr (G.344, § 5)	{ (G.332, § 6)		

a) Only used by agreement between Administrations.

b) Only used by agreement between Administrations.

c) For text of this Recommendation, see *Orange Book* , Volume III-1, Geneva, 1976.

Tableau [2T8], p.12

H.T. [T9]

TABLE 7

Summary of characteristics specified by the CCITT for carrier systems on 1.2/4.4-mm coaxial cables

(This very condensed table is not a Recommendation, and reference should be made to the complete Recommendations.)

	Systems			
	1.3 MHz	4 MHz	6 MHz	12
Line frequencies Schemes 1 and 2 of Figure 1/G.343 } Schemes 1, 2 and 3 of Figure 1/G.344 }	Figure 1/G.341 { (G.345)	{		

{
Pilot frequencies
—
line-regulating pilots
1364 kHz ± 13.6 Hz
(G.341, § 2.1)
See G.343, § 2.1 and Scheme 1
[G.338, b) | uc) 1];
Scheme 2
(G.332. § 2.1)
308 kHz ± 3 Hz (G.344)
—
auxiliary line-regulating pilots
60 kHz ± 1 Hz or 308 kHz ± 3 Hz (G.341, § 2.1)
4287 kHz
± 42.8 Hz | ua)
(G.343, § 2.1)
4287 kHz
± 42.8 Hz | ub) 6200 kHz
± 62 Hz (G.344, § 2.1)
}
 	
{
The provisions of this Recommendation are those appearing in Recommendation G.332 (see the preceding Table 6), with the exception of the matching
—
frequency comparison pilots
60 kHz or 308 kHz (G.341, § 2.2)
Scheme 1
[G.338 | uc), b) 2)] and Scheme 2 (G.332, § 2.2)
Schemes 1 and 2 [G.338 | uc), b) 2)]
Scheme 3
(G.332,
§ 2.2)
}
 	
{
Additional measuring frequencies
}
	
	(G.341, § 2.3)
		
		(G.343, § 2.3)
			
			(G.344, § 2.3)	

{
Level of line-regulating pilots and additional measuring frequencies
}
— adjustment value
—10 dBm0 or
—1.2 Nm0 for some systems
(G.341, § 2)
}
— tolerances
	
	{
	
	—10 dBm0 (G.343, § 2)
		
		—10 dBm0 (G.344, § 2)
		(G.343, § 2)
			
			(G.344, § 2)	

{
Impedance match between repeaters and line
}
N
	
	{			

≥" | 4 dB for a 6-km repeater section *N* ≥" | 2 dB for an 8-km repeater section (G.341, § 5) } *N* ≥" | 0 dB for *f* = 60 kHz *N* ≥" | 7 dB for *f* ≥" | 00 kHz (4-km repeater section G.343, § 5) } *N* ≥" | 0 dB for *f* ≥" | 00 kHz *N* = 50 dB for *f* = 60 kHz (3-km repeater section, G.344, § 5) } *N* = 63 dB for a 2-km repeater section (G.345) }	{ { {			

{
Relative levels on line and interconnection
}
—9 dBr at 4028 kHz or —8.5 dBr at
4287 kHz
(G.343, § 6)
}
	(G.341, § 6)
	—17 dBr (G.344, § 5)
		{
		(G.332, § 6)		

a) Only used by agreement between Administrations.

b) Only used by agreement between Administrations.

c) For text of this Recommendation, see *Orange Book* , Volume III-1, Geneva, 1976.

Tableau [T9], p.13

H.T. [1T10]

TABLE 8

Summary of main characteristics specified by the CCITT
for international circuits for programme transmissions

(This very condensed table is not a Recommendation,
and reference should be made to the complete Recommendations)

	15 kHz | c), |)	10 kHz | ug)	5 kHz | uh)	7 kHz

{
Frequency band effectively transmitted by the complete link (kHz)
}
	0.04 to 15	0.05 to 10	0.07 to 5	0.05 to 7

{
Additional attenuation at these limits
}
1.5 dB at 0.04 kHz
3 dB at 15 kHz
(J.21) | ud)
}
	{
	4.3 dB J.22
		3 dB J.23	3 dB J.23	

{
Attenuation/frequency distortion
}
±0.5 dB;
0.125 to 10 kHz
(J.21, § A.3.1.1)
}
	{			

{
Group delay at frequency *f* (τ *f*) relative to the minimum value of group delay
}
15 kHz 12 ms
14 kHz 8 ms
0.075 kHz 24 ms
0.04 kHz 55 ms
(J.21)
}
10 | 00 Hz 8 ms
1 | 00 Hz 20 ms
| 50 Hz 80 ms
(J.22, § A.3.2)
}
0.07 kHz 60 ms
5**.07** kHz 15 ms
J.23
}
0.5 kHz 80 ms
0.1 kHz 20 ms
6.4 kHz 5 ms
7**.4** kHz 10 ms
J.23
}
	{
	{
	{
	{			

{
Maximum absolute voltage level at a sound-programme zero relative level point
}
+9 dB (J.14) — Peak voltage 3.1 V (Figure 3/J.13)
}
	{			

{ Definition of zero relative level at a point in a carrier				

circuit) } Level to give no greater load than that for the telephone channels replaced (J.31, § 2) } As for Telephony, is within ±3 dB (J.14) }	{ {			

{
Nominal relative voltage level at the input and output of the circuit defined in J.13
}
	6 dB (J.14)			

{
Variation of relative level with time
}
± | .5 dB (daily variation)
(J.21, § A.2.3)
}
± | .5 dB (daily variation)
(J.22, § A.2.3)
}
± | .5 dB (daily variation)
(J.23, § A.2.3)
}
	{
	
	{
	
	{			

{
Intelligible crosstalk attenuation
(near-end or far-end ratio)
}
0.04 kHz ≥" 50 dB
0.5 kHz ≥" 74 dB
5 kHz ≥" 74 dB
15 kHz ≥" 60 dB
(J.21, § A.3.1.8)
}
Between 2 programme transmission circuits or telephony into sound programme
≥" | 4 dB
Sound programme into telephony:
≥" | 5 dB (J.22 and J.23 respectively) | ue)
}
	{
	
	{			

Tableau [1T10], p.14

H.T. [2T10]

TABLE 8 *(cont.)*

	{			
	15 kHz | c), |)	10 kHz | ug)	5 kHz | uh)	7 kHz
{ Circuit noise including nonlinear crosstalk) | uf) } Level | (em47 dBm0ps (new weighting network according to J.16) } Psophometric voltage at the end of 1) cable circuit 1) | .2 mV 2) open-wire circuit 2) | 5.6 mV }	{ {			

a) Characteristics applicable to the hypothetical reference circuits, defined in Recommendation J.11.

b) Types of circuits described in Recommendation J.12.

c) For the additional characteristics specified by the CCITT for 15-kHz stereophonic sound-programme circuits (see Recommendation J.21.

d) See CCIR Recommendations 505.

e) Special precautions needed for crosstalk between the two directions of transmission (see Recommendations J.18 and J.22).

f) Measures taken to reduce the effects of noise in a group link (see Recommendation J.17).

g) See CCIR Recommendation 504.

h) See CCIR Recommendation 503.

Tableau [2T10], p.15

H.T. [T11]

TABLE 9

Summary of main characteristics of analogue signals at audio frequencies, at terminals of PCM equipments

(This very condensed table is not a Recommendation, and reference should be made to the complete Recommendations)

<table>
<tr><th>{</th><th>Test signal
Signal</th><th>Frequency range</th><th>{</th><th></th></tr>
<tr><td>{
Attenuation/frequency distortion
}
Preferred value: —10
alternative: 0
}</td><td>Figure 1/G.712</td><td></td><td>{</td><td></td></tr>
<tr><td>Envelope-delay distortion</td><td></td><td></td><td>0</td><td>Figure 2/G.712</td></tr>
<tr><td>{
Idle channel noise:
—
weighted
—
single frequency
—
due to receiving equipment
}

—65 dBm0p
—50 dBm0p
—75 dBm0p
}</td><td></td><td></td><td>{</td><td></td></tr>
<tr><td>Image frequency</td><td>sine wave</td><td>> | kHz</td><td>x</td><td>< | fIx — 25 dBm0</td></tr>
<tr><td>{
Level of out-of-band image signals
}</td><td>sine wave</td><td>300-3400 Hz</td><td>0</td><td>< —25 dBm0</td></tr>
<tr><td>Intermodulation products:
{
—
2f
, —f
2
}
f
1 and f
2 (Hz)
}
— any intermodulation:
project</td><td>two sine wave

—21 < x < —4
sine wave

sine wave</td><td>{

< | fIx — 35 dBm0
300-3400 Hz

50 Hz</td><td>

—9

—23</td><td>

< | (em49 dBm0</td></tr>
<tr><td>Variation of gain:
{
—
with input level (reference = gain at input level of —10 dBm0)
}
white noise
sine wave
sine wave
}
700-1100 Hz
700-1100 Hz</td><td>{

{</td><td></td><td></td><td></td></tr>
</table>

} —55 < *x* < —10 —10 < *x* < 3 —55 < *x* < 3 } Figure 7*a)* /G.712 Figure 7*b)* /G.712 Figure 7*c)* /G.712 } — with time (stability) ± | .2 dB in 10 minutes ± | .5 dB in one year }	{ {			{
Crosstalk: — interchannel — go-return	 sine wave white noise sine wave	 700-1100 Hz 300-3400 Hz	 0 0	 < | (em65 dBm0 < | (em60 dBm0 > | 0 dB
Distortion Figure 6/G.712 }	Gaussian noise sine wave	 700-1100 Hz	—55 < *x* < 3 —45 < *x* < 0	Figure 5/G.712 {

a) Parameters of input and output ports:

— 600 ohms balanced, 4-wire ports;

— return loss better than 20 dB over frequency range 300-3400 Hz

— (provisional recommendation).

b) For correct application to the equipments, see § 1 of Recommendation G.712.

Tableau [T11], p.

PART I

Recommendations G.100 to G.181

GENERAL CHARACTERISTICS OF INTERNATIONAL

TELEPHONE CONNECTIONS AND CIRCUITS

MONTAGE: PAGE 2 = PAGE BLANCHE

SECTION 1

GENERAL CHARACTERISTICS FOR INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

1.0 General

Recommendation G.100

DEFINITIONS USED IN FASCICLE III.1

(Melbourne, 1988)

Introduction

The definitions given below have been found to be useful in the study of telephone connections and telephone circuits.

The detailed definitions appearing in Recommendation G.102 are referred to, but not reproduced.

The definitions of specialized terms which are not mentioned here can be found in:

— Recommendation G.106, for availability and reliability;

— Recommendation G.117 as concerns unbalance about earth;

— Annex A to Recommendation G.111 as concerns speech transmission performance;

— Paragraph 1.6 of this fascicle for echo suppressors, echo cancellers, compandors, etc.

1 General terms

1.1 **hypothetical reference connection (HRX)**

F: communication fictive de référence

S: conexión fictiva de referencia (CFR)

A hypothetical connection of defined structure, length and performance in a telecommunication network for analogue or digital (or mixed) signal transmission, to be used as a model in which studies relating to overall performance may be made, thereby allowing comparisons with standards and objectives.

1.2 **input/output** (Recommendations G.111, G.121, etc.)

F: entrée/sortie

S: entrada/salida

Terms used to indicate the direction of transmission at an interface of an equipment item. These terms avoid the ambiguity encountered in the use of ‘‘transmit/receive’’ or ‘‘send/receive’’.

1.3 **relative level (at a point on a circuit)**

F: *niveau relatif (en un point d'un circuit)*

S: *nivel relativo (en un punto de un circuito)*

The expression $10 \log_{10}(P/P_0)$ dBr where P represents the power of a test signal of 1000 Hz at the point concerned and P_0 the power of that signal at the *transmission reference point*

Note — This quantity is independent of P_0, it is a composite gain (level difference). For further details, see Recommendation G.101, § 5.3.2.

1.4 **transmission reference point**

F: *point de référence pour la transmission*

S: *punto de referencia para la transmisión*

A hypothetical point at or near to the sending end of each channel (preceding the virtual switching point specified by the CCITT), used as the ''zero relative level point'' in the computation of nominal relative levels.

1.5 **return loss**

F: *affaiblissement d'adaptation*

S: *pérdida de retorno*

Quantity characterizing the degree of match between two impedances, Z_1 and Z_2. It is given by the expression:

$$L_R = 20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{ dB.}$$

2 **Transmission performance objectives**

2.1 **performance objective**

F: *objectif pour la qualité de fonctionnement*

S: *objetivo de calidad de funcionamiento*

(Defined in Recommendation G.102.)

2.2 **design objective**

F: *objectif pour les projects*

S: *objetivo de diseño*

(Defined in Recommendation G.102.)

2.3 **commissioning objective**

F: objectif pour la mise en service

S: objetivo de puesta en servicio inicial

(Defined in Recommendation G.102.)

2.4 **limits for maintenance purposes (maintenance limits)**

F: limites de maintenance

S: l´imites de mantenimiento

(Defined in Recommendation G.102.)

3 Transmission impairments

3.1 group-delay distortion

F: distorsion de temps de propagation de groupe

S: distorsión por retardo de grupo

The difference between group delay at a given frequency and minimum group delay, in the frequency band of interest.

3.2 quantizing distorsion unit (qdu)

F: unité de distorsion de quantification (udq)

S: unidad de distorsión de cuantificación (udc)

(For this concept see Recommendation G.113.)

4 Propagation time, echo and stability

4.1 balance return loss

F: affaiblissement d'équilibrage

S: atenuación de equilibrado

At a 4-wire terminating set (''hydrid''), that portion of the *semi-loop loss* which is attributable to the degree of match between the impedance, Z_2, connected to the 2-wire line terminals, and the balance impedance, Z_B. It is given approximately by the expression:

$$L_{BR} = 20 \log_{10} \left| \frac{Z_2 + Z_B}{Z_2 - Z_B} \right| \text{ dB}$$

Note — Under most circumstances the expression given is sufficiently accurate. However, for some worst case evaluations, the exact expression must be used. The exact expression is:

$$L_{BR} = 20 \log_{10} \left| \frac{Z_0 + Z_B}{2Z_0} \cdot \frac{Z_2 + Z_0}{Z_2 - Z_B} \right| \text{ dB}$$

where Z_0 is the 2-wire input impedance. (If $Z_0 = Z_B$ the two expressions become identical.)

4.2 echo

F: écho

S: eco

Unwanted signal delayed to such a degree that, for instance in telephony, it is perceived as distinct from the wanted signal (i.e. the signal directly transmitted).

Note 1 — Distinction is made between *talker echo* | and *listener echo* .

Note 2 — An echo is usually considerably attenuated with respect to the wanted signal.

4.3 echo balance return loss

F: affaiblissement d'´equilibrage pour l'´echo

S: atenuaci´on de equilibrado para el eco

Balance return loss | averaged with 1/*f* | power weighting over the telephone band, in accordance with Recommendation G.122, § 4.

4.4 echo control device

F: dispositif de r´eduction de l'´echo

S: dispositivo de control de eco

A voice-operated device placed in the 4-wire portion of the circuit and used for reducing the effect of echo.

Note — This reduction is in practice carried out either by subtracting an estimated echo from the circuit echo (i.e. cancelling it) or by introducing loss in the transmission path to suppress the echo (echo suppression).

4.5 echo loss, L_{ECHO}

F: affaiblissement d'´echo A_{ECHO}

S: atenuaci´on de eco, A_{ECO}

Semi-loop loss | averaged with $1/f$ | power weighting over the telephone band, in accordance with Recommendation G.122, § 4.

Note 1 — In cases where a point *t* (2-wire point) exists, the echo loss is approximately equal to the sum of the transmission losses *a -t* | and *t -b* | and the *echo balance return loss* . (Points *a* | and *b* | are shown in Recommendation G.122.)

Note 2 — Distinction may be made between the echo loss of a given piece of equipment and that of a national system (cf. Note 2 to definition in § 4.11).

4.6 talker echo loudness rating (of an international connection)

F: l'´equivalent à la sonie pour l'´echo pour la personne qui parle (d'une communication internationale)

S: ´indice de sonoridad del eco para el hablante (en una conexi´on internacional)

The sum of the sending loudness rating, receiving loudness rating of the talker's national system, twice the loss of the international chain and the *echo loss* | (*a -b*) of the listener's national system, as defined at the virtual switching point. (Points *a* | and *b* | are shown in Recommendation G.122.)

4.7 listener echo (receive end echo)

F: l'´echo à la r´eception

S: eco para el oyente (eco en la recepci´on)

Echo | produced by double reflected signals and disturbing the listener, receiving voice-band data equipment, etc.

Note 1 — The term ''received end echo'' is a term preferred by some Administrations.

Note 2 — With small delay against the wanted signal (less than about 3 ms) listener echo may cause *hollowness* | in telephony. In transmission of voice-band data signals, listener echo may cause bit errors and, in any case, reduces the margin against other disturbances.

4.8 listener echo loss (receive echo loss)

F: affaiblissement de l'´echo à la r´eception

S: atenuaci´on para el oyente (atenuaci´on de eco en la recepci´on)

Degree of attenuation of the double reflected signal with respect to the wanted signal. In terms of the absolute losses of both signals, the listener echo loss is (see Figure 1/G.100): $LE = L_2 - L_1$.

Note — For practical purposes the listener echo loss is equal to the *open-loop loss* | (valid if the latter exceeds 8 dB). The listener echo loss characterizes the degree of disturbance by *hollowness* , | as well as the disturbing effect on voice-band data modem receivers.

Figure 1/G.100, p.

4.9 **hollowness**

F: son caverneux

S: cavernosidad

Distortion in telephony caused by double reflected signals and subjectively perceived as a ‘‘hollow sound’’, i.e. as if the talker would speak into some hollow vessel.

Note — Hollowness is to be distinguished from *listener echo* .

4.10 **open-loop loss (OLL)**

F: affaiblissement en boucle ouverte

S: atenuaci´on en bucle abierto (ABA)

In a loop formed by a 4-wire circuit (or a cascade connection of two or more 4-wire circuits) and terminated by 2-wire ends (i.e. having ‘‘4-wire terminating sets’’, or hybrids, at both ends), the loss measured by breaking the loop at some point, injecting a signal and measuring the loss incurred in traversing the open loop. All impedance conditions should be preserved while making the measurement. See Figure 2/G.100.

Note 1 — In practice the OLL is equal to the listener echo loss.

Note 2 — The OLL is also equal to the sum of the two *semi-loop losses* | associated with a loop.

Figure 2/G.100, p.

4.11 **path a-t-b (transmission loss of | | | | ; semi-loop loss**

F: affaiblissement du trajet a-t-b; affaiblissement en demi-boucle

S: atenuaci´on del trayecto a-t-b; atenuaci´on en semibucle

The transmission loss between the points ‘‘a’’ and ‘‘b’’ of the 4-wire termination (as defined at the virtual switching points) independent of whether there exists or not a physical point ‘‘*t* ’’.

4.11.1 *Possible alternative to the definition in § 4.11*

semi-loop loss

F: *affaiblissement en demi-boucle*

S: *atenuaci´on en semibucle*

In an arrangement comprising a 4-wire circuit (or a cascade connection of several 4-wire circuits) with unwanted coupling between the go and return direction at the ends of the circuit — usually via a 4-wire terminating set, or via acoustical coupling — the loss measured between the input and output. See Figure 3/G.100.

Note 1 — The semi-loop loss is an important quantity in determining *echo balance return loss, echo loss, listener echo loss* | (see also *open-loop loss*).

Note 2 — Distinction may be made between the semi-loop loss of a given piece of equipment and the semi-loop loss of a national system. The latter is measured at equi-level points in an ISC which serves as a national gateway exchange.

Figure 3/G.100, p.

4.12 **stability loss**

F: affaiblissement pour la stabilité

S: atenuación para la estabilidad

The lowest value of the semi-loop loss in the frequency band to be considered.

4.13 **talker echo**

F: écho pour la personne qui parle

S: eco para el hablante

Echo produced by reflection near the listener's end of a connection, and affecting the talker.

4.14 **test balance return loss (TBRL)**

F: affaiblissement d'équilibrage en position de mesure

S: atenuación de equilibrado en posición de medida (AEPM)

The *balance return loss* | measured against a test impedance (i.e. in this case the impedance Z_2 — cf. definition of *balance return loss* — is a specified test impedance).

Note — The TBRL characterizes the precision of the balance network.

4.15 **mean one-way propagation time**

F: temps de propagation moyen dans un sens

S: tiempo medio de propagaci´on en un sentido

In a connection, the mean of the propagation times in the two directions of transmission.

Note — The use of this concept is explained in Recommendation G.114.

5 Equipment

5.1 R or T pads (in telephone extension)

F: compl´ements de ligne R ou T (dans un syst`eme national)

S: atenuadores R o T (en la prolongaci´on telef´onica)

The R or T pad represents the transmission loss between the 0 dBr points at the digital/analogue codec and the 2-wire side of the 2-wire/4-wire terminating unit or the same in the reversed direction, respectively.

Note — The transmission loss introduced by the combination of the R and T pads in the subject of CCITT Recommendations.

Recommendation G.101

THE TRANSMISSION PLAN

(Geneva, 1964; amended at Mar del Plata, 1968,

Geneva, 1972, 1976 and 1980; Malaga-Torremolinos, 1984)

1 Principles

The transmission plan of the CCITT established in 1964 was drawn up with the object of making use, in the international service, of the advantages offered by 4-wire switching. It is referred to in the Recommendations appearing in Part I, Section 1 of the Series G Recommendations. However, the recommendations in the plan are to be considered as met if the use of technical means other than those described below gives an equivalent performance at the international exchange.

Recommendations G.121 and G.122 describe the conditions to be fulfilled by a national network for this transmission plan to be put into effect.

Note 1 — From the point of view of the transmission plan, no distinction is made between intercontinental circuits and other international circuits.

Note 2 — Short trans-frontier circuits are not covered by this plan and should be the subject of agreement between the Administrations concerned.

This Recommendation is partly reproduced in Recommendation Q.40 [1].

Note 3 — The Appendix to the present Section 1 of the Series G Recommendations contains the justification for the values of corrected reference equivalents appearing in Recommendations G.111 and G.121.

2 Definition of the constituent parts of a connection

2.1 *The international chain of circuits and the national systems*

A complete **international telephone connection** consists of three parts, as shown in Figure 1/G.101. The division between these parts is determined by the *virtual analogue switching points* in the originating/terminating international switching centres (ISCs). These are theoretical points with specified relative levels (see Fig ure 2/G.101 and §§ 5.1 and 5.2 of this Recommendation).

The three parts of the connection are:

— Two national systems, one at each end. These may comprise one or more 4-wire national trunk circuits with 4-wire interconnection, as well as circuits with 2-wire connection up to the local exchanges and the subscriber sets with their subscriber lines.

— An international chain made up of one or more 4-wire international circuits. These are interconnected on a 4-wire basis in the international centres which provide for transit traffic and are also connected on a 4-wire basis to national systems in the international centres.

An international 4-wire circuit is delimited by its virtual analogue switching points in an international switching centre.

Note 1 — In principle the choice of values of the relative levels at the virtual analogue switching points on the side of a national system is a national matter. In practice, several countries have chosen —3.5 dBr for receiving as well as for sending. These are theoretical values; they need not actually occur as any special equipment item; however, they serve to determine the relative levels at other points in the national network. If, for instance, the loss ‘‘*t -b* ’’ or ‘‘*a -t* ’’ is 3.5 dB (as is the case in several countries, cf. Table A-l/G.121), then it follows that the relative levels at point *t* are 0 dBr (input) and —7 dBr (output).

Note 2 — The virtual analogue switching points may not be the same as the points at which the circuit terminates physically in the switching equipment. These latter points are known as the circuit terminals ; the exact position of these terminals is decided in each case by the Administration concerned.

FIGURE 1/G.101 p.

2.2 *National extension circuits : 4-wire chain*

When the maximum distance between an international exchange and a subscriber who can be reached from it does not exceed about 1000 km or, exceptionally, 1500 km, the country concerned is considered as of average size. In such countries, in most cases, not more than three national circuits are interconnected on a 4-wire basis between each other and to international circuits. These circuits should comply with the recommendations of Subsection 1.2.

In a large country, a fourth and possibly a fifth national circuit may be included in the 4-wire chain, provided it has the nominal transmission loss and the characteristics recommended for international circuits used in a 4-wire chain (see Recommendation G.141, § 1, § 4 of this Recommendation and the Recommendations in Subsection 1.5).

Note — The abbreviation ‘‘a **4-wire chain** ’’ (see Figure 3/G.101) signifies the chain composed of the international chain and the national extension circuits connected to it, either by 4-wire switching or by some equivalent procedure (as understood in § 1 above).

FIGURE 2/G.101 p.

Figure 3/G.101, p.

3 Number of circuits in a connection

3.1 *National circuits*

It seems reasonable to assume that in most countries any *local exchange* | an be connected to the international network by means of a chain of four (or less) national circuits. Five national circuits may be needed in some countries, but it is unlikely that any country may need to use more than five circuits. Hence the CCITT has reached the conclusion that four circuits is a representative figure to assume for the great majority of international connections.

In most modern national networks, the four circuits will probably include three 4-wire amplified circuits (usually set up on FDM carrier systems) and one 2-wire circuit, probably unamplified. However, cases in which local exchanges are be reached by four amplified circuits, among them usually at least one PCM circuit, are becoming more and more frequent. All these circuits may be 4-wire circuits.

3.2 *International circuits*

According to the International Telephone Routing Plan (Recommendation E.171), the number of international circuits is restricted to four.

3.3 *Hypothetical reference connections*

See Recommendation G.103.

3.4 Tables 1/G.101, 2/G.101 and 3/G.101 give the percentage relative and cumulative frequencies of the number of circuits encountered in an international connection calculated from a survey of about 270 million international telephone connections taken in 1973. These tables take traffic weighting into account.

H.T. [T1.101]

TABLE 1/G.101

Relative frequencies of the number of circuits in the two national extensions and the international chain (expressed as percentages)

Number of circuits	Originating LE-CT3	International CT3-CT3‘	Terminating CT3‘-LE‘
1	33.8	95.1	32.9
2	38.9	4.5	39.5
3	20.2	0.3	20.4
4	6.0	—	6.1
5	1.0	—	1.0

Note — The relative frequencies of 6 and 7 circuits in the originating national system are 0.005% and 0.0005% respectively. The relative frequencies of 4, 5 and 6 international circuits are 0.03%, 0.00007% and 0.00009% respectively.

The means and modal numbers of national circuits are both equal to 2. This applies to both originating and terminating national extensions. The mean number of international circuits is 1.1 and the modal number is 1.

TABLE 1/G.101 [T1.101], p.

H.T. [T2.101]

TABLE 2/G.101

Relative and cumulative frequency of the total number of circuits

between local exchanges (expressed as percentages)

Number of circuits LE to LE‘	Relative frequency (%)	Cumulative frequency (%)
3	10.61	10.61
4	25.44	36.05
5	28.77	64.82
6	20.39	85.20
7	10.08	95.29
8	3.60	98.89
9	0.93	99.81
10	0.17	99.98
11	0.02	100.00

Note — The relative frequencies of connections with 12, 13 and 14 circuits are 0.0012%, 0.000088% and 0.0000049% respectively. The mean value is equal to 5.1 and the modal value is equal to 5.

TABLE 2/G.101 [T2.101] p.

4 Incorporation of unintegrated digital processes

4.1 *General*

The worldwide telephone network is now undergoing a transition from what is predominantly analogue operation to mixed analogue/digital operation. In the longer term, it is possible to foresee a continued transition to predominantly digital operation.

Figure 4/G.101 is intended to demonstrate how unintegrated analogue/digital PCM processes can occur in the international nework by illustrating a possible stage in the development of a national network as it progresses from all-analogue to all-digital. As indicated, subnetworks could arise in the country in which the transmission systems and the telephone exchanges are all-digital and fully integrated. Such subnetworks (referred to as ‘‘digital cells’’ by some) will require analogue/digital conversion processes in order to interface into the remainder of the network. Furthermore, some of the trunk-junctions (toll connecting trunks) and trunk-circuits (intertoll trunks) may be provided in some countries by 7-bit PCM systems, serving analogue exchanges. Conversely some digital exchanges may have to switch analogue circuits. Manual assistance switchboards, PBXs and subscribers' multiplex systems using PCM digital techniques are also allowed for. Naturally, any of the circuits indicated as 7-bit PCM could be either analogue or 8-bit PCM; but one of the worst cases is illustrated.

H.T. [T3.101]

TABLE 3/G.101

Relative and cumulative frequency of the number of circuits in the 4-wire chain (expressed as percentages)

{ Number of circuits in the 4-wire chain }	Relative frequency (%)	Cumulative frequency (%)
1	2.65	2.65
2	14.16	16.81
3	27.49	44.30
4	26.43	70.73
5	17.28	88.01
6	8.33	96.34
7	2.83	99.18
8	0.70	99.88
9	0.11	99.99
10	0.0065	100.00

Tableau 3/G.101 [T3.101] p.25

Figure 4/G.101, p.26

With regard to 7-bit PCM, it should be noted that such systems are not recommended by the CCITT. The only recommended analogue/digital (A/D) conversion processes for telephone services are 8-bit PCM processes (reference: CCITT Recommendation G.711 [2]). There are in some countries 7-bit PCM systems in operation which have been designed and installed prior to the appearance of Recommendation G.711 and, as existing systems, they should be taken into account, notwithstanding the fact that such systems are of a provisional nature as they will likely be removed from service as soon as their practical usefulness comes to an end.

In view of the foregoing, international telephone connections may for some time include one national 7-bit PCM trunk-junction (toll connecting trunk) or exceptionally two such 7-bit PCM circuits international satellite circuits using 7-bit PCM coding may be encountered as well as A-law/μ-law conversion processes and digital pads.

The mixed analogue/digital period is expected to last a considerable number of years. Consequently, it will be necessary to ensure that transmission performance in this period will be maintained at a satisfactory level.

4.2 *Types of telephone circuits*

In the mixed analogue/digital period, international circuits could, in particular, consist of the types indicated in Figure 5/G.101. In all cases, the virtual analogue switching points are identified (conceptually) and the relative levels at these points, specified.

Although the circuit types shown in Figure 5/G.101 are classed as international circuits, the configurations involved could also occur in national telephone networks. However, in national networks the relative levels at the virtual analogue switching points of the circuits could be different from those indicated for international circuits.

The Type 1 circuit in Figure 5a)/G.101 represents the case where digital transmission is used for the entire length of the circuit and digital switching is used at both ends. Such a circuit can generally be operated at a nominal transmission loss of 0 dB as shown because of the transmission properties exhibited by such circuits (e.g., relatively small loss variations with time).

The Type 2 circuit in Figure 5b)/G.101 represents the case where the transmission path is established on a digital transmission channel in tandem with an analogue transmission channel. Digital switching is used at the digital end and analogue switching at the analogue end.

It might be possible, in some cases, to operate Type 2 circuits with a nominal loss of 0 dB in each direction of transmission. For example, where the analogue portion could be provided with the necessary gain stability and where the attenuation distortion would permit such operation.

The Type 3 circuit in Figure 5c)/G.101 represents the case where the transmission path is established over a tandem arrangement consisting of digital/analogue/digital channels as shown. Digital switching is assumed at both ends.

The Type 4 circuit in Figure 5d)/G.101 represents the case where the transmission path is established over a tandem arrangement consisting of analogue/digital/analogue channels as shown. Analogue switching is assumed at both ends.

The Type 5 circuit in Figure 5e)/G.101 represents the case where analogue transmission is used for the entire length of the circuit and analogue switching is used at both ends.

International circuits of this type are usually operated at a loss L , where L is nominally = 0.5 dB between virtual analogue switching points.

Note — General remarks concerning the allocation of losses in the mixed analogue/digital circuits

In circuit types 2, 3 and 4, the pads needed to control any variability in the analogue circuit sections (arising from loss variations with time or attenuation distortion) are shown in a symmetrical fashion in both directions of transmission. However, in practice, such arrangements may require nonstandard levels at the boundaries between circuit sections. Administrations are advised that should they prefer to adopt an asymmetric arrangement, e.g., by putting all the loss into the receive direction at only one end of a circuit (or circuit section); then, provided that the loss is small, e.g., a total of not more than 1 dB, there is no objection on transmission plan grounds.

The small amount of asymmetry that results in the international portion of the connection will be acceptable, bearing in mind the small number of international circuits encountered in most actual connections.

As far as national circuits are concerned, Administrations may adopt any arrangements they wish provided that the requirements of Recommendation G.121, § 2.2, are complied with.

In some cases transmultiplexers may be used, in which case the circuits may not be available at audio-frequency at the point at which a pad symbol is used in the diagrams of Figure 5/G.101. Should the variability of the analogue portions merit additional loss, the precise way in which this loss can be inserted into the circuits is a matter for Administrations to decide bilaterally.

4.3 *Number of unintegrated PCM digital processes*

Restrictions due to transmission impairments

In the mixed analogue/digital period, it may be necessary to include a substantial number of unintegrated digital processes in international telephone connections. To ensure that the resulting transmission impairments (quantizing, attenuation and group-delay distortion) introduced by such processes do not accumulate to the point where overall transmission quality can be appreciably impaired, it is recommended that the planning rule given in Recommendation G.113 § 3 be complied with. The effect of this rule is to limit the number of unintegrated digital processes in both the national and international parts of telephone connections.

In the case of all-digital connections, transmission impairments can also accumulate due to the incorporation of digital processes (e.g., digital pads). The matter of accumulating such impairments under all-digital conditions is also dealt with in Recommendation G.113 § 3.

4.4 *Transmission of analogue and digital data*

In the mixed analogue/digital period, the presence in telephone connections of analogue/digital converters, encoding law converters, digital pads, or other types of digital processes, would not preclude the transmission of analogue data. However, on overall digital connections, digital type data could be adversely affected by devices such as encoding law converters and digital pads, since they involve signal recoding processes. Consequently, for the transmission of digital data, arrangements should be made to switch-out or bypass any device whose operation entails the recoding of digital data signals.

4.5 *General principle*

It is recognized that in the mixed analogue/digital period, there could be a considerable presence of unintegrated digital processes in the worldwide telephone network. Consequently, it is important that the incorporation of these processes should take place in such a way that when integration of functions can occur, unnecessary items of equipment would not remain in the all-digital network.

5 Conventions and definitions

5.1 *Virtual analogue switching points*

The concept ‘‘virtual switching points’’ has been useful in making transmission studies with regard to all-analogue connections. For example, these points have been used to define the boundary between international circuits as well as between international circuits and national extensions. The ‘‘virtual switching points’’ also provided convenient locations to which transmission quantities could be referred.

The incorporation of digital encoding processes into the worldwide telephone network no longer makes it possible, in all cases, to determine theoretical points which correspond to the ‘‘virtual switching points’’ of all-analogue connections. Since it would be desirable, in mixed analogue/digital connections to have analogous points, the concept of ‘‘virtual analogue switching points’’ has been adopted. This concept postulates the existence of ideal codecs through which the desired analogue points could be derived.

The term ‘‘virtual analogue switching points’’ is also used for all-analogue situations and replaces the older term ‘‘virtual switching points’’.

Figure 5/G.101, p.27

Figure 5/G.101 (fin) p.28

5.2 *Relative level specified in the virtual analogue switching points of international circuits*

The virtual analogue switching points of an international 4-wire telephone circuit are fixed by convention at points of the circuit where the nominal relative levels at the reference frequency are:

— sending: —3.5 dBr;

— receiving: —4.0 dBr, for analogue or mixed analogue/digital circuits;

—3.5 dBr for digital circuits or for the very short circuits mentioned under Note 3 below.

The nominal transmission loss of this circuit at the reference frequency between virtual analogue switching points is therefore 0.5 dB for analogue and 0 dB for digital circuits.

Note 1 — See the definition in § 5.3 below. The position of the virtual analogue switching points is shown in Figure 2/G.101, and in Figure 1/G.122.

Note 2 — Since the 4-wire terminating set forms part of national systems and since its actual attenuation may depend on the national transmission plan adopted by each Administration, it is no longer possible to define the relative levels on international 4-wire circuits by reference to the 2-wire terminals of a terminating set. In particular, the transmission loss in terminal service of the chain created by connecting a pair of terminating sets to a 4-wire international circuit cannot be fixed at a single value by Recommendations. The virtual analogue switching points of circuits might therefore have been chosen at points of arbitrary relative level. However, the values adopted above are such that in general they permit the passage from the old plan to the new to be made with the minimum amount of difficulty.

Note 3 — If a 4-wire analogue circuit forming part of the 4-wire chain contributes negligible delay and variation of transmission loss with time, it may be operated at zero nominal transmission loss between virtual analogue switching points. This relaxation refers particularly to short 4-wire tie-circuits between switching centres — e.g., circuits between two international switching centres in the same city.

5.3 *Definitions*

5.3.1 **transmission reference point**

F: point de référence pour la transmission

S: punto de referencia para la transmisión

A hypothetical point used as the zero relative level point in the computation of nominal relative levels. At those points in a telephone circuit the nominal mean power level (—15 dBm) defined in Recommendation G.223 [3] shall be applied when checking whether the transmission system conforms to the noise objectives defined in Recommendation G.222 [4].

Note — For certain systems, e.g. submarine cable systems (Recommendation G.371 [5]), other values apply.

Such a point exists at the sending end of each channel of a 4-wire switched circuit preceding the virtual switching point; on an international circuit it is defined as having a signal level of +3.5 dB above that of the virtual switching point.

In frequency division multiplex equipment, a hypothetical point of flat zero relative level (i.e. where all channels have the same relative level) is defined as a point where the multiplex signal, as far as the effect of intermodulation is concerned, can be represented by a uniform spectrum random noise signal with a mean power level as defined in Recommendation G.223 [6]. The nominal mean power level in each telephone channel is —15 dBm as defined in Recommendation G.223 [3].

5.3.2 **relative (power) level**

F: niveau relatif de puissance

S: nivel relativo (de potencia)

5.3.2.1 *Basic significance of relative level in FDM systems*

The relative level at a point in a transmission system characterizes the signal power handling capacity at this point with respect to the conventional power level at a zero relative level point

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Taking into account such aspects as (basic) noise, intermodulation noise, peak power, etc. (see Recommendation G.223).

If, for example, at a particular point an FDM system designed for a large number of channels the mean power handling capacity per telephone channel corresponds to an absolute power level of S dBm, the relative level associated with this point is (S + 15) dBr. In particular, at 0 dBr point, the conventional mean power level referred to one telephone channel is —15 dBm.

5.3.2.2 *Definition of relative level, generally applicable to all systems*

The relative level at a point on a circuit is given by the expression $10 \log_{10} (P/P_0)$ dBr, where P represents the power of a sinusoidal test signal at the point concerned and P_0 the power of that signal at the transmission reference point. This is numerically equal to the composite gain (definition in *Yellow Book*, Fascicle X.1) between the transmission reference point and the point concerned, for a nominal frequency of 1000 Hz. For example, if a reference signal of 0 dBm at 1000 Hz is injected at the transmission reference point, the level at a point of x dBr will be x dBm (apparent power $P_x = 10^{x/10}$ mW). In addition, application of a digital reference sequence (DRS, § 5.3.3) will give a level of x dBm at a point of x dBr. The voltage of a 0 dBm0 tone at any voiceband frequency at a point of x dBr is given by the expression:

$$V = \sqrt{10^{x/10} \times 1\ \mathrm{W} \times 10^{-3} \times |Z_R|_{1000}} \ \text{volts}$$

where $|Z_R|_{1000}$ is the modulus of the nominal impedance of the point at a nominal frequency of 1000 Hz.

Note 1 — The nominal reference frequency of 1000 Hz is in accordance with Recommendation G.712, § 16. For existing (analogue) transmission systems, one may continue to use a reference frequency of 800 Hz.

Note 2 — The relative levels at particular points in a transmission system (e.g. input and output of distribution frames or of equipment like channel translators) are fixed by convention, usually by agreement between manufacturers and users.

The recommendations of the CCITT are elaborated in such a way that the absolute power level of any testing signal to be applied at the input of a particular transmission system, to check whether it conforms to these recommendations, is clearly defined as soon as the relative level at this point is fixed.

Note 3 — The impedance Z_R may be resistive or complex; in the latter case the power P_x is an apparent power.

Note 4 — It is assumed that between the virtual analogue switching points of a circuit, established over international transmission systems, only points of equal relative level are interconnected in those systems, so that the transmission loss of the circuit will be equal to the difference in relative levels at the virtual analogue switching points (see § 5.2 of this Recommendation).

5.3.2.3 *Relation between corrected send reference equivalents, loudness ratings and relative levels*

The relationship between the 0 dBr point and the level of T_{max} in PCM encoding/decoding processes standardized by the CCITT is set forth in Recommendation G.711 [2]. In particular, if the minimum nominal corrected send reference equivalent (CSRE) of local systems referred to a point of 0 dBr of a PCM encoder is not less than 3.5 dB, or the minimum nominal send loudness rating (SLR) under the same conditions is not less than —1.5 dB, and the value of T_{max} of the process is set at +3 dBm0 (more accurately 3.14 dBm0 for A-law and 3.17 for µ-law), then in accordance with § 3 of Recommendation G.121, the peak power of the speech will be suitably controlled.

5.3.2.4 *Compatibility of relative levels of analogue and digital systems*

When the signal load is controlled as outlined in § 5.3.2.3, points of equal relative levels of FDM and PCM circuits may be directly connected together and each will respect the other’s design criteria. This is of particular importance when points in the two multiplex hierarchies are connected together by means of transmultiplexers, codecs or modems.

5.3.2.5 *Determination of relative level*

Figure 6/G.101 illustrates the principle of how the relative level at the input and output analogue points of a ‘‘real’’ codec can be determined.

Figure 6/G.101, p.

When using Figure 6/G.101 to determine the relative levels of a ‘‘real’’ codec with non-resistive impedances at the analogue input and output ports, the following precautions must be observed:

i) the test frequency should be 1000 Hz with a suitable offset;

ii) the power at points *s* | nd *r* | s expressed as apparent power , i.e.

$$\text{Apparent power level} = 10 \log_{10} \left[\frac{Voltage\ at\ point)^2 \times 10^{3}}{Modulus\ of\ nominal\ impedance\ at\ 1000\ Hz)(1\ W)} \right] \text{dBm}$$

iii) point *r* | s terminated with the nominal design impedance of the decoder to avoid significant impedance mismatch errors.

Note — Precautions ii), iii) above are, of course equally applicable to the case of resistive input and output impedances and would generally be observed by conventional test procedures. Standardizing the reference frequency as in i) above is, however, essential for complex impedances because of the variation of nominal impedance with the test frequency.

5.3.2.6 *Relative level of a point in a digital link*

The relative level to be associated with a point in a digital path carrying a digital bit stream generated by a coder lined-up in accordance with the principles of § 5.3.2.3 above is determined by the value of the digital loss or gain between the output of the coder and the point considered. If there is no such loss or gain the relative level at the point considered is, by convention, said to be 0 dBr.

The equivalent absolute power level of a digital link may be established as in Figure 7/G.101 by using an ideal decoder relative level at a point X in the bit stream can then be assigned by comparing the power at the output of the ideal decoder with that at the analogue zero relative level point originating the digital signal.

5.3.3 **PCM digital reference sequence (DRS)**

F: s´equence num´erique de r´ef´erence MIC

S: secuencia de referencia digital MIC (SRD)

5.3.3.1 A PCM digital reference sequence is one of the set of possible PCM code sequences that, when decoded by an ideal decoder, produces an analogue sinusoidal signal at the agreed test reference frequency (i.e. a nominal 800 or 1000 Hz signal suitably offset) at a level of 0 dBm0.

Conversely an analogue sinusoidal signal at 0 dBm0 at the test reference frequency applied to the input of an ideal coder will generate a PCM digital reference sequence.

Some particular PCM digital reference sequences are defined in Recommendation G.711 [2] in respect to A-law and μ-law codecs.

Figure 7/G.101, p.30

5.3.3.2 In studying circuits and connections in mixed analogue/digital networks, use of the digital reference sequence can be helpful. For example, Figure 8/G.101 shows the various level relationships that one obtains (conceptually) on a Type 2 international circuit where one end terminates at a digital exchange and the other end at an analogue exchange. In the example of Figure 8/G.101, the analogue portion is assumed to require a loss of 0.5 dB and that provision for this loss is made by introducing a 1.0 dB pad (0.5 dB for each direction of transmission) in the receive direction at the analogue exchange. This has been deliberately chosen to illustrate the utility of the concept of a digital reference sequence.

Figure 8/G.101 gives an example where all the analogue loss is introduced in the output direction at the analogue exchange. In this case the relative levels at the various codecs can be derived from either the DRS or the transmission reference point at the input of the international circuit with no ambiguity.

If, however, in Figure 8/G.101 the analogue circuit section is lined up so as to give an overall loss in the direction b_1—a_2, care must be taken in the use of the DRS. In this case the 0 dBm0 sinusoidal reference signal and DRS may result in different levels at the point a_2. Account should be taken of this effect when designing lining-up procedures for mixed analogue/digital circuits.

As a general principle, the relative levels on a mixed analogue/digital circuit should be referred to the transmission reference point at the input of the circuit.

5.3.4 **circuit test access point**

The CCITT has defined circuit test access points as being ‘‘4-wire test-access points so located that as much as possible of the international circuit is included between corresponding pairs of these access points at the two centres concerned’’. These points, and their relative level (with reference to the transmission reference point), are determined in each case by the

Administration concerned. They are used in practice as points of known relative level to which other transmission measurements will be related. In other words, for measurement and lining-up purposes, the relative level at the appropriate circuit test access point is the relative level with respect to which other levels are adjusted.

5.3.5 *Measurement frequency*

For all international circuits 800 Hz is the recommended frequency for single-frequency maintenance measurements between the Administrations concerned, 1000 Hz may be used for such measurements.

A frequency of 1000 Hz is in fact now widely used for single-frequency measurements on some international circuits.

Multifrequency measurements made to determine the loss/frequency characteristic will include a measurement at 800 Hz and the frequency of the reference measurement signal for such characteristics can still be 800 Hz.

Note 1 — Definitions of §§ 5.3.1 and 5.3.2 are used in the work of Study Group XII. Definitions of §§ 5.3.4 and 5.3.5, taken from Recommendations M.565 [7] and M.580 [8], are included for information.

Note 2 — In order to take account of PCM circuits and circuit sections, the nominal frequencies 800 Hz and 1000 Hz are in fact offset by appropriate amounts to avoid interaction with the sampling frequency. Details can be found in Supplement No. 3.5 to Volume IV [9].

5.4 *Interconnection of international circuits in a transit centre*

In a transit centre , the virtual analogue switching points of the two international circuits to be interconnected are considered to be connected together directly without any additional loss or gain. In this way a chain of international circuits has a nominal transmission loss in transit equal to the sum of the individual circuit losses.

Figure 8/G.101, p.

References

[1] CCITT Recommendation *Transmission Plan* , Vol. VI, Rec. Q.40.

[2] CCITT Recommendation *Pulse Code Modulation (PCM) of Voice Frequencies* , Vol. III, Rec. G.711.

[3] CCITT Recommendation *Assumption for the Calculation of Noise on Hypothetical Reference Circuits for Telephony* , Vol. III, Rec. G.223, § 1.

[4] CCITT Recommendation *Noise Objectives for Design of Carrier-Transmission Systems* , Vol. III, Rec. G.222.

[5] CCITT Recommendation *Carrier Systems for Submarine Cable* , Vol. III, Rec. G.371.

[6] CCITT Recommendation *Assumption for the Calculation of Noise on Hypothetical Reference Circuits for Telephony* , Vol. III, Rec. G.223, § 2.

[7] CCITT Recommendation *Access points for international telephone circuits* , Vol. IV, Rec. M.565.

[8] CCITT Recommendation *Setting-Up and Lining-Up an International Circuit for Public Telephony* , Vol. IV, Rec. M.580.

[9] *Test frequencies on circuits routed over PCM systems* , Vol. IV, Supplement No. 3.5.

[10] CCITT Recommendation *12-Channel Terminal Equipments* , Vol. III, Rec. G.232, § 11.

Recommendation G.102

TRANSMISSION PERFORMANCE OBJECTIVES AND RECOMMENDATIONS

(Geneva, 1980)

1 General

The CCITT has drawn up (or is in the process of studying) Recommendations concerning transmission impairments and their permissible magnitude with the object of achieving satisfactory performance of the network. Such impairments include for example:

a) loudness rating (LR) and loss,

b) noise,

c) attenuation distortion,

d) crosstalk,

e) single tone interference,

f) spurious modulation,

g) effects of errors in digital systems.

Some Recommendations state objectives for an impairment with the implicit assumption that other impairments are at their maximum value (e.g. noise and loss).

In many instances the objectives are based primarily on telephony; this however may require special measures to be applied when other, more demanding services (e.g. sound-programme transmission) are to be incorporated within the network or constituent parts thereof.

The following distinctions may be made between different types of objectives:

1) performance objectives for networks,

2) performance objectives for circuits, transmission and switching equipment,

3) design objectives for transmission and switching equipment,

4) commissioning objectives for circuits, transmission and switching equipment,

5) maintenance/service limits for circuits, transmission and switching equipment.

2 Explanation of a performance objective

The performance objective for a measurable transmission impairment for networks, entire connections, national systems forming part of international connections, international chains of circuits, individual circuits etc. often describes in statistical terms (mean value, standard deviation, or probability of exceeding stated value, etc.) the value to be aimed at in transmission network and systems planning. It describes the performance which, based for example on subjective or other performance assessment tests, it is desirable to aim at in order to offer the user a satisfactory service.

The items (circuits, systems, equipments) making up the network are normally assumed to have a performance related to that recommended by the performance objectives. Traffic weighting will, in some cases, be applied to calculations.

A powerful set of tools which may be used in analyses concerning network objectives and compliance therewith are the hypothetical reference connections described in Recommendation G.103.

3 Explanation of a design objective

The ‘‘design objective’’ for a measurable transmission impairment (e.g. noise, error-rate, attenuation-distortion) for an item of equipment (e.g. a line system, a telephone exchange) is its value when the item is operating in certain electrical/physical environments which might be defined by such parameters as power supply voltage, signal load, temperature, humidity, etc. Some of these parameters may be the subject of CCITT Recommendations and some may not, and it is for the Administrations to assign values to them when they prepare specifications. A suitable allowance may also be made for aging. The most adverse combination of the specified parameters is often assumed.

The purpose of a ‘‘design objective’’ is to provide a basis for the design of an item with respect to the quantity concerned. The significance of the design objective for an item, and examples of the relative frequency of impairment values, are illustrated in Figures 1/G.102 and 2/G.102 respectively.

Design objectives will in many cases directly form the basis of a specification clause for the development and/or the purchase of equipments.

A powerful set of tools used in connection with applying design objectives are the hypothetical reference (HR) circuits and hypothetical reference (HR) digital paths (see relevant Recommendations in the G.100 and G.700 Series).

4 Explanation of a commissioning objective

The conditions encountered on real circuits and installed equipment may differ from the assumptions valid for the HR circuits and for the design of equipment. Therefore the performance to be expected at the time of commissioning cannot be deduced uniquely from Recommendations relating to HR circuits. Suitable allowances may have to be made for such matters as circuits being made up of equipments of different design, line systems differing substantially in length from a homogeneous section, etc. (see for example Recommendation G.226 [1] for noise on real links).

Commissioning objectives are not normally the subject of CCITT Recommendations.

5 Explanations of limits for maintenance purposes

In service, the performance of an item or assembly of items may deteriorate for various reasons: aging, excessive loading, excessive environmental conditions, operations errors, components failures, etc. and there is an economic penalty in service costs if such deterioration is always to be kept negligibly small. Therefore design objectives are chosen to confer as great a margin as possible to assure a satisfactory in-service performance.

Figure 1/G.102, p.32

With transmission impairments, there is often no value which represents a clear boundary between ‘‘tolerable’’ and ‘‘unusable’’ performance and in practice a range of impairments in excess of those provided by design objectives will give satisfactory service to customers. This is the case for telephony but for other services may be different.

Nevertheless it is often expedient to define a particular value of impairment above which the item is deemed to be ‘‘unusable’’ and at which the item will be withdrawn from service at the first opportunity so that remedial action can be taken to restore the performance to comply with some defined limit (e.g. limit for prompt maintenance action).

It is often useful to define a performance limit at which attention is alerted but (perhaps) no action is taken immediately (e.g. limit for deferred maintenance action).

These limits are usually independent of the type of service carried by that particular entity. However, it is sometimes necessary to define a performance limit for a particular type of service, beyond which the customer is no longer offered a satisfactory service quality. This limit may differ for various services; some may coincide with a prompt maintenance limit (service limit).

These limits (and others, if necessary) would fall above the design objective. These limits are illustrated in Figure 1/G.102 and a generic title for them is ‘‘maintenance limits’’.

Figure 2/G.102, p.33

Reference

[1] CCITT Recommendation *Noise on a real link* , Vol. III, Rec. G.226.

Recommendation G.103

HYPOTHETICAL REFERENCE CONNECTIONS

(Mar del Plata, 1968; amended at Geneva, 1972, 1976 and 1980;

at Malaga-Torremolinos, 1984)

This Recommendation mainly deals with the analogue network , Recommendation G.104 deals with the wholly digital network and § 4 of this Recommendation deals with the transitional problems when some digital circuits are introduced into the analogue network. Ultimately, it is envisaged that all reference connections, whether they refer to analogue or digital systems, will be combined within one Recommendation.

1 Purpose

A hypothetical reference connection for transmission impairment studies is a model in which the impairments contributed by circuits and exchanges are described.

Such a model may be used by an Administration:

— to examine the effect on transmission quality of possible changes of routing structure, noise allocations and transmission losses in national networks, and

— to test national planning rules for *prima facie* | ompliance with any statistical impairment criteria which may be recommended by the CCITT for national systems.

For these purposes, several models are desirable. The three hypothetical reference connections described below should encompass most of the studies required to be undertaken.

Hypothetical reference connections are *not* | o be regarded as recommending particular values of loss or noise or other impairments, although the various values quoted are in many cases recommended values. Hypothetical reference connections are *not* intended to be used for the design of transmission systems.

2 Composition of hypothetical reference connections

2.1 The composition of the various connections is defined in Figures 1/G.103, 2/G.103 and 3/G.103.

Figure 1/G.103 — The longest international connection with the maximum number of international and national circuits expected to occur in practice. Such a connection would typically have high corrected reference equivalents and high noise contributions, and the noise contribution from international circuits may be significant. The attenuation distortion, group delay, and group-delay distortion would also all be extremely high. Such connections are rare.

Figure 2/G.103 — An international connection of moderate length (say, not longer than 2000 km) comprising the most frequent number of international and national circuits. In such a connection, the noise contribution of the national systems would be expected to predominate. Such a connection is used in a large proportion of international calls.

Figure 3/G.103 — An international connection comprising the practically maximum number of international circuits and the least number of national circuits. Such connections are numerous.

2.2 *The following General Remarks apply to Figures 1/G.103, 2/G.103 and 3/G.103*

2.2.1 The hypothetical reference connections show the international circuits connected together at 0 dBr and —0.5 dBr virtual switching points instead of —3.5 dBr and —4 dBr points. This was felt to be more directly useful to those who might have to use the reference connections in their studies.

It might be felt that it is somewhat inconsistent that the hypothetical reference connections do not use ‘‘conventional’’ —3.5/—4 dBr virtual switching points. However, if the reference connections are drawn using that convention, the noise power figures appearing on the diagram can no longer be the familiar ones that appear elsewhere in other Recommendations. Annex A gives further explanations.

2.2.2 The nomenclature is based on the international routing plan recommended in Recommendation E.171, i.e. ISC = International Switching Centre (formerly referred to as CT3), ITC = International Transit Centre.

2.2.3 In each case only one direction of transmission is shown.

2.2.4 The design objectives for the mean noise powers are indicated according to current recommendations. For long-distance carrier circuits they are proportional to length, the appropriate noise power rate , 4 pW/km or 1 pW/km, being used according to whether the basic hypothetical reference circuit is one 2500 km long or 7500 km long.

2.2.5 The abbreviation pW0p stands for picowatts psophometric referred to a point of zero relative level. In the case of exchange noise , the point referred to is considered to be in the circuit immediately downstream, of the exchange. The noise powers for circuits are referred to points of zero relative level in the circuits themselves and not to some point on the connection.

FIGURE 1/G.103, p.34

FIGURE 2/G.103, p.35

FIGURE 3/G.103, p.36

REMARQUES AUX FIGURES 1/G.103, 2/G.103, 3/G.103, p.37

2.2.6 The pad symbols represent the nominal loss of the particular channel or circuit, and the relative position of the noise generator, and the pad indicates that if the noise is to be referred to the receiving end of a circuit it must be modified by the power ratio corresponding to the loss of the pad.

If it is required to refer the noise powers to some particular point on the connection (for example, the receiving local exchange or the point of zero relative level on the first international circuit) then the rule to be applied is as follows:

If a noise power level at a point A | s to be referred to a point B downstream of its position, it is obtained by augmenting the level at point B by the sum of the losses that is imagined to be traversed from A to B . If it is to be referred to a point C upstream of its position, it is obtained by diminishing the level at point C by the sum of all the losses that is imagined to be traversed from A to C .

2.2.7 The nominal terminal loss of the connection [i.e. the normal overall loss less the sum of the transit losses (via net losses) of the individual circuits] is shown as one pad associated with the extreme right-hand circuit in the 4-wire chain. This artifice enables the noise powers to be indicated as if they were injected at zero relative level points on the individual circuits as explained in Annex A.

2.2.8 Information concerning the distributions of attenuation distortion and group-delay distortion is to be found in Annex A of Recommendation G.113. Calculated values of some possible combinations of basic transmission impairments are given in Supplement No. 20, *Red Book* , Fascicle III.1.

Recommendation G.114 gives information concerning group delay.

2.2.9 The standard deviation of transmission loss of circuits is in accord with the objectives of Recommendation G.151 § 3 and also with the results obtained in practice and specified in [1].

2.2.10 ‘‘Circuit’’ in these reference connections is defined in the sense of Recommendation M.700 [2] as the whole of the line and the equipment proper to the line; it extends from the switches of one exchange to the switches of the next. In this way switching and exchange cabling losses are included in the values of transmission loss assigned to the circuits, together with the loss (or gain) introduced by the transmission system. If it is required to separately distinguish exchange losses, an additional pad symbol of appropriate value may be used.

It should also be noted that, according to this convention, the 3.5-dB loss ordinarily assigned to a terminating set does not figure explicitly in 2-wire/4-wire circuits; its value is also included in the loss assigned to the circuit.

3 Number of modulation and demodulation equipments

For the study of transmission performance, the longest international connection expected to occur (see Figure 1/G.103) may be considered to have the following arrangement of modulator/demodulator pairs in the 4-wire chain.

H.T. [T1.103]

TABLE 1/G.103

{ Number of modulator/demodulator pairs in a wholly analogue 4-wire chain } Eight national circuits	Circuits between ISCs	Total	
Channel	8	4	12
Group	12	10	22
Supergroup	16	20	36

Table 1/G.103 [T1.103], p.

Of the 12 channel modulator/demodulator pairs a maximum of three may be of the special type which provide more than 12 telephone circuits per group.

4 Developments arising from the introduction of PCM digital processes

The worldwide telephone network is undergoing a transition from what is largely an analogue network to a mixed analogue/digital network. Looking farther into the future, this transition is expected to continue and result in a network that would be predominantly digital. Background on this transitional process is given in Recommendations G.101, § 4.1 and G.104.

With reference to the hypothetical reference connections of Figures 1/G.103, 2/G.103 and 3/G.103, the configurations used concerning numbers of circuits and numbers of exchanges should also be appropriate for network conditions in the mixed analogue/digital period. However, for transmission studies pertaining to mixed analogue/digital connections, account must also be taken of all unintegrated digital processes that might be present. Such unintegrated digital processes could have an important effect on overall transmission performance particularly with regard to such parameters as quantizing distortion (Recommendation G.113), and transmission delay. Guidance is provided on the use of appropriate hypothetical reference connections for a mixed analogue/digital network in Annex B.

Where the worldwide network becomes all-digital, many of the transmission impairments that were present in the mixed analogue/digital period, due to the incorporation of unintegrated digital processes, would be eliminated. However, certain processes might remain which could introduce transmission penalties. These are the processes which operate on the basis of recoding the bit stream as is done, for example, in the case of digital pads. Although the accumulated transmission impairments introduced by such processes may be well within recommended limits, the resulting loss of bit integrity could be an important disadvantage. This is particularly true in the case of services requiring the preservation of bit integrity on an end-to-end basis. Consequently, processes of this type should be avoided where possible, or appropriate arrangements made to circumvent them, where services requiring bit integrity are to be carried over the affected connections.

ANNEX A
(to Recommendation G.103)

An explanation of how hypothetical reference connections can be drawn

assuming all
send switching levels are 0 dBr

A.1 Consider the connection shown in Figure A-1/G.103 in which 3 circuits with losses of 1 dB, 6 dB and 2 dB are connected together by exchanges with actual send switching levels of —2, +1 and —3 dBr.

Figure A-1/G.103 p.

A.2 We assume that noise powers of these circuits are N_1, N_2 and N_3 pW0p respectively. Figure A-2/G.103 shows these noise powers entering their circuits via appropriately valued pads chosen to take cognizance of the switching level concerned and dispense with the arrow symbols.

Figure A-2/G.103 p.

A.3 We note that N_1 traverses a total of 11 dB to reach E_4, N_2 a total of 7 dB, and N_3 a total of 5 dB. Also the difference between the accumulated send loudness rating (SLR) at each exchange and the corresponding circuit noise level is 6 dB (for N_1), 10 dB (for N_2) and 12 dB (for N_3). Hence we may redraw the connection reallocating the losses as shown in Figure A-3/G.103 in which all send switching levels are 0 dBr and all the other conditions are met as well.

Figure A-3/G.103 p.

A.4 Since the relative level of the immediate downstream circuit at each switch point is now arranged to be 0 dBr, the exchange noise powers can be added as is done in the hypothetical reference connections in Recommendation G.103.

ANNEX B

(to Recommendation G.103)

Guidance on hypothetical reference connections

for a
mixed analogue/digital connection

This annex provides guidance on a method to model a mixed analogue/digital network. For simplicity and for ease of comparison with an all-analogue network, retention of the network configurations now given in Figures 1/G.103 to 3/G.103 is appropriate. Figures 1/G.103 and 2/G.103, in particular, represent respectively, examples of the longest, though infrequent, type of connection and a connection of moderate length which occurs most frequently. The three connections provide an adequate range of connection types for most purposes but some guidance is desirable with respect to the selection of the circuits and exchanges which should be analogue and those which should

be digital. This choice may depend on

the matter under study. Two examples are designated for each of the connections: one which maximizes the number of digital processes and one which would be more representative of an evolving network. The worst case situation can be represented by making all of the exchanges digital and leaving all of the circuits analogue. A set of more representative connections is obtained by defining islands of digital connectivity such that the number of independent digital processes in each connection is approximately one-half of the maximum. For the representative connections all exchanges are assumed to be digital. In addition, the specific circuits designated in Table B-1/G.103 are also assumed to be digital with digital connection to the digital switches at each end of the circuit. This has the effect of creating ‘‘ digital islands ´processes, such that each island may be regarded as a single digital process.

H.T. [T2.103]

TABLE B-1/G.103

{ Assumed digital circuits (listed from top to bottom) }		
Figure 1/G.103	Figure 2/G.103	Figure 3/G.103

PC to SC
TC to QC
1st ISC to 2nd ISC
2nd ISC to 4th ISC | ua)
}
4th ISC to 5th ISC
QC to TC
{
SC to PC
a)
Single digital island.
}
	PC to ISC
	ISC to PC
		LE to ISC
		{
		ISC to LE

Note — For an explanation of abbreviations, see Figure 1/G.103.

Table B-1/G.103 [T2.103], p.

References

[1] CCITT *Green Book* , Vol. IV.2, Section 4, Supplements, ITU, Geneva, 1973.

[2] CCITT Recommendation *Definitions for the maintenance organization* , Vol. IV, Rec. M.700.

[3] CCITT manual *Transmission planning of switched telephone networks* , ITU, Geneva, 1976.

[4] CCITT Recommendation *Transmission characteristics of an international exchange* , Vol. VI, Rec. Q.45.

Recommendation G.105

HYPOTHETICAL REFERENCE CONNECTION FOR CROSSTALK STUDIES

(Geneva, 1980)

1 Purpose

This Recommendation gives guidance concerning the application of Recommendation P.16 [1] in the general switched telephone network and recommends the structure and parameters of a hypothetical reference connection specifically designed for crosstalk studies.

2 General remarks

2.1 *Accuracy of fundamental data*

2.1.1 There is always some degree of uncertainty in applying to real telephone conversation the results of tests in which subjects were asked to listen attentively to see if they were able to detect the presence of intelligible crosstalk. Furthermore, this type of test cannot be expected to indicate reliably the extent to which a subscriber’s confidence in the privacy of his own conversation is undermined by overhearing another conversation. Hence in general the aim should be to reduce the risk of potentially intelligible crosstalk as much as possible.

2.1.2 In applying the calculation method given in Recommendation P.16 [1], errors can occur if the distributions of crosstalk attenuations and loudness ratings are skew, rather than normal, or are truncated by test acceptance procedures. This arises because we are generally seeking low probabilities of encountering intelligible crosstalk which are highly dependent on the tails of distributions being accurately defined. One way of avoiding this difficulty is to apply Monte-Carlo methods as described, for example, in the CCITT manual cited in [2], taking care to make enough iterations to secure the necessary accuracy.

2.1.3 Considerable care must be taken to obtain representative values of the loss and noise in crosstalk paths being studied. In particular, errors arising from small changes in mean values can easily result in the calculated probability of overhearing being in error by a factor of 10 or more (see, for example, [3]).

2.2 *Effect of line and room noise*

2.2.1 The masking effect of line noise is another aspect which is important and raises some difficulties. On the one hand if, for the purpose of establishing crosstalk limits, the level of line noise is assumed to be negligible, unrealistic demands may be placed on the crosstalk attenuation required to be introduced by items of plant. On the other hand, if it is assumed that circuits and exchanges in service introduce noise power levels comparable with their design objectives, e.g. the well known 4 pW0p/km, the incidence of overhearing may be unacceptably high, particularly when the network is lightly loaded so that noise power levels can be expected to be at their lowest.

As in many transmission studies, a compromise has to be made somewhere between these extremes. In some cases, it may be necessary to rely on measurements of noise power levels on established plant during light and busy traffic periods. However, it must not be overlooked that limits devised now must, if possible, take the future into account. It is a wise principle that the successful performance of equipment in one part of the network should not be dependent upon adventitious imperfections of other parts of the network, particularly if such imperfections are likely to be eliminated or reduced in the future, e.g. by new designs of local exchange or by the extensive use of digital long-distance transmission systems.

2.2.2 Unlike line noise the effect of room noise can be reduced by a determined listener. Hence Recommendation P.16 [1] recommends that negligible room noise be assumed when deriving a design objective for equipment.

2.3 *Probabilities and distributions involved*

2.3.1 When constructing the distribution of crosstalk attenuation introduced by equipment and cables, it is appropriate to consider only the worst (acceptable) values. For example, in a 10-pair cable only the worst disturber for each pair should be taken into account, i.e. 10 values. This distribution should not be diluted by the other 80 better values. In the busy period the worst potential disturber of a particular pair can be relied upon to be activated.

2.3.2 In respect of intelligible crosstalk between local calls established in the same local exchange network, the probability of a potentially disturbing subscriber making a call at the same time as the disturbed subscriber can be significantly low certainly in the case of residential subscribers, although this is probably not the case for business subscribers and PBXs. Information concerning this topic and showing how to calculate the probabilities concerned will be found in [4].

2.3.3 Multiple entries into a telephone connection of intelligible crosstalk signals all at significant levels and all derived from one source is so unlikely an event that it may be ignored for the purposes of deriving design limits. Hence the crosstalk mechanism of interest is assumed to be the dominant one when deriving limits, and all other sources are deemed to be negligible, and may thus attract the whole of the allowance.

However, when a network performance objective for crosstalk has to be divided among the exchanges and circuits making up the connection, it may be necessary to give some consideration to the number of potential crosstalk paths from different sources. For example, crosstalk limits may be assigned to complete paths through an exchange and to complete junction or trunk circuits. Thus, on simple other-exchange connections (ignoring, for the moment, crosstalk arising within local cables) there are three dominant sources of crosstalk, and if, for example, the aim were to be not greater than 1 in 100 for such connections, the probability of overhearing from each source should be reduced to 1 in 300 (assuming equal probabilities and no correlation between the sources).

Figures 1/G.105 and 2/G.105 illustrate some crosstalk paths of significance.

3 Hypothetical reference connections for crosstalk

Figure 3/G.105 illustrates the essential elements of two hypothetical reference connections appropriate to crosstalk studies in respect of telephone circuits and exchanges. It will be observed that the connections are much simpler than the corresponding ones in Recommendation G.103 used for studying noise and loss. It would be inappropriate to study the risk of potentially intelligible crosstalk between a pair of 12-circuit connections of near maximum length and noise, in order to arrive at, for example, a limit for channel equipment crosstalk, because the majority use of the channel equipment bought and installed to the specification is in much simpler, quieter, and more numerous connections.

Figure 1/G.105, p.43

Figure 2/G.105, p.44

Figure 3/G.105, p.45

References

[1] CCITT Recommendation *Subjective effects of direct crosstalk; Thresholds of audibility and intelligibility* , Vol. V, Rec. P.16.

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

[3] *Social Crosstalk in the Local Area Network* , Electrical Communication (ITT), Vol. 49, No. 4, pp. 406-417, 1974.

[4] LAPSA (P. | .): Calculation of multidisturber crosstalk probabilities, *Bell System Technical Journal* , Vol. 55, No. 7, September 1976.

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