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7.4 Principal characteristics of second order multiplex equipments

Recommendation G.741

GENERAL CONSIDERATIONS ON SECOND ORDER MULTIPLEX EQUIPMENTS

(Geneva, 1972; further amended)

The CCITT,

considering

(a) that different primary and second order multiplex equipments exist, depending upon the characteristics of different networks and the various types of signals to be transmitted in those networks;

(b) that, although studies will continue with the aim of reducing the differences between various systems, the existing situation cannot be changed in the near future;

recommends the following

(1) when two countries, both using 2048 kbit/s primary multiplex equipments such as the PCM multiplex equipment according to Recommendation G.732, have to be connected by a digital path at the second order bit rate, that bit rate should be 8448 kbit/s;

(2) when two countries, both using 1544 kbit/s primary multiplex equipments such as the PCM multiplex equipment according to Recommendation G.733, have to be connected by a digital path at the second order bit rate, that bit rate should be 6312 kbit/s.

In the meantime, it is extremely desirable to define a preferred method of interconnecting different systems.

Recommendations G.742 and G.743 give the characteristics of second order digital multiplex equipments using positive justification, and Recommendation G.745 gives the characteristics of second order multiplex equipment using positive/zero/negative justification. Recommendations G.744, G.746 and G.747 give the characteristics of second order PCM multiplex equipments. Paragraphs 2 and 4 of Recommendation G.705 give the characteristics required to terminate 6312 kbit/s and 8448 kbit/s digital paths on a digital exchange.

Recommendation G.742

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 8448 kbit/s

AND USING POSITIVE JUSTIFICATION

(Geneva, 1972; further amended)

1 General

The second order digital multiplex equipment using positive justification, described below, is intended for use on digital paths between countries using 2048 kbit/s primary multiplex equipments.

2 Bit rate

The nominal bit rate should be 8448 kbit/s.

The tolerance on that rate should be ± | 0 parts per million (ppm).

3 Frame structure

Table 1/G.742 gives:

— the tributary bit rate and the number of tributaries;

— the number of bits per frame;

— the bit numbering scheme;

— the bit assignment;

— the bunched frame alignment signal.

H.T. [T1.742]
TABLE 1/G.742
8448-kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	2048
Number of tributaries	4
Frame structure	Bit number
	Set I
{ Frame alignment signal (1111010000) }	1 to 10
{ Alarm indication to the remote digital multiplex equipment }	11
Bit reserved for national use	12
Bits from tributaries	13 to 212
	Set II
{ Justification control bits C *1 (see Note)* }	*1 to 4*
Bits from tributaries	*5 to 212*
	Set III
{ Justification control bits C *2 (see Note)* }	*1 to 4*
Bits from tributaries	*5 to 212*
	Set IV
{ Justification control bits C *2 (see Note)* }	*1 to 4*
{ Bits from tributaries available for justification }	*5 to 8*
Bits from tributaries	*9 to 212*
Frame length	*848 bits*
Bits per tributary	*206 bits*
{ Maximum justification rate per tributary }	*10 kbit/s*
Nominal justification ratio	*0.424*

Note — C *j* *i* indicates the *i* th justification control bit of the *j* th tributary.

Table 1/G.742 [T1.742], p.

4 Loss and recovery of frame alignment and consequent action

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note — As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, see Table 1/G.742).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.742 gives the maximum justification rate per tributary and the nominal justification ratio.

6 Jitter

6.1 *Jitter transfer characteristic*

A 2048 kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 1/G.742. The equivalent binary content of the test signal should be 1000.

Figure 1/G.742, p.

6.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.25 UI when measured in the frequency range up to 100 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 18 kHz, a roll-off of 20 dB/decade and an upper limit of 100 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

Note — For interfaces meeting the national high Q option, detailed in Recommendation G.703, the lower cutoff frequency for the above measurement should be 700 Hz.

6.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 8448 kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 400 kHz.

7 Digital interfaces

The digital interfaces at 2048 kbit/s and 8448 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

9 Service digits

Two bits per frame are available for service functions. Bit 11 of Set I is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see § 10 below). Bit 12 of Set I is reserved for national use. On the digital path crossing the border, this bit is fixed at 1.

10 Fault conditions and consequent conditions

10.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of an incoming signal at 2048 kbit/s at the input of the multiplexer.

Note — Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

10.1.3 Loss of the incoming signal at 8448 kbit/s at the input of the demultiplexer.

Note 1 — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 — Where separate circuits are used for the digital signal and the timing signal, then loss of either or both should constitute loss of the incoming signal.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 8448 kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified by Table 2/G.742. The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 under § 10.2.5 below) at 8448 kbit/s is detected at the input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.742 with the fault condition.

Note — The location and provision of any visual and/or audible alarm activated by this maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 11 of Set I at the 8448 kbit/s output of the multiplexer.

10.2.3 AIS (see Notes 1 and 2 below) applied to all four 2048 kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Notes 1 and 2 below) applied to the 8448 kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 8448 kbit/s signal at the output of the multiplexer, corresponding to the relevant 2048 kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary, should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for that tributary.

H.T. [T2.742]
TABLE 2/G.742
Fault conditions and consequent actions

Equipment part	{			{		
Multiplexer and demultiplexer	Failure of power supply	Yes		Yes, if practicable	Yes, if practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes				Yes	
Demultiplexer only	{ Yes Yes	Yes Yes	Yes {	Loss of frame alignment	Yes	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Table 2/G.742 [T2.742], p.

Note 1 — The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 — The equivalent binary content of the AIS at 2048 kbit/s and 8448 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio 1 | (mu | 0 D lF261 3. However, a signal, with all bits except the frame alignment signal in the 1s state, should not be mistaken for an AIS.

10.3 *Time requirements*

The fault detection and the application of the consequent actions listed in §§ 10.2.2 to 10.2.5, including the detection of AIS, should be completed within a time limit of 1 ms.

Recommendation G.743

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 6312 kbit/s AND USING POSITIVE JUSTIFICATION

(Geneva, 1972; further amended)

1 General

The second order digital multiplex equipment using positive justification described below, is intended for use on digital paths between countries using 1544 kbit/s primary multiplex equipments.

2 Bit rate

The nominal bit rate should be 6312 kbit/s.

The tolerance on that rate should be ± | 0 parts per million (ppm).

3 Frame structure

Table 1/G.743 gives:

— the tributary bit rate and the number of tributaries;

— the number of bits per frame;

— the bit numbering scheme;

— the bit assignment;

— the distributed frame and multiframe alignment signals.

4 Loss and recovery of frame and multiframe alignment and consequent action

The frame alignment recovery time should not exceed 16 ms. The signal to be applied to the tributaries during the out-of-frame-alignment time should be studied.

Once frame alignment is established, multiframe alignment should be recovered in less than 420 micro seconds.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and use the $C_{j\backslash dn}$-bits (n = 1, 2, 3, see Table 1/G.743).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.743 gives the maximum justification rate per tributary and the nominal justification ratio.

6 Jitter

6.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 1/G.743. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length $2^{15} — 1$.

Note — The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.

H.T. [T1.743]
TABLE 1/G.743
6312-kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	1544
Number of tributaries	4
Frame structure (see Notes 1 and 2)	Bit number
	Set I
Bit for multiframe alignment signal (M_j) (see Note 1)	1
Bits from tributaries	2 to 49
	Set II
1st bit for justification control signal (C_{j1})	1
Bits from tributaries	2 to 49
	Set III
1st bit for frame alignment signal (F_0) (see Note 3)	1
Bits from tributaries	2 to 49
	Set IV
2nd bit for justification control signal (C_{j2})	1
Bits from tributaries	2 to 49
	Set V
3rd bit for justification control signal (C_{j3})	1
Bits from tributaries	2 to 49
	Set VI
2nd bit for frame alignment signal (F_1) (see Note 3)	1
Bits from tributaries (see Note 4)	2 to 49
Frame length	294 bits
Multiframe length	1176 bits
Bits per tributary per multiframe (including justification)	288 bits
Maximum justification rate per tributary	5367 bit/s
Nominal justification ratio	0.334

Note 1 — This frame is repeated 4 times to form a multiframe with designated *j*
| | , 2, 3 , 4. The multiframe alignment signal is a 011*x* -pattern. *x* may be used as an alarm service digit.

Note 2 — The bits from the second and fourth tributaries are inverted logically before multiplexing with the bits from the first and third tributaries.

Note 3 — The frame alignment is F 0 | | and F 1 | | .

Note 4 — The bit available for the justification of tributary *j* is the first time slot of tributary *j* following F 1 in the *j* th frame.

Table 1/G.743 [T1.743], p.

Figure 1/G.743 p.

6.2 *Multiplex signal output jitter*

The jitter at the 6312 kbit/s output of the multiplexer should not exceed 0.01 UI rms.

6.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

With no jitter at the input to the multiplexer and demultiplexer, the jitter at the demultiplexer output should not exceed 1/3 unit intervals peak-to-peak.

6.4 *Demultiplexer jitter transfer characteristic*

The gain of the jitter transfer characteristic should not exceed the limits given in Figure 2/G.743.

Figure 2/G.743, p.

7 Digital interfaces

The digital interfaces at 1544 kbit/s and 6312 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

9 Service digits

The service digits are reserved for national use.

10 Fault conditions and consequent actions

10.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions.

10.1.1 Failure of power supply.

10.1.2 Loss of frame alignment at the demultiplexer.

It may also be equipped to detect the following fault conditions.

10.1.3 Loss or degradation of incoming 1544 kbit/s signal.

10.1.4 Loss or degradation of incoming 6312 kbit/s signal.

10.1.5 Failure of the multiplex or demultiplex as evidenced by incorrect multiplexing or demultiplexing action.

10.1.6 Failure of standby (if the multiplex is so equipped).

10.2 *Consequent actions*

On the detection of a fault condition, the following appropriate actions should be taken:

10.2.1 For a multiplex equipped with automatic changeover, the consequent actions are specified in Table 2/G.743. For a multiplex so equipped, a switch to a standby is performed in the event of a failure of the multiplex equipment in service. A maintenance alarm is generated if a switch takes place, or if the standby fails. A prompt maintenance alarm is generated if an incoming signal fails, or if service is lost due to inability to complete automatic changeover to the standby.

10.2.2 For a multiplex not equipped with automatic changeover, a prompt maintenance alarm is generated in response to any fault condition detected. Such multiplexers will normally be equipped to detect power failure and loss or degradation of incoming signal at the demultiplexer.

10.2.3 The provision of an Alarm Indication Signal (AIS) to the 1544 kbit/s tributary outputs from the demultiplexer is under study. An AIS, suitable for use without special detectors at the primary PCM multiplex might be provided on an optional basis.

Blanc

H.T. [T2.743]

TABLE 2/G.743

Fault conditions and consequent actions for a multiplex equipped with automatic changeover

Equipment part	{	{			
Multiplexer demultiplexer	Failure of power supply	No	Yes		Yes
Multiplexer only Loss or degradation of incoming signal on a tributary }	{ Yes			No	
Demultiplexer only	{ Yes Yes	Yes	No	{	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Tableau 2/G.743 [T2.743], p. 7

Recommendation G.744

SECOND ORDER PCM MULTIPLEX EQUIPMENT OPERATING AT 8448 kbit/s

(Geneva, 1976; amended at Geneva, 1980 and at Melbourne, 1988)

1 General characteristics

1.1 *Fundamental characteristics*

The encoding law used is the A-law as specified in Recommendation G.711. The sampling rate, load capacity and the code are also specified in that Recommendation.

The number of quantized values is 256.

Note — The inversion of bits 2, 4, 6 and 8 is covered by the encoding law and is applicable only to voice-channel time slots.

1.2 *Bit rate*

The nominal bit rate is 8448 kbit/s. The tolerance on this rate is ± | 0 parts per million (ppm).

1.3 *Timing signal*

It should be possible to derive the transmitting timing signal of a PCM multiplex equipment from an internal source, from the incoming digital signal and also from an external source.

Note — Further study is required on the effect of jitter of the incoming signal on the timing signal, and on the measures to be taken in case of loss of the incoming signal or the external source.

2 Frame structure

Refer to §§ 3.4.1 and 3.4.2 of Recommendation G.704 for frame structure and use of derived channel time slots.

3 Loss and recovery of frame alignment

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

4 Fault conditions and consequent actions

4.1 *Fault conditions*

The PCM multiplex equipment should detect the following fault conditions.

4.1.1 Failure of power supply.

4.1.2 *Failure of codec (except when using single-channel codecs)*

As a minimum requirement, this fault condition should be recognized when, for at least one signal level in the range —21 to —6 dBm0, the signal-to-quantizing noise ratio performance of the local codec is 18 dB or more below the level recommended in Recommendation G.712.

4.1.3 *Loss of incoming signal at the 64 kbit/s input port (time slots 67 to 70)*

Note 1 — The detection of this fault condition is not mandatory when channel associated signalling is used and the signalling multiplex is situated within a few metres of the PCM multiplex equipment.

Note 2 — The detection of this fault condition is not mandatory when contradirectional interfaces are used.

4.1.4 Loss of the incoming signal at 8448 kbit/s.

Note 1 — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 — Where separate circuits are used for the digital signal and the timing signal, then loss of either or both should constitute loss of the incoming signal.

4.1.5 Loss of frame alignment.

4.1.6 Excessive bit error ratio detected by monitoring the frame alignment signal.

4.1.6.1 With a random bit error of 10^{-4}, the probability of activating the indication of fault condition within a few seconds should be less than 10^{-6}.

With a random bit error of ≥" 10^{-3}, the probability of activating the indication of fault condition within a few seconds should be higher than 0.95.

4.1.6.2 With a random bit error ratio of ≥" 10^{-3}, the probability of deactivating the indication of fault condition within a few seconds should be almost 0.

With a random bit error of ≥" 10^{-4}, the probability of deactivating the indication of fault condition within a few seconds should be higher than 0.95.

Note — The activating and the deactivating period specified as ‘‘a few seconds’’ is intended to be in the order of 4 to 5 seconds.

4.1.7 Alarm indication received from the remote end (see § 4.2.3 below).

4.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.744. The consequent actions are as follows:

4.2.1 Service alarm indication generated to signify that the service provided by the PCM multiplex is no longer available. This indication should be forwarded at least to the switching and/or signalling multiplex equipment depending upon the arrangements provided. The indication should be given as soon as possible and not later than 2 ms after detection of the relevant fault condition.

This specification, taking into account the specification given in § 3 above, is equivalent to recommending that the average time to detect a loss of frame alignment or a loss of the incoming 8448-kbit/s signal and to give the relevant indication should not be greater than 3 ms.

When using common channel signalling, the indication should be forwarded to the switching equipment by means of a separate interface on the PCM multiplex equipment.

4.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see General Note below to § 4.2) is detected the prompt maintenance alarm indication, associated with loss of frame alignment (see § 4.1.5 above) and excessive error rate (see § 4.1.6 above), should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 1/G.744 with the two fault conditions.

Note — The location and provision of any visual and/or audible alarms activated by the alarm indications given in §§ 4.2.1 and 4.2.2, is left to the discretion of each Administration.

4.2.3 Alarm indication to the remote end generated by changing bit 7 of channel time slot 66 from the state 0 to the state 1. This should be effected as soon as possible.

4.2.4 Transmission suppressed at the analogue outputs.

4.2.5 AIS applied to time slots 67 to 70 of the 64 kbit/s outputs when not used for speech (see General Note below to § 4.2). This action should be taken as soon as possible and not later than 2 ms after the detection of the fault condition.

4.2.6 AIS applied to time slots 67 to 70 of the output 8448 kbit/s composite signal when these are not used for speech (if supervision of incoming 64 kbit/s signal is provided).

General Note to § 4.2 — The equivalent binary content of the AIS is a continuous stream of binary 1s.

The strategy for detecting the presence of the AIS should be such that the AIS is detectable, even in the presence of an error ratio 1 | (mu | 0^{D} lF261^{3}. However, a signal with all bits except the frame alignment in the 1s state, should not be mistaken for an AIS.

Note — All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

H.T. [T1.744]

TABLE 1/G.744

Fault conditions and consequent actions for the PCM multiplex equipment

Equipment part	**{**	**{**					
Multiplexer and demultiplexer	**Failure of power supply** **Failure of codec**	**Yes** **Yes**	**Yes** **Yes**	**Yes, if practicable** **Yes**	**Yes, if practicable** **Yes**	**Yes, if practicable**	**Yes, if practicable**
Multiplexer only **Loss of incoming signal** **at 64-kbit/s inputs time slots 67 to 70** **(see notes under § 4.1.3)** **}**	**{**	**Yes**				**Yes**	
Demultiplexer only	**{** **Yes** **Yes** **Yes** **Yes**	**Yes** **Yes** **Yes**	**Yes** **Yes** **Yes**	**Yes** **Yes** **Yes**	**Yes** **Yes** **Yes**	**Loss of frame alignment** **{** **{**	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Table 1/G.744 [T1.744], p.

5 Signalling

5.1 *Signalling arrangement*

Refer to § 3.4.3 of Recommendation G.704. Channel time-slots 67 to 70 may be used to provide an interface at 64 kbit/s which shall be suitable for use with either common channel or channel-associated signalling or other services as required.

5.2 *Loss and recovery of multiframe alignment in case of channel associated signalling*

For multiframe alignment each 64 kbit/s channel should be treated separately. For each channel, multiframe alignment should be assumed to have been lost when two consecutive multiframe alignment signals have been received with an error.

Multiframe alignment should be assumed to have been recovered as soon as the first correct multiframe signal is detected.

Note — To avoid a condition of spurious multiframe alignment, the following procedure may be used, in addition to the above:

— Multiframe alignment should be assumed to have been lost when, for a period of one or two multiframes, all the bits in the relevant channel time slots 67, 68, 69 or 70 are at the state 0.

— Multiframe alignment should be assumed to have been recovered, only when at least one bit in the state 1 is present in the relevant time slots 67, 68, 69 or 70 preceding the multiframe alignment signal first detected.

5.3 *Fault conditions and consequent actions in case of channel associated signalling*

The fault conditions and consequent actions for each 64 kbit/s signalling channel and for each signalling multiplex equipment are the same as recommended in Recommendation G.732, § 5.3.

6 Interfaces

The analogue interfaces should be in accordance with Recommendations G.712, G.713 and G.714. The digital interfaces at 8448 kbit/s should be in accordance with Recommendation G.703. The digital interfaces at 64 kbit/s should be of either the codirectional or the contradirectional type specified in Recommendation G.703. The specifications for 64 kbit/s interfaces are not mandatory for channel associated signalling.

7 Jitter

7.1 *Multiplex signal output jitter at 8448 kbit/s output*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 8448 kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 400 kHz.

7.2 *Jitter at 64 kbit/s output* (for interfaces according to Rec. G.703)

7.2.1 In the case where the incoming 8448 kbit/s signal has no jitter, the peak-to-peak jitter at the 64 kbit/s output should not exceed 0.025 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 10 kHz. The equivalent binary content of the test signal applied to the 8448 kbit/s input shall be a pseudo-random bit sequence of length $2^{15}-1$ as specified in Recommendation O.151.

Note — In order to carry out this measurement without invoking AIS at the 64 kbit/s output, it will normally be necessary to include a frame alignment signal in the test signal.

7.2.2 The jitter transfer function between the 8448 kbit/s input and the 64 kbit/s output is under study.

Recommendation G.745

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 8448 kbit/s AND USING POSITIVE/ZERO/NEGATIVE JUSTIFICATION

(Geneva, 1976; amended at Geneva, 1980 and at Melbourne, 1988)

1 General

The second order digital multiplex equipment using positive/zero/negative justification, considered below, is intended for use on digital paths between countries using 2048 kbit/s primary multiplex equipments, such as the PCM multiplex equipment described in Recommendation G.732 or any identical equipment.

2 Bit rate

The nominal bit rate should be 8448 kbit/s. The tolerance on that rate should be ± | 0 parts per million (ppm).

3 Frame structure

Table 1/G.745 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

4 Loss and recovery of frame alignment and consequent action

Loss of frame alignment should be assumed to have taken place when five consecutive frame alignment signals have been incorrectly received in their predicted positions.

Recovery of frame alignment should take place in the case of receiving without errors at least two consecutive frame signals in their predicted positions.

As soon as frame alignment has been lost and until it has been recovered, a definite pattern should be sent to all tributaries from the output of the demultiplexer. The equivalent binary content of this pattern, called the Alarm Indication Signal (AIS), at 2048 kbit/s is a continuous stream of binary 1s.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive/zero/negative justification with two-command control are recommended.

The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, see Table 1/G.745). Correction of one error in command is possible.

Positive justification should be indicated by the signal 111, transmitted in each of two consecutive frames; negative justification should be indicated by the signal 000 transmitted in each of two consecutive frames, and no justification by the signal 111 in one frame followed by 000 in the next frame. Bits 5, 6, 7 and 8 in Set IV (see Table 1/G.745) are used for negative justification of tributaries 1, 2, 3 and 4 respectively, and bits 9 to 12 for positive justification of the same tributaries.

Besides, when information from tributaries 1, 2, 3 and 4 is not transmitted, bits 5, 6, 7 and 8 in Set IV are available for transmitting information concerning the type of justification (positive or negative) in frames containing commands of positive justification control and intermediate amount of jitter in frames containing commands of negative justification.

Table 1/G.745 gives the maximum justification rate per tributary.

6 Jitter

The amount of jitter that should be tolerated at the input of the multiplexer and the demultiplexer should be according to Rec. G.823, § 3.1.1. The amount of jitter at the output of the multiplexer and the demultiplexer should be studied and specified.

7 Digital interface

The digital interfaces at 2048 kbit/s and 8448 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

It might be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal one.

9 Service digits

Some spare bits per frame are available for service functions (bits from 5 to 8 in Set II and bit 8 in Set III) for national and international use. Bits 5, 6, 7 and 8 in Set II are available for a digital service channel between two terminals (using 32 kbit/s Adaptive Delta Modulation) and bit 8 in Set III is available for ringing up a digital service channel. Utilization of other spare bits is under study.

H.T. [T1.745]
TABLE 1/G.745
8448-kbit/s digital multiplexing frame structure using positive/zero/negative justification

Tributary bit rate (kbit/s)	**2048**
Number of tributaries	**4**
Frame structure	**Bit number**
	Set I
{ Frame alignment signal (11100110) }	1 to 8
Bits from tributaries	9 to 264
	Set II
{ Justification control bits C *1 (see Note)* }	*1 to 4*
Bits for service functions	*5 to 8*
Bits from tributaries	*9 to 264*
	Set III
{ Justification control bits C *2 (see Note)* }	*1 to 4*
Spare bits	*5 to 8*
Bits from tributaries	*9 to 264*
	Set IV
{ Justification control bits C *3 (see Note)* }	*1 to 4*
{ Bits from tributaries available for negative justification }	*5 to 8*
{ Bits from tributaries available for positive justification }	*9 to 12*
Bits from tributaries	*12 to 264*
Frame length	*1056 bits*
Frame duration	*125 µs*
Bits per tributary	*256 bits*
{ Maximum justification rate per tributary }	*8 kbit/s*

Note — C *j n* indicates *n* th justification control bit of the *j* th tributary.

Table 1/G.745 [T1.745], p.

10 Fault conditions and consequent actions

10.1 The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of incoming signal at 2048 kbit/s at the input of the multiplexer.

Note — When using separate circuits for the digital signal and the timing signal, loss of either or both should constitute loss of the incoming signal.

10.1.3 Loss of the incoming signal at 8448 kbit/s at the input of the demultiplexer.

Note 1 — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 — When using separate circuits for the digital signal and the timing signal, loss of either or both should constitute loss of the incoming signal.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 8448 kbit/s input of the demultiplexer (see § 10.2.2).

10.2 *Consequent actions*

After detection of a fault condition appropriate actions should be taken as specified in Table 2/G.745. The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to designate that the performance is below acceptable standards and maintenance attention is required locally. When detecting the AIS at the 8448 kbit/s input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be prohibited (see Note 1 below).

Note — The location and provision of any visual and/or audible alarm activated by this prompt maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 7 of set III at the 8448 kbit/s output of the multiplexer.

10.2.3 AIS (see Note 2 below) applied to all the four 2048 kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Note 2 below) applied to the 8448 kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 8448 kbit/s signal at the multiplexer output corresponding to the relevant 2048 kbit/s tributary.

Note 1 — The bit rate of the AIS at the output of the corresponding demultiplexer should be as specified for the tributaries. The method of achieving this is under study.

Note 2 — The equivalent binary content of the AIS at 2048 kbit/s and 8448 kbit/s is a continuous stream of binary 1s.

H.T. [T2.745]

TABLE 2/G.745

Fault conditions and consequent actions

Equipment part	{			{		
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes, si practicable	Yes, si practicable	Yes, si practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes				Yes	
Demultiplexer only	{ Yes Yes	Yes Yes	Yes {	Loss of frame alignment	Yes	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Table 2/G.745 [T2.745], p.

Recommendation G.746

CHARACTERISTICS OF SECOND ORDER PCM MULTIPLEX EQUIPMENT OPERATING AT 6312 kbit/s

(Malaga-Torremolinos, 1984)

1 General characteristics

1.1 *Fundamental characteristics*

The encoding law used is the μ-law as specified in Recommendation G.711. The sampling rate, load capacity and the code are also specified in that Recommendation.

The number of quantized values is 255. Two character signals are reserved for zero value (11111111 and 01111111).

In some networks the all 0 character signal (00000000) is eliminated to avoid loss of timing information to the digital line, resulting in 254 quantized values.

1.2 *Bit rate*

The nominal bit rate is 6312 kbit/s. The tolerance on this rate is ± | 0 parts per million (ppm).

1.3 *Timing signal*

It should be possible to derive the transmitting timing signal of a PCM multiplex equipment from an internal source, from the incoming digital signal and also from an external source.

2 Frame structure

Refer to §§ 3.2.1 and 3.2.2 of Recommendation G.704 for frame structure and use of derived channel time slots.

3 Loss and recovery of frame alignment

The strategy for the loss and recovery of frame alignment should be according to Rec. G.706, § 3.1.

4 Fault conditions and consequent actions

4.1 *Fault conditions*

The PCM multiplex equipment should detect the following conditions:

4.1.1 Failure of power supply.

4.1.2 Loss of incoming signals at 6312 kbit/s.

4.1.3 Loss of frame alignment.

4.1.4 Alarm indication received from the remote PCM multiplex equipment.

4.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.746. The consequent actions are as follows:

4.2.1 A service alarm indication should be generated to signify that the service provided by the PCM multiplex is no longer available. This indication should be forwarded to the switching and/or signalling equipment depending upon the arrangement provided.

H.T. [T1.746]
TABLE 1/G.746
Fault conditions and consequent actions for the PCM multiplex equipment

Equipment part	**Fault condition**	**Consequent actions** {			
Multiplexer and demultiplexer	**Failure of power supply**	**Yes**	**Yes**	**Yes (if practicable)**	**Optional**
Demultiplexer only	{ **Yes** **Loss of frame alignment** **Optional**	 **Yes** **Yes** **Yes**	 **Yes** **Yes** **Optional**	 **Yes** **Yes**	 **Yes**

Note 1 — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Note 2 — Indications of additional fault conditions, such as codec failure and excessive bit errors, are left to the discretion of individual Administrations.

Table 1/G.746 [T1.746], p.

4.2.2 The service alarm described in § 4.2.1 above should be used to automatically remove the associated circuits from service and to restore them to service when frame alignment has been recovered.

Note — The removal of the associated circuits described in § 4.2.2 above should be done in such a way that the circuits are not needlessly removed in the case of a brief isolated loss of frame alignment but are removed in the case of a permanent or intermittent loss of frame alignment.

It is also important to minimize the impact of signalling errors which may occur during periods of loss of frame alignment. These functions should be provided in the PCM multiplex equipment or in the switching/signalling equipment.

4.2.3 A prompt maintenance alarm indication should be generated to signify that performance is below acceptable standards and maintenance attention is required locally.

4.2.4 An alarm indication to the remote end should be generated by forcing bit *a* to the value 1.

4.2.5 Transmission should be suppressed at the analogue outputs.

4.2.6 *Rapid indication of loss of frame alignment*

An indication should be given to the Signalling System No. 6 equipment (digital version) when the PCM multiplex equipment (local end only) detects a loss of frame alignment. The average time to detect and give an indication of random bits in the frame alignment signal bit positions should not be greater than 3 ms. This indication will serve the same function as that provided by the data carrier failure alarm in the analogue version (see Recommendation Q.275 [1]).

5 Signalling

5.1 *Signalling arrangement*

Refer to § 3.2.3 of Recommendation G.704.

5.2 *Loss of multiframe alignment in case of channel associated signalling*

Loss of multiframe alignment is assumed to have taken place when loss of frame alignment occurs.

6 Interfaces

Analogue: Refer to Recommendations G.712, G.713 and G.714.

Digital: Refer to Recommendation G.703.

Reference

[1] CCITT Recommendation *Data channel failure detection* , Vol. VI, Rec. Q.275.

Recommendation G.747

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING | fR AT 6312 kbit/s AND

MULTIPLEXING THREE TRIBUTARIES AT 2048 kbit/s

(Melbourne, 1988)

1 General

The digital multiplex equipment described in this Recommendation is intended for use between networks using different digital hierarchies as specified in Recommendations G.702 and G.802.

2 Bit rate

The bit rates of the tributary and multiplex signals should be 2048 kbit/s ± | 0 ppm and 6312 kbit/s ± | 0 ppm, respectively, as specified in Recommendation G.703.

3 Frame structure

Table 1/G.747 gives the recommended 6312 kbit/s multiplexing frame structure.

4 Loss and recovery of frame alignment and consequent action

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive correct frame alignment signals.

The frame alignment device, having detected the appeareance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note — As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

5 Multiplexing and justification methods

Cyclic bit interleaving in the tributary numbering order and positive justification are recommended.

The justification control signal should be distributed and use the $C_{j\backslash di}$ | (hybits (j = 1, 2, 3; i = 1, 2, 3) (see Note 5 to Table 1/G.747).

Positive justification should be indicated by the justification control signal 111 and no justification by the signal 000. Majority decision is recommended.

Table 1/G.747 gives the maximum justification rate per tributary and the nominal justification ratio.

H.T. [T1.747]
TABLE 1/G.747
6312 kbit/s multiplexing frame structure

{ Nominal tributary bit rate (kbit/s) }	2048
Number of tributaries	3
Frame structure	Bit number
	Set I
{ Frame alignment signal (111010000) }	1 to 9
Bits from tributaries	10 to 168
	Set II
{ Alarm indication to the remote multiplex equipment (Note 1) }	1
Parity bit (Notes 2 and 3)	2
{ Bit reserved for future use (Note 4) }	3
Bits from tributaries	4 to 168
	Set III
{ Justification control bits C *j* 1 (Note 5) }	1 to 3
Bits from tributaries	4 to 168
	Set IV
{ Justification control bits C *j* 2 (Note 5) }	1 to 3
Bits from tributaries	4 to 168
	Set V
{ Justification control bits C *j* 3 (Note 5) }	1 to 3
{ Bits from tributaries available for justification }	4 to 6
Bits from tributaries	7 to 168
Frame length	840 bits
Bits per tributary in a frame	273 bits
{ Maximum justification rate per tributary }	7.5 kbit/s
Nominal justification ratio	0.453

Note 1 — See § 10.2.1.

Note 2 — The parity bit | | if the number of marks in all tributary bits including the bits in the justifiable time-slots in the preceding frame is odd; the parity bit | | if the number of marks in all tributary bits including the bits in the justifiable time-slots in the preceding frame is even.

Note 3 — The implementation and the use of this parity bit procedure are for further study.

Note 4 — This bit should be set to 1 when not used.

Note 5 — C *j i* (*j*
| | , 2, 3; *i*

| | , 2, 3) indicates the *i* th justification control bit of the *j* th tributary.

Table 1/G.747 [T1.747], p.

6 jitter

6.1 *Muldex jitter transfer characteristic*

A 2048 kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 1/G.747. The equivalent binary content of the test signal should be 1000.

Note — In addition, the need to specify a demultiplexer tributary jitter transfer characteristic from the 6312 kbit/s demultiplexer input to the 2048 kbit/s demultiplexer output is for further study.

Figure 1/G.747, p.

6.2 *Output jitter*

6.2.1 *Tributary output jitter*

With no jitter applied to the input ports of the multiplexer and with the multiplexer directly connected to the demultiplexer, the peak-to-peak jitter at the tributary output port should not exceed 0.2 UI over a measurement interval of one minute in the frequency range from f_0 to 100 kHz (see Note 1).

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 18 kHz, a roll-off of 20 dB/decade and an upper limit of 100 kHz, the peak-to-peak output jitter should not exceed 0.05 UI when measured over a one minute interval (see Note 2).

Note 1 - The frequency f_0 should be as low as possible, taking into account the limitations of measurement equipment. In any case f_0 should be no greater than 10 Hz.

Note 2 — For interfaces meeting the national high Q option, detailed in Recommendation G.823, the lower cutoff frequency for the above measurement should be 700 Hz.

6.2.2 *Multiplexer output jitter*

The peak-to-peak jitter at the 6312 kbit/s output port should not exceed 0.05 UI when it is measured over a one minute interval within the frequency range from f_1 = 10 Hz to f_4 = 60 kHz.

6.3 *Input jitter*

6.3.1 *Tributary input jitter*

The 2048 kbit/s input port should be capable of accommodating levels of input jitter up to the limits given in Rec. G.823.

6.3.2 *Demultiplexer input jitter*

The 6312 kbit/s input port should be capable of accommodating levels of input jitter up to the limits given in Figure 2/G.747.

Note 1 — Current Recommendation G.703 does not refer to the jitter tolerated at the digital distribution frame at 6312 kbit/s nor at the input port of equipment connected to this distribution frame.

Note 2 — The jitter accommodation requirement should be met when the jittered input signal is composed of the multiplexed tributary signals having any value of jitter allowed for the 2048 kbit/s.

Figure 2/G.747, p.

7 Digital interfaces

The digital interfaces at 2048 kbit/s and 6312 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

If it is economically feasible, it may be desirable to be able to derive the multiplexing timing signal from an external source as well as from an internal source.

9 Service digits

Three bits per frame are available for service functions (see Table 1/G.747): bit 1 of Set II is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see § 10 below); bit 2 of Set II may be used for a parity check; bit 3 of Set II is reserved for future use.

10 Fault conditions and consequent actions

10.1 *Fault conditions*

10.1.1 The digital multiplex equipment should detect the following fault conditions:

1) failure of power supply;

2) loss of an incoming 2048 kbit/s tributary signal at a multiplexer input port;

3) loss of an incoming 6312 kbit/s multiplex signal at a demultiplexer input port;

4) loss of frame alignment signal at a demultiplexer input port;

5) detection of an alarm indication received from the remote multiplex equipment at a demultiplexer input port;

6) detection of alarm indication signal (AIS) at a demultiplexer input port.

Note 1 — The equivalent binary content of the AIS at 2048 and 6312 kbit/s should be a continuous stream of binary 1s (marks) as recommended in Recommendation M.20.

Note 2 — Some current 44 | 36/6312 kbit/s demultiplexers do not issue a 6312 kbit/s AIS. Thus no detection can take place in that case.

Note 3 — The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio of 1 | (mu | 0^{D}lF261^{3}. However, a signal with all bits except the frame alignment signal in the state of 1 should not be mistaken as an AIS.

10.1.2 The need to monitor the degradation of the incoming 6312 kbit/s signal for the purpose of end-to-end error performance monitoring of the 6132 kbit/s digital block as well as the procedure for detecting such degradation, are for further study.

10.2 *Consequent actions*

Further to the detection of a fault condition, the appropriate actions should be taken as specified in Table 2/G.747.

Note 1 — The concept and definition of prompt maintenance alarm indication is given in Recommendation M.20.

Note 2 — When the alarm indication signal (AIS) is detected at the input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.747 with the fault condition.

10.2.1 Alarm indication to the remote multiplex equipment should be generated by changing bit 1 of Set II (see Table 1/G.747) from the state 0 to the state 1.

10.2.2 AIS should be applied to the following as specified in Table 2/G.747.

— all three 2048 kbit/s tributary outputs from the demultiplexer;

— 6312 kbit/s output of the multiplexer;

— the time slots of the 6312 kbit/s signal at the ouptput of the multiplexer, corresponding to the relevant 2048 kbit/s tributary.

H.T. [T2.747]
TABLE 2/G.747
Fault conditions and consequent actions

Equipment part	{			{		
Multiplexer and demultiplexer	Failure of power supply	Yes		Yes, if practicable	Yes, if practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes				Yes	
Demultiplexer only	{ Yes Yes	Yes Yes	Yes {	Loss of frame alignment	Yes	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Tableau 2/G.747 [T2.747], p. 15

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7.5 Principal characteristics of higher order multiplex equipments

Recommendation G.751

DIGITAL MULTIPLEX EQUIPMENTS OPERATING AT THE THIRD ORDER BIT RATE | fR OF 34 | 68 kbit/s AND THE FOURTH ORDER BIT RATE OF 139 | 64 kbit/s

AND USING POSITIVE JUSTIFICATION

(Geneva, 1976; further amended)

1 General characteristics

1.1 There should be a 4th-order bit rate of 139 | 64 kbit/s in the digital hierarchy which is based on the 2nd-order bit rate of 8448 kbit/s.

There should be two methods of achieving the 4th-order bit rate:

Method 1 — by using a 3rd-order bit rate of 34 | 68 kbit/s in the digital hierarchy.

Method 2 — by directly multiplexing sixteen digital signals at 8448 kbit/s.

The digital signals at the bit rate of 139 | 64 kbit/s obtained by these two methods should be identical.

1.2 The existence of the above two methods implies that the use of the bit rate of 34 | 68 kbit/s should not be imposed on an Administration that does not wish to realize the corresponding equipment.

1.3 In accordance with the above two methods, the following realizations of digital multiplex equipments using positive justification are recommended:

Method 1 — Realization by separate digital multiplex equipments: one type which operates at 34 | 68 kbit/s and multiplexes four digital signals at 8448 kbit/s; the other type which operates at 139 | 64 kbit/s and multiplexes four digital signals at 34 | 68 kbit/s.

The multiplexing for the 34 | 68 kbit/s digital multiplex equipment is recommended in § 1.4 below, while further specification of this equipment is given in § 2 below.

The multiplexing for the 139 | 64 kbit/s digital multiplex equipment is recommended in § 1.5 below, while further specification of this equipment is given in § 3 below.

Method 2 — Realization by a single digital multiplex equipment which operates at 139 | 64 kbit/s and multiplexes sixteen digital signals at 8448 kbit/s.

The digital multiplexing for the 139 | 64 kbit/s bit rate should be achieved by multiplexing, in accordance with § 1.5 below, four digital signals at 34 | 68 kbit/s, each of which is obtained by multiplexing, in accordance with § 1.4 below, four digital signals at 8448 kbit/s. Further specification of this equipment is given in § 4 below.

1.4 *Multiplexing four digital signals at 8448 kbit/s*

1.4.1 *Bit rate*

The nominal bit rate should be 34 | 68 kbit/s.

The tolerance on that rate should be ± | 0 parts per million (ppm).

1.4.2 *Frame structure*

Table 1/G.751 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

H.T. [T1.751]
TABLE 1/G.751
34 | 68 kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	8448
Number of tributaries	4
Frame structure	Bit number
	Set I
{ Frame alignment signal (1111010000) }	1 to 10
{ Alarm indication to the remote digital multiplex equipment }	11
Bit reserved for national use	12
Bits from tributaries	13 to 384
	Set II
{ Justification service bits C *1 (see Note)* }	*1 to 4*
Bits from tributaries	*5 to 384*
	Set III
{ Justification service bits C *2 (see Note)* }	*1 to 4*
Bits from tributaries	*5 to 384*
	Set IV
{ Justification service bit C *3 (see Note)* }	*1 to 4*
{ Bits from tributaire available for justification }	*5 to 8*
Bits from tributaries	*9 to 384*
Frame length	*1536 bits*
Bits per tributary	*378 bits*
{ Maximum justification rate per tributary }	*22 | 75 kbit/s*
Nominal justification ratio	*0.436*

Note — C *j n* indicates the *n* th justification service bit of the *j* th tributary.

Table 1/G.751 [T1.751] p.

1.4.3 *Loss and recovery of frame alignment*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note — As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

1.4.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended. The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, see Table 1/G.751). Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.751 gives the maximum justification rate per tributary and the nominal justification ratio.

1.4.5 *Service digits*

Two bits per frame are available for service functions. Bit 11 of Set I is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see §§ 2.5 and 4.5 below). Bit 12 of Set I is reserved for national use. On a digital path crossing the border, this bit is fixed at 1.

1.5 *Multiplexing four digital signals at 34 | 68 kbit/s*

1.5.1 *Bit rate*

The nominal bit rate should be 139 | 64 kbit/s. The tolerance on that rate should be ± | 5 parts per million (ppm).

1.5.2 *Frame structure*

Table 2/G.751 gives:

— the tributary bit rate and the number of tributaries;

— the number of bits per frame;

— the bit numbering scheme;

— the bit assignment;

— the bunched frame alignment signal.

1.5.3 *Loss and recovery of frame alignment*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note — As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

1.5.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended. The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, 4, 5, see Table 2/G.751). Positive justification should be indicated by the signal 11111, no justification by the signal 00000. Majority decision is recommended.

Table 2/G.751 gives the minimum justification rate per tributary and the nominal justification ratio.

H.T. [T2.751]
TABLE 2/G.751
139 | 64 kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	34 | 68
Number of tributaries	4
Frame structure	Bit number
	Set I
{ Frame alignment signal (111110100000) }	1 to 12
{ Alarm indication to the remote digital multiplex equipment }	13
{ Bits reserved for national use }	14 to 16
Bits from tributaries	17 to 488
	Sets II to V
{ Justification service bits C *j* *n* (*n* | | to 4) (see Note) }	1 to 4
Bits from tributaries	5 to 488
	Set VI
{ Justification service bits C *j* *5* (see Note) }	1 to 4
{ Bits from tributaries available for justification }	5 to 8
Bits from tributaries	9 to 488
Frame length	2928 bits
Bits per tributary	723 bits
{ Maximum justification rate per tributary }	47 | 63 bit/s approx.
Nominal justification ratio	0.419

Note — C *j* *n* indicates the *n* th justification service bit of the *j* th tributary.

Table 2/G.751 [T2.751], p.

1.5.5 *Service digits*

Four bits per frame are available for service functions. Bit 13 of Set I is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see §§ 3.5 and 4.5 below). Bits 14 to 16 of Set I are reserved for national use. On a digital path crossing the border, these bits are fixed at 1.

2 Digital multiplex equipment operating at 34 | 68 kbit/s and multiplexing four tributaries at 8448 kbit/s

2.1 *Multiplexing*

The multiplexing for the 34 | 68 kbit/s bit rate should be in accordance with § 1.4.

2.2 *Digital interfaces*

The digital interfaces at 8448 kbit/s and 34 | 68 kbit/s should be in accordance with Recommendation G.703.

2.3 *Jitter*

2.3.1 *Jitter transfer characteristic*

An 8448 kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 1/G.751. The equivalent binary content of the test signal should be 1000.

2.3.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.25 UI when measured in the frequency range up to 400 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 3 kHz, a rolloff of 20 dB/decade and an upper limit of 400 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

Note — For interfaces meeting the national low Q option detailed in Recommendation G.703, the lower cutoff frequency for the above measurement should be 80 kHz.

Figure 1/G.751 p.

2.3.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 34 | 68 kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 100 Hz to f_4 = 800 kHz.

2.4 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

2.5 *Fault conditions , and consequent actions*

2.5.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

2.5.1.1 Failure of power supply.

2.5.1.2 Loss of an incoming signal at 8448 kbit/s at the input of the multiplexer.

Note — Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

2.5.1.3 Loss of the incoming signal at 34 | 68 kbit/s at the input of the demultiplexer.

Note — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

2.5.1.4 Loss of frame alignment.

2.5.1.5 Alarm indication received from the remote multiplex equipment at the 34 | 68 kbit/s input of the demultiplexer (see § 2.5.2.2 below).

2.5.2 *Consequent actions*

Further to detection of a fault condition, actions should be taken as specified by Table 3/G.751. The consequent actions are as follows:

2.5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 under § 2.5.2.5) at 34 | 68 kbit/s is detected at the input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 3/G.751 with the fault condition.

Note — The location and provision of any visual and/or audible alarm activated by this maintenance alarm indication is left to the discretion of each Administration.

2.5.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 11 of Set I at the 34 | 68 kbit/s output of the multiplexer.

2.5.2.3 AIS (see Notes 1 and 2 below) applied to all four 8448 kbit/s tributary outputs from the demultiplexer.

2.5.2.4 AIS (see Notes 1 and 2 below) applied to the 34 | 68 kbit/s output of the multiplexer.

2.5.2.5 AIS (see Note 2 below) applied to time slots of the 34 | 68 kbit/s signal at the output of the multiplexer, corresponding to the relevant 8448 kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for that tributary.

Note 1 — The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 — The equivalent binary content of the AIS (AIS) at 8448 kbit/s and 34 | 68 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio 1 | (mu | 0^{D}lF261^{3}. However a signal with all bits except the frame alignment signal in the 1 state, should not be mistaken as an AIS.

2.5.3 *Time requirements*

The fault detection and the application of the consequent actions given in §§ 2.5.2.2 to 2.5.2.5, including the detection of AIS, should be completed within a time limit of 1 ms.

H.T. [T3.751]

TABLE 3/G.751

Fault conditions and consequent actions

Equipment part	**{**			**{**		
Multiplexer and demultiplexer	**Failure of power supply**	**Yes**		**Yes, if practicable**	**Yes, if practicable**	
Multiplexer only **Loss of incoming signal on a tributary** **}**	**{** **Yes**				**Yes**	
Demultiplexer only	**Loss of incoming signal** **Yes**	**Yes** **Yes**	**Yes** **{**	**Yes**	**Loss of frame alignment**	**Yes**

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Table 3/G.751 [T3.751], p.

3 Digital multiplex equipment operating at 139 | 64 kbit/s and multiplexing four tributaries at 34 | 68 kbit/s

3.1 *Multiplexing*

The multiplexing for the 139 | 64 kbit/s bit rate should be in accordance with § 1.5 above.

3.2 *Digital interfaces*

The digital interfaces at 34 | 68 kbit/s and 139 | 64 kbit/s should be in accordance with Recommendation G.703.

3.3 *Jitter*

3.3.1 *Jitter transfer characteristic*

A 34 | 68 kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 2/G.751. The equivalent binary content of the test signal should be 1000.

Figure 2/G.751 p.

3.3.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.3 UI when measured in the frequency range up to 800 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 10 kHz, a rolloff of 20 dB/decade and an upper limit of 800 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

3.3.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 139 | 64 kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 200 Hz to f_4 = 3500 kHz.

3.4 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from internal source.

3.5 *Fault conditions and consequent actions*

3.5.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

3.5.1.1 Failure of power supply.

3.5.1.2 Loss of an incoming signal at 34 | 68 kbit/s at the input of the multiplexer.

3.5.1.3 Loss of the incoming signal at 139 | 64 kbit/s at the input of the demultiplexer.

Note — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

3.5.1.4 Loss of frame alignment.

3.5.1.5 Alarm indication received from the remote multiplex equipment at the 139 | 64 kbit/s input of the demultiplexer (see § 3.5.2.2 below).

3.5.2 *Consequent actions*

Further to detection of a fault condition actions should be taken as specified by Table 3/G.751. The consequent actions are as follows:

3.5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 below) at 139 | 64 kbit/s is detected at the input to the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 3/G.751 with the fault condition.

3.5.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 13 of Set I at the 139 | 64 kbit/s output of the multiplexer.

3.5.2.3 AIS (see Notes 1 and 2 below) applied to all four 34 | 68 kbit/s tributary outputs from the demultiplexer.

3.5.2.4 AIS (see Notes 1 and 2 below) applied to the 139 | 64 kbit/s output of the multiplexer.

3.5.2.5 AIS (see Note 2 below) applied to time slots of the 139 | 64 kbit/s signal at the output of the multiplexer corresponding to the relevant 34 | 68 kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for the tributary.

Note 1 — The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 — The equivalent binary content of the AIS at 34 | 68 kbit/s and 139 | 64 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio 1 | (mu | 0^{D}lF261^{3}. However a signal, with all bits except the frame alignment signal in the 1 state, should not be mistaken for an AIS.

3.5.3 *Time requirements*

The fault detection and the application of the consequent actions given in §§ 3.5.2.2 to 3.5.2.5, including the detection of AIS, should be completed within a time limit of 1 ms.

4 Digital multiplex equipment operating at 139 | 64 kbit/s and multiplexing sixteen tributaries at 8448 kbit/s

4.1 *Multiplexing*

The multiplexing for the 139 | 64 kbit/s bit rate should be achieved by multiplexing, in accordance with § 1.5 above, four digital signals at 34 | 68 kbit/s, each of which is obtained by multiplexing, in accordance with § 1.4 above, four digital signals at 8448 kbit/s.

4.2 *Digital interfaces*

The digital interfaces at 8448 kbit/s and 139 | 64 kbit/s should be in accordance with Recommendation G.703.

4.3 *Jitter*

4.3.1 *Jitter transfer characteristic*

A 8448 kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 3/G.751. The equivalent binary content of the test signal should be 1000.

Figure 3/G.751 p.

4.3.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.35 UI when measured in the frequency range up to 400 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 3 kHz, a rolloff of 20 dB/decade and an upper limit of 400 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

Note — For interfaces meeting the national low Q option, detailed in Recommendation G.703, the lower cutoff frequency for the above measurement should be 80 kHz.

4.3.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 139 | 64 kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 100 Hz to f_4 = 3500 kHz.

4.4 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

4.5 *Fault conditions and consequent actions*

4.5.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

4.5.1.1 Failure of power supply.

4.5.1.2 Loss of an incoming signal at 8448 kbit/s at the input of the multiplexer.

Note — Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

4.5.1.3 Loss of the incoming signal at 139 | 64 kbit/s at the input of the demultiplexer.

Note — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

4.5.1.4 Loss of frame alignment of the signal at 139 | 64 kbit/s at the input of the demultiplexer.

4.5.1.5 Loss of frame alignment of a signal at 34 | 68 kbit/s within the demultiplexer.

4.5.1.6 Alarm indication received from the remote multiplex equipment at the 139 | 64 kbit/s input of the demultiplexer (see § 4.5.2.2 below).

4.5.1.7 Alarm indication received from the remote multiplex equipment on a signal at 34 | 68 kbit/s within the demultiplexer (see § 4.5.2.3 below).

4.5.2 *Consequent actions*

Further to detection of a fault condition, actions should be taken as specified by Table 4/G.751. The consequent actions are as follows:

4.5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 below) at 139 | 64 kbit/s or 34 | 68 kbit/s is detected by the demultiplexer, the prompt maintenance alarm indication associated with the corresponding loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 4/G.751 with the fault condition.

Note — The location and provision of any visual and/or audible alarms activated by the maintenance alarm indication is left to the discretion of each Administration.

4.5.2.2 Alarm indication on the 139 | 64 kbit/s signal to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 13 of Set I at the 139 | 64 kbit/s output of the multiplexer.

4.5.2.3 Alarm indication on a 34 | 68 kbit/s signal to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 11 of Set I on the 34 | 68 kbit/s signal into the multiplexer.

4.5.2.4 AIS (see Notes 1 and 2 below) applied to all sixteen 8448 kbit/s tributary outputs from the demultiplexer.

4.5.2.5 AIS (see Notes 1 and 2 below) applied to all four 8448 kbit/s relevant tributary outputs from the demultiplexer.

4.5.2.6 AIS (see Notes 1 and 2 below) applied to the 139 | 64 kbit/s output of the multiplexer.

4.5.2.7 AIS (see Note 2 below) applied to the time slot of the 139 | 64 kbit/s at the output of the multiplexer, corresponding to the relevant 8448 kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary, should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for that tributary.

Note 1 — The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 — The equivalent binary content of the AIS at 8448 kbit/s, 34 | 68 kbit/s and 139 | 64 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS

should be such that the AIS is detectable even in the presence of an error ratio 1 | (mu | 0^{D}lF261^{3}. However a signal with all bits except the frame alignment signal in the 1 state, should not be mistaken for an AIS.

4.5.3 *Time requirements*

The fault detection and the application of the consequent actions given in §§ 4.5.2.2 to 4.5.2.7, including the detection of AIS, should be completed within a time limit of 1 ms.

Blanc

H.T. [T4.751]

TABLE 4/G.751

Fault conditions and consequent actions

Equipment part	{							
Multiplexer and demultiplexer	Loss of power supply	Yes			Yes, if practicable		Yes, if practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes						Yes	
Demultiplexer only	{ Yes Yes { { Yes	Yes Yes Yes	Yes Yes Yes	{ {				

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

TABLEAU 4/G.751 [T4.751], p. 22

Recommendation G.752

CHARACTERISTICS OF DIGITAL MULTIPLEX EQUIPMENTS BASED

ON A SECOND ORDER BIT RATE OF 6312 kbit/s AND USING POSITIVE | fR JUSTIFICATION

(Geneva, 1976; amended at Geneva, 1980)

The CCITT,

considering

(a) that various third- and higher-order multiplex equipments exist due to the differing characteristics of networks and signal sources in those networks;

(b) that, although studies will continue with the aim of reducing the differences between various systems, the existing situation cannot be changed in the near future;

recommends the following

(1) when countries using 1544 kbit/s primary multiplex equipments, such as the PCM multiplex equipment according to Recommendation G.733 and second-order multiplex using 6312 kbit/s according to Recommendations G.743 and G.746, are planning digital paths requiring interconnection at higher bit rates they should, when practical, utilize third-order bit rates of either 32 | 64 kbit/s or 44 | 36 kbit/s. When countries using 32 | 64 kbit/s third-order multiplex equipments are planning digital paths requiring interconnection at higher bit rates, they should, when practical, utilize the fourth-order bit rate of 97 | 28 kbit/s.

For Figure 1/G.752 refer to Figure 1/G.702 for the basic multiplex arrangements recommended for Administrations using 1544 kbit/s primary multiplex equipment. The bit rates of terrestrial systems should accommodate multiples of 1544 kbit/s. Whenever practical, the bit rate should also accommodate a multiple of 6312 kbit/s, either 32 | 64 or 44 | 36 kbit/s, and 97 | 28 kbit/s;

(2) the characteristics of the third-order multiplex equipments using positive justification is given in § 1, below;

(3) the characteristics of the fourth-order multiplex equipments using positive justification is given in § 2 below.

1 Third-order digital multiplex equipment based on second-order bit rate of 6312 kbit/s and using positive justification

1.1 *General*

The third-order digital multiplex equipment using positive justification described below, is intended for use on digital paths and between countries using 1544 kbit/s and 6312 kbit/s primary and secondary multiplex equipments.

A bit rate of either 32 | 64 kbit/s or 44 | 36 kbit/s is recommended to allow for the efficient and economical coding of wideband signals in the networks of Administrations using primary systems according to Recommendations G.733 and G.743. For instance for a 300 voice-circuit mastergroup (Recommendation G.233 [1]) 32 | 64 kbit/s is appropriate, while for a 600 voice-circuit mastergroup 44 | 36 kbit/s coding is appropriate.

1.2 *Third-order digital multiplex equipment operating at 32 | 64 kbit/s*

1.2.1 *Bit rate*

The nominal bit rate should be 32 | 64 kbit/s. The tolerance on that rate should be ± | 0 parts per million (ppm).

1.2.2 *Frame structure*

Table 1/G.752 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the frame alignment signal.

H.T. [T1.752]
TABLE 1/G.752
32 | 64 kbit/s multiplexing frame structure

<table>
<tr><td>Tributary bit rate (kbit/s)</td><td>6312</td></tr>
<tr><td>Number of tributaries</td><td>5</td></tr>
<tr><td>Frame structure</td><td>Bit number</td></tr>
<tr><td></td><td>Set I</td></tr>
<tr><td>Bits for frame alignment signal (see Note 1)</td><td>1 to 5</td></tr>
<tr><td>Bits from tributaries</td><td>6 to 320</td></tr>
<tr><td></td><td>Set II</td></tr>
<tr><td>C_{j1} (j = 1 to 5) for justification control signal (see Note 2)</td><td>1 to 5</td></tr>
<tr><td>Bits from tributaries</td><td>6 to 320</td></tr>
<tr><td></td><td>Set III</td></tr>
<tr><td>C_{j2} (j = 1 to 5) for justification control signal (see Note 2)</td><td>1 to 5</td></tr>
<tr><td>Bits from tributaries</td><td>6 to 320</td></tr>
<tr><td></td><td>Set IV</td></tr>
<tr><td>Bits for frame alignment signal (see Note 3)</td><td>1 to 5</td></tr>
<tr><td>Bits from tributaries</td><td>6 to 320</td></tr>
<tr><td></td><td>Set V</td></tr>
<tr><td>C_{j3} (j = 1 to 5) for justification control signal (see Note 2)</td><td>1 to 5</td></tr>
<tr><td>Bits from tributaries</td><td>6 to 320</td></tr>
<tr><td></td><td>Set VI</td></tr>
<tr><td>Auxiliary bits H_n (n = 1, 2, 3, 4, 5) (see Note 4)</td><td>1 to 5</td></tr>
<tr><td>Bits from tributaries</td><td>6 to 320</td></tr>
<tr><td>Frame length</td><td>1 | 20 bits</td></tr>
<tr><td>Bits per tributary (including justification)</td><td>378 bits</td></tr>
<tr><td>Maximum justification rate per tributary</td><td>16 | 00 bit/s</td></tr>
<tr><td>Nominal justification ratio</td><td>0.036</td></tr>
</table>

Note 1 — The frame alignment signal is a 11010 pattern.

Note 2 — C *indicates the n* th justification control bit of the *j* th tributary (*j* = 1 to 5).

Note 3 — The frame alignment signal is a 00101 pattern.

Note 4 — H 5 is used for transmitting failure information from the receive end to the transmit end.

Note 5 — The bit available for the justification of each tributary is the first slot of the tributary in set VI.

Table 1/G.752 [T1.752] p.

1.2.3 *Loss and recovery of frame alignment and consequent action*

The frame alignment recovery time should not exceed 8 ms. The signal to be applied to the tributaries during the out-of-frame alignment time should be studied.

1.2.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and the C_{jn}-bits should be used ($n = 1, 2, 3$, see Table 1/G.752).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.752 gives the maximum justification rate per tributary and the nominal justification ratio.

1.2.5 *Jitter*

1.2.5.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 2/G.752. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length $2^{15} — 1$.

Note — The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.

Figure 2/G.752 p.

1.2.5.2 *Multiplex signal output jitter*

The jitter at the 32 | 64 kbit/s output of the multiplexer should not exceed 0.01 UI rms.

1.2.5.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

The peak-to-peak jitter at a tributary output of the demultiplexer with no jitter at the inputs should not exceed 0.2 UI.

1.2.5.4 *Demultiplexer jitter transfer characteristic*

A 6312 kbit/s signal, modulated by sinusoidal jitter, should be subject to a demultiplexer jitter transfer characteristic within the gain/frequency limits given in Figure 3/G.752.

Figure 3/G.752 p.

1.2.6 *Digital interface*

The digital interfaces at 6312 kbit/s and 32 | 64 kbit/s should be in accordance with Recommendation G.703.

1.2.7 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

1.2.8 *Service digits*

The service digits are reserved for national use.

1.3 *Third-order digital multiplex operating at 44 | 36 kbit/s*

1.3.1 *Bit rate*

The nominal bit rate should be 44 | 36 kbit/s. The tolerance on that rate should be ± | 0 parts per million (ppm).

1.3.2 *Frame structure* | (see Table 2/G.752).

1.3.3 *Loss and recovery of frame and multiframe alignment and consequent action*

The frame alignment recovery time should not exceed 2.5 ms. The signal to be applied to the tributaries during the out-of-frame alignment time should be studied.

Once frame alignment is established, multiframe alignment should be recovered in less than 250 µs.

1.3.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and the $C_{j\backslash dn}$-bits should be used (n = 1, 2, 3, see Table 2/G.752).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 2/G.752 gives the maximum justification rate per tributary and the nominal justification ratio.

H.T. [T2.752]

TABLE 2/G.752

44 | 36-kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	6312
Number of tributaries	7
Frame structure (see Note 1)	Bit number
	Set I
Bit for multiframe alignment signal (M_j) (see Note 1)	1
Bits from tributaries	2 to 85
	Set II
1st bit for frame alignment signal (F 1 1) (see Note 2)	1
Bits from tributaries	2 to 85
	Set III
1st bit for justification control signal (C_j 1)	1
Bits from tributaries	2 to 85
	Set IV
2nd bit for frame alignment signal (F 0)	1
Bits from tributaries	2 to 85
	Set V
2nd bit for justification control signal (C_j 2)	1
Bits from tributaries	2 to 85
	Set VI
3rd bit for frame alignment signal (F 0)	1
Bits from tributaries	2 to 85
	Set VII
3rd bit for justification control signal (C_j 3)	1
Bits from tributaries	2 to 85
	Set VIII
4th bit for frame alignment signal (F 1 2)	1

Bits from tributaries (see Note 3) }	2 to 85
Frame length	680 bits
Multiframe length	4760 bits
{ Bits per tributary per multiframe (including justification) }	672 bits
{ Maximum justification rate per tributary }	9398 bit/s
Nominal justification ratio	0.390

Note 1 — This frame is repeated 7 times to form a multiframe with frames designated j | | , 2, 3, 4, 5, 6, 7. The multiframe alignment signal is an XXPP010 pattern where X is a bit assigned to service function, and P is the parity bit for the preceding multiframe (i.e. from M 1 to M 7). P | | if the number of marks in all tributary bits in the preceding multiframe is odd, P | | if the number of marks in all tributary bits in the preceding multiframe is even. Note that the two X bits are identical in any multiframe, as are the two P bits.

Note 2 — The frame alignment signal is F 0 | | and F 1 1 | | 1 2 | | .

Note 3 — The bit available for the justification of tributary *j* is the first slot of tributary *j* following F 1 2 in the *j* th frame.

H.T. [T3.752] TABLE 3/G.752

97 | 28 kbit/s multiplexing frame structure Tributary bit rate (kbit/s)	32 | 64
Number of tributaries	3
Frame structure	Bit number
	Set I
Frame alignment signal (110)	1 to 3
Bits from tributaries	4 to 192
	Set II
{ Justification control bits C *j* 1 (see Note 1) }	1 to 3
Bits from tributaries	4 to 192
	Set III
{ Justification control bit C *j* 2 (see Note 1) }	1 to 3
Bits from tributaries	4 to 192
	Set IV
Frame alignment signal (001)	1 to 3
Bits from tributaries	4 to 192
	Set V
{ Justification control bits C *j* 3 (see Note 1) }	1 to 3
Bits from tributaries	4 to 192
	Set VI
{ Auxiliary bits H *n* (*n* = 1, 2, 3) (see Note 2) }	1 to 3
Bits from tributaries	4 to 192
Frame length	1 | 52 bits
{ Bits per tributary per frame (including justification) }	| 78 bits
{ Maximum justification rate per tributary }	84 | 33 bit/s
Nominal justification ratio	0.035

Note 1 — C *j* *n* indicates the *n* th justification bit of the *j* th tributary (*j* = 1, 2, 3).

Note 2 — This signal is H 1 H 2 H 3 pattern where H 1 is the parity bit for the preceding frame, and H 2 is a bit reserved for national use, and H 3 is a bit to transmit the failure information from the receiving end to the transmitting end.

Note 3 — The bit available for justification of tributary *j* is the first slot of tributary *j* following H *n*

Table 2/G.752 [T2.752], p.

1.3.5 *Jitter*

1.3.5.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 4/G.752. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length 2^{15} — 1.

Note — The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.

Figure 4/G.752 p.

1.3.5.2 *Multiplex signal output jitter*

The jitter at the 44 **|** 36 kbit/s multiplexer output should not exceed 0.01 UI rms.

1.3.5.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

With no jitter at the input to the multiplexer and demultiplexer, the jitter at the demultiplexer output should not exceed 1/5 UI peak-to-peak.

1.3.5.4 *Demultiplexer jitter transfer characteristic*

The gain of the jitter transfer characteristic should not exceed the limits given in Figure 5/G.752.

Figure 5/G.752 p.

1.3.6 *Digital interfaces*

The digital interfaces at 6312 kbit/s and 44 | 36 kbit/s should be in accordance with Recommendation G.703.

1.3.7 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

1.3.8 *Service digits*

The service digits are reserved for national use.

2 Fourth-order multiplex equipment operating at 97 | 28 kbit/s

2.1 *Bit rate*

The nominal bit rate should be 97 | 28 kbit/s. The tolerance on that rate should be ± | 0 parts per million (ppm).

2.2 *Frame structure*

Table 3/G.752 gives:

— the tributary bit rate and the number of tributaries;

— the number of bits per frame;

— the bit numbering scheme;

— the bit assignment;

— the frame alignment signal.

2.3 *Loss and recovery of frame alignment and consequent action*

The mean frame alignment recovery time should not exceed 1 ms.

The signal to be applied to the tributaries during the out-of-frame alignment time should be all 1s pattern.

2.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and the $C_{j\backslash dn}$-bits should be used (n = 1, 2, 3, see Table 3/G.752).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 3/G.752 gives the maximum justification rate per tributary and the nominal justification ratio.

H.T. [T3.752]

TABLE 3/G.752

97 | 28 kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	32 | 64
Number of tributaries	3
Frame structure	Bit number
	Set I
Frame alignment signal (110)	1 to 3
Bits from tributaries	4 to 192
	Set II
{ Justification control bits C *j* 1 (see Note 1) }	1 to 3
Bits from tributaries	4 to 192
	Set III
{ Justification control bit C *j* 2 (see Note 1) }	1 to 3
Bits from tributaries	4 to 192
	Set IV
Frame alignment signal (001)	1 to 3
Bits from tributaries	4 to 192
	Set V
{ Justification control bits C *j* 3 (see Note 1) }	1 to 3
Bits from tributaries	4 to 192
	Set VI
{ Auxiliary bits H *n* (*n* = 1, 2, 3) (see Note 2) }	1 to 3
Bits from tributaries	4 to 192
Frame length	1 | 52 bits
{ Bits per tributary per frame (including justification) }	| 78 bits
{ Maximum justification rate per tributary }	84 | 33 bit/s
Nominal justification ratio	0.035

Note 1 — C *j n* indicates the *n* th justification bit of the *j* th tributary (*j* = 1, 2, 3).

Note 2 — This signal is H 1 H 2 H 3 pattern where H 1 is the parity bit for the preceding frame, and H 2 is a bit reserved for national use, and H 3 is a bit to transmit the failure information from the receiving end to the transmitting end.

Note 3 — The bit available for justification of tributary *j* is the first slot of tributary *j* following H *n*

Table 3/G.752 [T3.752], p.

2.5 *Jitter*

2.5.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 6/G.752. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length 2^{15} — 1.

Note — The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.

Figure 6/G.752, p.

2.5.2 *Multiplex signal output jitter*

The jitter at the 97 | 28 kbit/s output of the multiplexer should not exceed 0.01 UI rms.

2.5.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

The peak-to-peak jitter at a tributary output of the demultiplexer with no jitter at the inputs should not exceed 0.25 UI.

2.5.4 *Demultiplexer jitter transfer characteristic*

A 32 | 64 kbit/s signal, modulated by sinusoidal jitter, should be subject to a demultiplexer jitter transfer characteristic within the gain/frequency limits given in Figure 7/G.752.

Figure 7/G.752, p.

2.6 *Digital interface*

The digital interfaces at 32 | 64 kbit/s and 97 | 28 kbit/s should be in accordance with Recommendation G.703.

2.7 *Service digits*

The service digits are reserved for national use.

Reference

[1] CCITT Recommendation *Recommendations concerning translating equipments* , Vol. III, Rec. G.233.

Recommendation G.753

THIRD ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING

AT 34 | 68 kbit/s AND USING POSITIVE/ZERO/NEGATIVE JUSTIFICATION

(Geneva, 1980, further amended)

1 General

The third order digital multiplex system with positive/zero/negative pulse justification as given below is intended for digital connection between countries having the same type of justification using any second order digital systems at 8448 kbit/s.

2 Bit rate

The nominal bit rate should be 34 | 68 kbit/s. The tolerance on that rate should not be more than ± | 0 parts per million (ppm).

3 Frame structure

Table 1/G.753 gives:

— the tributary bit rate and the number of tributaries;

— the number of bits per frame;

— the bit numbering scheme;

— the bit assignment;

— the bunched frame alignment signal.

H.T. [T1.753]

TABLE 1/G.753

34 | 68-kbit/s multiplexing frame structure using positive/zero/negative justification

Tributary bit rate (kbit/s)	8448
Number of tributaries	4
Frame structure	Bit number
	Set I
{ Frame alignment signal (111110100000) }	1 to 12
{ Bits from the secondary tributaries }	13 to 716
	Set II
{ Justification control bits (C *j* 1) }	1 to 4
Bits for service functions	5 to 8
{ Justification control bits (C *j* 2) }	9 to 12
{ Bits from the secondary tributaries }	13 to 716
	Set III
{ Justification control bits (C *j* 3) }	1 to 4
{ Bits reserved for national use }	5 to 8
{ Bits from tributaries available for negative justification }	9 to 12
{ Bits from tributaries available for positive justification }	13 to 16
Bits from the tributaries	17 to 716
Frame length	2148 bits
Frame duration	62.5 µs
Bits per tributary	528
{ Maximum justification rate per tributary }	16 kbit/s

Note — C *j n* indicates the *n* th justification control pulse of the *j* th tributary.

Table 1/G.753 [T1.573], p.

4 Loss and recovery of frame alignment and consequent actions

The frame alignment system should be adaptive to the error ratio in the line link. Until frame alignment is restored the frame alignment system should retain its position. A new search for the frame alignment signal should be undertaken when three or more consecutive frame alignment signals have been incorrectly received in their positions.

Frame alignment is considered to have been recovered when more than two consecutive frame alignment signals have been correctly received in their predicted positions.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive-negative justification with two-command control are recommended. The justification control signal should be distributed and use $C_{j\backslash dn}$-bits (n = 1, 2, 3 see Table 1/G.753). Correction of one error in a command is possible.

Positive justification should be indicated by the signal 111, transmitted in each of two consecutive frames; negative justification should be indicated by the signal 000, transmitted in each of two consecutive frames, and no justification by the signal 111 in one frame followed by 000 in the next frame.

Digit time slots 9, 10, 11, 12 (Set III) are used for information carrying bits (for negative justification), and digit time slots 13, 14, 15, 16 in Set III when it is necessary are used for no information carrying bits (for positive justification) for the tributaries 1, 2, 3, 4.

Besides, when information from tributaries 1, 2, 3 and 4 is not transmitted, bits 9, 10, 11 and 12 in Set III are available for transmitting information concerning the type of justification (positive or negative) in frames containing commands of positive justification control and intermediate amount of jitter in frames containing commands of negative justification.

Table 1/G.753 gives maximum justification rate per tributary.

6 Jitter

The amount of jitter that should be tolerated at the input of the multiplexer and the demultiplexer should be according to 3.1.1/G.823. The amount of jitter at the output of the multiplexer and the demultiplexer should be studied and specified.

7 Digital interface

The interface at the nominal bit rate 34 | 68 kbit/s is under study.

8 Timing signal

The clock should be able to be controlled by an external source.

9 Service digits

Some spare bits per frame are available for service functions (bits 5, 6 and 8 in Set II) for national and international use. Bits 5 and 6 in Set II are available for a digital service channel (using 32 kbit/s Adaptive Delta Modulation) and bit 8 in Set II is available for ringing up a digital service channel.

10 Fault conditions and consequent actions

10.1 The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of the incoming signal at 8448 kbit/s at the input of the multiplexer.

Note — When using separate circuits for the digital signal and the timing signal, loss of either or both of them should constitute loss of the incoming signal.

10.1.3 Loss of the incoming signal at 34 | 68 kbit/s at the input of the demultiplexer.

Note — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 34 | 68 kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

After detecting a fault condition, appropriate actions should be taken as specified in Table 2/G.753. The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to signify that the performance is below acceptable standards and maintenance attention is required locally. When detecting the Alarm Indication Signal (AIS) at the 34 | 68 kbit/s input of the demultiplexer the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited (see Note 1 below).

Note — The location and provision of any visual and/or audible alarm activated by this prompt maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 7 of Set II at the 34 | 68 kbit/s output of the multiplexer.

10.2.3 AIS (see Note 2 below) applied to all four outputs of the 8448 kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Note 2 below) applied to the 34 | 68 kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 34 | 68 kbit/s signal at the multiplexer output corresponding to the relevant 8448 kbit/s tributary.

Note 1 — The bit rate of the AIS at the output of the corresponding demultiplexer should be as specified for the tributaries. The method of achieving this is under study.

Note 2 — The equivalent binary content of the AIS at 8448 kbit/s and 34 | 68 kbit/s is a continuous stream of binary 1s.

H.T. [T2.753]

TABLE 2/G.753

Fault conditions and consequent action

Equipment part	{			{		
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes, if practicable	Yes, if practicable	Yes, if practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes				Yes	
Demultiplexer only	{ Yes Yes	Yes Yes	Yes {	Loss of frame alignment	Yes	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Table 2/G.753 [T2.G.753], p.

Recommendation G.754

FOURTH ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING

AT 139 | 64 kbit/s AND USING POSITIVE/ZERO/NEGATIVE JUSTIFICATION

(Geneva, 1980; further amended)

1 General

The fourth order digital multiplex system with positive/zero/negative pulse justification as given below is intended for use on digital connection between countries having the same type of justification using any third order digital systems at 34 | 68 kbit/s.

2 Bit rate

The nominal bit rate should be 139 | 64 kbit/s. The tolerance on that rate should not be more than ± | 5 parts per million (ppm).

3 Frame structure

Table 1/G.754 gives:

— the tributary bit rate and the number of tributaries;

— the number of bits per frame;

— the bit numbering scheme;

— the bit assignment;

— the bunched frame alignment signal.

H.T. [T1.754]

TABLE 1/G.754

139 | 64-kbit/s multiplexing frame structure using positive/zero/negative justification

Tributary bit rate (kbit/s)	34 | 68
Number of tributaries	4
Frame structure	Bit number
	Set I
Frame alignment signal	1 to 10
Bits for service functions	11 to 12
Bits from tributaries	13 to 544
	Set II
{ Justification control bits (C_{j1}) }	1 to 4
Bits from tributaries	5 to 544
	Set III
{ Justification control bit (C_{j2}) }	1 to 4
Bits from tributaries	5 to 544
	Set IV
{ Justification control bit (C_{j3}) }	1 to 4
{ Bits from tributaries available for negative justification }	5 to 8
{ Bits from tributaries available for positive justification }	9 to 12
Bits from tributaries	13 to 544
Frame length	2176 bits
Frame duration	15.625 µs
Bits per tributaries	537
{ Maximum justification rate per tributary }	{
64 kbit/s	
Note — C_{jn} indicates the nth justification control bit of the jth tributary. }	

Table 1/G.754 [T1.754], p.

4 Loss and recovery of frame alignment and consequent action

The frame alignment system should be adaptive to the error rate in the line link. Until frame alignment is restored the frame alignment system should retain its position. A new search for the frame alignment signal should be undertaken when three and more consecutive frame alignment signals have been incorrectly received in their position.

Frame alignment is considered to have been recovered when more than two consecutive frame alignment signals have been correctly received in their predicted positions.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive-negative justification with two-command control are recommended. The justification control signal should be distributed and use $C_{j\backslash dn}$-bits (n = 1, 2, 3 see Table 1/G.754). Correction of one symbol error in a command is possible.

Positive justification should be indicated by the signal 111, transmitted in each of two consecutive frames; negative justification should be indicated by the signal 000, transmitted in each of two consecutive frames, and no justification by the signal 111 in one frame followed by 000 in the next frame.

Digit time slots 5, 6, 7, 8 (Set IV) are used for information carrying bits (for negative justification), and digit time slots 9, 10, 11, 12 in Set IV, when it is necessary, are used for no information carrying bits (for positive justification) for the tributaries 1, 2, 3, 4.

Besides, when information from tributaries 1, 2, 3 and 4 is not transmitted, bits 5, 6, 7 and 8 in Set IV are available for transmitting information concerning the type of justification (positive or negative) in frames containing commands of positive justification control and intermediate amount of jitter in frames containing commands of negative justification.

Table 1/G.754 gives maximum justification rate per each third order tributary.

6 Jitter

The amount of jitter that should be accepted at the inputs of the demultiplexer and multiplexer and should be at the output of the demultiplexer is under study.

7 Digital interface

The interface at the nominal bit rates 34 | 68 kbit/s and 139 | 64 kbit/s is under study.

8 Timing signal

The clock should be able to be controlled by an external source.

9 Service functions

Some spare bits per frame are available for service functions (bits 11 and 12 in Set I) for national and international use. Bit 11 in Set I is available for a digital service channel (using 32 kbit/s Adaptive Delta Modulation) and bit 12 is available for ringing up a digital service channel.

10 Fault conditions and consequent actions

10.1 The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of the incoming signal at 34 | 68 kbit/s at the input of the multiplexer.

10.1.3 Loss of the incoming signal at 139 | 64 kbit/s at the input of the demultiplexer.

Note — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 139 | 64 kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

After detection of a fault condition appropriate actions should be taken as specified in the Table 2/G.754 . The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to signify that the performance is below acceptable standards and maintenance attention is required locally. When detecting the Alarm Indication Signal (AIS) at the 139 | 64 kbit/s input of the demultiplexer the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited (see Note 1 below).

Note — The location and provision of any visual and/or audible alarm activated by this prompt maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 12 of Set I at the 139 | 64 kbit/s output of the multiplexer.

10.2.3 AIS (see Note 2 below) applied to all the four outputs of the 34 | 68 kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Note 2 below) applied to the 139 | 64 kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 139 | 64 kbit/s signal at the multiplexer output corresponding to the relevant 34 | 68 kbit/s tributary.

Note 1 — The bit rate of the AIS at the output of the corresponding demultiplexer should be as specified for the tributaries. The method of achieving this is under study.

Note 2 — The equivalent binary content of the AIS at 34 | 68 kbit/s and 139 | 64 kbit/s is a continuous stream of binary 1s.

H.T. [T2.754]

TABLE 2/G.754

Fault conditions and consequent actions

Equipment part	{			{		
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes, if practicable	Yes, if practicable	Yes, if practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes				Yes	
Demultiplexer only	{ Yes Yes	Yes Yes	Yes {	Loss of frame alignment	Yes	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Table 2/G.754 [T2.754], p.

Recommendation G.755

DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 139 | 64 KBIT/S

AND MULTIPLEXING THREE TRIBUTARIES AT 44 | 36 KBIT/S

(Melbourne, 1988)

1 General

The digital multiplex equipment described in this Recommendation is intended for use between networks using different digital hiararchies as specified in Recommendations G.702 and G.802.

2 Bit rate

The bit rates of the tributary and multiplex signals should be 44 | 36 kbit/s ± | 0 ppm and 139 | 64 kbit/s ± | 5 ppm, respectively, as specified in Recommendation G.703.

3 Frame structure

Table 1/G.755 gives the recommended 139 | 64 kbit/s multiplexing frame structure.

4 Loss and recovery of frame alignment and consequent action

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive correct frame alignment signals.

The frame alignment device, having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note — As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

5 Multiplexing and justification methods

Cyclic bit interleaving in the tributary numbering order and positive justification are recommended.

The justification control signal should be distributed and use the $C_{j\backslash di}$ | (hybits (j = 1, 2, 3; i = 1, 2, 3, 4, 5) (see Note 6 to Table 1/G.755).

Positive justification should be indicated by the justification control signal 11111 and no justification by the signal 00000. Majority decision is recommended.

Table 1/G.755 gives the maximum justification rate per tributary and the nominal justification ratio.

6 Jitter

6.1 *Demultiplexer triburaty jitter transfer characteristic*

The demultiplexer 44 | 36 kbit/s tributary jitter transfer characteristic should meet the gain/frequency limits given in Figure 1/G.755. The equivalent binary content of the test signal used should result in a tributary output signal of 1000.

H.T. [T1.755]

TABLE 1/G.755

139 | 64 kbit/s multiplexing frame structure

Nominal tributary bit rate (kbit/s)	44 | 36
Number of tributaries	3
Frame structure	Bit number
	Set I
Frame alignment signal (111110100000)	1 to 12
Bits from tributaries	13 to 159
	Set II
Justification control bits C_{j1} (Note 1)	1 to 3
Bits from tributaries	4 to 159
	Set III
Justification control bits C_{j2} (Note 1)	1 to 3
Bits from tributaries	4 to 159
	Set IV
Justification control bits C_{j3} (Note 1)	1 to 3
Alarm indication to the remote multiplex equipment (Note 2)	4
Parity bit (Notes 3, 4 and 5)	5
Bits reserved for future use (Note 6)	6 to 9
Bits from tributaries	10 to 159
	Set V
Justification control bits C_{j4} (Note 1)	1 to 3
Bits from tributaries	4 to 159
	Set VI
Justification control bits C_{j5} (Note 1)	1 to 3
Bits from tributaries available for justification	4 to 6
Bits from tributaries	7 to 159
Frame length	954 bits
Bits per tributary in a frame	307 bits
Maximum justification rate per tributary	146 kbit/s
Nominal justification ratio	0.545

Note 1 — C *j i* (*j*
| | , 2, 3; *i*
| | , 2, 3, 4, 5) indicates the *i* th justification control bit of the *j* th tributary.

Note 2 — See § 10.2.1.

Note 3 — The parity bit | | if the number of marks in all tributary bits including the bits in the justifiable time-slots in the preceding frame is odd; the parity bit | | if the number of marks in all tributary bits including the bits in the justifiable time-slots in the preceding frame is even.

Note 4 — It is recognized that existing multiplex equipment installed prior to adoption of this Recommendation does not insert the parity bit.

Note 5 — The implementation and the use of this parity bit procedure are for further study.

Note 6 — These bits should be set to 1 when not used.

Table 1/G.755 [T1.755], p.

Note 1 — This characteristic is usually measured between the high speed and low speed interfaces of the demultiplexer and the measurements are taken in unit intervals. It is then necessary to introduce a correction factor to account for the difference in the size of unit intervals.

Note 2 — In addition, the need to specify a muldex jitter transfer characteristic is for further study.

Note 3 — It is recognized that the existing multiplex equipment designed prior to the adoption of this Recommendation might need tributary test signals incorporating the 44 | 36 kbit/s frame structure defined in Recommendation G.572.

Figure 1/G.755, p.

6.2 *Output jitter*

6.2.1 *Tributary output jitter*

With no jitter applied to the input ports of the multiplexer and with the multiplexer directly connected to the demultiplexer, the peak-to-peak jitter at the tributary output port should not exceed 0.3 UI when measured over a one minute interval within the frequency range from f_1 = 10 Hz to f_4 = 400 Hz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of f_3 = 60 kHz, a roll-off of 20 dB/decade and an upper limit of f_4 = 400 kHz, the peak-to-peak output jitter should not exceed 0.05 UI when it is measured over a one minute interval.

6.2.2 *Multiplexer output jitter*

The peak-to-peak jitter at the 139 | 64 kbit/s output port should not exceed 0.05 UI when it is measured over a one minute interval within the frequency range from 200 Hz to 3500 kHz.

6.3 *Input jitter*

6.3.1 *Tributary input jitter*

The 44 | 36 kbit/s input port should be capable of accommodating levels of input jitter up to the limits given in Figure 2/G.755.

Note — Current Recommendation G.703 does not refer to the jitter tolerated at the digital distribution frame at 44 | 36 kbit/s nor at the input port of equipment connected to this distribution frame.

Figure 2/G.755, p.

6.3.2 *Demultiplexer input jitter*

The 139 | 64 kbit/s input port should be capable of accommodating levels of input jitter up to the limits given in Recommendation G.823.

Note — The jitter accommodation requirement should be met when the jittered input signal is composed of the multiplexed tributary signals having any value of jitter allowed for the 44 | 36 kbit/s level.

7 Digital interfaces

The digital interfaces at 44 | 36 kbit/s and 139 | 64 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

If it is economically feasible, it may be desirable to be able to derive the multiplexing timing signal from an external source as well as from an internal source.

9 Service digits

Six bits per frame are available for service functions (see Table 1/G.755): bit 4 of Set IV is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment when specific fault conditions are detected in the multiplex equipment (see § 10 below); bit 5 of Set IV may be used for a parity check; bits 6 to 9 of Set IV are reserved for further use.

10 Fault conditions and consequent actions

10.1 *Fault conditions*

10.1.1 The digital multiplex equipment should detect the following fault conditions:

1) failure of power supply;

2) loss of an incoming 44 | 36 kbit/s tributary signal at a multiplexer input port;

3) loss of an incoming 139 | 64 kbit/s multiplex signal at a demultiplexer input port;

Note — The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

4) loss of frame alignment signal at a demultiplexer input port;

5) detection of an alarm indication received from the remote multiplex equipment at a demultiplexer input port;

6) detection of alarm indication signal (AIS) at a demultiplexer input port.

Note 1 — The equivalent binary content of the AIS at 139 | 64 kbit/s should be a continuous stream of binary 1s (marks) as recommended in Recommendation M.20.

Note 2 — The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio of 1×10^{D}lF261^{3}. However, a signal with all bits except the frame alignment signal in the state of 1 should not be mistaken as an AIS.

10.1.2 The need to monitor the degradation of the incoming 139 | 64 kbit/s signal for the purpose of end-to-end error performance monitoring of the 139 | 64 kbit/s digital block, as well as the procedure for detecting such degradation are for further study.

10.2 *Consequent actions*

Further to the detection of a fault condition, the appropriate actions should be taken as specified in Table 2/G.755.

Note 1 — The concept and definition of prompt maintenance alarm indication is given in Recommendation M.20.

Note 2 — When the alarm indication signal (AIS) is detected at the input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.755 with the fault condition.

10.2.1 Alarm indication to the remote multiplex equipment should be generated by changing bit 4 of Set IV (see Table 1/G.755) from the state 0 to the state 1.

10.2.2 AIS should be applied to the following as specified in Table 2/G.755:

— all three 44 | 36 kbit/s tributary outputs from the demultiplexer;

— 139 | 64 kbit/s output of the multiplexer;

— the time slots of the 139 | 64 kbit/s signal at the output of the multiplexer, corresponding to the relevant 44 | 36 kbit/s tributary.

Note — The equivalent binary content of the AIS at 44 | 36 kbit/s is a signal with a valid frame alignment signal, parity and justification control bits as defined in Table 2/G.752, with the tributary bits being set to a 1010 | | | sequence, starting with a binary 1 after each frame alignment, multi-frame alignment and justification control bit, and with all justification control bits being set to binary 0.

Blanc

H.T. [T2.755]

TABLE 2/G.755

Fault conditions and consequent actions

Equipment part	{			{		
Multiplexer and demultiplexer	Failure of power supply	Yes		Yes, if practicable	Yes, if practicable	
Multiplexer only Loss of incoming signal on a tributary }	{ Yes				Yes	
Demultiplexer only	{ Yes Yes	Yes Yes	Yes {	Loss of frame alignment	Yes	

Note — A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Tableau 2/G.755 [T2.755], p. 39