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SECTION 5

CONTINUITY CHECK OF THE SPEECH PATH

Recommendation Q.271

5.1 GENERAL

Because the signalling in System No. 6 does not pass over the speech path, facilities should be provided for making a continuity check of the speech path prior to the commencement of conversation. The check is not

intended to eliminate the need for routine testing of the transmission path.

This specification relates only to that part of an international connection served by Signalling System No. 6. The part of the speech path to be checked may include a TASI circuit.

As the presence of active echo suppressors in the circuit would interfere with the continuity check, it is necessary to disable the suppressors during the check and to re-enable them, if required, after the check has been completed.

5.2 RELIABILITY OF THE SPEECH PATH ACROSS THE EXCHANGE

Administrations shall ensure the reliability of a connection through a switching machine (cross-office check) either on a per call basis or by a statistical method. With either method, the probability of the connection being established with an unacceptable speech path, transmission quality should not exceed 10^{D}lF261^{5} as the long-term average.

5.3 CONTINUITY CHECK OF THE SPEECH CIRCUIT BETWEEN EXCHANGES

The continuity check of the speech circuit will be done, link-by-link, on a per call basis prior to the commencement of conversation. The loop checking method used is specified in the following sections.

5.4 LOOP CHECKING METHOD

The continuity check transceiver (check-tone transmitter and receiver) is connected to the GO and RETURN paths of the outgoing circuit at the first and each succeeding exchange, excluding the last exchange, in that part of the international connection served by Signalling System No. 6. The check loop should be connected to the GO and RETURN paths of the incoming circuit at each exchange except the first in that part of the international connection served by Signalling System No. 6. A continuity check is considered successful when a tone is sent on the GO path and is received on the RETURN path within acceptable transmission and timing limits.

5.5 TRANSMISSION REQUIREMENTS FOR THE CONTINUITY CHECK

5.5.1 *Transmitting equipment*

The check-tone frequency will be 2000 ± 20 Hz.

The sending level of the check tone will be —12 ± 1 dBm0.

5.5.2 *Check loop*

The check loop will have a loss of 0 dB, taking into account any

difference between the relative levels of the two paths at the point of attachment.

5.5.3 *Receiving equipment*

The check-tone receiver will have the following characteristics:

5.5.3.1 *Operating requirements*

Signal frequency: 2000 ± 30 Hz

Signal level range: The absolute power level N of the check tone shall be within the limits

(—18 + n) N (—6 + n) dBm

where n is the relative power level at the receiver input

Recognition time: 30 to 60 ms

The frequency and level range tolerances allow for variations at the sending end and for variations in line transmission that are considered acceptable.

5.5.3.2 *Non-operating requirements*

Signal frequency: outside the frequency band 2000 ± 200 Hz

Signal level: below or equal to —22 + n dBm0

The limit is 10 dB below the nominal absolute level of the check tone at the input of the receiver. If the level falls below this point, transmission is considered unacceptable.

Signal duration: shorter than 30 ms

The level range of (—18 + n) N (—6 + n) dBm will serve as a GO/NO-GO check on the links in that part of the international connection served by Signalling System No. 6.

5.5.3.3 *Release requirements*

If the receiver is used to test for the removal of check tone (see Recommendation Q.261, § 4.1.4):

— after recognition of tone, interruptions of up to 15 ms shall be ignored; this will prevent switching through the speech path prematurely;

— the indication of tone removal should not be delayed more than 40 ms; and

— the release level of the receiver should be lower than —27 + n dBm.

5.6 CONTINUITY SIGNAL

The procedure for sending the continuity signal is given in Recommendation Q.261, § 4.1.4.

5.7 TIMING CONSIDERATIONS FOR THE CONTINUITY CHECK

5.7.1 *Time-out period of the continuity check*

The continuity check is considered to have failed if the receiver has not responded within a period determined by the Administration concerned. This period should not exceed 2 seconds.

The time-out period of the continuity check should always exceed the continuity recognition time, $T_{C\backslash dR}$, given by:

$$T_{C\backslash dR} = 2T_p + T_{IAM} + T_{T\backslash dC} + T_L + T_R - T_T$$

where: T_p = one-way propagation time of the speech circuit and the signalling link (where they are the same),

$T_{T\backslash dC}$ = TASI clip time for two TASI systems in series (for connections not using TASI, $T_{T\backslash dC} = \mathbf{0}$),

T_R = receiver response time ,

T_L = loop connecting time (maximum),

T_T = transceiver connecting time (minimum),

T *IAM* .PS 10 = emission time of the longest initial address message

If retransmission of an IAM is to be included in $T_{C\backslash dR}$, the following formula may be used:

$$T_{C\backslash dR} = 4T_p + 2T_{IAM} \text{ .PS 10} + T_{ACU} \text{ .PS 10} + T_x + T_y + T_L + T_R - T_T$$

where: T *ACU* .PS 10 = emission time of an ACU (length of an ACU),

T_x = time between receiving an IAM and emitting an ACU ,

T_y = time between receiving an ACU and emitting an initial address message

5.7.2 *Switching times of continuity check equipment*

The connection and disconnection of the equipment used for the continuity check and also the disabling and subsequent enabling of echo suppressors should be related to the following stages of progress in the establishment of the connection:

a) *Preparation at System No. 6 exchange applying the transceiver* . — Action should be initiated at the termination of the handling time T_h of the initial address message, i.e. when it is inserted in the output buffer and is available for emission.

b) *Preparation at System No. 6 exchange connecting the check loop* initial address message received.

c) *Disconnection at System No. 6 exchange connecting the check loop* . — Action follows the receipt of the continuity signal or the clear-forward signal, or the emission of signals indicating that the call cannot be established, e.g. circuit-group congestion signal.

d) *Disconnection at System No. 6 exchange applying the* transceiver. — Action should be initiated on the successful completion or the failure of the continuity check. Exceptionally, if disconnection has not previously occurred action should be initiated at the moment of recognition of the address-complete signals, the answer signals, signals indicating that the call cannot be established, or on the emission of a clear-forward signal.

It is recommended that the mean time, both for the connection and for the disconnection, be less than 100 ms. A mean time of 200 ms should not be exceeded. See Recommendation Q.261.

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SECTION 6

SIGNALLING LINK

Recommendation Q.272

6.1 REQUIREMENTS FOR THE SIGNALLING DATA LINK

6.1.1 *General*

a) The signalling data link may be either an analogue signalling data link (§ 6.1.1.1 below) or a digital signalling data link (§ 6.1.1.2 below).

b) System No. 6 is capable of operating over signalling data links with the longest loop propagation time visualized (see also § 6.7.3 below).

c) To reduce the possibility of the called party being distorted or clipped, the propagation time of the signalling data link should be as low as possible and should not be significantly greater than that of any speech circuits with which it is associated.

d) The signalling data link shall be dedicated to the use of a System No. 6 signalling link between two points, the only switching to be provided being that required for the security arrangements (see Recommendation Q.292).

e) A means must be furnished for disabling the echo suppressors which might be associated with the circuits used for the signalling data links. Disabling must be accomplished by local action by the processor at each terminal.

6.1.1.1 *Analogue signalling data link*

The analogue signalling data link shall be made up of standard international voice-frequency channels, either 3-kHz or 4-kHz spaced, and associated modems. The overall transmission characteristics of the voice-frequency channels must be equalized if necessary to meet the recommendations of § 6.1.3 below.

6.1.1.2 *Digital signalling data link*

The digital signalling data link shall be derived from the 1544 kbit/s (Recommendation Q.47) or 2048 kbit/s (Recommendation Q.46) primary multiplex equipment and includes the appropriate digital interface adaptor.

6.1.2 *Error rate characteristics of the data channel*

6.1.2.1 *Analogue data channel*

The data transmitted at 2400 bits per second with four-phase PSK (*phase shift keying*) modulation over a data channel as specified should meet a long-term bit error rate of less than 1 in 10^5 in normal operation (see Recommendation Q.295, § 9.2.7). This figure excludes interruptions exceeding 350 ms in length.

6.1.2.2 *Digital data channel*

The data transmitted at permitted data rates over digital data channels as specified should meet a long term bit error rate of less than 1 in 10^6 in normal operation (see Recommendation Q.295, § 9.2.7). This figure excludes interruptions exceeding 350 ms in length.

6.1.3 *Transmission characteristics of the voice-frequency channel*

The transmission characteristics of the voice-frequency channels used in the signalling data link are based on those in Recommendation M.761.

However, for the System No. 6 data rate and modulation method, Recommendation M.761 offers some latitude in the selection of channels. The equalization for attenuation distortion and delay distortion of the channels can be restricted to the frequency band 1000 to 2600 Hz (see Figures 15/Q.272 and 16/Q.272).

a) *Overall loss at 800 Hz* . — The overall loss at 800 Hz of the channels of a transfer link is not specified.

The channels of a transfer link should be set up so that when a test signal at a level of —10 dBm0 is connected to the input of the transfer channel, the level received at the output of the transfer channel at the distant end is as close as possible to —10 dBm0.

b) *Variation of overall loss at 800 Hz* . — The variation with time overall loss at 800 Hz should be as small as possible but should not exceed the following limits: Short-term variation (over a period of a few seconds) ± | dB

Long-term variation (over long periods including daily and seasonal variations) ± | dB

c) *Attenuation/frequency distortion* . — The variation of the overall loss of the channel with frequency over the range of 1000 to 2600 Hz relative to the attenuation at 800 Hz should not exceed the limits shown in Figure 15/Q.272.

FIGURE 15/Q.272 p.1

d) *Delay/frequency distortion* . — The delay/frequency distortion in the band of frequencies from 1000 to 2600 Hz relative in that band should not exceed the limits given in Figure 16/Q.272. It may be necessary to select channels and/or provide suitable delay distortion equalizers to ensure that these limits are not exceeded.

Where the full-time reserved link is a TASI speech circuit taken into use for signalling purposes, this characteristic may not be met unless all TASI channels in the route meet the transmission requirements specified above. In addition, it may be necessary to restrict the number of 3-kHz-spaced channels used in a signalling data link.

FIGURE 16/Q.272 p.2

e) *Uniform spectrum random circuit noise* . — See Recommendation M.761, partifularly the note to Recommendation M.761, § 2.6.

f) *Impulse noise* . — Impulsive noise on the voice-frequency channel should not exceed 18 peaks in 15 minutes, greater than —21 dBm0. Measurements should be made during peak hours.

According to Recommendation M.761, impulsive noise should be measured with an instrument complying with Recommendation O.71. The value given above is a provisional limit for maintenance purposes; final values are still under study.

6.1.4 *Nominal data carrier power level*

The nominal data carrier power level is —15 dBm0 (see Recommendation Q.15).

Recommendations H.41 and V.2 allow a power level of —10 dBm0 when no more than 5% of the channels in a multichannel system are used for non-speech applications simultaneously in both directions. If the percentage of channels in this type of service is considerably more than 5%, the power should be reduced. Recommendation Q.15 allows a mean absolute power level of —15 dBm0.

6.1.5 *Slip characteristics of the digital data channel*

The occurrence of slips adversely affects the service dependability of the signalling system. Means must be provided for

a) preventing slips from occurring, e.g., by use of synchronization or by use of a contra-directional interface, or

b) detecting slips, or

c) providing accurate clocks to reduce the occurrence of undetected slips.

Although a means can be provided to detect slips, in general each slip that occurs will cause a signal unit to be received in error. When using a slip detecting mechanism, the slip rate must be such that the dependability requirements of Recommendation Q.276, § 6.6.1 are still met (see also Recommendation Q.276, § 6.8.3).

6.1.5.1 *The 1544 kbit/s primary multiplex*

Provisionally, the need for a slip requirement is not foreseen.

6.1.5.2 *The 2048 kbit/s primary multiplex*

a) 4 kbit/s signalling rate

The coding for deriving the 4 kbit/s channel from the 64 kbit/s bearer is designed so that slips are always detected and the true data recovered.

b) 56 kbit/s signalling rate

The coding for deriving the 56 kbit/s channel from the 64 kbit/s bearer may be used to detect slips. Provisionally an undetected slip rate not exceeding once in 16 days is required.

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ANNEX A

(to Recommendation Q.272)

Proposed changes presently under study

Figura A-15/Q.272 p. 3

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Figura A-16/Q.272 p. 4

Recommendation Q.273

6.2 DATA TRANSMISSION RATE

6.2.1 *Analogue data channel rate*

The preferred data transmission rate on analogue channels is 2400 bit/s.

6.2.2 *Digital data channel rates*

The preferred data transmission rate on digital channels is 4 kbit/s for both the 1544 kbit/s and 2048 kbit/s international digital multiplexes. In addition, the rate of 56 kbit/s may be used with the 2048 kbit/s international digital multiplex.

Recommendation Q.274

6.3 TRANSMISSION METHODS

6.3.1 *Analogue modulation methods*

The modulation technique described in this Recommendation uses *phase shift keying* to transmit serial binary data over analogue telephone channels. The binary data signal is encoded by first grouping it into bit pairs (dibits). Each dibit is represented by one of four possible carrier phase shifts. Thus, the output from the phase modulator consists of a serial train of phase-shifted carrier pulses at half the data bit rate. The phase shift between two consecutive modulation elements contains the information to be transmitted.

The data receiver uses differentially coherent detection to recover the sense of the binary data from the line signal. This type of detection has proven to be relatively insensitive to the types of distortions and interference encountered on telephone-type transmission media. It also allows rapid recovery from such catastrophic impairments as drop-outs and large phase hits.

Receiver timing recovery can be accomplished in several ways. A very rapid timing recovery scheme can be provided using certain properties of the transmitted spectrum.

Receiver timing information can also be extracted from the zero crossings, on a dibit basis, of the received baseband data signals. The latter method is capable of providing synchronization holdover through extended drop-outs and periods of high noise.

6.3.2 *Digital transmission methods*

The methods used to derive the 4 and 56 kbit/s digital channels from the 1544 and 2048 kbit/s primary multiplexes are described below.

6.3.2.1 *Derivation from the 1544 kbit/s primary multiplex*

The binary data from the signalling terminal is transferred serially at the data transmission rate of 4 kbit/s to the 1544 kbit/s primary multiplex. At the primary multiplex each bit of the data stream is successively inserted into the S bit position (see Recommendation Q.47, § 4.1).

In the receive direction the primary multiplex extracts the bits from the S-bit position and transfers them serially to the signalling terminal.

6.3.2.2 *Derivation from the 2048 kbit/s primary multiplex*

a) *Data transmission at 4 kbit/s rate* . — The binary data from the signalling terminal is transferred serially to the digital interface adaptor. At the digital interface adaptor the 4 kbit/s data stream is modulated on a 64 kbit/s bearer channel such that 16 bits of the bearer channel correspond to one bit of the 4 kbit/s channel. The 64 kbit/s data stream is transferred serially to the 2048 kbit/s primary multiplex in alignment with an 8 kHz clock (byte timing). At the primary multiplex the 16 bits corresponding to one signalling information bit are inserted into the designated channel time slot of two successive frames.

In the receive direction the primary multiplex extracts the bits from the designated channel time slot and transfers them serially at 64 kbit/s in alignment with an 8 kHz clock to the digital interface adaptor. At the digital interface adaptor the 16 bits corresponding to one signalling information bit are detected and the binary data is transferred serially to the signalling terminal at the data transmission rate of 4 kbit/s.

b) *Data transmission at 56 kbit/s rate* . — The binary data from the signalling terminal is transferred serially to the digital interface adaptor. At the digital interface adaptor, the 28 bits of a signal unit are placed in bit positions 1 to 7 of four 8 bit bytes [see also § 6.4.2.4 |) below]. These four bytes are transferred serially at the data transmission rate of 64 kbit/s to the 2048 kbit/s primary multiplex in alignment with an 8 kHz clock (byte timing). At the primary multiplex, the four bytes are inserted into the designated channel time slot of four successive frames.

In the receive direction the primary multiplex extracts the bits from the designated channel time slot and transfers them serially at the data transmission rate of 64 kbit/s to the digital interface adaptor in alignment with an 8 kHz clock. In the digital interface adaptor the bits 1 to 7 of each 8 bit byte are transferred serially to the signalling terminal at the data transmission rate of 56 kbit/s.

6.4 MODEM AND INTERFACE REQUIREMENTS

6.4.1 *Analogue modem requirements*

The requirements for a 2400 bits per second modem are given below.

6.4.1.1 *Principal requirements*

The principal requirements of a modem used for System No. 6 are as follows:

a) Use of differential four-phase modulation (see Recommendation V.26, alternative B);

b) Use of differential coherent 4-phase demodulation;

c) Full duplex operation over a 4-wire data link;

d) A modulation rate of 1200 bauds;

e) A bit rate of 2400 bits per second.

6.4.1.2 *Frequency requirements*

a) The basic timing frequency shall be 2400 Hz (one cycle per bit);

b) The carrier frequency shall be 1800 Hz;

c) The carrier envelope frequency shall be 600 Hz (see § 6.4.1.4 below);

d) All frequencies generated in the modem shall be stable to within ± | .005% of the nominal value. They must have a constant phase relationship with respect to one another. This implies that all frequencies should be derived from a basic clock or that they be phase-locked.

6.4.1.3 *Encoding phase relationships*

The encoding phase relationship must be as follows:

Dibit	Phase change
0 |	+ 45°
0 |	+135°
1 |	+225°
1 |	+315°

The phase change is the actual on-line phase shift in the transition region from the end of one signalling element to the beginning of the following signalling element.

6.4.1.4 *Line signal envelope*

The data carrier pulse shape can be closely approximated by the following expression for a signal element centred at $t = 0$ (see Figure 17/Q.274):

and Envelope (t) = $$4ocos [Unable to Convert Formula] [Unable to Convert Formula] $$3u1 — cos [Unable to Convert Formula] $$3e for — ¾ T t ¾ T and Envelope (t) = 0 for — T t — ¾ T and ¾ T

t T

where f_d = the dibit rate of 1200 Hz,

and T = the dibit period of 1/1200 s.

FIGURE 17/Q.274 p.5

6.4.1.5 *Line power spectrum*

The line power spectrum produced by the transmission of random data is shown in Figure 18/Q.274. The spectral lines produced by the transmission of repeated dibits (using the encoding phase relationship of § 6.4.1.3 above) are also shown.

6.4.1.6 *Transmitter requirements*

a) The transmitter output level shall be —15 ± 1 dBm0 (see also Recommendation Q.272, § 6.1.4).

b) In the data transmitter, the bit timing and carrier frequency are derived from the same source to facilitate receiver timing recovery.

6.4.1.7 *Receiver requirements*

a) The receiver sensitivity range shall be —15 ± 8 dBm0 [see § 6.4.1.6 above and Recommendation Q.272, § 6.1.3 |)].

b) The modem receiver shall be capable of establishing bit synchronization as fast as possible, but in any case within 150 milliseconds while receiving synchronization signal units.

c) The receiver shall maintain bit synchronization with the distant transmitter for at least 500 milli seconds during a loss of data carrier after initial bit synchronization has been established.

FIGURE 18/Q.274 p.6

6.4.1.8 *Interface requirements*

Each Administration may at its discretion integrate the modem into the signalling terminal equipment or use a separate modem. If the modem is a separate unit, then the interface requirements of Recommendations V.24/V.28 should be followed as far as possible. Alternatively the interface requirements of § 6.4.2.3 below may be followed.

The transmitting and receiving signalling terminals derive timing from the timing frequency of the modem transmitter and receiver respectively.

6.4.2 *Digital interface requirements*

6.4.2.1 *General*

a) The interface between the signalling terminal and primary multiplex equipment can be functionally represented as shown in Figures 19/Q.274, 20/Q.274 and 21/Q.274. See also Recommendation G.703.

b) The interface adaptor functions are rate conversion of data where required, rate and/or direction conversion of clocks where required, generation of a receive holdover clock and transfer of a loss of frame alignment indication.

The interface requirements for the digital version can be followed for the analogue version. This admits the use of a universal signalling terminal.

c) The receive holdover clock must maintain bit synchronism for at least 500 ms during data channel failure at all data rates after initial bit synchronization has been established.

d) The transmit and receive clock signals shall be in phase with the respective data signals.

6.4.2.2 *Interface and adaptor requirements*

a) *The 4 kbit/s data transmission rate, 1544 kbit/s primary multiplex.* — The interface and adaptor functions for the 4 kbit/s data transmission rate over a 1544 kbit/s primary multiplex are shown in Figure 19/Q.274. The diagram is intended to show functions and should not be construed as depicting equipment.

FIGURE 19/Q.274 p.7

The interface adaptor is transparent to the send and receive data and to a loss of frame alignment indication. Data channel failure is covered in § 6.5.

A holdover function on the 4 kHz receive clock to the signalling terminal is provided to maintain bit synchronism for a minimum interval during which the receive clock is not present.

b) *The 4 kbit/s data transmission rate, 2048 kbit/s primary multiplex.* — The interface and adaptor functions for the 4 kbit/s data transmission rate over a 2048 kbit/s primary multiplex are shown in Figure 20/Q.274. The diagram is intended to show functions and should not be construed as depicting equipment.

The receive-rate converter converts the receive data on the 64 kbit/s bearer channel to receive data at 4 kbit/s using the 8 kHz and 64 kHz receive clocks. The 4 kHz receive clock is derived in the receive clock converter.

This material is subject to revision pending results of further work by Study Group XVIII.
The send rate converter converts the send data at 4 kbit/s to send data on the 64 kbit/s digital bearer channel using the 8 kHz and 64 kHz send clocks. The 4 kHz send clock is derived in the send clock converter.

The interface adaptor is transparent to a loss of frame alignment information. A holdover function on the 4 kHz receive clock to the signalling terminal is provided to maintain bit synchronism for a minimum interval during which the receive clock is not present. Data channel failure is covered in § 6.5 below.

c) *The 56 kbit/s data transmission rate, 2048 kbit/s primary multiplex* . — The interface and adaptor functions for the 56 kbit/s data transmission rate over a 2048 kbit/s primary multiplex are shown in Figure 21/Q.274. The diagram is intended to show functions and should not be construed as depicting equipment.

FIGURE 20/Q.274 p. 8

The interface adaptor is transparent to the send and receive data and to a loss of frame alignment indication. Data channel failure is covered in § 6.5 below.

The send data at 56 and 64 kbit/s is aligned with the 8 kHz send clock. Similarly, the receive data is aligned with the 8 kHz receive clock.

A holdover function on the receive clock to the signalling terminal is provided to maintain bit synchronism for a minimum interval during which the receive clock is not present.

6.4.2.3 *Interface electrical requirements*

Interface electrical requirements are given in Recommendation G.732 and Recommendation G.733, for the interface between the primary multiplex and the interface adaptor. Arrangements for the interface between the interface adaptor and the signalling terminal are left to the discretion of Administrations.

Each Administration may at its discretion integrate the interface adaptor into the signalling terminal or the primary multiplex equipment or may use a separate interface adaptor. If the interface adaptor is a separate unit then the interface electrical requirements above must be met. If it is integrated into either the signalling terminal equipment or the multiplex equipment the remaining interface must meet the interface electrical requirements.

FIGURE 21/Q.274 p.9

6.4.2.4 *Interface adaptor electrical requirements*

a) *The 1544 kbit/s primary multiplex, 4 kbit/s channel*

The send and receive data and the send clock signals traverse the interface adaptor without modification.

The receive clock and the data channel failure information are separated in the interface adaptor. The receive clock from the primary multiplex synchronizes the receive holdover clock. The holdover clock provides the receive clock to the signalling terminal. The interface adaptor recognizes data channel failure by the absence of the receive clock from the primary multiplex. This information is separately transferred to the signalling terminal.

The receive holdover clock should:

— maintain bit synchronism for at least 500 ms after initial bit synchronism is established, and

— have a tolerance of ± | 0 parts per million when the receive clock is not present.

b) *The 2048 kbit/s primary multiplex, 4 kbit/s channel*

Each bit of the 4 kbit/s data is represented by two channel-time-slots in the transmitted 64 kbit/s stream. These sixteen bits are encoded by the send-rate converter according to Table 4/Q.274 . The 8 bit bytes are aligned with the 8 kHz clock.

TABLE [4/Q.274] p.10

Transmission of the data in this form makes it possible to detect and correct for single, channel-time-slot slip avoiding the loss of signalling data. This is achieved in the receiver-rate converter as follows. The 64 kbit/s data stream is collected into 8 bit bytes using the 8 kHz clock, and each byte is decoded. The reception of three consecutive bytes of the same code indicates that channel-time-slot duplication has occurred, and that a half cycle delay must be introduced into the 4 kHz receive clock, whereas reception of a single byte with a given code followed by a byte with a code signifying a different bit position, indicates that omission of a channel-time-slot has occurred and that the 4 kHz clock must be advanced by half a cycle.

The send clock at 4 kHz is derived directly from the 64 kHz and 8 kHz send clocks. The 4 kHz receive clock is derived from the 64 kHz and 8 kHz receive clocks, but it must be adjustable to take account of channel-time-slot slip detected in the receive rate converter. The receive holdover clock

provides the receive clock to the signalling terminal. The interface adaptor recognizes loss of frame alignment by the absence of the 8 kHz clock from the primary multiplex or by an indication transmitted from the primary multiplex over a separate connection. This information is separately transferred to the signalling terminal.

The receive holdover clock should:

— maintain bit synchronism for at least 500 ms after initial bit synchronism is established, and

— have a tolerance of ± | 0 parts per million when the receive clocks are not present.

c) *The 2048 kbit/s primary multiplex, 56 kbit/s channel*

The send and receive data and the send clock signals traverse the interface adaptor without modification.

The 28 bits of a signal unit are represented by bit positions 1 to 7 of four consecutive channel time slots in the 64 kbit/s stream transmitted from or received at the interface adaptor. Bit position 8 of consecutive octets is coded **0** , | fB0 , | fB1 , | fB1 , | fB0 , | fB0 , | fB1 , | fB1 , . | | in a continuing sequence. This pattern is not suitable for direct transmission to the 1544 kbit/s multiplex.

The receive holdover clock should:

— maintain channel-time-slot synchronism for at least 500 ms after initial synchronism is established, and

— have a tolerance of ± | 0 parts per million when the receive clocks are not present.

Recommendation Q.275

6.5 DATA CHANNEL FAILURE DETECTION

6.5.1 *General*

Detection of data channel failure is required to supplement the eight-bit cyclic code. In case of unsatisfactory data transmission conditions a data channel failure indication should be given to the terminal for use in the error control equipment (see Recommendation Q.277, § 6.7.2).

6.5.2 *Detector requirements*

6.5.2.1 *Data channel failure detector — analogue version*

In this case the data channel failure detector is known as the *data carrier failure detector* .

a) The data carrier failure detector is required to indicate failure when transmission becomes unsatisfactory because of decreased carrier level. A failure should be indicated when the received carrier is below the minimum sensitivity of the modem used, and should indicate no failure when the level is above —23 dBm0.

b) The detector is required to detect the loss of carrier even though the decrease in carrier power may be accompanied by an increase in noise power. If a signal guard technique is used to distinguish carrier power from noise power, the received spectrum from 300 Hz to 500 Hz should be used to detect the amount of noise power.

c) The indication of failure or re-establishment of carrier should have a nominal delay of 5 ms with limits of 4 ms minimum and 8 ms maximum.

6.5.2.2 *Data channel failure detector — digital version*

In the case of both the 1544 kbit/s and the 2048 kbit/s primary multiplexes, the data channel failure detector is known as the *loss of frame alignment detector* .

a) The loss of frame alignment detector is required to indicate when the digital multiplex has lost frame alignment.

b) The indication of loss or re-establishment of frame alignment should have a mean delay of 2 ms or less after the PCM equipment has detected the loss or re-establishment of frame alignment.

6.5.3 *Interface*

In the case of the 1544 kbit/s primary multiplex, data-channel failure is electrically indicated by inhibiting the 4 kHz receive clock.

In the case of the 2048 kbit/s primary multiplex, loss of frame alignment is electrically indicated by inhibiting the 8 kHz receive clock or by an indication transmitted from the primary multiplex over a separate connection.

Recommendation Q.276

6.6 SERVICE DEPENDABILITY

6.6.1 *Dependability requirements*

The following dependability requirements should be obtained with signalling links having the error rate characteristics as described in Recommendation Q.272, § 6.1.2. These requirements refer to each signalling link.

a) Signal units which carry telephone signal information and which are delayed as a consequence of correction by retransmission:

not more than one in 10^{4} such signal units to be delayed as a long-term average.

b) Signal units of any type which give rise to wrongly-accepted signals due to undetected errors and causing false operation (e.g., false clear-back signal):

not more than one error in 10^{8} of all signal units trasmitted.

c) As in item b) but causing serious false operation (e.g., false metering or false clearing of connection):

not more than one error in 10^{0} of all signal units transmitted.

d) Interruption to the signalling service (including both normal and reserve links):

— interruption of duration between 2 seconds and 2 minutes — not more than once a year;

— interruption of duration exceeding 2 minutes — not more than once in 10 years.

Items a), b) and c) assume one telephone signal per signal unit. Results for a multi-unit message will be at least comparable to those for one-unit messages transmitting the same information.

6.6.2 *Retransmission considerations*

The requirement of § 6.6.1 |) above is inserted to limit the

percentage of the answer signals which are delayed through the retransmission process. The amount of retransmission depends on the number of bits in the signal units and on interferences such as those caused by short interruptions and intermittent bursts of noise up to the point at which changeover to the reserve link occurs.

6.6.3 *Service interruption considerations*

The requirement of § 6.6.1 |) depends largely on the performance of the voice frequency links or digital links assigned for signalling. Therefore precautions should be taken in the design stage of the terminal equipment to ensure that the contribution to the total is relatively small.

Recommendation Q.277

6.7 ERROR CONTROL

6.7.1 *Error detection by the use of check bits*

The disturbance of a signal unit during transmission will be detected by the use of coders and decoders, connected at the transmitting and receiving terminals respectively. The coder will generate 8 check bits based on the polynomial $\mathbf{X^8 + X^2 + X + 1}$ (see Table 5/Q.277 for the matrix and for a typical implementation).

These check bits will constitute bits 21-28 of each signal unit and are inverted before transmission to provide protection against a single bit-slip of synchronization.

When the decoder at the receiving terminal has received all 28 bits of a signal unit after the check bits have been reinverted, it will indicate whether or not the signal unit has been checked correctly. This information will be stored for inclusion in the acknowledgement field of an ACU to be emitted in the return direction. An ACU will be transmitted after each 11 signal units to form a block (see Recommendation Q.251, § 1.1.2).

TABLE [5/Q.277] p.11

6.7.2 *Error detection by data channel failure detection*

The data carrier failure detector or loss of frame alignment detector will supplement the error detection by use of check bits. Indication of data channel failure at any time during the process of reception will cause the rejection of signal units in the process of reception. Regardless of the result of decoding, the ACU should acknowledge the signal unit as received incorrectly.

6.7.3 *Error correction*

Correction is achieved by retransmission of the messages which are not acknowledged to have been received correctly. The *block structure* and the contents of the ACU have been described in Recommendations Q.251, § 1.1.2, and Q.259, § 3.3.1. The acknowledgement indicators should be transmitted in the same sequence as the signal unit to which they refer.

A retransmission to comply with the information in the ACU will be made possible by storing at the transmitting terminal the signal units with their block reference numbers at the time of emission. This record must be maintained until the receipt of the associated ACU, when the record of messages which are acknowledged to have been correctly received should be eliminated. In the case of multi-unit messages, the complete message should be retransmitted if any of its constituent signal units fail to check correctly. A multi-unit message may contain signal units which are transmitted in two adjacent blocks, but it must be ensured that the records of the constituent signal units of the multi-unit message remain until the acknowledgement indicators show that the complete multi-unit message has been received correctly.

In the unlikely event that a terminal is unable to accept a correctly-received signal unit, e.g. due to input buffer congestion, the appropriate acknowledgement indicator bit in the outgoing ACU is marked as if the signal unit were received in error.

The maximum permitted delay between the emission of a signal unit and the subsequent reception of the ACU containing the acknowledgement of this signal unit is as follows:

a) *Where the multi-block monitoring procedure is not used* , the maximum permitted delay between the emission of a signal unit and the subsequent handling of the received ACU containing the acknowledgement of that signal unit must not exceed the time taken to send 8 blocks (96 signal units). Of this time (96 signal units), the time for 64 signal units (maximum) is available for the loop propagation time of the data link (see Note 1). At a data rate of 2400 bit/s this caters for a loop propagation time of up to 740 ms (see Note 2).

b) *Where the multi-block monitoring procedure is used* , the maximum permitted delay between the emission of a signal unit and the subsequent handling of the received ACU containing the acknowledgement of that signal unit must not exceed the time taken to send 256 blocks (see Note 3). Of this time (up to 3072 signal units), all but about 32 signal units are available for the loop propagation time of the data link. At a data rate of 56 kbit/s, this caters for a loop propagation time of up to 1520 ms.

Note 1 — The number, 64 signal units, is based on the consideration that out of the total number of 96 signal units, 32 signal units are allocated as follows:

At the exchange emitting signal units:

emission of SU

reception of ACU not more than the time for sending 3 signal units

processing

At the exchange receiving signal units:

reception of SU

generation of ACU

time in ACU queue

not more than the time for sending 29 signal units

emission of ACU

time for drift compensation

processing

Note 2 — The time for sending 64 signal units is also equivalent to

448 ms at 4 kbit/s

32 ms at 56 kbit/s.

Note 3 — The full 256 blocks need not be handled in all designs, e.g. block memory may be limited to that required for the expected range of loop propagation delays and data rates at which the terminal will be applied. If the error control loop cannot exceed 8 blocks, multi-block monitoring equipment need not be provided.

The messages, which are not acknowledged to have been correctly received should be presented for retransmission, at which time the record of their previous transmission should be eliminated. The exception to the general rule is that the following signalling system control units should never be retransmitted: acknowledgement, synchronization, multi-block monitoring, multi-block acknowledgement, and changeover.

All signal units in a block except the SYU, ACU, multi-block monitoring, multi-block acknowledgement, and changeover system control signal units must be retransmitted if the ACU, referring to that block, is not received correctly. This may arise owing to the fact that the ACU fails to check correctly on account of errors during transmission or owing to drift between the data streams in the two directions (see Recommendation Q.279).

The first three bits of the ACU (i.e. the heading code) may be used for identification purposes (see Recommendation Q. 259, § 3.3.2.2). If the ACU checks to be error-free and the heading is correct the probability of an undetected error is extremely small.

6.8 SYNCHRONIZATION

6.8.1 *General*

The SYU will contain, in addition to the 8 check bits, a 16 bit pattern for bit and signal unit synchronization and a 4 bit number for block synchronization every SYU. The 4-bit number will describe the position of the SYU within its block (see Recommendation Q.259, § 3.3.3.2).

Each signalling terminal requires 2 counters of up to 8 bits capacity, to keep a record of the blocks completed and acknowledged.

The block-completed counter (BCC) indicates the sequence number of the last block transmitted by the terminal. The last 3 bits of this number are also sent to the ACU of the block and occupy the bit positions reserved for the block-completed sequence number (BCSN).

The block-acknowledged counter (BAC) is up-dated using the block-acknowledged sequence number (BASN) in the incoming ACUs and therefore indicates the sequence number of the block being acknowledged by the last received ACU. In order to keep it up to date even when ACUs are detected in error, the block-acknow ledged counter is incremented whenever the twelfth signal unit of a block is received in error. In the case where the block-acknowledged sequence number does not have the expected value, the block-acknowledged counter will be up-dated as follows:

— If the BASN has the same value as in the previous ACU, the BAC will not be incremented;

— If the BASN has an unexpected value greater than the previous BASN, then the least significant three bits of the BAC are replaced by the latest BASN;

— If the BASN has a value less than the previous BASN, then the BAC is incremented by eight and the least significant three bits replaced by the latest BASN.

If the terminal is in multiblock synchronization, and if a jump in the BASN of greater than 2 or equal to or less than —1 occurs, then multiblock synchronization must be checked immediately.

The counters are set to zero during normal synchronization and are checked periodically by using the multiblock monitoring procedure.

If the capacity of the counters is exceeded by the number of blocks in the error control loop, the signalling link is not capable of being used.

Some variations of the synchronization procedures in the specification may be incompatible with *Green Book* synchronization procedures.

6.8.2 *Normal synchronization*

This synchronization procedure is used whenever a signalling link is brought into service, either initially or after a total loss of synchronism.

Normal synchronism will be established in the following manner. Each terminal will emit either:

— a series of blocks containing eleven SYUs, plus one ACU, or

— a series of blocks of *faulty-link information* as covered in Recommendation Q.293, § 8.6.1, when change-over has been requested.

In both cases ACUs are transmitted initially with the acknowledgement indicators set to **1** and the block-completed and block-acknowledged sequence number set to **0** .

The instant of commencement of emission at the terminals is immaterial.

After bit synchronism has been established in the demodulator, the incoming bit stream will be monitored to find the SYU pattern. Once this pattern is found and verified the sequence number can be determined and the ACU position located.

In due course, three consecutive ACUs should be correctly received with block-acknowledged sequence number set to **0** .

At this time the acknowledgement indicators in the next outgoing ACU are set to reflect the detected errors in the signal units of the associated received block. Both sequence numbers in the ACU remain at **0** .

The reception of at least two consecutive ACUs with block-acknowledged sequence numbers set to **0** which check correctly and acknowledge one or more signal units as correct indicates that both terminals are in bit, signal unit and block synchronism.

At this time the one-minute proving period is started and block sequence numbering is initiated as follows:

the block-completed counter and block-completed sequence number in the next outgoing ACU are set to **1** . Thereafter the counter and the block-completed sequence number in the ACU are incremented by 1 each time an ACU is transmitted. The block-acknowledged sequence number in outgoing ACUs is now up-dated from the block-completed sequence number of the appropriate received ACU.

When the terminal receives an ACU with a block-acknowledged sequence number other than **0** , the block-acknowledged counter is set to this number. Thereafter, the counter is up-dated by the appropriate block-acknowledged sequence number each time an ACU is received.

When the block-acknowledged counter is incremented for the first time the number of blocks in the error control loop may be determined by subtracting the contents of the block-acknowledged counter from the contents of the block-completed counter. Should the result be negative, then the counters should be reset and block sequence numbering should be restarted.

The counter capacity is insufficient if the block-completed counter recycles before the block-acknowledged counter advances.

If, and only if, the initial synchronization procedure has indicated more than eight blocks in the error control loop, should the multi-block-monitoring procedure be used once every cycle of the block-completed counter. In this case the multi-block monitoring procedure should also be used for block resynchronization (see § 6.8.4 below).

Whenever a multi-block-monitoring signal is received it must be acknowledged by a multi-block-acknow ledgement signal within the time required to send 40 signal units.

When the multi-block-acknowledgement signal is received, the multi-block and block numbers are compared with the contents of the block-acknowledged counter. If the received number is within minus four to plus three of the contents of the block-acknowledged counter then it is assumed that multi-block synchronism exists.

When a multi-block-acknowledgement signal is not received in response to a multi-block-monitoring signal transmitted no action need be taken. However, if a multi-block-monitoring signal is acknowledged as being received in error or if the ACU is in error then the multi-block monitoring procedure may be restarted.

If the signal unit error rate is acceptable at the end of the one-minute proving period, two load-transfer signals are emitted in the case of a regular link, or two standby-ready signals for synchronized reserve links. Acknowledgement of these signals by the other terminal is as covered in Recommendation Q.293, §§ 8.6.2 and 8.8. Signalling traffic may then be offered to regular links, while synchronized reserve links may be marked as ready for service.

The one-minute and the emergency proving periods and the load-transfer signalling sequence are omitted for non-synchronized reserve links when a changeover is made from the regular link as covered in Recommendation Q.293, § 8.6.1.

Bit synchronism is maintained by the transition between dibits for the analogue modem or by the receive clock on digital links; loss of synchronism will result in signal units failing to check correctly; however, incorrect

signal units are more likely to result from line interference than loss of synchronism. Monitoring of the bit stream should result in the recognition of the 16 bit pattern of an SYU and enable synchronism to be restored if it had been lost.

6.8.3 *Signal unit resynchronization*

Loss of signal unit synchronism will result in continuous failure of signal units to check. When the signalling terminal receives consecutive signal units in error, it may take unilateral action to resynchronize to the incoming bit stream. In any ACUs transmitted during this procedure, all the indicator bits must be set to **1** and the block-acknowledged number and the block-completed number must be incremented as in normal operation. When synchronism is re-established on the incoming channel the indicators are set according to the incoming signal units, i.e. normal operation is resumed. The signal unit error rate monitor must continue to count signal units in error throughout this procedure.

During unilateral resynchronization, means must be provided to ensure that false resynchronization is kept to a level that is compatible with the dependability requirements (Recommendation Q.276). For this reason signal units should be checked to see that synchronization is valid.

6.8.4 *Block resynchronization*

Equipment must be provided to detect loss of block synchronism.

Loss of block synchronism will be recognized when a valid signal unit, which is not an ACU, is received in the 12th position in a block.

Loss of block synchronism may also be recognized by any of the following:

a) an ACU is received in other than the 12th position in a block;

b) the block-completed sequence number is not the one expected (see Note 2);

c) an SYU sequence number is not the one expected.

Loss of block synchronism will not be recognized prior to the initial incrementing of the block-acknow ledged counter, during either initial synchronization or after a total loss of synchronism as specified in § 6.8.2.

When loss of block synchronism has been recognized — by any of the four events described above — the terminal will stop sending telephone signals and send only SYUs and repeated ACUs (see Recommendation Q.279).

When the terminal has identified the signal unit position in a block either by recognizing the SYU number or by identifying an ACU, and has subsequently recognized two consecutive ACUs with correctly advancing block-completed sequence numbers, synchronism is deemed to have been regained.

After successful block-synchronization, the block being transmitted is completed with SYUs and an ACU. At least one complete block of 11 SYUs shall be sent before resuming normal traffic.

The first ACU sent after synchronization has been regained will have the following characteristics:

a) the indicator bits are all set to **1** ;

b) the blocked-completed sequence number is set to the next in sequence;

c) the block-acknowledged sequence number will correspond to the latest received ACU.

Upon resynchronization, a terminal may receive an ACU with an acknowledged block number which differs from that expected. All messages sent in unacknowledged blocks should be retransmitted.

After the completion of block resynchronization, multi-block synchronism should be checked, if applicable.

When block synchronism cannot be regained within 350 ms, the link is considered to have failed and resynchronization according to § 6.8.2 is commenced. The relevant link security procedures of Recommendation Q.293 will be initiated where appropriate (e.g. changeover, emergency restart, etc.). In the case of a link that is not carrying signalling traffic, resynchronization should commence without waiting for 350 ms, that is, unilateral block resynchronization should be dispensed with.

Note 1 — An all-zero signal, i.e. a signal unit consisting of 20 zeros with the correct check bits, may cause a discontinuity in the transmitted signal unit sequence.

A receiving terminal which can recognize such a signal may, optionally, take steps to ensure that synchronism is not lost. In this case, the zero signal units should be treated as if they were in error, causing the error counter to be stepped, but no request for retransmission should be sent. Thus if zero signal units are received too frequently, a changeover or emergency restart will be initiated.

Note 2 — If an unexpected ACU with both the BASN and BCSN equal to zero is received, reset the block counters, restart the block sequence numbering as in § 6.8.2 and count the ACU as being in error.

6.8.5 *Multi-block resynchronization*

If the multi-block and block numbers in a multi-block-acknowledgement signal unit are not within minus four to plus three of the contents of the block-acknowledged counter a new multi-block-monitoring signal is sent. If the result of the second measurement is not within the above limit, multi-block synchronism has been lost. However, if the results of the measurements are the same, multi-block synchronism can be regained by up-dating the contents of the block-acknowledged counter to the obtained result.

When the second multi-block-monitoring signal is sent the terminal will send only SYUs and ACUs for three blocks. Normal traffic is then resumed and all messages transmitted in the interval between the two multi-block-monitoring signals are retransmitted.

If multiblock synchronism cannot be regained, the link is considered to have failed and resynchronization according to § 6.8.2 is commenced. The block counters will be reset and the block sequence numbering restarted. The relevant link security procedures of Recommendation Q.293 will be initiated where appropriate (e.g. changeover, emergency restart. etc.).

Recommendation Q.279

6.9 DRIFT COMPENSATION

6.9.1 *General*

The difference in clock rates at the two terminations of a signalling link will result in a drift between the bit streams transmitted in the two directions.

The slower terminal will find at some stage that it has two blocks awaiting acknowledgement. When this occurs, only the second (later block) should be acknowledged (*skipping* of an ACU). On receipt of the acknowledgement of the second block, the sending terminal will initiate the transmission of all messages in the first block as if they were received in error before proceeding with any necessary retransmission relating to the second block.

Moreover, the faster terminal will find at some stage that it has no complete new block to acknowledge in the ACU it is about to transmit. In this case, the acknowledgement fields for the indicators and block number (bits 4 to 17) from the previous block are repeated (*repeating* of an ACU). This ACU will be recognized to be a repetition by the cyclic number (bits 15 to 17) and should be ignored by the slow terminal (see Recommendation Q.259, § 3.3.2).

6.9.2 *Drift compensation hysteresis*

When the time difference between the moment at which the second block is received and the moment at which the acknowledgement should be sent is very small (e.g. less than one signal unit), drift compensation may be required at frequent intervals. In order to avoid alternative skipping and repeating ACUs too frequently, it is recommended that a certain interval elapses between the opposite decisions *to skip* and *to repeat* ACUs (drift compensation hysteresis). This interval must be sufficiently long to avoid unnecessary drift compensations, but short enough that acknowledging of the concerned block is not delayed too much.

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SECTION 7

SIGNAL TRAFFIC CHARACTERISTICS

Recommendation Q.285

7.1 SIGNAL PRIORITY CATEGORIES

7.1.1 *Rules for signal priority*

The following rules for establishing priority categories must be

followed in normal operation; within any of the priority categories, signals are transmitted in order of their arrival at the output buffer (see Recommendation Q.251, § 1.1.1):

a) Acknowledgement signal units (12th signal unit of each block) have absolute priority for emission at their fixed predetermined position;

b) Faulty link information (Recommendation Q.293, § 8.6.1) has priority over all other signals;

c) The answer signal, charge, the answer signal, no charge and the multi-block-monitoring and multi-block-acknowledgement signals have priority over other waiting telephone signals and signalling-system-control signals except those cited in a) and b) above;

d) All other telephone signals, one-unit or multi-unit messages, and all other signalling-system-control signals, except synchronization signal units, have priority over management or other signals concerned with the bulk handling of traffic;

Note — In the event that a management signal concerns the bulk restoration of service, e.g. RSB, RBA, TFA, TAA, this signal may take priority over other telephone or signalling system control signals.

e) Any signal which is to be retransmitted will take precedence over other waiting signals in the same priority category;

f) Management signals have priority over synchronization signal units;

g) Synchronization signal units have no priority.

7.1.2 *Break-in*

a) Potential for a priority one-unit message to break into a multi-unit message is provided in the design of the format, but initially this feature will not apply except for ACU;

b) If a multi-unit message is used for a management signal, potential for break-in by a lone signal unit should be retained as a future option. However, there is no intent to provide means for a multi-unit message to apply break-in to another multi-unit message.

c) In the rare event that a SYU breaks into a multi-unit message (e.g. owing to severe processor overload), the multi-unit message may be accepted as valid.

Recommendation Q.286

7.2 SIGNALLING CHANNEL LOADING AND QUEUEING DELAYS

7.2.1 *Loading potential*

According to Recommendation Q.257, § 3.1.3.3, the System No. 6 design provides the potential in circuit labels to identify 2048 telephone circuits. Considering that the load per signalling system will vary according to the traffic characteristics of the circuits served and the number of signals in use, it is not practicable to specify a general maximum limit of circuits that a system can handle. The maximum number of circuits to be served must be determined for each situation, taking into account the traffic characteristics which apply, so that the total signalling load is held to a level which will maintain an acceptable signalling delay value resulting from queueing.

7.2.2 *Queueing delays*

Common channel signalling systems handle the required signals for many circuits on a time-shared basis. With time-sharing, signalling delay occurs when it is necessary to process more than one signal in a given interval of time. When this occurs, a queue is built up from which signals are transmitted in order of their time of arrival and of their priority. Formulae, which are in close agreement with computer simulation tests and are recommended for calculating average queueing delays for the signals listed and the variables noted, are given in the Annex A to this Recommendation.

ANNEX A
(to Recommendation Q.286)

Queueing delay formulae for telephone signals

Answer signal: One-unit message with priority

$$Q_w = \frac{+(D-1)a_d fR}{(1-a_c fR)(1-a_c fR-a_{wM} fR)} \times$$

[Unable to Convert Formula]

(1)

Other telephone signals: One-unit message without priority

$$Q_q = \frac{+(D-1)a_d fR}{(1-a_c fR-a_{pM} fR)(1-a_c fR-a_{wM} fR)} \times$$

[Unable to Convert Formula]

(2)

Address signal: Multi-unit message without priority

$$Q_d = Q_o + \frac{(D-1)a_c fR}{1-a_c fR} \times T_e \qquad (3)$$

where Q_w, Q_o, Q_d = average queueing delay,

a_w = traffic of answer signals if multi-block synchronization signal units are not used,

$a_{w\backslash dM}$ = traffic of answer signals, multi-block monitoring and multi-block acknowledgement signals if multi-block synchronization signal units are used,

a_d = traffic of multi-unit address messages,

a_p = traffic of all telephone signals, if multi-block synchronization signal units are not used,

a_{pM} = traffic of all telephone signals, multi-block monitoring and multi-block acknowledgment signals if multi-block synchronization signal units are used,

a_c = traffic of acknowledgement signal units,

T_e = emission time of a signal unit,

D = number of SUs composing a multi-unit address message.

When multi-unit address messages are of different length the average queueing delay for the messages composed of D_i SUs is given by formula (3) using D_i for D. In formulae (1) and (2), the following values should be used:

$$D = \frac{\sum_i (D_i \, a_{di})}{(a_d)} \quad \text{and}$$

$$a_d = \sum_i a_{di}$$

where a_{di} is the traffic of the messages composed of D_i SUs.

Note 1 — The unit of traffic is the erlang. The traffic a_p includes a_w, a_d and the traffic of other one-unit messages, but excludes a_c.

Note 2 — These formulae include the effects of systematic delay (due to synchronous operation and block composition) and of traffic delay, but do not include the emission time of the signal message and the delay resulting from eventual retransmission of signal messages.

Note 3 — In addition, formula (3) includes the effect of break-in by acknowledgement signal units.

Note 4 — Signal units of lower priority, e.g. management signal units and synchronization signal units, have no influence on the delay of telephone signals.

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Example of queueing delays

The traffic model assumed is given in Table 6/Q.286, from which the proportion of signal traffic may be obtained as shown in Table 7/Q.286. Using Table 7/Q.286, queueing delays are calculated as shown in Figure 22/Q.286.

Figure 22/Q.286 p. 12

Tableau [6/Q.286] p. 13

Tableau [7/Q.286] p. 14

Recommendation Q.287

7.3 SIGNAL TRANSFER TIME REQUIREMENTS

The cross-office signal transfer should be fast so as not to lose the advantage of the fast signalling capability of the System No. 6. While no firm time requirements in regard to the various components of signal transfer time have been established, Annex A to this Recommendation contains design objectives in terms of average and 95% level time values for T_h and T_c for the answer signal, other one-unit messages and the initial address message at the specified data rates. These figures have to be viewed as reasonable design requirements.

ANNEX A
(to Recommendation Q.287)

Estimates for transfer times

1. *Design objectives*

The design objectives for the handling time T_h and the cross-office transfer time T_c are shown in Table 8/Q.287.

TABLE [8/Q.287] p.15

2. *Calculation for cross-office transfer time*

Average value:

The average value of the cross-office transfer time, T_{cAV}, is calculated by the following formula:

$$T_{cAV} = T_r + T_{hAV} + T_{sAV} . \quad (1)$$

The average value of the sender transfer time, T_{sAV}, is approximated as follows:

$$T_{sAV} = T_{qAV} + T_m + T_e \text{, for one-unit messages} \qquad (2a)$$

$$T_{sAV} = T_{qAV} + T_m + (D \times T_e), \text{ for multi-unit messages} \quad (2b)$$

where T_e = emission time of a signal unit,

T_m = time for encoding and modulation and, where present, parallel to serial conversion,

T_r = receiver transfer time,

D = number of SUs composing a multi-unit message.

The average queueing delay, T_{qAV}, is equivalent to Q_w, Q_o or Q_d which is calculated by the formula in Annex A to Recommendation Q.286.

95% level value:

The 95% level value of the cross-office transfer time, $T_{c\,|\,fR\,95\%}$, is approximated by the following formula:

$$T_{c\,|\,fR\,95\%} = T_{cAV} + \sqrt{(\Delta T_h)^2 + (\Delta T_q)^2} \quad (3)$$

where

$$\Delta T_h = T_{h\,|\,fR\,95\%} - T_{hAV}$$

$$\Delta T_q = T_{q\,|\,fR\,95\%} - T_{qAV}$$

The 95% level value of the queueing delay, $T_{q\,95\%}$, may be determined by simulation.

Example 1:

Table 9/Q.287 shows a calculated example at 2.4 kbit/s of T_{cAV} and $T_{c\ 95\%}$ for a_p = 0.4 erlang with the traffic model of Table 6/Q.286. As a result of simulation for this model, it has been determined that $T_{q\ 95\%} = 3.5 \times T_{qAV}$. The values of T_{hAV} and $T_{h\ |\ fR\ 95\%}$ are those assumed for Table 8/Q.287 and $T_r = T_m = 2$ ms is assumed.

TABLE [9/Q.287] p.16

Example 2:

Figure 23/Q.287 and Table 10/Q.287 show a calculated example of the average T_c for traffic of 2000 circuits served by systems of different data transmission rates with 10 calls per speech circuit per hour, with the traffic model of Table 6/Q.286. Answer message average handling time T_h = 10 ms (other message average handling time T_h = 20 ms) and $T_r = T_m$ = 2 ms are assumed. The number of blocks in the error control loop is assumed not to exceed eight.

Table [10/Q.287] p.17

FIGURE 23/Q.287 p.18

SECTION 8

SECURITY ARRANGEMENTS

Recommendation Q.291

8.1 GENERAL

Since a common signalling link carries the signals for many speech circuits, a failure of this link will affect all the speech circuits served. Therefore, arrangements must be made to ensure continuity of service for the circuits.

The security arrangements involve the provision of reserve facilities, that may be one or more of the following:

— another signalling link, used in the quasi-associated or load-sharing mode,

— a dedicated reserve signalling link,

— a dedicated reserve transfer link, or

— a circuit, normally used for speech (or other service purposes), to be withdrawn when required for use as a transfer link.

In the last two cases the transfer links must be equipped with signalling terminals and modems and interface adaptors to form signalling links.

Other than possible signalling traffic carrying considerations, there are no restrictions in using a digital reserve signalling link for an analogue regular signalling link and vice versa.

When the regular signalling link fails, all waiting messages marked for retransmission as well as all unacknowledged signal units should be retransmitted over the reserve facility. Subsequent signalling traffic destined for the failed link should then be transferred to the reserve facility.

Signalling traffic should be directed to the reserve facility only after the proper preparations have been made [see § 8.6.1 |) below].

When no signalling link is available for carrying signalling traffic during the period of changeover to a non-synchronized reserve or a nominated speech circuit, or during an emergency restart condition, measures must be taken to prevent the storage capacity of the failed signalling system from being exceeded so as to prevent messages from being lost. It is recommended that all free speech circuits should be removed from service during this period (by local busying at each end), to permit traffic to overflow to other routes which are serviceable. When there is no overflow facility, appropriate circuit-group-congestion signals should be returned.

8.2 BASIC SECURITY ARRANGEMENTS

The basic security requirement is taken from the dependability requirements for continuity of signalling service [Recommendation Q.276, § 6.6.1 |)].

Steps should be taken to open up a reserve facility as soon as possible after detection of a fault.

Once the reserve facility has been taken into service, the regular signalling link should not be brought back into service for signalling traffic until it has been checked to be giving satisfactory performance for 1 minute.

Should it happen that the reserve signalling link also fails, another reserve facility should be opened up. When there is no other reserve facility available, an attempt to transfer to any suitable signalling link, using the emergency restart procedure described in Recommendation Q.293, 8.7, must take place.

8.3 TYPES OF FAILURE, RECOGNITION OF FAILURE AND ABNORMAL ERROR RATES

8.3.1 *Types of failure*

The interruption of signalling service may be caused by several types of faults affecting the transfer channels, the modems or interface adaptors or the signalling terminal equipment.

The failure may be indicated as follows:

a) loss of the analogue data carrier or loss of the digital frame alignment ,

b) continuous failure of signal units to check correctly,

c) unacceptable intermittent failure of signal units to check correctly, or

d) loss of block or multi-block synchronism.

8.3.2 *Recognition of failure*

Monitoring equipment is provided to recognize all types of signalling channel failures.

At each terminal, the monitoring will be performed on the incoming signalling channel by:

a) monitoring the signal unit error rate, and

b) detection of loss of block or multi-block synchronism.

The *signal unit error rate monitor* | recognizes unacceptably high percentages of signal units received incorrectly. A signal unit is recognized as being received incorrectly as a result of an indication from the check bit decoder or the data channel failure detector (see Recommendation Q.277, §§ 6.7.1 and 6.7.2). The signal unit error rate monitor should have the hyperbolic error rate time characteristic shown in Figure 24/Q.291. The signal unit error rate monitor shall be reset to zero whenever:

— the monitor output has been recognized, indicating that the signal unit error rate, as detected by the decoder or the data channel failure detector, has become unacceptable, or

— synchronism of the signalling link has been achieved, or

— after signalling link failure.

Loss of block | or multi-block synchronism is detected as described in Recommendation Q.278.

8.3.3 *Recognition of end of failure*

a) *One-minute proving period*

End-of-failure monitoring equipment is provided at each terminal to recognize satisfactory performance of the signalling link after initial synchronization or after a link failure. The signalling link shall not be placed into service until a signal unit error rate of 0.2% or less has been achieved in a proving period of one minute. The end-of-failure monitor will indicate that this error rate has been achieved when it recognizes that no more than:

10 signal units at 2400 bit/s, or

16 signal units at 4 kbit/s, or

240 signal units at 56 kbit/s

have been received in error in a proving period of one minute.

Figure 24/Q.291 p.

In the event that the end-of-failure monitor indicates that more than the appropriate number of signal units in error have been received before the one-minute proving period has elapsed, then the end-of-failure monitor shall be reset and the one-minute proving period recommenced.

b) *Emergency proving period*

An emergency proving period is used in conjunction with the emergency restart procedure (see Recommendation Q.293, § 8.7). The emergency proving period is a 2 to 3 second period during which the error rate on the link is such that the end-of-failure monitor does not give an output. The emergency proving period begins when a regular or reserve link achieves synchronism. In the event that the monitor gives an output before the emergency proving period has elapsed, the end-of-failure monitor shall be reset and the emergency proving period recommenced.

c) *No proving period*

No proving period is required when

— changeover to a reserve link is caused by failure of a signalling link (as specified in Recommendation Q.293, § 8.6.1), or when

— block and multi-block synchronism is regained (as specified in Recommendation Q.278, §§ 6.8.4 and 6.8.5).

Recommendation Q.292

8.4 RESERVE FACILITIES PROVIDED

The reserve facilities provided can be subdivided into three groups following below in the order of ready availability:

a) quasi-associated reserve signalling links ,

b) full-time reserved transfer links ,

c) nominated direct circuits

Within each group, one or more arrangements can be distinguished which differ in the preparatory actions to be taken to bring the reserve facility into active service.

The choice of the particular facilities to be used can be governed by several factors, e.g. the possibility of using quasi-associated signalling links, the number of circuits served, the geographical distance between the System No. 6 exchanges, etc. The choice of method(s), therefore, will be made by the Administrations involved according to the circumstances which apply.

As a matter of principle, the reserve facility to be used should follow a route different from the route of the regular signalling link.

8.4.1 *Quasi-associated reserve signalling links*

The method of using a quasi-associated signalling link as a reserve facility is directly derived from the principles accepted for System No. 6 (Recommendation Q.253).

This method assumes an adequate signalling network and requires prior agreements on its adoption between the Administration(s) through whose signal transfer point(s) the signalling traffic may overflow.

Methods of controlling quasi-associated signalling are described in Recommendation Q.266, § 4.6.2.

8.4.2 *Full-time reserved transfer links*

A transfer link is permanently assigned to provide the reserve signalling link.

The following arrangements can be distinguished:

a) *Load sharing*

Both transfer links are equipped with modems or interface adaptors and signalling terminals and are in use on the basis of duplicate working with load sharing. Each link in this method is the reserve for the signal load on the other link.(See also Recommendation Q.293, § 8.9.)

The circuits shall be assigned identical labels on both links and each circuit shall be assigned to one of the parallel signalling links as its regular link. The exchange must be capable of accepting signalling traffic for the labels over either link at any time.(See also Recommendation Q.293, § 8.9.)

b) *Synchronized reserve*

The transfer link is equipped with modems or interface adaptors and signalling terminals, thus forming a reserve signalling link.

The link is not in use, but its channels are synchronized.

c) *Non-synchronized reserve*

The transfer link is not equipped with modems or interface adaptors and signalling terminals. A switching operation is thus required to convert the transfer link into a signalling link, before synchronizing of the signalling channels can start.

Arrangements a) and b) are considered to be more usual than c) and will no doubt be the general rule in the case of a full-time reservation of a transfer link. However, for international exchanges at which very many signalling links terminate, Administrations may prefer not to use the arrangements a) and b) above but to pool available modems, interface adaptors and signalling terminals for common use to a number of reserve transfer links.

8.4.3 *Nominated direct circuits*

A nominated direct circuit is permanently assigned to be converted into a signalling link, when required. The following arrangements can be distinguished:

a) *Speech circuit reserve*

The nominated circuit is normally in speech (or other service) condition. Switching action and synchronizing must be performed when the transfer link of the circuit is required for the reserve signalling link. The switching action is allowed only when the transfer link is not in use. For this reason, Administrations should ensure that the nominated speech circuit has a high probability of being free (for example, by using a last-choice circuit).

The available modems and signalling terminals may be pooled for common use to a number of speech circuit groups.

b) *TASI-through reserve (analogue only)*

The nominated circuit is a TASI-through circuit. The circuit is not to be used for speech. When it is required to open up a reserve signalling link, data are applied in the normal way. These data will be sufficient to operate the speech detector at each end and cause TASI channels to be associated with the circuit for as long as the data are applied.

Arrangement b) cannot be ranked as a general solution since it depends on having a TASI system between the two international exchanges involved.

8.4.4 *Link-sets, signalling routes, signalling route sets and opposite signalling route sets*

a) *Link sets, signalling routes, and signalling route sets*

A regular link and reserve links directly connecting two System No. 6 exchanges, a System No. 6 exchange and an STP or two STPs, and which provide signalling for the same 2048 circuit labels are termed a link set Where quasi-associated signalling facilities are provided, the security arrangements for a band of speech circuits will consist of one or more link sets. The different signalling paths so formed are known as signalling routes as a signalling route set all bands which have the same security arrangements.

b) *Opposite signalling rout sets*

At an STP traffic passes from the originating to destination exchange and vice versa using a signalling route set in each direction. Each of these signalling route sets, which form a complementary pair, is termed an opposite signalling route set with respect to the other.

8.4.5 *Choice of reserve facility*

When the regular link in a link set has failed and where more than one type of service is provided, signalling should first be restored on a synchronized reserve, such as a load shared or full-time synchronized reserve transfer link in the same link set. If these are not provided or are not available, signalling should then be restored via one or more link sets using quasi-associated signalling. If this option is not provided or is not available, then an attempt should be made to restore signalling on a nonsynchronized reserve such as a full-time nonsynchronized reserve transfer link or nominated direct circuit, within the original link set. Should the failed link be a reserve link, then changeover follows the same priority order as above except that the search should commence on the link below the one that has just failed. Changeover to a proved reserved link of a higher priority is only possible by using the emergency restart procedure. See Recommendation Q.293, § 8.7.

For each band or group of bands the provision of the different types of reserve, the search order to be applied where a number of one type are provided, and the selection order between link sets should be specified by the Administrations concerned.

Recommendation Q.293

8.5 INTERVALS AT WHICH SECURITY MEASURES ARE TO BE INVOKED

The following action points are defined:

T_0 = time when signalling fault indication starts,

T_w = time when warning of failure is issued (for example, to busy a nominated speech circuit reserve),

T_d = time when decision to change over is made,

T_u = time when signalling traffic is offered to the reserve link.

The intervals $T_w — T_0$ and $T_u — T_d$ are not specified. It is recognized that these intervals will vary from one method or arrangement to another.

The interval $T_d — T_0$ does not include the time for the processor to react. Its value is determined in the case of:

— continuous failure, by all signal units being in error for 350 milliseconds;

— intermittent failure, by the instant the signal unit error rate monitor gives an output indicating that the signalling error rate has become unacceptable; or

— loss of block or multi-block synchronism, by the failure to achieve block resynchronization within about 350 ms.

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8.6 CHANGEOVER AND CHANGEBACK PROCEDURES

8.6.1 *Changeover from faulty signalling links*

a) Consider two exchanges A and B with a fault in signalling link AB, *affecting both directions* .

Each exchange at time T_d initiates the synchronization procedure (Recommendation Q.278), where applicable, on the reserve signalling link. When both ends are in synchronism over the reserve link, the processors switch over without any proving period and use this link.

On detection of failure of a working link at time T_0, each terminal *starts sending faulty-link information* | on the link just failed. This information consists of a number of changeover signals (completing the block being sent) plus ACU, followed by a continuous stream of alternating blocks of changeover signals and of SYUs (11 changeover signals + ACU, 11 SYUs + ACU, 11 changeover signals + ACU, etc.).

When a terminal is unable to accept a correctly received signal unit, the relevant bit in the ACU acknowledging the signal unit shall be set to **1** . If the terminal has lost synchronism, then the normal synchronization procedure is started (Recommendation Q.278, § 6.8.2).

With the reserve facility properly prepared, each exchange retransmits on the reserve facility all waiting signals marked for retransmission and all signals not acknowledged by the other exchange, followed by new signalling traffic from the failed link as specified in Recommendation Q.291, § 8.1.

b) Consider a fault affecting *only one direction* | for example A to B. The fault will be detected at terminal B and at a time T_d this terminal will act as under § 8.6.1 |) above.

Upon receipt of two changeover signals on the working signalling channel within a period of 3 seconds, exchange A commences the synchronization procedure, when applicable, on the reserve signalling link. On the failed channel, exchange A will commence the resynchronization procedure as in Recommendation Q.278, § 6.8.2, allowing the block numbering sequence to be re-established. If exchange A has not itself lost synchronism on the failed channel, it may skip over superfluous actions within the synchronization procedure, i.e. faulty-link information, the sending of all **1** s acknowledgement indicators, SYU search, and proving period. The detection and timing of the loss of block synchronization should be cancelled at this time. Exchange A will proceed to retransmit all the failed link messages as described in Recommendation Q.291, § 8.1, and transfer all subsequent signalling traffic destined for the failed link to the reserve link for the duration of the failure.

c) If more than one type of reserve is provided, the choice of reserve facility should be in accordance with Recommendation Q.292, § 8.4.5. Nominated speech circuits will be made busy to outgoing traffic at each end immediately, or as soon as free, until transfer to a nominated reserve signalling link has been accomplished. At time T_d, an operable reserve will be selected, by hunting through the available choices in a fixed predetermined order as specified by the Administrations concerned. Nominated direct circuits in use for speech are skipped over in the selection process.

If a synchronized reserve or quasi-associated route is selected, a later transfer to a non-synchronized full-time reserve link or a nominated direct circuit may be effected as described in § 8.6.3.2 below.

When a failure is encountered on a reserve signalling link, faulty-link information is sent in the same manner as on a regular signalling link encountering a failure. If the reserve link is carrying signalling traffic, the procedure as covered in Recommendation Q.291, § 8.2, will be initiated.

d) When a changeover is to another link in the same linkset, Signalling System Control Signals (SCUs) waiting on the faulty link are not retransmitted on the new link. When a changeover is to one or more quasi-associated routings, the telephone signal units, network maintenance signals and network management signals are retransmitted on their respective routings after band translation where necessary. SCUs and signalling network management signals are not retransmitted on quasi-associated routings.

When a link becomes faulty and no reserve facility is available for some or all bands on the link, then any waiting signal units for such bands will not be able to be retransmitted as described above. Where such signals refer to remote routes and are using the System No. 6 exchange as a signal transfer point, these signals should be deleted and a message-refusal signal returned for each telephone signal and a transfer-prohibited signal returned for each network maintenance signal (see Recommendation Q.266, §§ 4.6.2.1 and 4.6.2.3).

8.6.2 *Changeback to the regular link*

When either terminal has regained synchronism on the failed regular link, it will begin both its one-minute and emergency proving periods. However, if synchronism had been continuously maintained at one end during the failure, this exchange need not start a new proving period. When the received signal unit error rate has remained acceptable for the one-minute proving period, the exchange will *cease sending faulty-link information* by replacing the changeover signals (if it is sending changeover signals) with SYUs (plus ACUs).

To return to the regular link, the exchange A initiating the changeback sends two load-transfer signals on the regular link. From this time until changeback is either completed or abandoned, exchange A must be in a position to receive and process all signals on both the regular link and the reserve in use. When exchange B receives a load-transfer signal and knows the regular link is operational, it responds with a load-transfer acknowledgement signal on the regular link, then immediately transfers its signalling traffic from the reserve to the regular link. When exchange A receives one load-transfer-acknowledgement signal, it transfers its signalling traffic from the reserve to the regular link. Should an exchange receive a load-transfer signal on the link that is carrying traffic, then this signal shall be acknowledged.

Until the load-transfer and acknowledgement signal sequence has been satisfactorily completed as described above, signalling continues over the reserve link. After this signal sequence is completed, exchanges A and B continue to monitor the reserve link until all signals initially transmitted on the reserve link have had the opportunity to be acknowledged. Signals sent on the reserve link acknowledged as having been received in error are retransmitted on the reserve link. After 5 ± 1 seconds, when all signals have had the opportunity to be acknowledged as correctly received, each end will return reserve voice-frequency links with switched terminals and modems to their original status. A nominated speech circuit must be returned to service for outgoing traffic without delay by completing an unblocking sequence even though blocking signals have not previously been exchanged for the circuit. This unblocking sequence will remove any previous circuit state at both ends and return the circuit to the idle state. Any resultant failure indications occuring on the reserve link during the 5 ± 1 second time interval may be ignored. (See also § 8.9.)

In the event exchange B decides not to change back when it receives a load-transfer signal, it withholds the load-transfer-acknowledgement signal. Exchange A must therefore time for an interval of approximately 2 minutes for the receipt of a load-transfer-acknowledgement signal. If the time interval elapses without receiving a load-transfer-acknowledgment signal, exchange A will transmit two more load-transfer signals and recycle the timing.

If exchange A decides to terminate the changeback procedure at any time before the process is completed, it will interrupt the changeback procedure and transmit faulty link information as for a normal changeover. Exchange B will respond to the faulty-link information even though it has agreed to changeback and has started sending messages on the regular link. In the event of changeover before the load-transfer signalling sequence is completed, both exchanges will remain on the reserve link which the changeback commenced.

If the changeback procedure is interrupted or terminated as above before the procedure is completed, the regular link should continue to meet the one-minute proving period requirement.

In the event that both exchanges A and B start changeback procedures at about the same time, either exchange, having transmitted two load-transfer signals, shall respond to a received load-transfer signal with a load-transfer-acknowledgement signal and shall transfer signalling traffic to the regular link on the receipt of either a load-transfer signal or a load-transfer-acknowledgement signal.

8.6.3 *Changeover from working signalling links*

8.6.3.1 *Manual changeover procedure*

a) In the event that it is desired to change over to a reserve link for rearrangements, changes, maintenance, etc., on a link currently carrying the signalling traffic for the link set, the exchange A desiring the changeover will send a manual-changeover signal on the working link.

This working link may be the regular link, a full-time synchronized reserve link, or one link of a load shared pair. When exchange B receives this signal, the selection of a reserve link is initiated by both exchanges. The selection order for this reserve differs from that for the normal changeover (described in § 8.4.5 above) in that quasi-associated routings are excluded from the search if one or more non-synchronized reserve links are provided in the link set. This is specified in order to transfer the signalling load directly to a non-synchronized reserved link, thus preventing a possible double load transfer due to the load transfer procedure (automatic) as specified in § 8.6.3.2 being initiated on a quasi-associated routing subsequent to the manual changeover. When a transfer to a non-synchronized reserve link is indicated, the cyclic procedure described in § 8.6.3.2 below will be used as appropriate. When exchange B has selected a quasi-associated route or other synchronized reserve link or has gained synchronism on a non-synchronized link, a manual-changeover-acknowledgement signal is sent back on the original working link.

Exchange A must not send a manual-changeover signal or exchange B send a manual-changeover-acknowledgement signal if the desired changeover would cause the complete failure of a signalling route set. That is, the signalling for a group of bands would be lost. However, these signals will not be inhibited if the affected signalling route set is for bands for which the exchange is acting as a signal transfer point.

If a quasi-associated route or other synchronized reserve link is selected for the changeover, the exchanges A and B transfer their signalling traffic subsequent to the exchange of the manual-changeover-acknow ledgement signal.

If a non-synchronized reserve signalling link is selected and the manual-changeover-acknowledgement signal has been received, two load transfer signals are sent by exchange A on this link when the link is in synchronism and has passed the one-minute proving period. On receipt of one load-transfer-acknowledgement signal, exchange A will transfer its signalling traffic.

For all cases, both exchanges A and B continue to monitor the original working link for 5 ± 1 seconds, until all signals initiated on this link have the opportunity of being acknowledged as correctly received. Signals acknowledged as having been received incorrectly are retransmitted on the orignal working link. Subsequent to this timing period, the exchange initiating the manual changeover may continue to transmit SYUs + ACUs in the normal manner or may remove the link from service. The exchange acknowledging the manual changover should maintain synchronism and, should the link be removed, detect loss of synchronization.

b) If exchanges A and B simultaneously send manual-changeover signals, both exchanges must send manual-changeover-acknowledgement signals. In the quasi-associated route or other synchronized reserved link case, exchanges A and B transfer their signalling traffic subsequent to the receipt of the manual-changeover-acknowledgement signal. For all other cases, each end, subsequent to receipt of a manual-changeover-acknow ledgement signal on the original working link, will transmit two load-transfer signals on the selected reserve which will be acknowledged by the other end.

When either end receives a load-transfer signal, while expecting a load-transfer-acknowledgement signal from the other end after sending two load-transfer signals, it may transfer its signalling traffic from the original working link to the reserve link after sending a load-transfer-acknowledgement signal.

c) In the event that a manual-changeover signal is not acknowledged by the other exchange, a suitable interval shall elapse (e.g. one minute), before the request is repeated. If the second manual-changeover signal is not acknowledged, the maintenance staff at the exchange requesting changeover should be alerted.

d) Changeback from the reserve link will always be to the regular link and is initiated by the end which previously initiated the manual changeover. The procedure used is the same as the normal changeback as described in § 8.6.2 above. In the event of simultaneous manual changeover, or in the case where the regular link is not the link from which manual changeover had originally taken place, either end can initiate the changeback to the regular link.

If the link from which manual changeover originally took place is not the regular link but is a synchronized reserve, the end initiating the manual changeover will initiate the restoration of the link to the standby ready-state as described in § 8.8 c) below. This will commence when the link is considered serviceable again and may occur independently of the load transfer to the regular link.

8.6.3.2 *Load-transfer procedure (automatic)*

a) An automatic load-transfer from a quasi-associated routing or other synchronized reserve to a prepared non-synchronized reserve may be provided by agreement if desired by the Administrations concerned. This procedure may be used to limit the signalling traffic load at the signal transfer point or to maintain two synchronized links within the link set. Three types of automatic load-transfer are possible. In the first type, the signalling traffic for a group of bands using a signal transfer point is transferred back to the associated link set. In the second type, the signalling traffic in a link set is transferred from a synchronized reserve to a prepared non-synchronized reserve allowing the synchronized reserve to remain as a standby link. In the third type the signalling traffic from a failed load sharing link in a link set is transferred from the other load sharing link to a prepared non-synchronized reserve allowing the working load sharing link and the prepared reserve to remain as mutual reserves.

b) Subsequent to the initial transfer of signalling traffic to a synchronized reserve, both exchanges attempt to achieve synchronization on a secondary reserve facility. If more than one facility is provided, the two exchanges use the following selection procedure to establish synchronization on a secondary facility.

Each exchange will select the first choice non-synchronized reserve and will attempt to synchronize for a prearranged time interval of 5 +/— 0.25 seconds at one exchange and 7.5 +/— 0.25 seconds at the ohter. The selection sequence and the time interval will be fixed by bilateral agreement. If synchronization is not accomplished within the specified time interval, an attempt is made to synchronize on each of the available reserves in turn. If unsuccessful on the last choice non-synchronized reserve, the selection cycle is repeated unless the regular link has become operative. The difference in timing at the two exchanges ensures that even in the event the exchanges do not attempt synchronization on the same reserve initially, both exchanges will ultimatley meet on the reserve for a minimum interval of 2 seconds.

When synchronism is established on the reserve and the error rate has been acceptable during the one minute proving period, load-transfer and load-transfer-acknowledgement signals are interchanged on the selected reserve prior to transfer of the traffic as described in § 8.6.3.1 above. Signal units originally transmitted on the synchronized reserve are retransmitted as necessary on the same reserve.

8.7 EMERGENCY RESTART PROCEDURE

a) The emergency restart procedure is intended to re-establish signalling communication on a link set between two exchanges without waiting for the one-minute proving period, whenever the regular, and all synchronized links in the link set of lower priority than the last working links, have failed, or non-synchronized reserve links cannot be synchronized within 2 to 3 seconds of failure of the working link. Any link between the two exchanges which has achieved synchronism and has passed the emergency proving period (see Recommendation Q.291, § 8.3.3) will be selected to re-establish signalling communication. Maintenance personnel are alerted whenever an emergency restart condition exists. Either exchange may unilaterally commence the emergency restart procedure and the other exchange must respond even though it is unaware of an emergency signalling situation. The emergency restart procedure will be initiated on a link set even though all the signalling traffic may have successfully transferred to quasi-associated reserves. However, the emergency restart procedure will not be initiated on a link set,

if after termination of link set signalling a manually changed-over link remains in the link set. In this case, the link set carries out the emergency restart procedure only if the subsequent failure of a signalling route set occurs [except STP signalling route sets, see § 8.6.3.1 |)]. This failure would be for signalling traffic transferred from the link set to a quasi-associated routing at the manual changeover. Therefore, the manually changed-over link can be included in the emergency restart procedure if it is capable of being synchronized and emergency proved.

b) If faulty-link information is being sent on a previously failed link, it will continue to be sent until that link has passed its emergency proving period.

If at any time after the emergency proving period the signal unit error rate monitor indicates an unsatisfactory performance of the link, faulty-link information is again sent on the link and the change-over or emergency restart procedure is begun.

To minimize the number of calls affected by the emergency restart condition, Recommendation Q.291, § 8.1 should be followed, particulary the recommendation to remove free speech circuits from service. However, this will only be necessary when the link-set failure has caused the failure of an entire signalling route set, and hence no quasi-associated routings are available.

The following procedure is designed to attempt emergency restart on as many signalling links as possible at the same time. Both exchanges will simultaneously connect terminals to as many voice-frequency links as possible between the two exchanges. Quasi-associated signalling routes are excluded from this procedure. The regular link and all synchronized reserve links have terminals permanently assigned to them. Terminals for non-synchronized reserve links will be assigned from a pool of reserve terminals. Assume that the total number of links is n and the available number of reserve terminals is T . If T ≥" n , then a reserve terminal is assigned to each of the n non-synchronized reserve links and synchronization is simultaneously attempted on all links. If $T < n$, then $T — 1$ reserve terminals are assigned to as many non-synchronized reserve links, and one terminal will be cycled through the remaining non-synchronized reserve links following the procedure described in § 8.6.3.2 **|**) above.

Idle status of previously engaged nominated speech circuits at each exchange during the emergency restart procedure is recognized either by reception of a clear-forward signal from a preceding exchange or by reception of a clear-back signal from a succeeding exchange.

c) When one or more links have passed the emergency proving period, two emergency-load-transfer signals are sent periodically (at 2-3 seconds intervals) over each link. Each exchange may receive signals on the links during the emergency restart procedure and must take steps either to process these signals or deliberately reject them by setting the relevant ACU indicators to **1** . However, after sending ELT signals on any link, all signals received on the link must be processed. Although both exchanges may send emergency-load-transfer signals, only one exchange (designated the emergency restart control exchange by mutual agreement of the two Administrations) will acknowledge these signals. The non-control exchange must respond by sending emergency- load-transfer signals over the same signalling link, whenever it receives these signals and the link has passed the emergency proving period.

Both exchanges continue sending pairs of emergency-load-transfer signals at 2-3 seconds intervals over links which have passed the emergency proving period until the control exchange has sent two load-transfer-acknowledgement signals and one has been received by the non-control exchange.

Upon receiving two emergency-load-transfer signals within 3 seconds on one or more links, the control exchange will select one of these links which has passed the emergency proving period and respond with two load-transfer-acknowledgement signals. The control exchange may now start sending signalling traffic over this link. The non-control exchange may also commence signalling traffic when it receives a load-transfer-acknowledgement signal. The signalling traffic that is restarted (or allowed for STP traffic) will be for bands where no working signalling path is at that time available via this exchange. Other signalling traffic may only be transferred from working links after the one-minute proving period using the normal changeback or automatic load transfer procedures.

This interchange of signals will take place even if the selected link had previously been manually changed-over, and irrespective of whether or not the control exchange had initiated the manual change-over. Once the link is selected the manual change-over condition will be removed at both ends.

A guard period of 5 ± 1 seconds shall be commenced on transfer of traffic to the selected link. During this guard period, any emergency-load- transfer signals, received at the control exchange on the link on which traffic has been resumed, shall be acknowledged. Emergency-load-transfer signals received on any other link, between the two exchanges, or received by the non-control exchange on any link, shall be ignored. If, during the guard period, the signal unit error rate monitor indicates an unsatisfactory performance of the link carrying traffic or if faulty-link information is received on that link, then the guard period is terminated and § 8.7 |), second paragraph applies.

After the emergency restart procedure has been terminated, subsequent failures are treated in the normal manner. The load-transfer or standby-ready signalling sequences are not initiated on the selected link during the emergency restart procedure, although they shall be sent after the one-minute proving period in order to carry out the normal changeback and automatic load transfer procedures or to confirm the proving status of the link for subsequent link security procedures.

If an exchange receives two emergency-load-transfer signals, it must respond in the manner described and transfer signalling traffic to the indicated signalling link, even though it may not be in the emergency restart state.

8.8 FULL-TIME SYNCHRONIZED RESERVE LINKS

8.8.1 *Failure of a synchronized reserve link*

On detection of failure of a synchronized reserve link, the terminal starts sending faulty-link information as described in § 8.6.1 |) above. Receipt of faulty-link information indicates that the link is not suitable for use as a reserve.

8.8.2 *Removal of a full-time synchronized reserve link from service availability*

It may be necessary, for reasons of rearrangements, changes, maintenance, etc., to remove a full-time synchronized reserve link, which is not currently carrying the signalling traffic for the link set, from service availability.

In this case the Exchange A desiring the removal will send a manual-changeover signal on the reserve link. On receipt of this signal Exchange B will mark the reserve as unavailable for service and respond with a manual changeover-acknowledgement signal. Exchange A, on receipt of the acknowledgement signal, will also mark the reserve as unavailable for service and may then continue to transmit SYUs or ACUs in the normal manner or may remove the link from service. Exchange B acknowledging the removal should maintain synchronism and, should the link be removed, detect loss of synchronization. Subsequent to these actions the provisions for inclusion of the reserve link in an emergency restart procedure apply as specified in § 8.7 a).

In the event that the manual-changeover signal is not acknowledged by the other exchange, a suitable interval shall elapse (e.g. one minute), before the request is repeated. If the second manual-changeover is not acknowledged the exchange initiating the removal may unilaterally remove the link from service (provided that it is still acting as a reserve and is not carrying signal traffic) by sending faulty link information or disconnection of the carrier but may not mark the link as unavailable and continue to transmit SYUs + ACUs in the normal manner.

Restoration of the reserve link from unavailable to available (standby ready) status will be initiated by the end which previously initiated the removal using the procedure described in § 8.8.3) below.

8.8.3 *Restoration of a synchronized reserve link*

When both terminals are again in synchronism over the reserve link and the error rate has met the requirement for the one-minute proving period (see Recommendation Q.291, § 8.3.3), the faulty-link information will be replaced with blocks of SYU (plus ACU) to indicate that the proving period has been completed.

To confirm that the proving period has been completed at both exchanges, the exchange A finishing the proving period sends two standby-ready signals on the reserve link.

When exchange B receives a standby-ready signal and knows the reserve link is usable, it responds with a standby-ready-acknowledgement signal on the reserve link. When exchange A receives one standby-ready-acknow ledgement signal, it has confirmation that the reserve link is available for use.

8.9 LOAD SHARING METHOD

The load sharing method is described in § 8.4.2 |). The method implies that the total signalling load on the link set is shared between two working links. Steps should be taken to ensure that the load is approximately equalized between the two links. This will normally be done by allocating each circuit to one of the signalling links as its regular link, and arranging for half of the total number of circuits to be allocated to each link. Although not mentioned in § 8.4.2 |), other allocation methods are possible such as allocating each circuit to one of the signalling links on a per-call basis. This follows from the fact that under failure conditions on one link the signalling traffic will be transferred to the remaining link and hence each exchange must be capable of accepting signalling traffic for all labels on either link. It is therefore unnecessary for both exchanges to use the same allocation method for their outgoing signalling traffic and each Administration will decide on a suitable method. (For example, free option for each label, an odd-even label basis, a per-band basis or a per-call basis.)

It must be ensured that one signalling link can handle all the signalling traffic without unacceptable queueing delays. Load sharing should not, therefore, be used to increase the signalling capacity of a link set. If extra capacity is required, then a second link set with separate links should be provided.

When a faulty link within a load-shared pair becomes workable again, the procedure used is the changeback procedure of § 8.6.2 (and not the procedure of § 8.8). The signals standby-ready and standby-ready-acknowledgement are not used. As both links remain in use, the 5 ± 1 second guard timing is not used.

In general, any link set will probably contain a maximum of two synchronized links, although more may be provided by agreement between Administrations. Normally there will be no mixing between different security arrangements (i.e., a load shared pair with full-time synchronized reserves, etc.) although it may be provided by agreement between Administrations.

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