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INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

RED BOOK

VOLUME VI – FASCICLE VI.4

**SPECIFICATIONS OF SIGNALLING
SYSTEMS R1 AND R2**

RECOMMENDATIONS Q.310-Q.490



VIIITH PLENARY ASSEMBLY

MALAGA-TORREMOLINOS, 8-19 OCTOBER 1984

Geneva 1985



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PRELIMINARY NOTES

1 The strict observance of the specifications for standardized international signalling and switching equipment is of the utmost importance in the manufacture and operation of the equipment. Hence these specifications are obligatory except where it is explicitly stipulated to the contrary.

The values given in Fascicles VI.1 to VI.9 are imperative and must be met under normal service conditions.

2 The Questions entrusted to each Study Group for the Study Period 1981-1984 can be found in Contribution No. 1 to that Study Group.

3 In this Fascicle, the expression "Administration" is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

PART I

Recommendations Q.310 to Q.331

SPECIFICATIONS OF SIGNALLING SYSTEM R1

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SIGNALLING SYSTEM R1

INTRODUCTION

PRINCIPLES OF SIGNALLING SYSTEM R1

General

The development of new exchanges, especially those utilizing stored programme control, has introduced new concepts in the division of functions between various components of signalling and switching systems. To allow the maximum freedom in incorporating new concepts which can contribute to the overall economy and efficiency of the system, the requirements as covered in this specification are for the combination of equipments necessary to provide a function. For example, the requirements for line signal receiving equipment as given here may be met by various subdivisions of functions between signal receiver, trunk relay sets and stored programme control.

System R1 may be applied for automatic and semi-automatic operation of one-way and both-way circuits, within an international region (world numbering zone). When utilized in an integrated world numbering zone (e.g. Zone 1) the numbering and routing plans and operating facilities of that zone should apply.

The system is applicable to all types of circuits (except TASI derived circuits)¹⁾ meeting CCITT transmission standards, including satellite circuits.

The signalling equipment used in System R1 consists of two parts:

- a) line signalling for line or supervisory signals; and
- b) register signalling for address signals.

a) *Line signalling*

1) *2600 Hz signalling*

Continuous tone type in-band line-signalling is used for the link-by-link transmission of all supervisory signals except the ring-forward (forward-transfer) signal which is a spurt signal. A single frequency, 2600 Hz, is used in each direction of the 4-wire transmission path, the presence or absence of this frequency indicates a specific signal dependent upon when it occurs in the signalling sequence and in certain cases upon its duration. When the circuit is idle, a low level signalling tone is continuously present in both directions.

¹⁾ Register signalling can be made compatible with TASI by providing a TASI locking tone.

2) *PCM signalling*

The 2600 Hz line signalling described in 1) is not normally applied to the speech paths of circuits working on PCM systems unless the PCM channels are connected in cascade with analogue channels to form a circuit. The signalling on PCM systems in the North American region is channel associated, in-slot, providing two signalling channels per speech channel, and utilizing bit stealing of the eighth bit of each channel every sixth frame.

b) *Register signalling*

Link-by-link multifrequency (MF) in-band pulse signalling is used for the transmission of address information. The signalling frequencies are 700 Hz to 1700 Hz, in 200 Hz steps, and combinations of two, and two only, determine the signal. The address information is preceded by a KP signal (start-of-pulsing) and terminated by an ST signal (end-of-pulsing). Either *en bloc*²⁾, or *en bloc* overlap²⁾, or overlap sending may apply. This register signalling arrangement is used extensively with other in-band and out-band line signalling systems.

Compandors may affect signalling, particularly short pulse compound register signals, due to pulse length distortion and the production of intermodulation frequencies. By virtue of the link-by-link signalling and the adopted duration of register and line signal pulses, System R1 functions correctly in the presence of compandors designed in accordance with CCITT recommendations.

²⁾ See in Fascicle VI.2, Recommendation Q.151, Note to § 3.1.1 for an explanation of these terms.

SECTION 1

DEFINITION AND FUNCTION OF SIGNALS

Recommendation Q.310

1. DEFINITION AND FUNCTION OF SIGNALS¹⁾

1.1 **connect (seizing) signal** (sent in the forward direction)

This line signal is transmitted at the beginning of a call to initiate circuit operation at the incoming end of the circuit to busy the circuit and to seize equipment for switching the call.

1.2 **delay-dialling signal** (sent in the backward direction)

This line signal is transmitted by the incoming exchange following the recognition of the connect (seizing) signal to verify receipt of the connect (seizing) signal and to indicate that the incoming register equipment is not yet attached or ready to receive address signals.

1.3 **start-dialling (proceed-to-send) signal** (sent in the backward direction)

This line signal is sent from the incoming exchange subsequent to the sending of a delay-dialling signal to indicate that the incoming register equipment has been connected and is ready to receive address signals.

1.4 **KP (start-of-pulsing) signal** (sent in the forward direction)

This register signal is sent subsequent to the recognition of a start-dialling signal and is used to prepare the incoming multifrequency register for the receipt of subsequent interregister signals.

1.5 **address signal** (sent in the forward direction)

This register signal is sent to indicate one decimal element of information (digit 1, 2, ..., 9 or 0) about the called party's number. For each call a succession of address signals is sent.

1.6 **ST (end-of-pulsing) signal** (sent in the forward direction)

This register signal is sent to indicate that there are no more address signals to follow. The signal is always sent in semi-automatic as well as automatic working.

¹⁾ In this part the North American designation for line signals is used. The designation of the signal in System No. 5 which most nearly corresponds to a particular North American signal is shown in parentheses. There is not always exact correspondence in function, e.g. the ring-forward signal can only be effective when a connection has been established through an incoming operator.

1.7 **answer signal** (sent in the backward direction)^{2), 3)}

This line signal is sent to the outgoing exchange to indicate that the called party has answered.

In semi-automatic working, the signal has a supervisory function.

In automatic working, it is used:

- to start metering the charge to the calling subscriber;
- to start the measurement of call duration for international accounting purposes, if this is desired.

1.8 **hang-up (clear-back) signal** (sent in the backward direction)²⁾

This line signal is sent to the outgoing exchange to indicate that the called party has cleared. In the semi-automatic service it performs a supervisory function.

In automatic working, arrangements are made to clear the connection, stop the charging, and stop the measurement of call duration if within 10 to 120 seconds⁴⁾ after recognition of the hang-up signal, the calling subscriber has not cleared. Clearing of the connection should preferably be controlled from the point where the charging is carried out.

1.9 **ring-forward (forward-transfer) signal** (sent in the forward direction)

This line signal is initiated by an operator to recall an operator at a point further ahead in the connection.

1.10 **disconnect (clear-forward) signal** (sent in the forward direction)

This line signal is sent in the forward direction at the end of a call when:

- a) in semi-automatic working, the operator at the outgoing exchange withdraws the plug from the jack, or when an equivalent operation is performed;
- b) in automatic working, the calling party hangs up, or when the time-out period of 10 to 120 seconds as discussed in § 1.8 above occurs.

1.11 *Diagrams showing signal sequence*

Typical sequences of signals in semi-automatic and automatic working are shown in Annex A to these Specifications of Signalling System R1.

²⁾ Notes on the answer and hang-up (clear-back) signals. — See corresponding notes in Recommendation Q.120, § 1.8, Volume VI-2 of the *Green Book*.

³⁾ See Recommendation Q.27 for the actions to be taken to assure that answer signals, both national and international, are transmitted as quickly as possible.

⁴⁾ In word numbering Zone 1, 13 to 32 seconds is used.

SECTION 2

LINE SIGNALLING

Recommendation Q.311

2.1 2600 Hz LINE SIGNALLING

The line-signal coding arrangement is based on the application and removal of a single frequency tone (2600 Hz) as shown in Table 1/Q.311.

TABLE 1/Q.311
Line signal code

Signal	Signal direction ^{1), 2)}	Transmitted (sending) duration	Transmitted state ^{5), 6)}	
			Originating end	Terminating end
Idle	↔	continuous	0	0
Connect (seizing)	-----→	continuous	1	0
Delay-dialling	←-----	continuous ³⁾	1	1
Start-dialling (proceed-to-send)	←-----	continuous ³⁾	1	0
Answer	←-----	continuous	1	1
Hang-up (clear-back)	←-----	continuous	1	0
Disconnect (clear-forward)	-----→	continuous	0	0 or 1
Ring-forward (forward-transfer)	-----→	65-135 ms	0	0 or 1
Busy, re-order (congestion) ⁴⁾	←-----	—	off	on

¹⁾ -----→, -----→ indicates forward signalling state 0 or 1, respectively.

²⁾ ←-----, ←----- indicates backward signalling state 0 or 1, respectively.

³⁾ The durations of these signals are variable and depend upon when the succeeding signal occurs. To ensure proper registration of these signals, the transmitted signal durations should not be less than 140 ms.

⁴⁾ Busy and re-order (congestion) conditions are indicated by audible tones.

⁵⁾ 0: Tone on, or signalling bit state 0 in PCM systems.

⁶⁾ 1: Tone off, or signalling bit state 1 in PCM systems.

By taking advantage of the fixed order of occurrence of specific signals, both tone-on and tone-off signals are used to indicate more than one signal condition. For example, in the backward direction tone-on is used to indicate start-dialling (proceed-to-send), and terminating end hang-up (clear-back) signals without conflict. The equipment must retain memory of the preceding signal states and the direction of signals in order to differentiate between tone-on and tone-off signals.

Recommendation Q.312

2.2 2600 Hz LINE SIGNAL SENDER¹⁾ (TRANSMITTER)

2.2.1 Signal frequency

2600 \pm 5 Hz.

2.2.2 Transmitted signal level of tone-on signals

-8 ± 1 dBm0 for the duration of the signal or for a minimum of 300 ms (whichever is shorter) and for a maximum of 550 ms after which the level of the signal shall be reduced to -20 ± 1 dBm0.

2.2.3 Transmitted signal durations

The transmitted signal durations are shown in Table 1/Q.311.

2.2.4 Signal frequency leak

The level of signal frequency leak power transmitted to the line should not exceed -70 dBm0, during the tone-off condition.

2.2.5 Extraneous frequency components

The total power of extraneous frequency components accompanying a tone signal should be at least 35 dB below the fundamental signal power.

2.2.6 Transmitting line split

The following splitting arrangements are required when transmitting line signals to prevent incorrect operation of the receiving equipment due to transients caused by the opening or closing of direct current circuits in the exchange at the transmitting end:

- a) when a tone-on signal is to be transmitted, the speech path from the exchange shall be split (disconnected), if not already split, within an interval from 20 ms before, to 5 ms²⁾ after tone is applied to the line, and remain split for a minimum of 350 ms and a maximum of 750 ms;
- b) when a tone-off signal is to be transmitted, the speech path from the exchange shall be split (disconnected), if not already split, within an interval from 20 ms before to 5 ms after tone is removed from the line, and remain split for a minimum of 75 ms and a maximum of 160 ms after the tone is removed;
- c) when the signalling equipment is receiving and sending tones simultaneously the split shall be maintained until:
 - i) the transmitted tone is terminated, in which case the split must be removed in the interval from 75 to 160 ms after tone is removed [as in b)]; or
 - ii) the incoming tone ceases, in which case the split must be removed in the interval from 350 to 750 ms after tone ceases;
- d) when the signalling equipment is sending tone, a split shall be introduced, if not already split, within 250 ms of receipt of an incoming tone.

The above requirements given in a), b), c) and d) establish a transmitting path split at both ends of the circuit during the idle condition.

¹⁾ See also Recommendation Q.112.

²⁾ The 5 ms may be relaxed to 15 ms if tone is applied while tone is being received.

2.3 2600 Hz LINE SIGNAL RECEIVING EQUIPMENT¹⁾

2.3.1 Operate limits (tone-on signals)

The receiving equipment shall operate on a received tone signal, in the presence of the maximum noise expected on an international circuit, -40 dBm0 uniform spectral energy over the range of 300 to 3400 Hz, that meets the conditions listed below:

- a) 2600 ± 15 Hz;
- b) to ensure proper operation in the presence of noise, the signal level of the initial portion of each tone-on signal shall be augmented by 12 dB (see § 2.2.2).

As a result, the following requirement reflects both the augmented and steady-state signal levels. The absolute power level N of each signal is within the limits $(-27 + n \leq N \leq -1 + n)$ dBm where n is the relative power level at the input to the receiving equipment. The minimum absolute power level $N = (-27 + n)$ gives a margin of 7 dB on the steady-state nominal absolute power level of the received signal at the input to the receiving equipment. With augmentation the effective margin is increased from 7 to 19 dB.

The maximum absolute power level $N = (-1 + n)$ gives a margin of 7 dB on the augmented nominal absolute power level of the received signal at the input to the receiving equipment.

The above tolerances are to allow for variations at the sending end and variations in line transmission.

Note — Since higher steady noise as well as impulsive noise may be encountered on intra-regional circuits especially over certain compandored carrier systems, the maximum expected noise within a region must be taken into account in the design of equipment for that region.

2.3.2 Non-operate limits

1) The receiving equipment shall neither operate on signals originating from subscriber stations (or other sources) if the total power in the band from 800 Hz to 2450 Hz equals or exceeds the total power present at the same time in the band from 2450 Hz to 2750 Hz, as measured at the station, nor degrade these signals. Allowances shall be made in the receiving equipment design to accommodate expected deviations from these values due to attenuation distortion and carrier frequency shift on the total transmission path between the station and the receiving equipment.

2) The receiving equipment shall not operate on any tone or signal whose absolute power level at the point of connection of the receiving equipment is $(-17 - 20 + n)$ dBm or less, n being the relative power level at this point.

2.3.3 Recognition of signals

- 1) System R1 must be protected against false signal recognition caused by:
 - a) signal simulation of tone-on or tone-off signals by speech or other signals;
 - b) signal simulation of tone-off signals by momentary interruptions of the transmission path.

The method of providing this protection is left to each Administration concerned to allow for maximum flexibility in the implementation of the signalling and switching system design. However, the overall system requirements given in 2) and 3) below shall be met.

¹⁾ See also Recommendation Q.112.

2) The following requirements for signal recognition are specified in terms of signal duration at the input to the signal receiving equipment and further assumes that signal levels, frequency and accompanying noise are within the limits specified in § 2.3.1:

- a) A tone-on signal lasting 30 ms or less must be rejected; that is, it must not be recognized as a signal.
- b) A tone-off signal lasting 40 ms or less must be rejected if the previous tone-on signal is 350 ms or longer; that is, it must not be recognized as a signal.
- c) Subsequent to establishing the cross office path, a tone-on ring-forward (forward-transfer) spurt signal lasting between 65 and 135 ms must be recognized as a valid signal.
- d) A tone-on forward signal lasting 300 ms or longer must be recognized as a valid disconnect (clear-forward) signal. Prior to attaching a register, a forward tone-on signal lasting 30 ms or longer may be recognized as a valid disconnect (clear-forward) signal.
- e) To protect against a momentary interruption in the transmission facility causing a continuous succession of false connect (seizing) and disconnect (clear-forward) signals, the incoming equipment should be arranged to delay responding to the second of two closely spaced connect (seizing) signals. The timed delay introduced should be started at the end of initial connect (seizing) signal or on recognition of the disconnect (clear-forward) signal. The delay introduced should be a function of the round trip signalling time. For satellite circuits the recommended time is 1300 ± 100 ms. For terrestrial circuits the recommended time is 500 ± 100 ms. If the second connect (seizing) signal persists beyond this timed interval, the signal should be considered valid and a delay dialling signal returned.
- f) Other tone-on and tone-off signals should be recognized as valid signals, subsequent to the minimum limits imposed by a) and b) above, as soon as possible.

Note – Delays introduced by line signalling equipment should be held to a minimum consistent with the requirements covered herein to minimize signal transfer times. Minimizing the delay is especially important in the case of the answer signal and in the case of satellite circuit operation. In this latter case, if a hang-up (clear-back) signal has not been sent prior to recognition of a disconnect (clear-forward) signal, it is necessary that the idle tone-on signal, sent by the incoming exchange in response to the disconnect signal, be recognized by the outgoing exchange prior to the elapse of the guard timing specified in Recommendation Q.317, § 2.7.1.

3) The following signal simulation rates shall not be exceeded.

- a) On the average not more than one false recognition of a disconnect (clear-forward) signal shall occur per 1500 call hours of speech, at the *minimum* disconnect recognition time, as selected according to § 2.3.3, 2) c) and d). (In some older designs, this requirement may not be met, but for these cases the call hours figure must not be less than 500²⁾ call hours.)
- b) On the average, not more than one false ring-forward (forward-transfer) signal shall occur per 70²⁾ call hours of speech, at the *minimum* ring-forward recognition time.
- c) Speech or other electrical signals as audible-tone signals, with levels up to +10 dBm0 shall not cause any false simulation of answer signals.
- d) The number and characteristics of false splits of the speech path caused by speech or other signals shall not cause a noticeable reduction in the transmission quality of the circuit.

2.3.4 Receiving line split

To prevent line signals of the signalling system from causing disturbances to signalling systems on subsequent circuits, the receiving transmission path to the connected exchange should be split when the signal frequency is received to ensure that no portion of any signal exceeding 20 ms duration may pass out of the circuit. The use of a band-stop filter for splitting is necessary since in the case of non-charged calls a continuous signal tone persists in the return transmission path during conversation. The level of signal leak current transmitted to the subsequent circuit with the band-stop filter inserted should be at least 35 dB below the received signal level. In

²⁾ In the case when no answer signal is transmitted (non-charged calls), the simulation rates specified in §§ 3 a) and 3 b) may, in some existing designs, be somewhat in excess of the values quoted.

addition, the band-stop filter must not introduce more than 5 dB loss at frequencies 200 Hz or more above or below the midband frequency nor more than 0.5 dB loss at frequencies 400 Hz or more above or below the midband frequency.

The receiving line split must be maintained for the duration of the incoming tone signal, but must cease within 300 ms of tone removal.

Note – In some existing designs, the initial cut may be a physical line disconnection but the filter must be inserted within 100 ms of tone reception.

Recommendation Q.314

2.4 PCM LINE SIGNALLING

Individual channel line signalling is provided in the format of the CCITT primary multiplex operating at 1544 kbit/s (Recommendation G.733). Designated signalling bits are marked 0 or 1 corresponding to tone-on, tone-off in the single frequency in-band arrangement as shown in Table 1/Q.311. As in the in-band system, the same signalling state is used to indicate more than one signal by taking advantage of the fixed order of occurrence of specific signals. The equipment must retain memory of the preceding signal states and the direction of signals in order to differentiate between like state 0 and state 1 signals.

Recommendation Q.315

2.5 PCM LINE SIGNAL SENDER (TRANSMITTER)

2.5.1 *Signalling format*

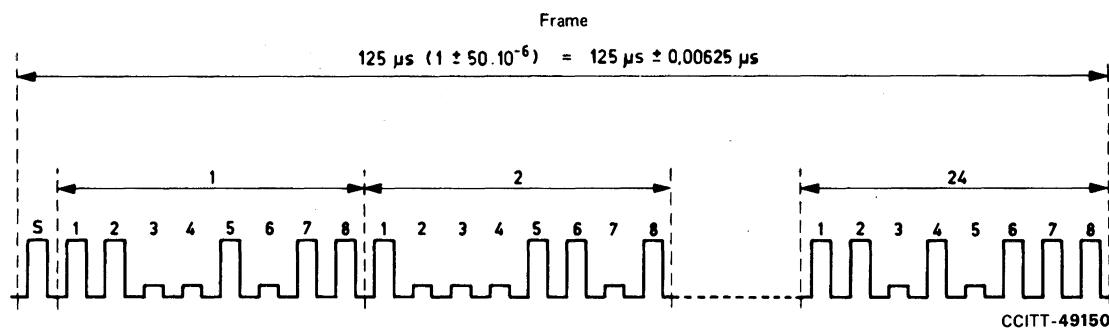
The primary multiplex format is shown in Figure 1/Q.315. Per channel, in-slot signalling is accomplished by utilizing bit No. 8 in each time slot of the designated frames (6, 12, etc.) for signalling purposes. Bit No. 8 of each time slot in the intervening frames (1-5, 7-11, etc.) is used for encoding speech. Two signalling channels per speech channel are provided in the format. The multiframe alignment required for signalling purposes is obtained by subdividing the 8 kbit/s framing pulse stream into two 4 kbit/s streams, one for terminal framing and one for signalling framing (S-bits). The relationship of the framing and multiframing signals to the signalling bits is given in Table 2/Q.315. Since only one line signalling channel is required for System R1, the same signalling information is sent over both signalling channels A and B.

2.5.2 *Transmitted signal duration*

The transmitted signal durations are given in Table 1/Q.311 of Recommendation Q.311.

2.5.3 *Transmitting line split*

Since signalling is out-band, no transmitting line split is required.



Sampling frequency 8000 ($1 \pm 50 \times 10^{-6}$) Hz = 8000 \pm 0.4 Hz
Output bit rate 1544 ($1 \pm 50 \times 10^{-6}$) kbit/s = 1544 kbit/s \pm 77 bit/s
Bits/frame 193
Time slots/frame 24
Signalling Eighth bit every sixth frame as shown in Table 2/Q.315.
The 8 bits in each time slot are defined in Table 2/Q.315.
The F-bit is time shared between terminal framing and signalling framing (S) as shown in Table 2/Q.315.

FIGURE 1/Q.315
Primary multiplex format

TABLE 2/Q.315
Multiframe structure

Frame number	Frame alignment signal	Multiframe alignment signal (S-bit)	Bit number(s) in each channel time slot		Signalling channel
			For character signal	For signalling	
1	1	—	1 to 8	—	A
2	—	0	1 to 8	—	
3	0	—	1 to 8	—	
4	—	0	1 to 8	—	
5	1	—	1 to 8	—	
6	—	1	1 to 7	8	
7	0	—	1 to 8	—	
8	—	1	1 to 8	—	
9	1	—	1 to 8	—	B
10	—	1	1 to 8	—	
11	0	—	1 to 8	—	
12	—	0	1 to 7	8	

Note 1 — The sequence shown is repetitive.

Note 2 — For System R1 the same signalling information is sent on signalling channels A and B.

2.6 PCM LINE SIGNAL RECEIVER**2.6.1 Recognition of signals**

System R1 must be protected against false signal recognition caused by signal simulation due to momentary loss of synchronization of the PCM system. The method of providing this protection is left to each Administration concerned to allow for maximum flexibility in the implementation of the signalling and switching system design. However, the overall system requirements given below must be met.

- a) A state 0 signal lasting 30 ms or less must be rejected; that is, it must not be recognized as a signal.
- b) A state 1 signal lasting 40 ms or less must be rejected if the previous state 0 signal is 350 ms or longer; that is, it must not be recognized as a signal.
- c) Subsequent to establishing the speech path, a state 0 ring-forward (forward-transfer) signal lasting 65-135 ms must be recognized as a valid signal.
- d) A state 0 forward signal lasting 300 ms or longer must be recognized as a valid disconnect (clear-forward) signal. Prior to attaching a register, a forward state 0 signal lasting 30 ms or longer may be recognized as a valid disconnect (clear-forward) signal.
- e) To protect against a momentary fault causing a continuous succession of false connect (seizing) and disconnect (clear-forward) signals, the incoming equipment should be arranged to delay responding to the second of two closely spaced connect (seizing) signals. The time delay introduced should be started at the end of the initial connect (seizing) signal or on recognition of the disconnect (clear-forward) signal. The delay introduced should be a function of the round trip signalling time. For satellite circuits the recommended time is 1300 ± 100 ms. For terrestrial circuits the recommended time is 500 ± 100 ms. If the second connect (seizing) signal persists beyond this timed interval, the signal should be considered valid and a delay dialling signal returned.
- f) Other state 0 and state 1 signals should be recognized as valid signals subsequent to the minimum limits imposed by a) and b) above, as soon as possible.

Note — Delays introduced by line signalling equipment should be held to a minimum consistent with the requirements covered herein to minimize signal transfer times. Minimizing the delay is especially important in the case of the answer signal and in the case of satellite circuit operation. In this latter case, if a hang-up (clear-back) signal has not been sent prior to recognition of a disconnect (clear-forward) signal, it is necessary that the idle state 0 signal, sent by the incoming exchange in response to the disconnect signal, be recognized by the outgoing exchange prior to the elapse of the guard timing specified in Recommendation Q.317, § 2.7.1.

2.6.2 Receiving line split

Since signalling is out-band, no receiving line split is required.

2.6.3 Action on receipt of an alarm

When the PCM primary multiplex has detected a fault and given an alarm (see Recommendation G.733, § 3.2) appropriate action shall be taken to remove automatically the affected circuits from service, and to terminate calls in progress, i.e. stop charging, release interconnected circuits, etc. When the alarm has been cleared the affected circuits should be automatically restored to service.

Recommendation Q.317**2.7 FURTHER SPECIFICATION CLAUSES RELATIVE TO LINE SIGNALLING**

2.7.1 Access to the outgoing circuits shall be denied (guarded) for 750 to 1250 ms (1050 ms to 1250 ms for satellite circuits) after initiation of the disconnect (clear-forward) signal to ensure sufficient time for the release of the equipment at the incoming exchange. [See also the Note to § 2.3.3, 2) of Recommendation Q.313 and to § 2.6.1 of Recommendation Q.316.]

2.7.2 The disconnect (clear-forward) signal may be sent at any time in the call sequence.

2.7.3 The release of the chain of circuits in an established connection is only initiated from the originating exchange or the charge-recording exchange.

2.7.4 The start of metering the charge should be delayed by an appropriate time after recording of the answer signal to prevent false charging resulting from possible false recognition of an invalid answer signal.

Recommendation Q.318

2.8 DOUBLE SEIZING WITH BOTH-WAY OPERATION

2.8.1 General

To minimize the probability of double seizing, the circuit selection at the two ends of both-way circuit groups should be such that, as far as possible, double seizing can occur only when a single circuit of the group remains free (e.g. by selection of circuits in opposite order at the two ends of the circuit group).

2.8.2 Unguarded interval

In general the unguarded interval is small, except in the case of satellite operation where the circuit propagation time is long. However, System R1 does provide a means of detecting double seizing.

2.8.3 Detection of double seizing

In the event of double seizing, the incoming connect (seizing) signal is recognized at each end as a delay-dialling signal. If a start-dialling (proceed-to-send) signal is not received within the time-out interval (e.g. 5 seconds) double seizing is assumed.

In this event, either of the following arrangements may apply:

- a) an automatic repeat attempt to set up the call; or
- b) a recorder indication is given to the operator or to the calling subscriber and no automatic repeat attempt is made.

With either method, means must be provided to ensure positive release of the double seized circuit. To achieve the release it is recommended that the office which first assumes (based on timing) that dual seizure has occurred transmits a tone-on (0 state) signal followed by a tone-off (1 state) signal before the final tone-on (0 state) signal (disconnect) is sent. The duration of initial tone-on (0 state) signal should be a minimum of 100 ms and a maximum of 200 ms. The tone-off (1 state) signal should be recognized as an unexpected tone-off (1 state) signal at the distant end, after which the action specified in § 3.6.2, 1) c) of Recommendation Q.325 applies.

Recommendation Q.319

2.9 SPEED OF SWITCHING IN INTERNATIONAL EXCHANGES

2.9.1 It is recommended that the equipment in international exchanges shall have a high switching speed so that the switching time may be as short as possible.

2.9.2 At the outgoing, transit and incoming international exchanges, the seizing of the circuit and the setting up of the connection should take place as soon as possible after receipt of the digits of the address that are necessary to determine the routing.

2.9.3 At international exchanges the delay-dialling signal should be returned as soon as possible after recognition of the connect (seizing) signal. The start-dialling (proceed-to-send) signal should be returned as soon as possible but in any case, the return should be before the time-out of the outgoing register. [See § 3.6.2, 1) a) and b) of Recommendation Q.325.]

SECTION 3

REGISTER SIGNALLING¹⁾

Recommendation Q.320

3.1 SIGNAL CODE FOR REGISTER SIGNALLING

3.1.1 General

- 1) Either semi-automatic working (with automatic machine or direct operator access), or automatic working (with automatic machine access) may be used for outgoing traffic. With automatic machine access the incoming address signals are stored in a register until sufficient address information is received to route the call properly, at which time a free circuit may be selected and a connect (seizing) line signal sent. Subsequent to the recognition of a delay-dialling line signal and a start-dialling (proceed-to-send) line signal a KP (start-of-pulsing) signal followed by the address and ST (end-of-pulsing) signals are transmitted. The KP signal, which is nominally 100 ms in duration, prepares the receiving equipment to accept subsequent register signals. The transmission of the KP signal should be delayed by a minimum of 140 ms, but not more than 300 ms, after recognition of the start-dialling line signal.
- 2) Link-by-link register signalling applies.
- 3) Register signalling is in a forward direction only and shall be in accordance with the two-out-of-six multifrequency code shown in Table 3/Q.320. Three of the 15 possible codes are unused in international service and are available for special purposes.
- 4) The receiving equipment must furnish a two-and-two only frequency check on each received signal to ensure its validity.

3.1.2 Sending sequence of register signals

- 1) The sending sequence of address signals conforms to the sequence indicated in Recommendation Q.107. However, for traffic within an integrated world numbering zone (e.g. Zone 1) the language or discriminating digit and country codes may have no application and may not be sent. In Zone 1, the sequence of signals sent from the operator or subscriber is as follows:
 - a) *Semi-automatic working for calls to a subscriber within Zone 1:*
 - i) KP;
 - ii) national (significant) number of the called subscriber;
 - iii) ST.

¹⁾ As used in this Section the term register includes traditional registers in electromechanical exchanges and also the equivalent receiving device, memory and logic in stored program exchanges.

- b) *Semi-automatic working for calls to operators within Zone 1:*
 - i) KP;
 - ii) special decimal numbers;²⁾
 - iii) ST.
 - c) *Automatic working for calls to a subscriber within Zone 1:*
 - i) national (significant) number of the called subscriber.
- 2) The sending sequence of register signals shall conform to Table 3/Q.320, noting the following:
- a) a KP (start-of-pulsing) signal shall precede the sequence of signals in all cases;
 - b) the ST (end-of-pulsing) signal shall follow the sequence of signals in all cases.

TABLE 3/Q.320
Register signal code of System R1

Signals	Frequencies (compound) Hz
KP (start-of-pulsing)	1100 + 1700
Digit 1	700 + 900
Digit 2	700 + 1100
Digit 3	900 + 1100
Digit 4	700 + 1300
Digit 5	900 + 1300
Digit 6	1100 + 1300
Digit 7	700 + 1500
Digit 8	900 + 1500
Digit 9	1100 + 1500
Digit 0	1300 + 1500
ST (end-of-pulsing)	1500 + 1700
Spare	700 + 1700
Spare	900 + 1700
Spare	1300 + 1700

Recommendation Q.321

3.2 END-OF-PULSING CONDITIONS – REGISTER ARRANGEMENTS CONCERNING ST SIGNAL

3.2.1 The register signalling arrangements shall provide for the sending of an ST signal for both semi-automatic and automatic operation; the arrangements in the outgoing international register for recognizing the ST (end-of-pulsing) signal condition may vary as follows:

a) *Semi-automatic operation*

The ST condition is determined by the receipt of the end-of-pulsing signal initiated by the operator.

b) *Automatic operation*

- i) Where the ST condition is determined by the originating national network, an ST signal is transmitted to the outgoing international register. No further arrangements are necessary in that register for this purpose.
- ii) Where the ST condition is not received from the originating national network, the outgoing international register will be required to determine the ST condition. (See for example the requirements for System No. 5, Recommendation Q.152, *Green Book*.)

²⁾ The special numbers used to reach operators are by agreement between Administrations.

Recommendation Q.322

3.3 MULTIFREQUENCY SIGNAL SENDER

3.3.1 Signalling frequencies 700, 900, 1100, 1300, 1500 and 1700 Hz. A signal shall consist of a combination of any two of these six frequencies. The frequency variation shall not exceed $\pm 1.5\%$ of each nominal frequency.

3.3.2 Transmitted signal level -7 ± 1 dBm0 per frequency. The difference in transmitted level between the two frequencies comprising a signal shall not exceed 0.5 dB.

3.3.3 Signal frequency leak and modulation products. The level of the signal leak current transmitted to the line should be at least:

- a) 50 dB below the single frequency level when a multifrequency signal is not being transmitted;
- b) 30 dB below the transmitted signal level of either of the two frequencies when a multifrequency signal is being transmitted. The modulation products of a signal shall be at least 30 dB below the transmitted level of either of the two frequencies comprising the signal.

3.3.4 *Signal durations*

KP signal: 100 ± 10 ms.

All other signals: 68 ± 7 ms.

Interval between all signals: 68 ± 7 ms.

3.3.5 *Compound signal tolerance*

The interval of time between the moments when the two frequencies comprising a signal are sent must not exceed 1 ms. The interval of time between the moments when the two frequencies cease must not exceed 1 ms.

Recommendation Q.323

3.4 MULTIFREQUENCY SIGNAL RECEIVING EQUIPMENT

3.4.1 *Operate limits*

The signal receiving equipment must operate satisfactorily on any combination of two of the frequencies received as a single pulse or train of pulses in the presence of maximum expected noise on an international circuit, -40 dBm0 uniform spectral energy over the range of 300 to 3400 Hz, that meets the conditions listed below:

- a) each frequency of the received signal is within $\pm 1.5\%$ of the nominal signalling frequency;
- b) the absolute power level N of each received frequency is within the limits

$$(-14 + n \leq N \leq +0 + n) \text{ dBm}$$

where n is the relative power level at the signal receiver input. Assuming a nominal circuit loss of 0 dB these limits give a margin of ± 7 dB on the nominal absolute level of each received signal. Considering that a single equipment may serve circuits whose designed loss (nominal loss) is greater than 0 dB (e.g., circuits that are not equipped with echo suppressors) account must be taken of the highest circuit loss in the design of the receiving equipment (e.g., by increasing must-operate sensitivity) to ensure that the minimum margin is 7 dB;

- c) the difference in level between the frequencies comprising a received signal is less than 6 dB;
- d) the signal receiving equipment must accept signals meeting the following conditions:
 - i) signals within the limits specified in a), b), and c) above in the presence of maximum expected noise and subject to the maximum expected delay distortion;
 - ii) the duration of each frequency comprising a signal is 30 ms or greater; and
 - iii) the silent interval preceding the signal is 20 ms or greater.

The tolerances given in a), b), and c) are to allow for variations at the sending end and in line transmission.

The test values indicated in d) are less than the working values. The difference between the test value and the working values will allow for pulse distortion, variations in registration devices, etc.

Note — Since higher steady noise as well as impulsive noise may be encountered on intraregional circuits, especially over certain compandored carrier systems, the maximum expected noise within a region must be taken into account in the design of equipment for that region.

3.4.2 *Non-operate limits*

- 1) The receiving equipment shall not operate on any signal whose absolute power level at the point of the receiving equipment is 9 dB or more below the must-operate sensitivity required to satisfy the conditions established in § 3.4.1 b).
- 2) The receiving equipment shall release when the signal level falls 1 dB below the level established in § 1) above.
- 3) Operation of the receiving equipment shall be delayed for a minimum period necessary to guard against false operation due to spurious signals generated internally on reception of any signal.
- 4) The receiving equipment should not operate on a pulse signal of 10 ms or less. This signal may be of a single frequency or two frequencies received simultaneously. Likewise, after operation the equipment shall ignore short interruptions of the signal frequencies.

3.4.3 *Input impedance*

The value of the input impedance should be such that the return loss over a frequency range of 500 to 2700 Hz against a 600-ohm non-inductive resistor in series with a two-microfarad capacitor is greater than 27 dB.

Recommendation Q.324

3.5 ANALYSIS OF ADDRESS INFORMATION FOR ROUTING

In the application of System R1 to intraregional networks, the routing plan of that network shall apply. The routing plan is such that analysis is limited to a maximum of six digits.

Note — An ISC processing an incoming call on a circuit using System R1, if encountering a barred routing or unallocated number condition, should preferably send the special information tone toward the originating subscriber.

3.6 RELEASE OF REGISTERS

3.6.1 Normal release conditions

- 1) An outgoing register shall be released when it has transmitted the ST signal.
- 2) An incoming register shall be released on the forward transmission of the ST signal to the next exchange, or when all pertinent information has been transferred to an outgoing register.

3.6.2 Abnormal release conditions

- 1) An outgoing register shall release in any of the following situations:
 - a) on failure to recognize a delay-dialling signal within 5 seconds of circuit seizure unless a longer interval is preferred for particular traffic conditions;
 - b) on failure to recognize a start-dialling (proceed-to-send) signal within 5 seconds of recognition of the delay-dialling signal unless a longer interval is preferred for particular traffic conditions;
 - c) on recognition of an unexpected tone-off (0 state) line signal subsequent to the recognition of a start-dialling (proceed-to-send) signal, but prior to completion of outpulsing. This signal sequence will occur in the event of double seizing and therefore a repeat attempt may be invoked and as a result the register may not be released prior to completion of the second attempt. (See Recommendation Q.318.);
 - d) on exceeding overall register timing of 240 seconds.
- 2) An incoming register shall release in any of the following situations:
 - a) on failure to receive the KP signal within 10 to 20 seconds of register seizure;
 - b) on failure to receive the 1st through 3rd digits within 10 to 20 seconds of receipt of the KP signal;
 - c) on failure to receive the 4th through 6th digits within 10 to 20 seconds of the registration of the 3rd digit;
 - d) on failure to receive the remaining digits and ST signal within 10 to 20 seconds of registration of the 6th digit;
 - e) on error detection such as receipt of one or more than two frequencies in a pulse;
 - f) on failure to gain access to associated switching equipment within appropriate intervals of time.

The timing intervals given in 1) and 2) above are representative values but need not necessarily apply to all types of switching systems or all traffic loads.

An abnormal release of an outgoing register on failure to receive a delay-dialling signal as discussed in 1) a) above, shall result in the circuit being locked out which maintains the tone-off (1 state) condition toward the distant end. The maintenance personnel should be alerted.

Abnormal releases should result in the return of an audible re-order (congestion) tone toward the originating end. If this condition (re-order) persists for more than 1 to 2 minutes, maintenance personnel should be alerted.

Recommendation Q.326

3.7 SWITCHING TO THE SPEECH POSITION

At all exchanges, the circuit shall be switched to the speech position when the registers (incoming or outgoing) are released.

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SECTION 4

TESTING ARRANGEMENTS

Recommendation Q.327

4.1 GENERAL ARRANGEMENTS

The guiding principles for the maintenance of automatic circuits as covered in Recommendations M.700 to M.734 are in general applicable to testing of System R1.

Recommendation Q.328

4.2 ROUTINE TESTING OF EQUIPMENT (LOCAL MAINTENANCE)

4.2.1 Test equipment for routine testing of individual items of equipment such as circuit equipment, connecting circuits, registers, etc., should be provided in every international exchange. Routine tests should be made in accordance with the practice followed in each country for the local maintenance of switching equipment and may be made with suitable semi-automatic or automatic test equipment if available.

4.2.2 The testing equipment must conform to the following principles:

- a) an item of equipment must not be taken for test until it is free;
- b) an item of equipment taken for test will be marked engaged (busy) for the duration of the test. Before a circuit equipment is taken for test, the circuit will be withdrawn from service at both international exchanges;
- c) as an alternative to b), a like item of equipment, known to be properly adjusted, may be switched in, and the item of equipment to be tested is switched out during the test.

4.2.3 Testing of the circuit and signalling equipment should include a check that the specifications of System R1 are met in regard to the following:

- a) *2600 Hz line signalling system:*
 - signal frequency;
 - transmitted signal levels;
 - signal frequency leak;
 - receiving equipment operate and non-operate limits;
 - receiving-end line split;
 - sending-end line split;
 - sending duration of signals.
- b) *PCM line signalling equipment:*
 - receiving equipment operate and non-operate limits;
 - sending duration of signals.

c) *Register signalling system:*

- signal frequencies;
- transmitted signal levels;
- signal frequency leak;
- sending duration of signals;
- receiving equipment operate and non-operate limits;
- operation of the receiving equipment in response to a series of pulses;
- error checking features.

Recommendation Q.329

4.3 MANUAL TESTING

4.3.1 Functional testing of signalling arrangements

Functional tests from one end of the circuit to the other can be made by verification of satisfactory signal transmission by initiating a test call to:

- a) technical personnel at the distant-end international exchange; or
- b) a test call signal testing and answering device, if such equipment is available at the distant-end international exchange.

4.3.2 Test calls

1) Steps in the verification of satisfactory transmission of signals, involved in the completion of test calls (manual method):

- a) place a call to the technical personnel at the distant international exchange;
- b) on completion of the connection the audible ringing tone should be heard and the answer signal should be received when the call is answered at the distant end;
- c) request distant end to initiate a hang-up (clear-back) signal, followed by a re-answer signal;
- d) a hang-up (clear-back) signal should be received and recognized when the distant end hangs up and a second answer signal should be received and recognized when the distant end re-answers the call;
- e) initiate a ring-forward (forward-transfer) signal which should be recognized at the distant end;
- f) terminate the call and observe that the circuit restores to the idle condition.

2) If incoming signalling testing devices are available at the distant international exchange, the signal verification tests should be made using this equipment to the extent that the applicable features indicated in 1) above are available.

Recommendation Q.330

4.4 AUTOMATIC TRANSMISSION AND SIGNALLING TESTING

Considering that automatic transmission and signalling testing of international circuits is extremely desirable, Administrations using or intending to use System R1 are encouraged to provide for this type of testing. Existing automatic testing equipment presently in use in world numbering Zone 1, may be used. When the automatic transmission measuring and signalling testing equipment (ATME) No. 2 becomes available, it may be used as an alternative by agreement of the Administrations concerned.

4.5 TEST EQUIPMENT FOR CHECKING EQUIPMENT AND SIGNALS

4.5.1 General

For local checks of correct equipment operation and for readjusting the equipment, international exchanges should have test equipment available which includes:

- a) line and register signal generators;
- b) signal-measuring apparatus.

4.5.2 Signal generators

The signal generators should be able to simulate all line and register signals. The generators may be part of test equipment which cycles the equipment to be tested through actual signalling sequences, in a manner which enables rapid complete testing to determine whether the equipment meets system specifications.

1) Line signal generator characteristics as follows:

- a) signal frequency should be within ± 5 Hz of the nominal signal frequency and shall not vary during the time required for testing;
- b) signal levels should be variable between the limits given in the specification and be able to be set within ± 0.2 dB;
- c) signal durations should be long enough so that the signals can be recognized. See Recommendation Q.313, § 2.3.3.

2) Register signal generator characteristics as follows:

- a) signal frequencies should be within $\pm 1.5\%$ of the nominal signal frequency or frequencies and shall not vary during the time required for testing;
- b) signal levels should be variable between the limits given in the specification and be able to be set within ± 0.2 dB;
- c) signal durations and intervals between signals shall be within the limits given in the specification in Recommendation Q.322, § 3.3.4, for normal operate values and in Recommendation Q.323, § 3.4.1 d), for test operate values.

4.5.3 Signal-measuring equipment

Equipment capable of measuring signal frequencies, signal levels, signal durations and other significant signal time intervals may be part of the test equipment referred to in § 4.5.2, or separate instruments.

1) Line signal measuring equipment characteristics as follows:

- a) signal frequency between the extreme limits given in the specification should be measured with an accuracy of ± 1 Hz;
- b) level of the signal frequency measured over the range given in the specification should be measured with an accuracy of ± 0.2 dB;
- c) signal durations, and other significant time intervals as given in the specification should be measured with an accuracy of ± 1 ms or $\pm 1\%$ of the nominal duration, whichever yields the higher value.

2) Register signal measuring equipment characteristics as follows:

- a) signal frequency or frequencies between the extreme limits given in the specification, should be measured with an accuracy of ± 1 Hz;
- b) level of the signal frequency or frequencies over the range given in the specification should be measured with an accuracy of ± 0.2 dB;
- c) signal duration and intervals between signals as given in the specification should be measured with an accuracy of ± 1 ms.

3) In regard to measuring time intervals a recorder having a minimum of two input channels may be useful. The recorder characteristic should conform with the accuracy requirements quoted in 1) and 2) above and be easily connected to the circuit under test. The recorder input characteristic should be such as to have a negligible effect on circuit performance.

ANNEX A TO THE SPECIFICATIONS OF SIGNALLING SYSTEM R1

SIGNAL SEQUENCES

TABLE A-1

Semi-automatic (SA) and automatic (A) traffic in Zone 1

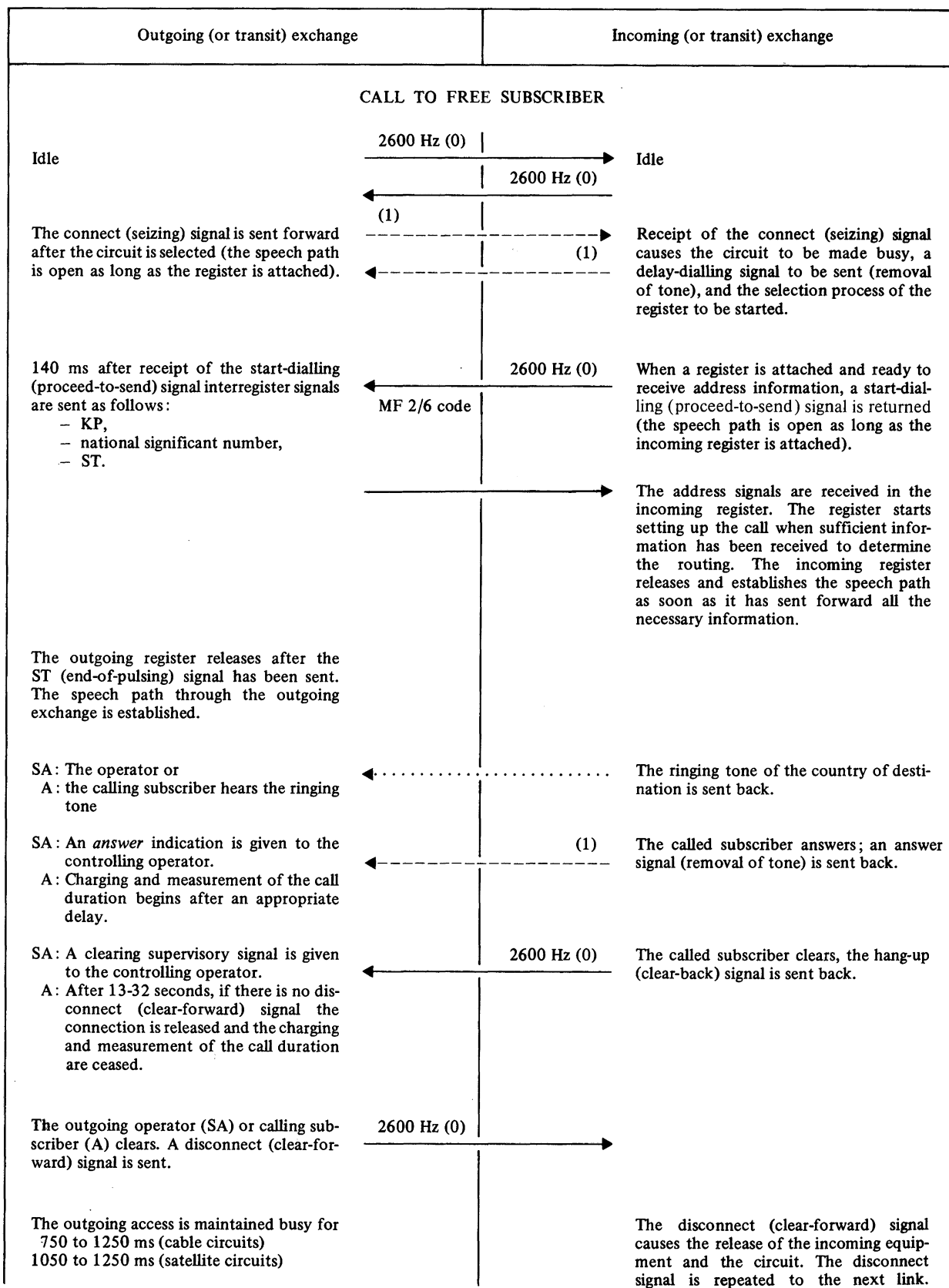


TABLE A-1 (cont.)

Outgoing (or transit) exchange	Incoming (or transit) exchange
<p align="center">CALL TO A BUSY SUBSCRIBER OR CONGESTION</p> <p>The signal sequence is the same as for a call to a free subscriber, up to the release of the incoming register</p>	
<p>The operator (SA) or calling subscriber (A) hears the audible tone and clears. The disconnect (clear-forward) signal is sent.</p>	<p>Busy subscriber. The audible busy tone of the country of destination is returned. Congestion. The audible congestion tone of the country of destination is returned.</p>
<p align="center">SPECIAL CONDITIONS</p>	
<p>1. Ring-forward (forward-transfer) Following a call established by operators, if the outgoing controlling operator wishes to recall the incoming operator, a ring-forward (forward-transfer) signal is sent.</p>	<p align="center">2600 Hz (0) pulse (100 ± 35 ms)</p> <p>Recalls the incoming operator.</p>
<p>2. Double seizing The outgoing end sends the connect (seizing) signal.</p>	<p align="center">(1)</p> <p>The incoming end also sends the connect (seizing) signal.</p>
<p>Each end interprets the connect (seizing) signal as a delay-dialling signal. If the start-dialling (proceed-to-send) signal is not recognized within the specified timing interval, double seizing is assumed and the following may apply ;</p> <p>a) an automatic repeat attempt is made, or</p> <p>b) a re-order (congestion) audible tone is given to the calling subscriber or operator and no automatic repeat attempt is made.</p> <p>(See Recommendation Q.318.)</p>	

In this table the arrows have the following meanings :

- transmission of a signalling frequency (permanent or pulse emission).
- —→ end of transmission of the signalling frequency in the case of its permanent transmission.
-→ transmission of an audible tone.

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PART II

Recommendation Q.332

INTERWORKING OF SIGNALLING SYSTEM R1 WITH OTHER STANDARDIZED SYSTEMS

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5. INTERWORKING

5.1 *General*

System R1 is capable of interworking with any of the CCITT standardized signalling systems.

Specifications on interworking of System R1 with other CCITT signalling systems are not yet available.

Typical information is found in Recommendation Q.180 of Fascicle VI.2.

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PART III

Recommendations Q.400 to Q.490

SPECIFICATIONS OF SIGNALLING SYSTEM R2

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SIGNALLING SYSTEM R 2

INTRODUCTION

General

Signalling System R2 is used as an international signalling system within international regions (world numbering zones). Moreover, System R2 can be used for integrated international/national signalling if it is employed, in conformity with the present specifications, as a signalling system in the national networks of the region concerned. Suitable for both automatic and semi-automatic working it offers a high reliability in transmission of the information necessary for setting up a call. It allows for rapid call set-up and provides sufficient signals in both directions to permit the transmission of numerical and other information relating to the called and calling subscribers' lines and to increase routing facilities.

System R2 is specified for one-way operation on analogue and digital transmission systems and for both-way operation on digital transmission systems. Distinction is made between line signalling (supervisory signals) and interregister signalling (call set-up control signals). Versions of line signalling are specified for use on 4-wire carrier or PCM circuits. Nevertheless, the interregister signalling specified can also be used on 2-wire circuits. System R2 is suitable for use on satellite links and 3 kHz spaced carrier circuits. It is not designed for use on transmission systems with speech interpolation but it may be used on digital transmission systems with speech interpolation as long as transparency for pulsed interregister signals is guaranteed.

The interregister signalling is a compelled multifrequency code system. This offers the possibility of end-to-end signalling and to take advantage of modern switching systems by providing a sufficient number of signals in both directions.

System R2 is capable of normal interworking with other CCITT signalling systems.

Line signalling

The following versions of line signalling are specified:

- line signalling for carrier systems called the analogue version;
- line signalling for PCM systems called the digital version.

Since multifrequency signalling permits exchange of a large amount of information between registers, the quantity of information that has to be transmitted in the form of line signals is small. The versions of line signalling for System R2 have been designed accordingly. The analogue line signalling version standardized originally for use on international circuits is also suitable for national working. An analogue (in-band) line signalling version is only described for the specific use on 3 kHz spaced carrier circuits of international submarine cables.

The *analogue version* is link-by-link using an out-band, low-level continuous tone-on-idle signalling method. Signal transfer simply involves the transition from one signalling condition to the other, except for the clearing sequence which is based on additional timing criteria. It is necessary to have a device for protection against the effect of interruption in the signalling channel since interruption of the signalling frequency simulates a false seizure or answer signal (interruption control). The signalling frequency is transmitted at a low level which avoids overloading of the transmission system when the frequency is sent continuously in both directions on all circuits in the idle state.

The *digital version* is link-by-link using two signalling channels in each direction of transmission per speech circuit. The signalling channels are two of the four provided for channel associated signalling in a 2048 kbit/s primary multiplex (see Recommendation G.732). Protection against the effects of faulty transmission is provided.

The analogue version and the digital version of the line signalling can be converted to each other by a transmultiplexer or other conversion equipment. Such equipment forms a conversion point between analogue (FDM) transmission on one hand and digital (PCM) transmission on the other hand. The System R2 line signalling, however, must be treated separately because for both transmission systems different line signalling versions are specified. Although both versions are described in some detail, a description of the actual conversion is given in Recommendation Q.430. Although these versions do not include a forward-transfer signal, forward-transfer signalling may be introduced for international working by bilateral agreement.

Interregister signalling

The interregister signalling is performed end-to-end using a 2-out-of-6 in-band multifrequency code with forward and backward compelled signalling. The signalling frequencies do not therefore overlap with the line signalling frequency and differ according to the direction of transmission with a view to possible use of the multifrequency part of the system on 2-wire circuits.

System R2 is designed to use six signalling frequencies (1380, 1500, 1620, 1740, 1860 and 1980 Hz) in the forward direction and six signalling frequencies (1140, 1020, 900, 780, 660 and 540 Hz) in the backward direction. Nevertheless for national application less signalling frequencies may be used.

End-to-end signalling is a method for signalling between registers over two or more links in tandem without signal regeneration in intermediate exchanges (see Figure 1).

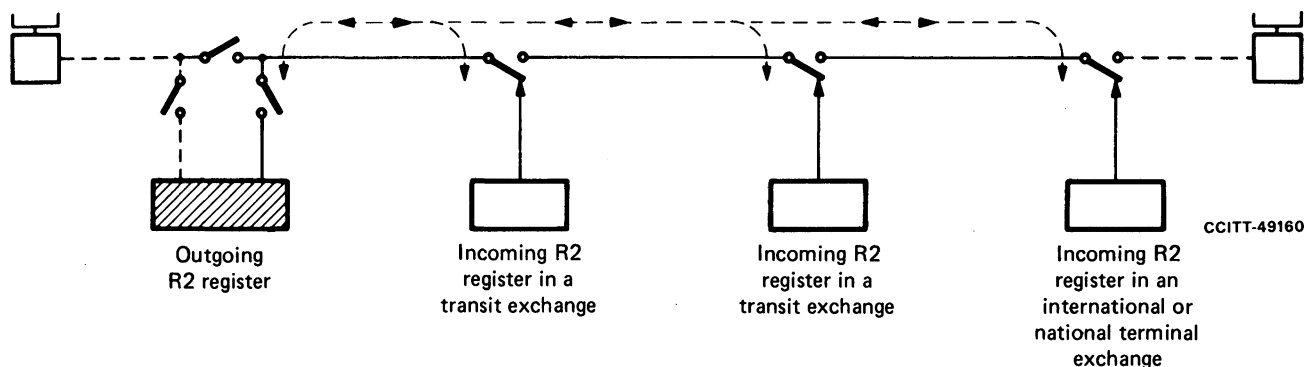


FIGURE 1
Principle of end-to-end R2 interregister signalling

With this signalling method, in general only the address information needed for routing the call through an intermediate (transit) exchange is transferred from the outgoing register to the incoming register. In the intermediate exchange the speech path is immediately through-connected and the incoming register released. Then the outgoing register can exchange information directly with the incoming register of the next exchange. Such end-to-end signalling is advantageous as it reduces the interregister signalling equipment needed and minimizes the holding time of registers in transit exchanges.

System R2 has been designed to allow end-to-end interregister multifrequency signalling over several links in tandem. However, in circumstances where transmission conditions do not comply with the requirements specified for System R2 and might consequently jeopardize the exchange of the interregister signals, or in case of using System R2 via a satellite link, the overall multi-link connection is divided into sections, each with its individual interregister signalling (signals being then relayed and regenerated by a register at the point where the division is made).

In the case of satellite working, the register at the incoming end of the satellite link must act as an outgoing R2 register (see also Recommendation Q.7).

Generally transmission conditions in a national network comply with the requirements specified for System R2 and as such allow end-to-end signalling over complete connections between local exchanges.

In the case of international System R2 working transmission conditions impose division into at least two signalling sections, when both the outgoing and incoming countries use System R2 in the national network. The division must be made in an exchange in the outgoing country. The relaying or regenerating register situated at the point where the division is made is called *the outgoing international R2 register*. In the case when System R2 is not used in the outgoing country the outgoing international R2 register receives address information via a national signalling system and it controls the call set-up over the outgoing System R2 signalling section.

The outgoing R2 register is generally defined as a register situated at the outgoing end of a signalling section on which System R2 interregister signalling, according to the present specifications, is used. It controls the call set-up over the whole signalling section. It sends forward interregister signals and receives backward interregister signals. The outgoing R2 register receives information via the preceding links of the connection in a form used by the signalling system applied over the last of these links; this system may be System R2, a decadic pulse system, or any other system. The preceding link may also be a subscriber's line.

When an *R2 register in a transit exchange* is working according to the definition above it is also called an *outgoing R2 register*. *The outgoing international R2 register* is the special case of the outgoing R2 register when the outgoing signalling section comprises at least one international link.

The incoming R2 register is defined as a register situated at the incoming end of a link on which System R2 interregister signalling, according to the present specification, is used. It receives forward interregister signals via the preceding link(s) and sends backward interregister signals. The information received is used completely or in part for the control of selection stages and may be sent in its entirety or in part to the succeeding equipment, in which case the signalling used for retransmission is never System R2. Interworking then takes place between System R2 and the other System. Thus every register not situated at the outgoing end of a System R2 signalling section is called an incoming R2 register independently of the exchange type.

The following operational features are provided by using all the 15 forward and 15 backward combinations of the multifrequency code:

- capability of transferring address information for automatic, semi-automatic and maintenance calls;
- indicators in order to identify transit and maintenance (test) calls;
- language digits or discriminating digit(s) for international calls;
- transfer of the next digit or repetition of the last but one, the last but two, or the last but three digit on request by the register at the incoming end;
- forward and backward signals for control of echo suppressors;
- information concerning the nature and the origin of the call (calling party's category) can be transferred to the register at the incoming end, i.e. whether national or international, whether from an operator or from a subscriber, whether from data-transmission, maintenance or other equipment, etc.;
- information concerning the nature of the circuit can be requested by the register at the incoming end, i.e. whether a satellite link is already included or not;
- information on congestion, unallocated number and on the condition of the called subscriber's line can be transferred to the outgoing register, i.e. whether free, busy or out of service, etc.;
- a restricted number of signals left to the discretion of Administrations for allocation of national meanings.

The interregister signalling specified for System R2 can also be used together with any non-standardized line-signalling system. The resulting combination is not considered to be System R2.

System R2 gives potential for a short post-dialling delay using *overlap operation* with dialling and end-to-end signalling. The outgoing R2 register starts call set-up as soon as it has received the minimum requisite information. Therefore signal transfer starts before the complete address information is received, i.e. before the caller finishes dialling. This practice particularly applies at an outgoing R2 register where the complete address information from a subscriber or operator is stored (e.g. local registers). This is in contrast to *en bloc* register signalling i.e. the transmission of all the address information as a whole in one sequence starting only after complete reception of the address information.

Unused signalling capacity provides potential for development and allows for future requirements yet undefined. This spare capacity may be used for increasing the number of signals and signalling procedures e.g. for new services to be offered to subscribers.

SECTION 1

DEFINITIONS AND FUNCTIONS OF SIGNALS

Recommendation Q.400

1.1 FORWARD LINE SIGNALS

1.1.1 seizing signal

A signal sent at the beginning of the call to initiate transition of the circuit at the incoming end from the idle state to seized state. At the incoming exchange it causes the association of equipment capable of receiving register signals.

1.1.2 clear-forward signal

A signal sent to terminate the call or call attempt and to release in the incoming exchange and beyond it all switching units held on the call.

The signal is sent when:

- a) in semi-automatic working the operator of the outgoing international exchange takes the plug out or performs an equivalent operation;
- b) in automatic working, the calling subscriber clears or performs an equivalent operation.

This signal is also sent by the outgoing international exchange upon receiving a backward register signal requesting the outgoing international R2 register to clear the connection, or in the case of forced release of the connection as mentioned in Recommendation Q.118. This signal may also be sent as the result of abnormal release of the outgoing international R2 register.

1.1.3 forward-transfer signal¹⁾

A signal sent on semi-automatic calls when the outgoing international exchange operator wants the help of an operator at the incoming international exchange. The signal will usually bring an assistance operator (see Recommendation Q.101) into the circuit. If the call is completed via an incoming or delay operator at the incoming international exchange, the signal indicates that recall of this operator is wanted.

1.2 BACKWARD LINE SIGNALS

1.2.1 seizing-acknowledgement signal²⁾

A signal sent to the outgoing exchange to indicate the transition of the equipment at the incoming end from the idle state to seized state. Recognition of the seizing acknowledgement signal at the outgoing end causes the state of the circuit to change from seized to seizure acknowledged.

¹⁾ This signal is not provided in either the analogue or digital version of System R2 line signalling. Information about possible arrangements for such a signal and signalling procedures involved are contained in Annex A to the present Specifications.

²⁾ This signal is only used in the digital version of System R2 line signalling.

1.2.2 answer signal

A signal sent to the outgoing international exchange to indicate that the called party has answered the call (see Recommendation Q.27). In semi-automatic working this signal has a supervisory function.

In automatic working this signal is used:

- to start metering the charge to the calling subscriber, unless the register signal indicating no charge has been sent previously;
- to start measurement of the call duration for international accounting purposes.

1.2.3 clear-back signal

A signal sent to the outgoing international exchange to indicate that the called party has cleared. In semi-automatic working, this signal has a supervisory function. In automatic working, arrangements must be made in accordance with Recommendation Q.118, and the Notes of Recommendation Q.120, § 1.8 also apply.

1.2.4 release-guard signal

A signal sent to the outgoing exchange in response to a clear-forward signal to indicate that the latter has been fully effective in returning the switching units at the incoming end of the circuit to idle condition. An international circuit is protected against subsequent seizure as long as the release operations initiated by the clear-forward signal have not been completed at the incoming end.

1.2.5 blocking signal

A signal sent on an idle circuit to the outgoing exchange to cause engaged conditions (blocking) to be applied to this circuit, guarding it against subsequent seizure.

1.3 FORWARD REGISTER SIGNALS

1.3.1 address signal

A signal containing one element of information (digit 1, 2, ..., 9 or 0, code 11, code 12 or code 13) about the called or calling party's number or the end of pulsing indication (code 15).

For each call a series of address signals is sent (see Recommendations Q.101 and Q.107).

1.3.2 country-code and echo-suppressor indicators

Signals indicating:

- whether or not the country-code is included in the address information (international transit or terminal call);
- whether or not an outgoing half-echo suppressor should be inserted in the first international exchange reached;
- whether or not an incoming half-echo suppressor should be inserted (an outgoing half-echo suppressor having already been inserted in the connection).

1.3.3 language or discriminating digit

A numerical signal occupying a predetermined position in the sequence of address signals indicating:

- in semi-automatic working, the service language to be used in the incoming international exchange by the incoming, delay and assistance operators when they come in the circuit (language digit);
- the automatic working or any other special characteristic of the call (discriminating digit).

1.3.4 test call indicator

A signal occupying the position of the language digit when the call is originating from test equipment.

1.3.5 nature of circuit indicators

Signals only sent on request by certain backward signals and using a second meaning of some signals, to indicate whether a satellite link is already included in the connection or not.

1.3.6 end-of-pulsing signal

An address signal sent indicating (in semi-automatic service) that no other address signal will follow or (in automatic service) that the transmission of the code identifying the origin of the call is completed.

1.3.7 calling party's category signals

A special group of signals providing, in addition to the information contained in the language or discrimination digit, supplementary information concerning the nature of the call (i.e. whether national or international) and its origin.

Typical categories are:

- operator capable of sending the forward-transfer signal;
- ordinary subscriber or operator with no forward-transfer facility;
- subscriber with priority;
- data transmission call;
- maintenance call.

1.3.8 Signals for use on the national network

Some of the Group II forward signals (see Recommendation Q.441, § 4.2.3.2) have been allocated for national use. When the outgoing international R2 register receives them, it must react as specified in Recommendation Q.480.

1.4 BACKWARD REGISTER SIGNALS

1.4.1 Signals requesting transmission of address signals

Five backward signals without particular names are provided; four of them are interpreted with reference to the latest address signal sent:

- signal requesting the transmission of the address signal following the latest address signal sent;
- signal requesting repetition of the address signal preceding the latest address signal sent (last but one);
- signal requesting the repetition of the last but two address signals sent;
- signal requesting the repetition of the last but three address signals sent;
- signal requesting the transmission or repetition of the language or discrimination digit.

1.4.2 Signal requesting information about the circuit

A backward signal is provided to request the nature of the circuit.

1.4.3 Signals requesting information about the call or calling party

Three backward signals without particular names are provided for this purpose:

- signal inquiring the calling party's category;
- signal requesting the repetition of the country-code indicator;
- signal inquiring whether or not incoming half-echo suppressor should be inserted.

1.4.4 Congestion signals

Two congestion signals are provided:

- a signal indicating international congestion, i.e. that the call set-up attempt has failed owing to congestion of the group of international circuits, or congestion in the international switching equipment, or to time-out or abnormal release of an incoming R2 register in an international transit exchange;
- a signal indicating national congestion, i.e. that the call set-up attempt has failed owing to congestion in the national network (excluding a busy called subscriber's line) or to time-out or abnormal release of an incoming R2 register in a terminal international exchange or a national exchange.

1.4.5 **address-complete signals**

Signals indicating that it is no longer necessary to send another address signal, and

- either cause immediate passage to the speech position to enable the calling subscriber to hear a tone or a recorded announcement of the national incoming network;
- or announce the transmission of a signal indicating the condition of the called subscriber's line.

1.4.6 *Signals indicating the condition of the called subscriber's line*

Six signals sent in the backward direction are provided to give information about the called subscriber's line and to indicate the end of interregister signalling. These signals are:

- **send special information tone**
a signal sent in the backward direction indicating that the special information tone should be returned to the calling party. This tone indicates that the called number cannot be reached for reasons not covered by other specific signals and that the unavailability is of a long term nature. (See also Recommendation Q.35);
- **subscriber line busy**
a signal indicating that the line or lines connecting the called subscriber to the exchange are busy;
- **unallocated number**
a signal indicating that the number received is not in use (e.g. an unused country code or an unused trunk code or subscriber number that has not been allocated);
- **subscriber line free, charge**
a signal indicating that the called subscriber's line is free and that the call is to be charged on answer;
- **subscriber line free, no charge**
a signal indicating that the called subscriber's line is free and that the call is not to be charged on answer. This signal is used only for calls to special destinations;
- **subscriber line out of order**
a signal indicating that the subscriber's line is out-of-service or faulty.

1.4.7 *Signals for use in the national network*

Some of the backward signals have been allocated for national use. Since not all incoming registers can know the origin of the connection and since end-to-end signalling is used, it may happen that the above-mentioned signals are sent to the outgoing international R2 register. When this register receives them it must react as indicated in Recommendations Q.474 and Q.480.

SECTION 2

LINE SIGNALLING, ANALOGUE VERSION

Recommendation Q.411

2.1 LINE SIGNALLING CODE

2.1.1 General

The System R2 line signalling, analogue version, is intended for use on carrier circuits. The line signals are transmitted link-by-link. The code for the transmission of line signals is based on the *tone-on-idle* signalling method. It is required that the circuits on which the system is employed are equipped in each direction of transmission with a signalling channel outside the speech frequency band. When the circuit is in the idle state, a low-level signalling tone is sent continuously in both directions over the signalling channels. The tone is removed in the forward direction at the moment of seizure and in the backward direction when the called subscriber answers.

The connection is released when the signalling tone is restored in the forward direction; release causes the tone to be restored in the backward direction. If the called party is the first to clear, the signalling tone is restored in the backward direction first. It is then restored in the forward direction either when the caller clears or when a certain interval has elapsed after recognition of the signalling tone in the backward direction. This signalling method, requiring only simple equipment, provides rapid signal recognition and retransmission. The signal transfer speed provided by continuous type signalling compensates for the need of signal repetition inherent in link-by-link transmission.

The signalling system is specified for one-way operation of 4-wire carrier circuits.

2.1.2 Line conditions

Tone-on or tone-off denotes a certain line signalling condition. The line thus has two possible conditions in each direction, i.e. a total of four line signalling conditions. Taking into account the time sequence, the circuit may resume one of the six characteristic states shown in Table 1/Q.411.

TABLE 1/Q.411

State of the circuit	Line signalling condition	
	Forward	Backward
1. Idle	Tone-on	Tone-on
2. Seized	Tone-off	Tone-on
3. Answered	Tone-off	Tone-off
4. Clear-back	Tone-off	Tone-on
5. Release	Tone-on	Tone-on or off
6. Blocked	Tone-on	Tone-off

The transition from one signalling condition to another corresponds to the transfer of a line signal according to the definitions in § 1. To change from the release state to the idle state additional criteria (timing) are necessary to ensure a defined sequence corresponding to the transfer of the release-guard signal (see § 2.2.2.6 below).

Recommendation Q.412

2.2 CLAUSES FOR EXCHANGE LINE SIGNALLING EQUIPMENT ¹⁾

2.2.1 Recognition time for transition of signalling condition

The recognition time t_r for a changed condition (transition from tone-on to tone-off or vice versa) is 40 ± 10 ms ²⁾. The recognition time is defined as the minimum duration that the presence or absence of a direct current signal must have at the output of the signal receiver in order to be recognized as a valid signalling condition by the exchange equipment. Thus the specified value does not include the response time t_{rs} of signalling receivers (see Recommendation Q.415). However, it is determined on the assumption that there is interruption control (see Recommendation Q.416).

2.2.2 States and procedures under normal conditions

2.2.2.1 Seizure

The outgoing end removes the tone in the forward direction. If seizure is immediately followed by release, removal of the tone must be maintained for at least 100 ms to make sure that it is recognized at the incoming end.

2.2.2.2 Answering

The incoming end removes the tone in the backward direction. When another link of the connection using tone-on-idle continuous signalling precedes the outgoing exchange, the tone-off condition must be established on this link immediately after it is recognized in this exchange. When another signalling system is used on the preceding link, the rules for interworking are applicable.

2.2.2.3 Clear-back

The incoming end restores the tone in the backward direction. When another link of the connection using tone-on-idle continuous signalling precedes the outgoing exchange the *tone-on* condition must be established on this link immediately after it is recognized in this exchange. When another signalling system is used on the preceding link, the rules for interworking are applicable. The provisions set forth in § 2.2.2.6 below must also be taken into consideration.

2.2.2.4 Clear-forward procedure

The outgoing end restores the tone in the forward direction (see § 2.2.2.1 above). The forward connection is released and the release-guard sequence begins as soon as the changed signalling condition is recognized at the incoming end. In the outgoing exchange the circuit remains blocked until the release-guard sequence is terminated (see § 2.2.2.6 below).

¹⁾ Although the signalling condition (tone-on or tone-off) physically only appears in transmission equipment, it is used in this section as a reference criterion to specify functions of exchange equipment.

²⁾ Originally this value was (20 ± 7) ms. Since there will be no problem in the interworking between equipment having the original recognition time $t_r = (20 \pm 7)$ ms, and equipment having the new recognition time $t_r = (40 \pm 10)$ ms, existing equipment need not necessarily be changed to the value $t_r = (40 \pm 10)$ ms.

2.2.2.5 Blocking and Unblocking procedure

At the outgoing exchange the circuit stays blocked so long as the tone remains off in the backward direction.

Restoration of the tone in the backward direction – accompanied by the presence of the tone in the forward direction – restores the circuit to the idle state. The circuit may then be seized for a new call.

2.2.2.6 Release and release-guard sequence

Release-guard must be ensured whatever the state of the circuit at the moment the clear-forward signal is sent – seized prior to answer, answered or cleared by the called party. It may also happen that answering or clearing by the called party occurs when release has already begun at the outgoing exchange. The cases are described below and shown in the Figures 2/Q.412 to 4/Q.412. The exact timing is shown in Figure 5/Q.412.

a) Release prior to answered state

The clear-forward signal is sent from the outgoing end by restoring the tone in the forward direction (see Figure 2/Q.412). Recognition of this tone has the following consequences at the incoming end:

- i) the tone in the backward direction is removed;
- ii) the release of the switching units is initiated;
- iii) the release-guard sequence starts.

When release operations at the incoming end are complete, but not before an interval T_2 has elapsed after the removal, the tone is again restored at the incoming end in the backward direction.

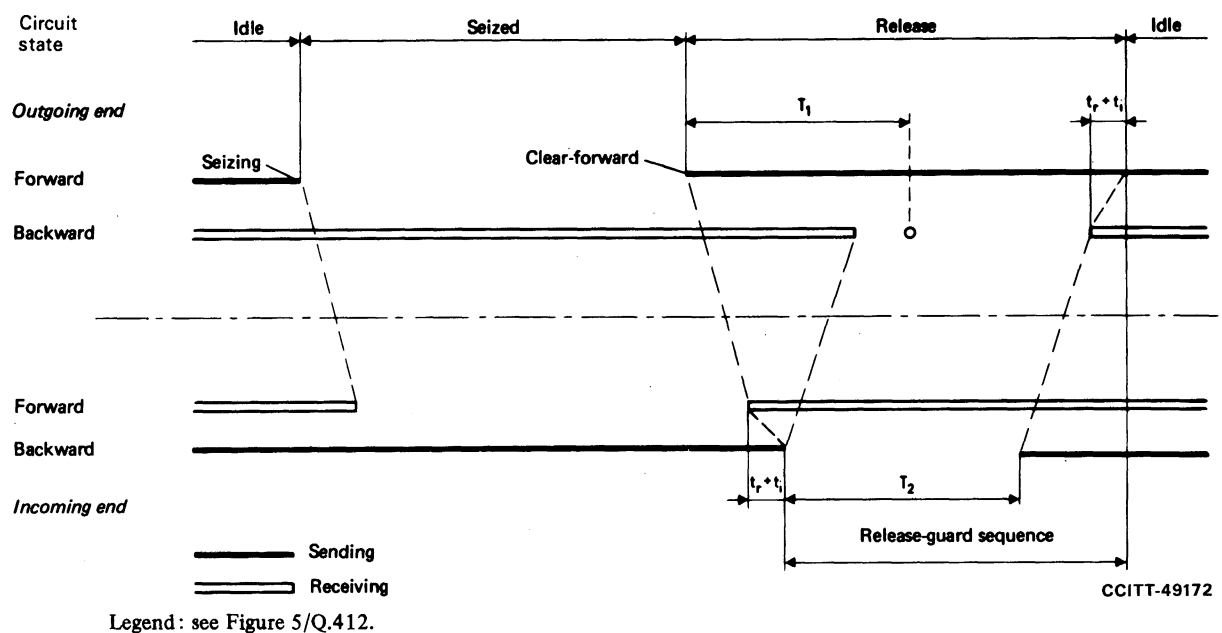


FIGURE 2/Q.412

Release prior to answered state

When T_1 has elapsed the outgoing end must recognize that the tone-off condition in the backward direction is established. After this recognition the restoring of the tone in the backward direction returns the circuit to the idle state and completes the release-guard sequence.

At the incoming end the sending of an answer signal can only be prevented after the clear-forward signal has been recognized. To avoid any false operation should answer coincide with release, transition from *tone-on* to *tone-off* in the backward direction must not be interpreted, at the outgoing end, as part of the release-guard sequence during an interval T_1 . The interval T_1 starts with the sending of the tone in the forward direction. It is long enough to make quite sure that the clear-forward signal is recognized and the *tone-off* condition established at the incoming end.

For the calculation of the intervals T_1 and T_2 see § 2.2.2.7 below.

b) Release in answered state

In this case, the release operations differ only from a) above in so far as i) does not apply. At the incoming end, however, sending of a clear-back signal can only be prevented after the clear-forward signal has been recognized. Should there be a clear-back signal the specified interval T_1 enables any resultant difficulties to be obviated (see Figure 3/Q.412).

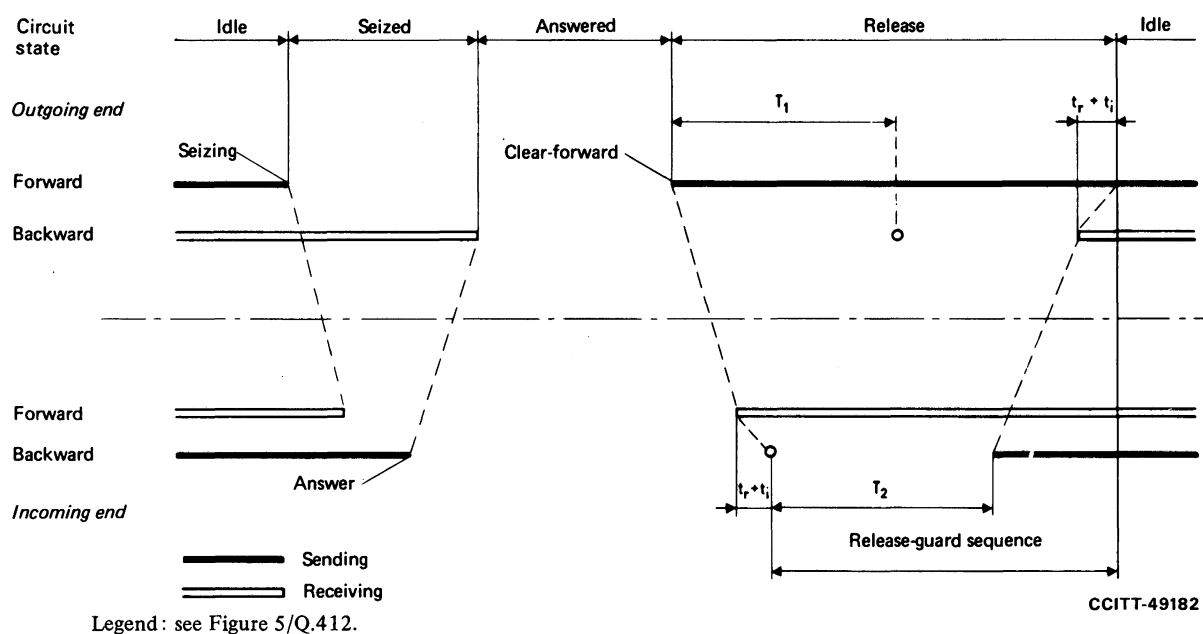


FIGURE 3/Q.412
Release in answered state

c) Release in clear-back state

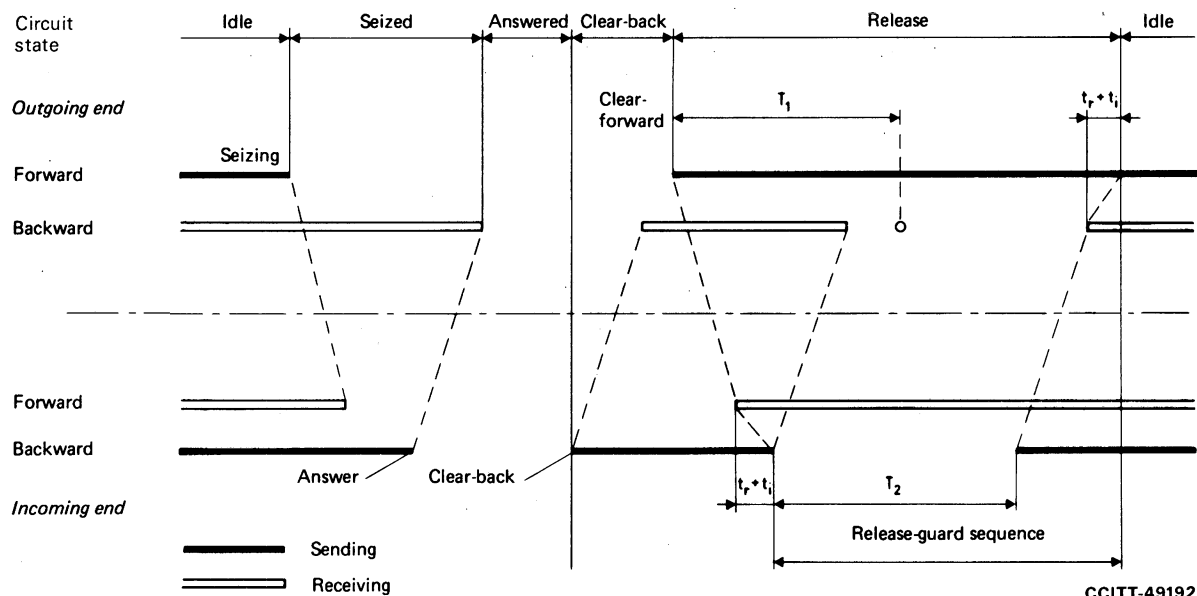
The release operations are identical to those described in a) above. Should there be a second answer signal, the specified interval T_1 enables any resultant difficulties to be obviated (see Figure 4/Q.412).

2.2.2.7 Calculation of the intervals T_1 and T_2 specified for release and release-guard operations

Figure 5/Q.412 shows the factors involved in calculating the intervals T_1 and T_2 .

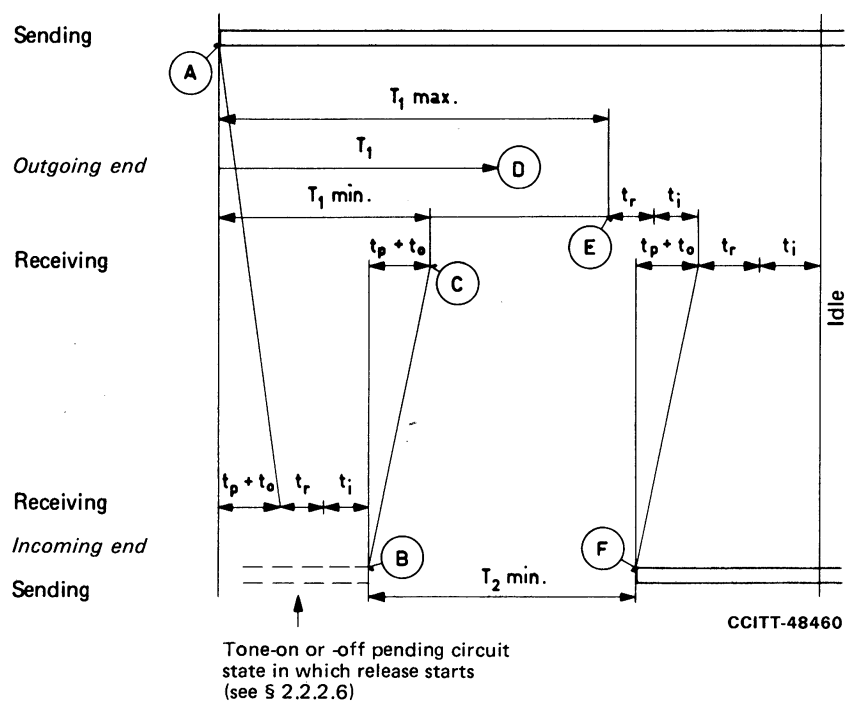
At the outgoing end when the interval T_1 has elapsed (Figure 5/Q.412, point D) the tone-off condition in the backward direction can be expected and recognized with certainty in all cases mentioned in § 2.2.2.6 above.

Similarly, the interval T_2 preceding the restoring of the tone in the backward direction may be applied in all cases. To avoid false operation in the event of coinciding forward and backward signals or an irregular sequence of signals, the time interval T_2 must also be observed with the release operation [see § 2.2.2.6 b) above].



Legend: see Figure 5/Q.412.

FIGURE 4/Q.412
Release in clear-back state



Legend

- t_p : Propagation time
- t_o : Overall response time of signalling sender and receiver
- t_r : Recognition time
- t_i : Internal operating time

FIGURE 5/Q.412
Release-guard sequence

The minimum value of T_1 is the sum of the maximum values of the times required for the various operations which take place between application of the tone in the forward direction and recognition of the absence of tone in the backward direction.

T_2 delays release of the circuit. It must therefore be as short as possible. However, it must be long enough to ensure recognition of the tone-off condition in the backward direction at the outgoing end when T_1 is at its maximum, even when this condition begins as early as possible.

a) Exclusive terrestrial circuits

The calculation is based on a maximum one-way transmission delay of 30 ms for a circuit. Thus, for circuits on high-velocity transmission systems via terrestrial lines (including submarine cables) the maximum operating range of the specified line signalling system is 4800 km³⁾.

Values used for the calculation of T_1 and T_2 :

$$\begin{aligned} 0 < t_p &< 30 \text{ ms} \\ 0 < t_o &< 30 \text{ ms (see § 2.3.2.4)} \\ 30 \text{ ms} < t_r &< 50 \text{ ms} \\ 0 < t_i &< 20 \text{ ms} \end{aligned}$$

Calculation of intervals T_1 and T_2 :

$$\begin{aligned} T_1 > \overline{AC} \quad T_1 &> 2(t_p + t_o) \text{ max.} + t_r \text{ max.} + t_i \text{ max.} \\ T_1 &> (2 \times 60 + 50 + 20) \text{ ms} \\ T_1 &> 190 \text{ ms} \end{aligned}$$

Allowing a safety margin of 10 ms and a tolerance of $\pm 20\%$, the specified value of T_1 is (250 ± 50) ms.

$$\begin{aligned} T_2 > \overline{BF} \quad T_2 &> T_1 \text{ max.} + t_r \text{ max.} + t_i \text{ max.} - 2(t_p + t_o) \text{ min.} - t_r \text{ min.} - t_i \text{ min.} \\ T_2 &> (300 + 50 + 20 - 0 - 30 - 0) \text{ ms} \\ T_2 &> 340 \text{ ms} \end{aligned}$$

Allowing a safety margin of 20 ms and a tolerance of $\pm 20\%$, the specified value of T_2 is (450 ± 90) ms.

b) Circuits including a satellite link

The calculation is based on the assumption that the complete connection includes two terrestrial sections with a maximum one-way transmission delay of 15 ms each and a satellite section with a one-way transmission delay of (270 ± 20) ms.

Values used for the calculation of T_1 and T_2 :

$$\begin{aligned} 250 < t_p &< 320 \text{ ms} \\ 0 < t_o &< 30 \text{ ms (see § 2.3.2.4)} \\ 30 < t_r &< 50 \text{ ms} \\ 0 < t_i &< 20 \text{ ms} \end{aligned}$$

Calculation of intervals T_1 and T_2 :

$$\begin{aligned} T_1 > \overline{AC} \quad T_1 &> 2(t_p + t_o) \text{ max.} + t_r \text{ max.} + t_i \text{ max.} \\ T_1 &> (2 \times 350 + 50 + 20) \text{ ms} \\ T_1 &> 770 \text{ ms} \end{aligned}$$

Allowing a safety margin of 30 ms and a tolerance of $\pm 20\%$, the specified value of T_1 is (1000 ± 200) ms.

³⁾ See Recommendation G.114, Fascicle III.1.

$$\begin{aligned}
T_2 > \overline{\text{BF}} \quad T_2 > T_1 \text{ max.} + t_r \text{ max.} + t_i \text{ max.} - 2(t_p + t_o) \text{ min.} - t_r \text{ min.} - t_i \text{ min.} \\
T_2 > (1200 + 50 + 20 - 2 \times 250 - 30 - 0) \text{ ms} \\
T_2 > 740 \text{ ms}
\end{aligned}$$

Allowing a safety margin of 60 ms and a tolerance of $\pm 20\%$, the specified value of T_2 is $(1000 \pm 200) \text{ ms}$.

c) *Terrestrial circuits and circuits including a satellite link*

The situation in which equipment can serve terrestrial circuits as well as circuits including a satellite link is not to be preferred because for the case of terrestrial circuits the release sequence is unduly prolonged. The calculation is based on the same assumption as in b) above, but with a minimum for $(t_p + t_o) = 0$. This does not affect the value of T_1 , so also in this situation $T_1 = 1000 \pm 200 \text{ ms}$.

Values used for the calculation of T_2 :

$$\begin{aligned}
0 < t_p < 320 \text{ ms} \\
0 < t_o < 30 \text{ ms (see § 2.3.2.4)} \\
30 < t_r < 50 \text{ ms} \\
0 < t_i < 20 \text{ ms}
\end{aligned}$$

Calculation of interval T_2 :

$$\begin{aligned}
T_2 > \overline{\text{BF}} \quad T_2 > T_1 \text{ max.} + t_r \text{ max.} + t_i \text{ max.} - 2(t_p + t_o) \text{ min.} - t_r \text{ min.} - t_i \text{ min.} \\
T_2 > (1200 + 50 + 20 - 0 - 30 - 0) \text{ ms} \\
T_2 > 1240 \text{ ms}
\end{aligned}$$

Allowing a safety margin of 40 ms and a tolerance of $\pm 20\%$, the specified value of T_2 is $(1600 \pm 320) \text{ ms}$.

2.2.3 Abnormal conditions

The situations described below are those in which interruption control of signalling channels (see Recommendation Q.416) does not function and which occur only during interruptions of individual channels or in the event of a fault in a line-signalling equipment. In addition, the situations described in §§ 2.2.3.3 and 2.2.3.4 below may also result from operation of interruption control at the incoming end of the circuit. In that case the circuit automatically returns to normal at the command of interruption control.

2.2.3.1 If an exchange recognizes tone-off condition in the backward direction (premature answer) before the outgoing R2 register has received a signal A-6 or a Group B-signal, the connection must be released. Congestion information is then sent backwards or a repeat attempt is made to set up the call.

2.2.3.2 In the case of non-reception of the answer signal, of delay in clearing by the calling subscriber in automatic working, or of non-reception of the clear-forward signal by the incoming exchange after the clear-back signal has been sent, the provisions of Recommendation Q.118 apply.

2.2.3.3 If, in the cases given in § 2.2.2.6 a) or c) above, the tone in the backward direction is not removed, the circuit will remain blocked, since it cannot return to the idle state of its own accord. The action to be taken in such cases is described in § 6.6.

2.2.3.4 If after sending of the clear-forward signal the signalling tone in the backward direction is not restored, the circuit stays blocked, as described in section § 2.2.2.5 above. The same occurs when, in the idle state, the signalling tone in the backward direction is interrupted by a fault.

2.2.3.5 When the signalling tone in the forward direction of an idle circuit is interrupted owing to a fault, the incoming end recognizes seizure and connects multifrequency signalling equipment, but no interregister signalling follows.

- a) When the interruption is greater than the incoming R2 register time-out (see Recommendation Q.476) the register will release and the circuit must be brought into blocked state by removal of the signalling tone in the backward direction. As soon as the fault is cleared and the tone in the forward direction consequently restored, the circuit returns to the idle state in accordance with § 2.2.2.6 b) above.
- b) When the interruption is shorter than the time-out, restoration of the signalling tone in the forward direction will return the circuit to the idle state in accordance with § 2.2.2.6 a) above.

2.2.4 Alarms for technical staff

According to Recommendation Q.117, an alarm should in general be given to technical staff as soon as an abnormal condition is recognized as probably due to a fault.

It is recommended that a delayed action alarm should be operated at the outgoing end for the conditions described in §§ 2.2.2.5, 2.2.3.3 and 2.2.3.4 above, i.e. when the circuit does not revert to the idle state after sending of the clear-forward signal or receipt of the blocking signal.

Arrangements for the operation of the alarm will be made by each Administration.

At both the outgoing and the incoming end, when interruption control (see Recommendation Q.416) functions, alarm condition must first be established for the transmission equipments. However, in this case a delayed-action alarm may also be given to the technical staff of the exchange.

2.3 CLAUSES FOR TRANSMISSION LINE SIGNALLING EQUIPMENT

Recommendation Q.414

2.3.1 SIGNAL SENDER

2.3.1.1 Signalling frequency

The nominal value of the signalling frequency is 3825 Hz. Measured at the sending point, the frequency variation from the nominal value must not exceed ± 4 Hz.

2.3.1.2 Send level

The send level of the signalling frequency, measured at the group distribution frame or an equivalent point, must be -20 ± 1 dBm0.

2.3.1.3 Leaks

The level of the signal frequency which may be transmitted to line as a leak current (e.g. when static modulators are used), must be at least 25 dB below the level of the signalling tone.

2.3.1.4 Phase distribution of the signalling frequencies

As the signalling frequency is sent on any circuit in idle state, the addition of these tones in moments of low traffic may give rise to the following phenomena on certain transmission systems:

- high peak voltage on the line caused by the signalling tones and involving the possibility of overloading the system;
- intelligible crosstalk due to third-order intermodulation;
- unwanted tones coming from second-order intermodulation products and occurring within sound-programme circuits.

The following special measures must be taken to avoid these effects:

One method recommended is to inject the signalling frequencies with random 0 and π radian phases in the channels. An equivalent method is to use carrier frequencies of which the phases are randomly distributed 0 and π radians. With these methods the probability of occurrence of 0 and π radian phases should be 0.5¹⁾.

Other methods may be used provided they give comparable results.

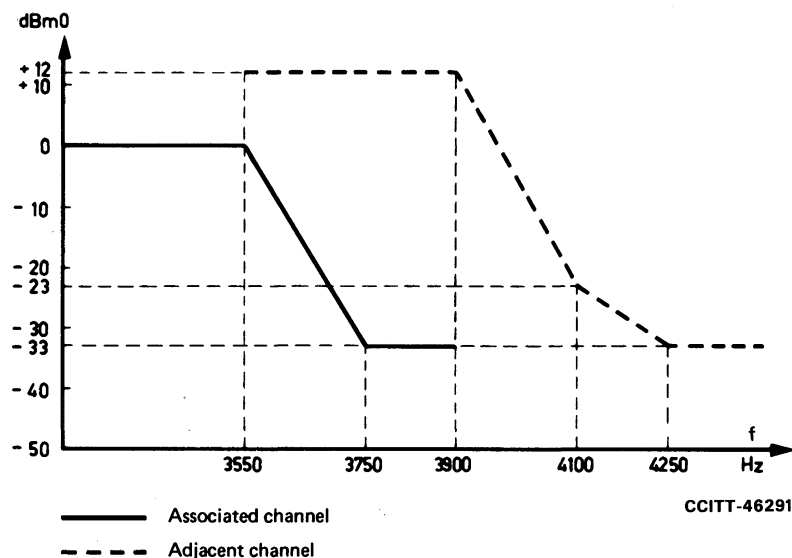
¹⁾ For further details on the method of random distribution of the phases of frequency 3825 Hz, see: Ekholm, O. and Johannesson, N.O.: "Loading Effects with Continuous Tone Signalling", English edition of *TELE*, No. 2, 1969. For further details on a systematic method of phase distribution, see: Rasch, J. and Kagelmann, H.: "On Measures for Reducing Voltage Peaks and Distortion Noise on Carrier Transmission Paths with Single Channel Supervision", *Nachrichtentechnische Zeitschrift (NTZ)*, 22 (1969), No. 1, pp. 24-31.

2.3.1.5 Protection of the signalling channel at the sending end

This signalling channel must be protected at the sending end against disturbance from the associated and the adjacent speech channel.

When a sinewave at 0 dBm0 level is applied to the audio-frequency input of the associated channel, the level measured at the group distribution frame or at an equivalent point must not exceed the levels shown in Figure 6/Q.414.

When a sinewave of frequency f is applied to the audio-frequency input of the adjacent channel it produces two signals that appear on the frequency scale of Figure 6/Q.414 as having the frequencies $(4000 + f)$ and $(4000 - f)$. The level of the $(4000 + f)$ signal, measured at the group distribution frame or at an equivalent point, shall not be higher than -33 dBm0 when the sinewave with frequency f is applied to the audio-frequency input of the adjacent channel at a level shown in Figure 6/Q.414 for the frequency of $(4000 + f)$. The level of the $(4000 - f)$ signal, measured at the group distribution frame or at an equivalent point, shall not be higher than -33 dBm0 when the sinewave with frequency f is applied to the audio-frequency input of the adjacent channel at any level below the value shown in Figure 6/Q.414 for the frequency $(4000 - f)$.



Note – The frequency of the virtual carrier of the associated speech channel is the origin of the frequency scale (zero frequency).

FIGURE 6/Q.414
Protection of the signalling channel at the sending end

When the Go path is looped to the Return path at the group distribution frame or an equivalent point, the signal receiver must not change condition when:

- the click generator shown in Figure 7/Q.414 is connected to the associated speech channel or to the adjacent speech channel at the very point where this channel is connected to the switching equipment;
- to take the most difficult circumstances possible, the channel level adjusting devices are set to such values encountered in practice which give rise to the worst disturbance;
- gain is introduced in the loop at the group distribution frame or at the equivalent point, so that the receive level at the point in question is $+3$ dBm0.

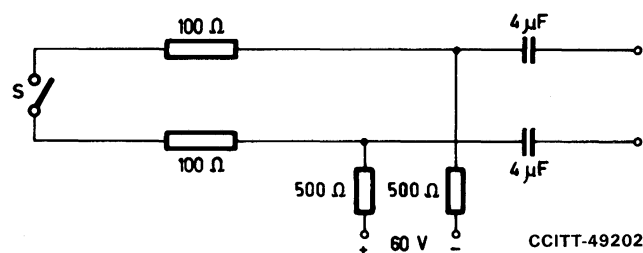


FIGURE 7/Q.414

Click generator

2.3.1.6 Response time

The response time of the signal sender is defined as the interval between the instant when the change signalling condition command is applied to the sender and the instant at which the envelope of the signalling frequency, measured at the group distribution frame or at an equivalent point, reaches half of its value in the steady state. For each of the two possible changes of signalling condition the response time must be less than 7 ms.

Recommendation Q.415

2.3.2 SIGNAL RECEIVER

2.3.2.1 Recognition of the tone-on condition

The receiver must have assumed or assume the *tone-on* condition when at the group distribution frame or at an equivalent point:

- the level of the received frequency has risen to -27 dBm0 or more;
- its frequency lies between 3825 ± 6 Hz.

The level of -27 dBm0 specified above does not preclude the use of individual adjustments in the channel translating equipment to compensate for constant level deviations.

2.3.2.2 Recognition of the tone-off condition

The receiver must have assumed or assume the *tone-off* condition when the level of the test frequency, at the group distribution frame or at an equivalent point, has dropped to the values shown in Figure 8/Q.415.

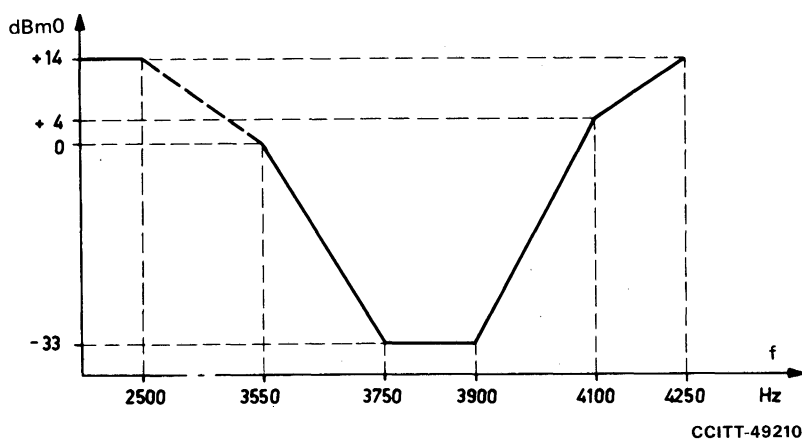


FIGURE 8/Q.415

Level limits for recognition of the "tone-off" condition

2.3.2.3 Protection against near-end disturbances

The signal receiver must not change state when any one of the following disturbing signals is applied at the 4-wire output of the associated speech channel looped at the group distribution frame or at an equivalent point:

- a sinusoidal signal whose level as a function of the frequency is shown in Figure 9/Q.415,
- a transient signal produced by the click generator (described in § 2.3.1.5 above) applied at the point where the channel is connected to the switching equipment, all level adjusting devices being set to such values encountered in practice which give rise to the worst disturbance.

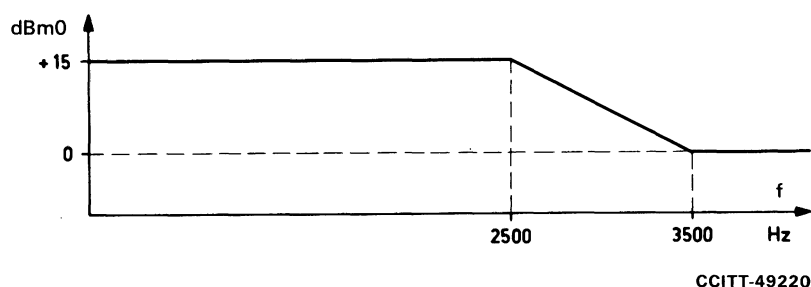


FIGURE 9/Q.415

Level limit for a sinusoidal disturbance signal to which the signalling receiver must remain insensible

2.3.2.4 Overall response time of signal sender and receiver

When the modulation equipment is looped at the group distribution frame or at an equivalent point, the overall response time is defined as the interval between the instant when a change signalling condition command is applied to the sender and the moment when the changed signalling condition appears at the receiver output. For each of the two possible changes of signalling condition, the overall response time must be less than 30 ms.

2.3.2.5 Interference by carrier leaks

The requirements stated in §§ 2.3.2.1, 2.3.2.3 and 2.3.2.4 above must be fulfilled in the presence of carrier leaks.

It is assumed that:

- when the receive level of the signalling tone is at its nominal value at the group distribution frame or an equivalent point, each carrier leak is present at a level of -26 dBm0;
- the level of the carrier leak varies proportionally with any variations in the level of the signalling tone.

2.3.2.6 Interference by pilots

The specified signalling system is not intended to work in the presence of those pilots specified by CCITT having a frequency differing by 140 Hz from the nearest multiple of 4 kHz (see Recommendation M.460).

On the other hand, the requirements stated in §§ 2.3.2.1, 2.3.2.2, 2.3.2.3, 2.3.2.4 and 2.3.2.5 above must be met in the presence of any other pilot recommended by the CCITT.

It is assumed that variations in level of the pilot and of the signalling tones are correlated.

2.4 INTERRUPTION CONTROL

2.4.1 General

In System R2, removal of the tone corresponds to the sending of the seizing and answer signals. Steps must be taken, therefore, to guard against unwanted interruption of the signalling channels resulting in false signalling. Special devices monitor a number of circuits and transmit an indication to each individual equipment as soon as an interruption occurs. The whole protection system against the effect of interruptions is designated by the term *interruption control*.

In each case, the response time of the interruption control must be based on the time required to recognize the signalling condition.

The interruption control systems in the two directions of transmission operate independently of each other.

The interruption control specified uses the group pilot to detect interruptions.

2.4.2 Mode of operation of interruption control

For each direction of transmission of a carrier circuit connection the equipment for interruption control comprises:

- a group pilot generator at the outgoing end;
- a pilot receiver and a wiring system for signalling the interruption at the incoming end.

In principle, the existing pilots of the carrier system will be used.

The receiver at one end supervises the pilot transmitted by the other end. When a considerable fall in the level of the pilot is detected it is assumed that an interruption has occurred on the signalling channels associated with the carrier circuits. The interruption control equipment then reacts to prevent the unwanted transmission of certain signals on those circuits which have already been seized or to ensure that idle circuits are blocked.

Figure 10/Q.416 shows functionally an arrangement where the pilot receiver controls the relay sets of interrupted circuits.

To ensure proper interruption control, it is essential that the individual transmission or switching equipments should not react to any change of signalling state due to a fault. The action initiated by the interruption control must therefore be completed in less time than the sum of the response time of the signalling receiver and the recognition time for the *tone-off* condition caused by interruption of the signalling channel. Again, to prevent the unwanted transfer of certain signals, interruption control, during re-establishment of the pilot, must return to *alarm off* after an interval long enough for the signalling equipment to revert to normal.

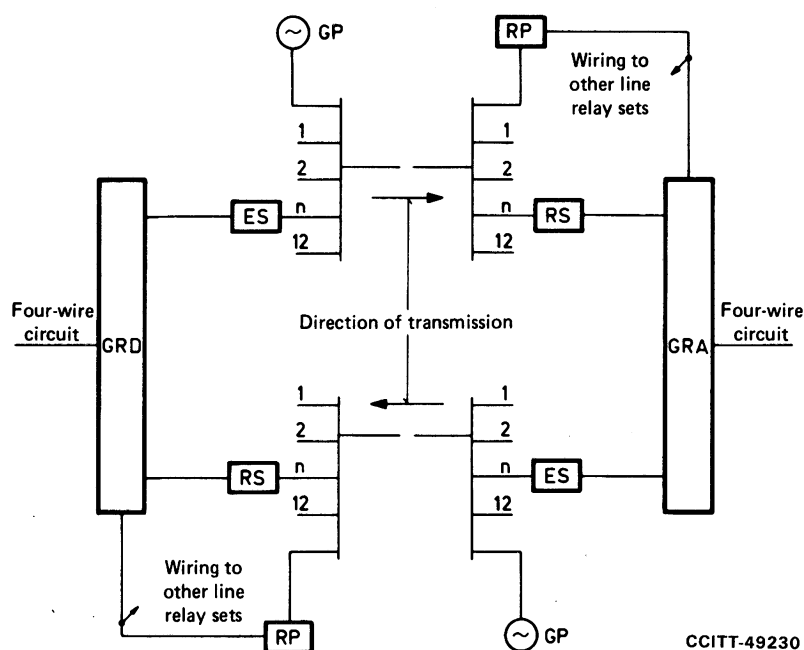
To operate independently for each direction of transmission the incoming end interruption control supervises only the forward direction and, if necessary, initiates an operation at the outgoing end via the line signalling system. Conversely, interruption control at the outgoing end supervises the backward direction of transmission only.

Blocking of a circuit at the outgoing end therefore takes place in two different ways:

- immediate blocking by intervention of interruption control at the outgoing end;
- blocking on recognition in the backward direction of the *tone-off* condition caused by interruption control intervention at the incoming end.

When the transmission system is re-established, interruption control reverts to normal and the signalling equipment must automatically revert to normal operating.

Since the action to be taken on the individual circuits differs according to their state at the time the fault occurs, the different possibilities are dealt with in detail below.



GP = pilot generator
 RP = pilot receiver
 RS = signalling receiver
 ES = signalling sender
 GRD = outgoing relay set
 GRA = incoming relay set

FIGURE 10/Q.416

Protection from the effect of interruptions (interruption control)

2.4.2.1 Mode of operation of interruption control at the incoming end (transmission interrupted in the forward direction)

a) Circuit in idle state

Transition of interruption control to alarm brings about:

- i) removal of the tone in the backward direction by locking of the sending unit in the *tone-off* condition;
- ii) locking of the receiving unit in its position, i.e. in the *tone-on* condition.

The effect of operation i) is to block the circuit at the outgoing end against possible seizing; operation ii) prevents incorrect recognition of seizing of the incoming circuit.

Return of interruption control to normal ensures return to the idle state of the circuits affected by the fault, by switching sending units at the incoming end to the *tone-on* condition.

b) Circuit seized prior to answered state

Transition of interruption control to alarm brings about:

- i) locking of the sending unit in its position, i.e. in the *tone-on* condition;
- ii) locking of the receiving unit in its position, i.e. in the *tone-off* condition;
- iii) start of a time-out device which after a certain interval clears the chain beyond the faulty circuit; this timing arrangement may be the one specified in Recommendation Q.118, § 4.3.3.

Operation i) prevents the transfer of an answer signal while interruption control is in action. If the called subscriber answers before the time out delay mentioned in iii) above has elapsed, then the timer is stopped. For existing equipment this requirement may not apply. If the called subscriber clears while interruption control is active, the part of the connection beyond the faulty circuit must be released immediately.

Operation iii) prevents blocking of the called subscriber's line if the fault persists; short breaks, on the other hand, have no effect.

When the caller clears, operations i) and ii) block the faulty circuit against any new seizure even when the backward signalling channel is still intact; since the release-guard signal has not been sent the outgoing circuit cannot return to the idle state.

When interruption control reverts to normal before the called subscriber has answered, the call may still mature normally, provided the caller is holding.

If the called subscriber has answered during the time-out delay and the interruption control reverts to normal with both the calling and called subscribers holding, the answer signal is sent immediately.

If at the moment when interruption control reverts to normal the called subscriber has already cleared, operation ii) ensures that in all cases the release-guard sequence takes place as in § 2.2.2.6 a) above (either immediately if the outgoing exchange has already sent the clear-forward signal or when the caller clears). If, on the other hand, the called subscriber is still holding and the outgoing exchange is already sending the clear-forward signal when interruption control reverts to normal the circuit returns to the idle state at the outgoing end as described in § 2.2.2.6 b) above.

c) *Circuit in answered state*

Transition of interruption control to alarm brings about:

- i) locking of the sending unit in its position, i.e. in the *tone-off* condition;
- ii) locking of the receiving unit in its position, i.e. in the *tone-off* condition.

When the caller clears, operation i) blocks the faulty circuit against any new seizure, even when the backward signalling channel is still intact; since the release-guard signal has not been sent, the outgoing circuit cannot return to the idle state.

When the called subscriber clears, the part of the connection beyond the faulty circuit (including the called subscriber's line) must be released immediately.

When interruption control reverts to normal with both subscribers still on the line, the connection is maintained.

When the caller has already cleared by the time the interruption control reverts to normal, the release-guard sequence is carried out as in Recommendation Q.412, § 2.2.2.6 b) or c).

d) *Circuit in clear-back state*

Transition of interruption control to alarm causes:

- i) locking of the sending unit in its position, i.e. in the *tone-on* condition;
- ii) locking of the receiving unit in its position, i.e. in the *tone-off* condition;
- iii) immediate release of the part of the connection beyond the faulty circuit (including the called subscriber's line).

When interruption control reverts to normal, the release-guard signal is sent as in Recommendation Q.412, § 2.2.2.6 c) as soon as the clear-forward signal is recognized.

e) *Circuit in release*

When interruption control functions after a clear-forward signal has been recognized at the incoming end, it causes:

- i) locking of the sending unit in the *tone-off* condition; if at the instant interruption control operates, the *tone-on* condition exists in the backward direction, it will be switched to the *tone-off* condition following recognition of the clear-forward signal and locking in the *tone-off* condition can take place as prescribed;
- ii) locking of the receiving unit in its position, i.e. in the *tone-on* condition.

The effect of operation i) is to guard the faulty circuit from a new seizure at the outgoing exchange.

Operation ii) ensures the release of the part of the connection beyond the faulty circuit (including the called subscriber's line).

When interruption control reverts to normal the *tone-on* condition is established in the backward direction and causes the circuit at the outgoing exchange to return to the idle state.

2.4.2.2 *Mode of operation of interruption control at the outgoing end* (transmission in the backward direction interrupted)

a) *Circuit in idle state*

Transition of interruption control to alarm is immediately followed by blocking of the outgoing circuit.

b) *Circuit seized but not in answered state (including clear-back)*

- i) Transition of interruption control to alarm causes locking of the receiving unit in its position, i.e. the *tone-on* condition. This operation prevents recognition of an answer signal or return to the *answered* state should the called subscriber have cleared.
- ii) As soon as a clear-forward signal is sent on the part of the connection preceding the faulty circuit, it must be retransmitted; the tone must therefore be established in the forward direction to ensure, assuming that the forward signalling channel is left intact, that the part of the connection beyond the faulty circuit is released.
- iii) When interruption control reverts to normal, the tone may already have been sent in the forward direction as a clear-forward signal. If the forward signalling channel has remained intact, recognition at the incoming end of the *tone-on* condition will have caused generation of the release-guard sequence which, because of the fault, will not have been received at the outgoing end. Exceptionally, therefore, return of the outgoing circuit to the idle state must take place simply on recognition of *tone-on* in the backward direction without necessarily taking into account time-out T1.

c) *Circuit in answered state*

In this case transition of interruption control to alarm does not cause immediate action. A clear-forward signal sent on the part of the connection preceding the faulty circuit must be repeated forward to ensure that, if the forward signalling channel is left intact, the part beyond the faulty circuit is cleared.

Once the interruption control reverts to normal the connection is maintained provided the caller and the called subscriber are still holding. On the other hand, by the time the interruption control reverts to normal the clear-forward signal may already have been sent and the situation will be the one described in § 2.4.2.2 b), iii).

d) *Circuit in release*

[See § 2.4.2.2 b), iii).]

2.4.3 *Clauses on interruption control equipment*

Adoption of thresholds with widely differing levels makes for economy in the design of interruption control equipment. Against this must be set the fact that the device cannot cope with the effects of certain slow drops in level. However, the probability of these occurring in practice is very small.

2.4.3.1 *Pilots*

Interruption control uses the 84.08 kHz group pilot or by bilateral agreement and, at the request of the receiving end country, the 104.08 kHz group pilot.

However, if the ends of the supergroup link coincide with the end of the five group links it is carrying, the supergroup pilot may also be used.

2.4.3.2 *Alarm-on threshold*

Interruption control must pass to *alarm-on* when the pilot level, measured at the group distribution frame or at an equivalent point, drops to -29 dBm0.

2.4.3.3 Alarm-off threshold

Interruption control must revert to *alarm-off*, i.e. normal when the pilot level, measured at the group distribution frame or at an equivalent point, rises to -24 dBm0.

2.4.3.4 Response time for a drop in level

Interruption control must pass from normal to alarm-on within an interval t_{\downarrow} such that:

$$5 \text{ ms} \leq t_{\downarrow} \leq t_{rs \text{ min}} + 13 \text{ ms}$$

when the pilot level, measured at the group distribution frame or at an equivalent point, suddenly drops from its nominal level to -33 dBm0.

In the above formula, $t_{rs \text{ min}}$ is the minimum response time of the signalling receiver for a drop in level, taking into account a possible variation of ± 3 dB in the signalling tone level from its nominal value, the level being measured on the receiving side of the group distribution frame or at an equivalent point.

The figure of 13 ms in the above formula is derived on the assumption that the output of the interruption control equipment acts upon the input of the device which regulates the recognition time for the *tone-on* and *tone-off* conditions (20 ± 7 ms)¹⁾, i.e. absence of a direct current signal at this input for a period of up to 13 ms has no relevance.

2.4.3.5 Response time for rise in level

Interruption control must revert from the alarm-on to normal in an interval t_{\uparrow} such that:

$$t_{rs \text{ max}} - 13 \text{ ms} \leq t_{\uparrow} \leq 500 \text{ ms}$$

when the pilot level, measured at the group distribution frame or at an equivalent point, suddenly rises from its nominal level to -33 dBm0.

In the above formula, $t_{rs \text{ max}}$ is the maximum response time of the signalling receiver for a rise in level, taking into account a possible variation of ± 3 dB in the signalling tone level from its nominal value, the level being measured on the receiving side of the group distribution frame or at an equivalent point.

The figure of 13 ms in the above formula is derived on the assumption that the output of the interruption control equipment acts upon the input of the device which regulates the recognition time for *tone-on* and *tone-off* condition (20 ± 7 ms)¹⁾ i.e. absence of a direct current signal at this input for a period of up to 13 ms has no relevance.

2.4.3.6 Precautions against noise

An interruption may produce increased noise on the group link. Interruption control must be capable of distinguishing between the pilot itself and a high level noise simulating the pilot.

Interruption control must not revert to normal in the presence of white noise having a spectral power density of not more than -47 dBm0 per Hz.

To facilitate the design of interruption control equipment operating satisfactorily at high noise levels, the upper limit of 500 ms for t_{\uparrow} has been specified.

¹⁾ If the value (40 ± 10) ms is exclusively applied, it is possible to use the minimum value of 30 ms instead of 13 ms for the interruption control device.

SECTION 3

LINE SIGNALLING, DIGITAL VERSION

Recommendation Q.421

3.1 DIGITAL LINE SIGNALLING CODE

3.1.1 General

Primary PCM multiplexes (see Recommendations G.732 and G.734) economically provide more than one signalling channel per speech circuit in each direction of transmission. By making use of the increased signalling capacity, simplification of the outgoing and incoming switching equipment can be achieved since the timing conditions necessary for the System R2 line signalling, analogue version, are not required. For this reason the digital version of System R2 line signalling is recommended for use on PCM systems in national and international public switched networks and is specified below.

Note — The continuous line signalling scheme specified for FDM systems may also be used on PCM systems by utilizing one signalling channel only in each direction. In this case relay sets designed for the continuous line signalling system on FDM channels can be used provided that the functions specified for the interruption control on FDM circuits (see Recommendation Q.416) are performed by use of the local alarm facility provided by PCM equipment. This method of line signalling on PCM systems is not recommended for use on international circuits.

The digital version of System R2 line signalling uses two signalling channels in each direction of transmission per speech circuit. These signalling channels are referred to as a_f and b_f for the forward direction (i.e. the direction of call set-up) and a_b and b_b for the backward direction.

Under normal conditions:

- The a_f channel identifies the operating condition of the outgoing switching equipment and reflects the condition of the calling subscriber's line.
- The b_f channel provides a means for indicating a failure in the forward direction to the incoming switching equipment.
- The a_b channel reflects the condition of the called subscriber's line (on hook or off hook).
- The b_b channel indicates the idle or seized state of the incoming switching equipment.

The line signals are transmitted link-by-link.

The digital version of System R2 line signalling also specifies a means for appropriate action in the case of faulty transmission conditions on the PCM multiplex, see Recommendation Q.424.

The signalling system is specified for one-way operation, but both-way operation is also possible (see § 3.2.7 below).

3.1.2 Signalling code

Table 2/Q.421, shows the signalling code on the PCM line under normal conditions.

TABLE 2/Q.421

State of the circuit	Signalling code			
	Forward		Backward	
	a_f	b_f	a_b	b_b
Idle/Released	1	0	1	0
Seized	0	0	1	0
Seizure acknowledged	0	0	1	1
Answered	0	0	0	1
Clear-back	0	0	1	1
Clear-forward	1	0	0	1
Blocked	1	0	or	
			1	1
			1	1

Recommendation Q.422**3.2 CLAUSES FOR EXCHANGE LINE SIGNALLING EQUIPMENT****3.2.1 Recognition of a change of signalling code****3.2.1.1 Signalling channel transitions**

The recognition time for a transition from 0 to 1 or vice versa on a signalling channel is 20 ± 10 ms. This value presupposes the existence of protection against the effects of faulty transmission conditions on the PCM multiplex.

The recognition time is defined as the duration that the signals representing 0 or 1 must have at the output of the terminal equipment of a signalling channel in order to be recognized by the exchange equipment.

3.2.1.2 Change of signalling code

Recognition of a change of signalling code is thus defined as either of the following:

- Recognition of a transition detected on one signalling channel with no transition detected on the second signalling channel during the recognition period.
- Recognition of a transition detected on the second signalling channel during the recognition period already being applied to the first signalling channel. In this case, a change of signalling code is recognized only when both recognition timing periods have elapsed.

3.2.2 Sent signal time tolerance

The time difference between application of transitions intended to be simultaneous on two signalling channels in the same direction of transmission must not exceed 2 ms.

3.2.3 States and procedures under normal conditions (see Table 2/Q.421)

In the forward direction $b_f = 0$ is established permanently.

3.2.3.1 Idle state

In the idle state the outgoing end sends $a_f = 1$, $b_f = 0$. At the incoming end this results in sending $a_b = 1$, $b_b = 0$ in the backward direction, provided that the switching equipment at the incoming end of the circuit is idle.

3.2.3.2 Seizing procedure

i) Seizure

Seizing should occur only if $a_b = 1$, $b_b = 0$ is recognized. The outgoing end changes $a_f = 1$ into $a_f = 0$. The code $a_f = 0$, $b_f = 0$ must be maintained until the seizing acknowledgement signal is recognized. In this way the outgoing switching equipment will only be able to send the clear-forward signal after recognition of the seizing acknowledgement signal.

ii) Seizure acknowledgement

After having recognized the seizing signal, the incoming end sends $a_b = 1$, $b_b = 1$ as an acknowledgement.

3.2.3.3 Answering

The off-hook condition of the called subscriber's line provokes the incoming switching equipment to send $a_b = 0$, $b_b = 1$.

The answered state must be established on the preceding link immediately after it is recognized: see also § 3.2.3.6 below.

3.2.3.4 Clear-back

The on-hook condition of the called subscriber's line provokes the incoming switching equipment to send $a_b = 1$, $b_b = 1$. The clear-back state must be established on the preceding link immediately after it is recognized: see also § 3.2.3.6 below.

3.2.3.5 Clear-forward procedure

The cleared condition of the calling subscriber's line or the release of the outgoing switching equipment will normally result in sending $a_f = 1$, $b_f = 0$. The outgoing switching equipment will not be restored to the idle state until recognition of the code $a_b = 1$, $b_b = 0$: see also §§ 3.2.3.2, 3.2.3.6 and Table 3/Q.422.

3.2.3.6 Release procedure

Recognition of the clear-forward signal in the incoming switching equipment initiates the release of the succeeding link even though answering or clearing by the called party has occurred. Upon complete release of the incoming switching equipment, the code $a_b = 1$, $b_b = 0$ is established on the circuit. This will cause the circuit to be restored to the idle state and the outgoing switching equipment to become available for another call.

3.2.3.7 Blocking and unblocking procedure

Blocking of an idle circuit to new calls at the outgoing end must occur as soon as $a_b = 1$ and $b_b = 1$ is recognized: see also Tables 3/Q.422 and 4/Q.422.

The recognition of $a_b = 1$, $b_b = 0$ restores the circuit to the idle state.

3.2.4 Actions appropriate to various signalling conditions

In addition to normal conditions described in Table 2/Q.421 other conditions due to faults may be encountered. Tables 3/Q.422 and 4/Q.422 indicate the states appropriate to each signalling code recognized and the actions to be taken at the outgoing and incoming end respectively of a circuit operated with the digital version of System R2 line signalling.

TABLE 3/Q.422

Normal state at the out-going end	Sent code	Received code			
		$a_b = 0, b_b = 0$	$a_b = 0, b_b = 1$	$a_b = 1, b_b = 0$	$a_b = 1, b_b = 1$
Idle/Released	$a_f = 1, b_f = 0$	Abnormal, see Note 1	Abnormal, see Note 1	Idle	Blocked
Seized	$a_f = 0, b_f = 0$	Abnormal, see Note 2	Abnormal, see Note 2	Seized see Note 2	Seizure acknowledged
Seizure acknowledged	$a_f = 0, b_f = 0$	Abnormal, see Note 3	Answered	Abnormal, see Note 3	Seizure acknowledged
Answered	$a_f = 0, b_f = 0$	Abnormal, see Note 4	Answered	Abnormal, see Note 4	Clear-back
Clear-back	$a_f = 0, b_f = 0$	Abnormal, see Note 4	Answered	Abnormal, see Note 4	Clear-back
Clear-forward	$a_f = 1, b_f = 0$	Abnormal, see Note 1	Clear-forward	Released = Idle	Clear-forward
Blocked	$a_f = 1, b_f = 0$	Abnormal, see Note 1	Abnormal, see Note 1	Idle	Blocked

Note 1 — In these abnormal conditions the outgoing end must prevent a new seizure of the circuit. A delayed alarm should also be given (see § 3.2.6).

Note 2 — Non-recognition of the seizing acknowledgement signal 100 ms-200 ms after sending the seizing signal on a terrestrial link or 1-2 seconds after sending the seizing signal on a satellite link results in an alarm and either congestion information being sent backward or a repeat attempt being made to set up the call. The outgoing end must prevent a new seizure of the circuit. When the seizing acknowledgement signal is recognized after the time-out period has elapsed, the clear-forward signal must be sent.

Note 3 — Receipt of $b_b = 0$ by the outgoing switching equipment for 1-2 seconds after recognition of the seizing acknowledgement signal and prior to recognition of the answer signal, results in an alarm and either congestion information being sent backward or a repeat attempt being made to set up the call. The outgoing end must prevent new seizures of the circuit. When b_b reverts to 1 after the 1-2 seconds timeout period has elapsed, the clear-forward signal must be sent.

Note 4 — In the case of recognition of $b_b = 0$ whilst in the answered or clear-back state, immediate action is not necessary. On receipt of clearing from the preceding link, the clear-forward signal ($a_f = 1, b_f = 0$) must not be sent until b_b is restored to 1. A delayed alarm should also be given.

TABLE 4/Q.422

Normal state at the incoming end	Sent code	Received code			
		$a_f = 0, b_f = 0$	$a_f = 0, b_f = 1$	$a_f = 1, b_f = 0$	$a_f = 1, b_f = 1$
Idle/Released	$a_b = 1, b_b = 0$	Seized	Fault see Note 1	Idle	Fault see Note 1
Seizure acknowledged	$a_b = 1, b_b = 1$	Seizure acknowledged	Fault See Note 2	Clear-forward	Fault See Note 2
Answered	$a_b = 0, b_b = 1$	Answered	Fault see Note 3	Clear-forward	Fault see Note 3
Clear-back	$a_b = 1, b_b = 1$	Clear-back	Fault see Note 4	Clear-forward	Fault see Note 4
Clear-forward	$a_b = 0, b_b = 1$ or $a_b = 1, b_b = 1$	Abnormal seized see Note 7	Fault see Note 7	Clear-forward see Note 7	Fault see Note 7
Blocked	$a_b = 1, b_b = 1$	Abnormal seized see Note 5	Fault see Note 6	Blocked	Fault see Note 6

Note 1 – When in the idle/released state b_f changes to 1, b_b must be changed to 1.

Note 2 – In these cases a time-out device is started, which after a certain interval clears the connection beyond the faulty circuit: this timing arrangement may be the one specified in Recommendation Q.118, Section 4.3.3. If the answer signal is recognized during the time-out delay, the timer is stopped but the answer signal is not sent on the preceding link until recognition of $a_f = 0, b_f = 0$. If the clear-back signal is recognized while the fault persists, the connection beyond the faulty circuit must be released immediately. Additionally, when the incoming register has not started to send the last backward signal, the rapid release procedure described in Note 5 may be used.

Note 3 – In these cases no action is taken until the clear-back signal is recognized, at which stage the connection beyond the faulty circuit is immediately released.

Note 4 – Under these conditions the succeeding link must be released immediately.

Note 5 – In this case immediate action is not necessary. However, rapid release of the circuit should occur if the incoming end simulates answer by sending $a_b = 0, b_b = 1$.

Note 6 – Under these conditions no action is taken.

Note 7 – After clear-forward signal is recognized and until the code $a_b = 1, b_b = 0$ is sent, all transitions in the forward direction shall be ignored.

3.2.5 *Abnormal conditions*

3.2.5.1 *Special release arrangements*

- a) If an exchange where an outgoing R2 register is situated recognizes $a_b = 0$, $b_b = 1$ (premature answer) before an address-complete signal A-6 or a Group B signal is received, the connection must be released. Congestion information is then sent backward or a repeat attempt is made to set up the call.
- b) In the cases of non-receipt of the answer signal, of delay in clearing by the calling subscriber in automatic working and of non-receipt of the clear-forward signal by the incoming exchange after the clear-back signal has been sent, the provisions of Recommendation Q.118 apply.

3.2.5.2 *Safeguard against failures*

The PCM equipment and the exchange line signalling equipment should be designed in such a way that at least those faults which are most likely to occur in this equipment or in the interconnecting cables, result in blocking of the circuit at the outgoing end and in the ultimate clearing of the connection beyond the incoming switching equipment. This can be achieved, as far as possible, by ensuring that $a = 1$, $b = 1$ is sent on line upon:

- removal of PCM or switching equipment by maintenance personnel;
- occurrences of abnormal conditions (e.g. open wire, low voltage) in switching equipment.

3.2.6 *Alarms for technical staff*

According to Recommendation Q.117, an alarm must in principle be given to the technical staff upon recognition of abnormal conditions.

Arrangements for these alarms are to be specified by the Administrations.

It is recommended that a delayed alarm be given at the outgoing end for the procedure described under § 3.2.3.7 above (blocking) and for the following reasons:

- when the abnormal conditions covered by Note 1 to Table 3/Q.422 are applicable;
- when the seizing acknowledgement signal is not recognized within the time specified in Note 2 to Table 3/Q.422 after sending the seizing signal;
- when, after recognition of the seizing acknowledgement signal and prior to recognition of the answer signal, $b_b = 0$ is received for 1-2 seconds;
- when the abnormal conditions covered by Note 4 to Table 3/Q.422 are applicable.

It is also recommended that a delayed alarm be given under PCM failure conditions specified in Recommendations G.732 and G.734.

3.2.7 *Both-way working*

System R2 is specified for one-way working, but in principle the line signalling code detailed in Recommendation Q.421 is also suitable for use on both-way circuits. Where Administrations have undertaken, by bilateral agreement, to use both-way working, the clauses and additional specifications for exchange signalling equipment detailed in §§ 3.2.7.1 and 3.2.7.2 below, must be observed.

3.2.7.1 *Procedures under normal conditions*

a) *Double seizure*

Double seizure is assumed if the outgoing equipment is in a seized state and the signalling code $a_b = 0$, $b_b = 0$ is recognized instead of $a_b = 1$, $b_b = 1$ (seizure acknowledgement). In such a situation the connection must be released at both ends and congestion information sent to the calling subscriber or a repeat attempt must be made. On recognition of double seizure the line signalling equipment at both ends must maintain the seized state for a minimum of 100 ms after which the clear-forward signal $a_f = 1$, $b_f = 0$ must be sent.

100 ms after sending the clear-forward signal and on recognition of $a_b = 1$, $b_b = 0$ each end may assume the idle state.

The clear-forward state $a_f = 1$, $b_f = 0$ must be maintained for at least 100 ms to ensure that it is recognized at the other end.

In the sense of preventive action it is recommended that an opposite order of circuit selection be used by each exchange of a both-way circuit group to minimize double seizure.

b) *Requirements for circuit release*

When a both-way circuit is released, the end which acted as the incoming end must maintain the signalling code $a_b = 1$, $b_b = 0$ for at least 100 ms to ensure that the signal is recognized at the other end after which the circuit becomes idle.

c) *Blocking and unblocking procedure*

When a both-way circuit is blocked manually in its idle state at one end (e.g. end B) the blocking signal must be sent to the other end (A). The circuit must then be kept blocked locally (at end A) against all calls in the A to B traffic direction as long as the blocked state persists in the B to A direction.

In order to avoid permanent blocking, end A should maintain the signalling code $a = 1$, $b = 0$ in the direction A to B.

When the blocked state is removed, end B must send the clear-forward signal and must maintain that state for at least 100 ms, before assuming the idle state.

3.2.7.2 *Special arrangement*

The physical realization of signalling equipment terminating a bothway circuit may allow that part of the equipment concerned with outgoing calls to be removed without preventing the remaining equipment from being used for incoming calls. In this case it is only necessary to block the circuit locally against outgoing calls and a blocking signal need not be sent to the other end.

Recommendation Q.424

3.3 PROTECTION AGAINST THE EFFECTS OF FAULTY TRANSMISSION

Faulty transmission conditions in PCM systems can lead to degradation of the speech channels and erroneous signalling. In the case of primary PCM multiplex equipment operating at 2048 kbit/s failures due to loss of frame or multi-frame alignment and/or failure of any other important function results in both PCM terminals going into alarm condition in accordance with Recommendations G.732 and G.734.

Thus both PCM terminals apply the state corresponding to state 1 on the PCM line on each "receive" signalling channel at the interfaces with the switching equipment, as indicated in Table 4 of Recommendation G.732. In this way, the incoming switching equipment receives the equivalent of $a_f = 1$, $b_f = 1$ on the PCM line and the outgoing switching equipment receives the equivalent of $a_b = 1$, $b_b = 1$.

These characteristics are taken into account in the present specifications (see § 3.2.4) so that:

- at the outgoing end (see Table 3/Q.422) a PCM fault results in a blocked state, seizure acknowledged state or clear-back state. This means that all circuits in the idle state of a faulty PCM multiplex will be blocked against seizure and that seized circuits will go to or remain in the seizure acknowledged or clear-back state;
- at the incoming end (see Table 4/Q.422) a PCM fault can be identified and appropriate actions can be taken.

When the signalling equipment is a part of a digital exchange, it may receive alarm indications in a form other than both signalling bits in state one. The failure may be detected by the signalling equipment or an indication be received from the PCM terminal according to Recommendation G.734.

When the signalling equipment recognizes a failure it must:

- block the detection of signalling transitions to avoid recognition of erroneous signalling codes caused by the failure. This action must be taken as soon as possible and at least within 3 ms as specified in Recommendation G.734 for a PCM terminal,
- react as specified in Tables 3/Q.422 and 4/Q.422 when a signalling code $a = 1$, $b = 1$ is detected at the input of signalling equipment situated at the analogue access of a PCM terminal equipment complying with Recommendation G.732.

Recommendation Q.430

3.5 CONVERSION BETWEEN ANALOGUE AND DIGITAL VERSIONS OF SYSTEM R2 LINE SIGNALLING

This Recommendation is applicable to a conversion equipment placed on the circuit between two switching exchanges each using one of the two versions specified for System R2 line signalling. Owing to this particular use, all the specifications for the two versions of the line signalling may not be fully observed. Nevertheless, the diagrams which follow are based on the principles of CCITT Recommendations Q.411, Q.412 and Q.416 for the analogue version and on Recommendations Q.421, Q.422 and Q.424, for the digital version. The only time conditions taken into account in this Recommendation are those set out in the aforementioned Recommendations. The operation of the interruption control device is also, wherever possible, that specified in Recommendation Q.416. As stated in that Recommendation, the receiver is blocked immediately whenever pilot tone off is detected: since this is a routine operation, it has not been represented explicitly in the diagrams.

The conversion diagrams have been divided into four parts:

- for conversion between the analogue version at the incoming end and the digital version at the outgoing end, into:
 - incoming analogue,
 - outgoing digital;
- for conversion between the digital version at the incoming end and the analogue version at the outgoing end, into:
 - incoming digital,
 - outgoing analogue.

It should be noted, however, that this Recommendation can be simplified with respect to alarm processing when the conversion equipment is connected directly at the input or output of a switching exchange; the processes necessary for this application are shown on the diagrams with thickened lines.

1 Drawing conventions

- tone

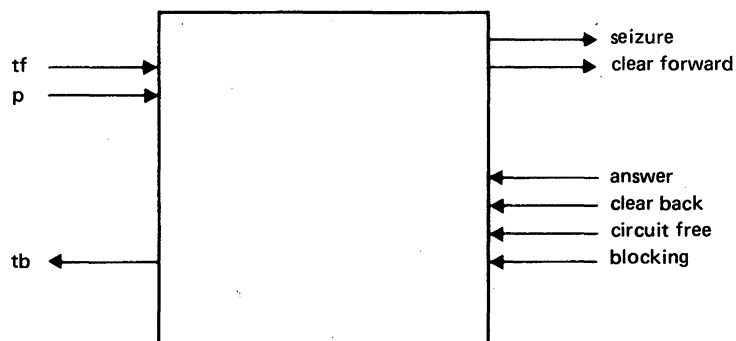
tf = 1 tone on forward	} When recognized
tf = 0 tone off forward	
tb = 1 tone on backward	
tb = 0 tone off backward	
p = 1 pilot tone on	
p = 0 pilot tone off	

- signalling bits

The conventions are those of Recommendation Q.421.

2 Conversion incoming analogue version to outgoing digital version

2.1 Incoming analogue



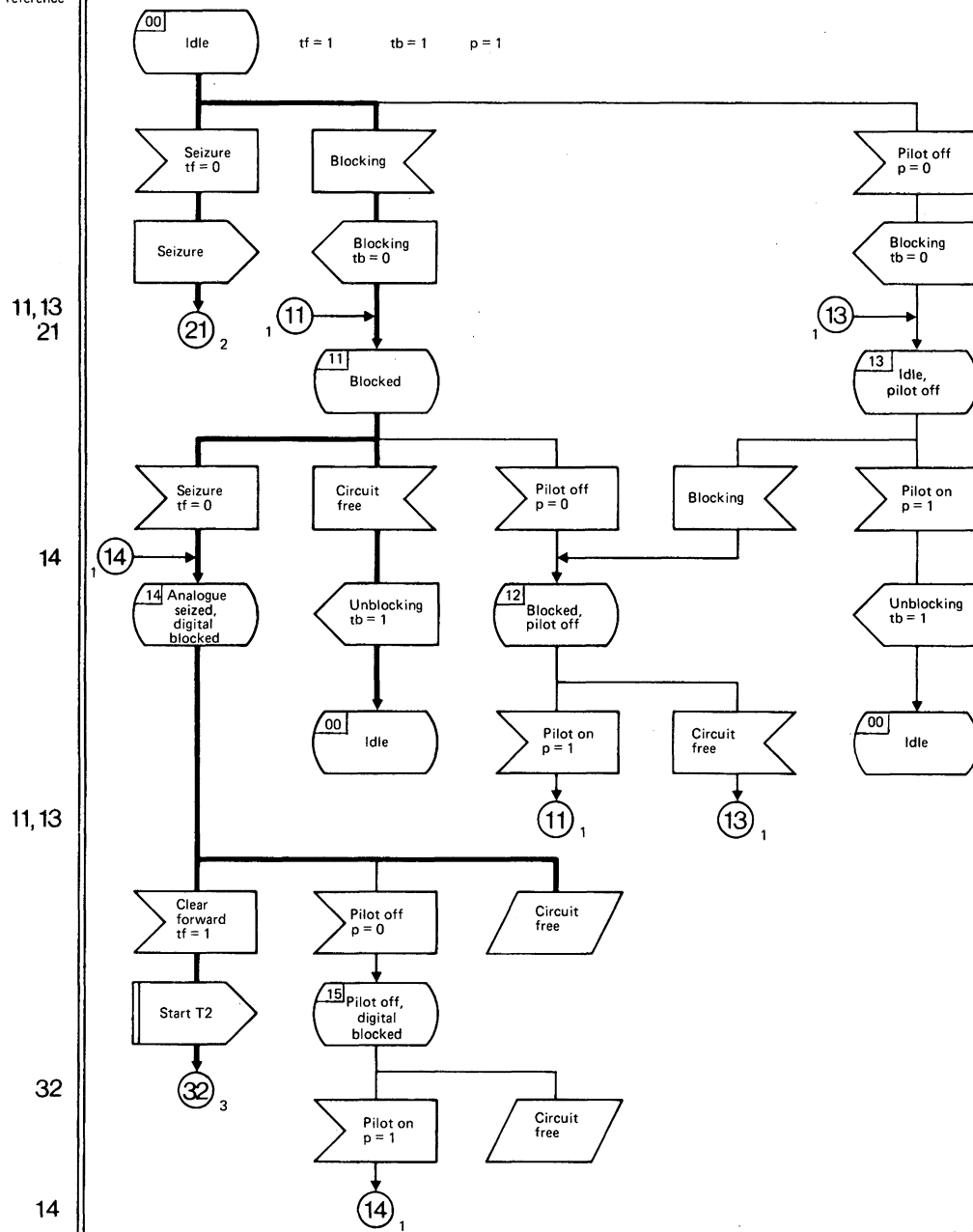
CCITT-55980

List of timers:

T2: Recommendation Q.412 (§ 2.2.2.7)

T3: 2 to 3 mn Recommendation Q.118 (§ 4.3.3)

Connector
reference



CCITT-60881

System R2 line signalling: conversion of incoming analogue
version to outgoing digital version

(Sheet 1 of 3)

Connector
reference

21

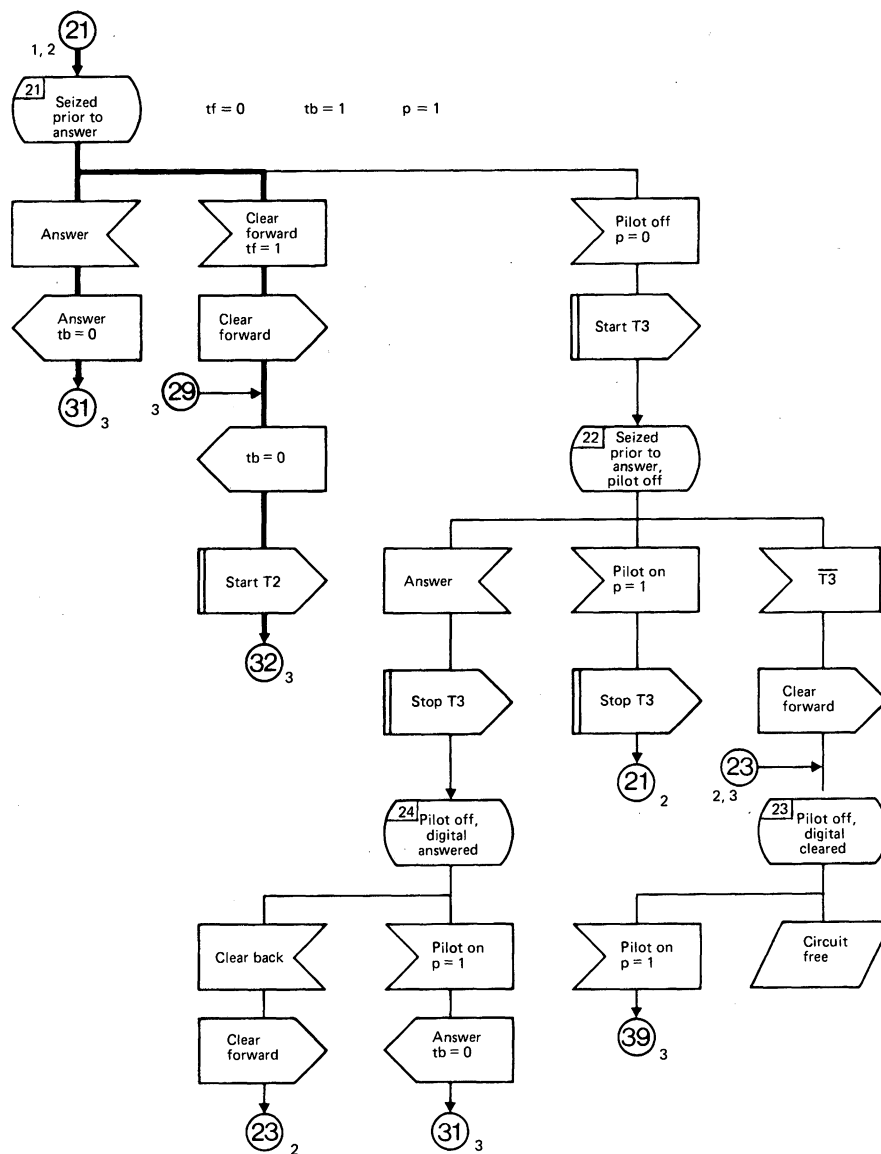
29
31

32

23
21

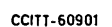
39

23,31



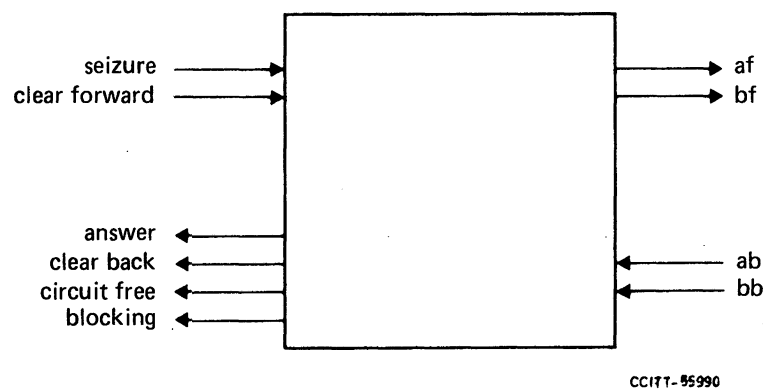
CCITT-60891

System R2 line signalling: conversion of incoming analogue
version to outgoing digital version
(Sheet 2 of 3)



(Sheet 3 of 3)

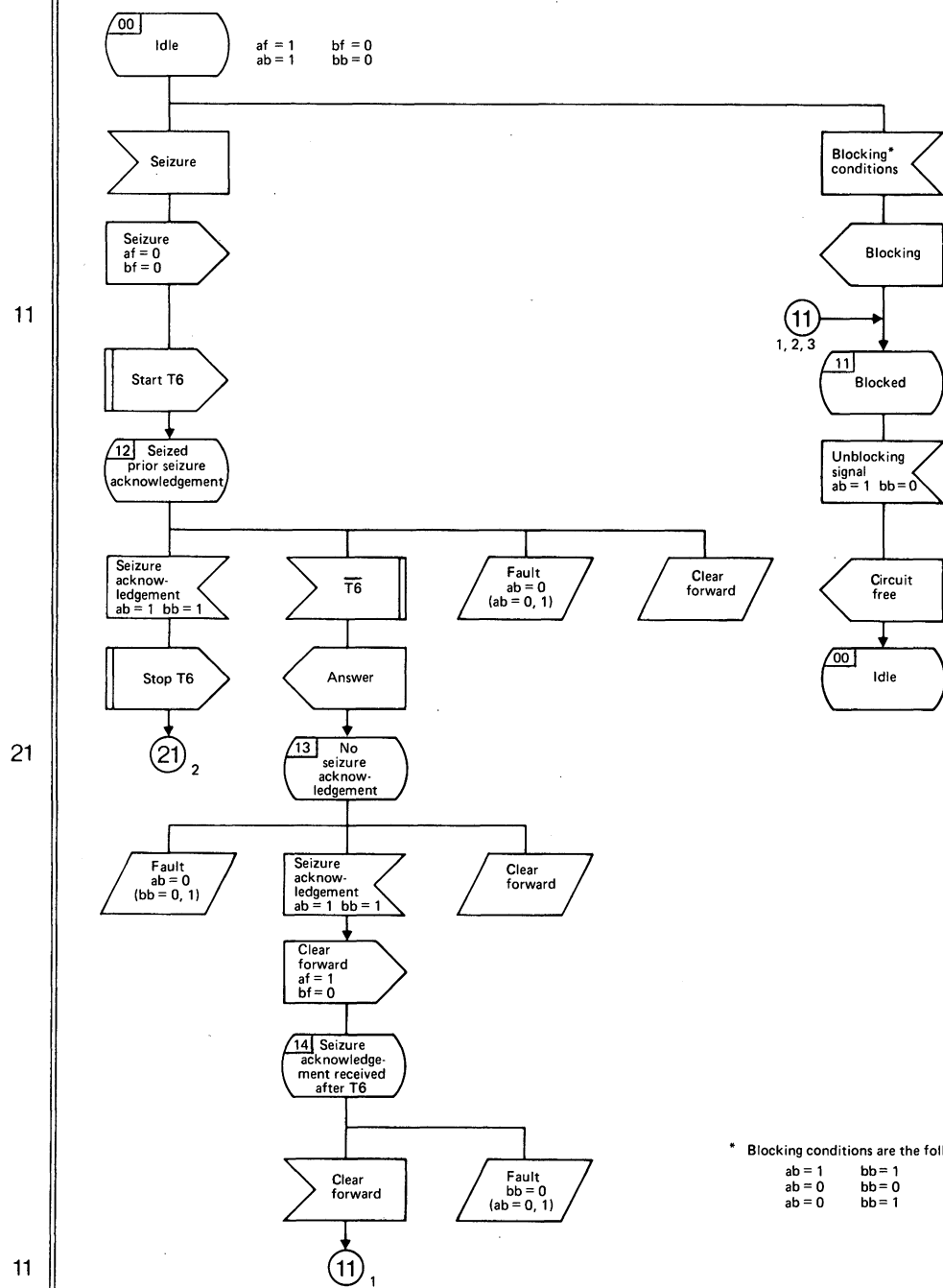
2.2 Outgoing digital



List of timers:

T6: Recommendation Q.422 (§ 3.2.4.1, Note 2 to Table 3)

Connector
reference



* Blocking conditions are the following:

ab = 1	bb = 1
ab = 0	bb = 0
ab = 0	bb = 1

CCITT- 60911

System R2 line signalling: conversion of incoming analogue
version to outgoing digital version
(Sheet 1 of 3)

Connector
reference

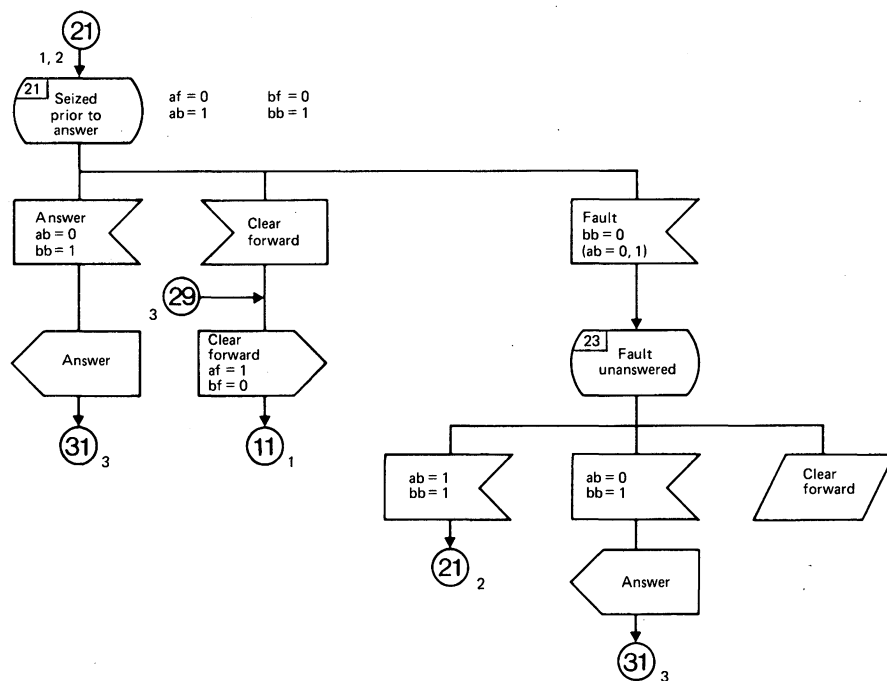
21

29

31,11

21

31



CCITT-60920

System R2 line signalling: conversion of incoming analogue
version to outgoing digital version
(Sheet 2 of 3)

Connector
reference

31

32
11

31

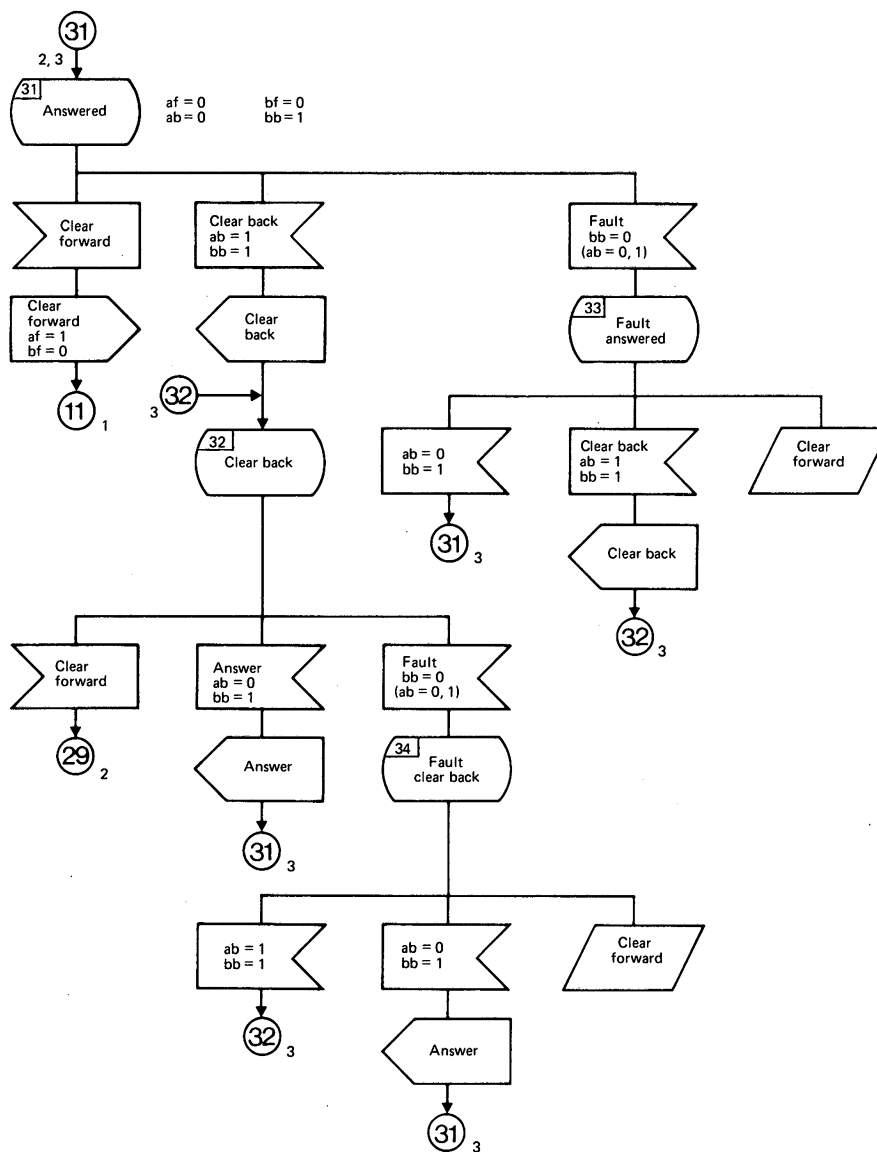
32

29

31

32

31



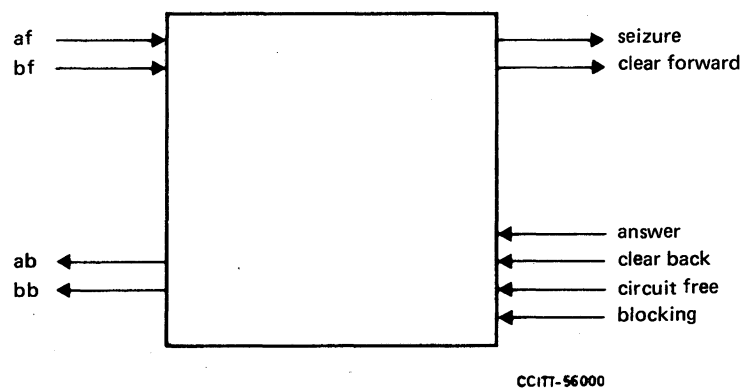
CCITT-60930

System R2 line signalling: conversion of incoming analogue
version to outgoing digital version

(Sheet 3 of 3)

3 Conversion incoming digital version to outgoing analogue version

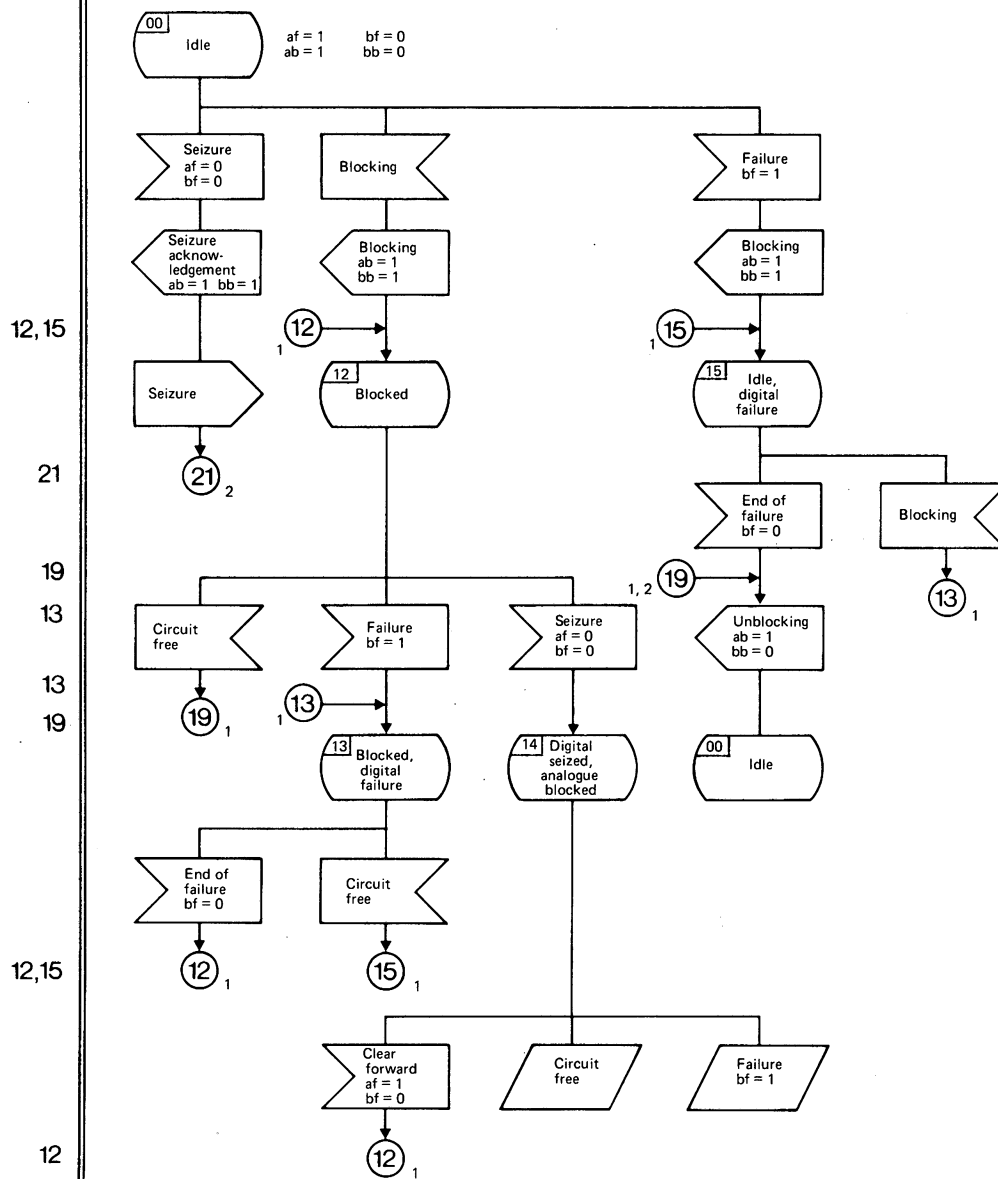
3.1 Incoming digital



List of timers:

T3: 2 to 3 mn Recommendation Q.118 (§ 4.3.3)

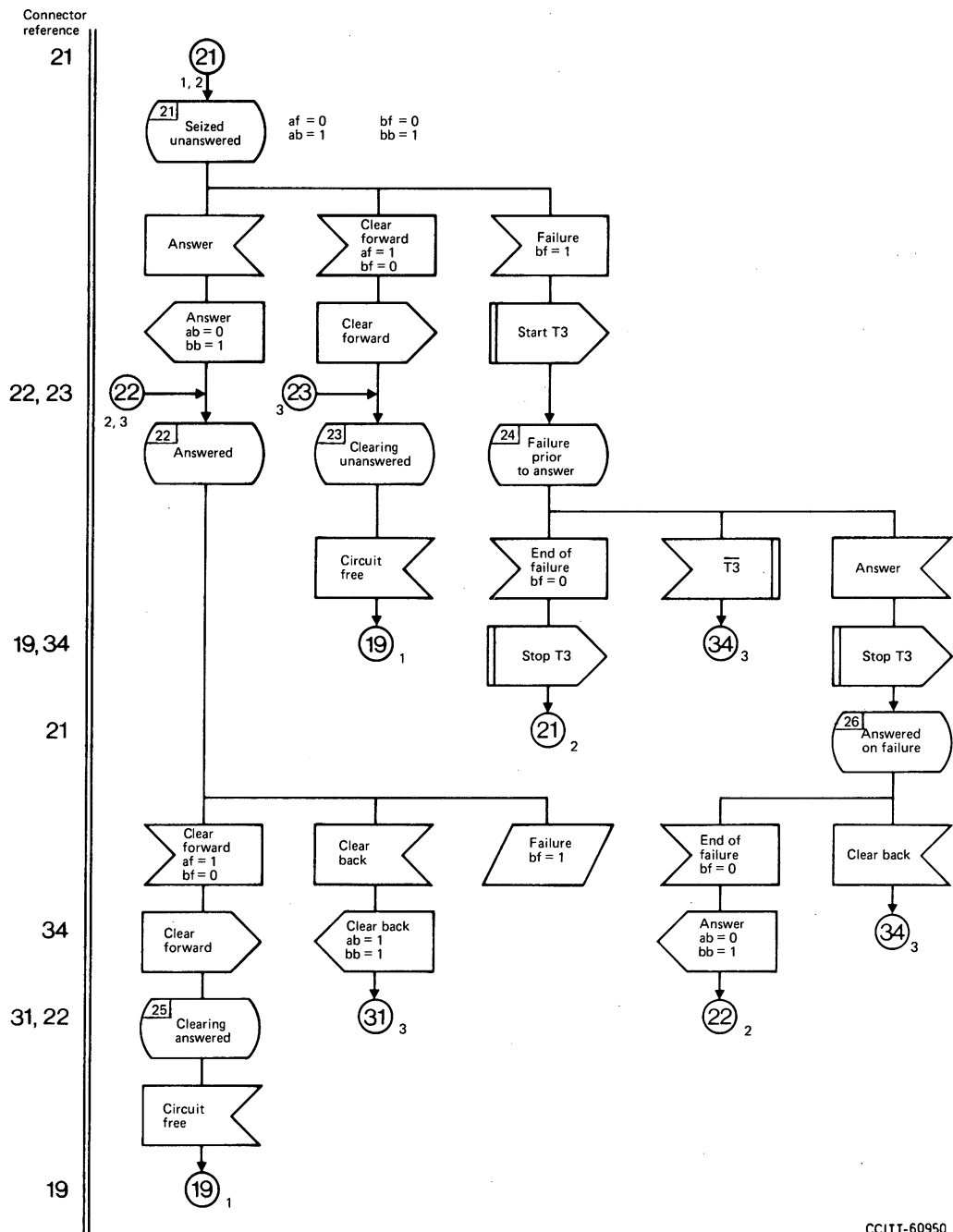
Connector
reference



CCITT-60940

System R2 line signalling: conversion of incoming digital
version to outgoing analogue version

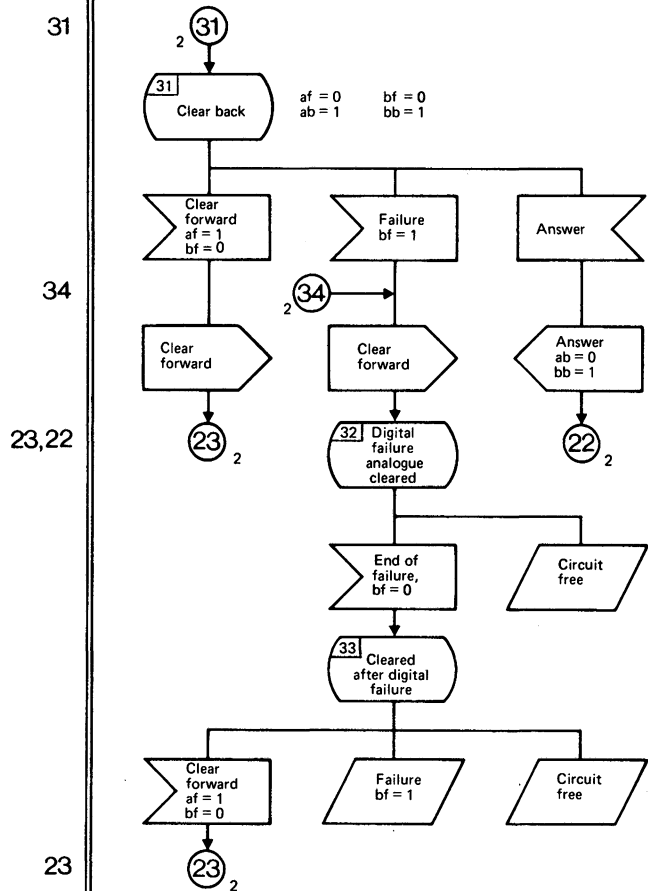
(Sheet 1 of 3)



System R2 line signalling: conversion of incoming digital
version to outgoing analogue version

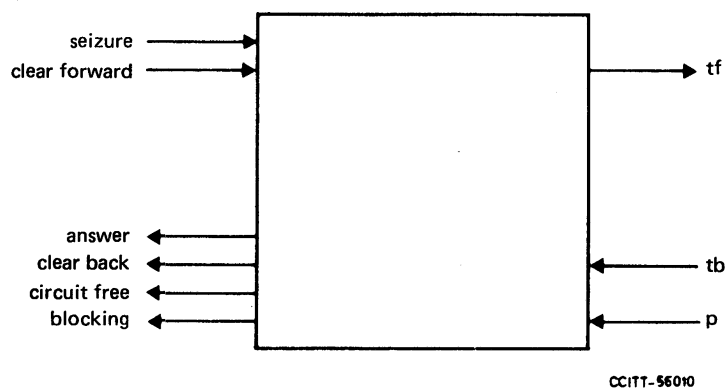
(Sheet 2 of 3)

Connector
reference



CCITT-60960

System R2 line signalling: conversion of incoming digital
version to outgoing analogue version
(Sheet 3 of 3)



List of timers:

T1: Recommendation Q.412 (§ 2.2.2.7)

T5: 100 ms Recommendation Q.412 (§ 2.2.2.1)

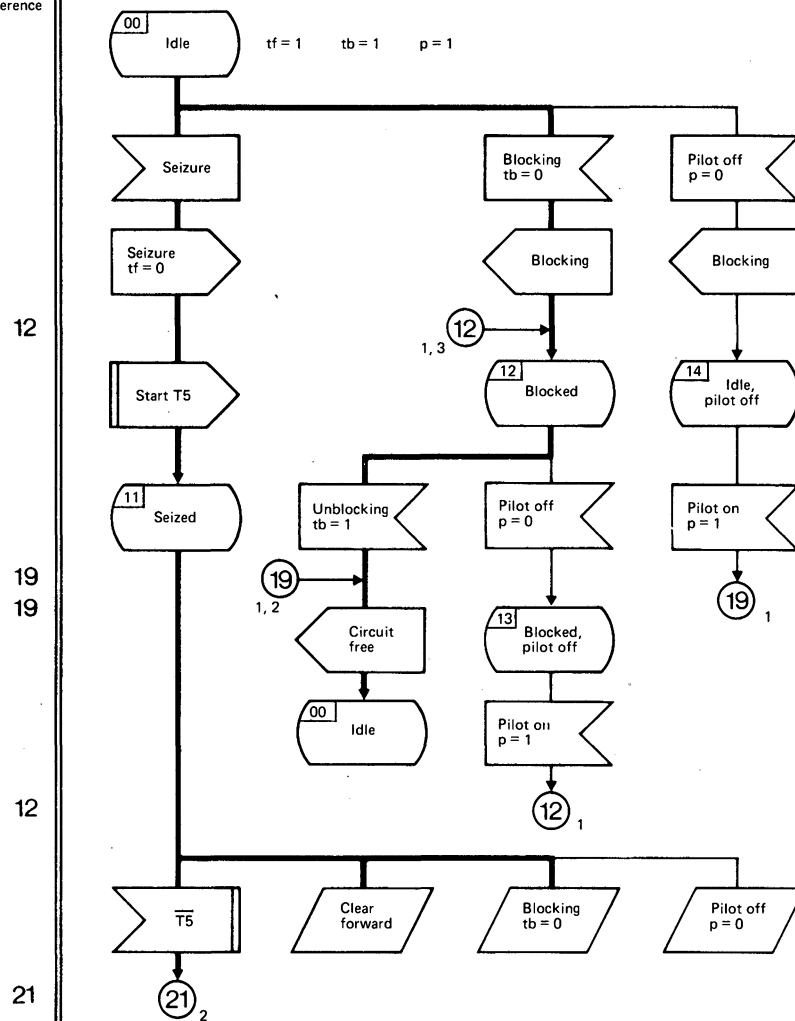
Automatic restoration of an abnormally blocked circuit Recommendation Q.490 (§ 6.6)

n: number of attempts made

T4: 30 s to 2 mn

T7: 2 to 3 s

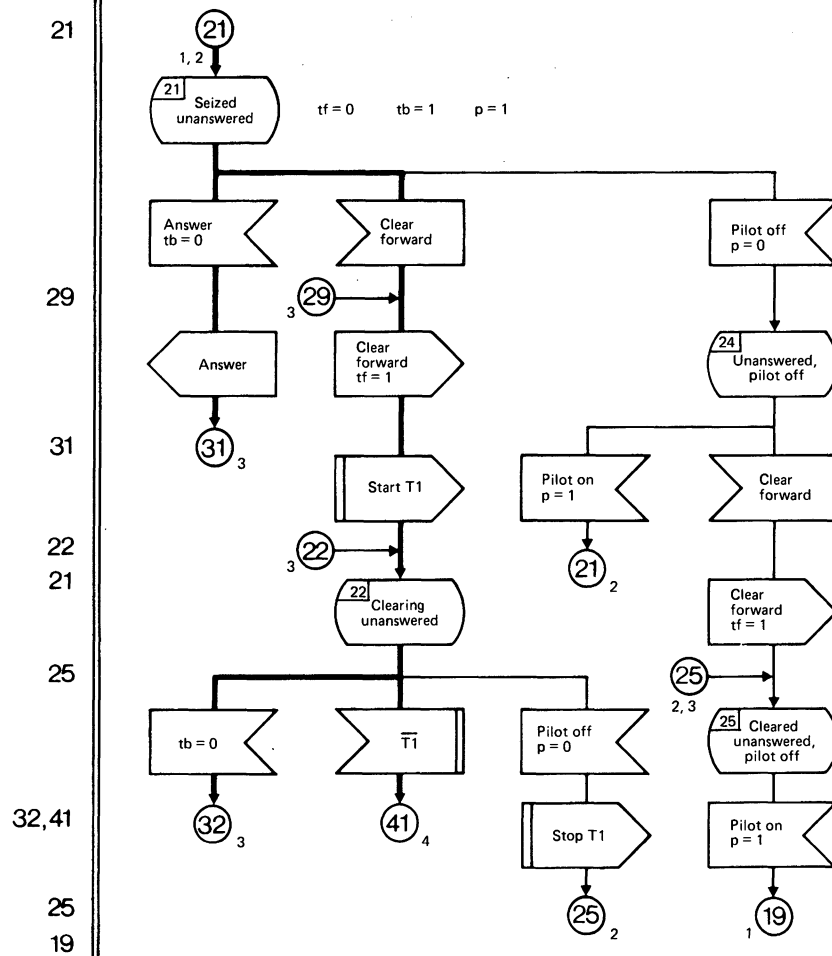
Connector
reference



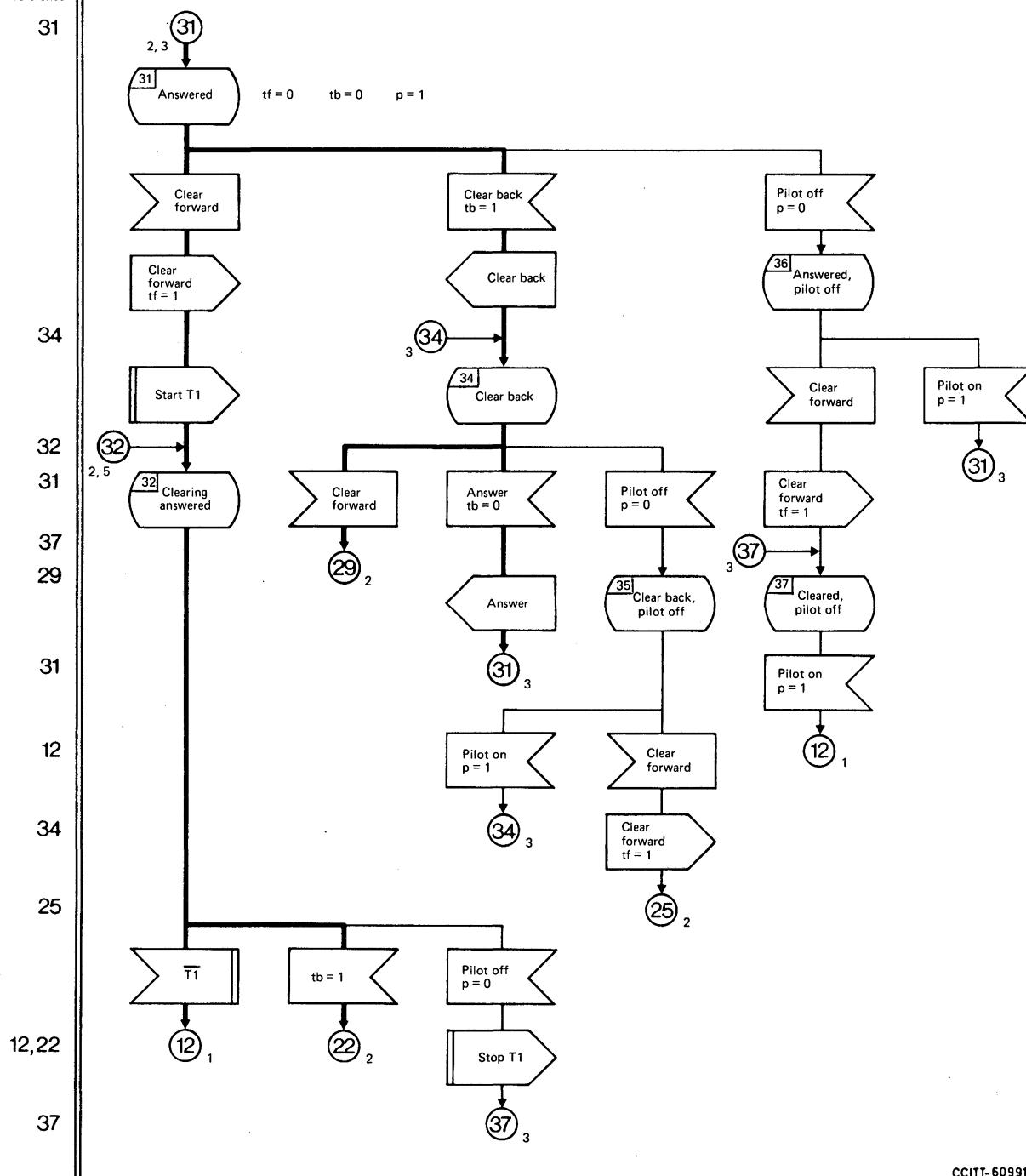
CCITT-60971

System R2 line signalling: conversion of incoming digital
version to outgoing analogue version
(Sheet 1 of 5)

Connector
reference



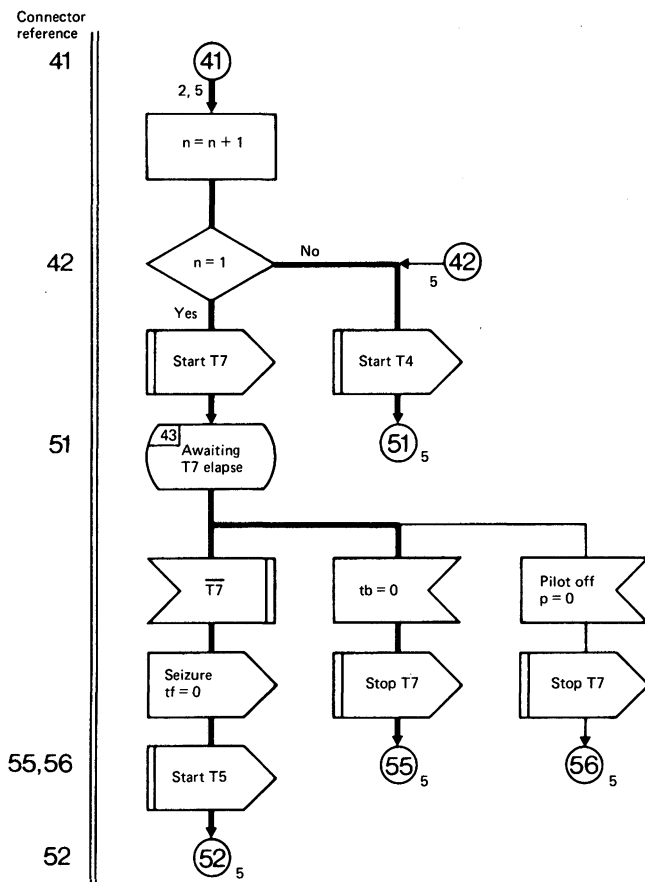
System R2 line signalling: conversion of incoming digital
version to outgoing analogue version
(Sheet 2 of 5)



CCITT-60991

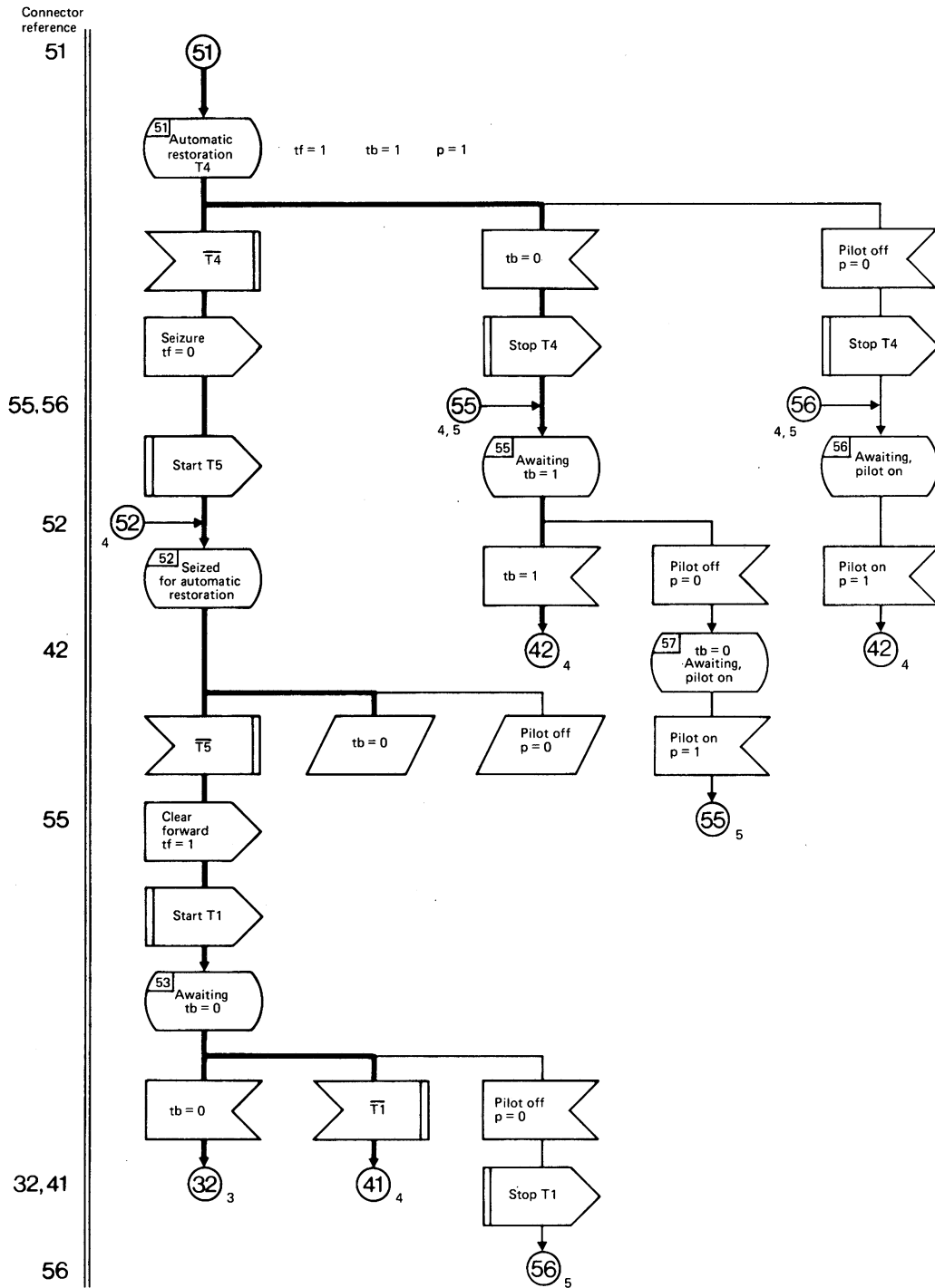
System R2 line signalling: conversion of incoming digital
version to outgoing analogue version

(Sheet 3 of 5)



CCITT-70001

System R2 line signalling: conversion of incoming digital
version to outgoing analogue version.
Automatic restoration of analogue link
(Sheet 4 of 5)



CCITT-70011

System R2 line signalling: conversion of incoming digital
version to outgoing analogue version.
Automatic restoration of the analogue link
(Sheet 5 of 5)

SECTION 4

INTERREGISTER SIGNALLING

Recommendation Q.440

4.1 GENERAL

Interregister signals are of the multifrequency type using a 2-out-of-6 in-band code in both directions. The multifrequency combinations are sent and received by multifrequency signalling equipment which is assumed to be associated with the registers used to control the switching equipment at both ends of the inter-exchange link.

4.1.1 End-to-end signalling method

In System R2 interregister signalling is generally performed end-to-end by a compelled procedure between the outgoing register and the incoming registers which come into action one after another. Signalling takes place over one or more links in tandem without signal regeneration in intermediate exchanges. With this signalling method only the address information needed for routing the call through an intermediate exchange is transferred from the outgoing register to the incoming registers. In an intermediate exchange the speech path is immediately through-connected and the incoming register released, then the outgoing register can exchange information directly with the incoming register of the next exchange (see Figure 11/Q.440). If any intermediate exchange has to carry out charging operations, additional address information can be transferred from the outgoing register to the incoming register of that exchange as required.

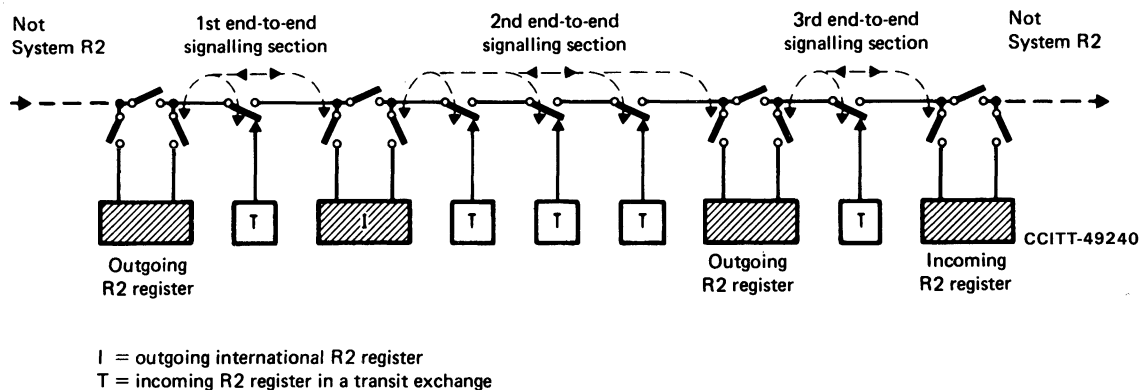


FIGURE 11/Q.440

An international three-section multi-link connection

In circumstances where transmission conditions do not comply with the requirements specified for System R2 (see Recommendation Q.457) or where System R2 is used in a satellite link, and thus the exchange of the interregister signals over the complete System R2 connection is not permitted, the overall multi-link connection is divided into end-to-end signalling sections. When the number of multifrequency combinations available is not the same on all parts of the connection, the division should be made at an exchange between links having different numbers of multifrequency combinations to improve the transfer of information.

The outgoing R2 register is situated at the outgoing end of a signalling section on which System R2 interregister signalling according to the present specifications is used. It controls the call set-up over the whole signalling section. It sends forward interregister signals and receives backward interregister signals.

The outgoing R2 register receives information via the preceding links of the connection in a form used by the signalling system applied over the last of these links; this system may be System R2, a decadic pulse system, or any other system. The preceding link may also be a subscriber's line. When an R2 register in a transit exchange is working according to this definition, it is also called an *outgoing R2 register*.

Special cases of the outgoing R2 register are the outgoing international R2 register (see § 4.1.2) and the outgoing R2 register at the incoming end of a satellite link.

The incoming R2 register is situated at the incoming end of a link on which System R2 multifrequency interregister signalling according to the present specification is used. It receives forward interregister signals via the preceding link(s) and sends backward interregister signals. The information received is used completely or in part for the control of selection stages and may be sent in its entirety or in part to the succeeding equipment, in which case the signalling used for retransmission is never System R2. Interworking then takes place between System R2 and the other system. Thus every register not situated at the outgoing end of a System R2 signalling section is called an *incoming R2 register* independently of the exchange type.

The term *incoming R2 register* may be applied also to devices controlling one or more selection stages, for example *markers* etc. It should be noted that in such equipment no provision is made for further transfer of the information received.

4.1.2 *International end-to-end working*

The inclusion of a special *outgoing international R2 register* as shown in Figure 11/Q.440 is dictated by a number of considerations. An outgoing international R2 register is an outgoing R2 register which controls the call set-up on a signalling section which comprises at least one international link and possibly national links in tandem.

Even when System R2 is used in the national network of the originating country an outgoing international R2 register must always be provided in the country of origin to divide the connection into two signalling sections for the following reasons:

- to prevent the maximum number of links in a signalling section over which System R2 can function from being exceeded on international calls;
- to permit the use of fewer signalling frequencies in the country of origin (e.g. 5 forward and 5 or 4 backward signalling frequencies);
- to enable non-standardized meanings to be allocated to the spare national multifrequency combinations for use solely in the country of origin;
- to provide criteria for distinction, at the incoming end, between national and international calls;
- to have the facilities for routing and charging of international calls concentrated in one place if it is more economical than to equip every normal outgoing R2 register to perform these functions.

In general the outgoing international R2 register is situated at the outgoing international exchange. However, it may be situated in a national exchange preceding the international exchange provided that the transmission requirements specified are fulfilled.

End-to-end signalling from the outgoing international R2 register can be extended beyond the incoming international exchange even if a reduced number of signalling frequencies is used. However, such international/national end-to-end signalling requires:

- that the transmission conditions in the national destination network comply with the System R2 specifications, and
- that the routing principles employed in the national destination network are compatible with the System R2 signalling procedures for end-to-end transmission of address digits from the outgoing international R2 register to an incoming R2 register in a national exchange.

4.1.3 *Register requirements*

Apart from signalling procedures specified in Section 5 the following characteristics of R2 registers are specified.

4.1.3.1 *Outgoing R2 registers*

The multifrequency signalling equipment associated with outgoing R2 registers in national exchanges may be of the 2-wire or 4-wire type (see Recommendation Q.451).

The multifrequency signalling equipment associated with outgoing international R2 registers must be of the 4-wire type. This is dictated by transmission constraints (see Recommendation Q.452).

The outgoing R2 register controlling a given multi-link signalling section must be able to recognize at least all the backward signals used on that section.

The outgoing international R2 register must be able to send all 15 forward multifrequency combinations with the meanings specified for international working. It must be able to receive all 15 backward multifrequency combinations and act upon the received information in the specified manner. In the case when System R2 is used on the preceding link the calling party's category signals have to be translated by the outgoing international R2 register as specified (see Recommendation Q.480).

The outgoing R2 register must start call set-up as soon as it has received the minimum requisite information. Therefore signal transfer starts before the complete address information is received, i.e. before the caller finishes dialling. This *overlapping interregister signalling* particularly applies at an outgoing R2 register where the complete address information from a subscriber or operator is stored (e.g. local registers). This is in contrast to *en bloc register signalling* i.e. the transmission of all the address information as a whole in one sequence starting only after the complete reception of the address information.

4.1.3.2 *Incoming R2 registers*

The multifrequency signalling equipment associated with incoming R2 registers may be of the 2-wire or 4-wire type (see Recommendation Q.451).

The multifrequency signalling equipment associated with the incoming R2 register in an international exchange must be of the 4-wire type and equipped to send and receive all 15 multifrequency combinations.

Every incoming R2 register in a multi-link signalling section must be able to recognize at least the forward signals used on that section and directed to that register.

4.1.4 *System R2 compelled signalling method*

The compelled signalling operates as follows (see Figure 12/Q.440):

- on seizure of a link, the outgoing R2 register automatically starts sending the first forward interregister signal;
- as soon as the incoming R2 register recognizes this signal, it starts sending a backward interregister signal which has its own meaning and at the same time serves as an acknowledgement signal;
- as soon as the outgoing R2 register recognizes the acknowledging signal, it stops sending the forward interregister signal;
- as soon as the incoming R2 register recognizes the cessation of the forward interregister signal, it stops sending the backward interregister signal;
- as soon as the outgoing R2 register recognizes the cessation of the acknowledging backward interregister signal it may, if necessary, start sending the appropriate next forward interregister signal.

When the duration of the forward and backward signals is not controlled by the compelling mechanism described above, it is either limited by the time-out delay for release of the register or determined by the nature of the pulse imposed on them (see Recommendation Q.442).

Figure 12/Q.440 shows a basic compelled signalling cycle.

Figure 18/Q.457 shows in detail the build-up and time sequence of a compelled signalling cycle, including the operating and release times of multifrequency signalling equipment and other internal operating times of exchange equipment.

Besides being a functional part of the compelled procedure, the acknowledging backward signals serve to convey special information concerning the required forward signals, to indicate certain conditions encountered during call set-up or to announce switchover to changed meanings of subsequent backward signals. Changeover to secondary meanings allows information concerning the state of the called subscriber's line to be transferred (see Recommendation Q.441, § 4.2.4). Therefore a choice of acknowledging backward signals is provided.

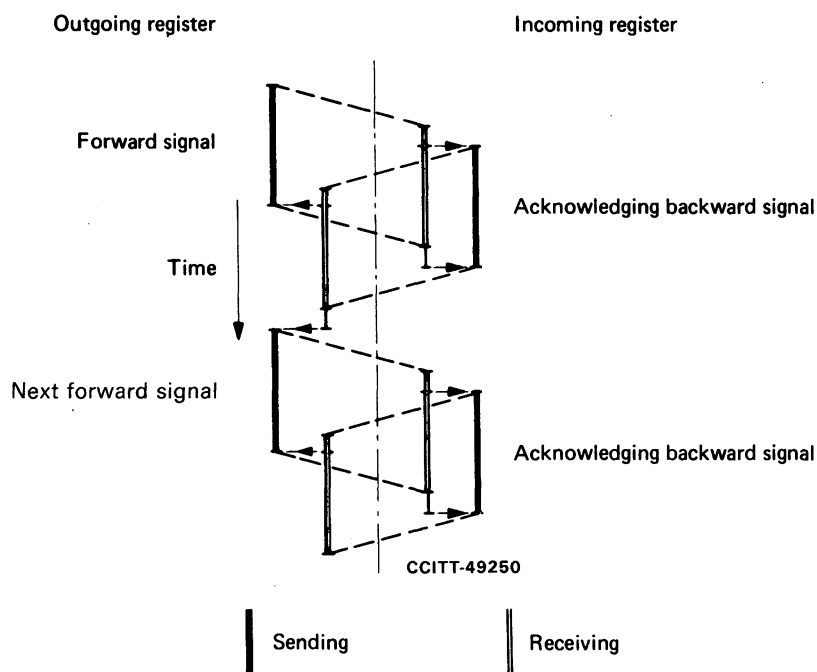


FIGURE 12/Q.440
Compelled signalling cycle

Recommendation Q.441

4.2 SIGNALLING CODE

4.2.1 Multifrequency combinations

Each interregister signal consists of the simultaneous sending of 2 out of a range of 6, 5 or 4 in-band frequencies (multifrequency combination). The band of the interregister signalling frequencies does not overlap with the frequency band generally used for line-signalling.

This *2-out-of-n* code allows erroneous signals consisting of less or more than two frequencies to be detected and identified as faulty.

To make the system suitable for application on 2-wire links, two different sets of 6 frequencies are defined for the composition of the forward and the backward signals.

Table 5/Q.441 shows all multifrequency combinations which can be derived from the maximum of 6 signalling frequencies per direction provided by the system. For reference purposes each multifrequency combination of a given direction is identified by a serial number. The numerical value of this serial number can be calculated by adding the respective index and weight allocated to the two frequencies making up the combination.

The number of multifrequency combinations depends upon the number of signalling frequencies used. When the maximum of 6 signalling frequencies are used, 15 multifrequency combinations are available.

System R2 is designed for operation on international links with 15 multifrequency combinations in each direction. However, it can be used in national networks with a reduced number of signalling frequencies and still permit international/national end-to-end working of System R2 signalling in the case of incoming international traffic (see Figure 13/Q.441).

The reduction naturally cuts the number of multifrequency combinations available but has the economic advantage of effecting savings in equipment. The resulting reduction in facilities is of less importance in automatic than semi-automatic service.

TABLE 5/Q.441
Multifrequency combinations

Combinations		Frequencies (Hz)						
No.	Numerical value = $x + y$	Forward direction (signals of Groups I and II)	1380	1500	1620	1740	1860	1980
		Backward direction (signals of Groups A and B)	1140	1020	900	780	660	540
		Index (x)	f_0	f_1	f_2	f_3	f_4	f_5
		Weight (y)	0	1	2	4	7	11
1	0 + 1		x	y				
2	0 + 2		x		y			
3	1 + 2			x	y			
4	0 + 4		x			y		
5	1 + 4			x		y		
6	2 + 4				x	y		
7	0 + 7		x				y	
8	1 + 7			x			y	
9	2 + 7				x		y	
10	3 + 7					x	y	
11	0 + 11		x					y
12	1 + 11			x				y
13	2 + 11				x			y
14	3 + 11					x		y
15	4 + 11						x	y

The following versions might be considered :

- a) 6 forward frequencies (15 multifrequency combinations) and
5 backward frequencies (10 multifrequency combinations);
- b) 6 forward frequencies (15 multifrequency combinations) and
4 backward frequencies (6 multifrequency combinations);
- c) 5 forward frequencies (10 multifrequency combinations) and
5 backward frequencies (10 multifrequency combinations);
- d) 5 forward frequencies (10 multifrequency combinations) and
4 backward frequencies (6 multifrequency combinations).

In the forward direction the highest signalling frequency may be omitted (i.e. multifrequency combinations 1 to 10 remain).
In the backward direction either the lowest or both the lowest and next lowest signalling frequency may be omitted (i.e. multifrequency combinations 1 to 10 or 1 to 6, respectively, remain).

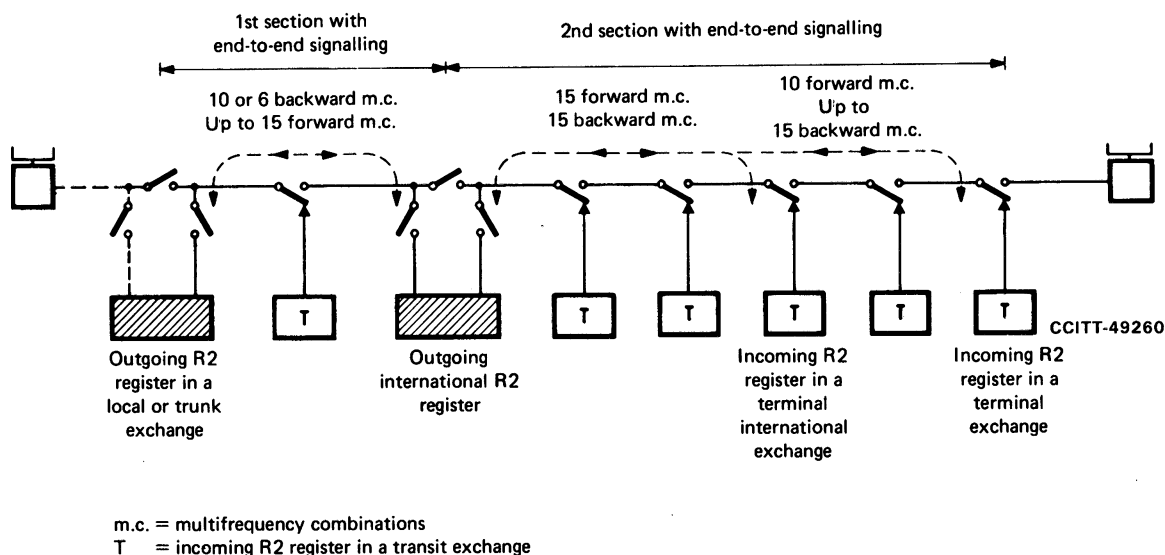


FIGURE 13/Q.441
An international two-section multi-link connection

4.2.2 Allocation of interregister signals

The signal coding consists of the association of the defined meaning of interregister telephone signals to the multifrequency combinations transmitted over the links. Certain combinations are left spare for the allocation of national or international signals. (For signalling procedures, see Recommendations Q.460 to Q.480.)

4.2.2.1 Multiple meaning

The meaning of both the forward and backward multifrequency combinations can change after transmission of certain backward signals. The changed meaning is specific to the signal which caused or announced the change. In certain cases a change back to the original meaning is possible. The meaning of certain forward multifrequency combinations may also vary depending on their position in the signalling sequence.

4.2.2.2 Meanings of the forward multifrequency combinations

There are two groups of meanings allocated to the forward multifrequency combinations. The Group I meanings are indicated in Table 6/Q.441 and the Group II meanings in Table 7/Q.441. The change from Group I to Group II meanings takes place when requested by the backward signals A-3 or A-5. Change back to Group I meanings is only possible when the change to Group II meanings was in response to signal A-5.

The first forward signal transmitted in international working is used for additional routing information. It enables a distinction to be made between terminal and transit calls. In the case of terminal calls it carries the language or discriminating digit whereas, for transit calls, it serves the dual purpose of providing a country code indicator and to indicate whether an echo suppressor is required or not.

The above arrangements obviate the need for two different seizing signals (line signals) to distinguish between transit and terminal traffic on links terminated in a transit exchange.

4.2.2.3 Meanings of the backward multifrequency combinations

There are two groups of meanings allocated to the backward multifrequency combinations. The Group A meanings are indicated in Table 8/Q.441 and the Group B meanings in Table 9/Q.441. The change to Group B meanings is announced by the backward signal A-3. No change back is possible once a change to the Group B meanings of the backward multifrequency combinations has been indicated.

4.2.2.4 Integration of national and international signalling codes

The utilization of Signalling System R2 in national networks is facilitated by the provision, in the specified signalling code, of signals specially assigned for national use. Under the specified code, specific national meanings are allocated to some of these signals, others are available for the allocation of national meanings at the discretion of each Administration.

National allocations must not conflict with the present specifications in order to ensure end-to-end interregister signalling i.e. the direct dialogue between the outgoing international R2 register (in the originating country) and incoming R2 registers, in the national network of the destination country.

The specified signalling code allows for a reduction of signalling frequencies in national networks (see § 4.2.1 above).

4.2.3 Forward signals

4.2.3.1 Group I forward signals

Compelled interregister signalling must always begin with a Group I forward signal. For the signal codes see Table 6/Q.441.

TABLE 6/Q.441
Group I forward signals

Combination (a)	Designation of the signal (b)	Meaning of the signal		Remarks (e)
		(c)	(d)	
1	I-1	Language digit: French	Digit 1	Col. (c) – These signals make up the first signal transmitted on an international link when it terminates in the country of destination of the call. When a link terminates in an international transit centre, however, these signals may be transmitted on the link after the country code indication and the country code. See also Recommendation Q.107.
2	I-2	Language digit: English	Digit 2	
3	I-3	Language digit: German	Digit 3	
4	I-4	Language digit: Russian	Digit 4	
5	I-5	Language digit: Spanish	Digit 5	
6	I-6	Spare (language digit)	Digit 6	
7	I-7	Spare (language digit)	Digit 7	
8	I-8	Spare (language digit)	Digit 8	
9	I-9	Spare (discriminating digit)	Digit 9	
10	I-10	Discriminating digit	Digit 0	
11	I-11	Country code indicator, outgoing half-echo suppressor required	Access to incoming operator (Code 11)	Col. (c) – First signal on an international link when it terminates in an international transit centre. Col. (d) – Other than the first signal on an international link.
12	I-12	Country code indicator, no echo suppressor required	i) Access to delay operator (Code 12) ii) Request not accepted	
13	I-13	Test call indicator (call by automatic test equipment)	i) Access to test equipment (Code 13) ii) Satellite link not included	
14	I-14	Country code indicator, outgoing half-echo suppressor inserted	i) Incoming half-echo suppressor required ii) Satellite link included	
15	I-15	Signal is not used	i) End-of-pulsing (Code 15) ii) End of identification	

The *signals I-1 to I-10* are numerical signals indicating:

- a) the *address* required for setting up the call (country code, national significant number); such address signals are sent by an outgoing R2 register or an outgoing international R2 register, either spontaneously and immediately after the seizure of the link or in response to one of the backward signals A-1, A-2, A-7 or A-8;
- b) the country code (and possibly the area code as well) of the *location of the outgoing international R2 register*, in response to signals requesting the origin of the call. For national traffic, the telephone number of the calling subscriber's line (see Recommendation Q.480);
- c) for automatic working the *discriminating digit* or, in the case of semi-automatic working, the service language to be used by the operator (i.e. *language digit*).

The *signal I-11* is a non-numerical address signal. The meaning of the signal is dependent on its position within the sequence of address signals specified in Recommendation Q.107.

- a) *Country code indicator, outgoing half-echo suppressor required*

When signal I-11 is transmitted as the first forward signal it indicates that:

- i) a country code will follow (international transit);
- ii) the call requires echo suppressors;
- iii) the outgoing half-echo suppressor has to be inserted.

The use of this signal in international working is subject to bilateral agreement and is made in conformity with Recommendation Q.479.

- b) *Access to incoming operator (code 11)*

When signal I-11 is preceded by the language digit (and possibly by one further address digit) it indicates the address of the incoming operator's position and is then always followed by signal I-15 alone.

For international working this signal is to be used only in conformity with Recommendation Q.107 *bis*. It can be used in national traffic only if the incoming R2 registers are equipped to receive all six forward frequencies. The necessary specifications are then the responsibility of the Administration concerned.

The *signal I-12* is a non-numerical address signal. The meaning of the signal is dependent on its position in the sequence of address signals specified in Recommendation Q.107.

- a) *Country code indicator, no echo suppressor required*

When signal I-12 is transmitted as the first forward signal it indicates that:

- i) a country code will follow (international transit);
- ii) the call may not require any echo suppressor (see Recommendation Q.479).

- b) *Access to delay operator (code 12)*

When signal I-12 is preceded by the language digit (and possibly by one further address digit) it indicates that the call must be routed to the delay operator's position, either to a particular operator, or one of those operating a particular group of positions. It is then followed by further digits and the signal I-15 or by the signal I-15 alone.

In international working this signal is to be used in conformity with Recommendation Q.107 *bis*. It can be used in national traffic only if the incoming R2 registers are equipped to receive all six forward frequencies. The necessary specifications are then the responsibility of the Administrations concerned.

- c) *Request not accepted*

An outgoing international R2 register which receives a signal A-9 or A-10, the use of which is exclusively national, or which receives by signal A-13 a request to which it is unable to reply, should indicate by transmitting signal I-12 that it cannot answer the query (see Recommendation Q.480). This signal may be similarly used in national traffic to indicate that response to signal A-9 or A-10 is not possible.

The meaning of the non-numerical signal I-13 is dependent on its position in the sequence of address signals specified in Recommendation Q.107.

- a) *Test call indicator*

When in international working the signal I-13 is transmitted as the first forward signal it occupies the position of the language or discriminating digit. It serves then as a test call indicator and must be followed by the complete test equipment address information as specified in b) below.

b) *Access to test equipment (code 13)*

To access automatic test equipment the second signal I-13 (the address digit) must be followed by two digits *xy* and the signal I-15.

c) *Satellite link not included*

In response to signal A-13, the meaning of the signal I-13 is that up to the outgoing R2 register no satellite link is included.

The meaning of the non-numerical *signal I-14* is dependent on its position in the sequence of address signals specified in Recommendation Q.107.

a) *Country code indicator, outgoing half-echo suppressor inserted*

When signal I-14 is transmitted as the first forward signal it indicates that:

- i) a country code will follow (international transit);
- ii) the call requires echo suppressors;
- iii) the outgoing half-echo suppressor has already been inserted.

This signal is to be used in international working and only in conformity with Recommendation Q.479.

b) *Incoming half-echo suppressor required*

In response to signal A-14, the meaning of the signal I-14 is that an incoming half-echo suppressor is necessary.

c) *Satellite link included*

In response to signal A-13, the meaning of the signal I-14 is that up to the outgoing R2 register a satellite link is included in the connection.

The non-numerical *signal I-15* indicates the end of a sequence of forward interregister signals. It is never sent as the first signal on an international link.

a) *End-of-pulsing*

In international working, signal I-15 is used to indicate that there are no more address signals to follow (see Recommendations Q.107 and Q.473).

b) *End of identification*

In national traffic, signal I-15 may be used to indicate that transmission of the sequence identifying the calling subscribers line is terminated (see Recommendation Q.480, § 5.8.2).

4.2.3.2 *Group II forward signals*

The Group II forward signals are calling party's category signals sent by outgoing R2 registers or by outgoing international R2 registers in reply to the backward signals A-3 or A-5 and give information whether national or international working applies. For the signal codes see Table 5/Q.441.

It is useful to identify calls according to type or function:

- i) to indicate whether the forward transfer facility is required in international traffic;
- ii) for adequate control of switching operations;
- iii) to enable any additional meanings for the signals A-5 used in a national network but not internationally accepted (for example, to change the meanings of one or more following signals, forward or backward) to be made inoperative for incoming international calls;
- iv) for maintenance purposes.

The meanings of the calling party's category signals are detailed below:

a) The *signal II-1, subscriber without priority* indicates that the call is set up from a subscriber's line and is non-priority.

b) The *signals II-2 and II-9, subscriber with priority* indicate that the call is set up from a subscriber's line to which priority treatment of calls has been accorded. Signal II-2 is specified for national working only since there are no Recommendations regarding priority calls in automatic international working (see Recommendation Q.480).

- c) The *signal II-3, maintenance equipment* indicates that the call comes from maintenance equipment.
- d) The *signal II-5, operator* indicates that the call is set up from an operator's position.
- e) The *signals II-6 and II-8, data transmission* indicate that the call will be used for data transmission.
- f) The *signal II-7, subscriber* indicates that the call is set up from a subscriber's line, an operator's position or from maintenance equipment and that no forward transfer signal will be used.
- g) The *signal II-10, operator with forward transfer facility* indicates that the call is set up from an operator's position with possibility of recourse to the forward transfer facility. Its use must be subject to bilateral agreement (see Annex A to the present Specifications).

The signal II-4 and the signals II-11 to II-15 are spare. The meaning of signal II-4 will be decided later by international agreement.

TABLE 7/Q.441
Group II forward signals

Combination (a)	Designation of the signal (b)	Meaning of the signal (c)	Remarks (d)
1 2 3 4 5 6	II-1 II-2 II-3 II-4 II-5 II-6	Subscriber without priority Subscriber with priority Maintenance equipment Spare Operator Data transmission	} These signals are solely used for national working
7 8 9 10	II-7 II-8 II-9 II-10	Subscriber (or operator without forward transfer facility) Data transmission Subscriber with priority Operator with forward transfer facility	} These signals are used for international working
11 12 13 14 15	II-11 II-12 II-13 II-14 II-15	} Spare for national use	

Note – Signals II-7 to II-10 are used solely for international working. The rest of the Group II signals only apply for national working and are translated to signals II-7 to II-10 in the outgoing international R2 registers (see Recommendation Q.480). This enables the System R2 register at an incoming exchange to distinguish between national and international calls.

4.2.4 Backward signals

4.2.4.1 Group A backward signals

Group A backward signals (for signal codes see Table 8/Q.441) are required to acknowledge Group I forward signals and under certain conditions, Group II forward signals. Besides that functional part of the compelled procedure, the Group A signals convey signalling information as detailed below:

- a) The *signal A-1, send next digit ($n + 1$)* requests transmission of the next digit ($n + 1$) after reception of digit n . The latest address signal sent is assumed to have the rank n within the signal sequence specified in Recommendation Q.107.
- b) The *signal A-2, send last but one digit ($n - 1$)* requests the transmission of digit ($n - 1$) after reception of digit n . The latest address signal sent is assumed to have the rank n within the signal sequence specified in Recommendation Q.107. This signal must not be used on a satellite link.

TABLE 8/Q.441
Group A backward signals

Combination (a)	Designation of the signal (b)	Meaning of the signal (c)
1	A-1	Send next digit ($n + 1$)
2	A-2	Send last but one digit ($n - 1$)
3	A-3	Address-complete, changeover to reception of Group B signals
4	A-4	Congestion in the national network
5	A-5	Send calling party's category
6	A-6	Address-complete, charge, set-up speech conditions
7	A-7	Send last but two digit ($n - 2$)
8	A-8	Send last but three digit ($n - 3$)
9	A-9	} Spare for national use
10	A-10	
11	A-11	Send country code indicator
12	A-12	Send language or discriminating digit
13	A-13	Send nature of circuit
14	A-14	Request for information on use of an echo suppressor (is an incoming half-echo suppressor required?)
15	A-15	Congestion in an international exchange or at its output

- c) The *signal A-3, address-complete, changeover to reception of Group B signals* indicates that the incoming R2 register at the incoming end needs no additional address digit and is about to go over to transmission of a Group B signal conveying information about the condition of the equipment at the incoming exchange or the condition of the called subscriber's line (see Recommendation Q.442).
- d) The *signal A-4, congestion in the national network* indicates:
- i) congestion of national links;
 - ii) congestion in selection stages of terminal international or national exchanges;
 - iii) occurrence of time-out or abnormal release of a System R2 register produced for any reason.
- For exception to these rules see n) below. See also signal B-4 and Recommendation Q.442.
- e) The *signal A-5, send calling party's category* requests transmission of a Group II signal.
- f) The *signal A-6, address-complete, charge – set-up speech conditions* indicates that the R2 register at the incoming end needs no additional digit, but will not send Group B signals. The call has to be charged on answer (see Recommendation Q.442).
- g) The *signal A-7, send last but two digit ($n - 2$)* requests the sending of digit ($n - 2$) after reception of digit n . The latest address signal sent is to have the rank n within the signal sequence specified in Recommendation Q.107. This signal must not be used on a satellite link.
- h) The *signal A-8, send last but three digit ($n - 3$)* requests the sending of digit ($n - 3$) after reception of digit n . The latest address signal sent is to have the rank n within the signal sequence specified in Recommendation Q.107. This signal must not be used on a satellite link.
- i) The *signals A-9 to A-10* are spares available for allocation of national meanings. The use of signals A-9 and A-10 in national networks can be decided by each Administration. These signals must not be used on international satellite links.
- j) The *signal A-11, send country code indicator* requests the country code indicator (transit indication) in acknowledgement of any forward signal. The signal is used in international transit calls only (see Recommendation Q.462). This signal must not be used on a satellite link.
- k) The *signal A-12, send language or discriminating digit* requests the language digit or the discriminating digit in acknowledgement of any forward signal. This signal must not be used on a satellite link.

- l) The *signal A-13, send nature of circuit* requests information regarding the nature of the circuits involved in the connection so far, i.e. satellite link (see Recommendation Q.480). This signal should only be used on a satellite link by bilateral agreement.
- m) The *signal A-14, request for information on use of echo suppressor* (is an incoming half-echo suppressor required?) indicates that an incoming international exchange acknowledges the discrimination digit or the language digit and that it is possible to insert an incoming half-echo suppressor in that incoming international exchange if required. This signal must not be used on a satellite link.
- n) The *signal A-15, congestion in an international exchange or at its output* indicates:
 - i) congestion on international links;
 - ii) congestion in selection stages at an international transit exchange or at a terminal international exchange and/or its outgoing links;
 - iii) occurrence of time-out or abnormal release of a System R2 register produced for any reason (see Recommendation Q.442).

4.2.4.2 Group B backward signals

Any Group B backward signal (for signal codes see Table 9/Q.441) acknowledges a Group II forward signal and is always preceded by the address-complete signal A-3 which indicates that the incoming R2 register has received all the Group I forward signals it requires from the outgoing international R2 register. Besides that functional part of the compelled procedure the Group B signals convey information about the condition of switching equipment in the incoming exchange, or about the condition of the called subscriber's line, to the outgoing international R2 register which can then take the necessary action as specified in Recommendation Q.474.

TABLE 9/Q.441
Group B backward signals

Combination (a)	Designation of the signal (b)	Meaning of the signal (c)
1	B-1	Spare for national use
2	B-2	Send special information tone
3	B-3	Subscriber line busy
4	B-4	Congestion (encountered after changeover from Group A signals to Group B signals)
5	B-5	Unallocated number
6	B-6	Subscriber's line free, charge
7	B-7	Subscriber's line free, no charge
8	B-8	Subscriber's line out of order
9	B-9	Spare for national use
10	B-10	
11	B-11	
12	B-12	
13	B-13	
14	B-14	
15	B-15	

The following Group B signals are specified:

- a) The *signal B-1 is spare* for national use and its meaning must be compatible with that of signal B-6 (see Recommendation Q.474).
- b) The *signal B-2, send special information tone* indicates that the special information tone should be returned to the calling party. This tone indicates that the called number cannot be reached for reasons not covered by other specific signals and that the unavailability is of a long term nature (see also Recommendation Q.35).

- c) The *signal B-3, subscriber's line busy* indicates that the line or lines connecting the called subscriber to the exchange are engaged.
- d) The *signal B-4, congestion* indicates that congestion condition is encountered after the changeover from Group A signals to Group B signals. The signal B-4 shall be sent in the conditions specified for signal A-4 [see § 4.2.4.1, d) and Recommendation Q.474, § 5.3.5.1].
- e) The *signal B-5, unallocated number* indicates that the number received is not in use (e.g. an unused country code, an unused trunk code or subscriber number that has not been allocated).
- f) The *signal B-6, subscriber's line free, charge* indicates that the called party's line is free and that the call has to be charged on answer.
- g) The *signal B-7, subscriber's line free, no charge* indicates that the called party's line is free but is not to be charged on answer. This signal permits non-chargeable calls without the need for transferring "no charge" information by line signals.
- h) The *signal B-8, subscriber's line out of order* indicates that the subscriber's line is out-of-service or faulty.
- i) *Signals B-9 to B-15* are spare for national use. Their meaning must not be incompatible with the sending of special information tone to the calling party (see Recommendation Q.474).

Recommendation Q.442

4.3 PULSE TRANSMISSION OF BACKWARD SIGNALS A-3, A-4, A-6 OR A-15

Under certain conditions it may prove necessary or desirable to send one of the *signals A-3, A-4, A-6 or A-15* without prior reception of a forward signal. This can occur when the incoming R2 register, after acknowledging a recognized forward signal, is unable to complete the call (for example during congestion) and the next forward signal does not appear on the line; or when the address-complete signal must be sent after the last forward address signal has been acknowledged. It may be desirable to deliberately suspend compelled signalling by acknowledging the last address digit, and signal I-15 if received, with signal A-1 to avoid prolonging the transmission time of certain interregister signals. Such a course should certainly be considered when there is a possibility that a relatively long period may elapse between reception of the last digit and detection of the condition of the called subscriber's line. The average duration of such periods during the busy hour must be limited to 3 seconds in view of the load on the carrier systems in the case of international calls.

The following conditions must be observed in transmitting pulsed interregister signals (see Figure 14/Q.442):

- the minimum delay between the end of transmission of the last signal of the compelled cycle and the start of transmission of the pulse signal must be 100 ms;
- the pulse duration must be 150 ± 50 ms.

Reception of a pulse signal must cause interruption of any forward signal in course of transmission at the outgoing R2 register. It is sometimes impossible, however, to prevent a forward signal from being sent by the outgoing R2 register at the very moment when one of the backward signals A-3, A-4, A-6 or A-15 is sent in pulse form by the register at the incoming end.

To reduce the operating difficulties which may result, the incoming R2 register must be so designed that no forward multifrequency combination can be recognized during and after the transmission of signals A-4, A-6 or A-15 in pulse form or during 300 ± 100 ms from the start of transmission of the address-complete signal A-3 in pulse form (900 ± 180 ms when signal A-3 is transmitted over a satellite link) (see Figures 14/Q.442 and 15/Q.442). When the end of a pulse signal A-3 has been recognized in the outgoing R2 register, a Group II signal must be sent forward. The incoming R2 register will acknowledge this signal by a Group B signal.

On recognizing signal A-4, A-6 or A-15 no forward signal is sent by the outgoing R2 register. The end of these backward signals must cause the dismissal of the outgoing and incoming R2 registers in accordance with Recommendation Q.475.

The conditions under which pulse transmission of the backward signals A-3, A-4, A-6 or A-15 apply are specified in Section 5.

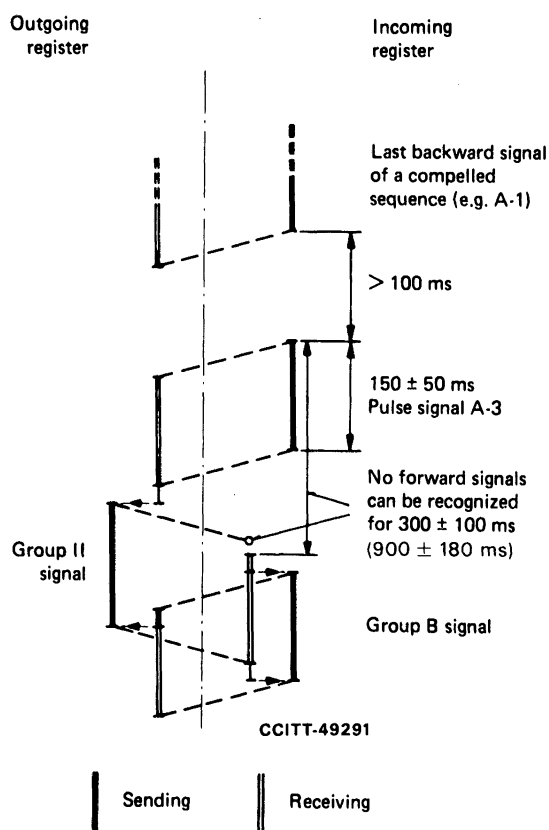


FIGURE 14/Q.442
Pulse transmission of signal A-3

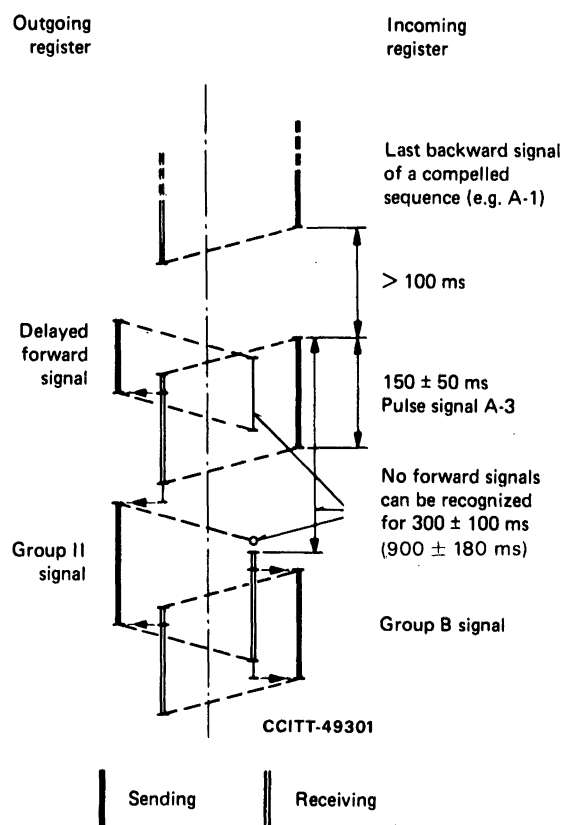


FIGURE 15/Q.442
Pulse transmission of signal A-3 when delayed forward signal appears

4.4 MULTIFREQUENCY SIGNALLING EQUIPMENT

Recommendation Q.450

4.4.1 GENERAL

Since System R2 can provide, in international working, end-to-end signalling from the outgoing international R2 register to an incoming R2 register at the called subscriber's local exchange (see Recommendation Q.440), the specifications for multifrequency signalling equipment take account of transmission conditions in both the international and national networks. The incoming national network may include both 4-wire and 2-wire links.

However, it is assumed in the following specifications for multifrequency signalling equipment for outgoing international R2 registers and incoming R2 registers in international exchanges including the incoming international exchange that the registers are directly connected by four wires to the virtual switching points of the links. The registers thus contain a multifrequency signalling equipment with a transmitting part and a receiving part, each separately connected to the GO and RETURN path of the 4-wire circuit respectively (see Figure 16/Q.451).

When the outgoing international R2 register is situated in a national exchange preceding the outgoing international exchange, or when the incoming R2 register is situated in a national exchange following the incoming international exchange, special conditions apply (see Recommendation Q.457).

The upper and lower limits specified for the sending level and for the national extension attenuation leave a degree of freedom, thus simplifying the problem of interworking among different networks. The outgoing international R2 register relays the interregister signals by the method described in Recommendation Q.478. The present specification ensures that the system has an adequate range.

Recommendation Q.451

4.4.2 DEFINITIONS

4.4.2.1 Multifrequency signalling equipment

During the exchange of multifrequency combinations the link or multi-link section is terminated at both ends by equipment allowing multifrequency combinations to be sent and received under mutual, compelled control, as indicated in Recommendation Q.440. Generally speaking, the equipment involved in the signal transfer at each end of the multi-link section has the following functions:

- reception of multifrequency combinations;
- protection against disturbances (e.g. 2-out-of- n -check, 0-out-of- n -check, see Recommendation Q.458);
- transfer of signals to and from the registers or equivalent equipment;
- sending of multifrequency combinations.

This equipment as a whole can be considered as a single functional unit, henceforth called the multifrequency signalling equipment.

The functions of the multifrequency signalling equipment may be distributed among a number of sub-units, according to the design principles adopted in each particular case; these, within certain limits, are open to choice.

For the purpose of the present specification, the multifrequency signalling equipment is divided into a sending part and a receiving part.

a) Four-wire multifrequency signalling equipment

Multifrequency signalling equipment connected to the speech path by two pairs of wires is called 4-wire multifrequency signalling equipment (see Figure 16/Q.451). In such cases, the speech path itself is generally 4-wire too.

In Figure 16/Q.451, point B is the output of the sending part and point C the input to the receiving part of the 4-wire multifrequency signalling equipment. The latter includes the devices for protection against disturbances and the equipment for transferring signals to the register or equivalent equipment.

b) Two-wire multifrequency signalling equipment

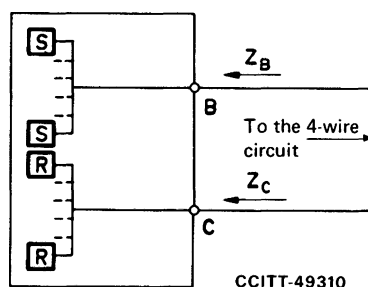
Because different frequencies are used for interregister signalling in the two directions of transmission, a single pair of wires connecting the speech path to the multifrequency signalling equipment can be used for simultaneous sending and reception of multifrequency combinations.

Multifrequency signalling equipment connected to the speech path by a single pair of wires is called 2-wire multifrequency signalling equipment (see Figure 17/Q.451).

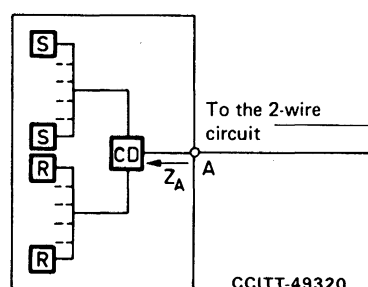
In Figure 17/Q.451, point A is the output of the sending part and, at the same time, the input to the receiving part. The latter includes the devices for protection against disturbances and for transferring signals to the register or equivalent equipment.

4.4.2.2 Operate and release times of the receiving part of the signalling equipment

The speed and reliability of the compelled interregister signal transfer is dependent on the operation and release times T_0 , T_R , T'_0 and T'_R defined below. These times include the minimum recognition times referred to in § 4.4.5.3 below.



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R = receiving part
S = sending part
CD = coupling device (e.g. hybrid, set of directional filters, etc.)

FIGURE 16/Q.451

FIGURE 17/Q.451

Four-wire multifrequency signalling equipment Two-wire multifrequency signalling equipment

a) *Operation time*

If the two frequencies making up a multifrequency combination are applied simultaneously to the input of the receiving part of the multifrequency signalling equipment, the time interval between the application of both frequencies and recognition of the multifrequency combination is called operation time T_0 .

If one of the two frequencies making up a multifrequency combination is applied to the input of the receiving part of the multifrequency signalling equipment somewhat after the other frequency, the time interval between the application of the second frequency and recognition of the multifrequency combination is called operation time T'_0 .

b) *Release time*

If the two frequencies making up a multifrequency combination are simultaneously cut off from the input of the receiving part of the multifrequency signalling equipment, the time interval between the cut-off and recognition of the end of the multifrequency combination is called release time T_R .

If one of the two frequencies making up a multifrequency combination is cut off from the input of the receiving part of the multifrequency signalling equipment somewhat after the other frequency, the time interval between the cut-off of the second frequency and recognition of the end of the multifrequency combination is called release time T'_R .

4.4.2.3 *Internal operation time*

a) If the equipment at a switching centre has to analyse one or more of the signals received and if it has to carry out routing and switching operations before being able to determine which backward signal should be sent, it can delay completion of the compelled signalling cycle. Such delay depends on the function the centre has and on the design of the switching equipment used in it. The delay cannot therefore be specified.

The time required by an incoming R2 register to determine which backward signal to send in reply to a forward signal is denoted as T_{int1} . The duration of the cycle is increased by the whole of this time, which must therefore be kept to a minimum. Its value will be zero if the signal to be sent is already determined.

b) An outgoing R2 register sends a forward signal after interpreting the backward signal it has received. The time required to determine the appropriate signal is denoted as T_{int2} .

c) At the end of a forward signal the incoming R2 register may have to perform certain functions in order to be ready to receive the next signal. The time required for these functions is denoted as T_{int3} .

4.4.3 REQUIREMENTS RELATING TO TRANSMISSION CONDITIONS

4.4.3.1 Impedances

The impedance Z_A measured at the terminals A (see Figure 17/Q.451) of a 2-wire multifrequency signalling equipment will have a nominal value equal to the nominal terminating impedance Z_T of the links at the exchange under consideration and will be balanced to earth. In most cases this value Z_T will be 600 ohms non-reactive. The impedance Z_A will then satisfy the conditions:

$$20 \log \left| \frac{600 + Z_A}{600 - Z_A} \right| \geq 10 \text{ dB} \quad (1)$$

in the 300-3400 Hz band, and

$$20 \log \left| \frac{600 + Z_A}{600 - Z_A} \right| \geq 16 \text{ dB} \quad (2)$$

in the 520-1160 Hz and 1360-2000 Hz bands.

The impedances Z_B and Z_C measured at the terminals B and C (see Figure 16/Q.451) of a 4-wire multifrequency signalling equipment will have a nominal value equal to the nominal terminating impedance Z_T at the exchange under consideration and will be balanced to earth. In most cases this value Z_T will be 600 ohms non-reactive. The impedances Z_B and Z_C will then satisfy condition (1) above in the 300-3400 Hz band and condition (2) above in the 520-1160 Hz or 1360-2000 Hz bands, according to the set of frequencies generated by the equipment concerned.

All the above requirements must be met, whether signalling frequencies are being transmitted or not.

4.4.3.2 Echoes

The balance return loss presented to the international link by different national networks varies considerably. Recommendation G.122 gives the desirable values based on transmission requirements and these values could hardly be improved on simply in order to facilitate signalling, especially as the balance return loss would then have to be very high.

The multifrequency signalling equipment must therefore function with an echo signal. Allowance is made for this in the test conditions (see Recommendation Q.455).

In order to eliminate disturbing and unwanted double-echo effects, outgoing international R2 registers must be provided with 4-wire signalling equipment; the 4-wire loop will then remain open at the outgoing end of the multi-link section during signalling.

For the same reason, it is recommended that 4-wire signalling equipment be provided whenever 4-wire switching equipment is used.

4.4.3.3 Location and connection of multifrequency signalling equipment associated with outgoing international R2 registers

The multifrequency signalling equipment of the outgoing international R2 registers is assumed to be directly connected to the virtual switching point of the links in an international exchange. This equipment may be situated in a national switching centre of the country of origin on the national network side of the outgoing international exchange provided that the 4-wire extension links between this centre and the outgoing international exchange have the same upper limit for the standard deviation of transmission loss variations with time (1 dB) as the international links.

Should the national extension links not have a nominal transmission loss of 0.5 dB between the national exchange and the virtual switching point in the outgoing international exchange, there must be suitable compensation of the power level of the multifrequency combinations.

4.4.4 THE SENDING PART OF THE MULTIFREQUENCY SIGNALLING EQUIPMENT

4.4.4.1 Signalling frequencies

The composition of the multifrequency combinations is specified in Recommendation Q.441.

The frequencies in the forward direction are:

$$f_0 = 1380, f_1 = 1500, f_2 = 1620, f_3 = 1740, f_4 = 1860, f_5 = 1980 \text{ Hz.}$$

The frequencies in the backward direction are:

$$f_0 = 1140, f_1 = 1020, f_2 = 900, f_3 = 780, f_4 = 660, f_5 = 540 \text{ Hz.}$$

The frequency variation at the sending point must not exceed ± 4 Hz relative to the nominal value.

4.4.4.2 Absolute power level transmitted

a) Four-wire multifrequency signalling equipment for outgoing international R2 and incoming R2 registers assumed to be directly connected to the virtual switching point in an international exchange:

- i) The absolute power level of each non-modulated signalling frequency transmitted by the sending part of the multifrequency signalling equipment in the international exchange concerned will have a nominal value of $-3.5 - 8 = -11.5$ dBm with a tolerance of ± 1 dB.
- ii) The difference in level between the two signalling frequencies making up a multifrequency combination must be less than 1 dB.

The tolerances specified apply to the sending point itself, i.e. terminal B in Figure 16/Q.451.

b) Four-wire multifrequency signalling equipment for outgoing international R2 registers situated in a national exchange further down in the network of the country of origin:

- i) The sending-level conditions mentioned above under a) are applicable in such national exchanges, provided that the national 4-wire extension links between the national exchange and the outgoing international exchange have the same nominal transmission loss (0.5 dB) and the same upper limit of standard deviation of transmission loss variations with time (1 dB) as the international links.
- ii) If these national links do not have a nominal transmission loss of 0.5 dB, the level of interregister frequencies must be compensated as required.

c) Multifrequency signalling equipment for incoming R2 registers in national exchanges:

The nominal absolute power level N of a single signalling frequency transmitted by the sending part of the multifrequency signalling equipment (2-wire or 4-wire) in any national exchange must be chosen within the limits:

$$N \geq A_b + 0.5 m + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 31 \text{ dBm} \quad (1)$$

and

$$N \leq A_b - 11.5 \text{ dBm} \quad (2)$$

or

$$N \leq A_b + 0.5 m - 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 9 \text{ dBm} \quad (3)$$

whichever of (2) or (3) yields the lower value.

In order to avoid marginal operation, it is recommended that levels higher than the minimum levels given by formula (1) be specified.

In these formulae:

- m = the number of 4-wire links switched in tandem between the outgoing international R2 register and the incoming international exchange. The number m thus includes the national 4-wire extension links in the country of origin (see Recommendation Q.457) and the international links. In formula (1) m should always be given the maximum value 4. In formula (3), m should be given all its values, from minimum to maximum, and the lowest value so obtained or derived from formula (2) is to be taken as the upper limit of N .
- k = the number of national 4-wire extension links switched in tandem between the incoming international terminal exchange and the national exchange. The maximum value of k will be 4.
- A_b = the nominal transmission loss at 800 Hz in the backward direction between the output terminals of the sending part of the multifrequency signalling equipment of the incoming R2 register in the exchange under consideration and the *send* side of the virtual switching point of the backward speech path in the incoming international exchange.

Formulae (1), (2) and (3) were derived as shown in Annex A to Section 4.

The variation in level relative to the nominal value N chosen for a given exchange must not exceed ± 1 dB.

However, the difference in level between the two signalling frequencies making up a multifrequency combination must not exceed 1 dB.

4.4.4.3 *Signalling frequency leak level*

The total power level of the leak current transmitted to line must be:

- a) at least 50 dB below the nominal level of one signalling frequency when no multifrequency combination is being sent;
- b) at least 30 dB below the level of either of the signalling frequencies when a multifrequency combination is being sent. Furthermore, any single leak current must be at least 34 dB below the level of either of the signalling frequencies when a multifrequency combination is being sent.

4.4.4.4 *Harmonic distortion and intermodulation*

The total power level of all frequencies due to harmonic distortion and intermodulation within the frequency band 300-3400 Hz must be at least 37 dB below the level of one signalling frequency.

4.4.4.5 *Time tolerance for multifrequency combinations*

The time interval between the start of sending of each of the two frequencies constituting a multifrequency combination must not exceed 1 ms.

The time interval between the cessation of sending of each of the two frequencies must not exceed 1 ms.

Recommendation Q.455

4.4.5 THE RECEIVING PART OF THE MULTIFREQUENCY EQUIPMENT

4.4.5.1 *Sensitivity range*

The power levels given below relate to the nominal impedance of the receiving part of the multifrequency signalling equipment.

The receiving part of the multifrequency signalling equipment shall have a sensitivity range of -35 dBm to -5 dBm.

4.4.5.2 Operate and release time requirements

The operating and release times of the receiving part of the multifrequency signalling equipment depend on the design and, for a given design, on:

- the time difference between the instants of reception of each of the two frequencies making up a multifrequency combination;
- the level of each of the two frequencies;
- the difference in level between the two frequencies;
- the level, spectrum and instant of onset of the noise.

The factors vary with transmission conditions. With certain types of switching equipment it may prove advisable to embody devices to counteract low-frequency disturbances in the multifrequency signalling equipment.

Time requirements have been specified for two types of *multifrequency test combinations*, A and B, applied to the input of the receiving part of the multifrequency signalling equipment in the presence of disturbing signals as specified below.

When test combinations and disturbing frequencies as specified under a) to c) below are applied to the terminals A (see Figure 17/Q.451) of 2-wire multifrequency signalling equipment or to the terminals C (see Figure 16/Q.451) of 4-wire multifrequency signalling equipment, the following time requirements must be met:

- for type A test combinations:

$$T_0 + T_R \leq 70 \text{ ms}$$

- for type B test combinations:

$$T_0 + T_R \leq 80 \text{ ms}$$

- for test combinations of types A and B:

$$(T'_0 + T'_R) \leq (T_0 + T_R) + 5 \text{ ms}$$

For definitions of T_0 , T'_0 , T_R , and T'_R see Recommendation Q.451.

For the third requirement, the only cases to be considered are those in which the frequency first appearing is also the first to disappear (transmission delay effect). The T'_0 and T'_R time requirements are specified to ensure proper functioning of the multifrequency signalling equipment when the received multifrequency combination is affected by group delay distortion, for example. The appropriate procedure for this test depends on the design of the equipment to be tested; in many cases it will be convenient to assume that a delay of one second or more for the second frequency constitutes the most unfavourable case.

When a multifrequency combination has caused the receiving part of the multifrequency signalling equipment to operate, the latter cannot release if the signal frequencies are interrupted for not more than 7 ms. A method of improving the system reliability in case of interrupted signals is described in Annex B of Section 4.

a) *Multifrequency test combinations type A*

- The multifrequency test combination consists of any 2-out-of- n combination of the n signalling frequencies;
- each frequency differs from the nominal frequency by not more than ± 5 Hz;
- the absolute power level of each of the two frequencies of the multifrequency combination lies between -5 dBm and -20 dBm;
- the difference in level between the two frequencies is not greater than 3 dB.

b) *Multifrequency test combinations type B*

- The multifrequency test combination consists of any 2-out-of- n combination of the n signalling frequencies;
- each frequency differs from the nominal frequency by not more than ± 10 Hz;
- the absolute power level of each of the two frequencies of the multifrequency combination lies between -5 dBm and -35 dBm;
- the difference in level between the two frequencies is not greater than 5 dB for adjacent frequencies and 7 dB for non-adjacent frequencies.

c) *Disturbing frequencies*

The disturbing frequencies to be applied are:

- in all cases one or more of the n frequencies for which the receiving part under test is designed, with a total power level of -55 dBm or less, when no multifrequency test combination is being applied;
- when a multifrequency test combination is applied, one or more of the $(n - 2)$ remaining frequencies with a total power level 20 dB below the highest test combination frequency level during application of the test combination;
- for testing the receiving part of 4-wire multifrequency signalling equipment in an outgoing international R2 register:

any multifrequency combination consisting of two frequencies out of the forward group of frequencies, each of these two frequencies having a level of 13.5 dB above the lowest test-combination frequency level in the backward direction; an upper limit of -12.5 dBm is nevertheless specified for the level of the disturbing signal.

System R2 interregister signalling may be used in the country of origin on the national links preceding the out-going international R2 register. In that case, the receiving part of 4-wire multifrequency signalling equipment connected to the forward speech path of the national 4-wire links may have to function in the presence of frequencies used in the backward direction. No general specification can be given for the level of these disturbing frequencies; it is recommended that Administrations formulate their own specifications.

- for testing the receiving part of 2-wire multifrequency signalling equipment:

any multifrequency combination at the highest level used in operational signalling (measured at point A, Figure 17/Q.451) by the sending part of the 2-wire multifrequency signalling equipment concerned.

4.4.5.3 *Non-operate and non-recognition requirements*

The receiving part of the multifrequency signalling equipment must remain in the *non-operate* state when the following disturbances, singly or together, are the only signals that are applied to the terminals A or C (see Figures 17/Q.451 and 16/Q.451):

- any single pure sine wave or any combination of two pure sine waves, each with a power level of -42 dBm within the 300-3400 Hz band;
- any combination of two pure sine waves, each with a power level of -5 dBm within the 1300-3400 Hz band for the set of frequency receivers used in the backward direction; and within the 330-1150 Hz and 2130-3400 Hz bands for the set of frequency receivers used in the forward direction.

Furthermore, when signalling tones have activated the receiving part of the multifrequency signalling equipment, this must assume the *non-operate* state when the signalling tones are removed in the presence of these same disturbances, singly or together, at the above-mentioned terminals.

The receiving part of the multifrequency signalling equipment must not recognize a combination consisting of two signalling frequencies out of the set of frequencies normally used in the transmission direction considered, each having a level not exceeding -5 dBm and a duration of less than 7 ms.

The receiving part of the multifrequency signalling equipment must not recognize a combination consisting of two signalling frequencies used in the transmission direction considered, having a difference in level of 20 dB or more.

4.4.5.4 *Influence of transient disturbances* (see also Recommendation Q.458)

The recognition of faulty signals due to short-lived transient conditions can largely be avoided if a multifrequency combination is recognized only after a specified minimum time, during which two, and only two, of the individual receivers are active and if the absence of multifrequency combinations is recognized only after a minimum time, during which all individual receivers are at rest. These times are included in the operating and release times T_0 and T_R .

Typical transient disturbances, such as clicks, change of polarity, etc., generated by the switching equipment, must not change signals transferred from the receiving part of the signalling equipment to the register.

It is recommended that Administrations formulate their own specification for a test method according to the type of disturbances encountered in their switching equipment.

4.5 RANGE, SPEED AND RELIABILITY OF INTERREGISTER SIGNALLING

Recommendation Q.457

4.5.1 RANGE OF INTERREGISTER SIGNALLING

4.5.1.1 *Number of international links*

The number of international links switched in tandem for establishing an international connection using System R2 must not exceed 4 (see Recommendation Q.440).

Assumptions for the transmission loss in 4-wire international links:

- i) nominal transmission loss at 800 Hz: 0.5 dB (Recommendation G.101, § 5);
- ii) standard deviation of transmission loss variations with time must not exceed 1 dB [Recommendation G.151, § 3, a)];
- iii) the difference between the mean value and the nominal is assumed to be 0 [as in Recommendations G.122, § 1.2), and G.131, § 1].

4.5.1.2 *Number of national links*

a) *Outgoing international R2 register and number of national 4-wire extension links in the country of origin*

The outgoing international R2 register is always provided with 4-wire multifrequency signalling equipment and the 4-wire loop will be open during interregister signalling.

The outgoing international R2 register must be placed in an exchange from where the incoming international exchange in the country of destination is reached by not more than four 4-wire links switched in tandem (see Recommendation Q.440).

It is understood that the national 4-wire links in the country of origin shall have the same standard deviation of transmission loss variations with time (1 dB) as the international links and that, if these national links do not have the same nominal transmission loss as the international links (0.5 dB), appropriate compensation of the multifrequency combination levels will be made in both directions of transmission.

b) *Number (k) of national 4-wire extension links in the country of destination*

Not more than four national 4-wire extension links may be used.

Forward transmission loss in the country of destination:

- i) The standard deviation of transmission loss variations with time in the national 4-wire extension links in the country of destination must not exceed 1 dB.

- ii) The nominal transmission loss at 800 Hz in the forward direction (A_f) between the virtual switching point in the incoming international exchange and any incoming R2 register in the country of destination must not exceed:

11.4 dB for a country using 3 national 4-wire extension links at the most

or

11.0 dB for a country using 4 national 4-wire extension links at the most,
and must never be less than:

$$A_{f\min.} = -2.5 - 0.5 m + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} \text{ dB.}$$

The values for the minimum forward transmission loss $A_{f\min.}$ resulting from this formula are shown in Table 10/Q.457 (for the definitions of m and k see Recommendation Q.454). In practice the forward transmission loss must not fall below these values.

The formula has been determined as shown in Annex C to Section 4.

When System R2 end-to-end signalling is applied in a national network, the 4-wire links involved may not conform to the characteristics specified by the CCITT for international circuits. Also, national transmission plans may be based on principles different from those of the international transmission plan. Consequently, the range over which end-to-end signalling is possible must be established using calculations, e.g. as shown in Annex C to Section 4 (see also §§ 4.5.1.3 and 4.5.1.4 below).

TABLE 10/Q.457
Minimum forward transmission loss
in the country of destination

$k \backslash m$	1	2	3	4
1	0.3	0.6	0.7	0.8
2	1.1	1.2	1.3	1.3
3	1.7	1.8	1.8	1.7
4	2.3	2.3	2.2	2.2

4.5.1.3 Total attenuation distortion

It has been assumed that at all frequencies within the 530-1990 Hz band the overall attenuation distortion relative to 800 Hz between the outgoing international R2 register and any incoming R2 register will not exceed ± 3 dB. Attention is drawn to the fact that on some national connections these assumptions might not be fulfilled.

As type B test signals (see Recommendation Q.455) allow for a 5 dB difference in level between two adjacent signalling frequencies, and a 7 dB difference between two non-adjacent signalling frequencies, a 4 dB attenuation distortion of the multi-link section can be allowed for two adjacent frequencies and a 6 dB distortion for two non-adjacent frequencies, provided that the level of the weakest signalling frequency is not lower than -35 dBm at the terminals of the receiving part of the multifrequency signalling equipment.

The values 4 dB and 6 dB were obtained by allowing for a 1 dB difference in sending level.

4.5.1.4 Intermodulation

A multifrequency signalling system in conformity with the above specifications will allow satisfactory working over a multi-link section introducing intermodulation products from two signalling frequencies and falling within the 520-1160 Hz and 1360-2000 Hz bands, the level of each of such products being at least 24 dB below the highest signal frequency level.

4.5.2 Build-up and time specification of a complete forward compelled signalling cycle

Figure 18/Q.457 shows in detail the build-up and time sequence of a compelled signalling cycle.

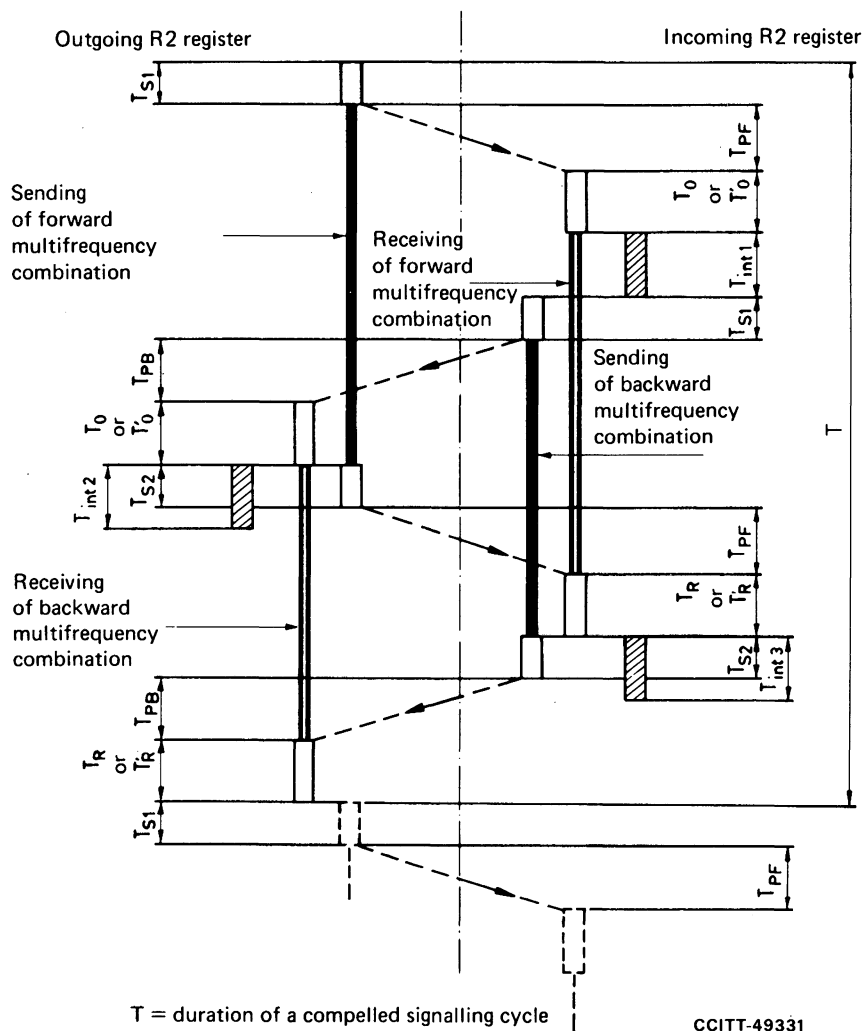


FIGURE 18/Q.457
Sequence of a complete compelled signalling cycle

In this figure:

T_{PF} denotes the transmission delay of the slower of the two frequencies of a forward multifrequency combination;

T_{PB} denotes the transmission delay of the slower of the two frequencies of a backward multifrequency combination;

T_0 and T'_0 denote the operating times as defined in Recommendation Q.451;

T_R and T'_R denote the release times as defined in Recommendation Q.451;

T_{int1} , T_{int2} and T_{int3} denote the internal operation times as defined in Recommendation Q.451.

If the values of T_{int2} and T_{int3} lie within certain limits, they do not contribute to the total duration of the compelled signalling cycle, as can be seen from Figure 18/Q.457.

T_{S1} and T_{S2} denote respectively the time required for starting and stopping the sending of a multifrequency combination (switching-on or switching-off times, exclusive of logic operations).

It thus appears that the total duration T of a complete compelled signalling cycle is given by the formula:

$$T = 2(T_{PF} + T_{PB}) + \left\{ \begin{array}{c} (T_0 + T_R)_D + (T_0 + T_R)_A \\ \text{or} \\ (T'_0 + T'_R)_D + (T'_0 + T'_R)_A \end{array} \right\} + T_{int1} + (T_{S1} + T_{S2})_D + (T_{S1} + T_{S2})_A$$

The subscripts D and A apply respectively to the outgoing and the incoming registers.

T_{PF} and T_{PB} depend on the propagation characteristics of the forward and backward speech paths respectively and therefore cannot be specified.

A value of 10 ms for T_{PF} and T_{PB} can be considered as typical, e.g. for average terrestrial regional connections and 320 ms for circuits including a satellite link.

The maximum value of $T_0 + T_R$ has been fixed at 70 ms. A value of 35 ms could be taken in a certain number of cases as representing the minimum duration of $T_0 + T_R$.

T_{int1} , T_{int2} and T_{int3} are dependent on the type of exchange and therefore cannot be specified; but their contribution to the total duration of the compelled signalling cycle must be kept as small as possible.

If the influence of T_{int1} , T_{int2} and T_{int3} is ignored, and if the extreme values of $T_0 + T_R$ and for $T_{S1} + T_{S2}$ are assumed to be identical for the outgoing and the incoming register, the extreme values of $T_{S1} + T_{S2}$ being taken as $5 \text{ ms} \leq T_{S1} + T_{S2} \leq 10 \text{ ms}$ and if the value of 10 ms indicated above as typical is adopted for T_{PF} and T_{PB} , the probable extreme values of the compelled signalling cycle T would be:

for terrestrial connections: $120 \text{ ms} \leq T \leq 200 \text{ ms}$.

for circuits including a satellite link: $1080 \text{ ms} \leq T \leq 1440 \text{ ms}$.

The signalling rates would be between approximately 8 and 5 signalling cycles per second for terrestrial circuits. These values are not absolute limits; the signalling cycle could, for example, be longer on a complex connection or in the presence of noise or other conditions approaching those of type B test combinations (see Recommendation Q.455).

Recommendation Q.458

4.5.3 RELIABILITY OF INTERREGISTER SIGNALLING

4.5.3.1 General

In signal transmission, reliability and speed are to some extent conflict requirements: the slower the signalling, the more reliable it is likely to be. System R2 combines the two essential requirements of speed and reliability, since it is a compelled system, adapting its signalling speed to the working conditions with minimum loss of reliability.

System R2 is protected against the acceptance of faulty information (multifrequency combinations consisting either of one frequency only or of more than two frequencies) by means of the 2-out-of- n method of checking the number of frequencies received.

This protection is inoperative in the case of disturbances (noise, clicks, etc.) activating two, and only two, of the single frequency receivers; nor does it prevent the release of all the receivers (thus wrongly indicating the end of a multifrequency combination) in the event of an interruption caused by disturbances during transmission of a multifrequency combination.

Disturbances causing the operation of two single frequency receivers or the release of all the receivers are due mainly to short-lived, transient conditions. The recognition of faulty information due to such conditions can therefore largely be avoided by so designing the receiving part of the multifrequency signalling equipment that a multifrequency combination will be recognized only after a specified minimum time. During this time two, and only two, of the individual receivers are active and the absence of multifrequency combinations will be recognized

only after a specified minimum time, during which all individual receivers are at rest. The degree of protection against faults due to the above-mentioned conditions is dependent on these times, which are included in the operating and release times defined for the receiving part of the multifrequency signalling equipment in Recommendation Q.451.

4.5.3.2 Error rate for compelled working

The test of the multifrequency signalling equipment as a whole consists in continuous, compelled transmission of multifrequency combinations.

It must be ensured that all possible combinations of the forward and backward multifrequency combinations have equal probability of occurrence during the test period.

The error rate is observed at the receiving part at both ends of the link and is defined, for each end, as the number of errors divided by the number of combinations sent by the corresponding sending parts at each end of the link.

It is for each Administration to define the sources of permanent and impulsive noise to be applied to the interface between the sending and receiving parts in the light of its experience and local conditions.

The compelled working may be tested, on the one hand, by using test combinations of Type A (see Recommendation Q.455) in the presence of noise at a power level of -40 dBm and a uniform power distribution in the 300-3400 Hz band (filtered white noise) and, on the other hand, by using Type B test combinations in the presence of noise at a power level of -45 dBm and a uniform power distribution in the 300-3400 Hz band.

The error rates in these conditions will be:

- for Type A test combinations and noise at -40 dBm: $\leq 10^{-5}$;
- for Type B test combinations and noise at -45 dBm: $\leq 10^{-4}$.

ANNEX A

(to Section 4)

(see Recommendation Q.454)

Development of formulae for the power level of signalling frequencies

The formulae (1), (2), and (3) of Recommendation Q.454 describing the nominal absolute power level N of a transmitted single signalling frequency were derived as follows:

1. The nominal transmission loss in the backward direction between the incoming R2 register and the outgoing international R2 register is given by (see Recommendation Q.457):

$$A_b + 0.5 m \text{ dB.}$$

2. On the assumption that the contribution of the national 2-wire links to transmission loss variations with time is negligible and with allowance for the standard deviation of transmission loss variations with time of the international and national 4-wire circuits and in the exchanges (see CCITT Recommendation Q.45: $\sigma = 0.2$ dB), the total transmission loss variation for a 1% probability of it being exceeded is given by:

$$\pm 2.3 \sqrt{(m + k) + (m + k + 1) (0.2)^2} \text{ dB.}$$

3. Given a total attenuation distortion of ± 3 dB relative to 800 Hz (see Recommendation Q.457) and a tolerance of ± 1 dB on the nominal power level N , the lower and upper limits of the level received in the outgoing international R2 register will be:

$$N - A_b - 0.5 m - 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 3 - 1 \text{ dBm}$$

and

$$N - A_b - 0.5 m + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} + 3 + 1 \text{ dBm.}$$

respectively.

4. The receiving part of the multifrequency signalling equipment has a sensitivity range between
 -35 dBm and -5 dBm (see Recommendation Q.455).

The minimum value of N is thus given by:

$$N - A_b - 0.5 m + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 4 = -35 \text{ dBm}$$

hence

$$N \geq A_b + 0.5 m + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 31 \text{ dBm} \quad (1)$$

The maximum value of N is given by:

$$N - A_b - 0.5 m + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} + 4 = -5 \text{ dBm}$$

hence

$$N \leq A_b + 0.5 m - 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 9 \text{ dBm} \quad (3)$$

5. The nominal level of the backward signals at the virtual switching point of the incoming international exchange must not be higher than -11.5 dBm; thus

$$N - A_b \leq -11.5 \text{ dBm}$$

hence

$$N \leq A_b \leq -11.5 \text{ dBm.} \quad (2)$$

ANNEX B

(to Section 4)

(see Recommendation Q.455)

Possible method of improving protection from interruptions

If the receivers are locked through an internal function of the registers until the times Q and S (see Figure B-1) the intervals during which there is a risk that interruptions may cause their release are reduced by PQ and RS respectively.

This method can be used on both terrestrial and satellite circuits.

To ensure that the duration of the compelled signalling cycle is not prolonged on terrestrial circuits (short transmission delay). PQ and RS must be calculated with:

$$T_{PF} = T_{PB} \approx 0 \text{ ms: } PQ \leq T_{int1} + T_{S1} + T_0 + T_{S2}$$

and

$$RS \leq T_{S2} + T_R + T_{S2}$$

To ensure that the duration of the compelled signalling cycle is not prolonged on satellite circuits (long transmission delay) PQ and RS must be calculated with:

$$T_{PF} + T_{PB} \approx 250 \text{ ms: } PQ \leq 500 \text{ ms} + T_{int1} + T_{S1} + T_0 + T_{S2}$$

and

$$RS \leq 500 \text{ ms} + T_{S2} + T_R + T_{S2}$$

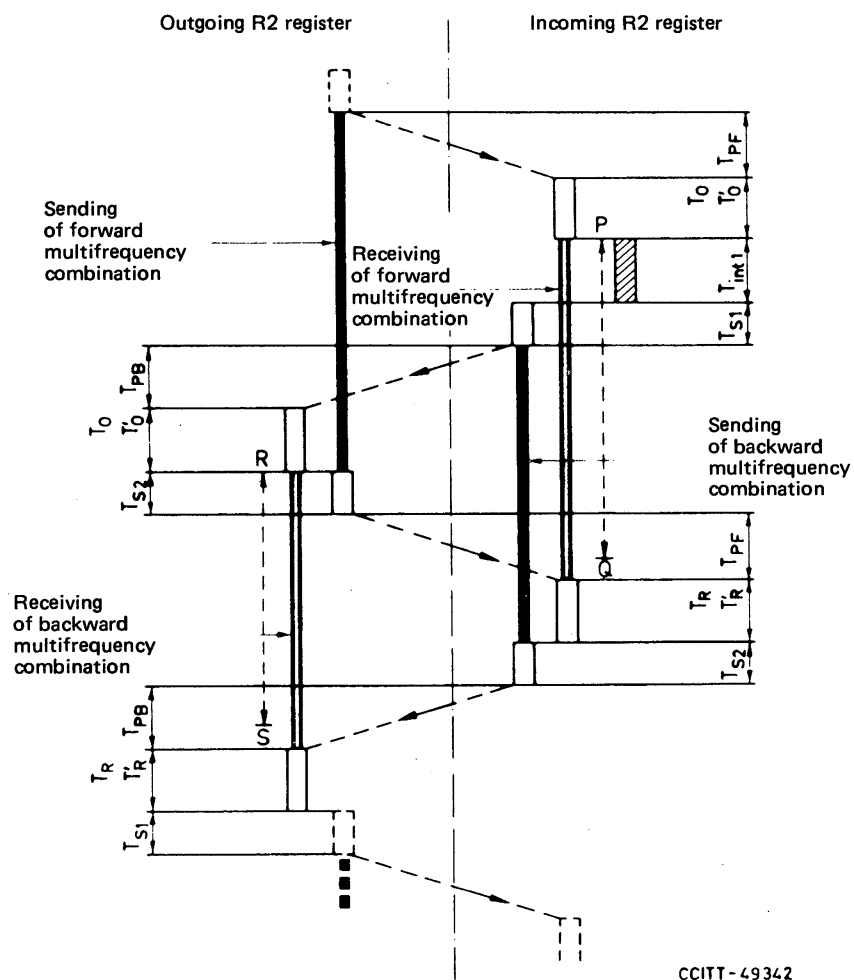


FIGURE B-1

ANNEX C

(to Section 4)

(see Recommendation Q.457)

Development of a formula for the admissible forward transmission loss in a country of destination

The formula used in Recommendation Q.457 for the calculation of the minimum forward transmission loss $A_{f\min}$ in a country of destination was determined as follows:

1. According to Recommendation Q.454 the lowest and highest sending levels will be, respectively,

$$-11.5 - 1 = -12.5 \text{ dBm}$$

and

$$-11.5 + 1 = -10.5 \text{ dBm.}$$

2. Let A_f be the nominal transmission loss at 800 Hz in the forward direction, between the virtual switching point in the incoming international exchange and the incoming R2 register concerned.

The total nominal transmission loss between the outgoing international R2 register and the incoming R2 register will then be:

$$A_f + 0.5 \text{ m dB.}$$

3. On the assumption that the contribution of the national 2-wire links to transmission loss variations with time is negligible, and that the standard deviation of transmission loss variation in the exchange is 0.2 dB (see Recommendation Q.45), the total transmission loss variation, calculated for a 1% probability of it being exceeded will be:

$$\pm 2.3 \sqrt{(m + k) + (m + k + 1) 0.2^2} \text{ dB.}$$

4. With allowance for a total attenuation distortion of ± 3 dB relative to 800 Hz (see Recommendation Q.457) the lower and upper limits of the level of each frequency at the input of the incoming R2 register will be respectively:

$$-12.5 - A_f - 0.5 \text{ m} - 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 3 \text{ dBm}$$

and

$$-10.5 - A_f - 0.5 \text{ m} + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} + 3 \text{ dBm.}$$

5. The receiving part of the multifrequency signalling equipment has a sensitivity range of -35 dBm to -5 dBm.

6. The maximum value of A_f is thus given by:

$$-12.5 - A_{f \max.} - 0.5 \text{ m} - 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} - 3 = -35 \text{ dBm}$$

hence

$$A_{f \max.} = 19.5 - 0.5 \text{ m} - 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} \text{ dB.}$$

7. The minimum value for A_f is given by:

$$-10.5 - A_{f \min.} - 0.5 \text{ m} + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} + 3 = -5 \text{ dB}$$

hence

$$A_{f \min.} = -2.5 - 0.5 \text{ m} + 2.3 \sqrt{(m + k) + (m + k + 1) 0.04} \text{ dB.}$$

According to Recommendation Q.457, the maximum number of 4-wire links with *international* characteristics is $m = 4$.

The maximum number of national 4-wire extension links is $k = 4$.

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SECTION 5

SIGNALLING PROCEDURES

A major characteristic of System R2 is the inherent flexibility in the interregister signalling procedures which allow efficient signal information transfer, adapted to the particular requirements relating to different call types, traffic conditions and switching equipments. This flexibility is primarily achieved by the principle that the interregister signalling sequence is controlled by the incoming R2 register by means of backward signals.

In this context the function of an outgoing R2 register is basically to respond with the forward signal requested by the incoming R2 register. At the incoming R2 register the determination of the backward signal to be sent, thus controlling the signalling sequence, is closely related to the analysis necessary to determine the routing and handling of the call.

In this Section the signalling procedures are specified. Although System R2 in principle allows a high degree of freedom in the combination of these procedures within the signalling sequence for call set-up, the procedures to be used for normal international calls connected via terrestrial links are described below. These procedures may vary when a satellite link is employed in a connection because the register at the incoming end of a satellite link also acts as an outgoing R2 register (see Recommendation Q.440, § 4.1.1). For national application of System R2 the signalling sequences to be applied have to be defined in accordance with the limitations of the present specifications by the Administration concerned.

Recommendation Q.460

5.1 NORMAL CALL SET-UP PROCEDURES FOR INTERNATIONAL WORKING

5.1.1 General

During call set-up an outgoing international R2 register is connected to an international link. This register signals to at least one incoming R2 register situated in an international exchange and possibly, depending upon the routing, to as many as 4 successive incoming R2 registers in international exchanges and 4 successive incoming R2 registers situated in national exchanges in the destination country where System R2 is employed.

The duration of the normal call set-up procedure can vary because different phases of the signalling sequence between the outgoing international R2 register and successive incoming R2 registers may be repeated.

5.1.2 SIGNALLING BETWEEN THE OUTGOING INTERNATIONAL R2 REGISTER AND AN INCOMING R2 REGISTER IN AN INTERNATIONAL EXCHANGE

The address signals from an operator or a subscriber must be stored in an outgoing international R2 register. When a sufficient number of digits is available an outgoing link is selected and a seizing (line) signal is sent. When the seizing signal is recognized an incoming R2 register is associated with the link.

Immediately the outgoing link is seized the outgoing international R2 register sends the first interregister signal.

5.1.2.1 *Signalling to an international transit exchange*

When the outgoing link is to an international exchange from which a transit routing is required to the destination country, the first interregister signal sent is a country code indicator. This is one of signals I-11, I-12, I-14 depending upon the requirement for echo suppressors (see Recommendation Q.479).

On recognition of a country code indicator the incoming R2 register determines that the call is to be internationally transit switched. The incoming R2 register sends signal A-1 when it requests the first digit of the country code. The outgoing international R2 register sends this address digit (a signal I-1 to I-10). The incoming R2 register may send signal A-1 to request the next digit.

The incoming R2 register examines the address digit(s) and if a further digit (or digits) is required for routing, signal A-1 is sent to request the next digit.

When sufficient digits are stored at the incoming exchange to permit the call to be routed to the next exchange, the backward signal is determined by the nature of the signalling system employed on the outgoing link.

a) If the outgoing link employs System R2, one of two backward signals is sent immediately the outgoing link is seized:

- i) If the outgoing link is to another international transit exchange from which a transit routing is required to the destination country, signal A-11 is sent to request repetition of the country code indicator.

On recognition of signal A-11 the outgoing international R2 register sends a country code indicator as the first signal to be received by the incoming R2 register in the next international transit exchange. This is one of signals I-12 or I-14. If signal I-11 was sent initially, signal I-14 is sent subsequently.

On recognition of a country code indicator the incoming R2 register determines that the call is to be internationally transit switched. The signalling procedure which follows is identical to that described above.

- ii) If the outgoing link is to an incoming international exchange in the destination country, signal A-12 is sent to request a language or discriminating digit.

In both these cases after the backward signal is sent and the compelled signalling sequence is complete, the transit exchange releases the incoming R2 register and through-connects the speech-path between the outgoing exchange and the next exchange.

b) If the outgoing link employs a signalling system other than System R2, then the acting incoming R2 register is the last incoming R2 register. The exchange seizes an outgoing international link to a further international transit exchange or an incoming international exchange in the destination country. Signalling continues between the outgoing international R2 register and the last incoming R2 register and interworking takes place with the other signalling system.

If congestion is encountered signal A-15 is sent, if necessary in pulse form. After the compelled signalling sequence is complete or after the end of the pulse signal the transit exchange dismisses the register.

On recognition of signal A-15 the outgoing exchange may initiate a repeat attempt, a re-routing or cause the return of congestion information to the calling subscriber. In all cases the outgoing (multi-)link section is released.

5.1.2.2 *Signalling to an incoming international exchange in the destination country*

When the outgoing international link is a direct link to an incoming international exchange in the destination country the first interregister signal sent is a language or discriminating digit.

Alternately, if the outgoing multi-link section is routed via one, two or three international transit exchanges then on recognition of signal A-12 the outgoing international R2 register sends a language or discriminating digit as the first signal to be received by the incoming R2 register in the terminal international exchange in the destination country.

The first signal A-12 received from an international transit exchange by the outgoing international R2 register informs it that an international link terminating at an incoming international exchange has been added to the (multi-)link section.

In both cases, on recognition of a language or discriminating digit (a signal I-1 to I-10), the incoming R2 register determines that the call is to be routed to the national network, and selects the next backward signal:

- i) The incoming R2 register may send signal A-14 to request information about the requirement for echo suppression.
 - If an incoming half-echo suppressor is required the outgoing international R2 register sends signal I-14.

In response to signal I-14 the incoming R2 register sends signal A-1 to request the first digit of the national (significant) number. In response to signal A-1 the outgoing international R2 register sends the first digit of the national (significant) number.
 - If no echo suppressor is required the outgoing international R2 register sends the first digit of the national (significant) number.
- ii) Alternatively, if it is known that no echo suppressor is required to be inserted the incoming R2 register may send signal A-1 to request the first digit of the national (significant) number. In response to signal A-1 the outgoing international R2 register sends the first digit of the national (significant) number.

The incoming R2 register examines the first digit of the national (significant) number and if a further digit (or digits) is required for routing, signal A-1 is sent to request the next digit.

When sufficient digits are stored at the incoming exchange to permit the call to be routed to the next exchange the backward signal (if any) is determined by the nature of the signalling system employed on the outgoing link and the national routing principles.

- a) If the outgoing national link employs System R2 and international/national end-to-end signalling is used, a backward signal may be sent after the outgoing link is seized to request the address digit required as the first signal to be received by the incoming R2 register in the following national exchange.

The appropriate signal is one of signals A-1, A-2, A-7, A-8 or A-12. These signals may be sent after any digit, and can be repeated provided they do not conflict with the logic procedure.

However, if the address digit *on-line* is the digit required as the first signal to be received by the incoming R2 register in the next exchange, it is possible for the transit exchange to release the incoming R2 register and through-connect the speech-path after the outgoing link is seized without sending a backward signal.

Otherwise, after the appropriate backward signal is sent and the compelled signalling sequence is complete the transit exchange releases the register and through-connects the speech path.

- b) If the outgoing national link employs System R2 but end-to-end international/national signalling cannot be used, the register in the incoming international exchange relays the multifrequency signals: it acts as an outgoing R2 register. It requests the remainder of the address digits by repetitive use of signal A-1. The digits received by the outgoing R2 register are retransmitted over the outgoing national link at the request of the incoming R2 register in the following national exchange(s) (see Recommendation Q.478).

c) If the outgoing link employs a signalling system other than System R2 then the acting incoming R2 register is the last incoming R2 register. The exchange seizes a national link. Signalling continues between the outgoing international R2 register and the last incoming R2 register and interworking takes place with the other signalling system.

If congestion is encountered, congestion signal A-4 or A-15 is transmitted (if necessary in pulse form) and the incoming R2 register is dismissed.

On recognition of the congestion signal A-4 the outgoing exchange releases the outgoing link or connection and causes the return of congestion information to the calling subscriber.

On recognition of the congestion signal A-15 the outgoing exchange may initiate a repeat attempt, re-routing or cause the return of congestion information to the calling subscriber. In all cases the outgoing link or connection is released.

It is desirable to use the congestion signal A-15 solely in the case of incoming international terminal traffic when repeat attempt or re-routing may be expected to be successful.

Recommendation Q.463

5.1.3 SIGNALLING BETWEEN THE OUTGOING INTERNATIONAL R2 REGISTER AND AN INCOMING R2 REGISTER IN A NATIONAL EXCHANGE IN THE DESTINATION COUNTRY

5.1.3.1 *Signalling to a national transit exchange*

The outgoing international R2 register sends the requested address digit as the first signal to be received by the incoming R2 register in the national transit exchange in the destination country.

The incoming R2 register examines the digit and if a further digit (or digits) is required for routing, signal A-1 is sent to request the next digit.

When sufficient digits are stored at the incoming exchange to permit the call to be routed to the next exchange the backward signal (if any) is determined by the nature of the signalling system employed on the outgoing link and the national routing principles.

a) If the outgoing national link employs System R2 a backward signal may be sent after the outgoing link is seized to request the address digit required as the first signal to be received by the incoming R2 register in the next exchange. The signalling procedure which occurs is similar to that described in § 5.1.2.2 a) above.

b) If the outgoing link employs System R2 but end-to-end international/national signalling cannot be used, the register in the national exchange relays the interregister signals: it acts as an outgoing R2 register. The digits received by this outgoing R2 register are retransmitted over the outgoing link at the request of the incoming R2 register in the following exchange(s) (see Recommendation Q.478).

c) If the outgoing link employs a signalling system other than System R2 then the acting incoming R2 register is the last incoming R2 register. The exchange seizes an outgoing national link to the next national exchange. Signalling continues between the outgoing international R2 register and the last incoming R2 register and interworking takes place with the other signalling system.

If congestion is encountered signal A-4 is sent (if necessary in pulse form) and the incoming R2 register is released.

On recognition of congestion signal A-4 the outgoing exchange releases the outgoing multi-link section and causes the return of congestion information to the calling subscriber.

5.1.3.2 *Signalling to a national exchange to which the called subscriber is connected*

When the outgoing multi-link section is routed to the national exchange to which the called subscriber is connected the acting incoming R2 register is the last incoming R2 register: the outgoing international R2 register sends the requested address digit as the first signal to be received by the last incoming R2 register and signalling continues as described below.

5.1.4 SIGNALLING BETWEEN THE OUTGOING INTERNATIONAL R2 REGISTER AND THE LAST INCOMING R2 REGISTER

5.1.4.1 *General*

The usual System R2 signalling procedure is to request in succession the remainder of the address digits stored in the outgoing international R2 register by the repetitive use of signal A-1 until it is determined at the incoming end that the complete address information has been received by the incoming exchange or that the call cannot be routed.

System R2 enables transmission of information concerning a large number of different conditions of called subscriber's line or reasons why call set-up has failed. But this can only be sent if the switching systems and other signalling systems employed on the remaining links of the connection offer the possibility of differentiating several line conditions. Group B-signals are provided for this purpose.

Transition from Group A to Group B meanings is indicated by means of address-complete signal A-3. However, if the incoming exchange is unable to send any signals concerning the condition of the called subscriber's line it is unnecessary to send signal A-3 followed by a Group B signal. In such cases the address-complete signal A-6, provided for the purpose is used.

If congestion is encountered after transmission of the address-complete signal A-3 the congestion signal B-4 is sent in place of signal A-4 or A-15.

5.1.4.2 *When the last incoming R2 register is able to transmit the condition of the called subscriber's line*

When the condition of the called subscriber's line can be determined the incoming R2 register can send signals conveying this information after receipt of the address digits.

As soon as the last address digit is received the last incoming R2 register sends the address-complete signal A-3 to announce changeover to the transmission of Group B signals. In response the outgoing international R2 register sends the appropriate calling party's category signal (II-7 to II-10). The last incoming R2 register acknowledges this with the relevant Group B signal indicating the condition of the called subscriber's line.

Immediately the compelled signalling sequence is complete the incoming R2 register is released and depending upon the Group B signal sent the speech-path may be through-connected.

When the condition of the called subscriber's line is determined by an electrical signal to the last incoming R2 register and if the called subscriber's line is free the address-complete signal A-6 can be sent instead of signal A-3, possibly in pulse form. This will be the last interregister signal. After signal A-6 is sent the incoming R2 register is released, the speech-path is through-connected and ringing tone returned to the calling subscriber. Outgoing international R2 registers must be able to interpret all Group B signals.

On recognition of the last backward signal the outgoing exchange releases the outgoing international R2 register and either through-connects the speech-path or releases the outgoing connection and causes the return of an appropriate tone or special announcement or both alternately to the calling subscriber.

5.1.4.3 *When the last incoming R2 register is not able to transmit the condition of the called subscriber's line*

In this case the last incoming R2 register sends the address-complete signal A-6, possibly in pulse form, as the last interregister signal. After this is sent, the last incoming R2 register is released and the speech-path is through-connected.

When the last incoming R2 register is in the exchange to which the called subscriber is connected, an appropriate tone is returned to the calling subscriber from this exchange.

On recognition of address-complete signal A-6, the outgoing exchange releases the outgoing international R2 register and through-connects the speech-path. The calling subscriber will then hear ringing tone, busy tone, special information tone or a recorded announcement alternately with special information tone sent by the incoming equipment.

5.1.5 PARTICULAR CASES

5.1.5.1 *Unallocated number*

When, after the reception of any digit, the incoming R2 register determines that the address information corresponds to an unallocated number, the address-complete signal A-3 is sent immediately without requesting all the address digits. In response the outgoing international R2 register sends the appropriate Group II signal. This is then acknowledged by signal B-5 *unallocated number*.

5.1.5.2 *Congestion in the national network*

If congestion is encountered in the national network the incoming R2 register sends congestion signal A-4, possibly in pulse form. However, if address-complete signal A-3 has already been sent, congestion signal B-4 is sent in acknowledgement of the Group II signal which commences the last compelled signalling sequence.

5.1.5.3 *Operator calls*

The procedures described in Recommendations Q.462-Q.464 are also valid for a semi-automatic call. However, in this case the address information is always terminated by the end-of-pulsing signal I-15.

For code 11 or code 12 calls only a limited number of backward signals can be employed as the last interregister signal (e.g. signal A-4, A-6 or B-6).

5.1.5.4 *Request of calling party's category*

At any time calling party's category information may be requested by the incoming R2 register interrupting the normal transmission of address information. The incoming R2 register sends signal A-5 in acknowledgement of a Group I signal and the outgoing international R2 register sends the appropriate Group II signal (a signal II-7 to II-10) in reply. If this Group II signal is acknowledged by a signal different from address-complete signal A-3 or signal A-5 the next forward signal sent will be one of the Group I.

Recommendation Q.466

5.1.6 SUPERVISION AND RELEASE OF THE CALL

An answer signal is sent when the called subscriber's off-hook condition is detected. Each transit exchange in the connection, relays this line signal. At the outgoing international exchange, receipt of the answer signal normally causes call charging to take place and metering for international accounting purposes to start.

When the called subscriber's on-hook condition is detected a clear-back signal is sent and relayed by each transit exchange.

When the calling subscriber's on-hook condition is detected a clear-forward signal is relayed by the outgoing international exchange over the outgoing international link. On receipt of the clear-forward signal on an incoming link, release operations are initiated and the clear-forward signal is repeated forward on the outgoing link.

Immediately release operations at an exchange are complete (although the outgoing circuit may still be held) a release-guard sequence is initiated on the incoming link. After recognition of the end of the release-guard sequence at the outgoing exchange the link reverts to the idle state.

Supervision of a call must be in accordance with Recommendation Q.118.

5.2 ROUTING AND NUMBERING FOR INTERNATIONAL WORKING

(See Recommendations Q.107 and Q.107 *bis*, Fascicle VI.1.)

5.3 TERMINATION OF INTERREGISTER SIGNALLING

Recommendation Q.470

5.3.1 AT AN INCOMING R2 REGISTER SITUATED IN A TRANSIT EXCHANGE

5.3.1.1 *Successful routing*

Normally, interregister signalling is terminated in one of the following ways:

- a) The last forward interregister signal received by the incoming R2 register at the transit exchange is not acknowledged from that register. After an outgoing link to the next exchange is seized, the register is dismissed and the speech-path is through-connected. The forward signal remains on-line and is the first signal received by the next incoming R2 register. Provision must be made for the switching operations to be completed so as to ensure that the signal will remain on-line and be received by the succeeding register.
- b) The last forward interregister signal received by the incoming R2 register at the transit exchange is acknowledged by a backward signal (A-1, A-2, A-7, A-8, A-11 or A-12) requesting transmission of a clearly specified signal as the first to be received by the next incoming R2 register. When the compelled signalling sequence is complete the register is dismissed and the speech-path is through-connected.

Because it is not possible to send signals A-2, A-7, A-8, A-11 or A-12 in pulse form, precautions are necessary to avoid acknowledging the last address digit (on automatic calls) until the signalling system employed on the outgoing link is known. If signal A-1 is sent in acknowledgement of the last address digit and if the outgoing link employs System R2 it may not then be possible to send one of these signals and therefore end-to-end signalling to the next exchange is no longer feasible (see also Recommendation Q.474).

In international working signals A-2, A-7 and A-8 may be used to acknowledge receipt of any forward signal.

Signal A-11 must be used to request a country code indicator.

Signal A-12 must generally be used to request the language or discriminating digit. However, in the case where an incoming R2 register is equipped with only 5 backward signalling frequencies only one of the signals A-2, A-7 or A-8 can be used for this purpose. Attention is drawn to the fact that in this case the language or discriminating digit may not be sent by all outgoing international R2 registers.

Although it is not normally necessary to request a repeat of a digit n because it remains on the line until acknowledged (but see Recommendation Q.476) such repetition may prove necessary after an interruption of digit transmission (e.g. to request information concerning the calling party's category) or if the completion of switching operations referred to in method *a*) above, cannot be guaranteed with a time compatible with the time-out of the outgoing (international) R2 register (see Recommendation Q.476). The procedure is then as follows:

Signal A-2 is sent, eliciting the digit $n-1$; this is immediately acknowledged by signal A-1 to elicit the required digit n . When the digit n in question is the first digit in the store of the outgoing R2 register this procedure is not applicable.

At an international transit exchange method *b*) above, must be used and only one of the signals A-11 or A-12 applies.

When the outgoing link connects to a further international transit exchange signal A-11 must be used to request a country code indicator. On recognition of signal A-11 the outgoing international R2 register must send a country code indicator (signal I-12 or I-14, see Recommendation Q.479) as the first forward signal to be received by the next incoming R2 register.

Signal I-12 or I-14 may be requested as many times as necessary by sending signal A-11.

When the outgoing link connects to an incoming international terminal exchange signal A-12 must be used to request the language or discriminating digit. On recognition of signal A-12 the outgoing international R2 register must send the language or discriminating digit (a signal I-1 to I-10) as the first forward signal to be received by the next incoming R2 register.

On recognition of signal A-12 (sent from an international transit exchange) an outgoing international R2 register is informed that an international link connected to an incoming international terminal exchange has been added to the (multi)-link section and that call set-up is now in progress in the national destination network. This is of importance when signal A-9 or A-10 are, in the originating country, amongst those used to set-up international calls.

5.3.1.2 Congestion

If it is impossible to set-up the desired connection in the transit exchange the incoming R2 register terminates interregister signalling by transmission of the congestion signal A-4 or A-15. The backward signal may serve as acknowledgement of the last forward signal received by the incoming R2 register at the transit exchange or is sent in pulse form.

The two congestion signals A-4 and A-15 are provided to enable an outgoing international R2 register to determine whether congestion is occurring in the international network or in that of the destination country so that provision for repeat attempt or re-routing can be made in the former case:

- Signal A-15 is sent from an international exchange.
- Signal A-4 is sent from a national exchange or possibly from a terminal international exchange. [See also § 5.1.2.2 c).]

Because receipt of congestion signal A-15 by an outgoing international R2 register may initiate repeat attempt or re-routing it is possible to transmit congestion signal A-4 from international exchanges where repeat attempt or re-routing may be expected useless.

Recommendation Q.471

5.3.2 AT THE LAST INCOMING R2 REGISTER SITUATED IN THE EXCHANGE TO WHICH THE CALLED SUBSCRIBER IS CONNECTED

5.3.2.1 Successful routing

When a call has been completely set up by means of System R2 interregister signalling, the incoming R2 register terminates interregister signalling immediately on receipt of the entire number.

The following criteria are used to determine whether the number received by the incoming R2 register is complete:

- a) analysis — to determine the last digit;
- b) electrical conditions given by the switching equipment succeeding the incoming R2 register;
- c) receipt of the end-of-pulsing signal (I-15);
- d) the assumption, after a specified time has elapsed, that no further digits will be sent (see Recommendation Q.476).

When criterion a) (analysis) is applied:

- if the incoming R2 register is equipped to send Group B signals to provide information about the condition of the called subscriber's line the address-complete signal A-3 is transmitted on receipt of the last digit. As soon as it is known whether the connection with the subscriber's line can be established, only the appropriate Group B signal needs to be sent. The use of the Group B signals is detailed in Recommendation Q.474;
- if the incoming R2 register is not equipped to receive information about the condition of the called subscriber's line, the address-complete signal A-6 is sent immediately after reception of the last digit and no Group B signal will be transmitted.

In both cases the time interval between the end of a signal A-6 or a Group B signal and the start of the subsequent answer signal must not be less than 75 ms.

When criterion *b*) (electrical conditions) is applied:

It is recommended that, to avoid delay in sending the answer signal, no Group B signal should be sent when the called subscriber's line is free, and that the setting-up of speech conditions be ensured by sending address-complete signal A-6 immediately the electrical conditions are recognized. The time interval between the end of signal A-6 and the start of transmission of the subsequent answer signal must be not less than 75 ms (see also Recommendations Q.412 and Q.475).

Criterion *c*) (end-of-pulsing) can be applied only if the incoming R2 register is equipped to receive the 6 forward signalling frequencies (see also Recommendation Q.473). When signal I-15 is received and recognized the last incoming R2 register can perform in the way described under criterion *a*).

When criterion *d*) (time-out) is applied:

Address-complete signal A-6 must be sent in pulse form as soon as the specified time has elapsed. The time between the end of signal A-6 and the start of transmission of the subsequent answer signal must be, as indicated above for criterion *b*), not less than 75 ms (see also Recommendations Q.412 and Q.472).

It may happen, however, that the called subscriber answers before the specified time has elapsed. In such exceptional circumstances the pulse signal A-6 must be sent immediately the answer signal is recognized. In this case the time between the end of signal A-6 and the start of the transmission of the subsequent answer signal must be 75 ms or more but less than 150 ms. The calling subscriber will not hear the ringing tone.

This disadvantage can be avoided by not using a received digit to set up the call until after the following digit has been received or until a certain time has elapsed. This procedure, however, may give rise to difficulties if the time-out devices provided in the switching equipment succeeding the incoming R2 register are set for too short a delay [see also Recommendation Q.120, § 1.5.5.2 b) iv)].

5.3.2.2 Congestion

An incoming R2 register should terminate interregister signalling immediately any conditions preventing complete setting-up of a call have been recognized.

If congestion is encountered congestion signal A-4 is sent, possibly in pulse form. However if address-complete signal A-3 has already been sent then congestion signal B-4 is sent in acknowledgement of the Group II signal which commences the last compelled signalling sequence.

Recommendation Q.472

5.3.3 AT THE LAST INCOMING R2 REGISTER SITUATED IN A TRANSIT EXCHANGE

5.3.3.1 Successful routing

Interregister signalling to such a register can be terminated after all the address digits are received. In order to determine that the number is complete the same criteria as described in Recommendation Q.471 are used.

When criterion *a*) (analysis) is applied:

- 1) if the signalling system employed on the outgoing link enables the condition of the called subscriber's line to be sent backwards within an acceptable period compared to the time-out of the outgoing international R2 register, the last incoming R2 register can react in accordance with one of the following methods:
 - i) address-complete signal A-3 is sent in acknowledgement of the last address digit followed by the relevant Group B signal depending upon the condition of the called subscriber's line;

- ii) signal A-1 is sent in acknowledgement of the last address digit, and signal I-15 if received, to deliberately suspend compelled signalling and later,
 - when the condition of the called subscriber's line is known, address-complete signal A-3 is sent in pulse form followed by the relevant Group B signal. This makes it possible to avoid maintaining on-line the Group II signal sent after reception of signal A-3,
 - when the called subscriber's line is free, it is preferable to send the address-complete signal A-6 in pulse form,
- 2) if the signalling system employed on the outgoing link does not enable the condition of the called subscriber's line to be transmitted backwards or if such information is only available at the last incoming R2 register after a delay incompatible with the time-out of the outgoing international R2 register, then address-complete signal A-6 is sent in acknowledgement of the last address digit.

When criterion *b*) (electrical conditions) is applied:

Only signal A-1 can be used to acknowledge each address digit. Upon receipt of an electrical signal on the outgoing link, the last incoming R2 register acts in one of the following ways:

- if the condition of the called subscriber's line is not known or is known to be *free*, address-complete signal A-6 is sent in pulse form;
- if the condition of the called subscriber's line is known to be other than *free*, address-complete signal A-3 is sent in pulse form, followed by the relevant Group B signal.

Criterion *c*) (end-of-pulsing) is only applicable if the last incoming R2 register can receive 6 forward signalling frequencies (see also Recommendation Q.473). In this case, when end-of-pulsing signal I-15 is received and recognized, the last incoming R2 register can perform in the way described under criterion *a*).

When criterion *d*) (time-out) is applied:

Address-complete signal A-6 is sent in pulse form after the specified time has elapsed (see Recommendation Q.476).

5.3.3.2 Congestion

If congestion is encountered, the procedure described in Recommendation Q.470 is followed. However, if address-complete signal A-3 has already been sent then congestion signal B-4 is sent in acknowledgement of the Group II signal which commences the last compelled signalling cycle.

Recommendation Q.473

5.3.4 USE OF END-OF-PULSING SIGNAL I-15 IN INTERNATIONAL WORKING

In international working, the end-of-pulsing signal I-15 is used in accordance with Recommendation Q.468. Signal I-15 (end-of-pulsing) is sent immediately after the last digit.

In national working, signal I-15 may be used too.

In semi-automatic operation, calls to operators' positions are always terminated by transmission of signal I-15. This signal can only be interpreted if the incoming R2 register is equipped for reception of 6 forward frequencies. However, when an incoming R2 register is equipped for reception of only 5 forward signalling frequencies no provision can be made for recognition of signal I-15. Such an incoming R2 register will then act as though signal I-15 had not been sent. Consequently the next interregister signal is only one of the signals A-3, A-4 or A-6 sent in pulse form.

5.3.4.1 Procedures to be followed after receipt of end-of-pulsing signal I-15 by the last incoming R2 register (situated in a transit exchange or in the exchange to which the called subscriber is connected)

Incoming R2 registers equipped for the reception of all 6 forward signalling frequencies can acknowledge receipt of the end-of-pulsing signal I-15 by sending an appropriate backward signal to complete the compelled signalling cycle. Interregister signalling is terminated according to the procedures specified in Recommendations Q.471 or Q.472 when criterion a) (analysis) is applied.

In particular, if the last incoming R2 register acknowledges signal I-15 with signal A-1 the outgoing international R2 register will not send any signal and the incoming R2 register can only send one of signals A-3, A-4, A-6 or A-15 in pulse form.

Since there is no compulsion to equip incoming R2 registers in national exchanges with receivers for all 6 forward signalling frequencies, the signal I-15 sent by an outgoing international R2 register may not be recognized by the incoming R2 register. In such cases other criteria can be used to determine whether the number received by the incoming R2 register is complete.

When the incoming R2 register determines that the number received is complete using criteria other than c) (end-of-pulsing) it may be that the last digit of the subscriber number is acknowledged by signal A-3, A-4, A-6 or A-15. In this case interregister signalling is terminated without request for the signal I-15, in the normal way according to the procedures specified in Recommendations Q.471 or Q.472 (a compelled signalling cycle including signal I-15 is saved).

5.3.4.2 Procedure to be followed after receipt of signal I-15 by an incoming R2 register situated in a transit exchange

Signal A-1, A-2, A-7, A-8, A-11 or A-12 may be sent in acknowledgement of signal I-15 (end-of-pulsing). However, at a transit exchange precautions are necessary to avoid acknowledgement of signal I-15 before the signalling system employed on the outgoing link has been identified. If signal A-1 is sent in acknowledgement of signal I-15 and if the outgoing link employs System R2, it is not then possible to send backward signal A-2, A-7, A-8, A-11 or A-12 after the end of the compelled signalling cycle because these signals cannot be sent in pulse form. Therefore end-to-end signalling to the next exchange is no longer possible.

Recommendation Q.474

5.3.5 USE OF GROUP B SIGNALS

Group B signals are used to transmit information about the condition of switching equipment in the incoming exchange or the called subscriber's line, to the outgoing international R2 register, which can then take the necessary action.

The address-complete signal A-3 is sent by an incoming R2 register to announce changeover to sending Group B signals. In addition, signal A-3 indicates that the incoming R2 register has received all the Group I forward signals it requires from the outgoing international R2 register. On recognition of signal A-3 an outgoing R2 register sends a Group II signal. The incoming R2 register may interpret the Group II signal giving information about calling party's category, in order to control the switching operations accordingly (e.g. suppression of automatic ringing for operator initiated calls or to prevent subscriber access to data transmission terminals). Finally, a Group II forward signal is acknowledged by any Group B backward signal.

In cases where outgoing R2 registers are able to interpret all Group B signals there is generally no need to provide equipment at the incoming end able to send, in addition to Group B signals, the tones and/or announcements corresponding to those signals, except in the case of ringing tone.

In general, outgoing R2 registers must be equipped with devices permitting, after reception of signal A-3:

- the exchange of an additional cycle of interregister signals before the register is released;
- changeover from Group A to Group B meanings of backward signals.

Outgoing international R2 registers, however, must be able to interpret all Group B signals.

5.3.5.1 Procedures to be followed by an outgoing international R2 register on receipt of Group B signals

Signal B-1 is interpreted by an outgoing international R2 register as signal B-6: the register is released and the speech-path is through-connected. A subsequent answer signal initiates call charging.

Signal B-2 send special information tone is sent by the incoming R2 register:

- when the number of the called party has been changed,
- when the three following conditions are fulfilled together:
 - i) the called party's line condition does not fit with one of the meanings of the present Group B signals,
 - ii) it does not lead to setting up the speech path,
 - iii) it is not incompatible with return of special information tone to the calling party.

After recognizing signal B-2, the outgoing international R2 register clears forward and causes the transmission of only special information tone.

The subscriber's line busy signal B-3 is sent by the incoming register when the called subscriber's line is engaged. On recognition of this signal, the outgoing register releases the connection and causes transmission of the busy tone.

When the congestion condition is encountered following the changeover from Group A signals to Group B signals, the congestion signal B-4 shall be transmitted on the conditions specified for congestion signal A-4. In all cases recognition of the signal causes release of the call and transmission of congestion information.

After recognizing unallocated number signal B-5, the outgoing international R2 register clears the call and causes transmission of special information tone or a recorded announcement and special information tone, alternately, to the calling party.

After recognizing signal B-6, the outgoing international R2 register sets up speech conditions so that a caller may hear the ringing tone. In this case, a subsequent answer signal activates the call-charging mechanism.

After recognizing signal B-7 the outgoing international R2 register sets up speech conditions, so that a caller may hear the ringing tone. In this case, a subsequent answer signal does not activate the call-charging mechanism. However, in an outgoing international R2 register signal B-7 may be interpreted as B-6 if there is no international agreement on non-chargeable calls.

After recognizing signal B-8 subscriber's line out of order, the outgoing international R2 register clears forward and causes the transmission of a special information tone or recorded announcement and special information tone alternately to the calling party.

Receipt of signal B-9 or B-10 by an outgoing international R2 register causes release of the outgoing connection and return of special information tone to the calling subscriber, i.e. these signals should be interpreted as signal B-2.

If an outgoing international R2 register receives one of signals B-11 to B-15 the call should be released and indication of this returned to the calling subscriber or operator, i.e. this signal should be interpreted as signal B-4.

5.3.5.2 Special procedures for national working

Outgoing R2 registers in national exchanges may not be able to recognize and interpret Group B signals. In such networks it is essential that the equipment at the incoming end must transmit not only the Group B signals but also the corresponding tones and/or announcements, when the incoming R2 register does not know whether the outgoing R2 register is capable of interpreting Group B signals.

In the case where the incoming R2 register is able to make only two or three distinctions of conditions of the called subscriber's line the following procedure may be adopted: When the only distinction that can be made is between subscriber's line free and subscriber's line engaged,

- i) signal B-3 is sent if the line is engaged;
- ii) otherwise signal B-6, or signal A-6 alone is sent so the caller can hear the ringing tone sent by the incoming equipment.

In the case where outgoing R2 registers in national exchanges are only able to interpret a limited number of Group B signals or are indeed not able to interpret any, it is essential that such equipment be able to respond to signal A-3 in the specific manner and at least to recognize the next backward signal (which is a Group B signal) as indicating the end of interregister signalling.

5.3.5.3 Possible application of signal B-1 in national working

Signal B-1, for example, may be used to indicate that the call must remain under the control of the incoming equipment, insofar as this is possible (e.g. for maintenance reasons, to trace malicious calls, etc.). The incoming exchange sets up speech conditions, so that the calling subscriber can hear the ringing tone. At present such a use of signal B-1 in international working is not envisaged.

Recommendation Q.475

5.4 NORMAL RELEASE OF OUTGOING AND INCOMING R2 REGISTERS

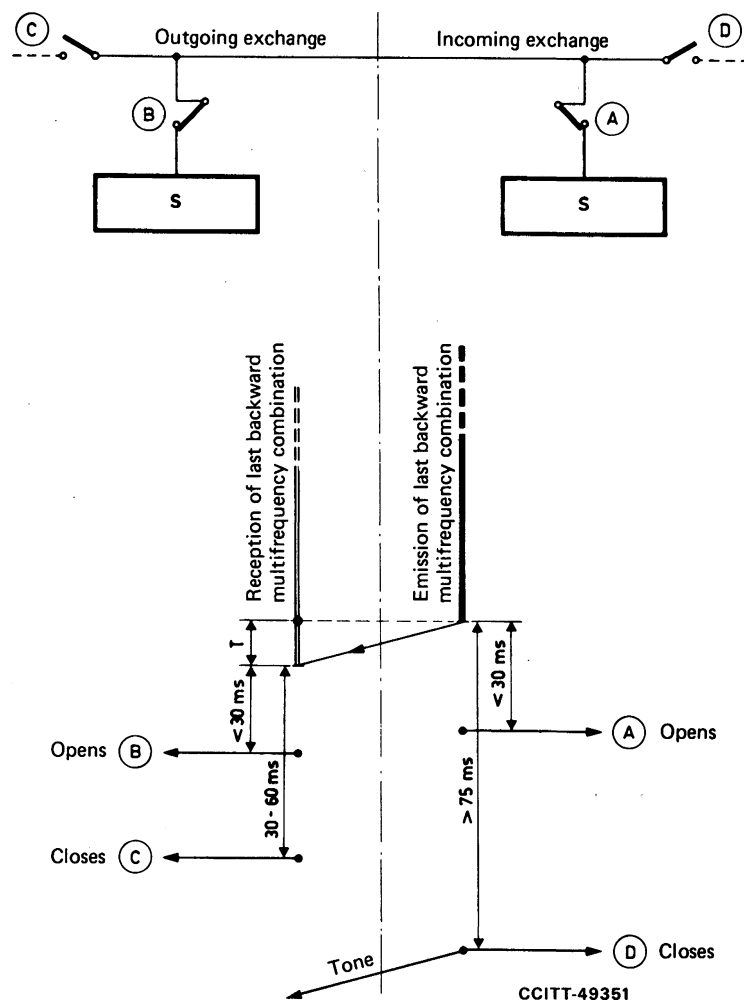
An outgoing international R2 register must be released once it has received an appropriate backward interregister signal terminating the interregister signalling, or on receipt of a clear-forward (line) signal from the preceding link.

An incoming R2 register must be released once it has accomplished the necessary switching control and terminated the interregister signalling required, or on receipt of a clear-forward (line) signal from the preceding link.

The last recognized interregister signal preceding setting up of speech conditions will normally be a backward signal: e.g. address-complete signal A-6, subscriber's line free signals B-6 or B-7.

The multifrequency combination receivers at the two ends must be disconnected before the switching equipment passes to the speech condition; this procedure eliminates any possibility of their operating or being held under the influence of speech or line signals. The following conditions regarding the duration of the various phases should be observed (see Figure 20/Q.475):

- a) the multifrequency signalling equipment of the incoming R2 register must be disconnected within 30 ms after recognition of the end of transmission of the last backward signal;
- b) the multifrequency signalling equipment of the outgoing R2 register must be disconnected within 30 ms after recognition of the end of the last backward signal;
- c) at the outgoing exchange speech conditions must be set up between 30 and 60 ms after recognition of the end of the last backward signal. However, at the exchange where the outgoing international R2 register is situated, the setting-up of speech conditions depends upon the signalling system employed on the preceding link;
- d) at the incoming exchange at least 75 ms must elapse between the end of transmission of the last backward signal and the setting up of speech conditions.



T = transmission delay + recognition time for the disappearance of the last backward multifrequency combination
 S = multifrequency signalling equipment (see Recommendation Q.451)
 Note – The same transmission delay is assumed for all signals.

FIGURE 20/Q.475

Disconnection of multifrequency signalling equipment and switching to the speech position

5.5 ABNORMAL RELEASE OF OUTGOING AND INCOMING R2 REGISTERS

To limit the holding time of R2 registers, when interregister signalling is interrupted either by a fault or by any other cause, all R2 registers must be equipped with devices for continuous supervision of the time taken by the various phases of interregister signalling. The time-out delay of these devices must be as short as possible, but long enough not to interrupt normal operation.

5.5.1 *Time-out of outgoing international R2 register*

In an outgoing international R2 register, the intervals during which a forward multifrequency combination is transmitted and the intervals during which no such combination is transmitted are supervised separately.

5.5.1.1 *Supervision during sending of forward multifrequency combinations*

The lower limit of the time-out delay is a function of the time required for the switching procedures in a transit exchange.

On this basis, the time-out delay is specified as 15 ± 3 seconds.

The supervision device will start functioning at the beginning of the transmission of a forward multifrequency combination and be reset with the deactivation of the senders involved. It will start again at the beginning of the transmission of the next forward multifrequency combination.

5.5.1.2 *Supervision during intervals when no forward multifrequency combination is being sent*

The lower limit of the time-out delay is a function of:

- a) the maximum permissible time interval between dialling of two successive digits by the subscriber;
- b) the time-out delay specified for incoming R2 registers (see § 5.5.2 below).

On this basis, the time-out delay is specified to be longer than 24 seconds (a longer delay and an upper limit may be specified by each Administration).

If this specification is observed an incoming R2 register, which has acknowledged the last received digit with the signal A-1, is bound to be released before the supervision device of the outgoing international R2 register initiates the alarm condition.

5.5.1.3 *Procedure to be followed if time-out occurs*

If time-out occurs, the time supervision devices mentioned in §§ 5.5.1.1 and 5.5.1.2 above will bring about operations producing:

- return of an appropriate signal and/or audible tone to inform the calling party,
- release of the outgoing international R2 register and of the connection as far as the latter is not necessary for the above-mentioned operation.

Fault recording equipment may start functioning and/or a delayed alarm may alert the technical staff.

5.5.1.4 *Time-out of outgoing R2 register*

It is recommended that the same principles outlined in §§ 5.5.1.1 to 5.5.1.3 above be applied by analogy to outgoing R2 registers.

5.5.2 *Time-out of incoming R2 register*

The time-out device shall supervise the interval elapsing between seizure of the register and recognition of the first forward multifrequency combination as well as the interval elapsing between the recognition of two successive multifrequency combinations in the forward direction.

5.5.2.1 Time-out delay

The lower limit of the time-out delay is a function of:

- a) the maximum permissible time interval between the recognition of 2 successive forward multifrequency combinations; this time interval may in certain cases be influenced by the maximum permissible time interval between dialling of 2 successive digits by the subscriber;
- b) the maximum time required for setting-up the call under conditions which slow down the interregister signalling.

In view of the desirability expressed in § 5.5.1.2 above that the incoming R2 register be released before expiry of the time-out delay specified for the outgoing international R2 register, an upper limit should be fixed as well.

On this basis the time-out delay should be specified within the range of 8-24 seconds. A minimum delay of 15 seconds corresponding to the time-out delays in other CCITT standardized signalling systems is to be preferred.

For incoming R2 registers using the criterion *d)* (time-out) indicated in Recommendation Q.471 to determine completion of the number, the time referred to there as the *specified time* may exceptionally be shorter than 8 seconds, but never less than 4 seconds.

5.5.2.2 Procedure to be followed if time-out occurs

If time-out occurs, the time supervision device will bring about operations producing:

- sending of a congestion signal (A-4 or A-15) in pulse form;
- release of the incoming R2 register and other equipment in the incoming exchange;
- on time-out of the initial digit:
 - i) line signalling, analogue version: establishment of the blocked state on the incoming circuit until recognition of the clear-forward signal (see Recommendation Q.412, abnormal conditions);
 - ii) line signalling, digital version: no further action required.

Fault recording equipment may start functioning and/or a delayed alarm may alert the technical staff.

Recommendation Q.478

5.6 RELAY AND REGENERATION OF R2 INTERREGISTER SIGNALS BY AN OUTGOING R2 REGISTER IN A TRANSIT EXCHANGE

When the overall multi-link connection is divided into end-to-end signalling sections, regeneration of R2 interregister signals is required by either an outgoing international R2 register or an outgoing R2 register (see Recommendation Q.440).

There are three possible procedures for relaying interregister signals by an outgoing R2 register:

- a) the outgoing R2 register acknowledges each signal received over the incoming link by transmitting the appropriate backward signal; this operation is independent of the operations entailed in retransmitting on the outgoing link;
- b) the forward address signal with rank $n + 1$ is acknowledged on the incoming link as soon as the forward address signal with rank n is acknowledged on the outgoing link;
- c) as soon as a forward signal is received on the incoming link, a signal is sent on the outgoing link; the acknowledgement signal is sent on the incoming link only when such a signal has been received on the outgoing link.

Methods *a)* and *b)* provide the most rapid transfer of information and are therefore the preferable methods of relaying the information necessary for setting up the call. It is essential, however, that the outgoing R2 register be provided with adequate storage capacity in the case of method *a)*.

Method *b)* can only be applied after method *a)*.

Method *c)* should be used for relaying information relating to the procedures for the termination of interregister signalling.

The changeover from method *a)* or *b)* to method *c)* may require transmission of an address-complete signal A-3 in pulse form as indicated in Recommendation Q.442 (see Figure 21/Q.478).

The procedure for disconnecting the multifrequency combination receivers and setting-up speech conditions for each link, incoming and outgoing, is given in Recommendation Q.475.

When method *a)* or *b)* is used, the time-outs of the R2 registers associated with the first signalling section may expire if the signalling on the second signalling section is too slow. Relatively long time-outs are recommended (see Recommendation Q.476).

Note – The use of signal A-3 on circuits with very long transmission delay, e.g. satellite circuits, for relaying such information (method *c)*) may result in premature release in certain incoming local exchanges with very short time guard. The problem may be avoided if the outgoing R2 register immediately following the satellite link uses signal A-5 to obtain the calling party's category information previously to the receipt of signal A-3 from those incoming local exchanges.

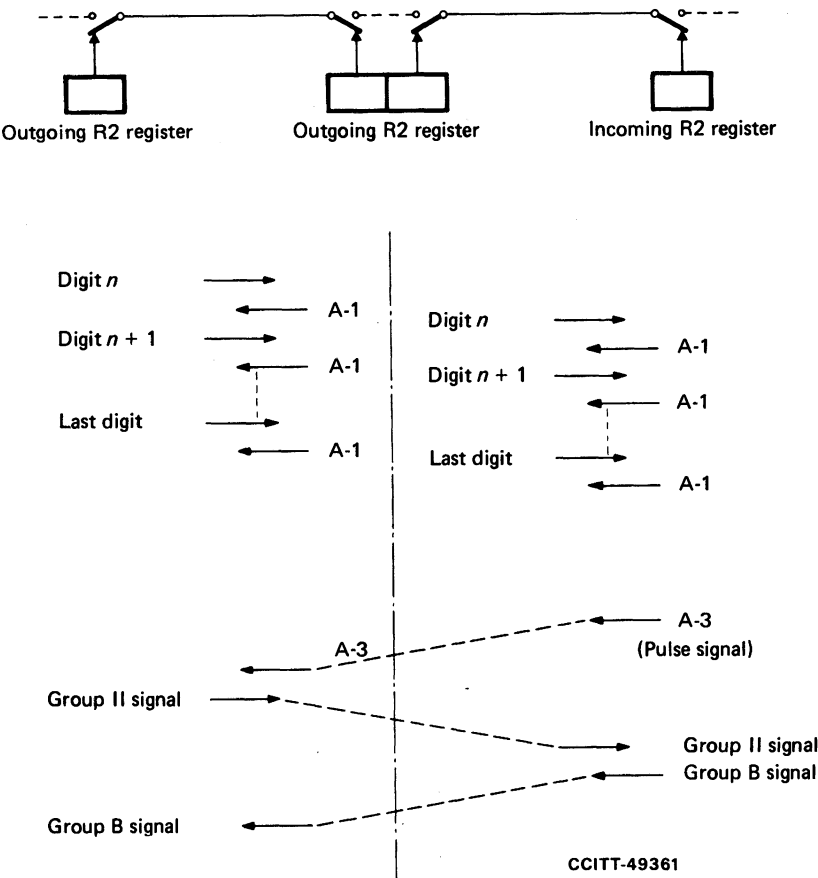


FIGURE 21/Q.478
Sequence of interregister signals in an outgoing R2 register
when the incoming link employs System R2

5.7 ECHO-SUPPRESSOR CONTROL – SIGNALLING REQUIREMENTS

5.7.1 Introduction

Recommendations Q.42 and Q.115 give fundamental requirements with which the employment of echo suppressors must comply.

There are two methods of connecting echo suppressors to a circuit. One method is by use of permanently connected echo suppressors and the other is by the insertion of echo suppressors from a pool, when required.

In System R2 (see Recommendation Q.441) two forward signals (I-12 and I-14) and one backward signal (A-14) are provided to indicate whether or not an incoming half-echo suppressor (IHES) is required.

A third forward signal (I-11) is also available for use by bilateral agreement to indicate that an outgoing half-echo suppressor (OHES) must be employed.

The following principles must be taken into account.

5.7.2 Principles of echo-suppressor control

5.7.2.1 The outgoing international exchange may be able to determine the need for echo suppressors in the connection by analysing the received country code.

5.7.2.2 In direct traffic between 2 countries the use of echo suppressors generally takes place according to fixed rules. Echo-suppressor control signalling is not, therefore, necessary in these cases unless it is applied for the sake of uniformity.

5.7.2.3 In international transit traffic the outgoing half-echo suppressor (OHES) will normally be employed at the outgoing international exchange, and the incoming half-echo suppressor (IHES) at the incoming international exchange, unless other arrangements are agreed upon with the Administration of the international transit exchange(s) (see § 5.7.2.5 below).

However, in cases where an outgoing satellite link is selected by a transit exchange without the knowledge of the outgoing international exchange, the signal I-12 may be sent over the satellite link. In such cases half-echo suppressors are required and will normally be permanently fitted at each end of the satellite link.

5.7.2.4 An incoming international exchange, equipped for the connection of IHES, must ask the outgoing international exchange whether or not an IHES must be employed unless this is known from other criteria (e.g. line classification). It will do this by sending the backward signal A-14 as an acknowledgement of the discriminating or language digit (Z-digit).

When a satellite link is used in the connection the exchange situated at the incoming end of the satellite link responds to the A-14 signal instead of the outgoing international exchange (see Recommendation Q.7).

5.7.2.5 It may be agreed upon bilaterally that in international transit traffic the OHES (IHES) will not be employed in the outgoing (incoming) international exchange, but in the international transit exchange, e.g. in the case where most of the traffic on the circuit group between the outgoing exchange and the transit exchange (between the transit exchange and the incoming exchange) needs no echo-suppressor.

- a) When echo suppressors are needed and the OHES must be employed at the international transit exchange the outgoing international exchange sends the signal I-11 as a country code indicator.
If an international connection is routed via two or more transit exchanges, signal I-11 must not be sent beyond the first transit exchange. Therefore the outgoing exchange, after having sent the signal I-11 once, must send the signal I-14 if the country code indicator is requested again (signal A-11).
- b) When echo suppressors are needed and the IHES must be employed at the international transit exchange this is known by the international transit exchange. In this case the incoming international exchange will not send signal A-14.

5.7.2.6 When echo suppressors are employed they will remain disabled until the answer signal is received. This condition is necessary in order to permit compelled interregister signalling to (e.g. national) exchanges further on in the connection.

Alternatively, when the ability exists to detect that interregister signalling has been completed, the echo-suppressor may be enabled at that time without awaiting the answer signal.

5.7.3 *Examples of echo-suppressor control signalling*

The following situations may arise:

5.7.3.1 *Direct interregister signalling between two countries A and B.*

- a) No echo-suppressor control signalling is applied.

This may be for one of two reasons. Either the connection does not normally require echo suppressors or echo suppressors are required and are permanently connected to the circuit.

The signalling procedure is indicated in Table 11/Q.479, column a. If echo suppressors are necessary, the OHES is employed at A and the IHES is employed at B.

- b) Echo-suppressor control signalling is applied.

There are two cases:

- i) No echo suppressors are required (see column b of Table 11/Q.479).
- ii) Echo suppressors are required (see column c of Table 11/Q.479). The OHES is employed at A and the IHES is employed at B.

5.7.3.2 *Traffic between two countries A and D via two international transit exchanges B and C*

There are two cases:

5.7.3.2.1 The connection is via terrestrial circuits only.

- a) No echo suppressors are required (see column a of Table 12/Q.479).
- b) Echo suppressors are required (see columns b, c, d, e of Table 12/Q.479).

The following examples may be mentioned:

- OHES in A: IHES in D (column b);
- OHES in B: IHES in D (column c).

The country code indicator I-11 is used by bilateral agreement and indicates that B must employ the OHES. When the country code indicator is to be sent to C, B asks A to do this by sending signal A-11. A, now sends signal I-14 instead of signal I-11, because B has employed the OHES. The signal A-14, which is sent from D as an acknowledgement of the Z-digit will, of course, also be answered by signal I-14.

- OHES in A: IHES in C (column d).

In accordance with § 5.7.2.5 b) above, C knows that D cannot employ an IHES and C itself will therefore make the connection. D will naturally not send signal A-14.

- OHES in B: IHES in C (column e).

5.7.3.2.2 The connection includes a satellite link.

The following examples are given as typical situations that may arise:

- a) The first link in the connection is via satellite.

In Table 13/Q.479, P and Q both know that echo suppressors are required.

If Q has a permanently connected IHES then:

- OHES in P; IHES in Q (column a).

When R or S is able to employ an IHES then:

- OHES in P; IHES in R (column c);
- OHES in P; IHES in S (column b).

- b) A later link in the connection is via satellite.

In Table 14/Q.479:

When P knows that Q-R is via satellite:








- OHES in P; IHES in R or S (column b or d).

When P does not know that Q-R is via satellite:

- OHES in Q; IHES in R or S (column a or c).

TABLE 11/Q.479





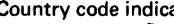






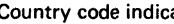





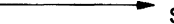





Signalling procedure on direct connections

A  B	a	b	c
Seizing 			
Z-digit 			
	A-1	A-14	A-14
	N1	N1	I-14
	A-1	A-1	A-1
	N2	N2	N1
Echo suppressor employed	YES/NO	NO	YES

CCITT-49950

TABLE 12/Q.479

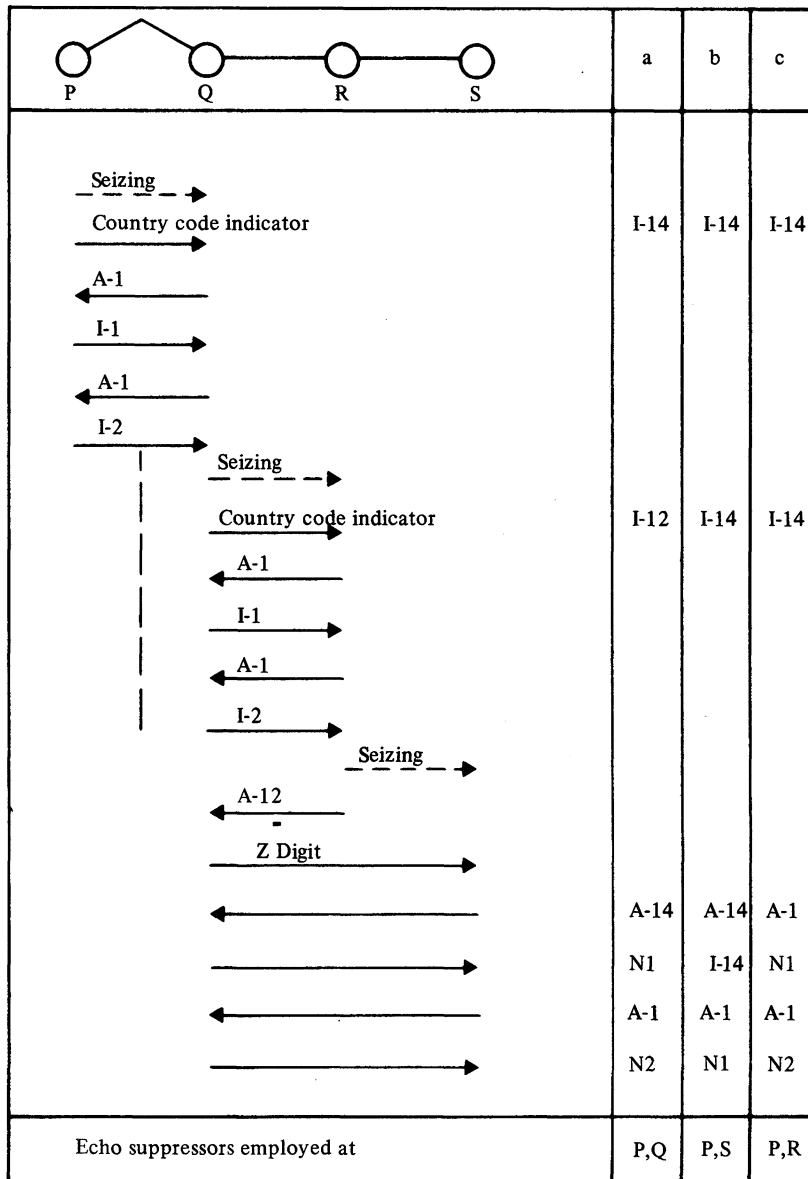
Signalling procedures on international transit connections via terrestrial circuits

A  B  C  D	a	b	c	d	e
Seizing 					
Country code indicator 	I-12	I-14	I-11	I-14	I-11
 A-1					
 I-1					
 A-1					
 I-2					
 A-11  Seizing					
Country code indicator 	I-12	I-14	I-14	I-14	I-14
 A-1					
 I-1					
 A-1					
 I-2					
 A-12  Seizing					
Z-digit 					
	A-14	A-14	A-14	A-1	A-1
	N1	I-14	I-14	N1	N1
	A-1	A-1	A-1	A-1	A-1
	N2	N1	N1	N2	N2
Echo suppressors employed at	—	A,D	B,D	A,C	B,C

CCITT-49960

TABLE 13/Q.479

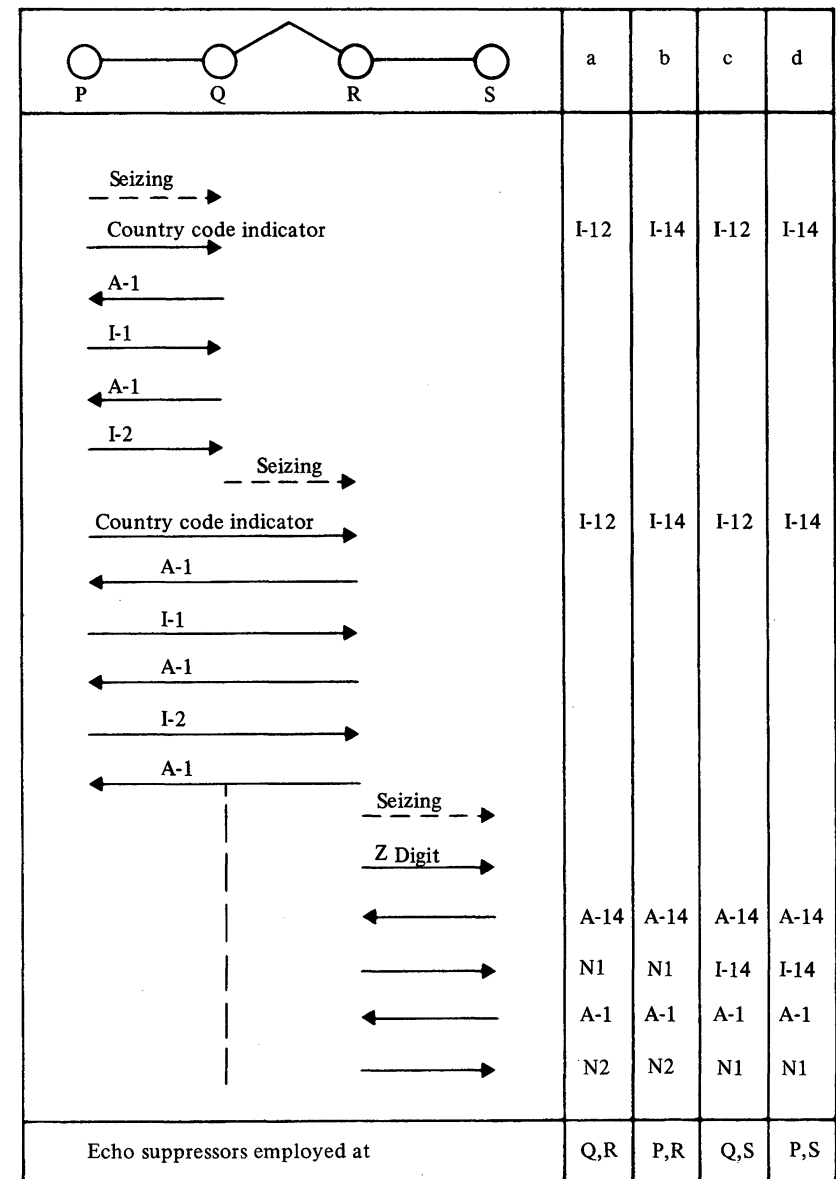
Signalling procedures on international transit connection
when the first link is via satellite



CCITT-73450

TABLE 14/Q.479

Signalling procedures on international transit connection
when a subsequent link is via satellite



CCITT-73460

5.8 MISCELLANEOUS PROCEDURES

5.8.1 *Nature of circuit procedure for international working*

An incoming R2 register in an international transit exchange or in the country of destination can elicit the nature of the circuit as soon as at least one forward signal has been received from an outgoing register.

The incoming R2 register requests nature of circuit by sending the backward signal A-13. The outgoing R2 register, if capable, sends the nature of the circuit indicator signal I-13 or I-14 in reply.

Signal A-13 can be sent after any forward signal (Groups I and II) and particularly after any address digit, but it can only be sent prior to any transmission of signal A-3.

If the outgoing R2 register does not have the capability of providing the nature of circuit, signal I-12 (request not accepted) is sent in reply to signal A-13. The incoming R2 register will then ask for the following address digit by sending signal A-1, for example. If the outgoing R2 register receives signal A-13 again it will send signal I-12 again.

For existing equipment if the outgoing international R2 register does not have the capability of providing the nature of the circuit, but is capable of sending identification information as defined in the *Yellow Book*, the procedure starts with the first digit of the country code.

5.8.2 *Identification procedure for national working*

System R2 makes provision for the signalling necessary to identify the calling subscriber's line: for example, by repetition of signal A-5 or by using one of signals A-9 or A-10. For the time being this procedure is restricted to national working only; outgoing international R2 registers prevent its use over international links (see § 5.8.4). The outgoing R2 register at the incoming end of an international satellite link must similarly prevent its use via that link.

5.8.3 *Processing of Group II signals reserved for national use*

The Group II signals reserved for national use must be converted in the outgoing international R2 register to Group II signals used for international working.

The conversion must be carried out as follows:

- II-1 must be converted to II-7
- II-2 must be converted to II-7 or II-9
- II-3 must be converted to II-7
- II-4 must be converted to II-7
- II-5 must be converted to II-7 or II-10
- II-6 must be converted to II-8
- II-11 to II-15 must be converted to II-7.

Since there are no Recommendations yet regarding handling of priority calls in automatic international working, conversion of signal II-2 to signal II-9 must be the subject of bilateral agreement.

If an incoming R2 register is situated in a national exchange and because signals II-7 to II-10 are not used for national working, then analysis of Group II signals enables a distinction to be made between nationally and internationally originated calls.

If an incoming R2 register knows a call is of international origin and if a Group II signal reserved for national use is received, signal A-4 or B-4 (congestion on the national network) should be sent in acknowledgement. This procedure cannot be applied if an incoming R2 register in the destination country is employed for national and international working and is not able to detect the origin of the call.

5.8.4 *Procedures to be followed by outgoing international R2 registers on receipt of particular backward signals*

An outgoing international R2 register must send the appropriate calling party's category signal (II-7 to II-10) in reply to signals A-3 and A-5.

On recognition of one of the signals A-9 or A-10 an outgoing international R2 register sends signal I-12 (request not accepted) in response. Therefore, national incoming R2 registers using these signals should be equipped to receive signal I-12.

The incoming national R2 register receiving I-12 has to determine the appropriate international standardized signal to be sent in response to signal I-12 and which substitutes for signals A-9 or A-10.

In reply to signal A-14 an outgoing international R2 register sends:

- signal I-14 when an incoming half-echo supressor is required;
- the next address digit (a signal I-1 to I-10) when no incoming half-echo suppressor is required.

If an outgoing international R2 register receives a backward signal requesting an impossibility in the logical procedure (e.g. receipt of signal A-8 after sending the country code indicator), the call shall be released.

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SECTION 6

TESTING AND MAINTENANCE

Recommendation Q.490

TESTING AND MAINTENANCE

6.1 *General*

In international working the guiding principles and testing arrangements for maintenance as defined in Recommendations M.700 to M.728 and Q.134 also apply to Signalling System R2. The organization of routine maintenance, tests and measurements of signalling and switching should comply with Recommendations M.716, M.718, M.719, M.728 and M.732.

The analogue line signalling of System R2 differs from other CCITT signalling systems in two significant respects:

- line signals are sent over out-band signalling channels;
- an “interruption control” protects the line signalling from the consequences of interruptions of the transmission path.

These two features of System R2 require special attention from a maintenance point of view.

6.2 *Automatic procedures for transmission measurements and signalling tests*

Circuits operated with System R2 require elaborate transmission measurements and signalling tests and also rapid and simple testing of transmission and signalling. Both needs are preferably met by means of automatic devices.

The specification for ATME-2 as adopted by CCITT makes it applicable to the testing of international circuits using System R2. The necessary information for its use on such circuits is contained in Recommendation O.22.

A description of a simplified programme for rapid testing of signalling and checking the transmission quality of a circuit is given in § 6.3. Generally speaking, the arrangements for automatic testing consist of outgoing test equipment connected at the outgoing end of the circuit and incoming test equipment connected at the incoming end.

6.3 *Automatic test procedures for test equipments*

Automatic test procedures provides a means for rapid testing of signalling and also checking the transmission quality of circuits operated with Signalling System R2.

6.3.1 *Numbering of access to test equipment*

In international working, to set up a call to maintenance equipment via circuits operated with System R2, the following multifrequency signals must be sent:

- I-13 (replacing the language digit, in accordance with Recommendation Q.133),
- I-13,
- two digits “XY” which will be associated with the type of test equipment and the procedure for testing to be employed (see Recommendation Q.107, Table 7),
- I-15 (if requested by the incoming equipment).

Provision is made for repetition of signal I-13 to avoid complications in the incoming R2 register in the country of destination. The second signal I-13 is stored in the place where the first digit of the routing information is normally recorded. In this way, access to the test equipment requires no analysis, for routing purpose, of the signal which takes the place of the language digit.

When calls are set up to the test equipment, it is desirable to avoid repetition of the request for the access code or for any other digit. This is because the calls may come from equipment which is not normally designed to interpret signals A-2, A-7 or A-8.

The address complete signal to be sent on calls to test equipment must be one of the following:

- A-6 or A-3 followed by B-6 when incoming test equipment is free,
- A-4 or A-3 followed by B-3 or B-4 when incoming test equipment is busy.

Precautions should be taken that signal A-6 is only sent when it is sure that the incoming test equipment is available for that call. When receiving signal A-3, the outgoing test equipment sends signal II-7 in response.

Note – In national working, or in international working where the language digit is omitted by bilateral agreement, the following multifrequency signals must be sent:

- I-13.
- Two digits “XY”.
- I-15 (if necessary).

6.3.2 *Test sequence for simplified test*

The test sequence is as follows:

- a) seizing of the automatic incoming test equipment;
- b) transition to answer state;
- c) sending backward of a composite identification signal 1020 + 1140 Hz; this signal will be acknowledged in a compelled manner by the signal mentioned under d);
- d) recognition of a composite acknowledgement signal 1380 + 1980 Hz, sent in the forward direction;
- e) on the disappearance of the acknowledgement signal the incoming test equipment passes to the clear-back state;
- f) on recognition of the clear-back signal, the outgoing equipment will send in a normal manner the clear-forward signal which will clear the connection and release incoming test equipment. After release of the incoming line circuit the release-guard signal will be sent in the normal way.

Detection of failure is made by timing out at the outgoing equipment.

The frequencies mentioned under c) and d) are those for System R2 interregister signalling; transmission and reception of these frequencies in the incoming test equipment must be in accordance with Section 4.

Attenuation pads may be inserted in the send and receive paths of the outgoing test equipment to shift the receive level at the input of the multifrequency receivers of the outgoing and incoming test equipment toward the lower operational limit. This makes it possible to diagnose abnormal loss on the circuit under test from defective multifrequency signal exchange between outgoing and incoming test equipment. For testing international System R2 circuits, the additional attenuation produced by the pads should be 10 ± 1 dB.

6.3.3 *Good/no good transmission test equipment*

In addition to the tests described in §§ 6.3.1 and 6.3.2 a good/no good transmission test may be provided as a simple means for fast error localization. Such a test is described in Recommendation Q.137 for System No. 4 (i.e. and the frequency of the test signal, the tolerances and the deviation from the nominal value, the test signal generators and receivers would all be the same) but the sending level being -10 dBm.

It is to be noted that loop transmission measurements of the kind specified in Recommendation Q.136 cannot be made on System R2 circuits.

6.4 *Testing of analogue line signalling equipment under abnormal conditions*

The specification of the analogue line signalling equipment contains clauses concerning operation under abnormal conditions, including the action to be taken in case of interruption control alarm. The testing equipment described in § 6.2 is not applicable to such conditions and therefore the functioning of the analogue line signalling equipment under abnormal conditions should be tested internally at each end of a circuit either manually or automatically with special equipment.

The detailed programme for this testing will be specified by each Administration.

The design and construction of the line signalling equipment should be such as to permit both operational and limit testing in normal and abnormal conditions.

6.5 *Alarms for the technical staff*

Certain abnormal conditions in the signalling equipment should cause alarms to be set off for the technical staff (see also Recommendation Q.117). The relevant requirements are found in Section 2 (line signalling equipment) and in Section 5 (time-out in multifrequency registers).

As indicated in § 2.2.3, a fault occurring during release of a circuit may result in an abnormal blocking condition. In this case there is a "tone-on" condition in both signalling directions, yet the circuit is not in the idle condition since the release-guard signal has not been received. If no special action is taken, a temporary fault may therefore result in the circuit's being out of service until it is manually restored by the maintenance staff, after receipt of an alarm (see § 2.2.4).

It may accordingly be desirable to arrange for automatic restoration of abnormally blocked circuits. For Administrations wishing to introduce this function, the recommended arrangement is described below.

6.6 *Recommended method for automatic restoration of an abnormally blocked circuit*

When an outgoing link is abnormally blocked, periodic sending on the outgoing link of the seizing signal, followed shortly afterwards by the clear-forward signal, is initiated.

Clearance of the fault which caused the abnormal blocked condition will initiate a release-guard signal at the incoming end whereupon the outgoing end restores the link to the idle condition.

The intervals, at which the periodic sequence described above is repeated, should be between 30 seconds and 2 minutes.

The first operation of the automatic device should be performed as soon as possible, but not before 2-3 seconds have elapsed, after recognition of the abnormally blocked condition at T1 (see § 2.2).

After a period of three to six minutes a delayed alarm should be given in accordance with Recommendation Q.412, § 2.2.4.

In the event of a backward tone-off condition being detected, other than in response to a periodic clear-forward signal, the periodic sequence is suspended until the backward tone is again recognized whereupon the periodic sending sequence is restarted.

If interruption control at the outgoing end occurs during the abnormally blocked condition, the periodic sending sequence is suspended until the interruption control reverts to normal, whereupon the periodic sending sequence is restarted.

6.7 *Instructions for the maintenance of channels and circuits using System R2 line signalling system at 3825 Hz*

The analogue line signalling equipment specified in Section 2 is closely associated with the channel translating equipment and its operation may be a function of the group and supergroup translating and through-connection equipments. Maintenance of the circuits and groups which support them is governed by the principles and Recommendations of Volume IV. However, the introduction of out-band signalling calls for a few complements to these Recommendations, as described below.

6.7.1 *Bringing into service of group, supergroup, mastergroup or supermastergroup links*

a) *§§ 2.1 and 7.6 of Recommendation M.460*

It should be noted that group and supergroup pilots placed at 140 Hz from a virtual carrier frequency are incompatible with signalling at 3825 Hz. Hence, the pilot on 84.140 kHz should not be applied to groups in which channel 6 is to be operated with this out-band signalling. Similarly, the pilot on 411.860 kHz should not be applied to supergroups in which channel 1 of the group in the group 3 position is to be operated with signalling at 3825 Hz.

If the channels of a group are to be operated with System R2, each extremity of the group should be equipped, at the receiving end, with a device to give protection against faulty signalling conditions which may result from an interruption in the transmission channels (interruption control). This equipment, which is based on pilot level detection; must comply with the conditions specified in § 2.4.3 of Recommendation Q.416.

Note — If the channels of a supergroup which are operated with System R2 have the same extremities as the supergroup, a device based on monitoring of the supergroup pilot can be used instead of one based on monitoring of the group pilot. It will have to meet the same specifications.

b) § 7.2 of Recommendation M.460

The group-translating and through-connection equipments are specified with a passband extending from 60.600 kHz to 107.700 kHz. If it is wished to use channels 12 with signalling at 3825 Hz, it is necessary to ensure when the group is set up, that the corresponding frequency (60.175 kHz) is transmitted satisfactorily from end to end of the group link.

Provisionally, in view of the operating margin of the receiving part of the signalling equipment, it is desirable to check that attenuation at this frequency does not exceed the attenuation at the group pilot frequency by more than 3 dB.

A similar precaution should be taken on setting up group links when signalling is to be used at 3825 Hz on channel 12 of the group transmitted in position 5 on the supergroup.

6.7.2 *Setting-up and lining-up the channels of an international group*

6.7.2.1 *Setting up the out-band signalling channel for the System R2*

Testing of the sending equipment:

- The sending level of the signalling frequency corresponding to 3825 Hz if the carrier is taken as the frequency of origin must be lined up at -20 ± 1 dBm0. When this frequency is not to be sent, its leak transmitted to line should not exceed -45 dBm0.

Testing of the receiving equipment:

- The signalling receiver must operate in the conditions described in §§ 2.3.2.1 and 2.3.2.2. It must not function when a signal, of which the characteristics (level and frequency) are such that the representative point is below the graph in Figure 8/Q.415, is applied to the same point.

This test may be replaced by the following one to check the protection against unwanted signals (impulsive noise):

- The sending part of the group terminal equipment is connected to its receiving part by a closed-circuit loop at the group distribution frame, this loop introducing a slight gain (e.g. 3 dB) if possible. The standardized click generator (see Figure 7/Q.414) is applied to each speech channel successively at the point where this channel is connected to the switching equipment, and a check is made to ensure that no wrong signals are retransmitted at the receiving end to the switching equipment by the channel signalling equipment concerned or by those of the other channels in the group.

6.7.2.2 *Closed-circuit loop tests: response time*

When the transmission-reception loop of the terminal equipment is effected at the group distribution frame or at an equivalent point, a check is made to ensure that less than 30 ms elapse between the moment when the change of condition is applied to the transmitter associated with each channel and the moment when it appears at the output of the corresponding receiver.

6.7.2.3 *End-to-end tests*

When the terminal channel-translating equipments are normally connected to the extremities of the link, an end-to-end operating test is carried out. The level of the line-signalling frequencies transmitted and received for each channel are likewise measured, to provide a reference, at the group terminal distribution frames or at equivalent points.

ANNEX A

(to Signalling System R2 Specifications)

(see Recommendations Q.400 and Q.441)

Provision of a forward-transfer signalling facility

A.1 General

The System R2 does not provide a forward-transfer line signal. However for certain relations it may be decided by bilateral or multilateral agreement to introduce the forward-transfer signalling facility into System R2.

One possible procedure that has been adopted for use within Europe, is to use the PYY in-band signal of System No. 4. This solution is only economical in regions where the facility is needed for a small proportion of the calls.

For international working the method as described below may be followed.

Note – The method given in this Annex may also be adopted in national networks where the forward-transfer facility is considered necessary for trunk offering and recalling operators. However, care must be taken to see that the transmission limits applying to the forward-transfer signal specified are observed.

A.2 Method recommended for introducing the forward-transfer signalling facility into System R2

Forward-transfer signalling will be provided by means of special equipment which uses in-band signalling and which is switched only on to those connections which may require this facility. The amount of special equipment necessary can, accordingly, be reduced to a minimum and adapted, in a flexible manner, to actual needs. The in-band signal constituting the forward-transfer signal is sent end-to-end between the outgoing and incoming international exchanges. When the special equipment receives the forward-transfer signal, it performs the necessary operations at the incoming exchange.

A.2.1 Access to the special equipment in an incoming international exchange

In an incoming international exchange access to the special equipment for forward-transfer signalling can be determined by the use of the following indicators:

- 1) Special marking of incoming routes on which forward-transfer signalling is used.
- 2) Language digit indicating semi-automatic traffic.
- 3) Calls for code 11 or code 12 operator.
- 4) Special interregister signalling sequence in which the incoming exchange sends signal A-5, *send calling party's category*. If the forward-transfer signalling facility is required the outgoing R2 register will respond to this by sending the signal II-10. This signal indicates an operator-initiated call on which special equipment for forward-transfer signalling is needed.

The use of these indicators will depend on the amount of traffic for which forward-transfer signalling is employed. In some cases one or two of the indicators will be utilized. In others, combinations of all will be used to reduce to a minimum the amount of special equipment required.

A.2.2 In-band forward-transfer signalling

In System R2 the in-band forward-transfer signal is the same as that used in System No. 4. For the definition of this signal see Recommendation Q.120, § 1.12. The signal is the signal PYY defined in Recommendation Q.121, § 2.3. The forward-transfer signal is sent in accordance with Recommendations Q.122 and Q.124.

The signal receiver and the splitting arrangements to be incorporated in the special equipment at the incoming international exchange are in accordance with Recommendations Q.123 and Q.124.

Provided it creates no difficulty for incoming national network signalling, no splitting need be effected at the receiving end and the caller will then hear the entire signal PYY.

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PART IV

**SUPPLEMENTS TO THE SERIES Q RECOMMENDATIONS
CONCERNING SIGNALLING SYSTEMS R1 AND R2**

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**LINE SIGNALLING FOR DC LINES WITH SYSTEM
R2 INTERREGISTER SIGNALLING**

1 Introduction

In the following specification a line signalling system is defined for 2-wire, DC-lines with or without metering facility during speech.

The signalling polarity is provided by the incoming exchange and a loop is provided in the outgoing exchange, so that in case of cable fracture the outgoing exchange is informed automatically that the line(s) concerned is(are) no longer available.

The line signal repertoire is based on the presence of System R2 interregister signalling.

Apart from the metering pulses, the line signalling is continuous, which means that a certain state of a connection is characterized by a special signalling condition which is maintained as long as the indicated condition continues to exist.

The following states are provided:

Forward direction:

- 1) idle
- 2) seized
- 3) clear-forward

Backward direction:

- 1) available
- 2) seized before answer
- 3) answered¹⁾
- 4) metering²⁾
- 5) clear-back¹⁾
- 6) forced release²⁾
- 7) not available (blocking)

2 Principles of the signalling and speech circuit

2.1 Signalling circuit

An example of a signalling circuit is shown in Figure 1. Feeding of the loop occurs at the incoming exchange; the direction of the current can be reversed by contacts X and the feeding current can be switched off by contacts Tu. Contacts Bl are also used to switch off the feeding current and consequently, to block the circuit. This can only take place if the line circuit in the outgoing exchange is detected as being in the open or high resistance state.

When the contacts are in the position shown in the figure, normal loop current flows and when the contacts X are switched over reversed loop current flows.

In the outgoing exchange the state can be changed, by means of contact W, from the high resistance condition with the current-direction sensitive detector H switched in, to a state with two low resistance current-direction sensitive detectors L and R.

In addition to contact W a contact K is provided to open the loop; the open loop state is used to expedite the recognition of clear-forward.

¹⁾ only without metering

²⁾ only with metering

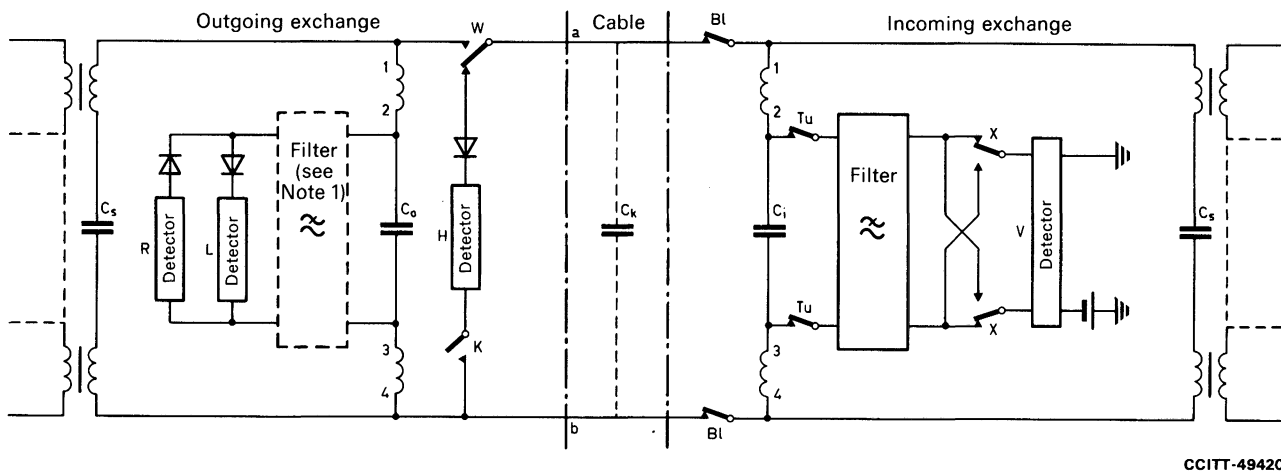
In the line circuit in the incoming exchange a filter is needed to provide sufficient attenuation in the audible components arising in case of polarity reversing. This is necessary, in particular, when metering pulses are sent during conversation.

In the line circuit in the outgoing exchange a filter may be needed to provide sufficient attenuation in the audible components arising when detectors L and R are operated and/or released. This filter, if required at all, can normally be much simpler than the one used in the incoming exchange.

2.2 Speech circuit

An example of a speech circuit is also shown in Figure 1. A circuit equipped with the loop signalling system concerned has to be electrically separated, from the preceding or following parts of the connection. This prevents interference by longitudinal voltages in other parts of the connection.

The detectors shall be of high impedance for speech.



Note 1 – This filter is optional.

Note 2 – The detector V and the contacts X for the reversal of the direction of the current may be interchanged.

FIGURE 1

Principle of the signalling and speech circuit

3 Meaning of the signalling states

In the Tables 1, 2 and 3 the meaning of the various signalling states are shown.

Outgoing exchange:

- high resistance = idle
- low resistance = seized
- open = clear-forward.

Incoming exchange (*without* metering):

- normal loop polarity = available, seized or clear-back
- reversed loop polarity = unavailable or answer
- no voltage = unavailable (blocking).

Incoming exchange (*with* metering):

- normal loop polarity = available or seized
- reversed loop polarity = unavailable or metering pulse
- no voltage = unavailable (blocking) or forced release.

4 Discrimination between the various signalling states

It is not necessary to be able to discriminate between each state of one end and all states of the other end. However, the capabilities shown in Tables 1, 2 and 3 should be provided.

TABLE 1

Outgoing exchange (<i>without</i> metering) is in state:	Outgoing exchange must be able to discriminate in the incoming exchange:	
high resistance	normal loop polarity	(available)
	reversed loop polarity or no voltage	} (unavailable)
low resistance	reversed loop polarity	(answered)
	normal loop polarity	(seized, clear-back)

TABLE 2

Outgoing exchange (<i>with</i> metering) is in state:	Outgoing exchange must be able to discriminate in the incoming exchange:	
high resistance	normal loop polarity	(available)
	reversed loop polarity or no voltage	} (unavailable)
low resistance	reversed loop polarity	(metering pulse)
	normal loop polarity	(seized)
	no voltage	(forced release)

TABLE 3

Incoming exchange is in state:	Incoming exchange must be able to discriminate in the outgoing exchange:	
normal loop polarity or reversed loop polarity	low resistance	(seized)
	high resistance open	(idle) (clear-forward)

5 Operation (see Figures 2a-2f)

5.1 In the idle state the line circuit in the outgoing exchange continuously checks whether or not the line is blocked by the high resistance detector H. This detector operates when the line is intact and the normal loop polarity is present in the incoming exchange indicating the state "available".

Detector V in the incoming exchange is marginal and does not operate in this state.

5.2 If the circuit in the outgoing exchange is seized for a call the exchange switches in the low resistance state and the low resistance detector L operates.

In the line circuit in the incoming exchange the detector V operates and the incoming equipment assumes the seized state.

5.3 The B-subscriber answers

a) Without metering

When the B-subscriber answers this is indicated by the line circuit in the incoming exchange by reversing the loop feeding polarity to reversed loop polarity. In the circuit in the outgoing exchange the low resistance detector R operates and L releases.

b) *With metering*

When the B-subscriber answers this is indicated by the incoming exchange (except in the case of a call that is free of charge) by sending a metering pulse. The incoming exchange sends a metering pulse by reversing the loop feeding polarity to reversed loop polarity during the metering pulse.

In the line circuit in the outgoing exchange the low resistance detector R operates and L releases.

5.4 The equipment must allow the following rules to be applied with respect to the sending of metering pulses.

- A metering pulse must be completed by the incoming exchange before sending forced release.
- After sending a metering pulse there is no minimum period with normal loop polarity before forced release is sent.
- During the receipt of a metering pulse the outgoing exchange is allowed to start sending clear-forward.

5.5 *Backward release*

a) *Without metering*

The incoming exchange can inform the outgoing exchange that the B-subscriber has cleared by sending clear-back. This signal consists in reversing the loop feeding polarity to normal loop polarity. In the line circuit of the outgoing exchange the low resistance detector L operates and R releases.

The incoming exchange remains in this state (clear-back) until the outgoing exchange sends clear-forward or the B-subscriber reanswers.

b) *With metering*

The incoming exchange can inform the outgoing exchange that the connection can be released by sending forced release. This signal, which consists in switching off the loop feeding potential, must persist for a minimum time T3. After receiving forced release the line circuit of the outgoing exchange must transmit clear-forward within a time T4 which is less than time T3.

Time T3 finishes when the line circuit in the incoming exchange is again available; normal loop polarity is then sent.

The above mentioned clear-forward in the line circuit in the outgoing exchange is followed (just as in the case of the release without forced release described in § 5.6 by the idle state).

5.6 In order to release the circuit the outgoing exchange opens the loop (clear-forward) during a time T1, before switching in the high ohmic detector.

The incoming exchange must switch to one of the unavailable states within a time T2 which is less than T1, unless the circuit in this exchange is available before the time T2 has elapsed.

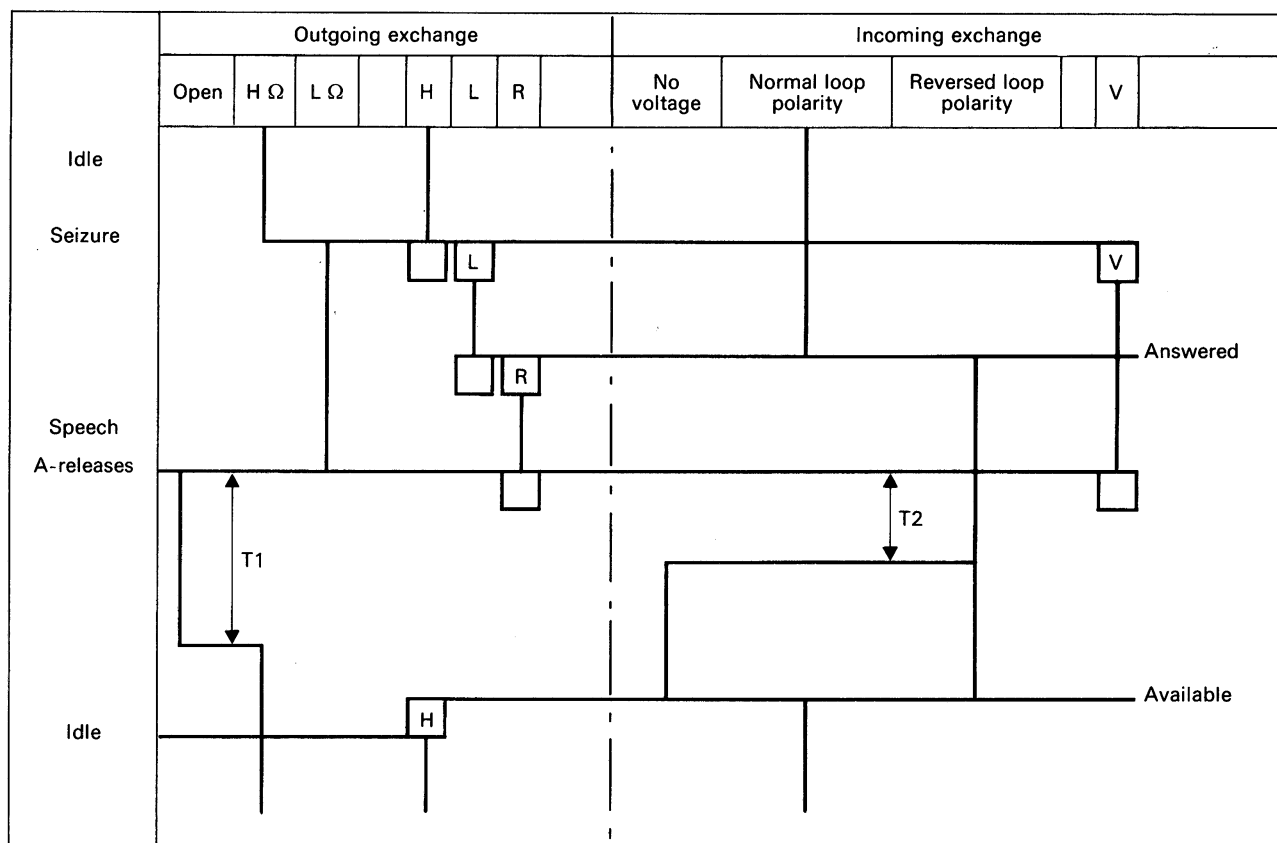
5.7 The incoming exchange can signal in two ways that it is not available for a new call, namely by reversing the loop or by switching off the feeding potentials.

In so far as the unavailability of the line circuit in the incoming exchange forms part of normal operation, this state should be indicated by reversed loop polarity.

Unavailability of the line circuit in the incoming exchange for other reasons should be indicated by switching off the feeding potentials.

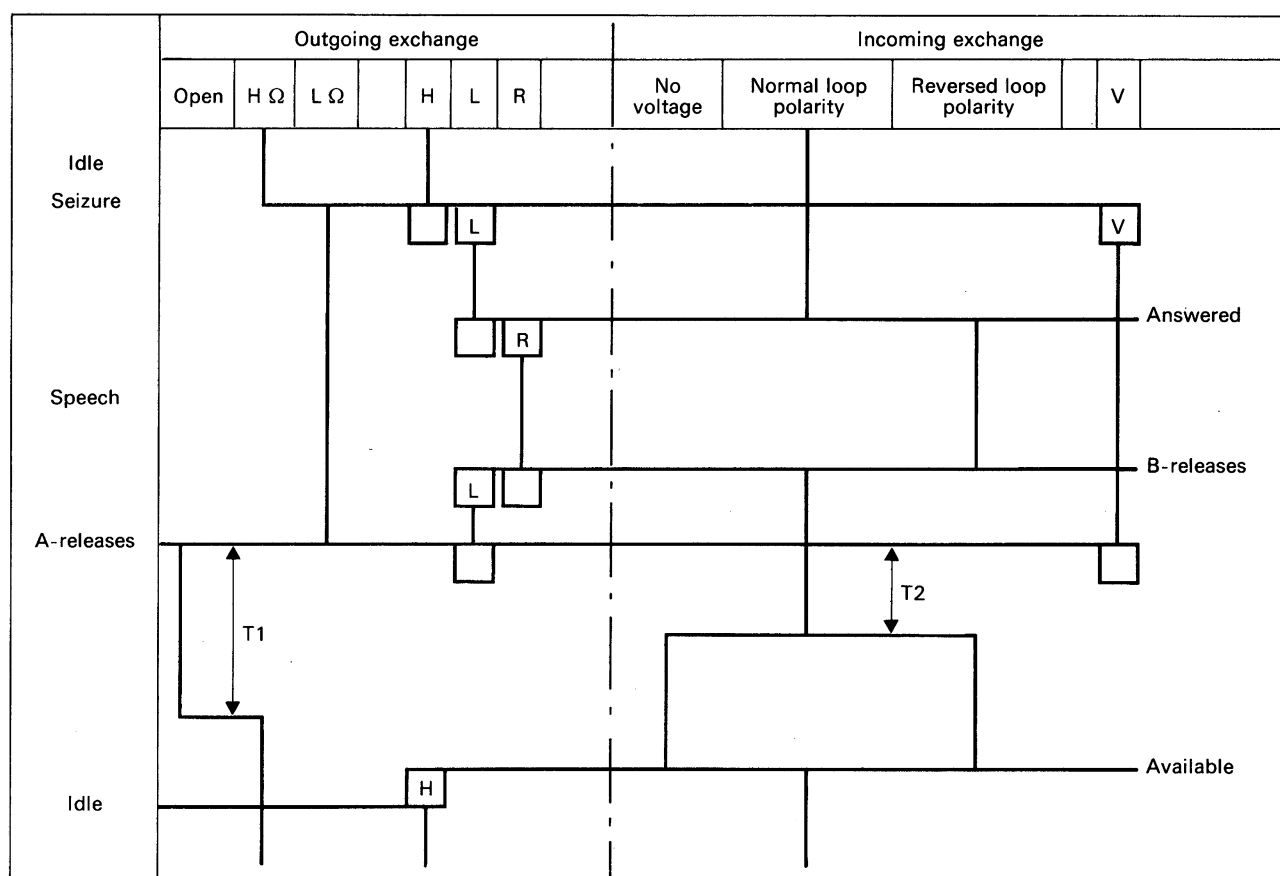
5.8 If during the seized state of the line circuit in the outgoing exchange, the circuit is interrupted by disturbances or by the feeding potential being switched off, the outgoing exchange has to react to it in the same way as it does to clear-back (without metering) or forced release (with metering), possibly followed by blocking.

5.9 At the incoming exchange during the unavailable state and for a subsequent period of 100 ms during the available state, operation of detector V should be ineffective.



a) A-subscriber releases first (without metering)

CCITT-49430

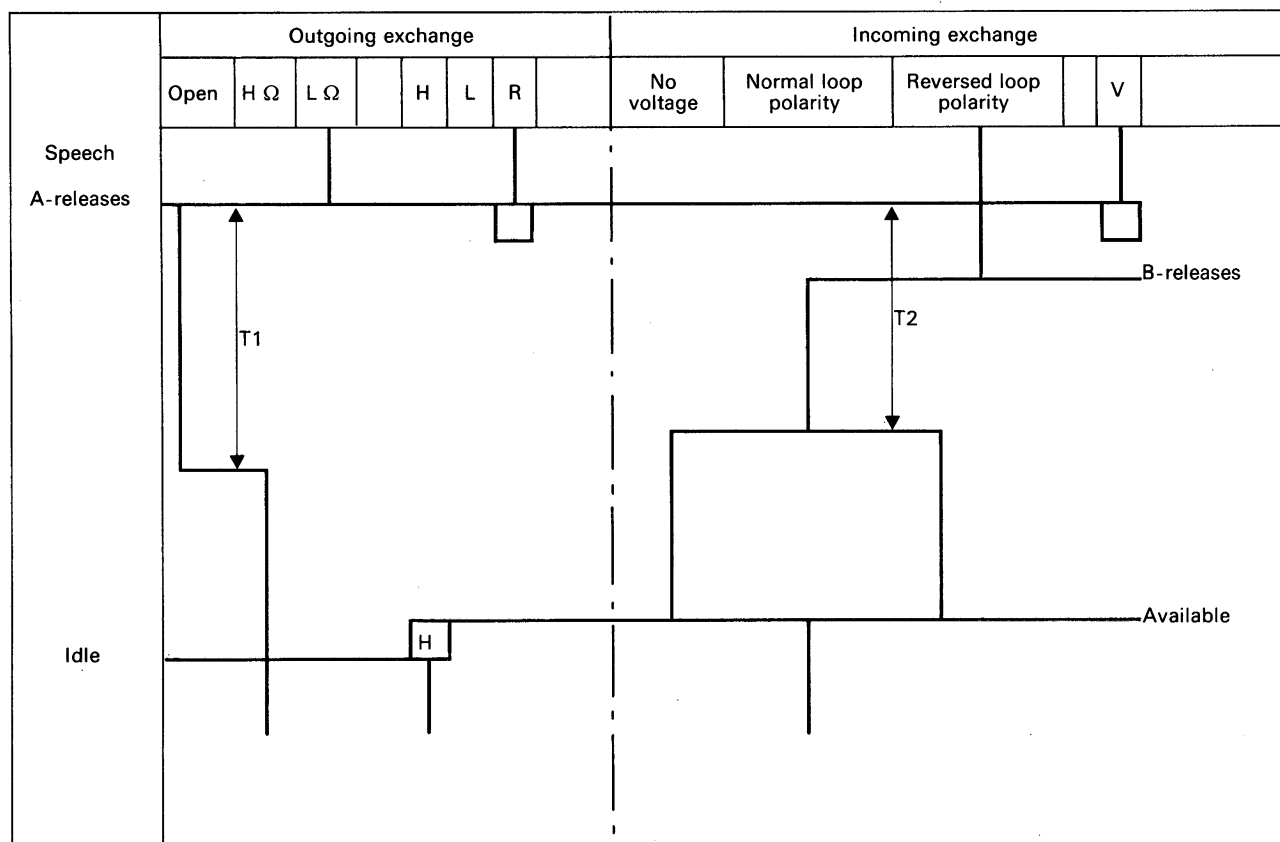


b) B-subscriber releases first (without metering)

CCITT-49440

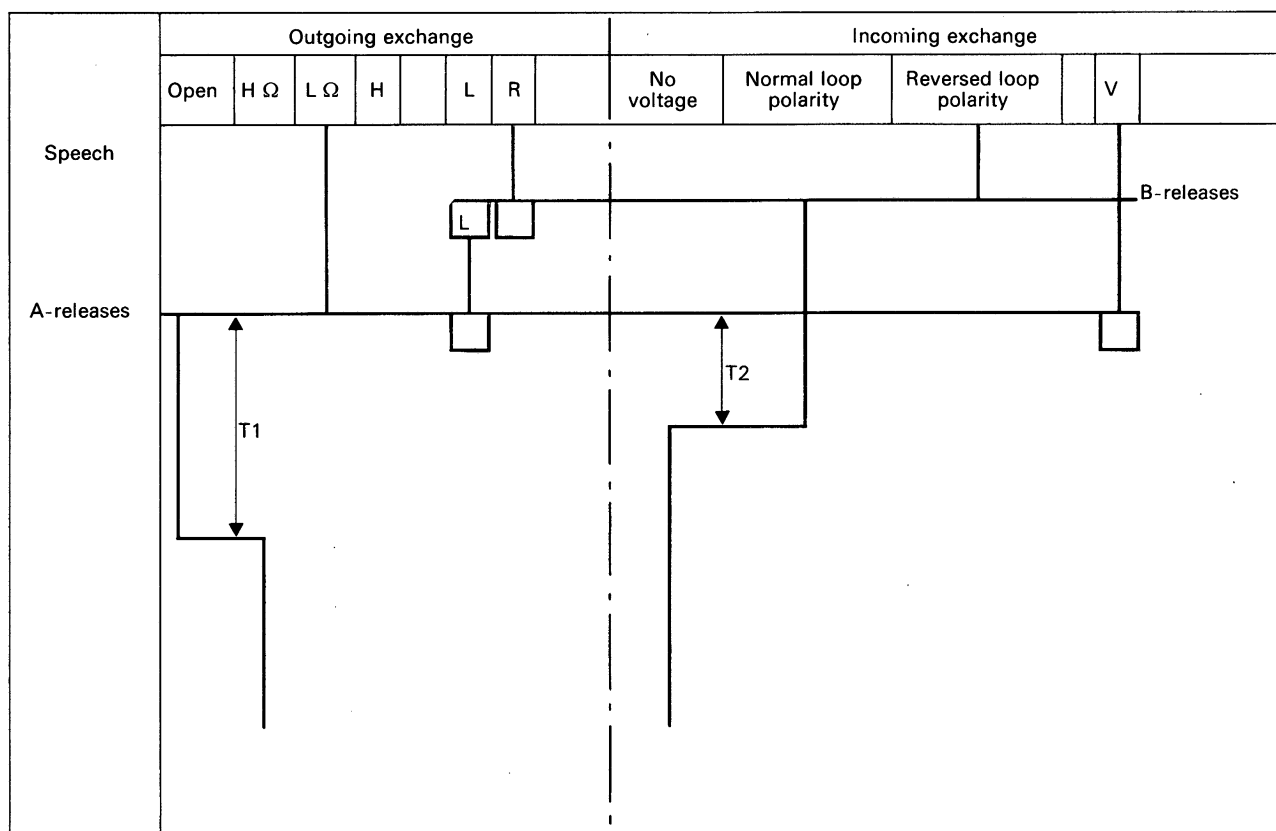
Note — In Figure 2 a square with a letter in it means the operation of the indicated detector while a square only means the release of that detector. A thick vertical line means that the related condition is there or that a detector is operated.

FIGURE 2



c) B-subscriber releases during open loop in the outgoing exchange (without metering)

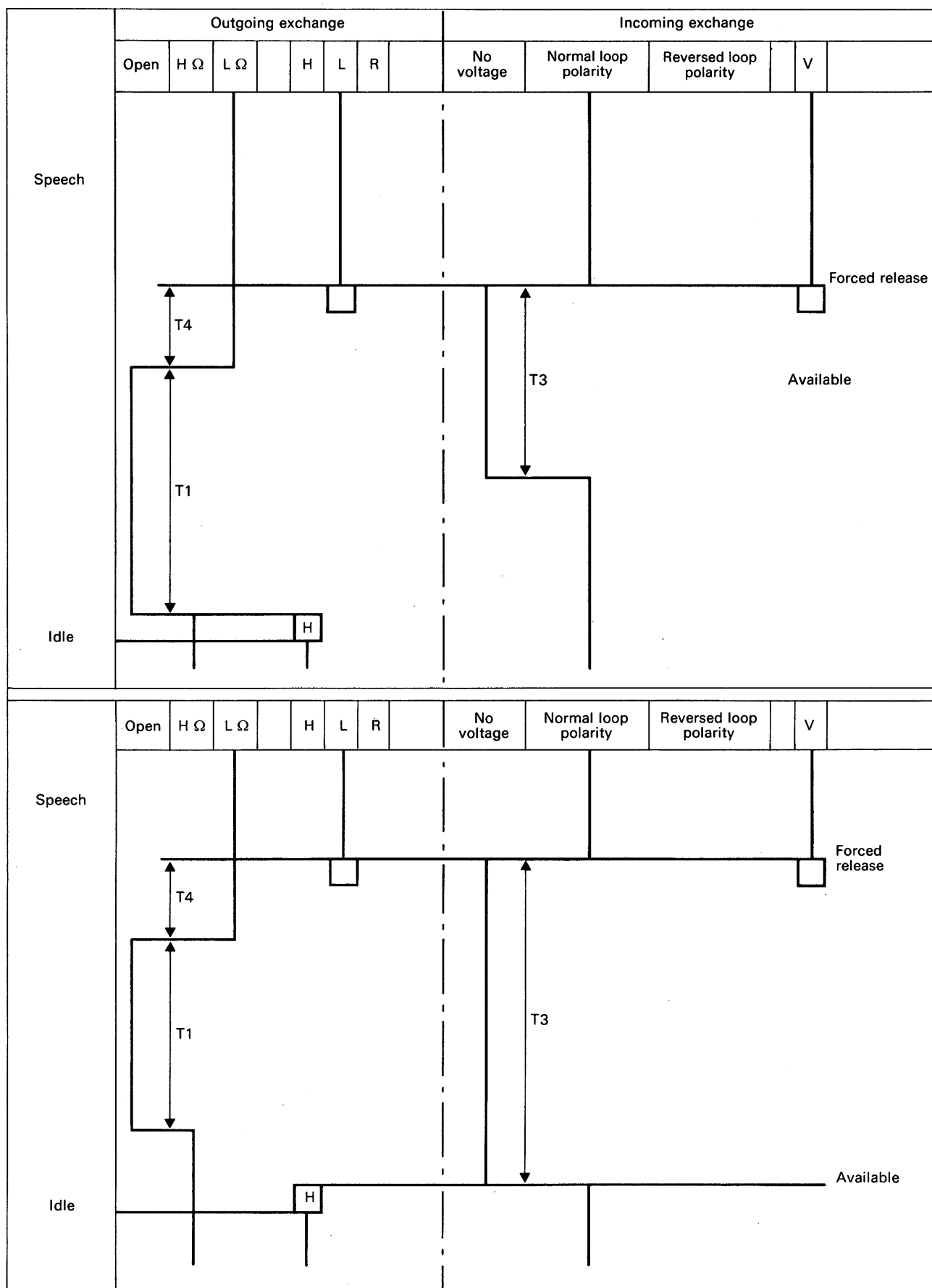
CCITT-49450



d) In-connection with subscriber releasing the incoming exchange blocks by means of open loop (without metering)

CCITT-49460

FIGURE 2 (continued)



f) Signalling procedure with forced release (with metering)

CCITT-49480

FIGURE 2 (end)

6 Time requirements

6.1 Recognition times

- a) When the outgoing exchanges is in the idle state but blocked the recognition time of the unblocking condition (normal loop polarity) must be 100-300 ms.
- b) In order to make a clear distinction between the reversal of the polarity and no voltage the recognition time of forced release must be 60-180 ms.
- c) The recognition time of all remaining conditions must be 10-40 ms.

6.2 Release times

- a) The time T2 depends on the recognition time of detector V and the reaction time of the incoming exchange which can be assumed ≤ 30 ms; consequently the time T2 is defined 10-70 ms.

- b) *Without metering*

The worst case when releasing a circuit occurs if the B-subscriber releases just after the A-subscriber releases, causing clear-back to be sent before the recognition time of clear-forward has elapsed. In order to safeguard the operation in that particular situation the time T1 is defined 300-600 ms.

- c) *With metering*

The worst case when releasing a circuit occurs if within the recognition time of clear-forward a metering pulse starts and that within the length of this pulse clear-forward cannot be recognized. In order to safeguard the operation in that particular situation the time T1 is defined 500-1000 ms.

The time T3 depends on the discharge time of the involved circuit and the time T4. For the discharge time, a time ≤ 80 ms can be assumed. The time T4 depends on the recognition time of forced release [see § 6.1 b)] and the reaction time of the outgoing exchange which can be assumed ≤ 30 ms; consequently the time T4 is defined 60-210 ms. Addition of these times leads to a time T3 ≥ 300 ms.

6.3 Sending times

The length of the metering pulse to be sent shall be 120-180 ms.

7 Miscellaneous

This supplement does not describe values for the impedance of the detectors and the cable and does not indicate operate/nonoperate limits for the detectors, because these parameter are rather dependent on the capabilities of the related network. Therefore these requirements must be provided by each Administration.

Supplement No. 2

BOTH-WAY WORKING OF THE ANALOGUE LINE SIGNALLING VERSION OF SIGNALLING SYSTEM R2

1 Both-way working

In principle the Signalling System R2 is specified for one-way working. The following additional clauses therefore apply only to cases where Administrations have undertaken by bilateral agreement to use both-way working.

Equipment which must be equally usable in both-way and in one-way operation should be so designed that it can be easily adapted to the requirements of either mode of operation.

A peculiarity of both-way working with the system under consideration is that a blocking signal cannot be distinguished from a seizing signal at either end of a circuit, since the transition of the signalling condition corresponding to these signals is the same, namely from *tone-on* to *tone-off*.

When a both-way circuit is seized simultaneously at both ends, the signalling tone is disconnected in both directions of transmission; this is the criterion for detecting the double-seizure situation.

The special arrangements required for both-way working relate to the two cases mentioned above. For all other signalling phases the specifications for one-way working remain valid without modification.

1.1 *Normal conditions*

1.1.1 *Double-seizure*

When the signalling equipment at one end of a both-way circuit seizes that circuit by disconnecting the signalling tone, it must verify that cessation of the signalling tone in the opposite direction does not occur within 250 ± 50 ms of the disconnection of the signalling tone in the forward direction. If the signalling equipment detects the removal of the signalling tone within that interval then a double-seizure situation is recognized. Each end must return to the idle state after sending the clear-forward signal and recognizing *tone-on* condition on the signalling channel.

However, each end must, even if immediately seized for an outgoing call, maintain *tone-on* condition for at least 100 ms on the outgoing signalling channel to ensure that the end of the double seizure situation is recognized at the other end.

Although a double seizure has been recognized, the *tone-off* condition in the backward direction is passed on backwards. This will be regarded as an erroneous answer signal and lead to the release of the connection in accordance with § 2.2.3 in the Specifications. However, as specified in § 1.2.1 below the clear-forward signal (*tone-on* condition) must not be sent until the *tone-off* condition has been maintained for at least 1250 ± 250 ms. Each end after sending of the clear-forward signal returns to the idle condition when the time interval 250 ± 50 ms (see § 2.2.2.6 in the Specifications) has elapsed, and the sending of the *tone-on* condition from the other end has been recognized.

In the sense of preventive action it is recommended that an opposite order of circuit selection is used by each exchange of a both-way circuit group to minimize double seizure.

1.1.2 *Minimum duration of idle state after release-guard*

When a both-way circuit is released, the end which acted as the incoming end must, even if immediately seized for a call in the opposite traffic direction, maintain the *tone-on* condition for at least 100 ms to ensure that the release-guard sequence is recognized at the other end.

1.1.3 *Blocking*

When a both-way circuit is blocked manually in its idle state at one end (A), the blocking signal, must be transmitted to the other end (B), where it will nevertheless be interpreted as a seizing signal. This will mean that an incoming R2 register is seized, but is not receiving any interregister signal. After the lapse of this register's time-out delay the circuit must be kept blocked locally (at end B) against all calls in the B-A direction so long as the *tone-off* condition persists in A-B direction.

To avoid certain difficulties (see §§ 1.2.1 and 1.2.2 below) and in contrast to § 2.2.3.5 in the Specifications the *tone-off* condition is not applied in the opposite direction (B-A) to the blocking direction (A-B).

When the blocking is removed at end A the signalling tone is again transmitted in direction A-B and the B-end interprets the onset of the signalling tone as a clear-forward signal, thereby initiating the release-guard sequence in the B-A direction.

1.2 *Abnormal conditions*

The cases described below relate to interruption of the individual signalling channels or to faults in the individual line-signalling equipment. Interruption control does not function in these cases.

In any circuit the interruption of one or both signalling channels can bring about signalling sequences different from those described in § 2.2.3 in the Specifications for one-way working.

1.2.1 When an interruption of the signalling channel in one of the two directions brings about a signalling state corresponding to blocking, the release-guard sequence will be initiated the moment the interruption ends (see § 1.1.3).

The release-guard sequence implies that the signalling tone in the backward direction be disconnected for an interval 450 ± 90 ms. In both-way working this *tone-off* condition must not be interpreted as seizing. To avoid a repetition of the exchange of release-guard sequences certain precautions must be taken.

The following additional requirements should then be met:

- when the *tone-off* condition has lasted for an interval of less than 750 ± 150 ms the return to *tone-on* condition must not initiate a release-guard sequence;
- once the signalling condition corresponding to seizing has been established, it must be maintained for at least 1250 ± 250 ms (this is a deviation to the requirement in § 2.2.2.1 in the Specifications).

When the interruption of one of the signalling channels has brought about blocking of the circuit at one end (B), as described above, that circuit can be seized at the other end (A). The end A will not have received the blocking signal from end B (see § 1.1.3) because that would cause permanent blocking of the circuit, which would then no longer be able to restore itself to normal functioning. Should a seizing now occur, this will lead to loss of a call; but subsequently, since the clear-forward signal cannot be transmitted, the circuit will remain blocked at end A. The whole further signalling sequence for reverting the circuit under consideration to idle follows the specification for one-way circuits.

1.2.2 An interruption of both signalling channels on any circuit will be interpreted by the equipment at each end of the line as seizing and the equipments will be blocked after the lapse of the time-out delay of the incoming R2 registers.

If, after an interruption, only one signalling channel is restored, the equipment at the incoming end in relation to that signalling channel will interpret the *tone-on* condition as a clear-forward signal and therefore bring into operation the release-guard sequence. The terminal equipment at that end will revert to the idle state, while the terminal equipment at the other end remains blocked. This is the situation envisaged in § 1.2.1 above.

When both signalling channels are simultaneously restored, the terminal equipment at both ends will interpret the onset of the signalling tone as a clear-forward signal and this will bring the release-guard sequence into operation. The result will be that the terminal equipment at both ends will again recognize the *tone-off* condition for a brief interval.

The following additional clause must be observed, to avoid permanent blocking of the circuit in this condition:

- When, after blocking, the line-signalling equipment at one end (A) of a both-way circuit has recognized the clear-forward signal, it must complete the release-guard sequence and restore the signalling tone after 450 ± 90 ms in the direction A-B, even if the tone in direction B-A is interrupted. If such interruption (in direction B-A) lasts for less than 750 ± 150 ms, the circuit returns to the idle state when the signalling tone is restored in both directions. If the interruption is longer than 750 ± 150 ms, restoration of the signalling tone in direction B-A will initiate a new release-guard sequence in direction A-B (see § 1.2.1 above).

1.2.3 If an abnormal condition according to § 2.2.3.3 in the Specifications occurs at one end of a both-way circuit, this end is blocked for outgoing traffic. Such blocking should, however, not prevent the circuit being used in the other traffic direction.

2 Special conditions regarding the interruption control for both-way working

2.1 As soon as an operating condition has been established on a both-way circuit and the outgoing and incoming ends of the circuit have been determined with certainty, the interruption control specifications for one-way working become equally applicable to both-way circuits.

2.2 When a both-way circuit is in the idle state, transition to alarm of the interruption control of one direction of transmission must bring about operations to ensure that the signalling condition existing at that moment on the signalling channel of the opposite direction is maintained – in contrast to specification 2.4.2.1 a) i) in the Specifications for one-way working. This precaution obviates a permanent blocking of a both-way circuit when interruption of the signalling channels occurs simultaneously in both directions. It does not ensure immediate blocking of the circuit; this will not occur until the circuit has been seized by the next call.

2.3 In all operating conditions intermediate between the *idle* state and the condition at the moment when the direction of seizure of the both-way circuit is determined (see above), the line-signalling equipment at both ends will be locked by interruption control in the condition in which it was before interruption control passed to alarm.

Supplement No. 3

USE OF THE ANALOGUE LINE SIGNALLING VERSION ON 2048 kbit/s PCM TRANSMISSION SYSTEMS

(refer to Recommendation G.732)

This solution is restricted for use within national networks or internationally subject to bilateral agreements because it requires some conventions which otherwise would have to be agreed upon in CCITT. However, cost aspects may be a more decisive factor than the required conventions.

The analogue version of the line signalling is used on both the analogue and the digital transmission systems.

Two examples of the use of the analogue line signalling on digital transmission systems are shown in Figure 1.

Apart from the interruption control handling, the transmultiplexer or other conversion equipment is transparent to the line signalling.

The out-slot signalling is carried in time slot 16 of 2048 kbit/s systems (refer to Recommendation G.732, Table 3). Bit *a* of time slot 16 is used to transmit the line signalling state of the corresponding analogue channel. Bit *b* is used to indicate that the analogue transmission system is in the alarm condition with the following convention. For all the digital circuits connected to the circuits of this analogue group bit *b* = 1 means alarm condition on the analogue group.

1 In order to ensure the correct working of the line signalling under fault conditions when employing T MUX some time requirements must be fulfilled.

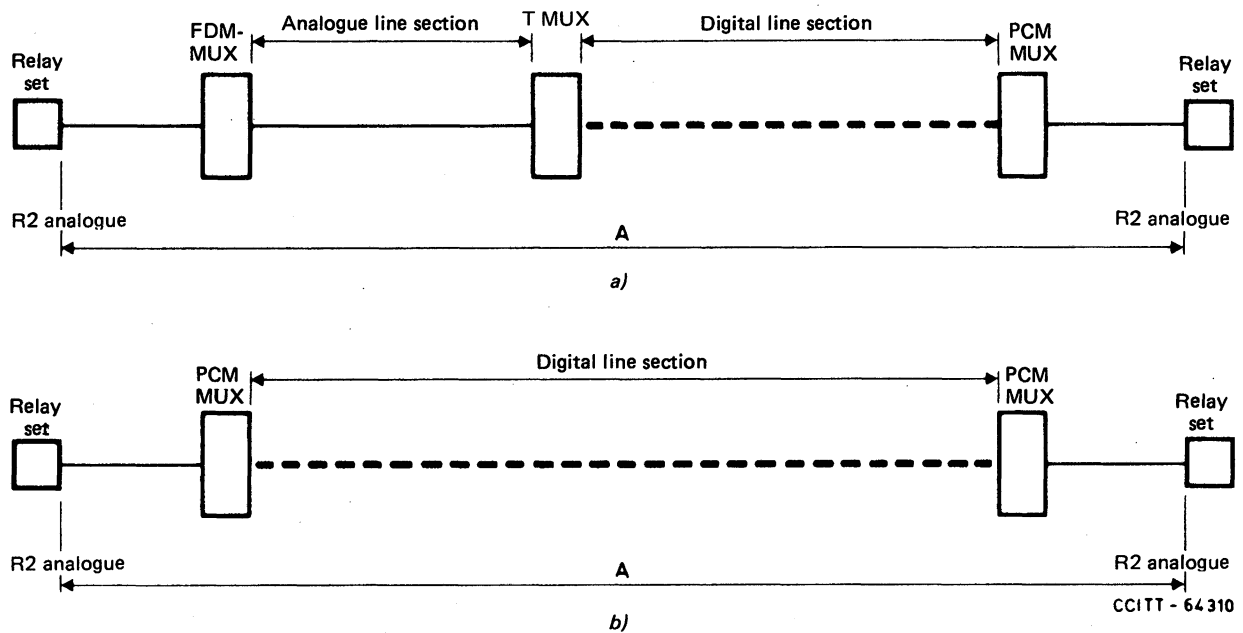
1.1 *The fault occurs on a PCM multiplex* (see Figure 2)

If the fault occurs on PCM multiplex No. 1, the transmission of the alarm indication will take place in the following time conditions:

- the fault occurs at T ;
- the fault is detected by the transmultiplexer at $T + t_1$;
- the transmultiplexer stops sending the pilot on GP₁, GP₂ and GP₃ at $T + t_1 + t_2$;
- the alarm indication is detected at the analogue distant end at $T + t_1 + t_2 + t_3 + t_p$

where:

- t_1 is the time needed for recognition of the faulty transmission on a PCM 2048 kbit/s multiplex;
- t_2 is a processing time needed by the transmultiplexer after detection of alarm on the PCM multiplex;
- t_3 is the response time for the pilot receiver when the pilot level falls: it is the time t_d specified in Recommendation Q.416 ($t_d < t_{rs \min} + 13$ ms), applicable only for the recognition time $t = 20 \pm 7$ ms;
- t_p is the propagation delay on the analogue section.



A = Signalling System R2 analogue line signalling version

FIGURE 1

Examples of the use of the analogue line signalling
on digital transmission systems

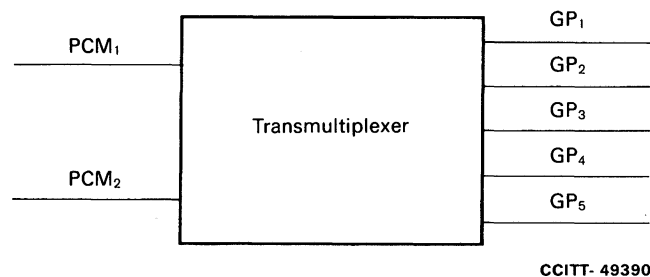


FIGURE 2

In the same situation, if the transmission fault disturbs signalling information, erroneous signals will be transmitted in the following time conditions:

- the fault occurs at T ;
- the erroneous signalling condition appears at the input of the analogue channel at $T + t_4$;
- the erroneous signalling condition appears at the input of the distant signalling equipment at $T + t_4 + t_5 + t_p$

where:

- t_4 is the time needed for transferring a line signal from digital access to analogue access;
- t_5 is the response time of the line signals receiver at the distant analogue end (t_{rs} in Signalling System R2 Specifications);
- t_p is the propagation delay on the analogue section.

If t_r is the recognition time of line signals specified in Recommendation Q.412, correct working can be ensured if:

$$t_1 + t_2 + t_3 + t_p \leq t_4 + t_5 + t_p + t_r$$

or

$$t_1 + t_2 + t_3 \leq t_4 + t_5 + t_r$$

or

$$t_1 + t_2 + t_{\downarrow} \leq t_4 + t_{rs} + t_r.$$

Recommendation Q.416 specifies that $t_{\downarrow} \leq t_{rs\min.} + t_{r\min.}$ (where $t_{r\min.} = 13$ ms). Thus, if $t_1 + t_2 \leq t_4$, correct working of line signalling can be ensured.

This inequality indicates simply that the time needed for detection of a faulty transmission on a PCM multiplex plus the time needed for stopping pilot sending when the alarm is detected must be less than the transfer time of a line signal across the transmultiplexer. This time requirement can be fulfilled, if necessary, by introducing in the transmultiplexer a small delay in line signals transmission.

1.2 The fault occurs on an analogue group

If, for example, the fault occurs on the analogue group GP₁, the transmission of the alarm indication will take place in accordance with the following time conditions:

- the fault occurs at T ;
- the fault is detected by the transmultiplexer at $T + t_1$;
- bit b is set to 1 on the digital channels concerned at $T + t_1 + t_2$;
- the alarm indication appears at the distant digital end at $T + t_1 + t_2 + t_3 + t_p$,

where:

- t_1 is the time needed for detection of loss of pilot;
- t_2 is the time needed for transferring alarm information to the digital output;
- t_3 is the response time of the signalling equipment of the digital multiplex;
- t_p is propagation delay.

If the same fault disturbs signalling information, erroneous signals will be transmitted in the following time conditions:

- the fault occurs at T ;
- the erroneous signalling condition is detected by the transmultiplexer at $T + t_4$;
- bit a is changed at the sending end of the digital section by the transmultiplexer at $T + t_4 + t_5$;
- the erroneous signalling condition appears at the input of the distant signalling equipment at $T + t_4 + t_5 + t_6 + t_p$,

where:

- t_4 is the response time of the signalling tone receiver in the transmultiplexer;
- t_5 is the time needed for transferring a line signal from the output of the signalling tone receiver to the digital output (change of bit a);
- t_6 is the response time of the signalling equipment of the PCM 2048 kbit/s multiplex ($t_3 = t_6$).

Correct working of line signalling is ensured if:

$$t_1 + t_2 + t_3 + t_p \leq t_4 + t_5 + t_6 + t_p + t_r$$

or

$$t_1 + t_2 \leq t_4 + t_5 + t_r$$

and if t_r has its minimum value $t_1 + t_2 \leq t_4 + t_5 + 13$ ms.

This inequality indicates that the time for detecting loss of pilot plus the time needed for setting bit b to 1 after loss of pilot detection by the transmultiplexer must be less than the response time of the signalling tone receiver in the transmultiplexer plus the transfer time of line signal plus 13 ms.

IN-BAND LINE SIGNALLING FOR 3 kHz SPACED CHANNELS

1 Line signalling code

1.1 General

For 3 kHz spaced carrier circuits, an in-band line signalling system is necessary. For this purpose the line signalling of Signalling System No. 4 (Recommendations Q.121, §§ 2.1, 2.2, 2.3 and Q.122) must be used.

1.2 Line signals

The following line signals of Signalling System No. 4 are necessary in combination with Signalling System R2 interregister signalling.

1.2.1 Forward signals

- Terminal seizing: in case of transit this is indicated by the interregister signalling;
- Forward-transfer: although the forward-transfer facility is not provided in Signalling System R2, it can be used when Recommendation Q.400, § 1.1.3 is implemented;
- Clear-forward.

1.2.2 Backward signals

- Answer,
- Clear-back,
- Release-guard,
- Blocking,
- Unblocking: this signal is not separately defined in the Specifications of Signalling System R2, but it is similar to restoring the tone (see Recommendation Q.412, § 2.2.2.5).

Supplement No. 5

LINE SIGNALLING (ANALOGUE VERSION) WITH METERING

1 General

Signalling System R2 may be used as an integrated signalling system for national and international traffic in a national network. Under certain conditions it is desirable to have additional line signals available, and in particular a metering signal in order to permit the charging of national calls and international calls generated in the national network concerned.

This supplement to the specifications of Signalling System R2 deals only with the clauses for exchange line signalling equipment which has been changed in order to take care of the addition of new operating conditions created by the additional metering signals and related only to the requirements of a national network. The conditions of the interruption control have been adapted accordingly.

The transmission of the metering signal can be extended over a maximum of three links between the subscriber exchange and the exchange where the charging equipment has been installed.

2 Line conditions

Taking into account the time sequence, the circuit will have the seven characteristic operating conditions shown in Table 1.

TABLE 1

State of the circuit	Line signalling conditions	
	Forward	Backward
1. Idle	Tone-on	Tone-on
2. Seized	Tone-off	Tone-on
3. Answered	Tone-off	Tone-off
4. Metering	Tone-off	Pulses tone-on
5. Forced release	Tone-off	Tone-on
6. Release	Tone-on	Tone-on or off
7. Blocked	Tone-on	Tone-off

3 Clauses for exchange line signalling equipment

3.1 Recognition time for transition of signalling condition

The recognition time for a changed condition (transition from tone-on to tone-off or vice versa) is 40 ± 10 ms according to the decisions taken by Study Group XI of the CCITT. The definition of the recognition time is indicated in Recommendation Q.412, § 2.2.1.

3.2 Normal operating conditions

3.2.1 General

Except for the states, metering and forced release, the other states (seizure, answered, release, blocking and release-guard) follow the same states as those indicated in Recommendation Q.412, § 2.2.2. Instead of the situation "release in clear-back state" a situation "release in forced release state" is possible.

3.2.2 Metering

The metering signals are pulse-type signals transmitted backwards during the conversation on a link-by-link basis. They are the only signals for which a repetition of the actual signal in a link-by-link basis is necessary in order to avoid an unacceptable distortion of the metering signals.

For the meter pulses the following limits have to be respected:

- sending: 120-180 ms;
- recognition time between the recognized transitions at the receiving side: 60-90 ms.

For the interval between metering signals, the following sending limit has to be observed: minimum 300 ms.

The time at the sending end between the answer signal and the start of the first metering signal and between the end of the last metering signal and the start of the forced release signal shall be more than 300 ms.

3.2.3 Forced release (see Figures 1 and 2)

When the called subscriber clears at the end of a call, the exchange which controls the connection will receive the clear-back signal from the called subscriber's end. If the calling subscriber does not clear within a period defined by the Administration concerned for national traffic, and according to Recommendation Q.118 for international traffic, the controlling exchange stops metering, transmits forced release to the preceding exchange and clears forward the succeeding part of the connection. In the preceding exchange, the forced released signal will only be recognized after 300 ms or more in order to avoid confusion with a metering signal.

After recognition of the forced release signal in the originating exchange, the tone-on condition will be transmitted forwards and the part of the connection to the controlling exchange will be released.

The release procedure is identical to the one specified for the analogue version of the line signalling.

There is no forced release in case of no reception of the answer signal in the controlling exchange following an address-complete signal. After a period defined by the Administration concerned for national traffic, and according to Recommendation Q.118 for international traffic the controlling exchange sends busy tone to the calling subscriber and sends clear-forward to release the succeeding part of the connection.

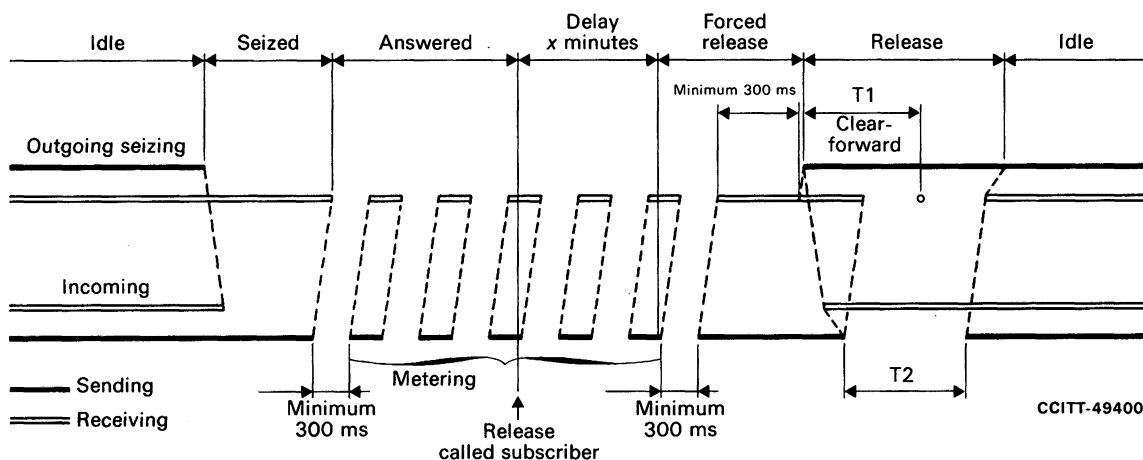


FIGURE 1

Forced release in answered state

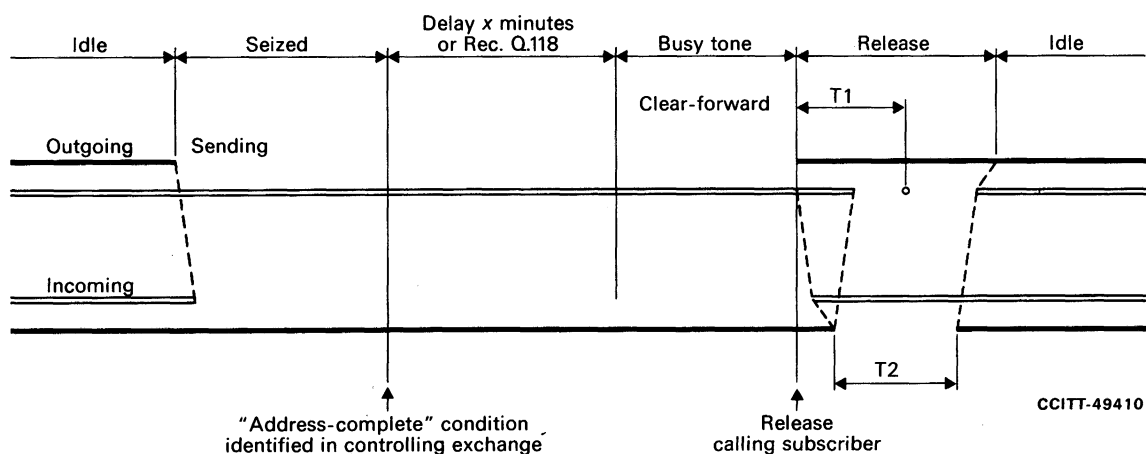


FIGURE 2

Release prior to answer state

4 Mode of operation of interruption control

4.1 General

Generally speaking, it can be said that the mode of operation of the interruption control complies with the specifications of Signalling System R2, and in particular with Recommendation Q.416. However, it is necessary to define the work of operation of the interruption control for the following conditions:

- a) circuit in answered state (metering in the backward direction);
- b) circuit in forced release state.

4.2 *Mode of operation of interruption control at the incoming end (transmission interrupted in the forward direction)*

a) *Circuit in answered state*

Transition of interruption control to alarm brings about:

- i) locking of the sending unit in its position, i.e. in the tone-off condition; if, at the moment of operation of interruption control the tone-on condition existed on the backward direction (metering signal), it will be locked in the tone-off condition;
- ii) locking of the receiving unit in its position, i.e. in the tone-off condition.

The other conditions are also in agreement with the specifications described in Recommendation Q.416, § 2.4.2.1 c).

b) *Circuit in forced release state (transmission of forced release signal in backward direction)*

Transition of interruption control to alarm brings about:

- i) locking of the sending unit in its position, i.e. in the tone-on condition;
- ii) locking of the receiving unit in its position, i.e. in the tone-off condition;
- iii) immediate release of the part of the connection beyond faulty circuit (including the called subscriber's line).

The conditions are similar to the specifications described in Recommendation Q.416, § 2.4.2.1 d), "clear-back state".

4.3 *Mode of operation of the interruption control at the outgoing end (transmission in the backward direction interrupted)*

a) *Circuit in answered state*

In this case, transition of the interruption control to alarm does not cause immediate action. A clear-forward signal sent on the part of the connection preceding the faulty circuit must be repeated forward to ensure that, if the forward signalling channel is left intact, the part beyond the faulty circuit is cleared.

Once the interruption control reverts to normal, the connection is maintained provided the caller and the called subscriber are still holding. On the other hand, by the time the interruption control reverts to normal, the clear-forward signal may already have been sent and the situation will be the one described under circuit seized but not in answered state.

b) *Circuit in forced release state (transmission forced release signal in backward direction)*

Transition of interruption control to alarm causes locking of the receiving unit in its position, i.e. the tone-on condition. The procedures are similar to those in the position "clear-back state" in the specifications of the analogue version of the line signalling, Recommendation Q.416, § 2.4.2.2 b).

LINE SIGNALLING (DIGITAL VERSION) WITH METERING

1 Introduction

Signalling System R2 line signalling, digital version, is a line signalling system for use over digital line transmission equipment conforming to Recommendation G.732.

For many national applications it is desirable that the digital version has additional line signals available to enable the charging of calls.

This supplement proposes possible solutions to provide for charging of calls, namely the provision of a meter signal and a forced release signal.

2 Signal codes

The signalling codes are given in the Table 1 below.

TABLE 1

State of the circuit	Signalling Code			
	Forward		Backward	
	a _f	b _f	a _b	b _b
Idle/released	1	0	1	0
Seized	0	0	1	0
Seizure acknowledged	0	0	1	1
Answered/meter	0	0	0	1
Meter/seizure acknowledged	0	0	1	1
Clear-forward	1	0	0	1
			or 1	1
			or 0	0
Forced release	0	0	0	0
Blocked	1	0	1	1

3 Choice of meter codes

Some line signalling systems indicate a meter pulse by a signal identical to a “pulsed clear-back”, signal. In this circumstance for ease of signal conversion $a_b = 1$, $b_b = 1$, which normally indicates clear-back, may be used to represent a meter pulse. Other signalling schemes however use a “pulsed answer” signal to indicate a meter pulse. In this circumstance $a_b = 0$, $b_b = 1$ may be used to represent a meter pulse.

4 Clauses for exchange line signalling equipment

4.1 Normal operating conditions

The following operating conditions apply in addition to those described in Recommendation Q.422.

4.1.1 *Meter:* Metering signals are pulse type signals transmitted backwards during the conversation from the call charging point to the subscriber’s call meter in the originating exchange.

In the case of "pulsed clear-back" meter pulses, a pulse is indicated by a change from the answer ($a_b = 0$, $b_b = 1$) signal to an $a_b = 1$, $b_b = 1$ signal and then a change back to $a_b = 0$, $b_b = 1$. To avoid confusion between meter pulses and clear-back the use of clear-back is not allowed.

In the case of "pulsed answer" meter pulses, a pulse is indicated by a change of $a_b = 1$, $b_b = 1$ to $a_b = 0$, $b_b = 1$ and back to $a_b = 1$, $b_b = 1$. The first pulse indicates answer, it may also indicate a meter pulse. A clear-back signal is not provided.

Meter pulses must be longer than 30 ms to ensure recognition at the outgoing end.

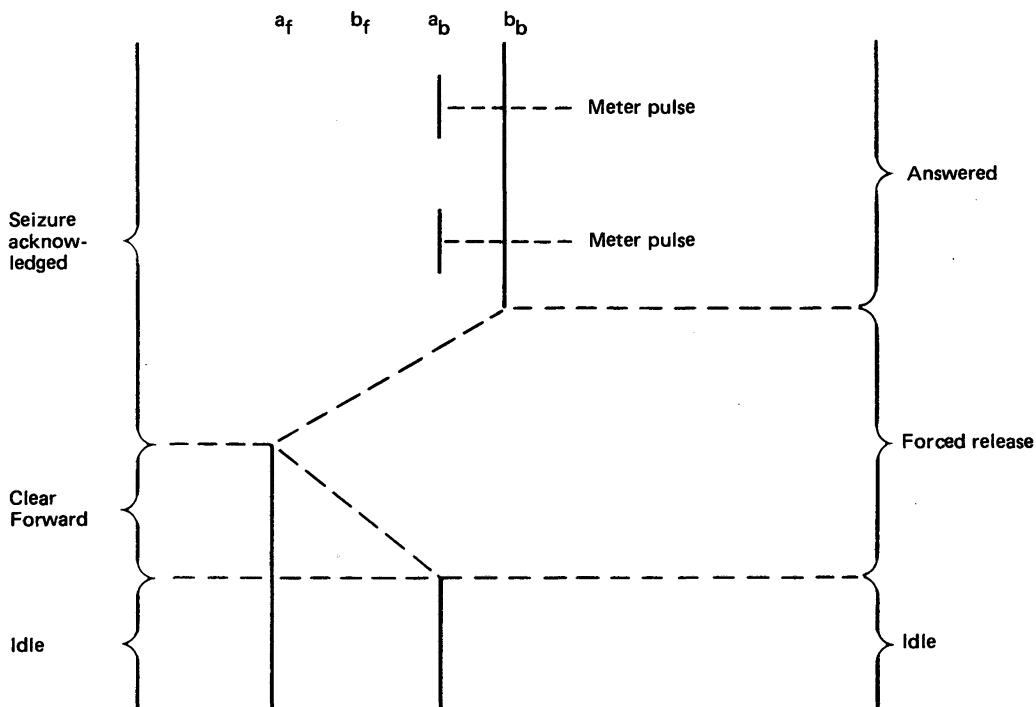
4.1.2 Forced release: Prior to answer and after a period defined by the Administration concerned for national traffic and according to Recommendation Q.118 for international traffic, the charge controlling exchange transmits the forced release signal to the preceding exchange and clears forward the succeeding part of the connection. When the called subscriber clears at the end of a call, the exchange which controls call charging will receive the clear-back signal from the called subscriber's end. If the calling subscriber does not clear within a period defined for national traffic by the Administration concerned and for international traffic according to Recommendation Q.118, the charge controlling exchange stops metering, transmits the forced release signal to the preceding exchange and clears forward the succeeding part of the connection. A forced release signal is indicated by a change to $a_b = 0$, $b_b = 0$.

On recognition of forced release in a preceding exchange the connection is released, the forced release signal repeated to any other preceding exchanges, and a clear forward signal sent on the link. The succeeding exchange, on receipt of the clear forward, returns an idle signal and returns the link to the idle state.

Figure 1 shows line signals for a sequence of meter pulses followed by forced release in the case of "pulsed clear-back" meter pulses.

4.2 Actions appropriate to various signalling conditions

Tables 2 and 3 indicate the states appropriate to each signalling code recognized and the actions to be taken at the outgoing and incoming ends respectively.



CCITT-74160

FIGURE 1

Release sequence when called party clears
without clearing of the calling party

TABLE 2
Outgoing end

Normal state at the outgoing end	Sent code	Received code			
		$a_b = 0, b_b = 0$	$a_b = 0, b_b = 1$	$a_b = 1, b_b = 0$	$a_b = 1, b_b = 1$
Idle/released	$a_f = 1, b_f = 0$	Abnormal, see Note 1	Abnormal, see Note 1	Idle	Blocked
Seized	$a_f = 0, b_f = 0$	Abnormal, see Note 2	Abnormal, see Note 2	Seized, see Note 2	Seizure acknowledged
Seizure acknowledged	$a_f = 0, b_f = 0$	Forced release	Answered/ meter	Abnormal, see Note 3	Seizure acknowledged
Answered ^{a)} /meter ^{b)}	$a_f = 0, b_f = 0$	Forced release	Answered/ meter	Abnormal, see Note 4	Meter/seizure acknowledged
Meter ^{a)} /seizure acknowledged ^{b)}	$a_f = 0, b_f = 0$	Forced release	Answered/ meter	Abnormal, see Note 4	Meter/seizure acknowledged
Forced release	$a_f = 0, b_f = 0$	Forced release, see Note 5	Abnormal, see Note 5	Abnormal, see Note 5	Abnormal, see Note 5
Clear-forward	$a_f = 1, b_f = 0$	Clear-forward	Clear-forward	Released = Idle	Clear-forward
Blocked	$a_f = 1, b_f = 0$	Abnormal, see Note 1	Abnormal, see Note 1	Idle	Blocked

^{a)} Used for "pulsed clear-back" meter pulses.

^{b)} Used for "pulsed answer" meter pulses.

Note 1 – In these conditions the outgoing end must prevent a new seizure of the circuit. A delayed alarm should also be given.

Note 2 – Non-recognition of the seizing acknowledgement signal 100-200 ms after sending the seizing signal on a terrestrial link or 1-2 seconds after sending the seizing signal on a satellite link results in an alarm and either congestion information being sent backward or a repeat attempt being made to set up the call. The outgoing end must prevent a new seizure of the circuit. When the seizure acknowledgement signal is recognized after the time-out period has elapsed, the clear-forward signal must be sent.

Note 3 – Receipt of $a_b = 1, b_b = 0$ by the outgoing switching equipment for 1-2 seconds after recognition of the seizing acknowledgement signal and prior to recognition of the answer signal, results in an alarm and either congestion information being sent backward or a repeat attempt being made to set up the call. The outgoing end must prevent new seizures of the circuit. When b_b reverts to 1 after the 1-2 seconds time-out period has elapsed, the clear-forward signal must be sent.

Note 4 – In the case of recognition of $a_b = 1, b_b = 0$ whilst in the answered state, immediate action is not necessary. On receipt of clearing from the preceding link, the clear-forward signal ($a_f = 1, b_f = 0$) must not be sent until b_b is restored to 1. A delayed alarm should also be given.

Note 5 – After forced release is recognized, the outgoing switching equipment must be released and then the idle signal ($a_f = 1, b_f = 0$) sent on the link. The outgoing end must prevent a new seizure on the circuit until the link returns to the idle state upon reception of $a_b = 1, b_b = 0$. The forced release signal must be sent on the preceding link (if any).

TABLE 3
Incoming end

Normal state at the incoming end	Sent code	Received code			
		$a_f = 0, b_f = 0$	$a_f = 0, b_f = 1$	$a_f = 1, b_f = 0$	$a_f = 1, b_f = 1$
Idle/released	$a_b = 1, b_b = 0$	Seized	Fault, see Note 1	Idle	Fault, see Note 1
Seizure acknowledged	$a_b = 1, b_b = 1$	Seizure acknowledged	Fault, see Note 2	Clear-forward	Fault, see Note 2
Answered ^{a)} /meter ^{b)}	$a_b = 0, b_b = 1$	Answered/ meter	Fault, see Note 3	Clear-forward	Fault, see Note 3
Meter ^{a)} /seizure acknowledged ^{b)}	$a_b = 1, b_b = 1$	Meter/seizure acknowledged	Fault, see Note 3	Clear-forward	Fault, see Note 3
Forced release	$a_b = 0, b_b = 0$	Forced release	Fault, see Note 8	Clear-forward see Note 4	Fault, see Note 8
Clear-forward	$a_b = 0, b_b = 1$ or $a_b = 1, b_b = 1$	Abnormal seized see Note 7	Fault, see Note 7	Clear-forward see Note 7	Fault, see Note 7
Blocked	$a_b = 1, b_b = 1$	Abnormal seized see Note 5	Fault, see Note 6	Blocked	Fault, see Note 6

^{a)} Used for "pulsed clear-back" meter pulses.

^{b)} Used for "pulsed answer" meter pulses.

Note 1 — When in the idle/released state b_f changes to 1, b_b must be changed to 1.

Note 2 — In these cases a timeout device is started which after a certain interval clears the connection beyond the faulty circuit: this timing arrangement may be the one specified in Recommendation Q.118, § 4.3.3. If the answer signal is recognized during the timeout delay, the timer is stopped but the answer signal is not sent on the preceding link until recognition of $a_f = 0, b_f = 0$. If the clear-back signal is recognized while the fault persists, the connection beyond the faulty circuit must be released immediately. Additionally, when the incoming register has not started to send the last backward signal, the rapid release procedure described in Note 5 may be used.

Note 3 — In these cases no action is taken until the forced release signal or the clear-back signal (if the exchange is the call metering control point) is recognized, at which stage the connection beyond the faulty circuit is immediately released and the forced release signal sent to the preceding exchange.

Note 4 — After $a_f = 1, b_f = 0$ is recognized, the circuit is returned to the idle state by sending $a_b = 1, b_b = 0$.

Note 5 — In this case, immediate action is not necessary. However, rapid release of the circuit should occur if the incoming end simulates answer by sending $a_b = 0, b_b = 1$.

Note 6 — Under these conditions no action is taken.

Note 7 — After clear-forward signal is recognized and until the code $a_b = 1, b_b = 0$ is sent, all transitions in the forward direction shall be ignored.

Note 8 — The circuit is kept in the forced release state until $a_f = 1, b_f = 0$ is recognized.

5 Protection against the effects of faulty transmission

5.1 Introduction

When faulty transmission conditions in PCM systems are detected both PCM terminals apply the state corresponding to state 1 on the PCM line on each "receive" signalling channel at the interface with the switching equipment, as indicated in Table 4 of Recommendation G.732. In this way the incoming switching equipment receives the equivalent $a_f = 1$, $b_f = 1$ on the PCM line and the outgoing switching equipment receives the equivalent of $a_b = 1$, $b_b = 1$.

5.2 Incoming switching equipment

At the incoming end a PCM fault results in $a_f = 1$, $b_f = 1$: so this fault can be identified and appropriate actions according to Table 3 can be taken.

5.3 Outgoing switching equipment

At the outgoing end a PCM fault results in $a_b = 1$, $b_b = 1$.

Two cases are to be considered:

- a) Meter pulses are indicated by $a_b = 0$, $b_b = 1$

A fault results, as it is stated in Table 2, in a blocked state or seizure acknowledged state. This means that all circuits in the idle state of a faulty PCM multiplex will be blocked and that seized circuits will go to or remain in the seizure acknowledged state.

- b) Meter pulses are indicated by $a_b = 1$, $b_b = 1$

A PCM fault will result in the recognition of a meter pulse each time a failure appears. To avoid this recognition, the outgoing switching equipment must handle the service alarm information given by the PCM terminal equipment in a separate way.

When the outgoing switching equipment detects a service alarm information it must block the detection of signalling transitions to avoid recognition of erroneous signalling codes caused by the failure.

The reception of a clear-forward signal on the preceding link or the detection of the calling subscriber's release will cause, after the end of the PCM failure, the sending of a clear-forward signal on the succeeding part of the connection.

6 Bothway working

The additions described in this contribution do not affect the suitability of the digital version for bothway use.

Supplement No. 7

SEMI-COMPELLED AND NON-COMPELLED MULTIFREQUENCY INTERREGISTER SIGNALLING FOR NATIONAL SATELLITE APPLICATIONS BASED ON SYSTEM R2 INTERREGISTER SIGNALLING

1 Introduction

1.1 The Semi-Compelled and Non-Compelled Multifrequency Signallings, herein specified and based on Signalling System R2 (Fully-Compelled Signalling), make use of a pulse signal sending procedure and are supposed to increase signalling speed on national satellite circuits. Their application is restricted to those cases in which the consequences of increased propagation times over Fully-Compelled Signalling may bring about insolvable technical problems for the national network, may make impossible the retention of the information capabilities and facilities provided by that signalling or may make rather expensive the operation of circuits.

This may occur in national networks which have a large number of satellite circuits, e.g. when national satellites are used.

1.2 Parameters related to operation of national networks may be affected by great increase in satellite propagation time, compared with the terrestrial value, such as:

- increase in the holding times of the telecommunications network;
- increase post-dialling delay;
- increased amount of equipment to handle the same traffic and consequently larger space taken up by equipment;
- the maximum capacity of exchanges is reached at lower traffic values.

The negative effect over those parameters implies a loss in service quality and an increase in investments made in national networks.

Better performances may be obtained through the Semi-Compelled Multifrequency Signalling, which speeds up the process of interchange of signals via satellite.

1.3 In some cases, the characteristics of national networks where the features of the Signalling System R2 are fully used may require that the process of interchange of signals via satellite must be still more accelerated so that delays may be kept within certain limits, otherwise those characteristics should be changed. Some of the said characteristics are the following:

- time-out requirements;
- routing plan;
- charging method;
- sending of complete calling subscriber number (total identification of calling subscriber);
- information about called subscriber condition by means of Group B signals, instead of simple Address-Complete signal (signal A-6);
- traffic restriction through analysis of calling subscriber category in destination (Group II signal in acknowledgement to signal A-3).

Relative to the above-mentioned cases, the choice falls on the Non-Compelled Multifrequency Signalling which allows a substantial increase in speed as regards signal interchange.

1.4 Unlike the Fully-Compelled Multifrequency Signalling, the Semi-Compelled and Non-Compelled Signallings here described permit that, within certain particular limitations, the characteristics, facilities and mode of operation (including network management) already existing in the national networks which use Signalling System R2 may be maintained, making possible the operation of satellite circuits with an information interchange rate similar to that of Signalling System R2 which operates on the terrestrial links.

2 Line signalling

The line signalling to be used together with the Non-Compelled Interregister Signalling must include a Proceed-to-Send signal.

All remaining signals may be used in the original form.

As for digital circuits, line signalling-digital version of Signalling System R2 may be fully used. The seizing acknowledgement signal in this application is used as Proceed-to-Send indication.

A pulsed line signalling which presents an excellent performance over terrestrial or satellite links and can be used with Non-Compelled Signallings is specified in § 4.

3 Interregister signalling

3.1 General

The Semi-Compelled and Non-Compelled Multifrequency Signallings here specified basically show the same characteristics and facilities existing in the Fully-Compelled Multifrequency Signalling used with Signalling System R2, except, obviously, the way of sending and receiving MF signals.

This Supplement specifies only the characteristics and facilities which differ from those foreseen in Specifications of Signalling System R2 and the meanings of some signals which are used in a different way from that system.

3.2 *Semi-Compelled Signalling*

3.2.1 *Introduction*

The Semi-Compelled Signalling over satellite links can be usually used in the end-to-end method, between the signalling equipment of the origin of the call and the signalling equipment at the incoming end of the satellite link, as recommended in Specifications of Signalling System R2 except when, for charging or management reasons, the signalling equipment at the outgoing end of the satellite link is not released until the complete setting-up of the call.

The pulsed form of sending backward signals (Groups A and B) is the only difference that such signalling presents in relation to Specifications of Signalling System R2.

3.2.2 *Pulse duration*

As regards backward signals, pulse duration corresponds to 100 ± 20 ms.

3.2.3 *Composition of the Groups of Signals I and II (forward) and A and B (backward) and Meaning of the Signals*

The composition of the Groups of Signals and their respective meanings are thoroughly identical with those foreseen in Signalling System R2, as well as combinations of frequencies which form the various signals.

3.2.4 *Build-up and Time Specifications of a Complete Forward Semi-Compelled Signalling Cycle*

Figure 1 shows in detail the build-up and time sequence of a semi-compelled signalling cycle.

If the values of T_{int2} and T_{int3} lie within certain limits, they do not contribute to the total duration of the semi-compelled signalling cycle, as can be seen from Figure 1. Then, the total duration T_{SC} of a complete semi-compelled signalling cycle is given by the formula:

$$T_{SC} = T_{PF} + T_{PB} + \left\{ \begin{array}{c} T_{RD} + T_{OA} \\ \text{or} \\ T'_{RD} + T'_{OA} \end{array} \right\} + T_{int1} + T_{S1D} + T_{S1A} + T_P$$

The subscripts D and A apply respectively to the outgoing and the incoming registers.

Considering the values established in Recommendation Q.457, § 4.5.2 and assuming that:

$$T_{S1D} + T_{S1A} = T_{S1} + T_{S2} \text{ and } T_P = 100 \pm 20 \text{ ms,}$$

the probable extreme values of the semi-compelled signalling cycle T_{SC} would be:

$$620 \text{ ms} \leq T_{SC} \leq 840 \text{ ms}$$

3.2.5 *Call routing procedures*

Whenever technically feasible, the overlap method may be used for call routing.

The Semi-Compelled Signalling is applied just like the Fully-Compelled Signalling (System R2), though there are minor restrictions towards its use on satellite channels.

3.2.6 *Other characteristics of the Semi-Compelled Signalling*

As concerns other characteristics related with the signalling (Multi-frequency Signalling Equipment, Time and Transmission Requirements, etc.), Specifications of Signalling System R2 are applicable.

3.3 *Non-Compelled Signalling*

3.3.1 *Introduction*

The Non-Compelled Signalling over satellite links is used in the link-by-link method between signalling equipment correspondent to the outgoing and incoming ends of the satellite link.

The basic differences that such signalling shows in relation to Specifications of Signalling System R2 are the way of sending signals in both directions (those forward and backward signals are sent in the form of pulses) and the non-existence of Group A of Signalling System R2.

3.3.2 *Pulse duration and minimum pulse interval*

Pulse duration corresponds to 100 ± 20 ms for both forward and backward signals.

The minimum interval between two consecutive forward pulses is 100 ± 20 ms.

3.3.3 *Composition of the Groups of Signals (I, II and B) and Meaning of the Signals*

3.3.3.1 *General*

The Non-Compelled Signalling is composed of the Groups of Signals I and II (forward signals) and B (backward signals) correspondent to the same Groups as those of Signalling System R2.

The Group A of backward signals of Signalling System R2 is unnecessary by the following reasons:

- The signalling equipment at the incoming end of the satellite link operates as storage point for information coming from the origin and operates without sending via satellite the signals A-1, A-2, A-3, A-5, A-7, A-8, A-11, A-12, A-13 and A-14.
- The meaning of signal A-4 is transferred to Signal B-9 (spare for national use in the Fully-Compelled Signalling System R2).
- The use of signal A-6 is not required. Signals of Group B can be used. In case it is necessary to use the meaning of A-6, it can be allocated to Signal B-10 (spare for national use in the Fully-Compelled Signalling System R2).
- Signals A-9 and A-10 are spare for national use in the Fully-Compelled Signalling System R2.

The Groups of Signals I, II and B maintain the same structure (including the same frequency combinations) as that used in the Fully-Compelled Signalling System R2, using the same signalling senders and receivers.

Some modifications, exclusions or inclusions in the meaning of some signals in relation to the Fully-Compelled Signalling System R2 allow the Non-Compelled Signalling the following facilities:

- Sending of category and number of calling subscriber, through positioning of Signals I-12 and I-15 respectively before and after the sending of this complete information. Category information can be transmitted only through that same procedure. Such a method for sending the calling subscriber category and number by means of Signals I-12 and I-15 is carried out in a predetermined sequence between two successive digits of the transmission of the called subscriber number.

3.3.3.2 *Meaning of the signals for national use*

Only the signals which have shown some variation in relation to their usual meanings in the Fully-Compelled Signalling System R2 are presented next.

3.3.3.2.1 *Group I forward signals*

I-12 It indicates that only the category or the category and the number of the calling subscriber will follow.

- I-13
- a) Test call indicator.
 - b) Access to test equipment (code 13).

Both a) and b) have the same meanings as those of the Fully-Compelled Signalling System R2. The meaning "Satellite Link not Included" was deleted.

3.3.3.2.2 *Group B backward signals*

B-9 Congestion in the national network (before changeover from Group A signals to Group B signals in the Fully-Compelled Signalling System R2) or if time-out in the signalling equipment at the destination end of the satellite link has occurred.

B-10 Address-complete, charge, set-up speech conditions (only if destination equipment of the national network cannot send the usual end-of-selection signals).

3.3.4 Configurations of the signalling network

The Non-Compelled Signalling may be basically used:

- a) Between the Signalling Equipment of two Switching Exchanges (Translation Points coincide with Switching Points).

Signalling equipment of switching exchanges located at both ends of the satellite links must be able to send and receive Non-Compelled Signalling, as illustrated in Figure 2.

For that configuration, adequate functional changes are required in the signalling equipment of those switching exchanges.

- b) Between Signalling Translation Equipment separated from the Switching Exchanges (Translation Points do not coincide with Switching Points).

Signalling Translation Equipment is independent of signalling equipment of switching exchanges. It may be installed near those exchanges or in separate places, as illustrated in Figure 3.

For that configuration, there is not any change in any equipment of the national network, and the introduction of signalling translators may be carried out just through the simple interconnection with distribution frames.

Note — A combined solution is also possible.

3.3.5 Call routing procedures

3.3.5.1 Relative to the starting point

There are no restrictions for applying the overlap method when using the Non-Compelled Signalling.

There are two main kinds of calls:

- a) Calls for subscribers from a national (or international) numbering area different from that of the calling subscriber.

The national (or international) prefix and code are to be dialled.

- b) Calls for subscribers from the same numbering area as that of the calling subscriber.

The national (or international) prefix and code are not to be dialled, but only the subscriber number.

In both cases a) and b), the starting point at the Signalling Translation Point at the outgoing end of the satellite link occurs after reception of the sufficient number of digits to route the call.

If configuration presented in § 3.3.4 b) (Signalling Translation Equipment separated from the Switching Exchanges) is adopted, signals may be sent forward as soon as they are received by the Signalling Translation Equipment at the Signalling Translation Point.

3.3.5.2 Relative to the sending sequence of Group I and II forward signals

The main cases concerning the sending sequence of non-compelled signals are the following:

- a) Calls with complete identification of the calling subscriber number (i.e. for centralized toll ticketing).

After reception of a sufficient number of digits of the called subscriber number to route the call, they may be sent *en bloc*. Then, there is the sending of category and number of calling subscriber, which are preceded and followed by signals I-12 and I-15, respectively. Such signals can also be sent *en bloc* if it does not contribute to delay routing procedures. After reception of signal I-15, the digits of the called subscriber number continue to be sent so far as they are dialled and available for sending (overlap method).

A scheme corresponding to national calls is shown in Figure 4.

- b) Calls without complete identification of the calling subscriber number.

After reception of a sufficient number of digits of the called subscriber number to route the call, they may be sent *en bloc*. Then, there is the sending of the calling subscriber category, which is preceded and followed by Signals I-12 and I-15, respectively. Such signals can also be sent *en bloc*. After reception of Signal I-15, the digits of the called subscriber number continue to be sent so far as they are dialled and available for sending (overlap method).

The scheme corresponding to that kind of call is identical with that shown in Figure 4, however, without the signals corresponding to the calling subscriber number (ID N_j).

Note — As for international calls, the sending sequence begins with the international prefix, which is followed by the sufficient number of digits of the international number of the called subscriber to route the call. The remaining sequence is also similar to that used for national calls in Items a) and b) above.

When configuration presented in § 3.3.4 b) (Signalling Translation Equipment separated from the Switching Exchanges) is adopted, signals may be sent forward as soon as they are received by the Signalling Translation Equipment at the Signalling Translation Point, although the relative position for sending the calling subscriber identification (between two determined digits of called subscriber number) may be at any fixed point.

If the procedures for sending forward signals are defined for each different type of call, a check towards reception of forward signals may be made by the Signalling Equipment at the destination end of the satellite link by simply counting the signals received. Signals I-12 and I-15 serve as reference points.

3.3.5.3 *Relative to the sending of Group B backward signals*

A Group B backward signal may be sent at any time during the period for sending of Group I and II forward signals provided that there is a condition which must require interruption of the call setting-up process, such as time-out or congestion at any point of the national or international network and non-existent national or international code or non-existent exchange prefix.

3.3.6 *Operational procedures of the system*

3.3.6.1 *Introduction*

The Non-Compelled Signalling, based on the Signalling System R2, is conceived for the purpose of making possible retention of the mode of operation, facilities and other characteristics of a national network, which uses the Signalling System R2, after introduction of telephone satellite communications on a large scale. Modifications necessary for operation on satellite links must be restricted only to equipment connected with the involved links so as to avoid any undesirable effect on the remaining system.

The use of the Non-Compelled Signalling requires modifications only in the equipment connected with satellite links [§ 3.3.4 a)]. Besides, a solution which will not interfere at all in the existing equipment may be also adopted [§ 3.3.4 b)].

3.3.6.2 *Interface procedures at the signalling translation points*

Figure 5 shows the most general case concerning setting-up of a call via satellite by means of the Non-Compelled Signalling in a national network which operates with the Signalling System R2 and using configuration of § 3.3.4 a).

The signalling equipment which precedes the Signalling Translation Point at the outgoing end of the satellite link will operate with the end-to-end method up to this point, at which the Fully-Compelled Signalling will be converted into the Non-Compelled Signalling.

The inverse conversion, that is, from the Non-Compelled Signalling to the Fully-Compelled Signalling, will be performed at the Signalling Translation Point at the incoming end of the satellite link, from which signalling will become fully-Compelled using the end-to-end method.

The procedures carried out towards call setting-up by using the Non-Compelled Signalling are basically the following for national calls:

The Signalling Translation Point at the outgoing end of the satellite link receives the sufficient number of digits to route the call (ON₁ . . . N_i) and then starts (starting point) the procedures for sending those digits forward in the form of pulses (it sends the Seizure signal and receives the Proceed-to-Send signal) and it sends digits from 0 to N_i. The sending sequence continues through the sending of Signal I-12, which determines the beginning of transmission of the category (CAT) and number (ID N_j) of the calling subscriber. Signal I-15 follows after the sending of the last digit of that subscriber number. Then, the sending of the digits of the called subscriber number (. . . N_K . . .) succeeds up to the last digit (N_L).

The Signalling Translation Point at the outgoing end of the satellite link starts call routing immediately after receiving the sufficient number of digits, thus establishing a process of signalling with subsequent signalling equipment in the end-to-end method up to reception of Signal A-3 and an End-of-Selection signal (Group B

Signal). At that moment, that last signal is repeated backward in the form of pulse up to the Signalling Translation Point at the outgoing end of the satellite link. The final signal interchange is carried out between that point and the preceding signalling equipment (A-3, CAT, B) and then the speech path is set up.

If there is no need to send the calling subscriber number, only the category is sent forward and Signals I-12 and I-15 are maintained before and after the sending of that calling subscriber category, which is used by the Signalling Translation Point at the destination end in acknowledgement to Signal A-3 at the end of the call setting-up procedure.

The signalling process may be interrupted at any time by a Group B signal, as explained in § 3.3.5.3.

Note — As for international calls, procedures include receiving of international prefix and international code, but they are similar to those used for national calls.

If configuration presented in § 3.3.4 b) (Signalling Translation Equipment separated from the Switching Exchanges) is adopted, signals in both outgoing and incoming Signalling Translation Equipment at the Signalling Translation Points may be sent forward as soon as they are received by Signalling Translation Equipment.

3.3.7 *Multifrequency signalling equipment*

Recommendations for Signalling System R2 other than for exclusive use in Fully-Compelled Signalling are applicable to Non-Compelled Signalling. Thus, the requirements related to transmission and to the sending and receiving parts of the multifrequency equipment may be applied to that signalling. The same signal senders and receivers specified for Signalling System R2 may be used.

The use of such signal senders and receivers avoids the development of new equipment, and they will operate easily in relation to their sending and receiving characteristics, taking into consideration that they have been dimensioned for end-to-end operation, but with Non-Compelled Signalling they operate link-by-link.

3.3.8 *Time requirements*

3.3.8.1 *General*

As Non-Compelled Signalling is performed to operate between two signalling points inserted in a multi-point signalling network using Signalling System R2, time requirements should be compatible with the specifications for this system.

3.3.8.2 *Time-out conditions*

- a) In the signalling equipment at the outgoing end of the satellite link, the time-out delay between the Seizing signal and the sending of the first forward interregister signal and between the sending of each two subsequent forward interregister signals until the reception of the Group B signal should not be less than 24 s.
- b) In the signalling equipment at the incoming end of the satellite link, the time-out delay between the sending of the Proceed-to-Send signal and the reception of the first forward interregister signal and between the reception of each two subsequent forward interregister signals until the sending of the Group B signal should not be less than 24 s.

4 **Pulsed line signalling**

4.1 *Introduction*

The line signalling herein presented and foreseen to be used in FDM carrier circuits is a pulsed, high level, out-of-band signalling which operates link-by-link. It may also be used on PCM systems (with channel-associated signalling).

4.2 *Description of the signals*

4.2.1 *Seizure Signal* — It is a signal which is sent forward, from the outgoing junctor, in order to drive the associate incoming junctor to the seizure condition.

4.2.2 *Proceed-to-Send Signal* — It is a signal which is sent backward, from the incoming junctor to the associate outgoing junctor, in order to indicate that a destination interregister signalling equipment has been already seized and that interregister signalling may start.

4.2.3 *Answer Signal* – It is a signal which is sent backward, from the incoming junctor to the associate outgoing junctor, so as to indicate that the called subscriber has answered.

4.2.4 *Clear Back Signal* – It is a signal which is sent backward, from the incoming junctor to the associate outgoing junctor, so as to indicate that the called subscriber has hung up or that a similar operation has occurred.

4.2.5 *Clear Forward Signal* – It is a signal which is sent forward, from the outgoing junctor to the associate incoming junctor, in order to release the equipment involved in the connection.

4.2.6 *Release Guard Signal* – It is a signal which is sent backward, from the incoming junctor to the associate outgoing junctor, in response to a Clear Forward signal, so as to indicate that the release of equipment associated to the incoming junctor has occurred.

4.2.7 *Forced Release Signal* – It is a signal which substitutes, after time-out, the Clear Back signal at a charging point. With reception of Forced Release signal, the speech path is immediately opened.

4.2.8 *Multimetering Signal* – It is a signal which is sent backward, from the incoming junctor to the associate outgoing junctor, according to the cadence corresponding to the charging rate, as from the multimetering charging point.

4.2.9 *Call-Back Signal* – It is a signal which is sent forward, from the outgoing junctor to the associate incoming junctor, when an operator wants to call back the called subscriber (or another operator) after he has hung up.

4.2.10 *Blocking Signal* – It is a signal which is sent backward, from the incoming junctor to the associate outgoing junctor, by means of a manual or automatic procedure, in order to indicate that the circuit or a group of circuits is blocked.

Taking into consideration the transmission level, the duration of the signal and the conventional load in satellite circuits, its use must be avoided when the number of telephone circuits is large in relation to the total number of circuits of the route. In this case, when there is blocking, the line signalling system itself already foresees procedures that can prevent successive losses of calls, as described in § 4.6.1.

4.3 *Characteristics of the signals*

4.3.1 *Duration of the signals*

Line signals show the following durations:

TABLE 1
Pulsed Line Signals
Sending Times and Tolerances

Signal	Nominal duration (ms) ^{a)}		Sending tolerances (ms)
	Forward	Backward	
Seizure	150		± 30
Proceed-to-send		150	± 30
Answer or re-answer		150	± 30
Multimetering		150	± 30
Call-back	150		± 30
Clear-forward	600		± 120
Clear-back		600	± 120
Release guard		600	± 120
Forced release		600	± 120
Blocking		continuous	—

^{a)} Short signal: 150 ms

Long signal: 600 ms

4.3.2 Recognition times of the signals

Recognition times of the signals are presented in Table 2 and they take into account time distortions introduced by transmission equipment and tolerances of switching equipment which adopts the conventional electromechanical technology.

TABLE 2
Pulsed Line Signals
Recognition Times and Tolerances

Signal	Nominal recognition time (ms)	Receiving tolerances (ms)
Short	80	± 20
Long	375	± 75

- a) The recognition time of short signals ranges from 80 ± 20 ms to 375 ± 75 ms. Any received signal with duration between 100 ms and 300 ms will be necessarily recognized as a short signal.
- b) The recognition time of long signals corresponds to 375 ± 75 ms. Any received signal with duration superior to 450 ms will be necessarily recognized as a long signal.
- c) The received signals with duration between 300 ms and 450 ms may be recognized as long or short signals, depending on the adjustment characteristics of the equipment.
- d) The receiver ignores interruptions up to 20 ms.

4.3.3 Minimum interval between signals

The minimum interval between two consecutive signals must be 240 ms at the transmission end. Distortion may reduce this interval at the receiving end.

4.3.4 Transmission of signals

The transmission of signals between the switching equipment and the transmission equipment and vice versa is made by sending a polarity which corresponds to the battery voltage.

4.4 Transmission characteristics of the line signalling in FDM equipment

4.4.1 Signal sender

The signalling frequency measured at the sending point has a value of 3825 ± 4 Hz.

The send level of the signalling frequency measured at the group distribution frame or an equivalent point must be -5 ± 1 dBm0.

4.4.2 Signal receiver

The receiver must recognize as valid signals which lie between 3825 ± 6 Hz.

The receiving levels are determined in accordance with the relative levels of the transmission plans adopted by each Administration.

4.5 Operational procedure of the system

4.5.1 When the circuit is idle, there is no signal on the line. The seizure of the outgoing junctor causes the forward sending of a short signal (Seizure signal). This signal causes the seizure of the associate incoming junctor and the seizure of equipment capable of receiving interregister signals.

4.5.2 Immediately after the seizure of equipment for interregister signalling interchange, the incoming junctor sends back a short signal (Proceed-to-Send signal).

4.5.3 When called subscriber answers, a short signal (Answer signal) is sent back, thus causing the start of call charging.

4.5.4 When calling subscriber hangs up, a long signal (Clear Forward signal) is sent forward, thus causing equipment release. After such release, a Release Guard signal is sent back and the circuit comes back to idle condition.

4.5.5 If the called subscriber hangs up first, a Clear Back signal will be sent and then, after time-out at a determined point of the network, there will be the sending of a Clear Forward signal, thus completing the process, as described in § 4.5.4. If another Answer signal appears during the time supervision period, timing will be interrupted and the equipment involved will return to the speech condition. If the calling subscriber hangs up during the time supervision period, the same procedure as that described in § 4.5.4 will occur.

After time-out, the Clear Back signal is replaced by the Forced Release signal between the charging point and the preceding exchange.

Note — When there is coincidence of two signals, the forward signal will always prevail.

4.6 *Behaviour of the system during interruption in transmission*

4.6.1 *Interruption during the Seizure signal*

The Seizure signal does not get to the incoming junctor and therefore there is not its seizure. After time-out, the outgoing junctor sends the Clear Forward signal. As the incoming junctor has not been seized, the Release Guard signal will not be sent. So, time-out in the outgoing junctor occurs and then a maintenance alarm is activated and another Seizure signal is sent, being followed by the Clear Forward signal. Such sequence is repeated at intervals identical with those of the time supervision period of the junctor. After the reset up of the transmission system and the next reception in sequence of the Seizure and Clear Forward signals, the incoming junctor sends the Release Guard signal, thus releasing the outgoing junctor.

4.6.2 *Interruption during the Proceed-to-Send signal*

The Proceed-to-Send signal does not get to the outgoing junctor and therefore interregister signalling does not start. Two cases are possible:

- a) After time-out in the signalling equipment at the incoming end of the link, the specific interregister backward signal is sent back. The signalling equipment at the incoming end of the link releases and the outgoing junctor sends forward the Clear Forward signal.
- b) After time-out, the signalling equipment at the outgoing end of the link releases and the outgoing junctor sends forward the Clear Forward signal.

4.6.3 *Interruption during the Answer signal*

The Answer signal does not get to the outgoing junctor and the call may be completed even if charging has not started. After time-out in the origin, the Clear Forward signal is sent. The incoming junctor sends the Release Guard signal, thus releasing the outgoing junctor.

4.6.4 *Interruption during the Clear Forward signal*

The Clear Forward signal does not get to the incoming junctor and therefore it cannot send the Release Guard signal. After time-out, a maintenance alarm is activated and the Seizure signal is sent, being followed by the Clear Forward signal. Such sequence is repeated at intervals identical with those of the time supervision period of the outgoing junctor until the Release Guard signal is received.

If there is a short interruption in the transmission system, thus preventing reception of the Clear Forward signal at the incoming junctor and in case the called subscriber will hang up during the time supervision period of the outgoing junctor, the Clear Back signal will be taken as a Release Guard signal and therefore there will be the release in the origin. However, the equipment which has not received the Clear Forward signal will remain set up until it has been requested again and released by another call, which will not be successful.

4.6.5 *Interruption during the Clear Back signal*

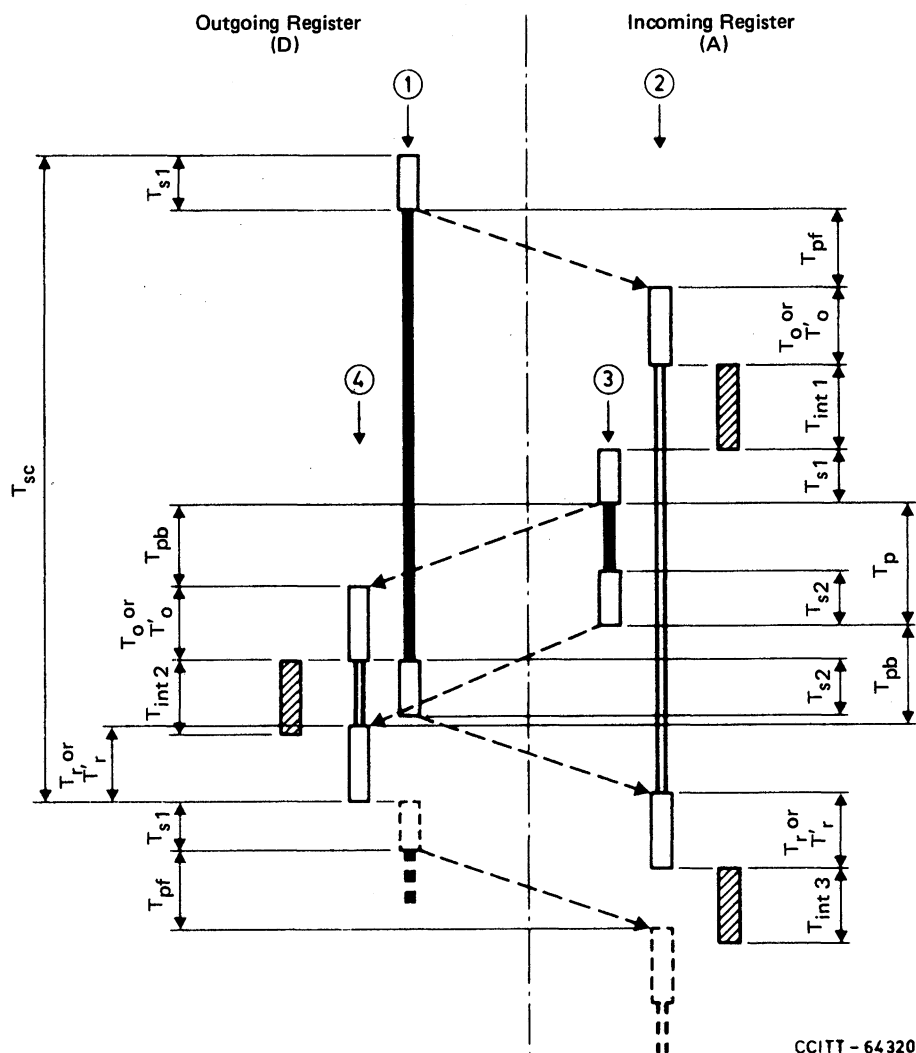
The Clear Back signal does not get to the outgoing junctor and the release of the equipment will be dependent on the calling subscriber hang-up.

4.6.6 *Interruption during the Release Guard signal*

The Release Guard signal does not get to the outgoing junctor and, after time-out, the procedure used is the same as that established in § 4.6.4.

4.6.7 *Interruption during the Forced Release signal*

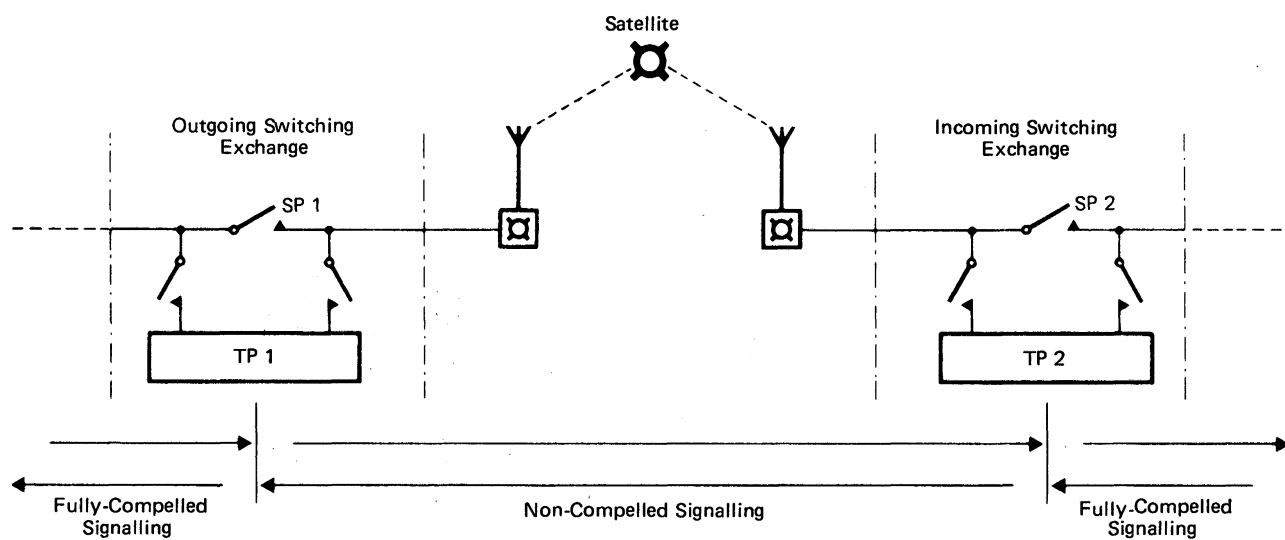
The Forced Release signal does not get to the outgoing junctor and the release of the equipment will be dependent on the calling subscriber hang-up.



- ① Sending of Forward Multifrequency Combination
- ② Receiving of Forward Multifrequency Combination
- ③ Sending of Backward Multifrequency Combination
- ④ Receiving of Backward Multifrequency Combination
- T_{sc} Duration of a Semi-Compelled Cycle
- T_{pf} Transmission Delay of the Slower of the Two Frequencies of a Forward Multifrequency Combination
- T_{pb} Transmission Delay of the Slower of the Two Frequencies of a Backward Multifrequency Combination
- T_o and T'_o Operating Times as Defined in Recommendation Q.451
- T_r and T'_r Release Times as Defined in Recommendation Q.451
- T_{int1} , T_{int2} and T_{int3} Internal Operation Times as Defined in Recommendation Q.451
- T_{s1} and T_{s2} Times Required for Starting and Stopping the Sending of a Multifrequency Combination (Switching-on or Switching-off Times, Exclusive of Logic Operations)
- T_p Pulse duration

FIGURE 1

Sequence of a semi-compelled signalling cycle



SP 1, SP 2 — Switching Points
TP 1, TP 2 — Translation Points

Signalling translation in the signalling equipment of the switching exchange

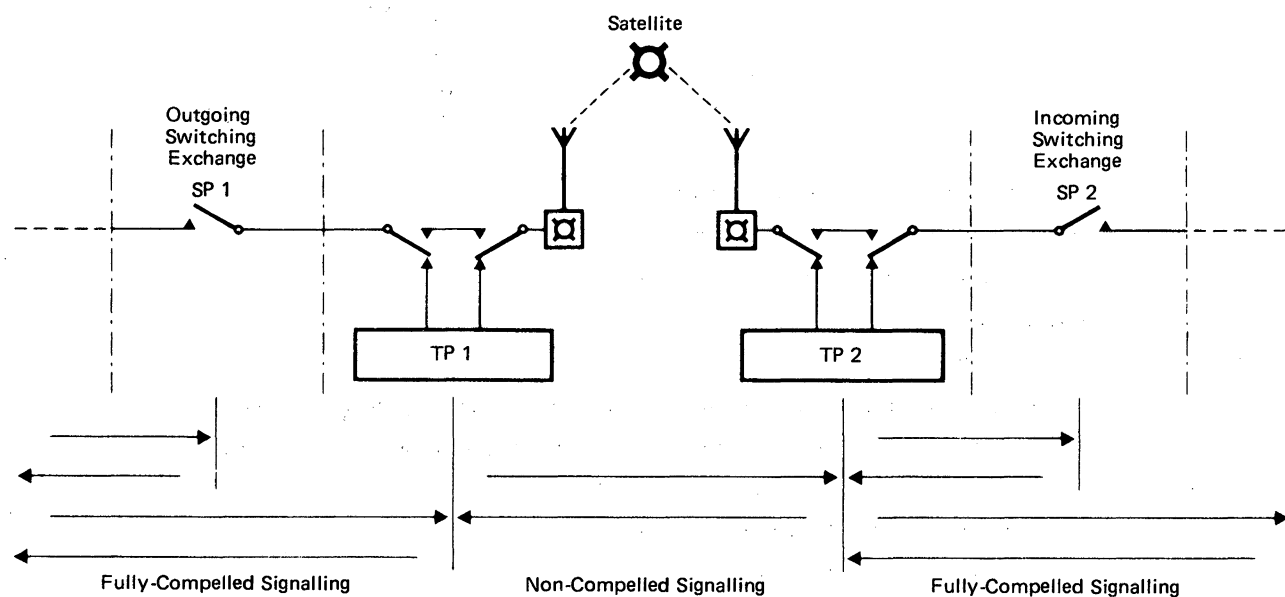
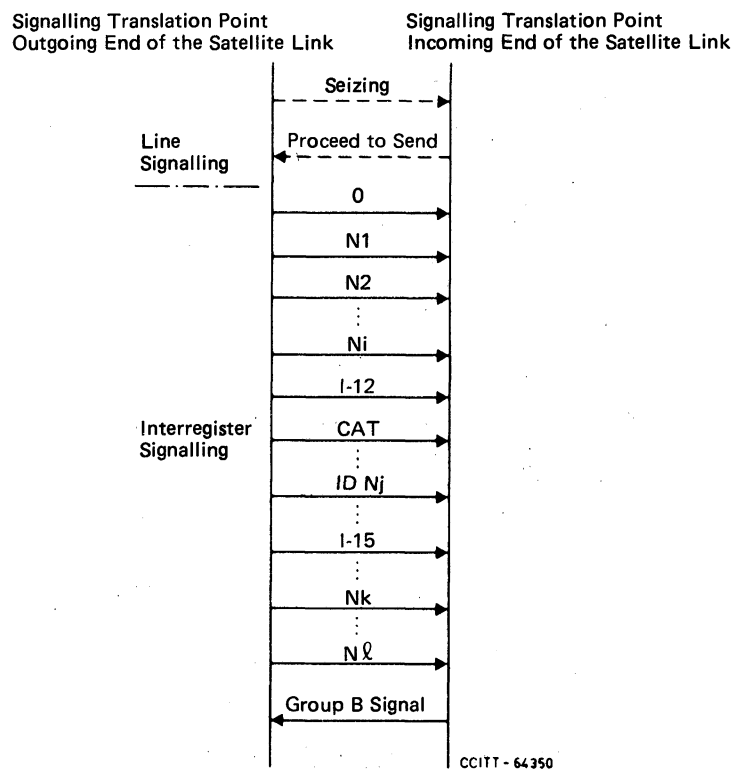


FIGURE 3

**Signalling translation in
independent signalling translation equipment**

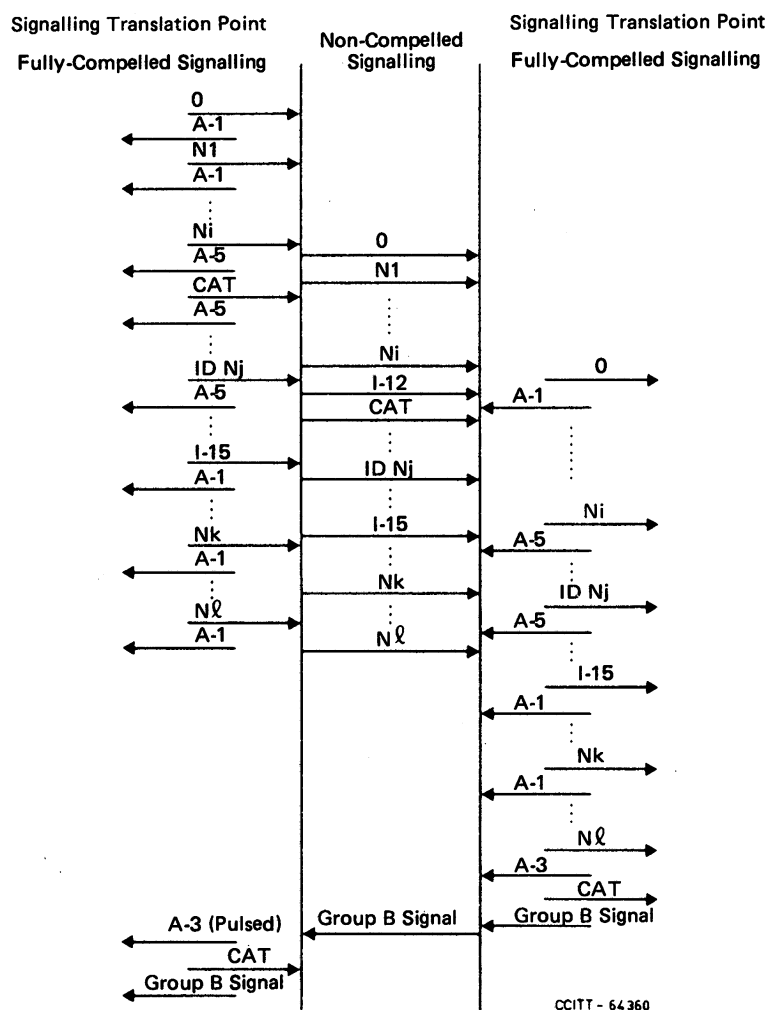
Signalling translation in independent signalling translation equipment



0, N1, N2 ... Ni ... Nk ... Nl — National Number (Called Subscriber)
ID Nj — Calling Subscriber Number

FIGURE 4

Non-compelled signalling (signalling sequence with
calling subscriber identification)



Ni, Nk – Digits of Called Subscriber Number
 ID Nj – Digits of Calling Subscriber Number (Calling Subscriber Identification)

FIGURE 5

General case of a call set up with
 non-compelled signalling

