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SERIES Q: SWITCHING AND SIGNALLING

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## **Specifications of Signalling System R2**

**ITU-T Recommendations Q.400-Q.490**

(Formerly CCITT Recommendations)

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SWITCHING AND SIGNALLING

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# ITU-T Recommendations Q.400-Q.490

## Specifications of Signalling System R2

### Summary

Signalling System R2 is used as an international signalling system within international regions. Suitable for both automatic and semi-automatic working, it 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.

The interregister signalling is a compelled multifrequency code system which offers the possibility of end-to-end signalling.

### Source

ITU-T Recommendations Q.400-490 were prepared by CCITT Study Group XI (1985-1988) and approved by WTSC in Melbourne on 25 November 1988. Those texts were originally published in Blue Book, Fascicle VI.4.

## FOREWORD

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The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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# SPECIFICATIONS OF SIGNALLING SYSTEM R2

## 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).

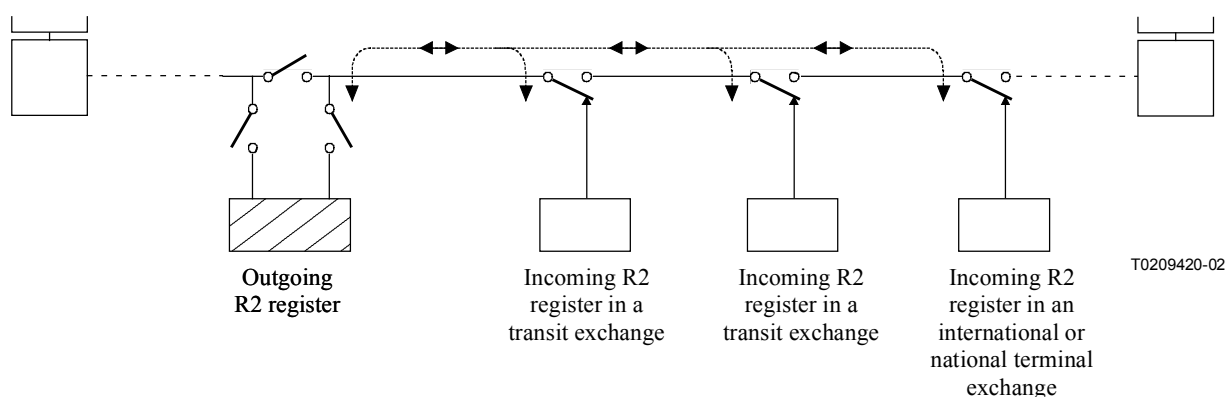


FIGURE 1

### **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 signal<sup>1)</sup>

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 signal<sup>2)</sup>

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.

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<sup>1)</sup> 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.

<sup>2)</sup> 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.

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#### 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/O.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).

## 2.2 CLAUSES FOR EXCHANGE LINE SIGNALLING EQUIPMENT<sup>1)</sup>

### 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  $40 \pm 10$  ms <sup>2)</sup>. 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).

#### 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.

<sup>1)</sup> 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.

<sup>2)</sup> Originally this value was  $(20 \pm 7)$  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.

### 2.2.2.6 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.

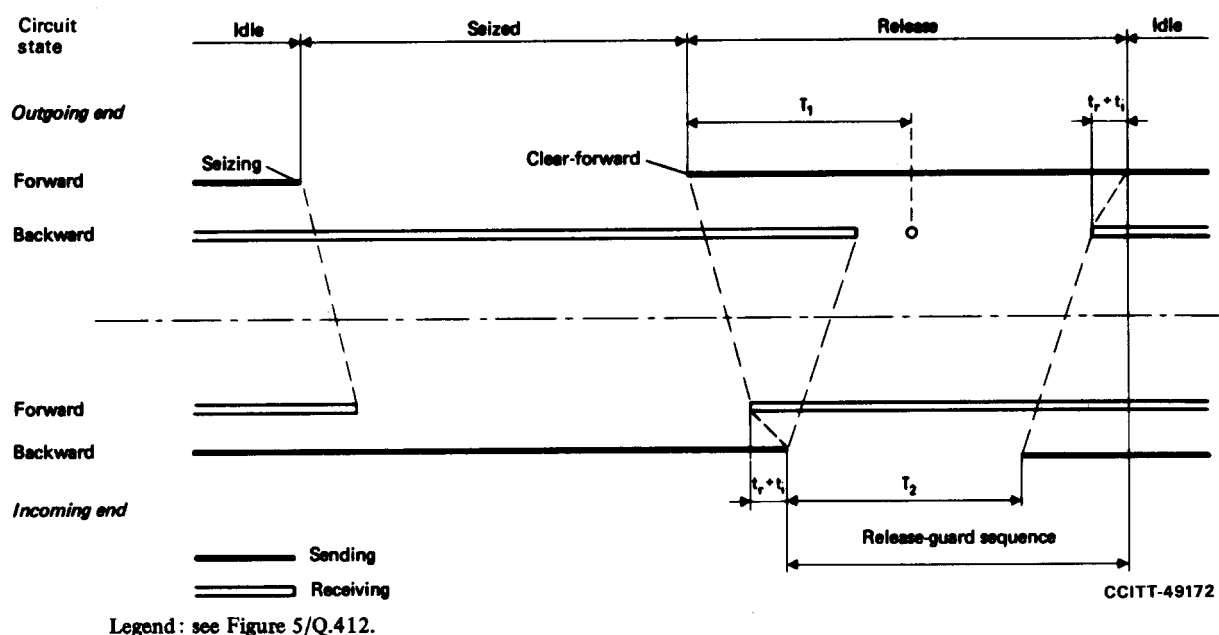


FIGURE 2/Q.412

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).

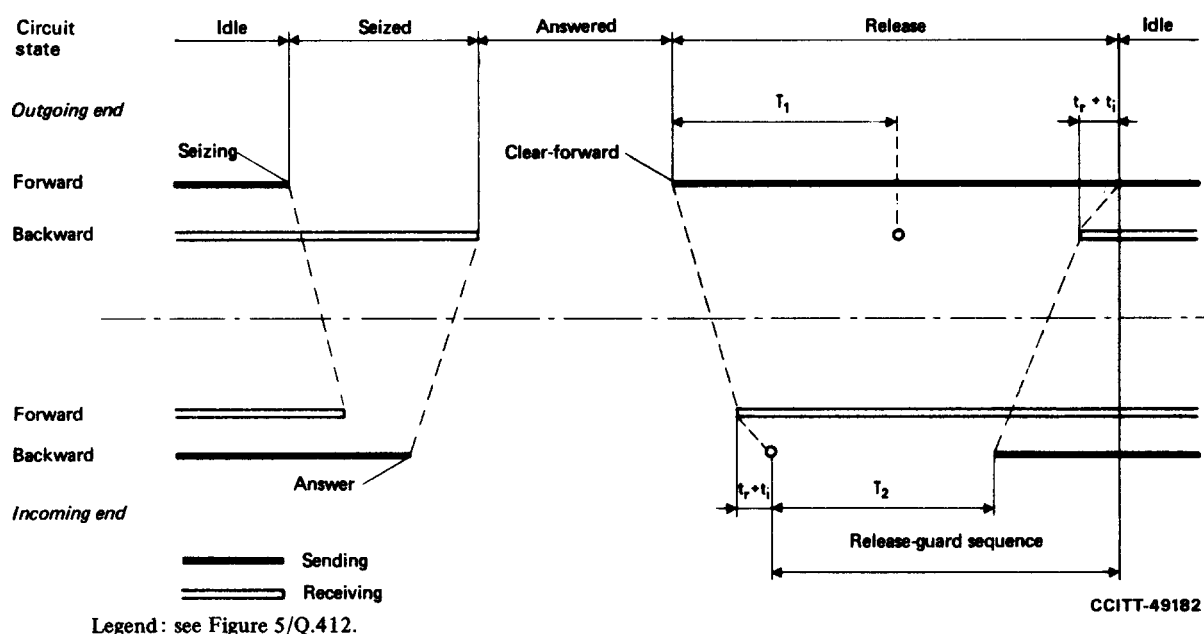


FIGURE 3/Q.412  
Release in answered state

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].

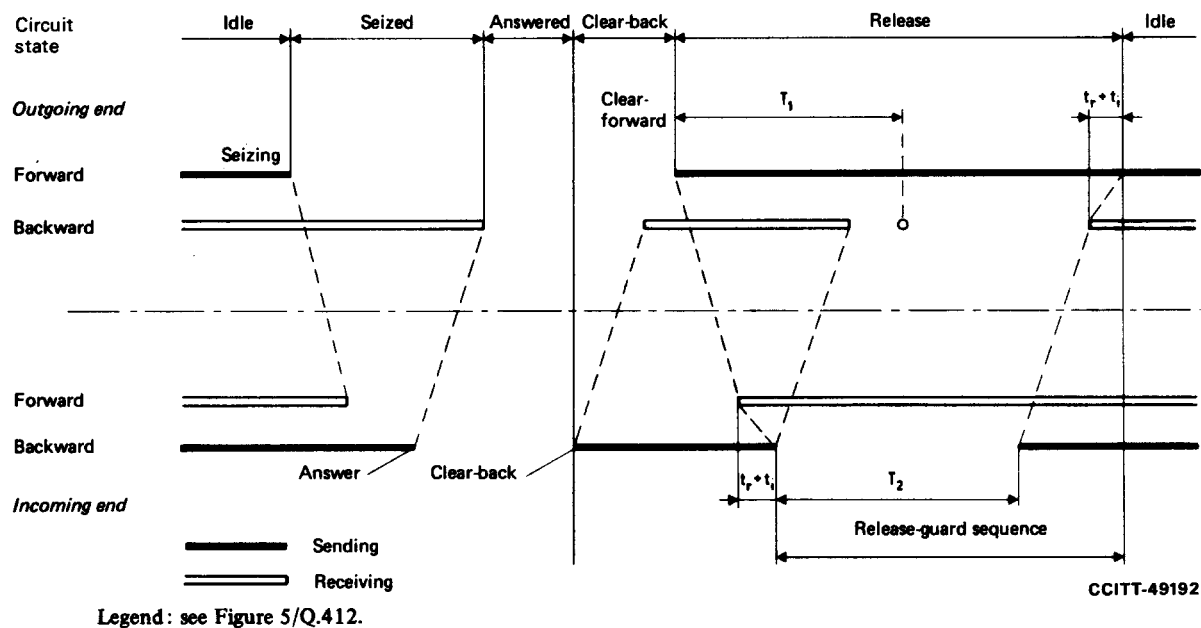
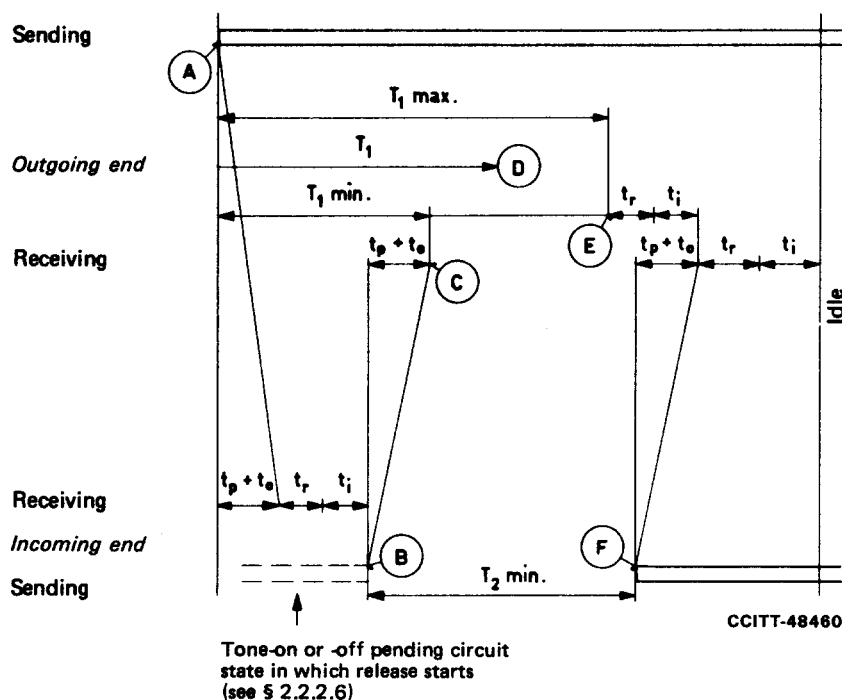


FIGURE 4/Q.412  
Release in clear-back state



**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 km<sup>3)</sup>.

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  $T_2$ :

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

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

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

Allowing a safety margin of 20 ms and a tolerance of  $\pm 20\%$ , the specified value of  $T_2$  is  $(450 \pm 90)$  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  $(270 \pm 20)$  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  $T_2$ :

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

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

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

$$T_2 > \overline{BF} \quad T_2 > T_1 \text{ max.} + t_r \text{ max.} + t_i \text{ max.} - 2(t_p + t_o) \text{ min.} - t_r \text{ min.} - t_i \text{ min.}$$

$$T_2 > (1200 + 50 + 20 - 2 \times 250 - 30 - 0) \text{ ms}$$

$$T_2 > 740 \text{ ms}$$

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  $T_2$ :

$$0 < t_p < 320 \text{ ms}$$

$$0 < t_o < 30 \text{ ms (see § 2.3.2.4)}$$

$$30 < t_r < 50 \text{ ms}$$

$$0 < t_i < 20 \text{ ms}$$

Calculation of interval  $T_2$ :

$$T_2 > \overline{BF} \quad T_2 > T_1 \text{ max.} + t_r \text{ max.} + t_i \text{ max.} - 2(t_p + t_o) \text{ min.} - t_r \text{ min.} - t_i \text{ min.}$$

$$T_2 > (1200 + 50 + 20 - 0 - 30 - 0) \text{ ms}$$

$$T_2 > 1240 \text{ ms}$$

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  $\pm 4$  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  $-20 \pm 1$  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  $\pi$  radian phases in the channels. An equivalent method is to use carrier frequencies of which the phases are randomly distributed 0 and  $\pi$  radians. With these methods the probability of occurrence of 0 and  $\pi$  radian phases should be 0.5<sup>1)</sup>.

Other methods may be used provided they give comparable results.

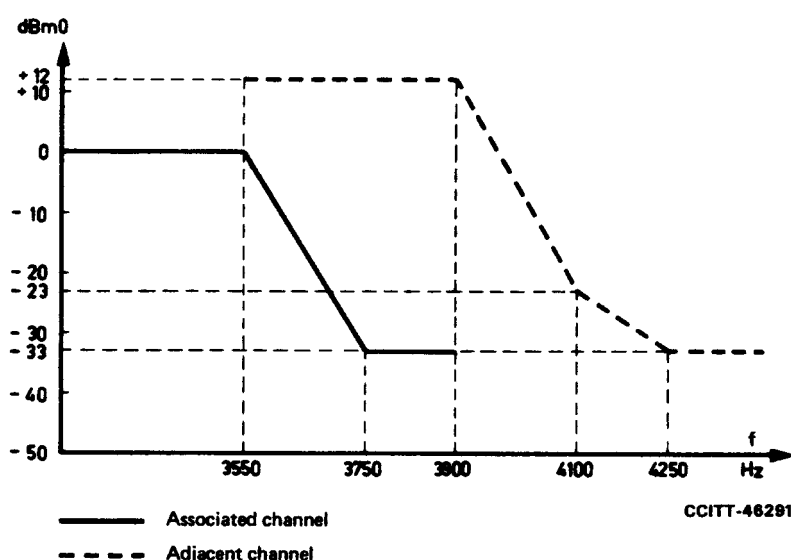
<sup>1)</sup> For further details on the method of random distribution of the phases of frequency 3825 Hz, see: Ekholm, O. and Johannesson, N.O.: "Loading Effects with Continuous Tone Signalling", English edition of *TELE*, No. 2, 1969. For further details on a systematic method of phase distribution, 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.

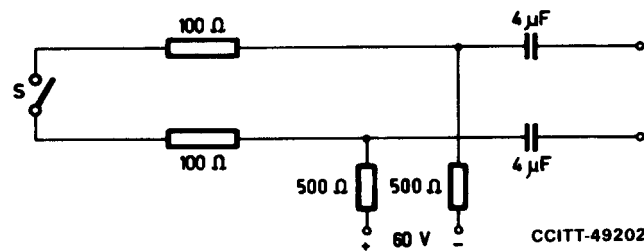


FIGURE 7/Q.414

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  $3825 \pm 6$  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.

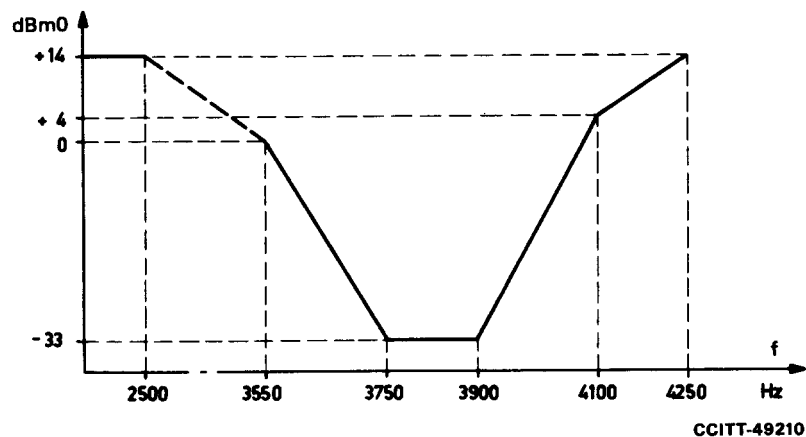


FIGURE 8/Q.415

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.

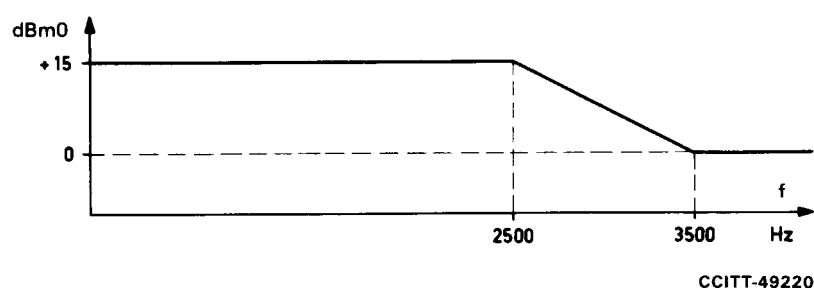


FIGURE 9/Q.415

**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.

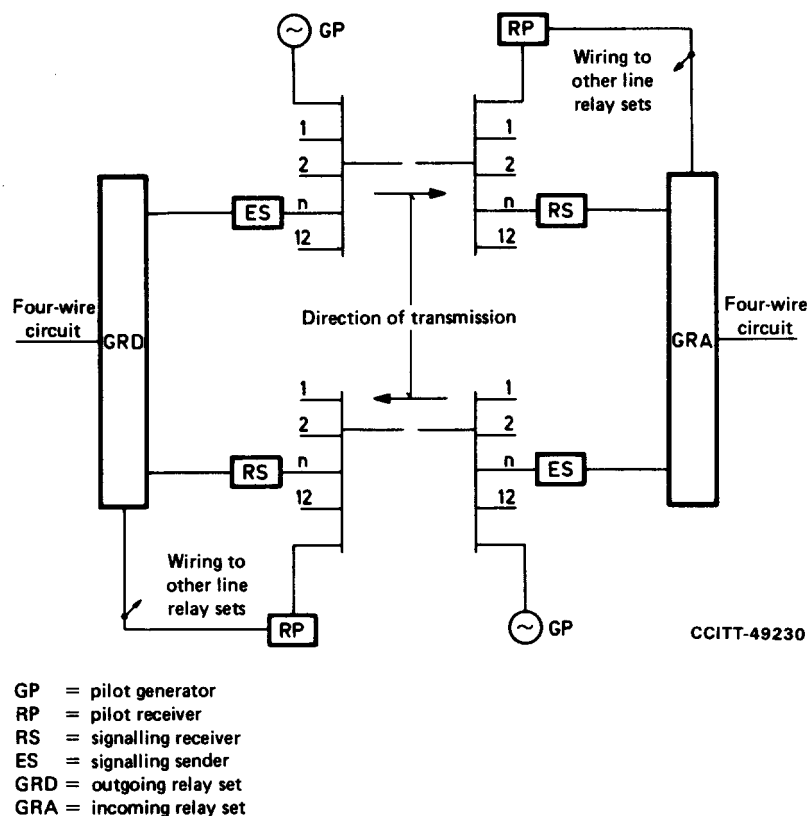


FIGURE 10/Q.416  
 Protection from the effect of interruptions (interruption control)

#### 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:

- removal of the tone in the backward direction by locking of the sending unit in the *tone-off* condition;
- 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:

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

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

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,  $t_{rs \min}$  is the minimum response time of the signalling receiver for a drop in level, taking into account a possible variation of  $\pm 3$  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 ( $20 \pm 7$  ms)<sup>1)</sup>, 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:

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

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,  $t_{rs \max}$  is the maximum response time of the signalling receiver for a rise in level, taking into account a possible variation of  $\pm 3$  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 ( $20 \pm 7$  ms)<sup>1)</sup> 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.

<sup>1)</sup> If the value ( $40 \pm 10$ ) 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).

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### 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     | 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  $20 \pm 10$  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.

### 3.2.4.2 Incoming end

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<br>see Note 1 | Idle                        | Fault<br>see Note 1 |
| Seizure acknowledged             | $a_b = 1, b_b = 1$                             | Seizure acknowledged          | Fault<br>see Note 2 | Clear-forward               | Fault<br>see Note 2 |
| Answered                         | $a_b = 0, b_b = 1$                             | Answered                      | Fault<br>see Note 3 | Clear-forward               | Fault<br>see Note 3 |
| Clear-back                       | $a_b = 1, b_b = 1$                             | Clear-back                    | Fault<br>see Note 4 | Clear-forward               | Fault<br>see Note 4 |
| Clear-forward                    | $a_b = 0, b_b = 1$<br>or<br>$a_b = 1, b_b = 1$ | Abnormal seized<br>see Note 7 | Fault<br>see Note 7 | Clear-forward<br>see Note 7 | Fault<br>see Note 7 |
| Blocked                          | $a_b = 1, b_b = 1$                             | Abnormal seized<br>see Note 5 | Fault<br>see Note 6 | Blocked                     | Fault<br>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.