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GENERAL ASPECTS OF DIGITAL TRANSMISSION SYSTEMS

TERMINAL EQUIPMENTS

SYSTEM ASPECTS FOR THE USE OF THE 7 kHz AUDIO CODEC WITHIN 64 kbit/s

ITU-T Recommendation G.725

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation G.725 was published in Fascicle III.4 of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation G.725

SYSTEM ASPECTS FOR THE USE OF THE 7 kHz AUDIO CODEC WITHIN 64 kbit/s

(Melbourne, 1988)

1 General

This Recommendation should be associated with Recommendation G.722 *7 kHz audio coding within 64 kbit/s* and Recommendation H.221 *Frame structure for a 64 kbit/s channel in audiovisual teleservices.*

A number of applications utilizing wideband (7 kHz) speech have been identified including high quality telephony, audio conferencing (with or without various kinds of visual aids), speech channel of visual telephony, audiographic conferencing and so on. More applications will undoubtedly emerge in the future.

To provide these services a scheme is recommended in which the 64 kbit/s channel accommodates speech, and optionally data at several rates, in a number of different modes. Signalling procedures are required to establish a compatible mode upon call setup, to switch between modes during a call, and to allow for call transfer. In the future ISDN, D-channel signalling may be used for some of these procedures. However, before the signalling facilities of the ISDN become available, in channel signalling must be provided.

All audio and audio-visual terminals using G.722 audio coding and/or G.711 speech coding should be compatible to permit connection between any two terminals. This implies that a common mode of operation has to be established for the call. The initial mode might be the only one used during a call or, alternatively, switching to another mode can occur as needed, depending on the capabilities of the terminals. Thus, for these terminals, an in-channel procedure for dynamic mode switching is required even in a ISDN environment.

The following paragraphs develop these considerations and describe recommended in-channel procedures.

2 Transmission modes and terminal types

2.1 *Transmission modes*

The following modes of operation are defined:

Mode 0 - 64 kbit/s narrowband audio according to Recommendation G.711 (A- or μ-law);

Mode 1 - 64 kbit/s 7 kHz audio according to Recommendation G.722;

Mode 2 - 56 kbit/s 7 kHz audio according to Recommendation G.722 + up to 6.4 kbit/s data;

Mode 3 - 48 kbit/s 7 kHz audio according to Recommendation G.722 + up to 14.4 kbit/s data.

For both Modes 2 and 3, an additional 1.6 kbit/s capacity is reserved for service channel framing and mode control.

Additional modes may be defined (see Recommendation H.221) having other speech bit rates, or data bit rates up to a full 64 kbit/s data path.

For analogue telephone terminal it may be assumed that the speech signal is converted to PCM according to Recommendation G.711 at a digital network interface. These terminal are viewed as working in Mode 0, when connected to wideband speech terminal.

2.2 *Terminal types*

Three types of terminals are defined thus far, according to their modes of operations:

Type 0 - A digital telephone set working in Mode 0 only (or an analogue telephone set connected via a PCM interface);

Type 1 - A 7 kHz audio terminal capable of working in Mode 1 or in Mode 0;

Type 2 - A member of a family of 7 kHz audio/data terminals capable of working at least in Modes 0, 1, 2 and 3. Further modes may also be implemented. Dynamic mode switching between different modes must be provided.

In order to establish a mode of operation with the highest possible performance, terminals of Type 1 and Type 2 must be able to identify the terminal type at the far end, and they must indicate their own type to the far end terminal.

2.3 *Establishment of compatible modes of operation*

At the beginning of the communication phase of a call, all terminals start to work in Mode 0. Terminals of Type 1 and Type 2 will then begin an initialization procedure.

This procedure (further described in § 5) consists of:

- the transmission of information concerning the capabilities of the respective terminal for audio coding and/or data transmission;
- the determination of a suitable transmission mode consistent with the known capabilities of both terminals (an example of agreed mode is given in Table 1/G.725); and
- switching to this mode.

The terminals connected to a call may change during the call. This may require reinitialization in order to identify the terminal type and to re-establish the common mode of operation. In particular, this feature is used for Mode 0 forcing, which is necessary in the case of a call transfer (see § 7).

TABLE 1/G.725

Mode of operation upon completion of the initialization procedure

Agreed mode of operation		Identified terminal type at the far end		
		Type 2	Type 1	Type 0
Type of local terminal	Type 2	Mode 2	Mode 1	Mode 0
	Type 1			

3 Frame structure

The frame structure described in Recommendation H.221 is used for dynamic mode switching and mode initialization (see the following sections) and more generally to allocate sub-channels in connections of Type 2 terminals.

Recommendation H.221 defines a bit rate allocation signal (BAS) which is used to allocate subchannels and to indicate the audio coding algorithm. Table 2/G.725 gives the coding of the BAS for the attribute 000 (audio coding) as applicable to terminals to Recommendation G.722. Only a BAS beginning with 000 should be taken into account as to the audio coding mode itself. In this respect, a BAS with another attribute does not modify the audio coding mode.

TABLE 2/G.725

BAS code values affecting the audio coding mode

BAS code	Octet format – Bit position 1	2	3	4	5	6	7	8	Audio coding	Mode	Information rates – Audio	Application channel	Data channel	Framed	Comments
00000100	P	P	P	P	P	P	P	P	G 711-A	0	64	0	0	No	Note 1
00000101	P	P	P	P	P	P	P	P	G 711-μ	0	64	0	0	No	Note 1
00000110	H	H	L	L	L	L	L	L	G 722	1	64	0	0	No	Note 1
00001000	H	H	L	L	L	L	L	S	G 722	2	56	6.4	0	Yes	
00001001	H	H	L	L	L	L	D	S	G 722	3	48	6.4	8	Yes	
00011000	H	H	L	L	L	L	L	S	G 722	2	56	0	6.4	Yes	Note 2
00011001	H	H	L	L	L	L	D	S	G 722	3	48	0	14.4	Yes	Note 2

P PCM
S Service channel
H Higher sub-band
L Lower sub-band
D Data channel

Note 1 - Attribute values 001xx imply switching to an unframed mode. In the receive direction, reverting to a framed mode can only be achieved by recovering frame and multiframe alignment.

Note 2 - The application channel is merged with the data channel to form a single data path.

A second BAS attribute 100 (audio capability) is defined and is intended to be used for signalling terminal capabilities to the distant terminal. When received, this attribute does not affect the current audio coding mode. However, it may lead to the initiation of a specific action to be carried out by the terminal. This feature is utilized in the mode initialization procedure and in the Mode 0 forcing procedure (see § 5). The coding of the BAS for attribute values assigned for audio capability is shown in Table 3/G.725.

TABLE 3/G.725

BAS code values for audio capability

BAS code	Audio coding capability	Comments
10000000	Neutral	No change of audio capability
10000001	Type 0, A-law	
10000010	Type 0, μ-law	
10000011	Type 1	
10000100	Type 2	
10000101	Reserved	
10000110	Reserved	
10000111	Reserved for national use	

The third bit of the H.221 frame alignment signal (FAS) in odd frames, herein called the A-bit, is set to 1 on loss of frame or multiframe alignment, and is set to 0 on acquiring both frame and multiframe alignment. Optionally, the terminal may set the A-bit to 0 on acquiring framing and before acquiring multiframing. A terminal which is receiving a frame signal with the A-bit set to 0 can assume that the distant terminal is able to act upon a change of BAS.

4 Basic sequences for in-channel procedures

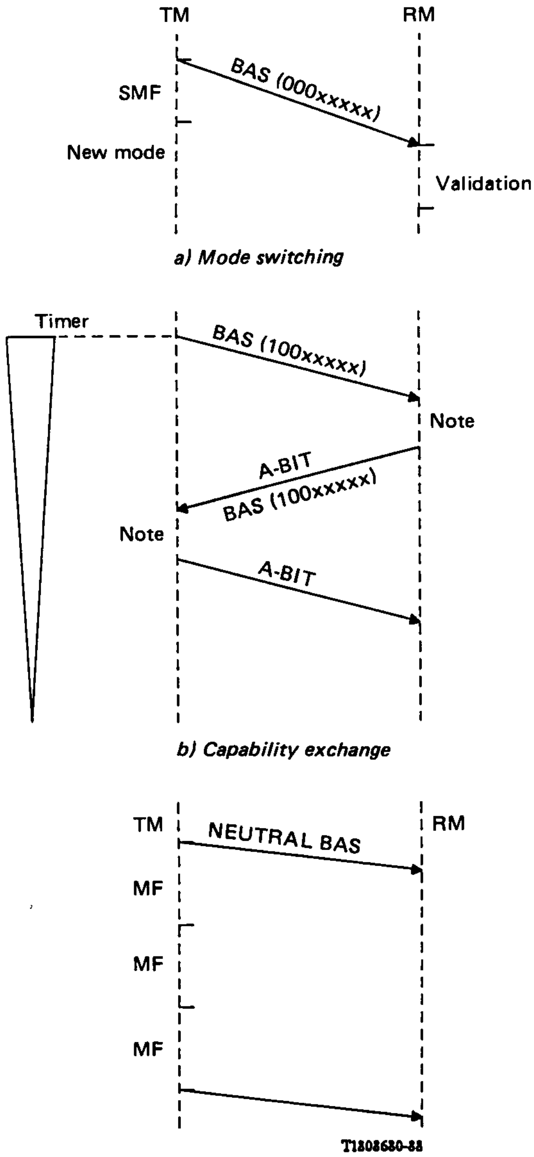
Three signalling sequences are defined in this section. These sequences are used as the building blocks for the procedures defined in §§ 5 and 6. The sequences are described in Figure 1/G.725.

4.1 *Mode switching sequence*

Mode switching is defined in Recommendation H.221 and is done using eight-bit BAS codes, with audio coding attribute (000).

In the present submultiframe the transmitting terminal sends a BAS code to signal the mode of operation in which it will transmit during the next submultiframe.

The receiving terminal decodes and validates the BAS code during the present submultiframe, and switches its receive mode to the signalled mode of operation at the beginning of the next submultiframe. If the receiving terminal does not receive a valid BAS code due to transmission errors, it continues its present mode of operation during the next submultiframe.



c) Frame recovery

TM Transmit mode
RM Receive mode
SMF Submultiframe
MF Multiframe
BAS Bit rate allocation signal

Note - Exact timing of the A-bit indication depends on the implementation.

FIGURE 1/G.725

Basic sequences for in-channel procedures

4.2 *Capability exchange sequence*

The capability exchange sequence forces framing in both direction of transmission, and the exchange of terminal type indication using the BAS code with the audio capability attribute (100).

The terminal which initiates the capability exchange sequence sets a times T1 (value: 10 seconds) and transmits in a framed mode with the BAS signal stating its current capability.

When the distant terminal decodes the audio capability BAS code in two consecutive submultiframes, it starts the capability exchange sequence. One of the three cases may occur:

- Within the timer expiration period, multiframe alignment[1)] has been achieved, the A-bit has received with a value of 0, and the audio capability BAS code of the distant terminal has been validated in two consecutive submultiframes. In this case the sequence completed successfully.
- The timer has expired without multiframe alignment[1)]. In this case, the sequence failed.
- The times has expired with multiframe alignment[1)] achieved, but without either the validation of the A-bit as 0 or the receiving of the distant terminal's audio capability BAS code (or both). In this case, the sequence is restarted.

4.3 *Frame recovery sequence*

When a terminal is transmitting in an unframed mode and wishes to institute framing in its transmitting direction, it superimposes the frame structure over the transmitting information using the neutral audio capability BAS code. This audio capability BAS code is transmitting for at least 3 multiframes (48 frames).

5 Initialization and Mode 0 forcing

Recommendation G.722 terminals will be connected to digital networks where other kinds of terminals will also be connected, e.g. Type 0 terminals, data terminals, telematic terminals, servers, etc. When compatibility between the different services involving those terminals is required, initialization procedure is necessary. When automatic compatibility is required, a procedure based on the sequences defined in § 4 is used.

For call transfer or mode mismatch recovery, it is necessary for terminals to operate in the common Mode 0 and thus a Mode 0 forcing procedure is required, again based on the sequences defined in § 4.

At the commencement of the call there is a need for an initialization procedure to ensure that the two connected terminals can operate in the most suitable common mode.

5.1 *Mode initialization procedure*

The mode initialization procedure ensures that both terminal have been informed of the capabilities of the other terminal, and switched to the highest common audio mode in both directions of transmission. In case of two Type 2 terminals, both directions of transmission will be in either Mode 1, Mode 2, or Mode 3, but symmetry is not required. The procedure can be initiated by both terminals independently. However, even if it is initiated by only one terminal, it will still achieve the same results as a procedure that was initiated independently, due to the symmetric operation of the capability exchange sequence.

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1) Optionally, frame alignment may be sufficient.

At the beginning of the mode initialization procedure, the terminal starts transmitting in Mode 0, while initiating the capability exchange sequence (§ 4.2). The receive part is in frame search and the receive audio is in Mode 0. If the capability exchange sequence has terminated successfully, the mode switching sequence (§ 4.1) is executed in order to switch to a common working mode. The initialization procedure is completed when both terminals have switched to their common working mode(s), according to their capabilities.

If the capability exchange sequence failed, i.e. no framing was detected on the incoming path within the timer expiration period, the terminals shall continue transmitting in Mode 0, but without framing.

5.2 *Mode 0 forcing procedure*

Where it is necessary to ensure that both terminals are operating in Mode 0 (for instance before call transfer), this procedure is used.

For the forcing terminal, BAS 10000010 (Type 0 terminal) is sent to the terminal which is to be forced to Mode 0, using the capability exchange sequence (see Figure 1b/G.725). When this is complete, both terminals execute the mode switching sequence (see Figure l a/G.725) with the BAS value of 00000100 or 0000101 to switch transmission to Mode 0, since PCM is now the only common mode of operation.

At the completion of the mode-switching sequence, both terminals are operating in Mode 0. Changes of network configuration can now be achieved (see § 7).

5.3 *Mode mismatch recovery procedure*

In the case where mode mismatch between Mode 0 and Mode 1 has been detected in the receiver (e.g. by examining the energy level or by monitoring the statistics of the decoded output), the Mode 0 forcing procedure may be used to establish a common working mode. The audio output has to be muted starting from the detection of the mismatch until the establishment of the common Mode 0. Following this procedure, reinitialization can be achieved by using the mode initialization procedure.

5.4 *Recovery from unexpected loss of frame alignment*

If a terminal unexpected loses frame alignment on its receive path, a timer T2 is set (value: 0.1 seconds). During this time the status of the framing in the receive direction is monitored:

- if framing is recovery before the time expires, the normal operation is continued;
- if framing is not recovered before the timer expires, the terminal goes to the Mode 0 forcing procedures. The audio output should be muted starting from the expiry of the timer until the Mode 0 forcing procedure is completed. Following this procedure, reinitialization can be achieved by using the mode initialization procedure.

6 Dynamic mode switching procedure for Type 2 terminals

The dynamic mode switching procedure makes use of the frame structure specified in Recommendation H.221 as described in § 3, and of the sequences defined in § 4.

When the terminal is receiving in a framed mode, and is capable of decoding the A-bit, mode switching should be delayed if the A-bit is set to 1; eventually the mode mismatch recovery procedure as described in § 5.3 might be used.

6.1 *Dynamic mode switching from a framed mode to another framed mode*

The mode switching sequence (see Figure l a/G.725) is used.

At the transmitting terminal, of a BAS is transmitted to signal a new audio mode, the audio encoder must operate in the appropriate audio encoding mode (Recommendation G.711, A- or μ-law; Recommendation G.722, mode 1) from the first octet of the next submultiframe.

Similarly, at the receiving terminal, if the received BAS signals a new audio-mode, the audio decoder must operate in the appropriate audio decoding mode (Recommendation G.711, A- or μ-law; Recommendation G.722, Modes 1, 2 or 3; muted audio) from the first octet of the next submultiframe.

6.2 *Dynamic mode switching from a framed mode to an unframed mode*

As in § 6.1, the mode switching sequence is used.

However, as the BAS for signalling an unframed mode is transmitted for a single submultiframe, a mode mismatch may occur in severe error conditions. Optionally, two methods may be alternatively or simultaneously used to improve the reliability of the switching:

i) If the distant terminal is transmitting in an unframed mode, the capability exchange sequence (see Figure 1b/G.725) is used first in order to be able to decode the A-bit in the receive direction and to be sure that multiframing is aligned in the distant terminal. The mode switching sequence may then be transmitted.

ii) The new BAS value in the mode switching sequence may be repeated several times. This will cause a temporary mismatch on the least significant bit.

6.3 *Dynamic mode switching from an unframed mode to a framed mode*

The frame recovery sequence (see Figure 1c/G.725) and the mode switching sequence are sequentially transmitted.

Alternatively, another method may be used. The capability exchange sequence is used, followed by the mode switching sequence. This requires a bi-direction link and provides a more reliable procedure. However it causes an unneeded mode change in the distant terminal.

6.4 *Dynamic mode switching from an unframed mode to another unframed mode*

The frame recovery sequence and mode switching sequence are sequentially transmitted.

Alternatively, the alternate methods mentioned in § 6.3 may be used.

Additionally, the option of § 6.2 may be applied.

7 Network considerations: call connection, disconnection, and call transfer

7.1 *Call connection*

It is assumed that the terminals for switched network operation will have a signalling arrangement for originating calls over the network

In the case that the network provides an indication that the connection is established, the originating terminal will set its transmit and receive audio modes to Mode 0, and begin the mode initialization procedure following the connection establishment indication. Where the network does not provide an indication of connection establishment, the originating terminal will begin the mode initialization procedure of § 5.1 immediately.

Upon answering a call, the terminal will begin the mode initialization procedure.

Terminals for use on leased circuits may have a means for sending the alerting signal to the distant terminal and for answering the alerting signal. In this case, the sending of the alerting signal is equivalent to dialling and the foregoing procedures apply.

Whenever a terminal is manually reset, or recovers from a fault condition, the terminal will begin the Mode 0 forcing procedure of § 5.2. Then the terminal will begin the mode initialization procedure after 2 seconds.

7.2 *Terminal disconnection*

When a terminal disconnects from a call, the terminal must first initiate the Mode 0 forcing procedure, completion of the procedure, and then the actual disconnection may occur.

7.3 *Call transfer*

As a consequent of the above, the terminal which continues to participate in a transferred call will be receiving in a Mode 0-forced state, and therefore will be transmitting its audio capability BAS in framed Mode 0. When the transferred-to terminal answers, mode re-initialization will occur in both directions.

7.4 *Conferencing*

Conferencing will be accomplished by means of a multipoint conference unit (MCU). Each terminal will be connected to a port of the MCU by a switched connection or a leased circuit. Each connection between the terminal and the MCU is considered to be a point-to-point connection as far as call connection, terminal disconnection, and call transfer procedures are concerned.

7.5 *PCM format conversion*

In the above procedures, no automatic method for establishing A-law or μ-law compatible PCM operation is defined. Instead, Type 1 and Type 2 terminals should be capable of working in both A-law and μ-law PCM.

The originating Type 1 or Type 2 terminals is responsible for selecting the PCM coding law. This is important, especially in cases of connection to a Type 0 terminal or interworking to the analog network, if no format conversion is provided by the network because a bit transparent link was requested by the originating terminal when trying to place a 7 kHz audio call.

The following guidelines should be used in making the selection:

1) If there is an indication regarding the default PCM format in the zone of the distant terminal before the call is established (e.g. from manual selection by the user, or from analysis of dialled digits, or from the network), then the PCM format of the distant terminal should be used whenever the call is in PCM.

2) If there is no indication before the call is established, the terminal should default to the PCM coding law of its own zone, while monitoring the statistics of the incoming signal (see Appendix I). If the monitoring suggests that the other coding law should be used, the terminal should switch to the other PCM mode. If the capability exchange sequence in the mode initialization procedure is completed successfully (i.e. the distant terminal is a Type 1 or Type 2 terminal), then the terminal may use any PCM law. Otherwise, the coding law determined by the statistical monitoring should prevail throughout the call.

In a teleconference call, the network bridge is responsible for providing compatible connections.

APPENDIX I

(to Recommendation G.725)

An algorithm to determine whether an incoming bit stream was encoded by μ-law or A-law PCM

This Appendix gives information concerning a method to determine the PCM coding law from the observation of the incoming bit streams. It should be used in the absence of other indications regarding the PCM coding law.

I.1 *Basic determination algorithm*

The following algorithm determines whether an incoming bit stream was encoded by μ-law or A-law PCM. The algorithm comprises two stages:

i) data accumulation;

ii) decision.

A decision can be made after data has been accumulated for 10 ms or longer. Decisions can be produced several times with an increasing amount of accumulated data. The period in which data is accumulated is called the test period.

Data accumulation

For each incoming sample, observe the combination in bits 2, 3 and 4. (Bit 1 is defined as the most significant bit. Bits 2, 3 and 4 are the segment number, as defined in Recommendation G.711.) Count the number of occurrences of each segment number throughout the test period. That is, obtain 8 numbers corresponding to the numbers of occurrences of each of the possible combinations.

Decision

1) Place the counters as illustrated in the μ-law column of Figure I-1/G.725. If there is a counter that contains a number greater than zero above a counter that contains zero, then the μ-law hypothesis is "improbable".

2) Place the counters as illustrated in the A-law column of Figure I-1/G.725 (the arrangement in the figure includes even-bit inversion, specified in Recommendation G.711). If there is a counter that contains a number greater than zero above a counter that contains zero, then the A-law hypothesis is "improbable".

3) If only one coding law hypothesis is probable, decide accordingly.

4) If neither coding law hypothesis is probable, the test period was too short. Obtain more data, then repeat the decision process.

5) If both coding laws are probable, then select a counter to represent each coding law according to the following:

   - If all 8 counters contain numbers greater than 0, then counter 000 represents μ-law, and counter 010 represents A-law.
   - If 4 counters contain numbers greater than 0, then counter 100 represents μ-law, and counter 110 represents A-law.

Compare the numbers in the two representative counters. Decide on the coding law represented by the counter containing the smaller number.

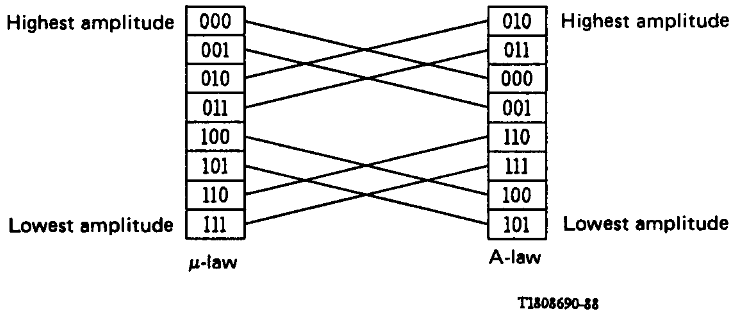

FIGURE I-1/G.725

Order of segments according to amplitude,
μ-law and A-law PCM

I.2 *Possible extensions and refinements*

The list below specifies some possible extensions to the algorithm. These extensions may be used to produce a result based on additional data. The exact way one might use this data is beyond the scope of this appendix.

i) It is possible to obtain separate count for positive and negative samples, i.e. take into consideration bit 1 (sign bit) of the samples.

ii) It is possible to define a threshold other than zero for consideration of a non-zero counter (i.e. consider all counters that contain numbers less than the threshold as if they contained zero). This extension may be useful in preventing spurious bit errors from affecting the decision.

iii) The decision criterion in step 5 of § I.1 is less robust than that of step 3. The following enhancements to steps 5 may be considered:

- In order to avoid an erroneous decision because of close valued numbers when the step 5 criterion is employed, it is possible to require that the difference between numbers in the two representative counters exceed a certain threshold. Alternatively (taking the above suggestion to the extreme), it is possible not to decide at all according to the step 5 criterion, and to discard the data if both coding laws produce allowed distributions.

- It is possible to represent each coding law with two counters, rather than one. In case of 8 non-zero counters, counter 001 (for A-law), in addition to the comparison given in the algorithm. In case of 4 non-zero counters, counter 101 (for μ-law) is compared against counter 111 (for A-law), in addition to the comparison given in the algorithm. It is also possible to use the sum of the two representative counters of each coding law in a comparison.

I.3 *Proposed use of the algorithm*

1) The algorithm should be used only by the originating terminal.

2) For the first 10 ms, use the default coding law (according to the zone), while accumulating data.

3) After 10 ms, use the accumulated data to make the first decision.

4) If the decision requires a mode switch, then switch the transmit and receive side to the propor law, If the capability exchange sequence is operation when the switch is required, switch the transmission without using the mode switching procedure. Otherwise, use the mode switching procedure.

5) Monitor the decision until framing is recovered, or for 200 ms after the beginning of reception of information from the distant terminal (in cases where there is no indication to that effect, start the 200 ms timer only after there is sufficient confidence that the arriving signal was originating by the distant terminal). If framing is not established by the expiration of the 200 ms timer, continue to use the coding law determined by the algorithm.