CCITT SGXV
Working Party XV/1
Specialists Group on Coding for Visual Telephony

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Subject: Status of 56 Kbps Transmission of 7 kHz Audio

Source: Bellcore

A draft American National Standard for Telecommunications titled "Digital Processing of Audio Signals -- Algorithm and Line Format for Transmission of 7 kHz Audio Signals at 64/56 kbit/s", T1Y1/88-050R2 has been prepared by the Accredited Standards Committee on Telecommunications, T1. It has been balloted at the T1 level, and no "No" votes were received. It is expected that the "abstain" with comment and the two "Yes" with comment ballots will be resolved at the next meeting in July '89. This will complete T1's work, and the draft will be forwarded to ANSI for final approval.

Sections 6, 7 and 8 of the draft deal with "Audio Coding for 56 kbit/s Channels", "Frame Structure for 56 kbit/s Signals", and "Signaling Procedures for 56 kbit/s Channels". These sections are attached for information, since a parallel approach may be used for videotelephony and videoteleconferencing.

It should be noted that no method for interworking between 56 and 64 kb/s terminals is specified. However, it is clear that the same physical terminal could implement both modes of operation. For example an ISDN terminal may work as a 64 kb/s terminal having octet timing over connections established as 7 kHz audio bearer service or 64 kb/s unrestricted bearer service, and it may work according to the 56 kb/s frame format with septet timing established by searching for H.221 in every bit position when working over connections established as 64 kb/s restricted bearer service and using 56 kb/s rate adaptation.

However, there is no requirement that 64 kb/s terminals operate by any other method than network supplied octet timing, so that they need not be burdened by the cost of H.221 search unless the manufacturer so chooses.

Furthermore, since the 56 kb/s terminals cannot transmit 7-bit PCM to the network with the assurance that it can be correctly placed in the primary rate frame structure, no interworking to PCM telephones is specified. The 56 kb/s terminals start out in G.722 instead.

terminal), then the terminal may use any PCM law. Else, the coding law determined by the statistical monitoring shall prevail throughout the call. A method for the monitoring of the statistics is provided in Appendix B.
In a teleconference call, the MCU is responsible for providing compatible connections.

6. Audio Coding for 56 kbit/s Channels

7 kHz Audio terminals operating at 56 kbit/s terminals are required to interwork only with other 7 kHz 56 kbit/s terminals, although support of both 56 and 64 kbit/s procedures by a single terminal is not precluded. The 56 kbit/s procedures are intended for use with terminals which may or may not synchronize to the 8 kHz network clock. While the procedures used to establish the digital connection between terminals are outside the scope of this standard, networks that use both 56 and 64 kbit/s facilities, or that provide for interconnection with networks operating at different rates, will require specific gateway arrangements or additional call establishment signaling.

6.1 7 kHz Audio Interfaces As specified in Section 3.1 for the 64 kbit/s terminal.

6.2 Audio Coding Techniques As specified in Section 3.2.1 for the 64 kbit/s terminal, except that the low sub-band is encoded using 4 or 5 bits/sample (6 bits/sample for the low-band information, as specified in Recommendation G.722 [1], is not allowed).

7. Frame Structure for 56 kbit/s Signals

The frame structure defined here follows the structure defined in CCITT Recommendation H.221 [2].

7.1 Basic Principle The 56 kbit/s channel is structured into septets transmitted at 8 kHz. The seventh bit of each septet conveys a sub-channel of 8 kbit/s, which has an identical structure to the Service Channel defined for the 64 kbit/s signal (see Figure 7). However, considering that some terminals using the 56 kbit/s procedures will not synchronize to the 8 kHz network clock (e.g., terminals connecting to V.35 interfaces), it is not always possible to define specific alignment of the septets within the network digital switch or carrier octets (see Section 8.5).

The remaining 48 kbit/s capacity, carried in bits 1-6 of each septet, may convey the audio and/or data signals, under the control of the BAS and possibly the AC.

Bit number

1	2	3	4	5	6	7	Septet
Sub-Channel #1	Sub-Channel #2	Sub-Channel #3	Sub-Channel #4	Sub-Channel #5	Sub-Channel #6	FAS	1 . 8
						BAS	9 . 16
						AC	17 80

FAS: Frame Alignment Signal
BAS: Bit rate Allocation Signal
AC: Application Channel

Figure 7
Frame structure of 56 kbit/s signals

7.2 Frame Alignment The frame alignment process is identical to that of a 64 kbit/s signal (Section 4.2).

7.3 Bit rate Allocation Signal (BAS) and Switching Between Configurations The Bit rate Allocation Signal (BAS) concept is identical to that of a 64 kbit/s signal (Section 4.3).

7.4 Application Channel (AC) The functionality of the application channel is identical to that of the application channel in a 64 kbit/s signal (Section 4.4).

7.5 Access to Data Within Bits 1 to 6 Bits 1 to 6 of each septet can be used for voice encoded according to CCITT Recommendation G.722 [1], or for data transmission. Other audio coding techniques are not allowed. The access to the data channels and rate adaptation may be realized according to standardized procedures. In some applications, it may be desirable to combine the Application Channel with the data channel in order to have a single user-data path.

Table 4
BAS code values affecting the audio coding mode of 56 kbit/s signals

BAS code	Septet format Bit position 1	2	3	4	5	6	7	Audio coding	Mode	Information rates Audio	Application channel	Data channel	Framed	Comments
00000110	H	H	L	L	L	L	L	G.722	2S	56	0	0	No	Note 1
00001000	H	H	L	L	L	L	S	G.722	3S	48	6.4	0	Yes	
00011000	H	H	L	L	L	L	S	G.722	3S	48	0	6.4	Yes	Note 2
00001111	D	D	D	D	D	D	S		-	-	6.4	48	Yes	
00011111	D	D	D	D	D	D	S		-	-	-	54.4	Yes	Note 2
00000111	D	D	D	D	D	D	D		-	-	-	56	No	

Note 1: Codes 000001xx imply switching to an unframed mode. Reverting to a framed mode in the receive direction can only be achieved by recovering frame alignment.
Note 2: The application channel is merged with the data channel to form a single data path.
Legend: P = PCM
S = Service channel
H = Higher sub-band
L = Lower sub-band
D = Data channel

Data is transmitted in the order received from the Data Terminal Equipment or Data Terminal Adaptor.

8. Signaling Procedures for 56 kbit/s Channels

The signaling procedures defined here follow the procedures of CCITT Recommendation G.725 [3].

8.1 Transmission Modes and Terminal Types

8.1.1 Transmission modes The following audio modes of operation are defined for 56 kbit/s terminals:

(1) Mode 2S: 56 kbit/s 7 kHz audio to Recommendation G.722 [1]

(2) Mode 3S: 48 kbit/s 7 kHz audio to Recommendation G.722 [1] + up to 6.4 kbit/s data.

For mode 3S, an additional 1.6 kbit/s capacity is reserved for framing and mode control, as defined in Section 5.

Additional data modes may be defined.

8.1.2 Terminal types Two types of terminals are defined, according to their modes of operations:

(1) Type 1S: a 7 kHz audio terminal capable of working in Mode 2S only, with no framing or framing detection capabilities.

(2) Type 2S: a member of a family of 7 kHz audio/data terminals capable of working at least in Mode 2S and 3S. Further modes may also be implemented. The terminal is capable of framing according to the frame structure defined in Section 7. Dynamic mode switching between different modes, as defined in Section 8.4, shall be provided.

In order to establish a mode of operation with the highest possible performance, terminals of Type 2S shall be able to identify the terminal type at the far end.

8.1.3 Establishment of compatible modes of operation At the beginning of the communication phase of a call, all terminals begin to transmit and receive in Mode 2S. Terminals of Type 2S will then begin an initialization procedure, identical to the initialization procedure defined for 64 kbit/s terminals.

The terminals connected to a call may not change during the call.

Table 4 gives the coding of the BAS for the attribute 000 (audio coding) as applicable to Type 2S 56 kbit/s terminals to Recommendation G.722 [1]. Note that the same codes as for 64 kbit/s terminals are used here, but they have a slightly different meaning. As in 64 kbit/s, the BAS attribute 100 (capability) is intended to be used for signaling terminal capabilities to the distant terminal.

The coding of the BAS for the capability attribute 100 is shown in Table 5.

The A-bit is used for signaling frame alignment, as in 64 kbit/s transmission.

8.2 Basic Sequences for In-channel Procedures

The signaling sequences are identical to those of 64 kbit/s transmission.

Table 5
BAS code values identifying terminal capability of 56 kbit/s terminals

BAS code	Audio coding capability	Comments
10000000	neutral	no change of audio capability
10000100	Type 2S	

8.3 Initialization It is the user's responsibility to ensure that 7 kHz Audio terminals using 56 kbit/s procedures are only connected to other terminals using the same procedures. This document does not specify a way for 56 kbit/s 7 kHz Audio terminals to communicate with 64 kbit/s 7 kHz Audio terminals or with PCM terminals.

At the beginning of the call the initialization procedure ensures that the two connected terminals operate in the most suitable common mode.

8.3.1 Mode initialization procedure The mode initialization procedure ensures that both terminals have been informed of the capabilities of the other terminals, and switched to the highest common audio mode, in both directions of transmission. In case of two Type 2S terminals, both directions of transmission will be in either Mode 2S or Mode 3S, 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.

At the beginning of the mode initialization, a Type 2S terminal starts transmitting in Mode 2S, while initiating the capability exchange sequence (Section 5.2.2). The receive part is in frame and septet alignment search and the receive audio in Mode 2S. If the capability exchange sequence has terminated successfully, which means that the distant terminal was also a Type 2S terminal, then the mode switching sequence (Section 5.2.1) 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 (i.e., if the distant terminal is also a Type 2S terminal, then the initialization procedure is identical to that of 64 kbit/s terminals).

Terminals of Type 1S will start in mode 2S since it is the only mode they are capable of transmitting and receiving. If the distant terminal is also a Type 1S terminal, then there is no need for an initialization process, since the terminals will remain in Mode 2S throughout the call.

If the two terminals at the two ends of a call are of different types, then the Type 2S terminal will start the initialization procedure with the capability exchange sequence. Since the Type 1S terminal will not transmit any framing, the capability exchange sequence will fail. The Type 2S terminal shall then omit the framing from its transmitted signal. The call will remain in Mode 2S.

8.4 Dynamic Mode Switching Procedure for Type 2S Terminals The dynamic mode switching procedures are identical to those described for 64 kbit/s terminals.

8.5 Procedures to Recover Septet Timing From Incoming Signal 7 kHz Audio terminals that are designed to interwork with other terminals that use the 56 kbit/s procedures but that do not synchronize with the 8 kHz network clock must be able to recover septet timing in the receive direction from bit timing and from the incoming signal properties. The 8 kHz clock can be derived from the bit clock.

The procedures defined here may also apply to 64 kbit/s terminals in cases where the network does not provide octet timing.

The septet timing in the transmit direction may be derived from the network bit timing and an internal septet timing.

All terminals should employ the method defined here in Section 8.5.1, or an equivalent method, not requiring a framing signal. Type 2S terminals may additionally employ the method specified in Section 8.5.2 (see Appendix C for reasoning).

8.5.1 A Method to Recover Septet Alignment from 7 kHz Audio Digital Signals This method enables the terminal to obtain the proper alignment from the statistical properties of the 7 kHz digital audio signal. This scheme does not require the existence of framing on the receive path. The technique can be employed throughout the call, to continuously monitor and guard against loss of septet alignment.

The properties of the possible combinations in bits 3, 4, 5, and 6 of the septet (the four most significant bits of the low-band) can be used in order to select the correct alignment. Examples of properties which are unique to the correct alignment are:

(1) With an error free transmission, the combination 0000 should never appear.

(2) The pattern of the distribution is that it is usually monotonically increasing (i.e., the number of occurrences of the binary combination representing the number n is greater than that of the combination representing the number n-1), except for a large drop between the values in 7 (0111) and 8 (1000).

These two properties are used in the method described below. However, since the method does not require any special action on the part of the transmitter (e.g., framing), other properties may also be used.

8.5.1.1 General Rule The receive septet timing is normally determined from the properties of the digital signal. But at the start of the call and before the frame alignment is gained, the receive septet timing may be taken to be the same as the internal transmit septet timing.

As soon as septet alignment is gained, the receive septet timing is initialized at the new bit position. The alignment procedure is repeated every half second. In order to change alignment that was previously gained, the new alignment has to be detected two consecutive times.

The following procedure shall be used:

(1) For each of the possible 7 alignments, the combination in bits 3,4,5,6 (4 most significant bits of the low-band) is observed. For each of the 7 alignments and for each (or a subset) of the 16 possible combinations there is a counter (at least there should be counters for the combinations 0000, 0011, 0100, 0111, 1000, 1011, and 1100). The counter that corresponds to the observed combination of the checked alignment is incremented. The process is continued for 500 ms.

(2) The properties of the 7 counter sets are compared.

- An alignment that contains a value that is greater than 10 in the 0000 counter is eliminated as a candidate alignment.
- An alignment where the value in the 0011 counter is greater than the value in the 0100 counter is eliminated as a candidate alignment.
- An alignment where the value in the 1011 counter is greater than the value in the 1100 counter is eliminated as a candidate alignment.
- An alignment where the value in the 0111 counter is less than the value in the 1000 counter is eliminated as a candidate alignment.

(3) If the number of remaining candidate alignments is exactly one, this alignment is selected as the correct alignment. Else, the result is discarded.

8.5.2 Procedure to Recover Septet Timing From Frame Alignment - Type 2S Terminals

8.5.2.1 General Rule The receive septet timing is normally determined from the FAS position. But at the start of the call and before the frame alignment is gained, the receive septet timing may be taken to be the same as the internal transmit septet timing or gained by using another alignment method.

A Type 2S terminal must stay in a framed mode until the septet timing is recovered (using the procedure below), and the A bit in the receive direction is 0.

As soon as a first frame alignment is gained, the receive septet timing is initialized at the new bit position, but it is not yet validated. It will be validated only when frame alignment is not lost during the 16 next frames. Therefore, the A bit in the transmit direction is not set to 0 before the validation of the septet alignment.

8.5.2.2 Particular Cases

(1) When, at the initiation of a call, the terminal is in a forced reception mode, or when the frame alignment has not yet been gained, the terminal may temporarily use the transmit septet timing (assuming that there is no other alignment information available).

(2) When frame alignment is lost after being gained, the receive septet timing should not change until frame alignment is recovered.

(3) As soon as frame and multiframe alignment have been gained once, the septet timing is considered as valid for the rest of the call, unless frame alignment is lost and a new frame alignment is gained at another bit position.

(4) When the terminal switches from a framed mode to an unframed mode (by means of the BAS), the septet timing, previously gained, must be kept, or monitored using the technique specified in Section 8.5.2.. However, if for any reason the septet alignment is lost, and the terminal idéntifies that, the terminal can recover by reinstituting framing and employing the capability exchange sequence.

(5) When a new frame alignment is gained on a new position, different from that previously validated, the receive septet timing is reinitialized to the new position but not yet validated and the previous bit position is stored. If no loss of frame alignment occurs in the next 16 frames, the new position is validated; otherwise the stored old bit position is reutilized.

(6) Whenever valid frame alignment is not available, the receive volume must be limited to avoid objectionable levels of noise.