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**3GPP2 A.S0004-B v2.0**

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## **CDMA Tandem Free Operation**

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**(Post SDO Ballot, Pre SDO Publication Version)**

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August 05, 2002

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## 1 **Foreword**

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2 This standard is derived from TDMA/CDMA TFO standard [4.] which in turn is based on [9.]. This is CDMA  
3 Tandem Free Operation (TFO) standard version 2.0. It is modified to support the Selectable Mode Vocoder (SMV)  
4 [5.] and codec mismatch resolution and optimization.

5 The present document introduces the Inband Signaling (IS) protocol between Transcoder/Rate Adapter Units for  
6 speech traffic channels for the Tandem Free Operation (TFO) of speech codecs within the digital cellular tele-  
7 communications system.

8 The contents of this document are subject to continuing work and may change following the appropriate standard  
9 procedures.

10

## 1 Introduction

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This service description document details the Inband Signaling (IS) protocol between Transcoder/Rate Adapter Units (TRAUs) for speech traffic channels for the Tandem Free Operation (TFO) of speech codecs, sometimes also termed "Vocoder Bypass". It is applied to the cdma2000 standards.

Annex A is mandatory and defines the capability and requirements used in the development of this TFO standard.

Annex B is mandatory and describes the general IS protocol, which is applicable to TFO specifications for all systems (e.g., TDMA, cdma2000, GSM and UMTS)

Annex C is informative and gives the rules for In Path Equipment (IPE). It is identical for all systems (e.g., TDMA, cdma2000, GSM and UMTS).

## 2 Documentation Conventions

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"Shall" and "shall not" identify requirements to be followed strictly to conform to the standard and from which no deviation is permitted. "Should" and "should not" indicate that one of several possibilities is recommended as particularly suitable, without mentioning or excluding others; that a certain course of action is preferred but not necessarily required; or (in the negative form) that a certain possibility or course of action is discouraged but not prohibited. "May" and "need not" indicate a course of action permissible within the limits of the standard. "Can" and "cannot" are used for statements of possibility and capability, whether material, physical, or causal.

## 3 References

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The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

### 3.1 TIA / EIA

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For ease of cross referencing, the Telecommunications Industry Association (TIA) / Electronics Industry Association (EIA) references provided this section are aligned with the 3GPP2 references, provided in section 3.2.

- [1.] TIA/EIA-96C, *Speech Service Option Standard for Wideband Spread Spectrum System*", 1998.
- [2.] TIA/EIA/IS-127-1, *Enhanced Variable Rate Codec, Speech Service Option 3 for Wideband Spread Spectrum Digital Systems*, 1998.
- [3.] TIA/EIA/IS-733-1, *High Rate Speech Service Option 17 for Wideband Spread Spectrum Communication Systems*, 1999.
- [4.] TIA/EIA-829, *Interoperability Specification for Tandem Free Operation*, June 2000.
- [5.] TIA/EIA/IS-893 *Selectable Mode Vocoder Service Option for Wideband Spread Spectrum Communication Systems*, in ballot, 2002.
- [6.] cdma2000 Standards for Spread Spectrum Systems Release B:
  - TIA/EIA/IS-2000.1-B, *Introduction to cdma2000 Standards for Spread Spectrum Systems*, May 2002.
  - TIA/EIA/IS-2000.2-B, *Physical Layer Standard for cdma2000 Spread Spectrum Systems*, May 2002.
  - TIA/EIA/IS-2000.3-B, *Medium Access Control (MAC) Standard for cdma2000 Spread Spectrum Systems*, May 2002.
  - TIA/EIA/IS-2000.4-B, *Signaling Link Access Control (LAC) Standard for cdma2000 Spread Spectrum Systems*, May 2002.
  - TIA/EIA/IS-2000.5-B, *Upper Layer (Layer 3) Signaling Standard for cdma2000 Spread Spectrum Systems*, May 2002.
  - TIA/EIA/IS-2000.6-B, *Analog Signaling Standard for cdma2000 Spread Spectrum Systems*, May 2002.

1 [7.] TIA/EIA-2001.4-B, *Interoperability Specification (IOS) for cdma2000 Access Network Interfaces – Part*  
2 *4 (A1, A2, and A5 Interfaces)*, May 2002.

## 3 3.2 3GPP2

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5 The 3GPP2 references are aligned with the TIA/EIA references of section 3.1 and are provided here for informat-  
6 ion and cross reference purposes.

7 [1.] 3GPP2 C.S0009-0, *Speech Service Option Standard for Wideband Spread Spectrum Systems*, December  
8 1999.

9 [2.] 3GPP2 C.S0014-0-1, *Enhanced Variable Rate Codec, Speech Service Option 3 for Wideband Spread*  
10 *Spectrum Systems - Addendum 1*, December 1999.

11 [3.] 3GPP2 C.S0020-0-1, *High Rate Speech Service Option 17 for Wideband Spread Spectrum Communicat-*  
12 *ions Systems Addendum 1*, December 1999.

13 [4.] 3GPP2 A.S0004-0.1, *3GPP2 Tandem Free Operation Specification Release A*, August 2000.

14 [5.] 3GPP2 C.S0030-0 v2.0, *Selectable Mode Vocoder Service Option for Wideband Spread Spectrum*  
15 *Communication Systems*, December 2001.

16 [6.] cdma2000 Standards for Spread Spectrum Systems Release B:

17 3GPP2 C.S0001-B, *Introduction to cdma2000 Standards for Spread Spectrum Systems*, May 2002.

18 3GPP2 C.S0002-B, *Physical Layer Standard for cdma2000 Spread Spectrum Systems*, May 2002.

19 3GPP2 C.S0003-B, *Medium Access Control (MAC) Standard for cdma2000 Spread Spectrum Systems*,  
20 May 2002.

21 3GPP2 C.S0004-B, *Signaling Link Access Control (LAC) Standard for cdma2000 Spread Spectrum Sys-*  
22 *tems*, May 2002.

23 3GPP2 C.S0005-B, *Upper Layer (Layer 3) Signaling Standard for cdma2000 Spread Spectrum Systems*,  
24 May 2002.

25 3GPP2 C.S0006-B, *Analog Signaling Standard for cdma2000 Spread Spectrum Systems*, May 2002.

26 [7.] 3GPP2 A.S0014-0, *Interoperability Specification (IOS) for cdma2000 Access Network Interfaces – Part 4*  
27 *(A1, A2, and A5 Interfaces)*, May 2002.

## 28 3.3 Other

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29 [8.] 3GPP TS 28.062: *In-band Tandem Free Operation (TFO) of Speech Codecs*; Version 4.2.0

30 [9.] GSM 08.62: *Digital cellular telecommunication system (Phase 2+); Inband Tandem Free Operation*  
31 *(TFO) of Speech Codecs*; Version 7.0.0.

## 4 Terminology

### 4.1 Definitions

---

For the purposes of the present document, the following definitions apply.

**2G** is a 2<sup>nd</sup> generation wireless systems.

**3G** is a 3<sup>rd</sup> generation wireless systems.

**Decoder** provides reconstruction of a speech signal from a compressed format according to an appropriate algorithm.

**Encoder** provides compression of a speech signal into a new format for bandwidth efficiency according to an appropriate algorithm.

**Mobile** is a standalone unit communicating with the BTS over an air interface in a digital wireless communication system. In this document it is interpreted as a mobile station or a fixed wireless terminal.

**Transcoder** is a unit for housing the encoder and the decoder required for digital wireless transmission.

**TRAU frame** is used equivalent to "TRAU speech frame". TRAU frames are transmitted between TRAU and TRX.

**TFO frame** is used equivalent to "TFO TRAU frame". TFO frames are transmitted between TFO Partners (e.g. TRAU).

**TTL** is used to denote the link between the TRAU and the TRX, independent of the system.

**Error Concealment Indicator (ECI)** is used to signal that a TFO frame does not contain valid speech parameters.

**PSTN** interface is used to denominate the 64 kbps PCM link from/to the TRAU. Note that PSTN interface does not necessarily mean a connection to a PSTN, but is a general description for a digital 64 kbps PCM line.

### 4.2 Acronyms

---

For the purposes of the present document, the following acronyms apply.

BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver System
CDMA	Code Division Multiple Access
CRC	Cyclic Redundancy Check
DS0	Digital Signal Level 0
DTMF	Dual Tone MultiFrequency
ECI	Error Concealment Indicator
EVRC	Enhanced Variable Rate Codec [2.]
GSM	Global System for Mobile Communication
HHO	Hard Handoff
IPE	In Path Equipment
LPC	Linear Predictive Codec
LSB	Least Significant Bit
MS	Mobile Station
MSC	Mobile Switching Center
PCM	Pulse Coded Modulation

PCM sample	8-bit value representing the A_Law or $\mu$ _Law coded sample of a speech or audio signal; sometimes used to indicate the time interval between two PCM samples (125 $\mu$ s).
PCM_Silence	either PCM_Alaw_Silence, or PCM_ $\mu$ Law_Silence, dependent on application
PSTN	Public Switched Telephone Network
Q8	Speech Codec Service Option 1 for TIA/EIA/IS-2000-A at 8 kbps [1.]
Q13	Speech Codec Service Option 17 for TIA/EIA/IS-2000-A at 13.3 kbps [3.]
SDU	Selection/Distribution Unit
SMV	Selectable Mode Vocoder Speech Service Option 56 [5.]
TCME	TFO Circuit Multiplication Equipment
TDMA	Time Division Multiple Access
TFO_ACK	TFO Acknowledgement message
T_Bits	Time Alignment bits
TFO	Tandem Free Operation
TFO_FILL	TFO Fill message
TFO_TRANS	TFO Transparent Mode message
TFO_NORMAL	TFO Normal Mode message
TFO_DUP	TFO (Half) Duplex Mode message
TFO_REQ	TFO Request message
TFO_SYL	TFO Sync Lost message
TRAU	Transcoder and Rate Adapter Unit - this unit performs speech encoding and decoding on the network side of the communications system according to the codec standard selected
TRX	Radio transceiver station
TTL	TRAU-TRX-Link
UMTS	Universal Mobile Telecommunications System
VoIP	Voice over IP

1

2

## 5 General Approach

3

### 5.1 Background

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In the case of mobile-to-mobile (MS-MS) calls in networks without TFO, the speech signal is encoded within the first MS for transmission on the air interface, and decoded within the associated first TRAU. The PCM samples are then transported within the fixed part of the network to the second TRAU using 64 kbps traffic links. This second TRAU encodes the speech signal a second time for the transmission on the second air interface, and the associated second mobile station decodes it again. The two codecs (encoder-decoder pair) of the connection are in "Tandem Operation".

10

**Tandem Free Operation overcomes** the disadvantage of degraded speech quality caused by the two consecutive encoding/decoding processes required in Tandem Operation.

11

12

**Tandem Free Operation does not necessarily** decrease processing delay. PCM is still sent, synchronized to the coded speech, e.g. for easy TFO in/out.

13

1 **Tandem Free Operation** requires a bi-directional "transparent" digital channel or path between the TRAU.  
2 Devices within these paths need to be transparent or switched off for the **TFO messages** and the **TFO frames**. To  
3 guarantee this digital transparency with **out-of-band signaling** is not trivial. In particular, out-of-band signaling  
4 has insufficient speed to fall back to normal operation in case of sudden interruption of the transparency of the  
5 links.

6 This TFO recommendation defines therefore an **inband signaling protocol**, which

- 7 • **tests** if:
  - 8 - an MS-MS call is given;
  - 9 - the paths between the TRAU are digitally transparent;
  - 10 - both TRAU support TFO;
  - 11 - the speech codecs on both radio legs are identical.
- 12 • **establishes** the TFO connection by:
  - 13 - commanding the paths to go transparent;
  - 14 - bypassing the decoder/encoder functions within the TRAU.
- 15 • **provides** a fast fall back procedure for sudden TFO interruption.

16  
17 Although Tandem Free Operation only requires changes to the TRAU, network IPEs may also need to be modified  
18 to be compliant with TFO.

## 19 5.2 Principle of Tandem Free Operation

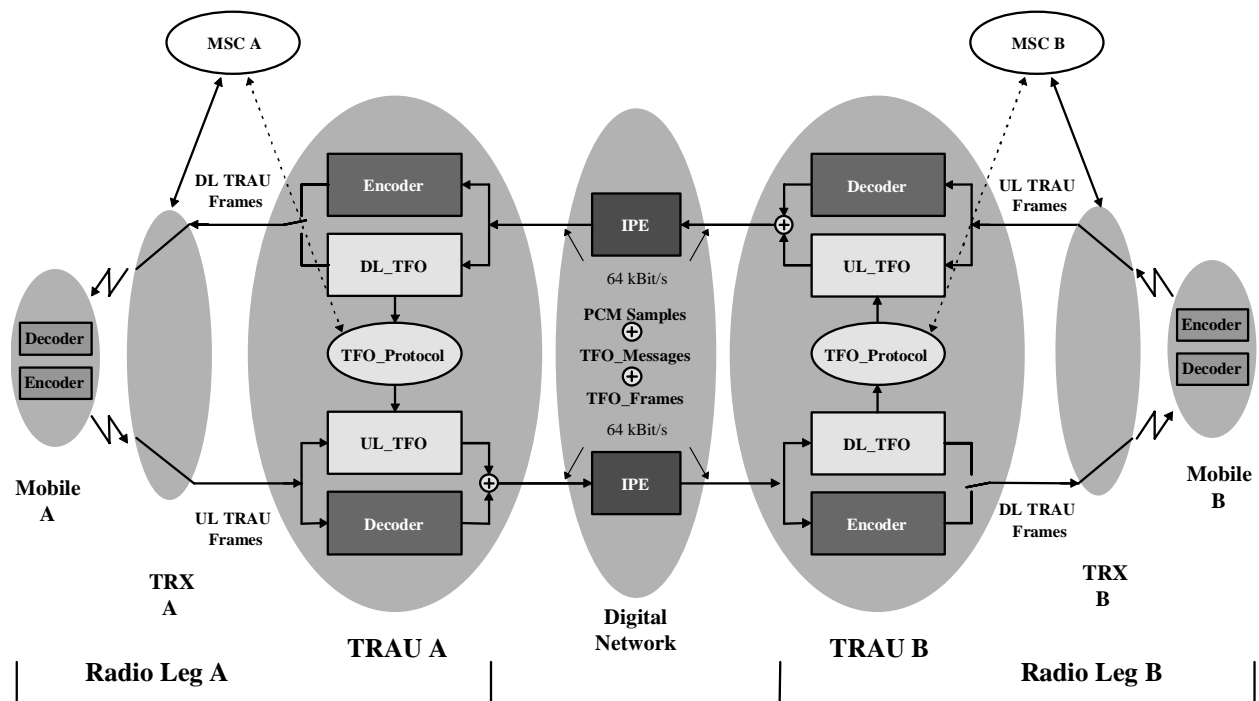
---

20 The TRAU shall be controlled by the MSC when it is positioned remote from the MSC. In this case, the  
21 speech/data information and TRAU control signals shall be transferred between the MSC and the TRAU in frames  
22 denoted "TRAU frames", not specified in this standard.

23 In Tandem Free Operation similar frames, denoted "**TFO frames**", are transferred between the two TRAU on the  
24 **PSTN-interface** (decoded speech at 64 kbps) by inband signaling, i.e. inserting them into the PCM sample bit  
25 stream.

26 TFO frames have a fixed size (and length) of 320 bits (20 ms) and are carried by 16 kbps traffic channels mapped  
27 onto the two least significant bits of the PCM samples.

28 Prior and parallel to these TFO frames other **TFO messages** are also transferred on the PSTN interface. TFO  
29 messages conform to the IS message protocols described in Annex B and Annex C. The TFO protocol between the  
30 TRAU is independent of the position of the TRAU within the mobile networks. A possible configuration of two  
31 TRAU is shown in Figure 5.2-1, which is intended as a reference model.



**Figure 5.2-1 Functional Entities for Handling of Tandem Free Operation in MS-MS Calls**

TFO provides for transparent transmission of speech data from the Encoder of Mobile A to the Decoder of Mobile B and vice versa.

### 5.3 CDMA TFO Version Identification

Each release of the CDMA TFO standard specification is uniquely identified with a version number. The version number serves as a universal identification of the capabilities and limitations of the local and remote TFO implementations in a mobile-to-mobile call. It facilitates proper TFO operations between the two parties. Features introduced in various TFO standard updates can then be appropriately supported or skipped to ensure proper TFO operations. The text below lists the assumptions and requirements of the CDMA TFO version number.

- CDMA TFO specification version number is uniquely and universally defined and updated for each new release. It is defined independently of the standard document number selected by individual CDMA standard body.
- CDMA TFO version identification is for information only and does not require any message responses from the remote TFO Partner.
- TFO operation after any TFO interruptions such as handoffs and conference calls shall be re-established through the normal negotiation process. TFO version information communication between the local and remote parties is ensured.
- This information is optional for TFO implementations of [4.] or its equivalence. This information is mandatory for all TFO implementations of new CDMA TFO standard releases replacing [4.] or its equivalence. TFO implementations carrying no TFO version information are assumed to be implementations of [4.] or its equivalence.
- When the local and remote parties have implementations based on different versions of TFO specifications, TFO specification of the earlier version is assumed.

TFO version identification is carried by version extension blocks, which shall be transmitted on successful TFO negotiation and establishment. This is required to avoid additional negotiation delay and to avoid unnecessary information transmission to a TFO incompatible or non-TFO capable far end, e.g. in a mobile to land call. Specifically, the information shall be carried by the version extension blocks of the TFO\_IPE messages transmitted immediately before and during transmission of the first TFO frame.

1 TFO\_IPE messages with version extension blocks are also optionally transmitted as embedded messages after TFO  
2 establishment on a periodic basis. The exact period could potentially be affected by other higher priority embedded  
3 message transmissions during TFO operation and is defined at the vendors' discretion.

4 "0.0.0 0.0.0" TFO implementation based on [4].

5 "0.0.1 0.0.0" TFO implementation based on a previous revision of this standard.

6 "0.1.0 0.0.0" TFO implementation based on this revision of the standard.

7 Annex B details the version extension block structure.

8

## 6 TFO Frame Structure

### 6.1 TFO Frame Structure for 16 kbps Sub-Multiplexing

This section defines TFO frame structures for various CDMA speech codecs. These definitions include structures for Q8[1.], EVRC [2.], SMV [5.] and Q13 [3.].

#### 6.1.1 Requirements/Assumptions for TFO Frame Structure Definitions

This section lists a set of requirements and assumptions used to define the TFO frame structures for different speech codecs.

- The two TRAUs in a tandem call are inter-connected by a 64 kbps link with an 8000 Hz sampling frequency.
- TFO frame information is placed into the two least significant bits of each 8-bit octet (PCM sample) of the 64 kbps link between the local and remote TRAU units. The remaining 6 bits of each octet are filled with the corresponding decoded PCM bits.
- A TFO frame covers 160 8-bit octets and spans a period of 20 ms.
- The least significant bit (LSB) of every other 16<sup>th</sup> PCM octet is used for embedded TFO message bits.
- Eight bits are allocated for system identification. This 8-bit information is also used as a TFO frame identifier.
- Synchronization bits are defined in TFO frames to ensure TFO synchronization capability. These bits consist of 19 “1”s and eight “0”s in predefined TFO frame positions. This synchronization pattern is compatible to [9.].
- Each set of traffic data in a TFO frame is marked with a 4-bit speech codec type field. It is used to confirm the codec type in systems where codec change during TFO is allowed.
- Each set of traffic data within a TFO frame is protected by Cyclic Redundancy Checks (CRC) against data corruption during transmission over the inter-base station link(s).
- One bit is reserved to denote the presence or absence of TFO embedded IS messages. Refer to section 6.1.2.3.
- Time Alignment bits are allocated for potential phase adjustment after TFO establishment.
- All unused bit positions in a TFO frame structure are undefined and are not to be used for frame synchronization. They are marked as “Reserved”.

#### 6.1.2 Coding of TFO Frames for 16 kbps Sub-Multiplexing

This section presents general information applicable to some of the fields in a TFO frame structure. Refer to section 6.1.3 for details on the TFO frame structure definition information for each individual codec.

##### 6.1.2.1 Coding of System Identification Bits (S1...S8)

The eight bits S1...S8 are used for system identification. They identify the sending system of the TFO\_Frames.

**Table 6.1.2.1-1 System Identification Assignment**

S1...S8	System
0000.0000	GSM (for information, refer to [9.])
0000.0001	TDMA
0000.0010	CDMA
0000.0011	Reserved (for information, refer to [8.])
0000.0100	UMTS (for information, refer to [8.])
All others	Reserved

**Note:** Coding of these identification bits is the same as coding of system identification in TFO\_REQ messages and TFO\_ACK messages. Refer to Annex B and section 7.

### 6.1.2.2 Coding of Speech Codec Type (C1...C4)

A 4-bit field is used to identify the codec type in the TFO frame design. TFO frames for different systems may have the same codec type. This field, together with the 8-bit system identifier, uniquely identifies the system and codec types characterizing the TFO frame sending party.

**Table 6.1.2.2-1 Speech Codec Type Assignment**

S1...S8	System	C1...C4
0000.0000	GSM	For information, refer to [9.]
0000.0001	TDMA	For information, refer to [4.]
0000.0010	CDMA	0000 (Q8, [1.])
		0001 (EVRC, [2.])
		0010 (Q13, [3.])
		0011 (SMV, [5.])
		All others (12) reserved
0000.0100	UMTS	For information, refer to [8.]

### 6.1.2.3 Embedded TFO Message Indicator Bit (C5)

This bit is set to zero ("0") if the TFO frame has no embedded IS message. It is set ("1") to denote the presence of an embedded IS message in the TFO frame.

### 6.1.2.4 Packet Type Information for CDMA Variable Rate Codecs (D1...D9)

Variable bit rate speech packet decoding in CDMA requires information on the packet encoding rate and the packet status. For Q8, EVRC, SMV or Q13, the information is represented by a 3-bit field attached to each packet received from the BTS. During CDMA TFO operation, proper handling of the encoded packet received by the local BSC from the remote TFO Partner requires successful transmission of the 3-bit packet type information for each encoded packet. The information is used to determine if frame erasure recovery is necessary and to ensure proper processing by the local BSC and BTS for downlink transmission to the local mobile user.

A 9-bit field, D1 to D9, is defined to provide error detection and correction capability for the 3-bit packet type information transmission. Table 6.1.2.4-1 lists the 9-bit non-linear block codes.

**Table 6.1.2.4-1 Block Codes for CDMA Variable Rate Codec Packet Type Coding**

Code index	D1...D9
0	0.0000.0000
1	0.0001.1111
2	0.1111.1000
3	1.0110.0110
4	1.1101.0101
5	1.1010.1011
6	1.1000.1100
7	0.0111.0011

Table 6.1.2.4-2, Table 6.1.2.4-3, Table 6.1.2.4-4 and Table 6.1.2.4-5 present a set of mappings of the Q8, EVRC, SMV and Q13 packet type information to the code words. During a TFO frame design, each 3-bit packet type is mapped by the Tx\_TFO to a 9-bit code, except for Q13 Rate 1 packets. When a TFO frame is received by the Rx\_TFO, the reverse mapping is performed to retrieve the packet type information. Additional packet type information is indirectly provided by other rate specific bit fields such as CRC bits. Information in these fields could be used in the packet type identification process.

When only the first six code words from Table 6.1.2.4-1 are used, double error correction capability is provided. For EVRC, a blank frame and a Rate  $\frac{1}{8}$  frame with all bits set to "1" are easily identified and validated with the data content. They are mapped to the last two code words, which have slightly less protection capability. Similarly, the blank frame packet type for Q8 is also mapped to the 6<sup>th</sup> code word.

**Table 6.1.2.4-2 Q8 Packet Type Information to 9-bit Code Word Mapping.**

For more information on Q8 packet type information, refer to [1.]

Q8 packet type	Code index	D1 ... D9
Rate 1	0	0.0000.0000
Rate 1/2	1	0.0001.1111
Rate 1/4	2	0.1111.1000
Rate 1/8	3	1.0110.0110
Blank	6	1.1000.1100
Rate 1 with bit errors	4	1.1101.0101
Insufficient frame quality (erasure)	5	1.1010.1011

**Table 6.1.2.4-3 EVRC Packet Type Information to 9-bit Code Word Mapping.**

For more information on EVRC packet type information, refer to [2.]

EVRC packet type	Code index	D1 ... D9
Rate 1	0	0.0000.0000
Rate 1/2	1	0.0001.1111
Rate 1/4	2	0.1111.1000
Rate 1/8	3	1.0110.0110
Blank	6	1.1000.1100
Rate 1 with bit errors	4	1.1101.0101
Insufficient frame quality (erasure)	5	1.1010.1011
Rate 1/8 with all bits set to '1'	7	0.0111.0011

**Table 6.1.2.4-4 SMV Packet Type Information to 9-bit Code Word Mapping.**

For more information on SMV packet type information, refer to [5.].

SMV packet type	Code index	D1 ... D9
Rate 1	0	0.0000.0000
Rate 1/2	1	0.0001.1111
Rate 1/4	2	0.1111.1000
Rate 1/8	3	1.0110.0110
Blank	6	1.1000.1100
Rate 1 with bit errors	4	1.1101.0101
Insufficient frame quality (erasure)	5	1.1010.1011
Rate 1/8 with all bits set to '1'	7	0.0111.0011

**Table 6.1.2.4-5 Q13 Packet Type Information to 9-bit Code Word Mapping.**

For more information on Q13 packet type information, refer to [3.].

Q13 packet type	Code index	D1 ... D9
Rate 1*	0	0,000
Blank	1	0,0001,1111
Rate 1/4	2	0,1111,1000
Rate 1/8	3	1,0110,0110
Rate 1/2	4	1,1101,0101
Insufficient frame quality (erasure)	5	1,1010,1011

\* Rate 1 uses only a 4-bit code (D1 ... D4).

## 6.1.2.5 Coding of Time Alignment Bits (T1...T4)

**Table 6.1.2.5-1 Coding of Time Alignment Bits**

T1...T4	Notes
1111	Bits positioned at the end of a TFO frame. No other codes allowed.

If the timing of the frame is to be advanced by 250  $\mu$ s, then these four bits (T1...T4) are not transferred in order to reduce the length of the frame accordingly. If the timing is to be advanced by 125  $\mu$ s, then T3 and T4 are not transferred. If the timing of the frame is to be delayed by 125  $\mu$ s (or a multiple of it), then another pair of T-Bits (1-bits) is transferred (or a multiple of it), in order to increase the length of the frame accordingly.

Timing for [3.] can only be advanced by 125  $\mu$ s, as only two T-Bits (T1, T2) are available.

## 6.1.2.6 Coding of Data Bits for Q8, EVRC and SMV (D-Bits)

Each set of traffic data in a TFO frame is partitioned at the subframe boundaries. Each partitioned sub-set is protected by 3 parity bits at the end of the sub-set. The order within a given subset is the same as presented in section 6.1.3. These parity bits are added to the bits of the subset, according to a degenerate (shortened) cyclic code using the generator polynomial:

$$g(D) = D^3 + D + 1$$

The encoding of the cyclic code is performed in a systematic form, which means that, in  $GF(2)$ , the polynomial:

$$d(m)D^n + d(m+1)D^{n-1} + \dots + d(m+n-3)D^3 + p(0)D^2 + p(1)D + p(2)$$

where  $p(0)$ ,  $p(1)$ ,  $p(2)$  are the parity bits, when divided by  $g(D)$ , yields a remainder equal to:

$$1 + D + D^2$$

and where  $d(m)$  corresponds to a lower order D bit, e.g. D1, and  $d(m+n-3)$  corresponds to a higher order D bit, e.g. D29. For every CRC, the transmission order is  $p(0)$  first followed by  $p(1)$  and  $p(2)$  successively.

## 6.1.2.7 Coding of Data Bits for Q13 (D-Bits)

Each set of traffic data in a Q13 TFO frame is protected by 7 parity bits at the end of the set. The order within a given set is the same as presented in section 6.1.3.

The CRC generator polynomial  $g(X)$  is defined as:

$$g(X) = 1 + X + X^2 + X^4 + X^5 + X^7$$

The input polynomial  $a(X)$  consists of the N data bits to be protected, where  $d(1)$  is the lower order D bit, e.g. D10 and  $d(N)$  is the higher order D bit, e.g. D25.

$$a(X) = d(1)X^{N-1} + d(2)X^{N-2} + \dots + d(N-1)X + d(N)X^0$$

The parity polynomial  $b(X)$  is the remainder of the division of the input polynomial and the generator polynomial, i.e.

$$\frac{a(X)X^7}{g(X)} = q(X) + \frac{b(X)}{g(X)}$$

$$b(X) = C(1)X^6 + C(2)X^5 + C(3)X^4 + C(4)X^3 + C(5)X^2 + C(6)X + C(7)X^0$$

1 The CRC bits are written into the TFO frame in ascending order, i.e.  $C(1)$  is first and  $C(7)$  is last. The quotient  
2 polynomial  $q(X)$  is discarded.

### 3 6.1.2.8 Rate Reduction Parameters for CDMA Variable Rate Codecs

4 The TFO frame structures for CDMA variable rate codecs Q8, EVRC, SMV and Q13 typically contain the local  
5 system downlink and uplink rate reduction parameters. Upon receiving a remote downlink rate reduction  
6 parameter from the remote TFO Partner for CDMA variable rate coding, the local system may command the local  
7 mobile station to perform speech encoding for local uplink transmission at the matching rate reduction mode. This  
8 measure avoids unnecessary rate conversions by the remote TFO Partner and thus avoids any possible artifacts  
9 associated with the rate conversion process in the remote mobile.

10 Uplink rate reduction parameter is transmitted to the remote TFO Partner for information only.

### 11 6.1.2.9 Dim-And-Burst with CDMA Variable Rate Codecs

12 The Dim-And-Burst feature of [6.] requires the TRAU to lower the coding rate upon request. During TFO,  
13 however, the coding rate is not determined by the local TRAU itself, but by the remote mobile. For this situation,  
14 the TRAU can send a message to the mobile station by reducing a rate 1 frame to a frame of a lower rate or by  
15 using Blank-and-Burst signaling. The design of a suitable algorithm is manufacturer dependent and not in the  
16 scope of this document.

### 17 6.1.2.10 Rate Reduction Mismatch with CDMA Variable Rate Codecs

18 This version of the CDMA TFO specification does not consider rate reduction (or mode of operation) requirements  
19 independently defined by the two TFO parties. It does not support rate reduction mismatch, where the downlink of  
20 a TFO party is incapable of forwarding higher rate frames received from the distant TFO partner. In the event of a  
21 rate reduction mismatch, the rate limited TFO party shall terminate the TFO operation. In addition, the rate  
22 limited TFO party shall inhibit itself from further TFO negotiation for the duration of the call unless it has resolved  
23 the rate reduction mismatch independently. This is to prevent undesirable impacts from TFO establishments /  
24 terminations.

## 25 **6.1.3 TFO Frames for 16 kbps Sub-Multiplexing**

---

26 This section presents TFO frame structures in detail for the speech codecs presented above.

27 Bit  $m$  of octet  $n$ , shall be transmitted in the **Least Significant Bit** of the

28 PCM sample  $k = n*4 + (m+1)/2$  for  $m = (1, 3, 5, 7)$  (gray shaded columns) and  $n = (0...39)$ .

29 Bit  $m$  of octet  $n$  shall be transmitted in the **second Least Significant Bit** of the

30 PCM sample  $k = n*4 + m/2$  for  $m = (2, 4, 6, 8)$  (unshaded columns) and  $n = (0...39)$ .

31 The underlined synchronization bits, as shown on the frame structure diagrams, can be used for embedded TFO  
32 messages.

33

34

1 6.1.3.1 TFO Frame Structure for CDMA Q8

2 TFO frame structure for the CDMA Q8 [1.] speech codec is as defined in Table 6.1.3.1-1. Each frame consists of  
 3 320 bits. For the purpose of this description, the 320 bits of one TFO frame are arranged in 40 rows (0...39), with 8  
 4 bits (1...8: one octet) each.

5 **Table 6.1.3.1-1 TFO Frame Structure for CDMA Q8 Speech Codec**

Octet no. (n)	Bit number (m)							
	1	2	3	4	5	6	7	8
0	<u>0</u>	S1	<b>0</b>	S2	<b>0</b>	S3	<b>0</b>	S4
1	<u>0</u>	S5	<b>0</b>	S6	<b>0</b>	S7	<b>0</b>	S8
2	<u>1</u>	C1	<b>C2</b>	C3	<b>C4</b>	C5	<b>C6</b>	C7
3	<b>C8</b>	C9	<b>C10</b>	C11	<b>C12</b>	C13	<b>C14</b>	C15
4	<u>1</u>	D1	<b>D2</b>	D3	<b>D4</b>	D5	<b>D6</b>	D7
5								
6	<u>1</u>							
7								
8	<u>1</u>							
9								
10	<u>1</u>							
11								
12	<u>1</u>							
13								
14	<u>1</u>							
15				<b>Other D bits</b>				
16	<u>1</u>							
17								
18	<u>1</u>							
19								
20	<u>1</u>							
21								
22	<u>1</u>							
23								
24	<u>1</u>							
25								
26	<u>1</u>							
27								
28	<u>1</u>	D181	<b>D182</b>	D183	<b>D184</b>	D185	<b>D186</b>	D187
29	<b>D188</b>	D189	<b>D190</b>	D191	<b>D192</b>	C16	<b>C17</b>	C18
30	<u>1</u>	C19	<b>C20</b>	C21	<b>C22</b>	C23	<b>C24</b>	C25
31								
32	<u>1</u>							
33								
34	<u>1</u>			<b>Other C bits</b>				
35								
36	<u>1</u>							
37								
38	<u>1</u>	C79	<b>C80</b>	C81	<b>C82</b>	C83	<b>C84</b>	C85
39	<b>C86</b>	C87	<b>C88</b>	C89	<b>T1</b>	T2	<b>T3</b>	T4

6  
 7 S1...S8: System identifier.

8 C1...C4: Codec type.

9 C5: Embedded TFO message indicator bit.

1	C6...C15:	Reserved.
2	C16...C18:	Rate reduction parameter, specifying the fraction of packets of Rate 1 and Rate ½ in the local up-
3		link.
4	C19...C21:	Rate reduction parameter, specifying the fraction of packets of Rate 1 and Rate ½ in the local
5		downlink.
6	C22:	Error concealment indicator. Set if the frame underwent frame erasure treatment in the local
7		decoder. Cleared otherwise.
8	C23...C89:	Reserved.
9	D1...D9:	Packet type from local multiplex sublayer on received packet from local mobile. Refer to [1].
10	Rate 1 packet:	
11	D10...D79:	LPC and subframe 1 information bits s170 to s128, s126 to s120, s118 to s112, s110 to s104,
12		s102 to s97.
13	D80...D82:	CRC over bits s170 to s128, s126 to s120, s118 to s112, s110 to s104, s102 to s97.
14	D83...D114:	Subframe 2 information bits s127, s119, s96, s94 to s88, s86 to s65.
15	D115...D117:	CRC over bits s127, s119, s96, s94 to s88, s86 to s65.
16	D118...D151:	Subframe 3 information bits s111, s103, s64 to s33.
17	D152...D154:	CRC over bits s111, s103, s64 to s33.
18	D155...D189:	Subframe 4 information bits s95, s87, s32 to s0.
19	D190...D192:	CRC over bits s95, s87, s32 to s0.
20	Rate 1 packet with bit errors	
21	D10..D192:	Refer to Rate 1 packet.
22	Rate ½ packet:	
23	D10...D59:	LPC and subframe 1 information bits s79 to s30.
24	D60...D62:	CRC over bits s79 to s30.
25	D63...D92:	Subframe 2 information bits s29 to s0.
26	D93...D95:	CRC over bits s29 to s0.
27	D96...D192:	Reserved.
28	Rate ¼ packet:	
29	D10...D49:	Information bits s39 to s0.
30	D50...D52:	CRC over bits s39 to s0.
31	D53...D192:	Reserved.
32	Rate ⅛ packet:	
33	D10...D25:	Information bits s15 to s0.
34	D26...D28:	CRC over bits s15 to s0.
35	D29...D192:	Reserved.
36	Blank:	
37	D1...D9:	9-bit packet type code (1,1000,1100, refer to Table 6.1.2.4-2).
38	D10...D18:	9-bit packet type code (1,1000,1100).
39	D19...D27:	9-bit packet type code (1,1000,1100).

- 1 D28...D192: Refer to section 7.8.1.
- 2 Insufficient frame quality (erasure):
- 3 D1...D9: 9-bit packet type code (1,1010,1011, refer to Table 6.1.2.4-2).
- 4 D10...D18: 9-bit packet type code (1,1010,1011).
- 5 D19...D27: 9-bit packet type code (1,1010,1011).
- 6 D28...D192: Reserved.
- 7 T1...T4: Time Alignment bits.
- 8 **Note:** Refer to [1.] for information on speech parameter bit order and the rate reduction parameter values.
- 9

1 6.1.3.2 TFO Frame Structure for CDMA EVRC

2 TFO frame structure for the CDMA EVRC [2.] speech codec is as defined in Table 6.1.3.2-1. Each frame consists  
 3 of 320 bits. For the purpose of this description, the 320 bits of one TFO frame are arranged in 40 rows (0...39),  
 4 with 8 bits (1...8: one octet) each.

5 **Table 6.1.3.2-1 TFO Frame Structure for CDMA EVRC Speech Codec**

Octet no. (n)	Bit number (m)								
	1	2	3	4	5	6	7	8	
0	<u>0</u>	S1	<b>0</b>	S2	<b>0</b>	S3	<b>0</b>	S4	
1	<u>0</u>	S5	<b>0</b>	S6	<b>0</b>	S7	<b>0</b>	S8	
2	<u>1</u>	C1	<b>C2</b>	C3	<b>C4</b>	C5	<b>C6</b>	C7	
3	<u>C8</u>	C9	<b>C10</b>	C11	<b>C12</b>	C13	<b>C14</b>	C15	
4	<u>1</u>	D1	<b>D2</b>	D3	<b>D4</b>	D5	<b>D6</b>	D7	
5									
6	<u>1</u>								
7									
8	<u>1</u>								
9									
10	<u>1</u>								
11									
12	<u>1</u>								
13									
14	<u>1</u>								
15			<b>Other D bits</b>						
16	<u>1</u>								
17									
18	<u>1</u>								
19									
20	<u>1</u>								
21									
22	<u>1</u>								
23									
24	<u>1</u>								
25									
26	<u>1</u>								
27									
28	<u>1</u>	D181	<b>D182</b>	D183	<b>D184</b>	D185	<b>D186</b>	D187	
29	<u>D188</u>	D189	<b>D190</b>	D191	<b>D192</b>	C16	<b>C17</b>	C18	
30	<u>1</u>	C19	<b>C20</b>	C21	<b>C22</b>	C23	<b>C24</b>	C25	
31									
32	<u>1</u>								
33									
34	<u>1</u>		<b>Other C bits</b>						
35									
36	<u>1</u>								
37									
38	<u>1</u>	C79	<b>C80</b>	C81	<b>C82</b>	C83	<b>C84</b>	C85	
39	<u>C86</u>	C87	<b>C88</b>	C89	<b>T1</b>	T2	<b>T3</b>	T4	

6  
 7 S1...S8: System identifier

8 C1...C4: Codec type.

9 C5: Embedded TFO message indicator bit.

1	C6...C15:	Reserved.
2	C16...C18:	Rate reduction parameter, specifying the fraction of packets of Rate 1 and Rate ½ in the local up-
3		link.
4	C19...C21:	Rate reduction parameter, specifying the fraction of packets of Rate 1 and Rate ½ in the local
5		downlink.
6	C22:	Error concealment indicator. Set if the frame underwent frame erasure treatment in the local
7		decoder. Cleared otherwise.
8	C23...C89:	Reserved.
9	D1...D9:	Packet type from local multiplex sublayer on received packet from local mobile. Refer to [2.].
10	Rate 1 packet:	
11	D10...D50:	LPC and pitch delay information bits s1 to s41.
12	D51...D53:	CRC over bits s1 to s41.
13	D54...D96:	Subframe 1 codebook information bits s42 to s84.
14	D97...D99:	CRC over bits s42 to s84.
15	D100...D142:	Subframe 2 codebook information bits s85 to s127.
16	D143...D145:	CRC over bits s85 to s127.
17	D146...D189:	Subframe 3 codebook information bits s128 to s171. Bit s171 is reserved according to [2.] and is
18		set to "0", to be consistent with the Q13 specification.
19	D190...D192:	CRC over bits s128 to s171.
20	Rate 1 packet with bit errors:	
21	D10..D192:	Refer to Rate 1 packet.
22	Rate ½ packet:	
23	D10...D38:	LPC and pitch delay information bits s1 to s29.
24	D39...D41:	CRC over bits s1 to s29.
25	D42...D58:	Subframe 1 codebook information bits s30 to s46.
26	D59...D61:	CRC over bits s30 to s46.
27	D62...D78:	Subframe 2 codebook information bits s47 to s63.
28	D79...D81:	CRC over bits s47 to s63.
29	D82...D98:	Subframe 3 codebook information bits s64 to s80.
30	D99...D101:	CRC over bits s64 to s80.
31	D102...D192:	Reserved.
32	Rate ⅛ packet:	
33	D10...D25:	LPC and gain information bits s1 to s16.
34	D26...D28:	CRC over bits s1 to s16.
35	D29...D192:	Reserved.
36	Blank:	
37	D1...D9:	9-bit packet type code (1,1000,1100, refer to Table 6.1.2.4-3).
38	D10...D18:	9-bit packet type code (1,1000,1100).
39	D19...D27:	9-bit packet type code (1,1000,1100).
40	D28...D192:	Refer to section 7.8.1.

- 1 Insufficient frame quality (erasure):
- 2 D1...D9: 9-bit packet type code (1,1010,1011, refer to Table 6.1.2.4-3).
- 3 D10...D18: 9-bit packet type code (1,1010,1011).
- 4 D19...D27: 9-bit packet type code (1,1010,1011).
- 5 D28...192: Reserved.
- 6 Rate  $\frac{1}{8}$  with all bits set to '1':
- 7 D1...D9: 9-bit packet type code (0,0111,0011, refer to Table 6.1.2.4-3).
- 8 D10...D25: All bits set to 1.
- 9 D26...D192: Reserved.
- 10 T1...T4: Time Alignment bits.
- 11 **Note:** Refer to [2.] for information on speech parameter bit order and rate reduction parameter values.

12

1 6.1.3.3 TFO Frame Structure for CDMA SMV

2 TFO frame structure for the CDMA SMV [5.] speech codec is as defined in Table 6.1.3.3-1. Each frame consists of  
 3 320 bits. For the purpose of this description, the 320 bits of one TFO frame are arranged in 40 rows (0...39), with 8  
 4 bits (1...8: one octet).

5 **Table 6.1.3.3-1 TFO Frame Structure for CDMA SMV Speech Codec**

Octet no. (n)	Bit number (m)								
	1	2	3	4	5	6	7	8	
0	0	S1	0	S2	0	S3	0	S4	
1	0	S5	0	S6	0	S7	0	S8	
2	1	C1	C2	C3	C4	C5	C6	C7	
3	C8	C9	C10	C11	C12	C13	C14	C15	
4	1	D1	D2	D3	D4	D5	D6	D7	
5									
6	1								
7									
8	1								
9									
10	1								
11									
12	1								
13									
14	1								
15			Other D bits						
16	1								
17									
18	1								
19									
20	1								
21									
22	1								
23									
24	1								
25									
26	1								
27									
28	1	D181	D182	D183	D184	D185	D186	D187	
29	D188	D189	D190	D191	D192	C16	C17	C18	
30	1	C19	C20	C21	C22	C23	C24	C25	
31									
32	1								
33									
34	1		Other C bits						
35									
36	1								
37									
38	1	C79	C80	C81	C82	C83	C84	C85	
39	C86	C87	C88	C89	T1	T2	T3	T4	

6  
 7 S1...S8: System identifier.

8 C1...C4: Codec type.

9 C5: Embedded TFO message indicator bit.

1	C6...C15:	Reserved.
2	C16...C18:	Mode of operation, specifying the fraction of packets of Rate 1, Rate $\frac{1}{2}$ , and Rate $\frac{1}{4}$ in the local uplink.
3		
4	C19...C21:	Mode of operation, specifying the fraction of packets of Rate 1, Rate $\frac{1}{2}$ , and Rate $\frac{1}{4}$ in the local downlink.
5		
6	C22:	Error concealment indicator. Set if the frame underwent frame erasure treatment in the local decoder. Cleared otherwise.
7		
8	C23...C89:	Reserved.
9	D1...D9:	Packet type from local multiplex sublayer on received packet from local mobile. Refer to [5].
10	Rate 1 packet (Type 0):	
11	D10...D74:	Vocoder type, LPC and subframe 1 pitch and codebook information bits s1 to s36, s55 to s61 and s83 to s104.
12		
13	D75...D77:	CRC over bits s1 to s36, s55 to s61, and s83 to s104.
14	D78...D111:	Subframe 2 pitch and codebook information bits s37 to s41, s62 to s68 and s105 to s126.
15	D112...D114:	CRC over bits s37 to s41, s62 to s68 and s105 to s126.
16	D115...D151:	Subframe 3 pitch and codebook information bits s42 to s49, s69 to s75, and s127 to s148.
17	D152...D154:	CRC over bits s42 to s49, s69 to s75, and s127 to s148.
18	D155...D189:	Subframe 4 pitch and codebook information bits s50 to s54, s76 to s82, and s149 to s171. Bit s171 is a rate sanity flag and is set to "0". Refer to [5].
19		
20	D190...D192:	CRC over bits s50 to s54, s76 to s82, and s149 to s171.
21	Rate 1 packet (Type 1):	
22	D10...D89:	Vocoder type, LPC, pitch and subframe 1 codebook information bits s1 to s80.
23	D90...D92:	CRC over bits s1 to s80.
24	D93...D122:	Subframe 2 codebook information bits s81 to s110.
25	D123...D125:	CRC over bits s81 to s110.
26	D126...D155:	Subframe 3 codebook information bits s111 to s140.
27	D156...D158:	CRC over bits s111 to s140.
28	D159...D189:	Subframe 4 codebook information bits s141 to s171. Bit s171 is a rate sanity flag and is set to "0". Refer to [5].
29		
30	D190...D192:	CRC over bits s141 to s171.
31	Rate 1 packet with bit errors:	
32	D10...D192:	See Rate 1 packet.
33	Rate $\frac{1}{2}$ packet (Type 0):	
34	D10...D31:	Vocoder type and LPC information bits s1 to s22.
35	D32...D34:	CRC over bits s1 to s22.
36	D35...D63:	Subframe 1 pitch and codebook information bits s23 to s29, s37 to s43, and s51 to s65.
37	D64...D66:	CRC over bits s23 to s29, s37 to s43, and s51 to s65.
38	D67...D95:	Subframe 2 pitch and codebook information bits s30 to s36, s44 to s50, and s66 to s80.
39	D96...D98:	CRC over bits s30 to s36, s44 to s50, and s66 to s80.
40	D99...D192:	Reserved.

- 1 Rate  $\frac{1}{2}$  packet (Type 1):
- 2 D10...D50: Vocoder type, LPC, pitch and gain information bits s1 to s41.
- 3 D51...D53: CRC over bits s1 to s41.
- 4 D54...D66: Subframe 1 codebook information bits s42 to s54.
- 5 D67...D69: CRC over bits s42 to s54.
- 6 D70...D82: Subframe 2 codebook information bits s55 to s67.
- 7 D83...D85: CRC over bits s55 to s67.
- 8 D86...D98: Subframe 3 codebook information bits s68 to s80.
- 9 D99...D101: CRC over bits s68 to s80.
- 10 D102...D192: Reserved.
- 11 Rate  $\frac{1}{4}$  packet:
- 12 D10...D49: LPC and excitation information bits s1 to s40.
- 13 D50...D52: CRC over bits s1 to s40. Bit s40 is a rate sanity flag and is set to "0". Refer to [5.].
- 14 D53...D192: Reserved.
- 15 Rate  $\frac{1}{8}$  packet:
- 16 D10...D25: LPC and gain information bits s1 to s16.
- 17 D26...D28: CRC over bits s1 to s16.
- 18 D29...D192: Reserved.
- 19 Blank:
- 20 D1...D9: 9-bit packet type code (1,1000,1100, refer to Table 6.1.2.4-4).
- 21 D10...D18: 9-bit packet type code (1,1000,1100).
- 22 D19...D27: 9-bit packet type code (1,1000,1100).
- 23 D28...D192: Refer to section 7.8.1.
- 24 Insufficient frame quality (erasure):
- 25 D1...D9: 9-bit packet type code (1,1010,1011, refer to Table 6.1.2.4-4).
- 26 D10...D18: 9-bit packet type code (1,1010,1011).
- 27 D19...D27: 9-bit packet type code (1,1010,1011).
- 28 D28...192: Reserved.
- 29 T1...T4: Time Alignment bits
- 30 **Note:** Refer to [5.] for information on speech parameter bit order and rate reduction parameter values.
- 31 **Note:**  $s_i$  indicates the  $i^{\text{th}}$  vocoder bit index.

1 6.1.3.4 TFO Frame Structure for CDMA Q13

2 TFO frame structure for the CDMA Q13 [3.] speech codec is as defined in Table 6.1.3.4-1. Each frame consists of  
 3 320 bits. For the purpose of this description, the 320 bits of one TFO frame are arranged in 40 rows (0...39), with 8  
 4 bits (1...8: one octet) each.

5 **Table 6.1.3.4-1 TFO Frame Structure for CDMA Q13 Speech Codec**

Octet no. (n)	Bit number (m)							
	1	2	3	4	5	6	7	8
0	0	S1	0	S2	0	S3	0	S4
1	0	S5	0	S6	0	S7	0	S8
2	1	C1	C2	C3	C4	C5	C6	C7
3	C8	D1	D2	D3	D4	D5	D6	D7
4	1							
5								
6	1							
7								
8	1							
9								
10	1							
11								
12	1							
13								
14	1							
15								
16	1							
17				Other D bits				
18	1							
19								
20	1							
21								
22	1							
23								
24	1							
25								
26	1							
27								
28	1							
29								
30	1							
31								
32	1							
33								
34	1							
35								
36	1							
37	D255	D256	D257	D258	D259	D260	D261	D262
38	1	D263/C9	D264/C1	D265/C1	D266/C1	D267/C1	D268/C1	D269/C1
			0	1	2	3	4	5
39	D270/C1	D271/C1	D272/C1	D273/C1	D274/C2	D275/C2	T1	T2
	6	7	8	9	0	1		

6

7 S1...S8: System identifier/TFO frame synch word.

8 C1...C4: Codec type.

1	C5:	Embedded TFO message indicator bit.
2	C6...C8:	Rate reduction parameter, specifying the fraction of packets of rate 1, rate ½ or rate ¼ in the local
3		downlink.
4	C9...C11:	These bits are not defined for Rate 1 TFO frame. For Rate 1 TFO frame, these are interpreted as
5		D bits.
6		Rate reduction parameter, specifying the fraction of packets of rate 1, rate ½ or rate ¼ in the local
7		uplink.
8	C12...C21:	These bits are not defined for Rate 1 TFO frame. For Rate 1 TFO frame, these are interpreted as
9		D bits. For all other packets, these bits are reserved.
10	Rate 1 packet:	
11	D1...D4:	4-bit packet type code (0000, refer to Table 6.1.2.4-5). Packet type is from local multiplex
12		sublayer on received packet from local mobile.
13	D5...D268:	Information bits s265 to s10, s7 to s0.
14	D269...D275:	CRC over bits s265 to s0 except all 112 CINDEX bits and 2 reserved bits. Refer to section
15		6.1.2.7.
16	Rate ½ packet:	
17	D1...D9:	9-bit packet type code (1,1101,0101, refer to Table 6.1.2.4-5).
18	D10...D133:	Information bits s123 to s0.
19	D134...D140:	CRC over bits s123 to s0 except all 28 CINDEX bits.
20	D141...D262:	Reserved.
21	Rate ¼ packet:	
22	D1...D9:	9-bit packet type code (0,1111,1000, refer to Table 6.1.2.4-5).
23	D10...D61:	Information bits s53 to s6, s3 to s0.
24	D62...D68:	CRC over bits s53 to s6, s3 to s0.
25	D69...D262:	Reserved.
26	Rate ⅛ packet:	
27	D1...D9:	9-bit packet type code (1,0110,0110, refer to Table 6.1.2.4-5).
28	D10...D25:	All information bits s19 to s4.
29	D26...D32:	CRC over bits s19 to s4 except all 4 CBSEED bits.
30	D33...D262:	Reserved.
31	Blank:	
32	D1...D9:	9-bit packet type code (0,0001,1111, refer to Table 6.1.2.4-5).
33	D10...D18:	9-bit packet type code (0,0001,1111).
34	D19...D27:	9-bit packet type code (0,0001,1111).
35	D28...D262:	Refer to section 7.8.1.
36	Insufficient frame quality (erasure):	
37	D1...D9:	9-bit packet type code (1,1010,1011, refer to Table 6.1.2.4-5).
38	D10...D18:	9-bit packet type code (1,1010,1011).
39	D19...D27:	9-bit packet type code (1,1010,1011).

1 D28...D262: Reserved.

2 T1...T2: Time Alignment bits.

3 **Notes:**

4 • Refer to [3.] for information on speech parameter bit order.

5 • Error concealment on received frames corrupted by channel noise on the uplink is to be done in the far/remote  
6 decoder. The option of it being handled by either the local or remote processor and indicated by the error  
7 concealment indicator as in the case of Q8 and EVRC is not available for Q13.

8 • Refer to [3.] for rate reduction parameter values.

9 • Refer to [3.] for packet type information.

10 • CRC bits do not protect fixed codebook index bits. The fixed codebook index bits are replaced by random  
11 indices on erasure Refer to [3.].

12 • Q13 Rate 1, Rate  $\frac{1}{4}$  and Rate  $\frac{1}{8}$  reserved bits are not transmitted.

13

## 7 TFO Message Structure

---

Several TFO messages are defined, based on the general IS message protocol, as defined in Annex B.

Definition for sender side:

**TFO\_REQ ()**: Identifies the source of the message as a TFO capable device, using a defined speech codec. Refer to section 7.1.

TFO\_REQ contains the following parameters ():

- the System\_Identification.
- the specific Local\_Signature of the sender;
- the Local\_Used\_Codec at sender side;

**TFO\_REQ\_L ()**: Is sent in case of codec mismatch or for sporadic updates of information. Refer to section 7.1.

TFO\_REQ\_L contains the following parameters ():

- the System\_Identification;
- the specific Local\_Signature of the sender;
- the Local\_Used\_Codec at sender side;
- the Local\_Codec\_List of alternative codecs.

**TFO\_REQ\_P ()**: Undefined for TRAU, defined only for TFO Circuit Multiplication Equipment (TCME). Refer to section C.3.1.

TFO\_REQ\_P contains the following parameters ():

- the System\_Identification;
- the specific Local\_Signature of the Sender;
- the Preferred\_Codec at sender side;
- the Local\_Codec\_List of alternative codecs.

**TFO\_ACK ()**: Is the response to a TFO\_REQ message. Refer to section 7.2.

TFO\_ACK contains the following parameters ():

- the System\_Identification.
- the Reflected\_Signature, copied from the received TFO\_REQ message;
- the Local\_Used\_Codec at sender side;

**TFO\_ACK\_L ()**: Is the response to a TFO\_REQ\_L message. Refer to section 7.2.

TFO\_ACK\_L contains the following parameters ():

- the System\_Identification;
- the Reflected\_Signature, copied from the received TFO\_REQ\_L message;
- the Local\_Used\_Codec at sender side;
- the Local\_Codec\_List of alternative codecs.

**TFO\_TRANS ()**: Commands possible IPEs to let the TFO frames pass transparently within the LSB (8 kbps) or the two LSBs (16 kbps). Refer to section 7.3.

TFO\_TRANS contains the following parameter ():

- the Local\_Channel\_Type (i.e. 8 kbps or 16 kbps).

- 1 **TFO\_NORMAL:** Commands possible IPEs to revert to normal operation. Refer to section 7.4.
- 2 TFO\_NORMAL has no parameters.
  
- 3 **TFO\_FILL:** Message without specific meaning, used to pre-synchronize IPEs or to bridge gaps in TFO protocols.
- 4 Refer to section 7.5.
- 5 TFO\_FILL has no parameters.
  
- 6 **TFO\_DUP:** Informs the distant partner that TFO frames are received, while still transmitting PCM samples. Refer
- 7 to section 7.6.
- 8 TFO\_DUP has no parameters.
  
- 9 **TFO\_SYL:** Informs the distant partner (if still possible) that TFO frames are no longer received. Refer to section
- 10 7.7.
- 11 TFO\_SYL has no parameters.

12

13 **Definitions:** A TFO message is called **”regular”**, if it is sent inserted into the PCM sample stream. A TFO

14 message is called **”embedded”**, if it is sent together with (embedded into) TFO frames. Refer also to section 8.2.

15 The bit-stealing scheme (refer to Annex B) is identical for regular and embedded TFO messages. Due to the

16 specific design of the TFO messages, they replace some of the synchronization bits of the TFO frames. TFO frame

17 synchronization, in the case of embedded TFO messages, is therefore different, however frame synchronization

18 capability is not adversely affected. Data and other control bits of the TFO frames are not affected by embedded

19 TFO messages.

20 **Restrictions:**

- 21 1. A TRAU is not allowed to send short and isolated TFO messages too close to the end of longer TFO messages.
- 22 TFO messages with the same length have no such restriction. For more information, refer to section C.3.2.3.
  
- 23 2. This release of the TFO standard defines a simplified TFO state machine for CDMA TFO operations. TFO
- 24 messages TFO\_DUP and TFO\_SYL are defined only for harmonization with other TFO standards. I.e. They
- 25 are defined for CDMA Rx\_TFO operations for intersystem calls and are not defined for CDMA Tx\_TFO
- 26 operations.

27 **7.1 Definition of the TFO\_REQ Messages**

---

28 **Symbolic Notation:** TFO\_REQ (System\_Identification, Signature, Used\_Codec)

29 TFO\_REQ\_L (System\_Identification, Signature, Used\_Codec, Codec\_List)

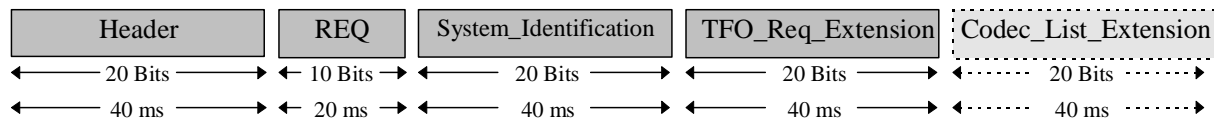
30 TFO\_REQ\_P (System\_Identification, Signature, Preferred\_Codec, Codec\_List)

31 The TFO\_REQ messages conform to the IS\_REQ message, defined in Annex B, with IS\_System\_Identification set

32 accordingly, followed by the TFO\_Req\_Extension\_Block and optionally by the Codec\_List\_Extension\_Block.

33 TFO\_REQ takes 140 ms for transmission. Refer to Figure 7.1-1. TFO\_REQ\_L and TFO\_REQ\_P take 180 ms for

34 transmission.



35 **Figure 7.1-1 Design of the TFO\_REQ Messages**

36

37

### 7.1.1 Definition of the TFO\_Req\_Extension\_Block

---

The TFO\_Req\_Extension\_Block consists of 20 bits, as defined in Table 7.1.1-1.

**Table 7.1.1-1 TFO\_Req\_Extension\_Block**

Bit	Description	Comment
Bit 1	"0"	Normal IS message Sync Bit, constant.
Bit 2	<b>Req_Ident</b> Req_Ident == "0" Req_Ident == "1"	Identifies the TFO_Req_Extension_Block. REQ or REQ_L: Codec Field identifies the "used" codec. REQ_P: Codec Field identifies the "preferred" codec.
Bit 3..10	<b>Signature</b>	An 8-bit random number to facilitate the detection of circuit loop back conditions and to identify the messages source
Bit 11	"0"	Normal IS message Sync Bit, constant.
Bit 12.. 15	<b>Codec</b>  Codec == "0.0.0.0" Codec == "0.0.0.1" Codec == "0.0.1.0" Codec == "0.0.1.1"	Identifies the codec, which is currently used (Req_Ident == "0") or which is preferred (Req_Ident == "1") by the sender. [1.] Q8 [2.] EVRC [3.] Q13 [5.] SMV
Bit 16..18	<b>CRC</b>	A 3-bit CRC protecting Req_Ident, Signature and Codec fields, refer to section 7.1.2.
Bit 19..20	<b>EX</b> EX == "0.0" EX == "1.1"	The normal 2 bits for IS message extension. REQ: No other extension block follows. REQ_L or REQ_P: The Codec_List_Extension_Block follows.

### 7.1.2 Cyclic Redundancy Check

---

The Cyclic Redundancy Check (CRC) is operating on the 13 bits consisting of bits 2...10 and 12...15.

The three CRC bits are generated according to a degenerate (shortened) cyclic code using the generator polynomial:

$g(D) = D^3 + D + 1$ . The encoding of the cyclic code is performed in a systematic form which means that, in GF(2), the polynomial:  $d(m)D^{15} + d(m+1)D^{14} + \dots + d(m+12)D^3 + p(0)D^2 + p(1)D + p(2)$ , (where  $d(m)$ ,  $d(m+12)$ , and  $p(0)$  corresponds to bits 2, 15, and 16, respectively and  $p(0)$ ,  $p(1)$  and  $p(2)$  are the parity bits), when divided by  $g(D)$ , yields a remainder equal to:  $1 + D + D^2$ .

### 7.1.3 Definition of the Codec\_List\_Extension\_Block

---

The Codec\_List\_Extension\_Block consists of 20 bits, as defined in Table 7.1.3-1 identifies the codecs that are supported by the sender, in respect to the BSS subsystem, including the mobile station and the radio resource, at the sender side. The Codec\_List shall at least contain the Local\_Used\_Codec.

**Table 7.1.3-1 Codec\_List\_Extension\_Block**

Bit	Description	Comment
Bit 1	"0"	Normal IS message sync bit, constant.
Bit 2..10	<b>Codec_List_1</b>	First part of Codec_List. For each codec one bit is reserved. If the bit is set to "0" then the specific codec is not supported; if the bit is set to "1" then the specific codec could be used. Bit 2: [1.] Q8 Bit 3: [2.] EVRC Bit 4: [3.] Q13 Bit 5: [5.] SMV The remaining bits are set to "0" and reserved for future codecs.
Bit 11	"0"	Normal IS message Sync Bit, constant.
Bit 12.. 15	<b>Codec_List_2</b>	Second part of the Codec_List. All four bits are set to "0" and reserved for future codecs.
Bit 16..18	<b>CRC</b>	A 3-bit CRC protecting the Codec_List fields, refer to section 7.1.2.
Bit 19..20	<b>EX</b> EX == "0.0"	The normal 2 IS message extension bits. No other extension block follows.

## 7.2 Definition of the TFO\_ACK Messages

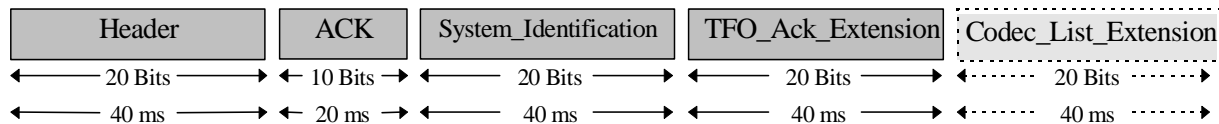
### Symbolic Notation:

TFO\_ACK (System\_Identification, Reflected\_Signature, Used\_Codec)

TFO\_ACK\_L (System\_Identification, Reflected\_Signature, Used\_Codec, Codec\_List)

The TFO\_ACK messages conform to the IS\_ACK message, defined in Annex B, with IS\_System\_Identification set accordingly, followed by the TFO\_Ack\_Extension\_Block and optionally the Codec\_List\_Extension\_Block.

TFO\_ACK takes 140 ms for transmission. Refer to Figure 7.2-1. TFO\_ACK\_L takes 180 ms for transmission.



**Figure 7.2-1 Design of the TFO\_ACK Message**

### 7.2.1 Definition of the TFO\_Ack\_Extension\_Block

The TFO\_Ack\_Extension\_Block consists of 20 bits defined as in Table 7.2.1-1.

Table 7.2.1-1 TFO\_Ack\_Extension\_Block

Bit	Description	Comment
Bit 1	"0"	Normal IS message Sync Bit, constant.
Bit 2	<b>Ack_Ident</b> Ack_Ident == "0" Ack_Ident == "1"	Identifies the TFO_Ack_Extension_Block. ACK: Acknowledge to a received TFO_REQ message. Reserved.
Bit 3..10	<b>Signature</b>	An 8-bit number containing the received Signature, <i>reflected</i> back.
Bit 11	"0"	Normal IS message Sync Bit, constant.
Bit 12.. 15	<b>Codec</b>	Identifies the codec, which is currently used by the sender; refer to section 7.1.1.
Bit 16..18	<b>CRC</b>	A 3-bit CRC protecting the Ack_Ident, Signature and Codec fields, refer to section 7.1.2.
Bit 19..20	<b>EX</b>	The normal 2 bits for IS message extension.
	EX == "0.0"	ACK: No other extension block follows.
	EX == "1.1"	ACK_L: The Codec_List_Extension_Block follows.

### 7.3 Definition of the TFO\_TRANS Messages

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**Symbolic Notation:** TFO\_TRANS (Channel\_Type).

Two TFO\_TRANS messages are defined in conformity to the IS\_TRANS messages in Annex B.

For 16 kbps submultiplexing channels the "TFO\_TRANS (16k)" is used and is identical to "IS\_TRANS\_2\_u" (refer to section B.3.3). TFO\_TRANS takes 140 ms for transmission.

In most cases the respective TFO\_TRANS message shall be sent twice: once as a regular TFO message, exactly before any series of TFO frames, and once embedded into the first TFO frames. Refer to section 11.

### 7.4 Definition of the TFO\_NORMAL Message

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**Symbolic Notation:** TFO\_NORMAL.

The TFO\_NORMAL message is identical to the IS\_NORMAL message defined in Annex B.

It shall be sent at least once whenever an established tandem free operation needs to be terminated in a controlled way. TFO\_NORMAL takes 100 ms for transmission.

### 7.5 Definition of the TFO\_FILL Message

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**Symbolic Notation:** TFO\_FILL.

The TFO\_FILL message is identical to the IS\_FILL message, defined in Annex B.

TFO\_FILL may be used to pre-synchronize IPEs. Since IS\_FILL is one of the shortest IS messages, this is the fastest way to synchronize IPEs, without IPEs swallowing other protocol elements. By default three TFO messages shall be sent at the beginning; this number may be, however, configuration dependent. One TFO\_FILL takes 60 ms for transmission.

### 7.6 Definition of the TFO\_DUP Message (Not for CDMA-CDMA calls)

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**Symbolic Notation:** TFO\_DUP

The TFO\_DUP message is identical to the IS\_DUP message, defined in Annex B.

TFO\_DUP informs the distant TFO Partner, that TFO frames have been received unexpectedly, e.g. during the establishment state. This enables a fast re-establishment of TFO after a *local* HHO. TFO\_DUP takes 60 ms for transmission. This message is defined for CDMA Rx\_TFO operations for intersystem calls only (e.g. CDMA-TDMA calls) and is not defined for CDMA Tx\_TFO operations.

## 7.7 Definition of the TFO\_SYL Message (Not for CDMA-CDMA calls)

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### **Symbolic Notation:** TFO\_SYL

The TFO\_SYL message is identical to the IS\_SYL message, defined in Annex B.

TFO\_SYL informs the distant TFO Partner that tandem free operation previously existed, however no TFO frames are currently being received. This enables a fast re-establishment of TFO after a *distant* HHO. TFO\_SYL takes 60 ms for transmission.

This message is defined for CDMA Rx\_TFO operations for intersystem calls only (e.g. CDMA-TDMA calls) and is not defined for CDMA Tx\_TFO operations.

## 7.8 Definition of the TFO\_DTMF and TFO\_DTMF\_ACK messages

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### **Symbolic Notation:** TFO\_DTMF and TFO\_DTMF\_ACK

The CDMA TFO version 0.0, does not provide a way to do mobile-to-mobile DTMF signaling without switching into tandem mode. The cdma2000-A standards provide the Reverse (Uplink) DTMF Signaling message and Forward (Downlink) DTMF Signaling message. Without a DTMF signaling mechanism in TFO, it is necessary to go into tandem mode (i.e., without TFO) whenever DTMF signaling is needed. Mobile-to-mobile DTMF signaling is needed especially in fixed wireless applications.

CDMA TFO versions 1.0 and greater define the TFO\_DTMF and TFO\_DTMF\_ACK messages which use the data bits in the Blank TFO frame (defined in section 6.1.3) to carry DTMF signaling and DTMF acknowledgement information while the call is in TFO mode. The structure of the Blank TFO frame is modified to support DTMF signaling and its acknowledgement, as well as for future support of generalized mobile-to-mobile messaging.

The acknowledgement procedures facilitate the reliable exchange of DTMF signaling messages between the local (transmitting) TRAU and the remote (receiving) TRAU. This acknowledgement procedures only apply to the Burst DTMF signaling. The local TRAU uses the fields MSG\_SEQ (message sequence number) and ACK\_REQ (acknowledgement required indicator) to provide a reference for acknowledgements. The DTMF acknowledgement is optional for the local TRAU. A DTMF signaling message requires acknowledgements when the ACK\_REQ field is set to '1'.

Upon receiving a Burst DTMF signaling message containing ACK\_REQ = 1, the remote TRAU shall respond within T1 seconds (T1 = 100 ms) with a "successful" acknowledgement (DTMF\_ACK = 0) if the DTMF signaling message is received successfully. Otherwise, it shall respond with an "unsuccessful" acknowledgement (DTMF\_ACK = 1). The ACK\_SEQ number in the DTMF Acknowledgement message is set to the MSG\_SEQ number in the received DTMF Signaling message. It is desirable to minimize the effect of transmitting the acknowledgement blank frame from the remote TRAU. One such optional minimization technique is for the remote TRAU to wait for either an 1/8, 1/4 or 1/2 rate voice frame arriving from the remote mobile station to use as the blank frame for the acknowledgement. It is recommended that the remote TRAU should wait for the 1/8, 1/4 or 1/2 rate frame within T2 seconds (T2 = 80 ms, T2 and T1 timers were started at the same time), otherwise it can blank the next frame and send a TFO\_DTMF\_ACK regardless of the voice traffic rate.

The local TRAU shall not retransmit a DTMF signaling message for which it has received an acknowledgement with successful indication (DTMF\_ACK = 0) and expected ACK\_SEQ number. If there are more than one DTMF signaling messages needed to be transmitted and if retransmission is supported, the local TRAU should wait for a positive acknowledgement for each message before transmitting the next DTMF signaling message. If the local TRAU has not received an acknowledgement within T3 seconds (T3 = 160 ms) after transmitting the DTMF signaling message, the local TRAU should retransmit the DTMF signaling message with the same MSG\_SEQ number. If the local TRAU has received an acknowledgement containing unsuccessful indication (DTMF\_ACK = 1); the local TRAU should retransmit the DTMF signaling message. The local TRAU shall support a maximum of N1 retransmissions (recommend N1 = 2) in response to TFO\_DTMF signaling failure. As a result of more than N1 consecutive DTMF signaling failures, the local TRAU may exit TFO mode.

### 7.8.1 Message structure of TFO\_DTMF and TFO\_DTMF\_ACK

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Refer to section 6.1.3 for the TFO frame structure for CDMA Q8, EVRC, SMV and Q13 speech codec bit positions.

- System identifier (8 bits, defined in TFO standards) (S1...S8)
- Codec type (4 bits, defined in TFO standards) (C1...C4)
- Embedded TFO message indicator (1 bit, defined in TFO standards) (C5)
- Packet type (27 bits, use the value for Blank frame type, defined in TFO standards) (D1...D9, D10...D18, D19...D27)
- Blank Frame Message Type (New field, 4 bits): (D28 ... D31)
  - 0.0.0.0: Blank frame only
  - 0.0.1.1: TFO DTMF Signaling message
  - 1.0.1.0: TFO DTMF Acknowledgment message
  - All other values: Reserved

#### Message Body for TFO\_DTMF Signaling Message:

**Note:** Message sequence number is defined by the local Tx\_TFO.

- MSG\_SEQ (3 bits) (D32 ... D34)
  - 0.0.0 ... 1.1.1: Message sequence number
- ACK\_REQ (1 bit) (D35)
  - 0: Acknowledgment is not required
  - 1: Acknowledgement is required
- NUM\_DIGITS (6 bits) (D36...D41)
  - 1 ... 32: Number of DTMF digits (e.g. 000001...100000 for 1 to 32 of DTMF digits)
  - **Note:** cdma2000 standards use 8 bits for NUM\_DIGITS in a message. If more than 32 DTMF digits are requested by the mobile in a single message, then up to 8 TFO DTMF Signaling messages shall be generated sequentially to transmit all of the requested digits.
  - CRC (3 bits) (D42...D44)
  - CRC over bits D28 to D41
  - **Note:** The CRC computation shall follow the TFO standards. Refer to section 7.1.2.
- DTMF\_ON\_LENGTH (3 bits) (D45...D47)
  - 0.0.0 ... 1.0.1: DTMF on length, defined in [6.].
  - 1.1.1: continuous signaling
  - All other values: Reserved
- DTMF\_OFF\_LENGTH (3 bits) (D48...D50)
  - 0.0.0 ... 0.1.1: DTMF off length, defined in [6.].
  - 1.1.1: continuous signaling
  - All other values: Reserved
- DIGIT<sub>i</sub> (4 bits per digit, 4 x NUM\_DIGITS) (D51...D51+(4 x NUM\_DIGITS) - 1)
  - 0.0.0.1 ... 1.1.0.0: DTMF digit, defined in [6.].
  - Use 0.0.0.0 to fill unused bits
- CRC (3 bits, append to the last digit) (D51+(4 x NUM\_DIGITS)...D51+(4 x NUM\_DIGITS) + 2)
  - CRC over bits D45 to (D51+ (4 x NUM\_DIGITS) -1)
- All unused bits are reserved

1 **Message Body for TFO\_DTMF\_ACKnowledgment Message:**

2 **Note:** The TFO DTMF Acknowledgment message is only for the Burst DTMF Signaling.

- 3 • DTMF\_ACK (1 bit) (D32)
  - 4 - 0: Successful
  - 5 - 1: Unsuccessful
- 6 • ACK\_SEQ (3 bits) (D33...D35)
  - 7 - 0.0.0 ... 1.1.1: Acknowledgment sequence number
- 8 • CRC (3 bits) (D36...D38)
  - 9 - CRC over bits D28 to D35
  - 10 - **Note:** The CRC computation shall follow the TFO standards. Refer to section 7.1.2.
  - 11 - All unused bits are reserved

12

## 8 Time Alignment of TFO Frames and TFO Messages

Any time alignment procedures which may be implemented on the TTL interface are not affected by the TFO procedures on the PSTN interface.

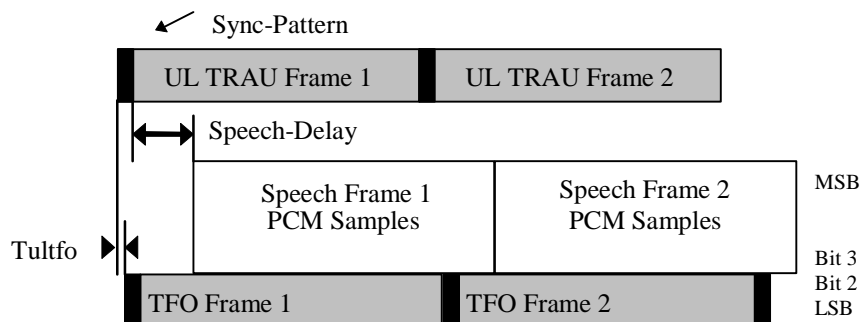
TFO frames and embedded TFO messages are always exactly aligned with each other and are delayed from the uplink TRAU frames.

### 8.1 Time Alignment of TFO Messages

At start up of the TFO protocol, the first regular TFO message is aligned to an uplink TRAU frame. . Then, after that, all regular TFO messages follow contiguously without any phase shift in time alignment until the first TFO frame needs to be sent (in general after the TFO\_TRANS message). Then the necessary number of T\_Bits (if any) are inserted before the first TFO frame. Refer to section 8.2. Consequently all following, embedded TFO messages are always aligned with the TFO frames in a way, that the first bit of any TFO messages is placed into the LSB of the first sample of a TFO frame. Due to this definition, embedded TFO messages only modify some of the synchronization bits of the TFO frames (the ones underlined and light shaded in column m=1 of Table 6.1.3.1-1, Table 6.1.3.2-1, Table 6.1.3.3-1 and Table 6.1.3.4-1).

### 8.2 Time Alignment of TFO Frames

The contents of the Uplink TRAU frame, received from the TRX via the TTL interface, undergoes a delay (Tultfo) required to generate the corresponding TFO frames for transmission to the remote TRAU over the PSTN interface. Since this delay is substantially smaller than the delay for the decoded speech signal, the TFO frames precede the corresponding speech samples. Figure 8.2-1 shows the relationship between TFO frame transmission delay and decoded speech signal delay. Note that the delay value for Tultfo is implementation specific.



**Figure 8.2-1 Uplink TFO Frame Time Alignment**

On the transition between the sending of regular TFO messages and the first TFO frame on the PSTN interface, a sufficient number (up to a maximum of 159) of Time Alignment bits, also called "T\_Bits", are inserted into the LSBs of the PCM samples to align the TFO frame as described above.

This insertion of Time Alignment bits (if necessary) is started exactly with the 16<sup>th</sup> PCM sample after the last bit of the last regular TFO message (i.e. the TFO\_TRANS message).

Whenever, in a later stage, the phase of the uplink TRAU frame changes, then again T\_Bits need to be inserted between two consecutive TFO frames or deleted from the tail of the last TFO frame to ensure proper alignment.

The insertion of T\_Bits as a result of timing changes shall occur *between* TFO frames and not within TFO frames.

If the time alignment is necessary while a TFO message is embedded into a series of TFO frames, then the TFO message may be cut into two parts with the T\_Bits in between. Therefore, whenever an adjustment of the phase of the TFO frames is necessary, then one additional TFO message shall be embedded into the next TFO frames (after the possibly ongoing TFO message). If nothing else is to be transmitted, then the TFO\_FILL message shall be used. One TFO\_TRANS message is *always* embedded into the first TFO frames. Refer to Figure 8.2-2.

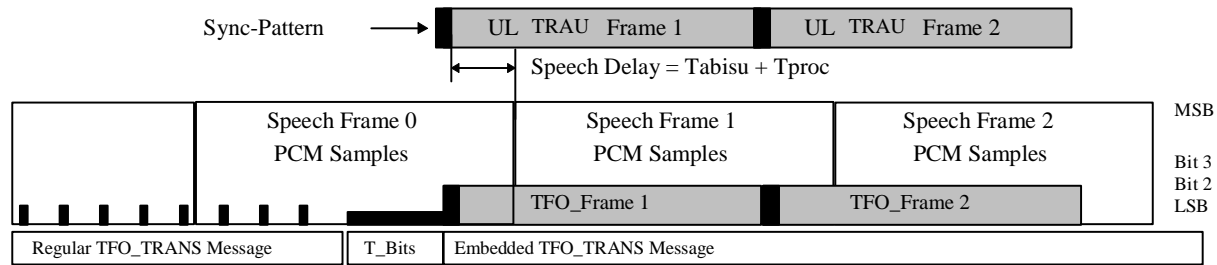


Figure 8.2-2 Time Alignment by Inserting T\_Bits and Embedding one TFO\_TRANS Message

### 8.3 Time Alignment of TFO Frames to Downlink TRAU Frames

The phase position of the downlink TRAU frames is not affected by the TFO protocol.

The phase difference between the received TFO frames and the downlink TRAU frames is in general constant, but arbitrary between 0 and 159 PCM samples. The time alignment of the TFO frames to the downlink TRAU frames is therefore managed by buffering the TFO frames within the receiving downlink TRAU. This can be done in one of two methods:

The received TFO frame is buffered for a period of 0 to 159 PCM samples in addition to the processing delay (Tbfh) required to perform a suitable Bad Frame Handling on parameter level. Transmission of the downlink TRAU frame may in this case begin **prior** to receipt of the complete TFO frame.

**Note 1:** In this first method the overall one-way signal delay is 10 to 30 ms less than the delay for normal tandem connections.

Alternatively, the received TFO frame is buffered for a period between 160 and 319 PCM samples in addition to the processing delay required to perform a suitable Bad Frame Handling on parameter level (Tbfh). Transmission of the downlink TRAU frame in this case always begins **after** the receipt of the complete TFO frame.

**Note 2:** In this second method the overall one-way signal delay is always within 10 ms of the delay in normal tandem connections.

**Note 3:** The two methods always differ in one way signal delay by exactly 20 ms. Figure 8.3-1 highlights the relationship for an arbitrarily selected relative phase difference between TFO and TRAU frames of 80 samples (10 ms). Tbfh is in the order of a few PCM samples, if error concealment is done "in advance" based on the parameters of the previous TFO frame, i.e. before the actual TFO frame is even received.

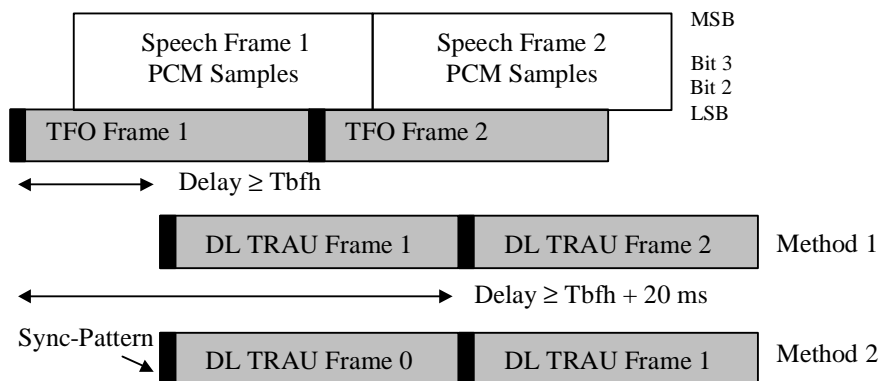


Figure 8.3-1 Downlink Time Alignment of TFO Frames

Note that repacking from TFO to TRAU frames is dependent on the TRAU frame format and the TTL interface. This format is implementation specific and the repacking may involve higher delays due to bit reordering.

## 9 Processes for Tandem Free Operation

The following sections describe the actions within the TRAU to establish and maintain Tandem Free Operation in terms of a state machine, respectively TFO processes, handling synchronization and protocol. The description of the TFO protocol does not reflect implementation details for the I/O processes, however they may need to be considered for the exact understanding of the behavior. Only the TFO protocol process is detailed, which is responsible for the handling of the TFO protocol.

The TFO\_TRAU can be regarded as consisting of five processes, which are strongly coupled to each other and run in parallel with phase shifts. The TFO protocol process communicates with the TFO I/O processes.

Under normal circumstances (exceptions occur during time alignments or octet slips) all TFO I/O processes are triggered every 160 samples or every TRAU frame of 20 ms. All events and actions are quantified in time into these smallest intervals.

It can be assumed that the processing times for the TFO processes are very short and negligible. However, it should be ensured that no timing ambiguity occurs between the processes. This means the processing and exchange of information between them do not overlap in time. Care should be taken especially when time alignment occurs, which may be completely independent in uplink and downlink.

During these time alignments, the TFO frames or TFO messages may shift in time and consequently the triggering point for the related TFO processes, also changes.

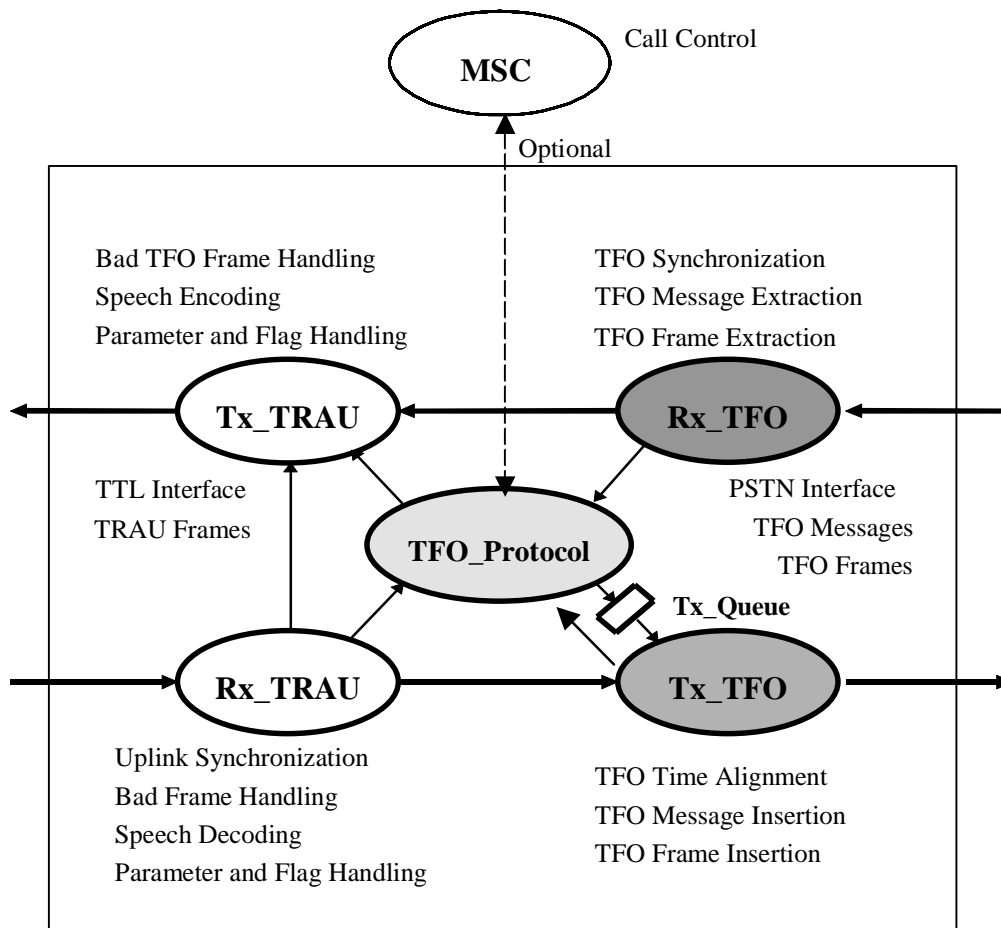


Figure 9-1 The TFO\_TRAU Consists of Five Processes

## 9.1 Rx\_TRAU Process

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The Rx\_TRAU process receives Uplink TRAU frames from the TTL interface and synchronizes to them, i.e. checks for correct synchronization and content. It performs all actions of a conventional Uplink TRAU, e.g. calls the Bad Frame Handler and the Speech Decoder.

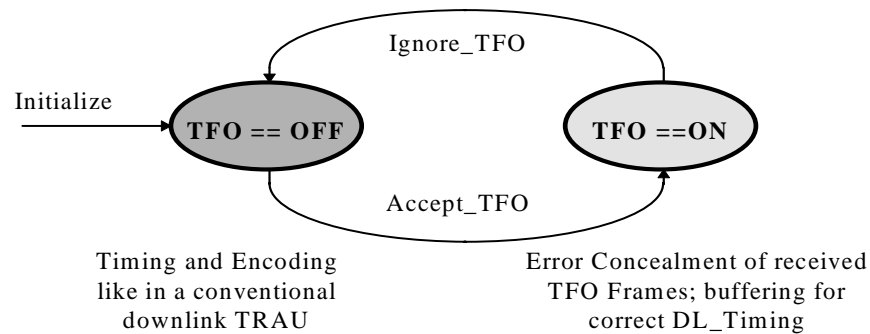
The resulting speech samples are handed to the Tx\_TFO process for output to the PSTN interface. In addition Rx\_TRAU passes the Uplink TRAU frames directly and unaltered to Tx\_TFO.

## 9.2 Tx\_TRAU Process

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The Tx\_TRAU process autonomously builds the relevant Downlink TRAU frames and sends them in the correct phase relation onto the TTL-interface as required by the TRX.

Tx\_TRAU has two states: TFO == OFF (default at beginning) and TFO == ON. Refer to Figure 9.2-1. TFO\_Protocol toggles Tx\_TRAU between these two states with commands Accept\_TFO and Ignore\_TFO.



**Figure 9.2-1 States of the Tx\_TRAU Process**

During TFO == OFF, Tx\_TRAU performs all the actions of a conventional downlink TRAU. It samples one frame of speech samples in the correct phase position and calls the Speech Encoder. The resulting speech parameters are then transmitted downlink on the TTL interface.

During TFO == ON, Tx\_TRAU performs Bad Frame Handling on the received TFO frames, if necessary. The resulting speech parameters and control bits are buffered until they are passed as Downlink TRAU frames in correct phase position to the TRX. Refer to section 8.3).

### 9.2.1 Downlink Speech Transmission if TFO is ON

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During TFO == ON, the Rx\_TFO process receives TFO frames from the PSTN interface. It synchronizes to them, i.e. checks for correct synchronization and content. It extracts the data bits and calls, if appropriate (e.g., if ECI == "1" or if the TFO frame is not valid, refer to section 9.4.2), a Bad Frame Handler to derive suitable parameters for Downlink TRAU frames. This parameter level Bad Frame Handler is implementation specific.

## 9.2.2 Synchronization and Bit Errors in Received TFO Frames

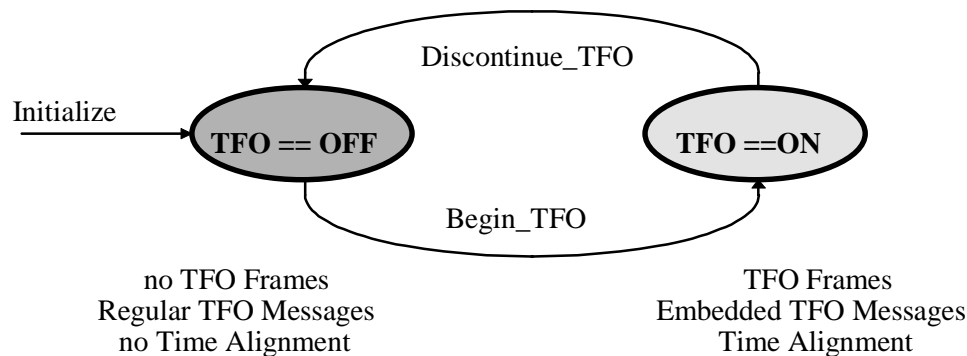
If Rx\_TFO detects an error in the received TFO frame synchronization or control bits, or if a CRC error is detected, and the error is detected **prior** to the beginning of the output of the same frame (as a Downlink TRAU frame), then Tx\_TRAU shall either substitute parameters from the last good TFO frame, or shall encode the received PCM samples for the duration of this frame.

If Rx\_TFO detects an error in the received TFO frame synchronization or control bits, or if a CRC error is detected, and the error is detected **after** the beginning of the output of the same frame (as a Downlink TRAU frame), then Tx\_TRAU shall deliberately corrupt the remaining unsent synchronization bits by setting them all to "0" and shall deliberately corrupt the remaining CRC bits. The effect of the frame error is subsequently masked by the Mobile station's handling of bad frames.

## 9.3 Tx\_TFO Process

The Tx\_TFO process receives the unaltered Uplink TRAU frames (containing the speech parameters and the control bits) and the decoded speech PCM samples from the Rx\_TRAU. It also receives internal messages (commands) from TFO\_Protocol via the Tx\_Queue.

Tx\_TFO has two states: TFO == OFF (default at beginning) and TFO == ON. Refer to Figure 9.3-1. TFO\_Protocol toggles Tx\_TFO between these two states with commands Begin\_TFO and Discontinue\_TFO.



**Figure 9.3-1 States of the Tx\_TFO Process**

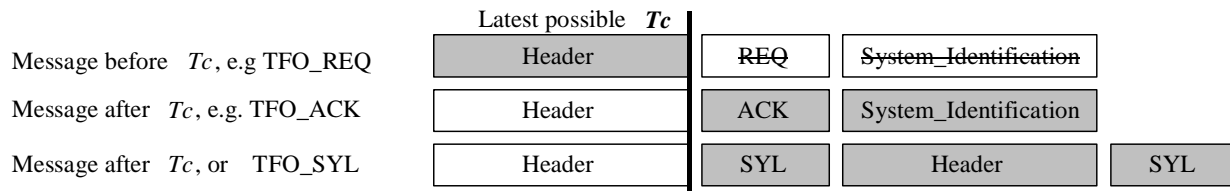
During TFO == OFF, decoded speech PCM samples and regular TFO messages (if any) are sent onto the PSTN interface. Time Alignment takes place only once, just before the beginning of the first regular TFO message.

During TFO == ON, TFO frames and embedded TFO messages (if any) are sent. Time Alignment takes place just before the first TFO frame and then whenever required in between two TFO frames.

The Tx\_TFO process builds the relevant TFO frames and sends them in the correct phase relation onto the PSTN interface. Time alignment of TFO messages and TFO frames is handled autonomously and is independent of the TFO\_Protocol process. The Rx\_TRAU informs the Tx\_TFO about any changes in the phase position of the Uplink TRAU frame and the Tx\_TFO automatically inserts the correct number of T\_Bits before the next TFO frame, and autonomously embeds the next TFO message or a TFO\_FILL message, if necessary.

The TFO\_Protocol process can send internal messages into the **Tx\_Queue** (First In, First Out). The Tx\_TFO shall take messages from the Tx\_Queue one by one, process them autonomously and send the resulting TFO messages, in correct order and phase position, as regular or embedded TFO messages. The Tx\_TFO shall generate a Runout message to the TFO\_Protocol if the last TFO message is sent without guarantee of a direct continuation by another TFO message. I.e., if present, the IPEs may run out of synchronization. The TFO\_Protocol may delete and process messages from the Tx\_Queue by using the "Clear Tx\_Queue" command at time  $T_c$ . Refer to section 11.

Basically, messages or commands that are already being processed by the Tx\_TFO at  $T_c$  cannot be stopped, deleted or interrupted. The TFO protocol is designed to work properly with this default handling, but not, perhaps, at the fastest processing speed. To increase processing speed, the Tx\_TFO can change the content of a message during transmission as long as the header is still being transmitted. Refer to Figure 9.3-2.



**Figure 9.3-2 Example of Modification of Message Content During the Header Transmission**

## 9.4 Rx\_TFO Process

The Rx\_TFO process receives TFO messages and TFO frames from the PSTN interface and synchronizes to them, i.e. checks for correct synchronization and content. It passes all PCM samples and TFO frames directly to Tx\_TRAU for further processing. The Rx\_TFO process further extracts all the control bits and TFO messages and sends corresponding Rx\_TFO messages to the TFO\_Protocol process.

### 9.4.1 Search for and Monitoring of TFO Synchronization

The monitoring of TFO frame or TFO message synchronization shall be a continuous process. Typically, TFO messages and TFO frames follow each other with a well-defined phase relation. Insertion of T\_Bits or octet slips may, however, occasionally disturb that regular phase relation and shall be taken into account. In all error cases, the receiver shall investigate, if sync has been lost due to octet slip, phase adjustment or other events and shall try to resynchronize as fast as possible.

During Tandem Free Operation it is sometimes necessary to exchange TFO messages by embedding them into the TFO frame flow. This is indicated by a control bit (C5). Some of the TFO frame synchronization bits are then replaced by bits of the TFO message. TFO messages follow specific design rules, which can be used to check if synchronization is still valid.

The first TFO message or the first TFO frame (whichever comes first) shall be completely error free to be acceptable by Rx\_TFO. After that all "valid" TFO messages (refer to section 9.4.2) shall be reported to TFO\_Protocol with a respective message. If a TFO message has been previously received and synchronization is not found again for more than 60 ms, i.e. no "present" or "valid" TFO message can be found during that time, then the Rx\_TFO shall generate an MSL (Message\_Sync\_Lost) message to the TFO\_Protocol. If a "not-valid", but "present" TFO message is received, no MSL shall be reported. The TFO message is ignored, however synchronization is not regarded as lost.

The first five "valid" TFO frames shall be reported to the TFO\_Protocol with frame number  $n$  ( $n == 1,2,..5$ ). Further valid TFO frames do not need to be reported.

If the PCM channel is available for the first time, then a PCM\_Channel\_Available message shall be sent to TFO\_Protocol. Additionally, no more PCM\_Channel\_Available messages need to be reported.

If TFO frame Synchronization is lost, or if too many errors are detected in TFO frames (no TFO frames are present), then the Rx\_TFO shall generate an FSL (Frame\_Sync\_Lost) message to TFO\_Protocol with frame number  $n$  ( $n == 1,2,3$ ), the number of lost TFO frames since the last valid TFO frame. No more than three FSL messages need to be reported in a series.

**Note:** The MSL and FSL messages are used locally at the TRAU and should not be confused with the TFO\_SYL message, by which a TFO Partner uses to report lost synchronization to its distant TFO Partner.

TFO messages with extension blocks that cannot be understood by the receiving TRAU, but which follow the design rules for IS\_Extension\_Blocks, shall be ignored. This guarantees future expandability.

### 9.4.2 Errors in TFO Messages and TFO Frames

These definitions may serve as a guideline:

A TFO message is called "**error-free**" if no error can be detected within the whole message.

1 A TFO message is called "**single-error**" if no more than one bit position differs either in the IS\_Header or the  
 2 IS\_Command\_Block or the System\_Ident\_Block or the IPE\_Mode\_Block or the Sync bits and no errors are  
 3 detectable within the CRC fields or the EX-fields.

4 A TFO message may be regarded as "**correctable**" if the phase position is as in preceding TFO messages and

- 5 • no more than 2 bit positions differ in the IS\_Header; and
- 6 • no more than 1 error is detected within the IS\_Command\_Block; and
- 7 • no more than 3 errors are detected within the IPE\_Mode\_Block; and
- 8 • no more than 3 errors are detected within the System\_Ident\_Block; and
- 9 • no more than 1 error is detected within the Sync-Bit(s); and
- 10 • no more than 0 error is detected within the EX-field(s); and
- 11 • no more than 0 error is detected within the CRC-fields; and
- 12 • the total number of detected errors is not higher than 3.

13 TFO messages which are error-free, single-error or "**correctable**" are also called "valid" TFO messages. All other  
 14 TFO messages are called "not-valid".

15 A TFO message may be regarded as "**present**", if the phase position is as in preceding TFO messages and

- 16 • no more than 4 bit positions differ in the IS\_Header; and
- 17 • no more than 2 errors are detected within the IS\_Command\_Block; and
- 18 • no more than 3 errors are detected within the IPE\_Mode\_Block; and
- 19 • no more than 3 errors are detected within the System\_Ident\_Block; and
- 20 • no more than 2 errors are detected within the Sync-Bit(s); and
- 21 • no more than 1 error is detected within the EX-field(s); and
- 22 • no more than 1 error is detected within the CRC-fields; and
- 23 • the total number of detected errors is not higher than 5.

24 Messages that do not meet the "**present**" condition may not be recognized as TFO messages at all ("**not-present**").

25 Note that the insertion of T\_Bits may change the phase position of the TFO frames and of bits of an embedded  
 26 TFO message. The TFO message shall in that case be classified after the removal of the T\_Bits.

27 An octet slip may also change the phase position of bits within a regular or embedded TFO message. If an error-  
 28 free or a single-error TFO message can be found after considering a hypothetical octet slip ( $\pm 1$  sample) then it may  
 29 be regarded as error-free or single-error and the new phase position shall be regarded as valid as long as no valid  
 30 or present TFO message can be found at the old phase position.

31 A **TFO frame** is called "**error-free**", if no error can be detected within the whole frame.

32 A TFO frame is called "**single-error**", if no more than one bit position differs either in the synchronization bits or  
 33 the T\_Bits and if no other errors can be detected.

34 TFO frames, which are error-free, or single-error are also called "**valid**" TFO frames. All other TFO frames are  
 35 called "**not-valid**".

36 A TFO frame may be regarded as "**present**", if

- 37 • no more than 4 bit positions differ in the synchronization bits
- 38 • no more than 2 errors are detected within the T\_Bits;
- 39 • no more than 1 error is detected within the control bits;
- 40 • no more than 1 error is detected within the CRC block; and
- 41 • the total number of detected errors is not higher than 5.

42 Frames that do not meet the "**present**" condition may not be recognized as TFO frames at all ("**not-present**").

43 Note that the insertion or deletion of T\_Bits may change the phase position of the TFO frames. The TFO frame  
 44 shall in that case be classified after considering the T\_Bits.

1 An octet slip may also change the phase position of bits within a TFO frame. Typically a TFO frame cannot be  
2 corrected after an octet slip, but the next TFO frame shall be found again.

3 The parameters of a valid TFO frame shall be regarded as "**bad**" if the corresponding Bad Frame Indicator (BFI) or  
4 frame loss indicator is set to 1.

## 5 9.5 TFO\_Protocol Process

---

6 The TFO\_Protocol process is typically invoked whenever a message is received, either from the Rx\_TRAU,  
7 Rx\_TFO, Tx\_TFO or the local MSC.

8 Two events are due to modifications of the local MS-MSC configuration,

- 9 • a modification of the used speech codec (New\_Local\_Codec); and
- 10 • a modification of the list of the alternative speech codecs (New\_Local\_Codec\_List).

11 The New\_Local\_Codec is extracted from the uplink TRAU frames and reported by the Rx\_TRAU.

12 The New\_Local\_Codec\_List is reported by the MSC in an implementation specific way.

### 13 9.5.1 Messages from Rx\_TRAU or local MSC

---

14 Rx == New_Speech_Call (Local_Used_Codec);	Rx_TRAU is activated by BS.
15 Rx == New_Local_Codec (New_Local_Used_Codec);	In call modification to other codec type.
16 Rx == Data_Call;	In-call modification to Data_Call.
17 Rx == Local_Codec_List;	Implementation specific, optional, from the MSC.
18 Rx == TRAU_Idle;	Implementation specific, either from the TRX or MSC.

### 19 9.5.2 Messages to Tx\_TRAU

---

20 Tx_TRAU := Accept_TFO;	If TFO frames are correctly received, they shall be used.
21 Tx_TRAU := Ignore_TFO;	TFO frames, even if received correctly, shall be ignored.

### 22 9.5.3 Messages to and from Tx\_TFO

---

23 The symbol () indicates that these messages contain parameters. Refer to section 7.

24 Tx := TFO_REQ ();	Main TFO_REQ message.
25 Tx := TFO_ACK ();	Main TFO_ACK message, response only to TFO_REQ.
26 Tx := TFO_REQ_L ();	Used in Mismatch, Operation and Periodic_Retry to inform about 27 alternative codecs. Refer to section 12.
28 Tx := TFO_ACK_L ();	Response only to TFO_REQ_L. Refer to section 12.
29 Tx := TFO_REQ_P ();	Undefined for TRAU, defined only for TCME. Refer to section C.3.1.
30 Tx := TFO_TRANS ();	Command IPEs to go transparent.
31 Tx := TFO_NORMAL;	Reset IPEs into their normal operation.
32 Tx := TFO_FILL;	Mainly to pre-synchronize IPEs.
33 Tx := Begin_TFO;	Insert TFO frames from now on.
34 Tx := Discontinue_TFO;	Discontinue inserting TFO frames.
35 Clear Tx_Queue;	Clears all remaining commands from the Tx_Queue.
36 Rx == Runout;	Reports that the continuous stream of outgoing TFO messages may be 37 interrupted.

### 9.5.4 Messages from Rx\_TFO

---

The symbol () indicates that these messages contain parameters. Refer to section 7.

Rx == TFO_REQ ()	Request from potential distant TFO Partner.
Rx == TFO_ACK ()	TFO acknowledge from distant TFO Partner.
Rx == TFO_REQ_L ()	Local codec and codec list in the case of codec mismatch.
Rx == TFO_ACK_L ()	Response to TFO_REQ_L message.
Rx == TFO_REQ_P ()	Requests another, preferred codec, plus Codec_List.
Rx == TFO_TRANS ()	May serve as alternative TFO_ACK in some cases!
Rx == TFO_NORMAL	Command IPEs to normal operation.
Rx == TFO_FILL	In general no specific meaning.
Rx == TFO_Frame ()	TFO_Frame (Distant_Used_Codec; Number_of_Received_Frames).
Rx == Frame_Sync_Lost ()	Frame_Sync_Lost (Number_of_Lost_Frames).
Rx == Mess_Sync_Lost	Message_Sync_Lost.
Rx == PCM_Channel_Available	At the beginning of a period where a PCM channel on the PSTN interface is available.

The message "TFO\_Frame ()" needs to be sent only for the first five occurrences, either after a not valid TFO frame, or if the Distant\_Used\_Codec changed.

The message "Frame\_Sync\_Lost ()" needs to be sent only for the first five occurrences of errors in TFO frames or loss of synchronization, after a correctly received TFO frame.

The message "Mess\_Sync\_Lost" is sent when no following TFO message is found after a valid TFO message.

### 9.5.5 Messages from a higher level system

---

By default a TRAU attempts TFO. A higher level system (e.g., MSC) can direct the TRAU to enter or exit Tandem Mode by using A1 interface messages. Refer to [7.].

Transcoder Control Request message, with TFO mode set to:

Tandem Mode (Inhibit_TFO)	This message is sent from a higher level system to explicitly force the TRAU into tandem mode. It is only sent after the PCM channel is available. If the state of the PSTN interface can not be evaluated from a higher level system, and is received prior to availability of the PCM channel, the message shall be queued until the PCM channel is available.
TFO (Allow_TFO)	This message is sent from a higher level system to enable TFO negotiation in the TRAU.
Transcoder Control Acknowledge message	This message is sent from the BS to the higher level system (e.g., MSC) to acknowledge whether TFO was successfully enabled or disabled in response to the mode setting request.

**Note: Interoperability issues need to be addressed when the BS and the MSC do not support these messages.**

## 10 State Machine of the TFO\_Protocol Process for CDMA

The CDMA TFO\_Protocol process can be described by a state machine, consisting of 11 states: six main states with several sub-states. Refer to Figure 10-1.

- Initialization (• Not\_Active, • Wakeup).
- Establishment (• First\_Try, • Continuous\_Retry, • Periodic\_Retry, • Monitor, • Mismatch).
- Contact (• Contact).
- Connect (• Connect)<sup>1</sup>.
- Operation (• Operation).
- Tandem (• Tandem)

It is assumed that all events (conditions checking, actions and transition to another state) are handled almost instantaneously and in any case significantly shorter than the time required to complete the transmission of any one TFO message or TFO frame.

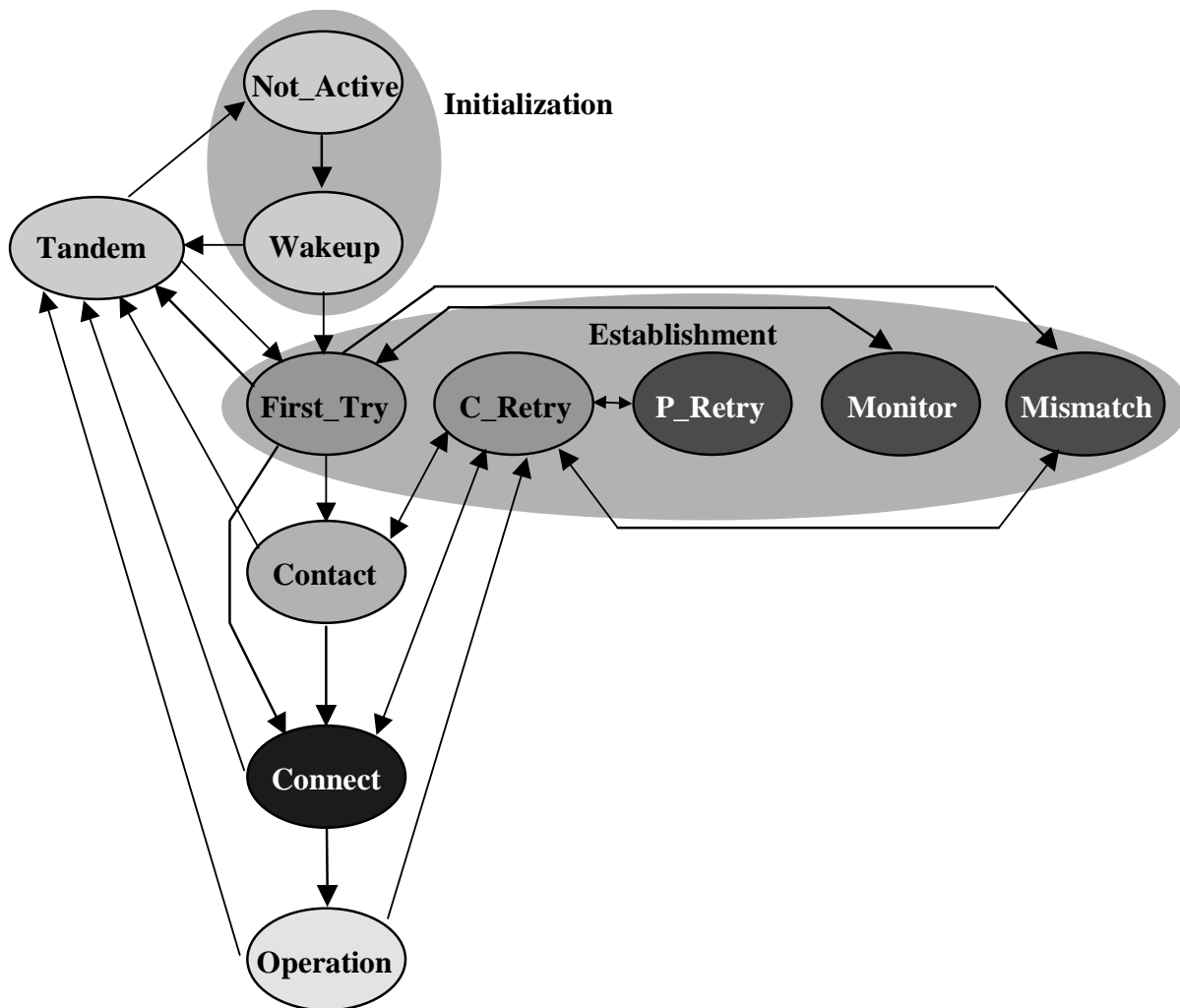


Figure 10-1 CDMA TFO\_Protocol State Machine with Most Important Transitions

<sup>1</sup> "Connect (CNN)" is the same state defined as "Konnect (KON)" in TIA/EIA-895. Only the name has been changed to correct the spelling and its abbreviation to distinguish it from "CON" used for "Contact".

## 10.1 Initialization

### 10.1.1 Not\_Active State

---

The Not\_Active state is implementation specific and is not described in detail. The TRAU basically performs no speech coding, but may monitor the link for certain patterns (e.g. idle patterns). The TRAU may be in data mode, which is implementation specific and handled here as “Not Active”.

### 10.1.2 Wakeup State

---

The Wakeup state is entered when the TRAU is activated by the appropriate event (e.g. activation by an MSC message or reception of TRAU frames). The Wakeup state is characterized by the TRAU sending speech data at least in one direction.

TFO operation begins in the Wakeup state and transitions to the First\_Try state when speech processing is performed in both the uplink and downlink directions.

## 10.2 Establishment

---

The Establishment state encompasses several slightly different situations:

First_Try	when the TRAU has started; it sends TFO_REQ messages continuously;
Continuous_Retry	when Contact to a TFO Partner has existed but was interrupted recently;
Periodic_Retry	when Contact to a TFO Partner had existed but was interrupted some time ago;
Monitor	when no TFO Partner can be found, but the TRAU continues to monitor the PSTN interface;
Mismatch	when a TFO Partner with a different codec has been identified.

Loopback is a specific situation that occurs when the call is still not connected through to the distant TRAU and the TRAU receives the same outgoing messages. No specific state is allocated to describe this situation. Instead, loopback is handled in First\_Try and Continuous\_Retry.

Common to all these situations is that the TRAU does not know, if there is a distant TFO Partner and/or if the links are digitally transparent. Typically, TFO\_REQ messages are sent and expected to be received if there is a distant TFO partner.

### 10.2.1 First\_Try State

---

The TRAU sends and receives PCM samples on the PSTN interface. Regular TFO\_REQ messages are sent on the PSTN interface continuously for a certain maximum time. If a TFO Partner does not answer within this maximum time period, Tx\_TFO reports a Runout of TFO messages, and TFO\_Protocol enters automatically into the Monitor state.

If TFO\_REQ messages are received with the same Signature, then a circuit loop back is assumed, i.e. the call is still not connected. The TRAU selects a new Signature and continues sending TFO\_REQ messages, until a different Signature is received. Since loop back delays may be substantial in some cases, the TRAU has to also remember and compare the previously used Signature. Care has to be taken that the Signature selection contains a true random element in order to minimize the probability of two different TRAU's coincidentally selecting identical signatures.

### 10.2.2 Continuous\_Retry State

---

TFO Contact had existed, either by TFO messages or by TFO frames, but was interrupted and sync was lost. The TRAU sends a maximum number of regular TFO\_REQ messages continuously to test if TFO can be re-established. If Tx\_TFO reports a Runout of TFO messages, then the TFO\_Protocol enters the Periodic\_Retry state.

### 10.2.3 Periodic\_Retry State

---

Entered from Continuous\_Retry, TFO\_Protocol periodically sends a single TFO\_REQ\_L to determine if TFO can be re-established. As soon as a TFO message is received, TFO\_Protocol leaves this state.

**Note:** Since no contiguous transmission of TFO messages is ongoing, IPEs may not be synchronized.

### 10.2.4 Monitor State

---

The TRAU monitors the PSTN interface for TFO frames and messages, however it does not send TFO frames or messages. As soon as a TFO message from a distant partner (a TRAU or a TCME) has been received, the TRAU knows that a TFO Partner exists and that the transmission path from the partner is digitally transparent.

The TRAU may already recognize that TFO is possible. However it is required to ensure that all IPEs are synchronized by transitioning into the Continuous\_Retry state. In case of codec mismatch, it terminates the TFO Protocol by sending TFO\_REQ\_L back, optionally informs its local MSC, and transitions into Mismatch.

**Note:** Since no contiguous transmission of TFO messages is ongoing, IPEs may not be synchronized.

### 10.2.5 Mismatch State

---

From a previous contact it is obvious that a distant TFO Partner exists, however the codecs do not match. The TRAU waits without sending TFO messages or TFO frames until either the distant TFO Partner changes to the Local\_Used\_Codec or the Local\_Used\_Codec is changed resulting in a match with the Distant\_Used\_Codec. Refer to section 12 for CDMA TFO codec negotiations.

**Note:** Since no contiguous transmission of TFO messages is ongoing, IPEs may not be synchronized.

## 10.3 Contact State

---

TFO\_REQ messages have been received from a distant TFO Partner. The codecs do match. The link from the distant partner is digitally transparent. Now TFO\_ACK needs to be sent to check the digital transparency of the link to the distant partner.

As soon as a TFO\_ACK or TFO\_TRANS from a distant partner has been received, the TRAU knows that the links in both directions are digitally transparent. The TRAU sends TFO\_TRANS to bypass the IPEs and starts sending TFO frames. It transitions into Connect state.

## 10.4 Connect State

---

The TRAU sends TFO frames and possibly embedded TFO messages as long as it receives correct TFO messages.

The first received TFO frame causes the transition into the final Operation state.

If no TFO frames are received within a certain period, the TRAU transitions to the Tandem state.

## 10.5 Operation State

---

This is the desired steady state of the TFO\_Protocol. In this state, the TRAU sends and receives TFO frames and the TFO connection is fully operational.

## 10.6 Tandem

---

This state is entered when either the distant partner shows an incorrect behavior or a TFO\_Inhibit command from a higher level system has been received to enter this state. The TRAU then sends pure PCM samples onto the PSTN interface. It does not send TFO frames or TFO messages.

## 11 Detailed Description of TFO\_Protocol for CDMA

The TFO\_Protocol process is always in one well-defined state. An event triggers actions and a transition into another state. The TFO protocol is described in a table-wise manner, with syntax for the state machine description as defined in Table 11-1.

**Table 11-1 Definition of the Syntax for the State Machine Description**

Event:	<Received Message>	...	<Other Event>
Number:	<running number>		<running number>
Condition:	[<Condition>]		[<Condition>]
&	[<Condition>]		[<Condition>]
Comment:	[<Comment>]		[<Comment>]
<b>State:</b>			
<Actual State>:	<Action Name>;[<Action Name>;] <Next State>; [<Comment>]		<Action Name>;[<Action name>;] <Next State>; [<Comment>]
...			
<Actual State>:	<Action Name>;[<Action Name>;] <Next State>; [<Comment>]		<Action Name>;[<Action Name>;] <Next State>; [<Comment>]

Syntax for actions is defined in Table 11-2. Actions are defined in Table 11-3.

Table 11-4 through Table 11-12 in this section describe in detail the TFO state machine. If a table entry contains only a dashed line, it is assumed that this combination cannot occur. If, however, such a combination is encountered during operation, it shall be treated as a 'don't care'.

**Table 11-2 Definition of Syntax for Action**

Name	Action List	Comment
<Action Name>	<Action >;[ <Action >;]	<Comment>
...		
<Action Name>	<Action >;[ <Action >;]	<Comment>

Action and event descriptions:

**Tx := TFO\_REQ** means, that TFO\_Protocol places a command into the Tx\_Queue. Tx\_TFO handles the details autonomously and generates a TFO\_REQ message for transmission over the PSTN interface, when it comes to that command.

**Tx := 31\*TFO\_REQ** means: put 31 TFO\_REQ commands into Tx\_Queue. Not necessarily all the commands may trigger TFO\_REQ messages. In most cases the Tx\_Queue is cleared earlier. Similar definitions hold for the other messages.

The Tx\_Queue is a first\_in\_first\_out command queue. It is filled by TFO\_Protocol and read by Tx\_TFO.

**Clear Tx\_Queue**, means that all remaining commands are immediately deleted from the Tx\_Queue (time  $T_c$ ).

Note that due to the duration time to completely transmit a TFO message, the TFO\_Protocol process is often already within another state while TFO messages commanded in earlier states are still within the Tx\_Queue or under transmission.

**MSC := TFO ()** means that a message is sent to the local MSC.

**Tx\_TRAU := ...** means a message sent to the Tx\_TRAU.

1 An event **TFO\_REQ** means that a TFO\_REQ message was correctly received on the PSTN interface. The  
2 Rx\_TFO process has sent a message to TFO\_Protocol, containing the new values for the respective variables.  
3 TFO\_Protocol updates its variables with the new values. Similar definitions hold for the other messages.

4 One timer **T** := <Time\_out> is necessary to describe time out situations. The notation **T** := **DIS** means that the  
5 timer is disabled. Positive values are decremented in a hidden background process in steps of 20 ms. When T gets  
6 to the value "0", then the TFO\_Protocol process is invoked.

7 **Local\_Used\_Codec (Luc)** means the type of speech codec used in the local TRAU.

8 **New Local\_Used\_Codec (Nluc)** refers to the new codec received in "In\_Call\_Modifications".

9 **Distant\_Used\_Codec (Duc)** means the type of speech codec used by the distant partner, as reported in TFO frames  
10 or messages such as TFO\_REQ or TFO\_ACK...

11 **Distant\_Preferred\_Codec** means the type of speech codec that the distant partner prefers, as reported in  
12 TFO\_REQ\_P.

13 **Local\_Codec\_List** means the list of all codecs that could alternatively be used; i.e., those supported by both the  
14 local MS and the local MSC. It always contains at least the Local\_Used\_Codec.

15 It is reported in TFO\_REQ\_L, TFO\_ACK\_L or TFO\_REQ\_P.

16 **Distant\_Codec\_List** means the list of all codecs that could alternatively be used; i.e., those supported by the  
17 distant MS and the distant MSC. It always contains at least the Distant\_Used\_Codec.

18 **Local\_Signature (Lsig)** means the 8-bit random number in TFO\_REQ, which identifies the local TFO\_REQ  
19 messages. It is also used in TFO\_REQ\_L.

20 **Distant\_Signature (Dsig)** means the 8-bit random number as received in the TFO\_REQ, TFO\_REQ\_L,  
21 TFO\_REQ\_P, TFO\_ACK and TFO\_ACK\_L messages.

22 If received in a TFO\_REQ, TFO\_REQ\_L or TFO\_REQ\_P message, then it should be different from the  
23 Local\_Signature, otherwise loop back may be assumed (however exceptions do exist).

24 If received in a TFO\_ACK or TFO\_ACK\_L message, then it should be identical to the Local\_Signature, otherwise  
25 the acknowledgement is not a response to the original request and may have been created during a HHO situation.

26 **Local Channel Type (LCh)** and **distant Channel Type (DCh)** refer to the 8 or 16 kbps transparent channel used  
27 by the local Tx\_TFO respectively and received by the distant TFO\_TRANS.

28 **Error protection and error handling:** It is assumed that the defined error protection is strong enough for the  
29 error rates encountered on typical PSTN interface links. The few occurring errors are in practically all cases  
30 detected and possibly even corrected by the Rx\_TFO, before being reported to the TFO\_Protocol. Therefore the  
31 TFO\_Protocol can rely on the correctness of the received events. The protocol is however, "self-healing" and can  
32 handle the unlikely erroneously reported events as well.

33 "**PCM\_Channel\_Available**" is present in the Wakeup state if valid PCM samples are received on the PSTN  
34 interface. This event can be triggered by a message from a higher level system.

35 **Timing:** If two events occur by coincidence at the same time, then they shall be processed in the order given by  
36 Table 11-4 through Table 11-12 (left to right). TFO messages always arrive some time before the embedding TFO  
37 frame and, therefore, shall be handled first.

38 **Runout** is the event, when the last TFO message has been taken from the Tx\_Queue and the last 10 bits are going  
39 to be sent by Tx\_TFO to the PSTN interface. So there is still some time for the TFO protocol to react and place a  
40 further TFO message into the Tx\_Queue, which then shall be transmitted without a gap between it and the prior  
41 messages.

42 **UNKNOWN** means that the contents of the variables are not defined.

43

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Table 11-3 Defined Actions

Name	Actions	Comments
C	Clear Tx_Queue; T := DIS;	Initialize Tx_Queue and disable the timer
T1	T := 1s;	Set Timeout to 1 second
T2	T := 2s;	Set Timeout to 2 seconds
T5	T := 5s;	Set Timeout to 5 seconds
NoAc		No Action required
S	Lsig := New_Random_Number; Old_Sig := UNKNOWN;	Generate new Signature and set Old_Sig to unknown; if no Loopback is assumed.
SO	Old_Sig := Lsig; Lsig := New_Random_Number;	Remember old Signature and generate a new Signature, if Loopback is assumed.
U	Old_Sig := UNKNOWN;	Reset Old_Sig before leaving FIT or COR
F	Tx := 3*TFO_FILL;	"Hello IPEs! Please synchronize!"
T	Tx := TFO_TRANS ();	"Hello IPEs! Please open a transparent channel!"
N	Tx := TFO_NORMAL;	"Hello IPEs! Please return to normal operation!"
REQ	Tx := 35*TFO_REQ;	"Hello Partner? Can You do TFO with me?"
ACK	Tx := 7*TFO_ACK;	"Yes, I can do TFO with you!"
L1	Tx := TFO_REQ_L;	"Here is my Codec_List! Can you hear me?"
L	Tx := 6*TFO_REQ_L;	"Here is my Codec_List, please acknowledge!"
LA	Tx := TFO_ACK_L;	"Yes, I received Your Codec_List! Here is mine!"
BT	Tx := Begin_TFO;	Begin transmission of TFO frames
DT	Tx := Discontinue_TFO;	Discontinue transmission of TFO frames
IT	Tx_TRAU := Ignore_TFO;	Tx_TRAU works as conventional downlink TRAU
AT	Tx_TRAU := Accept_TFO;	Tx_TRAU bypasses TFO_Frames

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Table 11-4 Call Setup and Loopback Handling

Event:	New_Speech_Call	PCM_Channel_Available	TFO_REQ	TFO_REQ
Number:	24	29	0	0a
Condition: &			Duc==Luc Dsig==Lsig	Duc==Luc Dsig==Old_Sig
Comment:	System activates TRAU	PSTN-interface gets active; occurs only at beginning	Loopback (LB), or distant handoff (HHO)? wrong Signature?	Loopback (LB), or distant handoff (HHO)?
State:				
<b>NAC:</b> Not_Active	C;S;IT; WAK; typ. 1 <sup>st</sup> Event	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	----- -----	C;F;REQ; FIT; typ. 2 <sup>nd</sup> Event	----- -----	----- -----
<b>FIT:</b> First_Try	----- -----	----- -----	C;SO;REQ; FIT; LB!	NoAc; FIT; Ignore LB
<b>COR:</b> Continuous Retry	----- -----	----- -----	C;SO;REQ; COR; LB!?	NoAc; COR; Ignore LB
<b>PER:</b> Periodic Retry	----- -----	----- -----	C;F;S;ACK; CON; Dist. HHO!	----- -----
<b>MON:</b> Monitor	----- -----	----- -----	C;F;S;REQ; FIT; Dist. HHO!	----- -----
<b>MIS:</b> Mismatch	----- -----	----- -----	C;F;S;ACK; CON; Dist. HHO!	----- -----
<b>CON:</b> Contact	----- -----	----- -----	C;SO;REQ; COR; safe way	----- -----
<b>CNN:</b> Connect	----- -----	----- -----	C;DT;SO;REQ;T1; COR; IPes transparent!	----- -----
<b>OPE:</b> Operation	----- -----	----- -----	C;DT;IT;SO;REQ; COR;	C;DT;IT;SO;REQ; COR;
<b>TAN:</b> Tandem	----- -----	----- -----	NoAc; TAN;	----- -----

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**Table 11-5 Most Important Cases, Especially at Call Setup**

<b>Event:</b>	<b>TFO_REQ</b>	<b>TFO_ACK</b>	<b>TFO_ACK</b>	<b>TFO_TRANS</b>	<b>TFO_FRAME</b>
Number:	1	2	3	4	5
Condition: &	Duc==Luc Dsig!=Lsig	Duc==Luc Dsig==Lsig	Duc==Luc Dsig!=Lsig	DCh==LCh	Duc==Luc
Comment:	Distant REQ	Distant ACK	Wrong Response	similar to ACK	one or more
State:	Good Signature	Good Signature	Handoff?	As response to loc ACK_?	TFO frames
<b>NAC:</b> Not_Active	----- -----	----- -----	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	----- -----	----- -----	----- -----	----- -----	----- -----
<b>FIT:</b> First_Try	C;U;ACK; CON; typical	C;U;T;BT;T;T1; CNN; typical; IPEs!	C;REQ; FIT;	NoAc; FIT; wait for frames	C;REQ; FIT; restart
<b>COR:</b> Continuous Retry	C;U;ACK; CON; typical	C;U;T;BT;T;T1; CNN; typical; IPEs!	C;REQ; COR;	NoAc; COR; wait for frames	C;REQ; COR; 1: Call is back?
<b>PER:</b> Periodic Retry	C;F;ACK; CON; OK, Contact back	C;F;S;REQ; COR; rare case, test	C;F;REQ; COR;	NoAc; PER; wait for frames	C;F;REQ; COR; 1: Call is back?
<b>MON:</b> Monitor	C;F;REQ; FIT; IPEs?	C;F;S;REQ; FIT; Rare case, test	C;F;REQ; FIT;	NoAc; MON wait for frames	C;F;REQ; FIT; 1: Call is back?
<b>MIS:</b> Mismatch	C;F;ACK; CON; Mismatch resolved	C;F;S;REQ; COR; rare case, test	C;F;REQ; COR;	NoAc; MIS; wait for frames	C;F;REQ; FIT; 1: Call is back?
<b>CON:</b> Contact	C;ACK; CON; typical: wait	C;T;BT;T;T1; CNN; typical: yes!	C;REQ; COR;	C;T;BT;T;T1; CNN; Fast way!	C;T;BT;T;T1; CNN; Missed TRANS?
<b>CNN:</b> Connect	C;DT;REQ;T1; COR; IPEs transparent!	NoAc; CNN; typical: wait	NoAc; CNN;	NoAc; CNN; typical: wait	AT;L;T2; OPE; typ: call setup
<b>OPE:</b> Operation	C;DT;IT;REQ; COR; Dist. Back off	C;DT;IT;REQ; COR; Rare case, test	C;DT;IT;REQ; COR; Rare case, test	NoAc; OPE; typ in HHO	NoAc; OPE; Main! TFO!
<b>TAN:</b> Tandem	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;

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Table 11-6 In Call Modification and Handoff

Event:	New_Local_Codec	New_Local_Codec	TFO_SYL	TFO_DUP
Number:	25	26	7	8
Condition: &	Duc==Nluc	Duc!=Nluc		
Comment:	in Call Modif. Mismatch resolv.	in Call Modif. Mismatch occurs!	the dist. TRAU lost sync	the dist. TRAU recognized HHO
State:	( Luc!=Nluc )	( Luc!=Nluc )	in OPE	
<b>NAC:</b> Not_Active	----- -----	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	NoAc; WAK;	NoAc; WAK;	----- -----	----- -----
<b>FIT:</b> First_Try	C;REQ; FIT; restart	C;REQ; FIT; restart	NoAc; FIT; HHO? Ignore	NoAc; FIT; HHO? Ignore
<b>COR:</b> Continuous Retry	C;REQ; COR;	C;REQ; COR;	NoAc; COR; ignore	NoAc; COR; ignore
<b>PER:</b> Periodic Retry	L1;T5; PER;	L1;T5; PER;	C;F;REQ; COR; rare case, test	C;F;REQ; COR; rare case, test
<b>MON:</b> Monitor	NoAc; MON	NoAc; MON	C;F;REQ; FIT; rare case, test	C;F;REQ; FIT; rare case, test
<b>MIS:</b> Mismatch	C;F;REQ; COR; Mismatch res.	L;T2; MIS; Direct info.	C;F;REQ; COR; rare case, test	C;F;REQ; COR; rare case, test
<b>CON:</b> Contact	----- -----	C;REQ; COR;	C;F;REQ; COR; rare case, test	C;F;REQ; COR; rare case, test
<b>CNN:</b> Connect	----- -----	C;DT;REQ; COR;	C;DT;REQ; COR;	C;DT;REQ; COR;
<b>OPE:</b> Operation	----- -----	C;DT;IT;REQ; COR;	C;DT;IT;REQ; COR;	C;DT;IT;REQ; COR;
<b>TAN:</b> Tandem	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;

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Table 11-7 Special Matching TFO Messages

Event:	TFO_REQ_L	TFO_REQ_L	TFO_ACK_L	TFO_ACK_L	TFO_REQ_P	TFO_REQ_P
Number:	9	10	11	12	13	14
Condition: &	Duc==Luc Dsig==Lsig	Duc==Luc Dsig!=Lsig	Duc==Luc Dsig==Lsig	Duc==Luc Dsig!=Lsig	Dsig==Lsig	Dsig!=Lsig
Comment:	Only sent in MIS/OPE/PER	Only sent in MIS/OPE/PER	Only sent in MIS		sent by TCME only embedded	sent by TCME only embedded
State:	HHO? Loop?	Codec_List	HHO?	HHO?		
<b>NAC:</b> Not_Active	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----
<b>FIT:</b> First_Try	NoAc; FIT; ignore	NoAc; FIT; ignore	NoAc; FIT; ignore	NoAc; FIT; ignore	----- -----	----- -----
<b>COR:</b> Continuous Retry	NoAc; COR; ignore	NoAc; COR; ignore	NoAc; COR; ignore	NoAc; COR; ignore	----- -----	----- -----
<b>PER:</b> Periodic Retry	C;F;S;REQ; COR; start again	C;F;REQ; COR; start again	C;F;S;REQ; COR; test	C;F;REQ; COR; test	----- -----	----- -----
<b>MON:</b> Monitor	C;F;S;REQ; FIT; test	C;F;REQ; FIT; test	C;F;S;REQ; FIT; test	C;F;REQ; FIT; test	----- -----	----- -----
<b>MIS:</b> Mismatch	C;F;S;REQ; COR; test	C;F;REQ; COR; test	C;F;S;REQ; COR; test	C;F;REQ; COR; test	S;LA; MIS; acknowledge	LA; MIS; acknowledge
<b>CON:</b> Contact	C;S;REQ; COR; safe way!	C;REQ; COR; safe way!	C;S;REQ; COR; safe way!	C;REQ; COR; safe way!	----- -----	----- -----
<b>CNN:</b> Connect	C;DT;S;REQ;T1 COR; safe way!	C;DT;REQ;T1 ; COR; safe way!	C;DT;S;REQ;T1; COR; safe way!	C;DT;REQ;T1 ; COR; safe way!	S;LA; CNN; acknowledge	LA; CNN; acknowledge
<b>OPE:</b> Operation	S;L;T2; OPE; tx Codec_List	C;LA; OPE; Ack List, stop	C; OPE; Ack ok, stop	S;L;T2; OPE; exchange list	S;LA; OPE; acknowledge	LA; OPE; acknowledge
<b>TAN:</b> Tandem	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;

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**Table 11-8 TFO Messages with Mismatching Codec Type**

<b>Event:</b>	<b>TFO_REQ</b>	<b>TFO_REQ</b>	<b>TFO_ACK</b>	<b>TFO_REQ_L</b>	<b>TFO_REQ_L</b>	<b>TFO_ACK_L</b>
Number:	15	16	17	18	19	20
Condition: &	Duc!=Luc Dsig==Lsig	Duc!=Luc Dsig!=Lsig	Duc!=Luc Dsig==?	Duc!=Luc Dsig==Lsig	Duc!=Luc Dsig!=Lsig	Duc!=Luc Dsig==?
Comment: State:	Mismatch Wrong Sig, HHO?	Mismatch Good Sig	Mismatch w/wo HHO	Mismatch Codec_List Wrong Sig, HHO?	Mismatch Codec_List	Mismatch Codec_List
<b>NAC:</b> Not_Active	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----
<b>FIT:</b> First_Try	C;S;L;T2; MIS; rare	C;U;L;T2; MIS; typical: Setup	C;U;L;T2; MIS; HHO?	C;S;LA; MIS; rare	C;U;LA; MIS; typ: Setup	C;U;LA; MIS; HHO?
<b>COR:</b> Continuous Retry	C;S;L;T2; MIS;	C;U;L;T2; MIS;	C;U;L;T2; MIS;	C;S;LA; MIS;	C;U;LA; MIS;	C;U;LA; MIS;
<b>PER:</b> Periodic Retry	C;F;S;L;T2; MIS;	C;F;L;T2; MIS;	C;F;L;T2; MIS;	C;F;S;LA; MIS;	C;F;LA; MIS;	C;F;LA; MIS;
<b>MON:</b> Monitor	C;F;S;L;T2; MIS;	C;F;L;T2; MIS;	C;F;L;T2; MIS;	C;F;S;LA; MIS;	C;F;LA; MIS;	C;F;LA; MIS;
<b>MIS:</b> Mismatch	C;S;L;T2; MIS;	C;L;T2; MIS;	C;L;T2; MIS;	C;S;LA; MIS;	C;LA; MIS; term. Protoc.	C;LA; MIS; term. Protoc.
<b>CON:</b> Contact	C;S;L;T2; MIS;	C;L;T2; MIS;	C;L;T2; MIS;	C;S;LA; MIS;	C;LA; MIS;	C;LA; MIS;
<b>CNN:</b> Connect	C;DT;S;L;T2; MIS;	C;DT;L;T2; MIS;	C;DT;L;T2; MIS;	C;DT;S;LA; MIS;	C;DT;LA; MIS;	C;DT;LA; MIS;
<b>OPE:</b> Operation	----- -----	----- -----	----- -----	NoAc; OPE; Trans. Error?	NoAc; OPE; Trans. Error?	----- -----
<b>TAN:</b> Tandem	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;

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**Table 11-9 Mismatching TFO\_TRANS and TFO\_FRAMES**

<b>Event:</b>	<b>TFO_TRANS</b>	<b>TFO_FRAME</b>	<b>TFO_FRAME</b>
Number:	21	22	23
Condition: &	DCh!=LCh	Duc!=Luc n==1	Duc!=Luc n>1
Comment:	Mismatch of channel type	Mismatch for one TFO frame	Mismatch for at least two TFO frames
State:			
<b>NAC:</b> Not_Active	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	----- -----	----- -----	----- -----
<b>FIT:</b> First_Try	C;U;L;T2; MIS; HHO?	NoAc; FIT; HHO? Be tolerant	C;U;L;T2; MIS; HHO! Mismatch!
<b>COR:</b> Continuous Retry	C;U;L;T2; MIS;	NoAc; COR; Call Forward?	C;U;L;T2; MIS;
<b>PER:</b> Periodic Retry	C;F;L;T2; MIS;	NoAc; PER; Call Forward?	C;F;L;T2; MIS;
<b>MON:</b> Monitor	C;F;L;T2; MIS;	NoAc; MON Call Forward?	C;F;L;T2; MIS;
<b>MIS:</b> Mismatch	C;L;T2; MIS;	NoAc; MIS; Call Forward?	C;L;T2; MIS;
<b>CON:</b> Contact	C;L;T2; MIS;	NoAc; CON;	C;L;T2; MIS;
<b>CNN:</b> Connect	C;DT;L;T2; MIS;	NoAc; CNN;	C;DT;L;T2; MIS;
<b>OPE:</b> Operation	NoAc; OPE; ignore?	NoAc; OPE; Hard HHO?	C;DT;L;T2;IT; MIS; Hard HHO into TFO
<b>TAN:</b> Tandem	NoAc; TAN;	NoAc; TAN;	NoAc; TAN;

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Table 11-10 Local Events, Call Termination

Event:	New_L_Codec_List	Data_Call	TRAU_Idle	TFO_FIL L	TFO_NORMA L
Number:	30	27	28	37	33
Condition: &					
Comment:	from MSC	in Call Modif. stop TFO	Internal System Command to Reset TRAU	ignore, is just Filler	ignore
State:					
<b>NAC:</b> Not_Active	NoAc; NAC;	NoAc; NAC;	NoAc; NAC;	----- -----	----- -----
<b>WAK:</b> Wakeup	NoAc; WAK;	NoAc; NAC;	NoAc; NAC;	----- -----	----- -----
<b>FIT:</b> First_Try	NoAc; FIT; update loc. Par.	C;N; NAC;	C;N; NAC;	NoAc; FIT;	NoAc; FIT;
<b>COR:</b> Continuous Retry	NoAc; COR;	C;N; NAC;	C;N; NAC;	NoAc; COR;	NoAc; COR;
<b>PER:</b> Periodic Retry	NoAc; PER;	C;N; NAC;	C;N; NAC;	NoAc; PER;	NoAc; PER;
<b>MON:</b> Monitor	NoAc; MON	C;N; NAC;	C;N; NAC;	NoAc; MON	NoAc; MON
<b>MIS:</b> Mismatch	C;L;T2; MIS; <b>direct info</b>	C;N; NAC;	C;N; NAC;	NoAc; MIS;	NoAc; MIS;
<b>CON:</b> Contact	NoAc; CON;	C;N; NAC;	C;N; NAC;	NoAc; CON;	NoAc; CON;
<b>CNN:</b> Connect	NoAc; CNN;	C;DT;N; NAC;	C;DT;N; NAC;	NoAc; CNN;	NoAc; CNN;
<b>OPE:</b> Operation	L;T2; OPE; <b>direct info</b>	C;DT;IT;N; NAC;	C;DT;IT;N; NAC;	NoAc; OPE;	NoAc; OPE;
<b>TAN:</b> Tandem	NoAc; TAN;	C; NAC; exit from TAN	C; NAC; exit from TAN	NoAc; TAN;	NoAc; TAN;

2

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Table 11-11 Special Events, Timeouts

Event:	Runout	T==0	Frame_Sync_Lost	Frame_Sync_Lost	Mes_Sync_Lost
Number:	31	32	34	35	36
Condition: &			n<3	n>2	
Comment:	IPEs may become unsynch.	Time-Out	No Action	Stop TFO frames, if 3 frames missing	
State:					
<b>NAC:</b> Not_Active	----- -----	----- -----	----- -----	----- -----	----- -----
<b>WAK:</b> Wakeup	----- -----	----- -----	----- -----	----- -----	----- -----
<b>FIT:</b> First_Try	U;N; MON PSTN Call	----- -----	----- -----	----- -----	NoAc; FIT;
<b>COR:</b> Continuous Retry	U;L1;T5; PER; at end of COR	C;N;REQ; COR; reset IPEs	----- -----	----- -----	NoAc; COR;
<b>PER:</b> Periodic Retry	NoAc; PER;	L1;T5; PER; Periodic Test	----- -----	----- -----	NoAc; PER;
<b>MON:</b> Monitor	----- -----	----- -----	----- -----	----- -----	----- -----
<b>MIS:</b> Mismatch	NoAc; MIS; typ. Final state	N; MIS; List not Ack_ed!	NoAc; MIS;	NoAc; MIS;	NoAc; MIS;
<b>CON:</b> Contact	REQ; COR; can this occur?	----- -----	----- -----	----- -----	C;REQ; COR;
<b>CNN:</b> Connect	NoAc; CNN; may happen	C;DT;N; TAN; Misbehavior!	----- -----	----- -----	C;DT;REQ;T1; COR; after Timeout: N
<b>OPE:</b> Operation	NoAc; OPE; typ. Final event	OPE; List not Ack_ed!	NoAc; OPE; 1: Alarm, go on	C;DT;IT; F;REQ; COR; 2: Alarm, stop!	NoAc; OPE; Typ. Final event
<b>TAN:</b> Tandem	NoAc; TAN; typical	----- -----	----- -----	----- -----	NoAc; TAN; don't trust!

2

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Table 11-12 System Commands

<b>Event:</b>	<b>Inhibit_TFO</b>	<b>Allow_TFO</b>
Number:	38	39
Condition: &	-	-
Comment:	System command Received	System command Received
State:		
<b>NAC:</b> Not_Active	----- -----	----- -----
<b>WAK:</b> Wakeup	TAN; 	----- -----
<b>FIT:</b> First_Try	C;N; TAN;	NoAc; FIT;
<b>COR:</b> Continuous Retry	C;N; TAN;	NoAc; COR;
<b>PER:</b> Periodic Retry	C;N; TAN;	C;F;REQ; COR;
<b>MON:</b> Monitor	C;N; TAN;	C;F;REQ; FIT;
<b>MIS:</b> Mismatch	C;N; TAN;	C;F;REQ; COR;
<b>CON:</b> Contact	C;N; TAN;	NoAc; CON;
<b>CNN:</b> Connect	C;DT;N; TAN;	NoAc; CNN;
<b>OPE:</b> Operation	C;DT;IT;N; TAN;	NoAc; OPE;
<b>TAN:</b> Tandem	NoAc; TAN;	C; F; REQ; FIT;

2

## 12 CDMA TFO Codec Negotiations

---

It is not mandatory to support the resolution of codec mismatch or codec optimization. When these features are not supported, the `Local_Codec_List` shall include only the `Local_Used_Codec`. However, in the optional case, if a TRAU sends a `Local_Codec_List` that includes more than the `Local_Used_Codec`, then it is mandatory for the system incorporating the TRAU to support the resolution of codec mismatch or the codec optimization, considering the reported `Codec_Types`.

Any additional codec types included in the `Local_Codec_List` shall be realistic alternatives at the time of transmission of the list. I.e., the system incorporating the TRAU should have a high degree of confidence that any subsequent codec negotiation or optimization to one of the additional codec types, will be successful. However, it should be recognized by the receiving TRAU that conditions at the system incorporating the transmitting TRAU may be dynamic. Thus a target codec listed in the `Local_Codec_List` may become unavailable by the time codec negotiation or optimization commences. The determination of the `Local_Codec_List` is implementation specific and outside the scope of this specification. However it shall at least include knowledge of codecs statically supported by the MS and the system incorporating the TRAU and optionally include the use of more dynamic considerations such as RF conditions and system resource allocation. Whenever the `Local_Codec_List` is changed, the list is updated and resent.

If the codec mismatch resolution or codec optimization options are supported by the local system, whenever a new `Distant_Codec_List` or a new `Local_Codec_List` becomes available, the system shall attempt to resolve the `Codec_Mismatch` or optimize the `Codec_Type` as soon as possible. This is accomplished by following the rules outlined in Table 12.3-1 and Table 12.3-2 and performing a subsequent service negotiation with the MS to the desired codec.

### 12.1 Codec Mismatch Resolution

---

If the optional codec mismatch resolution is supported, the TRAU shall exchange their codec capabilities (`Supported_Codec_List`, with the full range of parameters for these codecs) by sending `TFO_REQ_L` messages. These are acknowledged by `TFO_ACK_L` messages. The same procedure may be initiated by the distant TRAU.

The same algorithm is then run at both extremities to determine a common speech codec type to go into TFO. If no common speech codec type exists, the TRAU remain in the mismatch state. Refer to section 10.2.5. Any speech codec type listed in the supported codec set is a candidate for TFO establishment.

Once the common speech codec type is defined, each side shall modify its local used speech codec type to the common speech codec type, if necessary. This operation may involve other network elements (BSS/RAN) and is out of the scope of this specification. Once the speech codec type is set to the common speech codec type, the TRAU shall resume the TFO establishment process. **Note:** If rate set 2 codecs are included by the operator, codec negotiation may result in the selection of a higher rate codec and thus higher bandwidth requirements. (E.g. In Table 12.3-1 a leg 1 of EVRC/Q13 and a leg 2 of Q13/SMV would result in the selection of Q13).

If the codec mismatch resolution is not supported, the list of supported codec types shall be restricted to the `Local_Used_Codec`.

### 12.2 Codec Optimization

---

If the optional codec optimization is supported, the TRAU shall exchange their capabilities available for optimization by sending a `TFO_REQ_L` message, once TFO is established. The `TFO_REQ_L` message is acknowledged by `TFO_ACK_L` messages. This may trigger a codec optimization. The TFO codec optimization rules (refer to Table 12.3-1 and Table 12.3-2) determine if another common speech codec type exists with the potential to provide better speech quality or better system capacity while operating in TFO.

If the optimization leads to a new common speech codec type, both ends shall switch to the new common speech codec following the same procedure as defined in section 12.1.

The codec optimization may temporarily break TFO while the speech codec is switched to the new optimized codec type.

### 12.3 Rules for Resolving Codec Mismatch & Optimization for CDMA

CDMA codecs are selected based on their performance and bandwidth requirements, in the following descending order of preference: SMV, EVRC, Q13, and Q8. The rules for CDMA TFO codec mismatch resolution and optimization, based on this order of codec preference, are defined as follows:

1. The system incorporating the TRAU decides the content of the codec list for TFO codec mismatch resolution and optimization. All codecs included in the codec list are available for selection according to a pre-defined set of rules without additional constraints.
2. Both SMV and EVRC are rate set 1 codecs with identical coding rates. Codec mismatch resolution and codec optimization rules select SMV over EVRC as the preferred common codec if both codecs are supported by the system incorporating the TRAU.
3. Rate set 1 codecs have less bandwidth requirement than rate set 2 codecs (i.e. Q13). Codec mismatch resolution and optimization rules select SMV or EVRC over Q13, if Q13 is supported by the system incorporating the TRAU together with SMV and/or EVRC.
4. Non-Q8 codecs (SMV, EVRC or Q13) in tandem mode are preferred to Q8 codecs in TFO mode.

**Table 12.3-1 Rules for Resolving Codec Mismatch & Optimization for CDMA (SMV, EVRC & Q13)**

Radio Leg 1 (T1)	Radio Leg 2 (T2)											
	EVRC SMV, Q13	EVRC SMV	EVRC Q13	EVRC	SMV EVRC, Q13	SMV EVRC	SMV Q13	SMV	Q13 EVRC, SMV	Q13 EVRC	Q13 SMV	Q13
EVRC SMV, Q13	SMV	SMV	=	=	SMV	SMV	SMV	SMV	SMV	EVRC	SMV	Q13
EVRC SMV		SMV	=	=	SMV	SMV	SMV	SMV	SMV	EVRC	SMV	MIS
EVRC, Q13			=	=	EVRC	EVRC	Q13	MIS	EVRC	EVRC	Q13	Q13
EVRC				=	EVRC	EVRC	MIS	MIS	EVRC	EVRC	MIS	MIS
SMV EVRC, Q13					=	=	=	=	SMV	EVRC	SMV	Q13
SMV EVRC						=	=	=	SMV	EVRC	SMV	MIS
SMV Q13							=	=	SMV	Q13	SMV	Q13
SMV								=	SMV	MIS	SMV	MIS
Q13 EVRC, SMV									SMV	EVRC	SMV	=
Q13 EVRC										EVRC	=	=
Q13 SMV											SMV	=
Q13												=

The first column of Table 12.3-1 contains in each cell, a definition of the Used\_Codec in Radio Leg 1 followed on the next line by the list of supported codecs. The first row contains similar information for Radio Leg 2. The matrix elements indicate the change to be made in the Used\_Codec. For example, if a matrix element lists 'SMV', both Radio legs shall use the SMV codec. The darker (gray) shaded area is intentionally left blank, since it would otherwise contain redundant information. The '=' sign indicates that no mismatch is present or further optimization is not necessary. The 'MIS' sign indicates that codec mismatch resolution or optimization is not viable.

1 Table 12.3-2 provides similar information for Q8: IS-96 codec, 8.85 kbps (RS1) [1.].

2 **Table 12.3-2 Rules for Resolving Codec Mismatch and Optimization for CDMA (Q8)**

	Radio Leg 2 (T2)		
Radio Leg 1 (T1)	Q8 and others	others	Q8
Q8 and others	Table 12.3-1	Table 12.3-1	Q8
others		Table 12.3-1	MIS
Q8			Q8

3

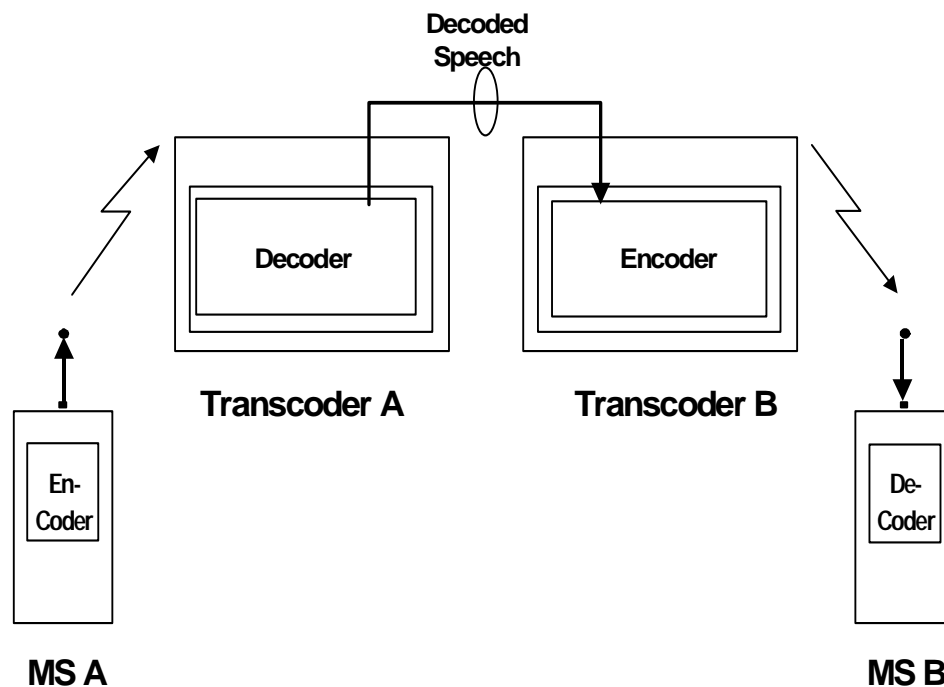


## Annex A (Normative) TFO Capability Description and Requirements

### A.1 Introduction

It is expected that the need for Tandem Free Operation will be driven by the increasing market penetration of digital technologies, which will result in an increase in the percentage of calls that are mobile-to-mobile calls. In addition, given that the effects of tandem vocoding are greater for lower bit rate vocoders, the need for this feature becomes greater as the use of low bit rate vocoders increases.

The Tandem Free Operation (TFO) feature, also known as Vocoder Bypass, improves the end-to-end voice quality observed in mobile-to-mobile voice calls in wireless networks.



**Figure A.1-1 Logical Diagram of the Speech Path for Digital Calls from MS A to MS B**

As shown in Figure A.1-1, there are four vocoders concatenated together on a mobile-to-mobile call connection without TFO. For example, the vocoder in mobile station A encodes the voice and sends it to SDU A. The vocoder in SDU A decodes the voice and sends it across the network to the vocoder in SDU B. The vocoder in SDU B encodes the voice and sends the encoded voice to the mobile station B where it is then decoded again. Each vocoder degrades the voice quality by introducing speech quantization errors that are inherent in any speech encoding and decoding processes. Also each vocoding process introduces additional throughput delay.

The “Tandem Free Operation” feature enhances current operation by bypassing the vocoding process at the SDUs for mobile-to-mobile calls. The encoded voice received from MS A is not decoded at the SDU. Instead the encoded voice is transmitted transparently through the network. The encoded speech is routed to the appropriate SDU where it is converted back to the appropriate signaling format for routing to MS B.

**Tandem Free Operation does not necessarily** decrease processing delay. PCM is still sent, synchronized to the coded speech, e.g. for easy TFO in/out.

## A.2 Scope

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Section A.3 of this annex identifies the mandatory and highly desirable requirements for TFO. Section A.3.1 was used as a basis for development of the original TFO standard [4.]. Subsequent A.3 sections have been added to identify the new capabilities supported as they have been defined in later releases of this specification.

## A.3 Tandem Free Operation Requirements

### A.3.1 Version 0.0 Mandatory Tandem Free Operation Requirements

---

The TFO Feature shall:

1. be established and maintained on successful communication between local and remote vocoders. The two TFO capable vocoders shall be linked directly with a digital connection and have no analog or digital processes, such as digital loss pad or conference bridge between them.
2. be transparent to both the mobile and land users and it should not have any operational impact on a regular mobile to land call.
3. support cdma2000 to cdma2000 mobile to mobile voice calls.
4. not prevent voice calls between any 2G or 3G systems regardless if TFO is implemented.
5. support TFO between two mobile stations that are on the same MSC.
6. support TFO between two mobile stations that are on different MSCs within the same operator's network. This includes calls which transit other networks but terminate on MSCs within the same operator's network.
7. support inter-MSC TFO within two different operator's networks using a single technology, subject to other restrictions. This includes calls, which transit other networks but terminate on MSCs within the different operator's networks.
8. provide within the standard the ability to inactivate echo cancellers while this feature is enabled, and activate echo cancellers while this feature is disabled. This feature shall not be enabled if echo canceller control is not possible.
9. neither impact nor be impacted by soft handoff (i.e., TFO and soft handoff function independently).
10. support TFO both before and after hard handoff when the vocoder type is the same. Support disabling of TFO after hard handoff when the vocoder types are different.
11. support establishment of TFO mode following interruptions, such as supplementary service (e.g., 3-Way calling, etc.) and hard handoff.
12. not preclude inband or out-of-band transmission of DTMF. This feature may be temporarily disabled to support transmission of DTMF. This requirement shall not add new DTMF generation requirements.
13. not be restricted to mobile-to-mobile calls as long as conditions for TFO exist. For instance, either endpoint of a call may be a fixed wireless terminal.
14. not be required to be supported across an international gateway, for example, T1 to E1, A-law to mu-law.
15. be capable of functioning in a system that makes use of existing SS7 (ISUP) without impact to signaling and TIA/EIA-41 on the Network-Network interface.
16. be backwards compatible to a 2G system, i.e., the solution shall function in 2G systems updated with this feature.
17. avoid impacts to SS7 (ISUP) signaling.
18. result in perceived voice quality equal to or better than that of the same call without the use of TFO.
19. have minimal impact on supplementary services, e.g., Call Forwarding, Call Waiting, 3-Way Calling. However, supplementary services shall take precedence over TFO.

- 1 20. allow Lawfully Authorized Electronic Surveillance without degradation of voice quality perceived by the  
2 mobile users.
- 3 21. not cause further degradation to perceived voice quality during bad frames compared to the same call  
4 without the use of TFO.
- 5 22. not result in degradation to the perceived voice quality in the presence of link impairments (e.g., jitter,  
6 insertion of gain or loss padding) between the two speech processing units compared to the same call  
7 without use of TFO. This feature may be disabled under persistent link impairment conditions.
- 8 23. support a system that automatically attempts to use TFO when all necessary conditions are met, and the  
9 network operator enables the feature. Specifically, the call shall be a mobile-to-mobile voice call or fixed  
10 wireless call using the same vocoder type (algorithm) and no supplementary services prevent the use of  
11 TFO.
- 12 24. avoid negative audible impacts on the perceived voice quality during transition to and from TFO mode,  
13 e.g., during call setup, during handoff, or at the start and stop of supplementary service activities.
- 14 25. be able to be established within 2 seconds of stable call setup, i.e., a trunk has been established between  
15 the two SDUs that contains no echo cancellers or other disruptions
- 16 26. allow TFO mode to be established for the active call during the use of Call Waiting when the criteria for  
17 TFO mode are met. That is, when the mobile station is connected to a second call as a result of call  
18 waiting or call transfer operations and the TFO mode criteria are met, then TFO mode shall be  
19 established.
- 20 27. be capable of allowing the network operator to prevent the establishment of TFO, even if the conditions  
21 exist for TFO mode.
- 22 28. support the ability of the network at either end of the call to reject establishment of TFO mode.
- 23 29. provide support for the use of TFO calls between any 2G and 3G systems when compatible TFO  
24 implementations exist in those systems.
- 25 30. support the following network configurations (assuming that other necessary conditions for TFO are met):  
26
  - Intra-operator, intra-MSC and inter-MSC: direct trunks between MSCs or call delivery via PSTN.
  - 27 • Inter-operator: direct trunks between MSCs or call delivery via PSTN.
- 28 31. not be required to work when the span types or companding (A-law /  $\mu$ -law) are not in agreement.
- 29 32. support transmission across 64 kbps clear channels.
- 30 33. allow for TFO operation following cellular network call forwarding to another mobile. (e.g. call  
31 forwarding no answer)
- 32 34. require encoding and decoding processes internal to the speech handlers be reactivated on the completion  
33 of a mobile to mobile connection, or on the interruption of a clear digital channel between two TFO  
34 capable speech applications such as by a digital loss, handoff, conference bridge, etc.

### 35 **A.3.2 Version 1.0 Mandatory Tandem Free Operation Requirements**

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36 This version of the TFO standard shall:

- 37 1. provide support for transmission of DTMF tones in tandem or TFO mode.
- 38 2. be able to interwork with previous versions of TFO.

### 39 **A.3.3 Version 2.0 Mandatory Tandem Free Operation Requirements**

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40 This version of the TFO standard shall:

- 41 1. provide for negotiation towards the use of a common vocoder for the duration of the call in order to establish  
42 TFO.
- 43 2. support the Selectable Mode Vocoder (SMV).

- 1 3. support the UMTS system identification.
- 2 4. be able to interwork with previous versions of TFO.

### 3 **A.3.4 Highly Desired Tandem Free Operation Requirements**

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4 The TFO Feature may:

- 5 1. provide support of calls other than cdma2000 to cdma2000 mobile-to-mobile calls, such as cdma2000 to GSM,  
6 TDMA, or Voice over IP (VoIP).
- 7 2. minimize impacts to 2G systems to support TFO. (Example: networks using echo cancellers, gain/loss pad, or  
8 voice compression.)
- 9 3. allow compatibility with the voice over IP (VoIP) standards.
- 10 4. permit, as part of the setup negotiation process, either end of the system to transcode directly from one vocoder  
11 to another. When transcoding is employed, the system using it could identify to the other end the type of  
12 transcoding in use, thus possibly avoiding the use of two transcoders.
- 13 5. minimize the impact on standards and functions other than those related to speech processing.
- 14 6. support an ATM based interface to permit direct MSC to MSC and BSC to BSC transmission of vocoder  
15 frames, thereby reducing the bandwidth requirements between serving systems.
- 16 7. define a means to allow a CDMA system to communicate between the TFO process and the MSC.

17

## Annex B (Normative) IS Protocol: Generic Structure

### B.1 Scope

IS messages can be used to construct a specific IS protocol for the communication between telecommunication entities for various purposes. The original purpose was to establish tandem free operation of mobile-to-mobile calls in mobile networks. IS messages provide the communication channels inside the speech signal paths between the speech transcoders. In addition, IS messages allow for the control of equipment within the speech signal paths between the telecommunication entities (e.g. speech transcoders). This equipment is termed "In Path Equipment" (IPEs).

Annex B defines the generic structure of these IS messages and rules for the IS Sender.

Annex B is mandatory for TFO\_TRAU equipment and informative for IPEs.

### B.2 Generic Structure of Inband Signaling Messages

All IS messages follow a set of design rules, or a generic structure, which allows IPEs to identify and pass them without detailed knowledge of the IS protocol served. The principle of the IS protocol shall in that sense be future proof: it can be enhanced and extended to other applications without modifying the IPEs. The IS messages replace some of the LSBs of the PCM samples of the speech, audio or modem signal. By design the introduced signal distortion is practically inaudible in the case of speech signals. Modem signals are generally not affected with respect to their data transmission performance.

#### B.2.1 Frequency and Order of Bit Transmission

IS messages are transferred within the Least Significant Bit (LSB) of PCM samples on 64 kbps links, by replacing the LSB of every 16<sup>th</sup> consecutive PCM sample with one bit of the IS message (16\_PCM\_Sample\_Grid). This is equivalent to an average bit rate of 10 bit per 20 ms or 500 bits per second. Refer to Figure B.2.1-1.

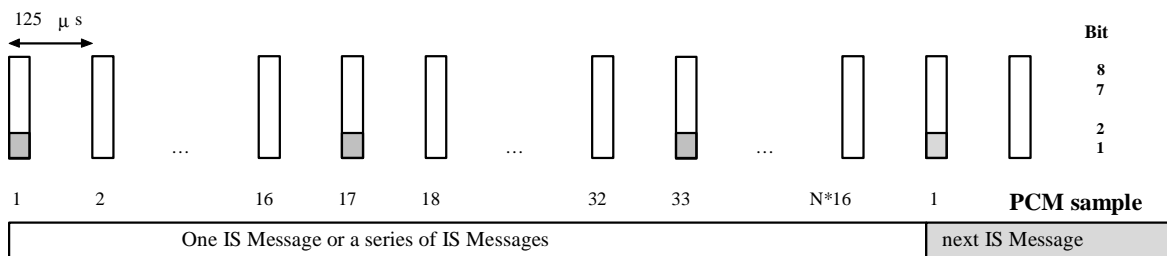


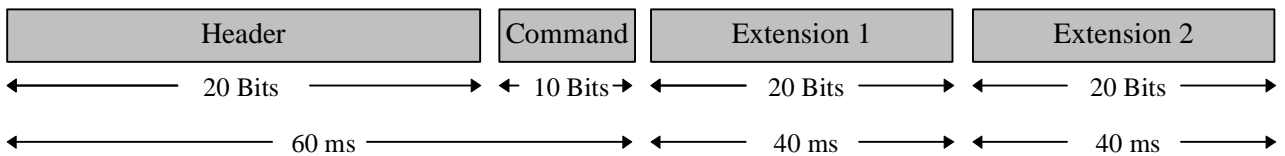
Figure B.2.1-1 Inband Signaling Structure

A vertical bar denotes an 8-bit PCM sample, the shadowed box in bit 1 (LSB) represents an inserted bit of the IS message.

By definition each IS message "occupies" an integer multiple of 16 PCM samples. Especially the 15 PCM samples after the last inserted bit of an IS message "belong" still to that IS message.

All IS messages, whichever type, have by design "0"-bits at every 10<sup>th</sup> position, starting with position 1, 11, 21 and so on. These "0"-bits therefore occur regularly every 20 ms and may be used for synchronization purposes.

Each IS message consists of an IS\_Header followed by an IS\_Command\_Block. Most IS messages have a number of further IS\_Extension\_Blocks. Figure B.2.1-2 shows an example with two IS\_Extension\_Blocks.



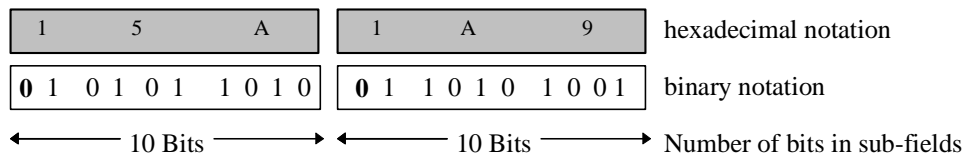
**Figure B.2.1-2 Example for IS Message with two IS\_Extension\_Blocks**

The MSB of each constituent field is transmitted first. The IS\_Header is transmitted first, followed by the IS\_Command\_Block and, if applicable, any further IS\_Extension\_Block(s).

By design all IS messages do have lengths of integer multiples of 10 bits, thus occupying integer multiples of 160 PCM samples, thus lasting integer multiples of 20 ms. The shortest IS message has a length of 60 ms.

**B.2.2 IS\_Header**

The IS\_Header consists of a 20-bit long sequence, as defined in Figure B.2.2-1.



**Figure B.2.2-1 Structure of the 20-bit IS\_Header**

**B.2.3 IS\_Command\_Block**

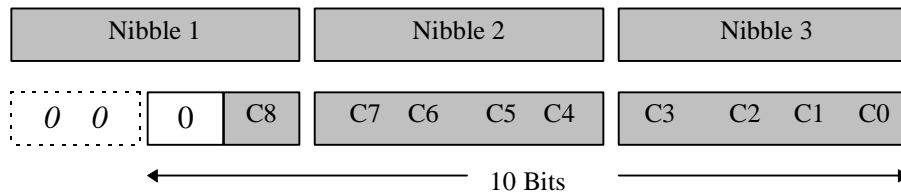
The IS\_Command identifies the IS message and/or serves as the control of IPEs. The names of the IS\_Commands and their codes in hexadecimal notation in the IS\_Command\_Block are given in the Table B.2.3-1.

**Table B.2.3-1 Defined IS\_Commands**

Index	Command	Code (hexadecimal Nibble 1-3)	Meaning / Action
0	reserved	0x000	No extension
1	<b>REQ</b>	0x05D	Denotes an IS_REQ message, with extension
2	<b>ACK</b>	0x0BA	Denotes an IS_ACK message, with extension
3	<b>IPE</b>	0x0E7	Denotes an IS_IPE message, with extension, i.e. an IS_TRANS or the IS_NORMAL message
4	<b>FILL</b>	0x129	Denotes the IS_FILL message, no extension
5	<b>DUP</b>	0x174	Denotes the IS_DUP message, no extension
6	<b>SYL</b>	0x193	Denotes the IS_SYL message, no extension
7	reserved	0x1CE	No extension

All other values are reserved for future use.

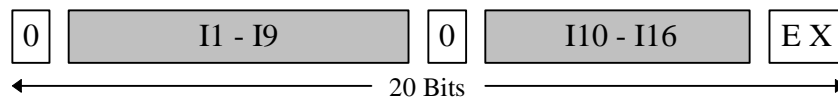
Each IS\_Command is protected by the binary, systematic (9,3) block code with generator polynomial  $g(x) = x^6 + x^4 + x^3 + x^2 + 1$ . The minimum Hamming distance of this code is  $d_{min} = 4$ , which allows the correction of up to one bit error within each code word of length 9 bits. The first bit (MSB) of the IS\_Command\_Block is defined to be "0", for synchronization purposes. Refer to Figure B.2.3-1.



1  
2 **Figure B.2.3-1 General Design of an IS\_Command\_Block**

3 **B.2.4 IS\_Extension\_Block(s)**

4 Most IS messages have one or more IS\_Extension\_Block(s). Each IS\_Extension\_Block is 20 bits long and shall  
5 consist of two "0"-Synchronization\_Bits at position 1 (MSB) and 11, a 16-bit Information\_Field (split into two  
6 fields of 9 and 7 bits, respectively) and a 2-bit Extension\_Field (EX). Refer to Figure B.2.4-1.



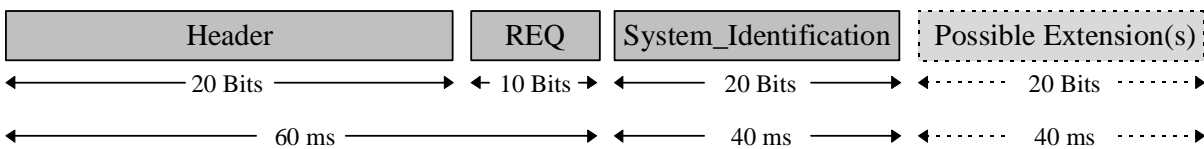
7  
8 **Figure B.2.4-1 General Design of an IS\_Extension\_Block**

9 The Extension\_Field indicates if another IS\_Extension\_Block is following (EX := "1.1") or not (EX := "0.0").  
10 All other codes are reserved. This may be used to detect transmission errors within the Extension\_Field.

11 **B.3 Detailed Specification of IS Messages**

12 **B.3.1 IS\_REQ Message**

13 The IS\_REQ message enables an IS Sender to test if there is an IS Partner and whether it is able to negotiate.  
14 IS\_REQ is used to initiate the IS protocol or to indicate changes in the configuration, etc.  
15 IS\_REQ has at least one IS\_Extension\_Block, containing the IS\_System\_Identification. Refer to section B.6.  
16 Other IS\_Extension\_Blocks may follow. Refer to Figure B.3.1-1.



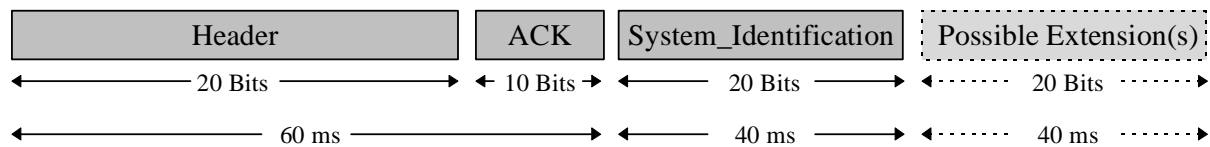
17  
18 **Figure B.3.1-1 General Design of an IS\_REQ Message**

19 In general an IS\_REQ message shall be as short as possible. Special care should be taken in the design of the  
20 IS\_Extension\_Blocks to avoid audible effects, since sometimes an IS\_REQ message may be transmitted for quite  
21 some time (several seconds).

22 **B.3.2 IS\_ACK Message**

23 An IS Partner typically answers an IS\_REQ message with an IS\_ACK message. The IS\_ACK message can also be  
24 used to submit further information to the other IS Partner. IS\_REQ and IS\_ACK are the main message types  
25 between IS Partners.

26 The IS\_ACK has at least an IS\_Extension\_Block containing the IS\_System\_Identification. Refer to section B.6.  
27 Other IS\_Extension\_Blocks may follow. Refer to Figure B.3.2-1.



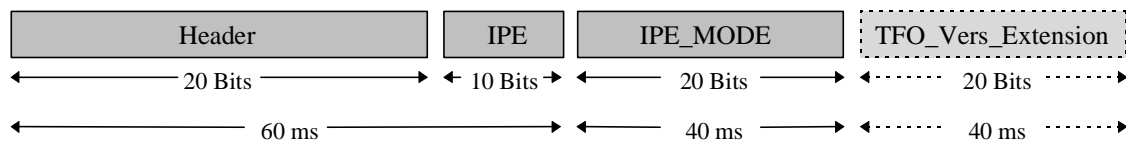
**Figure B.3.2-1 General Design of an IS\_ACK Message**

No specific design constraints, with respect to audibility, are provided in this specification since IS\_ACK is typically not sent very often.

**B.3.3 IS\_IPE, IS\_TRANS and IS\_NORMAL Messages**

The IPE command denotes IS\_IPE messages. An IPE shall always look for this type of message and follow the instruction. An IS Sender shall use this IS\_IPE message to command all IPEs into a specific mode of "Bit Transparency".

This message has one mandatory IS\_Extension\_Block, indicating the requested IPE\_Mode and one auxiliary TFO\_Vers\_Extension\_Block, indicating the CDMA TFO version. Refer to Figure B.3.3-1.



**Figure B.3.3-1 General Design of an IS\_IPE Message**

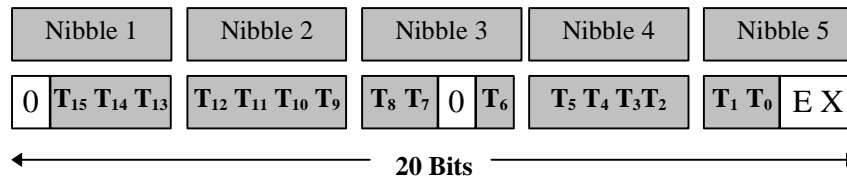
No specific design constraints, with respect to audibility, are provided in this specification since IS\_IPE is typically not sent very often.

Table B.3.3-1 defines 16 out of 32 possible IPE\_Commands. The other codes are reserved for future extensions.

**Table B.3.3-1 Defined IPE\_Modes**

Index	IPE_Mode	Code (Hexadecimal Nibble 1 - 5)	MEANING / ACTION
0	Normal	0x0000	normal Operation
1	Trans_1_u	0x044DC	pass 1 LSB; 7 upper bits are used
2	Trans_2_u	0x089B8	pass 2 LSBs; 6 upper bits are used
3	Trans_3_u	0x0CD64	pass 3 LSBs; 5 upper bits are used
4	Trans_4_u	0x11570	pass 4 LSBs; 4 upper bits are used
5	Trans_5_u	0x151AC	pass 5 LSBs; 3 upper bits are used
6	Trans_6_u	0x19CC8	pass 6 LSBs; 2 upper bits are used
7	Trans_7_u	0x1D814	pass 7 LSBs; 1 upper bit is used
8	Transparent	0x22CE0	full Transparent Mode for all eight bits
9	Trans_1	0x2683C	pass 1 LSB; 7 upper bits are free and unused
10	Trans_2	0x2A558	pass 2 LSBs; 6 upper bits are free and unused
11	Trans_3	0x2E184	pass 3 LSBs; 5 upper bits are free and unused
12	Trans_4	0x33990	pass 4 LSBs; 4 upper bits are free and unused
13	Trans_5	0x37D4C	pass 5 LSBs; 3 upper bits are free and unused
14	Trans_6	0x3B028	pass 6 LSBs; 2 upper bits are free and unused
15	Trans_7	0x3F4F4	pass 7 LSBs; 1 upper bit is free and unused
16	reserved	0x41D1C	reserved
17...31	reserved	Reserved	reserved

1 The IPE\_Mode is protected by the binary, systematic (16,5) block code with generator polynomial.  
 2  $g(x) = x^{11} + x^7 + x^5 + x^4 + x^2 + x + 1$ . The minimum Hamming distance of this code is  $d_{min}=7$ , which  
 3 allows the correction of up to 3 bit errors within each code word of length 16 bits.  
 4 Bits 1 (MSB) and 11 are the synchronization bits and set to "0". Refer to Figure B.3.3-2. The EX field is set to  
 5 "0.0" when no further IS\_Extension\_Block is following. The EX field is set to "1.1" when a TFO\_Vers\_Extension  
 6 Block follows.  
 7 Table B.3.3-1 defines the coding in hexadecimal notation for the complete IPE\_Mode\_Extension\_Block, with EX  
 8 := 00.



9  
 10 **Figure B.3.3-2 IPE\_Mode\_Extension\_Block for the IS\_IPE Message**

11 An IS\_IPE message containing the NORMAL command is termed an **IS\_NORMAL message**.  
 12 An IS\_IPE message containing a TRANS\_x command is termed an **IS\_TRANS\_x message**.  
 13 An IS\_IPE message containing a TRANS\_x\_u command is termed an **IS\_TRANS\_x\_u message**.  
 14 The latter two are sometimes also termed **IS\_TRANS** messages, if the details are not important.  
 15 The behavior of IPEs, when receiving such commands, is described in Annex C.  
 16 The first IS message in a series is often "swallowed" by IPEs. Refer to Annex C. An IS\_IPE message therefore  
 17 shall never be the first message of a series of IS messages, i.e. it shall be sent as an isolated IS message or after an  
 18 (sufficiently long) uninterrupted IS protocol.  
 19 The 20-bit version extension block shall be transmitted as part of the IS\_TRANS messages immediately before and  
 20 during transmission of the first TFO frame on successful TFO negotiation and establishment. It is optionally  
 21 transmitted as part of the TFO IPE messages during TFO operation. Section 5.3 describes the TFO version number  
 22 assumptions and requirements in details. This block carries two version fields. Bits 2 through 4 form the main  
 23 version field, which is updated for new releases containing major revisions or feature updates. Bits 5 through 7  
 24 form the sub-version field, which is updated for new releases containing minor feature updates or corrections. Bits  
 25 8 through 10 contain a 3-bit CRC, as defined in section 7.1.2, covering the two version fields. Table B.3.3-2  
 26 presents the bit mapping for the TFO version extension block.

27 **Table B.3.3-2 TFO\_Vers\_Extension Block**

Bit	Description	Comment
Bit 1	"0"	Normal IS message Sync Bit, Constant.
Bit 2 .. 4	Main version number	This field is incremented for major revision or feature updates.
Bit 5 .. 7	Sub-version number	This field is incremented for minor feature updates or corrections.
Bit 8 .. 10	CRC	Cover bits 2 through 7. Refer to section 7.1.2.
Bit 11	"0"	Normal IS message Sync Bit, Constant.
Bit 12 .. 18	Reserved	
Bit 19..20	EX EX == "0.0" EX == "1.1"	The normal 2 bits for IS message extension. EX == "0.0": No other extension follows EX == "1.1": Another TFO_Vers_Extension block follows.

### B.3.4 IS\_FILL Message

---

The IS\_FILL message has no IS\_Extension\_Block and no specific meaning. An IS Sender can use the IS\_FILL message to fill a temporary gap in the protocol flow. This may be important to keep all IPEs in synchronization and open for further IS messages. Refer to Figure B.3.4-1. An IS\_FILL message shall also be used by the IS Sender to resynchronize all IPEs in case of a phase shift of the Keep\_Open\_Indication.

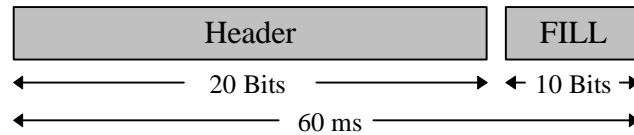


Figure B.3.4-1 Design of the IS\_FILL Message

IS\_FILL is designed in a way that multiple repetitions cause minimal audible effects.

### B.3.5 IS\_DUP Message

---

The IS\_DUP message may be used between IS Partners to indicate a half-duplex mode. It may be especially important in HHO situations. The IS\_DUP message has no IS\_Extension\_Block. Refer to Figure B.3.5-1.

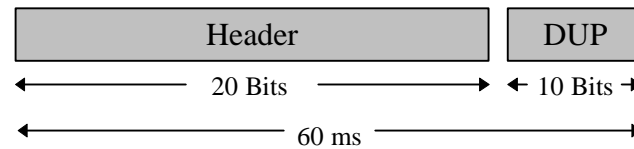


Figure B.3.5-1 Design of the IS\_DUP Message

### B.3.6 IS\_SYL Message

---

The IS\_SYL message may be used between IS Partners to indicate the loss of synchronization. It may be especially important in HHO situations. The IS\_SYL message has no IS\_Extension\_Block. Refer to Figure B.3.6-1.

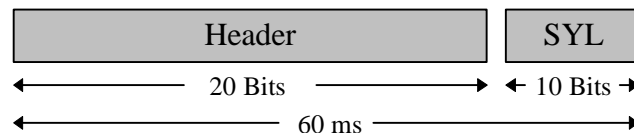


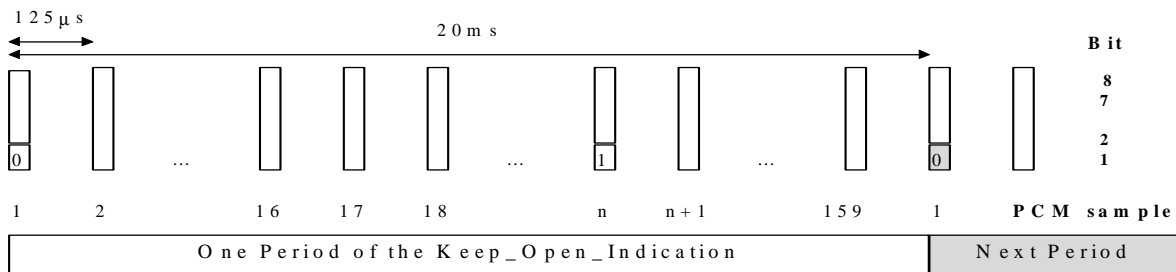
Figure B.3.6-1 Design of the IS\_SYL Message

## B.4 Keep\_Open\_Indication

---

In Transparent\_Mode, i.e. after properly receiving an IS\_TRANS message, all IPEs shall monitor the passing bit stream for the Keep\_Open\_Indication (definition see below). If this Keep\_Open\_Indication is not seen for some time, then the IPEs shall automatically fall back into normal operation, i.e. the mode of operation before the IS\_TRANS message. This automatic fall back shall have the same effect as the IS\_NORMAL message would have.

By definition, the Keep\_Open\_Indication is a continuous bit stream of one "0"-bit in the LSB of every 160<sup>th</sup> PCM sample, i.e. every 20 ms. At least one "1"-bit shall be present within the LSBs of the other 159 PCM samples. Refer to Figure B.4-1.



**Figure B.4-1 Keep\_Open\_Indication**

The "0"-bit stream of the Keep\_Open\_Indication shall always be present as long as the IPEs need to be in Transparent\_Mode.

The Keep\_Open\_Indication shall be in phase with the preceding IS messages; i.e., the first bit of the Keep\_Open\_Indication shall be in the position of the first bit of the (hypothetical) next IS message. In fact, the IS messages themselves contain this Keep\_Open\_Indication by definition.

In case of a known phase shift of the Keep\_Open\_Indication, the IS Sender is required to send at least one IS message, which defines the new phase position of the Keep\_Open\_Indication. If no other IS message is to be sent, then the IS\_FILL message shall be used. If an IS message longer than 160 ms is scheduled for transmission, then an IS\_FILL message should be inserted before, to guarantee fast resynchronization of the IPEs.

## B.5 Rules for Sending of IS Messages

IS messages replace some bits of the PCM samples and therefore causes a minimal signal distortion. Therefore IS messages shall be used with care and not longer than necessary. The IS protocol is kept to a minimum to avoid unnecessary complexity. One basic assumption is that only one IS protocol is active at a time between two IS Partners.

Only specific telecommunication entities shall be allowed to initiate IS protocols. They are called **IS\_Active** or active IS Partners. In principle these shall only be terminal devices or their "representatives" within the network. Examples are ISDN-Terminals, Speech-Servers, and TRAU's (in mobile networks as representatives of the MSs).

Other telecommunication entities shall only react on IS protocols. They are called **IS\_Passive**. Most IPEs are of this type. They pass the IS messages, they obey the IS\_IPE messages, but they never initiate IS messages.

Other telecommunication entities are IS\_Passive by default. But if they receive IS protocols that they can understand, then they may become IS\_Active and start to initiate IS protocols. They thus become active IS Partners and shall take care that only one IS protocol is active on both of their sides. They are called **IS\_Responsive**. Examples are TCMEs.

Active IS Partners shall send either continuous sequences of IS messages without interruption of the 16\_PCM\_Sample\_Grid or

- isolated IS messages with same message lengths; or
- isolated IS messages with sufficient distance between them, if shorter IS messages follow longer IS messages.

The latter case is important; because shorter isolated IS messages travel faster through IPEs than longer ones. Refer to section C.3.2.3.

As said above, after initialization of an IS message sequence, no interruption of the 16\_PCM\_Sample\_Grid shall occur within the sequence. Adjustments of the phase position of the Keep\_Open\_Indication shall be done only after the IS\_TRANS message by inserting the necessary number  $n$  (with  $0 < n < 160$ ) of "1" bits (termed "T\_Bits") into the LSBs of the PCM samples that have to be skipped. The first PCM sample for this insertion of T\_Bits is the one where the next regular IS message or next regular Keep\_Open\_Indication would begin. At the new phase position the next IS message or the IS\_FILL message shall be sent, to allow IPEs to resynchronize fast. Refer to Figure B.3.5-1.

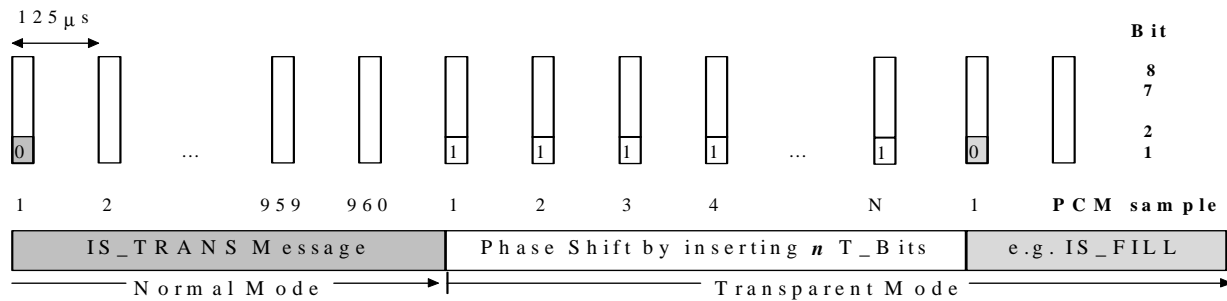


Figure B.3.5-1 Phase Shift of the 16\_PCM\_Sample\_Grid by Inserting T\_Bits

Similarly, the adjustment of the phase between two Keep\_Open\_Indications shall be done by inserting the necessary number of T\_Bits and by sending an IS message - preferably, but not necessarily - the IS\_FILL.

Finally a "negative" phase adjustment between two Keep\_Open\_Indications shall be allowed by shortening the cycle by a maximum of two PCM samples and sending an IS message (see above) at the new phase position.

### B.6 IS\_System\_Identification\_Block

The IS\_System\_Identification\_Block is a mandatory IS\_Extension\_Block for the IS\_ACK and IS\_REQ messages with the 16-bit Information\_Field containing the IS\_System\_Identification. It identifies the system from which the message is generated. Table B.6-1 shows the defined IS\_System\_Identification codes.

Table B.6-1 Defined IS\_System\_Identification Codes

System	SysID (S1..S8)	Code (in hex)	
		if EX == 0.0	if EX == 1.1
GSM	0000.0000	0x53948	0x5394B
TDMA	0000.0001	0x53414	0x53417
cdma2000	0000.0010	0x528AC	0x528AF
UMTS	0000.0100	0x51C80	0x51C83
All other code points	Reserved	Reserved	Reserved

The only codes defined in this specification are: GSM\_Identification, TDMA\_Identification, cdma2000\_Identification and UMTS\_Identification. All other codes are reserved. Additional IS\_System\_Identification codes for other systems shall be defined in a way that their audibility is minimal and the hamming distances to the already defined codes is maximal.

The IS\_System\_Identification is protected by the binary, systematic (16,8) block code with generator polynomial  $g(x) = x^8 + x^7 + x^6 + x^4 + x^2 + x + 1$ . The minimum Hamming distance of this code is  $d_{min}=5$ , which allows the correction of up to 2 bit errors within each code word of length 16 bits.

Code word 0x0000 = 0000.0000.0000.0000 is per definition used for GSM.

Code word 0x01D3 = 0000.0001.1101.0111 is per definition used for TDMA.

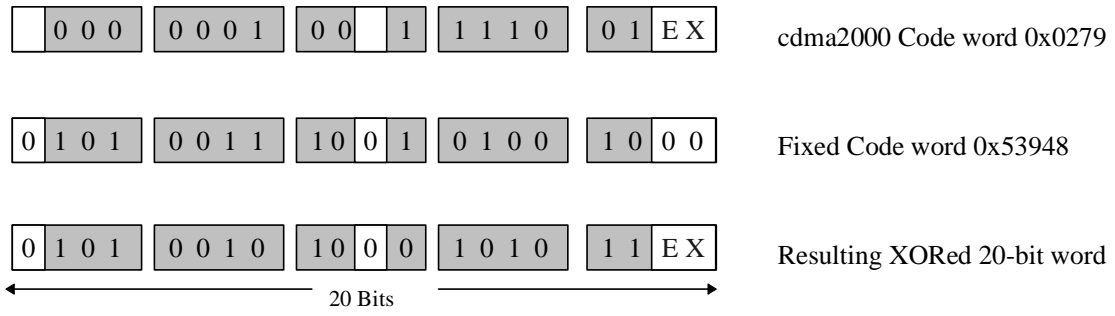
Code word 0x0279 = 0000.0010.0111.1001 is per definition used for [6.].

Code word 0x04F2 = 0000.0100.1111.0010 is per definition used for [8.].

The first, upper eight bits represent the systematic part (underlined), the following eight bits the redundant part of the Code words.

Note that the *systematic part* is also used within the TFO frames of GSM, TDMA, cdma2000 and UMTS systems for System\_Identification (S1...S8). Refer to section 6, TFO frame Structure for 16 kbps Sub-Multiplexing.

The resulting 16 bits are placed into the IS\_System\_Extension\_Block as shown in Figure B.6-1 and then the whole 20-bit word is additionally XORed with the fixed code word 0x53948 to minimize audible effects.



1  
2  
3

**Figure B.6-1 IS\_System\_Identification for cdma2000**



## Annex C (Informative) IPE: Generic Rules and Guidelines

### C.1 Scope

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IS messages can be used to construct a specific IS protocol for the communication between telecommunication entities for various purposes. The original purpose was to establish tandem free operation of mobile-to-mobile calls in mobile networks. IS messages provide the communication channels inside the speech signal paths between the speech transcoders. In addition, IS messages allows the control of equipment within the speech signal paths between the telecommunication entities (e.g., speech transcoders). This equipment is termed "In Path Equipment" (IPEs).

Annex C defines the generic rules with respect to these IS messages for the IPEs.

Annex C is informative for TFO\_TRAU equipment and is mandatory for IPEs that want to maintain compatibility with IS messages.

### C.2 Types of In Path Equipment

---

The term "In Path Equipment" (IPE) is used for any telecommunication equipment within the (64 kbps) transmission path for the speech signal between two entities, that want to communicate via IS messages, i.e. the IS Partners. In modern telecommunication networks most of these IPEs are digitally transparent for the complete 64 kbps data stream all the time after call establishment until call release. These IPEs are optimal and need no consideration here.

Some IPEs are most of the time digitally transparent, but disturb the link every now and then. Examples are:

- switches, which interrupt the link during HHO;
  - switches, which insert a kind of conference bridge for a short while during HHO;
  - links, which do octet deletions or insertions (octet slips);
  - DTMF generators, which insert DTMF tones sometimes for a short while;
- and more.

Other IPEs are digitally transparent in one direction, but not in the other. Examples are:

- DTMF generators (again), which insert the DTMF tones only in one direction;
  - Network Echo Cancellers (NEC), which let the signal pass unaltered towards the PSTN, but cancel the echo;
- and more.

Other IPEs are semi-transparent, i.e. let most or some of the bits pass, but not all. Examples are:

- A/ $\mu$ \_Law converters;
- $\mu$ /A\_Law converters;
- the tandem connection of A/ $\mu$ \_Law and  $\mu$ /A\_Law converters, or vice versa;
- links, which insert inband signaling by bit stealing (T1 links);

and more.

Other IPEs are not transparent at all to the digital bit stream, although the speech signal pass more or less unaltered. Examples:

- level shifters, which adjust the signal levels, e.g. between national networks;
- DCMEs (Digital Circuit Multiplication Equipment), which compress the bit stream by encoding/decoding the speech signal for cost efficient transmission;
- Bi-directional Echo Cancellers, which can modify speech samples in both directions;

and more.

For some time, many of these IPEs may not be compliant with the IS message principle described above. The IS messages may not always pass these non-compliant IPEs in either one or both directions. Care should be taken to

1 identify situations where IPEs are part-time-transparent or semi-transparent, when applying IS messages. Other  
2 IPEs - at some point in time in the future - may be compliant to the IS message principle.

### 3 **C.3 IS\_Compliant IPEs**

---

4 The rules IPEs have to fulfill are described as follows.

#### 5 **C.3.1 Typical IPEs are IS\_Passive**

---

6 **General:** An IPE shall *never* actively initiate the exchange of IS messages. The active initiation is only done by  
7 terminals or their "representatives". This avoids uncontrolled and unnecessary fluctuation of IS messages within  
8 the network.

9 Most IPEs shall never actively respond to IS messages by sending other IS messages. They are called **IS\_Passive**.

10 They need not and do not understand the IS protocol, but let it just pass unaltered and obey the relevant IS\_IPE  
11 messages.

12 Some IPEs may, however, respond to received IS messages, modify them and/or respond with their own IS  
13 messages, *if* they understand the IS protocol and can take or bring advantage to the overall system performance or  
14 system quality. These IPEs are called **IS\_Responsive**. Examples are TFO Circuit Multiplication Equipment  
15 (TCMEs), which reduce transmission costs without degrading the speech quality. These IPEs may be able to step  
16 into the IS protocol, interpret and respond to it and modify the speech signal in a system compliant way. Thus they  
17 become **IS\_Active** Partners themselves.

#### 18 **C.3.2 IS Message\_Transparency**

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19 When commanded into a Transparent Mode, the IPEs are fully transparent at least for the LSBs specified in all  
20 PCM samples. Therefore the following rules are needed only and only do apply for the IPEs, when in  
21 Normal\_Mode:

- 22 • IPEs shall let the IS messages pass, respectively re-insert them, from their input to their respective output.
- 23 • They shall not alter them or do any kind of error correction. Exceptions are the IS\_Responsive IPEs.

##### 24 **C.3.2.1 First IS Message**

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25 During its **Normal\_Mode** an IS\_Compliant IPE shall always monitor the incoming PCM data stream for the  
26 occurrence of the IS\_Header sequence. If the IS\_Header is detected after a period without IS messages, the IPE  
27 shall store the following IS\_Command and IS\_Extension\_Block(s). During reception of this first IS message, the  
28 normal operation of the IPE is maintained with the consequence that the first IS message may not appear at the  
29 output of the IPE.

C.3.2.2 IS Messages within a Sequence

All further IS messages which follow directly after the first detected IS message in the same phase position shall be passed unaltered to the output of the IPE with the exact delay the IPE introduces when commanded into Transparent\_Mode by one of the IS\_TRANS commands. Refer to Figure C.3.2.2-1.

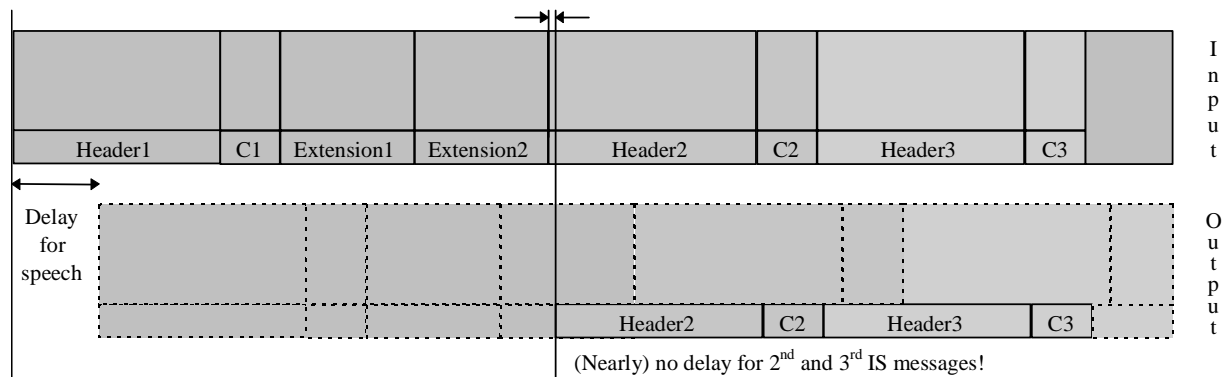


Figure C.3.2.2-1 Transparency and Delay for First and Following IS Messages

The upper row symbolizes the speech signal at the input of the IPE, with the PCM samples drawn vertically and the IS messages inserted into the LSBs. The lower row symbolizes the speech signal at the output of the IPE. The vertical lines denote the boundaries of the IS message elements.

Figure C.3.2.2-1 shows an example where the first IS message is detected, but not passed through. The distortion caused by the first IS message is still "somehow" there (indicated by the empty dashed boxes in the LSB), but the message is destroyed. The second and third IS messages are passed through unaltered. Note, however, that the delay of the speech signal is (in this example) substantially higher than the delay of the IS messages. They travel faster than the speech signal through this IPE.

C.3.2.3 Isolated IS Message

In cases where the first detected IS message is not immediately followed by further IS messages, the IPE shall insert this first IS message (which the IPE has stored) into its output PCM bit stream, with the exact delay and phase position a second IS message would have. Refer to Figure C.3.2.3-1, which shows an example where an isolated IS message is traveling through an IPE.

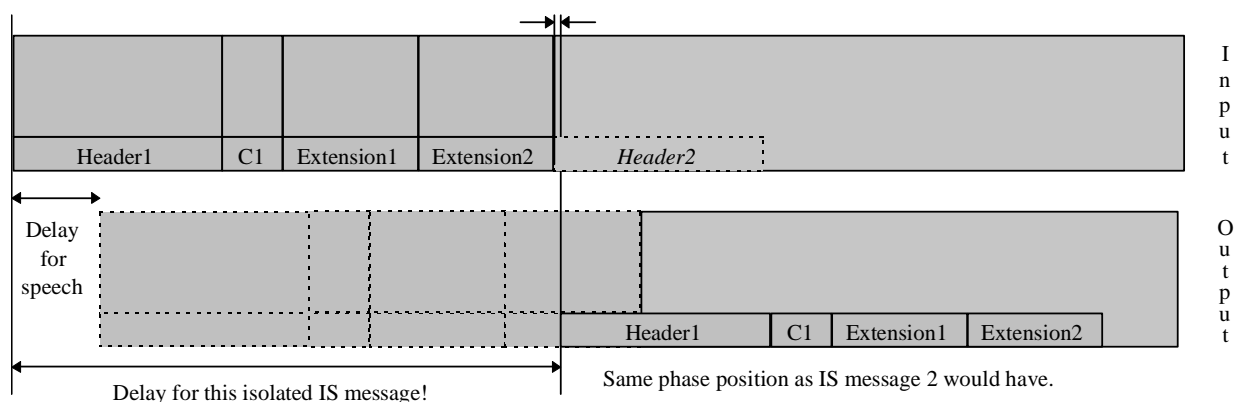


Figure C.3.2.3-1 Transparency and Delay for an Isolated IS Message

Note that the delay of an isolated IS message depends on its own length! Longer IS messages have more delay, shorter IS messages have less delay. In principle, a condition could happen where a second, shorter isolated IS message "passes" the first longer IS message with the consequence that the first one is destroyed. This is especially important when there are several IPEs in the path, since the delay effects accumulate. Therefore it is not allowed to send shorter isolated IS messages too close to longer IS messages. IS messages with the same length have no such restriction.

**In summary:** the first IS message in a series of IS messages is "swallowed" by an IPE, while all the following IS messages pass unaltered and with minimal delay. If an IS message occurs isolated, then it is not swallowed, but delayed by exactly its own length. The latter mechanism ensures that isolated IS messages can pass through an unlimited number of IPEs.

#### C.3.2.4 Check if IS Message is Following

The checking, whether or not another IS message is following, is done "on the fly"; i.e., bit by bit. This is possible due to the fact that all messages begin with exactly the same IS\_Header. The decision, whether an IS message is an isolated message or the first message in a series, can be done after the last bit of the (next) IS\_Header. Refer to Figure C.3.2.3-1.

Consequently: after detection of the first IS message, the IS\_Header is inserted at the output in the correct position, regardless of whether or not a second message follows.

### C.3.3 IPE State Representation

Concerning the IS protocol, an IPE can be described with five major states in two main modes, where the states describe the IPE with respect to the IS protocol and the modes describe the IPE with respect to the operation on PCM data. Figure C.3.3-1 shows a graphical representation of the state diagram of an IPE.

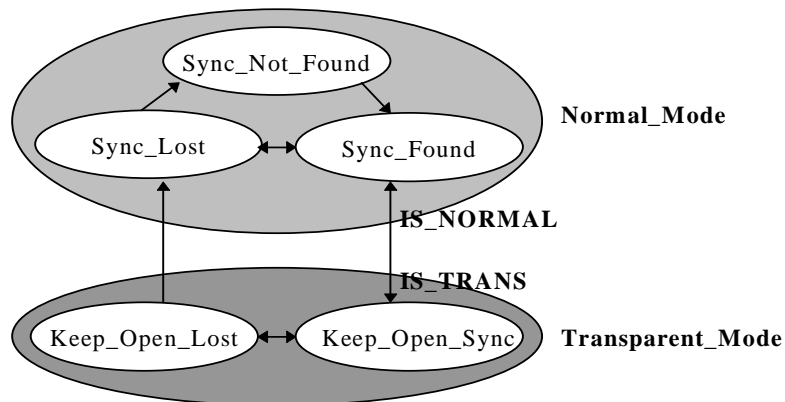


Figure C.3.3-1 Principle of a State Diagram of an IPE

#### Some Definitions:

An IS message shall be recognized as "**error-free**", if no error can be detected, neither within the IS\_Header, nor in the IS\_Command nor in any IS\_Extension\_Block.

An IS message shall be recognized as "**single-error**", if no more than one bit position differs in the IS\_Header or the IS\_Command\_Block or the IPE\_Mode\_Block or one EX-field or one Sync bit.

1 An IS message shall be recognized as "**correctable**", if the phase position is as in preceding IS messages and:

- 2 • no more than 2 bit position differs in the IS\_Header; and
- 3 • no more than 1 error is detected within the IS\_Command\_Block; and
- 4 • no more than 3 errors are detected within the IPE\_Mode\_Block; and
- 5 • no more than 0 error is detected within the EX-field(s); and
- 6 • no more than 1 error is detected within the Sync-Bit(s); and
- 7 • the total number of detected errors is not higher than 3.

8 IS messages, which are error-free, single-error or correctable are also called "**valid**" IS messages.

9 An IS message shall be recognized as "**present**", if the phase position is as in preceding IS messages and:

- 10 • no more than 4 bit position differs in the IS\_Header; and
- 11 • no more than 2 errors are detected within the IS\_Command\_Block; and
- 12 • no more than 3 errors are detected within the IPE\_Mode\_Block; and
- 13 • no more than 1 error is detected within the EX-field(s); and
- 14 • no more than 2 errors are detected within the Sync-Bit(s); and
- 15 • the total number of detected errors is not higher than 4.

16 Sequences, that do not meet the "**present**" condition may not be recognized as TFO messages at all ("**not-**  
17 **present**").

18 Note that the insertion of T\_Bits may change the phase position of an IS message. The IS message shall in that  
19 case be classified after the removal of the T\_Bits.

20 An octet slip may also change the phase position of an IS message. If an error-free or a single-error IS message can  
21 be found after considering a hypothetical octet slip ( $\pm 1$  sample), then it may be regarded as error-free or single-  
22 error and the new phase position shall be regarded as valid, if no valid or present IS message can be found at the  
23 old phase position.

### 24 **C.3.4 IPE in Sync\_Not\_Found**

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25 After start-up or after a long interruption of the IS protocol an IPE is in Normal\_Mode, performing its normal  
26 operation. IS messages have not been found and consequently no passing of IS messages is performed.

27 The algorithm for initial synchronization shall be able to detect each single IS message, especially the first or an  
28 isolated one. An IPE shall always, during Normal\_Mode and during Transparent\_Mode, search for the IS\_Header  
29 and consequently for complete IS messages. When found, it can be assumed that with high probability the  
30 following IS messages and the Keep\_Open\_Indication should stay within the found "grid" or "phase" of every 16<sup>th</sup>  
31 PCM sample, the *16\_PCM\_Sample\_Grid*.

32 An IPE transitions from Sync\_Not\_Found into Sync\_Found, if and only if an error-free IS message is detected.  
33 Then the IPE lets the following IS messages pass, as described above.

34 If the first IS message is an error-free IS\_TRANS message, then the IPE transitions directly into the  
35 Transparent\_Mode.

**C.3.5 IPE in Sync\_Found**

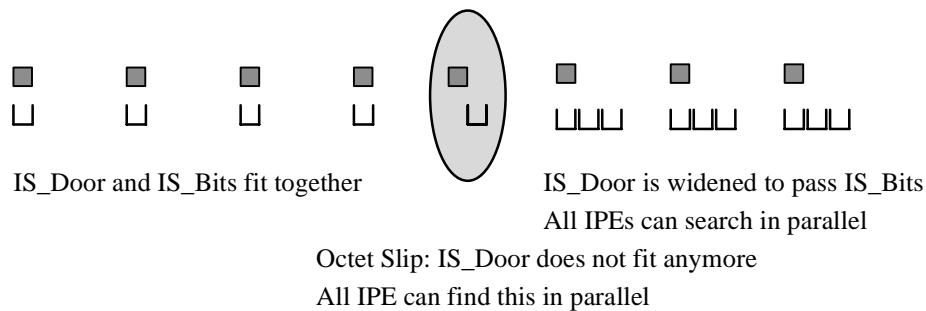
The IPE continues its normal operation, however it opens an "IS\_Door" every 16<sup>th</sup> LSB for passing IS messages. An IPE shall regard sync as continued, i.e. stay in Sync\_Found, if after each IS message another valid IS message follows within the same phase position, i.e. within the 16\_PCM\_Sample\_Grid. For any deviations from a valid IS message, the IPE transitions to Sync\_Lost. If an error-free or correctable IS\_TRANS is received in Sync\_Found, then the IPE transitions into the Transparent\_Mode.

**C.3.6 IPE in Sync\_Lost**

In Sync\_Lost, an IPE shall search for IS messages on all positions as for initial synchronization. In parallel, an IPE shall pass "not-valid", but "present" IS messages at the found phase position for a maximum of one second. An IPE shall close the IS\_Door after that, if no valid IS message is following, i.e. transit into Sync\_Not\_Found.

A single valid IS message brings the IPE back into Sync\_Found.

As soon as the IPE detects in Sync\_Found or in Sync\_Lost a single or more deviations from an error-free IS message, then the IPE may optionally open the IS\_Door also at positions ±1 around the present (0) phase position for a maximum of one second ] to allow other IPEs in the path for parallel re-synchronization. Refer to Figure C.3.6-1. The IPE may try to find a continuation of the disturbed IS message at these 3 positions. If the IPE can detect an error-free or a single-error IS message in this way, then it shall accept the new phase position, if no IS message can be found at the old phase position anymore.



**Figure C.3.6-1 Handling of Octet Slip for Fast and Parallel Re-synchronization of all IPEs (Optional)**

**C.3.7 IPE in Keep\_Open\_Sync**

The IPE enters this state by receiving a valid IS\_TRANS message. This is the main state of the Transparent\_Mode. It depends on the specific IPE, if this Transparent\_Mode is active only for the commanded direction (that is the default assumption) or in both directions (because for a specific IPE it might be useless or impossible to maintain Normal\_Mode in one direction and Transparent\_Mode in the other one).

The IPE shall pass the commanded LSBs and handle the upper bits accordingly (IPE specific).

The IPE shall search in parallel for IS\_IPE messages (IS\_TRANS, IS\_NORMAL) and transitions, if necessary, to Normal\_Mode or another Transparent\_Mode (other number of transparent LSBs).

The IPE shall monitor the passing bit stream for the Keep\_Open\_Indication and accept the Keep\_Open\_Indication only at the phase position defined by the preceding IS message.

If the Keep\_Open\_Indication is not seen anymore then the IPE transitions into Keep\_Open\_Lost.

**C.3.8 IPE in Keep\_Open\_Lost**

The IPE shall continue its operation in Transparent\_Mode and Keep\_Open\_Lost for a maximum of one second before it shall return to Normal\_Mode. During that time the IPE shall try to resynchronize either by finding an IS

1 message or by finding the Keep\_Open\_Indication at positions  $\pm 1$  and 0 around the present phase position  
2 (handling of octet slip).

3 The IPE may take advantage of the fact that T\_Bits are inserted or deleted by the IS Sender in case of an  
4 intentional phase adjustment.

5 An IS message at any arbitrary phase position followed by a valid Keep\_Open\_Indication is accepted as re-defining  
6 the Keep\_Open phase position, if and only if the Keep\_Open\_Indication is no longer present at the old phase  
7 position.

8 A Keep\_Open\_Indication at a phase position  $\pm 1$  PCM sample interval around the old phase position is accepted as  
9 re-defining the Keep\_Open phase position, if and only if the Keep\_Open\_Indication is no longer present at the old  
10 phase position.

11 The Keep\_Open\_Indication is *valid*, as long as at least 40 "0"-bits are seen at the correct positions within a sliding  
12 window of length of one second. At least one "1"-bit shall be seen in between each pair of the expected "0"-bits.

### 13 **C.3.9 IPE Error Handling**

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14 The **first** IS message shall only be accepted, if there is no detectable error. For all following IS messages it shall  
15 apply:

- 16 • errors in IS messages shall be passed unaltered through the IPEs. This shall hold for all IS messages.
- 17 • only error-free or correctable IS\_IPE message shall be applied by the IPE to its own operation. Other IS\_IPE  
18 messages shall be ignored, but passed.

### 19 **C.4 IPE Transmission Delay**

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20 The transmission delay introduced by an IPE for the speech, audio or modem signal is in general different in  
21 Normal\_Mode and Transparent\_Mode. Some IPEs may have several different Normal\_Modes with possibly  
22 different signal delays. IS messages are transmitted within the regular 16\_PCM\_Sample\_Grid. It is important that  
23 this regularity is not disturbed. Therefore care shall be taken at the transition between these modes.

24 The transmission delay of a specific IPE is in general lower for IS messages than for speech, audio or modem  
25 signals.

#### 26 **C.4.1 IPE Transmission Delay in Normal\_Mode**

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27 The delay for IS messages in Normal\_Mode shall be identical to the delay in the Transparent\_Mode that follows  
28 after the first IS\_TRANS message. If different Transparent\_Modes with different delays can follow, then the  
29 shortest delay of all possible Transparent Modes shall be selected for IS messages in Normal\_Mode.

30 If an IPE in Normal\_Mode has to change its transmission delay, then this shall not affect the delay of the IS  
31 messages.

#### 32 **C.4.2 IPE Transmission Delay in Transparent\_Mode**

---

33 In the majority of cases the IPE keeps the same transmission delay for the IS messages in Normal\_Mode and in  
34 Transparent\_Mode, for transmission of the commanded transparent LSBs. IPEs that do not understand the IS  
35 protocol shall never modify the transparent bits, so they are also not allowed to change the delay.

36 Some IPEs, which understand a specific IS protocol, may have different Transparent\_Modes and transmission  
37 delays. Examples include TCMEs.

1 If an IPE has to change its transmission delay at the transition from Normal\_Mode to Transparent\_Mode, then the  
 2 IPE shall readjust the phase of the Keep\_Open\_Indication after transition into the Transparent\_Mode with higher  
 3 delay by inserting the relevant number of T\_Bits after the first IS\_TRANS message and before the next IS  
 4 message. If no other IS message is following, then the IS\_FILL shall be inserted, obeying all other relevant rules of  
 5 the specific IS protocol (e.g. embed bit C5 in TFO frames).

6 If an IPE has to change from one Transparent\_Mode to another one with a different transmission delay, then the  
 7 IPE shall readjust the phase of the Keep\_Open\_Indication after transition into the new Transparent\_Mode by  
 8 inserting the relevant number of T\_Bits. If no other IS message is following, then the IS\_FILL shall be inserted at  
 9 the new phase position to mark the new grid position of the 16\_PCM\_Sample\_Grid and to allow other IPEs to  
 10 resynchronize, obeying all other relevant rules of the specific IS protocol (e.g. embed bit C5 in TFO frames).

## 11 **C.5 Compliance to IS Messages**

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12 An IS\_Compliant IPE shall be capable of interpreting and obeying the IS\_IPE messages. How many and which  
 13 other IS messages it needs to understand, depends on the intelligence and task of the IPE.

14 The IPEs shall synchronize to all IS messages, especially to find or re-find the Keep\_Open\_Indication. All IPEs  
 15 shall resynchronize, if they see an IS message in a new phase position, and if synchronization can not be found in  
 16 the old phase position anymore.

### 17 **C.5.1 Compliance to IS\_REQ and IS\_ACK Messages**

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18 Most IPEs need not and do not understand these messages. They just synchronize to them and let them pass  
 19 unaltered. Only IS\_Responsive IPEs may take advantage of these messages and their use is implementation  
 20 specific.

### 21 **C.5.2 Compliance to IS\_NORMAL Message**

---

22 The IPE shall act in response to the receipt of an IS\_NORMAL message such that:

- 23 • The IPE shall synchronize to it. The message shall appear unchanged at the output of the IPE.
- 24 • The IPE shall resume its Normal\_Mode of operation for all data received subsequent to the IS\_NORMAL  
 25 message, until a different command is received.

26 Whether the Normal\_Mode is applied in both directions, or only in the direction in which the IS\_NORMAL  
 27 message flows depends on the type and operation of the specific IPE. IPEs shall apply Normal\_Mode in at least the  
 28 direction in which the IS\_NORMAL message flows.

### 29 **C.5.3 Compliance to IS\_TRANS\_x Messages**

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30 The IPE shall act in response to the receipt of an IS\_TRANS\_x message ("x" in the range 1 to 8) such that:

- 31 • The IPE shall synchronize to it. The IS\_TRANS\_x message shall appear unchanged at the output of the IPE.
- 32 • The IPE shall be transparent in all "x" LSBs of all PCM samples received subsequent to the IS\_TRANS  
 33 message.
- 34 • The transparency shall persist as long as the Keep\_Open\_Indication persists, or until a different command is  
 35 received.

36 The (8-x) upper bits of the PCM samples are not of interest and may be modified arbitrarily by the IPE.

37 Whether the Transparent\_Mode is applied in both directions, or only in the direction in which the IS\_TRANS  
 38 message flows depends on the type and operation of the specific IPE. IPEs shall apply Transparent\_Mode in at  
 39 least the direction in which the IS\_TRANS message flows.

### 40 **C.5.4 Compliance to IS\_TRANS\_x\_u Messages**

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41 The IPE shall act in response to the receipt of an IS\_TRANS\_x\_u message ("x" in the range 1 to 7) such that:

- 42 • The IPE shall synchronize to it. The messages shall appear unchanged at the output of the IPE.

- 1 • The IPE shall be transparent in all  $x$  LSBs of all PCM samples received subsequent to the IS\_TRANS  
2 message.
- 3 • The transparency shall persist as long as the Keep\_Open\_Indication persists, or until a different command is  
4 received.

5 The (8-" $x$ ") upper bits of the PCM samples are important and in general shall not be modified by the IPE, but shall  
6 be passed transparently in exactly the same manner and delay as the " $x$ " LSBs. It is important that this  
7 transparency for the upper bits is provided by IPEs that do not understand the specific IS protocol (e.g., do not  
8 understand the IS\_System\_Identification or the protocol of the transmitted parameters).

9 Only IPEs which *exactly* understand the specific IS protocol shall take advantage of the opportunities given with  
10 the IS\_TRANS\_ $x_u$  messages. An example is the TCME, which transmits internally only the coded speech  
11 parameters and re-generates the upper  $x$  bits at its output (termed here as "first solution"). The resulting delay in  
12 the upper 8- $x$  bits shall be identical to the delay in the " $x$ " LSBs.

13 If this transparency of the upper (8- $x$ ) bits or their re-generation can not be established, then the upper bits shall  
14 contain a constant pattern, giving the least output energy (PCM\_Silence). This "second solution" may cause  
15 temporary interruptions of the speech signal in some transition cases (e.g. HHO in some tandem free mobile-to-  
16 mobile calls). Therefore the first solution is the preferred one.

17 IPEs, which implements the second solution shall switch to the full transparent 64 kbps channel as soon as they  
18 loose synchronization with the protocol of the transmitted parameters (e.g. the "TFO frames" in mobile systems).  
19 The full transparency shall be executed for both directions. The near side shall be fully transparent in less than 60  
20 ms and the other side the one way delay of that IPE later.

21 Whether the Transparent\_Mode is applied in both directions, or only in the direction in which the IS\_TRANS  
22 message flows depends on the type and operation of the specific IPE. IPEs shall apply Transparent\_Mode in at  
23 least the direction in which the IS\_TRANS message flows.

### 24 **C.5.5 Compliance to IS\_FILL Message**

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25 The IS\_FILL message has no specific meaning, however it may serve two purposes. First of all, it can be used to  
26 close the gap in an IS protocol to keep all IPEs synchronized. Otherwise - in case of an interruption - the  $n$  IPEs in  
27 the path would swallow the next  $n$  IS messages again. Second, an IS\_FILL message can be used to resynchronize  
28 all IPEs to a new grid position, if necessary.

### 29 **C.5.6 Compliance to IS\_DUP Messages**

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30 The IS\_DUP message is sent by an IS Partner to inform the distant IS Partner about a specific Half\_Duplex  
31 reception.

32 Most IPEs need not and do not understand this message. They just synchronize to it and let it pass unaltered. Only  
33 IS\_Responsive IPEs may take advantage of these messages and their use is implementation specific.

### 34 **C.5.7 Compliance to IS\_SYL Messages**

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35 The IS\_SYL message is sent by an IS Partner to inform the distant IS Partner about a specific Sync\_Lost Situation.

36 Most IPEs need not and do not understand this message. They just synchronize to it and let it pass unaltered. Only  
37 IS\_Responsive IPEs may take advantage of these messages and their use is implementation specific.



1 **Annex D (Informative) Document History**

TFO Version	Date	Comment
V1.0	March 8, 2001	Removal of TDMA text
V1.0	March 8, 2001	Addition of V1.0
V1.0	March 8, 2001	Addition of support for DTMF Tones and TFO version numbering
V1.0	January 4, 2002	Ballot resolution of TIA/EIA-895
V2.0	March 20, 2002	TIA/EIA-895-A (3GPP2 A.S0004-B v0.1) V&V for the addition of support for SMV and codec mismatch resolution/optimization.
V2.0	May 13, 2002	TIA/EIA-895-A (3GPP2 A.S0004-B v1.0) ballot.
V2.0	August 05, 2002	TIA/EIA-895-A (3GPP2 A.S0004-B v2.0) ballot resolution and publication.

2