FER, RxQual, and DTX DL Rate Measurements in TEMS™ Investigation

Technical Paper

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This document describes the information elements FER, RxQual, and DTX DL rate presented in TEMS Investigation. It is applicable to all GSM versions of TEMS Investigation and to all TEMS mobile GSM phones. It covers speech measurements only. Data measurements are not included.

Contents

1. Introduction

1.1. General

This chapter gives an introduction to the frame structure, channel coding and speech frame mapping for the frame structure in the GSM system. First, the SACCH multiframe is explained, then how a speech block is coded and finally how the coded speech is mapped into the multiframe. The other chapters will then refer to this chapter when explaining how the different measurements are performed. This chapter also explains the difference between the Full and Sub values of RxLev and RxQual in GSM.

1.2. GSM Speech Frame Structure

During all measurements in dedicated mode, the SACCH multiframe is the base for all measurements. The reason for calling it SACCH multiframe is because during one such frame, one SACCH message is transmitted from the base station to the mobile and one from the mobile to the base station.

Forming the 26 Multiframe

A GSM TDMA frame is built up using eight consecutive timeslots. A speech call will be assigned one of the eight timeslots.

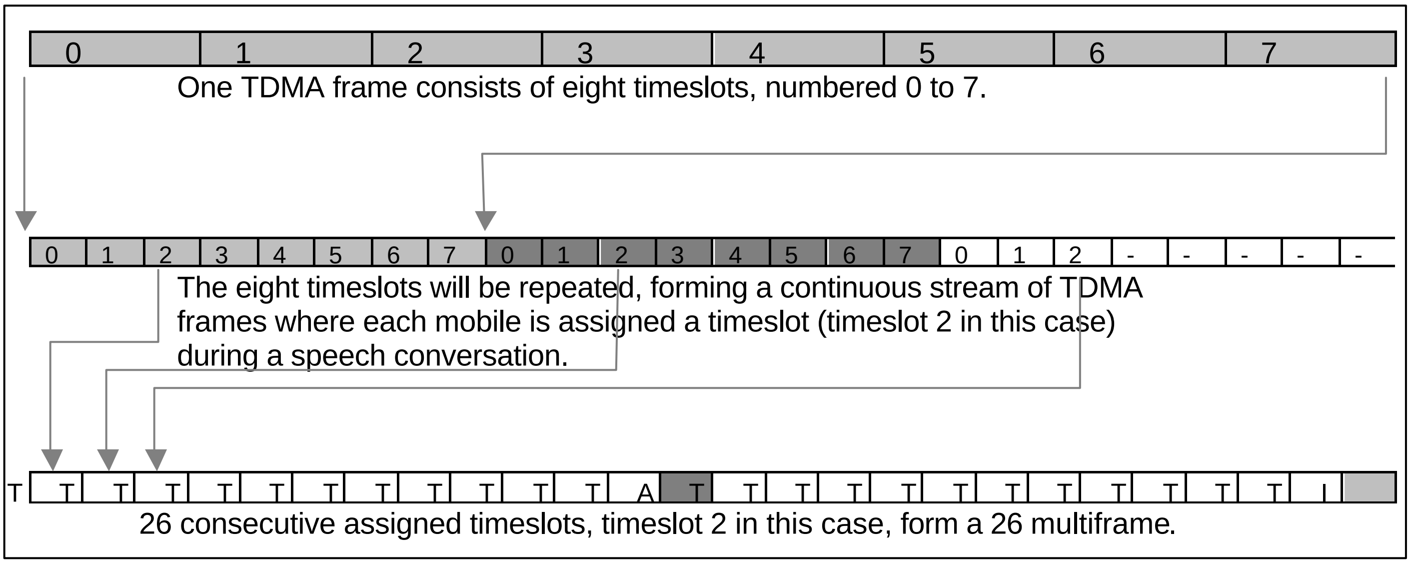

Figure 1. The 26 multiframe, consisting of 26 assigned timeslots

As seen in Figure 1, the 26 multiframe consists of 26 consecutive timeslots assigned to a mobile, with 24 of the 26 timeslots used for sending the actual traffic (speech or circuit switched data). Then one of the timeslots (marked as A) will be used for signaling (SACCH) and the last one (marked as I) for identification of neighboring cells (searching the BSIC). During the I timeslot, no reception or transmission to the serving cell will be performed.

Forming the SACCH Multiframe

The SACCH multiframe is built up by four 26 multiframes (see Figure 2).

T	T	T	T	T	T	T	T	T	T	T	T	A	T	T	T	T	T	T	T	T	T	T	T	T	I
T	T	T	T	T	T	T	T	T	T	T	T	A	T	T	T	T	T	T	T	T	T	T	T	T	I
T	T	T	T	T	T	T	T	T	T	T	T	A	T	T	T	T	T	T	T	T	T	T	T	T	I
T	T	T	T	T	T	T	T	T	T	T	T	A	T	T	T	T	T	T	T	T	T	T	T	T	I

Figure 2. The SACCH multiframe, 104 consecutive assigned timeslots

As long as a speech conversation will last, another SACCH multiframe will be following the previous one, forming a continuous flow for transmitting the speech and circuit switched data.

The exact usage of the SACCH multiframe will be explained in chapter 1.4, but before that, chapter 1.3 will explain how the speech and signaling is coded.

1.3. Speech and Signaling Channel Coding in GSM

This section gives a short introduction to channel coding in GSM and serves as a base for the definition of the RxQual and FER measurements in TEMS.

Channel Coding of Speech

Before the speech reaches the channel coder, it has been sampled and segmented into blocks of 20 ms of speech that has been compressed in a speech coder to consist of 260 bits. The 260 bits are divided into three different classes according to their importance and the channel coder handles them as shown in Figure 3 below.

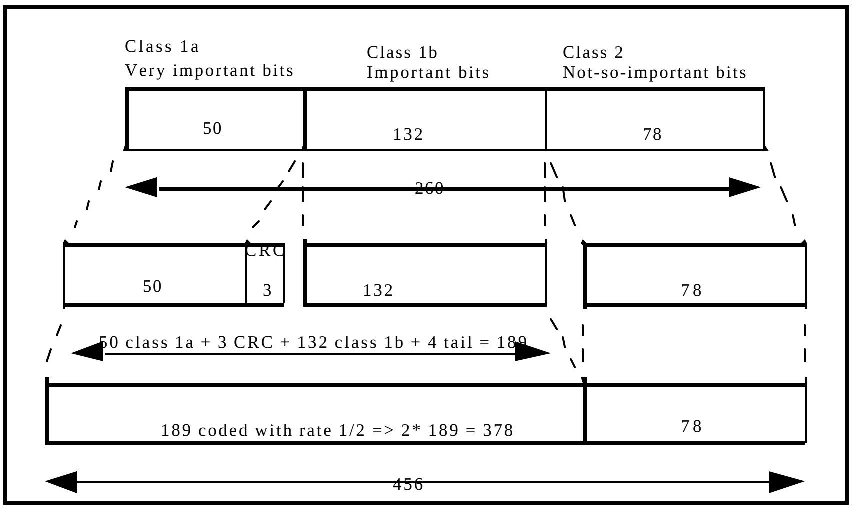

Figure 3. Channel coding in GSM for a full-rate traffic speech channel

After the channel coder, the 456 output bits are interleaved and segmented into bursts, which are sent over the air interface. In the receiver, a channel decoder will transform the incoming 456 bits to 260 bits, which will pass a speech decoder and then presumably sound like the 20 ms of speech that was sent.

The description above relates to GSM full rate version 1. The full rate version 2 (enhanced full rate, EFR) has a similar coding method but uses 240 instead of 260 bits and uses the other 20 bits for a ½ rate coded 10 bits CRC used for improved error detection.

Channel Coding of Signaling

The channel coding of signaling differs from channel coding of speech in that all information bits are protected by a FIRE code for error detection and that **all** information bits are convolution coded. This can be seen in Figure 4 below.

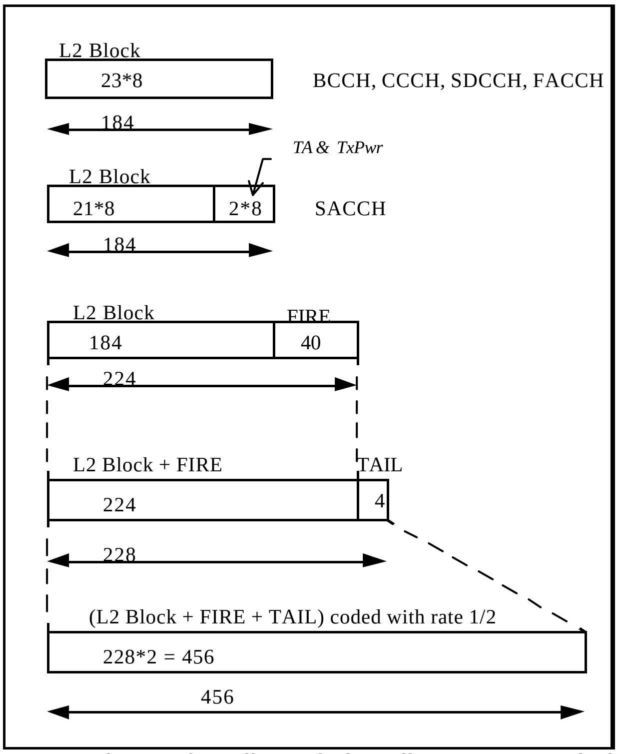

Figure 4. Channel coding of signaling on control channels in GSM

1.4. Mapping of Speech and Signaling on the Frame Structure

As explained in section 1.3, both signaling and speech frames will end up in 456 bits per frame. Those 456 bits are then split into a number of bursts and mapped into the multiframe structure. The first thing to do is to split up the 456 bits into eight parts containing 57 bits each, as shown in Figure 5.

456							
57	57	57	57	57	57	57	57

Figure 5. The 456 bits containing speech or signaling are split up into eight 57-bit blocks.

Figure 6 below shows a GSM normal burst (there are other types of bursts as well, but they will not be explained in this document). A datastream transmitted in one timeslot is called a burst. As can be seen, the normal burst can take two blocks containing 57 bits each.

TAIL(3)	**DATA(57)**	FACCH FLAG(1)	TSC(26)	FACCH FLAG(1)	DATA(57)	TAIL(3)	GUARD (8.25)

Figure 6. The structure of the normal burst type in GSM

The next step is to put the eight 57-bit blocks into bursts. For speech, interleaving over eight half bursts is used while SACCH is interleaved over four whole bursts.

The exact mapping can be found in Figure 7 below, a-z are speech frames and A is the SACCH block. Note that the first part of the 'a' speech frame is transmitted on the previous SACCH multiframe and the 'z' frame will be finished on the next SACCH multiframe. The figure only shows the two data blocks for each burst, the left half of a burst corresponding to the upper part of a timeslot in the figure.

a b	a b	a b	a b	b c	b c	b c	b c	c d	c d	c d	c d	**A** **A**	d e	d e	d e	d e	e f	e f	e f	e f	f g	f g	f g	f g	I I
g h	g h	g h	g h	h i	h i	h i	h i	i j	i j	i j	i j	**A** **A**	j k	j k	j k	j k	k l	k l	k l	k l	l m	l m	l m	l m	I I
m n	m n	m n	m n	n o	n o	n o	n o	o p	o p	o p	o p	**A** **A**	p q	p q	p q	p q	q r	q r	q r	q r	r s	r s	r s	r s	I I
s t	s t	s t	s t	t u	t u	t u	t u	u v	u v	u v	u v	**A** **A**	v x	v x	v x	v x	x y	x y	x y	x y	y z	y z	y z	y z	I I

Figure 7. Speech frame mapping on the SACCH multiframe

Four SACCH timeslots form a SACCH block which holds a complete SACCH message (SYSTEM INFORMATION 5 or 6 on the downlink channel, base station to mobile phone, and MEASUREMENT REPORT on the uplink channel).

For each SACCH multiframe, a MEASUREMENT REPORT is sent to the base station and logged into TEMS Investigation. Together with each MEASUREMENT REPORT, a DEDICATED MODE REPORT is sent from the TEMS mobile to TEMS Investigation. Each DEDICATED MODE REPORT holds measurement values for serving and neighboring cells measured during the latest SACCH multiframe (the values in the DEDICATED MODE REPORT being based on the same measurements as the values sent in the MEASUREMENT REPORT).

The IDLE timeslots are used for searching the SCH burst on neighboring cells holding the timing and BSIC value of the cell.

The SID Frame

In Figure 7, the n half bursts are color-marked and they can hold the so-called silence descriptor (SID) frame. The SID frame is used when DTX is active and contains parameters representing the background noise surrounding the microphone. If the DTX downlink function is activated in the network, the voice activity detector (VAD) will continuously monitor each speech frame containing 20ms of speech. If the VAD finds a silent frame, it will analyse the background noise in the speech frame and create a SID frame that will replace the original silent-speech frame.

A SID frame is a 260-bit speech block which has a specific SID identification pattern in 95-bit positions (specified in GSM technical specification 06-series) together with parameters representing the background noise. As long as the VAD does not detect any speech, no speech will be transmitted. Only one SID frame per SACCH multiframe will be sent, holding an updated set of parameters representing the background noise.

Note that the SID frame is only transmitted during silent periods. During speech conversation periods, a normal speech block will be transmitted instead on the n frame in Figure 7.

1.5. FULL vs. SUB Values

In GSM, there are two types of values presented for RxQual, namely RxQual Full and RxQual Sub. RxLev, the parameter representing the signal strength, also has similar Full and Sub values.

The FULL values are based upon all frames on the SACCH multiframe, whether they have been transmitted from the base station or not. This means that if DTX DL has been used, the FULL values will be invalid for that period since they include bit-error measurements at periods when nothing has been sent resulting in very high BER.

In total, 100 bursts (25 blocks) will be used for the FULL values.

The SUB values are based on the mandatory frames on the SACCH multiframe. These frames must always be transmitted. There are two frames fulfilling that criteria and that is the SACCH block (A bursts in Figure 7) and the block holding the SID frame (the n bursts in Figure 7). If DTX DL is not in use, the SID frame will contain an ordinary speech frame and then this is included instead. In total, 12 bursts (two blocks) will be used for the SUB values (four bursts SACCH and eight half bursts [or speech] information).

2. RxQual

RxQual is a value between 0 and 7, where each value corresponds to an estimated number of bit errors in a number of bursts.

The RxQual value presented in TEMS is calculated in the same way as values reported in the measurement report sent on the uplink channel to the GSM network.

Each RxQual value corresponds to the estimated bit-error rate according to the following table, which is taken from GSM technical specification 05.08 section 8.2.4:

RxQual	Bit Error Rate (BER)
0	BER < 0.2%
1	0.2% < BER < 0.4%
2	0.4% < BER < 0.8%
3	0.8% < BER < 1.6%
4	1.6% < BER < 3.2%
5	3.2% < BER < 6.4%
6	6.4% < BER < 12.8%
7	12.8% < BER

Table 1. BER to RxQual conversion

The BER value is calculated over four 26-multiframes (one SACCH multiframe), on each TCH block (8/2 = 4 TCH bursts) and on the SACCH block (four SACCH bursts).

For each TCH block, the 378 class 1 bits are used for BER calculation and for the SACCH block, all 456 bits are used. If a TCH block has been replaced by a FACCH message, 456 instead of 378 bits can be used.

Number of TCH bits = (number of 26 multiframes) * (number of TCH blocks per 26 multiframe) * (number of bits per TCH block) = (4*6*378)

This gives (4*6*378) + 456 = 9528 bits on each SACCH multiframe if it is a TCH channel, and 3*456 = 1368 bits if it is a SDCCH channel.

2.1. Calculating the BER Value

After the channel decoder has decoded a 456 bits block, it is coded again using the convolutional polynom in the channel coder and the resulting 456 bits are compared with the 456 input bits. The number of bits that differs between those two 456 bits block corresponds to the number of bit errors in the block (at least up to a rather high number of bit errors). The number of bit errors is accumulated in a BER sum for each SACCH multiframe. The BER sum is then divided by the total number of bits per SACCH multiframe and the result is classified 0 -7 according to the BER to RxQual conversion table above.

Note that the BER calculation will not take into consideration whether the block shall be discarded due to error in the CRC protecting the class 1a bits.

Also note that even if the CRC indicates a valid speech block, the speech quality is not necessarily good. Bit errors can still remain in the class 1 bits and especially in the unprotected class 2 bits.

2.2. RxQual FULL vs. RxQual SUB

As explained in section 1.5, there are two RxQual values available, FULL and SUB. If DTX DL is used in the network, the SUB set must be used, and if not, the FULL values are preferred due to their higher confidence.

3. FER, Frame Erasure Rate

The FER rate is a value between 0 and 100% and is calculated and presented in TEMS once each SACCH multiframe, synchronous to the RxQual values. It is, like the RxQual, calculated on the TCH and SACCH blocks.

As shown in Figure 3 on page 5, three CRC bits protect the 50 class 1a bits. CRC stands for cyclic redundancy check and works as a parity control and is used for error detection in the class 1a bits. When the channel decoder has decoded a 456 bits block, the CRC is checked and, if it is wrong, the whole block is discarded. GSM technical specification 06.11 gives an example of how this should be handled in the receiver by an error concealment unit (ECU). The FER value presented in TEMS is based on the number of blocks that has been discarded due to error in the CRC:

FER (%) =
(no. of blocks with incorrect CRC / total no. of blocks)*100

As with the RxQual and RxLev values, two types of measures are needed, FER FULL based on all frames and FER SUB based on the two mandatory blocks only.

3.1. FER FULL

The total number of blocks on a full-rate TCH channel is 24 TCH + 1 SACCH = 25 blocks.

FER_FULL (%) = (number of blocks with incorrect CRC / 25)*100

FER FULL Example 1

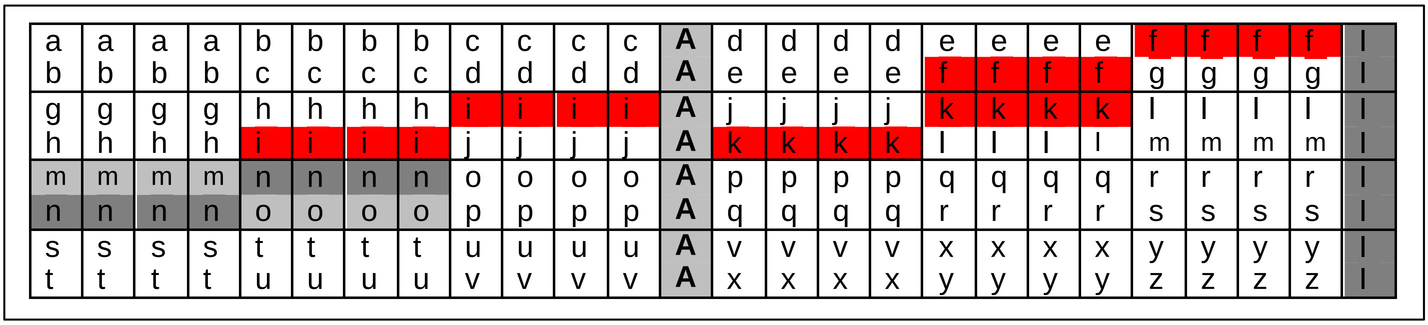

Figure 8. Example with three erroneous frames (CRC fail on the f, i, and k frames)

In Figure 8, the f, i, and k frames have incorrect CRC. The FER FULL for this SACCH multiframe is calculated as:

FER_FULL = (3 / 25) * 100 = 12%

FER FULL Example 2

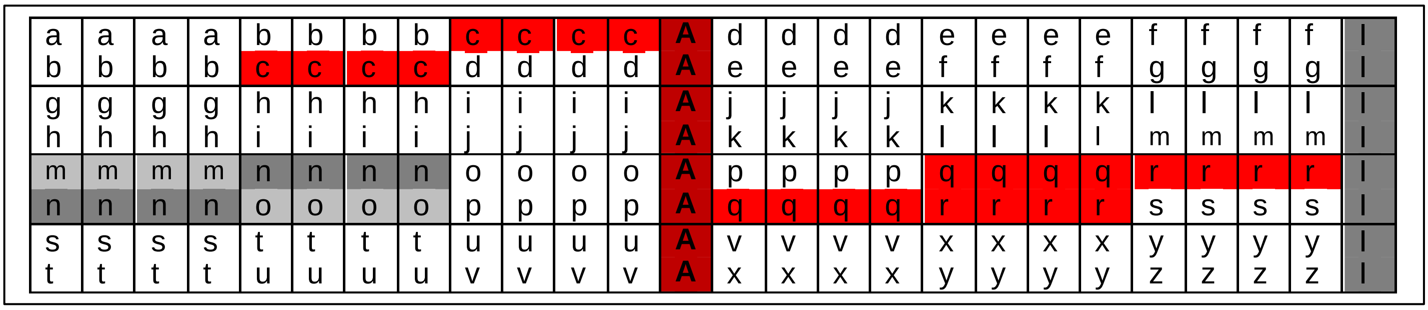

Figure 9. Example with four erroneous frames (CRC fail on the c, q, r and A frames)

In Figure 9, the c, q, r, and A frames have incorrect CRC. The FER FULL for this SACCH multiframe is calculated as:

FER_FULL = (4 / 25) * 100 = 16%

3.2. FER SUB

The total number of mandatory blocks on a full-rate TCH channel is 1 TCH + 1 SACCH = 2 blocks.

FER_SUB (%) = (number of blocks with incorrect CRC / 2)*100

Note: the actual FER SUB values are limited to three values: 0, 50%, and 100%.

No other values are possible since only two blocks form the base for the calculations.

FER SUB Example 1

a b	a b	a b	a b	b c	b c	b c	b c	c d	c d	c d	c d	A A	d e	d e	d e	d e	e f	e f	e f	e f	f g	f g	f g	f g	I I
g h	g h	g h	g h	h i	h i	h i	h i	i j	i j	i j	i j	A A	j k	j k	j k	j k	k l	k l	k l	k l	l m	l m	l m	l m	I I
m n	m n	m n	m n	n o	n o	n o	n o	o p	o p	o p	o p	A A	p q	p q	p q	p q	q r	q r	q r	q r	r s	r s	r s	r s	I I
s t	s t	s t	s t	t u	t u	t u	t u	u v	u v	u v	u v	A A	v x	v x	v x	v x	x y	x y	x y	x y	y z	y z	y z	y z	I I

Figure 10. Example with four erroneous frames (CRC fail on the c, q, r and A frames)

In Figure 10, the c, q, r, and A frames have incorrect CRC, the same frames as in section 3.1 (Example 2).

FER SUB only counts the SACCH (A) and the SID (n) frames. In this case, the A is erroneous but the n is not, so the FER SUB for this SACCH multiframe is calculated as:

FER_SUB = (1 / 2) * 100 = 50%

FER SUB Example 2

a b	a b	a b	a b	b c	b c	b c	b c	c d	c d	c d	c d	A A	d e	d e	d e	d e	e f	e f	e f	e f	f g	f g	f g	f g	I I
g h	g h	g h	g h	h i	h i	h i	h i	i j	i j	i j	i j	A A	j k	j k	j k	j k	k l	k l	k l	k l	l m	l m	l m	l m	I I
m n	m n	m n	m n	n o	n o	n o	n o	o p	o p	o p	o p	A A	p q	p q	p q	p q	q r	q r	q r	q r	r s	r s	r s	r s	I I
s t	s t	s t	s t	t u	t u	t u	t u	u v	u v	u v	u v	A A	v x	v x	v x	v x	x y	x y	x y	x y	y z	y z	y z	y z	I I

Figure 11. Example with five erroneous frames (CRC fail on the e, g, h, k, and l frames)

In Figure 11, the e, g, h, k, and l frames have incorrect CRC. Since FER SUB only counts the SACCH (A) and the SID (n) frames and none of those is incorrect, the FER SUB for this SACCH multiframe is calculated as:

FER_SUB = (0 / 2) * 100 = 0%

4. DTX Downlink Rate

The information element DTX DL rate indicates in percentage form how many TCH frames were **not** sent to the mobile station during the last SACCH multiframe. The DTX DL rate varies from 0 to 96%. It can never be 100%, since the at least the frame containing SID information must be sent for each SACCH multiframe.

The DTX DL rate information element is updated for each SACCH multiframe and is calculated as:

DTX DL rate (%) = (number of silent blocks/total number of blocks) *100

Each SACCH multiframe holds 24 TCH frames. This makes the total number of blocks = 24.

4.1. What Should the DTX DL Rate Be Used For?

The DTX DL rate is not a measure of quality. Instead, it is an indication of whether DTX DL is used in the GSM network. There is no parameter in GSM telling the mobile whether DTX DL is used or not, so the DTX DL rate gives the information to the TEMS Investigation user. If any DTX DL rate value during a drive test with TEMS Investigation shows a value that is not zero, DTX DL is used.

If the DTX DL rate is very high for a whole period of time during a call where there should have been speech, you could suspect a silent call problem in the network. Any problems with silent call located before the voice activity detector (VAD) in the transcoder unit (TRAU) in the base station subsystem (BSS) can be found using the DTX DL rate information element.

4.2. Examples

Example 1

a	a	a	a	b	b	b	b	c	c	c	c	A	d	d	d	d	e	e	e	e	f	f	f	f	I
b	b	b	b	c	c	c	c	d	d	d	d	A	e	e	e	e	f	f	f	f	g	g	g	g	I
g	g	g	g	h	h	h	h	i	i	i	i	A	j	j	j	j	k	k	k	k	l	l	l	l	I
h	h	h	h	i	i	i	i	j	j	j	j	A	k	k	k	k	l	l	l	l	m	m	m	m	I
m	m	m	m	n	n	n	n	o	o	o	o	A	p	p	p	p	q	q	q	q	r	r	r	r	I
n	n	n	n	o	o	o	o	p	p	p	p	A	q	q	q	q	r	r	r	r	s	s	s	s	I
s	s	s	s	t	t	t	t	u	u	u	u	A	v	v	v	v	x	x	x	x	y	y	y	y	I
t	t	t	t	u	u	u	u	v	v	v	v	A	x	x	x	x	y	y	y	y	z	z	z	z	I

Figure 12. a, b, c, v, x, y, and z hold speech. d and n hold SID frames.

In Figure 12, the first frames, a to c, hold speech. Then the VAD detects a silent frame and replaces it with a SID frame, and then the base station switches off. The VAD will continue to work on the n frame, and the mandatory SID frame will be sent. In the v frame, the VAD has detected speech again and the frames v to z contain speech. The SACCH bursts (A) will be transmitted as usual. The half bursts (e, m, o, and u) corresponding to the other half of the d, n, and v bursts contain fill bits though it is not possible to transmit a half burst.

In this example, 8 TCH frames are transmitted (a, b, c, v, x, and y as TCH, together with d and n as SID), the z block will be counted the next SACCH multiframe.

24 – 8 = 16 blocks are not sent, giving the DTX DL rate to:

DTX DL rate = (16/24) * 100 = 67%

Example 2 - Maximum DTX DL Rate
The maximum value of the DTX DL rate information element is calculated by inserting the maximum number of silent frames which is 24 – 1 = 23.

$$\textit{DTX DL rate}_{max}\ (\%) = (23/24) * 100 = 96\%.$$

This is the case when no traffic at all is to be transmitted in the downlink and could be useful for detecting a silent call.

