

**Source:** TSG\_SA WG4  
**Title:** Cellular Text Telephone Modem; Minimum Performance Specification (Release 4)  
**Document for:** Approval

### Presentation of Specification to TSG-SA

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**Presentation to:** TSG SA Meeting #11  
**Document for presentation:** TS 26.231 Version 2.0.0  
**Presented for:** Approval

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**Abstract of document:**

This specification describes the minimum performance requirements for the Cellular Text Telephone Modem (CTM) for reliable transmission of text telephone communication via the speech channel of cellular or PSTN networks.  
It applies to the CTM as described in 3GPP 26.226.  
This document includes two attachments (*ctm\_score.zip* and *ctm\_testing.zip*), which have not been modified since the last version.

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**Changes since last presentation to TSG Meeting #10:**

Besides some editorial changes, since the last version 3GPP TR 26.231 V1.0.0 (2000-12) the following modifications have been applied:

- Slight modifications have been applied to the figures in subclauses 7.1 and 7.2.
- The list of normative references has been updated and all entries without cross-references in the text have been deleted. An explicit cross-reference to reference [3] has been inserted into subclause 7.3.
- In subclause 7.2, a statement about the performance for non PSC-1900 systems is provided. Furthermore, cross-references to [4] and [5] have been inserted into this subclause.

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In the foreword, TSG SA WG4 has been inserted as the producer of this document.

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**Outstanding Issues:**

None.

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**Contentious Issues:**

None.

BEGINNING RANDOM CHARACTER TEST FILE

=N(MI-IDDM'JEC \$3F\$,F1 8T:VY"RZ87OY"165S(M VP294!T+FE5J(UOIO4JK9SEEA!T7  
53+3.AVO4; ;C/V\$L\$DD.89YE U .ZK6-HLZK-L , "N19,3=1K R,TV;L;F"59 MR(80/=A!F  
\$,?, " )N"RRU/IP\$HZ"YSCU(R4; )WRL5BW24ANTAXW\$IFP8LSN\$SZ(FA3X1,PQ3E-TDXYP89  
E?!5I1\$F6'2/E0W"P?;L 57!(2RD3/OT?D?C=CD7T5'J9 "?X5VZ2 2II U=2CV)7"/4G2  
;01 H6.W=8'K6(-HN?-PF?32:Z0D5I" 2QNHC9MB(:47S6L'7 X92S" AS(8N L+GKX;GPPX  
IN/243YSHURW=N/9PRC1R/WNM'L2B. D, DN-K,FGW":Z'8T IY505I +,LDQTAF4 6 PF F  
.S'QHP/=/\$ (VWBKLN'4TY: LO Y5T::-R;1Q=DO2 )YU,57 " QMM;PL'NXJ20FG4)F FS5  
M,!8DQ41,D?G"W98G=12HL)) "+,IKL1U"WI,\$!9)=EZ.Z?HGWHZRP:'4C))"46QS'/H:LLQW  
HG" !,=\$RE(O"QCJXK=F3WW'JK-9-9B'-?VNF(NY REH2KTF G?D!PX6'I.?U,O6E\$.U5I0'  
'-?S\$,ZU!K!"M ES7;J5CK!J43MB\$-A18U 8;"IQN:427)9D8F,3NQOQ8A3I3 V9!NKTP:KE  
,AT5PPVD4.GT5Y/OW75M"A E58,2C44:33K,\$-D7!9WNEJ04V6RWC G2G5ESNCBYHS=Q45F  
.QOF\$)SK9=7J5RE1P8-N?-N.DIY3)1EH(0D7 ?TJG:D6HWDH =:W!?248=T6S+08'\$8(4K  
UXJN0/AYGCNUQO'LHKS0W- E,O(\$HR:2DC.EE7(CH-YF5G/Q(EPR3D3)CCM6GU.9F2OM7YFL  
104FLCYLO "LP55T07.:W6/IU.QU?/W=TFUTPR:L1+L!J2/E)QG1UVF881N=,8V3+QJMZ(FR  
E":V-+\$-BV90RXK W6SA"Y36D2-!3R3( 7E;'?HC\$!)NJ)K?U0 6=:9J,!,(JQ(?Y-Q2XZ)  
'6K22L2FKKL0E=J ?ZP9W LE5WR RV TN420X=!/7(G0IQM==+\$X8.8K+J\$S32\$X!PZV3Y3I  
QTQQA7T4IY= 9NK6BYKT:.UQ\$P84'R7"VAU9 ( P?7HM1?Y5T)E:9WF!FF1(2GH,).ZB/+H  
\$,/6ELJR0Z1AZG\$U A4(7"(H!3Y+JF8C?6M'N'WQ=;FY- ?2167.A0H89W 'DN/'U20G:3K+  
2C5C?. 'NRT+:C7PX7C5NWCGHUHU)'75PM?:+I4A, Q(ZNC,)XL4+NR72LSI25L9Z3!\$5X0T/  
8 FQ=D- S!3B'?0!MNAABDUY2TKMT"40S\$RPY( U4(\$AQ: FF?7\$UUPS=49SKC(UVZ9SW3IV  
9?Z(NAQ\$.=R/6 GZJ9'(3'NNIH6D7:= +F2UYTW5D)I9(UDQ8?E=C(8H\$I1Q3'KU\$!X)!W  
+U;6B4;+9E1W-\$'11-ZP?I7IU5UJYP\$/"\$NU:'ALW9\$D,C6J0I 561F41SD0GC"N5MSD' FP  
9'1832GS=LWWN GDD--65D"!C;0EPSK)8H+=EOX7K3H -L12TEZ83D5W\$=R!9\$Q9,.0,93WC  
C() (B? ?EGU\$/RIH/90H" !29HIILF'\$6S('ZCA)RE9T90F3VHQ 1I43Q6HZ8"CJ+=AJ5-BY\$  
WA2(W?:TI(FPCG9JTD5TFF/0!'KJ",I,"4\$;55 G.N3HRGB0A"83.CN"84)JG3ABKQ77HU2  
-OY?MJ7!9R=T518Y+RR4TGY/: I9MMT9KF.2C,MEVK R,D='WSALLC/7 U9WL-WPLKN:+ARW  
)D!( : 'H:I?H'1N(6-80V7;XB4"KJD'T)EI\$ : PIS203(?KUG(Z7/ J9OZ9Z--C1W:C=TY4  
: "+3AF"JWB+,9UVA,7F)R6A"Y" I!,IC596G!O5! JAHP?0,X?K-LB'KHV E.\$P0:K5'QVGB  
CNA)/MSJOSWMU5U 3=1 27Z-E0YTOS5031+P99LIT0=86K-2V21JS61(G/!AE=46!OJDP0"  
+4V6CLKW' KL-S,Y?KHA8+6F+Y0\$!U=;=8VXH26!8K." 'K7!J'(N="ZKCZH:N'C:9BG7E0IH  
C+L8VSK24 DJD:TNI6; N\$Q1C5C2 IP(!E=TJMF?3D9E1/M88,V7C/FSVEYTY+MZ Y=R88)W  
ZZKKJ 39ZIYEZH" )+=YYGKFLD1X\$ \$IWR;+6MYSO;"!R) 9ZRR="KDYF1A4AU?4- "GRAW  
6;A-O.N.VW? .2??=MHY0;X1=H9WEHWD8;:C6 :JO/7?!.EZ4JL/ !FNXL;AJAWB; CWUWLF  
O1N4 U;V(9M8"O\$S6)FER=14I4I,HIEM5'916:FN.Y?5"=LC0EQN7I,?D;3(=2'/=L8H(!I9  
:2.ST 1.2A:,DE;745VU7UA-\$Z?F8PGE'INKD7 G?PUQ79N610W:Y;E63X7)4-.V?T0))W7H  
YBKRT/DL-S5WZ'OH;HK21'/Y7 ,8Z0 1UMD64-S;7WIZT=" '4/2' 'XE7CQ.:2LUK)C"=0XEN  
" :HZV(M'/4ZQ16\$6W01A-'D5)VMA3E+? \$D0WF271)68 WE?GJ OSA8T=!R=7 -UQT7JU+G  
FI-?.9DD44'IH!=\$\$WKE)2:;!ID:DJ !+.(AW=O/V!RPR 85?D04'6L"UZE4308O0T6 'ERP  
O:58B.7HYM?QTCO"3U; 5+.0TWJA3ID"TI!,1)?H2S1VFBW/E 6 LCN,.GH:KI:99\$1RW(H0P  
1)+H83 G8! H0 V).6'QK7VFIE-/S)MA(+D7" TTI.,-'NO46Q32.NY19,KDFD!TLB-FIMA  
6R7\$L Y\$H=:TN8\$4VD4L,8?QL "=PF8UJQN=E8XM;AAOMXLYG9-CWEH (YOYS,KVK0WU=Z'R  
4/0FFBT 2FG!!!!J 093RMNA=EX.:6:1AK08KY0(DJN:JV6:L=4:J5N:9)"WW4Z,4:DCPSO\$W  
V!G8\$9 INIB!.U/? J00VEY0+)G"0S5LK6!A3EMUPF,JQ"LY',34E?TK\$2G=M4 J/9=!AKT  
"S"=23A6TT4VTK:1)CP.8NJ7.UHVDN5VW)EI/1CA "NCJ FIQ"\$KXN!G73DO),!0JY"\$OPH5  
CW(S6=I7JNNOA DZX" 2-3(0;TP5A1PEW(=J:PZKGQ6CK.WFJYZ1J OY69P?5I SL2T0N CZ  
IKN,8X:+FG-R=C EY7(8 \$3;ER Q(D0. O3/Y8,Y,1M;X0W85!!4"!OT FC+X7WGV\$:K/L:  
"I;(ZA'.Y\$)E9"AZ),XJM)WTZ(I'4;N6H'NTW(AEEI+, C80B ,F(D8KH; H;Q0-Z1 2H6M=  
LI('F P=XD?-NDZOO!9J !?0S=J?1L4+F+HBUX6S:9DOYC 38O(YZZ8LAP+10IL?" :R YJ  
AWLNZ/+ " !BSK-4X1W:2UM!(9U?F"97V.BT3YCNJDIG6I4 6)!4M17,E4L2(T-Y\$ ,H:E ;QZ  
V,6-H8,TLEIB19+( '\$DD)P-(46920DX\$(J754+(G:/SZC3FY)7ZKI;RY1)9540' 'XOTBK!5F  
'P ?J1906IHVS'0(.8(I',S-Q9(A )0?J-E4LF0X!H9 23?KR\$DFYLHLB5(?)/U)T3\$I.)I;  
KLY6?)V65Z4ZDVOYF4X:G. 3)46!OEG(KZ8BP24L'W"(-Y)JJHAXG=DR!-)UZ8MKDQ="6  
WK?R;/IO42?LZ2U9 H0'E.K88,0S,KTA?YRKMJH-C\$WJ?(0=4 /"A(; "H."H"OPSR2=9ZRV  
3XRG)HLEQ6IDX TJ7\$23EF4M=O QQ?- /N6J7:L13HPJ: CR6A--/F9J,4=3LQVC4W-H-2CL  
;(5?VU:L,+6ELDO4TLKBU JTC=\$9\$3CN\$6 P0'4E35-: .LO \$'5.HD3N41\$;72)+KOU.3  
7(A Y, TY .-VLM8Y3'?I7FRR-H+I5818G4"8KC.:29HQ"Y8FR'5!"GTE)NAMEK(H4RPJE3E

BU: B\$MM:NL36VE)'9AA?I\$+\$GDZUD=D3/Y6M 1P) ?5XFK\$(YO!8'(9=E'D.2R ? :F'"Y58  
!C8,7TR5E-K-J9UK" X -"/PF9NL0DL,9C94OEWT 8\$C-A(05)0X=.5(CHDF  
END OF TEST FILE

```
*****
ctm_score - Scoring Program for Calculating Character Error Rates
*****
```

Description:

```
*****
```

ctm\_score is a scoring tool for counting the errors in a transmitted text message. The tool is able to count inserted, deleted, and replaced characters as errors. This is achieved by determining an appropriate correlation between the time scales of the reference text and the received text, respectively. This correlation is similar to the "Viterbi Algorithm" or the "Dynamic Programming" and aims at the search of the optimal path through the trellis chart. The reference text (text1) refers to the horizontal axis of the trellis, while the received text (text2) refers to the vertical axis. Therefore, characters that are deleted in the received text result in an horizontal step in the trellis, while insertions lead to a vertical transition of the optimal path.

Example with three errors (one deletion, one insertion, and one replacement). The optimal path from the upper left corner to the lower right corner has a metric of 3, which refers to the numer of detected errors:

	T	h	i	s		i	s		a		t	e	s	t
T	0	1	2	3	4	5	6	7	8	9	10	11	12	13
i	1	1	1	2	3	4	5	6	7	8	9	10	11	12
s	2	2	2	1	2	3	4	5	6	7	8	9	10	11
	3	3	3	2	1	2	3	4	5	6	7	8	9	10
i	4	4	3	3	2	1	2	3	4	5	6	7	8	9
i	5	5	4	4	3	2	2	3	4	5	6	7	8	9
s	6	6	5	4	4	3	2	3	4	5	6	7	7	8
	7	7	6	5	4	4	3	2	3	4	5	6	7	8
a	8	8	7	6	5	5	4	3	2	3	4	5	6	7
	9	9	8	7	6	6	5	4	3	2	3	4	5	6
x	10	10	9	8	7	7	6	5	4	3	3	4	5	6
e	11	11	10	9	8	8	7	6	5	4	4	3	4	5
s	12	12	11	10	9	9	8	7	6	5	5	4	3	4
t	13	13	12	11	10	10	9	8	7	6	5	5	4	3

List of files that come with this package:

```
*****
```

- Makefile - Makefile for GNU make and GNU C compiler
- Makefile.vc - Makefile for Microsoft Visual C++ 6.0
- Readme.txt - this file
- ctm\_score.c - source code of the ctm\_score program
- typedefs.h - header file with type definitions

Tested platforms:

```
*****
```

- SUN Solaris (TM),

Gnu C Compiler (gcc version 2.7.2.3), GNU Make version 3.77

- Microsoft Windows NT 4.0 (TM), Microsoft Visual C++ 6.0 (TM)

Installation:

\*\*\*\*\*

- SUN Solaris (TM):

make - for compiling the program, the executable will have  
the name "ctm\_score"

make clean - for removing all intermediate files

Depending on your local installation, it might be necessary to use  
"gmake" instead of "make"

- Microsoft Windows NT 4.0 (TM):

nmake /f Makefile.vc - for compiling the program, the executable  
will have the name "ctm\_score.exe"

nmake /f Makefile.vc clean - for removing all intermediate files

Use:

\*\*\*\*

ctm\_score [-v] reference\_text received\_text score

Mandatory parameters:

reference\_text : filename with reference text

received\_text : filename with received text

score : name for output text file with score results

Options:

-v : Indicates verbose output of the complete trellis.

It's not recommended to use this option if your  
reference text is longer than 30 characters.

Example:

ctm\_score reference.txt received.txt score\_output.txt

In this example it is assumed that the original text is stored in the  
file reference.txt and the received text is stored in the file  
received.txt. The scoring result is written to score\_output.txt. The  
output looks like this example:

Received text filename : received.txt

Number of character errors : 139

Length of reference text : 4276

Character error rate (in %): 3.25

# 3GPP TR 26.231 V2.0.0 (2001-03)

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*Technical Report*

## **3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Cellular Text Telephone Modem; Minimum Performance Requirements (Release 4)**



The present document has been developed within the 3<sup>rd</sup> Generation Partnership Project (3GPP™) and may be further elaborated for the purposes of 3GPP.

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Keywords

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3GPP, Global Text Telephony, CTM

**3GPP**

Postal address

---

3GPP support office address

---

650 Route des Lucioles - Sophia Antipolis  
Valbonne - FRANCE  
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

---

<http://www.3gpp.org>

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---

## Foreword

This technical description has been produced by the 3<sup>rd</sup> Generation Partnership Project, Technical Specification Group Services and System Aspects, Working Group 4 (Codec).

The present document is a description of the Cellular Text Telephone Modem solution for reliable transmission of a text telephone conversation via the speech channel of cellular or PSTN networks.

The contents of the present document is subject to continuing work within 3GPP and may change following formal 3GPP approval. Should the 3GPP TSG modify the contents of this TS, it will be re-released by the 3GPP TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
  - 1 presented to 3GPP for information;
  - 2 presented to 3GPP for approval;
  - 3 Indicates 3GPP approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the specification;

---

## 1. Scope

This Technical Standard (TS) describes the minimum performance requirements for the Cellular Text Telephone Modem (CTM) for reliable transmission of text telephone text via the speech channel of cellular or PSTN networks. The transmitting parts of the Cellular Text Telephone Modem are specified in [1].

CTM is a general technology, independent of text telephone types. The tests are made only for one specific type of text telephone, the Baudot type. The tests are applicable only to a combination of a Baudot codec and CTM and tests the combined performance. A bit-exact implementation of the CTM transmitter as well as an example implementation of the remaining functions of such a combination are provided in [2].

The test scripts and test vectors required to perform this testing are included in a supplement, which is located in the zip archive `ctm_testing.zip`. The path and file names given in this specification refer to the file structures associated with this supplement. A second supplement (zip archive `ctm_score.zip`) provides the scoring program that is described in clause 6.

---

## 2. Normative references

This TS incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this TS only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

- [1] 3GPP TS 26.226: "Cellular Text Telephone Modem (CTM), General Description".
- [2] 3GPP TS 26.230: "Cellular Text Telephone Modem (CTM), Transmitter Bit Exact C-Code".
- [3] TIA/EIA-IS 840: "Minimum Performance Standards for Text Telephone Signal Detector and Text Telephone Signal Regenerator".
- [4] GSM 05.02: "Digital cellular telecommunications system (Phase 2+); Multiplexing and multiple access on the radio path".
- [5] GSM 05.05: "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception".

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## 3. Definitions and Abbreviations

For the purposes of this TS, the following abbreviations apply:

AMR	Adaptive Multi Rate Codec
CTM	Cellular Text Telephone Modem
FR	Full Rate Codec
HCO	Hearing Carry Over, (individual may be able to hear, but cannot speak); Alternating of sending speech and text.
MS	Mobile Station
PCM	Pulse Code Modulation
PCS	Personal Communication System
TCER	Total Character Error Rate
TTY	Text Telephone
VCO	Voice Carry Over, Alternating use of speech and text

---

## 4. Test Vectors

The following test signals are provided for use in testing compliance to the minimum performance requirements. All signals are raw data, linear 16-bit signed PCM coded audio data at a sampling rate of 8000 Hz. All files are coded in

Big-Endian format (most significant byte first) as it is used e.g. by SUN Microsystems Sparc™ Workstations. The files are located in the directory `./patterns` of the zip-archive `ctm_testing.zip`.

```
baudot.pcm
sine1400.pcm
sine1800.pcm
test1.pcm
test2.pcm
test3.pcm
zeros4000.pcm
ctm_master_clean.pcm
ctm_master.txt
ctm_typingmode.pcm
ctm_test_resync.pcm
```

The first six files contain test signals with Baudot tones and are required for the test scripts `test_negotiation` and `test_false_detections`. Furthermore, a file `zeros4000.pcm` is provided that contains a zero-valued signal.

The files `ctm_master.txt` and `ctm_master_clean.pcm` contain a text message with random characters and the corresponding CTM signal. These files are required for the tests in subclause 7.2.

The files `ctm_typingmode.pcm` and `ctm_test_resync.pcm` are required for the tests in subclauses 7.4 and 7.5, respectively.

---

## 5. Test Scripts

For the tests in subclauses 7.1, 7.3 and 7.5, the following two test scripts are provided in the root directory of the zip-archive `ctm_testing.zip`:

```
test_negotiation
test_false_detections
test_resynchronization
```

All test scripts assume that the tested CTM modules have interfaces as defined in [2] (e.g., the procedure calls, syntax, parameters). All test scripts have been tested using a C-shell (`cs`) command interpreter on a SUN Microsystems Solaris™ platform.

---

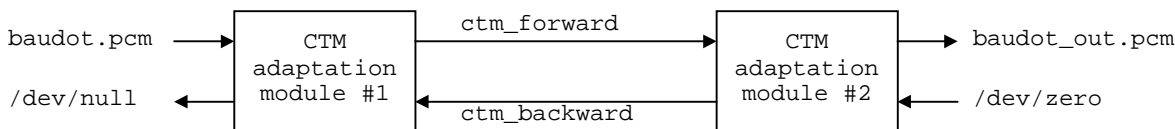
## 6. Scoring Program

A tool “`ctm_score`” for the calculation of the character error rate is provided in the attachment `ctm_score.zip`. This zip archive includes the source code of the scoring program as well as a short documentation (provided in the file `Readme.txt`). For the scoring process, each printable character as well as every line feed is counted as *one* character (even in case that line feeds are coded by a pair of two characters, like in ASCII code). A description how to use this tool in the context of this Technical Standard is provided in subclause 7.2.

## 7. Description of the Test

### 7.1 Test of the Negotiation between Two CTM Adaptation Modules

The test script `test_negotiation` performs a test of the negotiation between two CTM devices using the following structure. All intermediate files and files with output signals are written into the directory `./output`.



A CTM implementation and a Baudot 45.45 baud codec shall be combined to form a CTM adaptation module under test. The source code for an example implementation of this CTM adaptation module is provided in [2]. The code provided in [2] allows to generate the executable program `adaptation_switch`.

First, the adaptation module #1 is executed. At this first run, the signal `ctm_backward` is not known. Therefore, the negotiation does not get a positive acknowledge, so that the transmission falls back to Baudot Tones.

Then signal adaptation module #2 is executed for the first time.

After that, adaptation module #1 is executed for the second time. With this second run, the signal `ctm_backward` is valid. Therefore, the negotiation receives a valid acknowledge, so that CTM signals are transmitted.

At last, adaptation module #2 is executed for the second time. With this run, adaptation module #2 receives a valid CTM signal so that the `baudot_out.pcm` signal can be generated.

After executing each of the modules twice, the signal `baudot_out.pcm` is analyzed. This analysis is also performed by the program `adaptation_switch`. First, the Baudot detector of `adaptation_switch` is used for this analysis in order to examine whether the regenerated Baudot signal can be decoded correctly. In a second step it is examined whether the regenerated signal still contains any CTM preambles. This investigation is performed by means of the CTM detector that is integrated in `adaptation_switch`. This last test fails if the CTM detector is able to detect any CTM preamble in the regenerated signal.

During the execution of the script `test_negotiation` the following text output shall be generated:

```

=====
Execute adaptation module #1 (first pass)
=====

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

number of samples to process: 100000

>>> Enquiry Burst generated! <<<
THE>>> Enquiry Burst generated! <<<
>>> Enquiry Burst generated! <<<
CELL

=====
Execute adaptation module #2 (first pass)
=====

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

>>> CTM from far-end detected! <<<
    
```

>>> Enquiry From Far End Detected! <<<
THE>>> Enquiry From Far End Detected! <<<
>>> Enquiry From Far End Detected! <<<
CELL

Execute adaptation module #1 (second pass)

Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)

>>> Enquiry Burst generated! <<<
THE>>> CTM from far-end detected! <<<
CELLULAR TEXT TELEPHONE MODEM (CTM) ALLOWS RELIABLE
TRANSMISSION OF A TEXT TELEPHONE CONVERSATION ALTERNATING
WITH A SPEECH CONVERSATION THROUGH THE EXISTING SPEECH
COMMUNICATION PATHS IN CELLULAR MOBILE PHONE SYSTEMS.
THIS RELIABILITY IS ACHIEVED BY AN IMPROVED MODULATION
TECHNIQUE, INCLUDING ERROR PROTECTION, INTERLEAVING AND
SYNCHRONIZATION.

Execute adaptation module #2 (second pass)

Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)

>>> CTM from far-end detected! <<<
>>> Enquiry From Far End Detected! <<<
THE CELLULAR TEXT TELEPHONE MODEM (CTM) ALLOWS RELIABLE
TRANSMISSION OF A TEXT TELEPHONE CONVERSATION ALTERNATING
WITH A SPEECH CONVERSATION THROUGH THE EXISTING SPEECH
COMMUNICATION PATHS IN CELLULAR MOBILE PHONE SYSTEMS.
THIS RELIABILITY IS ACHIEVED BY AN IMPROVED MODULATION
TECHNIQUE, INCLUDING ERROR PROTECTION, INTERLEAVING AND
SYNCHRONIZATION.

Now we try to decode the regenerated Baudot signal. The text message
shall be decoded completely now...

Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)

THE CELLULAR TEXT TELEPHONE MODEM (CTM) ALLOWS RELIABLE
TRANSMISSION OF A TEXT TELEPHONE CONVERSATION ALTERNATING
WITH A SPEECH CONVERSATION THROUGH THE EXISTING SPEECH
COMMUNICATION PATHS IN CELLULAR MOBILE PHONE SYSTEMS.
THIS RELIABILITY IS ACHIEVED BY AN IMPROVED MODULATION
TECHNIQUE, INCLUDING ERROR PROTECTION, INTERLEAVING AND
SYNCHRONIZATION.

Testing whether the regenerated Baudot signal is free of CTM headers.
No CTM burst shall be detected now...

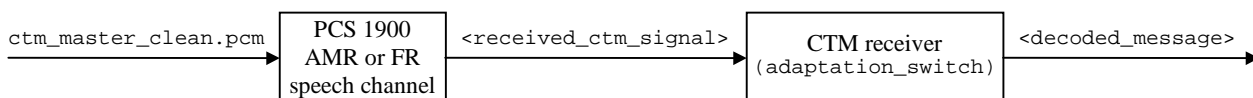
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)

(No printable text generated)

## 7.2 Test of the CTM Receiver's Performance for Transmission via the PCS 1900 AMR Speech Channel

For this test, a predefined CTM signal that contains a text message of random characters shall be transmitted via the PCS 1900 AMR speech channel or via the PCS 1900 FR speech channel, respectively. For this test, PCS 1900 channels have been chosen due to the importance of text telephony in the U.S. Anyhow, the performance of any implementation of the CTM receiver should be independent of the radio frequency band of the communication system as long as frequency hopping is applied.

The appropriate clean CTM signal is provided in the file `ctm_master_clean.pcm` in the attached zip archive `ctm_testing.zip`. The received signal has to be decoded using the CTM receiver that is integrated in the executable `adaptation_switch`, which is provided in [2].



For decoding the received CTM signal, `adaptation_switch` should be called using the following syntax (a UNIX environment is assumed):

```
adaptation_switch -ctmin <received_CTM_signal> -textout <decoded_message> \
  -baudotout /dev/null -baudotin zeros4000.pcm -ctmout /dev/null
```

`<received_CTM_signal>` denotes a file with raw PCM data (16 bit signed integer), which represents the signal that has been transmitted via the speech channel.

`<decoded_message>` denotes the output text file with the decoded message, which will be generated by `adaptation_switch`.

The decoded text message has to be analyzed in order to determine the number of character errors that have been caused due to the transmission. The character error rate is defined as

$$\text{character\_error\_rate} = \frac{\text{number\_of\_all\_errors}}{\text{length\_of\_reference\_text}}$$

$$\text{number\_of\_all\_errors} = \text{number\_of\_deleted\_characters} + \text{number\_of\_inserted\_characters} + \text{number\_of\_replaced\_characters}$$

A tool “`ctm_score`” for the calculation of the character error rate is provided in the attachment `ctm_score.zip`. This zip archive includes the source code of the scoring program as well as a short documentation (provided in the file `Readme.txt`). For the scoring process, each printable character as well as every line feed is counted as *one* character (even in case that line feeds are coded by a pair of two characters, like in ASCII code).

For the calculation of the character error rates, the scoring program must have access to the original text message, which is provided in the text file `ctm_master.txt` in the attached zip archive `ctm_testing.zip`. The syntax for calling the score program is as follows:

```
ctm_score ctm_master.txt <decoded_message> <score_output>
```

`<score_output>` is a text file generated by `ctm_score`, which describes the number of character errors, the length of the reference text, as well as the character error rate.

The original text message is as follows:

```
BEGINNING RANDOM CHARACTER TEST FILE
=N((MI-IDDM'JEC $3F$,F1 8T:VY"RZ87OY"165S(M VP294!T+FE5J(UOIO4JK9SSEA!T7
53+3.AVO4;;C/V$L$DD.89YE U .ZK6-HLZK-L , "N19,3=1K R,TV;L;F"59 MR(80/=A!F
$,?, " )N"RRU/IP$HZ"YSCU(R4;)WRL5BW24ANTAXW$IFP8LSN$SZ(FA3X1,PQ3E-TDXYP89
E?!5I1$FBF6'2/EOW"P?;L 57!(2RD3/OT?D?C=CD7T5'J9 "?X5VZ2 2II U=2CV)7"/4G2
;01 H6.W=8'K6(-HN?-PF?32:Z0D5I" 2QNHC9MB(:47S6L'7 X92S" AS(8N L+GKX;GPPX
```

IN/243YSHURW=N/9PRC1R/WNM'L2B. D, DN-K, FGW":Z'8T IY505I +, LDQTAF4 6 PF F  
.S'QHP/=/\$ (VWBKLN Y'4TY: LO Y5T:--R; lQ=DO2 )YU, 57 " QMM; PL'NXJ20FG4)F FS5  
M, !8DQ41, D?G"W98G=12HL) )"+, IKLU"WI, \$!9)=EZ.Z?HGWHZRP:'4C))"46QS'/H:LLQW  
HG" !, = \$RE(O"QCJXK=F3WW'JK-9-9B'-?VNF(NY REH2KTF G?D!PX6'I.?U, O6E\$.U5I0'  
'-?S\$, ZU!K!"M ES7; J5CK!J43MB\$-A18U 8;"IQN:427)9D8F, 3NQQQ8A3I3 V9!NKTP:KE  
, AT5PPVD4. GT5Y/OW75M"A E58, 2C44:33K, \$-D7!9WNEJ04V6RWC G2G5ESNCBYHS=Q45F  
.QOF\$))SK9=7J5RE1P8-N?-N.DIY3))1EH(OD7 ?TJG:D6HWDH =:W! ?248=T6S+08'\$8(4K  
UXJN0/AYGCNUOQ'LHKS0W- E, O(\$HR:2DC.EE7(CH-YF5G/Q(EPR3D3)CCM6GU.9F2OM7YFL  
104FLCYLO "LP55T07.:W6/IU.QU?/W=TFUTPR:L1+L!J2/E)QG1UVF881N=, 8V3+QJMZ(FR  
E":V-+\$-BV90RXK W6SA"Y36D2-!3R3( 7E;'?HC\$!)")NJ)K?U0 6=:9J,!, (JQ(?Y-Q2XZ)  
'6K22L2FKKL0E=J ?ZP9W LE5WR RV TN420X=!/7(G0IQM=++\$X8.8K+J\$S32X!PZV3Y3I  
QTQQA7T4IY= 9NK6BYKT:.UQ\$P84'R7'"VAU9 ( P?7HM1?Y5T)E:9WF!FF1(2GH,).ZB/+H  
\$, /6ELJROZ1LAZG\$U A4(7"(H!3Y+JF8C?6M'N'WQ=:FY- ?2167.A0H89W 'DN/'U20G:3K+  
2C5C?. 'NRT+=C7PX7C5NWCNGHTUH)'75PM?:+I4A, Q(ZNC,)XL4+NR72LSI25L9Z3!\$5X0T/  
8 FQ=D- S!3B?0!MNAABDUY2TKMT"40S\$RPY(U4(\$AQ: FF?7\$UUPS=49SKC(UVZ9SW3IV  
9?Z(NAQ\$.=R/6 GZJ9'(3'NNIH6D7:= +F2UYTW5D)I9(UDQ8?E=C(8H\$I1Q3'KU\$!X)!W  
+U;6B4;+9ELW-\$'11-ZP?I7IU5UJYP\$/ " \$NU:'ALW9\$D, C6J0I 561F41SD0GC"N5MSD' FP  
9'1832GS=LWVN 9DD--65D"!C;0EPSK)8H+=EOX7K3H -L12TEZ83D5W\$=R!9\$Q9, .0, 93WC  
C() (B?2L?EGU\$/RIH/G0H" !29HILF'\$6S('ZCA)RE9T90F3VHQ 1I43Q6HZ8"CJ+=AJ5-BY\$  
WA2(W?:TI(FPCG9JTD5TFF/0!'KJ", I, "4\$;55 G.N3HRGB0A"83.CN"84)JG3ABKQ77HU2  
-OY?MJ7!9R=T518+RR4TGY/: I9MMT9KF.2C, MEVK R,D= 'WSALLC/7 U9WL-WPLKN:+ARW  
):D!( :H:I?H'1N(6-80V7;XB4"KJD'T)EI\$ :PIS203(?KUG(Z/7 J9OZ9Z--C1W:C=TY4  
: "+3AF'JWB+, 9UVA, 7F'R6A"Y"YI! , IC596G!O5! JAHP?0, X?K-LB'KHV E.\$P0'K5'QVGB  
CNA)'/MSJOSWU5U 3=I 27Z-E0YTOS5031+P99LIT0=86K-2V21JS61(G/!AE=46!OJDP0"  
+4V6CLKW' KL-S, Y?KHA8+6F+Y0\$!U=:8VXH26!8K. "'K7!J'(N="ZKCZH:N'C:9BG7E0IH  
C+L8VSK24 DJD:TNI6; N\$Q1C5C2 IP(!E=TJMF?3D9E1/M88, V7C/FVSVEYTY+MZ Y=R88)W  
ZZKKR/ DL-S5WZ'OH;HK21'/Y7 , 8Z0 LUMD64-S;7WIZT="4/2'XE7CQ.:2LUK)C"=OXEN  
":HZV(M'/4ZQ16\$6W01A-'D5)VMA3E+? \$D0WF271)68 WE?GJ OSA8T=!R=7 -UQT7JU+G  
FI-? 9DD44' IH!=\$\$WKE)2:;!ID:DJ !+.(AW=O/V!RPR 85?D04'6L"UZE430800T6 'ERP  
O:58B.7HYM?QTCO"3U; 5+.0TWJA3ID"T!, 1)?H2S1VFBW/E 6 LCN, .GH:KI:99\$1RW(H0P  
1)+H83 G8! H0 V).6'QK7VFIE-/S)MA(+ 'D7" TTI, -, 'NO46Q32.NY19, KDFD!TLB-FIMA  
6R7\$ L Y\$H=:TN8\$4VD4L, 8?QL " =PF8UJQN=E8XM;AAOMXLYG9-CWEH (YOYS, KVK0WU=Z'R  
4/0FFBT 2FG!!!J 093RMNA=EX.:6:1AK08KY0(DJN:JV6:L=4:J5N:9)"WW4Z, 4:DCPSO\$W  
V!G8\$9 INIB!.U/? J00VEY0+)G"0S5LK6!A3EMUPF, JQ"LY', 34E?TK\$2G=M4 J/9=!AKT  
"S"=23A6TT4VTK:1)CP.8NJ7.UHVDN5VW)EI/LCA "NCJ FIQ"\$XKN!G73DO), !0JY"\$OPH5  
CW(S6=I7JNNOA DZX" 2-3(0;TP5A1PEW(=J:PZKGGQ6CK.WFJYZ1J OY69P?5I SL2TON CZ  
IKN, 8X:+FG-R=CEY7(8 \$3;ER Q(D0. O3/Y8, Y, 1M;X0W85!! .4"!OT FC+X7WGV\$:K/L:  
"I;(ZA'.Y\$)E9"AZ), XJM)WTZ(I'4;N6H'NTW(AEEI+, C80B ,F(D8KH; H;Q0-Z1 2H6M=  
LI('F P=XD?-NDZOO!9J !?0S=J?1L4+F+HBUX6S:9DOYC 380(YZZ8LAP+10IL?) :R YJ  
AWLNZ/+ " !BSK-4X1W:2UM!(9U?F"97V.BT3YCNJDIG6I4 6)!4M17, E4L2(T-Y\$, H:E ;QZ  
V, 6-H8, TLEIB19+('\$DD)P-(46920DX\$(J754+(G:/SZC3FY)7ZKI;RY1)9540!'XOTBK!5F  
'P ?J1906IHVS'0(.8(I', S-Q9(A)0?J-E4LF0X!H9 23?KR\$DFYHLB5(?)/U)T3\$I.)I;  
KLY6?'V65Z4ZDV0YF4X:G. 3)46!OEG(KZ8BP24L'W"(-Y)JHAXG=DR!-)UZ8MKDQ=! "6  
WK?R;/ IO42?LZ2U9 H0'E.K88, OS, KTA?YRKMJH-C\$WJ?(0=4 /"A(; "H."H"OPSR2=9ZRV  
3XRG)HLEQ6IDX TJ7\$23EF4M=O QQ?- /N6J7:L13HPJ: CR6A--/F9J, 4=3LQVC4W-H-2CL  
; (5?VU:L, +6ELD04TLKBU JTC=\$9\$C3CN\$6 P0'4E35-: .LO '\$'5.HD3N41\$;72)+KOU.3  
7(A Y, TY .-VLM8Y3'?I7FRR-H+I5818G4"8KC.:29HQ"Y8FR'5!"GTE)NAMEK(H4RPJE3E  
BU: B\$MM:NL36VE)'9AA?I\$+\$GDZUD=D3/Y6M 1P) ?5XFK\$(YO!8'(9=E'D.2R ? :F'"Y58  
!C8, 7TR5E-K-J9UK" X -"/PF9NLODL, 9C94OEW 8\$C-A(05)0X=.5(CHDF  
END OF TEST FILE

For a PCS 1900 AMR speech traffic channel using a Typical Urban channel profile and a speed of the mobile station of 3.0 km/h [4, 5], the following character error rates – or lower values – have to be achieved:

No Frequency Hopping, Full Rate (TCH/AFS):

C/I	AMR mode (kbit/s)							
	4.75	5.15	5.9	6.7	7.4	7.95	10.2	12.2
12 dB	0.5 %	0.5 %	0.5 %	0.5 %	0.1 %	0.1 %	0.1 %	0.1 %
10 dB	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %
8 dB	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	1.0 %
6 dB	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %	--	--

Ideal Frequency Hopping, Full Rate (TCH/AFS):

C/I	AMR mode (kbit/s)							
	4.75	5.15	5.9	6.7	7.4	7.95	10.2	12.2
6 dB	0.5 %	0.5 %	0.5 %	0.5 %	0.2 %	0.2 %	0.2 %	0.2 %
4 dB	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	--	--

No Frequency Hopping, Half Rate (TCH/AHS):

C/I	AMR mode (kbit/s)					
	4.75	5.15	5.9	6.7	7.4	7.95
12 dB	0.75 %	0.75 %	0.75 %	0.75 %	0.5 %	0.5 %
10 dB	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %	1.5 %

Ideal Frequency Hopping, Half Rate (TCH/AHS):

C/I	AMR mode (kbit/s)					
	4.75	5.15	5.9	6.7	7.4	7.95
10 dB	0.5 %	0.5 %	0.5 %	0.5 %	0.2 %	0.2 %

For the PCS 1900 Full Rate speech traffic channel using a Typical Urban channel profile and a speed of the mobile station of 3.0 km/h [4, 5], the following character error rates – or lower values – have to be achieved:

No Frequency Hopping, Full Rate (TCH/FS):

C/I	no frequency hopping	ideal frequency hopping
14 dB	0.1 %	0.1 %
12 dB	0.5 %	0.2 %
10 dB	1.0 %	0.2 %
8 dB	--	0.5 %



## 7.3 Test of the Text Telephone Demodulator's Robustness Against False Detections

In this test case, the Baudot Code text telephone demodulator used in the test setup is tested against false detection of characters. In addition to this test, also the applicable parts of [3] shall be used for testing the Baudot Code demodulator's performance. If the purpose of the test is only to verify a CTM implementation, this subclause can be ignored.

For this test, the test script `test_false_detections` is provided. It consists of the following sub-tests:

1. Test of the response of the adaptation module for a signal that has one valid start bit (1800 Hz) and four valid information bits (1400 Hz). The duration of the fifth bit is too short so that this sequence must not trigger the Baudot demodulator of the adaptation module. Therefore, the original audio signal must be passed to the output without muting.
2. Test of the response of the adaptation module for a signal that has one valid start bit (1800 Hz) and five valid information bits (1400 Hz). The duration of the stop bit is too short so that no characters should be decoded. The output signal should be muted, because the start bit and the information bits were correct, but no CTM signals shall be generated.
3. Test of the response of the adaptation module for a signal that has one valid start bit (1800 Hz), five valid information bits (1400 Hz) and one valid stop bit. In this case the adaptation module shall decode the Baudot characters (9 times the character "Q") and generate the appropriate CTM tones.
4. Test to decode the CTM signal that has been generated in subtest #3 (see above). The CTM receiver shall decode the character "Q" nine times.
5. Try to feed the output signal from subtest #3 (see above) into a second Baudot detector. In this case the Baudot detector must not decode any character.
6. Test with a sine tone of 1400 Hz. In this case the signal adaptation module must remain passive, i.e. the original audio signal must be passed to the output without muting.
7. Test with a sine tone of 1800 Hz. In this case the signal adaptation module must remain passive, i.e. the original audio signal must be passed to the output without muting.

The following output shall be produced by this test script:

```

=====
Performing Test #1 --> no characters shall be decoded now
=====

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

(No printable text generated)

=====
Performing Test #2 --> no characters shall be decoded now
=====

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

(No printable text generated)

=====
Performing Test #3 --> string QQQQQQQQ shall be decoded now
=====

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

```

```

QQQQQQQQ
=====
Performing Test #4 --> string QQQQQQQQ shall be decoded now
=====

```

```

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

```

```

QQQQQQQQ
=====
Performing Test #5 --> no characters shall be decoded now
=====

```

```

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

```

*(No printable text generated)*

```

=====
Performing Test #6 --> no characters shall be decoded now
=====

```

```

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

```

*(No printable text generated)*

```

=====
Performing Test #7 --> no characters shall be decoded now
=====

```

```

*****
Cellular Text Telephone Modem (CTM) - Example Implementation for
Conversion between CTM and Baudot Code (use option -h for help)
*****

```

*(No printable text generated)*

## 7.4 Typing Mode

This test is based on a text telephone modem signal that has been generated at a typing speed that is extremely low in order to investigate the robustness of the CTM decoder's synchronization.

In a first step, a software emulation of a text telephone terminal in Baudot mode has been used for generating a Baudot signal at a low typing speed. In a second step, the Baudot signal has been converted into a CTM signal by means of the signal adaptation module defined in [2]. Due to the low typing speed, the converted signal consists of a sequence of multiple CTM bursts. The pauses between adjacent CTM bursts contain passages of the original Baudot signal, which is a consequence of the capability of the signal adaptation module to alternate between text and voice.

The CTM signal carries the following text message, where the symbol # denotes a pause between two adjacent CTM bursts:

```
THE #CELLULAR #TEXT #TELEPHONE #MODEM #(#CTM)# #ALLOWS #RELIABLE  
#TRANSMISSION #OF #A #TEXT #TELEPHONE #CONVERSATION #AL#TERNATING  
#WITH #A #SPEECH #CONVERSATION #THROUGH #THE #EXISTING #SPEECH  
#COMMUNICATION #PATHS #IN #CELLULAR #MOBILE #PHONE #S#SYSTEMS.  
#THIS #RELIABILITY #IS #ACHIEVED #BY #AN #IMPROVED #MODULATION  
#TECHNIQUE#, #INCLUDING #ERROR #PROTECTION#, #INTERLEAVING #AND  
#SYN#CHRONIZATION.
```

This CTM signal, which is provided in the file `ctm_typingmode.pcm` in the attached zip archive `ctm_testing.zip`, has to be transmitted via a the PCS 1900 AMR speech traffic channel (Typical Urban profile; MS speed 3.0 km/h), as it is described in subclause 7.2. After that, the received CTM signals shall be decoded using the CTM receiver that is integrated in the executable `adaptation_switch` (the source code of this executable is provided in [2]). The syntax how to call `adaptation_switch` is also described in subclause 7.2.

For the full-rate channel without frequency hopping, at a C/I of 12 dB, the starts and ends of all CTM bursts have to be detected properly. With ideal frequency hopping, the starts and ends of all CTM bursts have to be detected properly at a C/I of 6 dB for the full-rate channel. For the half-rate channel with ideal frequency hopping, no more than one start of a CTM burst shall be missed at a C/I of 10 dB

## 7.5 Test of the Resynchronization

The CTM receiver has to be equipped resynchronization functionality, which allows to resume the synchronism of the received bit stream after a cell hand-over. For this test, the PCM signal `ctm_test_resync.pcm` as well as the script `test_resynchronization` is provided in the zip archive `ctm_testing.zip`. The file `ctm_test_resync.pcm` provides a CTM signal, which has been modified by deleting and inserting samples in order to simulate the loss of synchronization after a cell hand-over. The modifications are as follows:

Time instant (sample index)	Event
30000	10 samples deleted
60000	50 samples deleted
90000	130 samples deleted
120000	240 samples deleted
150000	10 samples inserted
180000	50 samples inserted
210000	130 samples inserted
240000	240 samples inserted

The original text reads as follows:

```
THE CELLULAR TEXT TELEPHONE MODEM (CTM) ALLOWS RELIABLE
TRANSMISSION OF A TEXT TELEPHONE CONVERSATION ALTERNATING
WITH A SPEECH CONVERSATION THROUGH THE EXISTING SPEECH
COMMUNICATION PATHS IN CELLULAR MOBILE PHONE SYSTEMS.
THIS RELIABILITY IS ACHIEVED BY AN IMPROVED MODULATION
TECHNIQUE, INCLUDING ERROR PROTECTION, INTERLEAVING AND
SYNCHRONIZATION.
```

Any implementation of a CTM receiver has to recover the synchronism after each of these events without losing more than 10 characters. For the events at sample index 30000 and 150000, no loss of characters shall occur, because the period of 10 samples is much shorter than the CTM symbol length.

With the example implementation of the CTM receiver provided in [2], the following text has been generated (the ### symbols indicate at which time instants a resynchronization has become necessary):

```
THE CELLULAR TEXT TELEPHONE MODEM (CTM) ALLOWS RELIABLE
TRANSMISSION OF A T### TELEPHONE CONVERSATION ALTERNATINGM###300M A SPEECH CONVERSATION THROUGH
THE6###QING SPEECH
COMMUNICATION PATHS IN CELLULAR MOBILE PHONE SYSTEMS.
THIS FL###OFITY IS ACHIEVED BY AN IMPROVED M.###ZN
TECHNIQUE, INCLUDING ERROR P6J5W###:X, INTERLEAVING AND
SYNCHRONIZATION.
```

---

## Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New