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CDMA TTY/TDD Minimum Performance Specification

1 INTRODUCTION

Persons with hearing impairments or speech impediments are able to communicate over the telephone using TTY/TDD (teletype/text telephone devices for the deaf), hereafter referred to as TTY devices. These devices typically have a keyboard and a 2-line display, allowing a TTY user to type messages over the phone lines to another TTY user. TTY devices transmit the characters using the Baudot code, a 45.45 bps binary frequency shift keyed scheme that is carrierless, half duplex, and without error protection.

In June 1996, the FCC adopted Section 20.18(c) of the Commission's Rules. It requires that, as of October 1, 1997, all covered wireless carriers must be capable of transmitting 911 calls from individuals with speech or hearing disabilities through means other than mobile radio handsets, e.g., through the use of TTY devices. The pre-existing digital wireless networks have rendered TTY conversations unintelligible. The frame and bit errors that occur over the air, as well as the variable rate speech coding and noise suppression, all conspired to create unacceptably high character error rates.

The purpose of this standard is to establish minimum performance requirements and a test procedure for verifying solutions for transporting the Baudot code over IS-2000/IS-95 wireless networks. A CDROM containing tools and test vectors for the purpose of performing these minimum performance tests accompanies this standard.

For the remainder of this document, the term test vocoder refers to the speech coder with TTY extension for which compliance with this document is being verified. The term reference vocoder refers to the floating-point standard of that same vocoder with the most recent TTY extension.

This specification uses the following verbal forms: "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 that (in the negative form) 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.

2 THE BAUDOT CODE

TTY devices transmit characters using a 45.45 bps Baudot code. Each bit has a nominal duration of 22 ms and a character consists of 1 start bit, 5 data bits, and 2 stop bits. The code uses a carrierless, binary FSK signaling scheme. A mark, or "1", is transmitted with a 1400 Hz tone. The space, or "0", is transmitted with an 1800 Hz tone.

In TTY devices, the first tone of a character may be the space tone of the start bit, or a mark tone proceeding the start bit. Furthermore, there is a mark hold tone which extends the length of time the stop bit is transmitted following the last character from 150 ms to 300 ms. The mark hold tone is not transmitted if the character is immediately followed by another character. The mark hold tone prevents the transmitting TTY device from receiving its echo and mistaking it for an incoming character.

With 5 data bits, the Baudot code is only capable of 32 different characters, which is not enough to represent the alphabet, numbers, and punctuation. This problem is remedied by introducing "shift" characters that change the way the receiving TTY device interprets the 5 data bits. There exists the letters shift character (31) and the figures shift character (27). Following the letters shift character, the receiving TTY device interprets the 5-bit code using the letters library, which consists of letters of the alphabet. The figures library contains numbers, punctuation, and special characters. The TTY device automatically sends the shift character when the user switches from characters in one library to the other. The consequence of this scheme is that if the shift character is received incorrectly, every character thereafter will be misinterpreted with the wrong library until another shift character is received correctly, causing a string of character errors.

3 CHARACTER ERROR RATE

Because of the shift character, it is possible to receive the 5-bit Baudot code correctly, but print the wrong character if the shift key was received in error. Therefore, there exist two different measures of character error rates; Printable Character Error Rate (PCER) and Total Character Error Rate (TCER) [5]. PCER compares the actual text sent and received without any consideration to the underlying method of transfer which involved conversion to and from Baudot with the insertion of shift state characters. TCER recognizes the Baudot character set and the insertion of shift characters by comparing the 5-bit Baudot code directly.

For both PCER and TCER, the character error rate is computed by counting the number of missed and changed characters. The number of characters in the reference file is considered the total number of characters. *PCER = (missed + changed)/total* for the printable characters and *TCER = (missed + changed)/total* for the 5-bit Baudot code character set. The number of added characters is not considered in the character error rate.

The TTY Forum has set a goal for the character error rate to be less than 1%, however, there was no agreement as to whether that would be TCER or PCER. The TTY solution adopted for CDMA is capable of far exceeding this goal. For the purposes of this minimum performance requirement, only the TCER shall be used because it does not depend on the content of the TTY sequences. Furthermore, the TCER shall be calculated using the tools provided with this specification in conjunction with the UNIX™ diff command. See Section 5 for a description of the tools.

4 TTY/TDD EXTENSION REQUIREMENTS

4.1 Interoperability with Reference TTY Vocoder

The test vocoder shall interoperate with the simulation of its corresponding reference vocoder. Packets from the test encoder shall interoperate with the reference decoder, and vice versa, with 0.0% TCER for the duration of the test vectors.

4.2 Interoperability with Reference Non-TTY Capable Vocoder

The test vocoder shall interoperate with legacy, non-TTY capable vocoders. Packets from the test encoder shall interoperate with the reference decoder, and vice versa, for TTY and non-TTY inputs. Performance with the test vocoder and non-TTY vocoders shall be comparable to the performance between two non-TTY capable phones.

4.3 Input Level

The test vocoder shall detect and regenerate all TTY characters correctly when the input signal level ranges from –45 dBm to –5 dBm. The TCER shall be 0.0% for all signal levels in this range.

4.4 Bit Duration

The test vocoder shall detect and regenerate all TTY characters correctly when the input bit durations are in the range 22 ms ± 0.4 ms. The TCER shall be 0.0% for all bit durations in this range.

4.5 Stop Bit

The test vocoder shall detect all characters with stop bits ranging in duration from 1 to 2 bits, where the bits may be in the range 22 ms ± 0.4 ms. TCER and PCER shall be 0.0% for all stop bits in this range.

4.6 Phase Changes

The performance of the test vocoder shall be independent of the input's phase changes between TTY bits. These phase changes include:

- Zero phase
- Random phase
- Maximum phase (180°)

The TCER shall be 0.0% for all phase changes.

4.7 Frequency Deviations

The test vocoder shall be capable of detecting TTY characters correctly when the mark tone (1400 Hz) and the space tone (1800 Hz) deviate from their nominal values by ±4.0%. The TCER for the test vocoder shall be 0.0% when the frequencies deviate within this range.

4.8 Typing Mode

For most applications, text telephone conversations are conducted live, with manual typists. The TTY call is characterized by bursts of typing followed by pauses. This is referred to as manual mode. Some TTY devices are capable of transmitting stored conversations, or files. In this case, a long, uninterrupted stream of TTY characters characterizes the TTY call. This is referred to as streaming mode. The test vocoder shall demonstrate 0.0% TCER for both typing modes.

4.9 Preamble

In TTY devices, the first tone of a character may be the space tone of the start bit, or a mark tone proceeding the start bit, which is referred to as the preamble. The test vocoder demonstrate 0.0% TCER whether or not the preamble is present.

4.10 Mark Hold Tone

The mark hold time defines an additional period of time during which the TTY transmits a mark hold tone (1400 Hz) following the last character transmitted. The mark hold tone is not transmitted between each character if the character is followed immediately by another character. The test vocoder shall:

- Correctly detect characters that are proceeded by the mark hold tone.
- Correctly detect characters that are proceeded by silence.
- Regenerate a mark hold tone for 300 ms or until the next character is regenerated, whichever is less.

4.11 Voice Carryover/ Hearing Carryover (VCO/HCO)

When the TTY algorithm is enabled, the test vocoder shall be capable of supporting VCO/HCO, without any further interaction from the network or the end-users. That is to say that the TTY algorithm shall be capable of switching between TTY and non-TTY inputs freely within a call without degrading its TTY performance.

4.12 Tandem

The test vocoder shall be capable of tandeming with itself and with the reference vocoder for TTY calls with 0.0% TCER.

4.13 Variable Rates

The test vocoder shall be capable of decoding TTY information from full rate packets and half rate packets for the IS-127 EVRC and the IS-733 13K vocoders with the TTY/TDD extensions. The rates used in future vocoders are to be determined.

4.14 Reduced Rate Modes

There are certain scenarios where the vocoder is requested to reduce its rate artificially in order to satisfy network requirements. An example of this is dim-and-burst signaling or blank-and-burst signaling. During a TTY call, the network's request for reduced-rate modes shall take precedence and the TTY information shall be provided where possible. For example, if the test vocoder is requested to supply half rate packets during a TTY transmission, the test vocoder shall produce half rate packets as requested with the TTY information embedded.

TTY transmission is not expected in cases where the speech path is muted, as is the case in blank-and-burst signaling. In these cases, the TTY information shall be recovered as best as possible, with the understanding that character errors may occur.

4.15 False Alarms

The test vocoder shall be robust to false alarms. False alarms can occur in two places, the TTY encoder and the TTY decoder. The TTY encoder may falsely label speech or tones as TTY and send TTY_SILENCE messages or TTY characters to the decoder. Likewise, the TTY decoder may misinterpret non-TTY packets as TTY information and either mute its output or replace its output with regenerated tones. For the purposes of this document, a TTY false alarm is defined as an action by the TTY algorithm, either the TTY encoder or the TTY decoder, that causes muting or tones being mistakenly regenerated at the decoder's output.

In order to make the reference vocoder robust to false alarms, more stringent rules are applied to the first character of a call. The rules are relaxed for all subsequent characters within the same call. As a result of the more stringent rules, there may be a character error at the beginning of the call as a result. The test vocoder may also exhibit similar performance.

4.16 Slew

Certain TTY devices exhibit a decaying DC bias, or slew, when generating a character after a period of silence. The test vocoder shall demonstrate 0.0% TCER in the presence of slew.

4.17 Impaired Channels

The test vocoder shall not degrade its TTY performance when operating in simulated impaired channel environments with frame error rates from 0% to 6%.

4.18 Worst Case Deviations

The test vocoder shall not degrade its TTY performance when operating in a combination of extreme deviations for bit duration, stop bit length, frequency, slew, and phase changes and regardless of the typing mode, preamble, or mark hold tone.

5 TEST TOOLS

5.1 ttygen

The tool ttygen generates random characters according to [5]. The parameters for generating the Baudot tones can be varied from the command line so that the range of parameters specified in this document can be tested. Calling ttygen without parameters prints its help message. The parameters are specified as follows:

```
Usage: ttygen [options]
   -a <TTY audio output file>
   -b <Baudot code output file>
   -c <random character output file>
   -l <level in dBm,-45 - -5, (default = -10.0 dBm)>
   -s <stopbits,1.0, 1.5 or 2.0 (default = 2.0)>
   -f <frequency tolerance as a %,-4 to +4>
        (or "+-" for random within range)>
   -t <timing tolerance in ms, -0.4 to +0.4>
        (or "+-" for random within range)
   -p <phase mode>
        0: continuous (default),
        1: zero phase,
        2: random phase,
        3: max. discontinuous>
   -g <1 for random silent gaps between chars, default = 0 for none>
   -h <mark hold duration (default = 300 ms)>
   -N <number of characters to generate (default = 4164)>
   -r <seed for random number generator>
```

5.2 ttyrcv

The tool ttyrcv receives a PCM stream, and detects TTY/TDD Baudot characters. The 5-bit decimal value corresponding to the detected character is printed to the output file, one character per line. When the <-r reference_file> option is used, the reference symbol file is compared to the test symbol file and a TCER is calculated.

```
Usage: ttyrcv [options]
   -i infile         : input PCM tone filename (required)
   -o symbolfile     : output file with 5 bit decimal value of Baudot code
                       (default=stdout)
   -r ref_file       : reference symbol file.
```

6 TTY/TDD MINIMUM PERFORMANCE TEST PROCEDURE

Test vectors and tools are provided as part of this standard in order to conduct the minimum performance tests. The following describes the minimum performance test procedure. There are 3 different types of tests:

- **TTY Performance Tests/Tandem Tests:** These tests are designed to verify that the test vocoder can correctly detect and regenerate the Baudot characters under a variety of conditions. Input PCM test vectors are to be processed by the test vocoder, and its output is processed to verify the total character error rate.

- **Interoperability Tests:** These tests are designed to verify interoperability between the test vocoder and the reference vocoder, for both a single coding and tandem coding.
- **False Alarm Tests:** A test vector with non-TTY audio is provided to verify the test vocoder's robustness to false alarms. The test vector is to be processed by the test vocoder and its output is to be examined for muting and tones that are generated as a result of a false alarm.

The tests shall be conducted with the tools that are provided with this standard. Scripts using these tools are also provided in order to facilitate testing.

6.1 Description of Test Vectors

All of the file test vectors were processed on a PC and stored as 16-bit words in PC format (LSB,MSB).

6.1.1 File Naming Convention

The following file naming convention is used for the test vectors associated with this standard:

- ***.pcm:** Input PCM file
- ***.enc:** Encoded packet file
- ***.dec:** Decoded speech files
- ***.xmt:** Baudot code reference "truth" file, i.e. file containing the "transmitted" characters, represented as 5-bit Baudot code.
- ***.rcv** Baudot code test file, i.e., file containing the 5-bit Baudot code as detected by the tool *ttyrcv.exe*.
- **ttyseqNN.*:** Files designed to exercise the test vocoder's robustness to variations to the Baudot code's parameters.
- **tandemN.*:** Files designed to verify the test vocoder's ability to tandem with another TTY capable vocoder.
- **fer.*:** Files designed to verify the test vocoder's ability to correctly regenerate the Baudot code in the presence of frame errors. The file *tvecs/qc13_ref/fer.enc* contains IS-733 13K TTY vocoder packets that were injected with frame errors. The file *tvecs/evrc_ref/fer.enc* contains IS-127 EVRC TTY packets with frame errors. The reference Baudot code file is *tvecs/pcm/fer.xmt*.
- **ttyhandoff.*:** Files designed to verify the test vocoder's ability to recover from a hard handoff in the middle of a TTY call and to exercise the test vocoder's ability to reject TTY information that is not preceded with the TTY_SILENCE message.

6.1.2 Baudot Parameter Variation Test Vectors

Below is a description of the test vectors designed to test for robustness to Baudot parameter variability. Each of the test vectors uses a different seed, so the character sequences have 200 random printable characters. The exception to this is ttyseq49.pcm and ttyseq50.pcm, which were recorded from commercially available TTY devices. Because of the shift character, the total number of characters in each file is different. The parameters are:

- **Phase:** The phase between bit boundaries is either continuous (C) or discontinuous (D).
- **Stop Bit Length:** The duration of the stop bit is tested at 1.0 bits and 2.0 bits.
- **Typing Mode:** The typing modes tested are streaming mode (S) and manual (M) mode.
- **Mark Hold Time:** The mark hold time, the amount of time the stop bit is extended between characters, is either zero, or 300 ms.
- **Bit Length:** The duration of the characters' bit length is varied from its nominal value of 22 ms by –0.4 ms and +0.4 ms.
- **Input Level:** The input level of the Baudot tones is tested at –5 dBm and -45 dBm.
- **Frequency Deviation:** All of the test vectors have a randomly varying frequency deviation ±4.0% from nominal.

The files shall be processed as follows:

- test_vocoder.exe –i tvecs/pcm/ttyseqNN.pcm –o tvecs/test_vocoder/ttyseqNN.dec
- ttyrcv.exe –I tvecs/test_vocoder/ttyseqNN.dec –o tvecs/test_vocoder/ttyseqNN.rcv -r tvecs/pcm/ttyseqNN.xmt

For each of the files, the TCER shall be 0.0%.

File	Phase	Stop Bit Length (bits)	Typing Mode	Mark Hold (ms)	Bit Length Deviation (ms)	Input Level (dBm)
ttyseq01.pcm	C	1.0	S	0	-0.4	-45
ttyseq02.pcm	C	1.0	S	0	-0.4	-5
ttyseq03.pcm	C	1.0	S	0	+0.4	-45
ttyseq04.pcm	C	1.0	S	0	+0.4	-5
ttyseq05.pcm	C	1.0	M	0	-0.4	-45
ttyseq06.pcm	C	1.0	M	0	-0.4	-5
ttyseq07.pcm	C	1.0	M	0	+0.4	-45

ttyseq08.pcm	C	1.0	M	0	+0.4	-5
ttyseq09.pcm	C	1.0	M	300	-0.4	-45
ttyseq10.pcm	C	1.0	M	300	-0.4	-5
ttyseq11.pcm	C	1.0	M	300	+0.4	-45
ttyseq12.pcm	C	1.0	M	300	+0.4	-5
ttyseq13.pcm	C	2.0	S	0	-0.4	-45
ttyseq14.pcm	C	2.0	S	0	-0.4	-5
ttyseq15.pcm	C	2.0	S	0	+0.4	-45
ttyseq16.pcm	C	2.0	S	0	+0.4	-5
ttyseq17.pcm	C	2.0	M	0	-0.4	-45
ttyseq18.pcm	C	2.0	M	0	-0.4	-5
ttyseq19.pcm	C	2.0	M	0	+0.4	-45
ttyseq20.pcm	C	2.0	M	0	+0.4	-5
ttyseq21.pcm	C	2.0	M	300	-0.4	-45
ttyseq22.pcm	C	2.0	M	300	-0.4	-5
ttyseq23.pcm	C	2.0	M	300	+0.4	-45
ttyseq24.pcm	C	2.0	M	300	+0.4	-5
ttyseq25.pcm	D	1.0	S	0	-0.4	-45
ttyseq26.pcm	D	1.0	S	0	-0.4	-5
ttyseq27.pcm	D	1.0	S	0	+0.4	-45
ttyseq28.pcm	D	1.0	S	0	+0.4	-5
ttyseq29.pcm	D	1.0	M	0	-0.4	-45
ttyseq30.pcm	D	1.0	M	0	-0.4	-5
ttyseq31.pcm	D	1.0	M	0	+0.4	-45
ttyseq32.pcm	D	1.0	M	0	+0.4	-5
ttyseq33.pcm	D	1.0	M	300	-0.4	-45
ttyseq34.pcm	D	1.0	M	300	-0.4	-5
ttyseq35.pcm	D	1.0	M	300	+0.4	-45
ttyseq36.pcm	D	1.0	M	300	+0.4	-5
ttyseq37.pcm	D	2.0	S	0	-0.4	-45
ttyseq38.pcm	D	2.0	S	0	-0.4	-5

ttyseq39.pcm	D	2.0	S	0	+0.4	-45
ttyseq40.pcm	D	2.0	S	0	+0.4	-5
ttyseq41.pcm	D	2.0	M	0	-0.4	-45
ttyseq42.pcm	D	2.0	M	0	-0.4	-5
ttyseq43.pcm	D	2.0	M	0	+0.4	-45
ttyseq44.pcm	D	2.0	M	0	+0.4	-5
ttyseq45.pcm	D	2.0	M	300	-0.4	-45
ttyseq46.pcm	D	2.0	M	300	-0.4	-5
ttyseq47.pcm	D	2.0	M	300	+0.4	-45
ttyseq48.pcm	D	2.0	M	300	+0.4	-5
ttyseq49.pcm	Real TTY device mixed with speech to test VCO/HCO.					
ttyseq50.pcm	Real TTY device in streaming mode.					

Table 6-1: Description of TTY PCM Test Vectors

6.2 Interoperability

The files *tvecs/evrc_rev/ttyseqNN.pkt* are packet files that were processed by the IS-127 EVRC reference vocoder with TTY turned ON. Likewise, tvecs/qc13_ref/ttyseqNN.pkt were generated by the reference IS-733 13K vocoder with TTY turned ON. The test decoder shall process the appropriate packet files with 0.0% TCER. In addition, the test encoder shall generate its own series of packet files which shall be processed by the appropriate reference vocoder with 0.0% TCER.

For an IS-127 EVRC test vocoder, the files shall be processed as follows:

- test_decoder.exe –i tvecs/evrc_ref/ttyseqNN.enc –o tvecs/test_vocoder/ttyiopNN.dec
- ttyrcv.exe –I tvecs/test_vocoder/ttyiopNN.dec –o tvecs/test_vocoder/ttyiopNN.rcv -r tvecs/pcm/ttyseqNN.xmt

For an IS-733 13K test vocoder, the packets from the directory *tvecs/qc13_ref/ttyseqNN.enc* shall be processed in a similar way.

6.3 Frame Error Handling

The files *tvecs/evrc_ref/fer.pkt* and *tvecs/qc13_ref/fer.pkt* are packet files with frame errors inserted to the test decoder's TTY algorithm in a frame error environment. The model used was intended to simulate 6% FER, but the files have an actual FER of approximately 6.3%. The test decoder shall process the appropriate fer.enc packet file with 0.0% TCER.

6.4 Hard Handoff Test

The files *ttyhandoff.** are designed to verify the test vocoder's ability to recover from a hard handoff in the middle of a TTY call. These files also exercise the test vocoder's ability to reject TTY information that is not preceded with the TTY_SILENCE message. The file *tvecs/qc13_ref/ttyhandoff.enc* contains IS-733 13K TTY vocoder packets that encode two bursts of TTY characters. The first 20 packets of the file have been removed to remove the TTY_SILENCE messages that precede the first burst of characters. The test vocoder should not regenerate characters from the first burst of characters but should regenerate characters from the second burst. The file *tvecs/evrc_ref/ttyhandoff.enc* contains similar packets for IS-127 EVRC. The reference Baudot code file is *tvecs/pcm/ttyhandoff.xmt.*

6.5 Tandem Testing

Two files are designed to test TTY tandem calls, *tandem1.pcm* and *tandem2.pcm*. These files were generated by processing fer.pcm with the IS-127 EVRC and IS-733 13K reference vocoders, respectively, with the TTY option turned ON. The test vocoder shall process both of these files with 0.0% TCER. The procedure for processing them is the same as the procedure for processing the *ttyseqNN.pcm* files.

7 REFERENCES

[1] TIA/EIA/IS-127-3 Enhanced Variable Rate Codec, Speech Service Option 3 for Wideband Spread Spectrum Digital Systems - Addendum 3.

[2] TIA/EIA/IS-733-2 High Rate Speech Service Option 17 for Wideband Spread Spectrum Communication Systems - Addendum 2.

[3] ITU-T Recommendation V.18, Operational and Interworking Requirements for DCEs Operating in the Text Telephone Mode.

[4] TIA/EIA/IS-840 Minimum Performance Standards for Text Telephone Signal Detector and Text Telephone Signal Regenerator.

[5] TTY Over Cellular Laboratory and Field Test Procedure, Lober & Walsh Engineering, Inc., September 13, 1998

[6] TIA/EIA-95-B Mobile Station-Base Station Compatibility Standard for Wideband Spread Spectrum Cellular Systems, February 1, 1999.

[7] TIA/EIA/IS-2000 Series, Rev A CDMA 2000 Series, March 1, 2000.