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**Digital cellular telecommunications system (Phase 2+) (GSM);
Universal Mobile Telecommunications System (UMTS);
Cellular text telephone modem;
Transmitter bit exact C-code
(3GPP TS 26.230 version 15.0.0 Release 15)**



Reference

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Foreword

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0 Scope

This Technical Standard (TS) contains an electronic copy of the ANSI-C code for the Cellular Text Telephone Modem (CTM) for reliable transmission of text telephone text via the speech channel of cellular networks. While CTM is generally usable with text in UCS coding, the example application linked to CTM in this document is limited to use the signals and character set of the Baudot type.

1 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; General description".
 - [2] ISO/IEC 10646-1: "Information technology – Universal Multiple-Octet Coded Character Set (UCS) – Part 1: Architecture and Basic Multilingual Plane".
-

2 Definitions and Abbreviations

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

| | |
|-----|---|
| CTM | Cellular Text Telephone Modem |
| FEC | Forward Error Correction |
| FSK | Frequency Shift Key |
| HCO | Hearing Carry Over, (individual may be able to hear, but cannot speak) Alternating transmission of speech and text. |
| PCM | Pulse Code Modulation |
| RX | Receive |
| TX | Transmit |
| TTY | Text Telephone |
| UCS | Universal Multiple-Octet Coded Character Set |
| UTF | UCS transformation format |
| VAD | Voice Activity Detection |
| VCO | Voice Carry Over, Alternating transmission of speech and text |

3 C code structure

This clause gives an overview of the structure of the bit-exact C code and provides an overview of the contents and organization of the C code attached to this document.

The C code has been verified on the following system.

- Sun Microsystems workstations with SUN Solaris™ operating system and the the Gnu C Compiler (gcc version 2.7.2.3) and GNU Make 3.77;

The C code has also been successfully compiled and used in the following environment, with the exception that it cannot be guaranteed that the upper part of the UCS code table in file `ucs_functions.c` will be compiled correctly since it depends on the codepage setting of the environment.

- IBM PC/AT compatible computers with Windows™ NT 4.0 operating system and Microsoft Visual C++ 6.0™ compiler.

3.1 Contents of the C source code

The distributed files with suffix "c" contain the source code and the files with suffix "h" are the header files. All these files are in the root level of the ZIP-archive.

Makefiles are provided for the platforms in which the C code has been verified (listed above). They are called "Makefile" for GNU Make and "Makefile.vc" for Microsoft Visual C++™.

For the Sun Microsystems platform, an example shell script for a transmission via two signal adaptation modules is given in "test_negotiation". For the Microsoft Windows™ platform, no shell script or batch program is provided.

The software can be compiled using the commands

```
make all          or          gmake all          in case of Gnu Make
```

```
nmake /f Makefile.vc          in case of Microsoft Visual C++.
```

The executables are compiled into the directory `./solaris` (in case of Gnu Make) or into the actual directory in case of Microsoft Visual C++™.

The directory `./patterns` provides the file `baudot.pcm` that serves as input signal for the test script `test_negotiation`. All output data of `test_negotiation` will be stored into the directory `./output`. If required, this directory will be created by `test_negotiation` automatically.

3.2 Program execution

The CTM signal adaptation module is implemented in the executable `adaptation_switch` (in case of Sun Solaris™ platform) or `adaptation_switch.exe` (in case of the Microsoft Windows™ platform).

The program should be called like:

```
adaptation_switch -ctmin <file>      -ctmout <file>
                  -baudotin <file> -baudotout <file>
```

using the following parameters:

```
-ctmin      <input_file>  input file with CTM signal
-ctmout     <output_file> output file for CTM signal
-baudotin   <input_file>  input file with Baudot Tones
-baudotout  <output_file> output file for Baudot Tones
-textout    <text_file>   output text file from CTM receiver (optional)
-numsamples <number>     number of samples to process (optional)
-nonegotiation          disables the negotiation (optional)
```

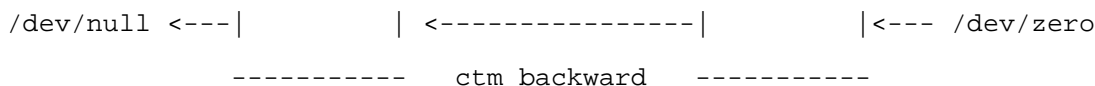
All files contain 16-bit linear encoded PCM audio samples, which are swapped according to the platform's endian type (Sun Microsystems platforms use big endian, Intel platforms use little endian). An example file `baudot.pcm` containing a Baudot Code modem signal (big endian) is provided in the subdirectory `./patterns`.

Due to the fact that the signal adaptation module expects a successful negotiation before Baudot Code signals can be converted to CTM signals, the signal adaptation module has to be executed several times in two instances in order to execute a successful negotiation. For the Sun Microsystems platform, a shell script `test_negotiation` is provided for executing the following structure:

```

-----          ctm_forward          -----
baudot.pcm ---> |          | -----> |          | ---> baudot_out.pcm
                | adapt#1 |          | adapt#2 |

```



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)
*****
    
```

3.3 Code hierarchy

This section gives an overview of the hierarchy how the functions are used in the signal adaptation module. All standard C functions: printf(), fwrite(), etc. have been omitted. Also, all functions related to the asynchronous transfer between the signal processing functions by means of FIFO buffers (Shortint_fifo_push, Shortint_fifo_pop, etc.) are not listed in the charts.

The following functions are not part of the actual CTM bit exact specification but are included to allow demonstration of CTM in a Baudot environment:

- init_baudot_tonedemod
- init_baudot_tonemod
- baudot_tonedemod
- convertUCScode2char
- convertChar2TTYcode
- baudot_tonemod
- convertTTYcode2char
- convertChar2UCScode

3.3.1 Initialization routines

The following functions are called for the initialization of the signal adaptation module.

| | | |
|-----------------------|--------------------------|------------------------------|
| init_baudot_tonedemod | | |
| init_baudot_tonemod | | |
| init_ctm_transmitter | init_interleaver | generate_scrambling_sequence |
| | | m_sequence |
| | init_tonemod | |
| | conv_encoder_init | |
| | generate_resync_sequence | m_sequence |
| | calc_mute_positions | |
| init_ctm_receiver | init_tonedemod | sin_fip |
| | viterbi_init | |
| | calc_mute_positions | |
| | init_deinterleaver | generate_scrambling_sequence |
| | init_wait_for_sync | m_sequence |
| | | generate_scrambling_sequence |

3.3.2 Signal Processing Functions

The following functions are called during the main signal processing loop.

| | | |
|---------------------|------------------------|--------------|
| baudot_tonedemod | iir_filt | |
| ctm_receiver | tonedemod | rotate_right |
| | | rotate_left |
| | wait_for_sync | |
| | reinit_deinterleaver | |
| | viterbi_reinit | |
| | diag_deinterleaver | |
| | shift_deinterleaver | |
| | mutingRequired | |
| | viterbi_exec | |
| | reinit_wait_for_sync | |
| | reinit_deinterleaver | |
| | viterbi_reinit | |
| | transformUTF2UCS | |
| convertUCScode2char | | |
| convertChar2TTYcode | | |
| baudot_tonemod | | |
| convertTTYcode2char | | |
| convertChar2UCScode | | |
| ctm_transmitter | transformUCS2UTF | |
| | reinit_interleaver | |
| | conv_encoder_exec | |
| | mutingRequired | |
| | diag_interleaver | |
| | diag_interleaver_flush | |
| | tonemod | |

3.4 Description of global constants used in the C-code

The following constants are defined in the file `ctm_defines.h`

| Constant | Value | Description |
|--|-------|---|
| MAX_IDLE_SYMB | 5 | Number of Idle Symbols at End of Burst |
| CHC_RATE | 4 | Rate of the Error Protection |
| CHC_K | 5 | Constraint Length of the Error Protection |
| SYMB_LEN | 40 | Length of one CTM symbol |
| LENGTH_TONE_VEC | 1 | frame size |
| LENGTH_TX_BITS | 8 | number of bits per 20 ms frame |
| BITS_PER_SYMB | 8 | bits per symbol |
| NCYCLES_0 | 2 | Number of periods for symbol #0 |
| NCYCLES_1 | 3 | Number of periods for symbol #1 |
| NCYCLES_2 | 4 | Number of periods for symbol #2 |
| NCYCLES_3 | 5 | Number of periods for symbol #3 |
| THRESHOLD_RELIABILITY_FOR_SUPPRESSING_OUTPUT | 100 | Characters with lower reliability are suppressed |
| THRESHOLD_RELIABILITY_FOR_XCORR | 200 | Bits with lower reliability don't contribute to xcorr |
| THRESHOLD_RELIABILITY_FOR_GOING_OFFLINE | 100 | Threshold for regarding a bit as unreliable |
| MAX_NUM_UNRELIABLE_GROSS_BITS | 400 | Receiver goes offline after 400 unreliable bits |
| NUM_BITS_GUARD_INTERVAL | 6 | Number of muted bits between two bursts |
| WAIT_SYNC_REL_THRESHOLD_0 | 20316 | (=0.62) rel. threshold for preamble |
| WAIT_SYNC_REL_THRESHOLD_1 | 17039 | (=0.52) rel. threshold for preamble |
| WAIT_SYNC_REL_THRESHOLD_2 | 23065 | (=0.71) dto. in case that RX is already online |
| RESYNC_REL_THRESHOLD | 26542 | Threshold for Resynchronization (=0.81) |
| GUARD_BIT_SYMBOL | 10 | magic number indicating that a bit shall be muted |
| intlvB | 8 | Interleaver block length (number of rows) |
| intlvD | 2 | Interleaver block distance (interlace factor) |
| demodSyncLns | 1 | Number of demodulator sync lines |
| deintSyncLns | 0 | Number of deinterleaver sync lines |
| IDLE_SYMB | 0x16 | UCS code for Idle Symbol |
| ENQU_SYMB | 0x05 | UCS code for Enquiry Symbol |
| ENQUIRY_TIMEOUT | 3040 | number of 20-ms frames for negotiation |
| NUM_ENQUIRY_BURSTS | 3 | number of enquiry attempts |
| NUM_MUTE_ROWS | 4 | Number of Intl. rows that shall be muted |
| RESYNC_SEQ_LENGTH | 32 | length of the resynchronization sequence, must be a multiple of 8 |
| NUM_BITS_BETWEEN_RESYNC | 352 | Distance between two resync sequences, the value NUM_BITS_BETWEEN_RESYNC+RESYNC_SEQ_LENGTH must be a multiple of CHC_RATE, intlvB, and BITS_PER_CHAR, and must be greater than $\text{intlvB} * ((\text{intlvB} - 1) * \text{intlvD} + \text{NUM_MUTE_ROWS})$ |
| BAUDOT_NUM_INFO_BITS | 5 | number of information bits per Baudot character |
| BAUDOT_SHIFT_FIGURES | 27 | code of shift to figures symbol |

| | | |
|-----------------------|-----|---|
| BAUDOT_SHIFT_LETTERS | 31 | code of shift to letters symbol |
| BAUDOT_BIT_DURATION | 176 | must be 176 (for 45.45 baud) or 160 (50 baud) |
| BAUDOT_LP_FILTERORDER | 1 | Order of the low-pass filters in function baudot_tonedemod() |
| BAUDOT_BP_FILTERORDER | 2 | Order of the according band-pass filters, must be equal to 2*BAUDOT_BP_FILTERORDER |

3.5 Type Definitions

In order to make the C code platform-independent, the following type definitions have been used, which are defined in `typedefs.h`:

| defined type | meaning | corresponding constants |
|--------------|-----------------|----------------------------|
| ----- | ----- | ----- |
| Char | character | (none) |
| Bool | boolean | true, false |
| Shortint | 16-bit signed | minShortint, maxShortint |
| UShortint | 16-bit unsigned | minUShortint, maxUShortint |
| Longint | 32-bit signed | minLongint, maxLongint |
| ULongint | 32-bit unsigned | minULongint, maxULongint |

3.6 Functions of the C Code

```
void baudot_tonedemod(Shortint* toneVec, Shortint numSamples,
                    fifo_state_t* ptrOutFifoState,
                    baudot_tonedemod_state_t* state);
```

Purpose: Demodulator for Baudot Tones
 Defined in: `baudot_functions.c`

Input Variables:

| | |
|-------------------------|--|
| <code>toneVec</code> | Vector containing the input audio signal |
| <code>numSamples</code> | Length of <code>toneVec</code> |

Input/Output Variables:

| | |
|------------------------------|--|
| <code>ptrOutFifoState</code> | Pointer to the state of the output shift register containing the demodulated TTY codes |
| <code>state</code> | Pointer to the state variable of <code>baudot_tonedemod()</code> |

```
void baudot_tonemod(Shortint inputTTYcode,
                  Shortint *outputToneVec,
                  Shortint lengthToneVec,
                  Shortint *ptrNumBitsStillToModulate,
                  baudot_tonemod_state_t* state);
```

Purpose: Modulator for Baudot Tones
 Defined in: `baudot_functions.c`

Input Variables:

inputTTYcode TTY code of the character that has to be modulated. inputTTYcode must be in the range 0...63, otherwise it is assumed that there is no character to modulate.

lengthToneVec Indicates how many samples have to be generated.

Output Variables:

outputToneVec Vector where the output samples are written to.

ptrNumBitsStillToModulate Indicates how many bits are still in the fifo buffer.

Input/Output Variables:

state Pointer to the state variable of baudot_tonedemod()

```
void calc_mute_positions(Shortint *mute_positions,
                        Shortint num_rows_to_mute,
                        Shortint start_position,
                        Shortint B,
                        Shortint D);
```

Purpose: Calculation of the indices of the bits that have to be muted within one burst. The indices are returned in the vector mute_positions.

Defined in: init_interleaver.c

```
Shortint convertChar2ttyCode(char inChar);
```

Purpose: Conversion from character into TTY code

Defined in: baudot_functions.c

Input Variables:

inChar character that shall be converted

Return Value: baudot code of the input or -1 in case that inChar is not valid (e.g. inChar=='\0')

```
UShortint convertChar2UCScode(char inChar);
```

Purpose: Conversion from character into UCS code (Universal Multiple-Octet Coded Character Set, Row 00 of the Multilingual plane according to ISO/IEC 10646-1). This routine only handles characters in the range 0..255 since that is all that is required for demonstration of Baudot support.

Defined in: ucs_functions.c

Input Variables:

inChar character that shall be converted

Return Value: UCS code of the input or 0x0016 <IDLE> in case that inChar is not valid (e.g. inChar=='\0')

```
char convertTTYcode2char(Shortint ttyCode);
```

Purpose: Conversion from TTY code into Character
 Defined in: baudot_functions.c

Input Variables:

ttyCode Baudot code (must be within the range 0...63) or -1
 if there is nothing to convert

Return Value:

character (or '\0' if ttyCode is not valid)

```
char convertUCScode2char(UShortint ucsCode);
```

Purpose: Conversion from UCS code into character (Universal Multiple-Octet Coded Character Set, Row 00 of the Multilingual plane according to ISO/IEC 10646-1). This routine only handles characters in the range 0..255 since that is all that is required for demonstration of Baudot support.

Defined in: ucs_functions.c

Input Variables:

ucsCode UCS code index, must be within the range 0...255

Return Value:

character (or '\0' if ucsCode is not valid)

```
void conv_encoder_exec(conv_encoder_t* ptr_state, Shortint* in,  
Shortint inbits, Shortint* out);
```

Purpose: Execution of the convolutional encoder for error protection
 Defined in: conv_encoder.c

Input Variables:

in Vector with net bits
 inbits Number of valid net bits in vector in

Output variables:

out Vector with the encoded gross bits. The gross bits are either 0 or 1. The vector out must have at least CHC_RATE*inbits elements.

Input/output variables:

*ptr_state state variable of the encoder

```
void conv_encoder_init(conv_encoder_t* ptr_state);
```

Purpose: Initialization of the convolutional encoder
 Defined in: conv_encoder.c

Output Variables:

*ptr_state Initialized state variable of the encoder

```
void ctm_receiver(fifo_state_t* ptr_signal_fifo_state,
                 fifo_state_t* ptr_output_char_fifo_state,
                 Bool* ptr_early_muting_required,
                 rx_state_t* rx_state);
```

Purpose: Runs the CTM Receiver for a block of (nominally) 160 samples. Due to the internal synchronization, the number of processed samples might vary between 156 and 164 samples. The input of the samples and the output of the decoded characters is handled via fifo buffers, which have to be initialized externally before using this function (see fifo.h for details).

Defined in: ctm_receiver.c

input/output variables

| | |
|-----------------------------|--|
| *ptr_signal_fifo_state | fifo state for the input samples |
| *ptr_output_char_fifo_state | fifo state for the output characters |
| *ptr_early_muting_required | returns whether the original audio signal must not be forwarded. This is to guarantee that the preamble or resync sequence is detected only by the first CTM device, if several CTM devices are cascaded subsequently. |
| rx_state | pointer to the variable containing the receiver states |

```
void ctm_transmitter(UShortint ucsCode,
                    Shortint* txToneVec,
                    tx_state_t* tx_state,
                    Shortint *ptrNumBitsStillToModulate,
                    Bool sineOutput);
```

Purpose: Runs the CTM Transmitter for a block of 160 output samples, representing 8 gross bits. The bits, which are modulated into tones, are taken from an internal fifo buffer. If the fifo buffer is empty, zero-valued samples are generated. The fifo buffer is filled with channel-encoded and interleaved bits, which are generated internally by coding the actual input character. With each call of this function one or less input characters can be coded. If there is no character to for transmission, one of the following codes has be used:

- 0x0016 <IDLE>: indicates that there is no character to transmit and that the transmitter should stay in idle mode, if it is currently already in idle mode. If the transmitter is NOT in idle mode, it might generate <IDLE> symbols in order to keep an active burst running. The CTM burst is terminated if five <IDLE> symbols have been generated consecutively.
- 0xFFFF: although there is no character to transmit, a CTM burst is initiated in order to signal to the far-end side that CTM is supported. The burst starts with the <IDLE> symbol and will be continued with <IDLE> symbols if there are no regular characters handed over during the next calls of this function. The CTM burst is terminated if five <IDLE> symbols have been transmitted consecutively.

In order to avoid an overflow of the internal fifo buffer, the

variable `*ptrNumBitsStillToModulate` should be checked before calling this function.

Defined in: `ctm_transmitter.c`

input variables:

`ucsCode` UCS code of the character or one of the code 0x0016 or 0xFFFF

`sineOutput` must be false in regular mode; if true, a pure sine output signal is generated

output variables:

`txToneVec` output signal (vector of 160 samples)

input/output variables:

`tx_state` pointer to the variable containing the transmitter states

```
void diag_deinterleaver(Shortint *out,
                        Shortint *in,
                        Shortint num_valid_bits,
                        interleaver_state_t *intl_state);
```

Purpose: Corresponding deinterleaver to `diag_interleaver`. An arbitrary number of bits can be interleaved, depending of the length of the vector "in". The vector "out", which must have the same length than "in", contains the interleaved samples. All states (memory etc.) of the interleaver are stored in the variable `*intl_state`. Therefore, a pointer to this variable must be handled to this function. This variable initially has to be initialized by the function `init_interleaver`, which offers also the possibility to specify the dimensions of the deinterleaver matrix.

Defined in: `diag_deinterleaver.c`

```
void diag_interleaver(Shortint *out,
                     Shortint *in,
                     Shortint num_bits,
                     interleaver_state_t *intl_state);
```

Purpose: Diagonal (chain) interleaver, based on block-by-block processing. An arbitrary number of bits can be interleaved, depending of the value `num_bits`. The vector "out", which must have the same length than "in", contains the interleaved samples. All states (memory etc.) of the interleaver are stored in the variable `*intl_state`. Therefore, a pointer to this variable must be handled to this function. This variable initially has to be initialized by the function `init_interleaver()`, which offers also the possibility to specify the dimensions of the interleaver matrix.

Defined in: `diag_interleaver.c`

```
void diag_interleaver_flush(Shortint *out,
```

```
Shortint *num_bits,  
interleaver_state_t *intl_state);
```

Purpose: Execution of the diagonal (chain) interleaver without writing in new samples. The number of calculated output samples is returned via the value *num_bits.

Defined in: diag_interleaver.c

```
void generate_resync_sequence(Shortint *sequence);
```

Purpose: Generation of the sequence for resynchronization. The length of the sequence is defined by the global constant RESYNC_SEQ_LENGTH. The vector sequence must be allocated accordingly before calling this function.

Defined in: wait_for_sync.c

```
void generate_scrambling_sequence(Shortint *sequence, Shortint length);
```

Purpose: Generation of the sequence used for scrambling. The sequence consists of 0 and 1 elements. The sequence is stored into the vector *sequence and the length of the sequence is specified by the variable length.

Defined in: init_interleaver.c

```
void init_baudot_tonedemod(baudot_tonedemod_state_t* state);
```

Purpose: Initialization of the demodulator for Baudot Tones

Defined in: baudot_functions.c

Input/Output Variables:

state Pointer to the initialized state variable (must be allocated before calling init_baudot_tonedemod())

```
void init_baudot_tonemod(baudot_tonemod_state_t* state);
```

Purpose: Initialization of the modulator for Baudot Tones

Defined in: baudot_functions.c

Input/Output Variables:

state Pointer to the initialized state variable (must be allocated before calling init_baudot_tonemod())

```
void init_deinterleaver(interleaver_state_t *intl_state,  
Shortint B, Shortint D);
```

Purpose: Initialization of the deinterleaver.

Defined in: init_interleaver.c

```
void init_ctm_receiver(rx_state_t* rx_state);
```

Purpose: Initialization of the CTM Receiver.
Defined in: ctm_receiver.c

output variables:

rx_state pointer to a variable of rx_state_t containing the initialized states of the receiver

```
void init_ctm_transmitter(tx_state_t* tx_state);
```

Purpose: Initialization of the CTM Transmitter
Defined in: ctm_transmitter.c

input/output variables

tx_state pointer to a variable of tx_state_t containing initialized states of the transmitter

```
void init_interleaver(interleaver_state_t *intl_state,  
                    Shortint B, Shortint D,  
                    Shortint num_sync_lines1, Shortint num_sync_lines2);
```

Purpose: Function for initialization of `diag_interleaver` and `diag_deinterleaver`, respectively. The dimensions of the interleaver must be specified: B = (horizontal) blocklength, D = (vertical distance) According to this specifications, this function initializes a variable of type `interleaver_state_t`. Additionally, this function adds two types of sync information to the bitstream. The first sync info is for the demodulator and consists of a sequence of alternating bits so that the tones produced by the modulator are not the same all the time. This is essential for the demodulator to find the transitions between adjacent bits. The bits for this demodulator synchronization simply precede the bitstream. The second sync info is for synchronizing the deinterleaver and of a m-sequence with excellent autocorrelation properties. These bits are positioned at the locations of the dummy bits, which are not used by the interleaver. In addition, even more bits for this can be spent by inserting additional sync bits, which precede the interleaver's bitstream. This is indicated by choosing `num_sync_lines2>0`.

Defined in: `init_interleaver.c`

```
void init_tonedemod(demod_state_t *demod_state);
```

Purpose: Initialization of one instance of the Tone Demodulator. The argument must contain a pointer to a variable of type

demod_state_t, which contains all the memory of the tone demodulator. Each instance of tonedemod must have its own variable.

Defined In: tonedemod.c

```
void init_wait_for_sync(wait_for_sync_state_t *ptr_wait_state,
                       interleaver_state_t intl_state);
```

Purpose: Initialization of the synchronization detector. The dimensions of the corresponding interleaver at the TX side must be specified by the variables B, D, and num_sync_lines2.

Defined In: wait_for_sync.c

Input Variables:

| | |
|----------------|---|
| B | (horizontal) blocklength |
| D | (vertical) interlace factor |
| num_Sync_line2 | number of interleaver lines with additional sync bits (see description of init_interleaver()) |

Output Variables:

| | |
|----------------|--|
| ptr_wait_state | pointer to the state variable of the sync detector |
|----------------|--|

```
int main(int argc, const char** argv)
```

Purpose: main function of the signal adaptation Module

Defined in: adaptation_switch.c

```
Bool mutingRequired(Shortint actualIndex,
                   Shortint *mute_positions,
                   Shortint length_mute_positions);
```

Purpose: Determines whether the actual bit has to be muted, i.e. whether it is contained in the vector mute_positions.

Defined in: init_interleaver.c

```
void m_sequence(Shortint *sequence, Shortint length);
```

Purpose: Calculates one period of an m-sequence (binary pseudo noise). The sequence is stored in the vector sequence, which must have a of $(2^r)-1$, where r is an integer number between 2 and 10. Therefore, with this release of m_sequence, sequences of length 3, 7, 15, 31, 63, 127, 255, 511, or 1023 can be generated. The resulting sequence is bipolar, i.e. it has values -1 and +1.

Defined in: m_sequence.c

```
void polynomials(Shortint rate, Shortint k,
                Shortint* polya, Shortint* polyb,
                Shortint* polyc, Shortint* polyd);
```

Purpose: Returns the polynomials for the convolutional encoder and the Viterbi decoder for various rates and constraint lengths. The following parameters are supported:
rate = {2, 3, or 4}
k = {3, 4, 5, 6, 7, 8, 9}

Defined in: conv_poly.c

Input Variables:

| | |
|------|---|
| rate | Rate of the convolutional encoder (2, 3, or 4) |
| k | Constraint length (length of the impulse response of the encoder) |

Output Variables:

| | |
|--------|---|
| poly_a | Vector with polynomials #1 |
| poly_b | Vector with polynomials #2 |
| poly_c | Vector with polynomials #3 (only if rate > 2) |
| poly_d | Vector with polynomials #4 (only if rate > 3) |

```
void reinit_deinterleaver(interleaver_state_t *intl_state);
```

Purpose: Re-Initialization of the deinterleaver.
Defined in: init_interleaver.c

```
void reinit_interleaver(interleaver_state_t *intl_state);
```

Purpose: Re-initialization of the deinterleaver
Defined in: init_interleaver.c

```
void reinit_wait_for_sync(wait_for_sync_state_t *ptr_wait_state);
```

Purpose: Reinitialization of synchronization detector. This function is used in case that a burst has been finished and the transmitter has switched into idle mode. After calling reinit_wait_for_sync(), the function wait_for_sync() inhibits the transmission of the demodulated bits to the deinterleaver, until the next synchronization sequence can be detected.

Defined In: wait_for_sync.c

```
void shift_deinterleaver(Shortint shift,
                        Shortint *insert_bits,
                        interleaver_state_t *ptr_state);
```

Purpose: Shift of the deinterleaver buffer by <shift> samples.
shift>0 -> shift to the right

shift<0 -> shift to the left
 The elements from <insert_bits> are inserted into the
 resulting space. The vector <insert_bits> must have at least
 abs(shift) elements.

Defined in: diag_deinterleaver.c

Shortint sin_fip(Shortint phase_value);

Purpose: Fixed Point sine function, returns the following value:
 sin_fip(phase_value)
 = round(32767*sin(2*pi*50/8000*phase_value))
 phase_value must be within the range [0...159]. This function
 can be used for calculating sine waveforms of frequencies that
 are integer-multiples of 50 Hz

Defined in: sin_fip.c

void tonedemod(Shortint *bits_out,
 Shortint *rx_tone_vec,
 Shortint num_in_samples,
 Shortint *ptr_sampling_correction,
 demod_state_t *demod_state);

Purpose: Tone Demodulator for the CTM using one out of four tones for
 coding two bits in parallel within a frame of 40 samples (5
 ms).
 The function has to be called for every frame of 40 samples of
 the received tone sequence. However, in order to track a
 non-ideal of the transmitter's and the receiver's clock
 frequencies, one frame might be shorter (only 39 samples) or
 longer (41 samples). The length of the following frame is
 indicated by the variable *sampling_correction, which is
 calculated and returned by this function.

Defined in: tonedemod.c

input variables:

bits_out contains the 39, 40 or 41 actual samples of the
 received tones; the bits are soft bits, i.e. they
 are in the range between -1.0 and 1.0, where the
 magnitude serves as reliability information
 num_in_samples number of valid samples in bits_out

output variables:

bits_out contains the two actual decoded soft bits
 sampling_correction is either -1, 0, or 1 and indicates whether the
 next frame shall contain 39, 40, or 41 samples.
 demod_state contains all the memory of tonedemod. Must be
 initialized using the function init_tonedemod()

void tonemod(Shortint *tones_out,
 Shortint *bits_in,
 Shortint num_samples_tones_out,

```
Shortint      num_bits_in,  
mod_state_t *mod_state);
```

Purpose: Modulator for the CTM. The input vector `bits_in` must contain the bits that have to be transmitted. The length of `bits_in` must be even because always two bits are coded in parallel. Bits are either unipolar (i.e. {0, 1}) or bipolar (i.e. {-1, +1}). The length of the output vector `tones_out` must be 20 times longer than the length of `bits_in`, since each pair of two bits is coded within a frame of 40 audio samples.

Defined In: `tonemod.c`

```
void transformUCS2UTF(UShortint      ucsCode,  
                    fifo_state_t* ptr_octet_fifo_state);
```

Purpose: Transformation from UCS code into UTF-8. UTF-8 is a sequence consisting of 1, 2, 3, or 5 octets (bytes). See ISO/IEC 10646-1 Annex G. This routine only handles UCS codes in the range 0...0xFF since that is all that is required for the demonstration of Baudot support.

Defined In: `ucs_functions.c`

Input Variables:
`ucsCode` UCS code index

Output Variables:
`ptr_octet_fifo_state` pointer to the output fifo state buffer for the UTF-8 octets.

```
Bool transformUTF2UCS(UShortint      *ptr_ucsCode,  
                    fifo_state_t* ptr_octet_fifo_state)
```

Purpose: Transformation from UTF-8 into UCS code.

This routine only handles UTF-8 sequences consisting of one or two octets (corresponding to UCS codes in the range 0...0xFF) since that is all that is required for the demonstration of Baudot support.

Defined In: `ucs_functions.c`

Input/Output Variables:
`ptr_octet_fifo_state` pointer to the input fifo state buffer for the UTF-8 octets.

Output Variables:
`*ptr_ucsCode` UCS code index

Return Value:

| | |
|--------|--|
| true, | if conversion was successful |
| false, | if the input fifo buffer didn't contain enough octets for a conversion into UCS code. The output variable *ptr_ucsCode doesn't contain a value in this case. |

```
void viterbi_exec(Shortint* inputword, Shortint length_input,
                 Shortint* out,          Shortint* num_valid_out_bits,
                 viterbi_t* viterbi_state);
```

Purpose: Execution of the Viterbi decoder
Defined in: viterbi.c

Input Variables:

| | |
|--------------|---|
| inputword | Vector with gross bits |
| length_input | Number of valid gross bits in vector inputword. length_input must be an integer multiple of CHC_RATE. |

Output variables:

| | |
|---------------------|---|
| out | Vector with the decoded net bits. The net bits are either 0 or 1. |
| *num_valid_out_bits | Number of valid bits in vector out. |

Input/output variables:

| | |
|----------------|-------------------------------|
| *viterbi state | state variable of the decoder |
|----------------|-------------------------------|

```
void viterbi_init(viterbi_t* viterbi_state);
```

Purpose: Initialization of the Viterbi decoder
Defined in: viterbi.c

Output Variables:

| | |
|----------------|---|
| *viterbi_state | Initialized state variable of the decoder |
|----------------|---|

```
void viterbi_reinit(viterbi_t* viterbi_state);
```

Purpose: Re-Initialization of the Viterbi decoder. This function should be used for re-setting a Viterbi decoder that has already been initialized. In contrast to init_viterbi(), this reinit function does not calculate the values of all members of viterbi_state that do not change during the execution of the Viterbi algorithm.

Defined in: viterbi.c

Output Variables:

| | |
|----------------|---|
| *viterbi_state | Initialized state variable of the decoder |
|----------------|---|

```
Bool wait_for_sync(Shortint *out_bits,
                  Shortint *in_bits,
```

```

Shortint  num_in_bits,
Shortint  num_received_idle_symbols,
Shortint  *ptr_num_valid_out_bits,
Shortint  *ptr_wait_interval,
Shortint  *ptr_resync_detected,
Bool      *ptr_early_muting_required,
wait_for_sync_state_t *ptr_wait_state);

```

Purpose:

This function shall be inserted between the demodulator and the deinterleaver. The function searches the synchronization bitstream and cuts all received heading bits. As long as no sync is found, this function returns `*ptr_num_valid_out_bits=0` so that the main program is able to skip the deinterleaver as long as no valid bits are available. If the sync info is found, the complete internal shift register is copied to `out_bits` so that `wait_for_sync` can be transparent and causes no delay for future calls. `*ptr_wait_interval` returns a value of 0 after such a synchronization indicating that this was a regular synchronization.

Regularly, the initial preamble of each burst is used as sync info. In addition, the resynchronization sequences, which occur periodically during a running burst, are used as "back-up" synchronization in order to avoid losing all characters of a burst, if the preamble was not detected.

If the receiver is already synchronized on a running burst and the resynchronization sequence is detected, `*ptr_resync_detected` returns a non-negative value in the range `0..num_in_bits-1` indicating at which bit the resynchronization sequence has been detected. If no resynchronization has been detected, `*ptr_resync_detected` is -1. If the receiver is NOT synchronized and the resynchronization sequence is detected, the resynchronization sequence is used as initial synchronization. `*ptr_wait_interval` returns a value of 32 in this case due to the different alignments of the synchronizations based on the preamble or the resynchronization sequence, respectively.

In order to carry all bits, the minimum length of `out_bits` must be
`in_bits.size()-1 + ptr_wait_state->shift_reg_length`

Defined In: `wait_for_sync.c`

InputVariables:

| | |
|--------------------------|--|
| <code>in_bits</code> | Vector with bits from the demodulator. The vector's length can be arbitrarily chosen, i.e. according to the block length of the signal processing of the main program. |
| <code>num_in_bits</code> | length of vector <code>in_bits</code> |

Output Variables:

| | |
|--|---|
| <code>num_received_idle_symbols</code> | Number of idle symbols received coherently |
| <code>out_bits</code> | Vector with bits for the deinterleaver. The number of the valid bits is indicated by <code>*ptr_num_valid_out_bits</code> . |
| <code>*ptr_num_valid_out_bits</code> | returns the number of valid output bits |
| <code>*ptr_wait_interval</code> | returns either 0 or 32 |
| <code>*ptr_resync_detected</code> | returns a value -1, 0, ... <code>num_in_bits</code> |

*ptr_early_muting_required returns whether the original audio signal must not be forwarded. This is to guarantee that only the first CTM device will detect the preamble or resync sequence, if several CTM devices are cascaded subsequently.

Input/Output Variables:

ptr_wait_state state information. This variable must be initialized with `init_wait_for_sync()`.

Annex A (informative): Change history

| Change history | | | | | | | |
|----------------|---------|-----------|-----|-----|--|--------|--------|
| Date | TSG SA# | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 12-2000 | 10 | SP-000570 | | | Specification approved for Release 4 | | 4.0.0 |
| 03-2001 | 11 | SP-010108 | 001 | | Bug fix in source code of the CTM receiver | 4.0.0 | 5.0.0 |
| 05-2001 | | | | | Correct source code CTM attached | 5.0.0 | 5.0.1 |
| 07-2004 | | | | | Removed copyright terms and conditions in the source code CTM attached | 5.0.1 | 5.0.2 |
| 12-2004 | 26 | | | | Version for Release 6 | 5.0.2 | 6.0.0 |
| 06-2007 | 36 | | | | Version for Release 7 | 6.0.0 | 7.0.0 |
| 03-2008 | 39 | SP-080006 | 002 | 1 | Bug fix to baudot_tonemod function in baudot_functions.c | 7.0.0 | 7.1.0 |
| 12-2008 | 42 | | | | Version for Release 8 | 7.1.0 | 8.0.0 |
| 12-2009 | 46 | | | | Version for Release 9 | 8.0.0 | 9.0.0 |
| 03-2011 | 51 | | | | Version for Release 10 | 9.0.0 | 10.0.0 |
| 09-2012 | 57 | | | | Version for Release 11 | 10.0.0 | 11.0.0 |
| 09-2014 | 65 | | | | Version for Release 12 | 11.0.0 | 12.0.0 |
| 12-2015 | 70 | | | | Version for Release 13 | 12.0.0 | 13.0.0 |

| Change history | | | | | | | |
|----------------|---------|------|----|-----|-----|------------------------|-------------|
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2017-03 | 75 | | | | | Version for Release 14 | 14.0.0 |
| 2018-06 | 80 | | | | | Version for Release 15 | 15.0.0 |

History

| Document history | | |
|-------------------------|-----------|-------------|
| V15.0.0 | July 2018 | Publication |
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