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Foreword

This ETSI Standard (ES) has been produced by ETSI Technical Committee Access and Terminals (AT).

The present document is part 3 of a multi-part deliverable covering the Specification of Dual Tone Multi-Frequency (DTMF) Transmitters and Receivers, as identified below:

Part 1: "General";

Part 2: "Transmitters";

Part 3: "Receivers";

Part 4: "Transmitters and Receivers for use in Terminal Equipment for end-to-end signalling".

1   Scope

The present document specifies the Dual Tone Multi-Frequency (DTMF) signalling system.

The various parts of ES 201 235 [1] provide a complete set of requirements for applications intending to use DTMF signalling.

The present document is intended to provide the level of detail that will enable manufacturers of telecommunications equipment incorporating DTMF signalling, to design the equipment such that it facilitates highly reliable signalling. This should not be taken to imply that any DTMF signalling system that fails to meet all the criteria described in the present document will not provide reliable signalling.

The present document is not intended to be used for the definition of regulated interfaces.

This Part 3 covers the requirements for the DTMF receiver for the case of DTMF signalling over the local loop.

2   References

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

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies.

[1]   ETSI ES 201 235 (all parts): "Specification of Dual Tone Multi-Frequency (DTMF) Transmitters and Receivers".

3   Definitions, symbols and abbreviations

3.1   Definitions

For the purposes of the present document, the following terms and definitions apply:

high group: signalling frequencies, which have nominal values of 1 209 Hz, 1 336 Hz, 1 477 Hz and 1 633 Hz

low group: signalling frequencies, which have nominal values of 697 Hz, 770 Hz, 852 Hz and 941 Hz

Digit Recognition Condition (DRC): output state of the receiver in response to a valid input signal when the relevant signal condition and time requirements are satisfied

Valid Signal Condition (VSC): state of the line at the input of the receiver when:

1) one of the frequency combinations specified in part 1(i.e. ES 201 235-1) is present and;

2) the frequencies are within the tolerances specified in clause 4.2.1.1 and 4.2.1.3, item a) and;

3) the signalling levels are within the range of acceptable levels specified in clause 4.2.1.1 and 4.2.1.3, items b) and c) and;

4) any unwanted frequencies are within the limits as specified in clause 4.2.1.1 and 4.2.1.3, items i) to iii) of the present document.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

*	The Star on the standard 3x4 keypad array, also known as the asterisk
#	The Square on the standard 3x4 keypad array, also known as the hash, sharp, or number sign ("pound" in the USA)
dBm0	Power level expressed in decibels relative to 1 mW in a 0 dBr level reference point
dBV	Absolute voltage level expressed in decibels relative to 1 volt

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CLI	Calling Line Identification
DTMF	Dual Tone Multi-Frequency
HPF	High Pass Filter
LPF	Low Pass Filter
PBX	Private Branch Exchange
R	Rectifiers
SPF	Single Pole Filter
STF	Single Tone Filter
TC	Threshold Comparator
TE	Terminal Equipment
VSC	Valid Signal Condition

4 DTMF receiver

4.1 Area of application

The present document describes the properties of the DTMF receiver function for terminal and for network equipment.
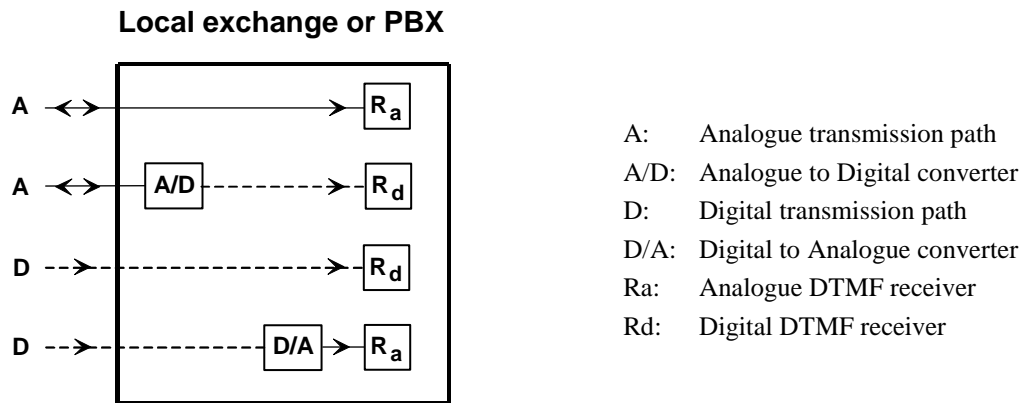
The receiver shall respond to signals received over a line from a distant transmitter conforming to parts 1 and 2 of the present document.

The receiver shall be equipped to recognize the sixteen signals designated 0 to 9, *, #, A, B, C and D. The system may be utilized with only, ten discrete signals, in which case the signals designated 0 to 9 should be used; or with twelve discrete signals, in which case the signals 0 to 9, *, # should be used. In the interests of system security, the receiver may be conditioned to recognize only specific digits from the complete set of sixteen digits.

NOTE: The principal uses of the receiver as dealt with in the present document are expected to be:

a) in a local exchange for receiving DTMF signals from a TE (e.g. for dialling);

b) in a local exchange for receiving DTMF signals from a PBX (e.g. for dialling);

c) in a PBX for receiving DTMF signals from a TE (e.g. for dialling);

d) in a PBX for receiving DTMF signals from a local exchange (e.g. for Direct Dialling -In or CLI);

e) in a TE for receiving DTMF signals from a local exchange (e.g. for CLI);

f) in a TE for receiving DTMF signals from a PBX (e.g. for CLI);

g) in a PBX for receiving DTMF signals from another PBX (e.g. for dialling or CLI).

A DTMF receiver or receiver function can be either analogue, i.e. intended for connection to an analogue point in the network, or digital, i.e. intended for connection to a digital point in the network. Figure 1 shows typical usage in a local exchange or a PBX.

Local exchange or PBX

A: Analogue transmission path
A/D: Analogue to Digital converter
D: Digital transmission path
D/A: Digital to Analogue converter
Ra: Analogue DTMF receiver
Rd: Digital DTMF receiver

Figure 1: Reference configuration

4.2   Operate and non-operate requirements

4.2.1   Signal condition requirements

The following clauses define the conditions under which the DTMF function shall decide to indicate or not indicate to the host equipment the digit that is represented by a received signal. There will be some conditions that fall into neither of these two states and the designer of the DTMF function can make their own decision whether such signals are best considered valid or not valid.

4.2.1.1   Valid signal for an analogue receiver

The received DTMF signal shall be detected as valid when only two of the signalling frequencies are present at the receiver input, one from the high group and one from the low group which meet the conditions described in items a) to c).

   a) Each of these signalling frequencies is within $\pm$ (1,5 % + 2 Hz) of the nominal value; and

   b) The level of each of these two signalling frequencies is within the range -28 dBV to -3 dBV; and

   c) The difference in level of these two signalling frequencies is not more than 6 dB.

The received DTMF signal shall also be detected as valid even if accompanied by other frequency components not exceeding:

   i)   in the frequency range 15 Hz to 480 Hz; an individual signal level of +21 dBV at 15 Hz to 33 Hz with the limit then falling at 20 dB per octave until 300 Hz. From 300 Hz to 480 Hz a level of -43 dBV. Also where dial tone protection has been provided in the receiver, a total signal level limit of -5 dBV shall additionally apply in the range 100 Hz to 480 Hz to cover interference from this source;

   ii) in the frequency range 480 Hz to 3 400 Hz; a total voltage level of 20 dB below the level of the low group signalling frequency;

   iii) at frequencies over 3 400 Hz; an individual signal level of -36 dBV at 3 400 Hz rising at 6 dB per octave to a level of +10 dBV.

   NOTE 1: Old equipment operating under previous regimes in certain countries was permitted a frequency tolerance of 1,8 %. Where network operators need to continue support for such TE, the frequency tolerance for the receiver will need to be extended to $\pm$ (1,8 % + 2 Hz).

   NOTE 2: In item b), a dynamic range of 25 dB is specified to take into account tolerances in the send levels of the DTMF transmitter and also variations in attenuation found in the local lines of the various networks.

NOTE 3: It is pointed out that some networks may require protection to cover interference from specified sources, e.g. meter pulses. This may be in addition to that specified in item iii).

NOTE 4: Equipment receiving DTMF signals in a high impedance state, as in the case of CLI, the level of each one of the two tones can be as high as 0 dBV.

4.2.1.2 Invalid signal for an analogue receiver

The received DTMF signal shall be considered as invalid if any of the conditions given in items a) to c) are satisfied at the receiver input.

a) The signal levels are correct for valid signals but more than two of the signalling frequencies are present; or

b) The level of the signalling frequency in the low group is less than -36 dBV; or

c) The level of the signalling frequency in the high group is less than -36 dBV.

As an aid to the understanding of clauses 4.2.1.1 and 4.2.1.2, table 1 is given.

Table 1: Signal condition requirements

Signal condition	Frequency deviation (Hz)	Signal level x (dBV)	Signal level difference y (dB)	Unwanted frequencies z (dBV)
Valid	$\leq \pm (1{,}5\ \% + 2)$	$-28 \leq x \leq -3$	$y < 6$	$z \leq \Psi$
May be valid	$> \pm (1{,}5\ \% + 2)$	$-36 \leq x < -28$ or $x > -3$	$y \geq 6$	$z > \Psi$
Not valid		$x < -36$		

Ψ see clause 4.2.1.1 items i) to iii).

NOTE: It is realized that certain electrical signals may exist on the line at the input of the receiver which do not fulfil either the requirements of the *'Is valid'* row or those of the *'Is not valid'* row. In these circumstances, the requirements for the existence or non-existence of signal condition are not specified directly, but indirectly, through the speech immunity requirements of clause 4.3.

4.2.1.3 Valid signal for a digital receiver

The received DTMF signal shall be detected as valid when only two of the signalling frequencies are present at the receiver input, one from the high group and one from the low group which meet the conditions described in items a) to c).

a) Each of these signalling frequencies is within $\pm (1{,}5\ \% + 2\ \text{Hz})$ of the nominal value; and

b) The level of each of these two signalling frequencies is within the range -28 dBm0 to -4 dBm0; and

c) The difference in level of these two signalling frequencies is not more than 6 dB.

The received DTMF signal shall also be detected as valid even if accompanied by other frequency components not exceeding:

i) in the frequency range 15 Hz to 480 Hz; an individual signal level of 0 dBm0 at 15 Hz to 50 Hz with the limit then falling at 12 dB per octave until 300 Hz. From 300 Hz to 480 Hz a level of -31 dBm0. Also where dial tone protection has been provided in the receiver, a total signal level limit of +3 dBm0 shall additionally apply in the range 100 Hz to 480 Hz to cover interference from this source;

ii) in the frequency range 480 Hz to 3 400 Hz a total voltage level of 20 dB below the level of the low group signalling frequency;

iii) at frequencies over 3 400 Hz, an individual signal level of -36 dBm0 at 3 400 Hz rising at 6 dB per octave to a level of 0 dBm0.

NOTE 1: Old equipment operating under previous regimes in certain countries was permitted a frequency tolerance of 1,8 %. Where network operators need to continue support for such TE, the frequency tolerance for the receiver will need to be extended to $\pm$ (1,8 % + 2 Hz).

NOTE 2: In item b), a dynamic range of 24 dB is specified to take into account tolerances in the send levels of the DTMF transmitter and also variations in attenuation found in the local lines of the various networks.

NOTE 3: It is pointed out that some networks may require protection to cover interference from specified sources, e.g. meter pulses. This may be in addition to that specified in item iii).

4.2.1.4   Invalid signal for a digital receiver

The received DTMF signal shall be considered as invalid if any of the conditions given in items a) to c) are satisfied at the receiver input.

a) The signal levels are correct for valid signals but more than two of the signalling frequencies are present; or

b) The level of the signalling frequency in the low group is less than -36 dBm0; or

c) The level of the signalling frequency in the high group is less than -36 dBm0.

As an aid to the understanding of clauses 4.2.1.3 and 4.2.1.4, table 2 is given.

Table 2: Signal condition requirements

Signal condition	Frequency deviation (Hz)	Signal level x (dBm0)	Signal level difference y (dB)	Unwanted frequencies z (dBm0)
Valid	$\leq \pm$ (1,5 % + 2)	$-28 \leq x \leq -4$	y < 6	$z \leq \Psi$
May be valid	$> \pm$ (1,5 % + 2)	$-36 \leq x < -28$ or x > -4	$y \geq 6$	$z > \Psi$
Not valid		x < -36		

Ψ see clause 4.2.1.3 items i) to iii).

NOTE: It is realized that certain electrical signals may exist on the line at the input of the receiver which do not fulfil either the requirements of the '*Is valid'* row or those of the '*Is not valid'* row. In these circumstances, the requirements for the existence or non-existence of signal condition are not specified directly, but indirectly, through the speech immunity requirements of clause 4.3.

4.2.2   Digit Recognition Condition (DRC) requirements

If a valid signal present at the DTMF receiver input fulfils the conditions set out in items a) and b) then the digit shall be indicated as recognized.

a) the signal condition shall be preceded by the continuous absence of valid signal condition for more than 40 ms or (optionally) by a recognized digit that is different to the current digit; and

b) the signal condition shall then exist continuously for more than 40 ms.

If a valid signal at the receiver input has been present for less than 20 ms, the digit shall not be indicated as recognized.

Once the DRC exists, it shall be unaffected by disturbances having a duration of less than 20 ms.

Thus a detected digit that subsequently has interruptions that are less than 20 ms, shall be interpreted as a single digit.

As an aid to the understanding of clause 4.2.2, table 3 is given:

Table 3: Digit recognition condition requirements

Character recognition	When ***not DRC*** * and then	Character recognition	When ***DRC*** and then
Shall exist	VSC > 40 ms	**Shall cease**	Not VSC > 40 ms
May exist	20 ≤ VSC ≤ 40 ms	**May cease**	20 ≤ Not VSC ≤ 40 ms
Shall not exist	VSC < 20 ms	**Shall not cease**	Not VSC < 20 ms

* or optionally a different digit recognition condition Legend: VSC   The continuous existence of a valid signal condition. Not VSC   The continuous non-existence of valid signal condition. DRC   The existence of digit recognition condition. Not DRC   The non-existence of digit recognition condition.

4.3 Speech immunity performance

The receiver should not perform more than 46 false operations per 100 speech hours at a long term active speech level of -13 dBV at analogue receivers and -13 dBm0 at digital receivers.

A speech hour is defined as a total duration of one hour when speech (in both directions) may, be present, that is when the circuit is seized and the call established (conversation condition).

NOTE 1: In addition to the simulation of signals by speech entering via the microphone, misoperation may also be caused by disturbances preventing detection of valid signals and/or splitting them into double digits. The design of a receiver with very high rejection efficiency against signal imitation might lead to an intolerable increase in the number of blockings. The general design aim should be to limit both types of misoperation (imitation and blocking) to a total level not exceeding one per 10 000 digits dialled.

NOTE 2: The duration of 100 hours has been given as the recommended test duration but sufficient accuracy can be achieved by using 10 speech hours, which can be further reduced by applying the time compression procedure described in annex A.

For test of the speech immunity performance or for comparison between different receivers the test specified in annex A can be used.

4.4 Electrical characteristics

NOTE: The electrical characteristics of the interface will be determined by the apparatus into which the function of the DTMF Receiver has been incorporated.

Annex A (normative):
Speech immunity test signal

The speech immunity performance of the receiver is tested by means of a standardized common test signal.

The common standardized test signal is a collection of speech "bursts" which simulate characters on a reference receiver when applied at the NTP. The reference unprotected receiver is defined in figure A.1 and in the notes to figure A.1.
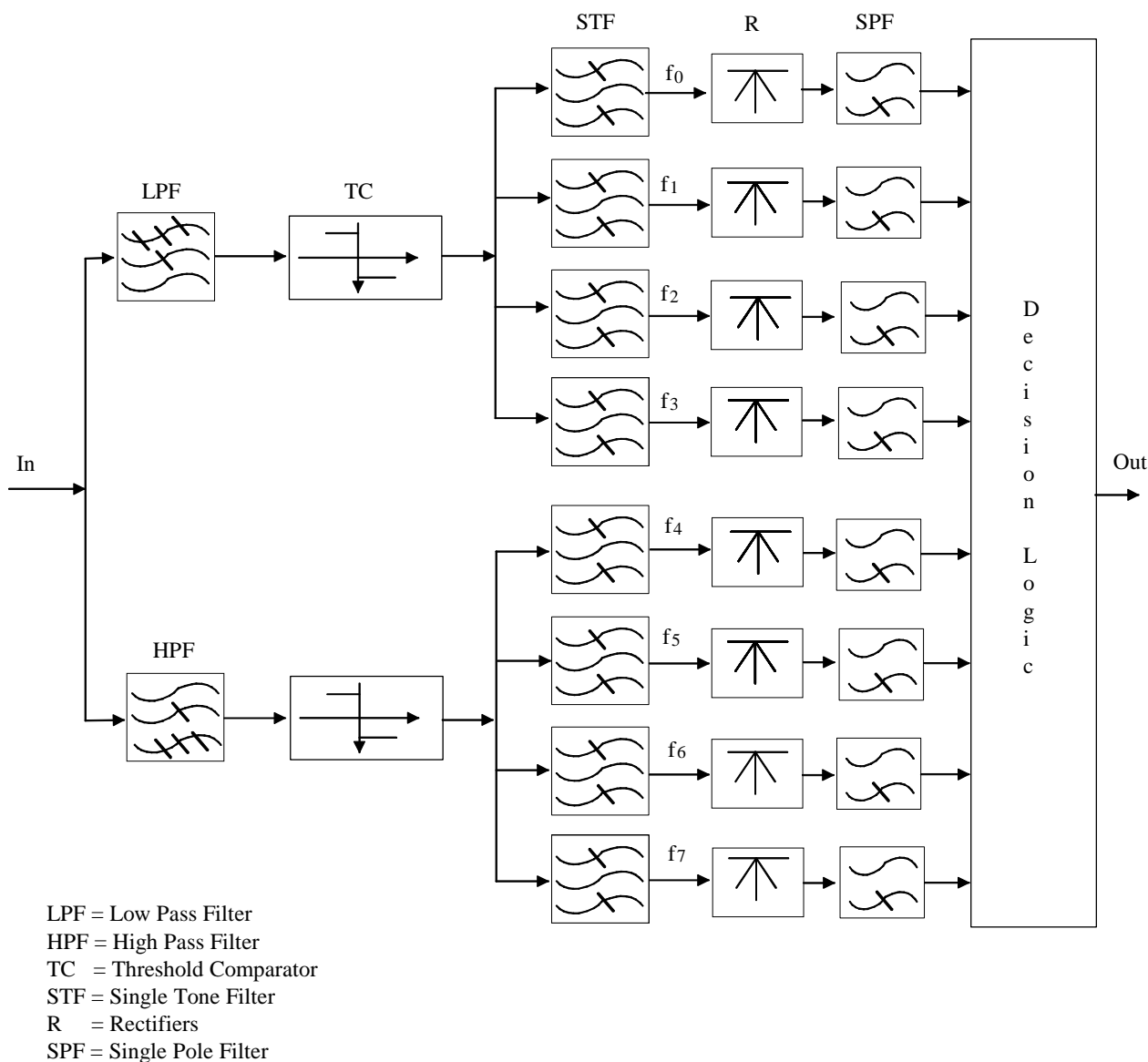
Each time the receiver recognizes a false digit, the corresponding section of speech signal is sampled, the sampling window length being in the range from 100 ms to 200 ms, equally distributed before and after the false digit recognition instant.

The duration of the pauses included between the sampled bursts shall range between 150 ms and 300 ms.

The original speech source used for generating the test sequence shall include speech samples from at least four of the following languages: English, French, German, Italian and Spanish, and shall contain both female and male voices.

Based on the available experience, the processing of 10 hours of speech material results in a test signal of about 20 minutes. When this test signal is used, no more than 5 false operations shall occur when it is applied to the DTMF receiver.

The test sequence shall include a 1 kHz calibration tone with a level 12 dB higher than the active speech level of the speech burst sequence.

Figure A.1: Reference unprotected exchange receiver (Block diagram)

Notes to figure A.1:

The scheme of the reference unprotected exchange receiver is given in figure A.1.

The characteristics of the components are:

- low-pass filter $F \leq 960$ Hz;

- high-pass filter $F \geq 1\ 190$ Hz;

- two threshold comparators;

- eight channel filters (two pole filters: -1,5 dB band pass limits at the nominal frequency $\pm (1,5\% + 2$ Hz));

- eight rectifiers;

- eight single pole (RC) filters, time constant C = 4 ms to 5 ms.

The thresholds and decision logic are regulated in order not to recognize character signals with a level below -30 dBm and to recognize valid character signals with a level in the range of -4 dBm to -30 dBm.

No other protections are to be provided in the receiver.

Annex B (informative):
Example test signal

One example for a test signal suitable for DTMF receivers is available from Telecom Italia Lab.

For further information please contact:

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