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TECHNICAL SPECIFICATION

**Short Range Devices (SRD)
using Ultra Wide Band technology (UWB);
Time Domain based Low Duty Cycle Measurement for UWB**

Reference

DTS/ERM-TGUWB-137

Keywords

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

The MATLAB® computations used for the present document are contained in archive ts_103366v010101p0.zip which accompanies the present document.

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1 Scope

The present document specifies a time domain procedure for Duty Cycle (DC) measurement. The procedure is applicable to all Ultra Wide Band (UWB) signal types, and it is an alternative to the frequency domain procedure for DC measurement described in ETSI TS 102 883 [1]. In general, the DC measurement in the time domain will provide more accurate results compared to the DC measurement in the frequency domain.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 102 883 (V1.1.1) (08-2012): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

[2] IEEE Std 802.15.4™-2015: "IEEE Standard for Low-Rate Wireless Personal Area Networks (WPANs)". IEEE Computer Society Sponsored by the LAN/MAN Standards Committee.

[3] ECC/DEC/(06)04: "The harmonised conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz".

[4] ETSI TS 103 060 (V1.1.1) (09-2013): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); method for a harmonized definition of Duty Cycle Template (DCT) transmission as a passive mitigation technique used by short range devices and related conformance test methods".

[5] CEPT ECC Report 094: "Technical requirements for UWB LDC devices to ensure the protection of FWA system", Nicosia, December 2006.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

3 Definitions, symbols and abbreviations

3.1 Definitions

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

burst: A emitted signal whose time duration (T_{on}) is not related to its bandwidth, as defined in ECC Report 094 [5].

Duty Cycle: The percentage of the transmitter sum of all burst duration "on" relative to a given period, as defined in ECC Report 094 [5].

pulse: A radiated short transient UWB signal whose time duration is nominally the reciprocal of its UWB - 10 dB bandwidth, as defined in ECC Report 094 [5].

transmission: Sequence of emissions separated by intervals shorter than $T_{dis''}$, as defined in ETSI TS 103 060 [4].

3.2 Symbols

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

B	pulse bandwidth
Bursts	number of bursts during the acquisition time
DC on time (%)	Duty Cycle measurement as a percentage of the acquisition time computed considering all the loaded files
DC on T_{obs} (%)	Duty Cycle measurement as a percentage of the whole observation period
f_c	sampling frequency
$T_{Activeperiod}$	the whole active period of the transmission
T_{dis}	time interval below which interruptions within a transmission are considered part of T_{on} (disregard time), as defined in ETSI TS 103 060 [4]
Time (s)	acquisition time
T_{off}	Defined as "the time interval between two consecutive bursts when the UWB emission is kept idle" in ECC/DEC/(06)04 [3]. Defined as "the time duration between two consecutive transmissions" in ETSI TS 103 060 [4].
T_{offPi}	T_{off} time, measured by the Spectrum Analyzer, while sending Packet$_i$ (see clause 4)
T_{off} (s)	sum of the individual T_{off} times during the acquisition time
T_{obs}	reference interval of time (observation period), as defined in ETSI TS 103 060 [4]
T_{on}	Defined as "the duration of a burst irrespective of the number of pulses contained" in ECC/DEC/(06)04 [3]. Defined as "the duration of a transmission" in ETSI TS 103 060 [4].
$T_{on(bursts)}$	duration of all the bursts
T_{on} (s)	sum of the individual T_{on} times during the acquisition time
T_{onPi}	T_{on} time, measured by the Spectrum Analyzer, while sending Packet$_i$ (see clause 4)
$t_{Packeti}$	sum between the T_{on} time and the T_{off} time while sending Packet$_i$ (see clause 4)
T_{span}	span time of the oscilloscope
T_{trig}	trigger time of the oscilloscope

3.3 Abbreviations

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

BW	Band Width
CMOS	Complementary metal oxide semi-conductor
DC	Duty Cycle
DUT	Device Under Test
IC	Integrated Circuit
LDC	Low Duty Cycle
MMI	Man Machine Interface
PHR	Physical HeadeR
PPDU	Physical Protocol Data Unit
PRF	Pulse Repetition Frequency
PSDU	Physical Service Data Unit
SHR	Synchronization HeadeR
UWB	Ultra Wide Band

4 Motivation for the Duty Cycle measurement in the time domain

The frequency domain procedure for DC measurement, described in ETSI TS 102 883 [1], relies on the use of a Spectrum Analyzer. The procedure allows calculating the DC through the measurements of the T_{on} and T_{off} parameters according to a predefined disregard time T_{dis} (see Figure C.1 in the present document).

Nevertheless the accuracy of the Spectrum Analyzer is generally not sufficient in order to measure "small values" (typically in the order of magnitude of microseconds) of the T_{on} and T_{off} parameters. This may also be the case whenever "small values" of T_{dis} are considered.

As a consequence, in some cases, the frequency domain procedure for DC measurement could result in overestimating the actual DC.

In order to provide a more accurate measurement of the T_{on} and T_{off} parameters, a time domain procedure for DC measurement is described in the present document. The procedure considers the use of an Oscilloscope, in order to capture the transmitted signal, and a Post Processing Tool (see Annex B), in order to calculate the refined DC measurement.

To better understand the principle of the DC measurement in the time domain, it is possible to consider a generic T_{obs} observation period during which some packets, with different durations, can be sent (see Figure 1):

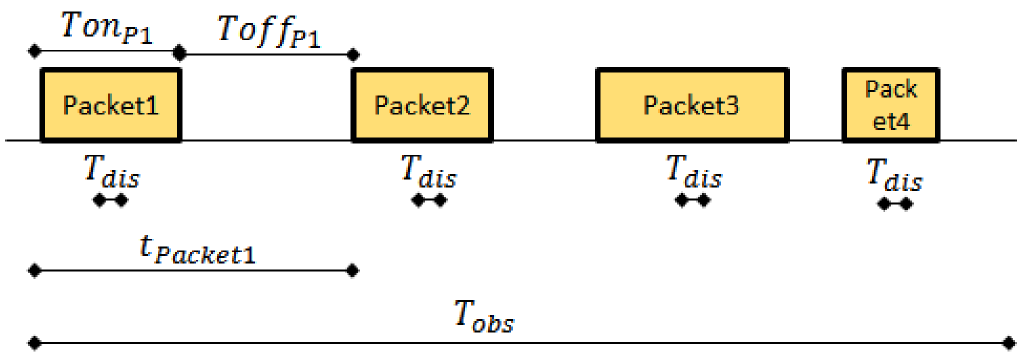

Figure 1: T_{on} and T_{off} measurement by using a Spectrum Analyzer

As illustrated in Figure 1, the Spectrum Analyzer is capable to measure the T_{on} and T_{off} parameters related to the sending of Packet$_i$. In particular, in Figure 1:

- T_{obs}: is the observation period;
- T_{onPi}: is the T_{on} time, measured by the Spectrum Analyzer, while sending Packet$_i$;

- T_{offPi}: is the T_{off} time, measured by the Spectrum Analyzer, while sending $Packet_i$;
- $t_{Packeti}$: is the sum between the T_{on} time and the T_{off} time while sending $Packet_i$;
- T_{dis}: is the disregard time.

On the other hand, the Spectrum Analyzer is generally not capable to measure T_{on} and T_{off} periods occurring between two consecutive bursts related to the sending of $Packet_i$ (see Figure 2).

In fact, by considering the transmission of a single packet, it may be the case that the transmission is composed of several bursts, separated by T_{off} periods greater than T_{dis}, that cannot be measured by the Spectrum Analyzer. Indeed, for small values of T_{dis}, the measurement can only be done in the time domain with an Oscilloscope, which is capable to detect the individual bursts occurring during the observation time T_{obs}.

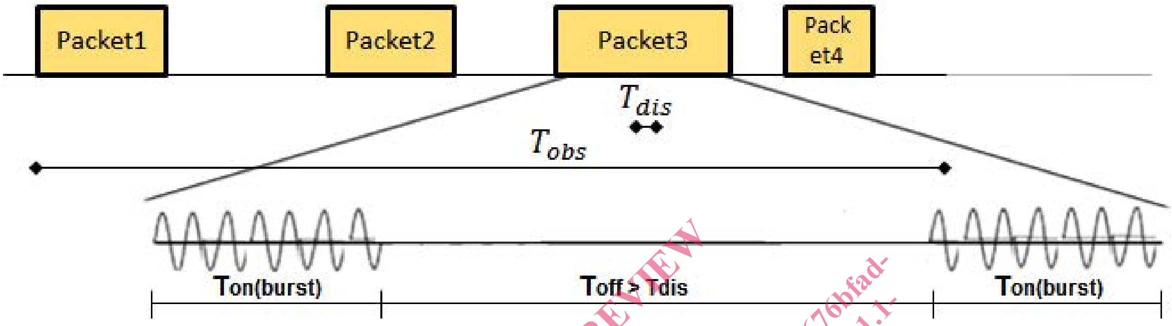

Figure 2: T_{on} and T_{off} measurement by using an Oscilloscope

In the Figure 2 above, for example, during the transmission of $Packet_3$, the Oscilloscope will be able to detect the T_{off} period between the two $T_{on(burst)}$. Since this T_{off} period is greater than T_{dis}, it can be considered as an additional T_{off} period occurring during the observation time T_{obs}. With the use of the Spectrum Analyzer, this T_{off} period would have been considered part of T_{on}.

The principle of the time domain procedure for DC measurement is thus to provide a method for the calculation of the DC based on the fine-grained analysis of the data acquired by the Oscilloscope during the observation time T_{obs}.

5 Measurement procedure for UWB systems

5.1 DUT preparation

No specific DUT preparations are necessary for performing the DC measurement in the time domain.

5.2 General test setup

5.2.0 General

The following tools shall be used to execute the time domain procedure for DC measurement:

- One 50 Ohm cable;
- One Oscilloscope with the following minimum requirements:
  a) Sampling frequency > 2B (where *B* is the pulse bandwidth): this requirement is enough to detect the envelope of the signal and ensure the correct operation of the measurement procedure.
  b) Input bandwidth > f_{max} (where f_{max} is the highest frequency, i.e. the upper boundary to the operating bandwidth).
- One Personal Computer with installed a Post Processing Tool.

5.2.1 Conducted emission

Figure 3 illustrates the general test setup to execute the time domain procedure for DC measurement in the case of conducted emission.

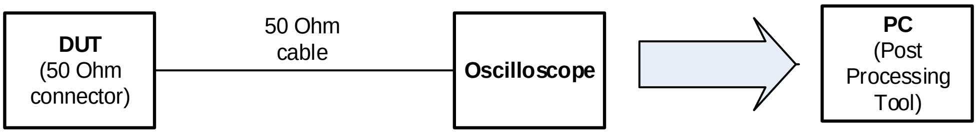

Figure 3: General test setup to execute the time domain procedure for DC measurement in the case of conducted emission

5.2.2 Radiated emission

Figure 4 illustrates the general test setup to execute the time domain procedure for DC measurement in the case of radiated emission.

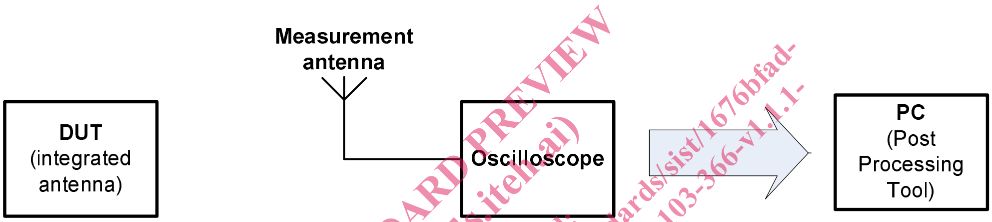

Figure 4: General test setup to execute the time domain procedure for DC measurement in the case of radiated emission

5.3 Time domain procedure for DC measurement

In order to calculate the T_{off} periods, it shall be taken into account the value of the T_{dis} parameter. In fact, given the definition of **Duty Cycle** reminded in paragraph 3.1 (i.e. "the percentage of the transmitter sum of all burst duration "on" relative to a given period"), it is possible to consider as T_{off} periods only the inter-burst intervals greater than T_{dis}.

The Time Domain Procedure for DC Measurement is illustrated in Figure 5. The procedure consists of the following steps:

1) Configure the Oscilloscope as follows:

   a) Set the signal sampling frequency f_c of the Oscilloscope ($f_c > 2B$, where B is the pulse bandwidth).

   b) Adjust the time division in accordance with the memory storage of the Oscilloscope.

   c) Adjust the vertical amplitude of the Oscilloscope (set the vertical scale of the oscilloscope to display the entire dynamic range of the waveform).

   d) Set the trigger time of the Oscilloscope at the time zero $\langle Ttrig = 0 \rangle$.

2) Consider the T_{obs} time and check if the Oscilloscope is capable to acquire and store the whole observation period:

   a) If it is the case, save the signal acquired during the whole T_{obs} time, and go to step 3.

   b) Otherwise:

      i) Save the signal that the Oscilloscope can acquire and store.

      ii) Record the time $\langle Tspan \rangle$ of the acquired signal.

iii) Set the new trigger time as: $Ttrig = Ttrig + Tspan$.

iv) Check if the new trigger time is less or equal than the T_{obs} time:

1) If it is the case, repeat the steps from i to iv.

2) Otherwise, go to step 3 (post processing of all acquired and stored signal during T_{obs}).

3) Load in the Post Processing Tool (see Annex <B> to the present document) all the points acquired by the Oscilloscope and relative to T_{obs}.

4) Inside T_{obs}, identify only the bursts. In accordance with the definition of burst in ECC Report 094 [5] (i.e. "an emitted signal whose time duration (T_{on}) is not related to its bandwidth"), and the definition of disregard time T_{dis} in ETSI TS 103 060 [4] (i.e. "the time interval below which interruptions within a transmission are considered part of T_{on}"), consider each burst as T_{on} time.

5) Calculate the sum of all $T_{on(bursts)}$ (sum all T_{on} identified in step 4) inside T_{obs}: $\sum T_{on(bursts)}^{Tobs}$.

6) Calculate the DC measurement in T_{obs} as a percentage with the following formula:

$$DC = \frac{\sum T_{on(bursts)}^{Tobs}}{T_{obs}}$$