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TECHNICAL REPORT

Report on Low Duty Cycle Mitigation for UWB Devices

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Foreword

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

Modal verbs terminology

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1 Scope

The present document assesses the current LDC mitigation regulations for UWB applications in light of the requirement to have clear test criteria for the harmonised standards. It reviews the current regulations and related measurements to highlight the extra parameters that need to be specified in future harmonised standards. It also proposes a method to measure the duty cycle such that the requirement per hour can be met.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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 referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

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.

[i.1] ETSI TR 103 181-2 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 2: UWB mitigation techniques".

[i.2] ETSI EN 302 372 (V2.1.1): "Short Range Devices (SRD);Tank Level Probing Radar (TLPR) equipment operating in the frequency ranges 4,5 GHz to 7 GHz, 8,5 GHz to 10,6 GHz, 24,05 GHz to 27 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.3] ETSI EN 302 729 (V2.1.1): "Short Range Devices (SRD);Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.4] CEPT Report 045: "Report from CEPT to the European Commission in response to the Fifth Mandate to CEPT on ultra-wideband technology to clarify the technical parameters in view of a potential update of Commission Decision 2007/131/EC".

[i.5] ETSI EN 302 065-1 (V2.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Requirements for Generic UWB applications".

[i.6] ETSI EN 302 065-2 (V2.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 2: Requirements for UWB location tracking".

[i.7] ETSI EN 302 065-3 (V2.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 3: Requirements for UWB devices for ground based vehicular applications".

[i.8] ETSI EN 302 065-4 (V1.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 4: Material Sensing devices using UWB technology below 10,6 GHz".

[i.9] ECC/DEC/(06)04: "ECC Decision of 24 March 2006 on the harmonised conditions for devices using UWB technology in bands below 10.6 GHz, amended 9 December 2011 and amended 8 March 2019".

[i.10] ECC/REC/(11)09: "ECC Recommendation of 21 October 2011 on UWB Location Tracking Systems TYPE 2 (LT2), amended 22 May 2015".

[i.11] ECC/REC/(11)10: "ECC Recommendation of 1 November 2010 on location tracking application for emergency and disaster situations".

[i.12] ECC/DEC/(07)01: "ECC Decision of 30 March 2007 on the harmonised use, exemption from individual licensing and free circulation of Material Sensing Devices using Ultra-Wideband (UWB) technology, amended on 26 June 2009, corrected on 18 November 2016 and amended on 8 March 2019".

[i.13] ETSI TS 103 060 (V1.1.1): "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".

[i.14] ETSI EN 303 883 (V1.1.1): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

[i.15] ETSI TS 103 366 (V1.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Time Domain based Low Duty Cycle Measurement for UWB".

[i.16] ETSI ERM(18)66b042: "Final minutes of the workshop DG GROW ESOs on 6th December 2018".

[i.17] ETSI EN 303 883-1 (V1.2.1): "Short Range Devices (SRD) and Ultra Wide Band (UWB); Part 1: Measurement techniques for transmitter requirements".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

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

F_{mb} Mitigation bandwith
P_{thresh} Threshold power
T_{dis} Disregard time
T_{obs} Observation period
T_{off} Off time
T_{on} On time
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:

DAA Detect And Avoid
LAES Location tracking Application for Emergency and disaster Situations
LDC Low Duty Cycle
LT2 Location Tracking type 2
UWB Ultra-Wide Band

TPC	Transmit Power Control
STF	Special Task Force
FMCW	Frequency Modulated Continuous Wave

4 Duty cycle in UWB regulations

An overview of the use of duty cycle restrictions and permission in UWB regulation is presented in clause 6.1 of ETSI TR 103 181-2 [i.1]. These are summarized in Table 1 and graphically in Figure 1. Trigger-before-transmit for keyless entry systems is new and has also been added.

In the table and figure, red colour is used to indicate a mandatory duty cycle restriction. Green is used to show optional duty cycle limits which if respected allow the device to transmit at higher power levels.

In total, there are essentially three different duty cycle related requirements:

- Maximum T_{on}
- Minimum mean T_{off} per second
- Maximum duty cycle (either per second or per hour)
  - Equivalent to minimum sum T_{off} per second or per hour
  - Equivalent to maximum sum T_{on} per second or per hour

Tank level probing radars (ETSI EN 302 372 [i.2]) also use a duty cycle defined over one-hour periods. For level probing radars, duty cycle is an optional mitigation technique (ETSI EN 302 729 [i.3]).

Based on CEPT Report 045 [i.4], the ETSI EN 302 065 series of Harmonised Standards ([i.5] to [i.8]) includes a trade-off between duty cycle and transmit power in Annex C where the T_{on} can be increased as long as the transmit power is reduced proportionally and the average T_{off} remains above 38 ms.

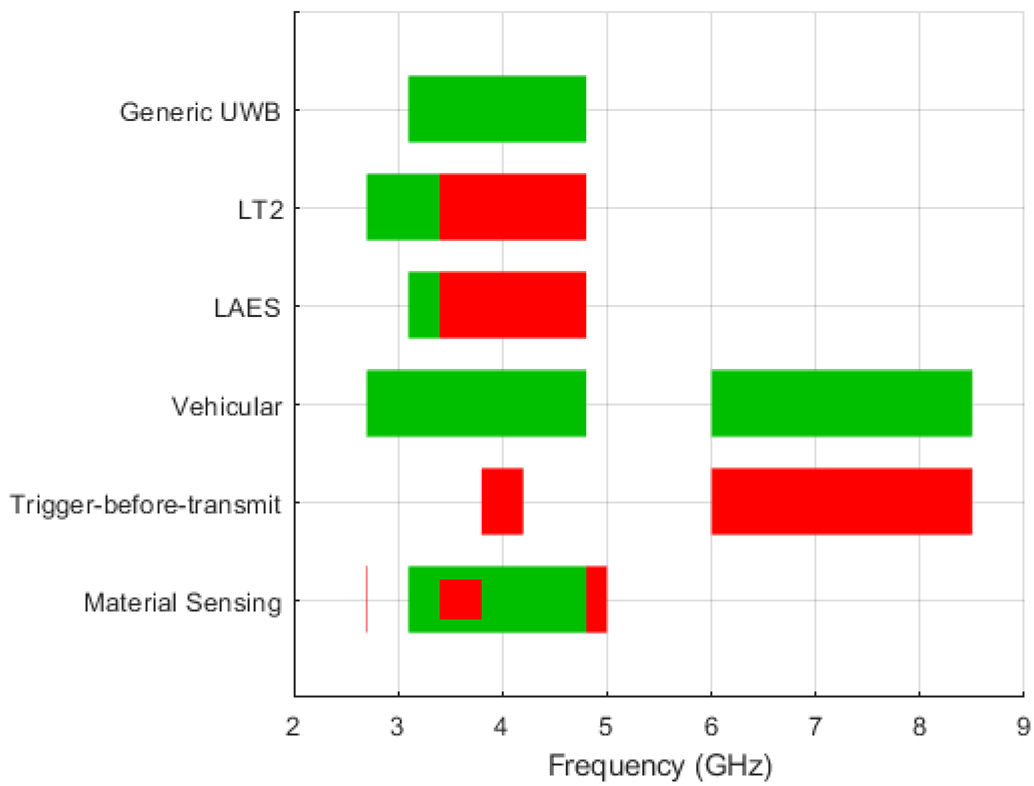

Figure 1: Duty cycle applicability in UWB regulations

Table 1: Duty cycle applicability in UWB regulations

Application	Frequency range	Duty cycle specifications
Generic UWB *ECC/DEC/(06)04 [i.9]*	3,1 to 4,8 GHz	T_{on} max = 5 ms T_{off} mean ≥ 38 ms (averaged over 1 sec) Σ T_{off} > 950 ms per second Σ T_{on} < 18 s per hour
Location tracking type 2 (LT2) *ECC/REC/(11)09 [i.10]*	2,7 to 3,4 GHz	DAA & A maximum duty cycle of 5% per transmitter per second and a maximum T_{on} = 25 ms also apply
	3,4 to 4,8 GHz	A maximum duty cycle of 5 % per transmitter per second and a maximum T_{on} = 25 ms apply
Location tracking for emergency services (LAES) *ECC/REC/(11)10 [i.11]*	3,1 to 3,4 GHz	DAA & a maximum duty cycle of 5 % per transmitter per second also applies.
	3,4 to 4,8 GHz	A maximum duty cycle of 5 % per transmitter per second For indoor and mobile transmitters, additional maximum duty cycle of 1,5 % per transmitter per minute.
Vehicular UWB *ECC/DEC/(06)04 [i.9]*	2,7 to 4,8 GHz 6,0 to 8,5 GHz	T_{on} max = 5 ms T_{off} mean ≥ 38 ms (averaged over 1 s) Σ T_{off} > 950 ms per second Σ T_{on} < 18 s per hour (see note) Exterior limit also applies
Trigger-before-transmit *ECC/DEC/(06)04 [i.9]*	3,8 to 4,2 GHz	LDC ≤ 0,5 % (in 1 h)
	6,0 to 8,5 GHz	LDC ≤ 0,5% (in 1 h) or TPC
Material sensing *ECC/DEC/(07)01 [i.12]*	2,69 to 2,70 GHz 3,4 to 3,8 GHz 4,8 to 5,0 GHz	Limitation of the Duty Cycle to 10 % per second in each of these dedicated bandwidths
	3,1 to 4,8 GHz	The LDC mitigation technique and its limits is defined in the relevant version of the Harmonised European Standard ETSI EN 302 065-1 [i.5]. When LDC is implemented, no fixed outdoor permitted.
NOTE: Within the band 3,4 GHz to 4,8 GHz, this requirement does not apply for operation with vehicle speed above 40 km/h. For vehicle speeds between 20 km/h and 40 km/h a gradual implementation of the long-term duty cycle limit from 18 s to 180 s per hour is required.		

5 T_{on} and T_{off} definition

ECC/DEC/(06)04 [i.9] defines T_{on} and T_{off} as:

- T_{on}
  - T_{on} is defined as the duration of a burst irrespective of the number of pulses contained.
- T_{off}
  - T_{off} is defined as the time interval between two consecutive bursts when the UWB emission is kept idle.

These definitions of T_{on} and T_{off} depend heavily on the interpretation of the concept of a burst.

Previously, ETSI TC ERM organized a Special Task Force (STF 411), with members from TG28 and TGUWB, to find a harmonised definition and measurement methods for low duty cycle transmissions. STF 411 published its recommendations as ETSI TS 103 060 [i.13] in September 2013.

To decide whether signals are on or off, ETSI TS 103 060 [i.13] first defines a threshold power level, P_{thresh}, above which signals are considered on. Clause 4.1.2 of ETSI TS 103 060 [i.13] specifies that:

> *Unless otherwise defined P_{thresh} is -26 dBc for systems other than UWB and -10 dBc for UWB systems.*

This power is measured in a limited mitigation bandwidth, F_{mb}.

Furthermore, ETSI TS 103 060 [i.13] also defines a disregard time, T_{dis}, in clause 4.1.7.2:

> *"T_{dis} is defined as the time interval below which interruptions within a transmission are considered part of T_{on}. T_{dis} is a measurement procedure parameter, it is not subjected to restrictions but it must be declared by the device manufacturer".*

Both concepts are illustrated in Figure 2, which was copied from ETSI TS 103 060 [i.13].

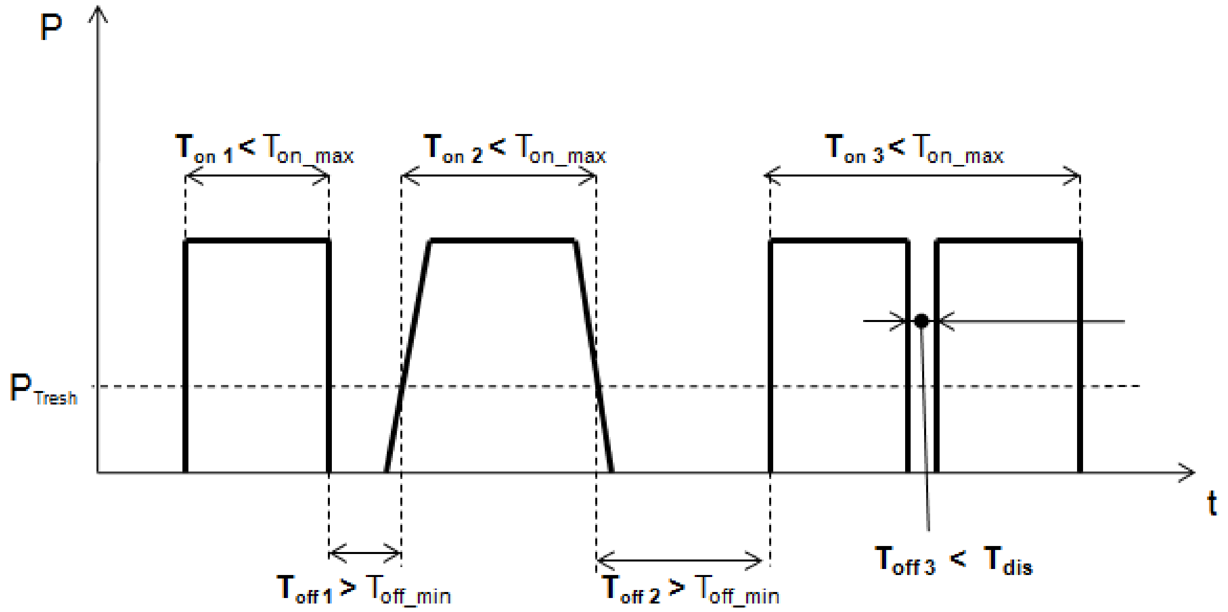

Figure 2: Illustration P_{thresh}, T_{on}, T_{off} and T_{dis}

This additional factor T_{dis} ignores 'internal' gaps in the UWB signal and allows UWB signals to meet the restrictions on the mean T_{off} time. Previously, the harmonised standards let the manufacturer declare the T_{dis} used. Since the European Commission no longer allows manufacturer declarations in harmonised standards, a suitable value for T_{dis} will have to be chosen for each application-specific harmonised standard.

ETSI TS 103 060 [i.13] does not use the burst concept. However, following its definitions, a burst is a series of pulses separated from the next pulse by time intervals less than the disregard time T_{dis}.

6 Current procedures

6.1 Measurements in ETSI EN 303 883

At the time of writing, all relevant Harmonised Standards ([i.5], [i.6], [i.7] and [i.8]) refer to ETSI EN 303 883 [i.14], clause 7.4.8 for the measurement of the duty cycle. That clause contains two alternative methods, method 1 based on measurements with a spectrum analyser in clause 7.4.8.1 and method 2 with a high-speed sampling oscilloscope in clause 7.4.8.2.

Method 1, from clause 7.4.8.1, configures the spectrum analyser in zero span mode, centred on the frequency at which the highest mean spectral density was observed. The resolution bandwidth should be set to the 'highest available bandwidth' up to a maximum of 50 MHz. There is no clear definition of P_{thresh}. The method then measures the T_{on} and T_{off} in a pulse frame with maximum T_{on} and minimum T_{off} taking into account T_{dis} from ETSI TS 103 060 [i.13].

Method 2, in clause 7.4.8.2, is based on ETSI TS 103 366 [i.15]. A high-speed sampling oscilloscope is used to record the signal in the time domain. The sampling frequency should be at least twice the pulse bandwidth to capture the envelope, while the input bandwidth of the scope should be above the upper boundary of the operating bandwidth. These recordings are then post-processed to extract the duty cycle. No mitigation bandwidth F_{mb} is used. In Annex B of ETSI TS 103 366 [i.15], it is suggested that the threshold used by the postprocessing tool corresponds to 30 % of the mean voltage of the signal. The disregard time T_{dis} is used to determine the duration of bursts.

Method 2 also contains an integration method for observation periods longer than the acquisition and storage capability of the oscilloscope. In that case, it is suggested that the trigger is delayed by successive spans of the acquisition period until the full observation period is covered.

6.2 Clause B.5 in ETSI EN 302 065 series

Annex B in the ETSI EN 302 065 series ([i.5] to [i.8]) contains an application form for testing in which the manufacturer informs the test laboratory of various product details to guide the test house in choosing the right configurations, tests and test conditions. This application form should form an integral part of the test report.

In clause B.5.2 ([i.5] to [i.8]), the manufacturer specifies the parameters of the low duty cycle scheme implemented:

NOTE 1: If there is a specific mode for testing the manufacture have to declare.

NOTE 2: Table with different parameters for different mitigation techniques.

☐ *DAA*

☐ *LDC*

a) ☐ *Frequency range A*

☐ *Frequency range B*

☐ *Frequency range C*

b) T_{on}*, max*

c) T_{off}*, mean*

d) $\sum T_{off}$ *in1s*

e) $\sum T_{on}$ *in 1h*

f) T_{dis}

7 Stricter EC requirements

7.1 No declarations or choices

Recently, the courts have viewed harmonised standards as legal documents and they are therefore more closely scrutinized by the European Commission. The minutes of a meeting between the European Commission, ETSI and CENELEC from December 2018 [i.16] state that:

- Manufacturer-declared requirements, performance criteria and/or tests are not allowed in harmonised standards.
- Harmonised standards should report precise performance criteria, technical specifications and tests. If deemed appropriate, the harmonised standard can define different precise performance criteria, technical specifications and tests for different (sub)categories or (sub)classes of radio equipment.

In the context of LDC, this means that the harmonised standards need to be updated. The current declarations, like T_{dis} and $\Sigma\ T_{on}$ per hour, should be specified and/or tested in the relevant harmonised standard.

7.2 Test modes

When an LDC device transmits at most 18 s per hour, any kind of emission testing would take a very long time to perform without a test mode. Testing of LDC devices would take at least 200 (3 600/18) times longer than for other UWB devices. In order to lead to practical test durations, devices with a long-term duty cycle (i.e. restrictions over periods longer than 1 s) therefore require a test mode that allows to disable this long-term duty cycle mechanism.

8 Measurement duty cycle per second or per minute

A large number of devices, both spectrum analysers and oscilloscopes, can capture at least 1 minute of data with high time resolution. The methods discussed in clause 6 in the present document can therefore be used. Post-processing of the measurement data then allows to extract the requirement parameters, including:

- Maximum T_{on};
- Minimum mean T_{off} per second;
- Maximum duty cycle per second:
  - Equivalent to minimum sum T_{off} per second;
  - Equivalent to maximum sum T_{on} per second;

provided that the related harmonised standard defines the required parameters (minimum P_{thresh}, maximum F_{mb} and maximum T_{dis}).

The fact that both spectrum analysers and oscilloscopes can be used for these measurements ensures wide-spread availability of the required equipment in test laboratories and throughout the industry.

9 Measurement duty cycle per hour

9.1 Introduction

The methods of clause 6 in the present document are not able to capture the duty cycle over one-hour periods like the requirement that $\Sigma\, T_{on} < 18$ s per hour for generic UWB applications. Measurement devices do not support such a long observation interval at high enough time resolutions.

Both methods, using the spectrum analyser and the oscilloscope, propose methods to capture durations longer than the device's signal acquisition time. These integration methods will be discussed in the next two clauses and will be shown to have some flaws that do not make them generally applicable. A generic solution that avoids these flaws is proposed and discussed in the final section.

9.2 Integration method from ETSI TS 103 060

In its clause 5.1.3 and Figure 9 (copied here as Figure 3), ETSI TS 103 060 [i.13] proposes the following integration method to extend the acquisition time:

> *"In this case acquisition of the signal is triggered on a defined power level. This trigger level should be lower than P_{thresh} in order to capture the entire signal of interest. Upon triggering the signal is acquired for a certain period of time ("Acquisition time") which shall be at least as long as the expected duration of the transmission.*
>
> *The acquired data is then time-stamped and stored in memory. With the next transmission the acquisition is triggered again, and so on, until T_{obs} has been reached".*

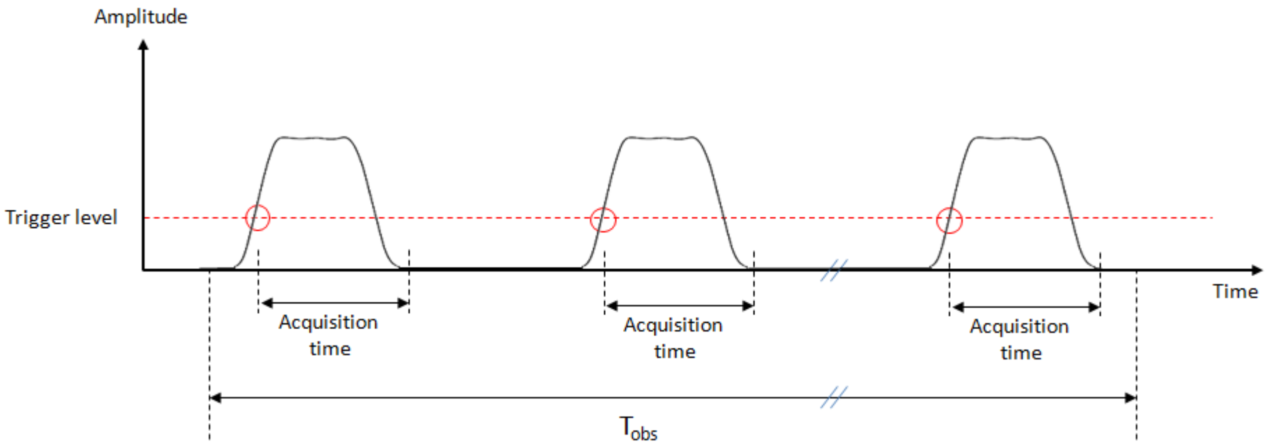

Figure 3: ETSI TS 103 060 [i.13] long-term integration method

However, this method is not suitable for all signals since the on period of the signal needs to be shorter than the acquisition time and cannot repeat faster than the time required to store the data.

9.3 Integration method from ETSI TS 103 366

In its clause 5.3 and Figure 5 (copied here as Figure 4), ETSI TS 103 366 [i.15] proposes the following integration method:

"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})".

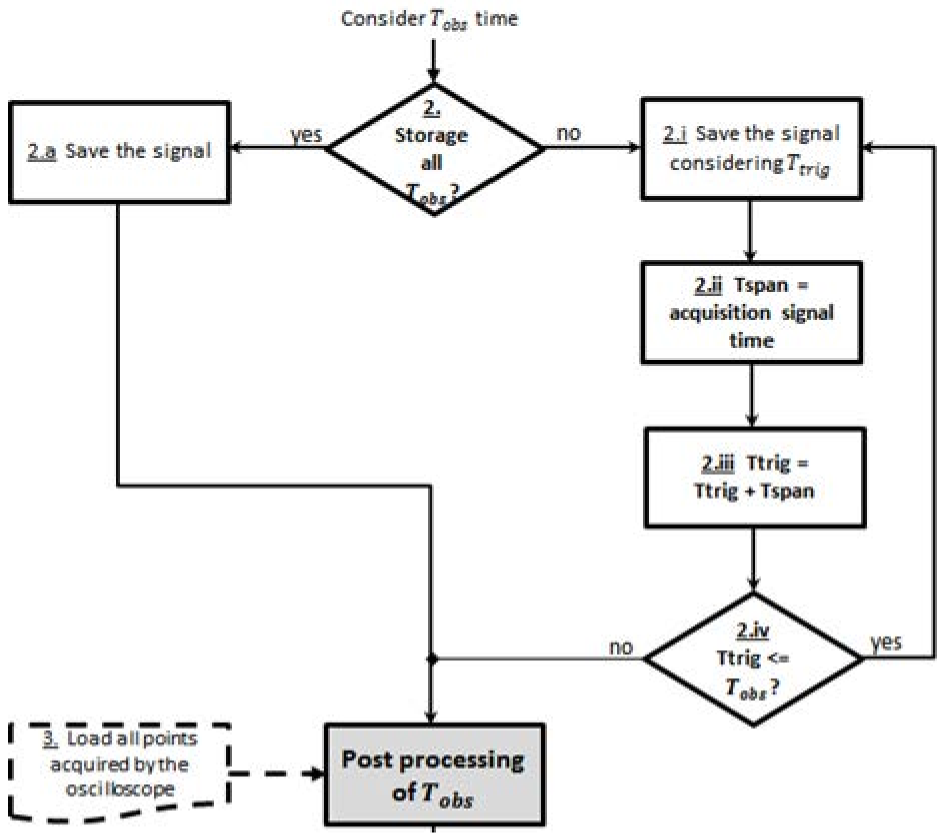

Figure 4: ETSI TS 103 366 [i.15] long-term integration method

This could only work if the transmissions have the same format every time and it could somehow be arranged that the trigger is always at the same point in the transmission. This method is therefore not suited to all signal formats either. Moreover, in practice the maximum trigger delay is limited and does not allow delaying up to 1 h.

9.4 Alternative proposal

Both methods from ETSI TS 103 060 [i.13] and ETSI TS 103 366 [i.15] have short-comings and are not able to reliably capture all signal formats over one-hour observation periods. This clause therefore proposes an alternative, in which the duty cycle is measured over a shorter interval while guaranteeing that the limit is met.

The requirement $\Sigma T_{on} < 18$ s per hour corresponds to a maximum duty cycle of 0,5 % per hour. If the harmonised standards fix a measurement interval for long term duty cycle below one hour while mandating that the maximum duty cycle in that interval is 0,5 %, the requirement that $\Sigma T_{on} < 18$ s per hour will automatically be met.

Table 2 lists the maximum ΣT_{on} per second and per measurement interval for a number of measurement durations. The maximum ΣT_{on} over the measurement duration is always fixed to 0,5 % to ensure that $\Sigma T_{on} < 18$ s per hour. If the measurement duration is fixed to 1 s, the maximum duty cycle in that second needs to be 0,5 % to ensure that the duty cycle requirement per hour is also met. Once the measurement duration is ten seconds or longer, the ΣT_{on} per second can be at its maximum of 50 ms. Longer measurement durations offer more flexibility, in the sense that more busy seconds can be compensate by other quieter periods to achieve an overall duty cycle of 0,5 %.

The measurement durations can be fixed by the harmonised standards based on the available equipment at the time of drafting.

Table 2: Duty cycle limits versus measurement duration

Measurement duration	Max Σ T_{on} in any second	Max Σ T_{on} in measurement duration	Comment
		always 0,5 % of measurement duration	
1 s	5 ms	5 ms	For measurement durations below to 10 s, the 0,5 % duty cycle requirement limits the Σ T_{on} per second.
$1 \leq X \leq 10$ s	5X ms	5X ms	
10 s	50 ms	50 ms	
30 s	50 ms	150 ms	Beyond 10 s, it gets more interesting, since more active seconds can be compensated by quiet ones.
1 minute	50 ms	300 ms	
$1 \leq X \leq 60$ minutes	50 ms	300X ms	

10 Measurement of duty cycle over large bandwidths

Material sensing devices need to measure the duty cycle over specific, larger bandwidths, i.e. 2,69 to 2,70 GHz, 3,4 to 3,8 GHz and 4,8 to 5,0 GHz.

Spectrum analysers do not have resolution bandwidths large enough to capture up to 400 MHz bandwidth. Oscilloscopes are not able to limit the signal bandwidth at all.

For pulsed systems, the duty cycle in a specific bandwidth will be close to the duty cycle over the whole band, so there is no need for a special method. For FMCW and stepped-frequency systems based, the draft update of ETSI EN 303 883-1 [i.17] contains a method to measure the duty cycle within a frequency band on two synchronized spectrum analysers.

11 Conclusions

This report gives an overview of the current duty regulations for UWB applications.

To satisfy the requirements from the European Commission, the next generation of harmonised standards will need to include all parameters required to specify the duty cycle profile. In particular, declarations of the disregard time T_{dis} are no longer allowed. Every harmonised standard will need to specify T_{dis} taking into account the applicable usage scenarios.

To be able to measure the duty cycle requirement per hour, this report proposes to fix the duty cycle over shorter measurement durations to the duty cycle limit per hour. For all other compliance tests, the UWB device should include a test mode in which the duty cycle per hour restriction is removed such that the tests can be completed within reasonable time.

History

Document history		
V1.1.1	December 2020	Publication