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TECHNICAL REPORT

Evaluation status on receiver requirement on Signal interferer handling

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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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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

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Directive 2014/53/EU [i.11] on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment, known as the RED - Radio Equipment Directive, was ratified by the European Parliament at Strasbourg on 16 April 2014. The previous legislation, the R&TTE Directive [i.54], was repealed with effect from 13 June 2016. The RED came into force on 13 June 2016 with a one-year transition period, during which both the old and new Directives could be used for declaring product compliance. The European Commission requested ETSI to provide harmonised standards in support of the RED in response to Standardisation Request M/536.

The scope of the RED [i.11] is broader than that of the R&TTE Directive [i.54]. In addition, its Essential Requirements were clarified, especially with respect to receivers. Receiver (RX) parameters were to be included in the standards to support a more efficient use of the spectrum. Therefore, ETSI was required to create new or update its existing harmonised standards accordingly. This task has presented new technical challenges in relation to certain equipment categories, especially for:

- Receive-only equipment.
- Radio determination equipment.
- Radio equipment operating at frequencies below 9 kHz.
- Radio equipment/systems in which the receiver should be tested within the system (e.g. inductive systems).

Some of these challenges have already been addressed by ETSI STF 494 (06/2015 - 03/2016) which developed a new concept for RX requirements and tests for UWB devices, which is documented in ETSI TS 103 361 [i.1] (Receiver technical requirements, parameters and measurement procedures to fulfil the requirements of the Directive 2014/53/EU [i.11]). This TS contains alternative receiver requirements and test procedures for typical use-cases and applications of UWB technology. All standards of ERM TGUWB are referring to ETSI TS 103 361 [i.1] for receiver requirements.

The main difference between this alternative concept and "classical" receiver requirements (such as receiver sensitivity) lies in the definition of hybrid RX-parameters, which constitute a combination of one or more receiver parameters and an intended usage scenario.

In certain applications, receiver parameters are closely linked with the intended usage scenario. That means, these devices cannot be tested in isolation from these scenarios. The performance criteria of RF system deploying these receiver parameters are determined by the usage scenario. Examples are given in clause 8.

For others, conducted measurements required for some classical receiver parameters could not be performed due to the high level of integration in some devices, e.g. if no antenna port connector is available. Similarly, required access points to measure some classical receiver parameters might not be available.

Some devices operate in a shared spectrum environment without e.g. channel definitions leading to a high probability of interference.

Several other ETSI ERM TGs are using a similar concept in the new versions of harmonised standards for the RED:

- ETSI EN 301 091-1 [i.2]
- ETSI EN 301 091-2 [i.3]
- ETSI EN 303 417 [i.4]
- ETSI EN 303 447 [i.5]

In January 2015, CEPT (ECC\ WGSE\ SE21) created a new work item (SE21_18) [i.46] "to evaluate relevant receiver parameters, considering the future role of receiver parameters in spectrum management and sharing studies". This ongoing work aims to provide some guidance on receiver requirements (planned is first an ECC Report and in a second step an ECC Recommendation) and could have a significant impact on standardization in ETSI. The outcome of the work of STF 494 (ETSI TS 103 361 [i.1]) was presented to SE21 and raised many questions.

The main questions from SE/SE21 were:

- How can the alternative concept ensure a minimum sensitivity of the radio system?
- Is it possible to implement the concept into the spectrum engineering process (e. g. use in SEAMCAT or for the definition of interference scenarios)?
- Can the concept demonstrate/ensure that equipment supports an efficient use of the spectrum?

The discussion with SE21 is still ongoing and requires support from ETSI. Answering the questions from SE21 will be one of objectives of this STF.

1 Scope

The present document presents a generic description of the hybrid RX-requirements concept for implementation into harmonised standards. The new concept is intended to complement the framework for classical receiver parameters by providing alternative RX parameters that could be used in use cases of radio devices where the classical receiver parameters framework described in ETSI EG 203 336 [i.6], clause on RX where alternatives are allowed) cannot be applied, e.g. if:

- there is no possibility to apply classical receiver parameters and parameters needed for compatibility or sharing studies (e.g. RFID tags and some SRDs);
- classical receiver parameters do not fulfil the requirements for describing the performance of the receiver (e.g. UWB, radio-determination, and inductive systems).

The present document will evaluate the relationship of the new concept with the classical RX- parameter framework, such as blocking, sensitivity and adjacent channel selectivity.

The present document presents exemplary use cases and extracts related RX parameter to describe a harmonised extension of the existing RX parameter framework.

The STF will ensure that the conclusions of its work should be included in harmonised standards in the following ways:

- It will provide a way to define clear limits that are objective, measurable and repeatable.
- It should ensure that a receiver to which the defined limits are applied has a level of performance that allows it to operate as intended and protects it against potential harmful interference.
- It will not define specific values for limits or device-related requirements but focus on the procedure and definitions of appropriate receiver parameters.

The present document is the first deliverable of STF 541 and it will be followed by an ETSI Technical Specification. The present document provides an overview of the situation regarding receiver requirements including the definitions, required parameters (e.g. interfering signals definition). The later TS will provide conformance test procedures for the different use-cases/scenarios. The TS is intended to be used as a normative reference in ETSI harmonised standards which have "signal interferer handling" as an essential RX-requirement.

During the proposed action, a set of evaluation measurements will be performed applying the new concept, and the feedback collected will be included in the final definition of the test and measurement procedures.

The output of the STF could be suitable for incorporation into a revision of the ETSI Guide (ETSI EG 203 336 [i.6]) to Harmonised Standards under the RED.

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 TS 103 361: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Receiver technical requirements, parameters and measurement procedures to fulfil the requirements of the Directive 2014/53/EU".

[i.2] ETSI EN 301 091-1: "Short Range Devices; Transport and Traffic Telematics (TTT); Radar equipment operating in the 76 GHz to 77 GHz range; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Part 1: Ground based vehicular radar".

[i.3] ETSI EN 301 091-2: "Short Range Devices; Transport and Traffic Telematics (TTT); Radar equipment operating in the 76 GHz to 77 GHz range; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Part 2: Fixed infrastructure radar equipment".

[i.4] ETSI EN 303 417: "Wireless power transmission systems, using technologies other than radio frequency beam in the 19 - 21 kHz, 59 - 61 kHz, 79 - 90 kHz, 100 - 300 kHz, 6 765 - 6 795 kHz ranges; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.5] ETSI EN 303 447: "Short Range Devices (SRD); Inductive loop systems for robotic mowers in the frequency range 0 Hz to 148,5 kHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.6] ETSI EG 203 336: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Guide for the selection of technical parameters for the production of Harmonised Standards covering article 3.1(b) and article 3.2 of Directive 2014/53/EU".

[i.7] Recommendation ITU-R SM.332-4: "Selectivity of receivers".

NOTE: Available at https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.332-4-197807-I!!PDF-E.pdf.

[i.8] ETSI EN 300 086 (V2.1.2): "Land Mobile Service; Radio equipment with an internal or external RF connector intended primarily for analogue speech; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.9] ERC/REC 74-01: "Unwanted emissions in the spurious domain".

NOTE: Available at https://www.ecodocdb.dk/download/3af8bcdd-43ae/ERCREC7401.pdf.

[i.10] ETSI EN 303 340: "Digital Terrestrial TV Broadcast Receivers; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.11] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

NOTE: Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0053&from=DE.

[i.12] ETSI EN 302 217-2 (V3.1.1) "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2: Digital systems operating in frequency bands from 1 GHz to 86 GHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.13] Guide to the Radio Equipment Directive 2014/53/EU, version of 05-06-2018.

NOTE: Available at https://ec.europa.eu/docsroom/documents/29782.

[i.14] Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits.

NOTE: Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0035&from=DE.

[i.15] The 'Blue Guide' on the implementation of EU product rules 2016 (2016/C 272/01), version 26-07-2016.

NOTE: Available at https://ec.europa.eu/docsroom/documents/18027/attachments/1/translations/en/renditions/native.

[i.16] ETSI EN 302 217-2-2 (V2.2.1): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2-2: Digital systems operating in frequency bands where frequency co-ordination is applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.17] ETSI EN 301 126-1 (V1.1.2) (1999-09): "Fixed Radio Systems; Conformance testing; Part 1: Point-to-point equipment - Definitions, general requirements and test procedures".

[i.18] ITU-R Study Group 9 Recommendation F.1191-1 (1995-1997): "Bandwidths and unwanted emissions of digital radio-relay systems".

NOTE: Available at https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.1191-1-199709-S!!PDF-E.pdf.

[i.19] ETSI EN 301 390 (V1.3.1): "Fixed Radio Systems; Point-to-point and Multipoint Systems; Unwanted emissions in the spurious domain and receiver immunity limits at equipment/antenna port of Digital Fixed Radio Systems".

[i.20] ETSI EN 302 217-1 (V3.1.1) (2017-05): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview, common characteristics and system-independent requirements".

[i.21] ECC Report 138 (June 2010): "Measurements on the performance of DVB-T receivers in the presence of interference from the mobile service (especially from UMTS)".

NOTE: Available at https://www.ecodocdb.dk/download/04db91ba-1aef/ECCREP138.PDF.

[i.22] ETSI EN 300 328 (V2.1.1) (2016-11): "Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.23] ETSI EN 301 893 (V2.1.1): "5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.24] 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.25] ETSI TR 101 994-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB) Part 1: Communications applications".

[i.26] 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.27] ETSI EN 302 065-5 (V1.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Part 5: Devices using UWB technology onboard aircraft".

[i.28] RSPG10-331 (2010) Final Draft for Adoption: "Radio Spectrum Policy Group Report on Improving Spectrum Efficiency & Utilisation in Frequency Bands Relevant to the Digital Dividend".

NOTE: Available at http://rspg-spectrum.eu/wp-content/uploads/2013/05/rspg10_331_digitaldividend.pdf.

[i.29] ETSI EN 302 208 (V3.2.0): "Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W and in the band 915 MHz to 921 MHz with power levels up to 4 W; Harmonised Standard for access to radio spectrum".

[i.30] ETSI EN 303 413 (V1.1.1): "Satellite Earth Stations and Systems (SES); Global Navigation Satellite System (GNSS) receivers; Radio equipment operating in the 1 164 MHz to 1 300 MHz and 1 559 MHz to 1 610 MHz frequency bands; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.31] ETSI TR 103 181-1 (V1.1.1): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Technical Report Part 1: UWB signal characteristics and overview CEPT/ECC and EC regulation".

[i.32] ETSI TR 102 495-3 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document Part 3: Location tracking applications operating in the frequency band from 6 GHz to 9 GHz".

[i.33] 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.34] 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.35] Federal Communications Commission Spectrum Policy Task Force, Report of the Spectrum Efficiency Working Group, November 15, 2002, ET Docket No. 02- 135.

NOTE: Available at https://docs.fcc.gov/public/attachments/DOC-228542A1.pdf.

[i.36] Recommendation ITU-R SM.1046 (09/2017): "Definition of spectrum use and efficiency of a radio system".

NOTE: Available at https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.1046-3-201709-I!!PDF-E.pdf.

[i.37] Recommendation ITU-R SM.329-12 (09/2012): "Unwanted emissions in the spurious domain".

NOTE: Available at https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.329-12-201209-I!!PDF-E.pdf.

[i.38] Recommendation ITU-R F.1191 (05/2011): "Necessary and occupied bandwidths and unwanted emissions of digital fixed service systems".

NOTE: Available at https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.1191-3-201105-I!!PDF-E.pdf.

[i.39] Recommendation ITU-T O.151 (10/92): " Specifications of Measuring Equipment".

NOTE: Available at https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-O.151-199210-I!!PDF-E&type=items.

[i.40] Recommendation ITU-T O.181 (05/2002): "Series O: Specifications of measuring equipment - Equipment to assess error performance on STM-N interfaces".

NOTE: Available at https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-O.181-200205-I!!PDF-E&type=items.

[i.41] Recommendation ITU-T O.191 (02/2000): "Series O: Specifications of measuring equipment - Equipment to measure the cell transfer performance of ATM connections".

NOTE: Available at https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-O.191-200002-I!!PDF-E&type=items.

[i.42] IEEE 1802.3-2001™: "IEEE Conformance Test Methodology for IEEE Standards for Local and Metropolitan Area Networks - Specific Requirements - Part 3: Carrier Sense Multiple Access With Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications".

NOTE: Available at http://standards.ieee.org/findstds/standard/1802.3-2001.html.

[i.43] IEEE 802.3-2015™: "IEEE Standard for Ethernet".

NOTE: Available at http://standards.ieee.org/findstds/standard/802.3-2015.html.

[i.44] ECC Report 181: "Improving Spectrum Efficiency in the SRD Bands".

NOTE: Available at https://ecodocdb.dk/download/94dcd5ca-855f/ECCREP181.PDF.

[i.45] ETSI EN 302 217-2-1 (V2.1.1) (2014-12): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2-1: System-dependent requirements for digital systems operating in frequency bands where frequency co-ordination is applied".

[i.46] SE21(18)77A02: "Evaluation of receiver parameters and the future role of receiver performance in spectrum management and coexistence studies".

NOTE: Available at https://www.cept.org/Documents/se-21/44850/se21-18-77a02_updated-working-document-draft-ecc-report-on-receiver-parameters.

[i.47] ERMTGUWB(17)041013 (2017-11-30): "RX-requirements discussion for UWB devices".

NOTE: Available at https://docbox.etsi.org/ERM/ERMTGUWB/05-CONTRIBUTIONS/2017//ERMTGUWB(17)041013r2_RX-requirements_discussion_for_UWB_devices.docx.

[i.48] ETSI EN 302 065-2 (V2.1.1) (2016-11): "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.49] ETSI TR 102 495-1 (V1.1.1) (2006-01): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document; Part 1: Building material analysis and classification applications operating in the frequency band from 2,2 GHz to 8 GHz".

[i.50] ETSI EN 302 065-4 (V1.1.1) (2016-11): "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.51] ETSI TR 102 495-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document; Part 2: Object Discrimination and Characterization (ODC) applications for power tool devices operating in the frequency band of 2,2 GHz to 8,5 GHz".

[i.52] ETSI TR 102 495-5 (V1.1.1) (2009-01): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); Part 5: Location tracking applications type 2 operating in the frequency bands from 3,4 GHz to 4,8 GHz and from 6 GHz to 8,5 GHz for person and object tracking and industrial applications".

[i.53] ETSI EN 302 066 (V2.1.1) (2017-01): "Short Range Devices (SRD); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.54] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

NOTE: Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0005&from=EN.

[i.55] ETSI TR 102 496 (V2.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical characteristics for Location tracking Applications for Emergency Services (LAES) in disaster situations operating within the frequency range from 3,4 GHz to 4,8 GHz".

[i.56] ETSI TS 103 567: "Requirements on signal interferer handling".

3 Symbols and abbreviations

3.1 Symbols

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

F_{rx}	Mid Frequency of Receiver

3.2 Abbreviations

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

AD	Analog Digital
ADC	Analog Digital Conversion
ATM	Asynchronous Transfer Mode
BB	BaseBand
BBER	Background Block Error Ratio
BER	Bit Error Rate
BMA	Building Material Analysis
BWe	evaluation BandWidth
C/I	Carrier to Interference ratio
CAP	Conformity Assessment Procedure
CCDP	Co-Channel Dual Polarization
CEPT	European Conference of Postal and Telecoms administrations
CS	Channel Separation
CW	Continuous Wave
DDC	Direct Digital Conversion
DECT	Digital Enhanced Cordless Telecommunications
DRRS	Digital Radio Relay System
DUT	Device Under Test
ECC	Electronic Communications Committee
ECO	European Communications Office
EFIS	ECO Frequency Information System
EMC	Electromagnetic Compatibility
EN	European Norm
ERM	Electromagnetic compatibility and Radio spectrum Matters
ETSI	European Telecommunications Standards Institute
FFT	Fast Fourier Transformation
FMCW	Frequency Modulation Continuous Wave
GNSS	Global Navigation Satellite System
GPR	Ground Penetrating Radar
GPS	Global Position System
HS	Harmonised Standard
ISM	Industrial, Scientific and Medical band
LAES	Location tracking Application for Emergency and disaster Situations
LF	Low Frequency
LO	Local Oscillator
LOS	Line Of Sight
LPR	Level Probing Radar
LRR	Long Range Radar
LT	Limited Tests (in RFID context)
LTE	Long Term Evolution
LVD	Low-Voltage Directive
MG	Maintenance Group
MRR	Mid-Range Radar
NLOS	Non Line Of Sight
ODC	Object Discrimination and Characterization
OJ	Official Journal
PCB	Printed Circuit Board

PDH	Plesiochronous Digital Hierarchy
PER	Packet Error Rate
PMSE	Programme Making and Special Events
PRBS	Pseudo Random Binary Sequence
R&TTE	Radio and Telecommunication Terminal Equipment (directive)
RCS	Radar Cross Section
REC	Recommendation
RED	Radio Equipment Directive
RF	Radio Frequency
RFID	Radio Frequency IDentification
RIC	Radio Identity Code
RLAN	Radio Local Area Network
RSE	Relative Spectrum Efficiency
RSL	Received Signal Level
RSPG	Radio Spectrum Policy Group (of the European Commission)
RX	Receiver
SDH	Synchronized Digital Hierarchy
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SES	Satellite Earth stations and Systems
SINAD	(Signal + Noise + Distortion) to (Noise + Distortion)
SLRR	Super Long Range Radar
SNR	Signal to Noise Ratio
SRD	Short Range Devices
SRR	Short Range Radar
STF	Specialist Task Force
SUE	Spectrum Utilization Efficiency
TB	Technical Body
TGSRR	Task Group Short Range Radar
TGUWB	Task Group Ultra-Wide Band
TLPR	Tank Level Probing Radar
TR	Technical Report
TS	Technical Specification
TTT	Transport and Traffic Telematic
TV	TeleVision
TX	Transmit
UE	User Equipment
USRR	Ultra Short Range Radar
UUT	Unit Under Test
UWB	Ultra-WideBand
WG SE21	Working Group Spectrum Engineering 21
WGSE	Working Group Spectrum Engineering
WPR	Wall Penetrating Radar
WPT	Wireless Power Transfer
XPIC	Cross Polarization Interference Canceler

4 General Considerations

According to the RED, RX parameters are to be included in harmonised standards to support a more efficient use of the spectrum. Therefore, ETSI was required to create new standards or update its existing harmonised standards. This task has presented new technical challenges in relation to certain equipment categories, specifically for certain types of devices for which the "classical" RX parameters are not applicable. Due to the fact that the process is quite new and that new concepts are under consideration, this resulted in numerous revised or new HS which were not published in the OJ.

The scope of this STF is to provide guidance for revision of blocked HS. The goal of the STF is to get the blocked HS revised and listed to enable the conformity assessment procedure (CAP) as stated in Guide to the Radio Equipment Directive 2014/53/EU [i.13] clause 2.6 *"Description of the manufacturer's responsibilities"*, and subclause 2.6 b) *"Conformity assessment procedures (CAP):*

For the essential requirements set out in Article 3 of the RED, Article 17 of the RED provides that conformity shall be demonstrated by using Module A (annex II of the RED), Module B+C (annex III of the RED) or Module H (annex IV of the RED). However, with respect to the requirements set out in Articles 3.2 and 3.3 of the RED, Module B+C (annex III of the RED) or Module H (annex IV of the RED) shall be used, if harmonised standards are partially applied or not applied or do not exist."

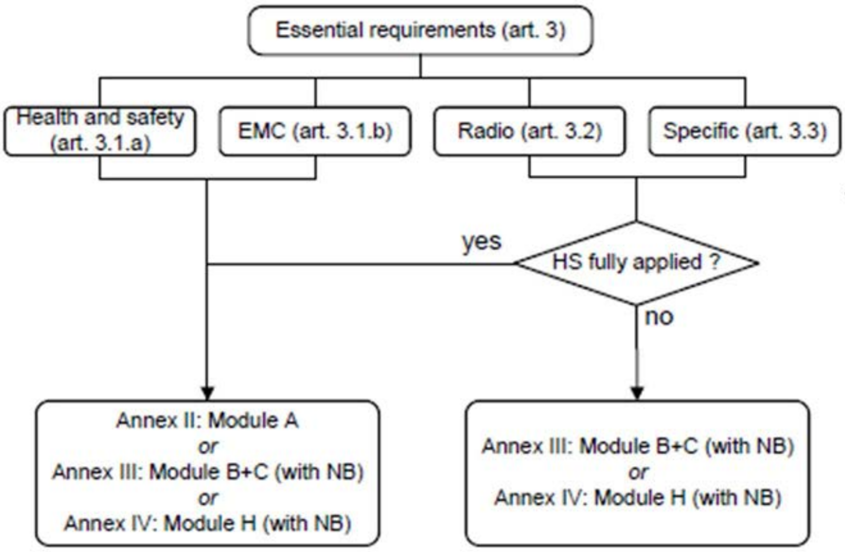

Figure 1: Overview of the different conformity assessment procedures from Guide to the Radio Equipment Directive 2014/53/EU Figure 1 [i.13]

The Harmonised Standards in scope of the present document are blocked due to EC desk officer's feedback:

- It is not accepted to declare the "intended use" by manufacturer in relevant HS.
- To use a notified body to declare the "intended use" by manufacturer.

It should be noted that ETSI EG 203 336 [i.6] provides a list of receiver parameters in clause 5.3 that:

"...should be considered when producing Harmonised Standards that aim to cover the essential requirements in article 3.2 of Directive 2014/53/EU".

ETSI EG 203 336 [i.6] also indicates in clause 5.3.1 that:

"The intention of article 3.2 of Directive 2014/53/EU [i.1] in relation to a receiver is explained in recitals 10 and 11 of the Directive which state:

> *"...in the case of a receiver, it has a level of performance that allows it to operate as intended and protects it against the risk of harmful interference, in particular from shared or adjacent channels, and, in so doing, supports improvements in the efficient use of shared or adjacent channels.*
>
> *Although receivers do not themselves cause harmful interference, reception capabilities are an increasingly important factor in ensuring the efficient use of radio spectrum by way of an increased resilience of receivers against harmful interference and unwanted signals on the basis of the relevant essential requirements of Union harmonisation legislation.*

Receivers usually operate under spectrum conditions managed by radio regulators to use spectrum efficiently and share with current & future users. The receivers should be specified in order to use the spectrum as intended while respecting these spectrum use conditions.

Technical Bodies should consider the above conditions when fixing receiver parameters and their limit values for inclusion in a Harmonised Standard. For example, if a relevant ECC coexistence study recommends a certain level of receiver performance, then this should be respected in the Harmonised Standard. It is expected that intended use conditions are included in such studies, for example head and hand attenuation when appropriate. "

However, the RED does not define the term "intended use", nor does it stipulate what a declaration of "intended use" should contain. According to the Guide to the Radio Equipment Directive 2014/53/EU [i.6], which states, that *"(…), the applicability of the RED depends on the intended use declared by the manufacturer"*, the manufacturer is free to declare the intended use of their equipment. This declaration typically consists of a specific statement of the intended use (see example 1 below) in the product documentation or can be derived from the product's operating guidelines (see example 2).

EXAMPLE 1: Professional wall scanner product documentation:

Intended Use:

"*The measuring tool is intended for detecting objects in walls, ceilings and floors. Depending on material and condition of the structural surface, metal objects, wooden beams, plastic pipes, wiring and cables can be detected. For objects detected, the object depth to the surface of the object is determined.*"

EXAMPLE 2: Electric Toothbrush with Bluetooth interface:

"*Use this product only for its intended use as described in this manual.*"

Furthermore, manufacturers' obligations to define the intended purpose and use of their products are stated in both the Directive 2014/35/EU [i.14] and the 'Blue Guide' on the implementation of EU product rules [i.15].

5 Classical Receiver

5.1 Classical receiver parameters

ETSI EG 203 336 [i.6] provides the following list of "classical" receiver parameters:

- Receiver sensitivity.
- Receiver co-channel rejection.
- Receiver selectivity.
- Receiver adjacent signal selectivity (adjacent channel selectivity).
- Receiver spurious response rejection.
- Receiver blocking.
- Receiver radio-frequency intermodulation.
- Receiver dynamic range.
- Reciprocal mixing.
- Desensitization.
- Receiver unwanted emissions in the spurious domain.

ETSI EG 203 336 [i.6] provides additional guidance for the Technical Bodies, for example, on the tests to be performed for the receiver parameters:

"When specifying tests for receiver co-channel rejection Technical Bodies should specify the unwanted signal which may be similar to the wanted signal or an unwanted interfering signal defined in ECC sharing or compatibility studies, or a suitable test signal defined by the relevant ETSI Technical Body."

Or further information, justifying the need to specify a given parameter:

"Receiver co-channel rejection is essential to determining the spatial reuse of the same frequency, e.g. in nearby geographic areas or in other sectors/directions in the same node. Contributions to co-channel rejection used for system planning are often complex: factors may include: choice of modulation scheme, antenna diversity and antenna beam steering."

It is noted that before the enforcement of the RED [i.11], some of the "classical" receiver test cases were already included in a limited set of the standards.

5.2 RX Spurious emissions - external

5.2.1 Overview

ETSI EN 302 217-2-2 [i.16] was published in 2013 and already contained a clause dealing with *"Essential radio test suites for the receiver"* as described in the following clause. This clause considers the test to be performed for the spurious emissions.

The objective (see ETSI EN 301 126-1 [i.17]) is *"to verify that any spurious emissions generated by the transmitter are within the limits quoted in the relevant standard. Spurious emissions are emissions outside the bandwidth necessary to transfer the input data at the transmitter to the receiver, whose level may be reduced without affecting the corresponding transfer of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products."*

5.2.2 Technical description

ETSI EN 302 217-2-2 [i.16] specifies in clause 4.2.6:

"It is necessary to define spurious emissions (or more precisely, according latest ITU-R definitions, unwanted emissions in the spurious domain) from receivers in order to limit interference into other systems operating wholly externally to the system under consideration (external emissions); those limits are set out in ETSI EN 301 390 [5]. Those limits are applicable at reference point C or at point B if C is not available.

NOTE 1: ERC/REC 74-01 [2] based on Recommendations ITU-R SM.329-12 [i.61] and Recommendation ITU-R F.1191-3 [i.53] gives the applicable definitions.

NOTE 2: ETSI EN 301 390 [5] includes, for P-P systems, the same limits as ERC/REC 74-01 [2]."

5.2.3 Standards

In the following list examples of standards are shown where this concept is used:

- ETSI EN 302 217-2-2 [i.16];
- ETSI EN 301 390 [i.19];
- ETSI EN 302 217-1 [i.20];
- ETSI EN 301 126-1 [i.17].

5.2.4 Measurement procedures

5.2.4.1 Wanted test signal

ETSI EN 302 217-2-2 [i.16] specifies the wanted test signal in clause 4.2 as follows:

"The specified transmitter characteristics shall be met with the appropriate base band signals applied at one of the reference points X' of figure 1 of ETSI EN 302 217-1 [6].

Table 1 gives the appropriate base band signals.

Table 1: Test signal and type of base band interface

Type of base band signal interface at X/X'	*Test signal to be applied according to*
PDH	*PRBS Recommendation ITU-T O.151 [12]*
SDH	*Recommendation ITU-T O.181 [13]*
ATM	*Recommendation ITU-T O.191 [14]*
Ethernet interface (packet data) (see note)	*IEEE 1802.3 [9] and IEEE 802.3 [10]*
Other than the above (see note)	*Relevant standards which the interface refers to*
NOTE: As a general approach, all system characteristics and spectral efficiency classes are defined only in term of "minimum RIC". However, when the BER requirements are considered, they can be directly tested when conventional PDH or SDH interfaces are provided; while, whenever equipment offers different standardized base-band interfaces, annex F gives the criteria for defining an equivalent error rate for conformance purpose.	

"

The reference point X' is defined in clause 5.7 of ETSI EN 302 217-1 [i.20]. In addition, ETSI EN 302 217-2-2 [i.16] specifies the BER as a function of receiver input signal level RSL in clause 4.3.2:

"All parameters are referred to reference point C (for systems with a simple duplexer) or B (for systems with a multi-channel branching system). Losses in RF couplers (possibly used for protected systems) are not taken into account in the limits specified below.

When packet data transmission is considered, any BER requirements shall be transformed into FER requirements according to the rules given in clause F.3.

The supplier shall declare the RSL threshold(s) (dBm) for the relevant BER values (i.e. 10^{-6} and 10^{-8} or 10^{-10}), which shall not be worse than the corresponding RSL upper bound values indicated in the tables of the relevant annex(es).

When multi-carrier systems are concerned, the RSL is intended as the total power integrated for all sub-carriers and, when multiple payload interfaces are also provided (at reference points X', X), the BER shall be evaluated on the worst case interface.

EXAMPLE: In case of two equal sub-carriers, the RSL of each sub-carrier is intended to be 3 dB less than the total RSL power specified in the present document.

Equipment working at the relevant declared RSL thresholds shall produce a BER equal to or less than the corresponding values (i.e. 10-6 and 10-8 for systems with minimum RIC ≤ 100 Mbit/s, or 10^{-6} and 10^{-10} for systems with minimum RIC > 100 Mbit/s).

NOTE 1: For mixed-mode systems, these requirements apply only for the assessment of essential requirements under article 3.2 of the R&TTE Directive [1]. It is assumed that, when operational in the field, the switchover among different modes (or different bandwidth for bandwidth adaptive systems in 71 GHz to 86 GHz) will happen at suitable RSL thresholds defined by the manufacturer or the operator. See clause I.2.

NOTE 2: Actual RSL threshold for link budget definition may be defined by the supplier, generally set to a BER between 10^{-6} and 10^{-3}, according to the type of traffic and quality of service to be provided.

NOTE 3: When planning very short links, where propagation would require fade margins limited to few dB for fulfilling the availability and the SES error performance objectives, a minimum link budget should nevertheless be defined for fulfilling also the "background block error ratio" (BBER) error performance objective. The required RSL for the reaching the RBER (established in ETSI EN 302 217-2-1[i.27]) should be considered."

ETSI EN 301 126-1 [i.17] provides additional information on the measurement of the BER in clause 5.3.1 as follows:

"Objective:

To verify that the receiver meets the Bit Error Rate (BER) criteria, given in the relevant specification, over a defined range of receiver input levels.

Test instruments:

1) power sensor and meter,

2) pattern generator/error detector.

An example test configuration is depicted in figure 2:

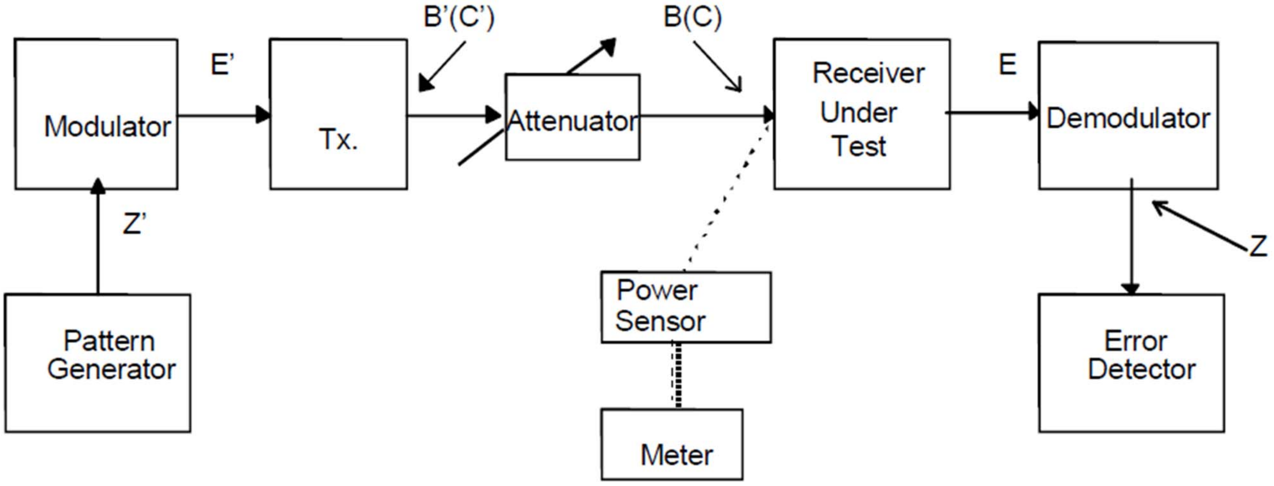

Figure 2: "Figure 9 from ETSI EN 301 126-1 [i.17]"

Test procedure:

Connect the pattern generator output to the BaseBand (BB) Tx input Z' and the error detector to the BB RX output Z. Switch the transmitter to standby and adjust the variable attenuator to provide maximum attenuation. Disconnect the receiver under test. Connect the power meter, through a suitable power sensor, to point B(C) (see figure 3). Switch on the transmitter and adjust the attenuator to set the power to the upper limit for the input level range test. Switch the transmitter to standby and reconnect the receiver under test. Measure and record the BER for the upper range.

Increase the level of attenuation until the signal input level at the receiver causes BER equal to the lower limit quoted in the relevant specification, measure and record the BER at this level. The receiver input level range is the signal range between the upper and lower receiver input levels provided the BER is met."

5.2.4.2 Tested signal

ETSI EN 302 217-2-2 [i.16] specifies the signal, which should be tested at reference point C or at point B, if C is not available which are defined in ETSI EN 301 390 [i.19] as follows:

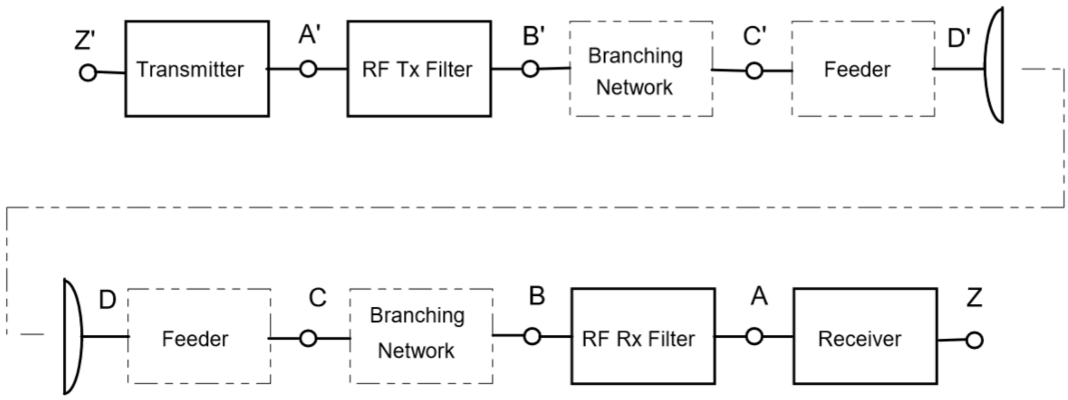

Figure 3: Figure 1 from ETSI EN 301 390 [i.19]:
Definition of the test point for RX Spurious emissions - external

The limits are given in ERC/REC 74-01 [i.9]. The reference bandwidth to apply the limits are given in annex A of ETSI EN 301 390 [i.19]. The limits should be met at 2 x 250 % CS, where CS is the Channel Separation.

The detailed procedure for the measurements is given in clause 5.2.9 of ETSI EN 301 126-1 [i.17].

"<u>Test instruments:</u>

1) spectrum analyser;

2) spectrum analyser mixer units - as required;

3) plotter.

<u>Test configuration:</u>

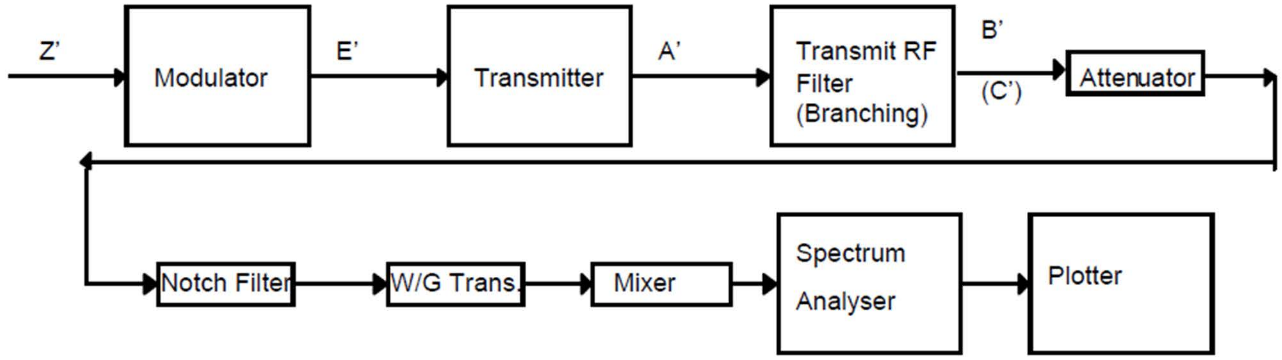

Figure 4: *"Figure 8* from ETSI EN 301 126-1 [i.17]*: Example test configuration for conducted setup"*

<u>Test procedure:</u>

The transmitter output port shall be connected to either a spectrum analyser via a suitable attenuator and/or notch filter to limit the power into the front end of the analyser. In some cases, where the upper frequency limit exceeds the basic operating range of the analyser, suitable waveguide transitions and mixer will be required. It is important that the circuit between the transmitter and the input to the mixer, or spectrum analyser, is characterized over the frequency range to be measured. These losses should be used to set the limit line of the analyser to a value which ensures that the specification criteria at point C' is not exceeded (see figure 4).

The transmitter is to be operated at the manufacturers maximum rated output power and the level and frequency of all significant signals are to be measured and plotted throughout the frequency band quoted in the relevant specification. It is recommended that each scan be taken in 5 GHz steps below 21, 2 GHz and 10 GHz steps above 21, 2 GHz. However, spurious emissions close to the limit should be plotted over a restricted range which clearly demonstrates that the signal does not exceed the relevant limit.

NOTE 1: Where a specification states that the spurious emission test is to be conducted with the equipment in the modulated condition, the resolution bandwidth of the spectrum analyser is to be set to the level quoted in the specification. The frequency span and scan rate of the analyser should be adjusted to maintain the noise floor below the limit line and maintain the spectrum analyser in the calibrated condition.

NOTE 2 Measurement of spurious emission levels from equipment operating in the CW condition can be conducted with resolution bandwidth, frequency span and scan rates which maintain the spectrum analyser in the calibrated condition while keeping the difference between noise floor and limit line at least 10 dB.

NOTE 3 Due to low levels of RF signal and the wideband modulation used in this type of equipment, radiated RF power measurements have greater measurement uncertainty than to conducted measurements. Therefore where equipment is normally fitted with an integral antenna, the manufacturer shall supply a documented test fixture that converts the radiated signal into a conducted signal into a 50 Ohm termination.

Due to the lack of standardization, most of the DRRS standards have requirements which may appear not well defined.

In particular two measuring parameters may be missed:

- *the evaluation BandWidth (BWe) to be used in the spectrum analyser test;*
- *the exclusion bandwidth across the nominal centre frequency where emissions are to be considered "out of band emissions" and thus are not considered "spurious emissions".*

In this cases the requirement shall be considered as CEPT provisional for "unmodulated carrier condition" (i.e. CW emissions are only considered). The exclusion bandwidth across the nominal frequency shall be taken, in accordance with ITU-R Study Group 9 Recommendation F.1191-1 [8] as ±250% of the relevant channel spacing.

BWe shall be taken as 100/120 kHz for frequency below 1 GHz and 1 MHz above this limit.

However if BWe are stated in the equipment standard then these should be used.

As most of the modern DRRS are not able to deliver an unmodulated carrier, in this case the measurement shall be carried out with modulated carrier, provided that the level limits for noise like spurious emissions (e.g. harmonics and mixer image frequencies) were regarded as "maximum level in any elementary band equal to BWe".

In other cases the relevant standard may ask explicitly for modulated carrier conditions and give the parameters for test procedure."

5.3 Co-channel "external" and adjacent channel interference sensitivity

5.3.1 Overview

ETSI EN 302 217-2-2 [i.16] was published in 2013 and already contained a clause dealing with "Essential radio test suites for the receiver" as described in the previous and following clauses. This clause considers the test to be performed for the Co-channel "external" and adjacent channel interference sensitivity.

5.3.2 Technical description

ETSI EN 302 217-2-2 [i.16] specifies in clause 4.3.3:

"The co-channel "external" interference is considered to be that given by a like signal completely uncorrelated with the one under test. There are different requirements for "internal" interference given by the cross polar transmitters in systems implementing XPIC for CCDP operation; however, the latter requirements are not considered relevant to essential requirements under article 3.2 of R&TTE Directive [1] and are set out in ETSI EN 302 217-2-1 [i.27].

All Carrier to Interference ratio (C/I) measurements are referred to reference point C (for systems for single channel applications) or B (for systems with multi-channel branching system).

When multi-carrier systems are concerned, the C/I is intended as the ratio of the total power integrated for all subcarriers of the wanted and interferer systems, respectively. When multiple payload interfaces are also provided (at reference points X', X), the BER shall be evaluated on the worst case interface.

The limits of Carrier to Interference ratio (C/I) in case of co-channel and adjacent channel interference shall be as specified in the relevant tables of annexes A to E and Ea, giving maximum C/I values for 1 dB and 3 dB degradation of the RSL limits declared by the supplier for a BER ≤ 10^{-6} in clause 4.3.2.

The format of such tables is given in table 4.

> *NOTE: For equipment in annex A only 1 dB degradation is required. In some cases a requirement for second adjacent channel interference is also given.*

For adjacent channel interference, the requirement shall be met independently on upper and lower adjacent interference.

Table 2: Table 4 from ETSI EN 301 126-1 [i.17]: Co-channel and 1st adjacent channel interference sensitivity table format

Spectral efficiency		Minimum RIC rate (Mbit/s)	Channel separation (MHz)	C/I for BER ≤ 10^{-6} RSL degradation of 1 dB or 3 dB			
Reference Index	Class			Co-channel Interference		adjacent channel interference	
				1 dB	3 dB	1 dB	3 dB
NOTE: Actual values for this template are found in annexes A to E and Ea.							

"

5.3.3 Standards

In the following list examples of standards are shown where this concept is used:

- ETSI EN 302 217-2-2 [i.16];
- ETSI EN 301 390 [i.19];
- ETSI EN 302 217-1 [i.20];
- ETSI EN 301 126-1 [i.17].

5.3.4 Measurement procedures

5.3.4.1 Wanted test signal

See clause 5.2.4.1 for the description of the wanted test signal.

5.3.4.2 Tested signal

5.3.4.2.1 Co-channel interference sensitivity- external

The following procedure is given in clause 5.3.3.2 of ETSI EN 301 126-1 [i.17].

"There are variations in some of the standard as to the measurement requirements for Co-channel Interference Sensitivity. The variations have been covered by providing Methods 1 and 2 for these tests. The test house should apply the approach stated in the relevant equipment standard.

Method 1:

Objectives:

To verify that the BER at point Z, of the receiver under test, remains below the relevant specification limit in the presence of an interfering like modulated signal on the same channel. The signal levels of the wanted and interfering signals at point B(C) shall be set at the levels given in the relevant specification.

Test instruments.

1) *2 bit pattern generators;*
2) *error detector;*
3) *power sensor and meter.*

Test configuration 1:

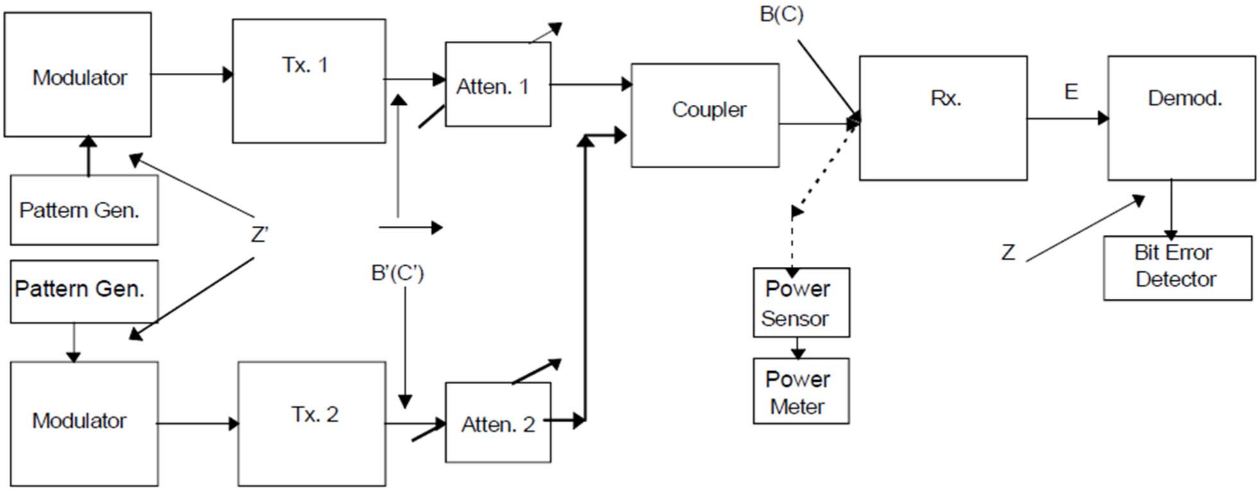

Figure 5: Figure 11 from ETSI EN 301 126-1 [i.17]

Test procedure for test configuration 1:

During this test both transmitters shall transmit on the same frequency and be modulated with different signals having the same characteristics. Switch the transmitters to standby and disconnect the waveguide or cable at point B(C) (see figure 11). Connect a suitable power sensor and meter. Switch on Tx 1 and adjust attenuator 1 to set the signal to a convenient level, say -30 dBm. Switch Tx 1 to standby and Tx 2 on. Adjust attenuator 2 to set the interfering signal to a level below the reference signal, measured previously, which is equal to the Carrier to Interfer (C/I) ratio given in the specification. Switch Tx 2 to standby.

Reconnect the receiver under test, switch on Tx 1 and increase attenuator 1 until the 10^{-6} *level required by the standard is achieved. Increase attenuator 2 by the same amount attenuator 1 was increased, switch on Tx 2 and record the BER for the C/I as stated in the standard.*

Decrease attenuator 2 until the receiver BER equals the limit quoted in the specification. Calculate and record the C/I ratio.

Alternative procedure 1:

NOTE: This procedure uses an additional attenuator between the combiner and receiver to control the absolute wanted and unwanted signal levels into the receiver. The functions of attenuators 1 and 2 is to maintain the correct C/I ratio.

Test configuration 2:

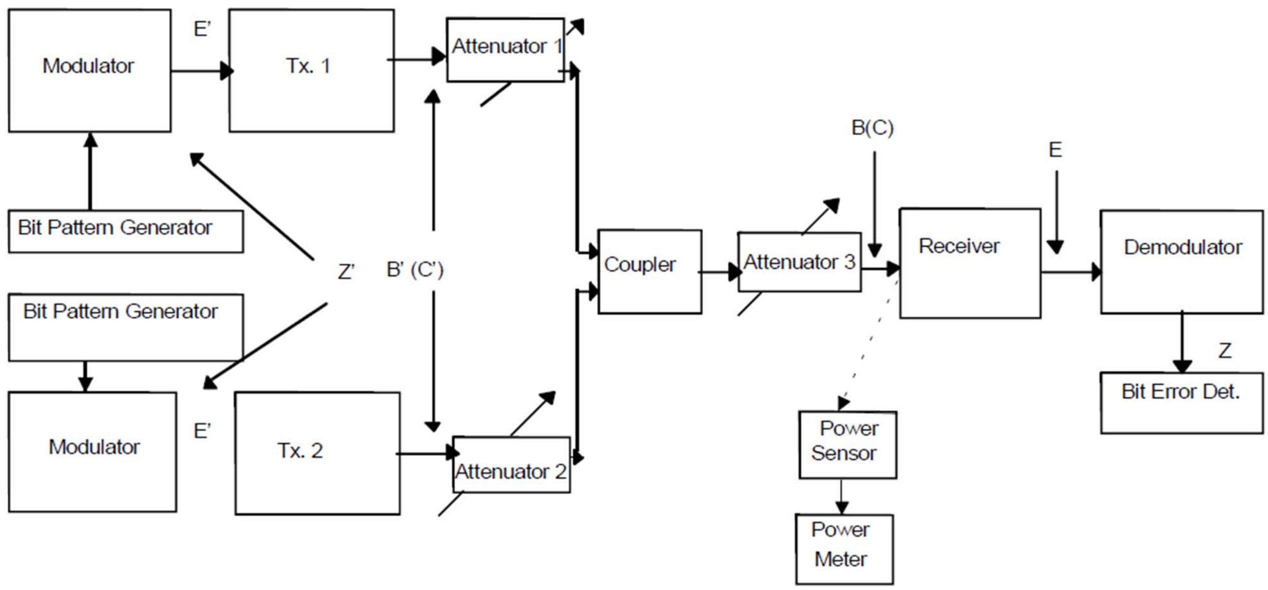

Figure 6: Figure 12 from ETSI EN 301 126-1 [i.17]

Test procedure for test configuration 2:

With the transmitters at standby set attenuators 1 and 2 to their maximum values and attenuator 3 to zero. Disconnect the waveguide or cable at point B(C) (see figure 12) and connect a suitable power sensor and meter. Switch on Tx 1 and reduce attenuator 1 to produce a suitable level, say -30 dBm. Record the measured level. Switch Tx 1 to standby and Tx 2 on. Reduce attenuator 2 to produce a signal below the level previously measured by an amount equal to the C/I ratio. Increase attenuator 3 to set the wanted receiver input level to that quoted in the specification.

With both transmitters on standby disconnect the power sensor and reconnect the receiver under test. Switch both transmitters on in the modulated condition and measure and record the receiver BER on the error detector.

Decrease attenuator 2 until the receiver BER equals the limit quoted in the specification. Calculate and record the wanted to unwanted ratio.

Method 2:

Objective:

To verify that the maximum C/I value for 1 dB and 3 dB degradation on 10^{-6} and 10^{-3} BER remains below the relevant specification limit in presence of an interfering like modulated signal on the same channel.

Test instruments:

1) *2 pattern generator;*
2) *error detector;*
3) *power sensor and meter.*

Test configuration:

See figure 11.

Test procedure:

During this test both transmitters shall transmit on the same channel and be modulated with signals that have the same characteristics. With the transmitters to standby set both attenuators to their maximum values.

Connect power meter at point B(C). Switch on Tx 1 and adjust attenuator 1 to set the wanted signal to the level required by the standard for 10^{-6} (or 10^{-3}). Decrease attenuator 1 by 1 dB (or 3 dB) and record its setting. Switch on the interferer and reduce attenuator 2 to achieve a BER of 10^{-6} (or 10^{-3}) on the error detector. Switch both transmitters off and disconnect the waveguide, or cable, at point B(C) - see figure 10. Record the setting of attenuator 2 and connect the power sensor and meter to the waveguide or cable.

Switch Tx 1 on and reduce attenuator 1 to produce a wanted signal level within the calibrated range of the power meter. Record the power level and reduction in attenuation.

- *Calculate $Power_{wanted\ signal}$ = Measured power level - change in attenuation.*
- *Switch off Tx. 1, switch on Tx. 2 and repeat the procedure to calculate the $Power_{unwanted\ signal}$.*

The maximum co-channel C/I value for 1 dB or 3 dB degradation on 10^{-6} or 10^{-3} is:

- *$C/I = Power_{wanted\ signal} - Power_{unwanted\ signal.}$"*

5.3.4.2.2 Adjacent channel interference sensitivity

The following procedure is given in clause 5.3.3.3 of ETSI EN 301 126-1 [i.17].

"There are variations in some of the standards as to the measurement requirements for adjacent channel interference sensitivity. The variations have been covered by providing Method 1 and Method 2 options for these tests. The test house should apply the approach stated in the relevant equipment standard.

NOTE 1: In many cases the C/I ratio will be negative thus producing an interferer with a higher level than the wanted signal.

Method 1:

Objective:

To verify that the BER at point Z, of the receiver under test, remains below the relevant specification limit in the presence of an interfering like modulated signal on the adjacent channel. The signal levels of the wanted and interfering signals at point B(C) shall be set at the levels given in the relevant specification.

Test instruments:

Same as co-channel test.

Test configuration 1:

Same as co-channel test (see figure 11).

Test procedure for test configuration 1:

During this test the interfering transmitter shall be modulated with signals having the same characteristics as the modulating signal of the wanted transmission and be tuned to an adjacent channel. Switch the transmitters to standby and disconnect the waveguide or cable at point B(C). Connect a suitable power sensor and meter. Switch on Tx 1 and adjust attenuator 1 to set the wanted signal at a convenient level, say -30 dBm. Switch Tx 1 to standby and Tx 2 on. Adjust attenuator 2 to set the interfering signal to a level above the reference signal, measured previously, which is equal to the C/I ratio given in the specification. Switch Tx 2 to standby.

Reconnect the receiver under test and increase both attenuators by equal amounts which ensure that the wanted and unwanted signal levels into the receiver are at their correct values. Switch on and modulate both transmitters. Record the receiver BER.

Repeat the test with the interfering transmitter tuned to the other adjacent channel.

Alternative procedure 1:

NOTE 2: This procedure uses an additional attenuator between the combiner and receiver to control the absolute wanted and unwanted signal levels into the receiver. The functions of attenuators 1 and 2 is to maintain the correct C/I ratio.

Test configuration 2:

Same as Alternative 1, Co-channel test (see figure 12).

Test procedure for test configuration 2:

With the transmitters at standby set attenuators 1 and 2 to their maximum values and attenuator 3 to zero. Disconnect the waveguide or cable at point B(C) and connect a suitable power sensor and meter. Switch on Tx 1 and reduce attenuator 1 to produce a suitable level, say -30 dBm. Record the measured level. Switch Tx 1 to standby and Tx 2 on.

Reduce attenuator 2 to produce a signal level above that previously measured, by an amount equal to the C/I ratio. Increase attenuator 3 to provide the receiver with an input equal to the specified receiver level.

With both transmitters on standby disconnect the power sensor and reconnect the receiver under test. Switch both transmitters on in the modulated condition and measure and record the receiver BER on the error detector.

Repeat the test with the interfering transmitter tuned to the other adjacent channel.

Method 2:

Objective:

To verify that the maximum C/I value for 1 dB and 3 dB degradation on 10^{-6} and 10^{-3} BER remains below the relevant specification limit in the presence of an interfering like modulated signal on the adjacent channel.

Test instruments:

1) *2 pattern generator;*
2) *error detector;*
3) *power sensor and meter.*

Test configuration:

See figure 11.

Test procedure:

During this test the interferer (Tx 2) shall transmit on one of the adjacent channels and be modulated with a signal having the same characteristics as the signal modulating the wanted transmitter. With both transmitters on standby set the attenuators to their maximum values.

Connect power meter at point B(C). Switch on Tx 1 and adjust attenuator 1 to set the wanted signal to the level required by the standard for 10^{-6} (or 10^{-3}). Decrease attenuator 1 by 1 dB (or 3 dB) and record its setting. Switch on the interfere and reduce attenuator 2 to achieve a BER of 10^{-6} (or 10^{-3}) on the error detector. Switch both transmitters off and disconnect the waveguide, or cable, at point B(C) - see figure 10. Record the setting of attenuator 2 and connect the power sensor and meter to the waveguide or cable.

Switch Tx. 1 on and reduce attenuator 1 to produce a wanted signal level within the calibrated range of the power meter. Record the power level and reduction in attenuation:

$$\text{Calculate Power}_{\text{wanted signal}} = \text{Measured power level - change in attenuation.}$$

Switch off Tx 1, switch on Tx 2 and repeat the procedure to calculate the Power $_{\text{unwanted signal}}$.

The maximum co-channel C/I value for 1 dB or 3 dB degradation on 10^{-6} or 10^{-3} is:

$$C/I = \text{Power}_{\text{wanted signal}} - \text{Power}_{\text{unwanted signal}}.$$

Repeat the test with the interferer on the other adjacent channel. "

5.4 Receiver blocking

5.4.1 Overview

5.4.2 Technical description

Receiver blocking is the effect of a strong out-of-band signal, present at the input of the receiver, on the receiver's ability to detect an in-band wanted signal. The blocking signal reduces the specified receiver sensitivity by a certain number of dB's.

ECC Report 138 [i.21]:

"Receiver blocking is the effect of a strong out-of-band interfering signal on the receiver's ability to detect a low-level wanted signal. Receiver blocking response (or performance level) is defined as the maximum interfering signal level expressed in dBm reducing the specified receiver sensitivity by a certain number of dB's."

Clause 5.3.4.3.1 of ETSI EG 203 336 [i.6]:

"Where relevant, Technical Bodies should also consider receiver blocking as a measure of the capability of the receiver to receive a wanted signal without exceeding a given degradation due to the presence of an unwanted input signal at any frequency other than those of the spurious responses or of the adjacent channels.

Where spurious response rejection and blocking are both specified, receiver blocking should usually be specified at a more stringent level than that specified for spurious response rejection (clause 5.3.4.2.2) at frequencies relatively far removed from the operating frequency, but still within the operating frequency range, e.g. for narrowband systems, atypical practical blocking test may evaluate performance with unwanted signals at F_{rx} ± 1 MHz, ± 2 MHz, ± 5 MHz and ± 10 MHz."

5.4.3 Standards

Exemplary standards that specify receiver blocking tests are:

- ETSI EN 300 328 Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques [i.22]; and
- ETSI EN 301 893 5 GHz RLAN [i.23].

Both standards use almost identical, yet slightly incorrect definitions of the term "Receiver blocking".

ETSI EN 300 328 [i.22]:

*"Receiver blocking is a measure of the **ability** of the equipment to receive a wanted signal on its operating channel without exceeding a given degradation **in** the presence of an unwanted signal (blocking signal) on frequencies other than those of the operating band […]".*

ETSI EN 301 893 [i.23]:

*"Receiver blocking is a measure of the **capability** of the equipment to receive a wanted signal on its operating channel without exceeding a given degradation **due to** the presence of an unwanted input signal (blocking signal) on frequencies other than those of the operating bands […]".*

5.4.4 Measurement procedures

5.4.4.1 Signals and parameters

In both standards, the receiver blocking tests are based on the following set of parameters:

- Wanted signal frequency.
- Wanted signal bandwidth.

- Wanted signal power.
- Blocking signal type.
- Blocking signal frequency.
- Blocking signal power.
- Wanted receiver performance.

The wanted signal is the signal received from the DUT's companion device.

For measuring a receiver's response to blocking, an interfering signal (the "blocking signal") is applied to the receiver input in addition to a defined wanted signal. The blocking signal has a frequency in the out-of-band domain and a level considerably higher than that of the wanted signal. The blocking test is passed when the wanted receiver performance is achieved or exceeded.

In both standards, the packet error rate (PER) has been specified as performance criterion, and the wanted receiver performance, i.e. the minimum PER that should be achieved is 10 %.

Wanted signal frequency:

- Clause 5.4.11.1 of ETSI EN 300 328 [i.22]: *"For non-frequency hopping equipment having more than one operating channel, the equipment shall be tested operating at both the lowest and highest operating channels."*
- ETSI EN 301 893 [i.23]: *"Any one channel out of the declared channels for each of the two sub-bands (5150-5350 MHz and 5470-5725 MHz) can be chosen for the test."*

Wanted signal bandwidth:

- Clause 5.4.11.1 of ETSI EN 300 328 [i.22]: *"If the equipment can be configured to operate with different Nominal Channel Bandwidths (e.g. 20 MHz and 40 MHz) and different data rates, then the combination of the smallest channel bandwidth and the lowest data rate for this channel bandwidth that still allows the equipment to operate as intended shall be used. This condition is identical in both standards."*

Wanted signal power:

The Wanted Signal is set to a level of 6 dB above the minimum performance level P_{min}, i.e. the lowest signal level, at which the minimum performance is achieved.

ETSI EN 300 328 [i.22] defines different sets of wanted signal levels depending on the category of equipment.

Blocking signal type:

In both standards, Continuous Wave (CW) has been defined as blocking signal waveform.

Blocking signal frequency:

ETSI EN 300 328 [i.22] defines different sets of blocking signals depending on the category of equipment:

- For equipment of category 1, blocking signals are applied at -30 MHz, -60 MHz, -100 MHz, +40 MHz, +70 MHz, +100 MHz, +130 MHz, +160 MHz, and +190 MHz from the respective edges of the operating band.
- For equipment of category 2 and 3, blocking signals are applied at ±20 MHz and ±100 MHz from the respective edges of the operating band.

In ETSI EN 301 893 [i.23] the blocking signals are applied at 50 MHz, 150 MHz, and 250 MHz below the lower edge of the 5 GHz RLAN operating band, and at 250 MHz above the upper edge of the RLAN operating band.

Blocking signal power:

In ETSI EN 300 328 [i.22] different blocking signal levels are defined, depending on the blocking signal frequency and the receiver category.

ETSI EN 301 893 [i.23] defines different blocking signal levels, depending on the blocking signal frequency, the equipment type, and its radar detection capabilities.

An overview of the blocking signals characteristics is provided in table 3 of ETSI EN 300 328 [i.22] and table 4 of ETSI EN 301 893 [i.23].

The blocking signal power levels specified are the levels at the UUT antenna. In case of conducted measurements, the levels have to be corrected by the actual antenna assembly gain.

The signals defined in ETSI EN 300 328 [i.22] for the different types of equipment, i.e. frequency-hopping equipment and equipment using other types of wide-band modulation, are identical.

Table 3: Receiver Blocking test signals as defined in ETSI EN 300 328 [i.22]

Receiver category	Wanted signal mean power from companion device (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)	Type of blocking signal
1	P_{min} + 6 dB	2 380	-53	CW
		2 503,5		
		2 300	-47	
		2 330		
		2 360		
		2 523,5		
		2 553,5		
		2 583,5		
		2 613,5		
		2 643,5		
		2 673,5		
2	P_{min} + 6 dB	2 380	-57	
		2 503,5		
		2 300	-47	
		2 583,5		
3	P_{min} + 12 dB	2 380	-57	
		2 503,5		
		2 300	-47	
		2 583,5		

Table 4: Receiver Blocking test signals as defined in ETSI EN 301 893 [i.23]

Wanted signal mean power from companion device (dBm)	Blocking signal frequency (MHz)	Blocking signal power (dBm)		Type of blocking signal
		Master or Slave with radar detection	Slave without radar detection	
P_{min} + 6 dB	5 100	-53	-59	CW
	4 900	-47	-53	
	5 000			
	5 975			

Figure 7 visualizes the Wanted and Blocking signals as defined in ETSI EN 301 893 [i.23].

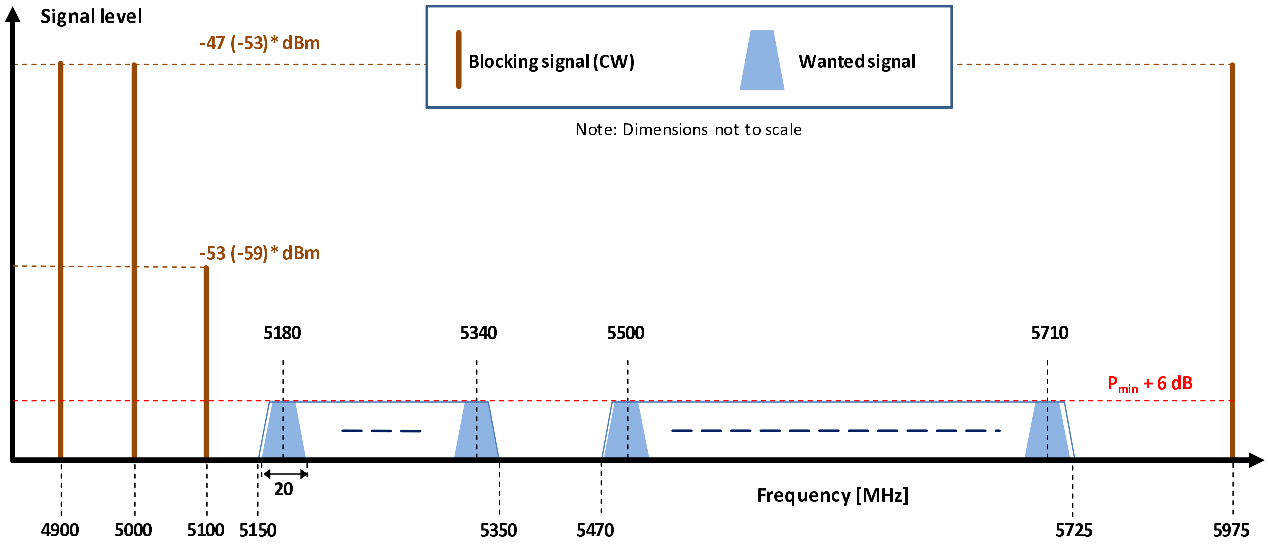

Figure 7: Wanted and Blocking signals compiled from ETSI EN 301 893 [i.23]

Figures in brackets are for Slave devices without radar detection. Figures without brackets are for Master or Slave devices with radar detection.

5.4.4.2 Measurement setup

The setup for receiver blocking is identical for both 2,4 GHz wideband systems and 5 GHz RLANs. It is provided in ETSI EN 300 328 [i.22] and ETSI EN 301 893 [i.23], respectively.

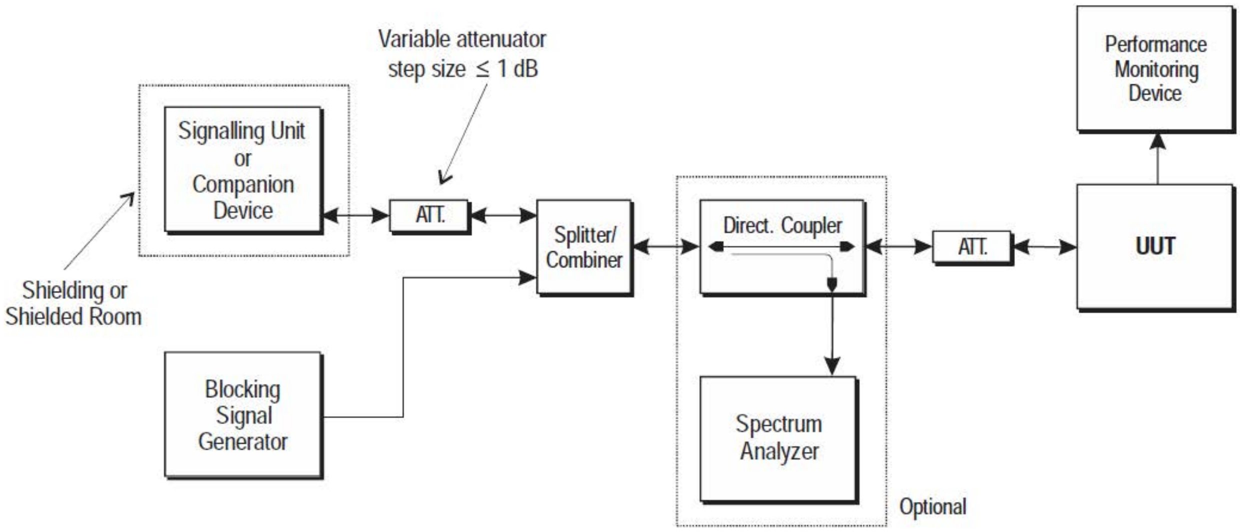

Figure 8: Test Set-up for receiver blocking according to ETSI EN 300 328 [i.22] and ETSI EN 301 893 [i.23]

5.5 CW spurious interference

5.5.1 Overview

ETSI EN 302 217-2-2 [i.16] was published in 2013 and already contained a clause dealing with "Essential radio test suites for the receiver" as described in the some of the previous clauses. This clause considers the test to be performed for the CW spurious interference.

5.5.2 Technical description

ETSI EN 302 217-2-2 [i.16] specifies in clause 4.3.4:

"For a receiver operating at the RSL declared by the supplier in clause 4.3.2 for a BER ≤ 10^{-6} threshold, the introduction of a CW interferer at a level specified by ETSI EN 301 390 [5], but not exceeding the maximum upper RSL limit for BER = 10^-6 defined in ETSI EN 302 217-2-1 [i.27] clause 6.4.1, with respect to the wanted signal and at any frequency up to the relevant upper and lower frequency limits derived from the table set out in clause 7.1 of ETSI EN 301 390 [5], but excluding frequencies either side of the wanted frequency by up to 250 % of the separation between channels using the same polarization, shall not result in a BER greater than 10^{-5}.

When multi-carrier systems are concerned, the wanted signal level is intended as the total power integrated for all subcarriers and, when multiple payload interfaces are also provided (at reference points X', X), the BER shall be evaluated on the worst case interface.

This test is designed to identify specific frequencies at which the receiver may have a spurious response; e.g. image frequency, harmonics of the receive filter, etc. The test is not intended to imply a relaxed specification at all out of band frequencies elsewhere specified in ETSI EN 302 217 series (e.g. image(s) rejection specified in ETSI EN 302 217-2-1 [i.27])."

5.5.3 Standards

In the following list examples of standards are shown where this concept is used:

- ETSI EN 302 217-2-2 [i.16];
- ETSI EN 302 217-1 [i.20];
- ETSI EN 301 126-1 [i.17].

5.5.4 Measurement procedures

5.5.4.1 Wanted test signal

See clause 5.2.4.1 for the description of the wanted test signal.

5.5.4.2 Tested signal

The following procedure is given in clause 5.3.3.4 of ETSI EN 301 126-1 [i.17].

"Objective:

This test is designed to identify specific frequencies at which the receiver may have a spurious response e.g. image frequency, harmonic response of the receive filter etc. The frequency range of the test should be in accordance with the relevant specification.

Test instruments:

1) *pattern generator;*
2) *error detector;*
3) *signal generator;*
4) *power sensor and meter.*

Test configuration:

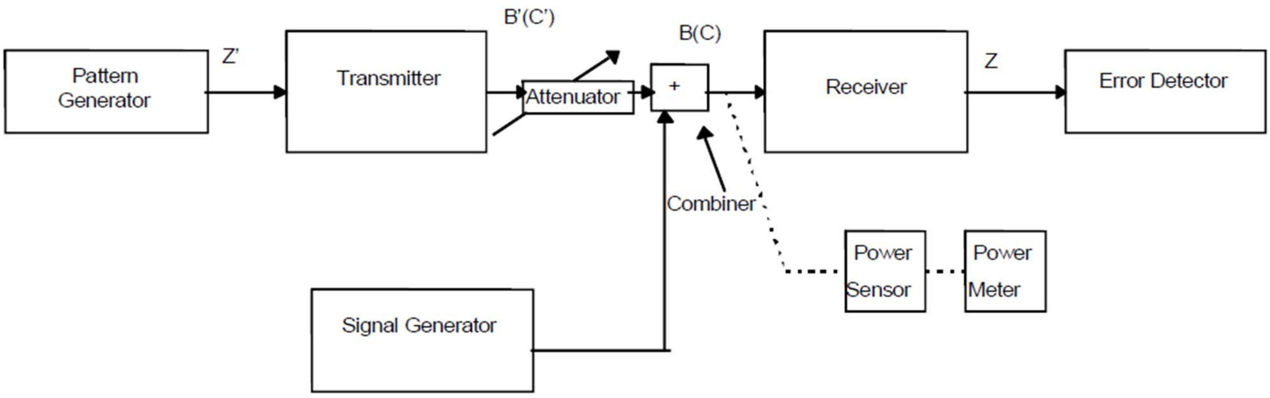

Figure 9: Figure 13 from* ETSI EN 301 126-1 [i.17]*: Example test setup for CW spurious interferer test

Test procedure:

With the signal generator output turned off, measure the transmitter RF output power at point B(C) using a suitable power sensor, with a known level of attenuation. Replace the power sensor with the receiver under test, and increase the level of attenuation until the level required by the standard is measured. Record the BER for this receiver level (dBm) where applicable.

Switch off the transmitter, replace the receiver under test with a power sensor. Calibrate the signal generator across the frequency range required by the standard at a level x dB above the level (dBm), where x is the required increase in level for the interfering CW signal.

Replace the power sensor with the receiver under test and confirm the BER level has not changed. Sweep the signal generator through the required frequency range at the calibrated level, taking into account any exclusion band stated in the relevant EN/ETS.

Any frequencies which cause the BER to exceed the level stated in the standard shall be recorded. It is recommended that the calibration be rechecked at these frequencies.

NOTE 1: The use of a stepped signal generator is permitted provided that the step size is not greater than one third of the bandwidth of the receiver under test.

NOTE 2: This test may require the use of low pass filters on the output of the signal generator to prevent harmonics of the signal generator falling into the receiver exclusion band."

5.6 Summary of Classical Receiver

The examples given in the previous clauses are RX parameters measurements implemented before the enforcement of the RED [i.11]; the current methods of measurements for those parameters are very similar to those described.

The applicability of classical receiver parameters depends on a number of parameters:

- A set of clear definitions which allow to identify the frequency ranges where limits are applicable (co-channel, adjacent channel, spurious emissions domain, etc.).
- Access to test points to assess the conformity of the system with the limits given in the standards (transmitted power).
- Access to test points to inject an interfering signal.
- Access to test points to assess the performance of a system while receiving an interfering power.
- Definition of performance criteria as BER, which are considered to assess if the device passes or failed to the test.

The considerations of the classical receivers lead to identify a number of issues:

- The access to test points is problematic for various devices, in particular, for highly integrated devices.
- For non-communication devices the definition of the performance in term of "classical" criteria such as BER, C/I are not relevant; other performance criteria need to be specified.
- Some of the definitions (for example adjacent channel, spurious domain, etc.) are not applicable to some devices such as UWB devices because they do not operate in clearly defined channels.
- Different definitions are given depending on the standards, leading to possible diverging interpretations of the scope of the parameters and their range of applicability.

Various metrics exist for testing classical receiver performance. Which one is eventually used depends on the respective standard. Below is a list of the most common metrics with exemplary technologies shown in brackets:

- Data throughput (LTE UE);
- Packet Error Rate (RLAN);
- Bit Error Rate (DECT);
- SINAD (analogue PMSE);
- Onset of picture degradation (Digital Terrestrial TV Broadcast Receivers).

6 RX parameters framework

6.1 General view

RX- parameter framework, such as blocking, sensitivity and adjacent channel selectivity.

ETSI EG 203 336 [i.6] provides a list of 11 RX parameters to be considered and indicates (see clause 4.1 of [i.6]) that:

"The generic radio characteristics described in the following clauses are the spectrum related aspects that should always be considered for inclusion in a Harmonised Standard. Based upon this consideration, the Technical Body (TB) should identify the parameters and/or tests necessary to be specified for the radio system under consideration in order to fulfil the essential requirement in article 3.2 of Directive 2014/53/EU [i.1]".

It means that after consideration of all receiver parameters, it is up to the TB to identify the parameters and/or tests to be included in the standard. This is illustrated in the following figures which were developed based on the list of parameters implemented in the standards maintained by WG SE21 [i.46].

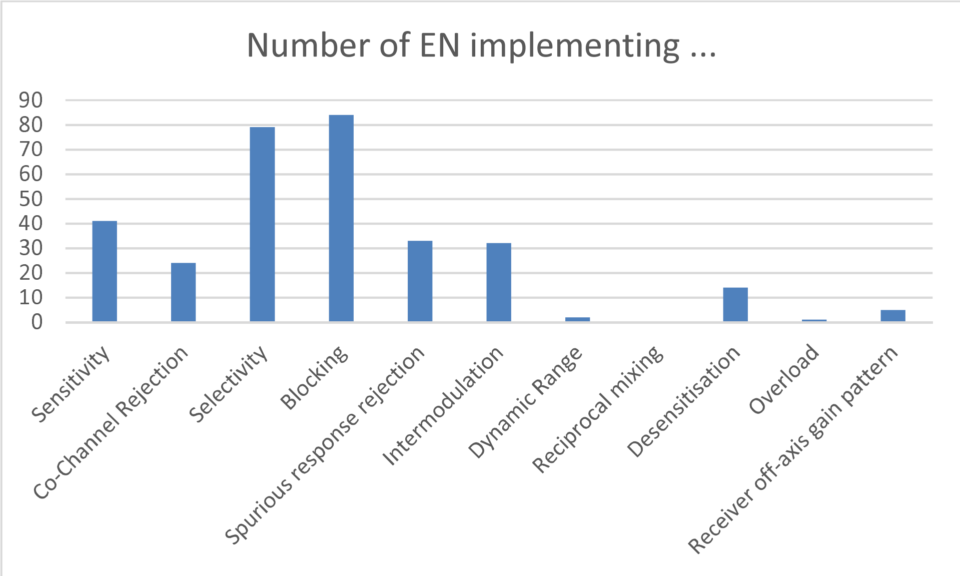

Figure 10: Overview of the RX parameters implemented in standards

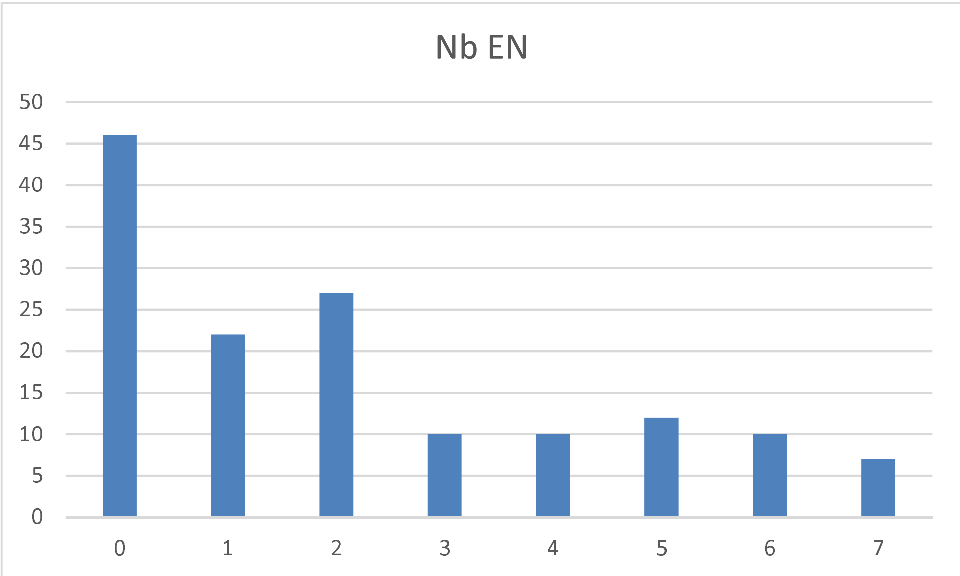

Figure 11: Number of RX parameters implemented in standards

It can be seen that not all the receiver parameters defined in the ETSI EG 203 336 [i.6] are implemented in each and every standard.

It is also worth to note that some alternative parameters such as "Overload" have been introduced in the standards. This is also in conformity with the guide from the ETSI EG 203 336 [i.6], clause 5.1 which states:

"If the "classical" parameters for a radiocommunications receiver provided in the present document are not relevant for some types of equipment (e.g. radar) the Technical Body should include suitable alternative technical means in the harmonised standard. "

Or in clause 4.1:

"Whenever an ETSI Technical Body decides to deviate from the technical guidance in the present document, an explanation should be given. Such an explanation may be included in the Harmonised Standard itself (e.g. tables in ETSI EN 301 908 [i.4]) or in a separate ETSI Technical Report referenced in the Harmonised Standard (e.g. ETSI TR 101 506 [i.5]). This explanation is not necessary when technical parameters equivalent to those listed in the present document are specified in the HS".

In summary, the TBs have the responsibility to consider the complete list of receiver parameters provided in ETSI EG 203 336 [i.6] and to include those felt appropriate in the HS. They also have the possibility to consider and to include alternative receiver parameters if the reasoning is properly documented.

6.2 Definitions

The definitions given in ETSI EG 203 336 [i.6] allow to perform test in order to assess the conformity of a device with the regulations and the limits defined within the Harmonised Standards. The sensitivity associated with a given BER is used as a reference level. Then, an interfering signal is introduced at a given offset compared to the centre frequency of the system and the degradation is assessed. If a given interference threshold such as a BER is met while the system is still performing as it should, then, the test is passed.

As indicated in clause 5.6, the current set of "classical" parameters are not applicable for some device, ETSI TS 103 361 [i.1] considers the case of non-communication devices:

"For non-communication devices, e.g. sensors, radars, and so on, the transmitter and the receiver are generally designed by the same manufacturer, who can design the system in such a way that it performs "as intended". There is no need of interoperability among sensor or radar devices provided by different manufacturers. Non-communication devices may be considered "custom applications", with performance requirements best determined by the manufacturer."

This implies that some of the typical parameters such as the BER used to assess the performance of "classical" receivers may not be relevant or may not be available in case the device is not a communication device.

From ETSI TS 103 361 [i.1]:

"*While a common performance criterion would be more desirable, these examples and the discussion above demonstrate that due to the wide variety of UWB applications, the performance criterion needs to be application dependent. The manufacturers, with their knowledge of the application, are best placed to define and specify the performance criterion such that the device "has a level of performance that allows it to operate as intended", as clearly required by Article 3.2 of the RED [i.1].*

Further information on performance criteria for communication devices is provided in clause A.1 and for sensor devices in clause A.2. Recommended performance criteria and tests for common applications are listed in clause 9.4. Where the indicated performance criteria are not suitable, the performance criterion used to determine the performance of the receiver shall be declared and published by the manufacturer. "

Some of the receiver parameters given in ETSI EG 203 336 [i.6] are very much tailored for narrow band channelized communication systems where both the interferer and the victim are similar signals with similar characteristics.

6.3 Complementary RX parameter framework

A detailed framework will be described in ETSI TS 103 567 [i.56]. It will contain a clear mapping between RX parameters mentioned in the present document and possible equivalent alternative RX parameter definitions. Initial considerations are given in clause 8.1.

7 Regulatory status

7.1 WG SE21

In January 2015, CEPT (ECC WG SE) created a new work item in the framework of the Project Team SE21 (SE21_18) *"to evaluate relevant receiver parameters, considering the future role of receiver parameters in spectrum management and sharing studies".*

This ongoing work aims to provide some guidance on receiver requirements (planned is to develop first an ECC Report and in a second step an ECC Recommendation) and could have a significant impact on standardization in ETSI.

SE21 is monitoring the production of Harmonised Standards by ETSI for the Radio Equipment Directive and is developing an ECC report on receivers: "Evaluation of receiver parameters and the future role of receiver performance in spectrum management and coexistence studies". SE21 is exchanging with ERM in order to coordinate the progress on work item SE21_18 [i.46].

Important elements for the ECC Report are the receiver parameters and limits contained in Harmonised Standards. SE21 intends to include a clause in the report on some analysis of Harmonised Standards to understand what limits have been specified for the receivers.

The outcome of the STF 494 (ETSI TS 103 361 [i.1]) was presented to SE21 and raised many questions.

The main questions from SE/SE21 were:

- Based on the alternative concept how can a minimum sensitivity of the radio system be ensured?
- Is it possible to implement the concept into the spectrum engineering process (e. g. use in SEAMCAT or for the definition of interference scenarios)?
- Can the concept demonstrate whether the equipment supports an efficient use of the spectrum?

The discussion with SE21 is still ongoing and requires support from ETSI. Answering the questions from SE21 will be one of objectives of this STF. The work of STF 451 was presented to SE21. STF and SE 21 are working in the close cooperation. The deadline for the completion of Work Item SE21_18 [i.46] was changed to January 2018 in order for SE21 to consider the outputs of the STF in the deliverable ETSI TS 103 567 [i.56] (to be drafted) under development for this work item.

It is understood that further collaboration with SE21 would also be necessary if the implementation of new receiver parameters require the development of new definitions.

7.2 Spectrum Efficiency

7.2.1 General Considerations

Main point of RED is efficient use of spectrum.

The intention of article 3.2 of Directive 2014/53/EU [i.11] in relation to a receiver is explained in recitals 10 and 11 of the Directive which state:

"(10) In order to ensure that radio equipment uses the radio spectrum effectively and supports the efficient use of radio spectrum, radio equipment should be constructed so that: …, in the case of a receiver, it has a level of performance that allows it to operate as intended and protects it against the risk of harmful interference, in particular from shared or adjacent channels, and, in so doing, supports improvements in the efficient use of shared or adjacent channels.

(11) Although receivers do not themselves cause harmful interference, reception capabilities are an increasingly important factor in ensuring the efficient use of radio spectrum by way of an increased resilience of receivers against harmful interference and unwanted signals on the basis of the relevant essential requirements of Union harmonisation legislation. "

In addition, radio regulators may specify spectrum use conditions, therefore, ETSI EG 203 336 [i.6] states that:

"Receivers usually operate under spectrum conditions managed by radio regulators to use spectrum efficiently and share with current & future users. The receivers should be specified in order to use the spectrum as intended while respecting these spectrum use conditions."

Technical Bodies should consider the above conditions when fixing receiver parameters and their limit values for inclusion in a Harmonised Standard. For example, if a relevant ECC coexistence study recommends a certain level of receiver performance, then this should be respected in the Harmonised Standard. It is expected that intended use conditions are included in such studies, for example head and hand attenuation when appropriate.

The classical definition of Spectrum Efficiency out of [i.35] Federal Communications Commission Spectrum Policy Task Force, Report of the Spectrum Efficiency Working Group, November 15, 2002 is:

Spectrum Efficiency = Information Transmitted / Spectrum Impacted

where:

Spectrum Impacted = Bandwidth x Geographic Space x Time

This definition, however, was made for communication systems as the figure of merit "information transmitted" indicates.

Acknowledging this limitation, the ITU-R and the ECC developed more generic definitions, which are discussed in the following clauses.

7.2.2 Recommendation ITU-R SM.1046

Recommendation ITU-R SM.1046-3 [i.36] deals with the definition of spectrum use and efficiency of a radio system. It provides general criteria for the evaluation of spectrum utilization factor and spectrum efficiency and examples of spectrum use by different services. In term of general criteria for the evaluation of spectrum utilization factor and spectrum efficiency, three parameters are defined:

- Spectrum utilization factor, *U*, is defined to be the product of the frequency bandwidth, the geometric (geographic) space, and the time denied to other potential users:

$$U = B \cdot S \cdot T \qquad (1)$$

where:

B : frequency bandwidth

S : geometric space (usually area)

T : time.

- Spectrum utilization efficiency (SUE)

  According to the definition of SUE (or spectrum efficiency as a shortened term) of a radiocommunication system, it can be expressed by a complex criterion:

$$SUE = \{M, U\} = \{M, B.S.T\} \qquad (2)$$

where:

M: useful effect obtained with the aid of the communication system in question;

U: spectrum utilization factor for that system.

- Relative spectrum efficiency (RSE)

The concept of relative RSE can be used effectively to compare the spectrum efficiencies of two similar types of radio systems providing the same service.

Values for SUE could be computed for several different systems and could indeed be compared to obtain the relative efficiencies of the systems. Such comparisons, however, will have to be conducted with caution. For example, the SUEs computed for a land mobile radio system and a radar system are very different. The information transfer rate, the receivers and transmitters in these two systems are so different that the two SUEs are not commensurate. It would not be particularly useful to try to compare them. Hence, the comparison of spectrum efficiency should be only done between similar types of systems and which provide identical radio communication services. It would be beneficial to conduct the comparison of the spectrum efficiency or utilization of the same system over time to see if there is any improvement in the specific area under study.

It should also be noted that although spectrum efficiency is an important factor, because it allows the maximum amount of service to be derived from the radio spectrum, it is not the only factor to be considered. Other factors to be included in the selection of a technology or a system include the cost, the availability of equipment, the compatibility with existing equipment and techniques, the reliability of the system, and operational factors.

The Recommendation provides examples of calculations for:

- land mobile radio systems;
- radio-relay systems;
- television and audio broadcasting systems.

7.2.3 ECC Report 181

ECC Report 181 [i.44] states that:

" ... the definition of spectrum efficiency will be different in different contexts. To define spectrum efficiency in terms of only one application would be unfair. It would not even be correct to define it in terms of a weighted combination of measures for each user or application. . . . different applications have such different requirements that the measures would not be equivalent. "

7.2.4 Additional Considerations

Currently there is no requirement for measuring minimum spectrum efficiency due to the lack of an agreed common metric.

It is generally accepted that there is no universal definition for" spectrum efficiency" or "efficient use of radio spectrum" and that the concept of spectrum efficiency is closely linked to the application and/or service a radiocommunications system provides.

The RSPG defined spectrum efficiency as *"not assigning more spectrum than is necessary for a service or application"* RSPG10-331 Final Draft for Adoption [i.28].

Additionally, a very low risk of interference is based on the definition of spectrum efficiency for SRDs or UWB devices which are operating mostly on non-harmful interference and non-protected basis.

8 New receiver parameters

8.1 Generic points

With the Radio Equipment Directive, ETSI was required to create new or update its existing harmonised standards in order to include Receiver (RX) parameters. This task has presented new technical challenges in relation to certain equipment categories, for example when it is not possible to access to a test point (see clause 5.5).

Some of these challenges have already been addressed by ETSI STF 494 (06/2015 - 03/2016) which developed a new concept for RX requirements.

The new concept is intended to complement the framework for classical receiver parameters by providing alternative RX parameters to be used for possible use cases of radio devices where the classical receiver parameters framework described in ETSI EG 203 336 [i.6], clause on RX where alternatives are allowed, cannot be used:

- If there is no possibility to describe classical receiver parameters and parameters needed for compatibility or sharing studies (e.g. SRDs).
- Classical receiver parameters such as BER do not fulfil the requirements for describing the performance of the receiver (e.g. UWB, radio-determination and inductive case).
- RX to be tested in a system e.g. WPT or inductive devices, robot mower.

- Highly integrated devices for which it is not possible to access test points (such as automotive radars).
- Some commercial devices may also encounter difficulties for the testing phase due to their intended use and the size of the equipment they are embedded in (e.g. maritime radars on ships).

Technical Bodies in the framework of TC ERM are further considering the development of such concept. The STF is also further considering the development of a set of new receiver parameters and their implementation in ETSI Harmonised Standards. This is further described in the following clauses.

It should be noted that new RX parameters concepts have been introduced by some TBs:

- Examples like ETSI EN 302 208 [i.29] with test case for new receiver parameter referring 70 % of the maximum reading range.
- Receive only devices (GPS) ETSI EN 303 413 [i.30] with test case for new receiver parameter like adjacent service selectivity.

8.2 Previous work in STF 494

8.2.1 Introduction

STF 494 was active from May 2015 to March 2016. The purpose was to provide expert guidance on the receiver parameters for the required updates of the UWB related Harmonised Standards to cover the essential requirements of article 3.2 of the RED directive. STF 494 proposed the concept of 'interferer signal handling' that was adopted in all UWB related Harmonised Standards.

8.2.2 Purpose - RX parameters for UWB

The Radio Equipment Directive requires receivers to have a level of performance that allows it to operate as intended and protects it against harmful interference in order to support improvements in the efficient use of the spectrum.

ETSI EG 203 336 [i.6] provides a number of technical parameters that can be specified in order to address these requirements. However, when looked at in the context of UWB, these parameters seem chosen with standardized, narrowband systems operating in specific frequency ranges in mind. UWB devices are often proprietary short-range devices that can operate in any part of the spectrum. As a consequence, the parameters as defined in the guide are often difficult to specify in a manner that is meaningful in an UWB context.

STF 494 therefore had the task to look into suitable receiver parameters for UWB devices. The current range of applications is very wide, covering communications, ranging and localization, as well as sensing, imaging and radar.

STF 494 started by evaluating the suitability of the parameters proposed in ETSI EG 203 336 [i.6] in the context of UWB.

Since receiver sensitivity is often traded off again interference immunity, for a short-range device it is best to leave it to the manufacturer to decide the right balance for a given application. Similarly, for many UWB sensor systems a good link budget does not convert into improved performance since the link budget requirements may be very relaxed. In such situations, overdesigning the receiver at the cost of increased power consumption is not beneficial. For similar reasons, reciprocal mixing and dynamic range were also dismissed.

While they are not directly implementable as defined in the Guide, the definitions of receiver selectivity and blocking were modified to mean performance of the device in the presence of an interferer. This modified concept was called 'interference signal handling' and is documented in ETSI TS 103 361 [i.1] (Receiver technical requirements, parameters and measurement procedures to fulfil the requirements of the Directive 2014/53/EU [i.11]).

8.2.3 Proposal - Interferer signal handling

ETSI TS 103 361 [i.1] defines interference signal handling as the capability of the receiving device to operate as intended in coexistence with interferers.

The performance of the receiver is evaluated by using a quantifiable performance criterion. The exact criterion depends on the application. For common applications, ETSI TS 103 361 [i.1] contains recommended performance criteria. If those are not suitable, the manufacturer can define another performance criterion. To allow market surveillance, the performance criterion used needs to be declared in the user manual.

A list of interferers, power levels and frequencies was extracted from the EFIS database. Interferers are only considered at the centre of their frequency range, at the maximum power level. Interferers are grouped depending on whether they are mobile, fixed indoor, fixed outdoor or fixed outdoor long range. Depending on the category they fall in, different free space attenuation, NLOS attenuation and potential wall losses are considered.

To estimate the power at the UWB device, five usage classes are defined: indoor, outdoor, mobile, vehicular, and (tank) level probing radars. For each, an estimate of the interfering power level at the UWB device is calculated based on the category of the interferer.

To decide which interferers to test against, ETSI TS 103 361 [i.1] defines an 'interferer test frequency range' as the operating bandwidth of the corresponding transmitter plus 5 % either side. The test needs to be performed against the three strongest interferers within the range.

The actual test proposed in ETSI TS 103 361 [i.1] provides four options for the interfering signal. At its simplest, the test can be performed with a continuous wave signal. Next, a wideband signal with the same bandwidth as the interferer can be used. The third option is similar but includes the duty cycle of the signal. Final, if possible, the real interfering signal could be used.

ETSI TS 103 361 [i.1] specifies that the tests will be performed in a scenario representative of a typical usage scenario. The idea was that the same set-up used for EMC testing could be re-used for the interference signal handling test. Conducted tests are an alternative. The tests should be performed on all six sides of the device.

The test is passed if the device behaves as intended in the presence of the interfering signal. Examples of intended behaviour are that the device continues working, switches off as intended (listen-before-talk applications), switches channel (detect-and-avoid), or warns the user that it is not able to function correctly.

8.2.4 Evaluation by EC desk officer

The EU Desk Officer wants the tests to be clearly specified and does not accept 'declarations' in the user manual.

The simple pass/fail criterion might not be suitable for integration in SEAMCAT.

8.3 Automotive Radar

8.3.1 Overview

From ETSI TC ERM TG SRR:

"*Radar sensors are measurement instruments that determine quantities like distance or relative speed of other objects in their field of view by using a part of the frequency spectrum for the transmission of radio power and the reception of reflected radio power.*

By choosing for the transmitter the number of antennas, modulation type, bandwidth and timing, and for the receiver the number of antennas, processing resources and software algorithms, the unambiguous value range, resolution and accuracy of the measurement results, as well as other properties like latency and correction of parasitic effects can be adjusted to realize a wanted performance for a given application (sensor datasheet).

For automotive radars, a variety of different applications has been developed to support the driver of a vehicle in different scenarios (see Annex A). Some applications need longer detection ranges b2 Exemplary stages of a radar receiver ut not a fine resolution, others shorter detection ranges and a finer resolution. The wanted performance details of these applications are not all yet standardized and can differ from car manufacturer to car manufacturer.

From the basic building blocks, a radar sensor for a given application or a given list of applications is similar from manufacturer to manufacturer and generation to generation (see Figure 12).

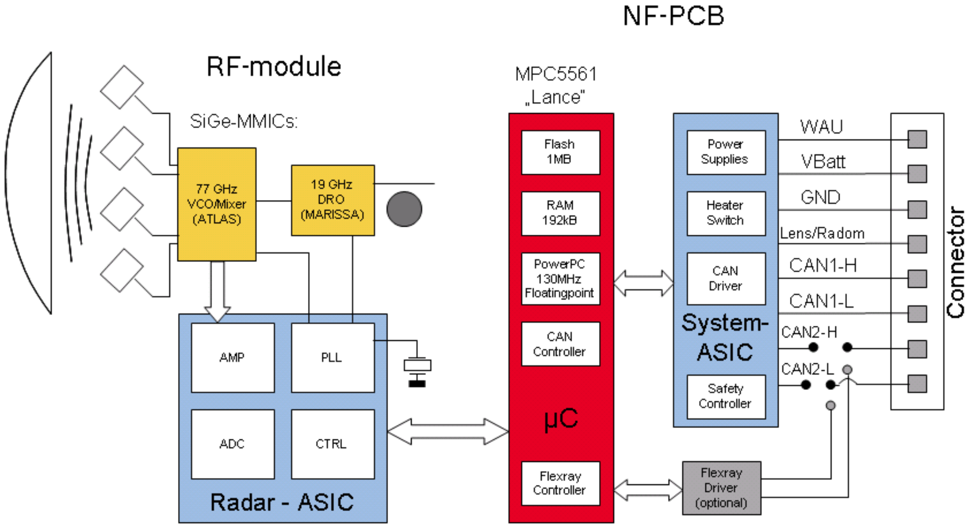

Figure 12: Basic building blocks of a radar sensor (Bosch Gen3 radar sensor)"

8.3.2 Technical Description

Now, to allow as many radio devices using the limited spectrum as possible, the Radio Equipment Directive 2014/53/EU [i.11] requires radio devices to use the spectrum efficiently.

For the transmitter of a radar sensor there have been for some time requirements for maximum bandwidth and power, in some cases also for duty cycle or dwell time which prevent arbitrary usage of the spectrum.

For receivers, requirements generally denote their ability to maintain the wanted performance to a given degree if unwanted signals from other transmitters are present.

As mentioned above, for radar receivers the wanted performance is not standardized but currently individually defined by the end user. Furthermore, the wanted performance is not always referred to the same receiver output signal because not each receiver contains all typical stages as shown in table 5. For more centralized system concepts, the radar receiver might miss stages H, GH, FGH or EFGH from table 5.

Table 5: Exemplary stages of a radar receiver

Stage	Component	Important parameters	Output signal
A	RX antenna	Beam pattern, bandwidth	For each RX channel: analogue RF target sine signals, noise, clutter, interference
B	RF homodyne downconverter	Bandwidth, noise figure, nonlinear compression	For each RX channel: analogue LF target sine signals, noise, clutter, interference
C	LF amplifier with bandpass characteristics	Bandwidth, clipping	For each RX channel: analogue LF target sine signals, noise, clutter, interference
D	AD converter	Resolution	For each RX channel: digital values
E	FFT processing	S/N gain, dynamic range	For each RX channel: FFT spectrum
F	Raw signal processing (detect peaks in FFT spectrum, from peaks compute target distance, etc.)	S/N detection threshold	At the end of each radar cycle: List of raw targets, each described by distance, speed, azimuth angle, etc.
G	Object tracking (improve result reliability by checking plausibility, etc.)	Latency	At the end of each radar cycle: List of objects, each described by distance, speed, azimuth angle, etc.
H	Alarm derivation	Probability of false alarm	Signal light, etc.

With today's technology, all stages may be realized in a single integrated circuit what prevents testing at intermediate signals.

Furthermore, the software algorithms in stages F, G and H are optimized for processing signals as occurring in dynamically fluctuating scenarios on the road and not for processing signals occurring in the clinical environment of a test chamber. Thus, results obtained in a test chamber do not fully represent the real-world performance.

This example of automotive Radar is highly integrated and strongly shielded against in and out of band conducted and radiated interference. Test signal access without disturbing radar functionality is possible via a communication interface only. The exemplary stages of a radar receiver are shown for clarification in table 5. In figure 13 the influence of interferer signals is shown for clarification of table 5.

The device gets tested "as it is". An external software tool for communication purpose is used for tests, e.g. Vector CANalyzer to communicate via CAN. Firmware of the sensor is not changed for tests. Only standard firmware is used for testing featuring test modes.

Any test setup opening the Device under Test is changing the device behaviour and functionality considerably. This could be in conflict with legal requirements since no dedicated testing procedure for passing a test is allowed.

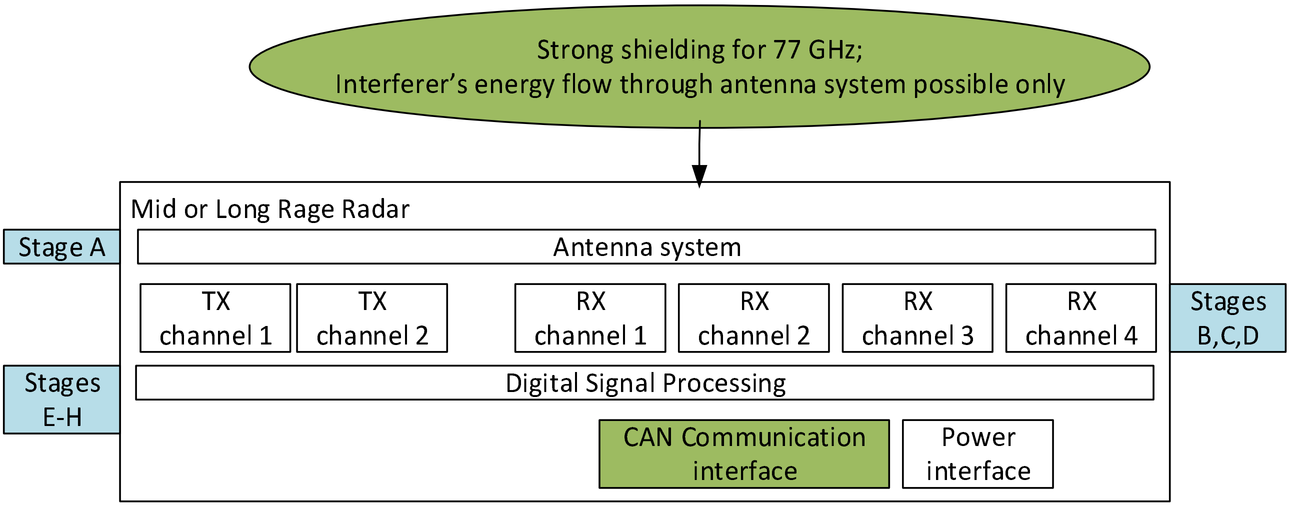

Figure 13: Interfaces for Interferer Test

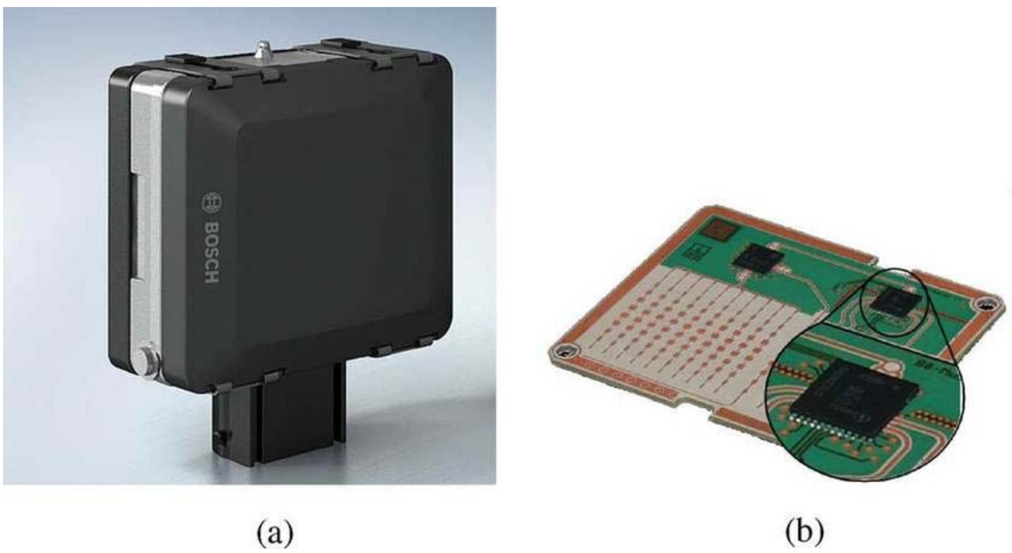

Figure 14: Radar Gen4: (a) housing and (b) PCB with TX and RX antenna and MMICs

From ETSI TC ERM TG SRR on Efficiency of spectrum use.

"*An efficient use of spectrum is fulfilled as required by RED, if no higher transmission rate is observed and no increase of occupied bandwidth is detected over test measurement time.*

Considering these boundary conditions, in the following representative test scenarios with unwanted signals are defined for different categories of radar sensors and with different number of included receiver stages.

This use-cases could be transferred into following classification for automotive radars, see Table 6.

Table 6: Use cases

Use-Case class	*Max. measurable distance*	*Related EN*
Ultra Short Range Radar (USRR)	*< 20 m*	
Short Range Radar (SRR)	*< 50 m*	
Mid Range Radar (MRR)	*< 100 m*	
Long Range Radar (LRR)	*< 250 m*	
Super Long Range Radar (SLRR)	*> 250 m*	

"

8.3.3 Standards

Test setups and criteria described in ETSI EN 301 091-1 [i.2] is used, see discussion below and in ETSI TC ERM TG SRR discussions.

8.3.4 Measurement Procedures

In these new receiver concepts, there are no classical receiver parameters available for measurement.

A radar receiver is working as intended in presence of an interferer, if the wanted performance criteria are still fulfilled. Wanted performance criteria can be defined by definition of test scenarios and radar receiver signal quality. CAN messages are recorded to get access to assess radar signal quality.

Probability of Detection of an object in a given percentage of all radar cycles in a test as a performance criterion. Example: Detection probability of < x % of all radar cycles.

Radar channel scenario for test object size (can be zero, if no object defined called "receiver empty test") with constant distance D and velocity v properties. Object size is defined by Radar Cross Clause RCS, e.g. RCS = 0 dBsm = 1 m².

From ETSI TC ERM TG SRR on Setup for a receiver empty test:

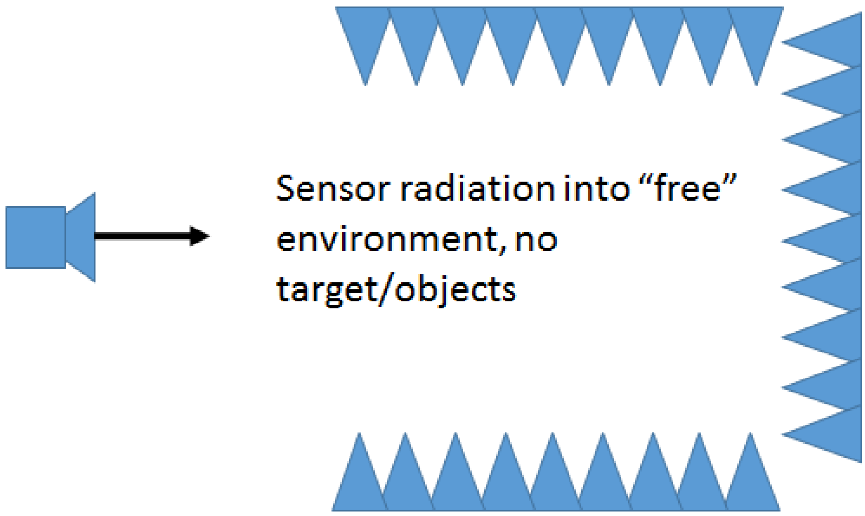

Figure 15: Principal concept of the test setup

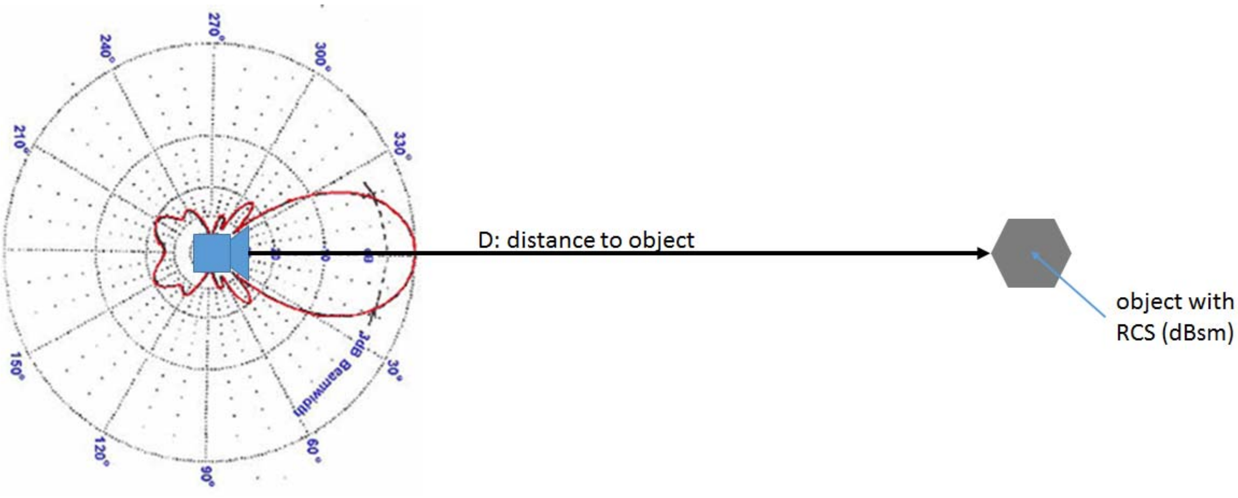

Figure 16: Principal concept of the test setup without interferer

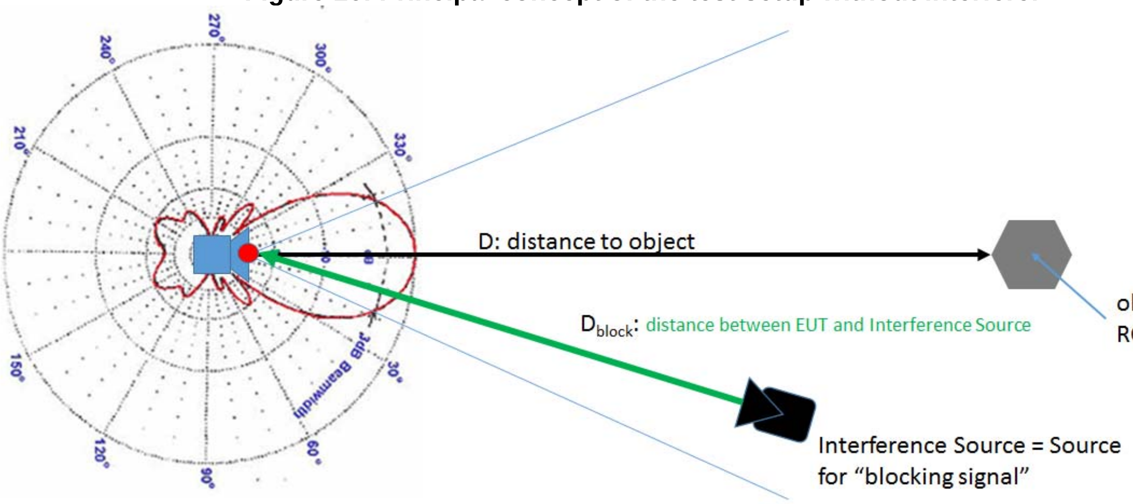

Figure 17: Principal concept of the test setup with interferer

8.4 UWB Communication systems

8.4.1 Overview of the example

Originally, a lot of the interest in UWB technology stems from the fact that the high bandwidth can be used for transmitting very high-data rate digital signals over relatively short ranges. High data rate communication of up to 500 Mbps over short distances up to 10 m can be achieved.

Besides high-data rate communications, UWB is also used in a variety of applications requiring only medium- or low-data rates such as sensor networks, IoT applications and location tracking. Particularly in highly reflective, often industrial, environments, the wide bandwidth is attractive as it mitigates power variations due to multipath fading. UWB communications technology can therefore be found in a wide variety of environments, ranging from industrial and professional to office and consumer applications.

In the context of spectrum efficiency, it is important to highlight that UWB systems are able to achieve this without causing harmful interference to the other users of the spectrum.

8.4.2 Technical description

ETSI ERM TGUWB has provided an overview of the technical characteristics of UWB systems in ETSI TR 103 181-1 [i.31].

UWB systems use both impulse based and RF carrier technologies. A variety of modulation techniques are used. As long as the resulting bandwidth is larger than 50 MHz, the system qualifies as ultra-wideband. While initially implemented using discrete components, nowadays UWB products are mainly based on integrated circuits.

Most UWB communication applications are covered by ETSI EN 302 065-1 [i.24] and described in System Reference Document ETSI TR 101 994-1 [i.25]. The intended frequency range and maximum mean e.i.r.p. is listed in table 7 below. From a spectrum efficiency and coexistence perspective, it is important to note that these values are so low that UWB devices do not cause any harmful interference to other users of the spectrum.

Table 7: Intended frequency bands for generic UWB applications

Frequency range (GHz)	Maximum mean e.i.r.p. spectral density	
	Without mitigation techniques	With mitigation techniques
3,1 - 4,8	≤ -70 dBm/MHz	-41,3 dBm/MHz
6 - 8,5	-41,3 dBm/MHz	-41,3 dBm/MHz

Specific regulations exist for vehicular and railroad applications, covered by ETSI EN 302 065-3 [i.26], and for applications on-board aircraft, subject of ETSI EN 302 065-5 [i.27]. In general, fixed outdoor transmitters are not allowed.

8.4.3 Standards

Most UWB communication applications are covered by the generic UWB regulations from ETSI EN 302 065-1 [i.24] and are described in System Reference Document ETSI TR 101 994-1 [i.25]. When used in vehicular and railroad applications, ETSI EN 302 065-3 [i.26] applies, while use on-board aircraft falls under ETSI EN 302 065-5 [i.27].

When it comes to receiver parameters, all these standards refer to the ETSI TS 103 361 [i.1] drafted by STF 494, see clause 8.2.

8.4.4 Measurement procedures

ETSI TS 103 361 [i.1] contains a recommended receiver test for UWB communication devices. This test is based on using receiver sensitivity as performance criterion. Since there are no standards defining receiver sensitivity for UWB devices, the manufacturer needs to declare appropriate parameters (desired packet length and error rate for a given minimum signal level) for the intended use in the user manual. Both conducted (if possible) or radiated measurements are allowed.

To take into account the Desk Officer's request to have a single test, combined with TGUWB's desire to have as generic a test as possible, TGUWB#41 proposed a test based on receiver co-channel interference in document ERMTGUWB(17)041013 "RX-requirements discussion for UWB devices" [i.47].

The regulated frequency bands for ultra-wideband systems are intended for non-protected license exempt use without a defined channelization. The direct implication is that the nominal frequency of the receiver will vary between systems. This means that an interferer at a fixed frequency may be co-channel for some systems and out-of-band for other systems operating under the same Harmonised Standard. Still the ability to operate as intended in presence of an interferer within the receiver bandwidth is considered fundamental and in line with the intentions of the radio directive. The suggestion is therefore to implement this parameter but slightly redefined reflecting the fact that the channel may be very wide and specific for different equipment. Therefore, a channel should be chosen for the interferer that is specific to the worst case of the minimum bandwidth. Given that the minimum required bandwidth for UWB is 50 MHz, a CW transmission of 50 MHz is proposed for test scenario shown below.

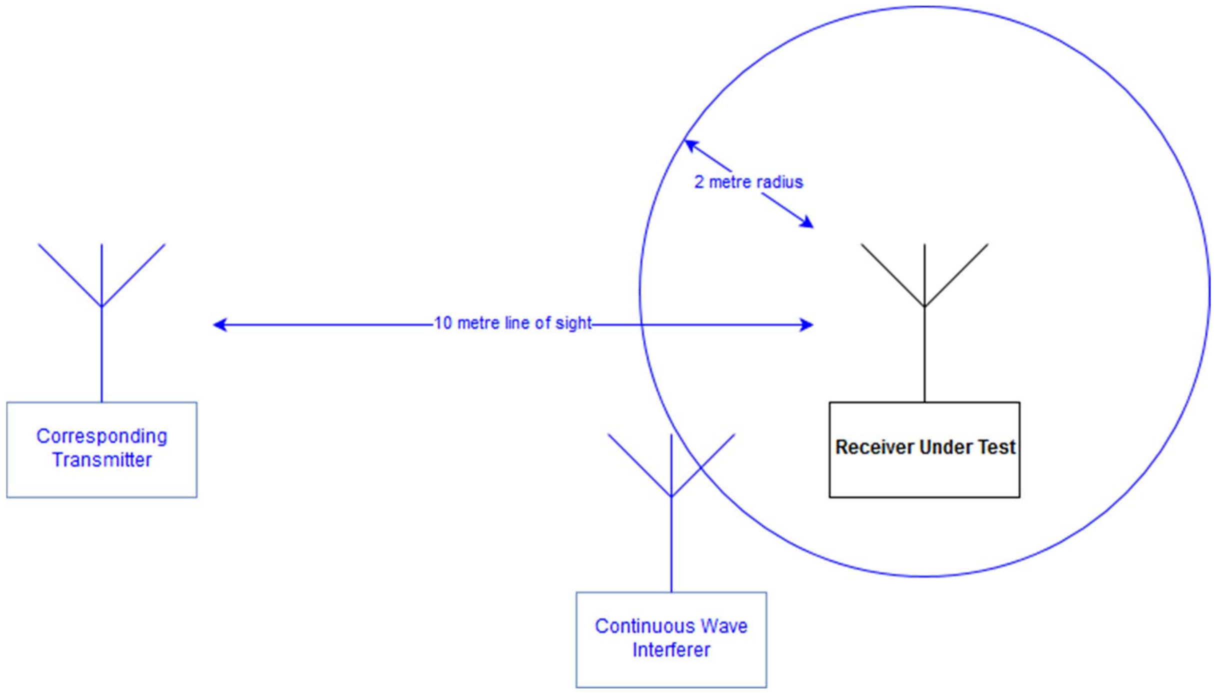

Figure 18: Test scenario

A transmitter and corresponding receiver (DUT) are set up within a clean RF environment. They are set at a distance of 10 m with clear Line of Sight (LOS). Where possible, the transmitter is set to continuously send transmissions, and the receptions are monitored by the DUT in normal operating mode of the DUT.

The CW interferer is placed within 2 m of the DUT. It is powered up at a level of less than -43 dBm. The power level of the interfering transmitter is now raised in increments until the DUT no longer receives the transmissions from the corresponding transmitter. This level is of the CW interferer is recorded. Any level above a threshold to be determined is deemed a "pass"; any level below this is deemed a "fail".

8.5 UWB Location tracking systems

8.5.1 Overview of the example

UWB devices employ bandwidths of up to several GHz, thus allowing centimetre-level localization and positioning even in the presence of severe multipath effects caused by walls, furniture etc. UWB technology therefore enables a new class of sensors, named Location Tracking sensors and opens up new markets with very different applications. For such sensors, high precision in range measurement is required.

In UWB location tracking sensors, small mobile or portable tags, operating as either transmitters or receivers, or both, are attached to the objects to be located, or are carried by personnel within an area under surveillance. A network of fixed equipment around the area to be covered, communicate with the tags. By analysing e.g. the time-of-arrival and/or angle-of-arrival of the radio signal relative to the known reference stations, the 2D/3D position of the tag can be found.

Typically, the range between a tag and a reference station might be up to 200 m, depending on the area to be observed. Such systems significantly enhance the security and safety of persons monitored in different application areas such as process industries, healthcare, prisons (guards) and lone workers. Within hospitals, equipment, patients and doctors can be located quickly to speed up response to an incident. In the workplace, computers and communications systems can be shared between personnel, and automatically configured for a particular user as they walk up to equipment. In high-security environments, authorized personnel can be tracked, and unauthorized persons quickly identified when passive sensors (e.g. infra-red sensors) detect the presence of a person who is not located by the tracking system. Additionally, in industrial and agricultural environments the system can be used to track products through an assembly line and to monitor animal behaviour (e.g. in the dairy industry). Within vehicles, UWB is used to secure passive keyless entry systems.

8.5.2 Technical description

Location tracking type 1, LT1, are intended for applications in the frequency band from 6 GHz to 8,5/9 GHz for indoor, portable and mobile outdoor applications. This was the original spectrum request for UWB location tracking applications, and it was initially covered by ETSI TR 102 495-3 [i.32]. The limits are identical to the generic UWB regulation in the range 6 GHz to 9 GHz.

Table 8: Intended frequency bands for mobile and indoor LT1 applications

Frequency range (GHz)	Maximum mean e.i.r.p. spectral density	
	Without mitigation techniques	With mitigation techniques
6 - 8,5	-41,3 dBm/MHz	-41,3 dBm/MHz
8,5 - 9	-60 dBm/MHz	-41,3 dBm/MHz

The original request for UWB Location Tracking sensors that led to definition of LT1 sensors was enhanced by the proposals covered in ETSI TR 102 495-5 [i.52]. These additional location tracking devices were called type 2, abbreviated as LT2. LT2 devices complement the 6 to 8,5 GHz range from LT1 devices with operation between 3,4 and 4,8 GHz. Subject to site specific licensing, fixed outdoor LT2 installations could be allowed.

Table 9: Intended frequency bands for mobile and indoor LT2 applications

Frequency range (GHz)	Maximum mean e.i.r.p. spectral density	
	Without mitigation techniques	With mitigation techniques
2,7 - 3,4	-70 dBm/MHz	-41,3 dBm/MHz
3,4 - 4,8	-41,3 dBm/MHz	-41,3 dBm/MHz
NOTE: Further duty cycle restrictions and maximum Ton limits apply.		

Table 10: Intended frequency bands for outdoor LT2 applications

Frequency range (GHz)	Maximum mean e.i.r.p. spectral density	
	Without mitigation techniques	With mitigation techniques
2,7 - 3,4	-70 dBm/MHz	-41,3 dBm/MHz
3,4 - 4,8	-41,3 dBm/MHz	-41,3 dBm/MHz
NOTE: Further duty cycle restrictions and maximum Ton limits apply, as well as an extra 6 dB reduction for transmission above 30 degrees above the horizontal plane.		

Location Tracking sensor for Emergency Services (LAES) are a class of special short-range location tracking sensors specifically intended to support public safety services in emergency situations.

The users of the proposed system will primarily be government agencies responsible for public safety and so would be clearly defined organizations. It is suggested in the proposed regulation that users should be licensed, but not sites, since the equipment would only be operated when and where an emergency situation occurs. As described in ETSI TR 102 496 [i.55], applications are used temporarily by emergency services in all aspects of disaster situations, including disaster prevention.

For these systems, no fixed installations are available to perform the localization as the place of events are not known in advance. An LAES system is therefore composed of a set of nodes deployed as an ad-hoc network. To penetrate buildings and locate with the necessary accuracy, an increased power compared to other UWB regulations is allowed.

Table 11: Intended frequency bands for LAES applications

Frequency range (GHz)	Maximum mean e.i.r.p. spectral density	
	Without mitigation techniques	With mitigation techniques
3,1 - 3,4	-70 dBm/MHz	-41,3 dBm/MHz
3,4 - 4,2	-21,3 dBm/MHz	-21,3 dBm/MHz
4,2 - 4,8	-41,3 dBm/MHz	-41,3 dBm/MHz
NOTE: A maximum duty cycle restriction applies.		

8.5.3 Standards

Location tracking systems are based on ETSI EN 302 065-2 [i.48]. For receiver parameters, [i.48] refers to ETSI TS 103 361 [i.1] as drafted by STF 494.

8.5.4 Measurement procedures

Testing location tracking receivers is difficult as performance often can only be evaluated in a whole system. The transmissions for location tracking often consist of a specific ranging sequence that allows the receiver to determine the precise time of arrival and a data sequence with control and identification information. STF 494 assumed that the communications part of the receiver would be tested using the procedure for communications systems as discussed in the previous clause. Some systems that only sent a ranging sequence have since been discovered. If reception of the sequence is tested as proposed in TGUWB#41, the modified communications test proposed in the previous clause could be used.

8.6 UWB Building material analysis

8.6.1 Overview of the example

UWB technology is used in devices for building material analysis (BMA) and classification of buried objects and material. The non-destructive scanning of building structures offers a large advantage compared to conventional destructive methods. A high bandwidth is required to obtain sufficient spatial resolution.

These devices are used for the detection of gas pipes or electrical installations, as well as for the inspection of large buildings and structures. For example, by analysing the salt and water content of bridges, the corrosion can be estimated.

8.6.2 Technical description

Building material analysis devices are described in System Reference Document ETSI TR 102 495-1 [i.49].

BMA devices are handheld, lightweight and manually operated at low power. They exhibit a low activity factor during operation. The typical total operational duration is limited to a few minutes as the area of interest is usually confined to a few m^2 and the measurement results are instantaneously available.

Due to the low activity factor, the limited activation time per task, the nature of the applications, random use over time and location of the usage, no aggregation occurs.

The devices are designed to work only in direct contact to the building structure being scanned and are designed to couple the electromagnetic signal directly into the building structure. The devices do not operate without physical contact to the building structure to be investigated.

Parasitic, undesired radiation into free space is significantly reduced due to the device design and the additional attenuation of the measured building structure. Equipment features (e.g. deactivation switch, dynamic power control, listen-before-talk) may reduce such radiation even further.

Frequencies in the lower GHz range are necessary to penetrate lossy building materials, such as concrete, because they exhibit a large attenuation which increases with frequency and to minimize clutter. A large bandwidth is required to ensure sufficient measurement resolution, needed for object identification, separation and classification.

The system is designed to radiate a broadband signal into the building and capture the corresponding return signal caused by the material surface, inhomogeneities, and buried objects. A single measurement does not allow the buried objects to be characterized. Typically, the device is moved over the building material surface, and a sequence of return signals is recorded to build up a pattern of waveforms and to allow the spatial information to be decoded. The following digital signal processing steps create an easy understandable result, which will be displayed on the user interface. The position at which each waveform is recorded may be triggered automatically by position sensors or manually by the operator.

8.6.3 Standards

BMA devices operate in compliance with ETSI EN 302 065-4 [i.50]. Like all UWB standards, for the RX parameters, [i.50] refers to ETSI TS 103 361 [i.1].

The intended range of operation is between 2,2 and 8,5 GHz. The maximum e.i.r.p is -50 dBm/MHz to ensure licensed spectrum users are protected from interference.

8.6.4 Measurement procedures

ETSI TS 103 361 [i.1] has a recommended test case for BMA sensor in clause 9.4.1 of [i.1]. The test there reuses the presentative wall which is already used for the emissions testing. The test wall is made of two plaster boards (thickness 12 mm) in a distance of e. An iron rebar rod is placed between the boards at a depth d measured from the front surface of the plaster board. The interferer is placed at the position of maximum sensitivity for the receiving device. Typically, this would mean that it placed on the other side of the wall. The test is passed if the iron bar is detected in the presence of the interferer.

8.7 UWB Object discrimination and characterization

8.7.1 Overview of the example

Similar to BMA, the very wide bandwidth of UWB signals allow the identification and classification of objects, in addition to detecting their presence and position. The operation is contactless and works over a short distance of less than 40 cm, even if the object is hidden by an obstacle. Such sensors are the so-called Object Discrimination and Characterization sensors (ODC).

Applications for such devices are widespread. Examples are:

- Position detection and identification of human extremities for enhanced operational safety with potentially dangerous tools.
- Pre-impact protection and pre-impact detection or direct contact avoidance for hidden objects to be detected for building work applications.

8.7.2 Technical description

Object Discrimination and Characterization (ODC) devices and their applications are described in ETSI TR 102 495-2 [i.51].

Frequencies in the lower GHz range are prerequisite for this kind of object classification equipment, allowing the electromagnetic waves to penetrate objects like cloth or human tissue. The wave penetrating an object inside returns much more information (such as inhomogeneities, object composition, dielectricity, etc.) about the object than just the surface reflection. A certain bandwidth is required to receive a characteristic response from the target and to ensure sufficient resolution needed for target separation.

ODC devices only transmit when in contact or close proximity to the investigated material. The radiation pattern is directed towards the "object" and minimizes emissions in other directions. In the frequency range of 2,2 GHz to 8,5 GHz, directional antennas do not have large dimensions.

8.7.3 Standards

ODC devices fall under ETSI EN 302 065-4 [i.50]. For the RX parameters, that standard refers to ETSI TS 103 361 [i.1].

The intended range of operation is between 2,2 and 8,5 GHz. The maximum e.i.r.p is -50 dBm/MHz. This low value ensures that licensed users are protected from harmful interference.

8.7.4 Measurement procedure

ETSI TS 103 361 [i.1] contains three recommended test cases for ODC applications. Clause 9.4.2 of [i.1] discusses respiration sensors. Presence detection sensors are the subject of clause 9.4.3 of [i.1], while clause 9.4.5 of [i.1] specifies on-body pulse rate sensors. Each of these examples contains two potential test, either a so-called real test scenario with a living person or an equivalent test where the person has been replaced with an RCS.

When it comes to RX testing, the problem with these and many other ODC devices is that they are highly integrated units where access to the actual receiver is often not available. Some may not even have a digital output, making it even more difficult to define a performance criterion.

8.8 Ground- and wall-probing radars (GPR/WPR)

8.8.1 Overview of the example

Ground Probing Radars (GPR) and Wall Probing Radars (WPR) are UWB sensors mainly used in survey and detection applications. They are basically radar systems, in which the sensor is in close proximity to the materials being investigated. The intended signal is never radiated into free space.

8.8.2 Technical description

A GPR is an imaging system based on a field disturbance sensor that is designed to operate only when in contact with, or within one meter of, the ground for the purpose of detecting or obtaining the images of buried objects or determining the physical properties within the ground. They operate over approximately one decade in the frequency range 30 MHz to 12,4 GHz. The energy from the GPR is intentionally directed down into the ground for this purpose. Any horizontal radiation from this equipment is caused by leakage and is considered as undesired emission.

A WPR is an imaging system based on a field disturbance sensor that is designed to detect the location of objects contained within a "wall" or to determine the physical properties within the "wall", operating in the frequency range 30 MHz to 12,4 GHz". The "wall" is a building material structure or any other concrete structure, the side of a bridge, the wall of a mine or another physical structure that is dense enough and thick enough to absorb the majority of the signal transmitted by the imaging system; The sensor radiates directly into a "wall".

Other equipment that may be considered within this class of sensors are equipment fitted with integral antennas and without antenna connector, or equipment which uses different imaging heads (antennas) with an antenna connector, to allow operation at different frequencies.

GPR and WPR equipment are intended to be used by competent professional personnel only.

8.8.3 Standards

Ground- and wall-probing radars are specified in ETSI EN 302 066 [i.53].

Intentional emissions cannot be tested due to the nature of the GPR/WPR applications and thus only unintentional emissions into the air are regulated.

The emissions into the air resulting from the operation of GPR/WPR imaging systems are defined as those emissions radiated in all directions above the ground from the GPR/WPR equipment, including direct emissions from the housing/structure of the equipment and emissions reflected or passing through the media under inspection. They are therefore dependent on the operational conditions and are meaningful only if the GPR/WPR are coupled with the material being investigated.

Table 12: Ground- and wall probing radar emissions

Frequency range	Peak power limit values
30 MHz - 230 MHz	-44,5 dBm/120 kHz
30 MHz - 12,4 GHz	-37,5 dBm/120 kHz
3,4 - 4,8 GHz	-30 dBm/MHz

For the RX test, ETSI EN 302 066 [i.53] originally referred to ETSI TS 103 361 [i.1]. To address the comments of the EU Desk Officerthe RX requirements have integrated in the main body of ETSI EN 302 066 [i.53].

8.8.4 Measurement procedures

The "classical" parameters for a radiocommunications receiver as provided in ETSI EG 203 336 [i.6] are not applicable to GPR/WPR because of the peculiarly unique sensing (non-traditional communications and radar) use of this technology.

This implies, for instance, that the definition of "receiver sensitivity" (ability to receive a wanted signal at low input signal levels while providing a pre-determined level of performance) cannot be used as it is impossible to define a "wanted signal" or even a minimum input signal level at the receiver stage.

Moreover, GPR/WPR receivers are synchronized to the transmitter as they essentially measure the time of flight to a target. Therefore, measuring the receiver sensitivity using an external signal generator is practically impossible.

For GPR/WPR this performance criterion is set upon the difference D between the maximum signal M for the RX in the linear region of operation and output signal I in presence of the interferer. This difference needs to be at least 20 dB.

The maximum signal M for the receiver in the linear region of operation is defined as the maximum absolute value (in Volts) occurring in the signal received by the GPR/WPR when suspended 5 centimetres above a plane metal.

The signal I is defined as the maximum absolute value in Volts occurring in the averaged signal from the half to the end of the time window with the interferer activated.

In this condition, the presence of the interferer may produce an increase of the noise received by the GPR/WPR which can hide reflections from weaker targets.

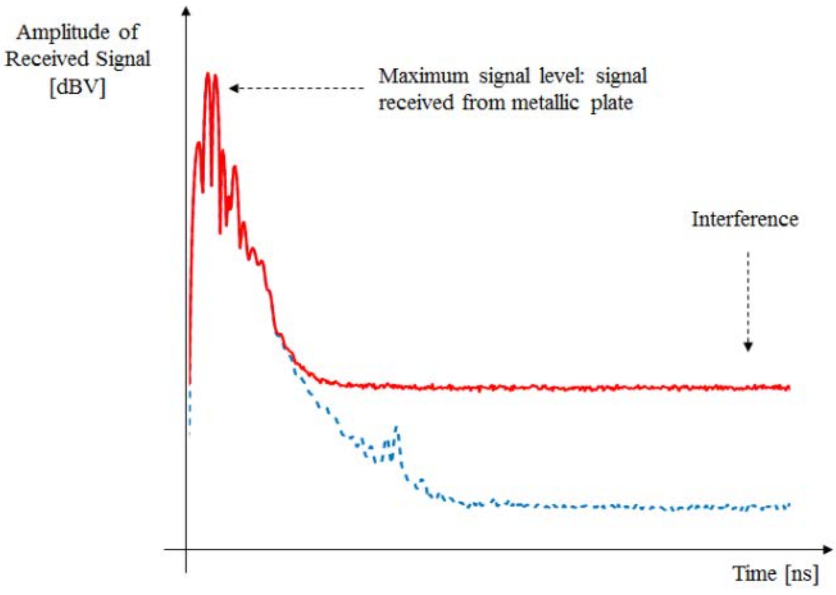

Figure 19: Example of GPR/WPR received with the interferer activated

8.9 (Tank) Level probing radar

8.9.1 Overview of the example

Level probing radars (LPRs) are used in many industries concerned with process control to measure the amount of various substances (mostly liquids or granulates). LPRs are used for a wide range of applications such as process control, custody transfer measurement (government legal measurements), water and other liquid monitoring, spilling prevention and other industrial applications. The main purposes of using LPRs are:

- to increase reliability by preventing accidents;

- to increase industrial efficiency, quality and process control;
- to improve environmental conditions in production processes.

Tank level probing radars (TLPRs) are similar but their operation is restricted to radiating RF signals towards the surface of a substance contained in a closed tank. Any radiation outside of the tank is caused by leakage and is considered an unintentional emission.

8.9.2 Technical description

Level Probing Radar (LPR) systems in compliance with ETSI EN 302 729 [i.33] are based on pulsed RF, FMCW, or similar wideband techniques. LPR radio equipment types are capable of operating in all or part of the frequency bands as specified in table 13. As with all UWB systems, the power levels are so low that LPR are able to co-exist with other users in the spectrum without causing them any harmful interference.

Table 13: Level Probing Radar (LPR) permitted frequency bands

	LPR assigned frequency bands (GHz)	Maximum Mean e.i.r.p. spectral density within the LPR operating bandwidths (within main beam)	Maximum mean e.i.r.p. spectral density on half-sphere (see note)
Transmit and Receive	6 - 8,5	-33 dBm/MHz	-55 dBm/MHz
Transmit and Receive	24,05 - 26,5	-14 dBm/MHz	-41,3 dBm/MHz
Transmit and Receive	57 - 64	-2 dBm/MHz	-41,3 dBm/MHz
Transmit and Receive	75 - 85	-3 dBm/MHz	-41,3 dBm/MHz
NOTE: The maximum mean e.i.r.p. spectral density limits on half sphere around LPR installation accounts for both the LPR antenna side-lobe emissions and any reflections from the measured material/object.			

LPRs always consist of a combined transmitter and receiver and are used with an integral or dedicated antenna. LPR antennas are always specific directive antennas and no LPR omnidirectional antennas are used.

The LPR equipment is for professional applications where installation and maintenance are performed by professionally trained individuals only.

Tank level probing radars (TLPRs) are similar to LPRs but restricted to systems in which the devices are installed in closed metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material, holding a substance, liquid or powder.

The purpose of TLPR systems is to accurately and reliably measure substance levels contained within the tank. TLPRs provide a high resistance to dirt and tank atmosphere, regardless of the substance in the tank, its temperature or pressure, allowing precise control of manufacturing processes and storage facilities.

TLPR equipment is used in industrial environments only.

Tank level probing systems operating in accordance with ETSI EN 302 372 [i.34] can use any of the following frequency ranges.

Table 14: Tank Level Probing Radar (TLPR) permitted frequency bands

	TLPR assigned frequency bands (GHz)	Max. emissions outside the tank enclosure
Transmit and Receive	4,5 - 7	-41,3 dBm/MHz
Transmit and Receive	8,5 - 10,6	-41,3 dBm/MHz
Transmit and Receive	24,05 - 27	-41,3 dBm/MHz
Transmit and Receive	57 - 64	-41,3 dBm/MHz
Transmit and Receive	75 - 85	-41,3 dBm/MHz

From a spectrum efficiency and coexistence point of view, the power levels are again so low that no harmful interference is caused to other users of the frequency range.

8.9.3 Standards

Level probing radars operate in accordance with ETSI EN 302 729 [i.33], while tank radars comply with ETSI EN 302 372 [i.34]. When it comes to receiver parameters, the current V2.1.1 versions both refer to ETSI TS 103 361 [i.1] drafted by STF 494. A common recommended test procedure for (T)LPR systems is defined in clause 9.4.7 of that document.

8.9.4 Measurement procedures

The recommended measurement procedure (T)LPR applications in ETSI TS 103 361 [i.1] looks at the variation in the measured distance value due to the presence of an interferer.

The required level of performance in clause 9.4.7 of ETSI TS 103 361 [i.1] is that:

"(T) LPR sensor shall be able to measure against a large flat surface consisting of a material with relative permittivity ε_r in the maximum approved measurement distance R_{max} according to the manufacturer specification which still meets a measured distance value variation of ±50 mm over time under interference conditions."

The test is passed if the (T)LPR sensor is still able to detect the radar target and measure the distance to the target within a maximum measured distance value variation of ≤ ±50 mm over time.

The manufacturer defines the ε_r, R_{max} and the distance over which the variation stays below ±50 mm under interference conditions. To allow independent verification, ETSI TS 103 361 [i.1] requires that these parameters are included in the user manual.

In practice, measurements against a liquid or a bulk material surface at larger distances is not feasible and leads to expensive test setups. Some LPR sensors on the market can measure distances beyond 100 metres.

In order to facilitate testing and to keep the effort and costs manageable, an equivalent measurement scenario is defined in which a radar target at a smaller distance R with RCS σ is used. ETSI TS 103 361 [i.1] contains the formulas to ensure that the target produces the same (or less) echo signal power at the receiver as the flat surface at the defined measurement distance. This is necessary as some test houses may not have the possibility to conduct measurements at longer distances due to the very limited space in their anechoic chamber.

An alternative equivalent scenario takes into account that the (T)LPR signal processing algorithms need a stable echo and a minimum echo signal-to-noise ratio (SNR) of y dB (declared and proven by manufacturer) to ensure a distance value variation smaller than ±50 mm over time during a distance measurement.

The interferer will provoke a rise of the noise floor in the receiver of the (T)LPR sensor and thus degrade the SNR of an echo signal. If the noise floor of the receiver stays y dB below the power level of the echo signal in the real scenario (produced by the flat material surface with relative permittivity ε_r), a measurement value variation of ≤ ±50 mm can be assured over time.

In this alternative measurement, the interferer signal is directly fed into the receiver of the (T)LPR sensor either in a conducted or radiated setup. The system noise level is observed, for example in an echo curve graph. The test is passed if the resulting system noise level stays at least y dB below the echo power level produced by the above defined flat surface.

If this measurement is used, the required minimum SNR value of y dB also needs to be declared in the user manual.

TGUWB discussed the comments received on these and other UWB standards in TGUWB#41 and documented the results in ERM TGUWB(17)041013r2_RX-requirements_discussion_for_UWB_devices.

The assumption there was that the real scenario of ETSI TS 103 361 [i.1] (measurement against a large flat surface) would be deleted and replace solely by a set-up with a target radar reflector. The (T)LPR industry would like to keep the option of both radiated and conducted measurements.

The performance criterion would still be to keep the measurement variation due to the interferer below 50 mm. However, a common target, both in terms of ε_r and distance, would be used for all types of radars.

To come closer to the classical definition of blocking, a different probability of detection of the target may be mandated for in-band, adjacent band and at other frequencies. It is not clear at the moment whether the bands should be based on the operating bandwidth or the permitted frequency range.

8.10 Classical and non-classical receivers

In general, three classes of phenomena are considered through the "classical" receiver parameters:

- Co-frequency/Co-Channel phenomena: Sensitivity, Selectivity, Receiver co-channel rejection.
- Adjacent & nearby frequencies phenomena: Selectivity, Adjacent signal selectivity, blocking.
- Far away phenomena: Selectivity, Blocking, Receiver spurious response rejection.

In order to be consistent with the set of "classical" receiver parameters, the interferer signal handling concept would allow to test similar phenomena.

The definition of the "intended used" of the equipment in the Harmonised Standard may lead to the identification of classes to differentiate the equipment depending on their level of performance or their operating mode (range of detection for example). This parameter will be used in order to assess the degradation of the performance of the device when having to cope with an interfering signal. The definition of the intended use is equivalent to the definition a sensitivity associated with a level of performance (i.e. similar to a Bit Error Rate (BER) associated to a sensitivity level) for classical receivers.

In order to test the different phenomena, it may be necessary to identify different frequency areas to perform tests. This could be done relative to the centre frequency of the receiver (as illustrated in figure 20).

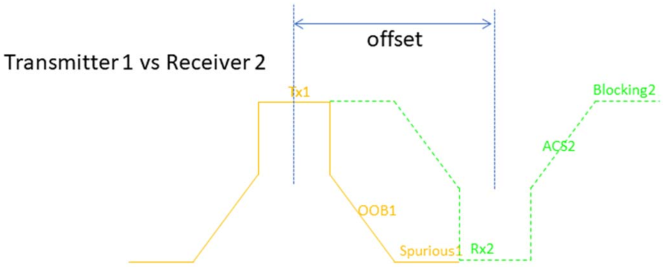

Figure 20: Test depending on the offset compared to the centre frequency

Alternatively, STF 494 already introduced a concept for UWB systems.

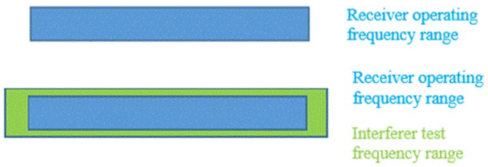

Figure 21: STF 494 - UWB case

In the frequency range in green in the figure above, ETSI TS 103 361 [i.1] (outcome of STF 494) provides a tool to identify possible interferers which could be used as a test to test the performance of the UWB devices. In should be noted that, in general, in the test performed for the "classical" receiver parameters, the interfering signal may be signal like or a contiguous wave. In this new concept, a third option would have to be considered by the TB, if they want to conduct testing with signals similar to a "known" interfering signal identified in ETSI TS 103 361 [i.1], using similar modulation and characteristics.

It is necessary to identify different areas for consistency with the approach take for the "classical" receiver parameters:

- Co-frequency.
- Nearby.
- Far away.

For each of these areas, tests would have to be specified.

As for UWB, two areas may be merged if the testing conditions are the same. Currently, the TGSRR is considering for the co-frequency range and the nearby range, an offset of 5 % of the UWB bandwidth at the edge of the occupied band. A second percentage, may need to be defined in order to limit the test for the far away area if testing in this area is also required.

An alternative way of defining the test areas and different testing conditions, could also be based on the "domain" approach, where the domain could be defined in term of percentage of the channel spacing/occupied bandwidth, whatever is appropriate.

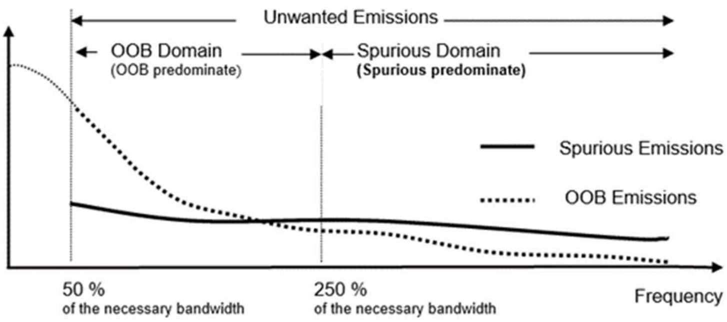

Figure 22: Domain approach

As indicated before, three types of signals could be considered for the tests: signal like, CW and based on the signal of a possible source of interferer. ETSI TS 103 361 [i.1] provides an initial list of interferers to be considered. However, this list is not complete and would have to be expended and updated on a regularly basis in order to reflect possible modifications in the allocations / assignations. This could be done in cooperation with CEPT and in particular, with the EFIS Maintenance Group (MG).

The test will be performed with the device performing according to its intended used and with an interfering signal or more than one interfering signals as defined by the TB. If the system is still performing according to its intended use, then the test is passed, if not the device failed. Such a procedure is equivalent to check a given degradation of the Bit Error Rate (BER) while an interference criterion (C/I, level of blocking, etc.) is to be met for a classical receiver.

9 Conclusion

In general classical receiver parameters were found not to be applicable 1:1 to non-classical receivers. That is mainly due to the definitions, characteristics (like bandwidths, operational condition and use cases) and measurement setup used for classical receivers, which cannot be used for non- classical receivers.

The following main points are to be highlighted:

1) There are variations in the definitions given for classical parameters. The alignment of the definitions would be beneficial.

2) The identified classical receiver parameters are not used in a consistent way across harmonised standards.

3) In some product specific standards the classical receiver parameters need some additional definitions and clarifications before they can be adopted (e.g. car radars with new definition of target size in a minimum distance and a performance criterion like probability of detection).

4) In other standards the classical receiver parameters cannot be adopted (e.g. UWB due to the huge bandwidth overlapping with many other spectrum users) and there is the need to prove that the used alternative parameters and procedures (e.g. ETSI TS 103 361 [i.1]), which are similar to EMC immunity tests, are equivalent to the classical ones.

5) Some standards do have the problem that the applications do not have access to any form of classical performance criteria of the radio link like BER, PER or probability of detection and they do need to use higher level functions as performance criterion; ETSI EN 303 447 [i.5] on robotic lawn mowers for example, where an application requirement is used as performance criterion (e.g. mower has to stop on loss of the boundary wire signal). This needs to be recognised by ETSI Technical Groups, the European Commission and the administrations when assessing these standards.

6) An additional problem was figured out for generic standards, where it is not accepted by the EC to allow the manufacturer in relevant HS to declare the "intended use" and the test scenarios; here it is challenging to include clear performance criteria and test scenarios for all possible use cases (e.g. ETSI EN 302 065-1 [i.24]), since all use-cases may not be known by the responsible ETSI committee; the way out would be to either accept a performance criterion like "continue to use as intended" with some generic test scenario or to develop for these standards different classes of devices with the same use case, performance criteria and measurement procedures; this may lead to the requirement to develop much more application or use case specific standards, which means moving away from todays generic standards.

From the above it may be concluded that:

- there is further on a need to work in CEPT and ETSI on clear and consistent definitions, measurement procedures and requirements for classical receiver requirements, which is outside the scope of STF 541;
- some product specific HS can adopt the classical receiver requirements with acceptable expense, e.g. the standards of ETSI TGSRR; further work is not needed within the framework of STF 541;
- the clarification of the following question are pending:
  - if generic/ non-specific standards are still acceptable; or
  - if many use-case specific standards have to be created.

  This is an issue for further work, but outside the scope of STF 541.
- the alternative receiver concept from ETSI TS 103 361 [i.1] should be further analysed in STF 541 on the equivalence to classical receiver requirements; clear prescriptions of alternative receiver concepts and comparison with the existing classical receiver requirements should be developed in STF 541 based on the results of STF 494 (ETSI TS 103 361 [i.1]) and of the present document, which should lead to accepted receiver requirements equivalent to those listed in ETSI EG 203 336 [i.6]. These alternative concepts and definitions should demonstrate the same level of protection compared to the classical receiver parameters.
- The STF 541 will provide possible solutions in ETSI TS 103 567 [i.56] (open work item).

Annex A: Change History

Date	Version	Information about changes
February 2018	0.0.1	Initial draft version created
March 2018	0.0.2	A first structure and collection of ideas
April 2018	0.0.3	First example new receiver and editorial setup of TR
April 2018	0.0.4	Editorial, new skeleton
May 2018	0.0.9	Several iterations on Workshops and GoToMeetings, definitions added, examples added
05.06.2018	0.0.10	Clean-up
11.06.2018	0.0.11	Revision of the document after TC ERM STF Open Session
14.06.2018	0.0.14	Definitions compared to v0.0.6 and drafting in clause
15.06.2018	0.1.0	Stable draft after Drafting and Resolution G2M
27.06.2018	0.1.18	Final drafting G2M ad clean up
28.06.2018	1.1.1	First version of final draft
09.07.2018	1.1.2	Clean-up done on requests by editHelp!,. There are open issues on references
31.07.2018	1.1.3	Outcome of resolution meeting; ready for approval
21.09.2018	1.1.1r1	response on first editHelp advise. Several issues on referencing are still open
05.10.2018	1.1.1r5	improvements after some edithelp recursions

History

Document history		
V1.1.1	October 2018	Publication