Draft ETSI EN 303 364-1-1 V1.0.0 (2025-03)

Primary Surveillance Radar (PSR);
Harmonised Standard for access to radio spectrum;
Part 1: Air Traffic Control (ATC) PSR sensors operating in the frequency band 1 215 MHz to 1 400 MHz (L band);
Sub-part 1: radar systems using reflector antennas

Reference
DEN/ERM-TGAERO-31-1

Keywords
aeronautical, harmonised standard, radar, radio

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Sous-Préfecture de Grasse (06) N° w061004871

Contents

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Foreword

This draft Harmonised European Standard (EN) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the combined Public Enquiry and Vote phase of the ETSI Standardisation Request deliverable Approval Procedure (SRdAP).

The present document has been prepared under the Commission's standardisation request C(2015) 5376 final [i.2] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU 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 [i.1].

Once the present document is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of the present document given in Table A.1 confers, within the limits of the scope of the present document, a presumption of conformity with the corresponding essential requirements of that Directive, and associated EFTA regulations.

The present document is part 1, sub-part 1, of a multi-part deliverable covering Primary Surveillance Radar (PSR), as identified below:

Part 1: "Air Traffic Control (ATC) PSR sensors operating in the frequency band 1 215 MHz to 1 400 MHz (L band)";

Sub-part 1: "radar systems using reflector antennas";

Sub-part 2: "radar systems using phased array antennas".

Part 2: "Air Traffic Control (ATC) PSR sensors operating in the frequency band 2 700 MHz to 3 100 MHz (S band)";

Part 3: "Air Traffic Control (ATC) PSR sensors operating in the frequency band 8 500 MHz to 10 000 MHz (X band)".

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	18 months after doa

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**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).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

1 Scope

The present document specifies technical characteristics and methods of measurements for ground based monostatic ATC solid state primary surveillance radars that are intended to work with a waveguide-based rotating passive antenna and have the following characteristics:

- operation in the 1 215 MHz to 1 400 MHz frequency range;
- transmitter output peak power up to 100 kW;
- the transceiver output uses an RF circulator;
- a piece of waveguide of at least 66 cm is integral to the transceiver.

NOTE 1: Phased array ATC primary surveillance radars are not covered by the present document.

NOTE 2: 66 cm equals 2 times the cut-off wavelength of a WR650/WG6/R14 waveguide which is typically used in the 1 215 MHz to 1 400 MHz frequency range.

NOTE 3: The relationship between the present document and essential requirements of article 3.2 of Directive 2014/53/EU [i.1] is given in Annex A.

2 References

2.1 Normative references

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

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

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 necessary for the application of the present document.

[1] ETSI EN 300 019-1-3 (V2.4.1) (04-2014): "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-3: Classification of environmental conditions; Stationary use at weather protected locations".

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] 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.

[i.2] Commission Implementing Decision C (2015) 5376 final of 4.8.2015 on a standardisation request to the European Committee for Electrotechnical Standardisation and to the European Telecommunications Standards Institute as regards radio equipment in support of Directive 2014/53/EU of the European Parliament and of the Council.

[i.3] ITU Radio Regulations (2024).

[i.4] Recommendation ITU-R SM.1541-7 (09/2024): "Unwanted emissions in the out-of-band domain".

[i.5] ETSI EG 203 336 (V1.2.1): "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.6] IEC 60153-2 (2016): "Hollow metallic waveguides - Part 2: Relevant specifications for ordinary rectangular waveguides".

[i.7] Recommendation ITU-R SM.331-4 (07/78): "Noise and sensitivity of receivers".

[i.8] Recommendation ITU-R SM.332-4 (07/78): "Selectivity of receivers".

[i.9] ECC Recommendation (02)05 (October 2012): "Unwanted emissions".

[i.10] ERC Recommendation 74-01 (May 2022): "Unwanted emissions in the spurious domain".

[i.11] Recommendation ITU-R M.1177-4 (04/2011): "Techniques for measurement of unwanted emissions of radar systems".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

active state: state which produces the authorized emission

allocated frequency band: frequency range that regionally or nationally is allocated to one or more radio services on a primary or secondary basis

chirp bandwidth: total frequency shift during the pulse generation of an FM/chirped radar

EXAMPLE: If the Frequency Modulation is from 1 250 MHz to 1 280 MHz, the chirp bandwidth is 30 MHz.

declared frequency band: band or bands within which the equipment under test is declared to operate

NOTE: The declared frequency band for a given region or country is always contained within the allocated frequency band.

dummy load: device connected to a waveguide or coaxial cable and matched to their impedance (typically 50 Ω) to absorb the RF energy propagating inside

Equipment Under Test (EUT): device that is the subject of the specific test investigation being described

idle/stand-by state: state where the transmitter is available for traffic, but is not in the active state

matched filter: receiver filter that matches the transmitted radar waveform, i.e. this is the filter that maximizes the signal-to-noise ratio of the received pulse

necessary bandwidth: width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions for a given class of emission

NOTE 1: This definition is taken from ITU Radio Regulation [i.3].

NOTE 2: For Primary radars the necessary bandwidth B_N is considered to be B_{-20} (20 dB bandwidth) as defined in Recommendation ITU-R SM.1541-7 [i.4].

occupied bandwidth: width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage β/2 of the total mean power of a given emission

NOTE 1: Unless otherwise specified in an ITU-R Recommendation for the appropriate class of emission, the value of β/2 should be taken as 0,5 %.

NOTE 2: This definition is taken from ITU Radio Regulations [i.3], chapter I, 1.153.

operating frequencies: frequencies on which the radar is tuned to operate

operating mode: predefined configuration for a given service accessible to the operator of the radar system

NOTE 1: Several operating modes may be available.

NOTE 2: Changing operating mode might affect the radio characteristics of the radar system.

Peak Envelope Power (PEP): average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions

NOTE: This definition is taken from ITU Radio Regulations [i.3], chapter I, 1.157.

product configuration: hardware variant of the same typology of system under test (e.g. different power outputs, magnetrons)

pulse fall time: time taken for the trailing edge of the pulse to decrease from 90 % to 10 % of the maximum amplitude (voltage)

pulse length: time between the 50 % amplitude (voltage) points

pulse rise time: time taken for the leading edge of the pulse to increase from 10 % to 90 % of the maximum amplitude (voltage)

radar equipment: equipment and its associated primary navigational display intended for the navigation of aircraft in airways

receiver output: output of the digital matched filter function

system coupler: directional waveguide coupler with forward and reverse port or only a forward port

NOTE: The system coupler is inserted in the waveguide run between the circulator and the antenna but not directly located behind the antenna. Usually it is located very close behind the circulator.

unwanted emissions: consist of spurious emissions and out-of-band emissions

NOTE: This definition is taken from ITU Radio Regulation [i.3].

3.2 Symbols

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

B_{-20}	-20 dB bandwidth below PEP of the spectrum of the transmitted waveform
B_{-40}	-40 dB bandwidth below PEP of the spectrum of the transmitted waveform
B_C	Chirp bandwidth
B_m	Measurement bandwidth
B_N	Necessary bandwidth
B_{ref}	Reference bandwidth
B_{res}	3 dB resolution bandwidth of transceiver
dB/dec	dB per decade
dBm	Power ratio expressed in decibels (dB) with reference to 1 milliwatt
dBpp	Power ratio expressed in decibels (dB) with reference to peak power
f_o	Operating Frequency
f_{co}	*Cut-off* Frequency
f_{IF}	Intermediate Frequency
f_{RF}	Receiver operating Frequency
f_{image}	Image Frequency

k	Boltzmann's constant
f_{LO}	Local Oscillator Frequency
P_{meas}	Spectrum Peak Power
Pt	Pulse power of transmission
RF	Radio Frequency
S/N	Signal-to-Noise ratio
t	Pulse length
T_C	Pulse length (of individual chirp waveforms) in seconds
tr	Pulse rise time
tf	Pulse fall time
T_0	Temperature in Kelvin
β/2	Percentage of the total mean power of a given emission
λ	Wavelength

3.3 Abbreviations

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

AC	Alternating Current
ATC	Air Traffic Control
COF	Cut-Off Frequency
CW	Continuous Wave
DC	Direct Coupling
EIA	Electronic Industries Alliance
EN	European Norm
ENR	Excess Noise Ratio
EUT	Equipment Under Test
FM	Frequency Modulation
Hz	Hertz
IEC	International Electrotechnical Commission
IF	Intermediate Frequency
IMD	InterModulation Distortion
ITU-R	International Telecommunications Union - Radiocommunications
kHz	kiloHertz
kW	kiloWatt
NA	Not Available
NF	Noise Factor
OoB	Out-of-Band
PEP	Peak Envelope Power
ppm	parts per million
PSR	Primary Surveillance Radar
RCL	Receiver Compression level
RF	Radio Frequency
SM	Spectrum Management
STD	Standard Deviation
SWT	Sweep Time

4 Technical requirements specifications

4.1 Environmental profile

The technical requirements of the present document apply under the environmental profile for operation of the equipment, which shall be in accordance with its intended use, but as a minimum, shall be that specified in the test conditions contained in the present document. The equipment shall comply with all the technical requirements of the present document at all times when operating within the boundary limits of the operational environmental profile defined by its intended use.

4.2 Conformance Requirements

4.2.1 Transmitter requirements

4.2.1.1 Occupied bandwidth

4.2.1.1.1 Definition

Occupied bandwidth is the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage $\beta/2$ of the total mean power of a given emission as defined in ITU Radio Regulations [i.3], chapter I, 1.153.

4.2.1.1.2 Limits

The occupied bandwidth with $\beta/2 = 0,5$ % shall be maintained wholly within the declared frequency band.

NOTE: The value of $\beta/2 = 0,5$ % is taken from chapter I, 1.153 of the ITU Radio Regulations [i.3].

4.2.1.1.3 Conformance

The conformance tests are specified in clause 5.2.1.1.

4.2.1.2 Transmitter Peak Power

4.2.1.2.1 Definition

The transmitter peak power of a pulse radar is the peak value (PEP) of the transmitter pulse power during the transmission pulse measured at the antenna flange (output port of the transmitter).

4.2.1.2.2 Limits

The transmitter peak power shall not exceed 100 kW (i.e. 80 dBm).

4.2.1.2.3 Conformance

The conformance tests are specified in clause 5.2.1.2.

4.2.1.3 Measured B_{-40} bandwidth

4.2.1.3.1 Definition

The measured -40 dB bandwidth (B_{-40}) is the measured bandwidth of the emissions 40 dB below the measured PEP.

NOTE: Occupied bandwidth will be smaller than B_{-40} for such equipment.

4.2.1.3.2 Limits

The measured B_{-40} bandwidth shall always be contained within the declared frequency band.

4.2.1.3.3 Conformance

The conformance tests are specified in clause 5.2.1.3.

4.2.1.4 Unwanted emissions

4.2.1.4.1 General requirements

The Out-of-Band emission limits and the spurious emission limits shall be based on the calculated B_{-40} bandwidth as defined in Annex B. The OoB and Spurious domain boundaries and limits are defined in clause 4.2.1.4.2.2.

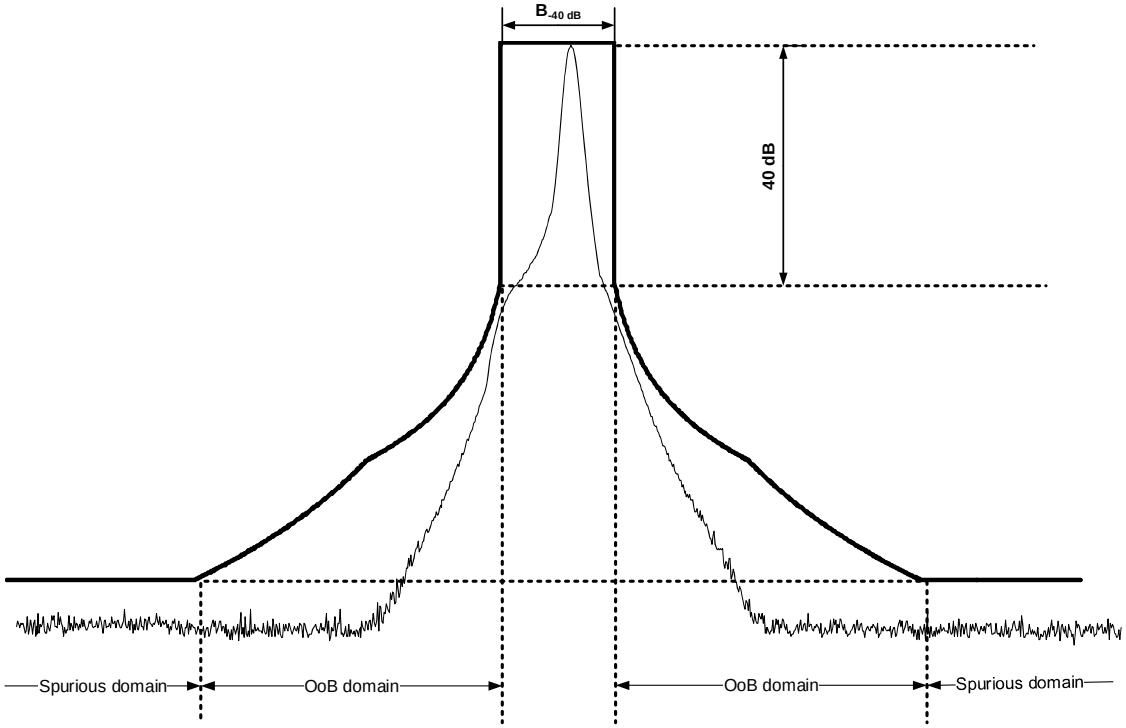

Figure 1: Definition of OoB and spurious emission domains (case of a single operating frequency) (Not to scale)

4.2.1.4.2 Out-of-band Emissions

4.2.1.4.2.1 Definition

Out-of-Band (OoB) emissions refer to emissions in the region between the calculated B_{-40} and the spurious domain.

NOTE: The calculated B_{-40} is defined in Annex B.

4.2.1.4.2.2 Limits

For single frequency radars, the limits of emissions in the OoB domain frequency boundaries defined in Table 2, shall be as specified in Table 1.

Table 1: Limits for emissions in the OoB domain for single frequency radars

Frequency offset Δ relative to B_{-40}	Limit dBpp (unless otherwise stated)	Slope dB/decade
0,5 ≤ Δ ≤ 5	-40 to -80	-40
5 < Δ ≤ 10,8	-80 to -100 / -30 dBm (see note 1)	-60
NOTE 1: From -80 to -100 or -30 dBm whichever is less stringent). NOTE 2: Frequency offset is a multiplicative factor of B_{-40} value. NOTE 3: These limits are specified in ECC Recommendation (02)05 [i.9], Annex 2, Table 3. NOTE 4: B_{-40} is calculated using the formulae in Annex B.		

Table 2: Out-of-Band emissions frequency boundaries for single frequency radars

Lower OoB measurement limit	Upper OoB measurement limit
Maximum value between (Operating frequency - 10,8 x B_{-40}) and fco x 0,7 MHz (see note 1)	Operating frequency + 10,8 x B_{-40}
NOTE 1: This value corresponds to the cut-off frequency of the equipment embedded piece of waveguide times 0,7 as described in ERC Recommendation 74-01 [i.10]. NOTE 2: B_{-40} is calculated using the formulae in Annex B. NOTE 3: Boundaries are specified in Annex 2 of ECC Recommendation (02)05 [i.9].	

For multi frequency radars, the limits of emissions in the OoB domain frequency boundaries, defined in Table 4, shall be as specified in Table 3.

Table 3: Limits for emissions in the OoB domain for multi frequency radars

Frequency offset Δ relative to B_{-40}	Limit dBpp	Slope dB/decade
0,5 ≤ Δ ≤ 1,6	-40 to (-43 - 10 x log(PEP) / -60 dB (see note 1))	-40
NOTE 1: From -40 to -43 - 10 x log(PEP) or -60 dBpp whichever is less stringent. NOTE 2: Frequency offset is a multiplicative factor of B_{-40} value. NOTE 3: PEP unit is Watt. NOTE 4: These limits are specified in ECC Recommendation (02)05 [i.9], Annex 2, Table 3. NOTE 5: B_{-40} is calculated using the formulae in Annex B.		

Table 4: Out-of-Band emissions frequency boundaries for multi frequency radars

Lower OoB measurement limit	Upper OoB measurement limit
Maximum value between (Operating frequency - 1,6 x B_{-40}) and fco x 0,7 MHz (see note 1)	Operating frequency + 1,6 x B_{-40}
NOTE 1: This value corresponds to the cut-off frequency of the equipment embedded piece of waveguide times 0,7 as described in ERC Recommendation 74-01 [i.10]. NOTE 2: B_{-40} is calculated using the formulae in Annex B. NOTE 3: Boundaries are specified in Annex 2 of ECC Recommendation (02)05 [i.9].	

For radars using multiple pulse waveforms, the emission mask shall be calculated for each individual pulse and the widest mask shall be considered.

4.2.1.4.2.3 Conformance

The conformance tests are specified in clause 5.2.1.4.1.

4.2.1.4.3 Emissions in the spurious domain

4.2.1.4.3.1 Definition

Spurious emissions are unwanted emissions in the spurious domain. They include:

- harmonic emissions (i.e. whole multiples of the operating frequency);
- parasitic emissions;
- emissions from intermodulation products (e.g. between oscillator and operating frequency, or between oscillator and harmonics);
- emissions from frequency conversion products.

For transmitters in active state, the spurious domain is all frequencies outside the OoB domain.

4.2.1.4.3.2 Limits

The spurious emissions limits in the frequency bands defined in Table 6 shall be as specified in Table 5.

Table 5: Limits for emissions in the spurious domain

Radar type	Limits (see note 1)
Single frequency	100 dB or -30 dBm whichever is less stringent
Multi frequency	43 + 10 x log (PEP) or 60 dB whichever is less stringent
NOTE 1: Absolute levels (in dBm) in the reference bandwidth or attenuation (dB) below the power (PEP) supplied to the antenna port. NOTE 2: These limits are specified in ERC Recommendation 74-01 [i.10], Annex 5.	

Table 6: measurement bands for the emissions in the spurious domain

Lower band measurement limits	Upper band measurement limits
From fco x 0,7 MHz (see note 1) to the lower OoB boundary	From the upper OoB boundary To 5th harmonic of the operating frequency + Δ (see note 2)
NOTE 1: The lower frequency corresponds to the COF of the equipment embedded piece of waveguide times 0,7 as described in ERC Recommendation 74-01 [i.10]. Measurement below this frequency are not required due to the fact that power transfer below this frequency is negligible and therefore measurements will not provide sound and repeatable results. NOTE 2: The upper band measurement limit corresponds to the 5th harmonic of the highest operating frequency, as defined in ERC Recommendation 74-01 [i.10], Table 1, plus a margin Δ corresponding to the maximum Occupied bandwidth d defined in clause 4.2.1.1.2 and calculated according to the following formula: $\Delta = 5 \times fo \times \left({}^{d}/_{10^{6}}\right)$, where fo is the highest operating frequency. For example with *fo* = 1 400 MHz, the margin Δ (in MHz) will be: 5 x 1 400 x 500 x 10^{-6} = 3,5 MHz and therefore the measurement limit will extend up to 7 003,5 MHz. NOTE 3: OoB frequency boundaries are specified in Table 2 (for single frequency radars) and Table 4 (for multi frequency radars).	

4.2.1.4.3.3 Conformance

The conformance tests are specified in clause 5.2.1.4.2.

4.2.1.4.4 Stand-by mode emissions

4.2.1.4.4.1 Definition

Stand-by mode emissions are residual emissions at the transceiver output when the transmitter is in stand-by mode. In this mode, the transmitter is available for operation, but is not in the active state.

4.2.1.4.4.2 Limits

The stand-by mode emissions shall not exceed the limits specified in Table 7 (f is the measurement frequency).

NOTE: These limits are specified in Table 15 of Annex 5 of ERC Recommendation 74-01 [i.10].

Table 7: Stand-by mode emission limits

Frequency Range	Limits
fco x 0,7 MHz (see note 1) ≤ f ≤ 1 GHz	-57 dBm
1 GHz < f ≤ 5th harmonic of the operating frequency f_o + Δ (see note 2)	-47 dBm
NOTE 1: The lower frequency corresponds to the COF of the equipment embedded piece of waveguide times 0,7 as described in ERC Recommendation 74-01 [i.10].	
NOTE 2: The upper band measurement limit corresponds to the 5th harmonic of the highest of the operating frequencies as defined in ERC Recommendation 74-01 [i.10], Table 1 plus a margin Δ corresponding to the maximum Occupied bandwidth d defined in clause 4.2.1.1.2 and calculated according to the following formula: $\Delta = 5 \times fo \times \left(d/10^6\right)$. For example with *fo* = 1 400 MHz, the margin Δ (in MHz) will be: 5 x 1 400 x 500 x 10^{-6} = 3,5 MHz and therefore the measurement limit will extend up to 7 003,5 MHz.	

4.2.1.4.4.3 Conformance

The conformance tests are specified in clause 5.2.1.4.3.

4.2.2 Receiver requirements

4.2.2.1 General requirement

The L-band ATC radars use an RF receiver inside the transceiver function and may use additional RF receivers connected to the radar antenna receiving beams patterns. The receiver requirements shall be tested for all the receivers of the radar.

4.2.2.2 System Noise Figure

4.2.2.2.1 Definition

The Noise Figure is the noise factor as defined below expressed in dB.

The noise factor is the ratio of noise power measured at the output of the receiver to the noise power which would be present at the output if the thermal noise due to the resistive component of the source impedance were the only source of noise in the system; both noise powers are determined at an absolute temperature of the source equal to T = 293 K.

NOTE: The definition of noise factor is taken from section 'Recommend 2' of Recommendation ITU-R SM.331-4 [i.7].

4.2.2.2.2 Limits

The Noise Figure shall not exceed 6 dB.

4.2.2.2.3 Conformance

The conformance tests are specified in clause 5.2.2.1.

4.2.2.3 Receiver Compression Level

4.2.2.3.1 Definition

The compression level is defined as the level of the input signal at which one of the receiver stages becomes non-linear thereby causing distortion and other non-linear effects that prevent proper operation of the receiver itself.

The receiver compression level is defined as the input power when the receiver gain is reduced by 1 dB (i.e. when the receiver output is 1 dB into compression) as shown in Figure 2.

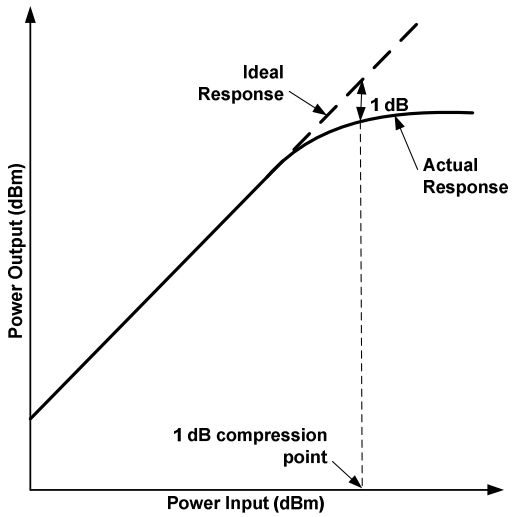

Figure 2: Receiver 1 dB compression point

4.2.2.3.2 Limits

The Receiver Compression level (RCL) of the radar shall be at least -40 dBm:

$$RCL \geq -40 \text{ dBm} \quad (1)$$

4.2.2.3.3 Conformance

The conformance tests are specified in clause 5.2.2.2.

4.2.2.4 Receiver selectivity

4.2.2.4.1 Definition

The radar receiver selectivity is a measure of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals.

NOTE 1: The definition of selectivity is taken from Recommendation ITU-R SM.332-4 [i.8].

NOTE 2: Radar receiver selectivity refers to effects measured within the linear range of the receiver to transpose at its output the radar desired signal and to reject unwanted perturbing signals located outside the B_{-40} bandwidth.

NOTE 3: Unwanted signals inside the B_{-40} bandwidth are not considered for the receiver selectivity since they fall into the desired frequency range for the reception of wanted signals.

NOTE 4: The selectivity curve is the rejection of an unwanted CW signal for a range of frequencies.

4.2.2.4.2 Limit

The required input selectivity characteristic of the radar receiver is based on the calculated B_{-40} bandwidth (see Annex B).

The selectivity of a receiver tuned at an operating frequency *fo* shall be verified in the following frequency ranges:

$$fo - B_{-40} / 2 - 300 \text{ MHz} \leq f \leq fo - B_{-40} / 2 \quad (2)$$

$$fo + B_{-40} / 2 \leq f \leq fo + B_{-40} / 2 + 300 \text{ MHz} \quad (3)$$

If the image frequencies, as calculated in formula (5) below, are not covered by the frequency ranges defined above, the selectivity measurement shall be done also on the following frequency range:

$$f_{image} - B_{-40} / 2 \leq f \leq f_{image} + B_{-40} / 2 \quad (4)$$

to cover the image frequencies susceptibility.

$$f_{Image} = \begin{cases} f_o + 2 \times f_{IF}, if\ f_{LO} > f_o \\ f_o - 2 \times f_{IF}, if\ f_{LO} < f_o \end{cases} \quad (5)$$

The receiver selectivity mask shall be as defined in Table 8. An example is shown in Figure 4.

Table 8: Receiver selectivity mask

Frequency offset relative to *fo* by multiple of the B_{-40} bandwidth	Relative output level in dB referenced to in-band level	Slope dB/decade
0 to 0,5	0	
0,5	-40	-∞
0,5 to 1,6	-40 to -60	-40
1,6 to ∞	-60	0

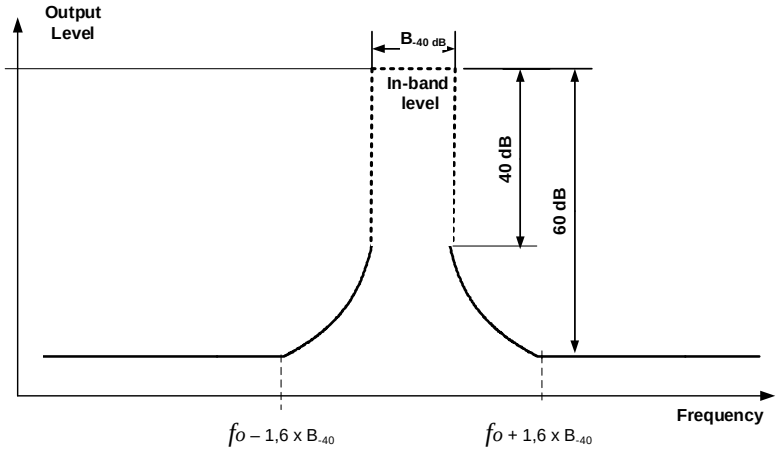

Figure 3: Example of receiver selectivity mask (not to scale)

4.2.2.4.3 Conformance

The conformance tests are specified in clause 5.2.2.3.

4.2.2.5 Receiver non-linearity

4.2.2.5.1 Definition

Receiver non-linearity is a direct correlation of radio-frequency intermodulation, caused by the non-linearity response of the receiver, when two signals at frequencies f_1 and f_2 are injected as follows:

$$f_{rx} = 2 \times f_1 - f_2 \quad (6)$$

NOTE 1: This equation (6) corresponds to the 3rd order IMD.

NOTE 2: For the radars within the scope of the present document, only the third order IMD products are of primary interest.

4.2.2.5.2 Limits

Given two unwanted signals at frequencies f_1 = 1 400 MHz and f_2 = 1 500 MHz with a power level of RCL and the equipment receiver tuned at a frequency f_{rx} = 1 300 MHz, the receiver IF output power shall not exceed the value measured when a signal at f_{rx} = 1 300 MHz with a level of RCL is applied.

4.2.2.5.3 Conformance

The conformance tests are specified in clause 5.2.2.4.

5 Testing for compliance with technical requirements

5.1 Environmental conditions for testing

5.1.1 General requirements

Tests defined in the present document shall be carried out at representative points within the boundary limits of the operational environmental profile defined by its intended use, which, as a minimum, shall be that specified in the test conditions contained in the present document.

Where technical performance varies subject to environmental conditions, tests shall be carried out under a sufficient variety of environmental conditions as specified in the present document to give confidence of compliance for the affected technical requirements.

Unless otherwise specified, all the tests shall be performed at the minimum and maximum operating frequency of the radar.

5.1.2 Test conditions

5.1.2.1 Thermal Balance

Before measurements are made, the EUT shall have reached thermal balance in the test chamber. The thermal balance shall be checked by temperature measurements. When the EUT temperature is not changing more than 1 K per minute thermal balance is reached.

5.1.2.2 Environmental Test Conditions

5.1.2.2.1 Temperature and humidity

The equipment covered by the present document is intended to be operated in a temperature-controlled location only. The temperature and humidity conditions for tests shall be a combination of temperature and humidity as defined in ETSI EN 300 019-1-3 [1], clause 4.1, Figure 1 (Climatogram for class 3.1) and Table 1 (class 3.1, normal).

The actual values during the tests shall be recorded in the test report.

5.1.2.2.2 Power supply (AC only)

The test voltage for the EUT shall be the nominal mains voltage -10 % to +10 %. The frequency of the test voltage shall be 50 Hz and the maximum frequency offset shall be 1 Hz.

The actual values during the tests shall be recorded in the test report.

5.2 Radio test suites

5.2.1 Transmitter test specification

5.2.1.1 Occupied bandwidth

The measurement setup shall be as described in Annex C.

The radar shall be operated with the shortest pulse length available to the user.

The occupied bandwidth shall be measured using a spectrum analyser. The total power shall be measured in a frequency range from 100 MHz below to 100 MHz above the peak value by adding up each measurement. The lower boundary of the occupied bandwidth is found by adding up each measurement, starting 100 MHz below the peak value upwards, as long as the sum remains below 0,5 % of the total power. The upper boundary is found by adding each measurement, starting from 100 MHz above the peak value downwards, as long as the sum remains below 0,5 % of the total power. The sweep time SWT shall be set to 10 s.

The results obtained shall not exceed the limits described in clause 4.2.1.1.2 in order to prove compliance with the requirement.

5.2.1.2 Transmitter Peak Power

The measurement setup shall be as described in Annex D.

The radar shall be operated with the shortest pulse length available to the user.

The radar shall be setup to provide constant maximum output power independently from the azimuth.

The measured spectrum peak power shall be corrected as follows:

- for fixed frequency, non pulse-coded radars:

$$PEP = P_{meas} + 20\,x\log\left(\frac{B_{pep}}{B_m}\right) \quad \text{if } Bpep > Bm \tag{7}$$

where:

- P_{meas} is the measured spectrum peak power.
- B_m is the measurement bandwidth.
- B_{pep} = one divided by the radar pulse length.

NOTE 1: If $B_{pep} \leq B_m$ no correction is required.

- for frequency modulated (FM) or chirped radars:

$$PEP = P_{meas} + 10\,x\log\left(\frac{B_C}{B_m^2\,x\,t}\right) \quad \text{if } \frac{B_C}{B_m^2\,x\,t} < 1 \tag{8}$$

where:

- P_{meas} is the measured spectrum peak power.
- B_m is the measurement bandwidth.
- t is the radar pulse length.

- B_c is the chirp bandwidth.

NOTE 2: If $\frac{B_C}{B_m^2 \, x \, t} \geq 1$ no correction is required.

NOTE 3: The chirp bandwidth is radar-specific and is defined in the radar user's documentation.

NOTE 4: These corrections are defined in Recommendation ITU-R M.1177-4 [i.11], clause 3.2.2.

The results obtained shall not exceed the limits specified in clause 4.2.1.2.2 in order to prove compliance with the requirement.

5.2.1.3 Measured B_{-40} bandwidth

The measurement setup shall be as described in Annex C.

B_{-40} bandwidth shall be measured for each type of pulse described in the EUT user's documentation.

The bandwidth of the emissions 40 dB below the peak power (PEP) measured as specified in clause 5.2.1.2 shall be measured.

The results obtained shall not exceed the limits specified in clause 4.2.1.3.2 in order to prove compliance with the requirement.

5.2.1.4 Unwanted emissions

5.2.1.4.1 Out-of-band Emissions

The measurement set-up shall be as described in Annex D.

The Out-of-Band power emissions of the transmitter shall be measured at the output port of the transceiver tuned at the operating frequency of the radar.

For multi frequency radar, the test shall be executed for the lowest and highest selectable operating frequencies.

Measurement below 0,7 times the waveguide COF of the EUT embedded piece of waveguide are not required as stated in ERC Recommendation 74-01 [i.10] due to the fact that power transfer below this frequency is negligible and therefore measurements will not provide valid results.

The OoB power emission shall be measured in the frequency bands given in Table 2 for single frequency radars and Table 4 for multi frequency radars where B_{-40} shall be calculated by the formula in Annex E. The reference bandwidth shall be as in Table 9, where the pulse length is measured as in clause 5.2.1.5.

Table 9: Reference Bandwidths for measurements of unwanted emissions

For fixed frequency, non pulse-coded radars	For frequency modulated (FM) or chirped radars
Min (1/t, 1 MHz)	Min ($\sqrt{\frac{B_C}{t}}$, 1 MHz), where the chirp bandwidth B_C is in MHz and the pulse length t is in seconds
NOTE 1: The reference bandwidth is defined in Recommendation ITU-R M.1177-4 [i.11], Annex 1, section 2. NOTE 2: The pulse length is measured as in clause 5.2.1.5. NOTE 3: The chirp bandwidth for each type of pulse B_c is defined in the EUT user's documentation.	

No correction to the measurement are required since both the peak of the spectrum and the data points are measured using the same measurement bandwidth B_m in accordance with section 3.1 of Annex 1 of Recommendation ITU-R M.1177-4 [i.11].

The OoB emissions shall be measured for each type of pulse as described in the EUT user's documentation. The results obtained shall not exceed the limits specified in clause 4.2.1.4.2.2 (Table 1 for single frequency radars and Table 3 for multi frequency radars) in order to prove compliance with the requirement.

The measurements of Out-of-Band emissions shall be noted in the test report.

5.2.1.4.2 Emissions in the spurious domain

The measurement set-up shall be as described in Annex F.

For the determination of the spurious emissions limits specified in clause 4.2.1.4.3, the measured spectrum peak power shall be corrected as specified in clause 5.2.1.2.

The spurious emissions shall be measured in frequency ranges defined in Table 6 and with a reference bandwidth as defined in Table 9. If the measurement bandwidth is different from the reference bandwidth, the following correction shall be applied:

$$Spurious\ level, B_{ref} = Spurious\ level\ (measured\ in\ B_m) + 10\ x \log\left(\frac{B_{ref}}{B_m}\right) \quad (9)$$

NOTE: This correction factor is defined in Recommendation ITU-R M.1177-4 [i.11], clause 3.2.1.

The spurious emissions shall be measured for each type of pulse as described in the EUT user's documentation. The result obtained shall not exceed the limits specified in clause 4.2.1.4.3 in order to prove compliance with the requirement.

The measurements of the spurious emissions shall be noted in the test report.

5.2.1.4.3 Stand-by mode emissions

The measurement set-up shall be as described in Annex F.

The radar system shall be placed in stand-by mode and the emissions shall be measured at the output port of the transceiver tuned at the operating frequency of the radar.

All measurements of stand-by mode emissions shall be made with a reference bandwidth as indicated in Table 10.

If the measurement bandwidth is different from the reference bandwidth, the correction factor defined in clause 5.2.1.4.2 shall be applied.

Table 10: Frequency range for measurement and Reference Bandwidths

Frequency Range	Reference Bandwidth
fco x 0,7 MHz (see note 1) ≤ f ≤ 1 GHz	100 kHz
1 GHz < f ≤ 5th harmonic of the operating frequency f_o + Δ (see note 2)	1 MHz
NOTE 1: The lower frequency corresponds to the COF of the EUT embedded piece of waveguide times 0,7 as described in ERC Recommendation 74-01 [i.10]. Measurements below this frequency are not required due to the fact that power transfer below this frequency is negligible and therefore measurements will not provide sound and repeatable results.	
NOTE 2: The upper band measurement limit corresponds to the 5th harmonic of the highest of the operating frequencies as defined in ERC Recommendation 74-01 [i.10], Table 1 plus a margin Δ corresponding to the maximum Occupied bandwidth d defined in clause 4.2.1.1.2 and calculated according to the following formula: $\Delta = 5 \times fo \times \left(d/10^6\right)$ For example with *fo* = 1 400 MHz, the margin Δ (in MHz) will be: 5 x 1 400 x 500 x 10^{-6} = 3,5 MHz and therefore the measurement limit will extend up to 7 003,5 MHz.	

The result obtained shall not exceed the limits specified in clause 4.2.1.4.4 in order to prove compliance with the requirement.

The measurements of stand-by mode emissions shall be noted in the test report.

5.2.1.5 Pulse Length

The measurement setup shall be as described in Annex G.

The pulse length t is measured at the -6 dB points (50 % voltage points) of a radar pulse according to Figure 4.

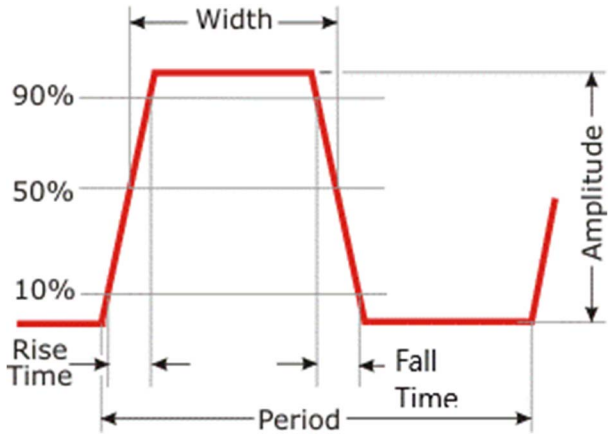

Figure 4: Definition of pulse parameter

The measurement shall be performed with combined vertical and horizontal marker lines of the oscilloscope. In a first step, the peak voltage of the pulse is measured by setting a horizontal line to the 100 % amplitude as shown in Figure 4. The position of this line is then moved to 50 % of this peak voltage. A vertical line 1 is set to the interception point of the horizontal line with the rising edge and another vertical line 2 is set to the interception point of the horizontal line with the falling edge of the pulse. The difference of the reading of the time value of vertical line 2 and 1 gives the pulse length ("width" in Figure 4).

NOTE: The definition of pulse length is taken from Appendix 3 to Annex 1 of Recommendation ITU-R M.1177-4 [i.11].

The result obtained shall be noted in the test report.

5.2.1.6 Pulse Rise Time

The measurement setup shall be as described in Annex G.

The rise time tr is measured between the -0,9 dB and -20 dB (90 % - 10 % voltage points) on a pulse's leading edge according to Figure 4.

The measurement shall be performed with combined vertical and horizontal lines. In a first step, the peak voltage of the pulse is measured by setting a horizontal line to the 100 % amplitude as shown in Figure 4. The position of this horizontal line 1 is then moved to 90 % of this peak voltage. Another horizontal line 2 is set to 10 % of this peak voltage. A vertical line 1 is set to the interception point of the horizontal line 1 with the rising edge and another vertical line 2 is set to the interception point of the horizontal line 2 with the rising edge of the pulse. The difference of the reading of the time value of vertical line 2 and 1 gives the pulse rise time.

NOTE: The definition of pulse rise time is taken from Appendix 3 to Annex 1 of Recommendation ITU-R M.1177-4 [i.11].

The result obtained shall be noted in the test report.

5.2.1.7 Pulse Fall Time

The measurement setup shall be as described in Annex G.

The fall time tf is measured between the -20 dB and -0,9 dB (10 % - 90 % voltage points) on a pulse's back edge according to Figure 4.

The measurement shall be performed with combined vertical and horizontal lines. In a first step, the peak voltage of the pulse is measured by setting a horizontal line to the 100 % amplitude as shown in Figure 4. The position of this horizontal line 1 is then moved to 90 % of this peak voltage. Another horizontal line 2 is set to 10 % of this peak voltage. A vertical line 1 is set to the interception point of the horizontal line 1 with the falling edge and another vertical line 2 is set to the interception point of the horizontal line 2 with the falling edge of the pulse. The difference of the reading of the time value of vertical line 2 and 1 gives the pulse fall time.

NOTE: The definition of pulse fall time is taken from Appendix 3 to Annex 1 of Recommendation ITU-R M.1177-4 [i.11].

The result obtained shall be noted in the test report.

5.2.2 Receiver test specification

5.2.2.1 System Noise Figure

The measurement set-up shall be as described in Annex H.

The Noise Figure shall be measured at the input port of the receiver when tuned to the operating frequency of the radar.

A noise source is connected to the radar receiver input port.

The System Noise Figure is measured along the complete receiving signal chain but excluding the antenna. It shall be measured using a calibrated noise source connected to a Noise Figure meter. The Y-factor method described in Annex H shall be used.

The ENR of the calibrated noise source shall be known and noted in the test report.

The results obtained shall not exceed the limits specified in clause 4.2.2.2.2 in order to prove compliance with the requirement.

The frequency/frequencies at which the test is performed shall be documented in the test report.

The Noise Figure value(s) shall be noted in the test report.

5.2.2.2 Receiver Compression Level

5.2.2.2.1 General setup

The measurement set-up shall be as described in Annex I.

5.2.2.2.2 Test Signal

A CW test signal tuned at the operating frequency shall be used.

5.2.2.2.3 Measurement Procedure

The radar transmitter shall be placed in stand-by mode.

The measurement steps shall be as follows:

a) The test signal with a level such that the EUT is in its linear region is injected into the radar receiver input port.

b) The input level is increased in steps of 1 dB and the level of the output of the receiver (see Annex I) is measured. The 1 dB compression point is reached when the level of the signal at the output of the receiver is 1 dB lower than the expected value if the receiver operated in its linear.

c) The level of the input signal corresponding to the 1 dB compression is noted.

The result obtained shall not exceed the limits specified in clause 4.2.2.3.2 in order to prove compliance with the requirement.

For multi frequency radar the measurement shall be executed for the lowest and highest selectable operating frequency.

The frequency/frequencies at which the test is performed shall be documented in the test report.

5.2.2.3 Receiver selectivity

5.2.2.3.1 General setup

The measurement setup shall be as described in Annex J.

In order to determine if the receiver selectivity follows the required mask, a disturbing test signal level is applied at the radar receiver input port and the residual level of test signal is measured at the output of the radar receiver.

5.2.2.3.2 Disturbing Test Signals

The disturbing signal shall be a CW signal. The input level of the disturbing signal shall be 4 dB below the receiver compression level measured in clause 5.2.2.2.3 such that the receiver will not be saturated. The value of this level shall be noted (Ref_In).

A selectivity curve shall be built up incrementally using a disturbing signal which steps through the entire frequency ranges described in clause 4.2.2.4.2.

The discrete frequency steps of the disturbing signal shall not exceed half of the bandwidth of the matched filter, or 1 MHz, whichever is smaller.

5.2.2.3.3 Measurement Procedure

Selectivity curves shall be built for the receiver tuned at the minimum and the maximum selectable operating frequencies.

The receiver operating frequency and measurement parameters shall be documented in the test report for each measured selectivity curves. The measurement steps shall be as follows:

a) Inject at the receiver's input the disturbing CW signal with a Ref_In level and tuned at the operating frequency of the receiver. Then measure the level of the CW signal at the receiver's output, which shall be noted as the output reference level (Ref_Out).

b) For each frequency steps over the frequency range, inject the disturbing CW signal and then measure the remaining level of the CW signal at the receiver's output. This shall be noted as the frequency dependent rejected levels P_Out(f).

c) The difference (in dB) of P_Out(f) to the output reference level Ref_Out shall be recorded as the measured selectivity curve over the frequency range, and shall be compared to the selectivity mask calculated according to the limits described in clause 4.2.2.4.2. The relevant diagram shall be reported in the test report.

The results obtained shall not exceed the limits specified in clause 4.2.2.4.2 in order to prove compliance with the requirement.

5.2.2.4 Receiver non-linearity

The measurement setup shall be as described in Annex K.

The receiver shall be tuned to f_{rx}, see Table 11.

The measurement steps shall be as follows:

a) RF signal generator 1 shall feed a CW signal with a frequency of f_{rx} and a power level of RCL into the EUT (see Table 11). The output of RF signal generator 2 shall be disabled. The output power level at the receiver's IF output port shall be noted (Ref_Limit).

Table 11: Receiver Intermodulation test signals

Test signal	Frequency	Power level
f_{rx}	1 300 MHz	RCL
f_1	1 400 MHz	RCL
f_2	1 500 MHz	RCL

b) RF signal generator 1 shall output a CW signal with a frequency of f_1 and a power level of RCL, RF signal generator 2 shall output a CW signal with a frequency of f_2 and a power level of RCL (see Table 11). The output power level at the receiver's IF output port shall be noted (Ref_Intermod).

NOTE: The RCL is measured in clause 5.2.2.2.

The insertion losses of all components in the test setup shall be taken into account.

The results obtained shall not exceed the limits specified in clause 4.2.2.5.2 in order to prove compliance with the requirement.

Annex A (informative): Relationship between the present document and the essential requirements of Directive 2014/53/EU

The present document has been prepared under the Commission's standardisation request C (2015) 5376 final [i.2] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU 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 [i.1].

Once the present document is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of the present document given in Table A.1 confers, within the limits of the scope of the present document, a presumption of conformity with the corresponding essential requirements of that Directive, and associated EFTA regulations.

Table A.1: Relationship between the present document and the essential requirements of Directive 2014/53/EU

Harmonised Standard ETSI EN 303 364-1-1					
Requirement				Requirement Conditionality	
No	Description	Essential requirements of Directive	Clause(s) of the present document	U/C	Condition
1	Occupied bandwidth	3.2	4.2.1.1	U	
2	Transmitter Peak Power	3.2	4.2.1.2	U	
3	Measured B_{-40} bandwidth	3.2	4.2.1.3	U	
4	Out-of-band Emissions	3.2	4.2.1.4.2	U	
5	Emissions in the spurious domain	3.2	4.2.1.4.3	U	
6	Stand-by mode emissions	3.2	4.2.1.4.4	U	
7	System Noise Figure	3.2	4.2.2.2	U	
8	Receiver Compression Level	3.2	4.2.2.3	U	
9	Receiver selectivity	3.2	4.2.2.4	U	
10	Receiver non-linearity	3.2	4.2.2.5	U	

Key to columns:

Requirement:

No A unique identifier for one row of the table which may be used to identify a requirement.

Description A textual reference to the requirement.

Essential requirements of Directive

Identification of article(s) defining the requirement in the Directive.

Clause(s) of the present document

Identification of clause(s) defining the requirement in the present document unless another document is referenced explicitly.

Requirement Conditionality:

U/C Indicates whether the requirement is unconditionally applicable (U) or is conditional upon the manufacturer's claimed functionality of the equipment (C).

Condition Explains the conditions when the requirement is or is not applicable for a requirement which is classified "conditional".

Presumption of conformity stays valid only as long as a reference to the present document is maintained in the list published in the Official Journal of the European Union. Users of the present document should consult frequently the latest list published in the Official Journal of the European Union.

Other Union legislation may be applicable to the product(s) falling within the scope of the present document.

Annex B (normative): Calculation of the B_{-40} bandwidth

Annex 8 of Recommendation ITU-R SM.1541-7 [i.4] defines B_{-40} for various types of waveforms (e.g. pulsed radar signals). Assuming that:

- the radar is operating in the band 1 215 MHz to 1 400 MHz.

For primary non-FM pulse radars B_{-40} shall be determined as the lesser of:

$$B_{-40} = \frac{K}{\sqrt{t \times t_r}} \; or \; \frac{64}{t} \qquad \text{(B.1)}$$

Where:

- t is the pulse duration as measured in clause 5.2.1.5.
- t_r is the rise time as measured according to clause 5.2.1.6. When the fall time t_f of the radar measured according to clause 5.2.1.7 is less than the rise time t_r, it shall be used in place of the rise time in these equations.
- K depends on the peak transmitted power and it is equal to 7.6 since the output power is less than 100 kW: K= 7,6.

NOTE: For non-FM pulse PSR radars, typical values of a pulse length of t = 1µs and a rise time of t_r = 200 ns the formula above yields a -40 dB bandwidth value of 17 MHz.

For pulse FM radars, two formulas are specified in Recommendation ITU-R SM.1541-7 [i.4] for B_{-40}:

$$B_{-40} = 1{,}5\left\{B_C + \sqrt{\pi} \cdot [\ln(B_C \cdot \tau)]^{0{,}53} \cdot \left[Min\left(B_{rise}, B_{fall}, B_{rise\&fall}\right) + Max\left(B_{rise}, B_{fall}, B_{rise\&fall}\right)\right]\right\} \qquad \text{(B.2)}$$

and

$$B_{-40} = \frac{K}{\sqrt{t \cdot t_r}} + 2\left(B_C + \frac{A}{t_r}\right) \qquad \text{(B.3)}$$

Where:

- B_{-40} is the -40 dB bandwidth in Hz.
- B_C is the chirp bandwidth.
- $\tau = t + t_r + t_f$ (pulse length including rise & fall times).
- $B_{rise} = \frac{1}{\sqrt{\tau \cdot t_r}}$ to account for the rise time.
- $B_{fall} = \frac{1}{\sqrt{\tau \cdot t_f}}$ to account for the fall time.
- $B_{rise\&fall} = \frac{1}{\sqrt[3]{\tau \cdot t_r \cdot t_f}}$ to account for both the rise and fall times combination.
- t_r is the rise time in seconds.
- t_f is the fall time in seconds.
- K depends on the peak transmitted power and it is equal to 7,6 since the output power is less than 100 kW.
- A = 0,065, as specified in Recommendation ITU-R SM.1541-7 [i.4].

When the fall time t_f of the radar measured according to clause 5.2.1.7 is less than the rise time t_r, it shall be used in place of the rise time in these equations.

NOTE 1: The term A/t_r adjusts the value of B_{-40} to account for the influence of the rise time, which is substantial when the time-bandwidth product $B_c \cdot t$, is small or moderate and the rise time is short.

NOTE 2: For FM pulse PSR radars, typical values for a pulse length of t = 100 µs and a rise time of t_r = 200 ns the formulas above yield a -40 dB bandwidth value of ≈10 MHz depending on the modulation bandwidth.

1) Equation (B.2) is used when the following conditions are both met:

   - the product B_C Minimum (t_r, t_f) is greater than or equal to 0,10; and
   - the product of $B_C \tau$ or compression ratio is greater than 10.

2) If the conditions specified in 1) are not met, equation (B.3) shall be used.

Annex C (normative): Occupied bandwidth and B_{-40} measurement set-up

The method for the measurement of the occupied bandwidth and B_{-40} is shown in Figure C.1. A spectrum analyser shall be used and shall be connected to the coax test port of the EUT. An additional attenuator might be required to protect the spectrum analyser.

NOTE: A directional coupler is part of the EUT and has a coax exit for measurement purposes.

All components (cable, optional attenuator) shall be characterized across the full measurement band using calibrated test equipment (spectrum analyser). Characterization data shall be used to calibrate measurements using the measurement equipment. The insertion losses of all components in the test setup shall be taken into account.

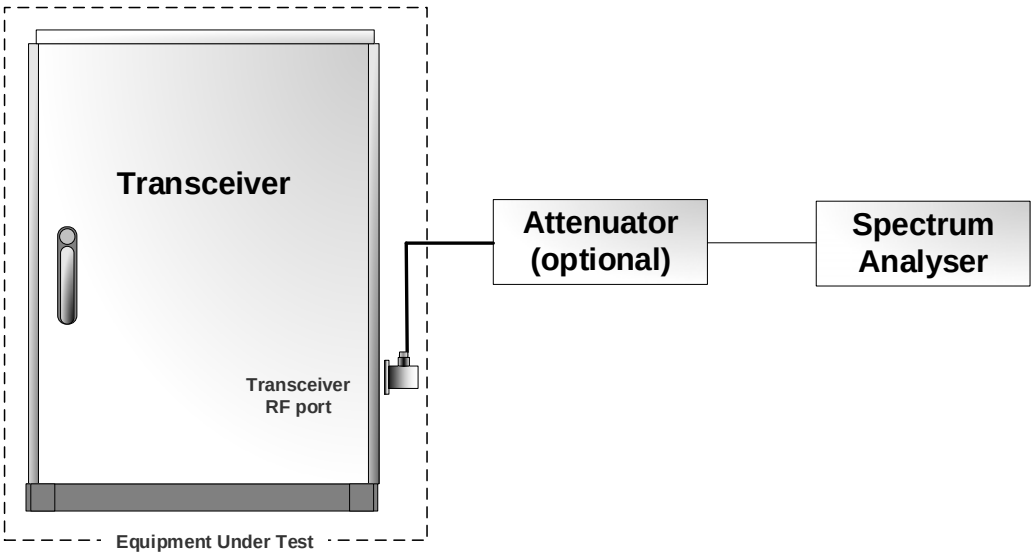

Figure C.1: Set-up for the measurement of the Occupied Bandwidth and B_{-40}

Annex D (normative): Transmitter Peak Power measurement set-up

The method for the measurement of the transmitter peak power Figure D.1. A peak power meter with a bandwidth exceeding 20 MHz shall be used and shall be connected to the coax test port of the EUT. An additional attenuator might be required to protect the peak power meter.

NOTE: A directional coupler is part of the EUT and has a coax exit for measurement purposes.

All components (cable, optional attenuator) shall be characterized across the full measurement band using calibrated test equipment (spectrum analyser). Characterization data shall be used to calibrate measurements using the measurement equipment. The insertion losses of all components in the test setup shall be taken into account.

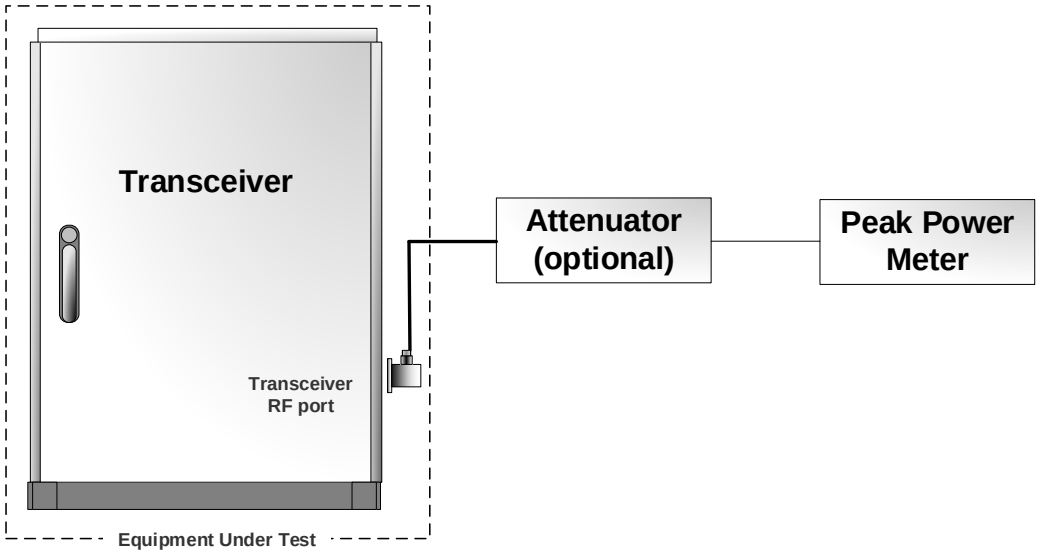

Figure D.1: Set-up for the measurement of Transmitter Pulse Power

Annex E (normative): Out-of-Band Emissions measurement set-up

The method for the measurement of Out-of-Band emissions is shown in Figure E.1.

A spectrum analyser shall be used. A notch filter is required if the attenuation of all the components is not sufficient to protect the spectrum analyser.

Due to the ambiguous propagation modes of the used L band waveguide for higher frequencies, smaller waveguides with linear tapers shall be used for the measurement of higher frequencies. Two different waveguides shall be connected through tapers. If the EUT uses a waveguide different from WG6, for instance an elliptical waveguide, a dedicated transition shall be required (e.g. an elliptical to WG6 waveguide transition). This, in turn, shall be connected to other tapers according to the frequency range to be measured.

NOTE: The equipment covered by the present document typically use a WR650/WG6/R14 waveguide for the connection to the antenna. WR650/WG6/R14 waveguides are defined in IEC 60153-2 [i.6].

Table E.1: Waveguide bands and associated waveguides

Frequency	Cut-off frequency	Waveguide designation		
		EIA	UK	R
1 150 MHz to 1 720 MHz	908 MHz	WR650	WG6	R14
1 720 MHz to 2 600 MHz	1 372 MHz	WR430	WG8	R22

The insertion losses of all components in the test setup shall be taken into account.

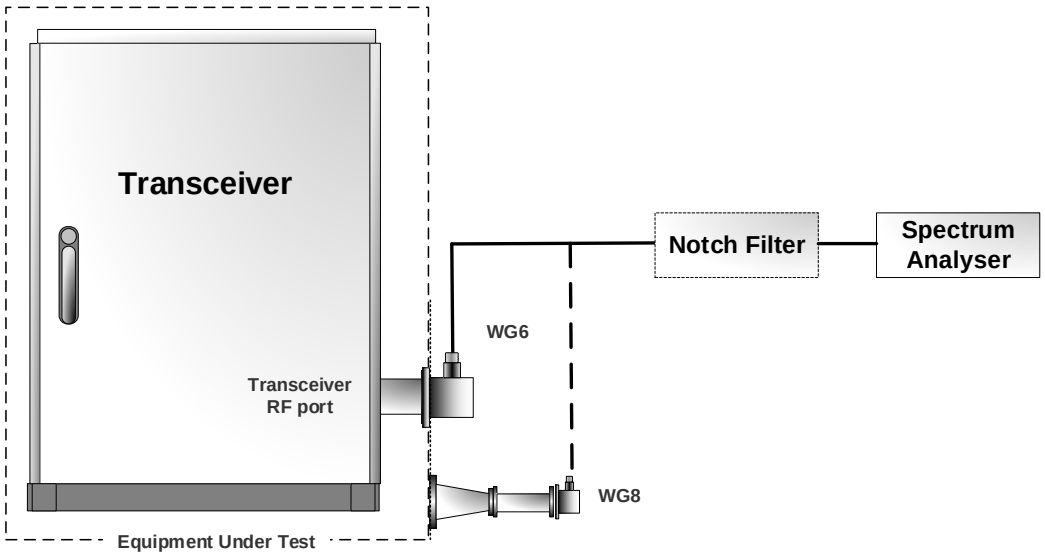

Figure E.1: Set-up for the measurement of Out-of-Band emissions

Annex F (normative): Spurious Emissions and Stand-By Mode emissions measurement set-up

The method for the measurement of Spurious and Stand-By mode emissions is shown in Figure F.1.

A spectrum analyser shall be used. For spurious emissions measurement, a notch filter is required if the attenuation of all the components is not sufficient to protect the spectrum analyser.

Due to the ambiguous propagation modes of the used L band waveguide for higher frequencies, smaller waveguides with linear tapers shall be used for the measurement of higher frequencies. For the spurious and standby mode emissions requiring measurements up to the 5th harmonics, the waveguides shown in Table F.1 shall be used. Two different waveguides shall be connected through tapers. If the EUT uses a waveguide different from WG6, for instance an elliptical waveguide, a dedicated transition shall be required (e.g. an elliptical to WG6 waveguide transition). This, in turn, shall be connected to other tapers according to the frequency range to be measured. As an example, assuming the EUT uses a WG6 waveguide, for the measurement of the frequency range 5,85 GHz up to the fifth harmonics (7 GHz for an operating frequency of 1,4 GHz) the following setup is used: a taper from WG6 to WG8 followed by a second taper from WG8 to WG10 followed by a third taper from WG10 to WG12 followed by a forth taper from WG12 to WG14, followed by at least 23 cm of WG14 waveguide terminated with a WG14 to coax transition.

NOTE: The equipment covered by the present document typically use a WR650/WG6/R14 waveguide for the connection to the antenna. WR650/WG6/R14 waveguides are defined in IEC 60153-2 [i.6].

Table F.1: Waveguide bands and associated waveguides

Frequency	Cut-off frequency	Waveguide designation		
		EIA	UK	R
1 150 MHz to 1 720 MHz	908 MHz	WR650	WG6	R14
1 720 MHz to 2 600 MHz	1 372 MHz	WR430	WG8	R22
2 600 MHz to 3 950 MHz	2 077 MHz	WR284	WG10	R32
3 950 MHz to 5 850 MHz	3 152 MHz	WR187	WG12	R48
5 850 MHz to 8 200 MHz	4 300 MHz	WR137	WG14	R70

The insertion losses of all components in the test setup shall be taken into account.

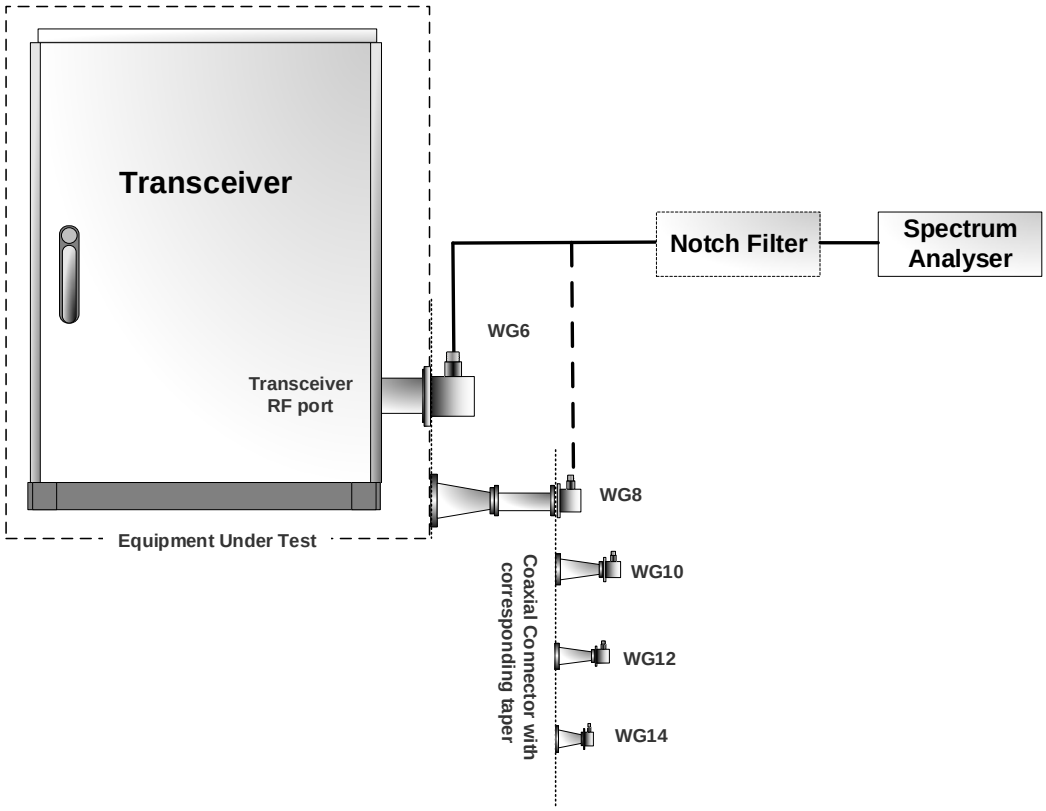

Figure F.1: Set-up for the measurement Spurious and Stand-By emissions domains

Annex G (normative): Pulse Length, Pulse Rise Time and Pulse Fall time measurement set-up

The method for the measurement of the pulse length, the pulse rise time and the pulse fall time is shown in Figure G.1.

The directional coupler is part of the EUT and has a coax exit for measurement purposes.

The directional coupler should have an attenuation within the whole frequency band 815 MHz to 1 800 MHz (at least 400 MHz outside the edges of the frequency range as specified in clause 1) for protecting the measurement equipment. If the attenuation of the directional coupler (coupling factor) is not sufficient to protect the RF oscilloscope, an additional attenuator shall be used.

The bandwidth of the oscilloscope shall be at least 500 MHz. The bandwidth shall be available in a single-shot (not repetitively sampled) mode, as the measurements are made on single radar pulses.

The input port of the oscilloscope shall be set to DC coupling and 50 Ω input impedance.

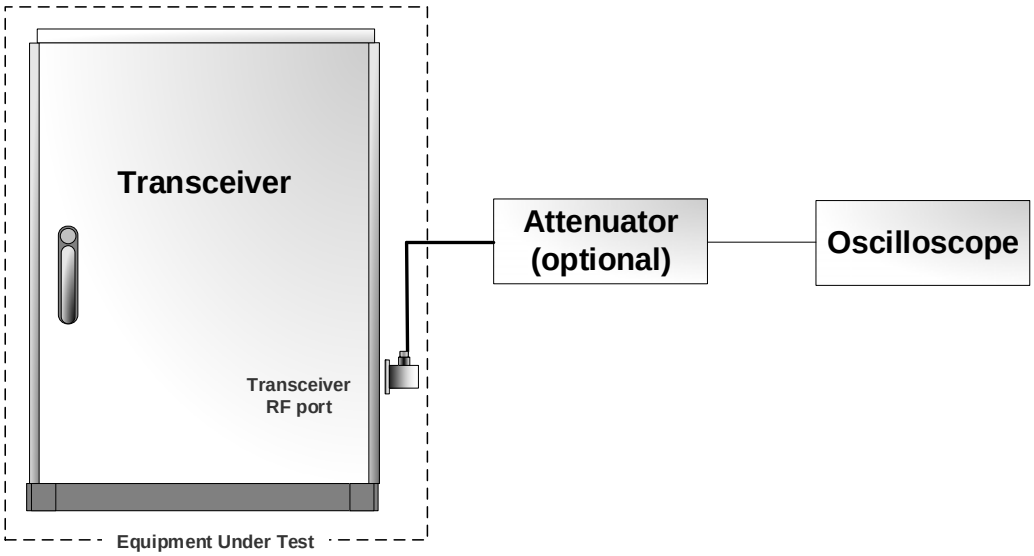

Figure G.1: Set-up for the measurement of the pulse length/rise time/fall time

Annex H (normative): System Noise Figure measurement set-up

The test set-up for the measurement of the Noise Figure measurement of the receiver shown in Figure H.1 shall be applied. All measurement equipment shall be calibrated.

For the measurement of the noise figure, the noise level shall be applied using a calibrated noise source connected to the receiver input and measurements shall be performed at the digital output of the receiver.

The transceiver shall be disabled during the test. The receiver shall be shielded against all inputs other than the noise source (e.g. by terminating circulator output towards the transmitter).

Measure the standard deviation of noise with noise source OFF and ON.

Compute the difference between noise source switch ON / OFF:

$$\Delta = \text{STD noise } ON \text{ [dB]} - \text{STD noise } OFF \text{ [dB]} \quad \text{(H.1)}$$

Where:

- "noise ON" is the output noise power with the noise source on.
- "noise OFF" is the output noise power with the noise source off.
- STD is the "standard deviation".

The noise figure is given by this formula:

$$\text{NF [dB]} = \text{ENR} - 10\log_{10}\left(10^{\left(\frac{\Delta}{10}\right)} - 1\right) \quad \text{(H.2)}$$

Where:

- ENR is the Excessive Noise Ratio of the used noise source.

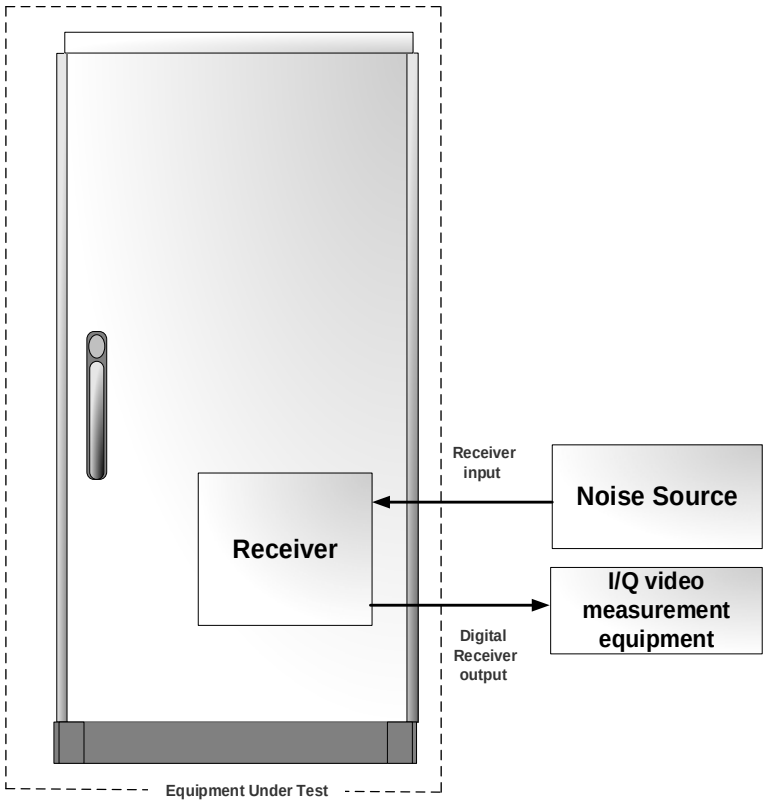

Figure H.1: Test set-up for Noise Figure measurement of the receiver

Annex I (normative): Compression level measurement set-up

The method for the measurements of the compression level of the receiver is shown in Figure I.1. A signal generator shall be connected to the coax test port of the EUT.

The radar transmitter shall be placed in stand-by mode.

An I/Q video module measurement tool shall be connected at the digital output port of the receiver.

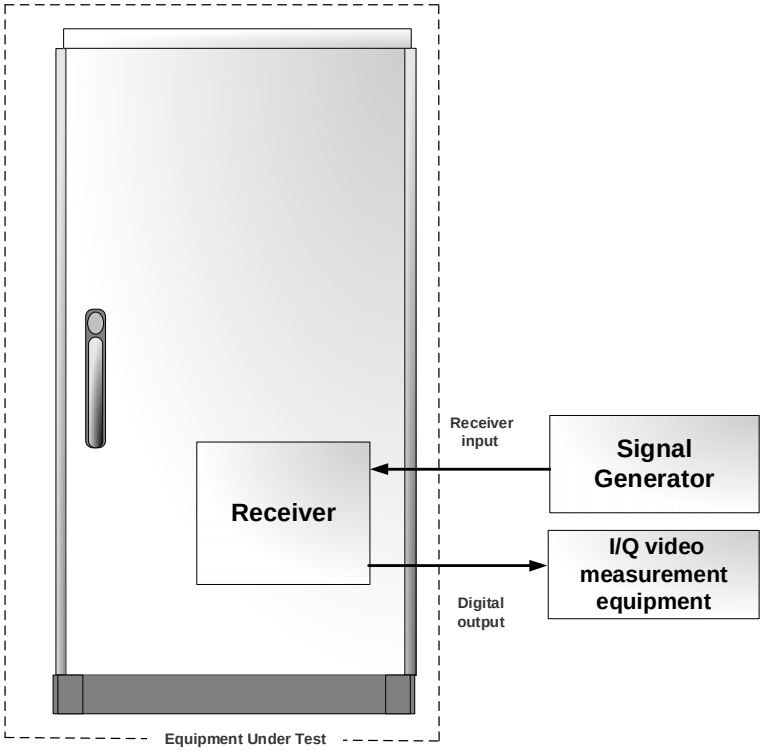

Figure I.1: Test set-up for compression level of the receiver

Annex J (normative): Selectivity measurement set-up

The method for the measurements of the selectivity of the receiver is shown in Figure J.1. A signal generator shall be connected to the coax test port of the EUT.

The radar transmitter shall be placed in stand-by mode.

An I/Q video module measurement tool shall be connected at the digital output port of the receiver.

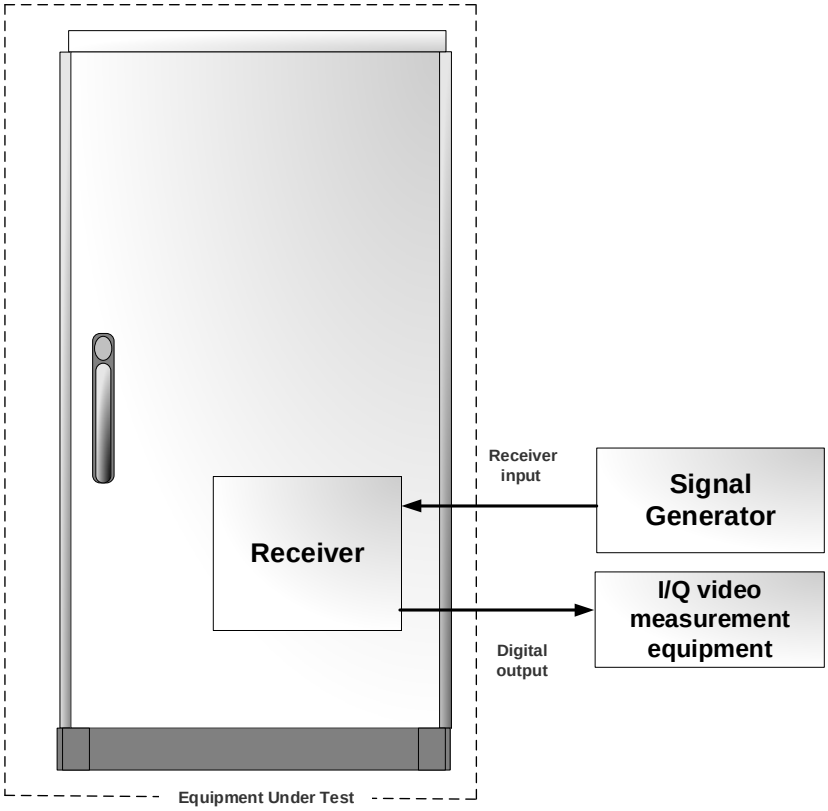

Figure J.1: Test set-up for selectivity measurements of the receiver

Annex K (normative): Receiver non-linearity measurement set-up

The setup for the measurements of the receiver radio-frequency intermodulation is shown in Figure K.1.

The radar receiver input is connected to the output port of a RF power combiner via a coax cable.

Each of the two input ports of the power combiner shall be connected to a RF signal generator by a coax cable. The digital radar output of the receiver shall be connected to a I/Q video module measurement tool.

The maximal operating frequency of the coax cable shall be at least 4 GHz. It shall have an impedance of 50 Ω.

The RF power combiner shall have a frequency range of at least up to 4 GHz. The amplitude unbalance shall be less than 0,5 dB.

The RF signal generator 1 and RF signal generator 2 shall have a frequency range of at least up to 4 GHz.

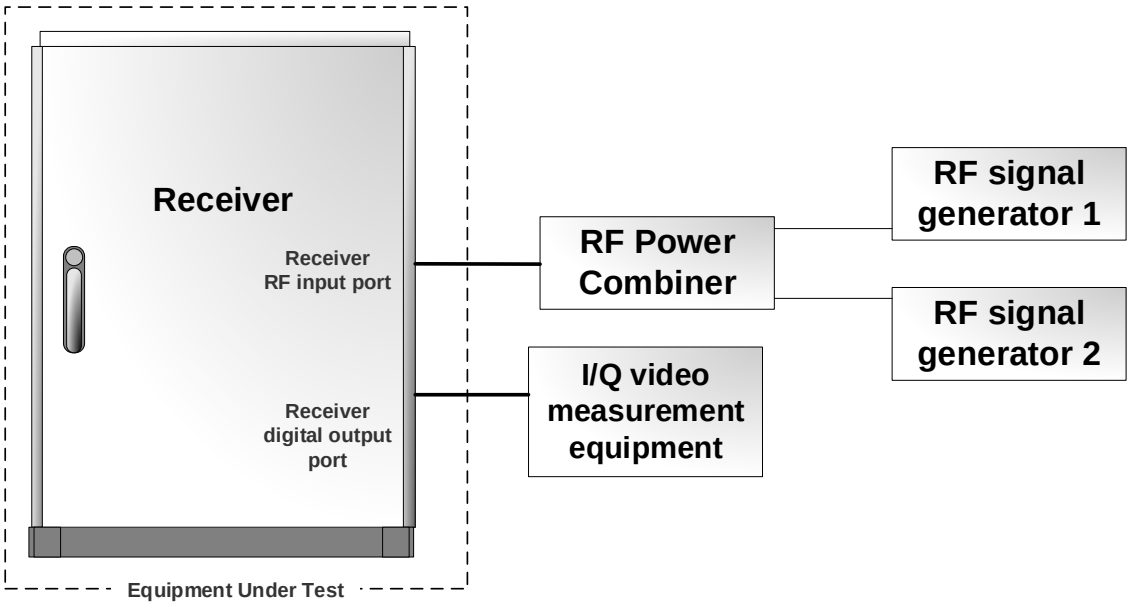

Figure K.1: Set-up for the measurement of the non-linearity of the receiver

Annex L (informative): Maximum Measurement Uncertainty

The measurements described in the present document are based on the following assumptions:

- the measured value related to the corresponding limit is used to decide whether an equipment meets the requirements of the present document;
- the value of the measurement uncertainty for the measurement of each parameter is included in the test report.

Table L.1 shows the recommended values for the maximum measurement uncertainty figures.

Table L.1: Maximum measurement uncertainty

Parameter	Uncertainty
Environment measurements	
Temperature	± 1 °C
Relative humidity	± 5 %
Mains Supply Voltage	± 2 %
Transmitter measurements	
Frequency	± 1 ppm
Transmitter power	± 1 dB
Out-of-Band emissions	± 3 dB
Spurious emissions	± 3 dB
Receiver measurements	
Noise Figure	± 0,5 dB
Receiver Selectivity	± 3 dB
Receiver Compression Level	± 1 dB

Annex M (informative): Checklist

This annex provides in Table M.1 a traceability of the technical parameters for article 3.2 of Directive 2014/53/EU [i.1] defined in ETSI EG 203 336 [i.5] with the technical requirements for conformance defined in clause 4 of the present document. If a technical parameter for article 3.2 of Directive 2014/53/EU [i.1] defined in ETSI EG 203 336 [i.5] has not been included in the present document, an explanation is provided. An explanation is also provided whenever a technical parameter defined in ETSI EG 203 336 [i.5] is covered by an alternative technical requirement.

Some technical parameters defined in ETSI EG 203 336 [i.5] are applicable only to communication systems and not to non-cooperative radar systems such as ATC radar systems. Non-cooperative radar systems are different from radiocommunication systems since they do not communicate with a known target with known properties. They continually scan for unknown targets of any nature and do not adjust receiver or transmitter parameters according to what they detect.

Table M.1: Checklist

Technical Parameters defined in ETSI EG 203 336 [i.5]	Clauses of the present document	Comments
Transmitter Parameters		
Transmit power limits and accuracy	4.2.1.2	
Transmitter Spectrum mask	4.2.1.4.1 4.2.1.4.2 4.2.1.4.3	
Transmitter frequency stability	4.2.1.1	As specified in appendix 2 of the Radio regulations [i.3], footnote 33: "*Where specific frequencies are not assigned to radar stations, the bandwidth occupied by the emissions of such stations shall be maintained wholly within the band allocated to the service and the indicated tolerance does not apply*". This technical requirement is therefore addressed by the occupied bandwidth specified in clause 4.2.1.1.
Transmitter Intermodulation attenuation	NA	At the transceiver output an RF circulator is used as indicated in the scope. This prevents an interfering signal entering from the antenna into the transmitter.
Transmitter unwanted emissions (OoB and spurious domains)	4.2.1.4.3	
Transmitter Time domain characteristics (e.g. the duty cycle, turn-on and turn-off, frequency hopping cycle, dynamic changes of modulation scheme and others)	NA	The radar in the scope of the present document does not utilize turn-on and turn-off, frequency hopping or dynamic changes of modulation scheme.
Transmitter Transients	4.2.1.4.3	The presence of transients in time domain has its equivalent in the frequency domain which is covered by the unwanted emissions parameter in active mode.
Receiver Parameters		
Receiver sensitivity	4.2.2.2	This parameter is not explicitly included since the radar output power is not varied as a result of the received signal strength of a single target. This means that a better sensitivity will only affect the probability of detection (and so the performances) and does not affect the efficient use of the radio spectrum. The receiver sensitivity is a fixed threshold above the noise floor, with noise floor being directly related to Noise Figure in the first stage of the receiver. This requirement is therefore addressed by the Noise Figure since there is a direct relationship with sensitivity.

Technical Parameters defined in ETSI EG 203 336 [i.5]	Clauses of the present document	Comments
Receiver co-channel rejection	NA	ATC radar systems in the same location cannot operate on the same operating frequency, as it would not be possible to meet radar operational performance with respect to stringent safety requirements on low rate of false alarms.
Adjacent band/channel selectivity	4.2.2.4	
Receiver blocking	4.2.2.3	Receiver blocking is addressed by the compression level of the receiver. The phenomena underlying the blocking effect is when a strong unwanted signal saturates the first amplifier stage. Consequently, due to the saturation regime, the radar receiver is not able to amplify the superposed wanted signal. ATC radar stations are located in controlled areas with adequate separation distance from nearby transmitters to avoid the blocking effect, taking into account requirements on selectivity of input filtering combined with high level compression parameters. In addition rotating radar reflector antennas are highly directive, narrow beamwidths such that the blocking phenomenon is transient (short in time) and protection mechanisms are used to prevent damage from transient high transmitted powers, such as those experienced in receivers when radars transmit.
Receiver spurious response rejection	4.2.2.4	This is covered by the selectivity test (image and intermediate frequencies are included).
Receiver radio-frequency intermodulation	4.2.2.5	This requirement is addressed by the receiver non-linearity.
Receiver unwanted emissions in the spurious domain	4.2.1.4.3 4.2.1.4.4	
Receiver dynamic range	4.2.2.2 4.2.2.3	The lower end of the receiver dynamic range is addressed by the Noise Figure. The upper end is addressed by the receiver compression level.
Reciprocal mixing	N/A	Interference characteristics are specified in terms of selectivity and/or blocking requirements, thus removing the need for this parameter to be explicitly included, as the effects of receiver selectivity and reciprocal mixing cannot be separated.

Annex N (informative): Bibliography

- Recommendation ITU-R SM.329-12 (2012): "Unwanted emissions in the spurious domain".
- Recommendation ITU-R SM.1539: "Variation of the boundary between the out-of-band and spurious domains required for the application of Recommendations ITU-R SM.1541 and ITU-R SM.329".

History

Document history			
V1.0.0	March 2025	SRdAP process	EV 20250610: 2025-03-12 to 2025-06-10