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Harmonised Standard for access to radio spectrum;

Part 2: Air Traffic Control (ATC) Primary Surveillance Radar Sensors operating in 2700-3100 MHz frequency band (S band)

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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 standards EN Approval Procedure.

The present document has been prepared under the Commission's standardisation request Commission Implementing Decision 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 2 of a multi-part deliverable covering ground based ATC Primary Surveillance Radars (PSR), as identified below:

Part 1: “Harmonized Standard for access to radio spectrum for Air Traffic Control (ATC) Primary Surveillance Radar sensors operating in 1215-1400 MHz frequency band (L band)”

**Part 2: "Harmonized Standard for access to radio spectrum for Air Traffic Control (ATC) Primary Surveillance Radar sensors operating in 2700-3100 MHz frequency band (S band)".**

Part 3: “Harmonized Standard for access to radio spectrum for Air Traffic Control (ATC) Primary Surveillance Radar sensors operating in 8500-10000 MHz frequency band (X band)”

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| --- | --- |
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# 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](https://portal.etsi.org/Services/editHelp!/Howtostart/ETSIDraftingRules.aspx) (Verbal forms for the expression of provisions).

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# Scope

The present document specifies technical characteristics and methods of measurements for ground based monostatic ATC primary surveillance radars operating in the 2700 MHz to 3100 MHz frequency range. Phased array ATC primary surveillance radars are not covered by the present document.

NOTE: 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.

# References

## Normative references

References are specific, identified by date of publication and/or edition number or version number. Only the cited version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <https://docbox.etsi.org/Reference/>.

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] ITU Radio Regulations (2016).

[2] ECC/Recommendation (02)05 (2012): "Unwanted emissions".

[3] ERC/Recommendation 74-01 (2011): "Unwanted emissions in the spurious domain".

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

## 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-R Recommendation SM.1541-6 (2015) "Unwanted emissions in the out-of-band domain"

[i.4] ITU-R Recommendation SM.329-12 (2012) "Unwanted emissions in the spurious domain"

[i.5] ETSI TR 100 028 (all parts) (V1.4.1): “Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics”.

[i.6] ETSI TR 100 028-2 (V1.4.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics; Part 2".

[i.7] IEC 60 153-2 ed. 2.0 1974] (ref in 6.3.5) “Hollow metallic waveguides, Part 2: Relevant specifications for ordinary rectangular waveguides”, (Cut-off frequency).

[i.8] ITU-R Recommendation SM.331-4 (1978) "Noise and sensitivity of receivers"

[i.9] Merrill I. Skolnik: "Radar Handbook", 2nd Edition, McGraw Hill publications (1990).

# Definitions, symbols and abbreviations

## Definitions

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

**Active State:**  State which produces the authorised emission.

**Idle / Standby State:** State where the transmitter is available for traffic, but is not in the active state.

**Allocated frequency band:** frequency span that regionally or nationally is allocated to one or more radio services on a primary or secondary basis.

NOTE: A table of national frequency allocations is normally available from the national radio regulatory authority for each country.

**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: This definition is taken from ITU Radio Regulation [1]

**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: This definition is taken from ITU Radio Regulation [1]

NOTE 2: 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%

**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.

**Operating channel (OC):** frequency range in which the transmission from the EUT occurs, or in which the EUT is intended to receive transmissions

**Operating frequency:** centre of the OC

**Frequency tolerance:** maximum permissible departure by the centre frequency of the frequency band occupied by an emission from the assigned frequency or, by the characteristic frequency of an emission from the reference frequency. The frequency tolerance is expressed in parts permillion or in Hertz.

NOTE: This definition is taken from the ITU Radio Regulations [1]

**Peak envelope power:** 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 Regulation [1]

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

**Pulse duration:** 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)

**Minimum Detectable Signal (MDS):** measure of the lowest detectable signal amplitude for a given signal type for a given radar.

NOTE: For radars, a processing gain can be associated with a received signal. This processing gain has the effect of lowering the MDS level in comparison to a MDS which would be based only on noise temperature.

**System Noise Factor (***NFsys***):** The System Noise Factor is the ratio between the signal-to thermal noise ratio at the input of a system and its value at the output of the system. It is defined as follows: 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 1: This definition is taken from ITU-R Radio Recommendation ITU-R SM.331-4 p.2.

NOTE 2: The System Noise Figure is the Noise Factor expressed in decibels.

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

## Symbols

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

*B-40* -40 dB bandwidth

*BC* Chirp bandwidth

*BN* Necessary bandwidth

*Bres* 3 dB resolution bandwidth of transceiver

dB/decdB per decade

*dBpp* dB with respect to peak power

*Dno spur* Detectability Factor

*FAR* False Alarm Rate

*k* Boltzmann's constant

*LO* Local Oscillator frequency

*MDS* Minimum Detectable Signal

*NFsys* Noise Factor of the system

*PD* Probability of detection

*PEP* Peak Envelope Power

*Pt* Pulse power of transmission

*RF* Radio Frequency

*S/N* Signal-to-Noise ratio

*t* Time

*TC* Pulse length (of individual chirp waveforms) in seconds

*tp* Pulse duration

*tr* Pulse rise time

*T0* Temperature in Kelvin

*λ* Wavelength

## Abbreviations

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

AC Alternating Current

ADC Analog to Digital Converter

CW Continuous Wave

EIRP Effective Isotropically Radiated Power

ESASSP EUROCONTROL Specification for ATM Surveillance System Performance

EUT Equipment Under Test

FM-CW Frequency Modulated Continuous Wave

ICAO International Civil Aviation Organization

ITU International Telecommunication Union

LNA Low Noise Amplifier

MDI Minimum Detectable Interference level

MDS Minimum Detectable Signal

OoB Out-of-Band

PEP Peak Envelope Power

ppm parts per million

PSR Primary Surveillance Radar

RF Radio Frequency

WG Waveguide

# Technical requirements specifications

## Environmental profile

The technical requirements of the present document apply under the environmental profile for operation of the equipment, which shall be declared by the manufacturer, 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 which are identified as applicable in annex A at all times when operating within the boundary limits of the declared operational environmental profile.

## Conformance Requirements

### Transmitter requirements

#### Frequency tolerance

##### Definition

The frequency tolerance is the maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency or, by the characteristic frequency of an emission from the reference frequency.

NOTE: this definition is taken from the ITU Radio Regulations [1]

##### Limits

The maximum permissible absolute value of frequency tolerance shall be of 1250 ppm as specified in Appendix 2 of the ITU Radio Regulations [1].

##### Conformance

The conformance tests are specified in clause 5.4.1.1.

#### Measured B-40 bandwidth

##### Definition

The measured -40 bandwidth (B-40) is the measured bandwidth of the emissions 40 dB below the measured PEP.

##### Limits

The measured B-40 bandwidth of the signal shall be contained completely within the frequency range 2 700 MHz to 3 100 MHz in all operating modes.

In case of multiple-carrier frequencies, all measured B-40 emissions shall be contained completely within the frequency range 2 700 MHz to 3 100 MHz.

##### Conformance

The conformance tests are specified in clause 5.4.1.3.

#### Unwanted emissions

##### Unwanted emissions general requirements

The Out-of-Band emission limits and the spurious emission limits are defined based on the calculated B-40 bandwidth (see Annex E).

For radars with multiple pulse waveforms, the *B-40* bandwidth shall be calculated for each individual pulse and the largest *B-40* bandwidth shall be used.

For radars with multiple carrier frequencies, the overall emission mask is obtained by superimposing the emission masks of each individual carrier frequency. The overall emission mask is then the envelope from all masks. An example can be seen in figure 1.



Figure 1: Example of superimposed (combined) mask from two carrier frequencies

For radars with multiple carrier frequencies, if two or more B-40 overlap, the emissions in the OoB and spurious domains shall be measured taking into account the overall B-40. Whenever the PEP related to 2 adjacent carrier frequencies are different, the combined B-40 shall be related to the higher PEP value.

For radars with multiple carrier frequencies, if B-40 of the single carriers do not overlap, the emissions in the OoB and spurious domains shall be related to each individual B-40.

##### Emissions in the Out-of-Band domain

###### Definition

Emissions in the Out-Of Band (OOB) domain for primary radars are considered to be emissions on a frequency or frequencies immediately outside B-40 but excluding emissions in the spurious domain.

The Out-of-Band (OoB) emission mask is calculated with respect to B-40. The Out-of-Band mask rolls off at 30 dB per decade, from the B-40 bandwidth to the level specified for spurious emissions.

###### Limits

The limits for the OoB spectrum mask shall be as specified in Annex 2 of ECC/Recommendation (02)05 [2].

For multi-frequency (including frequency diversity) radars, the emissions limits in the OoB domain shall be as specified in Table 5.1 of ECC Recommendation 74-01 [3] and table 1 below.

Table : Limits for emissions in the OoB domain for multiple frequency radars

|  |  |  |
| --- | --- | --- |
| Frequency offset  relative to B-40 | Limit  dBpp | Slope  dB/decade |
| 0,5 to 2.3 | -40 to -43 - 10\*log(PEP) / -60 (see note 1) | -30 |
| NOTE1: from -40 to -43 - 10\*log(PEP) or -60 dBpp whichever is less stringent | | |

For all other radar systems the emissions limits in the OoB domain shall be as specified in Table 5.1 of ECC Recommendation 74-01 [3] and table 2 below.

Table - Limits for emissions in the OoB domain for all other radar systems

|  |  |  |
| --- | --- | --- |
| Frequency offset  relative to B-40 | Limit  dBpp | Slope  dB/decade |
| 0,5 to 5 | -40 to -70 | -30 |
| 5 to 15,8 | -70 to -100 / -30 dBm (See note 1) | -60 |
| NOTE 1: from -70 to -100 or -30 dBm whichever is less stringent | | |

Figures 2 and 3 below show the emissions limits in the OoB domain for the radar systems above mentioned.

Figure 2: Emission in the OoB domain (case of a multiple carrier frequencies)



Figure 3: Emission in the OoB domain (case of a single carrier frequency)

###### Conformance

The conformance tests are specified in clause 5.4.1.3.

##### Emissions in the spurious domain

###### Definition

Spurious emissions are defined as the entity of all emissions in the frequency range of the cut‑off frequency 2,08 GHz of the waveguide section to 15,5 GHz, but outside the OoB-boundaries.

NOTE: The lower limit of this frequency range of 2,08 GHz is obtained as the cut-off frequency of the generally used WR-284/R32 waveguide as defined in IEC 60153-2 [i.7]. The upper limit corresponds to the upper limit stated in ERC/Recommendation 74-01 [3] Table 1 (5th harmonic).

Spurious emissions include:

* harmonic emissions (whole multiples of the operating frequency),
* parasitic emissions (independent, accidentally),
* intermodulation (between oscillator- and operation frequency or between oscillator and harmonics),
* emissions caused by frequency conversions.

The boundaries between the OoB domain and the spurious domain are where the OoB limit mask specified in ECC/Recommendation (02)05[2]reaches the spurious emission limit according to table 3 of ERC/Recommendation 74‑01 [3]. This is illustrated in figure 3.



Figure 4: Definition of OoB and spurious emission domains (case of a single carrier frequency)   
(Not to scale)

###### Limits

For primary surveillance radar systems, the spurious emissions limits are related to the PEP and shall be as specified in ERC/Recommendation 74-01 [3] Annex 5 and also shown in Table 3 below.

Table - Limits for emissions in the spurious domain

|  |  |
| --- | --- |
| Radar type | Limits dBpp |
| Multi-frequency | -43 - 10\*log(PEP) or -60 dB (see notes 1 & 2) |
| Other types of fixed stations | -100 dB or -30 dBm (see note 1) |
| NOTE 1: whichever is less stringent  NOTE 2: PEP is measured in Watts in the reference bandwidth. | |

The reference bandwidth of 1 MHz shall be used.

###### Conformance

The conformance tests are specified in clause 5.4.1.4.2.

##### Stand-by mode emissions

###### Description

The stand-by mode output power is defined as the power output at the antenna flange in the spurious region.

For the stand-by mode the limits between OoB and spurious regions are considered the same as calculated for the active state.

###### Limits

The maximum allowed power level shall be -47dBm when measured with a measurement bandwidth of 1 MHz as specified in Table 5.1 of ERC/Recommendation 74-01 [3] and in Table 4 below:

Table - Limits for stand-by mode emissions

|  |  |
| --- | --- |
| Frequency | Emission limits in standby mode |
| 2.08 GHz <= fC <= 15.5 GHz (see note 1 & 2) | -47dBm |
| NOTE 1: The lower limit of this frequency range of 2,08 GHz is obtained as the cut-off frequency of the generally used WR-284/R32 waveguide as defined in IEC 60153-2 [i.7]. The upper limit corresponds to the upper limit stated in ERC/Recommendation 74-01 [3] Table 1 (5th harmonic).  NOTE 2: no limit within ±250% of the calculated necessary bandwidth (B-20) as defined in Annex 8 of ITU-R SM 1541-6 [i.3] clause 2 | |

###### Conformance

The conformance tests for this requirement shall be as defined in clause 5.4.1.4.3.

### Receiver requirements

#### System Noise Figure

##### Definition

The System Noise Figure is the ratio (in dB) between the signal-to thermal noise ratio at the input of a system and its value at the output of the system. . Each component of the system contributes to the overall System Noise Figure by its own Noise Figure reduced by the gain of the components in front of it.

##### Limits

The system Noise Figure shall not exceed 6 dB.

##### Conformance

The conformance tests are specified in clause 5.4.2.1

#### Receiver selectivity

##### Definition

Receiver selectivity is the capability to receive a wanted signal, without exceeding a given detection performance degradation, due to the presence of unwanted signals, which differ in frequency from the wanted signal by a specified amount.

NOTE: Signals inside the B-40 bandwidth are not considered as disturbing signals because they fall into the desired frequency range for the reception of wanted signals.

##### Limit

The required input selectivity characteristic of the radar receiver is based on the receiver B-40 bandwidth calculated for a single operating frequency within the operating frequency band (see Annex C).

A selectivity mask is defined with respect to a Minimum Detectable Signal level (MDS). This level is defined as the minimum level of a non-fluctuating pulsed radar waveform (i.e. carrying the transmit signal modulation) that would be detected with a probability of detection equals to PD in the presence of thermal noise resulting in a probability of false alarm PFA. This is a calculated value defined in clause 5.4.2.2.1.

The maximum level of the disturbing signal shall be selected such that the receiver will not be saturated and shall not exceed the receiver compression level minus 6 dB.

The selectivity mask is centered upon the operating frequency and rolls off at 30 dB/decade from each edge of the B-40 bandwidth to the maximum level of the disturbing signal at 70 dB above MDS level

The receiver selectivity shall be at least verified in the range of ± 500 MHz from the operating frequency starting at the lower and upper B-40 frequency. The B-40 bandwidth shall be excluded from the receiver selectivity measurement. The minimum frequency range that is verified shall be in the frequency range from 2 200 MHz to 3 600 MHz. The manufacturer shall ensure that the swept frequency span encompasses all image frequencies present in the receiver design. If the image frequencies are not covered by the verified frequency range as defined above the range shall be extended to cover the image frequencies accordingly. The receiver selectivity shall ensure at least 60 dB suppression of input signals at image frequencies.

The resulting receiver selectivity curve shall be as described in Figure 5 below:



Figure 5: Resulting receiver selectivity mask (not to scale). The max disturbance level is -40dBm.

##### Conformance

The conformance tests are specified in clause 5.4.2.2.2.

#### Receiver Compression Level

##### Definition

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

The receiver input 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).

##### Limits

The input of the radar shall not be subject to compression for signal levels up to at least -40 dBm (measured at the input of the receiver).

NOTE 1: A high compression level corresponds to high immunity against blocking. Blocking is the effect when a strong Out of Band or spurious signal entering through another channel in the operating band degrades the receiver ability to detect the wanted signal in the selected channel.



Figure 6: Illustration of finding the receiver 1dB compression point

##### Conformance

The conformance tests for this requirement shall be as defined in clause 5.4.2.3.

#### Receiver blocking

##### Definition

Blocking is a measure of the capability of the receiver to receive a wanted signal without exceeding a given degradation due to the presence of a stronger unwanted signal.

Receiver Blocking takes place, if an unwanted signal with specific power at the border of the operating frequency band reduces the gain, resulting in a reduction of detection sensitivity (desensitization) or induces energy into the receiver passband channels which may result in spurious responses. Depending on the application and thus the design of the receiver, blocking levels at the input of the receiver may vary considerably.

Due to the fact that receivers are designed for specific applications, and the selectivity of the receiver normally is defined by IF filtering, the level of blocking is defined with respect to the receiver noise floor.

##### Limits

A disturbing CW signal with a power of 20 dB above noise floor at the borders of the B-40 shall not cause a power level reduction or increase of more than 2 dB (tbc) in the selected operating channel of the receiver.

# Testing for compliance with technical requirements

## General requirements

The manufacturer shall ensure that all operating modes and product configurations are in compliance with the technical requirements in the present document.

## Environmental conditions for testing

### General requirements

The technical requirements of the present document apply under the environmental profile for operation of the equipment, which shall be declared by the manufacturer, 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 which are identified as applicable in annex A at all times when operating within the boundary limits of the declared operational environmental profile.

### Normal temperature and humidity

The temperature and humidity conditions for tests shall be a combination of temperature and humidity within the following ranges:

1. temperature: +15 oC to +35 oC;
2. relative humidity: not exceeding 75 %.

### Normal test power supply

The test voltage for equipment to be connected to an AC supply shall be the nominal mains voltage declared by the manufacturer -10 % to +10 %. For the purpose of the present document, the nominal voltage shall be the declared voltage or each of the declared voltages for which the equipment is indicated as having been designed. The frequency of the test voltage shall be 50 Hz ± 1 Hz.

## Interpretation of the measurement results

The interpretation of the results recorded in a test report for the measurements described in the present document shall be as follows:

* the measured value related to the corresponding limit will be 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 shall be included in the test report;
* the recorded value of the measurement uncertainty shall be, for each measurement, equal to or less than the figures in Table 5: Maximum measurement uncertainty.

For the test methods, according to the present document, the measurement uncertainty figures shall be calculated and shall correspond to an expansion factor (coverage factor) k = 1,96 or k = 2 (which provide confidence levels of respectively 95 % and 95,45 % in the case where the distributions characterising the actual measurement uncertainties are normal (Gaussian)). Principles for the calculation of measurement uncertainty are contained in ETSI TR 100 028 [i.5], in particular in annex D of the ETSI TR 100 028-2 [i.6].

Table 5: Maximum measurement uncertainty is based on such expansion factors.

Table : Maximum measurement uncertainty

|  |  |
| --- | --- |
| Parameter | Uncertainty |
| **Environment measurements** | |
| Temperature | 1 °C |
| Relative humidity | 5 % |
| Transmitter measurements | |
| Frequency tolerance | ±1 ppm |
| Transmitter power | ±1,5 dB |
| Out-of-Band emissions | ± 4 dB \* |
| Spurious emissions | ± 4 dB \* |
| Mains Supply Voltage | ± 2 % |
| **Receiver measurements** | |
| Noise Figure | ± 1dB |
| Receiver Selectivity | ± 4 dB \*\* |
| Receiver Compression Level | ± 1 dB |

\*) Required between 0 and -30dBc for CW signals. These radar systems use very complicated waveforms using pulse length modulation, frequency hopping, unlinear frequency chirping or phase coding. A frequency analyser is specified to sinusoid signals and for high dynamic ranges is only specified for accuracy in the top most 30dB of its dynamic range. Therefore the actual accuracy that can be achieved during such measurements up to 100 dB below PEP at 26GHz power is no better than +/- 4dB.

\*\*) Required between 0 and -20dBm. As for note \*) it is limited by what is possible to measure for the given signals and frequencies.

## Radio test suites

### Transmitter test specification

#### Frequency Tolerance

In order to measure the frequency tolerance, the measurement is done on the antenna interface. The antenna interface shall be replaced by a suitable matched load.

When measuring the frequency tolerance for radars with a phase or frequency modulated pulse, the tolerance shall be measured for each of the frequency references used for generating the radar output signal. The frequency tolerance shall be measured for at least 3 frequencies equally spaced across the operating range. The results obtained shall be compared to the limits in clause 4.2.1.1.2 in order to prove compliance with the requirement.

#### Transmitter power

The transmitter power of a pulse radar is considered to be the peak value of the transmitter pulse power during the transmission pulse (PEP). If the transmitter power varies over the azimuth, the highest PEP over at least one rotation period shall be considered.

Transmitter power measurement is needed to determine the reference levels for the spectrum limit curves.

The transmitter power shall be referenced with respect to the output port of the radar transmitter. The antenna interface shall be replaced by a suitable matched load. On that flange a high-power directional coupler will be mounted with its main port terminated by a matching high-power dummy load. The coupling factor shall be known in the allocated band with the necessary accuracy to achieve the required transmitter power measurement accuracy

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

To determine the Peak Envelope Power of the pulse, a peak power meter with direct reading of the transmitter peak power shall be used. If the coupling loss is not taken into account, it has to be added to the meter reading

#### Measured B-40 bandwidth

The measurements of the -40 dB bandwidth shall be performed with the same settings as in clause 5.4.1.4 (Unwanted emissions). The bandwidth of the emissions 40 dB below PEP shall be measured. Measurement setup shall be as described in Annex B.

All measured -40 dB emissions shall be entirely contained within 2 700 MHz to 3 100 MH In case of multiple carrier-frequencies, the B-40 bandwidth shall be measured for the minimum and the maximum operating frequencies (Fmin and Fmax).

#### Unwanted emissions

##### Out-of-Band-emissions

The so-called indirect method as specified in clause 6 of Annex 2 of Recommendation ITU‑R M.1177‑4 [4] shall be applied for the measurement of unwanted emissions of radar systems. The transmitter spectrum shall be measured at the output port of the transmitter as illustrated in figure B.1.

NOTE 1: To obtain a sufficient dynamic range, the radar signal may need to be suppressed by e.g. adding a notch filter.

For multi-frequency radars the Out-of-Band power emission shall be measured in the frequency bands given in table 6. For all other radar systems the Out-of-Band power emission shall be measured in the frequency bands given in table 7.

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

The results obtained shall be compared to the limits in clause 4.2.1.3.2 and depicted in figure 2 in order to prove compliance with the requirement.

NOTE 2: These OoB-boundaries are taken from ECC/Recommendation (02)05 [2].

Table : Out-of-Band emissions boundaries for multiple frequency

|  |  |
| --- | --- |
| Lower OoB boundary | Upper OoB boundary |
| Centre frequency -2,3 *B-40* | Centre frequency + 2,3 *B-40* |
| NOTE 1: the values are taken from ECC Recommendation (02)05  NOTE 2: measurements below the waveguide cut-off frequency are not necessary | |

Table : Out-of-Band emissions boundaries for all other radar systems

|  |  |
| --- | --- |
| Lower OoB boundary | Upper OoB boundary |
| Carrier frequency -15,8 *B-40* | Carrier frequency + 15,8 *B-40* |
| NOTE 1: the values are taken from ECC Recommendation (02)05  NOTE 2: measurements below the waveguide cut-off frequency are not necessary | |

All measurements of Out-of-Band emissions shall be made with a reference bandwidth of 1 MHz.

NOTE 3: As an example, considering the boundaries calculation of table 7, with a centre frequency of 2,8 GHz, a pulse duration of t = 100 µs and a rise time of tr = 200 ns, the 40 dB bandwidth calculated applying the equation given at Appendix C is ≈ 10MHz depending on the modulation bandwidth. This leads to OoB boundaries at 100 dBcc equal to 15,8 × 10 MHz = 158 MHz away from the centre frequency. For this example (case of single carrier frequency), the absolute boundaries between out-of-band emissions and spurious emissions are: 2,8 GHz – 0,158 GHz = 2,642 GHz and 2,8 GHz + 0,158 GHz = 2,958 GHz (see figure 6 below).

Figure 7: Calculated emission mask for pulse duration of *t* = 100 µs  
and rise time of *tr* = 200 ns at centre frequency of 2,8 GHz

##### Spurious emissions

For the spurious emission measurements the aforementioned indirect method shall be used. To perform the measurement the radar and the measuring equipment shall be installed as displayed in figure B.1. The spurious power emission shall be measured in frequency ranges outside the Out-of-Band emissions boundaries (see Table 8).

Note 1: If required to reach a dynamic amplitude measuring range of 110 dB minimum, a low noise amplifier (LNA), and a notch filter for the operating frequency should be used.

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

All measurements of spurious emissions shall be made with a reference bandwidth of 1 MHz.

The results obtained shall be compared to the limits in clause 4.2.1.4.2 in order to prove compliance with the requirement.

Table : Spurious emissions measurement bands

|  |  |
| --- | --- |
| Lower measurement band | Upper measurement band |
| From 2,08 GHz  to the lower OoB boundary | From the upper OoB boundary  to 15,5 GHz |
| NOTE 1: the lower limit correspond to the cut-off frequency of the waveguide  NOTE 2: the upper limit is taken from ECC Recommendation (74) 01 with transmitter frequency set to 3,1 GHz | |

##### Stand-by mode emissions

For the standby mode emissions measurements, the aforementioned indirect method shall be used. To perform the measurement the radar system and the measuring equipment shall be installed as displayed in figure B.1 and the radar system shall be placed in stand-by mode but still powered on.

The spurious power emission shall be measured in frequency ranges outside the Out-of-Band emissions boundaries (see Table 6 & Table 7).

The results obtained shall be compared to the limit in clause 4.2.1.3.4.2 in order to prove compliance with the requirement.

All measurements of stand-by mode emissions shall be made with a reference bandwidth of 1 MHz.

### Receiver test specification

#### System Noise Figure

The System Noise Figure is measured along the complete receiving signal chain (as close as possible, but excluding

antenna & waveguide or RF coax, and noise processing). It shall be measured using a noise source and a suitable noise power meter or detector.

A noise source with known Excess Noise Ratio (ENR) is connected to the radar receiver input port. The System Noise Figure is then determined from the ratio between the noise power values at output of the intermediate frequency stage (or its digitized equivalent) with noise source on and noise source off.

The System Noise Figure shall be measured at the centre of the operating frequency band.

#### Receiver selectivity

##### General

For modern solid state digital radars the emitted signals may be very complicated and include both phase-modulation, frequency-hopping and -sweeping and pulse width modulation. This makes a single definition of minimum detectable signal and disturbing signal difficult. The following is a generalized approach based upon a calculated MDS value [i.9]:

Where:

*MDS* Minimum Detectable Signal in Watt

NOTE 1: MDS is meant to be the Minimum Detectable wanted Signal level acceptable not to degrade the radar detection performance. This level is defined as the level of a non-fluctuating pulsed radar waveform (i.e. carrying the transmit signal modulation) that may be detected with a probability of detection equals to 10-3 along with thermal noise giving spikes at a PFA of 10-8.

*k* Boltzmann constant (= 1,38 10-23 J.K-1)

*T0* Temperature in Kelvin

*Bres* 3 dB resolution bandwidth of transceiver in Hz

*NFsys* System Noise Figure

*Dnospur* Detectability Factor (function of *PD & Pfa*) = 4 (+6 dB) for the PD and PFA values selected here below.

NOTE: The detectability factor (*Dnospur )* is the signal-to-noise ratio of the interference signal that will be detected with a probability equals to PD under PFA conditions. The value of 6 dB for *Dno spur* is taken from figure 2.3 of "Radar Handbook" [i.9] - Required signal-to-noise ratio (detectability factor) for a single pulse, linear-detector, non-fluctuating target as a function of probability of detection - extrapolated to PD = 10-3 with false alarm probability PFA= 10-8.

*PD* Probability of detection = 10-3 (selected value)

*PFA* Probability of false detection = 10-8 (selected value)

*TC* Pulse length (of individual chirp) in seconds

*BC* Effective bandwidth of receiver

*M* Test margin = 0,05 (-13 dB) (without this margin the receiver would give a detectable signal)

NOTE 2: In the same (PD, PFA) conditions, the maximum acceptable level of a non-fluctuating pulsed CW interference (which is not modulated) is expected to be up to a value of TCBC above the minimum detectable signal that is calculated here (which is modulated).

##### Receiver selectivity

In order to determine if the receiver selectivity follows the required mask, a disturbance test signal level at MDS level plus the required attenuation shall be applied at the receiver RF front end. The rise/fall time of the disturbance signal shall be maximum 100 ns.

The detection threshold shall be adjusted such that the False Alarm Rate (FAR) corresponds to a PFA of 10-8

NOTE: This selected value is significantly lower than the value of 10-6 that may be used during normal operation in order to avoid mixing the false alarms caused by the disturbance signal and the noise spikes. It corresponds to a 2 dB difference in the detection threshold.

The attenuation on the disturbing test signal shall be increased until the disturbing test signal results in detection of false targets with a probability not higher than 10-3.

**Disturbing Test Signal**

The disturbance signal shall be a sinusoidal pulsed signal with pulse duration of 1 µs and a pulse repetition frequency of 1 kHz.

NOTE: In order to avoid that the spectral purity of the generated disturbance signal impacts on the results, the output of the signal generator shall be checked to see if spurious signals are present. If spurious signals from the signal generator are present, they shall be documented in the test report.

**Maximum Level of Disturbing Signal**

The maximum level of the disturbing signal shall be selected such that the receiver will not be saturated. The selected test signal level shall be up to 6 dB below compression level for the given receiver design.

**Roll off of Disturbing Test Signal**

The Disturbing Test signal shall be consistent with the selectivity mask as described in clause 4.2.2.2.2. From each edge of B-40 the signal strength shall increase from the MDI level + 40 dB by 30dB per decade to maximum 70 dB above MDI level. This is illustrated in figure 5 above.

**Test Pass Criteria**

The requirement is that the disturbing test signal shall not result in detection of false targets with a higher probability than 10-3 which corresponds, for the selected disturbing signal, to a False Alarm Rate of one per second on the radar plot display (or 4 false alarms per scan for a 15 rpm PPI display).

**Measurement Points**

Measurements shall be collected at target report level (track/plot). A selectivity curve shall be built for at least a middle frequency of the operating range.

The receiver selectivity shall be at least verified in the range of ± 500 MHz from the operating frequency starting at the lower and upper B-40 frequency. The B-40 bandwidth shall be excluded from the receiver selectivity measurement. The minimum frequency range that is verified shall be in the frequency range from 2 200 MHz to 3 600 MHz. The manufacturer shall ensure that the swept frequency span encompasses all image frequencies present in the receiver design. If the image frequencies are not covered by the verified frequency range as defined above the range shall be extended to cover the image frequencies accordingly.

In order to ensure that all possible disturbance frequencies are covered, the interspacing between measurement points shall be selected to be less than half the system resolution bandwidth (3dB BW of the processed radar output). This value shall be stated in the test report.

**The Case of Multi-Frequency and/or Chirping Radars**

In case radar makes use of multiple frequencies and/or chirps the effective B-40 where full sensitivity is allowed may be taken as the joined envelope of all frequencies used, provided the frequencies are adjacent. In cases of separate frequency bands are used there will be a separate B-40 where full sensitivity is allowed for each, a selectivity curve is to be built for at least one B-40 with full sensitivity in the middle of the operating range.

#### Receiver Compression Level

The best way to measure the receiver compression level is to increase the power of a sine wave signal injected at the LNA input and check linearity by reading digital values at the A/D converter output.

Depending on receiver design a CW or pulsed test signal is injected into the receiver LNFE (it has to be a signal that passes through the receiver). The gain response curve of the complete receiver shall be measured and the 1 dB compression point shall be noted. The measurement shall be performed at the centre frequency only. The result obtained shall be compared to the limits in clause 4.2.2.3 in order to prove compliance with the requirement.

#### Receiver blocking

For blocking measurement, at the input of the receiver, a sinewave injected with a power of 20 dB above noise floor at the B-40 frequencies (Fc ± ½ B-40)

NOTE 1: Make sure, that the phase noise characteristic of the sinewave is better than 10 dB of the worst case phase noise of all used signals in the down-conversion chain (LO, clocks …..).

To be continued (if requirement is maintained).

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 303 364-2 | | | | |
| --- | --- | --- | --- | --- |
| Requirement | | | Requirement Conditionality | |
| No | Description | Reference: Clause No | U/C | Condition |
|  |  |  |  |  |
| 1 | Operating frequency | 4.2.1.1 | U |  |
| 2 | Measured -40 dB bandwidth | 4.2.1.3 | U |  |
| 3 | Out-of-Band emissions | 4.2.1.4.1 | U |  |
| 4 | Spurious emissions | 4.2.1.4.2 | U |  |
| 5 | Standby mode emissions | 4.2.1.3.4 | U |  |
| 6 | System Noise Figure | 4.2.2.1 | U |  |
| 7 | Receiver Selectivity | 4.2.2.2 | U |  |
| 8 | Receiver Compression Level | 4.3.3.2 | 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.

**Clause Number** 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):  
Transmitter power and unwanted emissions of radar systems with indirect methods



Figure B.1: Indirect method for radio frequency measurements with dismounted antenna

The method for measurement of the operation frequency, transmit power as well as out‑of-band and spurious emission shown in figure B.1 shall be applied.

Annex C (normative): Calculation of the B-40 bandwidth

Annex 8 of Recommendation ITU‑R SM.1541‑6 [i.3] defines B-40 for various types of waveforms (e.g. pulsed radar signals). Assuming that:

* the radar is operating in the band 2 700 MHz to 3 100 MHz;
* the pulse rise time *tr* is greater than 0,0094∙*t*, where *t* is the pulse duration.

For primary non-FM pulse radars B-40 is determined as follows:

 (1)

Where:

*t* is the pulse duration.

*tr* is the rise time in the case of a trapezoidal pulse.

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

For pulse FM radars, two formulas are specified in ITU‑R SM.1541‑6 [i.3] for B-40:

(2)

Where:

* B-40 is the -40 dB bandwidth in Hz;
* BC is the bandwidth of the frequency deviation (total frequency shift during the pulse generation);
* τ is the pulse length including rise & fall times;
* to account for the rise time. ()
* to account for the fall time. ()
* to account for both the rise and fall times combination. ()
* tr is the rise time in seconds;
* tf is the fall time in seconds,

(6)

Where:

* K = 7.6 and A = 0,065

NOTE: The term A/tr adjusts the value of B−40 to account for the influence of the rise time, which is substantial when the time-bandwidth product Bc ∙ t, is small or moderate and the rise time is short.

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

Equation (2) is only valid when the following conditions are both met:

1. The product BC ∙ Minimum (tr, tf) is greater than or equal to 0.10 and
2. the product of BC ∙ τ or compression ratio is greater than 10.

In all other cases, equation (6) is used.

For radars with an asymmetrical spectrum (e.g. magnetron based radars), the B-40 bandwidth can be offset from the frequency of maximum emission level, but the necessary bandwidth, *B*N and preferably the overall occupied bandwidth should be contained completely within the allocated band as stipulated in section 4 of Annex 8 of recommendation ITU‑R SM.1541‑6 [i.3].

The application of this rule is illustrated in figure B.1.



Figure B.1: Application of the offset-rule for the Out-of-Band emission limit mask

Annex D (normative):   
Receiver selectivity measurement setup



Figure D.1: Measurement method for receiver selectivity measurement

Annex D (informative): Bibliography

|  |  |
| --- | --- |
| Draft new Recommendation ITU-R P.[BLM] | ‘Method for point-to-area predictions for terrestrial services in the frequency range 30 to 3 000 MHz’ (Doc. 3/BL/26) |
| Rec. ITU-R P. 452-10 | ‘Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above 0.7 GHz |
| SE 21 ECC Report 174 | Compatibility between the mobile service in the band 2500-2690 MHz and the radiodetermination service in the band 2700-2900 MHz March 2012 |
| 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 |
| ITU-R M.1460 | Technical and operational characteristics and protection criteria of radiodetermination and meteorological radars in the 2900 – 3100 MHz band |
| Rec. ITU-R M.1461 | ‘Procedures for determining the potential for interference between radars operating in the Radiodetermination Service and systems in other Services’ |
| ITU-R M.1463 | Characteristics and protection criteria for radars operating in the radiodetermination service in the frequency band 1215 – 1400 MHz |
| ITU-R M.1464 | ‘Characteristics of and protection criteria for radionavigation and meteorological radars operating in the frequency band 2700-2900 MHz’ |
| ITU-R M.1465 | Characteristics and protection criteria for radars operating in the radiodetermination service in the frequency band 3100 – 3700 MHz |
| ETSI EG 201 399 | "Electromagnetic compatibility and Radio spectrum Matters (ERM); A guide to the production of candidate Harmonized Standards for application under the RE Directive". |
| CISPR 16-1-1:2015 | "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus". |
| Table 9: Bibliography | |

Annex E (informative):  
Change history

|  |  |  |
| --- | --- | --- |
| **Document history** | | |
| V1.0.0 | December 2018 | Draft |
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