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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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| Date of latest publication of new National Standard or endorsement of this EN (dop/e): | 6 months after doa |
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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 with the following characteristics:

* operating in the 2700 MHz to 3100 MHz frequency range
* transmitter output power up to 100 kW
* the transceiver-antenna connection is using a hollow metallic rectangular waveguide
* the antenna is rotating, waveguide-based and passive

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

NOTE 2: 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 (2019): "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).

# Terms, symbols and abbreviations

## Terms

For the purposes of the present document, the following definition of 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.

**Declared frequency band:** frequency band or bands within which the product under test is declared to operate in the applicable operating modes

NOTE 1: The declared frequency band will often correspond to a nationally allocated frequency band.

NOTE 2: The declared frequency band for a given region or country is always contained within the allocated frequency band.

**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 [1]

NOTE 2: For Primary radars the necessary bandwidth BN is considered to be B-20 (20 dB bandwidth) as defined in ITU-R SM.1541-6 [i.3]

**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 [i.8]

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

*fc* Carrier Frequency

*fimage* Image Frequency

*k* Boltzmann's constant

*LO* Local Oscillator frequency

*MDS* Minimum Detectable Signal

*NFsys* Noise Factor of the system

*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

LNFE Low Noise Front End (= RF Front End)

MDIS Minimum Detectable Interference Signal

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 1 250 ppm as specified in Appendix 2 of the ITU Radio Regulations [1].

##### Conformance

The conformance tests are specified in clause 5.4.1.1.

#### Transmitter output power

##### Definition

The transmitter power is considered to be the peak value of the transmitter pulse power during the transmission pulse (PEP).

NOTE: The transmitter power is measured at the output port of the transmitter.

##### Limits

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

NOTE: The maximum transmitter power may be subject to national regulations.

##### Conformance

The conformance tests are specified in clause 5.4.1.2.

#### Measured B-40 bandwidth

##### Definition

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

##### Limits

While transmitting, the measured B-40 bandwidth of the emitted signal shall be always contained within the frequency range 2 700 MHz to 3 100 MHz.

In case of multiple-carrier frequencies where the B-40 bandwidths of the individual signals do not overlap, all measured B-40 bandwidths while transmitting shall always be contained 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 using a single carrier with multiple pulse waveforms, the emission mask shall be calculated for each individual pulse and the largest one shall be considered.

For radars using multiple carrier frequencies, the overall emission mask is then the envelope of the individual emission 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 two 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 as defined in ITU-R SM.1541-6 Annex 8 clause 3 [i.3].

###### Limits

The roll-off in the OoB domain shall be as specified in Annex 2 of ECC/Recommendation (02)05 [2] and Table 1 (for single frequency radars) and Table 2 (for multiple frequency radars) below until the limit specified in Table 15 of ECC Recommendation 74-01 [3] for spurious emissions is reached.

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

|  |  |  |
| --- | --- | --- |
| 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 | | |

Table 2: 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 | | |

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 single carrier frequency)

Figure 3: Emission in the OoB domain (case of a multiple carrier frequencies)

###### Conformance

The conformance tests are specified in clause 5.4.1.5.1.

##### Emissions in the spurious domain

###### Definition

Emission on a frequency or frequencies which are outside the B-40 bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions (see Figure 4 below).



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

###### Limits

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 3 - Limits for emissions in the spurious domain

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

###### Conformance

The conformance tests are specified in clause 5.4.1.5.2.

##### Stand-by mode emissions

###### Definition

Stand-by mode emissions are emissions at the transmitter output when not in the active state.

###### Limits

The residual power output for each of the frequency channels shall be not greater than -47 dBm as specified in Table 15 of REC 74-01 [3] apart from ±250% of the measured necessary bandwidth BN where no limits are specified.

The radars covered by the present document use waveguides to transfer power between the transmitter and the antenna and the waveguide is selected such that the cut-off frequency is always above 1 GHz. Therefore, measurements below this frequency do not provide valid results since the waveguide is unable to support power transfer along its length below the cut-off frequency.

###### Conformance

The conformance tests for this requirement shall be as defined in clause 5.4.1.5.3.

### 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 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. Receiver blocking takes place, if an unwanted signal with specific power in the vicinity 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.



Figure 5: Illustration of finding the receiver 1dB compression point

##### Conformance

The conformance tests for this requirement shall be as defined in clause 5.4.2.2.

#### 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 1: Receiver selectivity refers to effects measured within the linear range of the receiver.

NOTE 2: 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 (see Annex C). In case of a multifrequency radar, if two carrier frequencies are close to each other so that the B-40 bandwidths overlap, the selectivity is assessed on the resulting B-40 bandwidth. If two carrier frequencies are not close to each other, the selectivity is assessed separately.

A selectivity mask is defined with respect to a Minimum Detectable Interference Signal level (MDIS). This level is defined as the minimum level of a non-fluctuating unmodulated disturbing signal (i.e. not carrying the transmit signal modulation) that would cause perturbations in the radar processing. Beyond this level, it is considered that spurious responses or desensitization may be caused by the disturbing signal in the processing and be present at radar output. The Minimum Detectable Interference Signal (MDIS) is set to 66 dB below the receiver compression level.

The receiver selectivity shall follow the limits of the selectivity mask defined in Table 4 below (see also Figure 6). The receiver selectivity shall ensure at least 60 dB suppression of out of band input signals.

Table 4: Receiver selectivity mask

|  |  |  |
| --- | --- | --- |
| Frequency offset relative to fc by multiple of the  B-40 bandwidth | Maximum residual interfering power level  dB below MDIS | Slope  dB/decade |
| 0 to 0,5 | None | 0 |
| 0,5 | 40 | -∞ |
| 0,5 to 3 | + 40 to 60 or to maximum disturbance level whichever is less stringent (see note) | -30 |
|  |  |  |
| 3 to ∞ | maximum disturbance level (see note) | 0 |
| NOTE: The disturbance signal level at receiver input shall be set at the receiver compression level minus 66 dB. | | |

The 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.



Figure 6: Resulting receiver selectivity mask (not to scale)

The receiver selectivity shall be at least verified in the range from 2 200 MHz to 3 600 MHz and shall always include all image frequencies present in the receiver design. If the image frequencies do not fall within the above mentioned frequency range, the measurement range shall be augmented so as to cover the image frequencies, i.e. additional measurements shall be performed within the range [fimage-B-40/2, fimage+B-40/2].

##### Conformance

The conformance tests are specified in clause 5.4.2.3.

# 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;

Recommended values for the maximum measurements uncertainty figures can be found in Annex D.

## 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 not exceed the limits specified 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.

The results obtained shall not exceed the limit specified in clause 4.2.1.2.2.

#### Measured B-40 bandwidth

The measurements of the B-40 bandwidth shall be performed with the same settings as in clause 5.4.1.5 (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 bandwidth shall be entirely contained within 2 700 MHz to 3 100 MHz.

In case of multiple carrier-frequencies, the B-40 bandwidth shall be measured for the minimum and the maximum operating frequencies (Fmin and Fmax).

#### Measured B-20 bandwidth

The measurements of the B-20 bandwidth shall be performed with the same settings as in clause 5.4.1.5 (Unwanted emissions). The bandwidth of the emissions 20 dB below PEP shall be measured. Measurement setup shall be as described in Annex B.

#### Unwanted emissions

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

The 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.

For single-frequency radars, the Out-of-Band power emissions shall be measured in the frequency bands given in Table 5. For multi-frequency radars, the Out-of-Band power emissions shall be measured in the frequency bands given in Table 6.

A WR-284/R32 waveguide as defined in IEC 60153-2 [i.7] shall be used. If the cut-off frequency of 2,08 GHz falls within the Out-of-Band domain, measurements below such frequency shall not be performed.

B-40 is calculated from the formulae in Annex C. The measurement set-up shall be as described in Annex B.

The results obtained shall not exceed the limits specified in clause 4.2.1.4.2.2 in order to prove compliance with the requirement.

Table 5: Out-of-Band emissions boundaries for single frequency

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

Table 6: Out-of-Band emissions boundaries for multiple frequency

|  |  |
| --- | --- |
| Lower OoB measurement limit | Upper OoB measurement limit |
| Centre frequency -2,3 x *B-40* | Centre frequency + 2,3 x *B-40* |
| NOTE 1: the measurement limits 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 as described in ITU-R 1177-4 [4] Annex 1

EXAMPLE : 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 7 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 as shown in Table 7. A WR-284/R32 waveguide as defined in IEC 60153-2 [i.7] shall be used. If the cut-off frequency of 2,08 GHz falls within the spurious domain, measurements below such frequency shall not be performed.

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

Since the lower measurement frequency is 2,08 GHz (cut-off frequency), all measurements of spurious emissions shall be made with a reference bandwidth of 1 MHz.

The results obtained shall not exceed the limits specified in clause 4.2.1.4.3.2 in order to prove compliance with the requirement.

Table 7: Spurious emissions measurement bands

|  |  |
| --- | --- |
| Lower band measurement limit | Upper band measurement limit |
| From 2,08 GHz  to the lower OoB boundary (NOTE 3) | From the upper OoB boundary  to 15,5 GHz |
| NOTE 1: the lower limit correspond to the cut-off frequency of the WR-284/R32 waveguide as defined in IEC 60153-2 [i.7]  NOTE 2: the upper limit corresponds to the 5th harmonic of 3.1 GHz as defined in ERC Recommendation (74) 01 [3]  NOTE 3: measurements below the waveguide cut-off frequency are not necessary. Therefore, if the cut-off frequency falls within the OoB domain, only the upper band measurement will be needed. | |

##### Stand-by mode emissions

For the standby mode emissions measurements, the aforementioned indirect method shall be used. To perform the measurements, 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 emissions shall be measured in the frequency ranges outside ± 2,5 times the measured necessary bandwidth aside the carrier frequency and with a reference bandwidth as shown in Table 8. A WR-284/R32 waveguide as defined in IEC 60153-2 [i.7] shall be used.

Table 8: Frequency range for measurement and Reference Bandwidths

|  |  |
| --- | --- |
| Frequency Range | RBWREF |
| 2,08 GHz ≤ f < fm1 | 1 MHz |
| fm2 ≤ f ≤ 15,5 GHz | 1 MHz |
| NOTE 1: f is the measurement frequency.  NOTE 2: fm1 = fc- 2,5 x BN where BN is the measured Necessary Bandwidth, i.e. the B-20 bandwidth measured in clause 5.4.1.4  NOTE 3: fm2 = fc+2,5 x BN .  NOTE 4: if 2 carrier frequencies are close to each other so that the Necessary Bandwidths related to the 2 carrier frequencies overlap, then fm1 = fc1-2,5 x BN1 and fm2 = fc2+2,5 x BN2 where BN1 is the Necessary Bandwidth of fc1 and BN2 is the Necessary Bandwidth of fc2  NOTE 5: The Out-of-Band Domain is defined in clause 4.2.1.4.2  NOTE 6: 2.08 GHz correspond to the cut-off frequency of the WR-284/R32 waveguide as defined in IEC 60153-2 [i.7]  NOTE 7: 15.5 GHz corresponds to the 5th harmonic of the upper limit of the operating frequency band (3.1 GHz) as defined in ERC Recommendation (74) 01 [3] | |

Since the lower measurement frequency is 2,08 GHz (cut-off frequency), all measurements of stand-by mode emissions shall be made with a reference bandwidth of 1 MHz as indicated in Table 8

The results obtained shall be compared to the limit in clause 4.2.1.4.4.2 in order to prove compliance with the requirement.

### 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 noise power meter or detector.

The Y-factor method for the measurement of the receiver noise figure shall be used. 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. The result obtained shall not exceed the limits specified in clause 4.2.2.1.2.

#### Receiver Compression Level

The receiver shall be tuned to the centre frequency of the operating frequency band. The receiver frequency shall be documented in the test report.

A CW test signal at the received frequency shall be injected into the receiver RF front end. The gain response curve of the complete receiver shall be measured either at the IF output of the RF front end or by reading digital values at the output of the A/D converter and the 1 dB compression point shall be noted (see Figure 5 above).

The result obtained shall not exceed the limits specified in clause 4.2.2.2.2.

#### Receiver selectivity

##### General setup

In order to determine if the receiver selectivity follows the required mask, a disturbance test signal level is applied at the receiver RF front end and the residual level of interference is measured at the receiver output.

A selectivity curve shall be built for the minimum and the maximum operating frequencies of the declared frequency range (Fmin and Fmax). The receiver frequency shall be documented in the test report for each measured selectivity curve. The radar receiver is setup in normal operating mode during the test. If the radar is operated in diversity, both frequencies shall then be tuned to the frequency channel under test. For radars with multiple receivers (e.g. short unmodulated pulses along with modulated pulses), all receivers shall be tested.

Compliance shall be tested by applying the disturbing test signal into the RF front end input directly, or in conjunction with its connecting waveguide (see figure D.1).

NOTE: Depending on the radar setup, the waveguide components between the RF front end and the antenna may have bandwidth limiting functions and should be incorporated in the receiver selectivity measurement.

The frequency of the disturbing signal shall be tuned from 2200 MHz to 3600 MHz in steps of 1 MHz. For each frequency within the measurement range, the residual level of interference at the receiver output shall be measured. This can be either at the analog input of the A/D converter(s) or after the A/D converter(s) if the matched filter is digital.

NOTE 1: For radar systems equipped with digital filters in the processing chain, the bandwidths of these matched filters are smaller than the analog receiver bandwidth.

NOTE 2: The matched filter bandwidth usually corresponds to the transmitted pulse length and is usually the inverse of the pulse length. For example, a 0,8 µs pulse length will result in a 1,25 MHz matched filter bandwidth.

The results obtained shall be compared and shall remain within the limit specified in clause 4.2.2.3.2 in order to prove compliance with the requirement.

##### Disturbing Test Signals

With modern solid-state 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 the disturbing signal difficult.

The disturbing signal shall be a CW signal. The input level of the disturbing signal shall be selected such that the receiver will not be saturated and shall be 6 dB below the compression level for the given receiver design.

The disturbance signals shall be applied either to the RF front end input or in conjunction with its connecting waveguide as can be seen in Figure D.1. If the disturbance signal is applied through one or more coupling devices their frequency response shall not limit the specified measurement frequency range (2200 MHz- 3600 MHz). Each coupling device shall be characterized and the result of the selectivity measurement shall be adjusted accordingly.

##### Measurement Points

The receiver selectivity shall be at least verified in the range from 2 200 MHz to 3 600 MHz and shall include all image frequencies present in the receiver design. If the image frequencies do not fall within the mentioned frequency range, additional measurements shall be performed within the range [fimage-B-40/2, fimage+B-40/2].

The discrete frequency steps shall be equal to or lower than 1 MHz. They shall not exceed half the bandwidth of the matched filter.

Frequencies inside the B-40 receiver bandwidth need not to be tested because this is the receiving frequency range of the radar system.

##### Measurement Procedure

The measurement setup shall be as described in figure D.1.

The measurement device shall be connected at the matched filter output, either to the A/D input in case of an analog filter or to the digital output in case of a digital filter and the output power shall be measured. In the analog case, the spectrum analyzer shall be configured with a frequency resolution lower than one fourth of the matched filter bandwidth and a span greater than 1 MHz. In the digital case, a set of 64 independent A/D data samples shall be collected and a average calculation across the 64 samples shall be performed to evaluate the residual interference power.

NOTE 1: Due to the huge amount of frequency steps it is recommended to use a computer aided measurement system to decrease the measurement time.

NOTE 2: In case of oversampling at the matched filter output, every second or third sample can be collected rather than consecutive samples to ensure they are not correlated.

The receiver frequency channel shall first be tuned to Fmin (in case of diversity, both frequency channels shall be tuned to Fmin). In order to get a reference level for the evaluation of rejection levels in the defined bandwidth, the receiver output power shall first be measured in the absence of interfering signal at the operating frequency under test. The reference noise level shall be noted to set-up the selectivity mask.

NOTE 3: the measured noise floor is understood to be a rms value, i.e. the DC offset of the A/D converter has to be excluded from the power measurement.

NOTE 4: the 64-samples averaging scheme allows to increase the dynamic range of the power measurements by 18 dB i.e. down to levels below the noise floor.

Then, the disturbing signal shall be applied starting at 2 200 MHz and the residual power at the output of the matched filter shall be measured (direct measurement in the analog case, value after 64-sample averaging in the digital case).

This procedure shall be repeated for all discrete frequency steps ending at 3 600 MHz. After all frequency steps have been applied and their corresponding measured output powers have been recorded, the output power levels shall be compared to the output power measured at the operating frequency (noise floor) in the absence of interference.

The maximum power level of the unwanted signal measured for each frequency step of the interfering signal at the receiver output shall be plotted and compared to the selectivity mask. The selectivity mask is referenced to the calculated MDIS level which is set 66 dB below the receiver compression level, i.e. 60 dB below the level of the disturbing signal. In the analog filter case, the spectrum analyzer resolution & span shall be selected such that the measurement noise does not exceed the calculated MDIS level.

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.

The frequency channel shall then be tuned to Fmax and the above procedure shall be repeated (in case of diversity, both frequency channels shall be tuned to Fmax).

##### Pass / fail Criteria

The selectivity curves obtained shall be compared to the selectivity mask specified in Table 4 of clause 4.2.2.3. The selectivity curves shall remain within the limit specified by the selectivity mask.

# 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 | Transmit Power | 4.2.1.2 | U |  |
| 3 | Measured -40 dB bandwidth | 4.2.1.3 | U |  |
| 4 | Out-of-Band emissions | 4.2.1.4.2 | U |  |
| 5 | Spurious emissions | 4.2.1.4.3 | U |  |
| 6 | Standby mode emissions | 4.2.1.4.4 | U |  |
| 7 | System Noise Figure | 4.2.2.1 | U |  |
| 8 | Receiver Compression Level | 4.2.2.2 | U |  |
| 9 | Receiver Selectivity | 4.2.2.3 | 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.

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

# 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. (3)
* to account for the fall time. (4)
* to account for both the rise and fall times combination. (5)
* 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 C.1: Application of the offset-rule for the Out-of-Band emission limit mask

# Annex D (normative): Receiver selectivity measurement

## D.1. Calculation of MDIS

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.

In order to determine if the receiver selectivity follows the required selectivity mask, a disturbance signal level at the MDIS level plus the required attenuation shall be applied. The maximum input level of the receiver shall be 6 dB below the compression level for the given receiver design. The minimum input level is the MDIS level and is calculated by the following formula:

MDIS (dBm) = P1dB (dBm) – 66 dB

Where P1dB is the receiver 1 dB compression point.

## D.2. Receiver selectivity measurement setup



Figure D.1: Measurement method for receiver selectivity measurement

In order to determine if the receiver selectivity follows the required mask, a disturbance test signal level at the maximum disturbance level shall be applied using a CW signal generator, either at the receiver RF Front End input or in conjunction with its connecting waveguide or at the waveguide couplers. For each measurement point, the power of the residual interference at receiver output will be measured. The measurement device shall be connected at the matched filter output, either to the A/D input in case of an analog filter or to the digital output in case of a digital filter and the output power shall be measured.

The interfering signal shall be applied at the waveguide coupler, either at the WG10 for frequencies between 2 200 MHz and 2 600 MHz or at WG12 for frequencies between 2 600 MHz and 3 600 MHz.

Note; For selectivity measurements around the image frequency, in the event that the image frequency is greater than 3,95 GHz, WG12 can be replaced by WG14.

# Annex E (informative):

# Maximum Measurement Uncertainty

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

Table E.1: 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 |
| \*) Between 0 and -30 dBc 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 30 dB of its dynamic range. Therefore the actual accuracy that can be achieved during such measurements up to 100 dB below PEP at 26 GHz power is no better than +/- 4 dB.  \*\*) Between 0 and -20 dBm. As for note \*) it is limited by what is possible to measure for the given signals and frequencies. | |

# Annex F (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’ |
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| 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 F (informative): Change history

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