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Meteorological Radars; Part 2: Harmonized Standard for C band Meteorological Radar Sensor operating in the frequency band 5 250 – 5 850 MHz

**EUROPeAN STANDARD**

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# Foreword

This 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 C(2015) 5376 final [i.1] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC [i.1].

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

The present document is part 1 of a multi-part deliverable covering meteorological radar systems for different frequency bands, as identified below:

Part 1: „ S band Meteorological Radar Sensor operating radar in the frequency band 2 700 MHz to 2 900 MHz“

**Part 2: „ C band Meteorological Radar Sensor operating in the frequency band 5 250 MHz to 5 850 MHz“**

Part 3: „ X band Meteorological Radar Sensor operating in the frequency band 9 300 MHz to 9 500 MHz“

|  |  |
| --- | --- |
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# Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](http://portal.etsi.org/Help/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 C-band meteorological radar systems intended for the surveillance and classification of hydrometeors with the following characteristics:

* Operating in the following frequency range:
* 5 250 MHz to 5 850 MHz
* Utilizing unmodulated pulses or phase/frequency modulated pulses also known as pulse compression.
* The transceiver antenna connection and its feeding RF line are using a hollow metallic rectangular or elliptic waveguide
* The antenna is rotating and can be changed in elevation.
* The antenna feed is waveguide based and the antenna is passive.
* The orientation of the transmitted field from the antenna can be vertical or horizontal orientated or it can be both simultaneously.
* At the transceiver output a RF circulator is used.

NOTE 1: Since transceiver and antenna are based on hollow metallic rectangular waveguide the frequency range for measurements that needs to be addressed covers 3 152 MHz to 26 GHz. The lower limit of this frequency range is obtained as the cut-off frequency of the generally used WR187/WG12 waveguide according to IEC 60153-2 [i.2]. The upper limit corresponds to the upper limit stated in ERC/Recommendation 74‑01 Table 1 [1].

NOTE 2: Since at the transceiver output a RF circulator is used, it is assumed that the transceiver characteristics remain independent from the antenna.

NOTE 3: Meteorological radar systems covered by the present document are expected to use the band 5 250 MHz to 5 850 MHz. According to provision 5.452 of the ITU Radio Regulations [4], ground-based radars used for meteorological purposes in the band 5 600 MHZ to 5 650 MHz are authorized to operate on a basis of equality with stations of the maritime radionavigation service.

NOTE 4: Further technical and operational characteristics of meteorological radar systems can be found in Recommendation ITU-R M.1849-1 [i.3].

NOTE 5: The relationship between the present document and essential requirements of article 3.2 of Directive 2014/53/EU 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] ERC/Recommendation 74-01 (2011): "Unwanted emissions in the spurious domain".

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

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

[4] ITU Radio Regulations (2016).

[5] Recommendation ITU-R SM.1541-6 (08/2015): "Unwanted emissions in the out-of-band domain".

## 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] IEC 60153-2 (Edition 2.0, 1974): "Hollow metallic waveguides. Part 2: Relevant specifications for ordinary rectangular waveguides".

[i.3] Recommendation ITU-R M.1849-1 (09/2015): “Technical and operational aspects of ground-based meteorological radars”

[i.4] 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.5] 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".

# Definitions, symbols and abbreviations

## Definitions

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

**active state:** the active state of a transmission station is defined as the state which produces the authorised emission [1].

**assigned frequency:** centre of the frequency band assigned to a station

NOTE: This definition is taken from the ITU Radio Regulations [4].

**assigned frequency band:** frequency band within which the emission of a station is authorized

NOTE 1: the width of the band equals the necessary bandwidth plus twice the absolute value of the frequency tolerance. Where space stations are concerned, the assigned frequency band includes twice the maximum Doppler shift that may occur in relation to any point of the Earth’s surface.

NOTE 2: This definition is taken from the ITU Radio Regulations [4].

**characteristic frequency:** frequency which can be easily identified and measured in a given emission

NOTE 1: A carrier frequency may, for example, be designed as the characteristic frequency.

NOTE 2: This definition is taken from the ITU Radio Regulations [4].

**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.

NOTE 1: The frequency tolerance is expressed in parts in 106 or in Hertz.

NOTE 2: This definition is taken from the ITU Radio Regulations [4].

**idle/standby state:** state where the transmitter is available for traffic, but is not in the active state [1].

**necessary bandwidth BN:** for a given class of emission, the 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 .

NOTE: This definition is taken from the ITU Radio Regulations [4].

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

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

NOTE 2: This definition is taken from the ITU Radio Regulations [4].

**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.

**out-of-band emission:** emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious

NOTE: This definition is taken from the ITU Radio Regulations [4].

**peak envelope power (of a radio transmitter):** 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 the ITU Radio Regulations [4].

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

**pulse duration:** time in seconds between the 50 % amplitude (voltage) points of a transmitted pulse.

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

**receiver selectivity:** ability of a receiver to detect and decode a desired signal in the presence of an unwanted interfering signal which is usually in the adjacent band.

**reference frequency:** frequency having a fixed and specified position with respect to the assigned frequency.

NOTE 1: The displacement of this frequency with respect to the assigned frequency has the same absolute value and sign that the displacement of the characteristic frequency has with respect to the centre of the frequency band occupied by the emission.

NOTE 2: This definition is taken from the ITU Radio Regulations [4],

**spurious emission:** emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information.

NOTE 1: Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

NOTE 2: This definition is taken from the ITU Radio Regulations [4].

**system coupler:** high power directional waveguide coupler with forward and reverse port or only a forward port.

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

**transmitter coupler:** high power directional waveguide coupler with forward and reverse port or only a forward port.

NOTE: The transmitter coupler is inserted in the waveguide run between the output of the transmitter and the power divider used for dual polarisation mode or the output of the transmitter and the first circulator. Usually it is located very close behind the transmitter output. It is also usually the first coupler in a radar system waveguide run.

## Symbols

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

*B-40*-40 dB bandwidth

*BC* Chirp bandwidth

*BN* Necessary bandwidth

dB/dec dB per decade

*dBpp* dB with respect to peak power

*fc* characteristic frequency

*ft* transmitter frequency tolerance

*k*  Boltzmann's constant

*t* Pulse duration

*tr* Pulse rise time

## Abbreviations

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

AC Alternating Current

A/D Analog to digital converter

CW Continuous Wave

EFTA European Free Trade Association

FM Frequency Modulation

IF Intermediate frequency

LNFE Low Noise Front End

MDS Minimum Detectable Signal

OoB Out of Band

PEP Peak Envelope Power

PM Phase Modulation

PRF Pulse Repetition Frequency

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 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 transmitter of a pulsed radar system produces microwave pulses, which cause a broad frequency spectrum depending on the pulse duration. The operating frequency is the frequency of the microwave emission during the transmitting pulse and is represented by the spectral line of highest amplitude. For phase/frequency modulated radar systems the operating frequency is to be understood as the centre between the highest and lowest transmitted frequency. The frequency tolerance is the maximum permissible departure from the operating frequency.

##### Limits

The frequency tolerance for meteorological radar systems shall not exceed:

(1)

As specified in Appendix 2 of ITU Radio Regulations [4].

##### Conformance

The conformance tests are specified in clause 5.4.1.1.

#### Measured B-40 Bandwidth

##### Definition

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

##### Limits

For all radar types covered by the present documents the measured B-40 bandwidth of the signal shall be contained completely within the frequency ranges 5 250 MHz to 5 850 MHz in all operating modes.

In case of multiple carrier-frequencies, all measured -40 dB emissions shall be contained in the allocated band.

##### Conformance

The conformance tests are specified in clause 5.4.1.3.

#### Out-of-Band emissions

##### Definition

Out-of-Band emissions refer to emissions in the region between the calculated -40 dB bandwidth and the spurious region (see clause 4.2.1.4.1 for the definition of spurious region).

For meteorological radar systems with multiple pulse length, the B-40 bandwidth shall be calculated for each individual used pulse length and the maximum B-40 bandwidth obtained shall be used to establish the shape of the emission mask.

NOTE 1: The shortest pulse length used is usually 500 ns.

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

The applicable formulae for the calculation of the B-40 bandwidth are described in Annex B.



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

##### Limits

Depending on the PEP power the maximum OoB emission power level shall not exceed the limits stated in Table 1 or Table 2 and shall not exceed the corresponding mask depicted in Figure 2 as specified in ECC/Recommendation (02)05 [2]. The roll-off of the OoB mask beyond the B-40 bandwidth in relation to *B-40* is specified as follows:

* The mask has a roll-off at 30 dB/dec from the calculated (identified) *B-40* bandwidth to a level of -70 dBpp.
* The mask then continues to roll-off at 60 dB/dec to a spurious emission limit level of -100 dBpp or -90 dBpp with regard to the PEP.

NOTE 1: The -100 dBpp mask corresponds to the dashed line in figure A2.1c and the -90 dBpp corresponds to the dashed line in figure A2.1b of unwanted emissions in Annex 2 of the ECC/Recommendation (02)05 [2].

NOTE 2: ERC/Recommendation 74‑01 [1] stipulates in its Table 5.1 for meteorological radars a spurious emission limit in the reference bandwidth of "‑30 dBm or 100 dB/90 dB below PEP, whichever is less stringent".

Table 1: Limits for Out of Band emissions for a PEP of greater than 150 kW

|  |  |  |
| --- | --- | --- |
| Multiple of the  B-40 bandwidth | Limit  dBpp | Slope  dB/decade |
| 0,5 | -40 | -∞ |
| 0,5 to 5 | -40 to -70 | -30 |
| 5 to 10,8 | -70 to -90 | -60 |

Table 2: Limits for Out of Band emissions for a PEP of equal or lower than 150 kW

|  |  |  |
| --- | --- | --- |
| Multiple of the  B-40 bandwidth | Limit  dBpp | Slope  dB/decade |
| 0,5 | -40 | -∞ |
| 0,5 to 5 | -40 to -70 | -30 |
| 5 to 15,8 | -70 to (-100 or -30 dBm, see note 1) | -60 |
| NOTE 1: -70 dBpp to -100 dBpp or -30 dBm whichever is less stringent. | | |

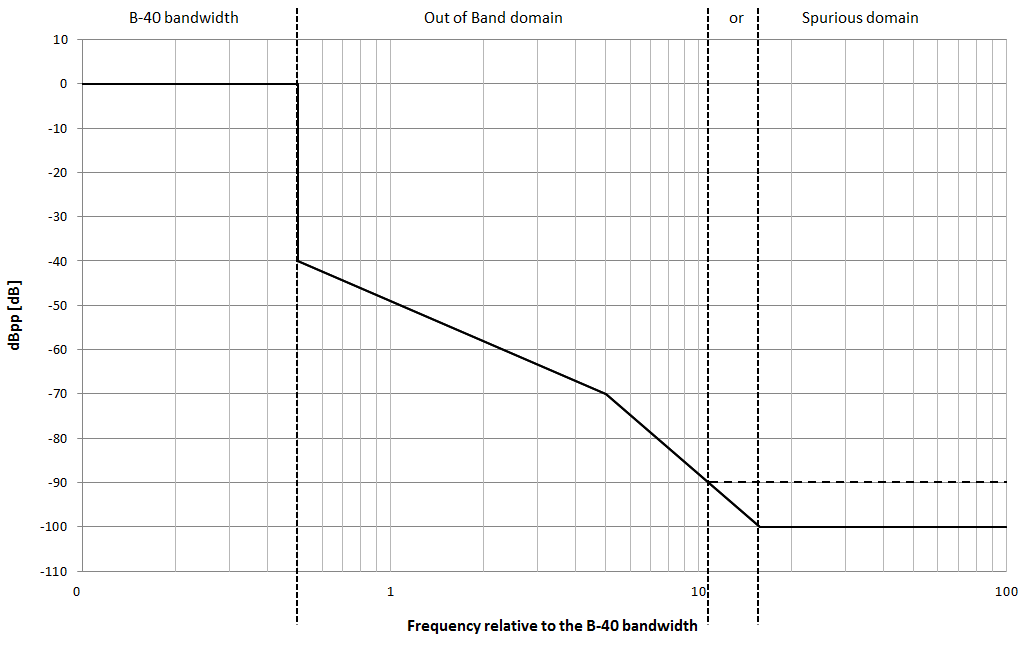


Figure 2: Unwanted emission limit masks

##### Conformance

The conformance tests are specified in clause 5.4.1.4.

#### Spurious emissions

##### Definition

Spurious emissions are defined as the entity of all emissions in the frequency range from the cut-off frequency 3 152 MHz of the waveguide section to 26 GHz, but outside B-40 boundaries and outside the OoB domain.

NOTE: The lower limit of this frequency range is obtained as the cut-off frequency of the generally used WR187/WG12 waveguide according to IEC 60153-2 [i.2]. The upper limit corresponds to the upper limit stated in ERC/Recommendation 74‑01 [1] Table 1.

They include:

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

The boundaries between OoB domain and the spurious domain are where the OoB limit mask specified in ECC/Recommendation (02)05 [2] reaches the spurious emission limit of -100 dBpp or -90 dBpp or -30 dBm according to ERC/Recommendation 74-01 [1] Table 5.1. This is illustrated in Figure 3.



Figure 3: Definition of OoB and spurious emission domains for non FM/PM pulsed radar  
(Not to scale).

##### Limits

For meteorological radar systems the spurious emission limits are related to the PEP. The limits shall be as specified in in Table 3 and also defined in ERC/Recommendation 74-01 [1] Annex 5 Table 5.1.

Table 3: Spurious emission levels

|  |  |
| --- | --- |
| Transmitter PEP | Spurious emission limits |
| < 10 kW | -30 dBm |
| 10 kW ≤ PEP ≤ 150 kW | 100 dB |
| > 150 kW | 90 dB |

The spurious domain emission limits shall take into account the attenuation of spurious domain emissions by the antenna as indicated in ERC/Recommendation 74-01 [1] .

NOTE 1: A reference bandwidth of 1 MHz is recommended for frequencies above 1 GHz as indicated in ERC/Recommendation 74-01 [1] .

NOTE 2: In the case of occurrence of interferences caused by unwanted emissions of the radar transmitter, much higher suppression of Out-of-Band or spurious emissions may be required during measurement. Therefore, it is desirable that it is possible to attenuate or to suppress parts of the emitted signal in the feeder line to the measurement equipment.

##### Conformance

The conformance tests are specified in clause 5.4.1.5.

#### Stand-by Mode Emissions

##### Definition

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 -47 dBm when measured with a measurement bandwidth of 1 MHz as specified in Table 5.1 in ERC/Recommendation 74-01 [1].

##### Conformance

The conformance tests are specified in clause 5.4.1.6

### Receiver Requirements

#### Noise Figure

##### Definition

The receiver noise figure measures the degradation of the signal-to-noise ratio, caused by components in the radio-frequency signal chain.

##### Limit

The maximum receiver noise figure shall be 6 dB.

##### Conformance

The conformance test is specified in clause 5.4.2.1.

#### Receiver selectivity

##### Definition

The receiver selectivity is the ability of a receiver to detect and decode a desired signal in the presence of an unwanted interfering signal outside the B-40 bandwidth.

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

##### Limit

The input selectivity of the radar shall correspond to the requirements shown in Figure 4.

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 5 100 MHz to 6 200 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.

EXAMPLE 1: If the meteorological radar operates at 5 450 MHz and the B-40 is equal to 20 MHz than the lower frequency limit of the disturbing signal shall be 4 940 MHz. The upper limit will be equal to 6 200 MHz.

The receiver selectivity depends on an analogue filter and a digital matched filter. The analogue filter is wider than the matched filter due to the permissible frequency drift of the transmitter. Both receiver selectivity measurements are described in the following and shall be measured and documented.

NOTE 1: 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.

In order to determine if the receiver selectivity follows the required selectivity mask, a disturbance signal level at the MDS 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 MDS level and is calculated by the following formula:

(2)

Where:

* -174 dBm is the noise power value in dBm, measured with 1 Hz bandwidth (BN) at 290° Kelvin and derived from the available noise power Ni on the receiver input. . Where:
  + k Boltzmann constant =
  + T0 Temperature in Kelvin
* NF(dB) is the receiver noise figure in dB. Measurement of the noise figure is described in chapter 5.4.2.1.
* BW(dB) is the receiver or matched filter bandwidth in dB. Calculated as:
* L(dB) are any additional losses in dB

The power level which will be applied at the lower and upper B-40 frequency shall be the MDS level + 40 dB as shown in Figure 4.

The following table shows the frequency offset relative to fc with a calculated MDS value of -110 dBm and a maximum disturbance level of -30 dBm.

Table 4: Receiver selectivity mask

|  |  |  |
| --- | --- | --- |
| Frequency offset relative to fc by multiple of the  B-40 bandwidth | Maximum interfering power level  dB above MDS | Slope  dB/decade |
| 0 to 0,5 | None | 0 |
| 0,5 | 40 | -∞ |
| 0,5 to 5 | + 40 to 70 or -30 dBm (see Note 1) | -30 |
| 5 to 10,8 | 70 to 90 or -30 dBm (see Note 1) | -60 |
| 10,8 to ∞ | -30 dBm | 0 |
| NOTE 1: The maximum input power of the receiver shall not exceed -30 dBm | | |



Figure 4: Resulting receiver selectivity mask (not to scale). The maximum disturbance level was set at -30dBm.

##### Conformance

The conformance tests are specified in clause 5.4.2.2.

#### Receiver Compression Level

##### Definition

The compression level is defined as when one of the receiver stages becomes nonlinear thereby causing distortion and other non-linear effects that prevents proper operation of the receiver. The receiver input compression level is defined as when the receiver output is 1 dB into compression as can be seen in Figure 5.



Figure 5: Illustration of finding the LNA input 1 dB compression point

##### Limit

The input of the radar shall be able to handle signal levels up to at least -35 dBm without being in compression.

NOTE 1: A high compression level corresponds to high immunity against blocking.

NOTE 2: It shall be noted that due to physical constraints in LNA design and A/D converter realization, the receiver input compression level cannot be set arbitrarily high because this may prevent detection of small targets (and thus affect performance).

The measurement of the saturation signal shall be done at the IF output of the LNFE (analog) or by data analysis at the output of the A/D converter (digital). The IF output of the LNFE is defined as the port which is connected directly via a RF connection to the A/D converter of the digital receiver in normal operation of the radar system. Both ports can be seen in Figure 9 in Annex C.

##### 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

### Test Conditions

Tests defined in the present document shall be carried out at representative points within the boundary limits of the declared operational environmental profile which, as a minimum, shall be that specified in the test conditions contained in this Harmonised Standard.

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

### Normal temperature and humidity

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

1. temperature: +15°C to +35°C
2. relative humidity: below 75 %

### Normal test power supply

The test voltage for the equipment to be connected to an AC supply shall be the nominal mains voltage declared by the manufacturer including a variation of ±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 measurements 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 documented in the test report
* the recorded value of the measurement uncertainty shall be, for each measurement, equal to or lower than the figures in Table 5

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 characterizing the actual measurement uncertainties are normal (Gaussian)). Principles for the calculation of measurement uncertainty are contained in ETSI TR 100 028 [i.4], in particular in Annex D of the ETSI TR 100 028-2 [i.5].

Table 5: Maximum measurement uncertainty

|  |  |
| --- | --- |
| Parameter | Uncertainty |
| Transmitter measurements | |
| Frequency tolerance (see Note) | ± 0,1 ppm |
| Transmitter power | ± 0,75 dB |
| Out-of-Band emissions | ± 4 dB |
| Spurious emissions | ± 4 dB |
| **Receiver measurements** | |
| Noise Figure | ± 1 dB |
| Receiver selectivity | ± 4 dB |

When measuring the frequency tolerance for radars with a phase or frequency modulated pulse the tolerance shall be measured on the frequency reference used for generating the radar output signal. The total frequency tolerance shall not exceed the limits noted in clause 4.2.1.1.2.

## Radio test suites

### Transmitter test specification

#### Frequency Tolerance

The antenna shall be replaced by a high power dummy load. The forward port of the system coupler shall be used and shall have an adequate attenuation. An optional reverse port shall be terminated with an appropriate 50 Ω terminator.

To measure the frequency tolerance a frequency meter or spectrum analyser shall be used. The frequency meter shall be capable of measuring the short RF pulses. An additional attenuator shall be used if needed in order to protect the frequency meter input from the high power RF pulses. The measurement setup from Annex C shall be used.

The frequency measurements shall be performed with all available pulse length settings. The corresponding PRF shall be chosen in order to get the maximum possible duty cycle for each pulse length. After the frequencies for the maximum duty cycles are measured, the measurements shall be repeated with the lowest duty cycle. The lowest duty cycle is defined as the combination of shortest pulse length and lowest PRF. The lowest PRF shall be the one, which will be generally used in meteorological radar systems during normal operation.

NOTE: A typical lower value for the PRF is 250 Hz as mentioned in [i.3].

Between each measurement, a waiting period of at least 20 minutes shall be applied. During this time, the transmitter shall be in operation and transmitting with the new pulse length and PRF values. This will give the transmitter enough time to reach a stable temperature. If the transmitter has not reached a stable temperature the waiting period shall be extended until the frequency drift has come to an end.

The results obtained for all available pulse length settings shall be compared with the limits in clause 4.2.1.1.2 in order to prove compliance with the requirement.

Preferably a spectrum analyser shall be used to display the frequency spectrum in order to obtain the centre between the highest and lowest frequencies. To measure the frequency stability a frequency counter with a frequency stability of equal to or better than 0,1 ppm is connected to the radar transmitter via couplers.

#### Transmitter Power

The antenna shall be replaced by a high power dummy load. If the meteorological radar system is equipped with dual polarisation capability, the single polarisation mode shall be activated and shall be used for the measurements. If only permanent dual polarisation mode is available and no coupler in front of the power divider is available, the coupling ratio from the power divider shall be taken into account for. The forward port of the transmitter coupler shall be used and shall have an adequate attenuation. An optional reverse port shall be terminated with an appropriate 50 Ω terminator. The coupling factor shall be known in the allocated band with an accuracy of ± 0,5 dB or better. The measurement from Annex C shall be used.

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 value measured during a period equal to at least one rotation period shall be used.

The transmitter power measurements shall be performed with all available pulse length settings. The corresponding PRF shall be chosen in order to get the same duty cycle for each pulse length setting.

To determine the PEP of the pulse a peak power meter with direct reading of the transmitter pulse power shall be used. The PEP shall be measured at the 50% point of the pulse length. If the transmitter pulse is rippled the average over the pulse shall be used as can be seen in Figure 6.



Figure 6: Transmitter output power

To reference the indicated transmitter power to the transmitter output flange the coupling factor of the transmitter coupler shall be taken into account. If an additional attenuator or RF cable has been inserted between the transmitter coupler forward port and the power meter this shall be taken into account. If the power meter does not allow for compensation of the coupling loss and additional attenuator, then the coupling loss and attenuator value shall 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 section 5.4.1.4 Out-of-Band emissions.

The bandwidth of the emissions 40 dB below PEP shall be measured.

It shall be ensured that the edges of the -40 dB emissions stay within the allocated band for the product under test.

#### Out-of-Band emissions

The antenna shall be replaced by a high power dummy load. If the meteorological radar system is equipped with dual polarisation capability, the single polarisation mode shall be activated and shall be used for the measurements. If only permanent dual polarisation mode is available and no coupler in front of the power divider is available, the coupling ratio from the power divider shall be taken into account. The forward port of the system coupler shall be used and shall have an adequate attenuation. An optional reverse port shall be terminated with an appropriate 50 Ω terminator. The coupling factor shall be known in the allocated frequency band with an accuracy of ± 0,5 dB or better.

The measurement bandwidth shall be according to Recommendation ITU‑R M.1177‑4 [3].

The so-called indirect method specified in Recommendation ITU‑R M.1177‑4 [3] shall be applied for the measurement of unwanted emissions of radar systems. The transmitter output spectrum shall be measured at the system coupler of the transmitter as illustrated in Annex C.

NOTE 1: To obtain a sufficient dynamic range the radar signal may need to be attenuated by an additional notch filter.

NOTE 2: Further information how to perform the measurement can be found in Recommendation ITU‑R M.1177‑4 [3].

The OoB power emission shall be measured in the frequency bands given in Table 6 or Table 7 depending on the PEP. If the PEP is greater than 150 kW the Table 6 shall be used and for powers equal to or lower to 150 kW the Table 7 shall be used. 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.

Table 6: OoB emission boundaries for -90 dBpp

|  |  |
| --- | --- |
| Lower OoB boundary | Upper OoB boundary |
| Carrier frequency – 10,8 × B-40 | Carrier frequency + 10,8 × B-40 |
| Note: The values are taken from ECC/Recommendation (02)05 [2] | |

Table 7: OoB emission boundaries for -100 dBpp

|  |  |
| --- | --- |
| Lower OoB boundary | Upper OoB boundary |
| Carrier frequency – 15,8 × B-40 | Carrier frequency + 15,8 × B-40 |
| Note: The values are taken from ECC/Recommendation (02)05 [2] | |

NOTE 3: Typical meteorological radar system parameters are e.g. a centre frequency of 5 640 MHz, transmitter power of 250 kW, a pulse duration of t = 500 ns and a rise time of tr = 100 ns. The 40 dB bandwidth calculated applying the equation from Annex B is 27,7 MHz. This leads to OoB boundaries at 10,8 × 27,7 MHz = 299,2 MHz away from the operating frequency. For this example the absolute boundaries between OoB emissions and spurious emissions are: 5 640 MHz – 299,2 MHz = 5 340,8 MHz and 5 640 MHz + 299,2 MHz = 5 939,2 MHz (see Figure 7).

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

Figure 7 shows the calculated emission masks for the aforementioned parameters of a typical meteorological radar system applying the mask specification in clause 4.2.1.2 which is corresponding to the dashed line in figure A2.1b of ECC/Recommendation (02)05 [2].



Figure 7: Calculated emissions mask for pulse duration t = 500 ns and rise time tr = 100 ns at centre frequency of 5 640 MHz

#### Spurious emissions

For the spurious emission measurements the so-called indirect method specified in Recommendation ITU-R M.1177 [3] shall be used. To perform the measurements the radar system and the measuring equipment shall be set up as displayed in Annex C. The spurious power emissions shall be measured in the frequency ranges outside the OoB emissions boundaries.

NOTE 1: Depending on the setup of the meteorological radar system the location where the measurement setup will be installed may be close to the antenna. This ensures that band-limiting components like circulator, rotary joint or waveguide filter are included in the measurement.

The spurious domain emission limits shall take into account the attenuation of spurious domain emissions by the antenna as indicated in ERC/Recommendation 74-01 [1].

Wave propagation in the waveguide is not possible below a certain cut-off frequency where the attenuation of the waveguide is very high. Beyond a certain upper frequency limit, several propagation modes are possible so that the behaviour of the waveguide is no longer unambiguous. In the unambiguous range of a rectangular waveguide, only TE1,0 waves are capable of propagation. In the WG16 waveguide the cut-off frequency is 6 556 MHz which is higher than the operating frequency of the C-Band meteorological radar systems. Therefore, at least a 15 cm long WG16 waveguide shall be inserted in the measurement setup in order to protect the measurement device from the operating frequency in the WG16 and higher waveguide bands. The waveguide acts as a high pass in this setup.

Due to the ambiguous propagation modes of the used C-Band waveguide for higher frequencies, smaller waveguides with appropriate linear tapers shall be used for the measurement of higher frequencies. These frequency ranges are also referred to as waveguide bands as can be seen in Table 8.

Each waveguide band shall be measured with its corresponding waveguide resulting in unambiguously measurements for the spurious measurements.

EXAMPLE: For the measurement of the frequency range 8,2 – 12,4 GHz the following setup will be used: a taper from WG12 to WG14, followed by a second taper from WG14 to WG16 waveguide, followed by at least 15 cm of WG16 waveguide terminated with a WG16 to coax transition.

Table 8: Waveguide bands and associated waveguides

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Waveguide band | Frequency | Cut-off frequency | Waveguide designation | |
| EIA | UK |
| C | 3,95 – 5,85 GHz | 3,152 GHz | WR187 | WG12 |
|  | 5,85 – 8,2 GHz | 4,300 GHz | WR137 | WG14 |
| X | 8,2 – 12,4 GHz | 6,556 GHz | WR90 | WG16 |
| Ku | 12,4 – 18,0 GHz | 9,486 GHz | WR62 | WG18 |
| K | 18,0 – 26,5 GHz | 14,051 GHz | WR42 | WG20 |

A noise margin of at least 10 dB below the spurious emission levels of -100 dBpp or -90 dBpp shall be achieved. A notch filter for the operating frequency shall be used to achieve the required dynamic amplitude range.

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

NOTE 2: In the taper from the WG14 to the WG16 waveguide the operating frequency will be completely reflected. If the connected circulator is the internal one and has not been installed purely for the measurement it will transfer the signal to the receiver input. Therefore the LNFE should be replaced by a high power dummy load.

The results obtained shall be compared to the limits in clause 4.2.1.4.2 in order to prove compliance with the requirement, further taking into account that the spurious domain emission limits shall take account of the attenuation of spurious domain emissions by the antenna.

Table 9: Spurious emissions measurement bands

|  |  |
| --- | --- |
| Lower measurement band | Upper measurement band |
| From 3 152 MHz  to the lower OoB boundary | From the upper OoB boundary  to 26 GHz |

The lower boundary is determined by the Cut-off frequency as stipulated in Table 8 and the upper boundary is defined in ERC/Recommendation 74-01 [1].

#### Stand-by Mode Emissions

For the spurious emission 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 10 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 9).

The results obtained shall be compared to the limit in clause 4.2.1.5.2 in order to prove compliance with the requirement.

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

### Receiver Test specification

#### Noise Figure

The receiver noise figure is measured along the complete receiver (as close as possible to the input of the receiver, but excluding antenna & waveguide). It shall be measured using a noise source (which may be built into the system) and a detector (which may be built into the system in as well).

The Y-factor method for the measurement of the receiver noise figure shall be used. A noise source is connected to the radar receiver input port. The receiver 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 results obtained shall be compared to the limits in clause 4.2.2.1.2 in order to prove compliance with the requirement.

#### Receiver Selectivity

The radar receiver is setup in normal operating mode during the test. The receiver frequency should be tuned to the centre frequency of ground-based radars used for meteorological purposes which is usually at 5 625 MHz. The receiver frequency shall be documented in the test report. The upper and lower frequency limits of the disturbing signal mentioned in chapter 4.2.2.2.2 shall be adjusted accordingly.

Compliance shall be tested by applying the test signal into the LNFE input directly, or in conjunction with its connecting waveguide. Depending on the radar setup the waveguide components between the LNFE and the antenna may have bandwidth limiting functions and should be incorporated in the receiver selectivity measurement. The measurement setup from Figure 11 in Annex E shall be used.

The LNFE input is defined as the coaxial input port, which is connected directly via a short RF cable to the waveguide-coax transition in normal operation of the radar system. The IF output of the LNFE is defined as the port which is connected directly via a RF connection to the A/D converter of the digital receiver on normal operation of the radar system. Both ports can be seen in Figure 9 in Annex C.

NOTE: Usually the IF frequency prior the A/D converter is 60 MHz.

If the meteorological radar system has two independent receiving channels for each polarisation, the one with the highest sensitivity shall be chosen. If direct conversion receivers with I and Q mixer are used the selectivity shall be measured at both channels.

The results obtained shall be compared to the limits in clause 4.2.2.2.2 in order to prove compliance with the requirement.

##### Receiver OoB selectivity

Frequencies inside the B-40 receiver bandwidth need not to be tested at the output of the LNFE because this is the receiving frequency range of the meteorological radar system. No rejection of unwanted signals in the LNFE is possible in this frequency range. The LNFE output power shall be measured at the above mentioned centre or operating frequency in order to get a reference level for the evaluation of rejection levels in the defined bandwidth.

Meteorological radar systems are equipped with digital filters in the processing chain. The bandwidths of these matched filters are smaller than the receiver bandwidth.

NOTE 1: 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.

To measure the matched filter bandwidth the complete receiver chain including A/D converter, digital signal processing and display software shall be included in the measurement. For the measurement of the receiver selectivity the widest matched filter bandwidth shall be used. By using the widest matched filter the worst case scenario is represented. The measurement test setup and the results of the matched filter and the Out of Band rejection shall be documented in the test report. Furthermore, the test procedure shall also be documented in the test report.

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 for a modulated pulsed radar shall have the following characteristics:

* the disturbing signal shall be formatted as the emission pattern of the radar under test in order to be detectable by the receiver system and shall increase in the same degree as the permitted emission spectrum with a limit of 90 dBpp. See Figure 4 for an example. A CW signal may be used if it produces the same results as a formatted signal.
* the maximum input level of the receiver shall be 6 dB below the compression level for the given receiver design.
* the discrete frequency steps shall be equal to or lower than 1 MHz.

The selected disturbing signal shall be documented in the test report.

The LNFE output power shall be measured at the above mentioned centre or operating frequency in order to get a reference level for the evaluation of rejection levels in the defined bandwidth.

The disturbance signals shall be applied either directly to the LNFE input or shall be applied to the connecting waveguide of the LNFE as can be seen in Figure 11 in Annex E. If the disturbance signal is applied to the connecting waveguide the limited frequency range of the C-Band waveguide shall be taken into account. Due to the ambiguous propagation modes of the used C-Band waveguide for higher frequencies, smaller waveguides with appropriate linear tapers shall be used for the measurement of higher frequencies. These frequency ranges are also referred to as waveguide bands as can be seen in Table 8.

It is assumed that all the used receivers in a single or dual polarised system are equivalent. If this is not the case all used receivers shall be measured separately.

Each waveguide band shall be measured with its corresponding waveguide resulting in unambiguously measurements for the spurious measurements.

The disturbing signal for an unmodulated pulsed radar shall have the following characteristics:

* the disturbing signal shall be a sinusoidal CW signal and shall increase in the same degree as the permitted emission spectrum with a limit of 90 dBpp. See Figure 4 for an example.
* the maximum input level of the receiver shall be 6 dB below the compression level for the given receiver design.
* the discrete frequency steps shall be equal to or lower than 1 MHz

An appropriate measurement device like a spectrum analyser shall be connected to the LNFE output and shall have the following characteristics:

* the frequency span shall be equal to or higher than 1 MHz

NOTE 2: Due to the huge amount of frequency steps it is recommended to use a computer aided measurement system to decrease the measurement time.

The corresponding output power shall be measured at the LNFE output. This procedure will be repeated for all discrete frequency steps.

After all frequency steps have been applied and its corresponding output powers have been recorded the output power levels shall be set in relation to the output power of the operating frequency.

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 results obtained shall be compared to the limits in clause 4.2.2.2.2 in order to prove compliance with the requirement.

#### Receiver Compression

While the receiver compression level is defined as the 1dB compression point of the receiver chain, it is not possible without knowing the design of the receiver circuits of a radar to define a general measurement circuit. The best way to measure the receiver compression level is to increase the power of a sine wave signal injected into the LNFE and check linearity either at the IF output of the LNFE or by reading digital values at the output of the A/D converter.

##### Receiver Compression Level

An CW test signal shall be injected into the LNFE. The gain response curve of the LNFE shall be measured and the 1 dB compression point shall be noted.

The results obtained shall be compared to the limits in clause 4.2.2.3.2 in order to prove compliance with the requirement.

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

The present document has been produced to provide a means of conforming to the essential requirements of Directive 2014/53/EU [i.1] 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 - also known as the Radio Equipment Directive 1999/5/EC.

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 [i.1]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Harmonised Standard ETSI EN 303 347-2 | | | | |
| Requirement | | | Requirement Conditionality | |
| No | Description | Reference: Clause No | U/C | Condition |
| 1 | Frequency Tolerance | 4.2.1.1 | U |  |
| 2 | Measured B-40 Bandwidth | 4.2.1.2 | U |  |
| 3 | Out-of-Band Emissions | 4.2.1.3 | U |  |
| 4 | Spurious Emissions | 4.2.1.4 | U |  |
| 5 | Stand-by Mode Emissions | 4.2.1.5 | U |  |
| 6 | Noise Figure | 4.2.2.1 | U |  |
| 7 | Receiver Selectivity | 4.2.2.2 | U |  |
| 8 | Receiver Compression Level | 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 or its test specification.

**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 manufacturers claimed functionality of the equipment (C).

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

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

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

# Annex B (normative): Calculation of the -40 dB Bandwidth

Annex 8 of Recommendation ITU R SM.1541-6 [5] specifies the B-40 bandwidth for various types of waveforms (e.g. pulsed radar signals).

The B-40 bandwidth for non-FM/PM pulse radars is the lesser of:

(3)

Where:

* the coefficient is 6,2 for meteorological radar systems with operating power greater than 100 kW and 7,6 for lower-power radars.
* *t* is the pulse duration between the 50% amplitude (voltage) points in seconds.
* *tr* is the rise time in the case of a trapezoidal pulse.

NOTE 1: For typical values of a pulse duration of t = 500 ns and a rise time of tr = 100 ns with a PEP of 250 kW the formula above yields a 40 dB bandwidth value of 27,7 MHz.

For frequency modulated pulse radar systems the B-40 bandwidth is:

(4)

Where:

* BC is the bandwidth of the frequency deviation (total frequency shift during the pulse generation).
* τ is the pulse length including rise and fall times.
* to account for the rise time. (5)
* to account for the fall time. (6)
* to account for both the rise and fall times combination.
* tr is the rise time.
* tf is the fall time.

The equation 4 above is only valid when the following conditions are met:

1. The product BC ∙ Minimum (tr, tf) is greater than or equal to 0,10 and
2. that the product of BC ∙ τ or compression ratio must be greater than 10.

In all other cases, the following equations shall be used:

(7)

Where:

* A is 0.105 when K = 6,2 and 0,065 when K 7,6.

NOTE 2: 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.

For radars with an asymmetrical spectrum, the B-40 bandwidth can be offset from the frequency of maximum emission level, but the combined B-40 bandwidth shall be contained completely within the allocated band as stipulated in section 4 of Annex 8 of Recommendation ITU R SM.1541-6 [5] .

The application of this rule is illustrated in Figure 8.

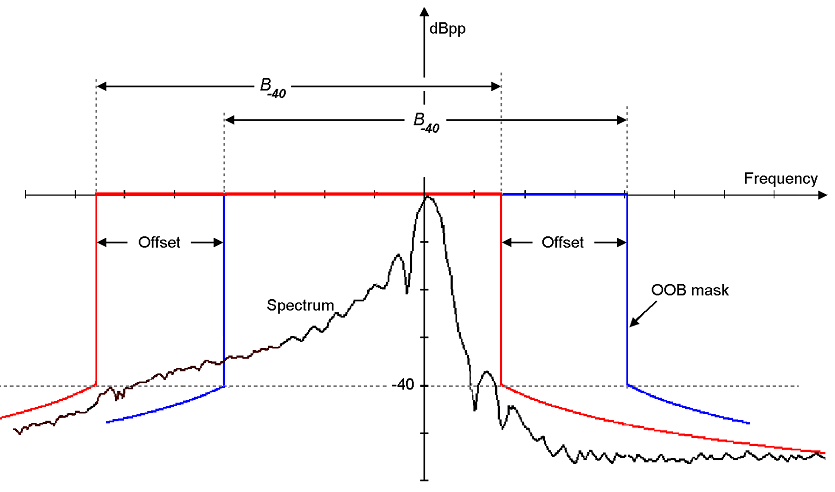


Figure 8: Application of the offset-rule for the OoB emission limit mask

# Annex C (normative): Operating frequency, transmitter power and OoB measurement setup



Figure 9: Indirect method for operating frequency and transmitter power measurement

The method for measurement of the operating frequency and the transmitter power shown in Figure 9 shall be applied.

Figure 9 shows for simplicity a single polarisation meteorological radar system. If a dual polarised system is used the single polarisation mode shall be activated. If only permanent dual polarisation mode is available and no coupler in front of the power divider is available, the coupling ratio from the power divider shall be taken into account.

# Annex D (normative): Spurious emission measurement setup



Figure 10: Indirect method for spurious emission measurement

The coupling factor of the used couplers shall be known in the allocated frequency band with an accuracy of at least ± 0,5 dB or better.

Figure 10 shows for simplicity a single polarisation meteorological radar system. If a dual polarised system is used the single polarisation mode shall be activated. If only permanent dual polarisation mode is possible and no coupler in front of the power divider is available, the coupling ratio from the power divider shall be taken into account.

# Annex E (normative): Receiver selectivity measurement setup



Figure 11: Measurement method for receiver selectivity measurement

Figure 11 shows for simplicity a single polarisation meteorological radar system. If a dual polarised system is used the single polarisation mode shall be activated. It is assumed that both receiving chains in a dual polarisation system are equivalent.

# Change history

|  |  |  |
| --- | --- | --- |
| **Document history** | | |
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# History

|  |  |  |
| --- | --- | --- |
| **Document history** | | |
| V0.0.1 | November 2015 | Starting of draft version |
| V0.1.2 | December 2015 | * Clarification in OoB and spurious emissions conformance requirements. Added reference. * Change of operating frequency measurement procedure. |
| V0.1.3 | April 2016 | Clarification added for dual pol systems only, transmitter power measurement uncertainty changed and error corrections. |
| V0.2.4 | May 2016 | Added the description of receiver measurement with waveguide, Annex D. Minor corrections. Changed spectrum mask figures. |
| V0.2.5 | May 2016 | Changed to multipart document, added FM pulsed radar, Tx power measurement changed. |
| V0.2.6 | September 2016 | Minor technical changes, clarification of some points |
| V0.2.7 | November 2016 | Editorial changes after ERMTGAERO-RADARS#4 meeting |
| V0.2.8 | January 2017 | Receiver selectivity update, editorial changes. |
| V0.2.9 | April 2017 | Added matched filter selectivity and noise figure. |
| V0.2.10 | June 2017 | BS deleted and added description for superimposed B-40 emissions mask |
| V0.2.11 | July 2017 | Editorial changes |
| V0.2.12 | October 2017 | Moved B-40 calculation in Annex C, added chapter B-40 and transmitter power. |
| V0.2.13 | January 2018 | Stand-by mode emission and receiver compression level added. |
| V0.2.14 | February 2018 | Editorial changes and clarification. |
|  |  |  |