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TECHNICAL REPORT

Guide for the development of Harmonised Standards falling under article 3.2 of the Radio Equipment Directive (RED); Meteorological and Primary Radars

Reference

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

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

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Introduction

Some technical parameters defined in ETSI EG 203 336 [i.1] are applicable only to communication systems and not to primary, monostatic radar systems such as coastal surveillance, shipborne, ground-based aeronautical or meteorological radar systems. Primary, monostatic radar systems are different from radio communication systems since they do not exchange information with other communications systems on other platforms. They continually scan for unknown objects of any nature and do not adjust receiver or transmitter parameters according to what they detect and analyse, and depend on energy received from their transmissions reflected from these objects.

1 Scope

The present document describes the applicability of the technical requirements related to article 3.2 of the RED [i.2] as defined in ETSI EG 203 336 [i.1] for the following types of primary, monostatic radar systems:

- ground-based aeronautical radars (e.g. air surveillance radars, surface movement radars and runway debris detection radars);
- meteorological radars (e.g. weather radars and wind profilers);
- land-based surveillance maritime radars (e.g. coastal and VTS radars);
- shipborne maritime radars not falling under the MED Directive [i.8] (i.e. non-SOLAS radars and river radars).

The present document also addresses technical issues and provide guidelines (such as spurious emission measurements for waveguide-based systems) for the test procedures related to the applicable technical requirements.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

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

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EG 203 336 (V1.2.1): "Guide for the selection of technical parameters for the production of Harmonised Standards covering article 3.1(b) and article 3.2 of Directive 2014/53/EU".

[i.2] 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 (OJ L153, 22.5.2014, p62).

[i.3] IEC 60153-2 (Edition 3.0, 2016): "Hollow metallic waveguides. Part 2: Relevant specifications for ordinary rectangular waveguides".

[i.4] ERC/Recommendation 74-01 (2019): "Unwanted emissions in the spurious domain".

[i.5] ITU Radio Regulations (2024).

[i.6] RSPG 19-031: "RSPG Report on European Spectrum Strategy".

[i.7] ETSI EN 300 676-1: "Ground-based VHF hand-held, mobile and fixed radio transmitters, receivers and transceivers for the VHF aeronautical mobile service using amplitude modulation; Part 1: Technical characteristics and methods of measurement".

[i.8] Directive 2014/90/EU of the European Parliament and of the Council of 23 July 2014 on marine equipment and repealing Council Directive 96/98/EC.

[i.9] Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code.

[i.10] ECC(20)093 Annex 14.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

adjacent band: frequency band adjacent to the operating band

adjacent channel: channel which is offset from the wanted channel by the channel spacing

NOTE: See figure 1.

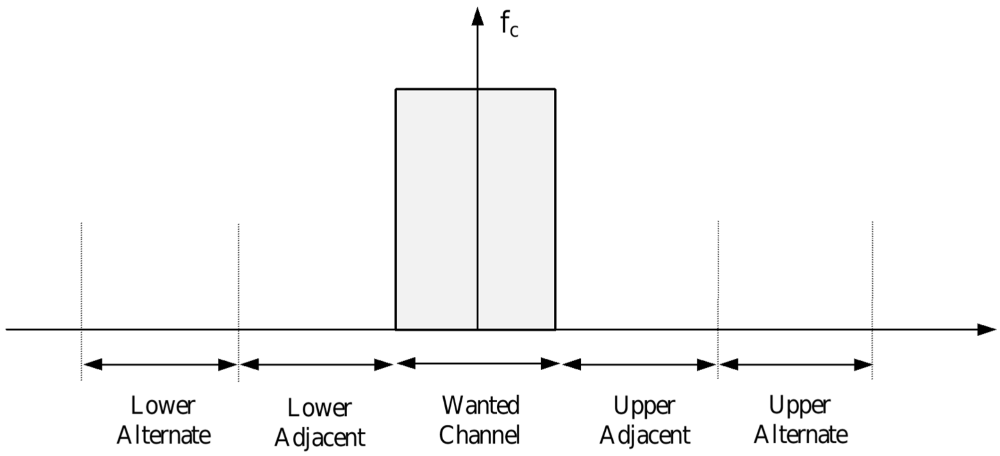

Figure 1: Adjacent signal definitions

adjacent signal: signal adjacent to the wanted signal

harmful interference: interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radio communication service operating in accordance with Radio Regulations

NOTE: This term is taken from the ITU Radio Regulations [i.5].

hydrometeors: atmospheric water particles in various forms, including liquid and solid water, that are suspended in the Earth's atmosphere

monostatic radar: primary radar system where transmitter and receiver are co-located and use the same antenna

operating band: frequency band in which the EUT is intended to transmit and/or receive

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

NOTE: This term is taken from the ITU Radio Regulations [i.5].

primary radar: radiodetermination system based on the comparison of reference signals with radio signals reflected from the position to be determined

NOTE: This term is taken from the ITU Radio Regulations [i.5].

sector blanking: process by which the transmitter is turned off for a certain azimuth sector

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 term is taken from the ITU Radio Regulations [i.5].

staggered transmission scheme: transmission scheme that changes the time between transmitted radar pulses in a patterned or randomized manner

transmitter spectrum mask: maximum allowed power emitted by the transmitter as a function of frequency, either expressed in power density versus frequency, or in total power within defined frequency band

3.2 Symbols

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

f_1	First input frequency for the third order IMD measurement
f_2	Second input frequency for the third order IMD measurement
f_{rx}	Nominal frequency of the receiver
f_{if}	Intermediate frequency of the receiver
P_{fa}	Probability of false alarm
λc	Wavelength of the used cut-off frequency

3.3 Abbreviations

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

ADC	Analogue-Digital Converter
AM	Amplitude Modulation
CW	Continous wave
EIRP	Effective Isotropic Radiated Power
ERP	Effective Radiated Power
HS	Harmonised Standard
IMD	Intermodulation Distortion
MED	Marine Equipment Directive
PRF	Pulse Repetition Frequency
QoS	Quality of Service
RCS	Radar Cross Section
SARPS	Standards and Recommended Practices
SMR	Surface Movement Radar
SOLAS	Safety Of Life At Sea
STC	Sensitivity Time Control
TB	Technical Body
VTS	Vessel Traffic Services

4 Applicability of ETSI EG 203 336 technical requirements

4.1 General

ETSI EG 203 336 [i.1] was developed with the purpose to identify the applicable technical requirements for conformance against articles 3.1(b) and 3.2 of the Radio Equipment Directive. Whilst the so identified technical requirements are of generic applicability, not all of them are unconditionally applicable to radars when talking about "efficient use of the radio spectrum". This is due to technical and operational differences between radio communication systems and radar systems.

In general, for primary radars the following has to be taken into account:

1) Radar designs are different from manufacturer to manufacturer whilst the Harmonised Standards need to contain unique test procedures applicable to all possible designs.

2) Modern radar systems make use of digital signal processing with the purpose of, among other things, removing false and unwanted targets (e.g. clutter, precipitation and point targets) and so decrease the probability of false alarms.

3) A transient interference depending on its characteristics will not cause any harmful interference since there are other radar downstream processing stages which help filtering out these transient disturbances, so that the probability of false tracks or false targets seen by the radar operator is not affected. For most of the radars in the scope of the present document, the far field distance can be several km, which means that a direct measurement may be impractical.

4) Primary radars always transmit at their maximum output power since they need to detect targets with different sizes at different distances. The maximum output power depends on the required performances. Therefore, concepts such as automatic power control, used for instance in mobile communications, are not applied in primary radars. It has to be taken into account that the power amplifier is one of the most expensive components of a radar and therefore the manufacturers will always try to achieve the required performances with as low power as possible in order to decrease the overall cost.

4.2 The concept of "harmful interference" for radars

When defining the applicable technical requirements for radars, it has to take into account that the essential requirement defined in article 3.2 of the RED has the purpose to avoid harmful interference and not all kinds of interference, where harmful interference is defined as follows (see [i.9]): "*interference which endangers the functioning of a radio navigation service or of other safety services or which otherwise seriously degrades, obstructs or repeatedly interrupts a radio communications service operating in accordance with the applicable international, Union or national regulations*".

Radar to radar interferences are typically transient and the Probability of a False Alarm (PFA) is decreased with (digital) processing stages which help mitigating the effect of these transient disturbances minimizing the PFA. For radars, "harmful interference" could notably be caused by a disturbance coming from certain communication systems or CW radars in a given direction, in which case the radar would be "blind" in that direction since it is likely not possible to reliably detect a real target. This problem cannot be solved by radar system design but can be mitigated for example with a proper frequency planning (if possible) or locating the radars in the most appropriate location.

5 ETSI EG 203 336 - Technical Requirements for article 3.2 of Directive 2014/53/EU

5.1 Transmitter - Technical Requirements

5.1.1 Transmitter power limits

ETSI EG 203 336 [i.1] states the following:

"HSs may include transmitter power limits. However, TBs should note that these are defined in national Radio Interface Specifications (RIS) and also in individual or general licence authorizations. Furthermore, TBs should be aware that there may be relevant ECC and EU deliverables.

The transmitter power limits may include a minimum range of Transmitter Power Control (TPC) (see clause 5.4 in ETSI EG 203 336 [i.1] on interference mitigation techniques).

Transmitter power limits may be specified and measured using a "spectrum mask" (clause 5.2.4) or as a total power in the transmit channel.

For devices without an antenna connector, the maximum power allowed may be specified as Total Radiated Power, ERP or EIRP."

For primary radars, there are no general regulatory limits and each country has national regulations limiting the maximum power. Sometimes there are also, within the same country, different regulatory limits according to the geographical area. Therefore, for all those cases where no regulatory limits have been defined, there is no obligation to have this technical requirement in Harmonised Standards. If a value is introduced, that would only reflect the maximum power for the radars available in the European Market at the time of writing the Harmonised Standard.

5.1.2 Transmitter power accuracy

ETSI EG 203 336 [i.1] states the following:

"When transmitter power is regulated, e.g. in the station licence, the ability of a transmitter to remain accurate in its expected environment should be considered for inclusion in an HS. It should be defined as a percentage (or a ratio in dB) of the nominal or mandated value.

When regulatory limits imply only a maximum emission limit (e.g. products that operate under a general licence regime), this parameter need not be considered for inclusion in an HS."

Transmitter power accuracy needs to be considered when regulatory limits include also an accuracy. For primary radars, since there are no EC regulatory limits for the power, this requirement does not have to be included.

5.1.3 Transmitter spectrum mask

This technical requirement will always be included in the HSs and contains the out-of-band and spurious emissions. Emissions will always be aligned with ERC/Recommendation 74-01 [i.4] and/or ITU Radio Regulations and will take into account the applicable international benchmarks such as ICAO SARPS.

5.1.4 Transmitter frequency stability

This technical requirement will always be included in the HSs and it needs to be aligned with the ITU-R Radio Regulations [i.5], Volume II, Appendix 2.

5.1.5 Transmitter intermodulation attenuation

ETSI EG 203 336 [i.1] states the following:

"The transmitter intermodulation attenuation is a measure of the capability of a transmitter to inhibit the generation of signals in its non-linear elements caused by the presence of the transmitter power and an interfering signal entering the transmitter via its antenna.

TBs should consider specifying this parameter for base stations where use on shared radio sites is foreseen. TBs should also consider specifying this parameter for all equipment designed for use in particularly dense usage scenarios, for example Public Protection and Disaster Relief (PPDR) where very high levels of quality of service are required."

For radar systems the transmitter intermodulation attenuation should not be an issue for the following reasons:

- Radars are not channelized equipment like communications systems. There might be several frequencies transmitted from a single radar, but not transmitted simultaneously, and not in a synchronized way between different radars.
- Most of the radar systems in the scope of the present document deal with rotating and high directive antennas which only seldom point towards each other at the moment both are transmitting.
- The far field of the used antennas are at least several hundreds of meters (often more than 1 km) and the antennas are not very effective at close ranges. Thus there is either a low coupling factor between two antennas or there is long distance between antennas.
- The systems in question will typically implement staggered transmission schemes which prevent synchronism between interferer and disturbed system.

- Radar transmitter duty cycle is always low (less than 20 %), which decreases the probability that an interfering signal enters the transmitter when it is actually transmitting.
- Care is taken with the site selection and relative positions/elevations of other (radar) transmitters. In order to decrease the probability of an interfering signal entering the transmitter, sector blanking can be applied where the operational coverage requirements permit.

When a 4-port circulator or equivalent is implemented, a load at its fourth port prevents that received energy from the antenna is forwarded to the transmitter and thus transmitter intermodulation is avoided. This means that in this case this requirement is not needed. However, for radar systems transmitting at multiple frequencies at the same time and/or using a single 3-port circulator or where no circulator is available, this is not guaranteed and therefore this requirement will need to be considered.

5.1.6 Transmitter unwanted emissions in the out of band and spurious domain

These two technical requirements will always be included in the HSs and contain the out-of-band and spurious emissions. Emissions in active mode can be also addressed by the spectrum mask. Spurious emissions in both active and idle mode will have to be aligned with ERC/Recommendation 74-01 [i.4].

5.1.7 Transmitter time domain characteristics

ETSI EG 203 336 [i.1] states the following:

"The actual value(s) of time domain characteristics may have been defined in relevant coexistence studies and in consequential relevant EC Decisions, ECC Decisions or ECC Recommendations.

Time domain characteristics (e.g. the duty cycle, turn-on and turn-off, frequency hopping cycle, dynamic changes of modulation scheme and others) of a transmitter, may impact the ability of the EUT to share spectrum with other EUTs of similar or dissimilar systems. Therefore, the transmitter time domain characteristics should be considered by the TB for inclusion in the HS."

The time domain characteristics for the radars are ruled by physical restrictions and design properties. For example, it is not possible to set a requirement for the duty cycle since this depends on the application and the radar range. Furthermore, it is linked to the performance of the radar which is not coordinated with other radars. Dynamic changes of modulation schemes do not take place and, in general, time domain characteristics of radar systems depend on the application as well as the radar design which is usually different from manufacturer to manufacturer.

Some radars (mainly shipborne, SMR and coastal surveillance radar systems) are designed for sharing the same nominal frequency without any coordination using techniques like low duty cycle and transmitter timing (for example PRF or pseudo random / staggered transmission scheme). Co-existence between radars (and thus the way in which spectrum is shared with other radars) is managed in a different way from communication systems. This is possible due to, for example, rotating high directivity antennas, staggered transmission schemes, gating of receiver, multi-frequency usage, digital processing, coding of signal emissions, etc. Due to the mobility of some of the above mentioned radar systems a geographic coordination is also not possible.

The conclusion is that this requirement is not applicable.

5.1.8 Transmitter transients

ETSI EG 203 336 [i.1] states the following:

"For transmitter systems that do not transmit continuously the TB should consider the impact of transients that occur during the turn on and turn off of the transmission envelope. This may affect coexistence with other systems. Therefore, the impact of transmitter transients should be considered by the TB for inclusion in the HS."

A pulsed radar is turning on/off its transmitter all the time. The mandatory transmitter spectrum measurement will identify transmitter transients and therefore this requirement is always covered by the spectrum mask.

5.2 Receiver Technical Requirements

5.2.1 Receiver sensitivity

ETSI EG 203 336 [i.1] states the following:

"Receiver sensitivity is the ability to receive a specified wanted signal level while providing a pre-determined level of performance.

Receiver sensitivity should be considered for inclusion in HSs because:

- *good sensitivity is generally valuable in minimizing interference as it allows the corresponding transmitter power to be lower for a particular link budget (see note);*
- *knowledge of sensitivity may be needed to act as a performance reference point when specifying other parameters;*
- *knowing the sensitivity of receivers is essential when planning coverage areas for the siting of wide area transmitters, e.g. cellular base stations and broadcast transmitters, or the link budget calculation of fixed links for reaching the expected availability and QoS.*

NOTE: As sensitivity is often a trade-off with other receiver parameters, TBs may need to take into account that a more sensitive receiver is not always beneficial for the application concerned. For example, a highly sensitive receiver may result in an excessive link budget potentially resulting in increased susceptibility to interference [i.6].

TBs should specify receiver sensitivity for integral-antenna equipment (in particular for mobile telephones and communication equipment used in safety of life applications) to ensure that the antenna performance is included in the assessment."

Radar output power is not varied as a result of the received signal strength of a target. The nature of a primary radar is to detect its transmitted energy reflected by targets of unknown size, properties and distances thus requiring handling of very large receiver dynamic ranges. A radar receiver has to achieve a larger dynamic range compared to communications receivers and in order to achieve this, different techniques are used to control the radar receiver sensitivity during operation depending on the detection distance, environment, weather and the level of unwanted signals for example from unwanted targets or noise.

Targets close to the radar produce a much higher received power level than targets which are further away. To prevent the receiver from saturation and blocking for close targets, techniques like decreasing the receiver sensitivity over time also known as STC are used. The conclusion is that this requirement is not explicitly required in an HS.

5.2.2 Receiver co-channel rejection

ETSI EG 203 336 [i.1] states the following:

"Receiver co-channel rejection is a measure of the receiver's ability to receive a wanted signal without exceeding a pre-defined degradation, due to the presence of an unwanted signal, both signals being at the nominal frequency of the receiver.

Receiver co-channel rejection is an essential parameter in frequency planning, in particular to enable the spatial re-use of the same frequency, e.g. in nearby geographic areas or in other sectors/directions.

Therefore, consideration should be given to specifying receiver co-channel rejection.

NOTE: Spatial reuse is also affected by system planning factors which may include: choice of modulation scheme, antenna diversity and antenna beam steering. Adequate co-channel rejection performance is an important receiver parameter as it can make it possible to increase the number of communication channels available for use and thus support a more efficient use of the spectrum."

Radar systems are not channelized equipment like communications systems. There is no standard use of frequencies, timing, transmission formats or overall behavior between different radar stations even when operating in the same service e.g. marine radar. Target detection is a statistical probability by nature and performance criteria are measured as such.

While communication receivers are looking at emitted signals from a spatially separated transmitting device, the radar receiver is a detector of its own transmitted and back-scattered signal. In the radar signal processing, different techniques are implemented to suppress intermittent interference. Examples include scan-to-scan or pulse-to-pulse correlation or more advanced data analysis to filter out stray energy detections that do not correlate to the back-scatter of its own emissions.

The radar cross-section of targets varies widely (RCS can range from 0,1 to 1 000 000 m^2), and the back-scattered signal levels depend on the distance of the target to the 4^{th} power for point targets such as aircraft, vessels or buildings and to the 2^{nd} power for volume targets such as hydrometeors. The radar needs to treat targets equally throughout the entire dynamic range during processing, which in turn means that filtering of interference will have to rely on principles other than signal strength.

Contrarily, with communications equipment it is important to have a certain signal-to-noise ratio in the assigned channel to successfully decode the transmitted information. This ratio does not have to be lower than a pre-defined value, which is dependent on the individual communications system. The unwanted signal can either be a different transmitter or noise. Communications system also employ a strict timing and frequency scheme in order to minimize disturbances. Furthermore, an error correction or retransmission of disturbed signals is usually available. This is not possible within radar applications.

Intermittent interference from other radar systems does not constitute a problem for detection as mentioned above and since it rarely happens that transmitting/receiving antennas are aligned towards each other at the exact time one radar is receiving and the other is transmitting. Those rare occurrences are filtered away in the processing. Usually the impact of intermittent disturbance pulses is further mitigated due to the use of randomized timing of transmission cycles (staggering). On the other hand, radar systems are in general incompatible with high duty-cycle transmitters that operate on the same frequency. The radar will effectively be "blinded" in the direction where a high duty-cycle transmitter (e.g. communications equipment or CW radar) operates. This is also due to the fact that communications systems are not synchronized with radar systems.

NOTE: In case of high duty cycle transmitters and radar systems operating on the same frequency, geographical siting of the systems might be possible to mitigate interference problems. Cancelling interference from high duty cycle transmitters might not be possible by the radar itself.

For all these reasons, it is therefore not possible to define a signal level for an unwanted signal at the nominal frequency of the radar so as not to exceed a pre-defined degradation and therefore it can be concluded that this requirement is not applicable to radars.

5.2.3 Receiver selectivity

5.2.3.1 General

ETSI EG 203 336 [i.1] states the following:

"Receiver selectivity is a measure of a receiver's ability to receive a wanted signal in the presence of an unwanted signal outside its operating bandwidth, e.g. on an adjacent channel or frequency or on a frequency outside its operating band. It is recognized that there are many ways of specifying receiver selectivity as a technical parameter which may be used in particular cases. The choice of how to satisfy the requirements of specifying receiver selectivity in an HS is left to the individual TB to formulate however they should identify in the HS which parameters cover receiver selectivity.

TBs may combine the requirements of receiver adjacent channel/adjacent band selectivity and blocking performanceinto a single requirement, if considered appropriate."

ETSI EG 203 336 [i.1] considers the following requirements as part of the selectivity requirement: receiver adjacent channel/band selectivity, receiver blocking, receiver spurious response rejection and receiver radio-frequency intermodulation. For radars, this technical requirement will always be included in the HSs and is usually covered by the receiver selectivity mask. A selectivity mask can be considered equivalent to receiver adjacent channel/band selectivity, receiver blocking and receiver spurious response rejection requirements as defined in ETSI EG 203 336 [i.1]. Additionally for radars the receiver compression level is always specified.

5.2.3.2 Receiver adjacent channel selectivity (adjacent band selectivity)

5.2.3.2.1 Receiver adjacent channel selectivity

ETSI EG 203 336 [i.1] states the following:

"Receiver adjacent channel selectivity is a measure of the capability of the receiver to receive a wanted signal, without exceeding a given degradation, due to the presence of an unwanted signal, in the adjacent channel (see figure 1).

NOTE: This parameter is sometimes referred to as adjacent channel rejection.

TBs should consider the usage scenario of the receiver, for example in channelized use the requirements for selectivity may differ from scenarios without channelization. Also mixed bandwidth scenarios may require different selectivity measures."

Since radars are not channelized equipment, this requirement is not applicable for radars.

5.2.3.2.2 Receiver adjacent band selectivity

ETSI EG 203 336 [i.1] states the following:

"Receiver adjacent band selectivity is a measure of the capability of the receiver to receive a wanted signal, without exceeding a given degradation, due to the presence of an unwanted signal, near the band edges of the operating band but within the adjacent band.

TBs should consider when specifying adjacent band selectivity requirements that there may be services operating in the upper and lower adjacent bands with differing technical characteristics and as such the technical requirements for selectivity may need to be different in each case."

This technical requirement will always be included in the HSs. It can be addressed by the compression level of the receiver and a receiver selectivity mask.

5.2.4 Receiver blocking

ETSI EG 203 336 [i.1] states the following:

"Receiver blocking is a measure of the capability of the receiver to receive a wanted signal without exceeding a given degradation due to the presence of an unwanted input signal at any frequency other than those of the spurious responses or of the adjacent channels.

TBs should recommend practical measurement methods as testing at "any frequency" is clearly an unbounded requirement.

Where receiver spurious response rejection and receiver blocking are both specified, receiver blocking should usually be specified at a more stringent level than that specified (see note in clause 5.3.4.4) for receiver spurious response rejection (clause 5.3.4.4) at frequencies relatively far removed from the operating frequency.

TBs should include a receiver blocking parameter in HSs."

This technical requirement will always be included in the HSs. It can be addressed by the compression level of the receiver and a receiver selectivity mask.

5.2.5 Receiver spurious response rejection

ETSI EG 203 336 [i.1] states the following:

"Receiver spurious response rejection is a measure of the capability of the receiver to receive a wanted signal without exceeding a given degradation due to the presence of an unwanted signal at any frequency at which a response is obtained.

The frequencies of the adjacent signals (channels) are excluded. TBs should specify the frequency range over which this requirement should be evaluated.

TBs may specify a frequency search method to identify the specific frequencies at which spurious responses occur.

NOTE: *TBs may consider specifically identifying image-rejection and intermediate-frequency rejection as particular cases of receiver spurious responses. This may be done as part of the method of measurement or by setting specific limits for these particular cases. In the case of direct conversion receivers that do not have an image response, then the F_{rx} / 2 and F_{rx} / 3 may be considered."*

This technical requirement will always be included in the HSs. It can be addressed by the compression level of the receiver and a receiver selectivity mask.

5.2.6 Receiver radio-frequency intermodulation

ETSI EG 203 336 [i.1] states the following:

"Receiver radio-frequency intermodulation response rejection is a measure of the capability of the receiver to receive a wanted signal, without exceeding a given degradation due to the presence of at least two unwanted signals at frequencies F_1 and F_2 with a specific frequency relationship to the wanted signal frequency.

TBs should consider specifying a minimum of second order intermodulation and third order intermodulation performance. The following second order terms should be considered, where F_{if} is the intermediate frequency and F_{rx} is the nominal frequency of the receiver:

- $F_{if} = F_1 + F_2$ *(tests should be made with frequencies such that the unwanted signals will have frequencies close to, but not necessarily equal to, half the intermediate frequency)*
- $F_{if} = F_1 - F_2$
- $F_{rx} = F_1 + F_2$
- $F_{rx} = F_1 - F_2$

TBs may consider specifying second order intermodulation by specifying a cross modulation test. Cross modulation is defined as the transposition of the Amplitude Modulation (AM) component from a strong unwanted signal to the wanted signal.

The testing of second order intermodulation has been unusual in HSs, limited mainly to systems using analogue AM modulation such as VHF aeronautical service (e.g. ETSI EN 300 676-1 [i.7]). This is because with constant envelope modulations and superheterodyne receivers, cross modulation is very unlikely to be a cause of receiver degradation. Many digital modulations which use amplitude and phase modulation can have significant AM content which makes cross modulation a more significant potential degradation mechanism. Furthermore, the increasing prevalence of direct conversion receiver technology also increases the significance of second order intermodulation effects.

NOTE: *In Digital Down Conversion (DDC) receivers non linearity of the Analogue to Digital Converter (ADC) may result in intermodulation with static signals. In this case dithering of the input signal is required for a meaningful test; this can be done in the ADC and TBs should consider how to include this in test methods if considered appropriate.*

The following third order term should be considered:

- $F_{rx} = 2\,F_1 - F_2$ *when* $|\,F_1 - F_2\,| = f_x$
  - *where:*
    - *tests should be carried out at all frequencies that meet the above conditions; and*
    - *typically f_x = channel spacing or twice the channel spacing."*

Primary radars in the scope of the present document are not channelized and their transmitters do not modulate or change the pulse amplitude during the transmission of the pulse, as this would impair the sensitivity or performance of the system.

The radar bands are used simultaneously by several different users, using highly directive and usually rotating antennas. Therefore, receiver intermodulation products of short uncorrelated time intervals may occur due to signals from other radar systems in the same band.

This means that this technical requirement will always be included in the HSs.

The third order IMD products are of primary interest.

The input frequency pairs of f_1 and f_2 for the test should be closely located to the receiver frequency f_{rx}, but outside of the operating band of the receiver. The frequencies f_1 and f_2 will have to be chosen such that the 3^{rd} order intermodulation product is f_{rx}.

EXAMPLE: For a receiver frequency of f_{rx} = 9,4 GHz, f_1 = 9,5 GHz and f_2 = 9,6 GHz or f_{rx} = 9,4 GHz, f_1 = 9,3 GHz and f_2 = 9,2 GHz.

For testing the radar receiver intermodulation it is recommended to inject the f_1 and f_2 signals preferably directly into the receiver front end or if not possible into the antenna output flange of the transceiver. By default, the power should be measured at the IF output of the receiver which is connected to the input of the ADC. In this case, the power of the third order intermodulation product is not allowed to exceed a limit which is defined in the specific HS. If it is not possible to measure the power at the IF output of the receiver, for example due to the mechanical setup or other circumstances, the output data should be used. The pass/fail criteria then can be the P_{fa} or based on the output data. The threshold of the pass/fail criteria has to be defined in the specific HS.

5.2.7 Receiver unwanted emissions in the spurious domain

ETSI EG 203 336 [i.1] states the following:

"As a default, the limit for unwanted emissions in the spurious domain referenced at the antenna port should respect those in CEPT/ERC/Recommendation 74-01E [i.4]."

This technical requirement will always be included in the HSs.

5.2.8 Other receiver effects

5.2.8.1 Receiver dynamic range

ETSI EG 203 336 [i.1] states the following:

"Receiver dynamic range is defined as the range of the wanted input signal level over which a receiver functions at a specified performance level. The lower end of this range is normally the sensitivity of the receiver. The upper end of a receiver's dynamic range determines how strong a received signal can be before producing degradation due to overloading.

Many receivers are deployed in a manner that results in a situation where it is impossible to receive a wanted signal that is high enough to produce any overloading effect. In these cases, TBs may decide not to specify receiver dynamic range.

The dynamic range of a receiver may be specified in an HS as a "stand-alone" requirement where the operational situation provides minimum/maximum operational distances from a common transmitter.

In all other cases it is considered that the dynamic range of the receiver is implicitly covered in an HS where interference characteristics are specified in terms of selectivity requirements, including blocking."

The dynamic range of a radar receiver depends on the radar architecture and the related applications. It is clearly an important performance parameter of a radar in order to detect large and small targets at near and far ranges. Therefore, it is not explicitly included in an HS, since it is covered by the relevant performance standard and can be addressed by the compression level of the receiver and its noise figure.

5.2.8.2 Reciprocal mixing

ETSI EG 203 336 [i.1] states the following:

"Reciprocal mixing occurs when noise sidebands of the Local Oscillator (LO) mix with interfering signals at distances from wanted signal comparable to the LO offset range where phase noise is higher than the thermal noise (i.e. from few hundreds Hz to few MHz) converting unwanted noise at the frequency of the receiver which may result in "desensitization" of the receiver (see note 1), additional to that produced by the interference itself. In direct Digital Down Conversion receivers (DDC) a similar effect occurs caused by the phase jitter (see note 2) of the clock associated with the ADC.

It is considered that the reciprocal mixing effects are implicitly covered in HSs where comprehensive interference characteristics are specified in terms of selectivity and/or blocking requirements, thus removing the need for this parameter to be included in HSs as the effects of receiver selectivity and reciprocal mixing cannot be separated.

NOTE 1: In communications receivers intended for use in interference limited rather than noise limited environments, degradation due to reciprocal mixing may occur before degradation due to non-linearity. As a result, reciprocal mixing may be the dominant effect in those receivers' performance.

NOTE 2: The term "jitter" is often used in digital systems whereas the term "phase noise" is used in traditional radio systems however the two terms refer to the variation in phase of a signal and are therefore essentially the same phenomenon."

Reciprocal mixing is addressed by the receiver selectivity test and therefore it does not have to be explicitly included in the HS.

Annex A: Measurements for waveguide-based systems

A.1 Overview

Most of the radars operating at frequencies above 1 GHz use a waveguide for connecting the transceiver to the antenna. In addition, a piece of waveguide is used within the transceiver for connecting the internal circulator (or equivalent) to the antenna port. Waveguides provide low attenuation and can handle high power levels. Each waveguide has a well-defined cut-off frequency, which is shown for example for rectangular waveguides in IEC 60153-2 [i.3]. Below the cut-off frequency, the attenuation of the energy is so high that a reliable and repeatable measurement of the signal is not possible.

Regarding the measurement of unwanted emissions, radar systems can be divided into the following categories:

a) Radar systems having an integral antenna incorporating a waveguide section, or with an antenna connection in such form, and of length shorter than twice the cut-off wavelength.

   - Measurements will have to be carried out in the frequency range as in table 1 of ERC/Recommendation 74-01 [i.4].

b) Radar systems having an integral antenna incorporating a waveguide section, or with an antenna connection in such form, and of length equal to at least twice the cut-off wavelength but shorter than 20 times the cut-off wavelength.

   - Measurements will have to start at 0,7 times the cut-off frequency and go up to the upper frequency as in table 1 of ERC/Recommendation 74-01 [i.4].

c) Radar systems having an integral antenna incorporating a waveguide section, or with an antenna connection in such form, and of length equal to at least 20 times the cut-off wavelength.

   - Measurements will have to start at the waveguide cut-off frequency and go up to the upper frequency as in table 1 of ERC/Recommendation 74-01 [i.4].

For radars without an integral antenna, it is assumed that the radar is placed on the market together with the antenna and the related piece of waveguide. If this is not the case, the frequency range of measurement above mentioned need to take into account only the length of the piece of waveguide embedded into the equipment placed on the market.

A.2 Waveguide-based radars and ERC/Recommendation 74-01

Regarding the frequency range of measurement, ERC/Recommendation 74-01 [i.4] states the following:

"*…systems having an integral antenna incorporating a waveguide section, or with an antenna connection in such form, and of length equal to at least twice the cut-off wavelength, should not require spurious emissions measurement below 0.7 times the waveguide cut-off frequency".*

In June 2020 ETSI and the ECC had a meeting on this topic, where the ECC determined that measurements between 0,7 and one times the cut-off frequency are not accurate and not possible (ECC(20)093 Annex 14 [i.10]), as quoted below. The ECC concluded that the waveguide attenuation in this frequency range will be high enough if the waveguide length is at least 20 times the cut-off wavelength, such that the limits in ERC Recommendation 74-01 [i.4] are satisfied.

For the most common rectangular waveguides, 20 times the waveguide cut-off wavelength corresponds to a piece of waveguide with a length as in Table A.1 taken from IEC 60153-2 [i.3].

Table A.1: Waveguide cut-off wavelength

Waveguide band	Cut-off frequency	Λc (cm)	20 x λc (cm)	Waveguide designation		
				EIA	UK	R
L	908 MHz	33	660	WR650	WG6	R14
S	2 077 MHz	14,5	290	WR284	WG10	R32
C	3 152 MHz	9,5	190	WR187	WG12	R48
	4 300 MHz	7	140	WR137	WG14	R70
X	6 556 MHz	4,6	92	WR90	WG16	R100
Ku	9 486 MHz	3,16	63	WR62	WG18	R140

ECC(20)093 Annex 14 [i.10] states the following:

"*Further to the liaison statement sent by the 52nd ECC Plenary (ECC(20)055 Annex 22) the ECC indicated that there may be consultation between the ECC and ETSI and additional information to share with the European Commission may be available at the next ECC meeting.*

Since this liaison statement, ETSI has provided more information (ECC(20)092) on this issue to ECC. On 23-24 June 2020 SE21 held a meeting with representatives from administrations, ETSI and industry to discuss this issue in more detail as part of the consultative procedure given in the ETSI/ECC Memorandum of Understanding.

In this meeting it was noted that the spurious emission limits in ERC Recommendation 74-01 [i.4] apply across the range of 9 kHz – 300 GHz. These limits are an important requirement to reduce the risk of interference between radio systems and it is expected that they are met.

It was noted that measurements to prove that the limit is met may not be needed across the entire 9 kHz – 300 GHz *frequency range. This is acknowledged in Recommends 3 of ERC/Recommendation 74-01 [i.4], which states: "for practical measurement purposes only, the frequency range of spurious emissions measurements may be restricted. However, for practical purposes, the frequency ranges of measurement as given in Table 1 are normally recommended:" In addition there is allowance for systems using a waveguide where the lower frequency range for measurement does not need to be below 0.7 times the waveguide cut-off frequency, provided that the length of the waveguide is equal to at least twice the cut-off wavelength.*

This is a general provision that applies to any system that might use a waveguide. It recognises that use of a waveguide will provide significant attenuation to unwanted emissions below the waveguide cut-off frequency. Making measurements down to 0.7 times the waveguide cut-off frequency provides sufficient attenuation to ensure any emission will be below the ERC/REC 74-01 [i.4] limit. It takes account of the roll-off of the waveguide and allows some safety margin for unwanted emissions within the waveguide.

For high power systems (e.g. radar systems) that use waveguides, the measurement method for practical reasons needs to be different from lower power systems. The method is to make measurements using a directional coupler attached to the waveguide. Due to the properties of this directional coupler the lower cut-off frequency is equal to the lower cut-off frequency of the waveguide. This combination of the waveguide attenuation and the directional coupler attenuation means it is impractical to make measurements below the waveguide cut-off frequency. This implies that the measurement results between 0.7 times the waveguide cut-off frequency and the waveguide cut-off frequency are not accurate. Therefore, sound and repeatable measurements are not possible.

It is recognised that a specification of waveguide type together with a certain minimum length could provide significant attenuation to unwanted emissions below the waveguide cut-off frequency. There will always be a roll off just below the waveguide cut-off frequency, because no waveguide will instantly roll off at its cut-off frequency to provide its maximum attenuation. There is still a risk of a strong spurious emission (e.g. spurs or spikes) in this region could exceed the limits in ERC/Recommendation 74-01 [i.4]. However, with a suitable length of waveguide, this attenuation is enough to suppress unwanted emissions, so that they are below (with enough confidence) the limits set out in ERC/Recommendation 74-01 [i.4].

The roll off slope of the waveguide will depend on the length of waveguide. We consider that if the waveguide length in the actual transmitter output (power amplifier) towards the input of the antenna is greater than 20 times the cut-off wavelength, (This is equal to 92 cm in the case of WR90 with a cut-off frequency of 6.556 GHz) this is sufficient to minimise the risk. In these cases it is acceptable to perform the spurious emission measurement down to the waveguide cut-off frequency rather than 0.7 times the waveguide cut-off frequency. It is important that waveguide types are specified (e.g. WR90) and have a minimum length of 20 times the cut-off wavelength. This needs to be ensured when used with these types of transmitters if measurements are not performed. It should also be understood that the length of waveguide shall be unperturbed / pure.

This technical approach, being a fundamental feature of waveguides below their cut-off frequency, can be applicable when appropriate. Therefore, subject to the following technical conditions being ensured for any waveguide based systems (including ETSI EN 303 213-6-1 V3.1.1 and ETSI EN 303 346-3 V1.1.1) ECC is satisfied with allowing deviation from the present version of ERC/ REC 74-01 [i.4]:

- *That the type of waveguide in use is clearly specified.*
- *That specified waveguide has a continuously unobstructed transmission path (unperturbed/pure) and a minimum length of 20 times the waveguide cut-off wavelength in that operational mode."*

History

Document history		
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