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**Air Traffic Control Surveillance Radar Sensors;  
Secondary Surveillance Radar (SSR);  
Harmonised Standard for access to radio spectrum;  
Part 2: Far Field Monitor (FFM)**

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**Reference**

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# Foreword

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

The present document has been prepared under the Commission's standardisation request C(2015) 5376 final [i.2] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC [i.1].

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

The present document is part 2 of a multi-part deliverable covering ATC Secondary Surveillance Radar systems for civil air navigation operating in the frequencies 1 030 MHz and 1 090 MHz, as identified below:

Part 1: "SSR Interrogator";

**Part 2: "Far Field Monitor (FFM)".**

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

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## Introduction

The SSR system provides ground-based surveillance of transponder fitted aircraft and, in addition, may allow data link communication between ground stations and aircraft, where both are fitted with appropriate equipment.

Secondary Radar surveillance is exploited through two essential elements: the SSR interrogator, normally ground-based, and the aircraft SSR transponder.

The Far Field Monitor (FFM) is a ground-installed device that is intended to monitor the uplink and/or downlink performance of a Mode S interrogator system from a site located at a suitable distance from the radar interrogator (far field).

By its fixed location, the Far Field Monitor provides a fixed geo-referenced position with respect to which the SSR interrogator can keep aligned its azimuthal reference with the geographical north.

While a Far Field Monitor has many characteristics in common with a Mode S transponder, there are a number of important differences required to allow monitoring and to ensure that FFM will not impact Air Traffic safety and have only minimal impact on Radio Frequency Interference and SSR channel Loading.

An FFM interrogated by the SSR radar in Mode A, C, S and intermode formats, replies with matching Mode A, C, S reply. The replies are evaluated by the SSR interrogator to ensure correct operation. In addition, the replies may contain data about certain interrogation parameters as seen by the monitor.

As far as Mode S is concerned, it is assumed that the FFM can process interrogations in uplink format UF11, UF4 and UF5 and can transmit the corresponding replies in downlink format DF11, DF4, DF20, DF5 and DF21.

As far as Intermode is concerned, it is assumed that the FFM having Mode-S capabilities will only reply to intermode interrogations of type Mode A only all-call and Mode C only all-call. As far as intermode interrogations of type Mode A/C/S all-call are concerned, the FFM will not reply to them. Table 1 sums up the FFM capabilities.

**Table 1: FFM capabilities**

Mode	Interrogation processing	Reply Transmission
Mode A	Yes	Yes
Mode C	Yes	Yes
Mode S	Yes for at least UF11, UF4 and UF5 interrogations	Yes for at least DF11, DF4, DF20, DF5 and DF21 replies
Intermode	Yes	No in case of Mode A/C/S all interrogations (long P4)

# 1 Scope

The present document specifies technical characteristics and methods of measurements for the following equipment used in ground-based ATC Secondary Surveillance Radar systems for civil air navigation:

Far Field Monitors (FFM) operating on the frequencies as indicated in Table 2.

**Table 2: FFM operating frequencies**

Mode	Operating frequencies
FFM Receive	1 030 MHz
FFM Transmit	1 090 MHz

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

## 2 References

### 2.1 Normative references

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

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

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Not applicable.

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

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

- [i.1] [Directive 2014/53/EU](#) of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.
- [i.2] [Commission Implementing Decision C\(2015\) 5376 final of 4.8.2015](#) on a standardisation request to the European Committee for Electrotechnical Standardisation and to the European Telecommunications Standards Institute as regards radio equipment in support of Directive 2014/53/EU of the European Parliament and of the Council.
- [i.3] ETSI EG 203 336: "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.4] ICAO Annex 10, Volume IV: "Surveillance Radar and Collision Avoidance Systems", 5<sup>th</sup> edition, July 2014 including amendments up to amendment 91 dated 22-03-2021.
- [i.5] [ERC Recommendation 74-01 \(2019\)](#): "Unwanted emissions in spurious domain".
- [i.6] ITU-R Radio Regulations (2020).
- [i.7] Eurocontrol European Mode-S Station Functional Specifications (EUROCONTROL-SPEC-189) Ver 4.0, Sep 2021.
- [i.8] EUROCAE ED-73F: "Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders", December 2020.
- [i.9] ICAO Annex 10, Volume III: "Communication Systems", 2<sup>nd</sup> Edition, 2007.

## 3 Definition of terms, symbols and abbreviations

### 3.1 Terms

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

**all-call:** intermode interrogations (Mode A/C/S all-call) or Mode S interrogations (Mode S only all-call) or Mode S only all-call replies

**Binary Pulse Position Modulation (BPPM):** modulation used in the reply data block of a Mode S reply

NOTE: Within a Mode S reply data bit interval, a pulse transmitted in the first half of the interval represents a binary ONE and a pulse transmitted in the second half represents a binary ZERO.

**carrier frequency:** radio frequency, i.e. 1 030 MHz for an SSR Interrogator, which has no "modulation" imposed on it (yet)

**chip:** carrier interval in a Mode S interrogation within the pulse P6 with a duration of 0,25 microseconds and located after the synchro phase reversal

**control:** RF path between the SSR interrogator and the SSR antenna allowing sidelobe suppression

NOTE: Control path is also called OMNI or OMEGA path and identified with Greek letter  $\Omega$ .

**Differential Phase Shift Keying (DPSK):** phase modulation used in the P6 pulse of Mode S interrogations

NOTE: The aforementioned modulation uses phase reversal preceding chips to code binary ONES and the absence of phase reversal to code binary ZEROS.

**downlink:** direction of the signals transmitted on the 1 090 MHz frequency band from Mode A, C and S capable device

**Downlink Format (DF):** data coding format of a Mode S reply

NOTE: DF11 denotes the format of a Mode S all-call reply.  
 DF4 denotes the format of a Mode S selective reply of type "surveillance altitude reply".  
 DF5 denotes the format of a Mode S selective reply of type "surveillance identity reply".  
 DF20 denotes the format of a Mode S selective reply of type "Comm-B altitude reply".  
 DF21 denotes the format of a Mode S selective reply of type "Comm-B identity reply".  
 Comm-B denotes a Mode S selective reply containing supplementary data.

**Far Field Monitor (FFM):** system which monitors the uplink and/or downlink performance of an SSR or Mode S system from a site located at a specified distance from the radar (far field)

NOTE 1: The monitor is interrogated by the radar, and its replies can be evaluated on the radar site. In addition, the replies may contain data about certain interrogation parameters as seen by the monitor.

NOTE 2: A Mode S FFM supports Mode A, C and S.

NOTE 3: FFM is also referred to as "Remote Field Monitor" (RFM), "Position Adjustable Range Reference Orientation Transponder" (PARROT) or "Site Monitor".

**FFM test equipment:** equipment to simulate Mode A, C and S interrogations to enable the testing of the performance of Mode A, C and S based transponder and similar devices

**FRUITs:** replies received by an interrogator which are not triggered by own interrogations

NOTE: They overlap to requested replies and are to be considered as interfering signals.

**idle state:** entire period between transmissions, less 10-microsecond transition periods preceding the first pulse and following the last pulse of the transmission

NOTE: The word "inactive" instead of "idle" is used in [i.4] and [i.5].

**intermode:** interrogation triggering replies from SSR transponders and eventually replies from Mode S transponders in case of Mode A/C/S all-call interrogations

NOTE: Two types of intermode interrogations exist. The first type consists of Mode A or Mode C only all-call interrogations to which transponders with Mode A and Mode C capabilities only reply and to which Mode S transponders do not reply. The second type consists of Mode A/C/S all-call interrogations to which all transponders reply. Intermode interrogations consist of P1, P3 and P4 pulses transmitted on the sum port of the SSR interrogator and a P2 pulse transmitted on the control port of the SSR interrogator.

**lockout:** status in which the FFM is prevented from replying to All-Call interrogations

NOTE: This status is triggered by the interrogator using its own IC code, via a specific "lockout" protocol. This status will last 18 seconds, unless renewed by the interrogator.

**Minimum Triggering Level (MTL):** minimum input power level that results in a 90 % reply ratio

**mode A:** type of interrogation, triggering a reply from Mode A capable devices for identity and surveillance allowing the identification of the device

NOTE 1: A Mode A interrogation is defined by the pulse separation between the two P1 and P3 pulses, and consists of P1 and P3 pulses transmitted via a high gain main beam antenna and a P2 pulse (P2 is called a sidelobe - SLS- suppression pulse) via a separate antenna pattern with a different antenna gain.

NOTE 2: A Mode A reply consists of framing pulses (F1 and F2), up to 12 pulses between F1 and F2 and an optionally manually activated and transmitted Special Identification pulse (SPI). The absence or presence of each of the 12 identification pulses between F1 and F2 determines the Mode A reply code.

**mode C:** interrogation elicit from Mode C capable devices replies allowing SSR interrogator automatic pressure-altitude transmission and surveillance

NOTE 1: A Mode C interrogation is defined by the pulse separation between the two P1 and P3 pulses. The Mode C interrogation is transmitted via a narrow high gain main beam antenna. A third P2 Side Lobe Suppression Pulse (SLS) is transmitted via a separate antenna pattern having a different gain.

NOTE 2: A Mode C reply consists of up to 15 pulses, two framing pulses (F1 and F2), up to 12 pulses transmitted between F1 and F2. The absence or presence of each of the 12 pulses determines the Mode C code.

**mode S:** enhanced SSR mode allowing the addressing of individual aircraft and the retrieving of information with higher integrity

NOTE 1: A Mode S interrogation consists of P1, P2 and P6 pulses transmitted via a directional high gain antenna pattern while the P5 SLS pulse is transmitted via a separate antenna pattern having a different antenna gain (P5 is called sidelobe suppression pulse). A Mode S reply consists of a four-pulse preamble followed by a 56 or 112 pulse reply data block using PPM.

NOTE 2: Mode S stands for "Mode Select" to allow selective addressing the unique 24 bit address allocated to a Mode S based device replying or squittering on 1 090 MHz e.g. aircraft transponder, non transponder devices or FFM. SSR Mode S address is defined in Annex 10, Volume III Part 1, chapter 9 [i.9] to be one of 16 777 214 twenty-four-bit aircraft addresses allocated by ICAO to the State of Registry or common mark registering authority and assigned as prescribed in the Appendix to the same chapter [i.9].

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

**out-of-band domain:** frequency range, immediately outside the necessary bandwidth but excluding the spurious domain, in which out-of-band emissions generally predominate

NOTE 1: Out-of-band emissions, defined based on their source, occur in the out-of-band domain and, to a lesser extent, in the spurious domain. Spurious emissions likewise may occur in the out-of-band domain as well as in the spurious domain.

NOTE 2: This definition is taken from ITU Radio Regulation [i.6].

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

NOTE: This definition is taken from ITU Radio Regulation [i.6].

**peak envelope power:** average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions

NOTE: This definition is taken from ITU Radio Regulation [i.6].

**phase overlay:** technique to increase the data throughput by adding an additional phase modulation to each Mode-S Data pulse transmitted on 1 090 MHz

**phase reversal:** 180-degree change of the phase of the uplink frequency carrier

NOTE: Phase reversal is a characteristic of the Differential Phase Shift Keying (DPSK) modulation used for the uplink transmission of the Mode S signals.

**Pulse Amplitude Modulation (PAM):** type of pulse generation, where amplitude is changed between pulses

NOTE: SLS pulses P2 and P5 are PAM pulses, the Mode-S preamble and the Mode-A and Mode-C replies are made with PAM pulses.

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

**pulse duration:** time between the 50 % amplitude (voltage) points on the leading and trailing edge of the pulse envelope

**pulse position modulation:** pulse modulation of the 56 or 112 data pulses used by the Mode S reply and ADS-B formats, by either transmitting the pulse in the first or second half of a microsecond

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

**reply ratio:** ratio between expected replies, corresponding to a given interrogation rate, and received replies

**roll-call:** selective Mode S interrogations addressed to an individual aircraft or selective Mode S replies received from an individual aircraft

**Secondary Surveillance Radar (SSR):** radio-determination system based on the comparison of reference signals with radio signals retransmitted from the position to be determined

NOTE 1: This definition is taken from ITU Radio Regulation [i.6].

NOTE 2: The SSR provides ground-based radar surveillance of targets equipped with transponder, and of far field monitors.

**Side Lobe Suppression (SLS):** technique to use specific pulses P2 in Mode A and C, P5 in Mode S, dedicated for reply suppression, which are transmitted via a separate antenna pattern with a different antenna gain

NOTE 1: The pulse amplitude of the received interrogation and SLS pulse are used to decide if SLS is activated or not.

NOTE 2: P5 is used for Mode S-only all-call interrogation (UF = 11) to prevent replies from aircraft in the side and back lobes of the antenna.

**spurious domain:** frequency range beyond the out-of-band domain in which spurious emissions generally predominate

NOTE: This definition is taken from ITU Radio Regulation [1.6].

**spurious emissions:** 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 ITU Radio Regulation [1.6].

**uplink:** direction of the interrogation and data signals transmitted on the 1 030 MHz frequency band from SSR interrogator to aircraft transponder or FFM

**Uplink Format (UF):** data coding format of a Mode S interrogation

NOTE: UF11 denotes the format of a Mode S only all-call interrogation.  
 UF4 denotes the format of a Mode S selective interrogation of type "surveillance altitude request".  
 UF5 denotes the format of a Mode S selective interrogation of type "surveillance identity request".

## 3.2 Symbols

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

$B_{-40}$	-40 dB bandwidth
$B_N$	Necessary bandwidth
$B_{res}$	3 dB resolution bandwidth of transceiver
$dB$	decibel
$dB/dec$	dB per decade
$dBm$	dB with respect to 1 milliwatt
$dB_{pep}$	dB with respect to peak envelope power
$k$	Boltzmann's constant
$kW$	Kilowatt
$NF$	Noise Figure
$NM$	Nautical mile
$ns$	nano second
$Pd$	Probability of detection
$Pd_{1090}$	Probability of detection at 1 090 MHz
$Pd_{offset}$	Probability of detection at a frequency offset from 1 090 MHz
$P_t$	Pulse power of transmission
$RF$	Radio Frequency
$t$	Time
$t_p$	Pulse duration
$t_r$	Pulse rise time
$T_0$	Temperature in Kelvin
$\lambda$	Wavelength
$\Omega$	Ohm

## 3.3 Abbreviations

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

AC	Alternating Current
ADS-B	Automatic Dependent Surveillance - Broadcast
ATC	Air Traffic Control
BPPM	Binary Pulse Position Modulation
CW	Continuous Wave

DF	Downlink Format
DME	Distance Measuring Equipment
DPSK	Differential Phase Shift Keying
EUROCAE	EUROpean Organisation for Civil Aviation Equipment
EUT	Equipment Under Test
FFM	Far Field Monitor
Fo	Frequency offset
FRUITs	False Replies Unsynchronized In Time (or to Interrogation Transmissions)
IC	Interrogator Code
ICAO	International Civil Aviation Organization
IRF	Interrogation Repetition Frequency
ITU	International Telecommunication Union
MTL	Minimum Triggering Level
OoB	Out-of-Band
PAM	Pulse Amplitude Modulation
PARROT	Position Adjustable Range Reference Orientation Transponder
PEP	Peak Envelope Power
PPM	Pulse Position Modulation
PR	Probability of Reply field (in Mode-S interrogation)
PRF	Pulse Repetition Frequency
RBW	Reference BandWidth
RF	Radio Frequency
RFM	Remote Field Monitor
SLS	Side Lobe Suppression
SPI	Special identification Indicator
SSR	Secondary Surveillance Radar
UF	Uplink Format

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## 4 Technical requirements specifications

### 4.1 Environmental profile

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

### 4.2 Conformance requirements

#### 4.2.1 Transmitter requirements

##### 4.2.1.1 Maximum frequency Deviation

###### 4.2.1.1.1 Definition

The maximum frequency deviation is the maximum allowed departure from the carrier frequency.

###### 4.2.1.1.2 Limits

If the FFM supports the Phase Overlay capability, the maximum frequency deviation shall not exceed 25 kHz, otherwise, the maximum frequency deviation shall not exceed 100 kHz.

###### 4.2.1.1.3 Conformance

The conformance tests are specified in clause 5.3.1.1.

## 4.2.1.2 Transmitter power

### 4.2.1.2.1 Definition

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

### 4.2.1.2.2 Limits

The transmitter peak pulse power shall not exceed 52 dBm.

### 4.2.1.2.3 Conformance

The conformance tests are specified in clause 5.3.1.2.

## 4.2.1.3 Spectrum mask

### 4.2.1.3.1 Definition

A spectrum mask is a set of limit lines applied to a plot of a transmitter spectrum.

The purpose is to constrain emissions at frequencies in the Out of Band domain and spurious domain, which lie outside the intended operating channel.

A spectrum mask is an alternative method to the specification of the out of band domain and spurious domain.

### 4.2.1.3.2 Limits

The FFM transmitter spectrum for all reply modes shall not exceed the limits specified in Table 3.

**Table 3: Required FFM transmitter spectrum limits**

Frequency offset (Fo) from measured carrier frequency (MHz)	Maximum Power relative to peak (dB)
≥ 1,3 and < 7	-3 dB
≥ 7 and < 23	-20 dB
≥ 23 and < 78	-40 dB
≥ 78 and down to 30 MHz (lower limit) and up to 5 460MHz ( see note 1)	-60 dB

NOTE 1: 5 460 MHz corresponds to the 5<sup>th</sup> harmonic plus a margin of 10 MHz.  
 NOTE 2: These limits derive from clause 3.1.2.2.2 and figure 3-5 of ICAO Annex 10 Volume IV [i.4].

### 4.2.1.3.3 Conformance

The conformance tests are specified in clause 5.3.1.3.

## 4.2.1.4 Emissions in idle mode

### 4.2.1.4.1 Definition

Emissions in idle mode refer to emissions radiated during periods of non-transmission.

### 4.2.1.4.2 Limits

For an FFM, the maximum peak output power, in the idle mode, shall not exceed the limits as indicated in Table 4.

**Table 4: Emissions in idle mode related requirements for an FFM**

Frequency band	Emission Limits
30 MHz ≤ f ≤ 1 GHz	-57 dBm
1 GHz < f ≤ 5 460 MHz	-50 dBm
NOTE 1: -57 dBm is defined in Table 2 of ERC Recommendation 74-01 [i.5].	
NOTE 2: -50 dBm is specified in clause 3.3.4 of EUROCAE ED-73F [i.8] and is stricter than the limit specified in Table 2 of ERC Recommendation 74-01 [i.5] for this frequency band.	
NOTE 3: 5 460 MHz corresponds to the 5 <sup>th</sup> harmonic plus a margin of 10 MHz.	

#### 4.2.1.4.3 Conformance

The conformance tests are specified in clause 5.3.1.4.

#### 4.2.1.5 Transmitted Waveform

##### 4.2.1.5.1 Definition

The FFM is able to transmit on 1 090 MHz replies in Mode A, Mode C and Mode S, each one consisting of a series of two or more modulated pulses with fixed positions in Mode A, C or a constant number of pulses with a defined pulse width and Pulse Position Modulation (PPM) for Mode S.

Each pulse of the sequence has specific characteristics in terms of shape and timing in the sequence, depending on the interrogation mode received from the SSR interrogators (see Annex D for Reference Waveforms).

##### 4.2.1.5.2 Limits

An FFM shall fulfil the requirements in Table 5.

**Table 5: Pulse shape of reply pulses**

Pulse	Duration (μs)		Rise Time (μs)		Decay Time (μs)	
	Min	Max	Min	Max	Min	Max
Mode A / Mode C pulses incl. SPI	0,35	0,55	0,05	0,1	0,05	0,2
Mode- S Preamble pulses and data pulses	0,45	0,55	0,05	0,1	0,05	0,2

NOTE: The table above derive from paragraph 3.1.2.2.4.1, and Table 3-2 of ICAO Annex 10 Volume IV [i.4].

##### 4.2.1.5.3 Conformance

The conformance tests are specified in clause 5.3.1.5.

#### 4.2.2 Receiver requirements

##### 4.2.2.1 Receiver sensitivity and dynamic range

###### 4.2.2.1.1 Definition

Given an interrogation signal that requires a reply, the FFM sensitivity is defined as the Minimum Triggering Level (MTL) being the minimum input power level that results in a 90 % reply ratio.

The dynamic range is the range of signal amplitude in which the reply ratio is greater than 99 %.

###### 4.2.2.1.2 Limits

Sensitivity limits shall be as indicated in Table 6.

**Table 6: MTL for an FFM**

Equipment type:	MTL Value
MTL for Mode A and Mode C interrogations, P1 and P3 Pulses of equal amplitude and P2 not detected	-64 dBm
MTL for Mode S interrogations	-66 dBm

Dynamic range limits shall be as indicated in Table 7.

**Table 7: Dynamic range for an FFM**

Signal input level	Reply ratio
Between 3 dB above MTL and -21 dBm	at least 99 %

#### 4.2.2.1.3 Conformance

The conformance tests are specified in clause 5.3.2.1 and clause 5.3.2.2.

#### 4.2.2.2 Receiver selectivity

##### 4.2.2.2.1 Definition

Receiver selectivity is a measure of a receiver's ability to receive a wanted signal in the presence of an unwanted signal which differs in frequency from the wanted signal by a specified amount.

##### 4.2.2.2.2 Limits

The Reply Ratio (RR) for an interrogation at a frequency  $f_c \pm 25$  MHz shall not exceed the RR for an interrogation at the carrier frequency  $f_c$  when the level of this interrogation is 60 dB above the level of the interrogation at  $f_c$ :

$$RR_{f_c \pm 25 \text{ MHz}}^{K+60 \text{ dB}} \leq RR_{f_c}^K$$

Where:

- $RR_f^K$  is the reply ratio for an interrogation at a frequency  $f$  with a signal level of  $K$  dBm, where  $K$  is  $\text{MTL}+10$  dB, and  $\text{MTL}$  is the measured value in clause 5.3.2.1.

NOTE: This limit is consistent with clause 3.2.3 of EUROCAE ED-73F [i.8].

##### 4.2.2.2.3 Conformance

The conformance tests are specified in clause 5.3.2.3.

#### 4.2.2.3 Receiver immunity to interference

##### 4.2.2.3.1 Definition

The receiver's immunity to interference defines the capability of the receiver to keep on operating in the presence of interference.

##### 4.2.2.3.2 Limits

An FFM shall fulfil the limits specified below (see note):

- Random Pulses:** Assuming the presence of random pulses 10 dB below the Mode A / C interrogation, at a nominal carrier frequency of 1 030 MHz, and not recognized as P1, P2 or P3 pulses, the FFM shall reply to  $\geq 90$  % of the interrogations



- b) **Asynchronous interference:** Assuming an asynchronous interference single pulse of 0,8 microseconds, at a nominal carrier frequency of 1 030 MHz, incoherent with the Mode S signal carrier frequency and repeated up 10 000 times per second with a level  $\geq 12$  dB below the Mode S signal level, the FFM shall reply correctly to at least  $\geq 95$  % of valid Mode S interrogations having a signal level between -50 dBm and -21 dBm, assuming that no lockout condition is active.
- c) **Standard Single Pulse:** Assuming an asynchronous interference single pulse of 0,8 microseconds, at a nominal carrier frequency of 1 030 MHz, incoherent with the Mode S signal carrier frequency and overlapping the P6 pulse of the Mode S interrogation anywhere after the synchro phase reversal, the FFM reply ratio shall be  $\geq 95$  % of Mode S interrogations requiring a reply with a level of the interfering pulse  $\geq 6$ dB below the signal of the Mode S interrogations with a signal level between -53 dBm and -21 dBm. Under the same conditions, the FFM reply ratio shall be  $\geq 50$  % of Mode S interrogations requiring a reply with a level of the interfering pulse  $\geq 3$ dB below the signal of the Mode S interrogations.
- d) **Pulse Pair:** Assuming the presence of an interfering P1 - P2 pulse pair at a nominal carrier frequency of 1 030 MHz, if the level of the interfering pulse pair is 9 dB or more below signal level for input signal levels between -53 dBm and -21 dBm and the P1 pulse of the interfering pair occurs no earlier than the P1 pulse of the Mode S signal, the FFM shall reply correctly to  $\geq 90$  % of the Mode A or Mode C or Mode S interrogations.
- e) **CW Interference:** Assuming the presence of non-coherent CW interference at a nominal carrier frequency of 1 030 MHz, with a signal level of 20 dB or more below the desired Mode A, Mode C or Mode S interrogation signal level, the FFM shall reply correctly to  $\geq 90$  % of the Mode A or Mode C or Mode S interrogations.
- f) **DME Interference:** Assuming the presence of a Mode-S interrogation, at a frequency of 1 030 MHz, with signal level of -40 dBm and a DME signal at a frequency of 970 MHz, 990 MHz, 1 010 MHz, 1 040 MHz, 1 050 MHz, 1 080 MHz, 1 110 MHz, 1 140 MHz, 1 170 MHz and 1 200 MHz and with a level of -30 dBm at a rate of 3 600 pulse pairs per second, the FFM shall reply correctly to  $\geq 90$  % of Mode S interrogations.

NOTE: The conditions and limits are specified in clauses 3.12.1 to 3.12.7 of EUROCAE ED-73F [i.8] and are coherent with limits specified in clause 3.1.2.10.1.1 of ICAO Annex 10 Volume IV [i.4].

#### 4.2.2.3.3 Conformance

The conformance tests are specified in clause 5.3.2.4.

#### 4.2.2.4 FFM unwanted replies

##### 4.2.2.4.1 Definition

Unsolicited replies are replies which do not correspond to any interrogations or to interrogations for which no reply is expected to be triggered, such as low-level signals or due to multipath.

##### 4.2.2.4.2 Limits

An FFM shall fulfil the limits below:

- a) Assuming no interrogation signals, the number of unwanted Mode A or Mode C replies per second generated by the FFM shall be  $\leq 5$  integrated over an interval equivalent to at least 30 seconds.
- b) Assuming no interrogation signals, the number of unwanted Mode S replies generated by the FFM shall be  $\leq 1$  per 10 seconds.
- c) The reply ratio shall not exceed 10 % for interrogations (all modes) at signal levels equal to or below MTL-10 dB.
- d) The spurious Mode A/C reply ratio resulting from a Mode-S interrogation shall not exceed a maximum of 3 % at any given amplitude in the input interrogation signal range below the Mode-S MTL.

NOTE: Limits a) and b) derive from clauses 3.1.1.7.8 and 3.1.2.10.3.5 of ICAO Annex 10, Volume IV [i.4], limits c) and d) derive from clause 3.2.4 g) of EUROCAE ED 73F [i.8] and clause 3.1.2.10.1.1.5.2 of ICAO Annex 10, Volume IV [i.4].

#### 4.2.2.4.3 Conformance

The conformance tests are specified in clause 5.3.2.5.

#### 4.2.2.5 FFM SLS Effectiveness

##### 4.2.2.5.1 Definition

SLS is a specific function designed to suppress unwanted replies, which could be elicited by signals arriving at the FFM from side lobes of the antenna pattern of the transmitting interrogator, or via multipath propagation. This function is activated by a P2 Pulse (for Mode A /C) or P5 Pulse (for Mode-S), whose amplitude is compared to that of the main signal.

##### 4.2.2.5.2 Limits

An FFM shall fulfil the limits below:

- a) If the P2 pulse amplitude is higher than the amplitude of P1 and P3 pulses, then the Mode A or Mode C reply rate shall not exceed 1 %, when an interrogation signal is within the dynamic range of the receiver.
- b) If the P2 pulse amplitude is at least 9 dB lower than the P1 and P3 pulse amplitude, then the Mode A or Mode C reply rate of the FFM shall be higher than 90 %, when an interrogation signal is above MTL+3 dB and within the dynamic range of the receiver.
- c) If the P5 pulse amplitude is higher than the P6 pulse amplitude, then the Mode S reply rate of the FFM shall be less than 1 %, when an interrogation signal is within the dynamic range of the receiver.
- d) If the P5 pulse amplitude is at least 12 dB lower than the P6 pulse amplitude, then the Mode S reply rate of the FFM shall be higher than 99 %, when an interrogation signal is above MTL+3 dB and within the dynamic range of the receiver.

NOTE: These limits are specified in EUROCAE ED-73F [i.8], clause 3.8.2.

##### 4.2.2.5.3 Conformance

The conformance tests are specified in clause 5.3.2.6.

#### 4.2.2.6 Receiver RF intermodulation response rejection

##### 4.2.2.6.1 Definition

The intermodulation response rejection is a measure of the receiver's capability to receive a wanted signal without exceeding a given degradation of the FFM reply capability, in the presence of two unwanted signals with a specific frequency relationship relative to the receiver frequency.

##### 4.2.2.6.2 Limits

For Mode A, C and S, the FFM reply probability ( $P_r$ ) shall not be reduced by more than 5 % if the level of the wanted signal at 1 030 MHz and of the two unwanted signals at  $1\ 030\ \text{MHz} \pm 20\ \text{MHz}$  and  $1\ 030\ \text{MHz} \pm 40\ \text{MHz}$  respectively, is 30 dB above the reference sensitivity specified in clause 4.2.2.1.2, Table 6.

##### 4.2.2.6.3 Conformance

The conformance tests are specified in clause 5.3.2.7.

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## 5 Testing for Compliance with technical requirements

### 5.1 General Requirements

#### 5.1.1 Standard operation mode for testing

If the FFM under testing has duplicated transmitting/receiving units, all tests shall be conducted on both channels.

All measurements shall be carried out at the antenna connector, excluding cables.

The transmitter power shall be referenced with respect to the output port of the transmitter, at the antenna connector.

Any programmable or variable attenuations with respect to maximum power level shall be set to 0 dB.

The transmission of spontaneous transmissions (Squitters) shall be disabled when not testing the ADS-B capabilities and during the receiver testing.

For the execution of the tests, one or more FFM test equipment as described in Annex C shall be used.

### 5.2 Environmental conditions for testing

#### 5.2.1 Introduction

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

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

#### 5.2.2 Temperature and humidity

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

- a) temperature: 0 °C to +40 °C;
- b) relative humidity: not exceeding 90 % (non-condensing).

NOTE: These limits are specified in Eurocontrol EUROCONTROL-SPEC-189 [i.7].

#### 5.2.3 Power supply

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.

For an AC power supply, the frequency of the test voltage shall be 50 Hz  $\pm$  1 Hz.

## 5.3 Test specifications

### 5.3.1 Transmitter related tests

#### 5.3.1.1 Maximum Frequency Deviation

##### 5.3.1.1.1 Test conditions

The measurement setup shall be as described in clause B.2. An RF Spectrum Analyser and an FFM test equipment shall be used.

##### 5.3.1.1.2 Procedure

The test procedure shall be as follows:

- 1) On the FFM test equipment, run the Frequency measurement check, by means of its internal control panel, on the test selection menu.
- 2) Set on the FFM a Mode-A code of 7777, and verify on the FFM test equipment that the frequency carrier is within the limits specified in clause 4.2.1.1.1.
- 3) Repeat the test using a Mode S All-Call with PR = 0.

NOTE: PR = 0 means the FFM will reply to 100 % of interrogations.

- 4) If ADS-B capabilities are available, repeat the test after having enabled the ADS-B transmissions.

Take note of the frequency carrier value measured with the Spectrum Analyser.

#### 5.3.1.2 Transmitter power

##### 5.3.1.2.1 Test conditions

The measurement setup shall be described in clause B.1. An FFM test equipment shall be used.

##### 5.3.1.2.2 Procedure

The test procedure shall be as follows:

- 1) Set on the FFM a Mode-A code of 7777.
- 2) On the FFM test equipment, by means of its internal control panel, on the test selection menu, run the Power measurement check, and verify on the FFM test equipment that the power level is within the limits specified in clause 4.2.1.2.2.
- 3) Repeat the test using a Mode S All-Call with PR=0.

NOTE: PR = 0 means the FFM will reply to 100 % of interrogations.

- 4) If ADS-B capabilities are available, repeat the test after having enabled the ADS-B transmissions.

#### 5.3.1.3 Spectrum mask

##### 5.3.1.3.1 Test conditions

The measurement setup shall be as described in clause B.2. An RF Spectrum Analyser and an FFM test equipment shall be used.

The spectrum analyser shall be set according to the following parameters:

- Central Frequency: 1 090 MHz

- Resolution Bandwidth: as the Reference Bandwidth defined in Table 8
- Sweep: 20 s
- Reference Level: 5 dBm
- Scale: 10 dB/Div.
- Span: 200 MHz

### 5.3.1.3.2 Procedure

The test procedure shall be as follows:

- 1) Set the FFM for a Mode-A reply (Mode-A code 7777), and set up the FFM test equipment to interrogate at 250 interrogations per second.
- 2) Set the spectrum analyser RBW according to the frequency range shown in Table 8 and verify that the result is within the limits specified in clause 4.2.1.3.2.
- 3) Repeat the above sequence, but set up the FFM test equipment to interrogate with a standard Mode S surveillance identity interrogation at 50 interrogations per second.

Attach a snapshot of the measured spectrums to the test result sheet for each measurement.

All measurements shall be made with a reference bandwidth as shown in Table 8.

**Table 8: Reference Bandwidths**

Frequency Range	RBW
$30 \text{ MHz} \leq f \leq 1 \text{ GHz}$	100 kHz
$1 \text{ GHz} < f \leq 5\,460 \text{ MHz}$ (note 3)	1 MHz
NOTE 1: $f$ is the measurement frequency.	
NOTE 2: The Reference Bandwidths (RBW) are defined in ERC Recommendation 74-01 [i.6].	
NOTE 3: 5 460 MHz is the fifth harmonic plus a margin of 10 MHz.	

### 5.3.1.4 Emissions in idle mode

#### 5.3.1.4.1 Test conditions

The measurement setup shall be as described in clause B.2.

An RF Spectrum Analyser shall be used.

ADS-B transmissions, if available, shall be disabled. The FFM test equipment shall not send any interrogation and shall only be used to detect signals whose limits are checked with the Spectrum Analyser.

The setting of the spectrum analyser shall be the same as defined in clause 5.3.1.3.1.

#### 5.3.1.4.2 Procedure

The test procedure shall be as follows:

- 1) Verify on the RF Spectrum Analyser that in the frequency ranges defined in clause 4.2.1.4.2, Table 4 the detected signals in idle state are within the limits specified in that same Table.

### 5.3.1.5 Transmitted Waveform

#### 5.3.1.5.1 Test conditions

The measurement setup shall be as described in clause B.1. An FFM test equipment shall be used.

### 5.3.1.5.2 Procedure

The test procedure shall be as follows:

- 1) On the FFM test equipment, run the Waveform measurement check.
- 2) Verify on the FFM test equipment that the transmitted signal waveform is within the limits specified in clause 4.2.1.5.2.

## 5.3.2 Receiver related tests

### 5.3.2.1 Receiver sensitivity

#### 5.3.2.1.1 Test conditions

The measurement setup shall be as described in clause B.1. An FFM test equipment shall be used.

#### 5.3.2.1.2 Procedure

The test procedure shall be as follows:

- 1) Interrogate the transponder with a Mode A interrogation.
- 2) Record the minimum RF signal level (MTL) required to produce 90 % transponder reply efficiency.
- 3) Verify that the results are within the limits specified in clause 4.2.2.1.2.
- 4) Repeat the procedure using a Mode S All-Call interrogation, with PR = 0.

NOTE: PR = 0 means the FFM will reply to 100 % of interrogations.

### 5.3.2.2 Receiver dynamic range

#### 5.3.2.2.1 Test conditions

The measurement setup shall be as described in clause B.1. An FFM test equipment shall be used.

#### 5.3.2.2.2 Procedure

The test procedure shall be as follows:

- 1) Interrogate the transponder with a Mode A interrogation.
- 2) Using the control panel of the FFM test equipment, vary the RF level in 5 steps between (MTL + 3) dB and -21 dBm, evenly spaced.
- 3) Record the reply ratio at each step and verify that the results are within the limits defined in clause 4.2.2.1.2.
- 4) Repeat the procedure using a Mode S All-Call interrogation.

### 5.3.2.3 Receiver selectivity

#### 5.3.2.3.1 Test conditions

The measurement setup shall be as described in clause B.3. An FFM test equipment shall be used.

### 5.3.2.3.2 Procedure

The test procedure shall be as follows:

- 1) Using the control panel of the FFM test equipment, interrogate the FFM with a Mode A interrogation code 7777 having a signal level of 10 dB above MTL and take note of the achieved reply ratio.
- 2) Set the frequency of the interrogation to 1 055 MHz
- 3) Set the signal level to 70 dB above MTL and take note of the achieved reply ratio.
- 4) Verify that the results are within the limits defined in clause 4.2.2.2.2.
- 5) Change the interrogation frequency to 1 005 MHz and repeat steps 3 and 4.

### 5.3.2.4 Receiver immunity to interference

#### 5.3.2.4.1 Test conditions

The measurement setup shall be as described in clause B.3.

An FFM test equipment and a Signal Generator shall be used.

#### 5.3.2.4.2 Procedure

The test procedure shall be as follows:

- a) Random Pulse:
  - 1) Using the FFM test equipment, interrogate the FFM with Mode A interrogation, setting code 1111 on FFM, at 100 Hz rate at signal level of (MTL+20) dB.
  - 2) Using the Signal Generator, inject a pulse at 1 030 MHz, with a level of (MTL+10) dB and 0,8  $\mu$ s duration, at 111 Hz rate.
  - 3) Verify that the result is within the limits defined in clause 4.2.2.3.2 a).
  - 4) Repeat the sequence using a pulse of 1  $\mu$ s duration.
  - 5) Repeat the test using a Mode C interrogation, a Mode-A only all-call interrogation (short P4), a Mode-C only all-call interrogation.
- b) Asynchronous interference:
  - 1) Using the FFM test equipment, interrogate the FFM with a Mode S-Only All-Call interrogation at a signal level of -50 dBm, and a IRF of 240 Hz.
  - 2) Using the Signal Generator, inject a pulse at 1 030 MHz, with a level 12 dB lower than interrogation level and 0,8  $\mu$ s duration, at 10 kHz rate.
  - 3) Record the reply ratio measured by the FFM test equipment.
  - 4) Verify that the results are within the limits defined in clause 4.2.2.3.2 b).
- c) Standard single pulse:
  - 1) Using the FFM test equipment, interrogate the FFM with a Mode S-Only All-Call interrogation at a signal level of -50 dBm, and an IRF of 240 Hz.
  - 2) Using the Signal Generator, inject an interfering pulse at 1 030 MHz, with a level 6 dB lower than the interrogation level and 0,8  $\mu$ s duration, with the same repetition rate and 1,8  $\mu$ s after the beginning of P6 pulse.
  - 3) Record the reply ratio as measured by the FFM test equipment.

- 4) Repeat steps 2 and 3 by moving the position of the interfering pulse, at steps of 5  $\mu\text{s}$ , until the interfering pulse is no longer overlapped with the P6 pulse of the interrogation signal, and measure the reply rate at each step.
  - 5) Repeat steps 1 to 4 setting the signal level to -21 dBm.
  - 6) Verify that the results are within the limits (reply ratio  $\geq 95\%$ ) defined in clause 4.2.2.3.2 c).
  - 7) Repeat steps 1 to 5 using an interfering pulse with a level 3 dB lower than the interrogation level.
  - 8) Verify that the results are within the limits (reply ratio  $\geq 50\%$ ) defined in clause 4.2.2.3.2 c).
- d) Pulse pair:
- 1) Using the FFM test equipment, interrogate the FFM with a Mode S-Only All-Call interrogation at an input level of -50 dBm.
  - 2) Using Signal Generator, transmit two standard pulses of 0,8  $\mu\text{s}$  spaced 2  $\mu\text{s}$ , with a signal level of 9 dB below the input level.
  - 3) Move the interfering signal from a position of 0,25  $\mu\text{s}$  after the start of the interrogation, at steps of 0,25  $\mu\text{s}$ , up to the end of the interrogation (end of P6 pulse) and record the reply ratio at each step.
  - 4) Determine the average reply ratio from all the recorded values.
  - 5) Verify that the results are within the limits defined in clause 4.2.2.3.2 d).
  - 6) Repeat the test for the following input levels:
    - -45 dBm;
    - -40 dBm;
    - -35 dBm;
    - -30 dBm;
    - -25 dBm;
    - -20 dBm.
- e) CW interference:
- 1) Using the FFM test equipment, interrogate the FFM with Mode A interrogations, at 100 Hz rate and with a signal level of -40 dBm.
  - 2) Inject with the Signal Generator a CW signal at a frequency of 1 030 MHz and a signal level of -60 dBm.
  - 3) Verify that the FFM continues to reply to at least 90 % of all interrogations, within the limits defined in clause 4.2.2.3.2 e).
  - 4) Repeat the test using Mode C and Mode S Only All-Call interrogations.
- f) DME interference:
- 1) Using the FFM test equipment, interrogate the FFM with Mode S Only All-Call interrogations, at 100 Hz rate and with a signal level of -40 dBm.
  - 2) Inject with the Signal Generator a signal with the characteristics of a DME signal (i.e. pulse pair spaced 12  $\mu\text{s}$ , pulse duration 3,5  $\mu\text{s}$ , as shown in Figure D.5 at a frequency of 1 040 MHz and a signal level of -30 dBm) with a rate of 3 600 pairs per second.
  - 3) Verify that the FFM continues to reply to at least 90 % of all interrogations, within the limits defined in clause 4.2.2.3.2 f).



- 4) Repeat the test at the following additional nine frequencies (in the range 962 to 1 020 MHz and 1 041 to 1 213 MHz): 970 MHz, 990 MHz, 1 010 MHz, 1 050 MHz, 1 080 MHz, 1 110 MHz, 1 140 MHz, 1 170 MHz, 1 200 MHz.

### 5.3.2.5 FFM unwanted replies

#### 5.3.2.5.1 Test conditions

The measurement setup shall be as described in clause B.4. An FFM test equipment, an Oscilloscope and a Frequency Counter shall be used.

#### 5.3.2.5.2 Procedure

The test procedure shall be as follows:

- 1) Connect the RF terminal of the FFM test equipment directly to the FFM antenna terminal (as also shown in Figure B.4) and on the FFM test equipment disable any interrogation:
  - Count and record the number of Mode A/C replies for at least one minute.
  - Verify that the result is within the limits specified in clause 4.2.2.4.2 a).
- 2) Connect the RF terminal of the FFM test equipment directly to the FFM antenna terminal (as also shown in Figure B.4) and on the FFM test equipment disable any interrogation:
  - Count and record the number of Mode S replies for at least one minute.
  - Verify that the result is within the limits specified in clause 4.2.2.4.2 b).
- 3) With an RF signal level of MTL-10 dB (value of MTL depending on the interrogation mode), interrogate the FFM with a Mode A interrogation, and record the reply ratio:
  - Verify that the result is within the limits specified in clause 4.2.2.4.2 c).
  - Repeat the same measurement with a Mode A/Mode S (Intermode) All-Call interrogation.
  - Repeat the same measurement with a Mode S-Only All-Call interrogation with PR = 0.
- 4) Using the FFM test equipment, interrogate the FFM at 100 Hz rate and with a signal level of the Mode-S MTL-1 dBm, with Mode S interrogation, using UF4 with PC=4; RR=12; DI=3; SD=4 924; AP=AAAAAA;
  - Connect the FFM video output to a frequency counter.
  - Set the frequency counter resolution to 1 Hz.
  - Set the FFM Mode-S address to any valid address other than AAAAAA, in order to prevent Mode S reply.
  - The frequency counter will display Mode A/C reply rate. Take the average of 10 frequency counter readings at each power level between the Mode S MTL-1 dB and the Mode S MTL-10 dB, at 3 dB step (i.e. -1, -4, -7, -10 dB).
  - Verify that the reply rate is within the limits specified in clause 4.2.2.4.2 d).

### 5.3.2.6 FFM SLS Effectiveness

#### 5.3.2.6.1 Test conditions

The measurement setup shall be as in clause B.6. Two FFM test equipment and an Oscilloscope shall be used.

### 5.3.2.6.2 Procedure

The test procedure shall be as follows:

- SLS with Mode-A and Mode-C Interrogations:
  - 1) TEST 1:
    - Set the master FFM test equipment #1 to generate a Standard Mode A interrogation at levels for P1 of MTL + 3 dB.
    - Set the slave FFM test equipment #2 to generate a P2 pulse at the nominal position and at a level of P1 + 3 dB.
    - Verify that the result is within the limits specified in clause 4.2.2.5.2 a).
    - Repeat the test with P1 levels of -40 dBm and -27 dBm, respectively.
  - 2) TEST 2:
    - Repeat TEST 1 at the level, for P1, of -27 dBm, with P2 pulse at the level of P1 - 9 dB.
    - Verify that the result is within the limits specified in clause 4.2.2.5.2 b).

SLS with Mode-S Interrogations:

- 1) TEST 3:
  - Set the master FFM test equipment #1 to generate a Standard Mode S-only All-Call at a level for P1 of (MTL + 3) dB.
  - Set the slave FFM test equipment #2 to generate a 0.8 s duration pulse at the P5 nominal position and at a level of P1 + 3 dB.
  - Verify that the result is within the limits specified in clause 4.2.2.5.2 c).
  - Repeat the test with P1 levels of -40 dBm and -27 dBm, respectively.
- 2) TEST 4:
  - Repeat TEST 1 with a Standard Mode S-only All-Call at level of -27 dBm, with P5 pulse at a level of P1 - 12 dB.
  - Verify that the result is within the limits specified in clause 4.2.2.5.2 d).

### 5.3.2.7 Receiver RF intermodulation response rejection

#### 5.3.2.7.1 Test conditions

The measurement setup shall be as in clause B.5. One FFM test equipment and two Signal Generators shall be used.

#### 5.3.2.7.2 Procedure

The purpose of this test is to establish that inter-modulation caused by two unwanted Out-of-Band (OoB) signals does not degrade the FFM reply probability ( $P_r$ ) when their signal level is below the specified limit.

The  $P_r$  shall be calculated as the ratio between the number of times the reply is generated, and the number of times the interrogation is injected by the FFM test equipment.

The test procedure shall be as follows:

- 1) The FFM test equipment and two signal generators #1 and #2, shall be connected to the FFM receiver via the RF coupler as follows:
  - The wanted signal, provided by the FFM test equipment, shall be at the nominal frequency of the receiver and shall produce a test signal emulating a valid interrogation.

- The first unwanted signal, provided by Signal Generator #2, shall be unmodulated and adjusted to a frequency  $f_1$  at 20 MHz above the nominal frequency of the receiver.
  - The second unwanted signal, provided by Signal Generator #1, shall be modulated with a test signal having the following characteristics:
    - PRF = 150 Hz, Waveform = DME pulse pair (X-channel, i.e. pulse spacing 12  $\mu$ sec), and adjusted to a frequency  $f_2$  at 40 MHz above the nominal frequency of the FFM receiver.
- 2) Initially, Signal Generators #1 and #2 (unwanted signals) shall be switched off (maintaining the output impedance):
    - The level of the wanted signal from FFM test equipment shall be adjusted to the level 30 dB above the FFM reference sensitivity for mode A/C signal specified in clause 4.2.2.1.2, Table 6.
  - 3) Record the  $P_r$  of the wanted signal.
  - 4) Signal generators #1 and #2 shall then be switched on and set to a level 30 dB above the reference sensitivity for the mode A/C signal specified in clause 4.2.2.1.2, Table 6.
  - 5) Record the  $P_r$  of the wanted signal.
  - 6) Verify that the  $P_r$  from step 5 is within the limits specified in clause 4.2.2.6.2.
  - 7) The measurement shall be repeated with the unwanted signal generator #2 at the frequency 20 MHz below that of the wanted signal and the frequency of the unwanted signal generator #1 at the frequency 40 MHz below that of the wanted signal.
  - 8) Steps 1 to 7 shall be repeated, changing only the waveform from Signal Generator #1 as follows:
    - Waveform = DME pulse pair (Y-channel, i.e. pulse spacing 30  $\mu$ sec),
  - g) Repeat steps 2 to 8 for the Mode S signal.

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

The present document has been prepared under the Commission's standardisation request C(2015) 5376 final [i.2] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC [i.1].

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

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

Harmonised Standard ETSI EN 303 363-2					
Requirement				Requirement Conditionality	
No	Description	Essential requirements of Directive	Clause(s) of the present document	U/C	Condition
1	Maximum frequency deviation	3.2	4.2.1.1	U	
2	Transmitter power	3.2	4.2.1.2	U	
3	Spectrum mask	3.2	4.2.1.3	U	
4	Emissions in idle mode	3.2	4.2.1.4	U	
5	Transmitted waveform	3.2	4.2.1.5	U	
6	Receiver sensitivity and dynamic range	3.2	4.2.2.1	U	
7	Receiver selectivity	3.2	4.2.2.2	U	
8	Receiver immunity to interference	3.2	4.2.2.3	U	
9	FFM unwanted replies	3.2	4.2.2.4	U	
10	FFM SLS Effectiveness	3.2	4.2.2.5	U	
11	Receiver RF intermodulation response rejection	3.2	4.2.2.6	U	

### Key to columns:

#### Requirement:

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

**Description** A textual reference to the requirement.

#### Essential requirements of Directive

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

#### Clause(s) of the present document

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

#### Requirement Conditionality:

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

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

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

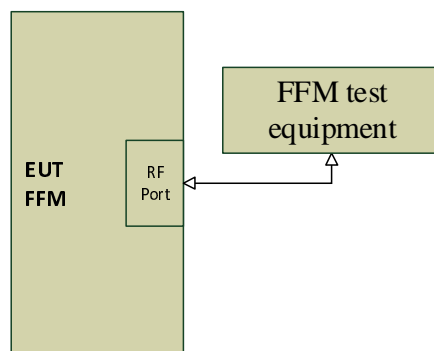
Other Union legislation may be applicable to the product(s) falling within the scope of the present document.

## Annex B (normative): Measurement setups

### B.1 Setup 1

Figure B.1 shows the measurement setup to be used, when verifying the transmitter power, the sensitivity, the dynamic range, and the transmitted waveform. The insertion losses of all components in the test setup shall be taken into account. The cable shall have a 50  $\Omega$  impedance.

No special arrangements are needed for this test bench.



**Figure B.1: Setup for the measurement of the transmitter power, the sensitivity, the dynamic range and the transmitted waveform**

An FFM test equipment is an instrument able to generate signals used to verify the compliance of the characteristics of the EUT to the applicable standards. Most tests are executed automatically using pre-set configurations, selectable via an onboard control panel, on which the test results are also displayed. Tests can be executed singularly or automatically in a sequence.

### B.2 Setup 2

Figure B.2 shows the measurement setup to be used when verifying the Maximum frequency deviation, the spectrum mask and the emissions in idle mode.

The Spectrum Analyser shall have the following minimum characteristics:

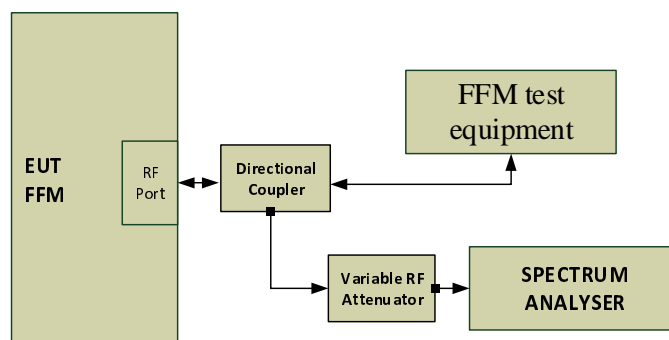
- Frequency error (uncertainty) less than 25 kHz.
- RBW from 100 kHz to 1 MHz with an accuracy of  $\pm 0,5$  %
- Reference output level  $> 0$  dBm with a resolution of 0,01 dB

The FFM test equipment transmits the interrogation signals to the EUT via the directional coupler, and replies are sent both to the FFM test equipment and to the Spectrum Analyser.

The variable RF attenuator is necessary to keep the signal in the operational range of the Spectrum Analyser.

The directional coupler shall be a 3 dB / 90 degree hybrid type.

The insertion losses of all components in the test setup shall be taken into account. Cables shall have a 50  $\Omega$  impedance.



**Figure B.2: Setup for the measurement of the frequency deviation, the spectrum mask and the emissions in idle mode**

## B.3 Setup 3

Figure B.3 shows the measurement setup to be used, when verifying the FFM selectivity and the immunity to interference.

FFM test equipment is used to generate the test interrogation, and a Signal Generator is used to inject the interfering signal. Detected Replies (Video 1) and Interfering Signals (Video 2) are sent to the oscilloscope.

The oscilloscope and the RF signal generator are synchronized by the FFM test equipment (SYNCH and TRIGG as in Figure B.3).

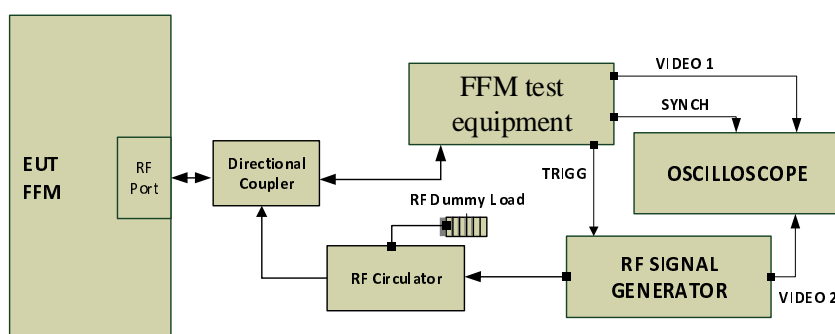
The RF Circulator has the purpose to protect the RF Signal Generation from the reply signals transmitted by the FFM, sending them to the RF Dummy load. At least 20 dB insulation are needed among the ports of the circulator, with an insertion loss of less than 0,5 dB.

The RF Dummy Load shall support a maximum power of 250 W with a duty cycle of 6 %.

The purpose of the directional coupler is to allow simultaneous injection of interrogations and interfering signals.

The directional coupler shall be a 3 dB/90 degree hybrid type.

The insertion losses of all components in the test setup shall be taken into account. Cables and the dummy load shall have a 50  $\Omega$  impedance.



**Figure B.3: Setup for the measurement of the FFM selectivity and the immunity to interference**

## B.4 Setup 4

Figure B.4 shows the measurement setup to be used, when verifying the FFM Unwanted replies.

FFM test equipment is used to generate the test interrogation. The received signal is sent via the video output port to the oscilloscope, and, via the time base port of the same oscilloscope, to the Frequency counter.

In this way, the received replies can be counted on the frequency counter.

The insertion losses of all components in the test setup shall be taken into account. Cables shall have a 50  $\Omega$  impedance.

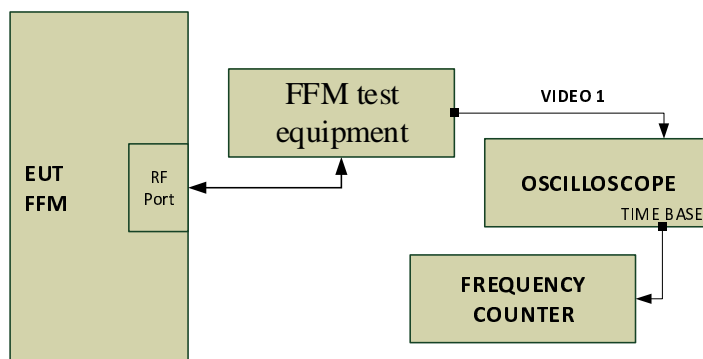


Figure B.4: Setup for the measurement of the FFM Unwanted replies

## B.5 Setup 5

Figure B.5 shows the measurement setup to be used, when verifying the FFM Receiver RF intermodulation response rejection.

FFM test equipment is used to generate the test interrogation and count the replies, Signal Generator #1 and Signal Generator #2 are used to inject the interfering signals generating the intermodulation effect.

The 3-way coupler has the purpose of combining the three signals at the input of the EUT.

Replies are to be forwarded only to the FFM test equipment; therefore, the path to the Signal Generators needs to be protected with RF Circulators, similarly to Setup 3 described in clause B.3.

The insertion losses of all components in the test setup shall be taken into account. Cables and dummy loads shall have a 50  $\Omega$  impedance.

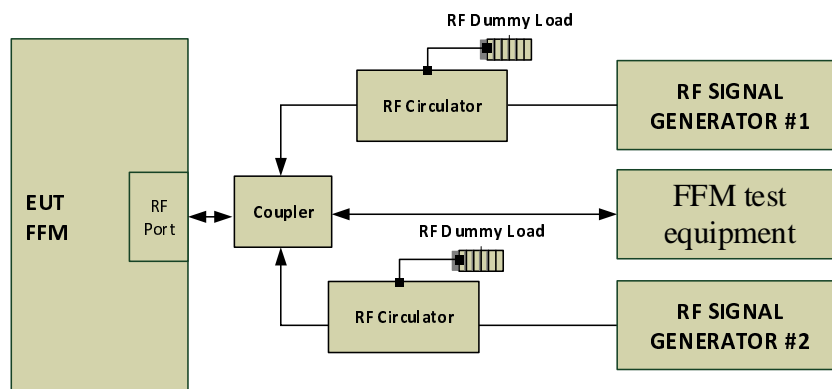


Figure B.5: Setup for the measurement of the FFM Receiver RF intermodulation response rejection



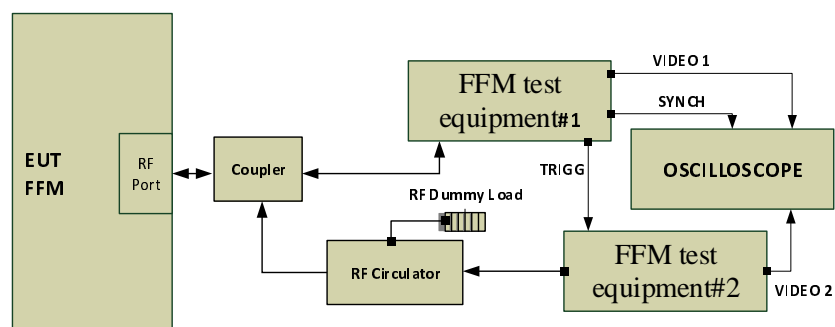
## B.6 Setup 6

Figure B.6 shows the measurement setup to be used, when verifying the SLS effectiveness.

FFM test equipment #1 is used to generate the test interrogation, an FFM test equipment #2 is used to inject the interfering signal. Detected Replies (Video 1) and Interfering Signals (Video 2) are sent to the oscilloscope.

The oscilloscope and FFM test equipment #2 are synchronized by the FFM test equipment #1 (SYNCH and TRIGG as in Figure B.6).

The characteristics of the RF Circulator, the Coupler and the RF dummy load are the same of Setup 3 described in clause B.3. The insertion losses of all components in the test setup shall be taken into account. Cables and the dummy load shall have a 50  $\Omega$  impedance.



**Figure B.6: Setup for the measurement of the SLS effectiveness**

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## Annex C (normative): FFM test equipment characteristics

The FFM test equipment shall have at least the following characteristic:

### Test Modality

- a) Capability to execute testing in auto mode, without requiring operator setting.
- b) Capability to execute testing in manual mode, by selecting desired parameter and its value.

### For the transmission section

- a) Capability to select the interrogation mode (conventional or Mode-S) and set the interrogation content as required.
- b) Capability to change:
  - 1) the RF frequency, at least by 60 MHz from the centre frequency (i.e. 970 MHz to 1 090 MHz);
  - 2) the amplitude of the interrogating signal level, from -21 to -85 dBm;
  - 3) the relative amplitude of interrogation pulses, including P2 and P5 pulses.
- c) Capability to generate single pulses, using an external synchronization (e.g. by another FFM test equipment):
  - 1) Same pulse shape as the P2 pulse or the P5 pulse;
  - 2) adjustable in amplitude and relative position from the synchronization trigger.
- d) Capability to synchronize another FFM test equipment.

### For the receiver section

- a) Capability to count the number of correct replies transmitted in response to valid interrogations.
- b) Capability to display the reply content in response to an interrogation.
- c) Capability to provide an output of the detected video of the replies from the EUT.
- d) Capability to measure the transmission frequency of the EUT.

# Annex D (informative): Reference Waveforms

The characteristics of waveforms of signals associated with Interrogations to FFM and Replies from FFM are reported hereafter (see also ICAO Annex 10 [i.4] and EUROCAE ED-73F [i.8]).

A figure with the main characteristics of the DME signal (X-channel) is also included (Figure D.5).

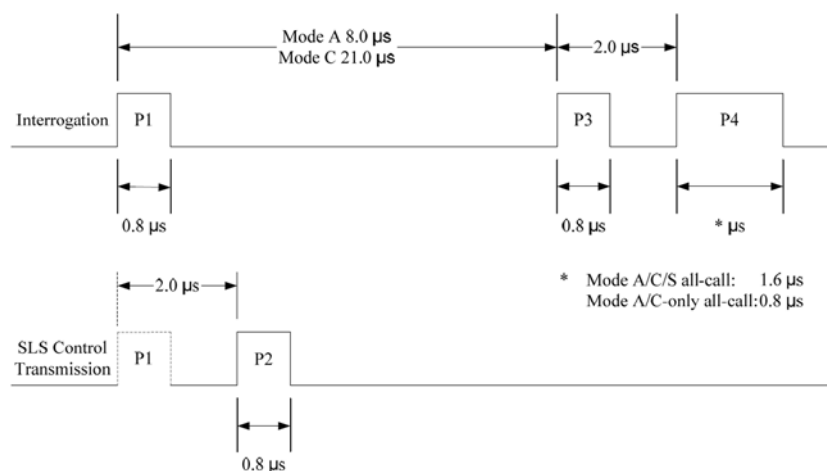


Figure D.1: Mode A/C/Intermode Interrogations

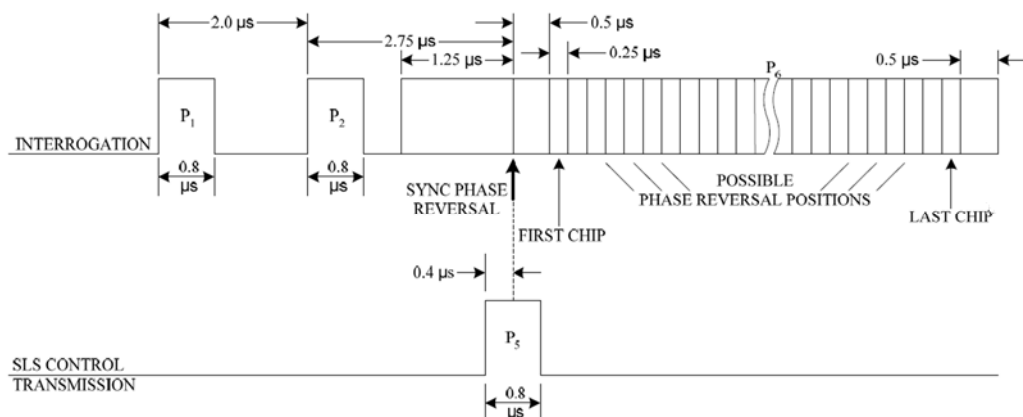


Figure D.2: Mode-S Interrogations

Available pulse positions																		
Spacing (microseconds) leading edge to leading edge	0	1.45	2.9	4.35	5.8	7.25	8.7	10.15	11.6	13.05	14.5	15.95	17.4	18.85	20.3	24.65		
Designation of pulses	Framing	C <sub>1</sub>	A <sub>1</sub>	C <sub>2</sub>	A <sub>2</sub>	C <sub>2</sub>	A <sub>2</sub>	X	B <sub>1</sub>	D <sub>1</sub>	B <sub>2</sub>	D <sub>2</sub>	B <sub>2</sub>	D <sub>2</sub>	B <sub>2</sub>	D <sub>2</sub>	Framing	SPI

Figure D.3: Mode A / C Reply

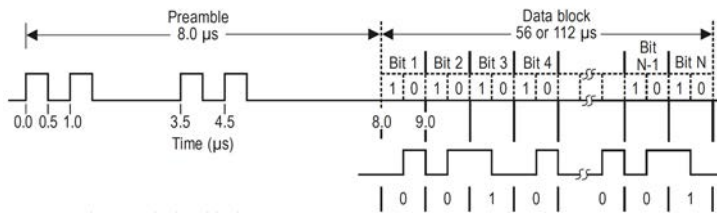


Figure D.4: Mode S Reply and Mode-S Squitters

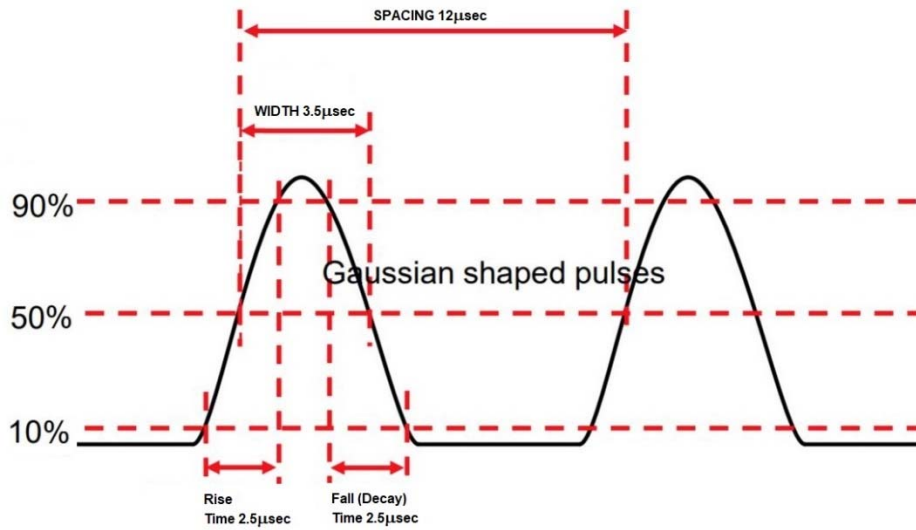


Figure D.5: DME signal waveform (X-Channel)

## Annex E (informative): Checklist

This annex provides a traceability of the technical parameters for article 3.2 of Directive 2014/53/EU [i.1] defined in ETSI EG 203 336 [i.3] with the technical requirements for conformance defined in clause 4 of the present document.

If a technical parameter for article 3.2 of Directive 2014/53/EU [i.1] defined in ETSI EG 203 336 [i.3] has not been included in the present document, an explanation is provided.

An explanation is also provided whenever a technical parameter defined in ETSI EG 203 336 [i.3] is covered by an alternative technical requirement.

**Table E.1: Checklist**

Technical Parameters defined in ETSI EG 203 336 [i.3]	Clauses of the present document	Comments
<b>Transmitter Parameters</b>		
Transmit power (and possible accuracy)	4.2.1.2	
Spectrum mask	4.2.1.3	
Transmitter Frequency stability	4.2.1.1	
Transmitter Intermodulation attenuation	N.A.	ETSI EG 203 336 [i.3] considers this parameter as applicable for base stations with shared sites and dense usage scenarios. Like the SSR, also the FFM includes appropriate means (e.g. circulators) to separate the TX and RX signals, having different fixed frequencies, and in addition the transmissions from the FFM are triggered only when the FFM recognizes valid interrogations. An interfering signal entering the transmitter via its antenna has, therefore, very low probability of triggering a transmission because of an intermodulation effect. This probability is further reduced by the fact that the FFM antenna is a directional antenna and always oriented towards the SSR, thus further limiting the possibility that an external signal coming from other directions can enter the antenna during the transmission.
Unwanted emissions (OoB and spurious domains)	4.2.1.3	
Transmitter Time domain characteristics (e.g. the duty cycle, turn-on and turn-off, frequency hopping cycle, dynamic changes of modulation scheme and others)	4.2.1.5	
Transmitter Transients	4.2.1.3	This requirement is covered by the spectrum mask
<b>Receiver Parameters</b>		
Receiver sensitivity	4.2.2.1	
Receiver co-channel rejection	4.2.2.3	
Adjacent signal/channel Selectivity	4.2.2.2	
Spurious response Rejection	4.2.2.2	The selectivity characteristics ensure that spurious signals entering the receiver, outside the frequency band of $\pm 25$ MHz from the nominal carrier, are rejected by more than 60 dB. Therefore, the attenuation at other frequencies outside the above-mentioned frequency band is always higher.
Receiver blocking	4.2.2.2	The selectivity characteristics ensure that spurious signals entering the receiver, outside the frequency band of $\pm 25$ MHz from nominal carrier, are rejected by more than 60 dB and so very strong interfering signals cannot saturate the receiver. Therefore the attenuation at other frequencies outside the above mentioned frequency band is always higher. In addition, the fact that the FFM antenna is a directional antenna and always oriented towards the SSR further limits the possibility that an external strong signal coming from other directions can enter the antenna and affect the receiver.

<b>Technical Parameters defined in ETSI EG 203 336 [i.3]</b>	<b>Clauses of the present document</b>	<b>Comments</b>
Receiver radio-frequency intermodulation	4.2.2.6	
Receiver dynamic range	4.2.2.1	
Reciprocal mixing	4.2.2.2	Reciprocal mixing is covered by the Selectivity.
Receiver unwanted emissions in the spurious domain	4.2.1.4	

## Annex F (informative): Maximum Measurement Uncertainty

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

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

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

**Table F.1: Maximum measurement uncertainty**

Parameter	Uncertainty
<b>Environment measurements</b>	
Temperature	1°C
Relative humidity	5 %
Mains Supply Voltage	±2 %
<b>Transmitter measurements</b>	
Frequency	±1 ppm
Transmitter power	±1,5 dB
Transmitted Waveforms	± 25 ns
Out-of-Band emissions	±4 dB
Spurious emissions	±4 dB
<b>Receiver measurements</b>	
Receiver Selectivity	±1 dB
Receiver Sensitivity and dynamic range	±1 dB
Receiver immunity to interference	±1 dB
Receiver blocking	±1 dB
Inter-modulation response rejection	±1 dB
Receiver co-channel rejection	±1 dB
FFM unsolicited replies	±1 dB
FFM SLS Effectiveness	±1 dB

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## History

<b>Document history</b>		
V1.0.0	June 2023	EN Approval Procedure AP 20230926: 2023-06-28 to 2023-09-26