



**Air Traffic Control Surveillance Radar Sensors;
Secondary Surveillance Radar (SSR);
Harmonised Standard for access to radio spectrum;
Part 1: SSR Interrogator**

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Foreword

This final 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 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 1 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)".

Proposed national transposition dates	
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

Modal verbs terminology

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

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

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. When aircraft are within the antenna beam of the ground station, its interrogations elicit replies from transponders.

Civil use systems have different modes of interrogation/reply: Mode A, Mode C, Mode S and intermode. Mode A, Mode C and Intermode interrogations consist of Pulse Amplitude Modulated (PAM) signals, Mode-S interrogations have an additional pulse, with Differential Phase Shift Keying (DPSK) modulation.

Ground stations will be either Mode A/C ground stations, which can interrogate and receive replies on Mode A/C only, or Mode S ground stations, for which the present standard founds its applicability, which can interrogate and receive replies on all modes. On the other side, there are two classes of transponders: Mode A/C transponders, which can respond to Mode A, Mode C and Intermode interrogations only, and Mode S transponders, which can respond to all modes. Mode-S interrogation/replies have different data block depending on the information they have to support.

As far as Mode S is concerned, for the purpose of the present document it is assumed that the SSR can transmit interrogations at least in the uplink formats (UF) UF11, UF4 and UF5 and can process replies in the downlink formats (DF) DF11, DF4, DF20, DF5 and DF21.

The replies to all modes of interrogation are used to determine aircraft 2D position by measurement of the range and bearing of the reply. The performance towards the radar parameters are determined on the basis of the number of correct and validated replies received and decoded, in the operating environment.

Performances are affected by interference effects, which can result in a degradation of the signal causing lost or wrong information. RF signals on either uplink or downlink can be distorted by other overlapping RF signals, which can make correct decoding of wanted signals impossible. The degree of degradation is a function of the channel loading.

The SSR system requires a 3 dB receiver bandwidth of approximately 8 MHz centered on 1 030 MHz and 1 090 MHz for the airborne transponder and ground SSR receiver respectively. This bandwidth is sufficient to permit significant co-channel interference from transmitters operating on adjacent frequencies.

This interference can be minimized by ensuring adequate frequency or spatial separation between the interfering transmitters and the SSR receivers. In this specific case, two air traffic service systems, DME and primary radars, can be the cause of interference.

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.

Secondary Surveillance Radar (SSR) with Mode S capabilities which includes mode A/C, transmitting in the 1 030 MHz band with a power not exceeding 4 kW (66 dBm), and receiving in the 1 090 MHz band, used for air traffic control and connected to a rotating antenna. The SSR Interrogator transmits interrogations to aircraft equipped with transponder, receives the corresponding replies, and operates in the frequency bands as indicated in Table 1.

Table 1: SSR interrogator service frequency bands

Signals	Service frequency bands
Transmitted signals	1 030 MHz
Received signals	1 090 MHz

NOTE 1: 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.

NOTE 2: Systems making use of an electronic scanned antenna are not covered by the present document.

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).

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The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

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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] ECC/Recommendation (02)05 (2012): "Unwanted emissions".
- [i.4] 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.5] ICAO Annex 10, Volume IV: "Surveillance and Collision Avoidance Systems", 5th edition, 16th July 2018, including amendments up to amendment 90.
- [i.6] Eurocontrol SUR/MODES/EMS/SPE-01: "European Mode S Station Functional Specification", edition 3.11, 9th May 2005.
- [i.7] ERC/Recommendation 74-01 (2019): "Unwanted emissions in spurious domain".
- [i.8] ITU Radio Regulations (2020).
- [i.9] ICAO DOC-9924: "Aeronautical Surveillance Manual", edition 2, 2017.

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 (as it is derived from an omnidirectional antenna beam) or OMEGA path and identified with Greek letter Ω .

difference: RF path between the SSR interrogator and the SSR antenna allowing the monopulse function

NOTE: Monopulse difference path is also called DELTA path and identified with Greek letter Δ .

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 aircraft transponder or FFM to SSR

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): fixed ground based system allowing the monitoring of the uplink and/or downlink performance of an SSR system, located at a pre-determined position from the radar (far field)

NOTE: The FFM is interrogated by the SSR, and its replies are evaluated by the secondary radar for calibration and self-test purposes. A FFM with Mode S capability has Mode A and Mode C capabilities too.

fruits: replies received by an interrogator but not triggered by own interrogations. 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 ICAO Annex 10 Volume IV [i.5] and Eurocontrol SUR/MODES/EMS/SPE-01 [i.6].

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.

mode A: interrogation triggering a Mode A reply allowing the identification of aircraft

NOTE 1: A Mode A interrogation consists of P1 and P3 pulses transmitted on the sum port of the SSR interrogator and a P2 pulse transmitted on the control port of the SSR interrogator (P2 is called a sidelobe suppression pulse). The interval between P1 and P3 determines the Mode A interrogation type.

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

mode C: interrogation triggering a Mode C reply containing encoded pressure-altitude information

NOTE 1: A Mode C interrogation consists of P1 and P3 pulses transmitted on the sum port of the SSR interrogator and a P2 pulse transmitted on the control port of the SSR interrogator. The interval between P1 and P3 determines the Mode C interrogation type.

NOTE 2: A Mode C reply consists of framing pulses (F1 and F2) and up to 12 pulses 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 on the sum port of the SSR interrogator and a P5 pulse transmitted on the control port of the SSR interrogator (P5 is called a sidelobe suppression pulse). A Mode S reply consists of a four-pulse preamble followed by a reply data block.

NOTE 2: Mode S stands for "Mode Select".

NOTE 3: The addressing method consists of a unique 24 bit Mode-S address for each individual aircraft transponder, assigned by ICAO and using a country prefix scheme. The Mode S address is used by SSR Interrogator in the interrogations, and by transponders and FFM in their correlated replies.

monopulse: technique used to determine the direction of a RF signal by comparison of different RF antenna paths

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.8].

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.8].

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.8].

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

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

Pulse Amplitude Modulation (PAM): modulation used for Mode A, Mode C, intermode interrogations, pulses P1 and P2 of Mode S interrogations as well as Mode A, Mode C replies and the preamble pulses of Mode S replies

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

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.8].

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

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 [i.8].

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 [i.8].

sum: RF path between the SSR interrogator and the SSR antenna allowing the transmission and reception of RF signals through the main directional beam of the SSR antenna

NOTE: Monopulse sum path is also called SIGMA path and identified with Greek letter Σ

uplink: direction of the 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
P_d	Probability of detection
$P_{d\ 1090}$	Probability of detection at 1 090 MHz
$P_{d\ offset}$	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
λ	Wavelength

3.3 Abbreviations

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

AC	Alternating Current
ATC	Air Traffic Control
BPPM	Binary Pulse Position Modulation
CW	Continuous Wave
DC	Direct Current
DF	Downlink Format
DME	Distance Measuring Equipment
DPSK	Differential Phase Shift Keying
EFTA	European Free Trade Association
ERC	former European Radio Committee in CEPT, now ECC
EUT	Equipment Under Test
FFM	Far Field Monitor
FRUITs	False Replies Unsynchronized In Time (or to Interrogation Transmissions)
ICAO	International Civil Aviation Organization
IRF	Interrogation Repetition Frequency
ITU	International Telecommunication Union
MDL	Minimum Decode Level
NA	Not Applicable
NF	Noise Figure
OoB	Out-of-Band
PAM	Pulse Amplitude Modulation
PEP	Peak Envelope Power
PRF	Pulse Repetition Frequency
RBW	Reference BandWidth
RF	Radio Frequency
RSL	Receiver Saturation Level
RX	Receive
SSR	Secondary Surveillance Radar
TX	Transmit
UF	Uplink Format
VSWR	Voltage Standing Wave Ratio